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CBSE New Pattern

Physics

Class 11 (Term I)

- Multiple Choice Questions
- Assertion-Reasoning MCQs
- Case Based MCQs

3 Practice Papers
On Latest Term I Syllabus

Including Chapterwise
Quick Revision Notes

As per Latest CBSE Circular **Dated 22 July 2021**

CBSE New Pattern

Physics

Class 11 (Term I)

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ARIHANT PRAKASHAN (School Division Series)

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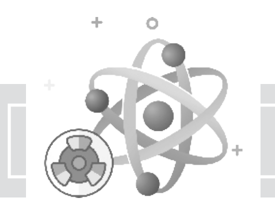

Contents

Syllabus (Rationalised)

(Term I)

Time : One and Half hours | **Max Marks : 35**

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	Chapter–2: Units and Measurements		
Unit II	**Kinematics**	16	
	Chapter–3: Motion in a Straight Line		
	Chapter–4: Motion in a Plane		
Unit III	**Laws of Motion**	10	
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	Chapter–6 : Work, Energy and Power		
Unit V	**Motion of System of Particles and Rigid Body**	16	
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	Chapter–8: Gravitation		
	Total	**68**	**35**

UNIT-I **Physical World and Measurement** *6 Periods*

Chapter-1 **Physical World**

Physics-scope and excitement; nature of physical laws; Physics, technology and society. (To be discussed as a part of Introduction and integrated with other topics)

Chapter-2 Units and Measurements

Need for measurement: Units of measurement; systems of units; SI units, fundamental and derived units. Length, mass and time measurements; accuracy and precision of measuring instruments; errors in measurement; significant figures.

Dimensions of physical quantities, dimensional analysis and its applications.

UNIT-II Kinematics *16 Periods*

Chapter-3 Motion in a Straight Line

Elementary concepts of differentiation and integration for describing motion, uniform and non- uniform motion, average speed and instantaneous velocity, uniformly accelerated motion, velocity - time and position-time graphs.

Relations for uniformly accelerated motion (graphical treatment).

Chapter-4 Motion in a Plane

Scalar and vector quantities; position and displacement vectors, general vectors and their notations; equality of vectors, multiplication of vectors by a real number; addition and subtraction of vectors, relative velocity, Unit vector; resolution of a vector in a plane, rectangular components, Scalar and Vector product of vectors.

Motion in a plane, cases of uniform velocity and uniform acceleration-projectile motion, uniform circular motion.

UNIT-III Laws of Motion *10 Periods*

Chapter-5 Laws of Motion

Intuitive concept of force, Inertia, Newton's first law of motion; momentum and Newton's second law of motion; impulse; Newton's third law of motion. (Recapitulation only)

Law of conservation of linear momentum and its applications.
Equilibrium of concurrent forces, Static and kinetic friction, laws of friction, rolling friction, lubrication.

Dynamics of uniform circular motion: Centripetal force, examples of circular motion (vehicle on a level circular road, vehicle on a banked road).

UNIT-IV Work, Energy and Power *12 Periods*

Chapter-6 Work, Energy and Power

Work done by a constant force and a variable force; kinetic energy, work-energy theorem, power.

Notion of potential energy, potential energy of a spring, conservative forces: conservation of mechanical energy (kinetic and potential energies); non-conservative forces: motion in a vertical circle; elastic and inelastic collisions in one and two dimensions.

UNIT-V Motion of System of Particles and Rigid Body *16 Periods*

Chapter-7 System of Particles and Rotational Motion

Centre of mass of a two-particle system, momentum conservation and centre of mass motion. Centre of mass of a rigid body; centre of mass of a uniform rod.

Moment of a force, torque, angular momentum, law of conservation of angular momentum and its applications.

Equilibrium of rigid bodies, rigid body rotation and equations of rotational motion, comparison of linear and rotational motions.

Moment of inertia, radius of gyration, values of moments of inertia for simple geometrical objects (no derivation).

UNIT-VI Gravitation *8 Periods*

Chapter-8 Gravitation

Universal law of gravitation. Acceleration due to gravity (recapitulation only) and its variation with altitude and depth.

Gravitational potential energy and gravitational potential, escape velocity, orbital velocity of a satellite, Geo-stationary satellites.

CBSE Circular

Acad - 51/2021, 05 July 2021

About Latest Exam Scheme Term I & II

केन्द्रीय माध्यमिक शिक्षा बोर्ड

(शिक्षा मंत्रालय, भारत सरकार के अधीन एक स्वायत संगठन)

CENTRAL BOARD OF SECONDARY EDUCATION

(An Autonomous Organisation under the Ministryof Education, Govt. of India)

CBSE/DIR (ACAD)/2021 **Date: July 05, 2021**

Circular No: Acad-51/2021

All the Heads of Schools affiliated to CBSE

Subject: Special Scheme of Assessment for Board Examination Classes X and XII for the Session 2021-22

COVID 19 pandemic caused almost all CBSE schools to function in a virtual mode for most part of the academic session of 2020-21. Due to the extreme risk associated with the conduct of Board examinations during the second wave in April 2021, CBSE had to cancel both its class X and XII Board examinations of the year 2021 and results are to be declared on the basis of a credible, reliable, flexible and valid alternative assessment policy. This, in turn, also necessitated deliberations over alternative ways to look at the learning objectives as well as the conduct of the Board Examinations for the academic session 2021-22 in case the situation remains unfeasible.

CBSE has also held stake holder consultations with Government schools as well as private independent schools from across the country especially schools from the remote rural areas and a majority of them have requested for the rationalization of the syllabus, similar to last year in view of reduced time permitted for organizing online classes. The Board has also considered the concerns regarding differential availability of electronic gadgets, connectivity and effectiveness of online teaching and other socio-economic issues specially with respect to students from economically weaker section and those residing in far flung areas of the country. In a survey conducted by CBSE, it was revealed that the rationalized syllabus notified for the session 2020-21 was effective for schools in covering the syllabus and helped learners in achieving learning objectives in a less stressful manner.

In the above backdrop and in line with the Board's continued focus on assessing stipulated learning outcomes by making the examinations competencies and core concepts based, student-centric, transparent, technology-driven, and having advance provision of alternatives for different future scenarios, the following schemes are introduced for the Academic Session for Class X and Class XII 2021-22.

2. **Special Scheme for 2021-22**

A. **Academic session to be divided into 2 Terms with approximately 50% syllabus in each term:**

The syllabus for the Academic session 2021-22 will be divided into 2 terms by following a systematic approach by looking into the interconnectivity of concepts and topics by the Subject Experts and the Board will conduct examinations at the end of each term on the basis of the bifurcated syllabus. This is done to increase the probability of having a Board conducted classes X and XII examinations at the end of the academic session.

B. **The syllabus for the Board examination 2021-22 will be rationalized** similar to that of the last academic session to be notified in July 2021. For academic transactions, however, schools will follow the curriculum and syllabus released by the Board vide Circular no. F.1001/CBSE-Acad/Curriculum/2021 dated 31 March 2021. Schools will also use alternative academic calendar and inputs from the NCERT on transacting the curriculum.

C. **Efforts will be made to make Internal Assessment/ Practical/ Project work more credible and valid** as per the guidelines and Moderation Policy to be announced by the Board to ensure fair distribution of marks.

3. **Details of Curriculum Transaction**

- Schools will continue teaching in distance mode till the authorities permit in-person mode of teaching in schools.
- **Classes IX-X: Internal Assessment** (throughout the year-irrespective of Term I and II) would include the *3 periodic tests, student enrichment, portfolio and practical work/ speaking listening activities/ project*.
- **Classes XI-XII: Internal Assessment** (throughout the year-irrespective of Term I and II) would include end of topic or unit tests/ exploratory activities/ practicals/ projects.
- Schools would create a student profile for all assessment undertaken over the year and retain the evidences in digital format.
- CBSE will facilitate schools to upload marks of Internal Assessment on the CBSE IT platform.
- Guidelines for Internal Assessment for all subjects will also be released along with the rationalized term wise divided syllabus for the session 2021-22.The Board would also provide additional resources like sample assessments, question banks, teacher training etc. for more reliable and valid internal assessments.

4. **Term I Examinations:**

- At the end of the first term, the Board will organize **Term I Examination** in a flexible schedule to be conducted between November-December 2021 with a window period of 4-8 weeks for schools situated in different parts of country and abroad. Dates for conduct of examinations will be notified subsequently.
- The Question Paper will have Multiple Choice Questions (MCQ) including case-based MCQs and MCQs on assertion-reasoning type. Duration of test will be **90 minutes** and it will cover only the rationalized syllabus of **Term I only** (i.e. approx. 50% of the entire syllabus).
- Question Papers will be sent by the CBSE to schools along with marking scheme.
- The exams will be conducted under the supervision of the External Center Superintendents and Observers appointed by CBSE.
- The responses of students will be captured on OMR sheets which, after scanning may be directly uploaded at CBSE portal or alternatively may be evaluated and marks obtained will be uploaded by the school on the very same day. The final direction in this regard will be conveyed to schools by the Examination Unit of the Board.
- Marks of the **Term I** Examination will contribute to the final overall score of students.

5. **Term II Examination/ Year-end Examination:**

- At the end of the second term, the Board would organize **Term II or Year-end Examination** based on the rationalized syllabus of Term II only (i.e. approximately 50% of the entire syllabus).
- This examination would be held around **March-April 2022** at the examination centres fixed by the Board.
- The paper will be of **2 hours duration** and have questions of different formats (case-based/ situation based, open ended- short answer/ long answer type).
- In case the situation is not conducive for normal descriptive examination **a 90 minute MCQ** based exam will be conducted at the end of the Term II also.
- Marks of the Term II Examination would contribute to the final overall score.

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6. **Assessment / Examination as per different situations**

   A. **In case the situation of the pandemic improves and students are able to come to schools or centres for taking the exams.**

   Board would conduct Term I and Term II examinations at schools/centres and the theory marks will be distributed equally between the two exams.

   B. **In case the situation of the pandemic forces complete closure of schools during November-December 2021, but Term II exams are held at schools or centres.**

   Term I MCQ based examination would be done by students online/offline from home - in this case, the weightage of this exam for the final score would be reduced, and weightage of Term II exams will be increased for declaration of final result.

   C. **In case the situation of the pandemic forces complete closure of schools during March-April 2022, but Term I exams are held at schools or centres.**

   Results would be based on the performance of students on Term I MCQ based examination and internal assessments. The weightage of marks of Term I examination conducted by the Board will be increased to provide year end results of candidates.

   D. **In case the situation of the pandemic forces complete closure of schools and Board conducted Term I and II exams are taken by the candidates from home in the session 2021-22.**

   Results would be computed on the basis of the Internal Assessment/Practical/Project Work and Theory marks of Term-I and II exams taken by the candidate from home in Class X / XII subject to the moderation or other measures to ensure validity and reliability of the assessment.

   In all the above cases, data analysis of marks of students will be undertaken to ensure the integrity of internal assessments and home based exams.

Dr. Joseph Emmanuel
Director (Academics)

01

Physical World

Quick Revision

1. **Science** It is exploring, experimenting and predicting from what we see around us. It is a systematic attempt to understand natural phenomena.
2. **Physics** It refers to the study of the physical world, i.e. the study of the basic laws of nature and their manifestation in different natural phenomena.
3. **Scope and Excitement of Physics** To define the scope and excitement of Physics, it is categorised into two groups, on the basis of magnitude of physical quantities involved in it, i.e. **macroscopic** and **microscopic groups** of Physics.
4. **Macroscopic Group of Physics** It deals with the subjects included in **Classical Physics**. It consists of phenomena at the laboratory, terrestrial and astronomical scales.

   Classical physics can be classified as
   - **Mechanics** It deals with the study of motion of particles, rigid and deformable bodies and general system of particles. It is based on the law of gravitation and Newton's laws of motion.
   - **Electrodynamics** It deals with the study of electric and magnetic phenomena associated with charged and magnetic bodies. It is based on the laws given by Coulomb, Oersted, Ampere and Faraday.
   - **Optics** It deals with the study of phenomena related to light, working of human eye, telescope, microscope, etc.
   - **Thermodynamics** It deals with the study of the system in macroscopic equilibrium considering changes in internal energy, temperature, entropy, etc.
5. **Microscopic Group of Physics** It deals with the study of constituents and structure of matter at minute scale of length, i.e. at the scale of atoms and nuclei or even smaller than these. This group of Physics can be studied under the subject **Quantum Physics**.
6. **Fundamental Forces in Nature** There are following four fundamental forces in nature
   - **Gravitational Force** The force of mutual attraction between any two objects because of their masses is called gravitational force. This force was discovered by **Isaac Newton.**
   - **Electromagnetic Force** The force associated with charged particles is called electromagnetic force.
   - **Strong Nuclear Force** It is the force which binds the protons and neutrons together inside a tiny nucleus.
   - **Weak Nuclear Force** The force which appears only between elementary particles involved in nuclear processes of radioactivity like β-decay of a nucleus, etc.

7. **Comparison between Four Fundamental Forces**

Name	Relative strength	Range
Gravitational force	10^{-39}	Infinite
Weak nuclear force	10^{-13}	Very short, sub-nuclear size ($\sim 10^{-16}$ m)
Electromagnetic force	10^{-2}	Infinite
Strong nuclear force	1	Short, nuclear size ($\sim 10^{-15}$ m)

8. **Nature of Physical Laws** Physicists observed that during a physical phenomenon governed by different forces, several quantities may change with time but some special physical quantities remain constant with time. They are called **conserved quantities of nature** and this is called **law of conservation**.

   There are four laws of conservation in classical Physics

   - **Law of Conservation of Energy** It states that, energy can neither be created nor be destroyed, but it can be changed from one form to another, i.e. the total sum of all kinds of energy in this universe remains same.
   - **Law of Conservation of Mass** Earlier it was assumed that, mass is indestructible and law of conservation of mass states that, matter can neither be created nor be destroyed.

     But Einstein's theory of relativity (energy-mass relation, $E = mc^2$, where m is the mass and c is the speed of light in vacuum) has modified it.

     In a nuclear process, mass gets converted to energy (or *vice-versa*). This is the energy which is released in a nuclear power generation and nuclear explosion.
   - **Law of Conservation of Momentum** Momentum is the quantity of motion of a moving body (generally measured as the product of mass and velocity of the body). Momentum of an isolated system is also conserved. It can be classified into two types (linear momentum and angular momentum) and law of conservation is valid for both of them.

     (a) **Law of Conservation of Linear Momentum** This law states that, if no external force acts on a system, then its linear momentum remains constant, i.e.

     When $\Sigma \mathbf{F}_{ext} = 0$, then $\mathbf{p}$ = constant.

     (b) **Law of Conservation of Angular Momentum** It states that, if no external torque acts on a system, then its angular momentum remains constant, i.e. when $\Sigma \tau_{ext} = 0$, then L = constant.
   - **Law of Conservation of Charge** This law states that, the net charge of an isolated system remains constant.

Objective Questions

Multiple Choice Questions

1. Physics is the branch of science which deals with the study of
(a) practical purposes
(b) living things
(c) technologies
(d) nature and natural phenomena

2. In Physics, quantitative measurement is central to the growth of science because
(a) laws of nature are expressible in precise mathematical equations
(b) basic laws universally apply in different contexts
(c) strategy of approximation turned out to be very successful
(d) All of the above

3. With which phenomena, classical Physics deals mainly?
(a) Macroscopic (b) Microscopic
(c) Natural (d) None of these

4. Microscopic domain includes
(a) quantum theory (b) mechanics
(c) thermodynamics (d) sound

5. Observable universe has range of mass of
(a) 10^{20} kg (b) 10^{30} kg
(c) 10^{40} kg (d) 10^{55} kg

6. Maxwell's set of equation encapsulated basic laws such as
(a) Coulomb and Oersted's laws
(b) Ampere and Faraday's laws
(c) Faraday's and Optic laws
(d) Both (a) and (b)

7. The phenomena that optics deals with are
(a) light
(b) working of telescopes and microscopes
(c) colours exhibited by thin films
(d) All of the above

8. Conservation laws are such that
(a) it cannot be proved but can be verified
(b) it can neither be proved nor can be verified
(c) it can be proved and verified
(d) it can be proved but not verified

9. Radio and television are based on
(a) inverse square law of charges
(b) production, propagation and reception of electromagnetic waves
(c) digital logic
(d) mechanics

10. The person who had been awarded the title of the Father of Physics of 20th century is
(a) Madam Curie
(b) Sir C.V. Raman
(c) Neils Bohr
(d) Albert Einstein

11. In Physics, the range of time scales used is ....
(a) 10^{15} s to 10^{-15} s (b) 10^{-22} s to 10^{18} s
(c) 10^{-20} s to 10^{9} s (d) 10^{-17} s to 10^{20} s

12. According to Einstein's theory of relativity, energy-mass relation is ....
(a) $E = mc$ (b) $E = m/c^2$
(c) $E = mc^2$ (d) $E = 2mc^2$

13. .... was discovered by Huygens'.
(a) Wave theory of light
(b) Quanta of light
(c) Particle nature of light
(d) None of the above

14. Which of the following statement is not correct?
(a) Physics is the study of nature and natural phenomena.
(b) Physics and technology are not related to each other.

(c) Electrodynamics deals with electric and magnetic phenomena associated with charged and magnetic bodies.
(d) The physical quantities that remain unchanged in a process are called conserved quantities.

15. Study the following statements regarding conservation law and choose the incorrect option.

(a) Conservation law is a hypothesis based on observations and experiments.
(b) Conservations laws do not have a deep connection with symmetries of nature.
(c) A conservation law cannot be proved.
(d) Conservation of energy, linear momentum and angular momentum are considered to be fundamental laws of physics.

16. Choose the correct statement from the following options.

(a) An axiom is self-evident truth while a model is a theory proposed to explain observed phenomena.
(b) Wireless communication followed the discovery of basic laws of electricity and magnetism.
(c) Bohr had dismissed the possibility of tapping energy from atoms.
(d) Both (a) and (b)

17. Match the Column I (domains) with Column II (relation) and select the correct option from the codes given below.

	Column I		Column II
A.	Mechanics	p.	electric and magnetic fields
B.	Electrodynamics	q.	macroscopic equilibrium
C.	Thermodynamics	r.	Newton's laws of motion

Codes

	A	B	C
(a)	p	q	r
(b)	r	p	q
(c)	p	r	r
(d)	q	r	p

18. Match the Column I (physical quantities) with Column II (scale) and select the correct option from the codes given below.

	Column I		Column II
A.	Size of electron or proton	p.	10^{-30} kg
B.	Mass of an electron	q.	10^{-14} m
C.	Extent of universe	r.	10^{26} m

Codes

	A	B	C
(a)	q	p	r
(b)	q	r	p
(c)	s	p	r
(d)	q	p	q

19. Match the Column I (name of physicists) with Column II (contribution/discovery) and select the correct option from the codes given below.

	Column I		Column II
A.	Johannes Kepler	p.	Nuclear model of the atom
B.	Tycho Brahe	q.	Planetary motion
C.	Nicolaus Copernicus	r.	Elliptical orbit theory
D.	Ernest Rutherford	s.	Circular orbit theory

Codes

	A	B	C	D
(a)	q	s	r	p
(b)	p	q	r	s
(c)	q	p	s	r
(d)	r	q	s	p

Assertion-Reasoning MCQs

*For question numbers 20 to 25, two statements are given-one labelled **Assertion** (A) and the other labelled **Reason** (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

20. **Assertion** The concept of energy is central to Physics and its expression can be written for every physical system.

Reason Law of conservation of energy is not valid for all forces and for any kind of transformation between different forms of energy.

21. **Assertion** Physics generates new technology.

Reason Technology give rise to new physics.

22. **Assertion** Symmetry of laws of nature with respect to translation in space give rise to conservation of linear momentum.

Reason Isotropy of space does not underlies the law of conservation of angular momentum.

23. **Assertion** According to the principle of conservation of energy, all heat can be converted into mechanical work.

Reason Due to various losses, it is impossible to convert all heat into mechanical work.

24. **Assertion** Matter can neither be created nor be destroyed.

Reason This is law of definite proportions.

25. **Assertion** Electric force and magnetic force are jointly called electromagnetic force.

Reason Electric and magnetic effects are inseparable.

ANSWERS

Multiple Choice Questions

1. (d)	2. (d)	3. (a)	4. (a)	5. (d)	6. (d)	7. (d)	8. (a)	9. (b)	10. (d)
11. (b)	12. (c)	13. (a)	14. (b)	15. (b)	16. (d)	17. (b)	18. (a)	19. (a)	

Assertion-Reasoning MCQs

20. (c)	21. (b)	22. (c)	23. (b)	24. (c)	25. (a)

SOLUTIONS

1. Nature and natural phenomena; for example motion of the moon around the earth, etc., are dealt with in Physics.

2. Quantitative measurement in Physics is central to the growth of science because all the basic universal laws apply in different context.

Also, laws of nature are expressible in mathematical equations and strategy of approximation turned out to be very successful.

3. Classical Physics deals mainly with macroscopic phenomena and includes subjects like mechanics, electrodynamics, optics and thermodynamics.

4. Quantum theory explains microscopic domain involving molecules, atoms, electrons and other elementary particles.

5. Mass of observable universe has a range of 10^{55} kg.

6. The basic laws regarding electromagnetism given by Oersted, Coulomb, Ampere and Faraday. These were encapsulated by Maxwell in his famous set of equations.

7. Optics deals with the study of phenomena related to light. So, the working of human eye, telescope, microscope, colours that exhibits by thin films etc., are all studied under this branch.

8. Conservation laws are basically hypothesis, based on observations and experiments. Thus, these laws cannot be proved but can be verified or disproved by experiments.

9. Radio and television are based on production (generation), propagation and reception (detection) of electromagnetic waves.

10. Albert Einstein was awarded the title of the Father of Physics of 20th century.

11. Range of time scales is 10^{-22} s to 10^{18} s.

12. Energy-mass relation is $E = mc^2$.

13. Huygens' discovered the wave theory of light.

14. The statement given in option (b) is incorrect and it can be corrected as,

Physics and technology are interdependent to each other.

15. The statement given in option (b) is incorrect and it can be corrected as,

Conservation laws have a deep connection with symmetries of nature. Symmetries of space and time and other types of symmetries play a central role in modern theories of fundamental forces in nature.

16. Wireless communication technology followed the discovery of the basic laws of electricity and magnetism in the nineteenth century.

Axiom is a self-evident truth that it is accepted without controversy while model is a theory proposed to explain observed phenomena.

17. A. Mechanics is based on Newton's laws of motion.

B. Electrodynamics deals with electric and magnetic phenomena associated with charged and magnetic bodies.

C. Thermodynamics in contrast to mechanics, does not deal with the motion of bodies as a whole. Rather, it deals with systems in macroscopic equilibrium and is concerned with changes in internal energy, temperature, entropy, etc., of the system through external work and transfer of heat.

Hence, A $\rightarrow$ r, B $\rightarrow$ p and C $\rightarrow$ q.

18. The correct match of this question is

A $\rightarrow$ q, B $\rightarrow$ p and C $\rightarrow$ r.

19. The correct match of this question is

A $\rightarrow$ q, B $\rightarrow$ s, C $\rightarrow$ r and D $\rightarrow$ p.

20. Law of conservation of energy is always valid for all forces and for any kind of transformation between different forms of energy.

Therefore, A is true but R is false.

21. Sometimes physics generates new technology and at others technology gives rise to new physics. Both have desired impact on society. Therefore, both A and R are true but R is not the correct explanation of A.

22. Symmetry of natural laws with respect to translation in space give rise to conservation of linear momentum.

Isotropy of space (no intrinsically preferred direction in space) underlies the law of conservation of angular momentum.

Therefore, A is true but R is false.

23. According to the law of conservation of energy, energy can neither be created nor it can be destroyed. Thus, it is physically possible to convert all of heat into mechanical work. But due to various energy losses, this cannot be achieved partically.

Therefore, both A and R are true but R is not the correct explanation of A.

24. Law of conservation of energy states that, matter can never be created nor be destroyed. Law of definite proportions states that, molecules will always have elements in a particular ratio which will also be fixed and not dependent on the method of preparation of the molecule.

Therefore, A is true but R is false.

25. Charges in motion produces magnetic effects, these effects give rise to a force on a moving charge. So, electric and magnetic effects are inseparable.

Therefore, it is named as electromagnetic force.

Therefore, both A and R are true and R is the correct explanation of A.

02

Units and Measurements

Quick Revision

1. **Physical Quantities** All the quantities which can be measured directly or indirectly and in terms of which laws of Physics are described are called physical quantities.

   These can be divided into two types, namely **fundamental** and **derived quantities.**

   - **Fundamental Quantities** The physical quantities which are independent of other physical quantities and are not defined in terms of other physical quantities are called fundamental or base quantities.
     e.g. Mass, length, time, temperature, luminous intensity, electric current, amount of substance, etc.
   - **Derived Quantities** Those quantities which can be derived from the fundamental physical quantities are called derived quantities.
     e.g. Velocity, acceleration, linear momentum, etc.

2. **Physical Unit** The standard amount of a physical quantity chosen to measure the physical quantity of same kind is called a physical unit. The physical units can be classified into following two types

   - **Fundamental Units** The units of fundamental quantities are known as fundamental units.
   - **Derived Units** The units of measurement of all other physical quantities, which can be obtained from fundamental units are called derived units.

3. **System of Units** It is the complete set of units, both fundamental and derived physical units.

   The common system of units used in mechanics are as follows

   - **The FPS System** It is the British engineering system of units. It uses foot as the unit of length, pound as the unit of mass and second as the unit of time.
   - **The CGS System** It is the French system of units, which uses centimetre, gram and second as the units of length, mass and time, respectively.
   - **The MKS System** It uses metre, kilogram and second as the fundamental units of length, mass and time, respectively.
   - **The International System of Units** (SI Units) The system of units which is accepted internationally for measurement is the 'Systeme International d' Units (French for International System of Units), abbreviated as SI.

4. **Fundamental Quantities and their SI Units**

Fundamental quantity	SI unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

5. **Supplementary Quantities and their SI Units**

Supplementary quantity	SI unit	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

6. **Some Important Practical Units**

For Length/Distance

- **Astronomical Unit** It is the mean distance of the earth from the sun.

$$1\text{ AU} = 1.496 \times 10^{11}\text{ m}$$

- **Light year** It is the distance travelled by light in vacuum in one year.

$$1\text{ ly} = 9.46 \times 10^{15}\text{ m}$$

- **Micro or micrometer**, $1\,\mu\text{m} = 10^{-6}$ m
- **Nanometer**, $1\text{ nm} = 10^{-9}$ m
- **Angstrom**, $1\text{ Å} = 10^{-10}$ m
- **Fermi** This unit is used for measuring nuclear sizes. $1\text{ Fm} = 10^{-15}$ m

For Mass

- **Pound**, 1 lb = 0.4536 kg
- **Slug**, 1 slug = 14.59 kg
- **Quintal**, 1 q = 100 kg
- **Tonne** or **metric tonne**, 1 t = 1000 kg
- **Atomic mass unit** (It is defined as the (1/12)th of the mass of one $^{12}_{6}$C-atom) 1 u or amu $= 1.66 \times 10^{-27}$ kg.

For Area

- **Barn**, 1 barn $= 10^{-28}\text{ m}^2$
- **Acre**, 1 acre $= 4047\text{ m}^2$
- **Hectare**, 1 hectare $= 10^4\text{ m}^2$

7. **Accuracy and Precision of Instruments**

The accuracy of a measurement is a measure of how close the measured value is to the true value of the quantity. While, precision tells us to what resolution or limit the quantity is measured.

8. **Errors in Measurement**

Difference in the true value and the measured value of a quantity is called error in measurement.

Error = True value − Measured value

In general, the errors can be further classified as

- **Systematic Errors** Those errors that tend to be in one direction, either positive or negative are called systematic errors. Some of the sources of systematic errors are
  - (a) **Instrumental errors** They occur due to imperfect design or manufacture or calibration of the measuring instrument.
  - (b) **Imperfection in experimental technique or procedure** These types of errors occur due to the experimental arrangement limitations.
  - (c) **Personal errors** These errors arise due to inexperience of the observer such as lack of proper setting of the apparatus and taking observations without observing proper precautions, etc.
  - (d) **Errors due to external causes** Various parameters such as change in temperature, pressure, volume, etc. during experiment may affect the reading of measurement.
- **Random Errors** The errors which occur irregularly and are random in magnitude and direction are called random errors.
- **Least Count Error** The smallest value that can be measured by a measuring instrument is called the least count of the instrument and error in its value is called least count error.

- **Absolute Error** The magnitude of the difference between the true value of the quantity and the individual measured value is called the absolute error of the measurement. It is denoted by $|\Delta a|$.

  Suppose, the measured values are $a_1, a_2, a_3, \ldots, a_n$, then arithmetic mean of these values is $a_{\text{Mean}} = \dfrac{a_1 + a_2 + \ldots + a_n}{n}$.

  If we take arithmetic mean a_{Mean} as the true value, then the absolute errors in the individual measured value will be

  $$\Delta a_1 = a_{\text{Mean}} - a_1$$

- **Mean Absolute Error** It is the arithmetic mean of the magnitudes of absolute errors in all the measurements of the quantity.

  Mean absolute error, $\Delta a_{\text{Mean}} = \sum_{i=1}^{n} \dfrac{|\Delta a_i|}{n}$

- **Relative Error or Fractional Error** It is defined as the ratio of mean absolute error to the mean value of the quantity measured.

  Relative error, $\delta a = \dfrac{\Delta a_{\text{Mean}}}{a_{\text{Mean}}}$

- **Percentage Error** When fractional error or relative error is expressed in percentage, then it is called percentage error.

  Percentage error, $\delta a\,\% = \dfrac{\Delta a_{\text{Mean}}}{a_{\text{Mean}}} \times 100\%$

9. **Combination of Errors**

- **Error in Sum or Difference**

  Let $X = A + B$ or $X = A - B$

  where, A and B are physical quantities have measured value $A \pm \Delta A$, $B \pm \Delta B$, respectively.

  So, the maximum possible error in sum and difference, $\Delta Z = \Delta A + \Delta B$

- **Error in Product or Quotient**

  Let $X = A \times B$ or $X = \dfrac{A}{B}$

  So, the maximum possible error in product or quotient is $\dfrac{\Delta Z}{Z} = \dfrac{\Delta A}{A} + \dfrac{\Delta B}{B}$

- **Error in Case of a Measured Quantity Raised to a Power**

  Relative error of $Z = A^n B^m$ is

  $$\frac{\Delta Z}{Z} = \pm\left[n\frac{\Delta A}{A} + m\frac{\Delta B}{B}\right]$$

10. **Significant Figures**

The digits that are known reliably plus the first uncertain digit are known as significant digits or significant figures.

Rules for Determining the Number of Significant Figures

***Rule* 1** All non-zero digits are significant.

***Rule* 2** All the zeros between two non-zero digits are significant, no matter where the decimal point is, if at all.

***Rule* 3** If the number is less than one, the zero(s) on the right of decimal point and to the left of first non-zero digit are not significant.

***Rule* 4** In a number without a decimal point, the terminal or trailing zeros is not significant.

***Rule* 5** The trailing zero(s) in a number with a decimal points are significant.

11. **Rules for Arithmetical Operations with Significant Figures**

Some rules of arithmetical operations with significant figures are as given below

- **Addition and Subtraction** In both, addition and subtraction, the final result should retain as **many decimal places** as are there in the number with the **least decimal places**.
- **Multiplication and Division** In multiplication or division, the final result should retain as many significant figures, as are there in the original number with the least significant figures.

12. **Rounding Off** The result of computation with approximate numbers, which contains more than one uncertain digit, should be rounded off. While rounding off measurements, we use the following rules by convention

***Rule* 1** If the digit to be dropped is less than 5, then the preceding digit is left unchanged.

***Rule* 2** If the digit to be dropped is more than 5, then the preceding digit is raised by one.

***Rule* 3** If the digit to be dropped is 5 followed by digits other than zero, then the preceding digit is raised by one.

***Rule* 4** If the digit to be dropped is 5 and followed by zeros, then the preceding digit is left unchanged, if it is even.

***Rule* 5** If the digit to be dropped is 5 and followed by zeros, then the preceding digit is raised by one, if it is odd.

13. **Dimensions of a Physical Quantity**

The dimensions of a physical quantity are the powers (or exponents) to which the units of base quantities are raised to represent a derived unit of that quantity. There are seven base quantities represented with square brackets [ ] such as length [L], mass [M], time [T], electric current [A], thermodynamic temperature [K], luminous intensity [cd] and amount of substances [mol].

14. **Dimensional Formulae and Dimensional Equations**

The expression which shows how and which of the fundamental quantities represent the dimension of the physical quantity is called the **dimensional formula** of the given physical quantity.

Some of the dimensional formulae are as given below

Acceleration = $[M^0 L^1 T^{-2}]$

Mass density = $[ML^{-3} T^0]$

Volume = $[M^0 L^3 T^0]$

The equation obtained by equating a physical quantity with its dimensional formula is called the **dimensional equation** of the given physical quantity.

15. **Dimensional Analysis and its Applications**

The dimensional analysis helps us in deducing the relations among different physical quantities and checking the accuracy, derivation and dimensional consistency or homogeneity of various numerical expressions. Its applications are as given below

- **Checking the Dimensional Consistency of Equations** The principle of homogeneity of dimension states that, a physical quantity equation will be dimensionally correct, if the dimensions of all the terms occurring on both sides of the equation are same.
- **Conversion of One System of Units into Another** If M_1, L_1 and T_1 are the fundamental units of mass, length and time in one system and while for other system, M_2, L_2 and T_2 are the fundamental units of mass, length and time, then $n_1 = [M_1^a\ L_1^b\ T_1^c]$ and $n_2 = [M_2^a\ L_2^b\ T_2^c]$.

  From $n_1 u_1 = n_2 u_2$, where u_1 and u_2 are two units of measurement of the quantity and n_1 and n_2 are their respective numerical values.

  $$\text{Then, } n_2 = \frac{n_1\ [M_1^a L_1^b T_1^c]}{[M_2^a L_2^b T_2^c]}$$

  $$= n_1 \left[\frac{M_1}{M_2}\right]^a \cdot \left[\frac{L_1}{L_2}\right]^b \cdot \left[\frac{T_1}{T_2}\right]^c$$

- **Deducing Relation among the Physical Quantities** The method of dimensions is used to deduce the relation among the physical quantities. We should know the dependence of the physical quantity on other quantities.

Objective Questions

Multiple Choice Questions

1. The quantity having the same unit in all system of unit is

(a) mass (b) time
(c) length (d) temperature

2. The SI unit of thermal conductivity is

(a) J $m^{-1}K^{-1}$ (b) W-m K^{-1}
(c) W $m^{-1}K^{-1}$ (d) Jm K^{-1}

3. The damping force on an oscillator is directly proportional to the velocity. The unit of the constant of proportionality is

(a) kg-ms^{-1} (b) kg-ms^{-2}
(c) kgs^{-1} (d) kg-s

4. The density of a material in SI units is 128 kg m^{-3} . In certain units in which the unit of length is 25 cm and the unit of mass is 50 g, the numerical value of density of the material is

(a) 40 (b) 16 (c) 640 (d) 410

5. If the value of work done is 10^{10} g-$cm^2 s^{-2}$, then its value in SI units will be

(a) 10 kg-$m^2 s^{-2}$ (b) 10^2 kg-$m^2 s^{-2}$
(c) 10^4 kg-$m^2 s^{-2}$ (d) 10^3 kg-$m^2 s^{-2}$

6. Amongst the following options, which is a unit of time?

(a) Light year (b) Parsec
(c) Year (d) None of these

7. The moon is observed from two diametrically opposite points A and B on earth. The angle θ subtended at the moon by the two directions of observation is 1°54′; given that the diameter of the earth to be about 1.276×10^7 m. Compute the distance of the moon from the earth.

(a) 4.5×10^9 m
(b) 3.83×10^8 m
(c) 2.5×10^4 m
(d) 4×10^7 m

8. The ratio of the volume of the atom to the volume of the nucleus is of the order of

(a) 10^{15} (b) 10^{25}
(c) 10^{20} (d) 10^{10}

9. Which of the following measurement is most precise? *(NCERT Exemplar)*

(a) 5.00 mm (b) 5.00 cm
(c) 5.00 m (d) 5.00 km

10. A student measured the length of a rod and wrote it as 3.50 cm. Which instrument did he use to measure it?

(a) A meter scale
(b) A vernier calliper where the 10 divisions in vernier scale matches with 9 divisions in main scale and main scale has 10 divisions in 1 cm
(c) A screw gauge having 100 divisions in the circular scale and pitch as 1 mm
(d) A screw gauge having 50 divisions in the circular scale and pitch as 1 mm

11. The length, breadth and height of a rectangular block of wood were measured to be $l = 12.13 \pm 0.02$ cm, $b = 8.16 \pm 0.01$ cm and $h = 3.46 \pm 0.01$ cm.

(a) 0.88% (b) 0.58%
(c) 0.78% (d) 0.68%

12. A student measures the time period of 100 oscillations of a simple pendulum four times. The data set is 90s, 91s, 92s and 95s. If the minimum division in the measuring clock is 1s, then the reported mean time should be

(a) (92 ± 2)s (b) (92 ± 5)s
(c) (92 ± 1.8)s (d) (92 ± 3)s

13. In successive experiments while measuring the period of oscillation of a simple pendulum. The readings turn out to be 2.63 s, 2.56 s, 2.42 s, 2.71s and 2.80 s. Calculate the mean absolute error.

(a) 0.11 s (b) 0.42 s (c) 0.92 s (d) 0.10 s

14. The period of oscillation of a simple pendulum is $T = 2\pi\sqrt{L/g}$. Measured value of L is 20 cm known to 1 mm accuracy and time for 100 oscillations of the pendulum is found to be 90 s using a wrist watch of 1s resolution.What is the percentage error in the determination of g?

(a) 5% (b) 3%
(c) 4% (d) 7%

15. Calculate the mean percentage error in five observations,

80.0, 80.5, 81.0, 81.5 and 82.

(a) 0.74% (b) 1.74%
(c) 0.38% (d) 1.38%

16. Calculate the relative errors in measurement of two masses 1.02 g ± 0.01g and 9.89g ± 0.01g .

(a) ± 1% and ± 0.2% (b) ± 1% and ± 0.1%
(c) ± 2% and ± 0.3% (d) ± 3% and ± 0.4%

17. The density of a material in the shape of a cube is determined by measuring three sides of the cube and its mass. If the relative errors in measuring the mass and length are respectively 1.5% and 1%, the maximum error in determining the density is

(a) 2.5% (b) 3.5% (c) 4.5% (d) 6%

18. Percentage errors in the measurement of mass and speed are 2% and 3%, respectively. The error in the estimation of kinetic energy obtained by measuring mass and speed will be

(a) 8% (b) 2%
(c) 12% (d) 10%

19. If the length of a pendulum is increased by 2%, then in a day, the pendulum

(a) loses 764 s (b) loses 924 s
(c) gains 236 s (d) loses 864 s

20. The length and breadth of a rectangular sheet are 16.2 cm and 10.1 cm, respectively. The area of the sheet in appropriate significant figures and error is *(NCERT Exemplar)*

(a) $164 \pm 3\ cm^2$ (b) $163.62 \pm 2.6\ cm^2$
(c) $163.6 \pm 2.6\ cm^2$ (d) $163.62 \pm 3\ cm^2$

21. In an experiment, four quantities a, b, c and d are measured with percentage error 1%, 2%, 3% and 4%, respectively. Quantity P is calculated as follows $P = \frac{a^3 b^2}{cd}$, percentage error in P is

(a) 14% (b) 10% (c) 7% (d) 4%

22. A physical quantity z depends on four observables a, b, c and d, as $z = \frac{a^2 b^{2/3}}{\sqrt{c} d^3}$.

The percentages of error in the measurement of a, b, c and d are 2%, 1.5%, 4% and 2.5% respectively. The percentage of error in z is

(a) 13.5% (b) 16.5% (c) 14.5% (d) 12.25%

23. The respective number of significant figures for the numbers 23.023, 0.0003 and 2.1×10^{-3} are

(a) 5, 1, 2 (b) 5, 1, 5
(c) 5, 5, 2 (d) 4, 4, 2

24. If 3.8×10^{-6} is added to 42×10^{-6} giving due regard to significant figures, then the result will be

(a) 4.58×10^{-5} (b) 4.6×10^{-5}
(c) 45×10^{-5} (d) None of these

25. The numbers 5.355 and 5.345 on rounding off to 3 significant figures will give

(a) 5.35 and 5.34 (b) 5.36 and 5.35
(c) 5.35 and 5.35 (d) 5.36 and 5.34

26. The mass and volume of a body are 4.237 g and 2.5 cm^3, respectively. The density of the material of the body in correct significant figures is *(NCERT Exemplar)*

(a) 1.6048 g cm^{-3} (b) 1.69 g cm^{-3}
(c) 1.7 g cm^{-3} (d) 1.695 g cm^{-3}

27. If mass M, distance L and time T are fundamental quantities, then find the dimensions of torque.

(a) $[ML^2T^{-2}]$ (b) $[MLT^{-2}]$
(c) $[MLT]$ (d) $[ML^2T]$

28. Let l, r, c and v represent inductance, resistance, capacitance and voltage, respectively. The dimension of $\frac{l}{rcv}$ in SI units will be

(a) $[LT^2]$ (b) $[LTA]$
(c) $[A^{-1}]$ (d) $[LA^{-2}]$

29. Obtain the dimensional formula for universal gas constant.

(a) $[ML^2 T^{-2} mol^{-1} K^{-1}]$
(b) $[ML^3 T^{-1} mol^{-2} K^{-2}]$
(c) $[M^2 LT^{-1} mol^{-1} K^{-1}]$
(d) $[M^3 LT^{-2} mol^{-1} K^{-2}]$

30. Which two of the following five physical parameters have the same dimensions?

I. Energy density
II. Refractive index
III. Dielectric constant
IV. Young's modulus
V. Magnetic field

(a) I and IV (b) III and V
(c) I and II (d) I and V

31. If P, Q, R are physical quantities, having different dimensions, which of the following combinations can never be a meaningful quantity?

(a) $(P-Q)/R$ (b) $PQ-R$
(c) PQ/R (d) $(PR-Q^2)/R$

32. The potential energy of a particle varies with distance x from a fixed origin as $U=\frac{A\sqrt{x}}{x+B}$, where A and B are constants. The dimensions of AB are

(a) $[ML^{5/2} T^{-2}]$ (b) $[ML^2 T^{-2}]$
(c) $[M^{3/2}L^3 T^{-2}]$ (d) $[ML^{7/2} T^{-2}]$

33. In the formula, $X=3YZ^2$, X and Z have dimensions of capacitance and magnetic induction. The dimensions of Y in MKSQ system are

(a) $[M^{-3}L^{-2}T^4Q^4]$ (b) $[ML^2T^8Q^4]$
(c) $[M^{-2}L^{-3}T^2Q^4]$ (d) $[M^{-2}L^{-2}TQ^2]$

34. If the velocity v (in cms^{-1}) of a particle is given in terms of t (in second) by the relation $v=at+\frac{b}{t+c}$, then the dimensions of a, b and c are

	a	b	c
(a)	$[L]$	$[LT]$	$[T^2]$
(b)	$[L^2]$	$[T]$	$[LT^{-2}]$
(c)	$[LT^2]$	$[LT]$	$[L]$
(d)	$[LT^{-2}]$	$[L]$	$[T]$

35. A book with many printing errors contains four different formulae for the displacement y of a particle under going a certain periodic motion,

where, a = maximum displacement of the particle, v = speed of the particle, T = time period of motion.
Which are the correct formulae on dimensional grounds?

(a) $y=a\sin\frac{2\pi t}{T}$ (b) $y=a\sin vt$
(c) $y=\left(\frac{a}{T}\right)\sin(t/a)$ (d) None of these

36. If speed V, area A and force F are chosen as fundamental units, then the dimensional formula of Young's modulus will be

(a) $[FA^2V^{-3}]$ (b) $[FA^{-1}V^0]$
(c) $[FA^2 V^{-2}]$ (d) $[FA^2V^{-1}]$

37. If dimensions of critical velocity v_c of a liquid flowing through a tube are expressed as $[\eta^x \rho^y r^z]$, where η, ρ and r are the coefficient of viscosity of liquid, density of liquid and radius of the tube respectively, then the values of x, y and z are given by

(a) 1, −1, −1 (b) −1, −1, 1
(c) −1, −1, −1 (d) 1, 1, 1

38. The density of a material in CGS system is 10 g cm^{-3}. If unit of length becomes 10 cm and unit of mass becomes 100 g, the new value of density will be

(a) 10 units (b) 100 units
(c) 1000 units (d) 1 unit

39. When 1 m, 1 kg and 1 min are taken as the fundamental units, the magnitude of the force is 36 units. What will be the value of this force in CGS system?

(a) 10^5 dyne (b) 10^3 dyne
(c) 10^8 dyne (d) 10^4 dyne

40. The solid angle subtended by the periphery of an area $1\ cm^2$ at a point situated symmetrically at a distance of 5 cm from the area is ……… steradian.

(a) 2×10^{-2} (b) 4×10^{-2} (c) 6×10^{-2} (d) 8×10^{-2}

41. Measure of two quantities along with the precision of respective measuring instrument is $A = 2.5\ ms^{-1} \pm 0.5\ ms^{-1}$, $B = 0.10\ s \pm 0.01\ s$. The value of AB will be ……… . *(NCERT Exemplar)*

(a) (0.25 ± 0.08) m (b) (0.25 ± 0.5) m
(c) (0.25 ± 0.05) m (d) (0.25 ± 0.135) m

42. It is claimed that two cesium clocks, if allowed to run for 100 yrs without any disturbance may differ by only about 0.02 s. Then the accuracy of the clock in measuring a time interval of 1 s is ……… .

(a) 10^{-10} (b) 10^{-11}
(c) 10^{-5} (d) 10^{-8}

43. Photon is quantum of radiation with energy $E = h\nu$, where ν is frequency and h is Planck's constant. The dimensions of h are the same as that of ……… .

(a) linear impulse
(b) angular impulse
(c) linear momentum
(d) energy

44. Which amongst the following statement is incorrect regarding mass?

(a) Its SI unit is kilogram.
(b) It does not depend on the location of the object in space.
(c) It is the basic property of matter.
(d) While dealing with atoms, kilogram is a convenient unit for measuring mass.

45. Choose the incorrect statement out of the following.

(a) Every measurement by any measuring instrument has some errors.
(b) Every calculated physical quantity that is based on measured values has some errors.
(c) A measurement can have more accuracy but less precision and *vice-versa*.
(d) The percentage error is different from relative error.

46. Given that T stands for time period and l stands for the length of simple pendulum. If g is the acceleration due to gravity, then which of the following statements about the relation $T^2 = l/g$ is correct?

(a) It is correct both dimensionally as well as numerically.
(b) It is neither dimensionally correct nor numerically.
(c) It is dimensionally correct but not numerically.
(d) It is numerically correct but not dimensionally.

47. Match the following columns.

	Column I		Column II
A.	Capacitance	p.	volt $(\text{ampere})^{-1}$
B.	Magnetic induction	q.	volt-sec $(\text{ampere})^{-1}$
C.	Inductance	r.	newton $(\text{ampere})^{-1}$ $(\text{metre})^{-1}$
D.	Resistance	s.	$\text{coulomb}^2(\text{joule})^{-1}$

Codes

	A	B	C	D
(a)	q	r	s	p
(b)	s	r	q	p
(c)	r	s	p	q
(d)	s	p	q	r

48. Match the Column I (unit) with Column II (value) and select the correct option from the codes given below.

	Column I		Column II
A.	1 are	p.	200 mg
B.	1 bar	q.	1.013×10^5 Pa
C.	1 carat	r.	10^2 m^2

Codes

	A	B	C
(a)	q	p	r
(b)	r	r	p
(c)	r	q	p
(d)	r	p	q

49. Names of units of some physical quantities are given in Column I and their dimensional formulae are given in Column II and select the correct option from the codes given below.

	Column I		Column II
A.	Pa-s	p.	$[L^2T^{-2}K^{-1}]$
B.	$Nm\text{-}K^{-1}$	q.	$[MLT^{-2}A^{-1}K^{-1}]$
C.	$J\ kg^{-1}\ K^{-1}$	r.	$[ML^{-1}T^{-1}]$
D.	$Wb\ m^{-1}\ K^{-1}$	s.	$[ML^2T^{-2}K^{-1}]$

Codes

	A	B	C	D
(a)	s	r	p	q
(b)	r	q	s	p
(c)	r	p	s	q
(d)	r	s	p	q

Assertion-Reasoning MCQs

*For question numbers 50 to 59, two statements are given-one labelled **Assertion** (A) and the other labelled **Reason** (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

50. **Assertion** Unit chosen for measuring physical quantities should not be easily reproducible.

Reason Unit should change with the changing physical conditions like temperature, pressure, etc.

51. **Assertion** The unit used for measuring nuclear cross-section is 'barn'.

Reason 1 barn = 10^{-14} m^2.

52. **Assertion** When we change the unit of measurement of a quantity, its numerical value changes.

Reason Smaller the unit of measurement smaller is its numerical value.

53. **Assertion** Parallax method is used for measuring distances of nearby stars only.

Reason With increase in the distance of star from earth, the parallactic angle becomes too small to be measured accurately.

54. **Assertion** Out of two measurements $l = 0.7$ m and $l = 0.70$ m, the second one is more accurate.

Reason In every measurement, the last digit is not accurately know.

55. **Assertion** Random errors arise due to random and unpredictable fluctuations in experimental conditions.

Reason Random errors occurred due to irregularly with respect to sign and size.

56. **Assertion** When a quantity appears with a power n greater than one in an expression, its error contribution to the final result decreases n times.

Reason In all mathematical operations, the errors are not additive in nature.

57. **Assertion** Special functions such as trigonometric, logarithmic and exponential functions are not dimensionless.

Reason A pure number, ratio of similar physical quantities, such as angle and refractive index, has some dimensions.

58. **Assertion** Specific gravity of a fluid is a dimensionless quantity.

Reason It is the ratio of density of fluid to the density of water.

59. **Assertion** The method of dimensions analysis cannot validate the exact relationship between physical quantities in any equation.

Reason It does not distinguish between the physical quantities having same dimensions.

Case Based MCQs

Direction Answer the questions from 60-64 on the following case.

Measurement of Physical Quantity

All engineering phenomena deal with definite and measured quantities and so depend on the making of the measurement. We must be clear and precise in making these measurements. To make a measurement, magnitude of the physical quantity (unknown) is compared.

The record of a measurement consists of three parts, i.e. the dimension of the quantity, the unit which represents a standard quantity and a number which is the ratio of the measured quantity to the standard quantity.

60. A device which is used for measurement of length to an accuracy of about 10^{-5} m, is

(a) screw gauge (b) spherometer
(c) vernier callipers (d) Either (a) or (b)

61. Which of the technique is not used for measuring time intervals?

(a) Electrical oscillator
(b) Atomic clock
(c) Spring oscillator
(d) Decay of elementary particles

62. The mean length of an object is 5 cm. Which of the following measurements is most accurate?

(a) 4.9 cm (b) 4.805 cm
(c) 5.25 cm (d) 5.4 cm

63. If the length of rectangle $l = 10.5$ cm, breadth $b = 2.1$ cm and minimum possible measurement by scale = 0.1 cm, then the area is

(a) 22.0 cm^2 (b) 21.0 cm^2
(c) 22.5 cm^2 (d) 21.5 cm^2

64. Age of the universe is about 10^{10} yr, whereas the mankind has existed for 10^6 yr. For how many seconds would the man have existed, if age of universe were 1 day?

(a) 9.2 s (b) 10.2 s
(c) 8.6 s (d) 10.5 s

Direction *Answer the questions from 65-69 on the following case.*

Significant Digits

Normally, the reported result of measurement is a number that includes all digits in the number that are known reliably plus first digit that is uncertain. The digits that are known reliably plus the first uncertain digit are known as significant digits or significant figures.

e.g. When a measured distance is reported to be 374.5 m, it has four significant figures 3, 7, 4 and 5. The figures 3, 7, 4 are certain and reliable, while the digit 5 is uncertain. Clearly, the digits beyond the significant digits reported in any result are superfluous.

65. In 4700 m, significant digits are

(a) 2 (b) 3 (c) 4 (d) 5

66. To determine the number of significant figures, scientific notation is

(a) a^b (b) $a \times 10^b$
(c) $a \times 10^2$ (d) $a \times 10^4$

67. 5.74 g of a substance occupies $1.2\ cm^3$. Express its density by keeping the significant figures in view.

(a) 4.9 g cm^{-3} (b) 5.2 g cm^{-3}
(c) 4.8 g cm^{-3} (d) 4.4 g cm^{-3}

68. Choose the correct option.

(a) Change in unit does not change the significant figure.
(b) 4.700 m = 4700 mm, here there is a change of significant number from 4 to 2 due to change in unit.
(c) 4700 m = 4.700×10^3 m, here there is change in numbers of significant numbers.
(d) Change in unit changes the number of significant figure.

69. Consider the following rules of significant figures.

I. All the non-zero digits are significant.
II. All the zeroes between two non-zero digits are significant.
III. The terminal or trailing zero(s) in a number without a decimal point are significant.

Which of the above statement(s) is/are correct?

(a) I and II (b) II and III
(c) I and III (d) All of these

Direction *Answer the questions from 70-74 on the following case.*

Combination of Errors

Maximum absolute error in the sum or difference of two quantities is equal to sum of the absolute error in the individual quantities, i.e. $Z = A + B$, then $\pm \Delta Z = \pm \Delta A \pm \Delta B$

Maximum fractional error in a product or division of quantities is equal to the sum of fractional errors in the individual quantities

i.e. AB or $\frac{A}{B}$, then $\frac{\Delta Z}{Z} = \pm \frac{\Delta A}{A} + \frac{\Delta B}{B}$

Two resistors of resistances $R_1 = 100 \pm 3\ \Omega$ and $R_2 = 200 \pm 4\Omega$ are connected (a) in series and (b) in parallel.

70. The percentage error in the value of R_1 is

(a) 3% (b) 4% (c) 6% (d) 0.3%

71. The fractional error in the value of R_2 is

(a) $\frac{1}{40}$ (b) $\frac{1}{50}$
(c) $\frac{1}{100}$ (d) $\frac{1}{200}$

72. Find the equivalent resistance of the series combination.

(a) $(250 \pm 7)\,\Omega$
(b) $(320 \pm 6)\,\Omega$
(c) $(300 \pm 7)\,\Omega$
(d) $(300 \pm 1)\,\Omega$

73. The percentage error in equivalent resistance in series combination is

(a) 2% (b) 2.3%
(c) 2.5% (d) 3%

74. Find the equivalent resistance of the parallel combination having error of 1.8 Ω.

(a) $(66 \pm 1)\,\Omega$ (b) $(66.7 \pm 1.8)\,\Omega$
(c) $(66.3 \pm 2)\,\Omega$ (d) $(67 \pm 3)\,\Omega$

Direction *Answer the questions from 75-79 on the following case.*

Dimensional analysis and its applications

The expression which shows how and which of the base quantities represent the dimensions of a physical quantity is called the dimensional formula of the given physical quantity. The recognition of concepts of dimensions, which guide the description of physical behaviour is of basic importance as only those physical quantities can be added or subtracted which have the same dimensions. A thorough understanding of dimensional analysis helps us in deducing certain relations among different physical quantities and checking the derivation, accuracy and dimensional consistency or homogeneity of various mathematical expressions. When magnitudes of two or more physical quantities are multiplied, their units should be treated in the same manner as ordinary algebraic symbols. We can cancel identical units in the numerator and denominator. The same is true for dimensions of a physical quantity. Similarly, physical quantities represented by symbols on both sides of a mathematical equation must have the same dimensions.

75. Statement I The method of dimensions analysis cannot validate the exact relationship between physical quantities in any equation.

Statement II It does not distinguish between the physical quantities having same dimensions.

Which of the following statement(s) is/are correct?

(a) Only I (b) I and II
(c) Only II (d) None of these

76. The quantity having same dimension as that of Planck's constant is

(a) work (b) linear momentum
(c) angular momentum (d) impulse

77. If speed v, acceleration A and force F, are considered as fundamental units, the dimension of Young's modulus will be

(a) $[v^{-4}A^{-2}F]$ (b) $[v^{-2}A^{2}F^{2}]$
(c) $[v^{-2}A^{2}F^{-2}]$ (d) $[v^{-4}A^{2}F^{1}]$

78. Given that, the amplitude of the scattered light is

(i) directly proportional to amplitude of incident light
(ii) directly proportional to the volume of the scattering dust particle
(iii) inversely proportional to its distance from the scattering particle and
(iv) dependent upon the wavelength λ of the light.

Then, the relation of intensity of scattered light with the wavelength is

(a) $\frac{1}{\lambda^2}$ (b) $\frac{1}{\lambda^4}$ (c) $\frac{1}{\lambda^6}$ (d) $\frac{1}{\lambda^7}$

79. Find the value of power of 60 J/min on a system that has 100 g, 100 cm and 1 min as the base units.

(a) 2.16×10^4 units (b) 2.16×10^6 units
(c) 3×10^4 units (d) 4×10^7 units

ANSWERS

Multiple Choice Questions

1. (b)	2. (c)	3. (c)	4. (a)	5. (d)	6. (c)	7. (b)	8. (a)	9. (a)	10. (b)
11. (b)	12. (a)	13. (a)	14. (b)	15. (a)	16. (b)	17. (c)	18. (a)	19. (d)	20. (a)
21. (a)	22. (c)	23. (a)	24. (b)	25. (d)	26. (c)	27. (a)	28. (c)	29. (a)	30. (a)
31. (a)	32. (d)	33. (a)	34. (d)	35. (a)	36. (b)	37. (a)	38. (b)	39. (b)	40. (b)
41. (a)	42. (b)	43. (b)	44. (d)	45. (d)	46. (c)	47. (b)	48. (c)	49. (d)	

Assertion-Reasoning MCQs

50. (d)	51. (c)	52. (c)	53. (a)	54. (b)	55. (b)	56. (d)	57. (d)	58. (a)	59. (a)

Case Based MCQs

60. (d)	61. (c)	62. (a)	63. (a)	64. (c)	65. (a)	66. (b)	67. (c)	68. (a)	69. (a)
70. (a)	71. (b)	72. (c)	73. (b)	74. (b)	75. (b)	76. (c)	77. (d)	78. (b)	79. (b)

SOLUTIONS

1. Time is the quantity which has same unit in all systems of unit, i.e. second. Other three quantities, i.e. mass, length and temperature have different units in different system of units.

2. The coefficient of thermal conductivity is given by

$$K = \frac{L}{A\Delta T}\frac{dQ}{dt}$$

where, L = length of conductor, A = area of conductor, ΔT = change in temperature and $\frac{dQ}{dt}$ = rate of flow of heat.

$\therefore$ Unit of $K = \frac{\text{metre}}{(\text{metre})^2 \times (\text{kelvin})} \times \text{watt}$

$= \text{Wm}^{-1}\text{K}^{-1}$

3. Given, damping force $\propto$ velocity

$$F \propto v \Rightarrow F = kv \Rightarrow k = \frac{F}{v}$$

Unit of $k = \frac{\text{Unit of } F}{\text{Unit of } v} = \frac{\text{kg - ms}^{-2}}{\text{ms}^{-1}} = \text{kg s}^{-1}$

4. To convert a measured value from one system to another system, we use

$$N_1 u_1 = N_2 u_2$$

where, N is numeric value and u is unit.

We get,

$$\therefore \quad 128 \cdot \frac{\text{kg}}{\text{m}^3} = N_2 \frac{50 \text{ g}}{(25 \text{ cm})^3}$$

$$\left[\because \text{density} = \frac{\text{mass}}{\text{volume}}\right]$$

$$\Rightarrow \frac{128 \times 1000 \text{ g}}{100 \times 100 \times 100 \text{ cm}^3} = \frac{N_2 \times 50 \text{ g}}{25 \times 25 \times 25 \text{ cm}^3}$$

$$\Rightarrow \quad N_2 = \frac{128 \times 1000 \times 25 \times 25 \times 25}{50 \times 100 \times 100 \times 100} = 40$$

5. Given, work done,

$$W = 10^{10} \text{g-cm}^2\text{s}^{-2}$$

which is in CGS system of units.

In SI unit, $W = 10^{10} \frac{\text{g}}{\text{s}^2}\text{cm}^2$

$$= 10^{10} \frac{(10^{-3}\text{kg})(10^{-4}\text{ m}^2)}{1\text{s}^2}$$

$$= 10^3 \text{kg-m}^2\text{s}^{-2}$$

6. We know that, 1 light year $= 9.46 \times 10^{11}$ m

= distance that light travels in 1 year with speed 3×10^8 m/s.

1 parsec = 3.08×10^{16} m

= Distance at which average radius of earth's orbit subtends an angle of 1 parsecond.

Here, year represent time.

7. We have, $\theta = 1^\circ 54' = (60 + 54)'$

$$= 114' = (114 \times 60)''$$

Since, $1'' = 4.85 \times 10^{-6}$ rad

$$= (114 \times 60)'' \times (4.85 \times 10^{-6}) \text{ rad}$$

$$= 3.33 \times 10^{-2} \text{ rad}$$

Also, diameter of earth, $b = 1.276 \times 10^7$ m

Hence, the earth-moon distance is given as

$$D = b/\theta = \frac{1.276 \times 10^7}{3.33 \times 10^{-2}} = 3.83 \times 10^8 \text{ m}$$

8. We know that, radius of atom, $r_a = 10^{-10}$ m

Radius of nucleus, $r_n = 10^{-15}$ m

$\therefore$ Ratio, $\dfrac{r_a}{r_n} = \dfrac{10^{-10}}{10^{-15}} = 10^5$

$$\text{Ratio of volume} = \frac{\frac{4}{3}\pi r_a^3}{\frac{4}{3}\pi r_n^3} = \left(\frac{r_a}{r_n}\right)^3$$

$$= (10^5)^3 = 10^{15}$$

9. All given measurements are correct upto two decimal places. As here 5.00 mm has the smallest unit and the error in 5.00 mm is least (commonly taken as 0.01 mm if not specified), hence 5.00 mm is most precise.

10. If student measure 3.50 cm, it means that there in an uncertainly of order 0.01 cm.

For vernier scale with 1 MSD

= 1mm and 9 MSD = 10 VSD

$\therefore$ LC of VC = 1 MSD − 1 VSD

$$= \frac{1}{10}\left(1 - \frac{9}{10}\right) = \frac{1}{100} \text{ cm}$$

11. Volume of block, $V = lbh$

The percentage error in the volume is given by

$$\frac{\Delta V}{V} \times 100 = \left(\frac{\Delta l}{l} + \frac{\Delta b}{b} + \frac{\Delta h}{h}\right) \times 100$$

$$= \left(\frac{0.02}{12.13} + \frac{0.01}{8.16} + \frac{0.01}{3.46}\right) \times 100$$

$$= \left(\frac{200}{1213} + \frac{100}{816} + \frac{100}{346}\right)$$

= 0.1649 + 0.1225 + 0.2890

= 0.58% (rounded off to two significant figures)

12. Arithmetic mean time of a oscillating simple pendulum $= \dfrac{\Sigma x_i}{N} = \dfrac{90 + 91 + 92 + 95}{4} = 92$ s

Mean deviation of a simple pendulum

$$= \frac{\Sigma |\bar{x} - x_i|}{N} = \frac{2 + 1 + 3 + 0}{4} = 1.5$$

Given, minimum division in the measuring clock, i.e. simple pendulum = 1 s. Thus, the reported mean time of a oscillating simple pendulum = (92 ± 2) s.

13. The mean period of oscillation of the pendulum,

$$T_{\text{mean}} = \frac{2.63 + 2.56 + 2.42 + 2.71 + 2.80}{5}$$

$$= \frac{13.12}{5} = 2.624 = 2.62 \text{ s}$$

The absolute errors in the measurements are

$$\Delta T_1 = 2.63 \text{ s} - 2.62 \text{ s} = 0.01 \text{ s}$$
$$\Delta T_2 = 2.56 \text{ s} - 2.62 \text{ s} = -0.06 \text{ s}$$
$$\Delta T_3 = 2.42 \text{ s} - 2.62 \text{ s} = -0.20 \text{ s}$$
$$\Delta T_4 = 2.71 \text{ s} - 2.62 \text{ s} = 0.09 \text{ s}$$
$$\Delta T_5 = 2.80 \text{ s} - 2.62 \text{ s} = 0.18 \text{ s}$$

The arithmetic mean of all the absolute errors is

$$\Delta T_{\text{mean}} = \sum_{i=1}^{5} \frac{|\Delta T_i|}{5}$$

$$= [(0.01 + 0.06 + 0.20 + 0.09 + 0.18)] / 5$$
$$= 0.54/5 = 0.108 \simeq 0.11 \text{ s}$$

14. As we know, time period of oscillation is $T = 2\pi\sqrt{\dfrac{L}{g}}$

So, $g = 4\pi^2 L/T^2$

Therefore, relative error in g is

$(\Delta g/g) = (\Delta L/L) + 2(\Delta T/T)$

Given, $\Delta L = 1$ mm = 0.1 cm, $L = 20$ cm, $\Delta T = 1$ s and $T = 90$ s

$$\Rightarrow \frac{\Delta g}{g} = \frac{0.1}{20} + 2\left(\frac{1}{90}\right) = 0.027$$

Thus, the percentage error in g is

$$= \frac{\Delta g}{g} \times 100\%$$

$$= 0.027 \times 100\% = 2.7\% \simeq 3\%$$

15. Mean of the five observations,

$$\mu = \frac{80.0 + 80.5 + 81.0 + 81.5 + 82}{5}$$

$= \frac{405.0}{5} = 81$

$\therefore$ Mean error

$$= \frac{\left[\begin{array}{l}|80-\mu|+|80.5-\mu|+|81.0-\mu| \\ \quad +|81.5-\mu|+|82-\mu|\end{array}\right]}{5}$$

$$= \frac{\left[\begin{array}{l}|80-81|+|80.5-81|+|81.0-81| \\ \quad +|81.5-81|+|82-81|\end{array}\right]}{5}$$

$$= \frac{1+0.5+0+0.5+1}{5} = \frac{3}{5} = 0.6$$

$\therefore$ Mean % error $= \frac{0.6}{81} \times 100\% = 0.74\%$

16. The error in the measurement of mass 1.02 g is ± 0.01 g,

whereas that of another measurement 9.89 g is also ± 0.01 g.

$\therefore$ The relative error in 1.02 g

$= [\pm 0.01/1.02)] \times 100\% = \pm 0.98\% \cong \pm 1\%$

Similarly, the relative error in 9.89 g

$= [\pm 0.01/9.89] \times 100\% = \pm 0.1\%$

The relative errors in measurement of two masses are ± 1% and ± 0.1%.

17. $\because$ Density, $\rho = \frac{\text{Mass}}{\text{Volume}} = \frac{M}{L^3}$ or $\rho = \frac{M}{L^3}$

$\Rightarrow$ Error in density $\frac{\Delta\rho}{\rho} = \frac{\Delta M}{M} + \frac{3\Delta L}{L}$

So, maximum % error in measurement of ρ is

$$\frac{\Delta\rho}{\rho} \times 100 = \frac{\Delta M}{M} \times 100 + \frac{3\Delta L}{L} \times 100$$

or % error in density $= 1.5 + 3 \times 1$

% error = 4.5%

18. Kinetic energy, $K = \frac{1}{2} mv^2$

$$\therefore \frac{\Delta K}{K} \times 100 = \frac{\Delta m}{m} \times 100 + \frac{2\Delta v}{v} \times 100$$

$$= 2\% + 2 \times 3\% = 8\%$$

19. Time period, $T = 2\pi\sqrt{\frac{l}{g}}$

or $\frac{\Delta T}{T} = \frac{1}{2}\frac{\Delta l}{l}$

For 1 s ,

$$\Delta T = \frac{1}{2}\left(\frac{\Delta l}{l}\right) T = \frac{1}{2} \times 0.02 \times T = 0.01\, T$$

For a day, the pendulum loses,

$$\Delta T = 24 \times 60 \times 60 \times 0.01 = 864 \text{ s}$$

20. Given, length, $l = (16.2 \pm 0.1)$ cm

Breadth, $b = (10.1 \pm 0.1)$ cm

Area, $A = l \times b$

$= (16.2 \text{ cm}) \times (10.1 \text{ cm}) = 163.62 \text{ cm}^2$

Rounding off to three significant digits,

area, $A = 164 \text{ cm}^2$

$$\frac{\Delta A}{A} = \frac{\Delta l}{l} + \frac{\Delta b}{b} = \frac{0.1}{16.2} + \frac{0.1}{10.1}$$

$$= \frac{1.01 + 1.62}{16.2 \times 10.1} = \frac{2.63}{163.62}$$

$$\Rightarrow \Delta A = A \times \frac{2.63}{163.62} = 163.62 \times \frac{2.63}{163.62}$$

$$= 2.63 \text{ cm}^2 \approx 3 \text{ cm}^2$$

(By rounding off to one significant figure)

$\therefore$ Area, $A = A \pm \Delta A = (164 \pm 3) \text{ cm}^2$

21. Given, $P = \frac{a^3 b^2}{cd}$, $\frac{\Delta a}{a} \times 100\% = 1\%$,

$\frac{\Delta b}{b} \times 100\% = 2\%$, $\frac{\Delta c}{c} \times 100\% = 3\%$

and $\frac{\Delta d}{d} \times 100\% = 4\%$

$\therefore$ % error in $P = \left(\frac{\Delta P}{P} \times 100\right)\%$

$$= \left(\frac{3\Delta a}{a} + \frac{2\Delta b}{b} + \frac{\Delta c}{c} + \frac{\Delta d}{d}\right) \times 100\%$$

$$= \left(\begin{array}{l} 3\frac{\Delta a}{a} \times 100\% + 2\frac{\Delta b}{b} \times 100\% \\ \quad + \frac{\Delta c}{c} \times 100\% + \frac{\Delta d}{d} \times 100\% \end{array}\right)$$

$$= 3 \times 1\% + 2 \times 2\% + 3\% + 4\% = 14\%$$

22. Given, $z = \frac{a^2 b^{2/3}}{\sqrt{c}\, d^3}$

According to question,

% error in $z = (2)$% error in $a + \left(\frac{2}{3}\right)$% error in b $+ \left(\frac{1}{2}\right)$% error in $c + (3)$% error in d

$$\frac{\Delta z}{z} = 2\frac{\Delta a}{a} + \frac{2}{3}\frac{\Delta b}{b} + \frac{1}{2}\frac{\Delta c}{c} + 3\frac{\Delta d}{d}$$

$$= 2 \times 2\% + \frac{2}{3} \times 1.5\% + \frac{1}{2} \times 4\% + 3 \times 2.5\%$$

$$= 14.5\%$$

23. The reliable digit plus the first uncertain digit is known as significant figures.
For the number 23.023, all the non-zero digits are significant, hence 5.
For the number 0.0003, number is less than 1, the zero(s) on the right of decimal point but to the left of the first non-zero digit are not significant, hence 1.
For the number 2.1×10^{-3}, significant figures are 2.

24. By adding 3.8×10^{-6} and 42×10^{-6}, we get
$= 45.8 \times 10^{-6} = 4.58 \times 10^{-5}$
As least number of decimal figures in given values is 1, so we round off the result to 4.6×10^{-5}.

25. The number 5.355 rounded off to three significant figures becomes 5.36, since preceding digit of 5 is odd, hence it is raised by 1.
On other hand, the number 5.345 rounded off to three significant figures becomes 5.34. Since, the preceding digit of 5 is even.

26. In this question, density should be reported to two significant figures.
$$\text{Density} = \frac{4.237\text{g}}{2.5\ \text{cm}^3} = 1.6948$$
As rounding off the number, we get density $= 1.7\ \text{g cm}^{-3}$

27. Dimensions of torque,
$$\tau = \mathbf{F} \times \mathbf{r} = [\text{MLT}^{-2}]\,[\text{L}] = [\text{ML}^2\text{T}^{-2}]$$

28. Dimensions of given quantities are
l = inductance = $[\text{M}^1\ \text{L}^2\ \text{T}^{-2}\ \text{A}^{-2}]$
r = resistance = $[\text{M}^1\ \text{L}^2\ \text{T}^{-3}\ \text{A}^{-2}]$
c = capacitance = $[\text{M}^{-1}\ \text{L}^{-2}\ \text{T}^4\ \text{A}^2]$
v = voltage = $[\text{M}^1\ \text{L}^2\ \text{T}^{-3}\ \text{A}^{-1}]$
So, dimensions of $\frac{l}{rcv}$ are
$$\left[\frac{l}{rcv}\right] = \frac{[\text{M L}^2\ \text{T}^{-2}\ \text{A}^{-2}]}{[\text{M}^1\ \text{L}^2\ \text{T}^{-2}\ \text{A}^{-1}]} = [\text{A}^{-1}]$$

29. According to ideal gas equation, i.e. $pV = nRT$, where n is the number of moles of gases.
$$\therefore \text{Universal gas constant, } R = \frac{(p)\,(V)}{(n)(T)}$$
$$\text{Dimensional formula of } R = \frac{[\text{ML}^{-1}\ \text{T}^{-2}]\,[\text{L}^3]}{[\text{mol}]\ [\text{K}]} = [\text{ML}^2\text{T}^{-2}\ \text{mol}^{-1}\text{K}^{-1}]$$

30. I. $\text{Energy density} = \frac{\text{Energy}}{\text{Volume}} = \frac{[\text{ML}^2\text{T}^{-2}]}{[\text{L}^3]} = [\text{ML}^{-1}\text{T}^{-2}]$
II. Refractive index has no dimensions.
III. Dielectric constant has no dimensions.
IV. Young's modulus,
$$Y = \frac{Fl}{A\Delta l} = \frac{[\text{MLT}^{-2}][\text{L}]}{[\text{L}]^2[\text{L}]} = [\text{ML}^{-1}\text{T}^{-2}]$$
V. Magnetic field,
$$B = \frac{F}{Il} = \frac{[\text{MLT}^{-2}]}{[\text{A}][\text{L}]} = [\text{MT}^{-2}\text{A}^{-1}]$$

31. In this question, it is given that P, Q and R are having different dimensions, hence they cannot be added or subtracted, so we can say that (a) is not meaningful. We cannot say about the dimension of product of these quantities, hence (b), (c) and (d) may be meaningful.

32. Given, $U = \frac{A\sqrt{x}}{x + B}$
Dimensions of U = Dimensions of potential energy $= [\text{ML}^2\text{T}^{-2}]$
According to the principle of homogeneity,
Dimensions of B = Dimensions of $x = [\text{M}^0\text{LT}^0]$
$\therefore$ Dimensions of A
$$= \frac{\text{Dimensions of } U \times \text{Dimensions of } (x + B)}{\text{Dimensions of } \sqrt{x}}$$
$$= \frac{[\text{ML}^2\text{T}^{-2}]\ [\text{M}^0\text{LT}^0]}{[\text{M}^0\text{L}^{1/2}\text{T}^0]} = [\text{ML}^{5/2}\ \text{T}^{-2}]$$
Hence, dimensions of AB
$$= [\text{ML}^{5/2}\ \text{T}^{-2}]\ [\text{M}^0\text{LT}^0] = [\text{ML}^{7/2}\text{T}^{-2}]$$

33. According to question, $[X]$ = Dimensions of capacitance $= [\text{M}^{-1}\text{L}^{-2}\text{T}^2\text{Q}^2]$
and $[Z]$ = Dimensions of magnetic induction.
$= [\text{MT}^{-1}\text{Q}^{-1}]$

Given, $X = 3YZ^2$,

$\therefore \quad [Y] = \dfrac{[X]}{[Z^2]}$

$\Rightarrow \quad [Y] = \dfrac{[M^{-1}L^{-2}T^2Q^2]}{[M^2 T^{-2}Q^{-2}]} = [M^{-3}L^{-2}T^4Q^4]$

34. Given, $v = at + \dfrac{b}{t+c}$

Since, LHS is equal to velocity, so at and $\dfrac{b}{t+c}$ must have the dimensions of velocity.

$\therefore at = v$ or $a = \dfrac{v}{t} \Rightarrow [a] = \dfrac{[LT^{-1}]}{[T]} = [LT^{-2}]$

Now, c = time ($\because$ quantities are added)

$\therefore \quad c = t$

$[c] = [T]$

Now, $\dfrac{b}{t+c} = v$

$\therefore \quad b = v \times \text{time}$

$[b] = [LT^{-1}][T] = [L]$

35. The dimensions of LHS of each relation is [L],therefore the dimensions of RHS should be [L] as per the principle of homogeneity and the argument of the trigonometrical function, i. e. angle should be dimensionless.

(a) As $\dfrac{2\pi t}{T}$ is dimensionless, therefore dimensions of RHS = [L]. Thus, this formula is correct.

(b) Dimensions of RHS

$= [L]\sin[LT^{-1}][T] = [L]\sin[L]$

As angle is not dimensionless here, therefore, this formula is incorrect.

(c) Dimensions of RHS

$= \dfrac{[L]}{[T]}\sin\dfrac{[T]}{[L]} = [LT^{-1}]\sin[TL^{-1}]$

As angle is not dimensionless here, therefore this formula is incorrect.

$\therefore$ Thus, the correct formula on the dimensional ground is option (a).

36. Let Young's modulus is related to speed, area and force, as $Y = F^x A^y V^z$

Substituting dimensions, we have

$[ML^{-1}T^{-2}] = [MLT^{-2}]^x[L^2]^y[LT^{-1}]^z$

Comparing power of similar quantities, we have

$x = 1,\ x + 2y + z = -1$ and $-2x - z = -2$

Solving these, we get $x = 1,\ y = -1,\ z = 0$

So, $[Y] = [FA^{-1}V^0]$

37. Given, critical velocity of liquid flowing through tube is expressed as , $v_c \propto \eta^x \rho^y r^z$

Coefficient of viscosity of liquid, $\eta = [ML^{-1}T^{-1}]$

Density of liquid, $\rho = [ML^{-3}]$

Radius of a tube, $r = [L]$

Critical velocity of liquid, $v_c = [M^0LT^{-1}]$

$\Rightarrow \quad [M^0LT^{-1}] = [ML^{-1}T^{-1}]^x[ML^{-3}]^y[L]^z$

$[M^0LT^{-1}] = [M^{x+y}L^{-x-3y+z}T^{-x}]$

Comparing powers of M, L and T, we get

$x + y = 0,\ -x - 3y + z = 1,\ -x = -1$

On solving above equations, we get

$x = 1,\ y = -1,\ z = -1$

38. $\because$ Density $= \dfrac{\text{Mass}}{\text{Volume}}$

$\therefore$ Dimensions of density $= \dfrac{[M]}{[L]^3} = [ML^{-3}]$

Given, $n_1 = 10,\ M_1 = 1\text{ g},\ L_1 = 1\text{ cm}$,

In new system, $n_2 = ?,\ M_2 = 100\text{ g},\ L_2 = 10\text{ cm}$

So, conversion of 10g cm^{-3} (n_1) into new system

$$n_2 = n_1 \times \left[\frac{M_1}{M_2}\right]\left[\frac{L_1}{L_2}\right]^{-3}$$

$$= 10 \times \left(\frac{1}{100}\right)\left(\frac{1}{10}\right)^{-3}$$

$$= 10 \times \frac{1}{100} \times 10 \times 10 \times 10$$

$= 100$ units

39. As, dimensional formula of force $= [MLT^{-2}]$

$n_1 = 36,\ M_1 = 1\text{ kg},\ L_1 = 1\text{ m},\ T_1 = 1\text{ min} = 60\text{ s}$

$n_2 = ?,\ M_2 = 1\text{ g},\ L_2 = 1\text{ cm},\ T_2 = 1\text{ s}$

So, conversion of 36 units into CGS system,

i. e. $n_2 = n_1\left[\dfrac{M_1}{M_2}\right]^a\left[\dfrac{L_1}{L_2}\right]^b\left[\dfrac{T_1}{T_2}\right]^c$

$\Rightarrow \quad n_2 = n_1\left[\dfrac{1\text{ kg}}{1\text{g}}\right]^1\left[\dfrac{1\text{ m}}{1\text{ cm}}\right]^1\left[\dfrac{1\text{ min}}{1\text{ s}}\right]^{-2}$

$= 36\left[\dfrac{1000\text{ g}}{1\text{ g}}\right]\left[\dfrac{100\text{ cm}}{1\text{ cm}}\right]^1\left[\dfrac{60\text{ s}}{1\text{ s}}\right]^{-2} = 10^3$ dyne

40. Solid angle, $d\Omega = \frac{dA}{r^2} = \frac{1\,\text{cm}^2}{(5\,\text{cm})^2}$

$= 0.04$ steradian

$= 4\times10^{-2}$ steradian

41. Given, $A = 2.5\ \text{ms}^{-1} \pm 0.5\ \text{ms}^{-1}$,

$B = 0.10\ \text{s} \pm 0.01\ \text{s}$

$x = AB = (2.5)(0.10) = 0.25\ \text{m}$

$$\frac{\Delta x}{x} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$$

$$= \frac{0.5}{2.5} + \frac{0.01}{0.10} = \frac{0.05 + 0.025}{0.25} = \frac{0.075}{0.25}$$

$\Delta x = 0.075 = 0.08$ m, rounding off to two significant figures.

$AB = (0.25 \pm 0.08)$ m

42. 100 years in seconds $= 100\times365\times24\times60\times60$ s. Error that may occur in the clock after these many seconds is 0.02 s

$\therefore$ Error in 1 s $= \frac{0.02\ \text{s}}{100\times365\times24\times60\times60}$

$= 10^{-11}$ (approx.)

43. We know that, energy of radiation, $E = h\nu$

$$[h] = \frac{[E]}{[\nu]} = \frac{[\text{ML}^2\text{T}^{-2}]}{[\text{T}^{-1}]} = [\text{ML}^2\text{T}^{-1}]$$

Dimensions of linear impulse = Dimension of momentum = $[\text{MLT}^{-1}]$

As we know that, linear impulse $J = \Delta P$

$\Rightarrow$ Angular impulse $= \tau dt = \Delta L$

= change in angular momentum

Hence, dimensions of angular impulse

= dimension of angular momentum

$= [\text{ML}^2\text{T}^{-1}]$

This is similar to the dimensions of Planck's constant h.

Dimensions of energy is $[\text{ML}^2\text{T}^{-2}]$.

44. Statement given in option (d) is incorrect and it can be corrected as

While dealing with atoms, kilogram is an inconvenient unit. In this case, there is an important standard unit of mass called unified atomic mass unit (u), which has been established for expressing the mass of atom.

Rest statements are correct.

45. When the relative error is expressed in percentage, we call it as percentage error.

Thus, statement (d) is incorrect while all other statements regarding measurement of a quantity are correct.

46. The correct relation for time period of simple pendulum is $T = 2\pi(l/g)^{1/2}$.

So, the given relation is numerically incorrect as the factor of 2π is missing.

But, it is dimensionally correct.

47. Capacitance,

$$C = \frac{Q}{V} = \frac{Q^2}{W} = (\text{coulomb})^2\,\text{joule}^{-1}$$

Magnetic induction,

$$B = \frac{F}{il} = \frac{\text{newton}}{\text{ampere}\times\text{metre}}$$

$= (\text{newton})\,(\text{ampere})^{-1}(\text{metre})^{-1}$

Inductance, $L = \frac{e}{dI/dt} = \frac{\text{volt}}{\text{ampere/second}}$

$= \text{volt-second}\,(\text{ampere})^{-1}$

Resistance, $R = \frac{V}{I} = \frac{\text{volt}}{\text{ampere}}$

$= \text{volt}\,(\text{ampere})^{-1}$

Hence, A $\rightarrow$ s, B $\rightarrow$ r, C $\rightarrow$ q and D $\rightarrow$ p.

48. Are is also unit of area, 1 are $= 10^2\ \text{m}^2$

Atmospheric pressure is measured in SI unit of bar.

1 bar $= 1.013\times10^5\ \text{N/m}^2 = 1.013\times10^5$ Pa

Carat is the unit of mass.

i.e. 1 carat = 200 mg

Hence, A $\rightarrow$ r, B $\rightarrow$ q and C $\rightarrow$ p.

49. Dimensions of Pa-s is $[\text{ML}^{-1}\text{T}^{-2}]\cdot[\text{T}]$

$= [\text{ML}^{-1}\text{T}^{-1}]$

Dimensions of Nm K^{-1} is

$[\text{MLT}^{-2}][\text{L}][\text{K}^{-1}] = [\text{ML}^2\text{T}^{-2}\text{K}^{-1}]$

Dimensions of J-kg^{-1} K^{-1} is

$[\text{ML}^2\text{T}^{-2}][\text{M}^{-1}][\text{K}^{-1}] = [\text{L}^2\text{T}^{-2}\text{K}^{-1}]$

Dimensions of Wbm^{-1} K^{-1} is

$[\text{ML}^2\text{T}^{-2}\text{A}^{-1}][\text{L}^{-1}][\text{K}^{-1}] = [\text{MLT}^{-2}\text{A}^{-1}\text{K}^{-1}]$

Here, W is for weber, unit of magnetic flux BA with dimensions

$$\frac{[MLT^{-2}]}{[AT]\,[LT^{-1}]}[L^2] = ML^2T^{-2}A^{-1}$$

Hence, A → r, B → s, C → p and D → q.

50. The unit chosen for measuring any physical quantity, should be easily reproducible, i.e. replicas of the unit should be available easily.

Also, unit should not change with changing physical conditions like temperature, pressure, etc.

Therefore, A is false and R is also false.

51. Barn is used in nuclear physics for measuring the cross-sectional area of nuclei.

One barn is equal to 10^{-28} m^2.

Therefore, A is true but R false.

52. Changing the unit of the measurement, the numerical value of the quantity also changes. For example, let the length of scale be 1 m.

Its value in CGS unit is 100 cm.

Therefore, the numerical value changes.

Also, we can say that from the above example smaller the unit of measurement, greater is its numerical value.

Therefore, A is true but R is false.

53. Parallax method is used for measuring distances of nearby stars only.

If D is a distance of a far away star from Earth, then $D = \frac{b}{\theta}$

where, θ is called parallactic angle and b is the distance between the two different positions on Earth from where the star is being observed.

∴ With increase in the distance of star, parallactic angle becomes too small to be measured accurately.

Therefore, both A and R are true and R is the correct explanation of A.

54. Accuracy of the measurement is the measure of how close the measured value is to the true value.

So, the greater the significant figures in the digit, greater will be its accuracy.

Since, 0.70 m has more significant figure (i.e., 2) as compare to 0.7 m (i.e., 1). So, it will be more accurate.

Also, in general, the last digit is not accurately known in every measurement.

Therefore, both A and R are true but R is not the correct explanation of A.

55. Random errors are those errors, which occur irregularly and hence are random with respect to sign and size.

These can arise due to random and unpredictable fluctuations in experimental conditions, personal (unbiased) errors by the observer taking readings, etc.

Therefore, both A and R are true but R is not the correct explanation of A.

56. In all mathematical operations, the errors are of additive nature.

When a quantity appears with a power n greater than one in an expression, its error contribution to the final result increases n times.

So, quantities with higher power in the expression should be measured with maximum accuracy.

Therefore, A is false and R is also false.

57. The arguments of special functions, such as the trigonometric, logarithmic and exponential functions must be dimensionless.

A pure number, ratio of similar physical quantities, such as angle as the ratio (length/length), refractive index as the ratio of (speed of light in vacuum/speed of light in medium), etc. has no dimensions.

Therefore, A is false and R is also false.

58. Relative density of a fluid $= \frac{\text{Density of fluid}}{\text{Density of water}}$

As the density of any substance has same units, hence relative density is dimensionless.

Therefore, both A and R are true and R is the correct explanation of A.

59. The method of dimensions can only test the dimensional validity but not the exact relationship between physical quantities in any equation.

This is because it does not distinguish between the physical quantities having same dimensions.

Therefore, both A and R are true and R is the correct explanation of A.

60. A screw gauge and a spherometer can be used to measure length accurately as less as 10^{-5} m.

61. Spring oscillator cannot be used to measure time intervals.

62. Given, length, $l = 5$ cm

Now, checking the errors with each options one-by-one, we get

$$\Delta l_1 = 5 - 4.9 = 0.1 \text{ cm}$$
$$\Delta l_2 = 5 - 4.805 = 0.195 \text{ cm}$$
$$\Delta l_3 = 5.25 - 5 = 0.25 \text{ cm}$$
$$\Delta l_4 = 5.4 - 5 = 0.4 \text{ cm}$$

Error Δl_1 is least.

Hence, 4.9 cm is most precise or accurate.

63. Area of rectangle, A = Length × Breadth

So, $A = lb = 10.5 \times 2.1 = 22.05 \text{ cm}^2$

Minimum possible measurement of scale = 0.1 cm.

So, area measured by scale = 22.0 cm^2.

64. Magnification in time $= \dfrac{\text{Age of mankind}}{\text{Age of universe}}$

$$= \frac{10^6}{10^{10}} = 10^{-4}$$

Apparent age of mankind $= 10^{-4} \times 1$ day

$$= 10^{-4} \times 86400 \text{ s}$$
$$= 8.64 \text{ s} \approx 8.6 \text{ s}$$

65. As, we know that, the terminal or trailing zero(s) in a number without a decimal point are not significant. So, 4700 m has two significant figures.

66. Every number is expressed as $a \times 10^b$, where a is a number between 1 & 10 and b is any positive or negative exponent (or power) of 10.

67. There are 3 significant figures in the measured mass whereas there are only 2 significant figures in the measured volume. Hence, the density should be expressed to only 2 significant figures.

Density $= \dfrac{5.74}{1.2} = 4.8 \text{ g cm}^{-3}$

68. There is no change in number of significant figures on changing the units. For it, the convention is that we write,

$$4700 \text{ m} = 4.700 \times 10^3 \text{ m}$$

This convention ensures no change in number of significant numbers.

69. Following rules of significant figures are

I. All the non-zero digits are significant.

II. All the zeroes between two non-zero digits are significant, no matter where the decimal point is, if at all.

III. The terminal or trailing zero(s) in a number without a decimal point are not significant. Thus, 123 m = 12300 cm = 123000 mm has three significant figures, the trailing zero(s) being not significant.

70. Given, $R_1 = (100 \pm 3)\ \Omega$

$$\therefore \frac{\Delta R_1}{R_1} \times 100 = \frac{3}{100} \times 100 = 3\%$$

71. Given, $R_2 = (200 \pm 4)\Omega$

$$\therefore \frac{\Delta R_2}{R_2} = \frac{4}{200} = \frac{1}{50}$$

72. The equivalent resistance of series combination,

i.e. $R_S = R_1 + R_2 = (100 \pm 3)\ \Omega + (200 \pm 4)\ \Omega$

$$= (300 \pm 7)\ \Omega$$

73. As, $R_S = (300 \pm 7)\ \Omega$

$$\therefore \frac{\Delta R_S}{R_S} \times 100 = \frac{7}{300} \times 100 = 2.3\%$$

74. The equivalent resistance of parallel combination,

$$R' = \frac{R_1 R_2}{R_1 + R_2}$$
$$= \frac{200}{3} = 66.7\Omega$$

Given, $\Delta R' = 1.8\ \Omega$

$\therefore \quad R' = (66.7 \pm 1.8)\ \Omega$

75. The method of dimensions can only test the dimensional validity but not the exact relationship between physical quantities in any equation.

This is because, it does not distinguish between the physical quantities having same dimensions.

76. Planck's constant, $h = \frac{E}{\nu}$

So, dimensions of $h = \left[\frac{ML^2T^{-2}}{T^{-1}}\right] = [ML^2T^{-1}]$

Angular momentum, $L = mvr$

Dimensions of $L = [M]\,[LT^{-1}]\,[L] = [ML^2T^{-1}]$

Work, W = Force × Displacement

$\therefore$ Dimensions of $W = [MLT^{-2}] \times [L] = [ML^2T^{-2}]$

Linear momentum, p = Mass × Velocity

Dimensions of $p = [M][LT^{-1}] = [MLT^{-1}]$

Impulse, $I = \frac{\text{Force}}{\text{Time}}$

Dimensions of $I = \frac{[MLT^{-2}]}{[T]} = [MLT^{-3}]$

Hence, only angular momentum has same dimensions as that of Planck's constant.

77. Dimensions of speed $[v] = [LT^{-1}]$

Dimensions of acceleration $[A] = [LT^{-2}]$

Dimensions of force $[F] = [MLT^{-2}]$

Dimensions of Young modulus $[Y] = [ML^{-1}T^{-2}]$

Let dimensions of Young's modulus is expressed in terms of speed, acceleration and force as

$$[Y] = [v]^{\alpha}[A]^{\beta}[F]^{\gamma} \quad \ldots(i)$$

Then substituting dimensions in terms of M, L and T, we get

$$[ML^{-1}T^{-2}] = [LT^{-1}]^{\alpha}[LT^{-2}]^{\beta}[MLT^{-2}]^{\gamma}$$
$$= [M^{\gamma}L^{\alpha+\beta+\gamma}\,T^{-\alpha-2\beta-2\gamma}]$$

Now comparing powers of basic quantities on both sides, we get

$$\gamma = 1$$
$$\alpha + \beta + \gamma = -1$$

and $-\alpha - 2\beta - 2\gamma = -2$

Solving these, we get

$$\alpha = -4,\ \beta = 2,\ \gamma = 1$$

Substituting the values of α, β and γ in Eq. (i), we get

$$[Y] = [v^{-4}A^2F^1]$$

78. According to the question, the expression for the scattered amplitude of light (A_s) in terms of amplitude of incident light (A_i), volume (V), distance from scattering particle (x) and wavelength (λ) can be given as

$\therefore \qquad A_s = kA_i^1\,V^1x^{-1}\lambda^d$

where, k is the constant of proportionality.

Writing the dimensions on both sides of the above equation, we get

$$[L] = [L]\,[L^3]\,[L^{-1}]\,[L^d] = [L^{3+d}]$$

Comparing the powers of L on both sides, we get

or $\qquad 1 = 3 + d$

or $\qquad d = -2$

i.e. $\qquad A_s \propto \frac{1}{\lambda^2}$

But, intensity $(I_s) \propto$ [amplitude $(A_s)]^2$

$\therefore \qquad I_s \propto \frac{1}{\lambda^4}$

79. Given, power, $P_1 = \frac{\text{Work done}}{\text{Time taken}}$

$$= \frac{60\text{ J}}{1\text{min}} = \frac{60\text{ J}}{60\text{ s}} = 1\text{ W or kg-m}^2\text{s}^{-3}$$

which is the SI unit of power.

Given, $P_1 = 1$ W, $M_1 = 1\text{kg} = 1000$ g

$L_1 = 1\text{ m} = 100$ cm, $T_1 = 1$ s

In new system, $P_2 = ?$, $M_2 = 100$ g, $L_2 = 100$ cm, $T_2 = 1\text{ min} = 60$ s

$\therefore$ Conversion of 60 J per min or 1W in a new system, i.e.

$$P_2 = P_1\left[\frac{M_1}{M_2}\right]^a\left[\frac{L_1}{L_2}\right]^b\left[\frac{T_1}{T_2}\right]^c$$

Now, $[\text{power}] = [ML^2T^{-3}]$

So, $\qquad a = 1,\ b = 2$

and $\qquad c = -3$

$$\Rightarrow \qquad P_2 = 1\left[\frac{1000}{100}\right]^1\left[\frac{100}{100}\right]^2\left[\frac{1}{60}\right]^{-3}$$

$$= 2.16 \times 10^6 \text{ units}$$

$\therefore$ 60 J min^{-1} = 2.16×10^6 new units of power

03

Motion in a Straight Line

Quick Revision

1. **Rest** If the position of an object does not change w.r.t. its surrounding with the passage of time, it is said to be at rest. e.g. Book lying on the table, a person sitting on a chair, etc.
2. **Motion** If the position of an object is continuously changing w.r.t. its surrounding w.r.t time, then it is said to be in the state of motion. e.g. The crawling insects, water flowing down a dam, etc.
3. **Types of Motion**
   On the basis of the nature of path followed, motion is classified as
   - **Rectilinear Motion** The motion in which a particle moves along a straight line is called rectilinear motion. e.g. Motion of a sliding body on an inclined plane.
   - **Circular Motion** The motion in which a particle moves in a circular path is called circular motion. e.g. A string whirled in a circular loop.
   - **Oscillatory Motion** The motion in which a particle moves to and fro about a given point is known as oscillatory motion. e.g. Simple pendulum.

   On the basis of the number of coordinates required to define the motion of an object, motion is classified as
   - **One-dimensional Motion (1-D)** The motion of an object is considered as 1-D, if only one coordinate is needed to specify the position of the object.
   - **Two-dimensional Motion (2-D)** The motion of an object is considered as 2-D, if two coordinates are needed to specify the position of the object. In 2-D motion, the object moves in a plane. e.g. A satellite revolving around the earth.
   - **Three-dimensional Motion (3-D)** The motion of an object is considered as 3-D, if all the three coordinates are needed to specify the position of the object.

     This type of motion takes place in three-dimensional space.

     e.g. Butterfly flying in garden, the motion of water molecules and motion of kite in the sky.
4. **Point Object** An object is considered as point object, if the size of the object is much smaller than the distance travelled by it in a reasonable duration of time. e.g. Earth can be considered as a point object in its orbit.
5. **Position** It is defined as the point where an object is situated.
6. **Path Length or Distance** The length of the path covered by the object in a given time-interval is known as its path length or distance travelled. It is a scalar quantity, i.e. it has only magnitude but no direction.

7. **Displacement** The change in position of an object in a particular direction is termed as displacement, i.e. the difference between the final and initial positions of the object in a given time. It is denoted by Δx. Mathematically, it is represented by

$$\Delta x = x_2 - x_1$$

where, x_1 and x_2 are the initial and final positions of the object, respectively.

Cases

- If $x_2 > x_1$, then Δx is positive.
- If $x_1 > x_2$, then Δx is negative.
- If $x_1 = x_2$, then Δx is zero.

It is a vector quantity as it possesses both, the magnitude and direction.

8. **Uniform Motion in a Straight Line** A body is said to be in a uniform motion, if it travels equal distances in equal intervals of time along a straight line. A distance (x)-time (t) graph for uniform motion is a straight line passing through the origin.
9. **Non-uniform Motion** A body is said to be in non-uniform motion, if it travels unequal displacements in equal intervals of time.
10. **Speed** The path length or the distance covered by an object divided by the time taken to cover that distance is called its speed.

$$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

It is a **scalar quantity**. The speed of the object for a given interval of time is always positive.

Unit of speed In SI (MKS) system, the unit of speed is ms^{-1} and in CGS, it is cms^{-1}.

Dimensional formula $[M^0LT^{-1}]$

- **Average Speed** Average speed of an object is defined as the total distance travelled divided by the total time taken.

$$\text{Average speed, } v_{av} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

- **Instantaneous Speed** Speed at an instant is defined as the limit of the average speed as the time interval (Δt) becomes infinitesimally small or approaches to zero.

Mathematically, instantaneous speed (v_i) at any instant of time (t) is expressed as

$$v_i = \lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t}$$

or $$v_i = \frac{ds}{dt}$$

where, ds is the distance covered in time dt.

11. **Velocity** The rate of change in position or displacement of an object with time is called the velocity of that object.

i.e. $$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}}$$

It is a **vector quantity**.

The velocity of an object can be positive, zero and negative according to its displacement.

Unit of velocity In CGS, the unit of velocity is cms^{-1} and in MKS or SI, it is ms^{-1}.

Dimensional formula $[M^0LT^{-1}]$

- **Average Velocity** Average velocity of a body is defined as the change in position or displacement (Δx) divided by the time interval (Δt) in which that displacement occurs.

Average velocity,

$$v_{av} = \frac{\text{Total displacement } (\Delta x)}{\text{Total time taken } (\Delta t)}$$

- **Instantaneous Velocity** Velocity at an instant is defined as the limit of average velocity as the time interval (Δt) becomes infinitesimally small or approaches to zero.

Mathematically, instantaneous velocity (v_i) at an instant of time (t) is given by

$$v_i = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$

or $$v_i = \frac{dx}{dt}$$

where, dx is displacement for time dt.

12. **Acceleration** Acceleration of a body can be expressed as the rate of change of velocity with time.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken}}$$

It is a vector quantity. The SI unit of acceleration is ms^{-2} and in CGS system, its unit is $cm\ s^{-2}$. Its dimensional formula is $[M^0LT^{-2}]$.

13. **Types of Acceleration**

- **Uniform Acceleration** If an object is moving with uniform acceleration, it means that the change in velocity is equal in equal intervals of time.
- **Non-uniform Acceleration** If an object has variable or non-uniform acceleration, it means that, the change in velocity is unequal in equal intervals of time.
- **Average Acceleration** The average acceleration over a time interval is defined as the change in velocity divided by the time interval.

  Average acceleration,

$$\mathbf{a}_{av} = \frac{\Delta \mathbf{v}}{\Delta t} = \frac{\mathbf{v}_2 - \mathbf{v}_1}{t_2 - t_1}$$

- **Instantaneous Acceleration** It is defined as the acceleration of a body at a certain instant or the limiting value of average acceleration when time interval becomes very small or tends to zero. So, instantaneous acceleration,

$$\mathbf{a}_{inst} = \lim_{\Delta t \to 0} \frac{\Delta \mathbf{v}}{\Delta t} = \frac{d\mathbf{v}}{dt}$$

  where, $\frac{d\mathbf{v}}{dt}$ is the differential coefficient of $\mathbf{v}$ w.r.t. t.

14. **Kinematic Equations for Uniformly Accelerated Motion** If the change in velocity of an object in each unit of time is constant, then the object is said to be moving with constant acceleration and such a motion is called **uniformly accelerated motion.** An object moves along a straight line with a constant acceleration a and u be the initial velocity at $t = 0$ and v be the final velocity of the object after time (t), then

- **Velocity-Time Relation** $v = u + at$
- **Position-Time Relation** $x = ut + \frac{1}{2}at^2$

  where, x is the position of the object at time t.
- **Position-Velocity Relation** $v^2 = u^2 + 2ax$
- **Displacement of the Object in *n*th Second** $s(n\text{th}) = u + \frac{a}{2}(2n - 1)$

15. **Non-uniformly Accelerated Motion**

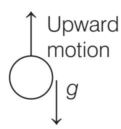
When acceleration of an object is not constant or acceleration is a function of time, then following relations hold for one-dimensional motion

- $v = \frac{dx}{dt}$
- $dx = v\,dt$
- $a = \frac{dv}{dt} = v\frac{dv}{dx}$
- $dv = a\,dt$ or $vdv = adx$

16. **Equations of Motion for the Motion of an Object under Gravity**

When an object is thrown upwards or fall towards the earth under the effect of gravity only, then its motion is called motion under gravity.

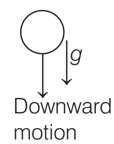
In this case, the equations of motion are given below



$$v = u + (\mp g)\, t$$

$$h = ut + \frac{1}{2}(\mp g)\, t^2$$

$$v^2 = u^2 + 2(\mp g)h$$



In case of upward motion, acceleration due to gravity, g is taken as **negative** and for downward motion, g is taken as **positive**.

17. **Stopping Distance for a Vehicle** When brakes are applied to a moving vehicle, the distance it travels before stopping is called stopping distance.

Stopping distance, $d_s = \frac{u^2}{2a}$

where, u = initial velocity of the vehicle

and a = retardation.

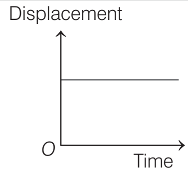
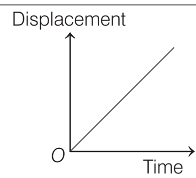
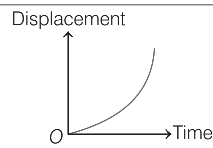
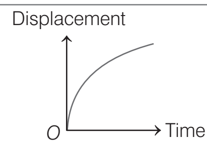
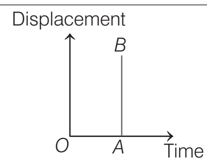
18. **Relative Velocity in 1-D** It is defined as the time rate of change of relative position of one object w.r.t. to another.

If an object A is moving with velocity v_A and an object B is moving with velocity v_B, then the velocity of object A relative to object B is given as $v_{AB} = v_A - v_B$

The relative velocity of object B relative to object A is $v_{BA} = v_B - v_A$

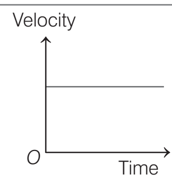
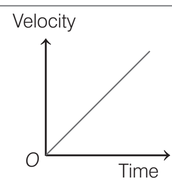
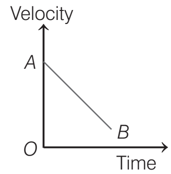
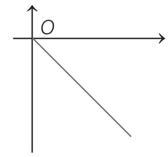
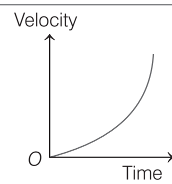
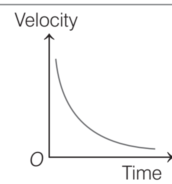
19. **Different Graphs related to Motion are as follows**

Displacement-Time Graph

Condition	Graph
For a stationary body	
Body moving with a constant velocity	
Body moving with a constant acceleration	
Body moving with a constant retardation	
Body moving with infinite velocity, but such motion of a body is never possible.	

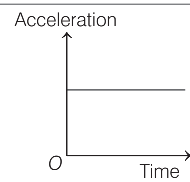
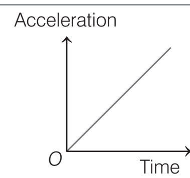
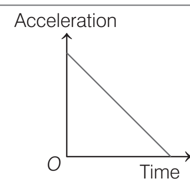
Note Slope of displacement-time graph gives average velocity.

Velocity-Time Graph

Condition	Graph
Body moving with a constant velocity	
Body moving with a constant acceleration having zero initial velocity	
Body moving with a constant retardation and its initial velocity is non-zero	
Body moving with a constant retardation with zero initial velocity	
Body moving with increasing acceleration	
Body moving with decreasing acceleration	

Note Slope of velocity-time graph gives average acceleration.

Acceleration-Time Graph

Condition	Graph
Body moving with a constant acceleration	
Body moving with constant increasing acceleration	
Body moving with constant decreasing acceleration	

Objective Questions

Multiple Choice Questions

1. Which of the following is an example of one-dimensional motion?

(a) Landing of an aircraft
(b) Earth revolving around the sun
(c) Motion of wheels of moving train
(d) Train running on a straight track

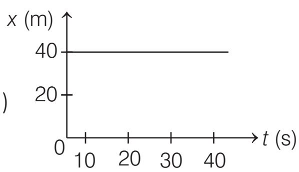
2. The coordinates of object with respect to a frame of reference at $t = 0$ s are $(-1, 0, 3)$. If $t = 5$ s, its coordinates are $(-1, 0, 4)$, then the object is in

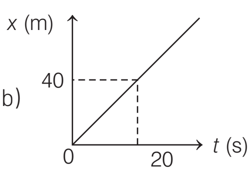
(a) motion along Z-axis
(b) motion along X-axis
(c) motion along Y-axis
(d) rest position between $t = 0$ s and $t = 5$ s

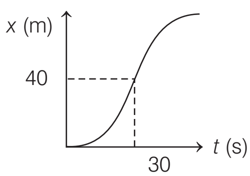
3. A person moves towards east for 3 m, then towards north for 4 m and then moves vertically up by 5 m. What is his distance now from the starting point?

(a) $5\sqrt{2}$ m (b) 5 m (c) 10 m (d) 20 m

4. For a stationary object at $x = 40$ m, the position-time graph is

(a)


(b)


(c)


(d) None of the above

5. The displacement of a car is given as – 240 m, here negative sign indicates

(a) direction of displacement
(b) negative path length
(c) position of car at that point
(d) no significance of negative sign

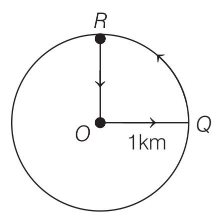
6. Snehit starts from his home and walks 50 m towards north, then he turns towards east and walks 40 m and then reaches his school after moving 20 m towards south. Then, his displacement from his home to school is

(a) 50 m (b) 110 m
(c) 80 m (d) 40 m

7. A vehicle travels half the distance l with speed v_1 and the other half with speed v_2, then its average speed is *(NCERT Exemplar)*

(a) $\frac{v_1 + v_2}{2}$ (b) $\frac{2v_1 + v_2}{v_1 + v_2}$ (c) $\frac{2v_1v_2}{v_1 + v_2}$ (d) $\frac{l(v_1 + v_2)}{v_1v_2}$

8. A runner starts from O and comes back to O following path $OQRO$ in 1h. What is his net displacement and average speed?



(a) 0,3.57 km/h (b) 0,0 km/h
(c) 0,2.57 km/h (d) 0,1 km/h

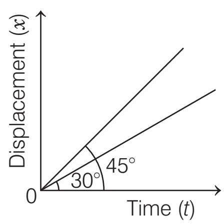
9. The sign (+ ve or – ve) of the average velocity depends only upon

(a) the sign of displacement
(b) the initial position of the object
(c) the final position of the object
(d) None of the above

10. Find the average velocity, when a particle completes the circle of radius 1m in 10 s.

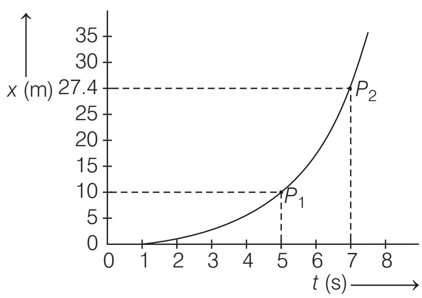
(a) 2 m/s (b) 3.14 m/s (c) 6.28 m/s (d) zero

11. The displacement-time graph of two moving particles make angles of 30° and 45° with the X-axis. The ratio of their velocities is



(a) $1:\sqrt{3}$ (b) 1:2 (c) 1:1 (d) $\sqrt{3}:2$

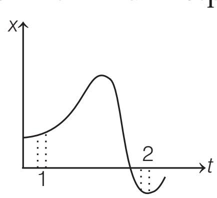
12. In figure, displacement-time $(x - t)$ graph given below, the average velocity between time $t = 5$ s and $t = 7$ s is



(a) 8 ms^{-1} (b) 8.7 ms^{-1}

(c) 7.8 ms^{-1} (d) 13.7 ms^{-1}

13. Figure shows the x-t plot of a particle in one-dimensional motion. Two different equal intervals of time show speed in time intervals 1 and 2 respectively, then



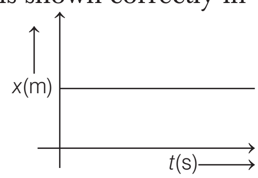
(a) $v_1 > v_2$

(b) $v_2 > v_1$

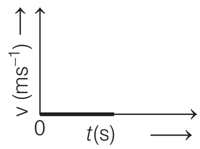
(c) $v_1 = v_2$

(d) Data insufficient

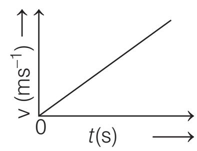
14. For the x-t graph given below, the v - t graph is shown correctly in



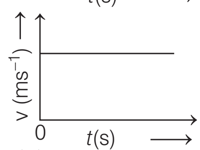
(a)



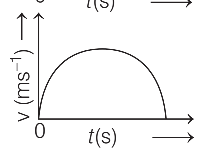
(b)



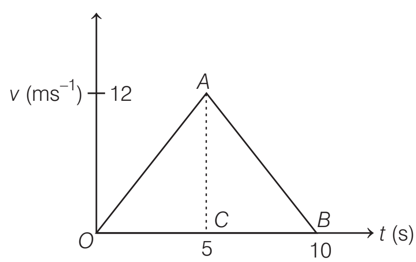
(c)



(d)



15. The speed-time graph of a particle moving along a fixed direction is as shown in the figure. The distance traversed by the particle between $t = 0$ s to $t = 10$ s is



(a) 20 m (b) 40 m (c) 60 m (d) 80 m

16. If an object is moving in a straight line, then

(a) the directional aspect of vector can be specified by + ve and – ve signs
(b) instantaneous speed at an instant is equal to the magnitude of the instantaneous velocity at that instant
(c) Both (a) and (b)
(d) Neither (a) nor (b)

17. In one dimensional motion, instantaneous speed v satisfies $0 \le v < v_0$. Then *(NCERT Exemplar)*

(a) displacement in time T must always take non-negative values
(b) displacement x in time T satisfies $-v_0 T < x < v_0 T$
(c) acceleration is always a non-negative number
(d) motion has no turning points

18. The x-t equation is given as $x = 2t + 1$. The corresponding v-t graph is

(a) a straight line passing through origin
(b) a straight line not passing through origin
(c) a parabola
(d) None of the above

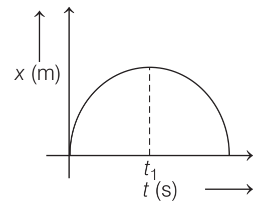
19. The displacement x of an object is given as a function of time, $x = 2t + 3t^2$. The instantaneous velocity of the object at $t = 2$ s is

(a) 16 ms^{-1} (b) 14 ms^{-1}
(c) 10 ms^{-1} (d) 12 ms^{-1}

20. The displacement of a particle starting from rest (at $t = 0$) is given by $s = 6t^2 - t^3$. The time in seconds at which the particle will attain zero velocity again is

(a) 2 (b) 4 (c) 6 (d) 8

21. A car moves along a straight line according to the x-t graph given below. The instantaneous velocity of the car at $t = t_1$ is

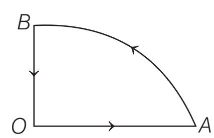


(a) zero
(b) positive
(c) Data insufficient
(d) Cannot be determined

22. A particle moves in a straight line. It can be accelerated

(a) only, if its speed changes by keeping its direction same
(b) only, if its direction changes by keeping its speed same
(c) Either by changing its speed or direction
(d) None of the above

23. An object is moving along the path *OABO* with constant speed, then



(a) the acceleration of the object while moving along to path *OABO* is zero
(b) the acceleration of the object along the path *OA* and *BO* is zero
(c) there must be some acceleration along the path *AB*
(d) Both (b) and (c)

24. The average velocity of a body moving with uniform acceleration travelling a distance of 3.06 m is 0.34 ms^{-1}. If the change in velocity of the body is 0.18 ms^{-1} during this time, its uniform acceleration is

(a) 0.01 ms^{-2}
(b) 0.02 ms^{-2}
(c) 0.03 ms^{-2}
(d) 0.04 ms^{-2}

25. The slope of the straight line connecting the points corresponding to (v_2, t_2) and (v_1, t_1) on a plot of velocity *versus* time gives

(a) average velocity
(b) average acceleration
(c) instantaneous velocity
(d) None of the above

26. The displacement x of a particle at time t along a straight line is given by $x = \alpha - \beta t + \gamma t^2$. The acceleration of the particle is

(a) $-\beta$ (b) $-\beta + 2\gamma$ (c) 2γ (d) -2γ

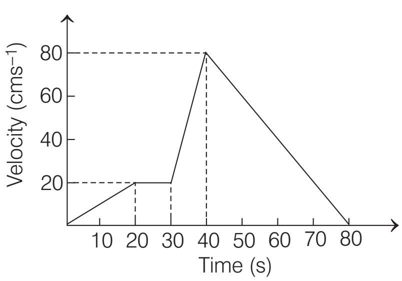
27. The displacement (in metre) of a particle moving along X-axis is given by $x = 18t + 5t^2$. The average acceleration during the interval $t_1 = 2$ s and $t_2 = 4$ s is

(a) 13 ms^{-2} (b) 10 ms^{-2}
(c) 27 ms^{-2} (d) 37 ms^{-2}

28. The relation between time and distance is $t = \alpha x^2 + \beta x$, where α and β are constants. The retardation is

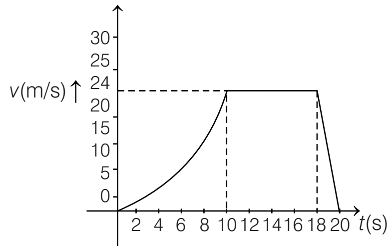
(a) $2\alpha v^3$ (b) $2\beta v^3$
(c) $2\alpha\beta v^3$ (d) $2\beta^2 v^3$

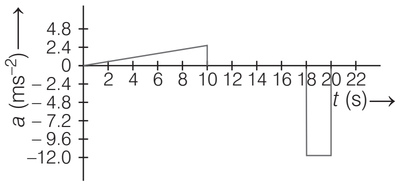
29. The v-t graph of a moving object is shown in the figure. The maximum acceleration is

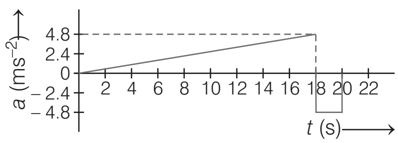


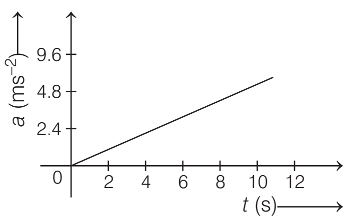
(a) 1 cms^{-2} (b) 2 cms^{-2}
(c) 3 cms^{-2} (d) 6 cms^{-2}

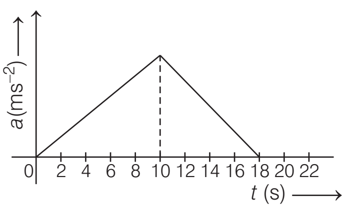
30. The resulting *a-t* graph for the given *v-t* graph is correctly represented in



(a)


(b)


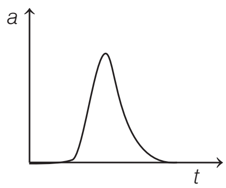
(c)


(d)


31. The kinematic equations of rectilinear motion for constant acceleration for a general situation, where the position coordinate at $t = 0$ is non-zero, say x_0 is

(a) $v = v_0 + at$
(b) $x = x_0 + v_0 t + \frac{1}{2}at^2$
(c) $v^2 = v_0^2 + 2a(x - x_0)$
(d) All of the above

32. The given acceleration-time graph represents which of the following physical situations?

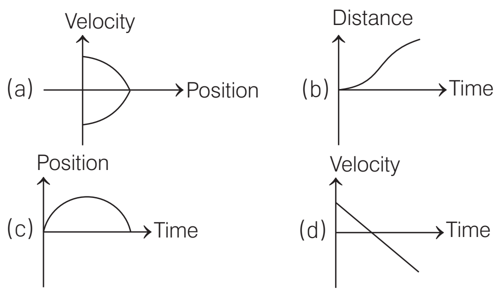


(a) A cricket ball moving with a uniform speed is hit with a bat for a very short time interval.
(b) A ball is falling freely from the top of a tower.
(c) A car moving with constant velocity on a straight road.
(d) A football is kicked into the air vertically upwards.

33. An object is moving with velocity 10 ms^{-1}. A constant force acts for 4 s on the object and gives it a speed of 2 ms^{-1} in opposite direction. The acceleration produced is

(a) 3 ms^{-2} (b) $-3\,ms^{-2}$
(c) 6 ms^{-2} (d) $-6\,ms^{-2}$

34. All the graphs below are intended to represent the same motion. One of them does it incorrectly. Pick it up.



35. Velocity of a body moving along a straight line with uniform acceleration a reduces by (3/4)th of its initial velocity in time t_0. The total time of motion of the body till its velocity becomes zero is

(a) $\frac{4}{3}t_0$ (b) $\frac{3}{2}t_0$ (c) $\frac{5}{3}t_0$ (d) $\frac{8}{3}t_0$

36. A particle is situated at $x = 3$ units at $t = 0$. It starts moving from rest with a constant acceleration of 4 ms^{-2}. The position of the particle at $t = 3$ s is

(a) $x = +21$ units (b) $x = +18$ units
(c) $x = -21$ units (d) None of these

37. Consider the relation for relative velocities between two objects A and B,

$$v_{BA} = -v_{AB}$$

The above equation is valid, if

(a) v_A and v_B are average velocities
(b) v_A and v_B are instantaneous velocities
(c) v_A and v_B are average speed
(d) Both (a) and (b)

38. A person is moving with a velocity of 10 ms^{-1} towards north. A car moving with a velocity of 20 ms^{-1} towards south crosses the person.
The velocity of car relative to the person is

(a) $-30\,ms^{-1}$ (b) $+20\,ms^{-1}$
(c) 10 ms^{-1} (d) $-10\,ms^{-1}$

39. A motion of a body is said to be ……, if it moves along a straight line in any direction.

(a) one-dimensional
(b) two dimensional
(c) three-dimensional
(d) All of the above

40. The numerical ratio of displacement to the distance covered by an object is always equal to or less than …… .

(a) 1 (b) zero
(c) Both (a) and (b) (d) infinity

41. The time taken by a 150 m long train to cross a bridge of length 850 m is 80 s. It is moving with a uniform velocity of …… km/h.

(a) 45 (b) 90
(c) 60 (d) 70

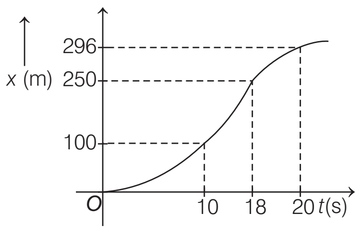
42. The distance-time graph of …… is a straight line.

(a) uniform motion
(b) non-uniform motion
(c) uniform acceleration
(d) None of the above

43. Which of the following statement is correct?

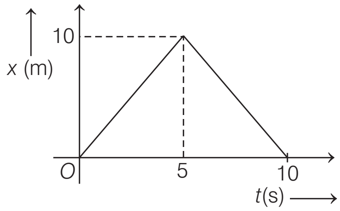
(a) The magnitude of average velocity is the average speed.
(b) Average velocity is the displacement divided by time interval.
(c) When acceleration of particle is constant, then motion is called as non-uniformly accelerated motion.
(d) When a particle returns to its starting point, its displacement is non-zero.

44. For motion of the car between $t = 18$ s and $t = 20$ s, which of the given statement is correct?



(a) The car is moving in a positive direction with a positive acceleration.
(b) The car is moving in a negative direction with a positive acceleration.
(c) The car is moving in positive direction with a negative acceleration.
(d) The car is moving in negative direction with a negative acceleration.

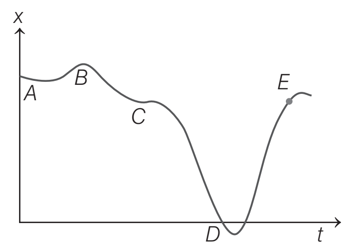
45. The x-t graph for motion of a car is given below



With reference to the graph, which of the given statement(s) is/are incorrect?

(a) The instantaneous speed during the interval $t = 5$ s to $t = 10$ s is negative at all time instants during the interval.
(b) The velocity and the average velocity for the interval $t = 0$ s to $t = 5$ s are equal and positive.
(c) The car changes its direction of motion at $t = 5$ s.
(d) The instantaneous speed and the instantaneous velocity are positive at all time instants during the interval $t = 0$ s to $t = 5$ s.

46. A graph of x *versus* t is shown in figure. Choose correct statement given below.



(a) The particle having some initial velocity at $t = 0$.
(b) At point B, the acceleration $a > 0$.
(c) At point C, the velocity and the acceleration vanish.
(d) The speed at E exceeds that at D.

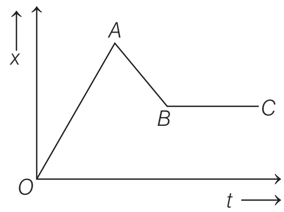
47. Match the Column I with Column II and select the correct option from the codes given below

	Column I		Column II
A.	$d\mathbf{v}/dt$	p.	Acceleration
B.	$d\lvert\mathbf{v}\rvert/dt$	q.	Rate of change of speed
C.	$\frac{d\mathbf{r}}{dt}$	r.	Velocity
D.	$\frac{d\lvert\mathbf{r}\rvert}{dt}$	s.	Magnitude of velocity

Codes

	A	B	C	D
(a)	p	q	r	s
(b)	p	r	s	q
(c)	q	p	r	s
(d)	s	r	p	q

48. Given x-t graph represents the motion of an object. Match the Column I (parts of graph) with Column II (representation) and select the correct option from the codes given below.

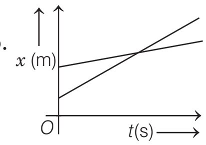
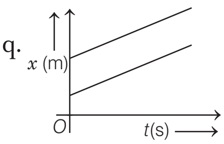
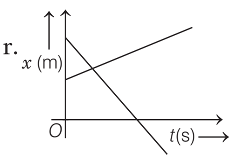


	Column I		Column II
A.	Part OA of graph	p.	Positive velocity
B.	Part AB of graph	q.	Object at rest
C.	Part BC of graph	r.	Negative velocity
D.	Point A in the graph	s.	Change in direction of motion

Codes

	A	B	C	D
(a)	p	q	r	s
(b)	p	r	q	s
(c)	q	p	r	s
(d)	s	r	q	p

49. Match the Column I (position-time graph) with Column II (representation) and select the correct option from the codes given below.

	Column I		Column II
A.	Position-time graph of two objects with equal velocities.	p.	
B.	Position-time graph of two objects with unequal velocities but in same direction.	q.	
C.	Position-time graph of two objects with velocities in opposite direction.	r.	

Codes

	A	B	C		A	B	C
(a)	p	q	r	(b)	q	p	r
(c)	p	r	q	(d)	q	r	p

Assertion-Reasoning MCQs

For question numbers 50 to 63, two statements are given-one labelled ***Assertion*** *(A) and the other labelled* ***Reason*** *(R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

50. Assertion In real-life, in a number of situations, the object is treated as a point object.

Reason An object is treated as point object, as far as its size is much smaller than the distance, it moves in a reasonable duration of time.

51. **Assertion** If the displacement of the body is zero, the distance covered by it may not be zero.

Reason Displacement is a vector quantity and distance is a scalar quantity.

52. **Assertion** An object can have constant speed but variable velocity.

Reason SI unit of speed is m/s.

53. **Assertion** The speed of a body can be negative.

Reason If the body is moving in the opposite direction of positive motion, then its speed is negative.

54. **Assertion** For motion along a straight line and in the same direction, the magnitude of average velocity is equal to the average speed.

Reason For motion along a straight line and in the same direction, the magnitude of displacement is not equal to the path length.

55. **Assertion** An object may have varying speed without having varying velocity.

Reason If the velocity is zero at an instant, the acceleration is zero at that instant.

56. **Assertion** Acceleration of a moving particle can change its direction without any change in direction of velocity.

Reason If the direction of change in velocity vector changes, direction of acceleration vector does not changes.

57. **Assertion** The v-t graph perpendicular to time axis is not possible in practice.

Reason Infinite acceleration cannot be realised in practice.

58. **Assertion** In realistic situation, the x-t, v-t and a-t graphs will be smooth.

Reason Physically acceleration and velocity cannot change values abruptly at an instant.

59. **Assertion** A body cannot be accelerated, when it is moving uniformly.

Reason When direction of motion of the body changes, then body does not have acceleration.

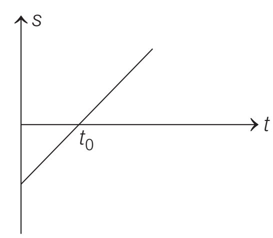
60. **Assertion** For uniform motion, velocity is the same as the average velocity at all instants.

Reason In uniform motion along a straight line, the object covers equal distances in equal intervals of time.

61. **Assertion** A body is momentarily at rest at the instant, if it reverse the direction.

Reason A body cannot have acceleration, if its velocity is zero at a given instant of time.

62. **Assertion** In the s-t diagram as shown in figure, the body starts moving in positive direction but not from $s = 0$.



Reason At $t = t_0$, velocity of body changes its direction of motion.

63. **Assertion** If acceleration of a particle moving in a straight line varies as $a \propto t^n$, then $s \propto t^{n+2}$.

Reason If a-t graph is a straight line,then s-t graph may be a parabola.

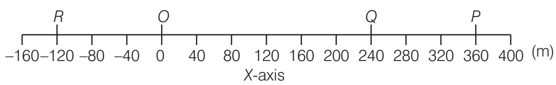
Case Based MCQs

Direction *Answer the questions from 64-68 on the following case.*

Motion in a Straight Line

If the position of an object is continuously changing w.r.t. its surrounding, then it is said to be in the state of motion. Thus, motion can be defined as a change in position of an object with time. It is common to everything in the universe.

In the given figure, let P, Q and R represent the position of a car at different instants of time.



64. With reference to the given figure, the position coordinates of points P and R are

(a) $P \equiv (+360, 0, 0)$; $R \equiv (-120, 0, 0)$
(b) $P \equiv (-360, 0, 0)$; $R \equiv (+120, 0, 0)$
(c) $P \equiv (0, +360, 0)$; $R \equiv (-120, 0, 0)$
(d) $P \equiv (0, 0, +360)$; $R \equiv (0, 0, -120)$

65. Displacement of an object can be

(a) positive
(b) negative
(c) zero
(d) All of the above

66. The displacement of a car in moving from O to P and its displacement in moving from P to Q are

(a) + 360 m and – 120 m
(b) – 120 m and + 360 m
(c) + 360 m and + 120 m
(d) + 360 m and – 600 m

67. If the car goes from O to P and returns back to O, the displacement of the journey is

(a) zero (b) 720 m
(c) 420 m (d) 340 m

68. The path length of journey from O to P and back to O is

(a) 0 m (b) 720 m
(c) 360 m (d) 480 m

Direction *Answer the questions from 69-73 on the following case.*

Average Speed and Average Velocity

When an object is in motion, its position changes with time. So, the quantity that describes how fast is the position changing w.r.t. time and in what direction is given by average velocity.

It is defined as the change in position or displacement (Δx) divided by the time interval (Δt) in which that displacement occur. However, the quantity used to describe the rate of motion over the actual path, is average speed. It defined as the total distance travelled by the object divided by the total time taken.

69. A 250 m long train is moving with a uniform velocity of 45 kmh^{-1}. The time taken by the train to cross a bridge of length 750 m is

(a) 56 s (b) 68 s
(c) 80 s (d) 92 s

70. A truck requires 3 hr to complete a journey of 150 km. What is average speed?

(a) 50 km/h (b) 25 km/h
(c) 15 km/h (d) 10 km/h

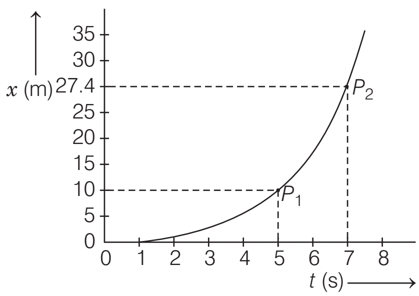
71. Average speed of a car between points A and B is 20 m/s, between B and C is 15 m/s and between C and D is 10 m/s. What is the average speed between A and D, if the time taken in the mentioned sections is 20s, 10s and 5s, respectively?

(a) 17.14 m/s (b) 15 m/s
(c) 10 m/s (d) 45 m/s

72. A cyclist is moving on a circular track of radius 40 m completes half a revolution in 40 s. Its average velocity is

(a) zero (b) 2 ms^{-1}
(c) 4π ms^{-1} (d) 8π ms^{-1}

73. In the following graph, average velocity is geometrically represented by



(a) length of the line P_1P_2
(b) slope of the straight line P_1P_2
(c) slope of the tangent to the curve at P_1
(d) slope of the tangent to the curve at P_2

Direction *Answer the questions from 74-78 on the following case.*

Uniformly Accelerated Motion

The velocity of an object, in general, changes during its course of motion. Initially, at the time of Galileo, it was thought that, this change could be described by the rate of change of velocity with distance. But, through his studies of motion of freely falling objects and motion of objects on an inclined plane, Galileo concluded that, the rate of change of velocity with time is a constant of motion for all objects in free fall.

This led to the concept of acceleration as the rate of change of velocity with time.

The motion in which the acceleration remains constant is known as to be **uniformly accelerated motion**. There are certain equations which are used to relate the displacement (x), time taken (t), initial velocity (u), final velocity (v) and acceleration (a) for such a motion and are known as kinematics equations for uniformly accelerated motion.

74. The displacement of a body in 8 s starting from rest with an acceleration of 20 cms^{-2} is

(a) 64 m (b) 640 m
(c) 64 cm (d) 0.064 m

75. A particle starts with a velocity of 2 ms^{-1} and moves in a straight line with a retardation of 0.1 ms^{-2}. The first time at which the particle is 15 m from the starting point is

(a) 10 s (b) 20 s
(c) 30 s (d) 40 s

76. If a body starts from rest and travels 120 cm in 6th second, then what is its acceleration?

(a) 0.20 ms^{-2} (b) 0.027 ms^{-2}
(c) 0.218 ms^{-2} (d) 0.03 ms^{-2}

77. An object starts from rest and moves with uniform acceleration a. The final velocity of the particle in terms of the distance x covered by it is given as

(a) $\sqrt{2ax}$ (b) $2ax$
(c) $\sqrt{\frac{ax}{2}}$ (d) $\sqrt{ax}$

78. A body travelling with uniform acceleration crosses two points A and B with velocities 20 ms^{-1} and 30 ms^{-1}, respectively. The speed of the body at mid-point of A and B is

(a) 25 ms^{-1} (b) 25.5 ms^{-1}
(c) 24 ms^{-1} (d) $10\sqrt{6}$ ms^{-1}

ANSWERS

Multiple Choice Questions

1. (d)	2. (a)	3. (a)	4. (a)	5. (a)	6. (a)	7. (c)	8. (a)	9. (a)	10. (d)
11. (a)	12. (b)	13. (b)	14. (a)	15. (c)	16. (c)	17. (b)	18. (b)	19. (b)	20. (b)
21. (a)	22. (c)	23. (d)	24. (b)	25. (b)	26. (c)	27. (b)	28. (a)	29. (d)	30. (a)
31. (d)	32. (a)	33. (b)	34. (b)	35. (a)	36. (a)	37. (d)	38. (a)	39. (a)	40. (a)
41. (a)	42. (a)	43. (b)	44. (a)	45. (a)	46. (c)	47. (a)	48. (b)	49. (b)	

Assertion-Reasoning MCQs

50. (a)	51. (b)	52. (b)	53. (d)	54. (c)	55. (d)	56. (d)	57. (a)	58. (a)	59. (d)
60. (b)	61. (c)	62. (c)	63. (b)						

Case Based MCQs

64. (a)	65. (d)	66. (a)	67. (a)	68. (b)	69. (c)	70. (a)	71. (a)	72. (b)	73. (b)
74. (c)	75. (a)	76. (c)	77. (a)	78. (b)					

SOLUTIONS

1. In one-dimensional motion, only one coordinate is required to specify the position of the object. So, a train running on a straight track is an example of one-dimensional motion.

2. Given, at $t = 0$ s, position of an object is $(-1, 0, 3)$ and at $t = 5$ s, its coordinate is $(-1, 0, 4)$. So, there is no change in x and y-coordinates, while z-coordinate changes from 3 to 4. So,the object is in motion along Z-axis.

3. Distance from starting point

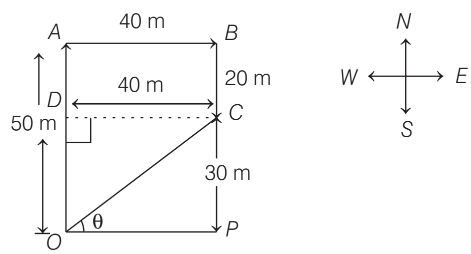
$$= \sqrt{(3)^2 + (4)^2 + (5)^2} = 5\sqrt{2} \text{ m}$$

4. For a stationary object, the position-time graph is a straight line parallel to the time axis, so for the given object at $x = 40$ m, x-t graph is correctly shown in option (a).

5. In I-D motion, positive and negative signs are used to specify the direction of motion.

Since, displacement is a vector quantity, so negative sign in −240 m indicates the direction of displacement.

6. Let O be the starting point, i.e. home. So, according to the question, Snehit moves from O to A (50 m) towards north, then from A to B (40 m) towards east and from B to C (20 m) towards south as shown in the figure below.



Displacement of Snehit is OC, which can be calculated by Pythagoras theorem, i.e.

In ΔODC, $OC^2 = OD^2 + CD^2 = (30)^2 + (40)^2$

$$= 900 + 1600 = 2500$$

$\Rightarrow$ $OC = 50$ m

7. Time taken to travel first half distance,

$$t_1 = \frac{l/2}{v_1} = \frac{l}{2v_1}$$

Time taken to travel second half distance,

$$t_2 = \frac{l}{2v_2}$$

$$\text{Total time} = t_1 + t_2 = \frac{l}{2v_1} + \frac{l}{2v_2} = \frac{l}{2}\left[\frac{1}{v_1} + \frac{1}{v_2}\right]$$

We know that, v_{av} = average speed

$$= \frac{\text{total distance}}{\text{total time}}$$

$$= \frac{l}{\frac{l}{2}\left[\frac{1}{v_1} + \frac{1}{v_2}\right]} = \frac{2v_1v_2}{v_1 + v_2}$$

8. As runner starts from O and comes back to O, so net displacement is zero.

Average speed

$$= \frac{\text{Total distance}}{\text{Total time}} = \frac{OQ + QR + RO}{\text{Total time}}$$

$$= \frac{1\text{ km} + (2\pi r)\left(\frac{90°}{360°}\right)\text{km} + 1\text{ km}}{1\text{h}}$$

($\because$ angle of sector OQR is 90°)

$$= \frac{1 + 2\pi \times 1\left(\frac{1}{4}\right) + 1}{1}$$

$$= 2 + \frac{\pi}{2} = 3.57 \text{ km/h}$$

9. Since, average velocity,

$$v = \frac{\Delta x}{\Delta t} = \frac{\text{Displacement}}{\text{Time interval}}$$

So, average velocity depends on the displacement and hence it depends on the sign of the displacement.

10. When a particle completes one revolution in circular motion, then average displacement travelled by particle is zero.

Hence, average velocity

$$= \frac{\text{average displacement}}{\Delta t} = \frac{0}{\Delta t} = 0$$

11. In case x - t graph is a straight line, the slope of this line gives velocity of the particle.

As slope = tan θ, where θ is the angle which the tangent to the curve makes with the horizontal in anti-clockwise direction.

The velocities of two particles A and B are

$$v_A = \tan 30° = \frac{1}{\sqrt{3}}$$

$$v_B = \tan 45° = 1$$

The ratio of velocities,

$$v_A : v_B = \frac{1}{\sqrt{3}} : 1 = 1 : \sqrt{3}$$

12. Given, $x_2 = 27.4$ m, $x_1 = 10$ m, $t_2 = 7$ s and $t_1 = 5$ s.

Average velocity between 5 s and 7s,

$$\bar{v} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{27.4 - 10}{7 - 5}$$

$$= \frac{17.4}{2} = 8.7 \text{ ms}^{-1}$$

13. Slope of x-t graph in a small interval

= Average speed in that interval

As, slope for interval 2 > slope for interval 1.

$\therefore \quad v_2 > v_1$

14. The x - t graph shown, is parallel to time axis. This means that, the object is at rest. So, the velocity of the object is zero for all time instants. Hence, v -t graph coincides with the time axis as shown in graph (a).

15. Distance travelled by the particle between time interval $t = 0$ s to $t = 10$ s

= Area of triangle OAB

$$= \frac{1}{2} \times \text{Base} \times \text{Height}$$

$$= \frac{1}{2} \times OB \times AC$$

$$= \frac{1}{2} \times 10 \times 12 = 60 \text{ m}$$

16. In one-dimensional motion, i.e. motion along a straight line, there are only two directions in which an object can move and these two directions can be easily specified by + ve and – ve signs.

Also, in this motion instantaneous speed or simply speed at an instant is equal to the magnitude of instantaneous velocity at the given instant.

17. For maximum and minimum displacements, we have to keep in mind the magnitude and direction of maximum velocity.

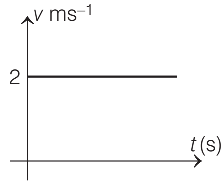
As, maximum velocity in positive direction is v_0 and maximum velocity in opposite direction is also $-v_0$.

Maximum displacement in one direction = v_0T

Maximum displacement in opposite directions = $-v_0T$

Hence, the range of displacement will be $-v_0T < x < v_0T$.

18. $v = \frac{dx}{dt} = 2\ ms^{-1}$ = constant



Hence, option (b) is correct.

19. Given, $x = 2t + 3t^2$

$$v = \frac{dx}{dt} = 2 + 6t$$

For $t = 2$ s, $v = 2 + 6(2) = 14\ ms^{-1}$

20. Displacement of the particle,

$$s = 6t^2 - t^3$$

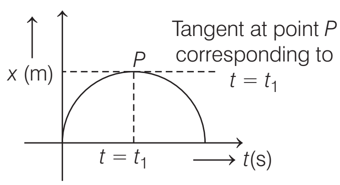
Velocity of the particle,

$$v = \frac{ds}{dt} = \frac{d}{dt}(6t^2 - t^3)$$

$$v = 12t - 3t^2$$

For $v = 0 \Rightarrow 12t = 3t^2 \Rightarrow t = 4$ s

21. The instantaneous velocity is the slope of the tangent to the x-t graph at that instant of time.



At $t = t_1$, the tangent is parallel to time axis as shown above and hence its slope is zero. Thus, instantaneous velocity at $t = t_1$ is zero.

22. Since velocity is a vector quantity, having both magnitude and direction. So, a change in velocity may involve change in either or both of these factors. Therefore, acceleration may result from a change in speed (magnitude), a change in direction or changes in both.

23. For paths OA and BO, the magnitude of velocity (speed) and direction is constant, hence acceleration is zero. For path AB, since this path is a curve, so the direction of the velocity changes at every moment but the magnitude of velocity (speed) remains constant.

Since, the direction of velocity is changing, i.e. there must be some acceleration along the path AB.

24. Time = $\frac{\text{Distance}}{\text{Average velocity}} = \frac{3.06}{0.34} = 9$ s

Acceleration

$$= \frac{\text{Change in velocity}}{\text{Time}}$$

$$= \frac{0.18}{9} = 0.02\ ms^{-2}$$

25. Average acceleration is defined as the average change of velocity per unit time. On a plot of v-t, the average acceleration is the slope of the straight line connecting the points corresponding to (v_2, t_2) and (v_1, t_1).

26. Given, $x = \alpha - \beta t + \gamma t^2$

$$v = \frac{dx}{dt} = \frac{d}{dt}(\alpha - \beta t + \gamma t^2) = -\beta + 2\gamma t$$

$$a = \frac{dv}{dt} = \frac{d}{dt}(-\beta + 2\gamma t) = 2\gamma$$

27. Given, $x = 18t + 5t^2$

$$v = \frac{dx}{dt} = \frac{d}{dt}(18t + 5t^2) = 18 + 10t$$

$\therefore\ v = 10t + 18$

At $t_1 = 2$ s, $v_1 = 10(2) + 18 = 38$ m/s

At $t_2 = 4$ s, $v_2 = 10(4) + 18 = 58$ m/s

$\therefore\ a = \frac{v_2 - v_1}{t} = \frac{58 - 38}{2} = \frac{20}{2} = 10\ ms^{-2}$

28. Given, $t = \alpha x^2 + \beta x$

$$\frac{dt}{dx} = 2\alpha x + \beta$$

$$\Rightarrow \frac{dx}{dt} = v = \frac{1}{2\alpha x + \beta}$$

As, acceleration, $a = \frac{dv}{dt} = \frac{dv}{dx}\frac{dx}{dt}$

$$\Rightarrow a = v \cdot \frac{dv}{dx} = \frac{1}{2\alpha x + \beta}\left(\frac{-v2\alpha}{2\alpha x + \beta}\right)$$

$$= -2\alpha v \cdot v^2 = -2\alpha v^3$$

$\therefore$ Retardation $= 2\alpha v^3$

29. Maximum acceleration means maximum change in velocity in minimum time interval. In time interval $t = 30$ s to $t = 40$ s,

$$a = \frac{\Delta v}{\Delta t} = \frac{80 - 20}{40 - 30} = \frac{60}{10} = 6\ cms^{-2}$$

30. Average acceleration for different time intervals is the slope of v-t graph, which are as follows

For 0 s -10 s, $\bar{a} = \frac{(24-0)\text{ ms}^{-1}}{(10-0)\text{ s}} = 2.4\text{ ms}^{-2}$

For 10 s -18 s, $\bar{a} = \frac{(24-24)\text{ ms}^{-1}}{(18-10)\text{ s}} = 0\text{ ms}^{-2}$

For 18 s - 20 s, $\bar{a} = \frac{(0-24)\text{ ms}^{-1}}{(20-18)\text{ s}} = -12\text{ ms}^{-2}$

So, the corresponding a -t graph for the given v-t graph is shown correctly in graph (a).

31. All the equations given in options (a), (b) and (c) are the kinematic equations of rectilinear motion for constant acceleration.

32. The acceleration-time graph represents the motion of a uniformly moving cricket ball turned back by hitting it with a bat for a very short time interval.

33. Given, $v = -2\text{ ms}^{-1}$ (opposite direction),

$t = 4$ s and $u = 10\text{ ms}^{-1}$

$\therefore\ v = u + at$ or $-2 = 10 + 4a$ or $a = -3\text{ms}^{-2}$

34. If velocity *versus* time graph is a straight line with negative slope, then acceleration is constant and negative.

With a negative slope, distance-time graph will be parabolic $\left(s = ut - \frac{1}{2}at^2\right)$.

Hence, options (a), (c) and (d) are correct, so option (b) will be incorrect.

35. According to kinematic equation of motion,

$$v = u - at$$

where, $v = u - \frac{3u}{4} = u/4 \Rightarrow \frac{u}{4} = u - at_0$

Negatve sign signifies that the body will decelerate, since the final velocity is decreasing.

or $\frac{u}{a} = \frac{4}{3}t_0$

Now, $0 = u - at$ or $t = \frac{u}{a} = \frac{4}{3}t_0$

36. Given, $x_0 = 3$ units, $a = 4\text{ ms}^{-2}$, $t = 3$ s

Using relation, $x = x_0 + v_0 t + \frac{1}{2}at^2$

$$= 3 + \frac{1}{2} \times 4 \times (3)^2 = +21 \text{ units}$$

37. Given, $v_{BA} = -v_{AB}$

The above relation is true for both average velocities of particles and instantaneous velocities of particles.

As speed is scalar quantity, ignorant of direction, so average speed may not be equal.

38. Let south to north direction be positive.

Velocity of car, $v_C = -20\text{ ms}^{-1}$

Velocity of person, $v_P = +10\text{ ms}^{-1}$

$$v_{CP} = v_C - v_P = (-20) - (10) = -30\text{ ms}^{-1}$$

39. **One-dimensional motion** is a motion along a straight line in any direction. e.g. A train is moving on a platform.

Hence, option (a) is correct.

40. Since, displacement d is always less than or equal to the distance D but never greater than it, i.e. $d \le D$. So, numerical ratio of displacement to the distance covered by an object is always equal to or less than one.

41. Total distance = Length of train + Length of bridge

$$= (150 + 850)\text{ m} = 1000\text{ m}$$

$$\text{Time} = \frac{\text{Distance}}{\text{Velocity}} \Rightarrow 80 = \frac{1000}{v}$$

$$v = \frac{1000}{80}\text{ m/s} \Rightarrow v = \frac{1000}{80} \times \frac{18}{5} = 45\text{ km/h}$$

42. In uniform motion, the velocity of an object does not change or it remains constant with time.

So, the graph of distance-time is a straight line.

43. Statement given in option (b) is correct but the rest are incorrect and these can be corrected as,

In general, average speed is not equal to magnitude of average velocity. It can be so, if the motion is along a straight line without change in direction.

When acceleration of particle is not constant, then motion is called as non-uniformly accelerated motion.

Displacement is zero, when a particle returns to its starting point.

44. For negative acceleration, the x - t graph moves downward. But the car is moving in positive direction as the position coordinate is increasing in the positive direction.

Thus, the statement given in option (a) is correct, rest are incorrect.

45. The instantaneous speed is always positive as it is the magnitude of the velocity at an instant, so it is positive during $t = 5$ s to $t = 10$ s.

For $t = 0$ s to $t = 5$ s, the motion is uniform and x-t graph has positive slope. So, the velocity and average velocity, instantaneous velocity and instantaneous speed are equal and positive.

During $t = 0$ s to $t = 5$ s, the slope of the graph is positive, hence the average velocity and the velocity both are positive.

During $t = 5$ s to $t = 10$ s, the slope of the graph is negative, hence the velocity is negative. Since, there is a change in sign of velocity at $t = 5$ s, so the car changes its direction at this instant.

Hence, option (a) is incorrect, while all others are correct.

46. As, point A is the starting point, therefore particle is starting from rest.

At point B, the graph is parallel to time axis, so the velocity is constant here. Thus, acceleration is zero.

Also point C, the graph changes slope, hence velocity also changes.

After graph at C is almost parallel to time axis, hence we can say that velocity and acceleration vanishes.

From the graph, it is clear that

$$|\text{ slope at } D| > |\text{ slope at } E|$$

Hence, speed at D will be more than at E.

47. $\frac{d\mathbf{v}}{dt}$ is the rate of change of velocity, so it represents acceleration.

$\frac{d|\mathbf{v}|}{dt}$ is rate of change of speed of the particle.

$\frac{d\mathbf{r}}{dt}$ is the rate by which distance of particle from the origin is changing.

$\left|\frac{d\mathbf{r}}{dt}\right|$ is the magnitude of rate of change of position of particle. This means it represents magnitude of velocity.

Hence, A $\rightarrow$ p, B $\rightarrow$ q, C $\rightarrow$ r and D $\rightarrow$ s.

48. In x-t graph, $OA \rightarrow$ Positive slope $\rightarrow$ Positive velocity

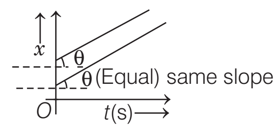
$AB \rightarrow$ Negative slope $\rightarrow$ Negative velocity

$BC \rightarrow$ Zero slope $\rightarrow$ Object is at rest

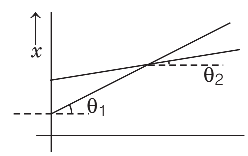
At point A, there is a change in sign of velocity, hence the direction of motion must have changed at A.

Hence, A $\rightarrow$ p, B $\rightarrow$ r, C $\rightarrow$ q and D $\rightarrow$ s.

49. A. For equal velocities, the slope of the straight lines must be same as shown below



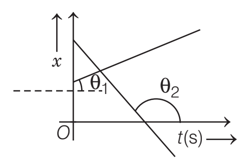
B. For unequal velocity, slope is different, but since, the objects are moving in the same direction, the slope for both the graphs must be of same sign (positive or negative) and they meet at a point as shown below



C. For velocities in opposite direction, slopes must be of opposite sign. Slope = tan θ, where θ is the angle of the straight line with horizontal in anti-clockwise direction. As, we know, $\tan\theta_1 > 0$, $\tan\theta_2 < 0$.

Hence, slopes are of opposite sign.

This condition is shown below



Hence A $\rightarrow$ q, B $\rightarrow$ p and C $\rightarrow$ r.

50. The approximation of an object as point object is valid only, when the size of the object is much smaller than the distance it moves in a reasonable duration of time.

Therefore, both A and R are true and R is the correct explanation of A.

51. Distance is the total path length travelled by the object. But displacement the shortest distance between the initial and final positions of the object. So, distance can never be negative or zero. But displacement can be zero, positive and negative.

Also, distance is a scalar quantity. It means that, it is always positive but however displacement is a vector quantity. So, it may be positive, zero or negative depending on given situation.

Therefore, both A and R are true but R is not the correct explanation of A.

52. Velocity is a vector quantity, so it has both direction and magnitude. Hence, an object can have variable velocity by keeping its magnitude constant, i.e. speed and by changing direction only.

The SI unit of speed is m/s.

Therefore, both A and R are true but R is not the correct explanation of A.

53. Speed can never be negative because it is a scalar quantity. So, if a body is moving in negative direction, then also the speed will be positive.

Therefore, A is false and R is also false.

54. For motion in a straight line and in the same direction,

Displacement = Total path length

$\Rightarrow$ Average velocity = Average speed

Therefore, A is true but R is false.

55. If speed varies, then velocity will definitely vary.

When a particle is thrown upwards, at highest point $a \neq 0$ but $v = 0$.

Therefore, A is false and R is also false.

56. Accleration, $a = \frac{\mathbf{v}_f - \mathbf{v}_i}{\Delta t} = \frac{d\mathbf{v}}{dt}$, i.e. direction of acceleration is same as that of change in velocity vector or in the direction of Δv.

Therefore, A is false and R is also false.

57. Acceleration, $a = \frac{dv}{dt}$ = Slope of v-t graph

It v-t graph is perpendicular to t-axis, slope $= \infty$

$\therefore \quad a = \infty$

Therefore, both A and R are true and R is the correct explanation of A.

58. In realistic situation, the x - t, v - t and a - t graphs will be smooth, as the values of acceleration and velocity cannot change abruptly since changes are always continuous.

Therefore, both A and R are true and R is the correct explanation of A.

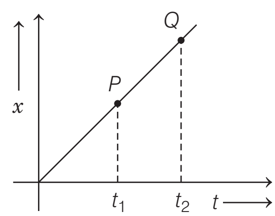
59. The uniform motion of a body means that, the body is moving with constant velocity.

But if the direction of motion is changing (such as in uniform circular motion), its velocity changes and thus uniform acceleration is produced in the body.

Therefore, A is false and R is also false.

60. In uniform motion along a straight line, the object covers equal distances in equal intervals of time.

For uniform motion, x - t graph is represented as a straight line inclined to time axis. The average velocity during any time interval $t = t_1$ to $t = t_2$ is the slope of the line PQ which coincides with the graph.



Also, velocity at any instant say $t = t_1$ is the slope of the tangent at point P which again coincides with PQ or with the graph. Hence, velocity is same as the average velocity at all instants.

Therefore, both A and R are true but R is not the correct explanation of A.

61. When a particle is released from rest position under gravity, then $v = 0$ but $a \neq 0$.

Also, a body is momentarily at rest at the instant, if it reverse the direction.

Therefore, A is true but R is false.

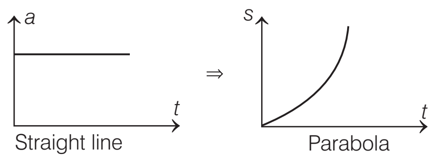
62. Slope of s-t graph = velocity = positive

At $t = 0$, $s \neq 0$, further at $t = t_0 : s = 0, v \neq 0$.

Therefore, A is true but R is false.

63. By differentiating a-t equation two times, we will get s-t equation.

Further



Therefore, both A and R are true but R is not the correct explanation of A.

64. The position coordinates of point $P = (+360, 0, 0)$ and point $R = (-120, 0, 0)$.

65. Displacement is a vector quantity, it can be positive, negative and zero.

66. Displacement, $\Delta x = x_2 - x_1$

For journey of car in moving from O to P,

$x_2 = +\,360$ m

$x_1 = 0$

$\Rightarrow \quad \Delta x = x_2 - x_1 = 360 - 0 = +\,360$ m

For journey, of car in moving from P to Q,

$x_2 = +\,240$ m

$x_1 = +\,360$ m

$\Rightarrow \quad \Delta x = x_2 - x_1 = 240 - 360 = -\,120$ m

Here, –ve sign implies that the displacement is in –ve direction, i.e. towards left.

67. Displacement, $\Delta x = x_2 - x_1 = 0 - 0 = 0$

68. Path length of the journey

$= OP + PO = +\,360\text{m} + (+\,360)\text{ m} = 720$ m

69. Total time taken $= \dfrac{\text{Total distance}}{\text{Speed}}$

$$t = \frac{250 + 750}{45 \times \frac{5}{18}} = 80 \text{ s}$$

70. Average speed $= \dfrac{\text{Total distance}}{\text{Total time}}$

$$= \frac{150}{3} = 50 \text{ km/h}$$

71. Total distance $(d = vt)$

$$= 20 \times 20 + 15 \times 10 + 10 \times 5 = 600 \text{ m}$$

Total time $= 20 + 10 + 5 = 35$ s

Therefore, average speed

$$= 600 / 35 = 17.14 \text{ m/s}$$

72. Given, $R = 40$ m and $t = 40$ s

Average velocity $= \dfrac{\text{Displacement}}{\text{Time taken}}$

$$= \frac{2R}{t} = \frac{2 \times 40}{40} = 2 \text{ ms}^{-1}$$

73. From the position-time graph, average velocity is geometrically represented by the slope of curve, i.e. slope of straight line P_1P_2.

74. Displacement, $s = \dfrac{1}{2} \times (0.2)\,(64) = 64$ cm

75. From equation of motion, $s = ut - \dfrac{1}{2} at^2$

$$15 = 2t - \frac{1}{2} \times (0.1) t^2 \Rightarrow t = 10 \text{ s}$$

76. From equation of motion,

$$s_n = u + \frac{a}{2}(2n - 1)$$

$$\Rightarrow \quad 1.2 = 0 + \frac{a}{2}(2 \times 6 - 1)$$

$$\Rightarrow \quad a = \frac{1.2 \times 2}{11} = 0.218 \text{ ms}^{-2}$$

77. Given, $\quad v_0 = 0$

Using relation, $v^2 = v_0^2 + 2ax$

$v^2 = 2ax$

$\therefore \quad v = \sqrt{2ax}$

78. Let the acceleration of the car $= a$

and distance between A and $B = d$

Given, $v = 30 \text{ ms}^{-1}$ and $u = 20 \text{ ms}^{-1}$

$2ad = (30)^2 - (20)^2$

$$ad = \frac{900 - 400}{2} = 250$$

When the car is at the mid-point of AB, then speed of car is v_1.

$v_1^2 - (20)^2 = 2a\,(d/2)$

$v_1^2 = ad + 400$

$= 250 + 400 = 650$

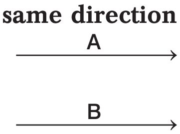
Therefore, $v_1 = 25.5 \text{ ms}^{-1}$

04

Motion in a Plane

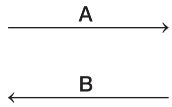
Quick Revision

1. **Scalar Quantity** is the physical quantity which has only magnitude but no direction. It is specified completely by a single number, alongwith the proper unit.
   e.g. Temperature, mass, length, time, work, etc.
2. **Vector Quantity** is the physical quantity which has both magnitude and direction and obeys the triangle/ parallelogram laws of vector addition and subtraction.
   e.g. Displacement, acceleration, velocity, momentum, force, etc.
3. **Representation of Vector** A vector is represented by a **bold face** type or by **an arrow** placed over a letter,
   i.e. **F**, **a**, **b** or $\vec{F}, \vec{a}, \vec{b}$.
   The length of the line gives the magnitude and the arrowhead gives the direction.
4. **Types of Vectors** Vectors are classified into two types **polar** and **axial** vectors.
   - **Polar Vectors** Vectors which have a starting point or a point of application are called polar vectors. e.g. Force, displacement, etc.
   - **Axial Vectors** Vectors which represent the rotational effect and act along the axis of rotation are called axial vectors.
     e.g. Angular velocity, angular momentum, torque, etc.
5. **Modulus of a Vector** The magnitude of a vector is called modulus of vector. For a vector **A**, it is represented by $|\mathbf{A}|$ or A.
6. **Unit Vector** It is a vector having unit magnitude. A unit vector of **A** is written as $\hat{\mathbf{A}}$. It is expressed as
   $$\hat{\mathbf{A}} = \frac{\mathbf{A}}{|\mathbf{A}|} = \frac{\mathbf{A}}{A}$$
   or $$\mathbf{A} = A\hat{\mathbf{A}}$$
   In cartesian coordinates, $\hat{\mathbf{i}}, \hat{\mathbf{j}}$ and $\hat{\mathbf{k}}$ are the unit vectors along X-axis, Y-axis and Z-axis.
   It has no unit or dimensions.
7. **Equal Vectors** Two vectors are said to be equal, if they have equal magnitude and same direction.
8. **Resultant Vector** It is the combination of two or more vectors and it produces the same effect as two or more vectors collectively produce.
   Two cases for resultant vectors are as follows
   ***Case* I When two vectors are acting in the same direction**



Resultant vector, $\mathbf{R} = \mathbf{A} + \mathbf{B}$

***Case* II When two vectors are acting in mutually opposite directions**



Resultant vector, $\mathbf{R} = \mathbf{A} - \mathbf{B}$

(i) If $\mathbf{B} > \mathbf{A}$, then direction of $\mathbf{R}$ is along $\mathbf{B}$.

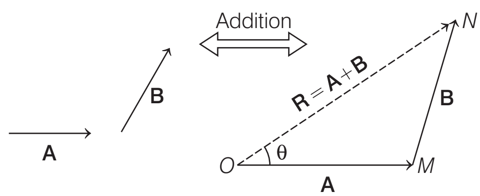
(ii) If $\mathbf{A} > \mathbf{B}$, then direction of $\mathbf{R}$ is along $\mathbf{A}$.

9. **Addition of Two Vectors (Graphical Method)**

Two vectors can be added, if both of them are of same nature. Graphical method of addition of vectors helps us in visualising the vectors and the resultant vector.

This method contains following laws

- **Triangle Law of Vector Addition** This law states that, if two vectors can be represented both in magnitude and direction by two sides of a triangle taken in the same order, then their resultant is represented completely, both in magnitude and direction, by the third side of the triangle taken in the opposite order.

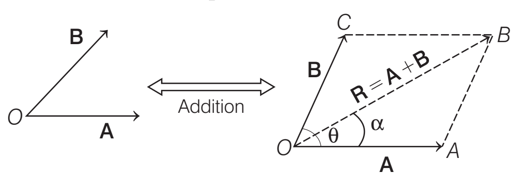


According to triangle law of vector addition,

$$\mathbf{ON} = \mathbf{OM} + \mathbf{MN}$$

Resultant vector, $\mathbf{R} = \mathbf{A} + \mathbf{B}$

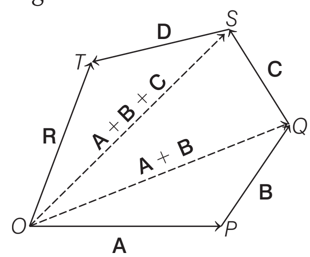
- **Parallelogram Law of Addition of Two Vectors** This law states that, if two vectors are acting on a particle at the same time be represented in magnitude and direction by two adjacent sides of a parallelogram drawn from a point, their resultant vector is represented in magnitude and direction by the diagonal of the parallelogram drawn from the same point.



The resultant vector formed in this method is also same as that formed in triangle law of addition. i.e. Resultant vector, $\mathbf{R} = \mathbf{A} + \mathbf{B}$

- **Polygon Law of Addition of Vectors** This law states that, when the number of vectors are represented in both magnitude and direction by the sides of an open polygon taken in an order, then their resultant is represented in both magnitude and direction by the closing side of the polygon taken in opposite order.

Consider a number of vectors $\mathbf{A}$, $\mathbf{B}$, $\mathbf{C}$ and $\mathbf{D}$ be acting in different directions as shown



According to this law,

$$\mathbf{OT} = \mathbf{OP} + \mathbf{PQ} + \mathbf{QS} + \mathbf{ST}$$

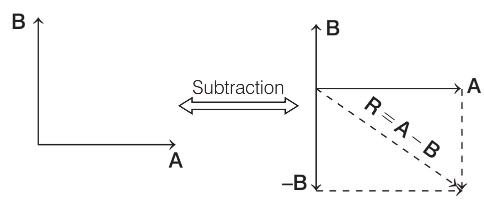
$\therefore$ Resultant vector, $\mathbf{R} = \mathbf{A} + \mathbf{B} + \mathbf{C} + \mathbf{D}$

10. **Properties of Addition of Vectors**

- It follows commutative law, i.e. $\mathbf{A} + \mathbf{B} = \mathbf{B} + \mathbf{A}$
- It follows associative law, $(\mathbf{A} + \mathbf{B}) + \mathbf{C} = \mathbf{A} + (\mathbf{B} + \mathbf{C})$
- It follows distributive law, $\lambda(\mathbf{A} + \mathbf{B}) = \lambda\mathbf{A} + \lambda\mathbf{B}$
- $\mathbf{A} + \mathbf{0} = \mathbf{A}$

11. **Subtraction of Two Vectors (Graphical Method)** If a vector $\mathbf{B}$ is to be subtracted from vector $\mathbf{A}$, then we have to invert the vector $\mathbf{B}$ and then add it with vector $\mathbf{A}$, according to laws of addition of two vectors.

Hence, the subtraction of vector $\mathbf{B}$ from a vector $\mathbf{A}$ is expressed as $\mathbf{R} = \mathbf{A} + (-\mathbf{B}) = \mathbf{A} - \mathbf{B}$

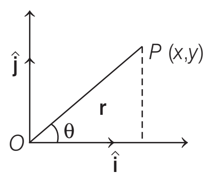


12. **Properties of Subtraction of Vectors**
    - Subtraction of vectors does not follow commutative law
    $$\mathbf{A} - \mathbf{B} \neq \mathbf{B} - \mathbf{A}$$
    - It does not follow associative law
    $$\mathbf{A} - (\mathbf{B} - \mathbf{C}) \neq (\mathbf{A} - \mathbf{B}) - \mathbf{C}$$
    - It follows distributive law
    $$\lambda(\mathbf{A} - \mathbf{B}) = \lambda\mathbf{A} - \lambda\mathbf{B}$$

13. **Resolution of Vectors in Plane (In Two-Dimensions)** The process of splitting a single vector into two or more vectors in different directions which collectively produce the same effect as produced by the single vector alone is known as resolution of a vector.

    The various vectors into which the single vector is splitted are known as **component vectors**.

    Any vector **r** can be expressed as a linear combination of two unit vectors $\hat{\mathbf{i}}$ and $\hat{\mathbf{j}}$ at right angle, i.e. $\mathbf{r} = x\hat{\mathbf{i}} + y\hat{\mathbf{j}}$.

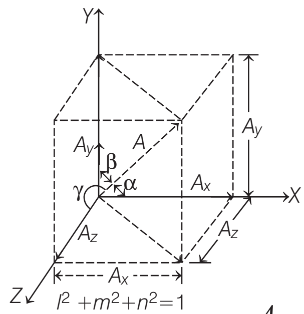


$\therefore$ Magnitude of resultant vector $= |\mathbf{r}| = \sqrt{x^2 + y^2}$

If θ is the inclination of **r** with *X*-axis, then

angle, $\theta = \tan^{-1}\left(\frac{y}{x}\right)$.

14. **Resolution of a Space Vector (In Three-Dimensions)** We can resolve a general vector **A** into three components along *X, Y* and *Z*-axes in three dimensions (i.e. space). While resolving we have,
    $$A_x = A\cos\alpha,$$
    $$A_y = A\cos\beta,\ A_z = A\cos\gamma$$
    $\therefore$ Resultant vector,
    $$\mathbf{A} = A_x\hat{\mathbf{i}} + A_y\hat{\mathbf{j}} + A_z\hat{\mathbf{k}}$$
    Magnitude of vector **A** is $A = \sqrt{A_x^2 + A_y^2 + A_z^2}$



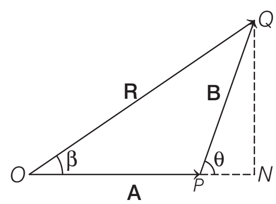
Remember that, $\cos\alpha = \dfrac{A_x}{\sqrt{A_x^2 + A_y^2 + A_z^2}} = l$

$$\cos\beta = \frac{A_y}{\sqrt{A_x^2 + A_y^2 + A_z^2}} = m$$

$$\cos\gamma = \frac{A_z}{\sqrt{A_x^2 + A_y^2 + A_z^2}} = n$$

Here, *l*, *m* and *n* are known as **direction cosines** of **A**.

15. **Addition of Vectors (Analytical Method)** According to triangle law of vector addition, the resultant (**R**) is given by OQ but in opposite order.

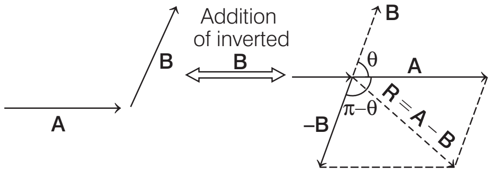


Resultant, $R = \sqrt{A^2 + B^2 + 2AB\cos\theta}$

and direction of resultant **R**,
$$\tan\beta = \frac{B\sin\theta}{A + B\cos\theta}$$

Regarding the Magnitude of *R*
- When $\theta = 0°$, then $R = A + B$ (maximum)
- When $\theta = 90°$, then $R = \sqrt{A^2 + B^2}$
- When $\theta = 180°$, then $R = A - B$ (minimum)

16. **Subtraction of Vectors (Analytical Method)** There are two vectors **A** and **B** at an angle θ. If we have to subtract **B** from **A**, then first invert the vector **B** and then add with **A** as shown in figure.



The resultant vector is $\mathbf{R} = \mathbf{A} + (-\mathbf{B}) = \mathbf{A} - \mathbf{B}$
The magnitude of resultant in this case is

$$R = |\mathbf{R}| = \sqrt{A^2 + B^2 + 2AB\cos(\pi - \theta)}$$

or $$R = \sqrt{A^2 + B^2 - 2AB\cos\theta}$$

Regarding the magnitude of R

- When $\theta = 0°$, then $R = A - B$ (minimum)
- When $\theta = 90°$, then $R = \sqrt{A^2 + B^2}$
- When $\theta = 180°$, then $R = A + B$ (maximum)

17. **Dot Product or Scalar Product** It is defined as the product of the magnitudes of vectors **A** and **B** and the cosine angle between them. It is represented by

$$\mathbf{A} \cdot \mathbf{B} = AB\cos\theta$$

***Case* I** When the two vectors are parallel, then $\theta = 0°$. We have

$$\mathbf{A} \cdot \mathbf{B} = AB\cos 0° = AB$$

***Case* II** When the two vectors are mutually perpendicular, then, $\theta = 90°$. We have

$$\mathbf{A} \cdot \mathbf{B} = AB\cos 90° = 0$$

***Case* III** When the two vectors are anti-parallel, then $\theta = 180°$. We have

$$\mathbf{A} \cdot \mathbf{B} = AB\cos 180° = -AB$$

18. **Properties of Dot Product**

- $\mathbf{a} \cdot \mathbf{a} = (\mathbf{a})^2$
- $\mathbf{a} \cdot \mathbf{b} = \mathbf{b} \cdot \mathbf{a}$
- $\mathbf{a} \cdot (\mathbf{b} + \mathbf{c}) = \mathbf{a} \cdot \mathbf{b} + \mathbf{a} \cdot \mathbf{c}$
- $\mathbf{a} \cdot \mathbf{b} = |\mathbf{a}||\mathbf{b}|\cos\theta$
  $= a_1b_1 + a_2b_2 + a_3b_3$

where, $\mathbf{a} = a_1\hat{\mathbf{i}} + a_2\hat{\mathbf{j}} + a_3\hat{\mathbf{k}}$,

and $\mathbf{b} = b_1\hat{\mathbf{i}} + b_2\hat{\mathbf{j}} + b_3\hat{\mathbf{k}}$

Here, $\hat{\mathbf{i}} \cdot \hat{\mathbf{i}} = \hat{\mathbf{j}} \cdot \hat{\mathbf{j}} = \hat{\mathbf{k}} \cdot \hat{\mathbf{k}} = 1$

$\hat{\mathbf{i}} \cdot \hat{\mathbf{j}} = \hat{\mathbf{j}} \cdot \hat{\mathbf{k}} = \hat{\mathbf{k}} \cdot \hat{\mathbf{i}} = 0$

19. **Vector Product or Cross Product**
It is defined as the product of the magnitudes of vectors **A** and **B** and the sine angle between them.
It is represented as, $\mathbf{A} \times \mathbf{B} = AB\sin\theta\ \hat{\mathbf{n}}$
where, $\hat{\mathbf{n}}$ is a unit vector in the direction of $\mathbf{A} \times \mathbf{B}$.

Cross Product of Two Vectors in Terms of Their Components

If $\mathbf{a} = a_1\hat{\mathbf{i}} + a_2\hat{\mathbf{j}} + a_3\hat{\mathbf{k}}$ and $\mathbf{b} = b_1\hat{\mathbf{i}} + b_2\hat{\mathbf{j}} + b_3\hat{\mathbf{k}}$,

then $$\mathbf{a} \times \mathbf{b} = \begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \end{vmatrix}$$

$$= (a_2b_3 - a_3b_2)\hat{\mathbf{i}} - (a_1b_3 - a_3b_1)\hat{\mathbf{j}} + (a_1b_2 - a_2b_1)\hat{\mathbf{k}}$$

where, $\hat{\mathbf{i}} \times \hat{\mathbf{i}} = \hat{\mathbf{j}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}} \times \hat{\mathbf{k}} = 0$

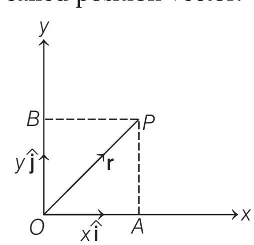
and $\hat{\mathbf{i}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}},\ \hat{\mathbf{j}} \times \hat{\mathbf{k}} = \hat{\mathbf{i}},\ \hat{\mathbf{k}} \times \hat{\mathbf{i}} = \hat{\mathbf{j}},$

$\hat{\mathbf{j}} \times \hat{\mathbf{i}} = -\hat{\mathbf{k}},\ \hat{\mathbf{k}} \times \hat{\mathbf{j}} = -\hat{\mathbf{i}}, \hat{\mathbf{i}} \times \hat{\mathbf{k}} = -\hat{\mathbf{j}}$

20. **Properties of Cross Product**

- $\mathbf{a} \times \mathbf{b} = -\mathbf{b} \times \mathbf{a}$
- $\mathbf{a} \times (\mathbf{b} + \mathbf{c}) = \mathbf{a} \times \mathbf{b} + \mathbf{a} \times \mathbf{c}$
- $(\mathbf{a} \times \mathbf{b}) + (\mathbf{c} \times \mathbf{d}) = (\mathbf{a} \times \mathbf{c}) + (\mathbf{a} \times \mathbf{d}) + (\mathbf{b} \times \mathbf{c}) + (\mathbf{b} \times \mathbf{d})$
- $m\mathbf{a} \times \mathbf{b} = \mathbf{a} \times m\mathbf{b}$
- $(\mathbf{b} + \mathbf{c})\ \mathbf{a} = \mathbf{b} \times \mathbf{a} + \mathbf{c} \times \mathbf{a}$
- $\mathbf{a} \times \mathbf{a} = 0$
- $\mathbf{a} \times (\mathbf{b} - \mathbf{c}) = \mathbf{a} \times \mathbf{b} - \mathbf{a} \times \mathbf{c}$
- $|\mathbf{a} \times \mathbf{b}|^2 = |\mathbf{a}|^2 |\mathbf{b}|^2 - |\mathbf{a} \cdot \mathbf{b}|^2$
- $\mathbf{a} \times (\mathbf{b} \times \mathbf{c}) = (\mathbf{c} \cdot \mathbf{a})\ \mathbf{b} - (\mathbf{b} \cdot \mathbf{a})\ \mathbf{c}$

21. **Position Vector** A vector that extends from a reference point to the point at which particle is located is called position vector.



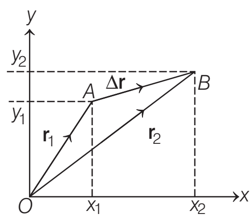
For a particle at point P, its position vector,

$$\mathbf{r} = x\hat{\mathbf{i}} + y\hat{\mathbf{j}}$$

In three-dimensions, the position vector is represented as $\mathbf{r} = x\hat{\mathbf{i}} + y\hat{\mathbf{j}} + z\hat{\mathbf{k}}$

22. **Displacement Vector** This vector represent the straight line joining the initial and final positions of a particle.

It does not depends on the actual path undertaken by the particle between the two positions.



Displacement vector, **AB**

$$\Delta\mathbf{r} = (x_2 - x_1)\,\hat{\mathbf{i}} + (y_2 - y_1)\,\hat{\mathbf{j}}$$

Similarly, in three-dimensions, the displacement vector can be represented as

$$\Delta\mathbf{r} = (x_2 - x_1)\,\hat{\mathbf{i}} + (y_2 - y_1)\hat{\mathbf{j}} + (z_2 - z_1)\,\hat{\mathbf{k}}$$

23. **Velocity** Rate of change of displacement of a body w.r.t. time is called velocity. It is of two types as given below

- **Average Velocity** It is defined as the ratio of the net displacement and the corresponding time interval.

  Thus, average velocity $= \dfrac{\text{net displacement}}{\text{time taken}}$

  Average velocity,

  $$\mathbf{v}_{\text{av}} = \frac{\Delta\mathbf{r}}{\Delta t} = \frac{\mathbf{r}_2 - \mathbf{r}_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}\hat{\mathbf{i}} + \frac{\Delta y}{\Delta t}\hat{\mathbf{j}}$$

  Velocity can be expressed in the component form as

  $$\mathbf{v} = v_x\hat{\mathbf{i}} + v_y\hat{\mathbf{j}}$$

  where, v_x and v_y are the components of velocity along x-direction and y-direction, respectively.

  The magnitude of $\mathbf{v}$ is given by

  $$|\mathbf{v}| = \sqrt{v_x^2 + v_y^2}$$

  and the direction of $\mathbf{v}$ is given by angle θ

  $$= \tan^{-1}\left(\frac{v_y}{v_x}\right)$$

- **Instantaneous Velocity** The velocity at an instant of time (t) is known as instantaneous velocity.

  The average velocity will become instantaneous, if Δt approaches to zero. The instantaneous velocity is expressed as

  $$\mathbf{v}_i = \lim_{\Delta t \to 0} \frac{\Delta\mathbf{r}}{\Delta t} = \frac{d\mathbf{r}}{dt} = \frac{d}{dt}(x\hat{\mathbf{i}} + y\hat{\mathbf{j}})$$

24. **Acceleration** The rate of change of velocity of a body w.r.t. time is called acceleration. It is of two types as given below

- **Average Acceleration** It is defined as the ratio of change in velocity ($\Delta\mathbf{v}$) and the corresponding time interval (Δt). It can be expressed as

  $$\mathbf{a}_{\text{av}} = \frac{\text{change in velocity}}{\text{time taken}} = \frac{\Delta\mathbf{v}}{\Delta t} = \frac{\mathbf{v}_2 - \mathbf{v}_1}{t_2 - t_1}$$

- **Instantaneous Acceleration** It is defined as the limiting value of the average acceleration as the time interval approaches to zero.

  It can be expressed as, $\mathbf{a}_i = \lim_{\Delta t \to 0} \dfrac{\Delta\mathbf{v}}{\Delta t} = \dfrac{d\,\mathbf{v}}{dt}$

  Instantaneous acceleration, $\mathbf{a}_i = a_x\hat{\mathbf{i}} + a_y\hat{\mathbf{j}}$

  In terms of x and y, a_x and a_y can be expressed as

  $$a_x = \frac{dv_x}{dt}$$

  and $$a_y = \frac{dv_y}{dt}$$

  The magnitude of instantaneous acceleration is given by

  $$a_i = \sqrt{a_x^2 + a_y^2}$$

  Direction of acceleration, $\theta = \tan^{-1}\left(\dfrac{a_y}{a_x}\right)$

25. **Motion in a Plane with Uniform Velocity** Consider an object moving with uniform velocity $\mathbf{v}$ in xy-plane. Let $\mathbf{r}(0)$ and $\mathbf{r}(t)$ be its position vectors at $t = 0$ and $t = t$, respectively.

Then, $$\mathbf{v} = \frac{\mathbf{r}(t) - \mathbf{r}(0)}{t - 0}$$

$\Rightarrow \quad \mathbf{r}(t) = \mathbf{r}(0) + \mathbf{v}t$

26. **Motion in a Plane with Constant Acceleration** For a body moving with uniform acceleration, we have

$$\mathbf{a} = \frac{\mathbf{v} - \mathbf{v}_0}{t - 0} \Rightarrow \mathbf{v} = \mathbf{v}_0 + \mathbf{a}\,t$$

In terms of rectangular components, we can express it as

$$v_x = v_{0x} + a_x t$$

and $$v_y = v_{0y} + a_y t$$

Also, $\mathbf{r}(t) = \mathbf{r}(0) + \mathbf{v}_0 + \frac{1}{2}\mathbf{a}t$

27. **Relative Velocity in Two-Dimensions** The relative velocity of an object A w.r.t. object B, when both are in motion, is the rate of change of position of object A w.r.t. object B.

Suppose two objects A and B are moving with velocities $\mathbf{v}_A$ and $\mathbf{v}_B$ w.r.t. ground or the earth. Then, relative velocity of object A w.r.t. object B,

$$\mathbf{v}_{AB} = \mathbf{v}_A - \mathbf{v}_B$$

Relative velocity of object B w.r.t. object A,

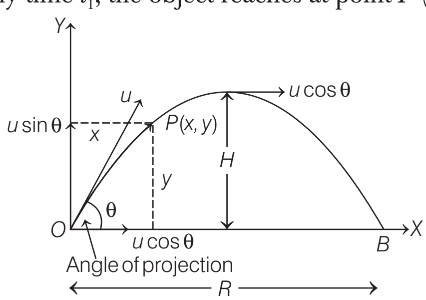
$$\mathbf{v}_{BA} = \mathbf{v}_B - \mathbf{v}_A$$

Clearly, $\mathbf{v}_{AB} = -\mathbf{v}_{BA}$

and $|\mathbf{v}_{AB}| = |\mathbf{v}_{BA}|$

28. **Projectile Motion** It is a form of motion in which an object or a particle is thrown with some initial velocity near the earth's surface and it moves along a curved path under the action of gravity alone. The path followed by a projectile is called its **trajectory**. e.g.,
   - A tennis ball or a baseball in a flight.
   - A bullet fired from a rifle.

29. **Equation of Path of a Projectile** Suppose at any time t_1, the object reaches at point $P(x, y)$.



- Position of the object at time t along horizontal direction is given by

$$x = x_0 + u_x t + \frac{1}{2} a_x t^2$$

- Position of the object at any time t along the vertical direction i.e. OY is

$$y = x \tan\theta - \left(\frac{1}{2}\frac{g}{u^2 \cos^2\theta}\right)x^2$$

This equation represents a parabola and is known as **equation** of **trajectory of a projectile.**

30. **Time of Flight** It is defined as the total time for which projectile is in flight, i.e. time during the motion of projectile from O to B. It is denoted by T.

Time of flight, $T = \dfrac{2u\sin\theta}{g}$

Time of flight consist of two parts such as
   - Time taken by an object to go from point O to H. It is also known as **time of ascent** (t).
   - Time taken by an object to go from point H to B. It is also known as **time of descent** (t).

31. **Maximum Height of a Projectile** It is defined as the maximum vertical height attained by an object above the point of projection during its flight. It is denoted by H.

Maximum height,

$$H = \frac{u^2 \sin^2\theta}{2g}$$

32. **Horizontal Range of a Projectile** The horizontal range of the projectile is defined as the horizontal distance covered by the projectile during its time of flight. It is denoted by R and is given as

$$R = u\cos\theta \times T$$

or $$R = \frac{u^2 \sin 2\theta}{g}$$

The horizontal range will be maximum, if $\theta = 45°$.

$\therefore$ Maximum horizontal range,

$$R_m = \frac{u^2}{g}$$

33. **Uniform Circular Motion** When an object follows a circular path at a constant speed, the motion of the object is called uniform circular motion.
e.g.,
- Motion of the tip of the second hand of a clock.
- Motion of a point on the rim of a wheel rotating uniformly.

34. **Terms Related to Circular Motion**
- **Angular Displacement** It is defined as the angle traced out by the radius vector at the centre of the circular path in the given time. It is denoted by $\Delta\theta$ and expressed in radians. It is a dimensionless quantity.
- **Angular Velocity** It is defined as the time rate of change of its angular displacement. It is denoted by ω and is measured in radians per second. Its dimensional formula is $[M^0 L^0 T^{-1}]$. It is a vector quantity.
  It is expressed as $\omega = \dfrac{\Delta\theta}{\Delta t}$.
- **Angular Acceleration** It is defined as the time rate of change of angular velocity of a particle. It is measured in radian per second square and has dimensions $[M^0 L^0 T^{-2}]$.
- **Time Period** It is defined as the time taken by a particle to complete one revolution along its circular path. It is denoted by T and is measured in second.
- **Frequency** It is defined as the number of revolutions completed per unit time. It is denoted by f and is measured in Hz.
- **Relation between Time Period and Frequency**
  Time period, $T = \dfrac{1}{f}$
- **Relation between Angular Velocity, Frequency and Time Period**
  Angular velocity, $\omega = \dfrac{\theta}{t} = \dfrac{2\pi}{T} = 2\pi f$
- **Relation between Linear Velocity** (v) **and Angular velocity** (ω)
  Linear velocity, $v = r\dfrac{\Delta\theta}{\Delta t} = r\omega$

35. **Centripetal Acceleration** The acceleration associated with a uniform circular motion and whose direction is towards the centre of the path is called centripetal acceleration.
Centripetal acceleration, $a = \dfrac{v^2}{r}$

Objective Questions

Multiple Choice Questions

1. In order to describe motion in two or three dimensions, we use

(a) positive sign (b) vectors
(c) negative sign (d) Both (b) and (c)

2. If length and breadth of a rectangle are 1 m and 0.5 m respectively, then its perimeter will be a

(a) free vector (b) scalar quantity
(c) localised vector (d) Neither (a) nor (b)

3. Consider the quantities, pressure, power, energy, impulse, gravitational potential, electrical charge, temperature, area. Out of these, the only vector quantities are *(NCERT Exemplar)*

(a) impulse, pressure and area
(b) impulse and area
(c) area and gravitational potential
(d) impulse and pressure

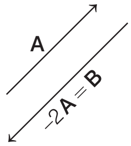
4. Suppose an object is at point P at time t moves to P' and then comes back to P. Then, displacement is a

(a) unit vector (b) null vector
(c) scalar (d) None of these

5. The relation between the vectors $\mathbf{A}$ and $-\lambda\mathbf{A}$ is that,

(a) both have same magnitude
(b) both have same direction
(c) they have opposite directions
(d) None of the above

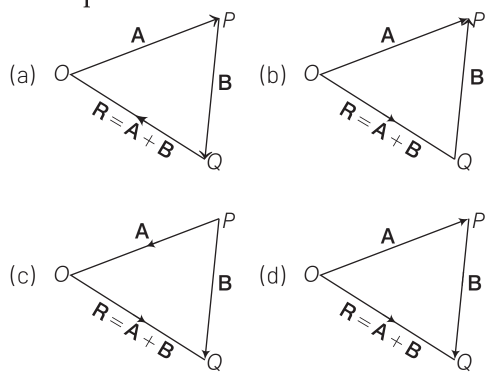
6. Choose the correct option regarding the given figure.



(a) $B = A$ (b) $B = -A$
(c) $|B| = |A|$ (d) $|B| \neq |A|$

7. A and B are two inclined vectors. R is their sum.

Choose the correct figure for the given description.



8. Find the correct option about vector subtraction.

(a) $A - B = A + B$ (b) $A + B = B - A$
(c) $A - B = A + (-B)$ (d) None of these

9. $\mathbf{A}$ is a vector with magnitude A, then the unit vector $\hat{\mathbf{a}}$ in the direction of vector $\mathbf{A}$ is

(a) $A\mathrm{A}$ (b) $\mathrm{A} \cdot \mathrm{A}$ (c) $\mathrm{A} \times \mathrm{A}$ (d) $\frac{\mathrm{A}}{A}$

10. Unit vector in the direction of the resultant of vectors $\mathbf{A} = -3\hat{i} - 2\hat{j} - 3\hat{k}$ and $\mathbf{B} = 2\hat{i} + 4\hat{j} + 6\hat{k}$ is

(a) $\frac{-3\hat{i} + 2\hat{j} - 3\hat{k}}{\sqrt{14}}$ (b) $-\hat{i} + 2\hat{j} + 3\hat{k}$
(c) $\frac{-\hat{i} + 2\hat{j} + 3\hat{k}}{\sqrt{14}}$ (d) $-2\hat{i} - 4\hat{j} + 8\hat{k}$

11. If $\mathbf{A} = \mathbf{B} + \mathbf{C}$ have scalar magnitudes of 5, 4, 3 units respectively, then the angle between $\mathbf{A}$ and $\mathbf{C}$ is

(a) $\cos^{-1}(3/5)$ (b) $\cos^{-1}(4/5)$
(c) $\pi/2$ (d) $\sin^{-1}(4/5)$

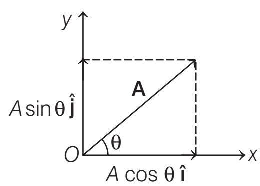
12. For two vectors **A** and **B**, $|\mathbf{A}+\mathbf{B}|=|\mathbf{A}-\mathbf{B}|$ is always true, when

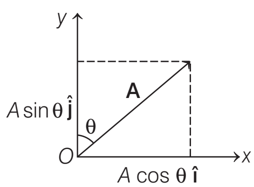
(a) $|\mathbf{A}|=|\mathbf{B}|\neq 0$
(b) $|\mathbf{A}|=|\mathbf{B}|\neq 0$ and **A** and **B** are parallel or anti-parallel
(c) either $|\mathbf{A}|$ or $|\mathbf{B}|$ is zero
(d) None of the above

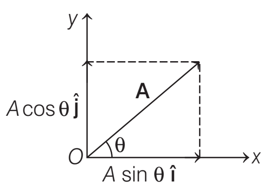
13. Two equal vectors have a resultant equal to either of the two. The angle between them is

(a) 90° (b) 60°
(c) 120° (d) 0°

14. Consider a vector **A** that lies in *xy*-plane. If A_x and A_y are the magnitudes of its *x* and *y* -components respectively, then the correct representation of **A** can be given by

(a) 

(b) 

(c) 

(d) None of the above

15. The component of a vector **r** along *X*-axis will have maximum value if *(NCERT Exemplar)*

(a) **r** is along positive *Y*-axis
(b) **r** is along positive *X*-axis
(c) **r** makes an angle of 45° with the *X*-axis
(d) **r** is along negative *Y*-axis

16. Magnitude of a vector **Q** is 5 and magnitude of its *y*-component is 4. So, the magnitude of the *x*-component of this vector is

(a) 8 (b) 3
(c) 6 (d) 9

17. Three vectors are given as $\mathbf{P}=3\hat{\mathbf{i}}-4\hat{\mathbf{j}}, \mathbf{Q}=6\hat{\mathbf{i}}-8\hat{\mathbf{j}}$ and $\mathbf{R}=(3/4)\hat{\mathbf{i}}-\hat{\mathbf{j}}$, then which of the following is correct?

(a) *P, Q* and *R* are equal vectors
(b) *P* and *Q* are parallel but *R* is not parallel
(c) *P, Q* and *R* are parallel
(d) None of the above

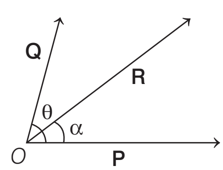
18. A vector is inclined at an angle 60° to the horizontal. If its rectangular component in the horizontal direction is 50 N, then its magnitude in the vertical direction is

(a) 25 N (b) 75 N
(c) 87 N (d) 100 N

19. The angle θ between the vector $\mathbf{p}=\hat{\mathbf{i}}+\hat{\mathbf{j}}+\hat{\mathbf{k}}$ and unit vector along *X*-axis is

(a) $\cos^{-1}\left(\frac{1}{\sqrt{3}}\right)$ (b) $\cos^{-1}\left(\frac{1}{\sqrt{2}}\right)$
(c) $\cos^{-1}\left(\frac{\sqrt{3}}{2}\right)$ (d) $\cos^{-1}\left(\frac{1}{2}\right)$

20. Two vectors **P** and **Q** are inclined at an angle θ and **R** is their resultant as shown in the figure.



Keeping the magnitude and the angle of the vectors same, if the direction of **P** and **Q** is interchanged, then their is a change in which of the following with regard to **R**?

(a) Magnitude
(b) Direction
(c) Both magnitude and direction
(d) None of the above

21. It is found that $|\mathbf{A}+\mathbf{B}|=|\mathbf{A}|$. This necessarily implies

(a) $|B|=0$
(b) A, B are parallel
(c) A, B are perpendicular
(d) A; B ≤ 0

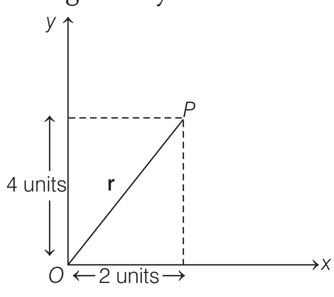
22. The sides of a parallelogram are represented by vectors $\mathbf{p}=5\hat{\mathbf{i}}-4\hat{\mathbf{j}}+3\hat{\mathbf{k}}$ and $\mathbf{q}=3\hat{\mathbf{i}}+2\hat{\mathbf{j}}-\hat{\mathbf{k}}$. Then, the area of the parallelogram is

(a) $\sqrt{684}$ sq. units (b) $\sqrt{72}$ sq. units
(c) 171 sq. units (d) 72 sq. units

23. If $\mathbf{a}\cdot\mathbf{b}=|\mathbf{a}\times\mathbf{b}|$, then the angle θ between **a** and **b** will be

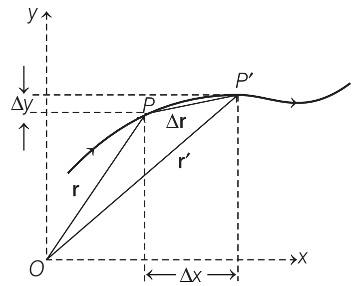
(a) 60° (b) 45° (c) 75° (d) 90°

24. Position vector **r** of a particle P located in a plane with reference to the origin of an *xy*-plane as shown in the figure below is given by



(a) $2\hat{i}+4\hat{j}$ (b) $4\hat{i}+2\hat{j}$
(c) $6\hat{k}$ (d) $\hat{i}+\hat{j}+4\hat{k}$

25. Suppose a particle moves along a curve shown by the thick line and the positions of particle are represented by P at t and P' at t'.



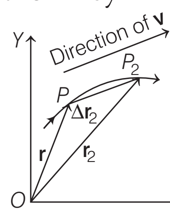
where, coordinates of P is (4, 3) and P' is (7, 6). Net displacement of the particle will be

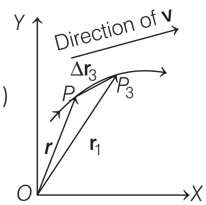
(a) zero (b) $7\hat{i}+9\hat{j}$
(c) $10\hat{i}+18\hat{j}$ (d) $3\hat{i}+3\hat{j}$

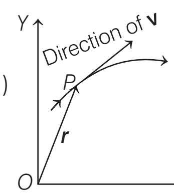
26. A particle moves in *xy*-plane from positions (2 m, 4 m) to (6 m, 8 m) is 2 s. Magnitude and direction of average velocity is

(a) $\sqrt{2}$ ms^{-1} and 45° (b) $2\sqrt{2}$ ms^{-1} and 45°
(c) $4\sqrt{2}$ ms^{-1} and 30° (d) $3\sqrt{2}$ ms^{-1} and 60°

27. The direction of instantaneous velocity is shown by

(a)


(b)


(c)


(d) None of these

28. The position of a particle is given by $\mathbf{r}=3t\,\hat{\mathbf{i}}+2t^2\,\hat{\mathbf{j}}+5\hat{\mathbf{k}}$, then the direction of $\mathbf{v}(t)$ at $t=1$ s in

(a) 45° with X-axis
(b) 63° with Y-axis
(c) 30° with Y-axis
(d) 53° with X-axis

29. In three dimensional system, the position coordinates of a particle (in motion) are given below

$$x = a\cos\omega t$$
$$y = a\sin\omega t$$
$$z = a\omega t$$

The velocity of particle will be

(a) $\sqrt{2}\,a\omega$ (b) $2\,a\omega$
(c) $a\omega$ (d) $\sqrt{3}\,a\omega$

30. The coordinates of a moving particle at any time t are given by, $x = 2t^3$ and $y = 3t^3$. Acceleration of the particle is given by

(a) $468\,t$ (b) $t\sqrt{468}$ (c) $234\,t^2$ (d) $t\sqrt{234}$

31. A particle starts from origin at $t = 0$ with a velocity $5.0\,\hat{\mathbf{i}}$ ms^{-1} and moves in xy-plane under action of force which produces a constant acceleration of $(3.0\,\hat{\mathbf{i}} + 2.0\,\hat{\mathbf{j}})$ ms^{-2}. What is the y-coordinate of the particle at the instant, if x-coordinate is 84 m?

(a) 36 m (b) 24 m
(c) 39 m (d) 18 m

32. A car driver is moving towards a fired rocket with a velocity of $8\hat{\mathbf{i}}$ ms^{-1}. He observed the rocket to be moving with a speed of 10 ms^{-1}. A stationary observer will see the rocket to be moving with a speed of

(a) 5 ms^{-1} (b) 6 ms^{-1}
(c) 7 ms^{-1} (d) 8 ms^{-1}

33. A man standing on a road has to hold his umbrella at 30° with the vertical to keep the rain away. He throws the umbrella and starts running at 10 kmh^{-1}.

He finds that raindrops are hitting his head vertically. The actual speed of raindrops is

(a) 20 kmh^{-1} (b) $10\sqrt{3}$ kmh^{-1}
(c) $20\sqrt{3}$ kmh^{-1} (d) 10 kmh^{-1}

34. A girl can swim with speed 5 kmh^{-1} in still water. She crosses a river 2 km wide, where the river flows steadily at 2 kmh^{-1} and she makes strokes normal to the river current. Find how far down the river she go when she reaches the other bank.

(a) 1 km (b) 2 km
(c) 800 m (d) 750 m

35. When a ball is thrown obliquely from the ground level, then the x-component of the velocity

(a) decreases with time
(b) increases with time
(c) remains constant
(d) zero

36. The motion of an object that is in flight after being projected is a result of two simultaneously occurring components of motion, which are the components in

(a) horizontal direction with constant acceleration
(b) vertical direction with constant acceleration
(c) horizontal direction without acceleration
(d) Both (b) and (c)

37. At the top of the trajectory of a projectile, the directions of its velocity and acceleration are

(a) parallel to each other
(b) antiparallel to each other
(c) inclined to each other at an angle of 45°
(d) perpendicular to each other

38. A projectile is given an initial velocity of $(\hat{\mathbf{i}} + 2\hat{\mathbf{j}})$ ms^{-1}, where $\hat{\mathbf{i}}$ is along the ground and $\hat{\mathbf{j}}$ is along vertical. If g is 10 ms^{-2}, then the equation of its trajectory is

(a) $y = x - 5x^2$
(b) $y = 2x - 5x^2$
(c) $4y = 2x - 5x^2$
(d) $4y = 2x - 25x^2$

39. The equations of motion of a projectile are given by $x = 18t$ and $2y = 54t - 9.8t^2$. The angle θ of projection is

(a) $\tan^{-1}(3)$ (b) $\tan^{-1}(1.5)$
(c) $\sin^{-1}\left(\frac{2}{3}\right)$ (d) $\cos^{-1}\left(\frac{2}{3}\right)$

40. A football player throws a ball with a velocity of 50 ms^{-1} at an angle 30° from the horizontal. The ball remains in the air for (Take, $g = 10 \text{ ms}^{-2}$)

(a) 2.5 s (b) 1.25 s
(c) 5 s (d) 0.625 s

41. The ceiling of a hall is 30 m high. A ball is thrown with 60 ms^{-1} at an angle θ, so that it could reach the ceiling of the hall and come back to the ground. The angle of projection θ that the ball was projected is given by

(a) $\sin\theta = \frac{1}{\sqrt{8}}$ (b) $\sin\theta = \frac{1}{\sqrt{6}}$
(c) $\sin\theta = \frac{1}{\sqrt{3}}$ (d) None of these

42. Two projectiles *A* and *B* are projected with same speed at angles 30° and 60° to be horizontal then, which amongst the following relation between their range, maximum height and time of flight is wrong?

(a) $R_A = R_B$ (b) $H_B = 3H_A$
(c) $T_B = \sqrt{3}T_A$ (d) None of these

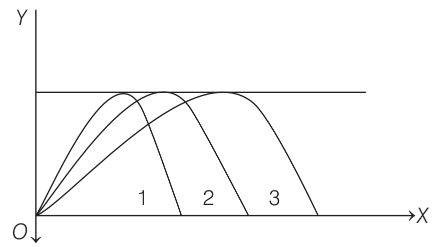
43. A man can throw a stone to a maximum distance of 80 m. The maximum height to which it will rise, is

(a) 30 m (b) 20 m
(c) 10 m (d) 40 m

44. Two stones were projected simultaneously in the same vertical plane from same point obliquely, with different speeds and angles with the horizontal. The trajectory of path followed by one, as seen by the other, is

(a) parabola (b) straight line
(c) circle (d) hyperbola

45. Given below figure show three paths of a rock with different initial velocities. The correct increasing order for the respective initial horizontal velocity component (ignoring the effect of air resistance) is



(a) $1 < 2 < 3$ (b) $3 < 2 < 1$
(c) $2 < 1 < 3$ (d) $3 < 1 < 2$

46. What is the centripetal acceleration of a point mass which is moving on a circular path of radius 5m with speed 25 ms^{-1}?

(a) 125 ms^{-2} (b) 90 ms^{-2}
(c) 60 ms^{-2} (d) None of these

47. The displacement of a particle moving on a circular path, when it makes 60° at the centre is

(a) $2r$ (b) r
(c) $\sqrt{2}r$ (d) None of these

48. If a car is executing a uniform circular motion, then its centripetal acceleration represents

(a) a scalar quantity (b) constant vector
(c) not a constant vector (d) None of these

49. A car revolves uniformly in a circle of diameter 0.80m and completes 100 rev min^{-1}. Its angular velocity is

(a) 10.467 rads^{-1} (b) 0.6 rads^{-1}
(c) 46.26 rads^{-1} (d) 8 rads^{-1}

50. If 2 balls are projected at angles 45° and 60° and the maximum heights reached are same, then the ratio of their initial velocities is ....

(a) $\sqrt{2} : \sqrt{3}$ (b) $\sqrt{3} : \sqrt{2}$
(c) 3:2 (d) 2:3

51. Two projectiles having different masses m_1 and m_2 are projected at an angle α and $(90° - \alpha)$ with the same speed from some point. The ratio of their maximum heights is ……… .

(a) $\cot\alpha : \sin\alpha$ (b) 1 : 1
(c) $\tan^2\alpha : 1$ (d) $1 : \tan\alpha$

52. A projectile fired with initial velocity u at some angle θ has a range R. If the initial velocity be doubled at the same angle of projection, then the range will be ……… .

(a) $2R$ (b) $R/2$
(c) R (d) $4R$

53. Two cars of masses m_1 and m_2 are moving in circles of radii r_1 and r_2, respectively. Their speeds are such that they make complete circles in the same time t. The ratio of their centripetal accelerations is …… .

(a) $m_1 r_1 : m_2 r_2$ (b) $m_1 : m_2$
(c) $r_1 : r_2$ (d) 1:1

54. Which one of the following statement is correct? *(NCERT Exemplar)*

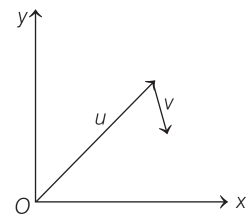
(a) A scalar quantity is the one that is conserved in a process.
(b) A scalar quantity is the one that can never take negative values.
(c) A scalar quantity is the one that does not vary from one point to another in space.
(d) A scalar quantity has the same value for observers with different orientation of the axes.

55. For two vectors **A** and **B** which lie in a plane. Which of the following statement is correct?

(a) If magnitude of A and B vector is 3 and 4 and they add upto give vector having magnitude of 5, then they must be perpendicular vector.
(b) If they add up to give more than 5, then they must be inclined at obtuse angle.
(c) If they add upto give less than 5, then they must be inclined at acute angle.
(d) None of the above

56. Figure shows the orientation of two vectors **u** and **v** in the xy-plane.

If $\mathbf{u} = a\hat{\mathbf{i}} + b\hat{\mathbf{j}}$ and $\mathbf{v} = p\hat{\mathbf{i}} + q\hat{\mathbf{j}}$



Which of the following statement is correct? *(NCERT Exemplar)*

(a) a and p are positive, while b and q are negative.
(b) a, p and b are positive, while q is negative.
(c) a, q and b are positive, while p is negative.
(d) a, b, p and q are all positive.

57. Match the Column I (example of motion) with Column II (type of motion) and select the correct answer from the codes given below.

	Column I		Column II
A.	Free fall	p.	One-dimensional motion
B.	Projectile motion	q.	Two-dimensional motion
C.	Circular motion	r.	Three-dimensional motion
D.	Motion along a straight road		

Codes

	A	B	C	D
(a)	q	p	r	p
(b)	p	q	r	q
(c)	p	q	q	p
(d)	p	r	q	p

58. Match the Column I (magnitude of vectors **A** and **B**) with Column II (relationship between **A** and **B**) and select the correct answer from the codes given below.

	Column I		Column II
A.	$\xrightarrow{\|\mathbf{A}\| = l}$ $\xrightarrow{\|\mathbf{B}\| = 2l}$	p.	$\mathbf{A} = -\mathbf{B}$
B.	$\xrightarrow{\|\mathbf{A}\| = l}$ $\xleftarrow{\|\mathbf{B}\| = l}$	q.	$\mathbf{A} = \mathbf{B}$
C.	$\xrightarrow{\|\mathbf{A}\| = 2l}$ $\xleftarrow{\mathbf{B} = l}$	r.	$2\mathbf{A} = \mathbf{B}$
D.	$\xrightarrow{\|\mathbf{A}\| = l}$ $\xrightarrow{\|\mathbf{B}\| = l}$	s.	$\mathbf{A} = -2\,\mathbf{B}$

Codes

	A	B	C	D		A	B	C	D
(a)	q	s	p	q	(b)	r	p	s	q
(c)	r	p	q	s	(d)	q	r	s	p

59. A vector is given by $\mathbf{A} = 4\hat{\mathbf{i}} + 3\hat{\mathbf{j}} + 5\hat{\mathbf{k}}$, where α, β and γ are the angles made by **A** with coordinate axes. Then, match the Column I with Column II (respective values) and select the correct option from the codes given below.

	Column I		Column II
A.	α	p.	$\cos^{-1}(1/\sqrt{2})$
B.	β	q.	$\cos^{-1}(4/5\sqrt{2})$
C.	γ	r.	$\cos^{-1}(3/5\sqrt{2})$

Codes

	A	B	C		A	B	C
(a)	p	q	r	(b)	q	r	p
(c)	r	q	p	(d)	p	p	q

Assertion-Reasoning MCQs

For question numbers 60 to 69, two statements are given-one labelled ***Assertion*** *(A) and the other labelled* ***Reason*** *(R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

60. Assertion Magnitude of resultant of two vectors may be less than the magnitude of either vector.

Reason Vector addition is commutative.

61. Assertion Vector addition of two vectors is always greater than their vector subtraction.

Reason At $\theta = 90^\circ$, addition and subtraction of vectors are unequal.

62. Assertion In case of projectile motion, the magnitude of rate of change of velocity is variable.

Reason In projectile motion, magnitude of velocity first increases and then decreases during the motion.

63. Assertion At highest point of a projectile, dot product of velocity and acceleration is zero.

Reason At highest point, velocity and acceleration are mutually perpendicular.

64. Assertion A particle is projected with speed u at an angle θ with the horizontal. At any time during motion, speed of particle is v at angle α with the vertical, then $v \sin\alpha$ is always constant throughout the motion.

Reason In case of projectile motion, magnitude of radial acceleration at topmost point is minimum.

65. Assertion For projection angle $\tan^{-1}(4)$, the horizontal and maximum height of a projectile are equal.

Reason The maximum range of projectile is directly proportional to square of velocity and inversely proportional to acceleration due to gravity.

66. Assertion The range of a projectile is maximum at 45°.

Reason At $\theta = 45^\circ$, the value of $\sin\theta$ is maximum.

67. **Assertion** Sum of maximum height for angles α and $90°-\alpha$ is independent of the angle of projection.

Reason For angles α and $90°-\alpha$, the horizontal range R is different.

68. **Assertion** The maximum height of projectile is always 25% of the maximum range.

Reason For maximum range, projectile should be projected at 90°.

69. **Assertion** Uniform circular motion is uniformly accelerated motion.

Reason Kinematic equations for uniform acceleration motion can be applied in the case of uniform circular motion.

Case Based MCQs

Direction *Answer the questions from 70-74 on the following case.*

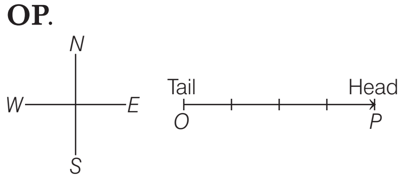
Vectors

Vectors are the physical quantities which have both magnitudes and directions and obey the triangle/parallelogram laws of addition and subtraction. It is specified by giving its magnitude by a number and its direction. e.g. Displacement, acceleration, velocity, momentum, force, etc. A vector is represented by a bold face type and also by an arrow placed over a letter, i.e.

F, **a**, **b** or $\vec{F}, \vec{a}, \vec{b}$.

The length of the line gives the magnitude and the arrowhead gives the direction.

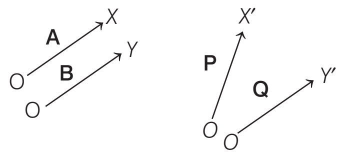
The point P is called head or terminal point and point O is called tail or initial point of the vector **OP**.



70. Amongst the following quantities, which is not a vector quantity?

(a) Force (b) Acceleration
(c) Temperature (d) Velocity

71. Set of vectors **A** and **B**, **P** and **Q** are as shown below



Length of **A** and **B** is equal, similarly length of **P** and **Q** is equal. Then, the vectors which are equal, are

(a) A and P (b) P and Q
(c) A and B (d) B and Q

72. $|\lambda \mathbf{A}| = \lambda |\mathbf{A}|$, if

(a) $\lambda > 0$ (b) $\lambda < 0$
(c) $\lambda = 0$ (d) $\lambda \neq 0$

73. Among the following properties regarding null vector which is incorrect?

(a) $A + 0 = A$ (b) $\lambda 0 = \lambda$
(c) $0A = 0$ (d) $A - A = \mathbf{0}$

74. The x and y components of a position vector **P** have numerical values 5 and 6, respectively. Direction and magnitude of vector **P** are

(a) $\tan^{-1}\left(\frac{6}{5}\right)$ and $\sqrt{61}$ (b) $\tan^{-1}\left(\frac{5}{6}\right)$ and $\sqrt{61}$
(c) 60° and 8 (d) 30° and 9

Direction *Answer the questions from 75-79 on the following case.*

Relative Velocity

Every motion is relative as it has to be observed with respect to an observer. Relative velocity is a measurement of velocity of an object with respect to other observer. It is defined as the time rate of change of relative position of one object with respect to another.

For example, if rain is falling vertically with a velocity v_r and a man is moving horizontally with v_m, the man can protect himself from the rain if he holds his umbrella in the direction of relative velocity of rain w.r.t. man.

75. Two bodies are held separated by 9.8 m vertically one above the other. They are released simultaneously to fall freely under gravity. After 2 s, the relative distance between them is

(a) 4.9 m (b) 19.6 m (c) 9.8 m (d) 39.2 m

76. If two objects P and Q move along parallel straight lines in opposite direction with velocities $\mathbf{v}_P$ and $\mathbf{v}_Q$ respectively, then relative velocity of P w.r.t. Q,

(a) $v_{PQ} = v_P = v_Q$ (b) $v_P - v_Q$
(c) $v_P + v_Q$ (d) $v_Q - v_P$

77. A train is moving towards East and a car is along North, both with same speed. The observed direction of car to the passenger in the train is

(a) East-North direction
(b) West-North direction
(c) South-East direction
(d) None of the above

78. Buses A and B are moving in the same direction with velocities $20\hat{\mathbf{i}}$ ms^{-1} and $15\hat{\mathbf{i}}$ ms^{-1}, respectively. Then, relative velocity of A w.r.t. B is

(a) $35\,\hat{i}\,ms^{-1}$ (b) $5\,\hat{i}\,ms^{-1}$
(c) $5\,\hat{j}\,ms^{-1}$ (d) $35\,\hat{j}\,ms^{-1}$

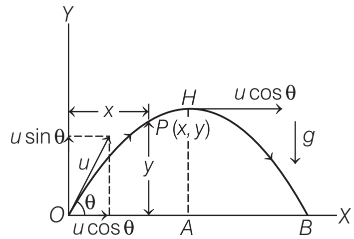
79. A girl riding a bicycle with a speed of 5 ms^{-1} towards east direction sees raindrops falling vertically downwards. On increasing the speed to 15 ms^{-1}, rain appears to fall making an angle of 45° of the vertical. Find the magnitude of velocity of rain.

(a) 5 ms^{-1} (b) $5\sqrt{5}$ ms^{-1}
(c) 25 ms^{-1} (d) 10 ms^{-1}

Direction *Answer the questions from 80-84 on the following case.*

Projectile Motion

Projectile motion is a form of motion in which an object or particle is thrown with some initial velocity near the earth's surface and it moves along a curved path under the action of gravity alone. The path followed by a projectile is called its trajectory, which is shown below. When a projectile is projected obliquely, then its trajectory is as shown in the figure below



Here velocity u is resolved into two components, we get (a) $u\cos\theta$ along OX and (b) $u\sin\theta$ along OY.

80. The example of such type of motion is

(a) motion of car on a banked road
(b) motion of boat in sea
(c) a javelin thrown by an athlete
(d) motion of ball thrown vertically upward

81. The acceleration of the object in horizontal direction is

(a) constant
(b) decreasing
(c) increasing
(d) zero

82. The vertical component of velocity at point H is

(a) maximum
(b) zero
(c) double to that at O
(d) equal to horizontal component

83. A cricket ball is thrown at a speed of 28 m/s in a direction 30° with the horizontal.

The time taken by the ball to return to the same level will be

(a) 2.0 s (b) 3.0 s
(c) 4.0 s (d) 2.9 s

84. In above case, the distance from the thrower to the point where the ball returns to the same level will be

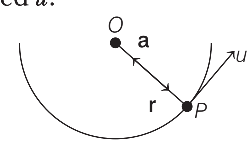
(a) 39 m (b) 69 m
(c) 68 m (d) 72 m

Direction *Answer the questions from 85-89 on the following case.*

Uniform Circular Motion

When an object follows a circular path at a constant speed, the motion of the object is called uniform circular motion. The word uniform refers to the speed which is uniform (constant) throughout the motion. Although the speed does not vary, the particle is accelerating because the velocity changes its direction at every point on the circular track.

The figure shows a particle P which moves along a circular track of radius r with a uniform speed u.



85. A circular motion

(a) is one-dimensional motion
(b) is two-dimensional motion
(c) it is represented by combination of two variable vectors
(d) Both (b) and (c)

86. For a particle performing uniform circular motion, choose the incorrect statement from the following.

(a) Magnitude of particle velocity (speed) remains constant.
(b) Particle velocity remains directed perpendicular to radius vector.
(c) Direction of acceleration keeps changing as particle moves.
(d) Angular momentum is constant in magnitude but direction keeps changing.

87. Two cars A and B move along a concentric circular path of radius r_A and r_B with velocities v_A and v_B maintaining constant distance, then $\frac{v_A}{v_B}$ is equal to

(a) $\frac{r_B}{r_A}$ (b) $\frac{r_A}{r_B}$
(c) $\frac{r_A^2}{r_B^2}$ (d) $\frac{r_B^2}{r_A^2}$

88. A car runs at a constant speed on a circular track of radius 100 m, taking 62.8 s for every circular lap. The average velocity and average speed for each circular lap, respectively is

(a) 0, 0
(b) 0, 10 ms^{-1}
(c) 10 ms^{-1}, 10 ms^{-1}
(d) 10 ms^{-1}, 0

89. A particle is revolving at 1200 rpm in a circle of radius 30 cm. Then, its acceleration is

(a) 1600 ms^{-2} (b) 4740 ms^{-2}
(c) 2370 ms^{-2} (d) 5055 ms^{-2}

ANSWERS

Multiple Choice Questions

1. (b)	2. (b)	3. (b)	4. (b)	5. (c)	6. (d)	7. (d)	8. (c)	9. (d)	10. (c)
11. (a)	12. (c)	13. (c)	14. (a)	15. (b)	16. (b)	17. (c)	18. (c)	19. (a)	20. (b)
21. (a)	22. (a)	23. (b)	24. (a)	25. (d)	26. (b)	27. (c)	28. (d)	29. (a)	30. (b)
31. (a)	32. (b)	33. (a)	34. (c)	35. (c)	36. (d)	37. (d)	38. (b)	39. (b)	40. (c)
41. (b)	42. (d)	43. (b)	44. (b)	45. (a)	46. (a)	47. (b)	48. (c)	49. (a)	50. (b)
51. (c)	52. (d)	53. (c)	54. (d)	55. (a)	56. (b)	57. (c)	58. (b)	59. (b)	

Assertion-Reasoning MCQs

60. (b)	61. (d)	62. (d)	63. (a)	64. (c)	65. (b)	66. (c)	67. (c)	68. (c)	69. (d)

Case Based MCQs

70. (c)	71. (c)	72. (a)	73. (b)	74. (a)	75. (c)	76. (c)	77. (b)	78. (b)	79. (b)
80. (c)	81. (d)	82. (b)	83. (d)	84. (b)	85. (d)	86. (c)	87. (b)	88. (b)	89. (b)

SOLUTIONS

1. In order to describe two dimensional or three dimensional motions, we use vectors. However, direction of the motion of an object along a straight line is shown by positive and negative signs.

2. The perimeter of the rectangle would be the sum of the lengths of the four sides, i.e. 1.0 m + 0.5 m + 1.0 m + 0.5 m = 3.0 m.

Since, length of each side is a scalar, thus the perimeter is also a scalar.

3. We know that, impulse $J = F \cdot \Delta t = \Delta p$, where F is force, Δt is time duration and Δp is change in momentum. As Δp is a vector quantity, hence impulse is also a vector quantity. Sometimes area can also be treated as vector.

4. In the given case, the initial and final positions coincides, so the displacement will be zero. Thus, it is a null vector.

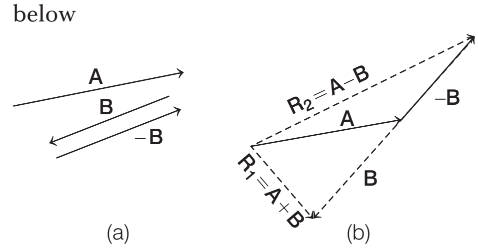
5. Multiplying a vector $\mathbf{A}$ by a negative number λ gives a vector $\lambda\mathbf{A}$, whose direction is opposite to the direction of $\mathbf{A}$ and its magnitude is $-\lambda$ times $|\mathbf{A}|$.

6. $|\mathbf{B}| = -2|\mathbf{A}|$. So, when $\mathbf{A}$ is multiplied by -2, then its direction gets reversed and magnitude would be 2 times $|\mathbf{A}|$.

Thus, $|\mathbf{B}| \neq |\mathbf{A}|$.

7. Vectors obey the triangle law of addition, according to which, if vector $\mathbf{B}$ is placed with its tail at the head of vector $\mathbf{A}$. Then, when we join the tail of $\mathbf{A}$ to the head of $\mathbf{B}$. The line OQ represents a vector $\mathbf{R}$, i.e. the sum of the vectors $\mathbf{A}$ and $\mathbf{B}$. Thus, figure given in option (d) is correct.

8. To subtract $\mathbf{B}$ from $\mathbf{A}$, we can add $-\mathbf{B}$ and $\mathbf{A}$. So, $\mathbf{A} + (-\mathbf{B}) = \mathbf{A} - \mathbf{B} = \mathbf{R}_2$. This is as shown below



(a) (b)

Hence, option (c) is correct about vector subtraction.

9. Unit vector of $\mathbf{A}$ is $\hat{\mathbf{a}} = \dfrac{\mathbf{A}}{|\mathbf{A}|} = \dfrac{\mathbf{A}}{A}$

10. Resultant vector of $\mathbf{A}$ and $\mathbf{B}$ is

$$\mathbf{R} = \mathbf{A} + \mathbf{B} = (-3\hat{i} - 2\hat{j} - 3\hat{k}) + (2\hat{i} + 4\hat{j} + 6\hat{k})$$

$$= -\hat{i} + 2\hat{j} + 3\hat{k}$$

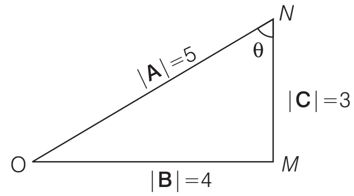
$$|\mathbf{R}| = \sqrt{(-1)^2 + (2)^2 + (3)^2}$$

$= \sqrt{1+4+9} = \sqrt{14}$

Unit vector in the direction of **R** is

$$\hat{R} = \frac{\mathbf{R}}{|\mathbf{R}|} = \frac{-\hat{i} + 2\hat{j} + 3\hat{k}}{\sqrt{14}}$$

11. Here, triangle *OMN* with its adjacent sides as vectors **A, B** and **C** are shown below



As, $\cos\theta = \frac{MN}{ON}$

$\Rightarrow \theta = \cos^{-1}\frac{|\mathbf{C}|}{|\mathbf{A}|} = \cos^{-1}\left(\frac{3}{5}\right)$

12. Given, $|\mathbf{A}+\mathbf{B}| = |\mathbf{A}-\mathbf{B}|$

$\Rightarrow \sqrt{|\mathbf{A}|^2 + |\mathbf{B}|^2 + 2|\mathbf{A}||\mathbf{B}|\cos\theta}$

$= \sqrt{|\mathbf{A}|^2 + |\mathbf{B}|^2 - 2|\mathbf{A}||\mathbf{B}|\cos\theta}$

$\Rightarrow |\mathbf{A}|^2 + |\mathbf{B}|^2 + 2|\mathbf{A}||\mathbf{B}|\cos\theta$

$= |\mathbf{A}|^2 + |\mathbf{B}|^2 - 2|\mathbf{A}||\mathbf{B}|\cos\theta$

$\Rightarrow 4|\mathbf{A}||\mathbf{B}|\cos\theta = 0$

$\Rightarrow |\mathbf{A}||\mathbf{B}|\cos\theta = 0$

$\Rightarrow |\mathbf{A}| = 0$

or $|\mathbf{B}| = 0$

or $\cos\theta = 0$

$\Rightarrow \theta = 90°$

Thus, $|\mathbf{A}+\mathbf{B}| = |\mathbf{A}-\mathbf{B}|$ is always true, when either $|\mathbf{A}|$ or $|\mathbf{B}|$ is zero or **A** and **B** are perpendicular to each other.

13. Let two vectors are **A** and **B**, inclined at an angle θ.

Resultant of the two vectors **A** and **B**,

$|\mathbf{R}| = \sqrt{|\mathbf{A}|^2 + |\mathbf{B}|^2 + 2|\mathbf{A}||\mathbf{B}|\cos\theta}$ ...(i)

Let, $|\mathbf{A}| = |\mathbf{B}| = a$

According to the question, $|\mathbf{R}| = a$

From Eq. (i),

$a = \sqrt{a^2 + a^2 + 2aa\cos\theta}$

$\Rightarrow a^2 = a^2 + a^2 + 2a^2\cos\theta$

$\Rightarrow 2a^2\cos\theta = -a^2$

$\Rightarrow \cos\theta = -1/2$

$\Rightarrow -\cos\theta = 1/2$

$\Rightarrow \cos(180° - \theta) = \cos 60°$

$\Rightarrow \theta = 120°$

14. Vector along *X*-axis (*x*-component)

$= A_x\hat{\mathbf{i}} = |\mathbf{A}|\cos\theta\hat{\mathbf{i}}$

$= A\cos\theta\hat{\mathbf{i}}$

Vector along *Y*-axis (*y*-component)

$= A_y\hat{\mathbf{j}} = |\mathbf{A}|\sin\theta\hat{\mathbf{j}}$

$= A\sin\theta\hat{\mathbf{j}}$

15. Let **r** makes an angle θ with positive *x*-axis, so the component of **r** along *X*-axis

$r_x = |\mathbf{r}|\cos\theta$

$(r_x)_{\text{maximum}} = |\mathbf{r}|(\cos\theta)_{\text{maximum}}$

$= |\mathbf{r}|\cos 0° = |\mathbf{r}|$

($\because$ cos θ is maximum of θ = 0°)

At θ = 0°, **r** will be along positive *X*-axis.

16. Given, $|\mathbf{Q}| = 5$

$Q_y = 4$

$Q_x = ?$

As, $|\mathbf{Q}| = \sqrt{Q_x^2 + Q_y^2}$

$\Rightarrow |\mathbf{Q}|^2 = Q_x^2 + Q_y^2$

Substituting the given values, we get

$(5)^2 = Q_x^2 + 4^2$

$\Rightarrow Q_x = \sqrt{9} = 3$

17. Given, $\mathbf{P} = 3\hat{\mathbf{i}} - 4\hat{\mathbf{j}}$

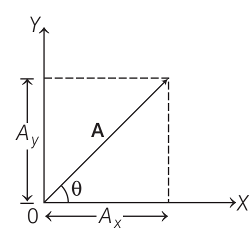
and $\mathbf{Q} = 6\hat{\mathbf{i}} - 8\hat{\mathbf{j}} = 2(3\hat{\mathbf{i}} - 4\hat{\mathbf{j}}) = 2\mathbf{P}$

Also, $\mathbf{R} = \frac{3}{4}\hat{\mathbf{i}} - \hat{\mathbf{j}} = \frac{1}{4}(3\hat{\mathbf{i}} - 4\hat{\mathbf{j}}) = \frac{\mathbf{P}}{4}$

So, **P**, **Q** and **R** are parallel with unequal magnitude.

Thus, they are not equals vectors.

18. Given, vector can be shown below as



where, $\theta = 60°$

Then, $\tan\theta = \dfrac{A_y}{A_x}$

or $A_y = A_x \tan\theta$

$\Rightarrow A_y = 50 \tan 60° = 50 \times \sqrt{3}$ $(\because \sqrt{3} = 1.732)$

$= 86.6 \simeq 87$ N

19. Given, $\mathbf{p} = \hat{\mathbf{i}} + \hat{\mathbf{j}} + \hat{\mathbf{k}}$

and unit vector along X-axis, $\mathbf{x} = \hat{\mathbf{i}}$.

So, the angle θ between them can be determine by

$$\cos\theta = \frac{\mathbf{p}\cdot\mathbf{x}}{|\mathbf{p}||\mathbf{x}|} = \frac{(\hat{\mathbf{i}} + \hat{\mathbf{j}} + \hat{\mathbf{k}})\cdot(\hat{\mathbf{i}})}{\sqrt{1^2 + 1^2 + 1^2}\cdot\sqrt{1^2}} = \frac{1}{\sqrt{3}}$$

$$\therefore \quad \theta = \cos^{-1}\left(\frac{1}{\sqrt{3}}\right)$$

20. Since, the magnitude and angle between the vectors is unchanged, so the magnitude of the resultant **R** will be same. However, the direction of **R** will get changed.

21. Given that, $|\mathbf{A} + \mathbf{B}| = |\mathbf{A}|$ or $|\mathbf{A} + \mathbf{B}|^2 = |\mathbf{A}|^2$

$\Rightarrow |\mathbf{A}|^2 + |\mathbf{B}|^2 + 2|\mathbf{A}||\mathbf{B}|\cos\theta = |\mathbf{A}|^2$

where, θ is angle between **A** and **B**.

$\Rightarrow |\mathbf{B}|(|\mathbf{B}| + 2|\mathbf{A}|\cos\theta) = 0$

$\Rightarrow |\mathbf{B}| = 0$ or $|\mathbf{B}| + 2|\mathbf{A}|\cos\theta = 0$

$\Rightarrow \cos\theta = -\dfrac{|\mathbf{B}|}{2|\mathbf{A}|}$ ...(i)

If **A** and **B** are anti-parallel, then $\theta = 180°$.

Hence, from Eq. (i),

$\cos 180° = -1 = -\dfrac{|\mathbf{B}|}{2|\mathbf{A}|} \Rightarrow |\mathbf{B}| = 2|\mathbf{A}|$

Hence, the given condition can only be implied of either $|\mathbf{B}| = 0$ or **A** and **B** are anti-parallel provided $|\mathbf{B}| = 2|\mathbf{A}|$.

22. Area of a parallelogram $= |\mathbf{a} \times \mathbf{b}|$

where, **a** and **b** are sides of parallelogram.

Given, $\mathbf{a} = \mathbf{p} = 5\hat{\mathbf{i}} - 4\hat{\mathbf{j}} + 3\hat{\mathbf{k}}$

and $\mathbf{b} = \mathbf{q} = 3\hat{\mathbf{i}} + 2\hat{\mathbf{j}} - \hat{\mathbf{k}}$

$$\therefore \quad \mathbf{a} \times \mathbf{b} = \begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ 5 & -4 & 3 \\ 3 & 2 & -1 \end{vmatrix}$$

$\Rightarrow \mathbf{a} \times \mathbf{b} = \hat{\mathbf{i}}(4-6) - \hat{\mathbf{j}}(-5-9) + \hat{\mathbf{k}}(10+12)$

$\Rightarrow \mathbf{a} \times \mathbf{b} = -2\hat{\mathbf{i}} + 14\hat{\mathbf{j}} + 22\hat{\mathbf{k}}$

Thus, $|\mathbf{a} \times \mathbf{b}| = \sqrt{(2)^2 + (14)^2 + (22)^2}$

$= \sqrt{684}$ sq. units

23. Given, $\mathbf{a}\cdot\mathbf{b} = |\mathbf{a} \times \mathbf{b}|$

$\Rightarrow ab\cos\theta = ab\sin\theta$

$(\because \mathbf{a}\cdot\mathbf{b} = ab\cos\theta$ and $\mathbf{a}\times\mathbf{b} = ab\sin\theta)$

$\Rightarrow \dfrac{\sin\theta}{\cos\theta} = \dfrac{ab}{ab} = 1$

$\Rightarrow \tan\theta = 1$

$\Rightarrow \tan\theta = \tan 45°$

$\therefore \theta = 45°$

24. Position vector **r** of an object in xy-plane at point P with its components along X and Y-axes as x and y, respectively is given as $\mathbf{r} = x\hat{\mathbf{i}} + y\hat{\mathbf{j}}$.

Given, $x = 2$ units and $y = 4$ units.

So, position vector at P will be $\mathbf{r} = 2\hat{\mathbf{i}} + 4\hat{\mathbf{j}}$.

25. Position vector of the particle at P,

$$\mathbf{r} = 4\hat{\mathbf{i}} + 3\hat{\mathbf{j}}$$

Position vector of the particle at P',

$$\mathbf{r}' = 7\hat{\mathbf{i}} + 6\hat{\mathbf{j}}$$

$\therefore$ Displacement of the particle is $\Delta\mathbf{r} = \mathbf{r}' - \mathbf{r}$

$\Rightarrow \Delta\mathbf{r} = (7\hat{\mathbf{i}} + 6\hat{\mathbf{j}}) - (4\hat{\mathbf{i}} + 3\hat{\mathbf{j}})$

$= (7-4)\hat{\mathbf{i}} + (6-3)\hat{\mathbf{j}} = 3\hat{\mathbf{i}} + 3\hat{\mathbf{j}}$

26. Displacement,

$$\Delta\mathbf{r} = \mathbf{r}_2 - \mathbf{r}_1 = 4\hat{\mathbf{i}} + 4\hat{\mathbf{j}}$$

$$\therefore \quad \mathbf{v}_{av} = \frac{\Delta\mathbf{r}}{\Delta t} = \frac{4\hat{\mathbf{i}} + 4\hat{\mathbf{j}}}{2} = 2(\hat{\mathbf{i}} + \hat{\mathbf{j}})\ \text{ms}^{-1}$$

$\Rightarrow$ Magnitude of velocity,

$$|\mathbf{v}_{av}| = 2\sqrt{1^2 + 1^2} = 2\sqrt{2}\ \text{ms}^{-1}$$

Direction,

$$\theta = \tan^{-1}\left(\frac{\Delta v_y}{\Delta v_x}\right) = \tan^{-1}\left(\frac{2}{2}\right) = \tan^{-1} 1 = 45°$$

27. The direction of instantaneous velocity at any point on the path of an object is tangential to the path at that point and is in the direction of motion. Also, direction of average velocity is same as that of $\Delta\mathbf{r}$.

So, amongst the given figures we can say that, options (a) and (b) are depicting the direction of averge velocity but option (c) is correctly depicting the direction of instantaneous velocity.

28. Given, $\mathbf{r} = 3t\hat{\mathbf{i}} + 2t^2\hat{\mathbf{j}} + 5\hat{\mathbf{k}}$

$$\therefore \mathbf{v}(t) = \frac{d\mathbf{r}}{dt} = \frac{d}{dt}(3t\hat{\mathbf{i}} + 2t^2\hat{\mathbf{j}} + 5\hat{\mathbf{k}}) = 3\hat{\mathbf{i}} + 4t\hat{\mathbf{j}}$$

At $t = 1$ s, $\mathbf{v} = 3\hat{\mathbf{i}} + 4\hat{\mathbf{j}}$

Thus, its direction is $\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{4}{3}\right)$

$\cong 53°$ with X-axis

29. Given that the position coordinates of a particle

$$\left.\begin{aligned} x &= a\cos\omega t \\ y &= a\sin\omega t \\ z &= a\omega t \end{aligned}\right\} \quad \ldots\text{(i)}$$

So, the position vector of the particle is

$$\hat{r} = x\hat{i} + y\hat{j} + z\hat{k}$$

$$\Rightarrow \hat{r} = a\cos\omega t\,\hat{i} + a\sin\omega t\,\hat{j} + a\,\omega t\,\hat{k}$$

$$\hat{r} = a[\cos\omega t\,\hat{i} + \sin\omega t\,\hat{j} + \omega t\,\hat{k}]$$

Therefore, the velocity of the particle is

$$\because \hat{v} = \frac{dr}{dt} = \frac{d[a][\cos\omega t\,\hat{i} + \sin\omega t\,\hat{j} + \omega t\,\hat{k}]}{dt}$$

$$\Rightarrow \hat{v} = -a\omega\sin\omega t\,\hat{i} + a\omega\cos\omega t\,\hat{j} + a\omega\hat{k})$$

The magnitude of velocity is

$$|v| = \sqrt{v_x^2 + v_y^2 + v_z^2}$$

or $|v| = \sqrt{(-a\omega\sin\omega t)^2 + (a\omega\cos\omega t)^2 + (a\omega)^2}$

$$= \omega a\sqrt{(-\sin\omega t)^2 + (\cos\omega t)^2 + (1)^2}$$

$$= \sqrt{2}\,\omega a$$

30. Given, $x = 2t^3$

$$\therefore v_x = \frac{dx}{dt} = 6t^2$$

$$\Rightarrow a_x = \frac{dv_x}{dt} = 12t$$

Also, $y = 3t^3$

$$\Rightarrow v_y = \frac{dy}{dt} = 9t^2$$

$$\Rightarrow a_y = \frac{dv_y}{dt} = 18t$$

$\therefore$ Acceleration, $a = \sqrt{a_x^2 + a_y^2} = t\sqrt{468}$

31. Given, initial velocity of the particle at $t = 0$ s,

$\mathbf{v}_0 = 5.0\,\hat{\mathbf{i}}$ ms^{-1}, acceleration,

$$\mathbf{a} = (3.0\hat{\mathbf{i}} + 2.0\hat{\mathbf{j}})\text{ ms}^{-2}$$

The position of the particle is given by

$$\mathbf{r}(t) = \mathbf{v}_0 t + \frac{1}{2}\mathbf{a}t^2$$

$$= 5.0\,\hat{\mathbf{i}}\,t + (1/2)(3.0\hat{\mathbf{i}} + 2.0\hat{\mathbf{j}})t^2$$

$$= (5.0t + 1.5t^2)\hat{\mathbf{i}} + 1.0t^2\hat{\mathbf{j}} \quad \ldots\text{(i)}$$

As, $\mathbf{r}(t) = x(t)\hat{\mathbf{i}} + y(t)\hat{\mathbf{j}}$ ...(ii)

Comparing Eqs. (i) and (ii), we get

$x(t) = 5.0t + 1.5t^2$ and $y(t) = +1.0t^2$

Given, $x(t) = 84$m

$\Rightarrow 5.0t + 1.50\,t^2 = 84$

or $1.50\,t^2 + 5.0t - 84 = 0$

Solving the above quadratic equation, the value of t is given as

$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{-5 \pm \sqrt{5^2 - 4(1.50)(-84)}}{2(1.50)}$$

$$= \frac{-5 \pm \sqrt{25 + 504}}{3} = \frac{-5 \pm \sqrt{529}}{3} = \frac{-5 \pm 23}{3}$$

$= 6$ or $- 9.33$

(Neglecting the negative values as t can never be negative)

$\Rightarrow t = 6$ s

At $t = 6$ s, $y = 1.0(6)^2 = 36$ m

32. The velocity of car driver $= 8\,\hat{\mathbf{i}}$ ms^{-1}

Velocity of rocket $= v_y\hat{\mathbf{j}}$ ms^{-1}

Relative velocity of rocket w.r.t. car $= 8\hat{\mathbf{i}} - v_y\,\hat{\mathbf{j}}$

Since, the speed of the rocket observed by the car driver is 10 ms^{-1}.

$\therefore (v_y)^2 + (8)^2 = (10)^2$

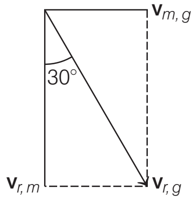
$v_y^2 = 100 - 64 = 36$

$\Rightarrow v_y = 6$ ms^{-1}

Velocity of rocket, $v_y\,\hat{\mathbf{j}} = (6\hat{\mathbf{j}})$ ms^{-1}

$\therefore$ Relative speed of rocket w.r.t. a stationary observer $= 6 - 0 = 6$ ms^{-1}

33. When the man is at rest with respect to the ground, the rain comes to him at an angle 30° with the vertical. This is the direction of the velocity of raindrops with respect to the ground.



Here, $\mathbf{v}_{r,g}$ = velocity of the rain with respect to the ground,

$\mathbf{v}_{m,g}$ = velocity of the man with respect to the ground $= 10\ \text{kmh}^{-1}$

and $\mathbf{v}_{r,m}$ = velocity of the rain with respect to the man.

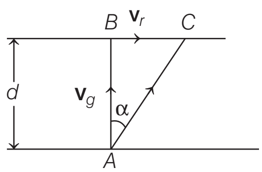
$$\therefore \quad v_{r,g} = \frac{10}{\sin 30°} = 20\ \text{kmh}^{-1}$$

34. Given, speed of girl, $v_g = 5$ km h^{-1}

Speed of river, $v_r = 2$ km h^{-1}

Width of river, $d = 2$ km

The given condition is as shown in the figure below



Since, the girl dive the river normal to the flow of the river, time taken by the girl to cross the river, so

$$t = \frac{d}{v_g} = \frac{2\ \text{km}}{5\ \text{kmh}^{-1}} = \frac{2}{5}\ \text{h}$$

In this time, the girl will go down the river by the distance AC due to river current.

$\therefore$ Distance travelled along the river

$$= v_r \times t = 2 \times \frac{2}{5}$$

$$= \frac{4}{5}\ \text{km} = \frac{4000}{5}\ \text{m} = 800\ \text{m}$$

35. After the object has been projected, the x-component of the velocity remains constant throughout the motion and only the y-component changes, like an object in free-fall in vertical direction.

36. An object that is in flight after being thrown or projected is called a projectile. The motion of projectile may be thought of as the result of two separate, simultaneously occurring components of motions. One component along a horizontal direction without any acceleration and the other along the vertical direction with constant acceleration due to the force of gravity.

37. Velocity is in horizontal direction and acceleration is vertical downwards. Therefore, the direction of velocity and acceleration of the projectile are perpendicular to each other.

38. Given, initial velocity,

$$\mathbf{u} = (\hat{\mathbf{i}} + 2\hat{\mathbf{j}})\ \text{ms}^{-1}$$

Magnitude of velocity,

$$u = \sqrt{(1)^2 + (2)^2} = \sqrt{5}\ \text{ms}^{-1}$$

Equation of trajectory of projectile,

$$y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}$$

$$= x\tan\theta - \frac{gx^2\sec^2\theta}{2u^2}$$

$$= x\tan\theta - \frac{gx^2}{2u^2}(1 + \tan^2\theta)$$

$$[\because \sec^2\theta = 1 + \tan^2\theta]$$

Substituting the given values, we get

$$\therefore \quad y = x \times 2 - \frac{10(x)^2}{2(\sqrt{5})^2}[1 + (2)^2]$$

$$\left[\because \tan\theta = \frac{u_y}{u_x} = \frac{2}{1} = 2\right]$$

$$= 2x - \frac{10(x^2)}{2 \times 5}(1 + 4) = 2x - 5x^2$$

39. Given, equations of motion are

$$x = 18t,\ 2y = 54t - 9.8t^2$$

General equations of projectile are

$$x = u\cos\theta \cdot t \ \text{and}\ y = u\sin\theta \cdot t - \frac{1}{2}gt^2$$

where, θ is the angle of projection.

Comparing it with given equation, we have

$$u\cos\theta = 18 \ \text{and}\ u\sin\theta = \frac{54}{2}$$

$$\Rightarrow \frac{u \sin\theta}{u \cos\theta} = \frac{54/2}{18}$$

$$\therefore \quad \tan\theta = \frac{54}{2\times 18} = 1.5 \Rightarrow \theta = \tan^{-1}(1.5)$$

40. Time of flight,

$$T = \frac{2u\sin\theta}{g} = \frac{2\times 50\times \sin 30^\circ}{10} = 5 \text{ s}$$

41. Given, $u = 60 \text{ ms}^{-1}$

Maximum height H that the ball will achieve
= height of ceiling of the hall
= 30 m

As, maximum height, $H = \dfrac{u^2 \sin^2\theta}{2g}$

$$\Rightarrow \quad 30 = \frac{(60)^2 \sin^2\theta}{2g}$$

$$\Rightarrow \quad \sin^2\theta = \frac{30\times 2g}{60\times 60} = \frac{10}{60} \qquad [\because g = 10 \text{ ms}^{-2}]$$

$$\Rightarrow \quad \sin\theta = \frac{1}{\sqrt{6}}$$

42. $T \propto \sin\theta, \dfrac{T_A}{T_B} = \dfrac{\sin 30^\circ}{\sin 60^\circ} = \dfrac{1}{\sqrt{3}}$ or $T_B = \sqrt{3}\, T_A$

$H \propto \sin^2\theta, \dfrac{H_A}{H_B} = \dfrac{\sin^2 30^\circ}{\sin^2 60^\circ} = \dfrac{1}{3}$

or $\quad H_B = 3 H_A$

As, $\quad R_\theta = R_{90^\circ - \theta}$

$\therefore \quad R_A = R_B$

43. Given, maximum horizontal range,

$$R_{max} = 80 \text{ m}$$

As, range of a projectile, $R = \dfrac{u^2 \sin 2\theta}{g}$

and it is maximum $\theta = 45^\circ$

$$\therefore \quad \frac{u^2}{g} = 80 \text{ m}$$

Maximum height, $h = \dfrac{u^2 \sin^2\theta}{2g}$

$$= \frac{80}{2}(\sin^2 45^\circ)$$

$$= 40 \times \frac{1}{2} = 20 \text{ m}$$

44. Velocities of the stones at some instant t can be given as

$$\mathbf{v}_1 = u_1 \cos\theta_1 \hat{\mathbf{i}} + (u_1 \sin\theta_1 - gt)\,\hat{\mathbf{j}}$$

and $\mathbf{v}_2 = u_2 \cos\theta_2 \hat{\mathbf{i}} + (u_2 \sin\theta_2 - gt)\hat{\mathbf{j}}$

Relative velocity,

$$\mathbf{v}_1 - \mathbf{v}_2 = (u_1 \cos\theta_1 - u_2\cos\theta_2)\hat{\mathbf{i}} + (u_1 \sin\theta_1 - u_2 \cos\theta_2)\,\hat{\mathbf{j}}$$

= constant

Since, their relative velocity is constant.

So, the trajectory of path followed by one as seen by other will be straight line, making a constant angle with horizontal.

45. Range of a projectile,

$$R = \frac{u^2 \sin 2\theta}{g} = \frac{2u^2 \sin\theta\cos\theta}{g}$$

$$= \frac{2(u\sin\theta)(u\cos\theta)}{g} = \frac{2u_x u_y}{g}$$

$\Rightarrow R \propto$ horizontal initial velocity component (u_x)

$\therefore$ From the given plot, we can see that for path 3, range is maximum. This implies that the rock has the maximum horizontal velocity component in this path. Thus, the correct order will be $1 < 2 < 3$.

46. Given, speed, $v = 25 \text{ ms}^{-1}$

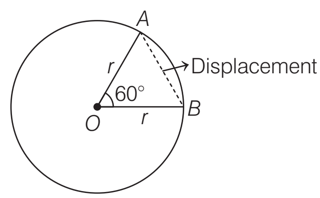
and radius, $r = 5$ m

Centripetal acceleration, $a_c = \dfrac{v^2}{r} = \dfrac{25\times 25}{5}$

$$= 125 \text{ ms}^{-2}$$

47. In the figure, AB is the required displacement of the particle.

In triangle OAB, $OA = OB$ and $\angle AOB = 60^\circ$



Therefore, ΔAOB is an equilateral triangle, so

$$OA = OB = r = AB$$

48. For a uniform circular motion,

centripetal acceleration, $a_c = \dfrac{v^2}{R}$

Since, v and R are constants, the magnitude of the centripetal acceleration of the car is also constant.

However, the direction changes pointing towards the centre. Therefore, a centripetal acceleration is not a constant vector.

49. Radius, $r = \frac{\text{diameter}}{2} = \frac{0.80 \text{ m}}{2} = 0.40 \text{ m}$

Frequency, $\nu = 100 \text{ rev min}^{-1} = \frac{100}{60} \text{ rev s}^{-1}$

Time period, $T = \frac{1}{\nu} = \frac{60}{100} = 0.60$

$\therefore$ Angular velocity, $\omega = \frac{2\pi}{T} = \frac{2 \times 3.14}{0.60}$

$= 10.467 \text{ rad s}^{-1}$

50. Given, $H_1 = H_2$

$$\Rightarrow \frac{u_1^2 \sin^2 45^\circ}{2g} = \frac{u_2^2 \sin 60^\circ}{2g}$$

$$\therefore \frac{u_1}{u_2} = \frac{\sin 60^\circ}{\sin 45^\circ} = \frac{\sqrt{3}/2}{(1/\sqrt{2})} = \sqrt{3} : \sqrt{2}$$

51. Maximum height, $H = \frac{u^2 \sin^2 \alpha}{2g}$

For same speed of projection,

$$H \propto \sin^2 \alpha$$

$$\therefore \frac{H_1}{H_2} = \frac{\sin^2 \alpha}{\sin^2(90^\circ - \alpha)} = \frac{\sin^2 \alpha}{\cos^2 \alpha} = \tan^2 \alpha$$

So, $H_1 : H_2 = \tan^2 \alpha : 1$

52. $R = \frac{u^2 \sin 2\theta}{g}$

$\therefore \quad R \propto u^2$

If initial velocity be doubled at same angle of projection, then range will become four times.

53. As, centripetal acceleration is given as

$$a_c = \frac{v^2}{r}$$

For the first body of mass m_1, $a_{c_1} = \frac{v_1^2}{r_1}$

For the second body of mass m_2, $a_{c_2} = \frac{v_2^2}{r_2}$

Also, time taken by both the cars to complete one revolution is same.

Hence, $T_1 = T_2$

$$\Rightarrow \frac{2\pi r_1}{v_1} = \frac{2\pi r_2}{v_2}$$

$$\Rightarrow \frac{v_1}{v_2} = \frac{r_1}{r_2} \quad \ldots\text{(i)}$$

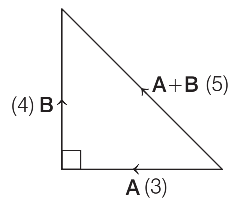
i.e. $a_{c_1} : a_{c_2} = \frac{v_1^2}{r_1} \times \frac{r_2}{v_2^2} = \frac{r_1^2}{r_2^2} \times \frac{r_2}{r_1} = \frac{r_1}{r_2} = r_1 : r_2$

[from Eq. (i)]

54. A scalar quantity is independent of direction hence has the same value for observers with different orientations of the axes.

Hence, the statement given in option (d) is correct, rest are incorrect.

55. Since, $(5)^2 = (3)^2 + (4)^2$, which is in accordance to Pythagoras theorem. So, the vectors can be shown in the figure



$\therefore$ **A** and **B** are perpendicular.

However, if the length of **A** + **B** vector is more than or less than 5, then they should be inclined at acute and obtuse angle, respectively.

Thus, the statement given in option (a) is correct, rest are incorrect.

56. Clearly from the given figure,

u is in the first quadrant, hence both components a and b will be positive.

For $\mathbf{v} = p\,\hat{\mathbf{i}} + q\,\hat{\mathbf{j}}$, as it is in positive x-direction and located downward hence x-component p will be positive and y-component q will be negative.

57. The correct sequence is

Hence, A $\rightarrow$ p, B $\rightarrow$ q, C $\rightarrow$ q and D $\rightarrow$ p.

58. A. As, $|\mathbf{B}| = 2|\mathbf{A}|$ and they both are in the same direction, so $2\mathbf{A} = \mathbf{B}$.

B. As, $|\mathbf{A}| = |\mathbf{B}|$ but both are in opposite directions, so $\mathbf{A} = -\mathbf{B}$.

C. As, $|\mathbf{A}| = 2|\mathbf{B}|$ but both are in opposite directions, so $\mathbf{A} = -2\mathbf{B}$.

D. As, $|\mathbf{A}| = |\mathbf{B}|$ and both are in same direction, so $\mathbf{A} = \mathbf{B}$.

Hence, A $\rightarrow$ r, B $\rightarrow$ p, C $\rightarrow$ s and D $\rightarrow$ q.

59. Magnitude of $\mathbf{A} = |\mathbf{A}| = \sqrt{A_x^2 + A_y^2 + A_z^2}$

$$= \sqrt{(4)^2 + (3)^2 + (5)^2}$$

$$= \sqrt{16 + 9 + 25} = 5\sqrt{2}$$

Angles made by **A** with coordinate axes,

$$\cos\alpha = \frac{A_x}{|\mathbf{A}|} = \frac{4}{5\sqrt{2}}$$

or $\alpha = \cos^{-1}\left(\frac{4}{5\sqrt{2}}\right)$

$$\cos\beta = \frac{A_y}{|\mathbf{A}|} = \frac{3}{5\sqrt{2}}$$

or $\beta = \cos^{-1}\left(\frac{3}{5\sqrt{2}}\right)$

$$\cos\gamma = \frac{A_z}{|\mathbf{A}|} = \frac{5}{5\sqrt{2}} = \frac{1}{\sqrt{2}}$$

or $\gamma = \cos^{-1}\left(\frac{1}{\sqrt{2}}\right)$

Hence, A $\rightarrow$ q, B $\rightarrow$ r and C $\rightarrow$ p.

60. Resultant of two vectors **A** and **B** is given as

$$R = \sqrt{A^2 + B^2 + 2AB\cos\theta}$$

$\therefore$ We can say that

(i) If θ is an obtuse angle, then magnitude of **R** will be less than magnitude of the either vectors **A** or **B**.

e.g. if $|\mathbf{A}| = 4$, $|\mathbf{B}| = 3$ and $\theta = 120°$, then

$$|\mathbf{R}| = \sqrt{4^2 + 3^2 + 2\times 4\times 3\cos(120°)}$$

$$= \sqrt{25 - 12} = \sqrt{13} \quad \left(\because \cos 120° = -\frac{1}{2}\right)$$

$\therefore$ $|\mathbf{R}| < |\mathbf{A}|$

(ii) If the vectors are in opposite direction and are equal in magnitude, then also the magnitude of **R** will be less than the magnitude of either vectors **A** or **B**.

e.g. If $|\mathbf{A}| = |\mathbf{B}| = a$ (say) and $\theta = 180°$

then, $|\mathbf{R}| = \sqrt{a^2 + a^2 - 2a^2\cos(180°)}$

$$= \sqrt{2a^2 - 2a^2} \quad [\because \cos 180° = -1]$$

$\therefore$ $|\mathbf{R}| < |\mathbf{A}|$ or $|\mathbf{B}|$

Also, vector addition is commutative in nature.

$$\mathbf{A} + \mathbf{B} = \mathbf{B} + \mathbf{A}$$

Therefore, both A and R are true but R is not the correct explanation of A.

61. $|\mathbf{A} + \mathbf{B}| = \sqrt{A^2 + B^2 + 2AB\cos\theta}$

$|\mathbf{A} - \mathbf{B}| = \sqrt{A^2 + B^2 - 2AB\cos\theta}$

So, for example, when $90° < \theta < 270°$,

$|\mathbf{A} + \mathbf{B}| < |\mathbf{A} - \mathbf{B}|$

Thus, vector addition of two vectors is not always greater than their vector subtraction.

Also, at $\theta = 90°$, $|\mathbf{A} + \mathbf{B}| = |\mathbf{A} - \mathbf{B}|$

$$= \sqrt{A^2 + B^2}$$

Therefore, A is false and R is also false.

62. In projectile motion, rate of change of velocity, $\left|\frac{dv}{dt}\right| = |a| = 9.8 \text{ ms}^{-2}$ = constant

Also, in case of projectile motion, the magnitude of velocity first decreases and then increases during the motion.

Therefore, A is false and R is also false.

63. Velocity is horizontal and acceleration is vertical. i.e. both are perpendicular to each other, hence their dot product is zero.

Therefore, both A and R are true and R is the correct explanation of A.

64. Horizontal component of velocity = $v \sin\alpha$ = constant

$$a_r = \sqrt{g^2 - a_t^2}$$

At highest point $a_t = 0$. Therefore, a_r is maximum.

Therefore, A is true but R is false.

65. $H = R$ or $\frac{u^2\sin^2\theta}{2g} = \frac{2u^2\sin\theta\cos\theta}{g}$

$\Rightarrow$ $\tan\theta = 4$

Maximum horizontal range (at $\theta = 45°$) is given by $R_{\text{max}} = \frac{u^2}{g}$

Therefore, both A and R are true but R is not the correct explanation of A.

66. Horizontal range, $R = \frac{u^2\sin 2\theta}{g}$

At $\theta = 45°$, $\sin 2\theta = 1$

$\therefore R_{\text{max}} = \frac{u^2}{g}$ = maximum range

$\because \sin\theta = 1$ (maximum), at $\theta = 90°$

Therefore, A is true but R is false.

67. Maximum height, $H_1 = \frac{u^2 \sin^2 \alpha}{2g}$

and $H_2 = \frac{u^2 \sin^2(90° - \alpha)}{2g} = \frac{u^2 \cos^2 \alpha}{2g}$

$\Rightarrow H_1 + H_2 = \frac{u^2}{2g}(\sin^2 \alpha + \cos^2 \alpha) = \frac{u^2}{2g}$

Thus, the sum of height for angles α and $90° - \alpha$ is independent of the angle of projection.

As, horizontal range, $R = \frac{u^2 \sin 2\theta}{g}$

So, for same value of initial velocity, horizontal range of projectile is same for complementary angles.

Therefore, A is true but R false.

68. To obtain maximum range, angle of projection must be 45°, i.e. $\theta = 45°$.

So, $R_{max} = \frac{u^2 \sin 2 \times 45°}{g} = \frac{u^2 \sin 90°}{g} = \frac{u^2}{g}$ ...(i)

$\therefore \; H_{max} = \frac{u^2 \sin^2 45°}{2g} = \frac{u^2}{2g}\left(\frac{1}{\sqrt{2}}\right)^2 = \frac{u^2}{4g} = \frac{R_{max}}{4}$ [from Eq. (i)]

So, H_{max} is 25% of R_{max}.

Therefore, A is true but R is false.

69. In uniform circular motion the velocity of the object is changing continuously in direction, the object undergoes uniform acceleration which is not a constant vector. However, for a uniformly accelerated motion, the acceleration of the object should be constant. Hence, it is not an example of uniformly accelerated motion.
Kinematic equations for constant acceleration is not applicable for uniform circular motion. Since, in this case the magnitude of acceleration is constant but its direction is changing.

Therefore, A is false and R is also false.

70. Temperature is not a vector quantity because it has magnitude only.

However, force, acceleration and velocity have both a magnitude and a direction. So, these are vectors in nature.

71. Two vectors are said to be equal, if and only if they have the same magnitude and direction.

Among the given vectors **A** and **B** are equal vectors as they have same magnitude (length) and direction.

However, **P** and **Q** are not equal even though they are of same magnitude because their directions are different.

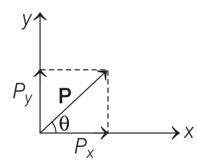
72. $|\lambda \mathbf{A}| = \lambda |\mathbf{A}|$, if $\lambda > 0$, as multiplication of vector **A** with a positive number λ gives a vector whose magnitude is changed by the factor λ but the direction is same as that of **A**.

73. Null vector **0** is a vector, whose magnitude is zero and its direction cannot be specified. So, it means, $|\mathbf{0}| = 0$.

Thus, $\lambda \mathbf{0} = \mathbf{0}$.

Hence, property given in option (b) is incorrect.

74. Let **P** be as shown in the figure, then according to the given information



$P_x = 5, \; P_y = 6$

$\therefore \; |\mathbf{P}| = \sqrt{P_x^2 + P_y^2}$

$= \sqrt{25 + 36}$

$\Rightarrow \; |\mathbf{P}| = \sqrt{61}$

and $\tan \theta = \frac{P_y}{P_x} = \frac{6}{5} \Rightarrow \theta = \tan^{-1}\left(\frac{6}{5}\right)$

75. Since, they are following freely, so both the bodies will fall same distance in same time interval.

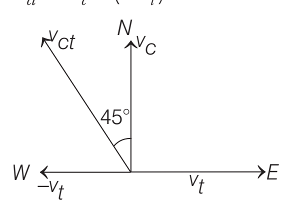
So, the relative separation between them will remain unchanged.

76. Relative velocity of P w.r.t. Q is given by

$$\mathbf{v}_{PQ} = \mathbf{v}_P - (-\mathbf{v}_Q) = \mathbf{v}_P + \mathbf{v}_Q$$

77. Velocity of car w.r.t. train, $\mathbf{v}_{ct} = \mathbf{v}_c - \mathbf{v}_t$

$\Rightarrow \; \mathbf{v}_{ct} = \mathbf{v}_c + (-\mathbf{v}_t)$



Velocity of car w.r.t. train (v_{ct}) is towards West-North.

78. Given, $\mathbf{v}_A = 20\hat{\mathbf{i}}\ \text{ms}^{-1}$

$$\mathbf{v}_B = 15\hat{\mathbf{i}}\ \text{ms}^{-1}$$

Relative velocity of A w.r.t. B,

$$\mathbf{v}_{AB} = \mathbf{v}_A - \mathbf{v}_B = 20\hat{\mathbf{i}} - 15\hat{\mathbf{i}} = 5\hat{\mathbf{i}}\ \text{ms}^{-1}$$

79. Given, velocity of girl, $v_g = 5\hat{\mathbf{i}}\ \text{ms}^{-1}$

Let velocity of rain, $v_r = v_x\hat{\mathbf{i}} + v_y\hat{\mathbf{j}}\ \text{ms}^{-1}$

Relative velocity of rain

$$= v_r - v_g = (v_x - 5)\hat{\mathbf{i}} + v_y\hat{\mathbf{j}}$$

Now, it is vertical, so $\tan\theta = \dfrac{v_x - 5}{v_y} = 0$

$$\Rightarrow v_x - 5 = 0 \Rightarrow v_x = 5 \quad \ldots\text{(i)}$$

On increasing the speed of the girl, relative velocity becomes $(v_x - 15)\hat{\mathbf{i}} + v_y\hat{\mathbf{j}}$

$$\tan\theta = \tan 45° = \frac{v_x - 15}{v_y} = 1$$

$$\Rightarrow v_x - 15 = v_y \Rightarrow v_y = -10 \quad \text{[using Eq. (i)]}$$

$\therefore$ Velocity of rain $= (5\hat{\mathbf{i}} - 10\hat{\mathbf{j}})\ \text{ms}^{-1}$

$\Rightarrow$ Magnitude of velocity of rain

$$= \sqrt{(5)^2 + (10)^2}$$

$$= \sqrt{125} = 5\sqrt{5}\ \text{ms}^{-1}$$

80. A javelin thrown by an athlete is an example of projectile motion.

81. The horizontal component of velocity ($u\cos\theta$) is constant throughout the motion, so there will be no acceleration in horizontal direction.

82. As the vertical components of velocity ($u\sin\theta$) decreases continuously with height, from O to H, due to downward force of gravity and becomes zero at H.

83. The time taken by the ball to return to the same level,

$$T = \frac{2v_0\sin\theta}{g} = \frac{2\times 28\times\sin 30°}{9.8} \approx 2.9\ \text{s}$$

84. The distance from the thrower to the point where the ball returns to the same level is

$$R = \frac{v_0^2\sin 2\theta}{g} = \frac{28\times 28\times\sin 60°}{9.8} \approx 69\ \text{m}$$

85. Circular motion is an example of two-dimensional motion with radius vector as

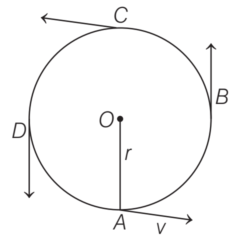
$$\mathbf{r} = a\cos\omega t\,\hat{\mathbf{i}} + a\sin\omega t\,\hat{\mathbf{j}}$$

Both the components $a\cos\omega t\,\hat{\mathbf{i}}$ and $a\sin\omega t\,\hat{\mathbf{j}}$ are perpendicular to each other.

86. If a particle is performing uniform circular motion, then its

(a) speed will be constant throughout the motion.

(b) velocity will be tangential in the direction of motion at a particular point.



(c) acceleration, $a = \dfrac{v^2}{r}$ will always be towards centre of the circular path.

(d) angular momentum (mvr) is constant in magnitude but direction keeps on changing.

87. Angular velocity ω is constant.

$$v = r\omega$$

$$\therefore\ v \propto r \text{ or } \frac{v_A}{v_B} = \frac{r_A}{r_B}$$

88. On a circular path in completing one turn,the distance travelled is $2\pi r$, while displacement is zero.

Hence, average velocity

$$= \frac{\text{displacement}}{\text{time interval}} = \frac{0}{t} = 0$$

$$\text{Average speed} = \frac{\text{Distance}}{\text{Time interval}}$$

$$= \frac{2\pi r}{t} = \frac{2\times 3.14\times 100}{62.8} = 10\ \text{ms}^{-1}$$

89. Given, $\nu = 1200\ \text{rpm} = \dfrac{1200}{60}\ \text{rps}$

$$r = 30\ \text{cm} = \frac{30}{100}\ \text{m}$$

Acceleration of the particle = Centripetal acceleration $= \omega^2 r = (2\pi\nu)^2 r$

$$= \left(2\times\frac{22}{7}\times\frac{1200}{60}\right)^2\times\frac{30}{100} \approx 4740\ \text{ms}^{-2}$$

05

Laws of Motion

Quick Revision

1. **Momentum** Momentum of a body is the quantity of motion possessed by the body. It is defined as the product of its mass m and velocity $\mathbf{v}$ and is denoted by $\mathbf{p}$.

   Momentum, $\mathbf{p} = m\mathbf{v}$

2. **Conservation of Momentum** According to this principle, "In the absence of an external force, the total momentum of a system remains constant or conserved and does not change with time".

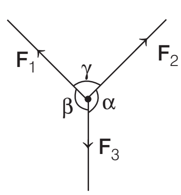
   If $\Sigma \mathbf{F}_{ext} = 0$, then momentum $\mathbf{p}$ = constant.

3. **Equilibrium of a Particle** The forces acting at the same point or on a particle are called **concurrent forces**.

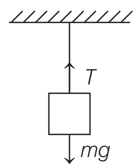
   These forces are said to be in equilibrium, when their resultant is zero, i.e. $\sum_{i=1}^{n} F_i = 0$.

4. **Lami's Theorem** According to this theorem, when three concurrent forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ acting on a body are in equilibrium, then

$$\frac{\mathbf{F}_1}{\sin\alpha} = \frac{\mathbf{F}_2}{\sin\beta} = \frac{\mathbf{F}_3}{\sin\gamma}$$



5. **Tension** When a body of mass m is fastened with the string, then the weight of the body acts downwards while a force acting just opposite to the downward force for balancing it is called tension.



$$T = mg$$

where, g = acceleration due to gravity
and T = tension in the string.

6. **Friction** Whenever a body moves or tends to move over the surface of another body, a force comes into play which acts parallel to the surface of contact and opposes the relative motion. This opposing force is called friction.

7. **Types of Friction**
   - **Static Friction** Force of friction which comes into play between two bodies, before one body actually starts moving over the other is called static friction and it is denoted by f_s.
   - **Limiting Friction** Maximum value of static friction which comes into play when a body just starts moving over the surface of another body is called limiting friction.

     Thus, $f_s \le f_{s\,(\max)}$

     The value of limiting static friction $f_{s\,(\max)}$ between two given surfaces is directly proportional to the normal reaction (R) between the two surfaces.

i.e. $f_{s\,(\max)} \propto R$

$$\Rightarrow \quad f_{s\,(\max)} = \mu_s R \Rightarrow \mu_s = \frac{f_{s\,(\max)}}{R}$$

The proportionality constant μ_s is called **coefficient of static friction**.

- **Kinetic Friction** Kinetic friction or dynamic friction is the opposing force that comes into play when one body is actually moving over the surface of another body. Thus, kinetic friction opposes the relative motion. The value of kinetic friction f_k is given as

or $$f_k = \mu_k R \Rightarrow \mu_k = \frac{f_k}{R}$$

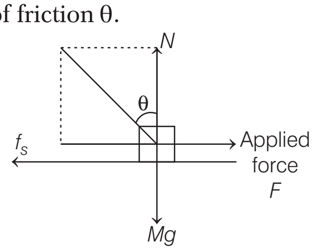
The proportionality constant μ_k is called **coefficient of kinetic friction**.
When the relative motion has begun, the acceleration of the body on the rough surface is given by

$$a = \frac{F - f_k}{m}$$

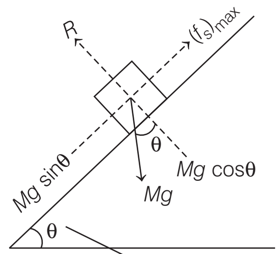
where, F = applied force and f_k = kinetic friction.

- **Rolling Friction** Friction which comes into play when a body like a ring or a sphere rolls without slipping over a horizontal surface, is known as rolling friction.

8. **Angle of Friction** The angle between the resultant of limiting friction f_s and normal reaction N with the direction of N is called angle of friction θ.



9. **Angle of Repose** The minimum angle of inclination of a plane with the horizontal, such that the body placed on the plane just starts to slide down is known as angle of repose.



Angle of repose

10. **Centripetal Force** When an object moves on a circular path, a force acts on it, whose direction is towards the centre of the path, this force is called centripetal force.

Centripetal force acting on a particle of mass m on a circular path of radius r is given by

$$F = \frac{mv^2}{r}$$

11. **Motion of a Car on Level Road** When a car of mass m is turning on the level road without skidding, centripetal force on the car must be equal or less than static friction.

i.e. $$F \geq \frac{mv_{\max}^2}{r}$$

or $$\mu g \geq \frac{mv_{\max}^2}{r}$$

(μ = coefficient of friction)

or $$v_{\max} \leq \sqrt{\mu \cdot rg}$$

$\therefore$ Maximum **velocity** on a curved road to avoid skidding is $v_{\max} = \sqrt{\mu rg}$.

12. **Motion of a Car on Banked Road** Maximum velocity of a car on banked road is given by

$$v_{\max} = \sqrt{rg\left(\frac{\mu + \tan\theta}{1 - \mu\tan\theta}\right)}$$

where, θ = inclination of road
and r = radius of turn.
If $\mu = 0$, then $v = \sqrt{rg \tan\theta}$.

Objective Questions

Multiple Choice Questions

1. According to Galileo's experiment for a double inclined plane that are smooth, when a ball is released from rest on one of the planes rolls down and climb up the other of decreased slope, the final height of the ball is

(a) less than the initial height
(b) more than the initial height
(c) equal to the initial height
(d) more or less than the initial height

2. Which of the Newton's laws of motion explain the concept of inertia?

(a) First law (b) Second law
(c) Third law (d) All of these

3. If a running bus stops suddenly, our feet stop due to friction, but the rest of the body continues to move forward due to

(a) momentum (b) force
(c) inertia (d) impulse

4. Suppose the earth suddenly stops attracting objects placed near surface. A person standing on the surface of the earth will

(a) remain standing (b) fly up
(c) sink into earth (d) either (b) or (c)

5. When a car is stationary, there is no net force acting on it. During pick-up, it accelerates. This happens due to

(a) net external force
(b) net internal force
(c) may be external or internal force
(d) None of the above

6. A smaller and a bigger iron balls are dropped from a small height on a glass pane placed on a table. Only bigger ball breakes the glass pane, because

(a) bigger ball transfers greater momentum than smaller
(b) bigger ball transfers lesser momentum than smaller
(c) bigger ball transfer equal momentum as smaller
(d) None of the above

7. A rocket is going upwards with accelerated motion. A man sitting in it feels his weight increased 5 times his own weight. If the mass of the rocket including that of the man is 1.0×10^4 kg, how much force is being applied by rocket engine? (Take, $g = 10 \text{ ms}^{-2}$).

(a) 5×10^4 N (b) 5×10^5 N
(c) 5×10^8 N (d) 2×10^4 N

8. The motion of a particle of mass m is described by $y = ut + gt^2$, find the force acting on the particle.

(a) Zero (b) mg
(c) $2\,mg$ (d) $3\,mg$

9. A bullet of mass 0.04 kg moving with a speed of 90 ms^{-1} enters a heavy wooden block and stopped after 3s. What is the average resistive force exerted by the block on the bullet?

(a) 1 N (b) 1.2 N
(c) 2 N (d) 3 N

10. A body of mass 6 kg is acted on by a force so that its velocity changes from 3 ms^{-1} to 5 ms^{-1}, then change in momentum is

(a) 48 N-s (b) 24 N-s
(c) 30 N-s (d) 12 N-s

11. A meter scale is moving with uniform velocity. This implies *(NCERT Exemplar)*

(a) the force acting on the scale is zero, but a torque about the centre of mass can act on the scale

(b) the force acting on the scale is zero and the torque acting about centre of mass of the scale is also zero
(c) the total force acting on it need not be zero but the torque on it is zero
(d) Neither the force nor the torque need to be zero

12. While launching a satellite of mass 10^4 kg, a force of 5×10^5 N is applied for 20s. The velocity attained by the satellite at the end of 20s, is

(a) 4 km/s (b) 3 km/s
(c) 1 km/s (d) 2 km/s

13. The momentum p (in kg-ms^{-1}) of a particle is varying with time t (in second) as $p = 2 + 3t^2$. The force acting on the particle at $t = 3$ s will be

(a) 18 N (b) 54 N
(c) 9 N (d) 15 N

14. A machine gun fires a bullet of mass 40 g with a velocity of 1200 ms^{-1}. The man holding it can exert a maximum force of 144 N on the gun.

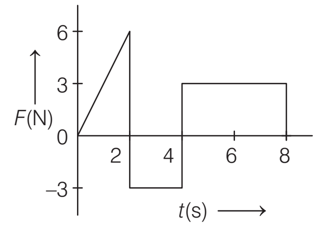
How many bullets can be fired per second at the most?

(a) Only one
(b) Three
(c) Can fire any number of bullets
(d) 144×48

15. A cricket ball of mass 150 g has an initial velocity $\mathbf{u} = (3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})\,\text{ms}^{-1}$ and a final velocity $\mathbf{v} = -(3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})\,\text{ms}^{-1}$, after being hit. The change in momentum (final momentum – initial momentum) is (in kgms^{-1}) *(NCERT Exemplar)*

(a) zero (b) $-(0.45\hat{i} + 0.6\hat{j})$
(c) $-(0.9\hat{i} + 1.2\hat{j})$ (d) $-5(\hat{i} + \hat{j})\hat{i}$

16. The force F acting on a particle of mass m is indicated by the force-time graph shown below. The change in momentum of the particle over the time interval from 0 to 8s is



(a) 24 N-s (b) 20 N-s
(c) 12 N-s (d) 6 N-s

17. A particle of mass m is moving in a straight line with momentum p. Starting at time $t = 0$, a force $F = kt$ acts in the same direction on the moving particle during time interval T, so that its momentum changes from p to $3p$. Here, k is a constant. The value of T is

(a) $\sqrt{\frac{2p}{k}}$ (b) $2\sqrt{\frac{p}{k}}$ (c) $\sqrt{\frac{2k}{p}}$ (d) $2\sqrt{\frac{k}{p}}$

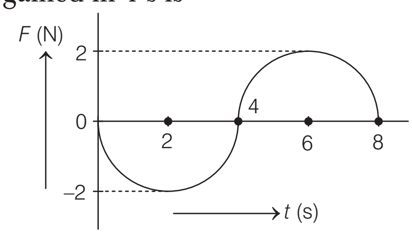
18. A constant retarding force of 50 N is applied to a body of mass 20 kg moving initially with a speed of 15 ms^{-1}. How long time does the body take to stop?

(a) 6 s (b) 8 s (c) 9 s (d) 10 s

19. A batsman hits back at ball straight in the direction of the bowler without changing its initial speed of 12 ms^{-1}. If the mass of the ball is 0.15 kg, find the impulse imparted to the ball. (Assume linear motion of the ball)

(a) 1.8 N-s (b) 3.6 N-s (c) 3.6 N-m (d) 1.8 N-m

20. The force-time $(F\text{-}t)$ graph for linear motion of a body initially at rest is shown in figure. The segments shown are circular, the linear momentum gained in 4 s is



(a) 8 N-s (b) 4π N-s (c) 2π N-s (d) 8π N-s

21. Every action has an equal and opposite reaction, which suggests that

(a) action and reaction always act on different bodies
(b) the forces of action and reaction cancel to each other
(c) the forces of action and reaction cannot cancel to each other
(d) Both (a) and (c)

22. An initially stationary device lying on a frictionless floor explodes into two pieces and slides across the floor. One piece is moving in positive x-direction then other piece is moving in

(a) positive y-direction
(b) negative y- direction
(c) negative x-direction
(d) at angle from x-direction

23. A shell of mass 200 g is fired by a gun of mass 100 kg. If the muzzle speed of the shell is 80 m/s, calculate the recoil speed of the gun.

(a) 16 cm/s (b) 18 m/s (c) 4 m/s (d) 16 m/s

24. In equilibrium of particle when net external force of the particle is zero. Then, the particle is

(a) at rest
(b) moving with uniform velocity
(c) moving with uniform acceleration
(d) Both (a) and (b)

25. Two forces $\mathbf{F}_1 = 3\hat{\mathbf{i}} - 4\hat{\mathbf{j}}$ and $\mathbf{F}_2 = 2\hat{\mathbf{i}} - 3\hat{\mathbf{j}}$ are acting upon a body of mass 2 kg. Find the force $\mathbf{F}_3$, which when acts on the body will make it stable.

(a) $5\hat{i}+7\hat{j}$ (b) $-5\hat{i}-7\hat{j}$
(c) $-5\hat{i}+7\hat{j}$ (d) $5\hat{i}-7\hat{j}$

26. Two equals forces are acting at a point with an angle of 60° between them. If the resultant force is equal to $40\sqrt{3}$ N, the magnitude of each force is

(a) 40 N (b) 20 N (c) 80 N (d) 30 N

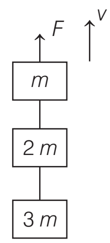
27. A hockey player is moving northward and suddenly turns westward with the same speed to avoid an opponent. The force that acts on the player is *(NCERT Exemplar)*

(a) frictional force along westward
(b) muscle force along southward
(c) frictional force along south-west
(d) muscle force along south-west

28. Three concurrent coplanar forces 1 N, 2 N and 3 N are acting along different directions on a body can keep the body in equilibrium, if

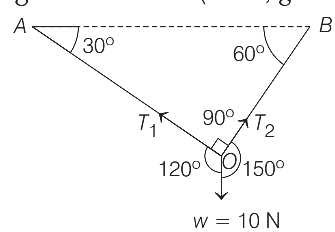
(a) 2 N and 3 N act at right angle
(b) 1 N and 2 N act at acute angle
(c) 1 N and 2 N act at right angle
(d) Cannot be possible

29. Three blocks with masses m, $2m$ and $3m$ are connected by strings, as shown in the figure. After an upward force F is applied on block m, the masses move upward at constant speed v. What is the net force on the block of mass $2m$? (Take, g is the acceleration due to gravity)



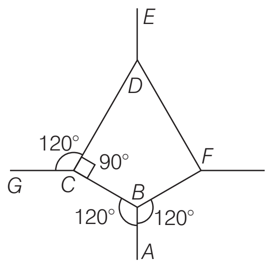
(a) Zero (b) 2 mg (c) 3 mg (d) 6 mg

30. A ball of mass 1 kg hangs in equilibrium from a two strings OA and OB as shown in figure. What are the tensions in strings OA and OB? (Take, $g = 10\ \text{ms}^{-2}$)



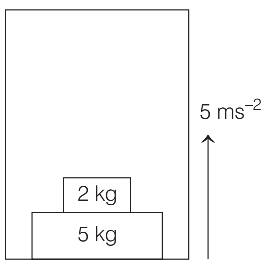
(a) 5 N, 5 N (b) $5\sqrt{3}$ N, $5\sqrt{3}$ N
(c) 5 N, $5\sqrt{3}$ N (d) $5\sqrt{3}$ N, 5 N

31. Given figure is the part of a horizontally stretched structure. Section AB is stretched with a force of 10 N. The tension in the sections BC and BF, are



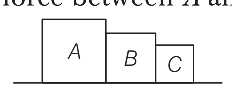
(a) 10 N, 11 N
(b) 10 N, 6 N
(c) 10 N, 10 N
(d) Cannot be calculated due to insufficient data

32. Find the force exerted by 5 kg block on floor of lift, as shown in figure. (Take, $g = 10\text{ ms}^{-2}$)



(a) 100 N (b) 115 N
(c) 105 N (d) 135 N

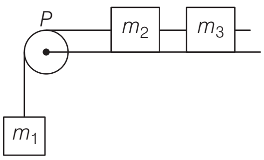
33. Three blocks A, B and C of masses 4 kg, 2 kg and 1 kg respectively, are in contact on a frictionless surface, as shown in the figure. If a force of 14 N is applied on the 4 kg block, then the contact force between A and B is



(a) 2 N (b) 6 N (c) 8 N (d) 18 N

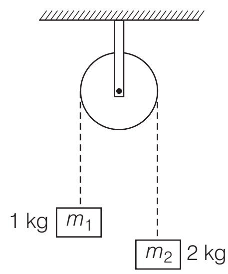
34. A system consists of three masses m_1, m_2 and m_3 connected by a string passing over a pulley P. The mass m_1 hangs freely and m_2 and m_3 are on a rough horizontal table (the coefficient of friction = μ).

The pulley is frictionless and of negligible mass. The downward acceleration of mass m_1 is (Assume, $m_1 = m_2 = m_3 = m$)



(a) $\frac{g(1-g\mu)}{9}$ (b) $\frac{2g\mu}{3}$
(c) $\frac{g(1-2\mu)}{3}$ (d) $\frac{g(1-2\mu)}{2}$

35. Two masses $m_1 = 1$ kg and $m_2 = 2$ kg are connected by a light inextensible string and suspended by means of a weightless pulley as shown in figure.



Assuming that both the masses start from rest, the distance travelled by 2 kg mass in 2 s is

(a) $\frac{20}{9}$ m (b) $\frac{40}{9}$ m
(c) $\frac{20}{3}$ m (d) $\frac{1}{3}$ m

36. If a box is lying in the compartment of an accelerating train and box is stationary relative to the train. What force cause the acceleration of the box?

(a) Frictional force in the direction of train
(b) Frictional force in the opposite direction of train
(c) Force applied by air
(d) None of the above

37. A box of mass 2 kg is placed on the roof of a car. The box would remain stationary until the car attains a maximum acceleration. Coefficient of static friction between the box and the roof of the car is 0.2 and $g = 10\ ms^{-2}$.

The maximum acceleration of the car, for the box to remain stationary, is

(a) $8\ ms^{-2}$
(b) $6\ ms^{-2}$
(c) $4\ ms^{-2}$
(d) $2\ ms^{-2}$

38. A car of mass m starts from rest and acquires a velocity along east, $\mathbf{v} = v\,\hat{\mathbf{i}}\ (v > 0)$ in two seconds. Assuming the car moves with uniform acceleration, the force exerted on the car is *(NCERT Exemplar)*

(a) $\frac{mv}{2}$ eastward and is exerted by the car engine
(b) $\frac{mv}{2}$ eastward and is due to the friction on the tyres exerted by the road
(c) more than $\frac{mv}{2}$ eastward exerted due to the engine and overcomes the friction of the road
(d) $\frac{mv}{2}$ exerted by the engine

39. A particle of mass 2 kg is moving on a circular path of radius 10 m with a speed of $5\ ms^{-1}$ and its speed is increasing at a rate of $3\ ms^{-1}$. Find the force acting on the particle.

(a) 5 N (b) 10 N (c) 12 N (d) 14 N

40. Two stones of masses m and $2m$ are whirled in horizontal circles, the heavier one in a radius $\frac{r}{2}$ and the lighter one in a radius r. The tangential speed of lighter stone is n times that of the value of heavier stone, when they experience same centripetal forces. The value of n is

(a) 2 (b) 3 (c) 4 (d) 1

41. If a car is moving in uniform circular motion, then what should be the value of velocity of a car, so that car will not moving away from the circle?

(a) $v < \sqrt{\mu_s Rg}$
(b) $v \le \sqrt{\mu_s Rg}$
(c) $v < \sqrt{\mu_k Rg}$
(d) None of these

42. A person is driving a vehicle at a uniform speed of $5\ ms^{-1}$ on a level curved track of radius 5 m. The coefficient of static friction between tyres and road is 0.1. Will the person slip while taking the turn with the same speed? (Take, $g = 10\ ms^{-2}$)

(a) A person will slip, if $v^2 = 5\ m^2s^{-2}$
(b) A person will slip, if $v^2 > 5\ m^2s^{-2}$
(c) A person will slip, if $v^2 < 5\ m^2s^{-2}$
(d) A person will not slip, if $v^2 > 5\ m^2s^{-2}$

43. A circular racetrack of radius 300 m is banked at an angle of 15°. If the coefficient of friction between the wheels of the race car and the road is 0.2. Find optimum speed of the race car to avoid wear and tear on its tyres and maximum permissible speed to avoid slipping. (Take, $g = 9.8\ ms^{-2}$ and $\tan 15° = 0.27$)

(a) $v_o = 48\ ms^{-1}$, $v_{max} = 60\ ms^{-1}$
(b) $v_o = 28.1\ ms^{-1}$, $v_{max} = 38.1\ ms^{-1}$
(c) $v_o = 62.2\ ms^{-1}$, $v_{max} = 73.4\ ms^{-1}$
(d) None of the above

44. A car is moving in a circular horizontal track of radius 10.0 m with a constant speed of $10.0\ ms^{-1}$. A plumb bob is suspended from the roof of the car by a light rigid rod of length 10.0 m. The angle made by the rod with the track is (Take, $g = 10\ ms^{-2}$)

(a) zero (b) 30° (c) 45° (d) 60°

45. Inertia of an object is directly dependent on ....

(a) impulse (b) momentum
(c) mass (d) density

46. A body with mass 5 kg is acted upon by a force $\mathbf{F} = (-3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})$ N. If its initial velocity at $t = 0$ is $u = (6\hat{\mathbf{i}} - 12\hat{\mathbf{j}})\text{ms}^{-1}$, the time at which it will just have a velocity along the Y-axis is .... *(NCERT Exemplar)*

(a) never (b) 10 s
(c) 2 s (d) 15 s

47. If impulse I varies with time t as $F(\text{kg ms}^{-1}) = 20t^2 - 20t$. The change in momentum is minimum at ....

(a) $t = 2\text{s}$ (b) $t = 1\text{s}$
(c) $t = \frac{1}{2}\text{s}$ (d) $t = \frac{3}{2}\text{s}$

48. The force which is dissipative in nature is ....

(a) electrostatic force (b) magnetic force
(c) gravitational force (d) frictional force

49. Suppose a light-weight vehicle (say, a small car) and a heavy weight vehicle (say, a loaded truck) are parked on a horizontal road. Then, which of the following statement is correct?

(a) Much greater force is needed to push the truck.
(b) Equal force is needed to push the truck and car.
(c) No force is required to move the vehicles.
(d) None of the above

50. Which one of the following statement is incorrect?

(a) Frictional force opposes the relative motion.
(b) Limiting value of static friction is directly proportional to normal reaction.
(c) Rolling friction is smaller than sliding friction.
(d) Coefficient of sliding friction has dimensions of length.

51. If no external force acts on particle, then which of the following statement is incorrect about particle?

(a) Particle may be at rest.
(b) Particle moves with uniform velocity on linear path.
(c) Particle moves with uniform speed on circle.
(d) None of the above

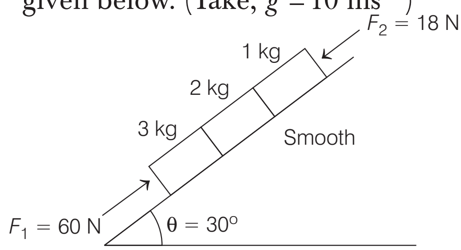
52. Match the Column I (type of friction) with Column II (value of μ) and select the correct option from the codes given below.

	Column I		Column II
A.	Static friction	p.	μ is highest
B.	Rolling friction	q.	μ is moderate
C.	Kinetic friction	r.	μ is lowest

Codes

	A	B	C		A	B	C
(a)	r	q	p	(b)	p	q	r
(c)	p	r	q	(d)	q	r	p

53. In the diagram shown in figure, match the Column I with Column II and select the correct option from the codes given below. (Take, $g = 10\text{ ms}^{-2}$)



	Column I		Column II
A.	Acceleration of 2 kg block	p.	8 (SI unit)
B.	Net force on 3 kg block	q.	25 (SI unit)
C.	Normal reaction between 2 kg and 1 kg	r.	2 (SI unit)
D.	Normal reaction between 3 kg and 2 kg	s.	None

Codes

	A	B	C	D
(a)	r	s	q	s
(b)	r	q	s	p
(c)	p	q	r	s
(d)	p	q	q	s

Assertion-Reasoning MCQs

*For question numbers 54 to 64, two statements are given-one labelled **Assertion** (A) and the other labelled **Reason** (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

54. Assertion Aristotle stated that an external force is required to keep a body in motion.

Reason Opposing forces are always present in the natural world.

55. Assertion A body is momentarily at rest but no force is acting on it at that time.

Reason When a force acts on a body, it may not have some acceleration.

56. Assertion At the microscopic level, all bodies are made up of charged constituents (like nuclei and electrons) and various contact forces exist between them.

Reason These forces are due to elasticity of bodies, molecular collisions and impacts, etc.

57. Assertion If force is not parallel to the velocity of the body, but makes some angle with it, it changes the component of velocity along the direction of force.

Reason The component of velocity parallel to the force remains unchanged.

58. Assertion If we consider system of two bodies A and B as a whole, $\mathbf{F}_{AB}$ and $\mathbf{F}_{BA}$ are internal forces of the system $(A + B)$. They add to give a null force.

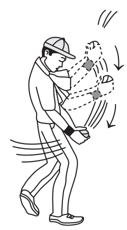
Reason Internal forces in a body or a system of particles cancel away in pairs.

59. Assertion It is not always necessary that external agency of force is in contact with the object while applying force on object.

Reason A stone released from top of a building accelerates downward due to gravitational pull of the earth.

60. Assertion A seasoned cricketer allows a longer time for his hands to stop the ball, while catching the ball. His hand is not hurt.

Reason The novice (new player) keeps his hand fixed and tries to catch the ball almost instantly. He needs to provide a much greater force to stop the ball instantly and this hurts.



61. Assertion Product of distance and velocity (i.e. momentum) is basic to the effect of force on motion.

Reason Same force for same time causes the same change in momentum for different bodies.

62. **Assertion** Newton's third law of motion is applicable only when bodies are in motion.

Reason Newton's third law does not applies to all types of forces, e.g. gravitational, electric or magnetic forces, etc.

63. **Assertion** Angle of repose is equal to angle of limiting friction.

Reason When a body is just at the point of motion, the force of friction of this stage is called as limiting friction.

64. **Assertion** A body of mass 1 kg is making 1 rps in a circle of radius 1 m. Centrifugal force acting on it is $4\pi^2$ N.

Reason Centrifugal force is given by $F = \frac{mv}{r}$.

Case Based MCQs

Direction *Answer the questions from 65-69 on the following case.*

Momentum and Newton's Second Law of Motion

Momentum of a body is the quantity of motion possessed by the body. It depends on the mass of the body and the velocity with which it moves.

When a bullet is fired by a gun, it can easily pierce human tissue before coming to rest resulting in casualty. The same bullet fired with moderate speed will not cause much damage. The greater the change in momentum in a given time, the greater is the force that needs to be applied.

The second law of motion refers to the general situation, where there is a net external force rating on the body.

65. A satellite in force-free space sweeps stationary interplanetary dust at a rate $\frac{dM}{dt} = \alpha v$, where M is the mass, v is the velocity of satellite and α is a constant. What is the deceleration of the satellite?

(a) $\frac{-2\alpha v^2}{M}$ (b) $\frac{-\alpha v^2}{M}$

(c) $-\alpha v^2$ (d) $\frac{\alpha v^2}{M}$

66. A body of mass 5 kg is moving with velocity of $v = (2\hat{i} + 6\hat{j})$ ms^{-1} at $t = 0$ s. After time $t = 2$ s, velocity of body is $(10\hat{i} + 6\hat{j})$ ms^{-1}, then change in momentum of body is

(a) $40\hat{i}$ kg-ms^{-1}

(b) $20\hat{i}$ kg-ms^{-1}

(c) $30\hat{i}$ kg-ms^{-1}

(d) $(50\hat{i} + 30\hat{j})$ kg-ms^{-1}

67. A cricket ball of mass 0.25 kg with speed 10 m/s collides with a bat and returns with same speed with in 0.01s. The force acted on bat is

(a) 25 N (b) 50N

(c) 250N (d) 500N

68. A stationary bomb explodes into three pieces. One piece of 2 kg mass moves with a velocity of 8 ms^{-1} at right angles to the other piece of mass 1 kg moving with a velocity of 12 ms^{-1}. If the mass of the third piece is 0.5 kg, then its velocity is

(a) 10 m s^{-1} (b) 20 ms^{-1}

(c) 30 m s^{-1} (d) 40 ms^{-1}

69. A force of 10 N acts on a body of mass 0.5 kg for 0.25s starting from rest. What is its momentum now?

(a) 0.25 N/s (b) 2.5 N/s

(c) 0.5 N/s (d) 0.75 N/s

Direction *Answer the questions from 70-74 on the following case.*

Conservation of Momentum

This principle is a consequence of Newton's second and third laws of motion.

In an isolated system (i.e. a system having no external force), mutual forces (called internal forces) between pairs of particles in the system causes momentum change in individual particles.

Let a bomb be at rest, then its momentum will be zero. If the bomb explodes into two equal parts, then the parts fly off in exactly opposite directions with same speed, so that the total momentum is still zero. Here, no external force is applied on the system of particles (bomb).

70. A bullet of mass 10 g is fired from a gun of mass 1 kg with recoil velocity of gun 5 m/s. The muzzle velocity will be

(a) 30 km/min
(b) 60 km/min
(c) 30 m/s
(d) 500 m/s

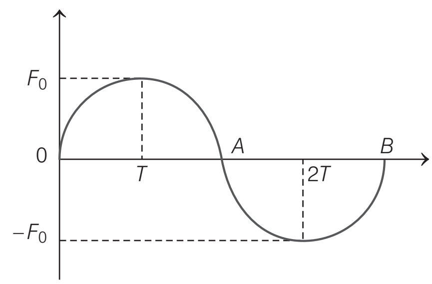
71. A shell of mass 10 kg is moving with a velocity of $10\ \text{ms}^{-1}$ when it blasts and forms two parts of mass 9 kg and 1 kg respectively. If the first mass is stationary, the velocity of the second is

(a) $1\ \text{m s}^{-1}$
(b) $10\ \text{m s}^{-1}$
(c) $100\ \text{m s}^{-1}$
(d) $1000\ \text{m s}^{-1}$

72. A bullet of mass 0.1 kg is fired with a speed of $100\ \text{ms}^{-1}$. The mass of gun being 50 kg, then the velocity of recoil becomes

(a) $0.05\ \text{m s}^{-1}$ (b) $0.5\ \text{m s}^{-1}$
(c) $0.1\ \text{m s}^{-1}$ (d) $0.2\ \text{m s}^{-1}$

73. A unidirectional force F varying with time T as shown in the figure acts on a body initially at rest for a short duration $2T$. Then, the velocity acquired by the body is



(a) $\frac{\pi F_0 T}{4m}$ (b) $\frac{\pi F_0 T}{2m}$
(c) $\frac{F_0 T}{4m}$ (d) zero

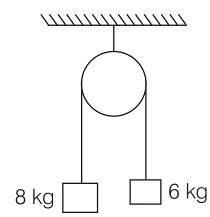
74. Two masses of M and $4M$ are moving with equal kinetic energy. The ratio of their linear momenta is

(a) 1:8 (b) 1:4
(c) 1:2 (d) 4:1

Direction *Answer the questions from 75-79 on the following case.*

Force of Friction on Connected Bodies

When bodies are in contact, there are mutual contact forces satisfying the third law of motion. The component of contact force normal to the surfaces in contact is called normal reaction. The component parallel to the surfaces in contact is called friction.



In the above figure, 8 kg and 6 kg are hanging stationary from a rough pulley and are about to move. They are stationary due to roughness of the pulley.

75. Which force is acting between pulley and rope?
(a) Gravitational force
(b) Tension force
(c) Frictional force
(d) Buoyant force

76. The normal reaction acting on the system is
(a) 8 g
(b) 6 g
(c) 2 g
(d) 14 g

77. The tension is more on side having mass of
(a) 8 kg
(b) 6 kg
(c) Same on both
(d) Nothing can be said

78. The force of friction acting on the rope is
(a) 20 N
(b) 30 N
(c) 40 N
(d) 50 N

79. Coefficient of friction of the pulley is
(a) $\frac{1}{6}$
(b) $\frac{1}{7}$
(c) $\frac{1}{5}$
(d) $\frac{1}{4}$

ANSWERS

Multiple Choice Questions

1. (c)	2. (a)	3. (c)	4. (a)	5. (a)	6. (a)	7. (b)	8. (c)	9. (b)	10. (d)
11. (b)	12. (c)	13. (a)	14. (b)	15. (c)	16. (c)	17. (b)	18. (a)	19. (b)	20. (c)
21. (d)	22. (c)	23. (a)	24. (d)	25. (c)	26. (a)	27. (c)	28. (d)	29. (a)	30. (c)
31. (c)	32. (c)	33. (b)	34. (c)	35. (c)	36. (a)	37. (d)	38. (b)	39. (a)	40. (a)
41. (b)	42. (b)	43. (b)	44. (c)	45. (c)	46. (b)	47. (c)	48. (d)	49. (a)	50. (d)
51. (c)	52. (c)	53. (a)							

Assertion-Reasoning MCQs

54. (a)	55. (d)	56. (a)	57. (c)	58. (c)	59. (c)	60. (b)	61. (d)	62. (d)	63. (a)
64. (c)									

Case Based MCQs

65. (d)	66. (a)	67. (d)	68. (d)	69. (b)	70. (d)	71. (c)	72. (d)	73. (d)	74. (c)
75. (c)	76. (d)	77. (a)	78. (a)	79. (b)					

SOLUTIONS

1. Galileo conducted an experiment using a double inclined plane. In this experiment, two inclined planes are arranged facing each other.

When an object rolls down one of the inclined planes, it climbs up the other. It almost reaches the same height but not completely because of friction. In ideal case, when there is no friction the final height of the object is same as the initial height as shown in figure.

Both planes are inclined at same angle

2. According to Newton's first law of motion, everybody continues in its state of rest or uniform motion. Unless an external force acts upon it. This depicts that a body by itself cannot change its state of rest or of uniform motion along a straight line.

This law is known as law of inertia.

3. This is because the feet of the passenger comes to rest along with the bus, but the upper part of his body, due to inertia of motion, tends to remain in motion.

4. If downward force on the earth stops, so upward self-adjusting force also stop. In vertical direction, there is no force. Due to inertia, person resists any change to its state of rest. So, person will remain standing.

5. During pick-up, the car accelerates. This must happens due to a net external force. This is because, the acceleration of the car cannot be accounted for by any internal force. The only conceivable external force along the road is the force of friction. It is the frictional force that accelerates the car as a whole.

6. Since, momentum is directly proportional to mass of the body. Hence, when both iron balls are dropped from same height, then bigger ball gain greater momentum than smaller ball at the time of striking the glass pane. Hence, it can transfer greater momentum to the glass pane and so it breaks.

7. Given, $m = 1.0 \times 10^4$ kg

As the weight of the man is increased 5 times, so acceleration of the rocket, also increase to 5 times.

i.e. $a = 5g = 5 \times 10 = 50 \text{ ms}^{-2}$

Force applied by rocket engine,

$$F = ma = 1.0 \times 10^4 \times 50 = 5 \times 10^5 \text{ N}$$

8. From equation of motion, $y = ut + \frac{1}{2}at^2$ ...(i)

where, a is the acceleration.

Given equation, $y = ut + gt^2 = ut + \frac{1}{2} \cdot 2gt^2$ ...(ii)

Comparing Eqs. (i) and (ii), we get

Acceleration, $a = 2g$

Force $= m \times a = m \cdot 2g = 2mg$

9. Given, mass of bullet, $m = 0.04$ kg

Initial speed of bullet, $u = 90 \text{ ms}^{-1}$

Time, $t = 3$ s

Final velocity of bullet, $v = 0$

If a be the retardation in the bullet in the wooden block, then

From equation of motion, $v = u - at$

$$0 = 90 - a \times 3$$

$\Rightarrow \quad 3a = 90 \Rightarrow a = 30 \text{ m/s}^2$

$\therefore$ Average resistive force,

$$F = m \cdot a = 0.04 \times 30 = 1.2 \text{ N}$$

10. Given, mass, $m = 6$ kg

Velocity, $\mathbf{v} = v_2 - v_1 = 5 - 3 = 2$

$\therefore$ Momentum, $p = m\mathbf{v} = 6 \times 2 = 12$ N-s

11. To solve this question we have to apply Newton's second law of motion, in terms of force and change in momentum.

We know that, $F = \frac{dp}{dt}$

Given that, meter scale is moving with uniform velocity, hence $dp = 0$.

Force, $F = 0$.

As all parts of the scale is moving with uniform velocity and total force is zero, hence torque will also be zero.

12. Given, mass of satellite, $m = 10^4$ kg

$F = 5 \times 10^5$ N, $t = 20$ s, $u = 0$, $v = ?$

Impulse applied on the satellite is equal to the change in momentum.

i.e. $F \cdot t = m(v - u)$

$5 \times 10^5 \times 20 = 10^4 (v - 0)$

$\Rightarrow \quad v = \dfrac{5 \times 10^5 \times 20}{10^4} = 1000$ m/s $= 1$ km/s

13. Given, $p = 2 + 3t^2$

Differentiate w.r.t. t, we get

$$\frac{dp}{dt} = 0 + 3 \times 2t = 6t$$

If $t = 3$ s, then $\dfrac{dp}{dt} = 6 \times 3 = 18$ N

$\therefore$ Force acting on the particle $= 18$ N

14. From Newton's second law, $F = n \cdot \left(\dfrac{\Delta p}{\Delta t}\right)$

where, F = force, n = number of bullets fired per second and $\dfrac{\Delta p}{\Delta t}$ = rate of change of momentum of one bullet.

$\Rightarrow \quad F = n\left(\dfrac{mv - 0}{\Delta t}\right)$

Given, $F = 144$ N, $m = 40$ g $= 40 \times 10^{-3}$ kg,

$v = 1200$ ms^{-1} and $\Delta t = 1$ s

$\therefore \quad 144 = n \times \dfrac{40 \times 10^{-3} \times 1200}{1}$

$\Rightarrow \quad n = \dfrac{144}{4 \times 12}$

$\Rightarrow \quad n = 3$

15. Given, $\mathbf{u} = (3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})$ m/s

and $\mathbf{v} = -(3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})$ m/s

Mass of the ball, $m = 150$ g $= 0.15$ kg

Δp = Change in momentum

= Final momentum − Initial momentum

$= m\mathbf{v} - m\mathbf{u}$

$= m(\mathbf{v} - \mathbf{u}) = (0.15)\,[-(3\hat{\mathbf{i}} + 4\hat{\mathbf{j}}) - (3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})]$

$= (0.15)\,[-6\hat{\mathbf{i}} - 8\hat{\mathbf{j}}]$

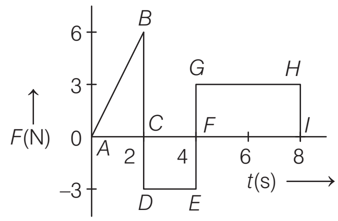
$= -[0.15 \times 6\hat{\mathbf{i}} + 0.15 \times 8\hat{\mathbf{j}}]$

$= -[0.9\hat{\mathbf{i}} + 1.20\hat{\mathbf{j}}]$

Hence, $\Delta \mathbf{p} = -[0.9\hat{\mathbf{i}} + 1.2\hat{\mathbf{j}}]$

16. The area under F-t graph gives change in momentum.

So, for the F-t graph as shown below



For 0 to 2s, Δp_1 = Area under the triangle ABC

$= \dfrac{1}{2} \times 2 \times 6 = 6$ kg-ms^{-1}

For 2 to 4s, Δp_2 = Area under the rectangle $CFEDC$

$= 2 \times -3 = -6$ kg-ms^{-1}

For 4 to 8s, Δp_3 = Area under the rectangle $FIHGF$

$= 4 \times 3 = 12$ kg-ms^{-1}

So, total change in momentum for 0 to 8s,

$\Delta p_{net} = \Delta p_1 + \Delta p_2 + \Delta p_3$

$= (+6 - 6 + 12) = 12$ kgms^{-1} = 12 N-s

17. Here, $F = kt$

When $t = 0$, then linear momentum $= p$

When $t = T$, then linear momentum $= 3p$

According to Newton's second law of motion,

Applied force, $F = \dfrac{dp}{dt}$

or $\quad dp = F \cdot dt$

or $\quad dp = kt \cdot dt$

Now, integrate both side with proper limit

$$\int_p^{3p} dp = k\int_0^T t\,dt \text{ or } [p]_p^{3p} = k\left[\frac{t^2}{2}\right]_0^T$$

or $(3p - p) = \dfrac{1}{2} k (T^2 - 0)$

or $\quad T^2 = \dfrac{4p}{k}$ or $T = 2\sqrt{\dfrac{p}{k}}$

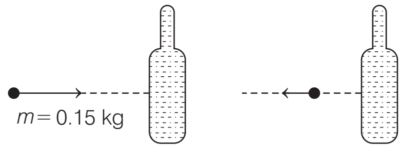
18. Given, $F = 50$ N, $m = 20$ kg, $v = 15$ ms^{-1}

Impulse, $F = \dfrac{mv}{\Delta t}$

Time, $\quad \Delta t = \dfrac{mv}{F}$

$$\Delta t = \frac{20 \times 15}{50} = 6 \text{ s}$$

19. The situation is as depicted below



Initial momentum $= mv = 0.15 \times 12$

$= 1.8$ N-s to right

Final momentum $= mv = 0.15 \times 12$

$= 1.8$ N-s to left

Impulse = Change in momentum

= Final momentum − Initial momentum

$= (1.8 \text{ N-s}) - (-1.8 \text{ N-s})$

$= (1.8 \text{ N-s}) + (1.8 \text{ N-s}) = 3.6$ N-s

= 3.6 N-s towards left

20. According to figure, radius of semi-circle, $r = 2$

Linear momentum gained

= Impulse from 0 to 4 s

= Area enclosed by graph from 0 to 4 s

$$= \frac{\pi r^2}{2} = \frac{\pi(2)^2}{2} = 2\pi \text{ N-s}$$

21. Action and reaction forces always act on different bodies, because if they work on same body, then net force on the body is zero and there could never be accelerated motion.

So, they cannot balance or cancel each other.

Hence, options (a) and (c) are correct.

22. From law of conservation of momentum,

$$p_i = p_f$$

and initial momentum, $p_i = mu = m(0) = 0$

$\therefore$ p_f should also be zero.

Hence, other piece will move in negative x-direction.

23. From conservation of linear momentum,

$$m_2 v_2 = m_1 v_1$$

$$100\, v_2 = \frac{200}{1000} \times 80$$

$$v_2 = \frac{200 \times 80}{1000 \times 100}$$

$\Rightarrow$ $v_2 = 0.16$ m/s

or $v_2 = 16$ cm/s

24. In equilibrium, net force is zero, therefore acceleration is zero, hence particle is either at rest or in motion with uniform velocity.

25. For stable condition,

$\mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3 = 0$

$(3\hat{\mathbf{i}} - 4\hat{\mathbf{j}}) + (2\hat{\mathbf{i}} - 3\hat{\mathbf{j}}) + \mathbf{F}_3 = 0$ (given)

$\Rightarrow$ $\mathbf{F}_3 = -5\hat{\mathbf{i}} + 7\hat{\mathbf{j}}$

26. Let equal forces $F_1 = F_2 = F$ newton

Angle between the forces, $\theta = 60°$

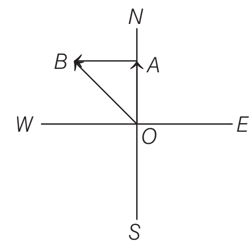
Resultant force, $R = 40\sqrt{3}$ N

Now, $R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2 \cos\theta}$

$\therefore$ $40\sqrt{3} = \sqrt{F^2 + F^2 + 2FF \cos 60°}$

or $F = 40$ N

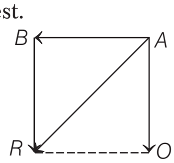
27. Consider the adjacent diagram



Let, $\mathbf{OA} = \mathbf{p}_1$

= initial momentum of player northward

and $\mathbf{AB} = \mathbf{p_2}$ = final momentum of player towards west.



Clearly, $\mathbf{OB} = \mathbf{OA} + \mathbf{AB}$

Change in momentum $= \mathbf{p}_2 - \mathbf{p}_1$

$= \mathbf{AB} - \mathbf{OA} = \mathbf{AB} + (-\mathbf{OA})$

= Clearly resultant $\mathbf{AR}$ will be along south-west.

28. From the given forces, we can say that first two forces 1 N and 2 N, if are in the same direction, then it would be equal to third force 3 N. But it is given that, all the three forces are in different directions.

So, there is no possibility that these three forces, are in equilibrium.

29. Since, all the blocks are moving with constant velocity and we know that, if velocity is constant, acceleration of the body becomes zero.

Hence, the net force on all the blocks will be zero.

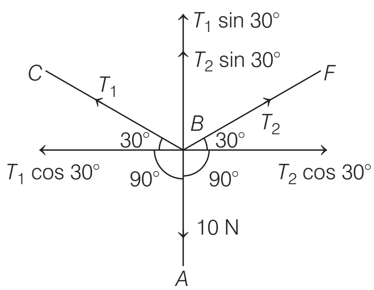
30. Apply Lami's theorem at O,

$$\frac{T_1}{\sin 150^\circ} = \frac{T_2}{\sin 120^\circ} = \frac{10}{\sin 90^\circ} = \frac{10}{1} = 10$$

$\therefore \quad T_1 = 10 \sin 150^\circ = 10 \times \frac{1}{2} = 5\,\text{N}$

$T_2 = 10 \sin 120^\circ = 10 \times \frac{\sqrt{3}}{2} = 5\sqrt{3}\,\text{N}$

31. T_1 and T_2 are the tensions in the sections BC and BF, then resolution of all forces at B in two perpendicular directions are shown below



For equilibrium along horizontal direction,

$T_1 \cos 30^\circ = T_2 \cos 30^\circ$

Let, $\quad T_1 = T_2 = T$

Again, for equilibrium along vertical direction.

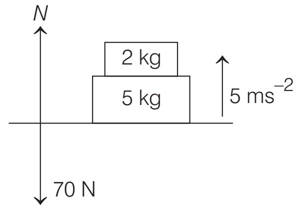
$T_1 \sin 30^\circ + T_2 \sin 30^\circ = 10$

$\Rightarrow \quad 2T \sin 30^\circ = 10$

$2T \times \frac{1}{2} = 10 \Rightarrow T = 10\,\text{N}$

So, the tension in both sections BC and BF is 10 N.

32.

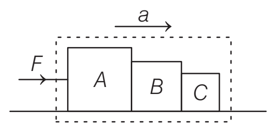


$N - 70 = 7 \times 5$

$\therefore \quad N = 105\,\text{N}$

33. Given, $\quad m_A = 4$ kg,

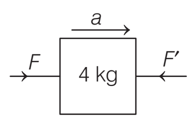
$m_B = 2$ kg, $m_C = 1$ kg and $F = 14$ N



So, total mass, $M = 4 + 2 + 1 = 7$ kg

Now, $F = Ma \Rightarrow 14 = 7a \Rightarrow a = 2\,\text{ms}^{-2}$

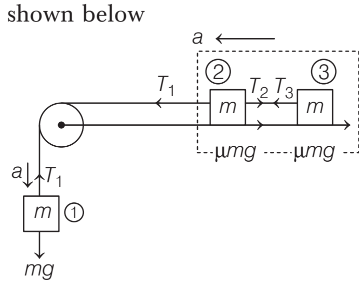
FBD of block A,



$\Rightarrow F' = F - 4a = 14 - 4 \times 2 \Rightarrow F' = 6\,\text{N}$

Hence, the contact force between A and B is 6 N.

34. First of all consider the forces on the blocks as shown below



For the Ist block, $mg - T_1 = m \times a \quad \ldots$(i)

Let us consider 2nd and 3rd blocks as a system,

so $\quad T_1 - 2\mu mg = 2m \times a \quad \ldots$(ii)

Adding Eqs. (i) and (ii), we get

$$mg(1 - 2\mu) = 3m \times a \Rightarrow a = \frac{g}{3}(1 - 2\mu)$$

35. Given, $m_1 = 1$ kg, $m_2 = 2$ kg and $g = 10$ ms^{-2}

Acceleration, $a = \left(\frac{m_2 - m_1}{m_1 + m_2}\right) g$

$$= \left(\frac{2-1}{1+2}\right) 10 = \frac{10}{3}$$

$$\left[\because s = ut + \frac{1}{2}at^2 \text{ and } u = 0 \text{ ms}^{-1}\right]$$

Distance, $s = \frac{1}{2} \times a \times t^2$

$$= \frac{1}{2} \times \frac{10}{3} \times 4 = \frac{20}{3} \text{ m}$$

36. Frictional force in the direction of train causes the acceleration of the box lying in the compartment of an accelerating train.

37. Given, $m = 2$ kg, $\mu = 0.2$

and $g = 10$ m/s^2

Here, $ma = \mu mg$

$\Rightarrow \quad a = \mu g = 0.2 \times 10 = 2$ ms^{-2}

38. Given, mass of the car $= m$

As car starts from rest, $u = 0$

Velocity acquired along east $= v\hat{\mathbf{i}}$

Duration, $t = 2$s.

We know that, $v = u + at$

$\Rightarrow \quad v\hat{\mathbf{i}} = 0 + a \times 2$

$\Rightarrow \quad \mathbf{a} = \frac{\mathbf{v}}{2}\hat{\mathbf{i}}$

Force, $\mathbf{F} = m\mathbf{a} = \frac{m\mathbf{v}}{2}\hat{\mathbf{i}}$

Hence, force acting on the car is $\frac{mv}{2}$ towards east. As external force on the system is only friction, hence the force $\frac{mv}{2}$ is by friction.

Hence, force by engine is internal force.

39. Given, $m = 2$ kg, $r = 10$ m and $v = 5$ ms^{-1}

Radial acceleration (centripetal acceleration)

$$= \frac{v^2}{r} = \frac{5 \times 5}{10} = 2.5 \text{ ms}^{-2}$$

Force = Mass × Acceleration = $2 \times 2.5 = 5$ N

40. Given that, two stones of masses m and $2m$ are whirled in horizontal circles, the heavier one in a radius $r/2$ and lighter one in radius r.

As, lighter stone is n times that of the value of heavier stone when they experience same centripetal forces, we get

$$(F_c)_{\text{heavier}} = (F_c)_{\text{lighter}}$$

$\Rightarrow \quad \frac{2m(v)^2}{(r/2)} = \frac{m(nv)^2}{r}$

$\Rightarrow \quad n^2 = 4$

$\Rightarrow \quad n = 2$

41. For car moving in circle of radius R, with velocity v and mass $= m$,

Centripetal force required

$$= \text{Frictional force} \le \mu_s N$$

$$\frac{mv^2}{R} \le \mu_s mg \qquad (\because N = mg)$$

$$v \le \sqrt{\mu_s Rg}$$

42. We know that, $F = \frac{mv_{\text{max}}^2}{r}$ ...(i)

and $\quad F = \mu_s mg$ ...(ii)

From Eqs. (i) and (ii) for maximum speed of vehicle

$$\mu_s mg \ge \frac{mv_{\text{max}}^2}{r}$$

where, v_{max} = maximum velocity of vehicle.

Given, $\mu_s = 0.1$, $r = 5$ m and $g = 10$ ms^{-2}

$\therefore \quad v_{\text{max}} = \sqrt{\mu_s rg}$

$v_{\text{max}}^2 = 0.1 \times 5 \times 10 = 5$ m^{2}s^{-2}

So, person or vehicle will slip, if $v^2 > 5$ m^{2}s^{-2}.

43. Given, $\mu_s = 0.2$, $R = 300$ m and $\theta = 15°$

Optimum speed, $v_o = \sqrt{gR \tan\theta}$

$$= \sqrt{9.8 \times 300 \times \tan 15°}$$

$$= \sqrt{2940 \times 0.27} = 28.1 \text{ ms}^{-1}$$

and $v_{\text{max}} = \sqrt{\frac{gR(\mu_s + \tan 15°)}{1 - \mu_s \tan 15°}}$

$$= \sqrt{\frac{9.8 \times 300\ (0.2 + 0.27)}{1 - 0.2\ (0.27)}}$$

$$= 38.1 \text{ ms}^{-1}$$

Thus, the optimum speed and maximum permissible speed are 28.1 ms^{-1} and 38.1 ms^{-1}, respectively.

44. If angle of banking is θ, then

$$\tan\theta = \frac{mv^2/r}{mg} \Rightarrow \tan\theta = \frac{v^2}{rg}$$

Given, $v = 10 \text{ ms}^{-1}$, $r = 10$ m

and $g = 10 \text{ ms}^{-2}$

So, $\tan\theta = \frac{(10)^2}{10 \times 10} = 1$

$\therefore \quad \theta = 45°$

45. The term inertia means resistance of any physical object. It is defined as the tendency of a body to remain in its position of rest or uniform motion. So, it is dependent on mass of the body.

46. Given, mass, $m = 5$ kg

Acting force, $\mathbf{F} = (-3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})$ N

Initial velocity at $t = 0$, $\mathbf{u} = (6\hat{\mathbf{i}} - 12\hat{\mathbf{j}})$ m/s

Retardation, $\hat{\mathbf{a}} = \frac{\mathbf{F}}{m} = \left(-\frac{3\hat{\mathbf{i}}}{5} + \frac{4\hat{\mathbf{j}}}{5}\right) \text{ m/s}^2$

As final velocity is along Y-axis only, its x-component must be zero.

From $v = u + at$, for x-component only,

$$0 = 6\hat{\mathbf{i}} - \frac{3\hat{\mathbf{i}}}{5}t$$

$$t = \frac{5 \times 6}{3} = 10 \text{ s}$$

47. Impulse is defined as rate of change of momentum. For change in momentum to be minimum.

$$\frac{d}{dt}(20t^2 - 20t) = 0$$

$$40t - 20 = 0$$

$$t = \frac{1}{2} \text{ s}$$

48. Frictional force is a non-conservative force because work done by it is dissipated (wasted) as heat energy. This is not the case with other forces.

49. Due to inertia, greater force is needed to push the truck than the car, to bring them to the same speed in same time.

Thus, the statement given in option (a) is correct, rest are incorrect.

50. The opposing force that comes into play when one body is actually sliding over the surface of the other body is called sliding friction.

The coefficient of sliding is given as

$$\mu_S = N / F_{\text{sliding}}$$

where, N is the normal reaction and F_{sliding} is the sliding force.

As, the dimensions of N and F_{sliding} are same. Thus, μ_S is a dimensionless quantity. When body is rolling, then it reduces the area of contact of surfaces, hence rolling friction is smaller than sliding friction.

Hence, statement (d) is incorrect.

51. When particle moves in a circle even with uniform or constant speed, it faces an external force towards its centre called centripetal force. Hence, the statement given in option (c) is incorrect.

52. A. Static friction is the frictional force between the surfaces of two objects when they are not in motion with respect to each other.

Due to this reason, static friction has the highest value of frictional force and hence μ is highest.

B. Rolling friction takes place when one body rolls over the surface of another body due to which the value of friction is less in case of rolling friction and hence μ is lowest.

C. Kinetic friction takes place when one body slides over the surface of the another body. Value of friction is moderate and lie in between the friction value of rolling and static friction and hence μ is moderate.

Hence, A → p, B → r and C → q.

53. Acceleration of system,

$$a = \frac{60 - 18 - (m_1 + m_2 + m_3)g \sin 30°}{(m_1 + m_2 + m_3)} = 2 \text{ ms}^{-2}$$

Net force on 3 kg block $= m_3 a = 6$ N

From free body diagram of 3 kg block, we have

$$N_{12} - m_1 g \sin 30° - 18 = m_1 a$$

$$\Rightarrow \quad N_{12} = 25 \text{ N}$$

From free body diagram of 3 kg block, we have

$60 - m_3 g \sin 30° - N_{32} = m_3 a$

$\therefore \quad N_{32} = 39 \text{ N}$

Hence, A → r, B → s, C → q and D → s.

54. Aristotle stated that an external force is required to keep a body in motion as it can be observed in our surrounding, i.e. to move a body, we need to push or pull an object. But Aristotle didn't give any reason behind this fact.

The reason behind this fact is that, there are number of opposing forces like friction, viscosity, etc., are always present in the natural world. To counter these opposing forces, some external force is required to keep a body in motion.

Therefore, both A and R are true and R is the correct explanation of A.

55. A stationary body $(v = 0)$ may still have some acceleration, e.g. when a body is thrown in upward direction, it comes to rest at highest position, but at that time, it still have acceleration equal to acceleration due to gravity g.

Hence, gravitational force is acting at highest position and when a force acts on a body, then its accelerates.

Therefore, A is false and R is also false.

56. At the microscopic level, all bodies are made up of charged constituents and various contact forces exist between them.

These forces are due to elasticity of bodies, molecular collisions and impacts etc.

Therefore, both A and R are true and R is the correct explanation of A.

57. Force is a vector quantity. Thus, if force is not parallel to the velocity of the body, but makes some angle with it, it changes the component of velocity along the direction of force.

The component of velocity normal to the force remains unchanged, e.g. in projectile motion, horizontal component of velocity does not change under the effect of vertical gravitational force.

Therefore, A is true but R is false.

58. If force on A by $B = \mathbf{F}_{AB}$ and force on B by $A = \mathbf{F}_{BA}$.

These forces add to give a null force when $\mathbf{F}_{AB} = -\mathbf{F}_{BA}$.

Here $\mathbf{F}_{AB}$ and $\mathbf{F}_{BA}$ are internal forces of $(A + B)$ system.

Internal forces in a body do not cancel away, as they do not act on the same particle.

Therefore, A is true but R is false.

59. It is not always necessary that external agency of force is in contact with the object, while applying force on object.

Force can be applied on a body/particle without contact or with contact, it depends on the agency, applying force. e.g.

earth pulls (exerts force) from distance.

A stone without any physical contact falls due to gravitational pull of the earth.

Therefore, A is true but R is false.

60. $\text{Force} = \dfrac{\text{Change in momentum}}{\text{Time interval}} = \dfrac{\Delta p}{\Delta t}$

If time interval is increased, then force will get decreased (for constant Δp). Therefore, reaction force on the hand is small, i.e. he experience less hurt.

This is what seasoned cricketer does.

New player make Δt small, so force is more, which hurt new player's hand.

Therefore, both A and R are true but R is not the correct explanation of A.

61. As we know, momentum, $\mathbf{p} = m\mathbf{v}$

Change in $\mathbf{p}$ can be brought by changing force $\mathbf{F}$ i.e.

$\mathbf{F} = \dfrac{d\mathbf{p}}{dt}$ = rate of change of momentum with time.

$\Rightarrow \quad m d\mathbf{v} = \mathbf{F} dt$

So, in order to keep, $\mathbf{F}dt$ constant, $md\mathbf{v}$ should be constant, here m and $d\mathbf{v}$ can change from one body to another body.

Thus, same force for same time can cause different change in momentum for different bodies.

Therefore, A is false and R is also false.

62. According to Newton's third law of motion, it is impossible to have a single force out of mutual interaction between two bodies, whether they are moving or at rest.

It means, third law of motion is applicable to all the bodies either at rest or in motion and this law is also applicable to all types of forces.

Therefore, A is false and R is also false.

63. Angle of repose is equal to angle of limiting friction and maximum value of static friction is called the limiting friction.

Maximum force of static friction which comes into play when a body just starts moving. Over the surface of another body is called limiting friction.

Therefore, both A and R are true and R is the correct explanation of A.

64. From relation, the centrifugal force,

$$F = \frac{mv^2}{r} = \frac{m\,(r\omega)^2}{r} = mr\omega^2$$
$$= mr\,(2\pi\nu)^2 = 4\pi^2\, mr\nu^2$$
$$= 4\pi^2 \times 1 \times 1 \times 1^2 = 4\pi^2 \text{ N}$$

Centripetal force, $F = \frac{mv^2}{r}$

Therefore, A is true but R is false.

65. Force, $F = \frac{dp}{dt} = v\left[\frac{dM}{dt}\right] = \alpha v^2$

$$\Rightarrow \quad a = \frac{F}{M} = \frac{\alpha v^2}{M}$$

66. Given, mass, $m = 5$ kg

Change in velocity, $\Delta v =$

$$v_f - v_i = [(10-2)\,\hat{\mathbf{i}} + (6-6)\hat{\mathbf{j}}]$$

Change in momentum

$$= m\Delta v = 5[8\hat{\mathbf{i}}] = 40\hat{\mathbf{i}} \text{ kg-ms}^{-1}$$

67. Momentum,

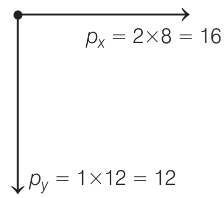
$$\Delta p = 2mv = 2 \times 0.25 \times 10 = 5 \text{ kg-m/s}$$

Force, $F = \frac{\Delta p}{\Delta t} = \frac{5}{0.01} = 500$ N

68. Momentum of third piece,

$$p = \sqrt{p_x^2 + p_y^2} = \sqrt{(16)^2 + (12)^2}$$
$$= 20 \text{ kg-m/s}$$

$$v = \frac{p}{m} = \frac{20}{0.5} = 40 \text{ m/s}$$



69. Given, $F = 10$ N, $v_i = 0$,

$$m = 0.5 \text{ kg}, \Delta t = 0.25 \text{ s}$$

$\because$ Change in momentum, $\Delta p = p_f - p_i$ ...(i)

Also, $\Delta p = F \cdot \Delta t$ ...(ii)

From Eqs. (i) and (ii), we get

$$F \cdot \Delta t = p_f - p_i$$

or $\quad 10 \times 0.25 = p_f - mv_i$

$$2.5 = p_f - 0.5 \times 0$$

$\Rightarrow \quad p_f = 2.5$ N/s

70. Conservation of linear momentum gives

$$m_1v_1 + m_2v_2 = 0$$
$$m_1v_1 = -m_2v_2$$
$$\Rightarrow \quad v_1 = \frac{-m_2v_2}{m_1}$$

Given, $m_1 = 10 \text{ g} = \left(\frac{10}{1000}\right)$ kg

$m_2 = 1$ kg and $v_2 = -5$ m/s

$\therefore$ Velocity of muzzle,

$$v_1 = \frac{+1 \times 5}{10/1000} = 500 \text{ m/s}$$

71. Given that, $v_1 = 10 \text{ m s}^{-1}$,

$$m_1 = 10 \text{ kg}, v_2 = 0,$$
$$m_2 = 9 \text{ kg}, v_3 = v,$$
$$m_3 = 1 \text{ kg}$$

According to conservation of momentum,

$$m_1v_1 = m_2v_2 + m_3v_3$$
$$10 \times 10 = 9 \times 0 + 1 \times v \Rightarrow v = 100 \text{ ms}^{-1}$$

72. From the law of conservation of momentum,

Initial momentum = Final momentum

$$\Rightarrow \quad m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$
$$\therefore \quad 0.1 \times 0 + 50 \times 0 = 0.1 \times 100 + 50\,(-v_2)$$
$$\Rightarrow \quad 0 = 10 - 50v_2$$
$$\therefore \quad v_2 = \frac{10}{50} = 0.2 \text{ ms}^{-1}$$

73. From 0 to T, area is positive and from T to $2T$, area is negative, so net area is zero. Hence, there is no change in momentum.

74. Two masses are moving with equal kinetic energy.

$$\frac{1}{2}Mv_1^2 = \frac{1}{2}4Mv_2^2$$

or $$\frac{v_1}{v_2} = 2$$

The ratio of linear momentum is

$$\frac{p_1}{p_2} = \frac{Mv_1}{4Mv_2}$$

or $$\frac{p_1}{p_2} = \frac{1}{4}\left(\frac{v_1}{v_2}\right)$$

or $$\frac{p_1}{p_2} = \frac{2}{4} = \frac{1}{2}$$

$\Rightarrow$ $p_1 : p_2 = 1 : 2$

75. Frictional force acts between pulley and rope.

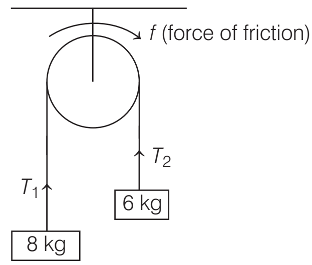
76. The reaction force is

$$R = T_1 + T_2 = (8 + 6)\, g = 14\, g$$

77. As, tension, $T = mg \Rightarrow T \propto m$

So, the side having 8 kg mass will have more tension.

78.



Due to friction, tension at all points of the thread is not alike.

$T_1 - T_2 = f$

$\Rightarrow$ $f = 8\,g - 6\,g = 2\,g$

$= 20$ N $\quad (\because g = 10 \text{ ms}^{-2})$

79. As, $\mu R = f = 20$ N

$$\mu = \frac{20}{R} = \frac{20}{14 \times 10} = \frac{1}{7} \quad (\because R = mg)$$

06

Work, Energy and Power

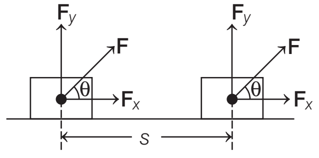
Quick Revision

1. **Work** Work is said to be done by a force, when the body is displaced actually through some distance in the direction of the applied force. Thus, work is done on a body only if the following two conditions are satisfied
   - A force acts on the body.
   - The point of application of the force moves in the direction of the force.
2. **Work Done by a Constant Force** Work done by the force (constant force) is the product of component of force in the direction of the displacement and the magnitude of the displacement. Then, the work done on the body by the force is given by

   Work done, $W = \mathbf{F} \cdot \mathbf{s}$

   SI unit of work is joule(J).

   Its dimensions are $[M^1L^2T^{-2}]$.
3. **Work Done when Force and Displacement are Inclined to Each Other**



   Work done, $W = \mathbf{F} \cdot \mathbf{s} = (F\cos\theta)\cdot s = Fs\cos\theta$

   Two cases can be considered as given below for the maximum and minimum work

   ***Case* I** When $\mathbf{F}$ and $\mathbf{s}$ are in the same direction, i.e. $\theta = 0°$, then work done is $W = Fs\cos 0° = Fs(1) = Fs$ i.e. maximum work done by the force.

   ***Case* II** When $\mathbf{F}$ and $\mathbf{s}$ are perpendicular to each other, i.e. then $W = \mathbf{F}\cdot\mathbf{s} = Fs\cos 90° = Fs(0) = 0$, i.e. no work done by the force, when a body moves in a direction perpendicular to the force acting.
4. **Work Done by a Variable Force** Work done by variable force is given as,

$$W_{x_i \to x_f} = \int_{x_i}^{x_f} \mathbf{F}\cdot d\mathbf{x} = \int_{x_i}^{x_f} (F\cos\theta)\, dx$$

   = Area under force-displacement curve

   When the magnitude and direction of a force vary in three dimensions, then it can be expressed in terms of rectangular components.

   So, work done from x_i to x_f,

$$W = \int_{x_i}^{x_f} F_x\, dx + \int_{x_i}^{x_f} F_y\, dy + \int_{x_i}^{x_f} F_z\, dz$$

   where, F_x, F_y and F_z are the rectangular components of force in x, y and z-directions, respectively.
5. **Conservative Force** If the work done by the force in displacing an object depends only on the initial and final positions of the object and not on the nature of the path followed between the initial and final positions, such a force is known as conservative force. e.g. Gravitational force is a conservative force.

6. **Non-Conservative Force** If the work done by a force in displacing an object from one position to another depends upon the path between the two positions. Such a force is known as non-conservative force. e.g. Friction is a non-conservative force.
7. **Energy** The energy of a body is defined as its capacity or ability for doing work.
   - The dimensions of energy are the same as the dimensions of work, i.e. $[M^1 L^2 T^{-2}]$.
   - It is measured in the same unit as work, i.e. joule in SI system and erg in CGS system.
8. **Kinetic Energy** The energy possessed by a body by virtue of its motion is called kinetic energy. In other words, the amount of work done, by a moving object before coming to rest is equal to its kinetic energy.

   $\therefore$ Kinetic energy, $KE = \frac{1}{2} mv^2$

   where, m is a mass and v is the velocity of a body.
   - **Relation between Kinetic Energy and Linear Momentum**

     $$p = \sqrt{2mK}$$
9. **Work Energy Theorem or Work Energy Principle** It states that, work done by the net force acting on a body is equal to the change produced in the kinetic energies of the body.

   $$K_f - K_i = \int_i^f \mathbf{F}_{net} \cdot dx$$

   $$\therefore K_f - K_i = W$$

   where, K_f and K_i are the final and initial kinetic energies of the body.
10. **Potential Energy** The potential energy of a body is defined as the energy possessed by the body by virtue of its position or configuration. So, if configuration of the system changes, then its potential energy changes.

    Dimensions = $[ML^2T^{-2}]$

    SI unit = Joule
11. **Gravitational Potential Energy** Gravitational potential energy of a body is the energy possessed by the body by virtue of its position above the surface of the earth. Gravitational potential energy, $U = mgh$
12. **Potential Energy of a Spring** For a small stretch or compression, spring obeys Hooke's law, i.e. restoring force $\propto$ stretch or compression

    $$-F_s \propto x \Rightarrow F_s = -kx$$

    where, k is called **spring constant**. Its SI unit is Nm^{-1}.The negative sign shows F_s acts in the opposite direction of displacement x.

    If the block is moved from an initial displacement x_i to final displacement x_f, then work done by spring force is

    $$W_s = \frac{1}{2} kx_i^2 - \frac{1}{2} kx_f^2$$

    $\therefore$ Change in potential energy of a spring

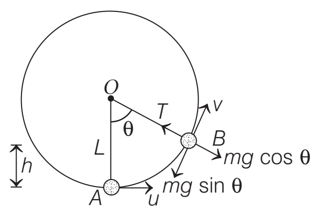
    $$\Delta U = -W_s = \frac{1}{2} k(x_f^2 - x_i^2)$$

    If $x_i = 0$, then $\Delta U = \frac{1}{2} kx_f^2$
13. **Conservation of Mechanical Energy** This principle states that, if only the conservative forces are doing work on a body, then its mechanical energy (KE + PE) remains constant.

    i.e. $K + U = \text{constant} = E$

    $\therefore K_i + U_i = K_f + U_f$

    The quantity $K + U$, is called the total **mechanical energy** of the system.
14. **Motion in a Vertical Circle** A particle of mass m is attached to an inextensible string of length L and is moving in a vertical circle about fixed point O (as shown)

    - Minimum velocity at highest point, so that particle complete the circle, $v_{min} = \sqrt{gL}$, at this velocity, tension in the string is zero.
    - Minimum velocity at lowest point, so that particle complete the circle, $v_{min} = \sqrt{5gL}$, at this velocity, tension in the string is 6 mg.
    - When string is horizontal, then minimum velocity is $\sqrt{3Rg}$ and tension in this condition is 3 mg.

15. **Power** Power of a person or machine is defined as the rate at which work is done or energy is transferred.
Average power (P_{av}) = rate of doing work
$$= \frac{\text{work done } (W)}{\text{time taken } (t)}$$
Thus, the **average power** of a force is defined as the ratio of the work (W) to the total time (t).
16. The **instantaneous power** of an agent at any instant is equal to the dot product of its force and velocity vectors at that instant.
$$P = \mathbf{F} \cdot \mathbf{v}$$
17. Power is a scalar quantity and its dimensional formula is $[ML^2T^{-3}]$.
The SI unit of power is watt (W).
$$1 \text{ watt} = \frac{1 \text{ joule}}{1 \text{ second}} = 1 \text{ Js}^{-1}$$
Another popular units of power are kilowatt and horse power.
1 kilowatt = 1000 watt or 1 kW = 10^3 W
1 horse power = 746 watt or 1 HP = 746 W
This unit is used to describe the output of automobiles, motorbikes, engines, etc.
18. **Collision** A collision is an isolated event in which two or more colliding bodies exert strong forces on each other for a relatively short time. For a collision to take place, the actual physical contact is not necessary.
Collision between particles have been divided into two types which can be differentiated as

Elastic Collision	Inelastic Collision
A collision in which there is absolutely no loss of kinetic energy.	A collision in which there occurs some loss of kinetic energy.
Forces involved during elastic collision must be conserved in nature.	Some or all forces involved during collision may be non- conservative in nature.
The mechanical energy is not converted into heat, light, sound, etc.	A part of the mechanical energy is converted into heat, light, sound, etc.
e.g. Collision between subatomic particles, collision between glass balls, etc.	e.g. Collision between two vehicles, collision between a ball and floor, etc.

19. **Conservation of Linear Momentum in Collision** Total linear momentum is conserved at each instant during collision.
$\therefore p_1 + p_2$ = constant
20. **Elastic Collision in One Dimension**
In one-dimensional elastic collision, relative velocity of separation after collision is equal to relative velocity of approach before collision.
$$u_1 - u_2 = v_2 - v_1$$
Velocities of the Bodies After the Collision
Velocity of Ist body after collision,
$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \left(\frac{2m_2}{m_1 + m_2}\right)u_2 \quad \ldots\text{(i)}$$
Velocity of IInd body after collision,
$$v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)u_2 + \left(\frac{2m_1}{m_1 + m_2}\right)u_1 \quad \ldots\text{(ii)}$$
Eqs. (i) and (ii) give the final velocities of the colliding bodies in terms of their initial velocities.
The two cases under the action of same and different masses can be considered as given below

***Case* I** When two bodies of equal masses collide.
i.e. $m_1 = m_2 = m$ (say)
From Eq. (i), we get
$v_1 = \frac{2mu_2}{2m} = u_2$ = velocity of body of mass m_2 before collision
From Eq. (ii), we get
$v_2 = \frac{2mu_1}{2m} = u_1$ = velocity of body of mass m_1 before collision.

***Case* II** When a light body collides against a massive stationary body.
Here, $m_1 << m_2$ and $u_2 = 0$
Neglecting m_1 in Eq. (i), we get
$$v_1 = -\frac{m_2u_1}{m_2} = -u_1$$
From Eq. (ii), we get
$$v_2 \simeq 0$$

21. **Perfectly Inelastic Collision in One Dimension**

When the two colliding bodies together move as a single body with a common velocity after the collision, then the collision is perfectly inelastic.

In perfectly inelastic collision between two bodies of masses m_1 and m_2, the body of mass m_2 happens to be initially at rest ($u_2 = 0$). After the collision, the two bodies move together with common velocity v. The change in their kinetic energies is KE $= \dfrac{m_1 m_2 u_1^2}{2(m_1 + m_2)}$

$\therefore$ ΔKE is a positive quantity.

Therefore, kinetic energy is lost mainly in the form of light, sound and heat.

22. **Elastic Collision in Two Dimensions** When the collision between two bodies is not head-on (the force during the collision is not along the initial velocity). The bodies move along different lines, then the collision is called elastic collision in two dimensions.

The three cases can be considered as given below

***Case* I Glancing Collision** In a glancing collision, the incident particle does not lose any kinetic energy and is scattered almost undeflected. Thus, for such collision, when $\theta = 0°$, $\phi = 90°$, $u_1 = v_1$ and $v_2 = 0$.

KE of the target particle $= \dfrac{1}{2} m_2 v_2^2 = 0$

***Case* II Head-on Collision** In this type of collision, the target particle moves in the direction of the incident particle, i.e. $\phi = 0°$.

$$m_1 u_1 = m_1 v_1 \cos\theta + m_2 v_2 \quad \text{and} \quad 0 = m_1 v_1 \sin\theta$$

So, the kinetic energy remains unchanged.

***Case* III Elastic Collision of Two Identical Particles** When two particles of same mass undergo perfectly elastic collision in two dimensions, i.e. $m_1 = m_2$.

$$\therefore \qquad \theta + \phi = 90°$$

Thus, after collision the two particles will move at right angle to each other.

23. **Inelastic Collision in Two Dimensions** When two bodies travelling initially along the same straight line collide involving some loss of kinetic energy and move after collision along different directions in a plane, then it is called inelastic collision in two dimensions.

24. **Coefficient of Restitution or Coefficient of Resilience**

It is defined as the ratio of relative velocity of separation after collision to the relative velocity of approach before collision. It is denoted by e.

$$e = \frac{\text{Relative velocity of separation (after collision)}}{\text{Relative velocity of approach (before collision)}}$$

$$e = \frac{|v_2 - v_1|}{|u_2 - u_1|}$$

where, u_1 & u_2 are velocities of two bodies before collision and v_1 & v_2 are their respective velocities after collision.

25. **Comparison between Different Types of Collisions**

Collision	Kinetic Energy	Coefficient of Restitution	Main Domain
Elastic	Conserved	$e = 1$	Between atomic particles
Inelastic	Non-conserved	$0 < e < 1$	Between ordinary objects
Perfectly inelastic	Maximum loss of KE	$e = 0$	During shooting
Super elastic	KE increases	$e > 1$	In explosions

Objective Questions

Multiple Choice Questions

1. A bicyclist comes to a skidding stop in 10 m. During this process, the force on the bicycle due to the road is 200N and is directly opposed to the motion. The work done by the cycle on the road is *(NCERT Exemplar)*

(a) +2000 J (b) −200 J
(c) zero (d) −20,000 J

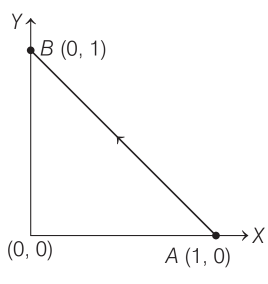
2. Force of 50 N acting on a body at an angle θ with horizontal. If 150 J work is done by displacing it 3 m, then θ is

(a) 60° (b) 30°
(c) 0° (d) 45°

3. A particle is pushed by forces $2\hat{\mathbf{i}} + 3\hat{\mathbf{j}} - 2\hat{\mathbf{k}}$ and $5\hat{\mathbf{i}} - \hat{\mathbf{j}} - 3\hat{\mathbf{k}}$ simultaneously and it is displaced from point $\hat{\mathbf{i}} + \hat{\mathbf{j}} + \hat{\mathbf{k}}$ to point $2\hat{\mathbf{i}} - \hat{\mathbf{j}} + 3\hat{\mathbf{k}}$. The work done is

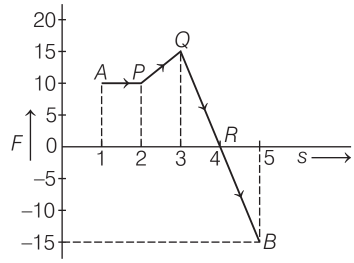
(a) 7 units (b) −7 units
(c) 10 units (d) −10 units

4. Consider a force $\mathbf{F} = -x\hat{\mathbf{i}} + y\hat{\mathbf{j}}$. The work done by this force in moving a particle from point $A(1, 0)$ to $B(0, 1)$ along the line segment is (all quantities are in SI units)



(a) $\frac{3}{2}$ (b) 2
(c) 1 (d) $\frac{1}{2}$

5. A body moves from point A to B under the action of a force varying in magnitude as shown in figure, then the work done is (force is expressed in newton and displacement in metre)



(a) 30 J (b) 22.5 J
(c) 25 J (d) 27 J

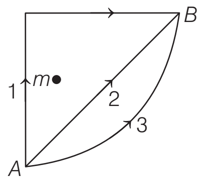
6. A string of length L and force constant k is stretched to obtain extension l. It is further stretched to obtain extension l_1. The work done in second stretching is

(a) $\frac{1}{2}kl_1(2l + l_1)$ (b) $\frac{1}{2}kl_1^2$
(c) $\frac{1}{2}k(l^2 + l_1^2)$ (d) $\frac{1}{2}k(l_1^2 - l^2)$

7. A uniform chain of length l and mass m is lying on a smooth table and one-third of its length is hanging vertically down over the edge of the table. If g is acceleration due to gravity, work required to pull the hanging part on to the table is

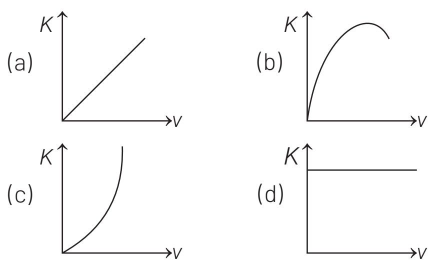
(a) mgl (b) $\frac{mgl}{3}$
(c) $\frac{mgl}{9}$ (d) $\frac{mgl}{18}$

8. If W_1, W_2 and W_3 are the work done in moving a particle from A and B along three different paths 1, 2 and 3 respectively (as shown) in the gravitational field of a point mass m, the relation between W_1, W_2 and W_3 is



(a) $W_1 > W_2 > W_3$ (b) $W_1 = W_2 = W_3$
(c) $W_1 < W_2 < W_3$ (d) $W_2 > W_1 > W_3$

9. Amongst the given graphs which one correctly represents the variation of the kinetic energy (K) of a body with velocity (v)?



10. The kinetic energy of a body of mass 4 kg and momentum 6 N-s will be

(a) 3.5 J (b) 5.5 J
(c) 2.5 J (d) 4.5 J

11. For a moving particle (mass m, velocity v) having a momentum p, which one of the following correctly describes the kinetic energy of the particle?

(a) $\frac{p^2}{2m}$ (b) $\frac{p}{2m}$ (c) $\frac{v^2}{2m}$ (d) $\frac{v}{2m}$

12. Two bodies of masses 4 kg and 5 kg are moving with equal momentum. Then, the ratio of their respective kinetic energies is

(a) 4 : 5 (b) 2 : 1
(c) 1 : 3 (d) 5 : 4

13. A heavy body and a light body have same kinetic energy. Which will have larger linear momentum?

(a) Heavy body
(b) Light body
(c) Both have same linear momenta
(d) None of the above

14. A mass of 5 kg is moving along a circular path of radius 1 m. If the mass moves with 300 rev/min, its kinetic energy (in J) would be

(a) $250\pi^2$ (b) $100\pi^2$ (c) $5\pi^2$ (d) zero

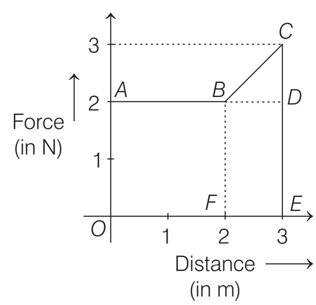
15. Two moving objects $(m_1 > m_2)$ having same kinetic energy are stopped by application of equal retarding force. Which object will come to rest at shorter distance?

(a) Bigger
(b) Smaller
(c) Both at same distance
(d) Cannot say

16. A particle which is experiencing a force, is given by $\mathbf{F} = 3\hat{\mathbf{i}} - 12\hat{\mathbf{j}}$, undergoes a displacement of $\mathbf{d} = 4\hat{\mathbf{i}}$. If the particle had a kinetic energy of 3 J at the beginning of the displacement, what is its kinetic energy at the end of the displacement ?

(a) 9 J (b) 15 J (c) 12 J (d) 10 J

17. A particle moves in one dimension from rest under the influence of a force that varies with the distance travelled by the particle as shown in the figure. The kinetic energy of the particle after it has travelled 3 m is



(a) 4 J (b) 2.5 J
(c) 6.5 J (d) 5 J

18. When a person lifts a brick above the surface of the earth, then its potential energy

(a) increases (b) decreases
(c) remains same (d) None of these

19. A massless spring of spring constant k, has extension y and potential energy E. It is now stretched from y to $2y$. The increase in its potential energy is

(a) $3E$ (b) $2E$
(c) E (d) $4E$

20. A bread gives 5 kcal of energy to a boy. How much height he can climbs by using this energy, if his efficiency is 28% and mass is 60 kg?

(a) 15m (b) 5m
(c) 2.5 m (d) 10 m

21. A body is falling freely under the action of gravity alone in vaccum. Which of the following quantities remain constant during the fall? *(NCERT Exemplar)*

(a) Kinetic energy
(b) Potential energy
(c) Total mechanical energy
(d) Total linear momentum

22. A stone is projected vertically up to reach maximum height h. The ratio of its kinetic energy to its potential energy at a height $\frac{4}{5}h$, will be

(a) 5 : 4 (b) 4 : 5
(c) 1 : 4 (d) 4 : 1

23. A spring of force constant 800 N/m has an extension of 5 cm. The work done in extending it from 5 cm to 15 cm is

(a) 16 J (b) 8 J
(c) 32 J (d) 24 J

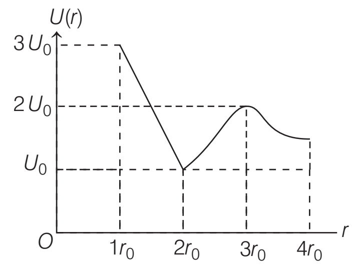
24. A 2 kg block slides on a horizontal floor with a speed of 4 m/s. It strikes a uncompressed spring and compresses it till the block is motionless. The kinetic friction force is 15 N and spring constant is 10000 N/m. The spring compresses by

(a) 5.5 cm (b) 2.5 cm
(c) 11.0 cm (d) 8.5 cm

25. 300 J of work is done in sliding a 2 kg block up an inclined plane of height 10 m (taking, $g = 10\ ms^{-2}$). Work done against friction is

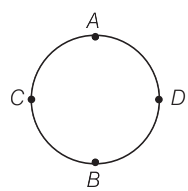
(a) 200 J (b) 100 J
(c) zero (d) 1000 J

26. The graph below represents the potential energy U as a function of position r for a particle of mass m. If the particle is released from rest at position r_0, what will its speed be at position $3r_0$?



(a) $\sqrt{\frac{3U_0}{m}}$ (b) $\sqrt{\frac{4U_0}{m}}$
(c) $\sqrt{\frac{2U_0}{m}}$ (d) $\sqrt{\frac{6U_0}{m}}$

27. A pebble is attached to one end of a string and rotated in a vertical circle. If string breaks at the position of maximum tension, so from the figure shown below, it will break at



(a) A (b) B (c) C (d) D

28. What is the ratio of kinetic energy of a particle at the bottom to the kinetic energy at the top, when it just loops a vertical loop of radius r?

(a) 5 :1 (b) 2 : 3
(c) 5 :2 (d) 7 : 2

29. A man can do work of 600 J in 2 min, then man's power is

(a) 7.5 W (b) 10 W
(c) 5 W (d) 15 W

30. A particle is acted by a constant power. Then, which of the following physical quantity remains constant?

(a) Speed
(b) Rate of change of acceleration
(c) Kinetic energy
(d) Rate of change of kinetic energy

31. An object of mass m moves horizontally, increasing in speed from 0 to v in a time t. The power necessary to accelerate the object during this time period is

(a) $\frac{mv^2 t}{2}$ (b) $\frac{mv^2}{2}$
(c) $2mv^2$ (d) $\frac{mv^2}{2t}$

32. A 60 HP electric motor lifts an elevator having a maximum total load capacity of 2000 kg. If the frictional force on the elevator is 4000 N, the speed of the elevator at full load is close to (take, 1 HP = 746 W and $g = 10\ ms^{-2}$)

(a) $2.0\ ms^{-1}$ (b) $1.5\ ms^{-1}$
(c) $1.9\ ms^{-1}$ (d) $1.7\ ms^{-1}$

33. A car of mass m starts from rest and accelerates, so that the instantaneous power delivered to the car has a constant magnitude P_0. The instantaneous velocity of this car is proportional to

(a) $t^2 P_0$ (b) $t^{1/2}$
(c) $t^{-1/2}$ (d) $t/\sqrt{m}$

34. For a system to follow the law of conservation of linear momentum during a collision, the condition is

I. total external force acting on the system is zero
II. total external force acting on the system is finite and time of collision is negligible
III. total internal force acting on the system is zero

(a) Only I (b) Only II (c) Only III (d) I or II

35. Two identical balls A and B having velocities of $0.5\ ms^{-1}$ and $-0.3\ ms^{-1}$ respectively, collide elastically in one dimension. The velocities of B and A after the collision respectively will be

(a) $-0.5\ ms^{-1}$ and $0.3\ ms^{-1}$
(b) $0.5\ m/s^{-1}$ and $-0.3\ ms^{-1}$
(c) $-0.3\ ms^{-1}$ and $0.5\ ms^{-1}$
(d) $0.3\ ms^{-1}$ and $0.5\ ms^{-1}$

36. A particle of mass 1g moving with a velocity $\mathbf{v}_1 = (3\hat{\mathbf{i}} - 2\hat{\mathbf{j}})\ ms^{-1}$ experiences a perfectly elastic collision with another particle of mass 2 g and velocity $\mathbf{v}_2 = (4\hat{\mathbf{j}} - 6\hat{\mathbf{k}})\ ms^{-1}$. The velocity of the particle is

(a) $2.3\ ms^{-1}$ (b) $4.6\ ms^{-1}$
(c) $9.2\ ms^{-1}$ (d) $6\ ms^{-1}$

37. A particle of mass m_1 moves with velocity v_1 collides with another particle at rest of equal mass. The velocity of second particle after the elastic collision is

(a) $2v_1$ (b) v_1 (c) $-v_1$ (d) zero

38. During inelastic collision between two bodies, which of the following quantities always remain conserved? *(NCERT Exemplar)*

(a) Total kinetic energy
(b) Total mechanical energy
(c) Total linear momentum
(d) Speed of each body

39. Two objects of mass m each moving with speed u ms^{-1} collide at 90°, then final momentum is (assume collision is inelastic)

(a) mu (b) $2\,mu$
(c) $\sqrt{2}\,mu$ (d) $2\sqrt{2}\,mu$

40. A body of mass 5×10^3 kg moving with speed 2 ms^{-1} collides with a body of mass 15×10^3 kg inelastically and sticks to it. Then, loss in kinetic energy of the system will be

(a) 7.5 kJ (b) 15 kJ (c) 10 kJ (d) 5 kJ

41. If the linear momentum of a body is increased by 50%, then the kinetic energy of that body increases by ....

(a) 100% (b) 125% (c) 225% (d) 25%

42. A ball of mass m moves with speed v and strikes a wall having infinite mass and it returns with same speed, then the work done by the ball on the wall is ....

(a) zero (b) mv J
(c) m/v J (d) v/mJ

43. A body of mass 5 kg is thrown vertically up with a kinetic energy of 490 J. The height at which the kinetic energy of the body becomes half of the original value is ....

(a) 12.5 m (b) 10 m
(c) 2.5 m (d) 5 m

44. If two persons A and B take 2 s and 4 s, respectively to lift an object to the same height h, then the ratio of their powers is ....

(a) 1:2 (b) 1:1
(c) 2:1 (d) 1:3

45. At time $t = 0$, particle starts moving along the x-axis. If its kinetic energy increases uniformly with time t, the net force acting on it must be proportional to t^n, where the value of n is ....

(a) 1 (b) $-1/2$
(c) 2 (d) 1/2

46. A man of mass m, standing at the bottom of the staircase, of height L climbs it and stands at its top. Which amongst the following statement is correct? *(NCERT Exemplar)*

(a) Work done by all forces on man is equal to the rise in potential energy mgL.
(b) Work done by all forces on man is zero.
(c) Work done by the gravitational force on man is mgL.
(d) The reaction force from a step does some work because the point of application of the force does not move while the force exists.

47. Which of the following statement is correct about non-conservative force?

(a) It depends on velocity of the object.
(b) It depends on the particular path taken by the object.
(c) It depend on the initial and final positions of the object.
(d) Both (a) and (b)

48. Which of the following statement is correct?

(a) Conservation of mechanical energy does not consider only conservative force.
(b) Conservation of energy consider both conservative and non-conservative forces.
(c) Conservation of energy consider only conservative force.
(d) Mass converted into energy in nuclear reaction is called mass-defect.

49. Which of the following statement does not specify an example of perfectly inelastic collision?

(a) A bullet fired into a block if bullet gets embedded into block.
(b) Capture of electrons by an atom.
(c) A man jumping on to moving boat.
(d) A ball bearing striking another ball bearing.

50. Match the Column I (angle) with Column II (work done) and select the correct option from the codes given below.

	Column I		Column II
A.	$\theta < 90°$	p.	Friction
B.	$\theta = 90°$	q.	Satellite rotating around the earth
C.	$\theta > 90°$	r.	Coolie is lifting a luggage

Codes

	A	B	C
(a)	p	q	r
(b)	r	q	p
(c)	p	r	q
(d)	r	p	q

51. A body is moved along a straight line by a machine delivering a power proportional to time ($P \propto t$). Then, match the Column I with Column II and select the correct option from the codes given below.

	Column I		Column II
A.	Velocity is proportional to	p.	t
B.	Displacement is proportional to	q.	t^2
C.	Work done is proportional to	r.	t^3

Codes

	A	B	C
(a)	p	q	r
(b)	r	q	p
(c)	p	q	q
(d)	r	p	p

Assertion-Reasoning MCQs

For question numbers 52 to 60, two statements are given-one labelled ***Assertion*** *(A) and the other labelled* ***Reason*** *(R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

52. Assertion Stopping distance

$$= \frac{\text{Kinetic energy}}{\text{Stopping force}}$$

Reason Work done in stopping a body is equal to change in kinetic energy of the body.

53. Assertion A spring of force constant k is cut into two pieces having lengths in the ratio 1 : 2. The force constant of series combination of the two parts is $2k/3$.

Reason The spring connected in series are represented by $k = k_1 + k_2$.

54. Assertion According to the law of conservation of mechanical energy, change in potential energy is equal and opposite to the change in kinetic energy.

Reason Mechanical energy is not conserved.

55. Assertion Decrease in mechanical energy is more in case of an object sliding up a relatively less inclined plane due to friction.

Reason The coefficient of friction between the block and the surface decreases with the increase in the angle of inclination.

56. **Assertion** For looping a vertical loop of radius r, the minimum velocity at lowest point should be $\sqrt{5gr}$.

Reason In this event, the velocity at the highest point will be zero.

57. **Assertion** Kilowatt-hour is the unit of energy.

Reason One kilowatt hour is equal to 3.6×10^6 J.

58. **Assertion** There is no loss in energy in elastic collision.

Reason Linear momentum is conserved in elastic collision.

59. **Assertion** Quick collision between two bodies is more violent than a slow collision; even when the initial and final velocities are identical.

Reason The momentum is greater in first case.

60. **Assertion** Two particles are moving in the same direction do not lose all their energy in completely inelastic collision.

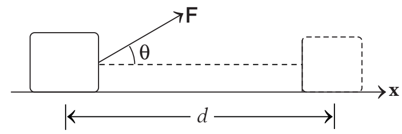
Reason Principle of conservation of momentum does not holds true for all kinds of collisions.

Case Based MCQs

Direction *Answer the questions from 61-65 on the following case.*

Work

A farmer ploughing the field, a construction worker carrying bricks, a student studying for a competitive examination, an artist painting a beautiful landscape, all are said to be working. In physics, however, the word 'Work' covers a definite and precise meaning. Work refers to the force and the displacement over which it acts. Consider a constant force F acting on an object of mass m. The object undergoes a displacement d in the positive x-direction as shown in figure.



The work done by the force is defined to be the product of component of the force in the direction of the displacement and the magnitude of this displacement, thus $W = (F\cos\theta)\, d = \mathbf{F} \cdot \mathbf{d}$.

61. The earth is moving around the sun in a circular orbit, is acted upon by a force and hence work done on the earth by the force is

(a) zero
(b) positive
(c) negative
(d) None of the above

62. In which case, work done will be zero?

(a) A weight-lifter while holding a weight of 100 kg on his shoulders for 1 min
(b) A locomotive against gravity is running on a level plane with a speed of 60 kmh^{-1}
(c) A person holding a suitcase on his head and standing at a bus terminal
(d) All of the above

63. Find the angle between force $\mathbf{F} = (3\hat{\mathbf{i}} + 4\hat{\mathbf{j}} - 5\hat{\mathbf{k}})$ unit and displacement $\mathbf{d} = (5\hat{\mathbf{i}} + 4\hat{\mathbf{j}} + 3\hat{\mathbf{k}})$ unit.

(a) $\cos^{-1}(0.49)$ (b) $\cos^{-1}(0.32)$
(c) $\cos^{-1}(0.60)$ (d) $\cos^{-1}(0.90)$

64. Which of the following statement(s) is/are correct for work done to be zero?

I. If the displacement is zero.

II. If force applied is zero.

III. If force and displacement are mutually perpendicular to each other.

(a) Only I (b) I and II
(c) Only II (d) I, II and III

65. A proton is kept at rest. A positively charged particle is released from rest at a distance d in its field. Consider two experiments; one in which the charged particle is also a proton and in another, a positron. In same time t, the work done on the two moving charged particles is

(a) same as the same force law is involved in the two experiments
(b) less for the case of a positron, as the positron moves away more rapidly and the force on it weakens
(c) more for the case of a positron, as the positron moves away a larger distance
(d) same as the work is done by charged particle on the stationary proton

Direction *Answer the questions from 66-70 on the following case.*

Kinetic Energy

The energy possessed by a body by virtue of its motion is called kinetic energy. In other words, the amount of work done, a moving object can do before coming to rest is equal to its kinetic energy.

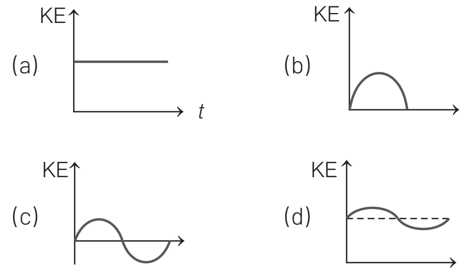
$\therefore$ Kinetic energy, $KE = \frac{1}{2} mv^2$

where, m is a mass and v is the velocity of a body.

The units and dimensions of KE are Joule (in SI) and $[ML^2T^{-2}]$, respectively.

Kinetic energy of a body is always positive. It can never be negative.

66. Which of the diagrams shown in figure most closely shows the variation in kinetic energy of the earth as it moves once around the sun in its elliptical orbit?



67. A force which is inversely proportional to the speed is acting on a body. The kinetic energy of the body starting from rest is

(a) a constant
(b) inversely proportional to time
(c) directly proportional to time
(d) directly proportional to square of time

68. The kinetic energy of an air molecule (10^{-21} J) in eV is

(a) 6.2 meV (b) 4.2 meV
(c) 10.4 meV (d) 9.7 meV

69. Two masses of 1 g and 4 g are moving with equal kinetic energy. The ratio of the magnitudes of their momentum is

(a) 4 : 1 (b) $\sqrt{2}$:1
(c) 1 : 2 (d) 1 : 16

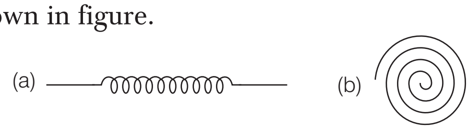
70. An object of mass 10 kg is moving with velocity of 10 ms^{-1}. Due to a force, its velocity become 20 ms^{-1}. Percentage increase in its KE is

(a) 25% (b) 50%
(c) 75% (d) 300%

Direction *Answer the questions from 71-75 on the following case.*

PE of Spring

There are many types of spring. Important among these are helical and spiral springs as shown in figure.



Usually, we assume that the springs are massless. Therefore, work done is stored in the spring in the form of elastic potential energy of the spring. Thus, potential energy of a spring is the energy associated with the state of compression or expansion of an elastic spring.

71. The potential energy of a body is increases in which of the following cases?
(a) If work is done by conservative force
(b) If work is done against conservative force
(c) If work is done by non-conservative force
(d) If work is done against non- conservative force

72. The potential energy, i.e. $U(x)$ can be assumed zero when
(a) $x=0$
(b) gravitational force is constant
(c) infinite distance from the gravitational source
(d) All of the above

73. The ratio of spring constants of two springs is 2 : 3. What is the ratio of their potential energy, if they are stretched by the same force?
(a) 2 : 3
(b) 3 : 2
(c) 4 : 9
(d) 9 : 4

74. The potential energy of a spring increases by 15 J when stretched by 3 cm. If it is stretched by 4 cm, the increase in potential energy is
(a) 27 J (b) 30 J
(c) 33 J (d) 36 J

75. The potential energy of a spring when stretched through a distance x is 10 J. What is the amount of work done on the same spring to stretch it through an additional distance x?
(a) 10 J (b) 20 J
(c) 30 J (d) 40 J

Direction *Answer the questions from 76-80 on the following case.*

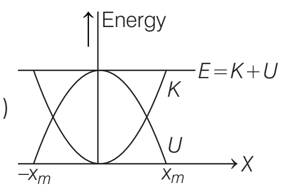
Principle of Conservation of Energy

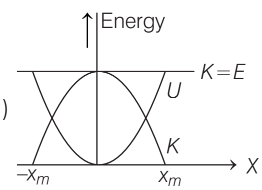
Total energy of an isolated system always remains constant. Since, the universe as a whole may be viewed as an isolated system, total energy of the universe is constant. If one part of the universe loses energy, then other part must gain an equal amount of energy.

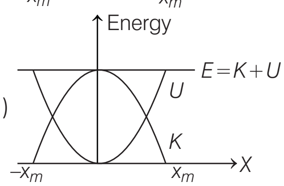
The principle of conservation of energy cannot be proved as such. However, no violation of this principle has been observed.

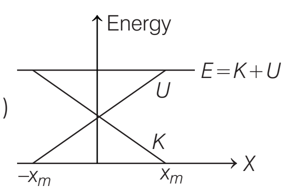
76. When we rub two flint stones together, got them to heat up and to ignite a heap of dry leaves in the form of
(a) chemical energy (b) sound energy
(c) heat energy (d) electrical energy

77. Which graph represents conservation of total mechanical energy?

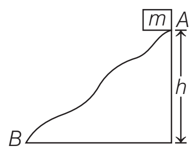
(a)


(b)


(c)


(d)


78. In the given curved road, if particle is released from A, then



(a) kinetic energy at B must be mgh
(b) kinetic energy at B must be zero
(c) kinetic energy at B must be less than mgh
(d) kinetic energy at B must not be equal to potential energy

79. U is the potential energy, K is the kinetic energy and E is the mechanical energy. Which of the following is not possible for a stable system?

(a) $U > E$ (b) $U < E$ (c) $E > K$ (d) $K > E$

80. A body of mass 5 kg is thrown vertically up with a kinetic energy of 490 J. The height at which the kinetic energy of the body becomes half of the original value is

(a) 12.5 m (b) 10
(c) 2.5 m (d) 5 m

ANSWERS

Multiple Choice Questions

1. (c)	2. (c)	3. (b)	4. (c)	5. (b)	6. (d)	7. (d)	8. (b)	9. (c)	10. (d)
11. (a)	12. (d)	13. (a)	14. (a)	15. (c)	16. (b)	17. (c)	18. (a)	19. (a)	20. (d)
21. (c)	22. (c)	23. (b)	24. (a)	25. (b)	26. (c)	27. (b)	28. (a)	29. (c)	30. (d)
31. (d)	32. (c)	33. (b)	34. (a)	35. (b)	36. (b)	37. (b)	38. (c)	39. (c)	40. (a)
41. (b)	42. (a)	43. (d)	44. (c)	45. (b)	46. (b)	47. (d)	48. (b)	49. (d)	50. (b)
51. (c)									

Assertion-Reasoning MCQs

52. (a)	53. (c)	54. (d)	55. (c)	56. (c)	57. (b)	58. (b)	59. (a)	60. (c)

Case Based MCQs

61. (a)	62. (d)	63. (b)	64. (d)	65. (c)	66. (d)	67. (c)	68. (a)	69. (c)	70. (d)
71. (b)	72. (d)	73. (b)	74. (a)	75. (c)	76. (a)	77. (c)	78. (a)	79. (a)	80. (d)

SOLUTIONS

1. Here, work is done by the frictional force on the cycle $= -\ 200 \times 10 = -\ 2000$ J.

As the road is not moving, hence work done by the cycle on the road is zero.

2. Given, $F = 50$ N, $W = 150$ J

and $s = 3$ m

Work done, $W = Fs\cos\theta$

$$150 = 50 \times 3 \times \cos\theta$$

$$\cos\theta = \frac{150}{150} = 1$$

$$\Rightarrow \quad \theta = 0^\circ$$

3. Net force, $\mathbf{F} = 2\hat{\mathbf{i}} + 3\hat{\mathbf{j}} - 2\hat{\mathbf{k}} + 5\hat{\mathbf{i}} - \hat{\mathbf{j}} - 3\hat{\mathbf{k}}$

$$= 7\hat{\mathbf{i}} + 2\hat{\mathbf{j}} - 5\hat{\mathbf{k}}$$

Displacement, $\mathbf{d} = 2\hat{\mathbf{i}} - \hat{\mathbf{j}} + 3\hat{\mathbf{k}} - \hat{\mathbf{i}} - \hat{\mathbf{j}} - \hat{\mathbf{k}}$

$$= \hat{\mathbf{i}} - 2\hat{\mathbf{j}} + 2\hat{\mathbf{k}}$$

Work done $= \mathbf{F}\cdot\mathbf{d} = (7\hat{\mathbf{i}} + 2\hat{\mathbf{j}} - 5\hat{\mathbf{k}})\cdot(\hat{\mathbf{i}} - 2\hat{\mathbf{j}} + 2\hat{\mathbf{k}})$

$$= 7 - 4 - 10 = -7 \text{ units}$$

4. Work done by a variable force on the particle,

$$W = \int \mathbf{F}\cdot d\mathbf{r} = \int \mathbf{F}\cdot(dx\hat{\mathbf{i}} + dy\hat{\mathbf{j}})$$

$\therefore$ In two dimension, $d\mathbf{r} = dx\hat{\mathbf{i}} + dy\hat{\mathbf{j}}$

and it is given $\mathbf{F} = -x\hat{\mathbf{i}} + y\hat{\mathbf{j}}$

$$\therefore \quad W = \int (-x\hat{\mathbf{i}} + y\hat{\mathbf{j}}) \cdot (dx\hat{\mathbf{i}} + dy\hat{\mathbf{j}})$$
$$= \int -x\,dx + y\,dy$$
$$= \int -x\,dx + \int y\,dy$$

As particle is displaced from $A(1, 0)$ to $B(0, 1)$, so x varies from 1 to 0 and y varies from 0 to 1.

So, with limits, work will be

$$W = \int_1^0 -x\,dx + \int_0^1 y\,dy$$
$$= \left[\frac{-x^2}{2}\right]_1^0 + \left[\frac{y^2}{2}\right]_0^1$$
$$= \frac{1}{2}[0 - (-1)^2 + (1)^2 - 0] = 1\,\text{J}$$

5. Work done = Area under F-s curve

$$W_{AB} = W_{12} + W_{23} + W_{34} + W_{45}$$
$$= \text{Area under } AP + \text{Area under } PQ + \text{Area under } QR - \text{Area above } RB$$
$$= 10 \times 1 + \frac{1}{2}(10 + 15) \times 1 + \frac{1}{2} \times 1 \times 15 - \frac{1}{2} \times 1 \times 15$$
$$= 10 + 12.5 = 22.5\,\text{J}$$

6. Work done in stretching a string to obtain an extension l,

$$W_1 = \frac{1}{2}kl^2$$

Similarly, work done in stretching a string to obtain an extension l_1 is

$$W_2 = \frac{1}{2}kl_1^2$$

$\therefore$ Work done in second case,

$$W = W_2 - W_1 = \frac{1}{2}k(l_1^2 - l^2)$$

7. The weight of hanging part $\left(\frac{l}{3}\right)$ of chain is $\left(\frac{1}{3}mg\right)$. This weight acts at the centre of gravity of the hanging part, which is at a distance of $\left(\frac{l}{6}\right)$ from the table.

Hence, work required to pull hanging part,

$$W = \text{force} \times \text{displacement}$$
$$\therefore \quad W = \frac{mg}{3} \times \frac{l}{6} = \frac{mgl}{18}$$

8. Gravitational force is a conservative force and work done by or against the force in moving a body depends only on the initial and final positions of the body and not on the nature of path followed by it.

So, $W_1 = W_2 = W_3$

9. As we know that, KE $= \frac{1}{2}mv^2$

So, kinetic energy is directly proportional to the square of velocity.

$$K \propto v^2$$

As this equation resembles equation of parabola as m is constant, hence option (c) represents a parabola.

10. The kinetic energy K and momentum p of a body are related as

$K = \frac{p^2}{2m}$, where m is the mass of the body

Here, $p = 6$ N-s and $m = 4$ kg

$$K = \frac{(6)^2}{2 \times 4} = 4.5\,\text{J}$$

11. The kinetic energy of the particle is

$$K = \frac{1}{2}mv^2$$

As, momentum, $p = mv$

or $\quad p^2 = m^2v^2$

or $\quad v^2 = \frac{p^2}{m^2}$

$$\therefore \quad K = \frac{1}{2}m\left(\frac{p^2}{m^2}\right) = \frac{p^2}{2m}$$

12. Kinetic energy of a body, $K = \frac{p^2}{2m}$

where, p is the momentum and m is the mass of the body.

As, $\quad p_1 = p_2 \quad$ (given)

$$\therefore \quad \frac{K_1}{K_2} = \frac{m_2}{m_1} = \frac{5}{4}$$

13. Kinetic energy of a body, $K = \frac{p^2}{2m}$

or $\quad p = \sqrt{2mK}$

Since, $K_H = K_L$ (given)
where, subscripts H and L represents for heavy and light bodies.

$$\therefore \quad \frac{p_H}{p_L} = \sqrt{\frac{m_H}{m_L}}$$

So, $m_H > m_L$
and $p_H > p_L$

14. Given, mass, $m = 5$ kg
Radius, $R = 1$ m
Revolution per minute, $\omega = 300$ rev/min

$$= (300 \times 2\pi) \text{ rad/min}$$
$$= \frac{300 \times 2 \times \pi}{60} \text{ rad/s} = 10\pi \text{ rad/s}$$

Linear speed, $v = \omega R = 10\pi \times 1$
$= 10\pi$ m/s

$$\therefore \quad \text{KE} = \frac{1}{2} mv^2$$
$$= \frac{1}{2} \times 5 \times (10\pi)^2$$
$$= 100\pi^2 \times 5 \times \frac{1}{2}$$
$$= 250\,\pi^2 \text{ J}$$

15. Applying work-energy theorem on both moving objects,

$$\frac{1}{2} m_1 v_1^2 = Fx_1$$

and $\frac{1}{2} m_2 v_2^2 = Fx_2$

Since, both moving objects have same kinetic energy,

i.e. $\frac{1}{2} m_1 v_1^2 = \frac{1}{2} m_2 v_2^2 \Rightarrow Fx_1 = Fx_2$

$\Rightarrow \quad x_1 = x_2$

Therefore, both the objects will come to rest at the same distance.

16. Work done in $\mathbf{F}$ is given by $\Delta W = \mathbf{F} \cdot \mathbf{d}$

By substituting given values, we get

$\Rightarrow \quad \Delta W = (3\hat{\mathbf{i}} - 12\hat{\mathbf{j}}) \cdot (4\hat{\mathbf{i}})$

$\Rightarrow \quad \Delta W = 12$ J ... (i)

Now, using work-energy theorem, we get work done, ΔW = change in kinetic energy, ΔK

or $\quad \Delta W = K_2 - K_1$ ... (ii)

Comparing Eqs. (i) and (ii), we get

$$K_2 - K_1 = 12 \text{ J} \text{ or } K_2 = K_1 + 12 \text{ J}$$

Given, initial kinetic energy, $K_1 = 3$ J

$\therefore$ Final kinetic energy, $K_2 = 3 \text{ J} + 12 \text{ J} = 15$ J

17. $\therefore$ Work done on the particle
= Area under the curve ABC

W = Area of square $ABFO$ + Area of ΔBCD + Area of rectangle $BDEF$

$$= 2 \times 2 + \frac{1}{2} \times 1 \times 1 + 2 \times 1 = 6.5 \text{ J}$$

Now, from work-energy theorem,

$$\Delta W = K_f - K_i$$

$\Rightarrow \quad K_f = \Delta W = 6.5$ J $\quad (\because K_i = 0)$

18. Potential energy of brick above the earth's surface is given by

$$U = mgh$$

i.e. $\quad U \propto h$

Hence, when a brick is lifted above the surface of the earth, then its potential energy increases.

19. The potential energy of the spring is

$$E = \frac{1}{2} ky^2 \quad \text{...(i)}$$

Now, it is stretched from y to $2y$, so its potential energy becomes

$$E' = \frac{1}{2} k(2y)^2$$
$$= 2ky^2 = 4E \quad \text{[using Eq. (i)]}$$

$\therefore$ The increase in its potential energy is

$$\Delta E = E' - E = 4E - E = 3E$$

20. Energy received by the boys from bread
$= 5000 \text{ cal} = 5000 \times 4.2$
$= 21 \times 10^3$ J

According to law of conservation of mechanical energy,

$$mgh = \frac{28}{100} \times 21 \times 10^3$$

$$\therefore \quad h = \frac{28 \times 21 \times 10^3}{100 \times 9.8 \times 60} = 10 \text{ m}$$

21. As the body is falling freely under gravity, the potential energy decreases and kinetic energy increases but total mechanical energy (PE + KE) of the body and earth system will be constant as external force on the system is zero.

22. At a height $\frac{4}{5}h$,

Potential energy $= mg \times \frac{4}{5}h = \frac{4}{5}\, mgh$

Total energy = mgh

$\therefore$ Kinetic energy at that height

$$= mgh - \frac{4}{5}mgh = \frac{1}{5}\, mgh$$

$\therefore$ At a height $\frac{4}{5}h$, the ratio of

$$\frac{\text{KE}}{\text{PE}} = \frac{\frac{1}{5}mgh}{\frac{4}{5}mgh} = \frac{1}{4}$$

23. The work done on the spring is stored as the PE of the body and is given by

$$U = \int_{x_1}^{x_2} F_{\text{ext}}\, dx$$

or $$U = \int_{x_1}^{x_2} kx\, dx$$

$$= \frac{1}{2}k(x_2^2 - x_1^2)$$

$$= \frac{800}{2}[(0.15)^2 - (0.05)^2]$$

$$= 400\ (0.2 \times 0.1) = 8\ \text{J}$$

24. According to work-energy theorem,
loss in kinetic energy = work done against friction + potential energy of spring

$$\frac{1}{2}mv^2 = f \cdot x + \frac{1}{2}kx^2$$

$\Rightarrow$ $\frac{1}{2} \times 2\,(4)^4 = 15\,x + \frac{1}{2} \times 10000\ x^2$

$\Rightarrow$ $5000\ x^2 + 15x - 16 = 0$

$\therefore$ $x = 0.055\ \text{m} = 5.5\ \text{cm}$

25. Net work done in sliding a body up to a height h on an inclined plane
= Work done against the gravitational force + Work done against the frictional force

$\Rightarrow$ $W = W_g + W_f$ ...(i)

But $W = 300$ J

Given, $m = 2$ kg and $h = 10$ m

$$W_g = mgh = 2 \times 10 \times 10 = 200\ \text{J}$$

Putting these values in Eq. (i), we get

$$300 = 200 + W_f$$

$\Rightarrow$ $W_f = 300 - 200 = 100$ J

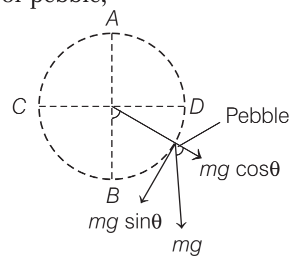
26. According to the law of conservation of energy, $U_i + K_i = U_f + K_f$ ...(i)

So, by putting the values in Eq. (i),

$$3U_0 + 0 = 2U_0 + \frac{1}{2}mv^2$$

$\Rightarrow$ $v = \sqrt{\frac{2U_0}{m}}$

27. FBD of pebble,



$\therefore$ $T - mg\cos\theta = \frac{mv^2}{l} \Rightarrow T = mg\cos\theta + \frac{mv^2}{l}$

Tension is maximum, when $\cos\theta = 1$ and velocity is maximum. Both conditions are satisfied at $\theta = 0°$, i.e. at lowest point B.

28. At top point, the tension (T_H) in string becomes zero, so velocity of the particle is

$$v_H = \sqrt{gr}$$

At the bottom, the velocity of the particle is

$$v_L = \sqrt{5gr}$$

Therefore, the ratio of kinetic energies at bottom and top is

$$\frac{K_L}{K_H} = \frac{\frac{1}{2}mv_L^2}{\frac{1}{2}mv_H^2} = \left(\frac{v_L}{v_H}\right)^2$$

$$= \frac{5\,gr}{gr} = \frac{5}{1} = 5:1$$

Hence, the ratio of kinetic energies is 5 : 1.

29. Given, $W = 600$ J

and $t = 2$ min $= 2 \times 60 = 120$ s

$\therefore$ Power, $P = \frac{W}{t} = \frac{600}{120} = 5$ W

30. By definition, $P = \frac{dW}{dt}$

$\because$ Work done = Kinetic energy

$\Rightarrow$ $P = \frac{dW}{dt} = \frac{d(\text{KE})}{dt} = \text{constant}$

31. Power, $P = \frac{W}{t}$

Since, K_i = initial KE = 0

and K_f = final KE = $\frac{1}{2}mv^2$

From work-energy theorem,

work done = change in KE

$$\therefore \quad P = \frac{K_f - K_i}{t} = \frac{\frac{1}{2}mv^2 - 0}{t}$$

$$\Rightarrow \quad P = \frac{mv^2}{2t}$$

32. At maximum load, force provided by motor to pull the lift,

$$F = \text{weight carried} + \text{friction} = mg + f$$
$$= (2000 \times 10) + 4000 = 24000 \text{ N}$$

Power delivered by motor at speed v of load, $P = F \times v$

$$\Rightarrow \quad v = \frac{P}{F} = \frac{60 \times 746}{24000} = 1.865 = 1.9 \text{ ms}^{-1}$$

33. As, $P_0 = Fv = \left(m\frac{dv}{dt}\right)v = mv\frac{dv}{dt}$

$\Rightarrow \quad P_0 \cdot dt = mvdv$

Integrating both sides, we get

$$\int_0 P_0 \, dt = \int mv \, dv$$

$$\Rightarrow \quad P_0 t = \frac{mv^2}{2}$$

$$\Rightarrow \quad v^2 = \frac{2P_0 t}{m}$$

$$\Rightarrow \quad v \propto t^{1/2}$$

34. From Newton's second law, $F = \frac{dp}{dt}$

If $F = 0$, then $\frac{dp}{dt} = 0$

$\Rightarrow \quad p$ = constant

Thus, if total external force acting on the system is zero during collision, then the linear momentum of the system remains conserved.

35. As, we know in a elastical collision of two identical bodies, i.e. $m_A = m_B$, the particles mutually exchange their velocities.

So, $(v_i)_A = 0.5 \text{ ms}^{-1}$ and $(v_i)_B = -0.3 \text{ ms}^{-1}$.

After collision,

$$(v_f)_A = -0.3 \text{ ms}^{-1} \text{ and } (v_f)_B = 0.5 \text{ ms}^{-1}.$$

36. From conservation of momentum,

$$m_1\mathbf{v}_1 + m_2\mathbf{v}_2 = (m_1 + m_2)\mathbf{v}$$
$$1 \times (3\hat{\mathbf{i}} - 2\hat{\mathbf{j}}) + 2 \times (4\hat{\mathbf{j}} - 6\hat{\mathbf{k}}) = (1 + 2)\ \mathbf{v}$$
$$\Rightarrow \quad 3\hat{\mathbf{i}} + 6\hat{\mathbf{j}} - 12\hat{\mathbf{k}} = 3\mathbf{v}$$
$$\Rightarrow \quad \mathbf{v} = \hat{\mathbf{i}} + 2\hat{\mathbf{j}} - 4\hat{\mathbf{k}}$$
$$\therefore \text{ Velocity,} \quad v = |\mathbf{v}| = \sqrt{1 + 4 + 16} = 4.6 \text{ ms}^{-1}$$

37. Given, mass, $m_1 = m_2 = m$ and velocity, $v = v_1$

For elastic collision,

$$v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)v_2 + \frac{2m_1v_1}{m_1 + m_2}$$

After putting given values, we will get

$$v_2 = \frac{2m_1v_1}{2m_1} \Rightarrow v_2 = v_1$$

38. When we are considering the two bodies as system, the total external force on the system will be zero.

Hence, total linear momentum of the system remain conserved.

39. Speed of objects = u ms^{-1}

Since, both objects collide with 90°.

According to the law of conservation of momentum,

Total moment before collision

= Total momentum after collision

$$|mu\hat{\mathbf{i}} + mu\hat{\mathbf{j}}| = p_f$$

$$\sqrt{m^2u^2 + m^2u^2} = p_f \Rightarrow p_f = \sqrt{2}\ mu$$

40. Given, mass of body, $m_1 = 5 \times 10^3$ kg

and mass of another body

$$m_2 = 15 \times 10^3 \text{ kg}$$

Velocity, $v_1 = 2 \text{ ms}^{-1}$

For perfectly inelastic collision ($e = 0$),

Loss in kinetic energy of system,

$$\Delta E_K = \frac{1}{2}\frac{m_1m_2}{m_1 + m_2} \times v_1^2$$
$$= \frac{1}{2} \times \frac{5 \times 10^3 \times 15 \times 10^3}{5 \times 10^3 + 15 \times 10^3} \times 2^2$$
$$= 7.5 \times 10^3 \text{ J} = 7.5 \text{ kJ}$$

41. Kinetic energy of the body,

$$K = \frac{p^2}{2m}$$

Since, the mass remains constant, so $K \propto p^2$.

$\therefore \quad \dfrac{K_2}{K_1} = \dfrac{p_2^2}{p_1^2} = \left[\dfrac{150}{100}\right]^2 = \dfrac{9}{4}$

Thus, $\left(\dfrac{K_2}{K_1} - 1\right) \times 100 = \left(\dfrac{9}{4} - 1\right) \times 100$

$= 125\%$

42. As, work done = force × displacement

As, there is no displacement produced in the wall, so work done by the ball on the wall is zero.

Alternative Method As, there is no change in kinetic energy of the ball, so according to work-energy theorem, work done should be zero.

43. According to the law of conservation of energy,

$$\frac{1}{2}mv^2 = \frac{1}{2}\left(\frac{1}{2}mv^2\right) + mgh$$

$\Rightarrow \quad 490 = 245 + 5 \times 9.8 \times h,$

$$h = \frac{245}{49} = 5\,\text{m}$$

44. Given, $t_1 = 2$ s, $t_2 = 4$ s

and $h_1 = h_2 = h$

As, $P_A = \dfrac{mgh_1}{t_1}$ and $P_B = \dfrac{mgh_2}{t_2}$ ...(i)

$\Rightarrow P_A : P_B = \dfrac{mgh_1/t_1}{mgh_2/t_2} = \left(\dfrac{h_1}{h_1}\right)\left(\dfrac{t_2}{t_1}\right) = \dfrac{t_2}{t_1} = \dfrac{4}{2} = \dfrac{2}{1}$

$\Rightarrow \quad P_A : P_B = 2:1$

45. Given, $k \propto t \Rightarrow \dfrac{dk}{dt} = \text{constant}$

$\Rightarrow \quad K \propto t$

$\dfrac{1}{2}mv^2 \propto t \quad \Rightarrow \quad v \propto \sqrt{t}$

Also, $P = Fv = \dfrac{dK}{dt} = \text{constant}$

$\Rightarrow \quad F \propto \dfrac{1}{v} \quad \Rightarrow \quad F \propto \dfrac{1}{\sqrt{t}}$

$\Rightarrow \quad F \propto t^{-1/2}$

46. When a man of mass m climbs up the staircase of height L, work done by the gravitational force on the man is mgl, work done by internal muscular forces will be mgL as the change in kinetic energy is almost zero.

Hence, total work done $= -mgL + mgL = 0$.

As the point of application of the contact forces does not move, hence work done by reaction forces will be zero.

47. If the work done or the kinetic energy depend on other factors such as the velocity or the particular path taken by the object, the force would be called non-conservative.

Thus, the statements given in options (a) and (b) are correct, rest is incorrect.

48. In elastic collision, the conservation of mechanical energy consider only conservative force while conservation of energy consider both conservative and non-conservative force.

Mass converted into energy in nuclear reaction is called nuclear energy.

Thus, the statement given in option (b) is correct, rest are incorrect.

49. Whenever there is a collision between two bodies, the total momentum of the bodies remains conserved. If after the collision of two bodies, the total kinetic energy of the bodies remains the same as it was before collision, then it a perfectly elastic collision.

A ball bearing striking another ball bearing is an example of elastic collision. If two bodies strick together after the collision, then the collision is said to be perfectly inelastic collision.

Options (a), (b) and (c) are examples of perfectly inelastic collisions.

50. Work done by an agent is given by

$$W = \mathbf{F} \cdot \mathbf{s} = Fs\cos\theta$$

where, F is the applied force, s is the displacement and θ is the smaller angle between F and s.

A. If $\theta < 90°$, i.e. acute angle, then work done is positive, as in case of coolie lifting luggage.

B. If $\theta = 90°$, i.e. right angle, then work done is zero, as in case of satellite rotation around the earth.

C. If $\theta > 90°$, i.e. obtuse angle, work done is negative, as in case of friction.

Hence, A → r, B → q and C → p.

51. As, power, $P \propto t$

So, $W = \int P dt = \int \alpha t \, dt$

or $W \propto t^2$

Since, work done is equal to change is KE.

Hence, $v^2 \propto t^2$ or $v \propto t$

Further, $v = \dfrac{ds}{dt}$

$\therefore \quad \dfrac{ds}{dt} \propto t$ or $ds \propto t \, dt$

or $s \propto t^2$ (by integration)

Hence, A $\rightarrow$ p, B $\rightarrow$ q and C $\rightarrow$ q.

52. According to work-energy theorem, work done by a body is equal to change in kinetic energy of the body.

$$\Rightarrow \quad W = \Delta \text{KE} = \frac{1}{2}mv^2 \quad \ldots\text{(i)}$$

But, W = stopping force × stopping distance

$$W = F \cdot d \quad \ldots\text{(ii)}$$

From Eqs. (i) and (ii), we have

Stopping distance (d)

$$= \frac{\text{Kinetic energy}\left(\frac{1}{2}mv^2\right)}{\text{Stopping force}\,(F)}$$

Therefore, both A and R are true and R is the correct explanation of A.

53. As we know, $k = \dfrac{F}{l} \Rightarrow k \propto \dfrac{1}{l}$

$$\Rightarrow \quad \frac{k_2}{k_1} = \frac{l_1}{l_2} = \frac{1}{2}$$

$$k_1 = 2k, \; k_2 = k$$

In series, $\dfrac{1}{k'} = \dfrac{1}{k_1} + \dfrac{1}{k_2} = \dfrac{1}{2k} + \dfrac{1}{k} = \dfrac{3}{2k}$

$\because \quad k' = \dfrac{2k}{3}$

Therefore, A is true but R is false.

54. According to the law of conservation of mechanical energy, for conservative forces, the sum of kinetic energy and potential energy remains constant and throughout the motion it is independent of time.

This is the law of conservation of mechanical energy, i.e. KE + PE = total energy = constant.

Therefore, A is false and R is also false.

55. Mechanical energy consists of both PE and KE. In the given cases, some of the mechanical energy is converted into heat energy and it is more in the case when inclination is less due to increased (as θ decreases, value of $\cos\theta$ will increases) friction force on an inclined plane.

$$f_r = \mu mg \cos\theta$$

The coefficient of friction does not depend on the angle of inclination of the plane. It depends only on the nature of surfaces in contact.

Therefore, A is true but R is false.

56. At the lowest point of a vertical circle, the minimum velocity at bottom,

$$v_{\min} = \sqrt{5gr}$$

Velocity at highest point, $v = \sqrt{gr}$

Therefore, A is true but R is false.

57. Power $= \dfrac{\text{Work done (or energy)}}{\text{Time}}$

$\Rightarrow$ Work done = Power × Time

$$W = P \times t$$

If $P = 1$ kilowatt, $t = 1$ hour, then

$W = 1$ kilowatt $\times 1$ hour

$= 1$ kilowatt-hour

$= 10^3$ watt $\times 60 \times 60$ s

$= 3.6 \times 10^6$ J

Therefore, both A and R are true but R is not the correct explanation of A.

58. In elastic collision, total energy, kinetic energy and momentum remain conserved, therefore no loss in energy occurs in elastic collision.

Therefore, both A and R are true but R is not the correct explanation of A.

59. As momentum, $p = mv$ or $p \propto v$, i.e.

momentum is directly proportional to its velocity, so the momentum is greater in a quicker collision between two bodies than in slower one.

Hence, due to greater momentum quicker collision between two bodies will be more violent even initial and final velocities are identical.

Therefore, both A and R are true and R is the correct explanation of A.

60. If two particles are initially moving in the same direction, then their resultant momentum will not be zero. Therefore, their resultant momentum cannot be zero after a completely inelastic collision.

As, kinetic energy is directly proportional to the square of the momentum, hence kinetic energy cannot be zero. This implies, not all the energy in inelastic collision is lost.

Therefore, A is true but R is false.

61. When earth is moving around the sun in a circular orbit, then gravitational attraction on earth due to the sun provides required centripetal force, which is in radially inward direction, i. e. in a direction perpendicular to the direction of motion of the earth in its circular orbit around the sun.

As a result, the work done on the earth by the force will be zero. i.e. $W = Fd\cos 90° = 0$.

62. Work done by weight-lifter is zero, because there is no displacement.

In a locomotive, work done is zero because force due to gravity and displacement are mutually perpendicular to each other.

In case of a person holding a suitcase on his head and standing at a bus terminal, work done is zero because there is no displacement.

Hence, options (a), (b) and (c) are correct.

63. Given, $\mathbf{F} = (3\hat{\mathbf{i}} + 4\hat{\mathbf{j}} - 5\hat{\mathbf{k}})$ unit

and $\mathbf{d} = (5\hat{\mathbf{i}} + 4\hat{\mathbf{j}} + 3\hat{\mathbf{k}})$ unit

$$\therefore \quad \mathbf{F}\cdot\mathbf{d} = F_x d_x + F_y d_y + F_z d_z = 3(5) + 4(4) + (-5)(3) = 16 \text{ units}$$

Now, $\mathbf{F}\cdot\mathbf{F} = F^2 = F_x^2 + F_y^2 + F_z^2 = 9 + 16 + 25 = 50$ units

$\Rightarrow \quad F = \sqrt{50}$ units

and $\mathbf{d}\cdot\mathbf{d} = d^2 = d_x^2 + d_y^2 + d_z^2 = 25 + 16 + 9 = 50$ units

$\Rightarrow \quad d = \sqrt{50}$ units

$$\therefore \quad \cos\theta = \frac{16}{\sqrt{50}\,\sqrt{50}} = \frac{16}{50} = 0.32 \qquad \left(\because \cos\theta = \frac{\mathbf{F}\cdot\mathbf{d}}{Fd}\right)$$

$\Rightarrow \quad \theta = \cos^{-1}(0.32)$

64. The work done in displacing an object by applying force F is given by

$$W = \mathbf{F}\cdot\mathbf{s} = Fs\cos\theta$$

So, work done will be zero, when

(i) either applied force F or displacement s is zero.

(ii) the force and displacement are mutually perpendicular to each other. i.e. $\theta = 90°$.

So, all statements are correct.

65. Force between two protons is same as that of between proton and a positron.

As positron is much lighter than proton, it moves away through much larger distance compared to proton.

We know that, work done = force × distance. As, forces are same in case of proton and positron but distance moved by positron is larger, hence work done will be more in case of positron.

66. When the earth is closest to the sun, speed of the earth is maximum, hence KE is maximum. When the earth is farthest from the sun, speed is minimum, hence KE is minimum but never zero and negative.

This variation is correctly represented by option (d).

67. $F = \dfrac{K}{v}$ (given)

$$m\frac{dv}{dt} = \frac{K}{v}$$

$$\Rightarrow \quad \int mv\,dv = \int K\,dt$$

$$\Rightarrow \quad m\frac{v^2}{2} = Kt$$

$$\Rightarrow \quad \text{KE} \propto t$$

68. The kinetic energy of an air molecule is

$$= \frac{10^{-21}\text{ J}}{1.6\times10^{-19}\text{ J/eV}} \simeq 0.0062\text{ eV}$$

This is the same as 6.2 meV.

69. As we know that, linear momentum, p

$$= \sqrt{2mK} \qquad \left(\because K = \frac{p^2}{2m}\right)$$

For same kinetic energy, $p \propto \sqrt{m}$

$$\frac{p_1}{p_2} = \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{1}{4}} = \frac{1}{2} = 1:2$$

70. Initial velocity $= 10 \text{ ms}^{-1}$

Final velocity $= 20 \text{ ms}^{-1}$

Initial KE $= \frac{1}{2} \times 10 \times 10 \times 10 = 5 \times 10^2$ J

Final KE $= \frac{1}{2} \times 10 \times 20 \times 20 = 20 \times 10^2$ J

% increase $= \frac{(20-5) \times 10^2}{5 \times 10^2} \times 100 = 300\%$

71. Potential energy of a body increases when work is done against a conservative force, e.g. if we raise the height of an object, its potential energy increases because work is done against gravitational force which is a conservative force.

72. The zero of the potential energy is arbitrary. It is set according to convenience. For the spring force, we took $U(x) = 0$, at $x = 0$, i.e. the unstretched spring had zero potential energy.

For the constant gravitational force mg, we took $U = 0$ on the earth's surface.

Also, for the force due to the universal law of gravitation, the zero is best defined at an infinite distance from the gravitational source.

73. $F = k_1 x_1$, $F = k_2 x_2$

$$k_1 x_1 = k_2 x_2 \Rightarrow \frac{k_1}{k_2} = \frac{x_2}{x_1}$$

$$\frac{\text{PE (1)}}{\text{PE (2)}} = \frac{k_1 \, x_1^2}{k_2 \, x_2^2}$$

$$= \frac{k_1}{k_2} \times \left(\frac{k_2}{k_1}\right)^2 = \frac{k_2}{k_1} = \frac{3}{2}$$

74. PE of spring $= \frac{1}{2} kx^2 \Rightarrow \text{PE} \propto x^2$

$\therefore$ $$\text{PE} = 15 \times \frac{(4)^2}{(3)^2} = 15 \times \frac{16}{9} \simeq 27 \text{ J}$$

75. Potential energy of the spring when stretched through a distance x,

$$U = \frac{1}{2} kx^2 = 10 \text{ J}$$

When x becomes $2x$, the potential energy will be

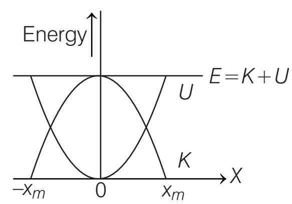
$$U' = \frac{1}{2} k(2x)^2 = 4 \times \frac{1}{2} kx^2$$

$$= 4 \times 10 = 40 \text{ J}$$

$\therefore$ Work done $= U' - U = 40 - 10 = 30$ J

76. One of the greatest technical achievements of human kind occurred when we discovered how to ignite and control fire . We learnt to rub two flint stones together (mechanical energy), got them to heat up and to ignite a heap of dry leaves (chemical energy), which then provided sustained warmth.

77. Parabolic plots of the potential energy U and kinetic energy K of a block attached to a spring obey in a Hooke's law. The two plots are complementary, one decreasing as the other increases. The total mechanical energy $E = K + U$ remains constant.



78. In a conservative field loss of PE or gain of KE depends only on initial and final point and not on path covered, i.e. at B, KE $= mgh$.

79. We know that, PE + KE = Mechanical energy

$$U + K = E$$

$$\Rightarrow \quad U = E - K$$

Now, K can never be negative, so

$$U < E$$

$$K = E - U$$

Now, U can be negative, so $K > E$ is possible.

80. According to the law of conservation of energy,

$$\frac{1}{2} mu^2 = \frac{1}{2}\left(\frac{1}{2} mu^2\right) + mgh$$

$$\Rightarrow \quad 490 = 245 + 5 \times 9.8 \times h$$

$$h = \frac{245}{49} = 5 \text{ m}$$

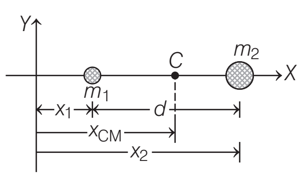
07

System of Particles and Rotational Motion

Quick Revision

1. **Rigid Body** A body is said to be a rigid body, when it has a perfectly definite shape and size. e.g. A wheel can be considered as rigid body by ignoring a little change in its shape.
2. **Rotational Motion (Fixed Axis of Rotation)** In pure rotational motion, every particle of the rigid body moves in circles of different radii about a fixed line, which is known as **axis of rotation**.

   e.g. A potter's wheel, a merry-go-round, etc.
3. **Centre of Mass** A point at which the entire mass of the body or system of bodies is supposed to be concentrated is known as the centre of mass.
   - **For a System of two Particles** The centre of mass of the system at a point which is at distance x_{CM} from origin is given by



$$x_{CM} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$$

   - **For a System of n-Particles** Suppose a system having masses $m_1, m_2, m_3, \ldots, m_n$ occupying x-coordinates $x_1, x_2, x_3, \ldots, x_n$, then x_{CM} is x-coordinates of centre of mass of system is expressed as,

$$x_{CM} = \frac{m_1x_1 + m_2x_2 + m_3x_3 + \cdots + m_nx_n}{m_1 + m_2 + m_3 + \cdots + m_n}$$

Centre of mass, $x_{CM} = \dfrac{\sum_{i=1}^{n} m_i x_i}{\Sigma m_i}$

   - If particles are distributed in three-dimensional space, then the centre of mass has 3-coordinates, which are

$$x_{CM} = \frac{1}{M}\sum_{i=1}^{n} m_i\, x_i,\ y_{CM} = \frac{1}{M}\sum_{i=1}^{n} m_i y_i$$

$$z_{CM} = \frac{1}{M}\sum_{i=1}^{n} m_i z_i$$

where, $M = m_1 + m_2 + m_3 + \ldots = \sum_{i=1}^{n} m_i$ is the total mass of the system. The index i runs from 1 to n, m_i is the mass of the ith particle and the position of the ith particle is given by (x_i, y_i, z_i).

   - **Relation between position vectors of particles and centre of mass**,

$$\mathbf{R} = \frac{\sum_{i=1}^{n} m_i \mathbf{r}_i}{m}$$

where, $\mathbf{r}_i = (x_i\hat{\mathbf{i}} + y_i\hat{\mathbf{j}} + z_i\hat{\mathbf{k}})$ is the position vector of the ith particle and $\mathbf{R} = (x\hat{\mathbf{i}} + y\hat{\mathbf{j}} + z\hat{\mathbf{k}})$ is the position vector of the centre of mass.

4. **Centre of Mass of Rigid Continuous Bodies** For a real body which is a continuous distribution of matter, point masses are differential mass elements dm and centre of mass is given as

$$x_{CM} = \frac{1}{M}\int x\, dm, \quad y_{CM} = \frac{1}{M}\int y\, dm$$

and $$z_{CM} = \frac{1}{M}\int z dm$$

where, M is total mass of that real body.

If we choose the origin of coordinates axes at centre of mass, then

$$\int x\, dm = \int y dm = \int z dm = 0$$

5. **Motion of Centre of Mass**
 - **Velocity** about centre of mass,

$$\mathbf{v}_{CM} = \frac{\sum_{i=1}^{n} m_i \mathbf{v}_i}{M}$$

where, $\mathbf{v} = \frac{d\mathbf{r}}{dt}$, i.e. rate of change of position vector is velocity.

 - **Acceleration** about centre of mass,

$$\mathbf{a}_{CM} = \frac{\sum_{i=1}^{n} m_i \mathbf{a}_i}{M},$$

But $m_i \mathbf{a}_i$ is the resultant force on the ith particle, so

$$M\mathbf{a}_{CM} = \mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3 + \dots + \mathbf{F}_n$$
$$M\mathbf{a}_{CM} = \mathbf{F}_{net}$$

6. **Linear Momentum of a System of a Particle** The total momentum of a system of particles is equal to the product of the total mass and velocity of its centre of mass.

$\therefore$ Total linear momentum, $\mathbf{p} = M\mathbf{v}_{CM}$

7. **Moment of Force (Torque)** Torque is also known as moment of force. We can define the torque for a particle about a point as the vector product of position vector of the point, where the force acts and with the force itself. Let us consider a particle P and force $\mathbf{F}$ acting on it.

Torque, $\tau = \mathbf{r} \times \mathbf{F}$

The magnitude of torque $|\tau|$ is

$$= Fr \sin\theta$$
$$\therefore \quad \tau = Fr_\perp$$

Here, $r_\perp$ is the perpendicular distance of the line of action of $\mathbf{F}$ from the origin.

8. **Angular Momentum of a Particle** The angular momentum of a particle of mass m moving with velocity $\mathbf{v}$ (having a linear momentum, $\mathbf{p} = m\mathbf{v}$) about a point O is defined by the following vector product,

$\mathbf{L} = \mathbf{r} \times \mathbf{p}$

or Angular momentum, $\mathbf{L} = m(\mathbf{r} \times \mathbf{v})$

Angular momentum will be zero $(L = 0)$, if

$p = 0$ or $r = 0$ or $\theta = 0°, 180°$

It is a vector quantity and its direction could be found out with the help of cross-product.

The SI unit of angular momentum is kg-m^{2}s^{-1}.

9. **Relation between Torque (τ) and Angular Momentum (L)**

$$\frac{d\mathbf{L}}{dt} = \tau$$

Above equation gives Newton's second law of motion in angular form, i.e. the rate of change of angular momentum is equal to the torque applied.

10. **Couple** A pair of equal and opposite forces with parallel lines of action are known as a couple. It produces rotation without translation.

11. **Principle of Moments** When an object is in rotational equilibrium, then algebraic sum of all torques acting on it is zero. Clockwise torques are taken as negative and anti-clockwise torques are taken as positive.

12. **Centre of Gravity** If a body is supported on a point such that total gravitational torque about this point is zero, then this point is called centre of gravity of the body.

13. **Moment of Inertia** For a rotating body, its moment of inertia is $I = \sum_{i=1}^{n} m_i r_i^2$

or Moment of inertia, $I = mR^2$

The SI unit of moment of inertia is kg-m^2 and its dimensional formula is $[ML^2]$.

14. **Relation between Angular Momentum and Moment of Inertia**

For a rigid body (about an fixed axis),

L = sum of angular momenta of all particles

$= (m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + \ldots\ldots)\,\omega$

$L = I\omega$

where, I = moment of inertia and ω = angular velocity of rigid body.

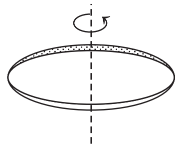
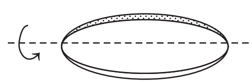
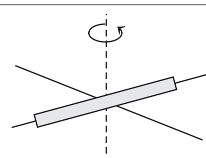
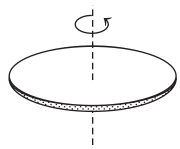
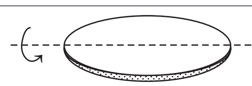
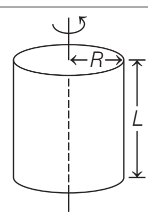
15. **Radius of Gyration** The radius of gyration of a body about an axis may be defined as the distance from the axis of a mass point whose mass is equal to the mass of whole body and moment of inertia is equal to the moment of inertia of the body about the axis. It is given as, $K = \sqrt{\dfrac{I}{M}}$

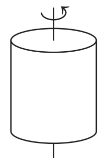
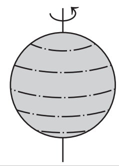
where, K is radius of gyration of the body.

For rotating body, $K = \sqrt{\dfrac{r_1^2 + r_2^2 + \cdots + r_n^2}{n}}$

Hence, radius of gyration of a rotating body about a given axis is equal to root mean square distance of constituent particles from the given axis.

16. **Moment of Inertia in Some Standard Cases**

Body	**Axis of Rotation**	**Figure**	**Moment of Inertia**	***K***	***K*²/*R*²**
Thin circular ring, radius R	About an axis passing through CG and perpendicular to its plane		MR^2	R	1
Thin circular ring, radius R	About its diameter		$\frac{1}{2}MR^2$	$\frac{R}{\sqrt{2}}$	$\frac{1}{2}$
Thin rod, length L	Perpendicular to rod at mid-point		$\frac{1}{12}ML^2$	$\frac{L}{\sqrt{12}}$	
Circular disc, radius R	Perpendicular to plane of disc at centre		$\frac{1}{2}MR^2$	$\frac{R}{\sqrt{2}}$	$\frac{1}{2}$
Circular disc, radius R	About its diameter		$\frac{1}{4}MR^2$	$\frac{R}{2}$	$\frac{1}{4}$
Hollow cylinder, radius R	About its own axis		MR^2	R	1

Body	Axis of Rotation	Figure	Moment of Inertia	K	K^2/R^2
Solid cylinder, radius R	About its own axis		$\frac{MR^2}{2}$	$\frac{R}{\sqrt{2}}$	$\frac{1}{2}$
Solid sphere, radius R	About its diametric axis		$\frac{2}{5}MR^2$	$\sqrt{\frac{2}{5}}R$	$\frac{2}{5}$

17. From the given table below, we can compare translational motion and rotational motion about a fixed axis, i.e. Z-axis.

Pure Translational	Pure Rotational
Linear position, x	Angular position, θ
Linear velocity, $v = \frac{dx}{dt}$	Angular velocity, $\omega = \frac{d\theta}{dt}$
Linear acceleration, $a = \frac{dv}{dt}$	Angular acceleration, $\alpha = \frac{d\omega}{dt}$
Mass, m	Rotational inertia, I
Newton's second law, $F = ma$	Newton's second law, $\tau = I\alpha$
Work done, $W = \int F\,dx$	Work done, $W = \int \tau\,d\theta$
Kinetic energy, $K = \frac{1}{2}mv^2$	Kinetic energy, $K = \frac{1}{2}I\omega^2$
Power, $P = Fv$	Power, $P = \tau\omega$
Linear momentum, $p = mv$	Angular momentum, $L = I\omega$

18. **Rolling Motion** The rolling motion can be regarded as the combination of pure rotation and pure translation. It is also one of the most common motions observed in daily life.

19. **Kinetic Energy of a Rolling Body** The kinetic energy of a body rolling without slipping is the sum of kinetic energies of translational and rotational motions.

$$\therefore \quad (\text{KE})_{\text{rolling}} = (\text{KE})_{\text{rotation}} + (\text{KE})_{\text{translation}}$$

$$= \frac{1}{2}I\omega^2 + \frac{1}{2}mv_{\text{CM}}^2$$

$$= \frac{1}{2}mv_{\text{CM}}^2\left[1 + \frac{K^2}{R^2}\right]$$

$$(\because v_{\text{CM}} = R\omega \text{ and } I = mK^2)$$

Objective Questions

Multiple Choice Questions

1. A system of particles is called a rigid body, when

(a) any two particles of system may have displacements in opposite directions under action of a force
(b) any two particles of system may have velocities on opposite directions under action of a force
(c) any two particles of system may have a zero relative velocity
(d) any two particles of system may have displacements in same direction under action of a force

2. The centre of mass of a system of particles does not depend on

(a) masses of the particles
(b) internal forces of the particles
(c) position of the particles
(d) relative distance between two particles

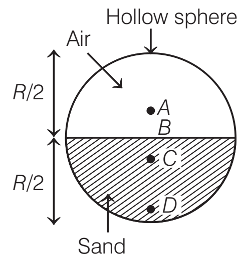
3. In pure rotation, all particles of the body

(a) move in a straight line
(b) move in concentric circles
(c) move in non-concentric circles
(d) have same speed

4. For n particles in a space, the suitable expression for the x-coordinate of the centre of mass of a system is

(a) $\frac{\Sigma m_i x_i}{m_i}$ (b) $\frac{\Sigma m_i x_i}{M}$
(c) $\frac{\Sigma m_i y_i}{M}$ (d) $\frac{\Sigma m_i z_i}{M}$

5. Which of the following points is the likely position of the centre of mass of the system shown in figure?
(NCERT Exemplar)



(a) A (b) B (c) C (d) D

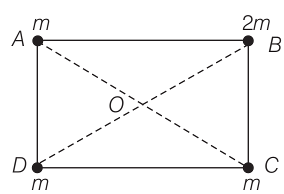
6. Two bodies of masses 1 kg and 2 kg are lying on x-y plane at (1, 2) and (– 1, 3) respectively. What are the coordinates of centre of mass?

(a) $(2, -1)$ (b) $\left(\frac{8}{3}, -\frac{1}{3}\right)$
(c) $\left(-\frac{1}{3}, \frac{8}{3}\right)$ (d) None of these

7. Three identical spheres of mass M each are placed at the corners of an equilateral triangle of side 2m. Taking one of the corner as the origin, the position vector of the centre of mass is

(a) $\sqrt{3}(\hat{i} - \hat{j})$ (b) $\frac{\hat{i}}{\sqrt{3}} + \hat{j}$
(c) $\frac{\hat{i} + \hat{j}}{3}$ (d) $\hat{i} + \frac{\hat{j}}{\sqrt{3}}$

8. Centre of mass of the given system of particles will be at



(a) OD (b) OC (c) OB (d) AO

9. Two particles of equal masses have velocities $\mathbf{v}_1 = 4\hat{\mathbf{i}}\ \text{ms}^{-1}$ and $\mathbf{v}_2 = 4\hat{\mathbf{j}}\ \text{ms}^{-1}$. First particle has an acceleration $\mathbf{a}_1 = (2\hat{\mathbf{i}} + 2\hat{\mathbf{j}})\ \text{ms}^{-2}$, while the acceleration of the other particle is zero. The centre of mass of the two particles moves in a path of

(a) straight line
(b) parabola
(c) circle
(d) ellipse

10. The centre of mass of three particles of masses 1 kg, 2 kg and 3 kg is at (3, 3, 3) with reference to a fixed coordinate system. Where should a fourth particle of mass 4 kg be placed, so that the centre of mass of the system of all particles shifts to a point (1, 1, 1)?

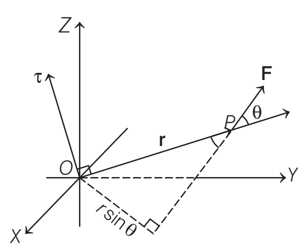
(a) $(-1, -1, -1)$ (b) $(-2, -2, -2)$
(c) $(2, 2, 2)$ (d) $(1, 1, 1)$

11. A ball kept in a closed box moves in the box making collisions with the walls. The box is kept on a smooth surface. The velocity of the centre of mass

(a) of the box remains constant
(b) of the box and the ball system remains constant
(c) of the ball remains constant
(d) of the ball relative to the box remains constant

12. A force **F** is applied on a single particle *P* as shown in the figure. Here, **r** is the position vector of the particle.

The value of torque τ is

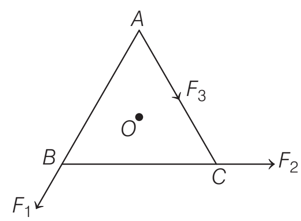


(a) $\mathbf{F} \times \mathbf{r}$ (b) $\mathbf{r} \times \mathbf{F}$ (c) $\mathbf{r} \cdot \mathbf{F}$ (d) $\mathbf{F} \cdot \mathbf{r}$

13. A force $\mathbf{F} = 5\hat{\mathbf{i}} + 2\hat{\mathbf{j}} - 5\hat{\mathbf{k}}$ acts on a particle whose position vector is $\mathbf{r} = \hat{\mathbf{i}} - 2\hat{\mathbf{j}} + \hat{\mathbf{k}}$. What is the torque about the origin ?

(a) $8\hat{i} + 10\hat{j} + 12\hat{k}$ (b) $8\hat{i} + 10\hat{j} - 12\hat{k}$
(c) $8\hat{i} - 10\hat{j} - 8\hat{k}$ (d) $10\hat{i} - 10\hat{j} - \hat{k}$

14. *ABC* is an equilateral triangle with *O* as its centre. $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ represent three forces acting along the sides *AB*, *BC* and *AC*, respectively. If the total torque about *O* is zero, then the magnitude of $\mathbf{F}_3$ is



(a) $F_1 + F_2$ (b) $F_1 - F_2$
(c) $\dfrac{F_1 + F_2}{2}$ (d) $2(F_1 + F_2)$

15. The angular momentum **L** of a single particle can be represented as

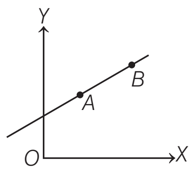
(a) $\mathbf{r} \times \mathbf{p}$ (b) $rp \sin\theta\, \hat{\mathbf{n}}$
(c) $rp \perp \hat{\mathbf{n}}$ (d) Both (a) and (b)

($\hat{\mathbf{n}}$ = unit vector perpendicular to plane of *r*, so that *r*, *p* and $\hat{\mathbf{n}}$ make right handed system)

16. Newton's second law for rotational motion of a system of particle can be represented as (**L** for a system of particles)

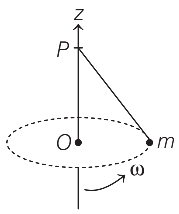
(a) $\dfrac{d\mathbf{p}}{dt} = \tau_{\text{ext}}$ (b) $\dfrac{d\mathbf{L}}{dt} = \tau_{\text{int}}$
(c) $\dfrac{d\mathbf{L}}{dt} = \tau_{\text{ext}}$ (d) $\dfrac{d\mathbf{L}}{dt} = \tau_{\text{int}} + \tau_{\text{ext}}$

17. A particle of mass *m* moves in the *xy*-plane with a velocity *v* along the straight line *AB*. If the angular momentum of the particle with respect to origin *O* is L_A, when it is at *A* and L_B when it is at *B*, then



(a) $L_A > L_B$
(b) $L_A = L_B$
(c) the relationship between L_A and L_B depends upon the slope of the line AB
(d) $L_A < L_B$

18. A point mass m is attached to a massless string whose other end is fixed at P as shown in figure. The mass is undergoing circular motion in xy-plane with centre O and constant angular speed ω. If the angular momentum of the system, calculated about O and P be $\mathbf{L}_O$ and $\mathbf{L}_P$ respectively, then



(a) $\mathbf{L}_O$ and $\mathbf{L}_P$ do not vary with time
(b) $\mathbf{L}_O$ varies with time while $\mathbf{L}_P$ remains constant
(c) $\mathbf{L}_O$ remains constant while $\mathbf{L}_P$ varies with time
(d) $\mathbf{L}_O$ and $\mathbf{L}_P$ both vary with time

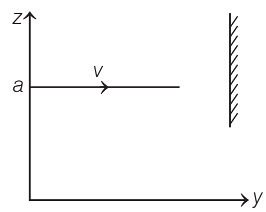
19. A child stands at the centre of a turntable with his two arms outstretched. The turntable is set rotating with an angular speed of 40 rev min^{-1}. How much is the angular speed of the child, if he folds his hands back and thereby reduces his moment of inertia to $(2/5)$ times the initial value? Assume that the turntable rotates without friction. *(NCERT Exemplar)*

(a) 40 rpm (b) 45 rpm (c) 55 rpm (d) 100 rpm

20. If the torque of the rotational motion will be zero, then the constant quantity will be

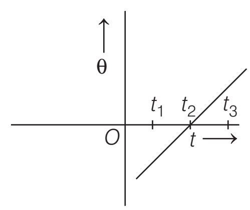
(a) angular momentum
(b) linear momentum
(c) angular acceleration
(d) centripetal acceleration

21. A particle of mass m is moving in yz-plane with a uniform velocity v with its trajectory running parallel to +ve y-axis and intersecting z-axis at $z = a$ in figure. The change in its angular momentum about the origin as it bounces elastically from a wall at $y =$ constant is *(NCERT Exemplar)*



(a) $mva\,\hat{\mathbf{e}}_x$ (b) $2\,mva\,\hat{\mathbf{e}}_x$
(c) $ymv\,\hat{\mathbf{e}}_x$ (d) $2\,ymv\,\hat{\mathbf{e}}_x$

22. The variation of angular position θ of a point on a rotating rigid body with time t is shown in figure.



In which direction, the body is rotating? *(NCERT Exemplar)*

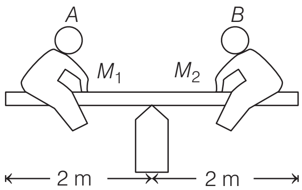
(a) Clockwise
(b) Anti-clockwise
(c) May be clockwise or anti-clockwise
(d) None of the above

23. A rigid body is said to be in partial equilibrium only, if

(a) it is in rotational equilibrium
(b) it is in translational equilibrium
(c) Either (a) or (b)
(d) None of the above

24. In the game of see-saw, what should be the displacement of boy B from right edge to keep the see-saw in equilibrium?

(Given, $M_1 = 40$ kg and $M_2 = 60$ kg)



(a) $\frac{4}{3}$ m (b) 1m
(c) $\frac{2}{3}$ m (d) Zero

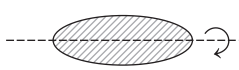
25. The centre of gravity of a homogeneous body is the point at which the whole

(a) volume of the body is assumed to be concentrated
(b) area of the surface of the body is assumed to be concentrated
(c) weight of the body is assumed to be concentrated
(d) All of the above

26. One solid sphere A and another hollow sphere B are of same mass and same outer radius. Their moments of inertia about their diameters are I_A and I_B respectively, such that

(a) $I_A = I_B$ (b) $I_A > I_B$
(c) $I_A < I_B$ (d) None of these

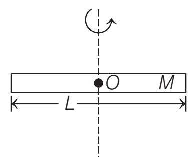
27. A disc of mass M and radius R is rotating about one of its diameter. The value of radius of gyration for the disc is



(a) $R/4$ (b) $R/2$
(c) $R/6$ (d) None of these

28. A rod is rotating about an axis passing through its centre and perpendicular to its length.

The radius of gyration for the rod is



(a) $L/12$ (b) $L/\sqrt{12}$ (c) $L/6$ (d) $L/\sqrt{6}$

29. A wheel is rotating at 900 rpm about its axis. When the power is cut-off, it comes to rest in 1 min. The angular retardation (in rad s^{-2}) is

(a) $-\frac{\pi}{2}$ (b) $\frac{\pi}{4}$ (c) $\frac{\pi}{6}$ (d) $\frac{\pi}{2}$

30. If object starts from rest and covers angle of 60 rad in 10 s in circular motion, then magnitude of angular acceleration will be

(a) 1.2 rad s^{-2} (b) 1.5 rad s^{-2}
(c) 2 rad s^{-2} (d) 2.5 rad s^{-2}

31. When a ceiling fan is switched OFF, its angular velocity fall to half while it makes 36 rotations. How many more rotations will it make before coming to rest? (Assume uniform angular retardation)

(a) 36 (b) 24 (c) 18 (d) 12

32. A disc is rotating with angular velocity ω. A force **F** acts at a point whose position vector with respect to the axis of rotation is **r**. The power associated with torque due to the force is given by

(a) $(r \times F) \cdot \omega$ (b) $(r \times F) \times \omega$
(c) $r \times (F \cdot \omega)$ (d) $r \cdot (F \times \omega)$

33. A flywheel of moment of inertia 0.4 kg-m^2 and radius 0.2 m is free to rotate about a central axis. If a string is wrapped around it and it is pulled with a force of 10N, then its angular velocity after 4 s will be

(a) 10 $rads^{-1}$ (b) 5 $rads^{-1}$
(c) 20 $rads^{-1}$ (d) None of these

34. Two discs having mass ratio (1/2) and diameter ratio (2/1), then find ratio of moment of inertia.

(a) 2 : 1 (b) 1 : 1 (c) 1 : 2 (d) 2 : 3

35. A solid sphere is rotating freely about its symmetry axis in free space. The radius of the sphere is increased keeping its mass same. Which of the following physical quantities would remain constant for the sphere?

(a) Rotational kinetic energy
(b) Moment of inertia
(c) Angular velocity
(d) Angular momentum

36. A body having a moment of inertia about its axis of rotation equal to 3 kg-m^2 is rotating with angular velocity of 3 rad s^{-1}. Kinetic energy of this rotating body is same as that of a body of mass 27 kg moving with a velocity v. The value of v is

(a) 1 ms^{-1} (b) 0.5 ms^{-1} (c) 2 ms^{-1} (d) 1.5 ms^{-1}

37. A disc of radius R is rotating with an angular speed ω_0 about a horizontal axis. It is placed on a horizontal table. The coefficient of kinetic friction is μ_k. What was the velocity of its centre of mass before being brought in contact with the table? *(NCERT Exemplar)*

(a) $\omega_0 R$ (b) Zero (c) $\frac{\omega_0 R}{2}$ (d) $2\omega_0 R$

38. Two bodies have their moments of inertia I and $2I$ respectively about their axis of rotation. If their kinetic energies of rotation are equal, their angular momenta will be in the ratio

(a) 1 : 2 (b) $\sqrt{2}$:1 (c) 2 :1 (d) 1: $\sqrt{2}$

39. By keeping moment of inertia of a body constant, if we double the time period, then angular momentum of body

(a) remains constant (b) becomes half
(c) doubles (d) quadruples

40. If frictional force is neglected and girl bends her hand, then (initially girl is rotating on chair)

(a) I_{girl} will reduce
(b) I_{girl} will increase
(c) ω_{girl} will reduce
(d) None of the above

41. A merry-go-round, made of a ring-like platform of radius R and mass M, is revolving with angular speed ω. A person of mass M is standing on it. At one instant, the person jumps off the round, radially away from the centre of the round (as seen from the round). The speed of the round of afterwards is *(NCERT Exemplar)*

(a) 2ω (b) ω
(c) $\frac{\omega}{2}$ (d) zero

42. A wheel of radius R rolls on the ground with a uniform velocity v. The velocity of topmost point relative to the bottommost point is

(a) v (b) $2v$
(c) $v/2$ (d) zero

43. A hoop of radius 2 m weighs 100 kg. It rolls along a horizontal floor, so that its centre of mass has a speed of 20 cms^{-1}. How much work has to be done to stop it? *(NCERT Exemplar)*

(a) 10 J (b) 12 J
(c) 4 J (d) 3 J

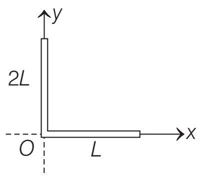
44. A drum of radius R and mass M rolls down without slipping along an inclined plane of angle θ. The frictional force

(a) converts translational energy into rotational energy
(b) dissipates energy as heat
(c) decreases the rotational motion
(d) decreases the rotational and translational motion

45. The centre of mass lie outside the body of a .... *(NCERT Exemplar)*

(a) pencil (b) shotput
(c) dice (d) bangle

46. Figure shows a composite system of two uniform rods of lengths as indicated. Then the coordinates of the centre of mass of the system of rods are......... .



(a) $\left(\frac{L}{2}, \frac{2L}{3}\right)$ (b) $\left(\frac{L}{4}, \frac{2L}{3}\right)$
(c) $\left(\frac{L}{6}, \frac{2L}{3}\right)$ (d) $\left(\frac{L}{6}, \frac{L}{3}\right)$

47. Analogue of mass in rotational motion is ....

(a) moment of inertia
(b) angular momentum
(c) gyration
(d) None of the above

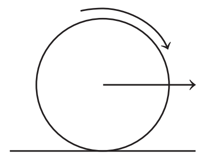
48. The angular acceleration of a flywheel of mass 5 kg and radius of gyration 0.5 m is ...., if a torque of 10N-m is applied on it.

(a) 2 rad s^{-2} (b) 4 rad s^{-2}
(c) 8 rad s^{-2} (d) zero

49. When a disc rotates with uniform angular velocity, which of the following statemnts is incorrect. *(NCERT Exemplar)*

(a) The sense of rotation remains same.
(b) The orientation of the axis of rotation remains same.
(c) The speed of rotation is non-zero and remains same.
(d) The angular acceleration is non-zero and remains same.

50. A bicycle wheel rolls without slipping on a horizontal floor. Which one of the following statements is true about the motion of points on the rim of the wheel, relative to the axis at the wheel's centre?



(a) Points near the top move faster than points near the bottom.
(b) Points near the bottom move faster than points near the top.
(c) All points on the rim move with the same speed.
(d) All points have the velocity vectors that are pointing in the radial direction towards the centre of the wheel.

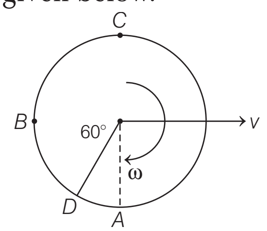
51. If radius of earth is reduced to half without changing its mass, then match the following columns and choose the correct option from the codes given below.

	Column I		Column II
A.	Angular momentum of earth	p.	Will become one fourth
B.	Time period of rotation of earth	q.	Will become four times
C.	Rotational kinetic energy of earth	r.	No change

Codes

	A	B	C		A	B	C
(a)	p	q	r	(b)	p	q	p
(c)	r	p	q	(d)	p	r	p

52. A rigid body is rolling without slipping on the horizontal surface, then match the Column I with Column II and choose the correct option from the codes given below.



	Column I		Column II
A.	Velocity at point A, i.e. v_A	p.	$v\sqrt{2}$
B.	Velocity at point B, i.e. v_B	q.	zero
C.	Velocity at point C, i.e. v_C	r.	v
D.	Velocity at point D, i.e. v_D	s.	$2v$

Codes

	A	B	C	D
(a)	q	p	s	r
(b)	p	r	s	q
(c)	s	r	q	p
(d)	q	r	s	p

Assertion-Reasoning MCQs

For question numbers 53 to 64, two statements are given-one labelled ***Assertion*** *(A) and the other labelled* ***Reason*** *(R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

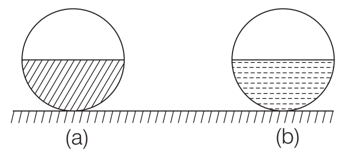
53. Assertion The motion of the centre of mass describes the translational part of the motion.

Reason Translational motion always means straight line motion.

54. Assertion The centre of mass of a body must lie on the body.

Reason The centre of mass of a body does not lie at the geometric centre of body.

55. Assertion Two identical spherical spheres are half filled with two liquids of densities ρ_1 and ρ_2 $(>\rho_1)$. The centre of mass of both the spheres lie at same level.



Reason The centre of mass does not lie at centre of the sphere.

56. Assertion If a particle moves with a constant velocity, then angular momentum of this particle about any point remains constant.

Reason Angular momentum does not have the units of Planck's constant.

57. Assertion When a particle is moving in a straight line with a uniform velocity, its angular momentum is constant.

Reason The angular momentum is non-zero, when particle moves with a uniform velocity.

58. Assertion For a system of particles under central force field, the total angular momentum is conserved.

Reason The torque acting on such a system is zero.

59. **Assertion** Inertia and moment of inertia are not same quantities.

Reason Inertia represents the capacity of a body that does not oppose its state of motion or rest.

60. **Assertion** Moment of inertia of a particle is different whatever be the axis of rotation.

Reason Moment of inertia does not depends on mass and distance of the particle from the axis of rotation.

61. **Assertion** The angular velocity of a rigid body in motion is defined for the whole body.

Reason All points on a rigid body performing pure rotational motion are having same angular velocity.

62. **Assertion** If bodies slide down an inclined plane without rolling, then all bodies reach the bottom simultaneously is not necessary.

Reason Acceleration of all bodies are equal and independent of the shape.

63. **Assertion** A solid sphere cannot roll without slipping on smooth horizontal surface.

Reason If the sphere is left free on smooth inclined surface, it can roll without slipping.

64. **Assertion** The work done against force of friction in the case of a disc rolling without slipping down an inclined plane is zero.

Reason When the disc rolls without slipping, friction is required because for rolling condition velocity of point of contact is zero.

Case Based MCQs

Direction *Answer the questions from 65-69 on the following case.*

Centre of Mass

The centre of mass of a body or a system of bodies is the point which moves as though all of the mass were concentrated there and all external forces were applied to it. Hence, a point at which the entire mass of the body or system of bodies is supposed to be concentrated is known as the centre of mass.

If a system consists of more than one particles (or bodies) and net external force on the system in a particular direction is zero with centre of mass at rest. Then, the centre of mass will not move along that direction. Even though some particles of the system may move along that direction.

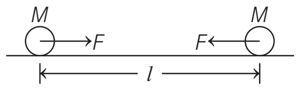
65. The centre of mass of a system of two particles divides, the distance between them

(a) in inverse ratio of square of masses of particles
(b) in direct ratio of square of masses of particles
(c) in inverse ratio of masses of particles
(d) in direct ratio of masses of particles

66. Two bodies of masses 1 kg and 2 kg are lying in xy-plane at $(-1, 2)$ and $(2, 4)$, respectively. What are the coordinates of the centre of mass?

(a) $\left(1, \frac{10}{3}\right)$ (b) $(1, 0)$
(c) $(0, 1)$ (d) None of these

67. Two balls of same masses start moving towards each other due to gravitational attraction, if the initial distance between them is l. Then, they meet at



(a) $\frac{l}{2}$ (b) l (c) $\frac{l}{3}$ (d) $\frac{l}{4}$

68. All the particles of a body are situated at a distance R from the origin. The distance of centre of mass of the body from the origin is

(a) $= R$ (b) $\leq R$ (c) $> R$ (d) $\geq R$

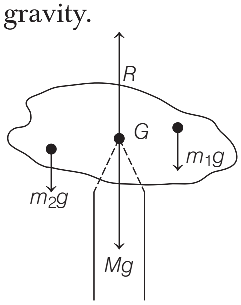
69. Two particles A and B initially at rest move towards each other under a mutual force of attraction. At the instant, when the speed of A is v and the speed of B is $2v$, the speed of centre of mass of the system is

(a) zero (b) v
(c) $1.5v$ (d) $3v$

Direction *Answer the questions from 70-74 on the following case.*

Torque and Centre of Gravity

Torque is also known as moment of force or couple. When a force acts on a particle, the particle does not merely move in the direction of the force but it also turns about some point. So, we can define the torque for a particle about a point as the vector product of position vector of the point where the force acts and with the force itself. In the given figure, balancing of a cardboard on the tip of a pencil is done. The point of support, G is the centre of gravity.



70. If the $\mathbf{F}_{\text{net, ext}}$ is zero on the cardboard, it means

(a) $R = Mg$ (b) $m_1 g = Mg$
(c) $m_2 g = Mg$ (d) $R = m_1 / g$

71. Choose the correct option.

(a) τ_{Mg} about CG $= 0$
(b) τ_R about CG $= 0$
(c) Net τ due to $m_1g, m_2g, \ldots, m_ng$ about CG $= 0$
(d) All of the above

72. The centre of gravity and the centre of mass of a body coincide, when

(a) g is negligible
(b) g is variable
(c) g is constant
(d) g is zero

73. If value of g varies, the centre of gravity and the centre of mass will

(a) coincide
(b) not coincide
(c) become same physical quantities
(d) None of the above

74. A body lying in a gravitational field is in stable equilibrium, if

(a) vertical line through CG passes from top
(b) horizontal line through CG passes from top
(c) vertical line through CG passes from base
(d) horizontal line through CG passes from base

Direction *Answer the questions from 75-79 on the following case.*

Moment of Inertia

A heavy wheel called flywheel is attached to the shaft of steam engine, automobile engine etc., because of its large moment of inertia, the flywheel opposes the sudden increase or decrease of the speed of the vehicle. It allows a gradual change in the speed and prevents jerky motion and hence ensure smooth ride of passengers.

75. Moment of inertia of a body depends upon

(a) axis of rotation (b) torque
(c) angular momentum (d) angular velocity

76. A particle of mass 1 kg is kept at (1m, 1m, 1m). The moment of inertia of this particle about Z-axis would be

(a) 1 kg-m^2
(b) 2 kg-m^2
(c) 3 kg-m^2
(d) None of the above

77. Moment of inertia of a rod of mass m and length l about its one end is I. If one-fourth of its length is cut away, then moment of inertia of the remaining rod about its one end will be

(a) $\frac{3}{4}I$ (b) $\frac{9}{16}I$
(c) $\frac{27}{64}I$ (d) $\frac{I}{16}$

78. A circular disc is to be made by using iron and aluminium, so that it acquires maximum moment of inertia about its geometrical axis. It is possible with

(a) iron and aluminium layers in alternate order
(b) aluminium at interior and iron surrounding it
(c) iron at interior and aluminium surrounding it
(d) Either (a) or (c)

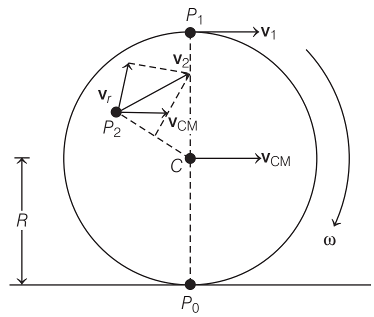
79. Three thin rods each of length L and mass M are placed along X, Y and Z -axes such that one end of each rod is at origin. The moment of inertia of this system about Z-axis is

(a) $\frac{2}{3}ML^2$
(b) $\frac{4ML^2}{3}$
(c) $\frac{5ML^2}{3}$
(d) $\frac{ML^2}{3}$

Direction *Answer the questions from 80-84 on the following case.*

Rolling Motion

The rolling motion can be regarded as the combination of pure rotation and pure translation. It is also one of the most common motions observed in daily life.



Suppose the rolling motion (without slipping) of a circular disc on a level surface. At any instant, the point of contact P_0 of the disc with the surface is at rest (as there is no slipping). If $\mathbf{v}_{CM}$ is the velocity of centre of mass which is the geometric centre C of the disc, then the translational velocity of disc is $\mathbf{v}_{CM}$, which is parallel to the level surface.

Velocity of centre of mass, $\mathbf{v}_{CM} = R\omega$

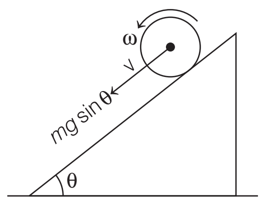
80. A solid cylinder is sliding on a smooth horizontal surface with velocity v_0 without rotation. It enters on the rough surface. After that it has travelled some distance, the friction force increases its

(a) translational kinetic energy
(b) rotational kinetic energy
(c) total mechanical energy
(d) angular momentum about an axis passing through point of contact of the cylinder and the surface

81. A cylinder rolls down an inclined plane of inclination 30°, the acceleration of cylinder is

(a) $\frac{g}{3}$ (b) g (c) $\frac{g}{2}$ (d) $\frac{2g}{3}$

82. Sphere is in pure accelerated rolling motion in the figure shown,



Choose the correct option.

(a) The direction of f_s is upwards
(b) The direction of f_s is downwards
(c) The direction of gravitational force is upwards
(d) The direction of normal reaction is downwards

83. Kinetic energy of a rolling body will be

(a) $\frac{1}{2} mv_{CM}^2 (1 + k^2 / R^2)$
(b) $\frac{1}{2} I \omega^2$
(c) $\frac{1}{2} mv_{CM}^2$
(d) None of the above

84. A body is rolling down an inclined plane. Its translational and rotational kinetic energies are equal. The body is a

(a) solid sphere
(b) hollow sphere
(c) solid cylinder
(d) hollow cylinder

ANSWERS

Multiple Choice Questions

1. (c)	2. (b)	3. (b)	4. (b)	5. (c)	6. (c)	7. (d)	8. (c)	9. (a)	10. (b)
11. (b)	12. (b)	13. (a)	14. (a)	15. (d)	16. (c)	17. (b)	18. (c)	19. (d)	20. (a)
21. (b)	22. (b)	23. (c)	24. (c)	25. (c)	26. (c)	27. (b)	28. (b)	29. (a)	30. (a)
31. (d)	32. (a)	33. (c)	34. (a)	35. (d)	36. (a)	37. (b)	38. (d)	39. (b)	40. (a)
41. (a)	42. (b)	43. (c)	44. (a)	45. (d)	46. (c)	47. (a)	48. (c)	49. (d)	50. (a)
51. (c)	52. (a)								

Assertion-Reasoning MCQs

53. (c)	54. (d)	55. (c)	56. (c)	57. (b)	58. (a)	59. (c)	60. (c)	61. (b)	62. (c)
63. (d)	64. (a)								

Case Based MCQs

65. (c)	66. (a)	67. (a)	68. (b)	69. (a)	70. (a)	71. (d)	72. (c)	73. (b)	74. (c)
75. (a)	76. (b)	77. (c)	78. (b)	79. (a)	80. (b)	81. (a)	82. (a)	83. (a)	84. (d)

SOLUTIONS

1. A rigid body does not deform under action of applied force and there is no relative motion of any two particles constituting that rigid body. So, it means that a system of particles is called a rigid body, when any two particles of system has a zero relative velocity.

2. A point at which the entire mass of the body or system of bodies. This is supposed to be concentrated is known as centre of mass.
It does not depend on the internal forces acting on the particle.

3. In pure rotational motion, all the particles of body moves in concentric circles without doing any translational motion.

4. For system of n-particles in space, the centre of mass of such a system is at (x, y, z), where

$$X = \frac{\Sigma m_i x_i}{M}, Y = \frac{\Sigma m_i y_i}{M}$$

and $Z = \frac{\Sigma m_i z_i}{M}$

Here, $M = \Sigma m_i$ is the total mass of the system. The index i runs from 1 to n. m_i is the mass of ith particle and position of ith particle is (x_i, y_i, z_i).

5. Centre of mass of a system lies towards the part of the system, having bigger mass. In the above diagram, lower part is heavier, hence CM of the system lies below the horizontal diameter.

Hence, option (c) is correct.

6. Let the coordinates of the centre of mass be (x, y) which are calculated as,

$$x = \frac{m_1x_1 + m_2x_2}{m_1 + m_2} = \frac{1 \times 1 + 2 \times (-1)}{3}$$

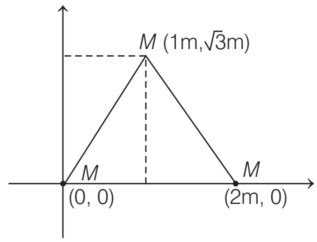
$$= \frac{1-2}{3} = -\frac{1}{3}$$

$$y = \frac{m_1y_1 + m_2y_2}{m_1 + m_2} = \frac{1 \times 2 + 2 \times 3}{3}$$

$$= \frac{2+6}{3} = \frac{8}{3}$$

Therefore, the coordinates of centre of mass be $\left(-\frac{1}{3}, \frac{8}{3}\right)$.

7. The given system of spheres is as shown below



The x and y -coordinates of centre of mass is

$$x = \frac{\Sigma m_i x_i}{\Sigma m_i} = \frac{M \times 0 + M \times 1 + M \times 2}{M + M + M} = 1$$

$$y = \frac{\Sigma m_i y_i}{\Sigma m_i} = \frac{M \times 0 + M(\sqrt{3}) + M \times 0}{M + M + M}$$

$$\Rightarrow \quad y = \frac{\sqrt{3}M}{3M} = \frac{1}{\sqrt{3}}$$

So, position vector of the centre of mass is $\left(\hat{\mathbf{i}} + \frac{\hat{\mathbf{j}}}{\sqrt{3}}\right)$.

8. If all the masses were same, the centre of mass was at O. But as the mass at B is 2m, so the centre of mass of the system will shift towards B. So, centre of mass will be on the line OB.

9. Given, $\mathbf{v}_1 = 4\hat{\mathbf{i}}\ \text{ms}^{-1}$, $\mathbf{v}_2 = 4\hat{\mathbf{j}}\ \text{ms}^{-1}$

$\mathbf{a}_1 = (2\hat{\mathbf{i}} + 2\hat{\mathbf{j}})\ \text{ms}^{-2}$, $\mathbf{a}_2 = 0\ \text{ms}^{-2}$

$\therefore$ Velocity of centre of mass,

$$\mathbf{v}_{CM} = \frac{m_1\mathbf{v}_1 + m_2\mathbf{v}_2}{m_1 + m_2} = \frac{(\mathbf{v}_1 + \mathbf{v}_2)m}{2m}$$

$[\because m_1 = m_2 = m]$

$$= \frac{4\hat{\mathbf{i}} + 4\hat{\mathbf{j}}}{2} = 2(\hat{\mathbf{i}} + \hat{\mathbf{j}})\ \text{ms}^{-1}$$

Similarly, acceleration of centre of mass,

$$\mathbf{a}_{CM} = \frac{\mathbf{a}_1 + \mathbf{a}_2}{2}$$

$$= \frac{2\hat{\mathbf{i}} + 2\hat{\mathbf{j}} + 0}{2} = (\hat{\mathbf{i}} + \hat{\mathbf{j}})\ \text{ms}^{-2}$$

Since, from above values, it can be seen that $\mathbf{v}_{CM}$ is parallel to $\mathbf{a}_{CM}$, so the path will be a straight line.

10. Centre of mass of a system of particles is given by

$$x_{CM} = \frac{1 \times x_1 + 2 \times x_2 + 3 \times x_3}{1 + 2 + 3} = 3$$

$[\because x_{CM} = y_{CM} = z_{CM} = 3]$

$\Rightarrow \quad x_1 + 2x_2 + 3x_3 = (1 + 2 + 3)3 = 18 \quad \ldots(i)$

When fourth particle is placed, then

$x_{CM} = y_{CM} = z_{CM} = 1$ (given)

$$\Rightarrow \quad x_{CM} = \frac{1 \times x_1 + 2 \times x_2 + 3 \times x_3 + 4 \times x_4}{(1 + 2 + 3 + 4)}$$

$\Rightarrow$

$x_1 + 2\,x_2 + 3\,x_3 + 4\,x_4 = 1\,(1 + 2 + 3 + 4) = 10 \quad \ldots(ii)$

On solving Eqs. (i) and (ii), we get

$4x_4 = 10 - 18 \Rightarrow x_4 = -2$

Similarly, $y_4 = -2,\ z_4 = -2$

$\therefore$ The fourth particle must be placed at the point $(-2, -2, -2)$.

11. Net external force on the system is zero. Hence, velocity of centre of mass of the box and ball system will remain constant.

12. If a force acts on a single particle at a point P whose position with respect to origin O is given by the position vector $\mathbf{r}$ as shown in given figure, the moment of the force acting on the particle with respect to the origin O is defined as the vector product.

$\tau = \mathbf{r} \times \mathbf{F}$

$\Rightarrow \quad |\tau| = r\,F \sin\theta$

13. Given, $\mathbf{F} = 5\hat{\mathbf{i}} + 2\hat{\mathbf{j}} - 5\hat{\mathbf{k}}$ and $\mathbf{r} = \hat{\mathbf{i}} - 2\hat{\mathbf{j}} + \hat{\mathbf{k}}$

We know that, $\tau = \mathbf{r} \times \mathbf{F}$

So, torque about the origin will be given by

$$= \begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ 1 & -2 & 1 \\ 5 & +2 & -5 \end{vmatrix}$$

$= \hat{\mathbf{i}}\,(10 - 2) - \hat{\mathbf{j}}\,(-5 - 5) + \hat{\mathbf{k}}\,(2 + 10)$

$= 8\hat{\mathbf{i}} + 10\hat{\mathbf{j}} + 12\hat{\mathbf{k}}$

14. If we take clockwise torque, then magnitude of total torque is

$\tau_{net} = \tau_{F_1} + \tau_{F_2} + \tau_{F_3}$

$0 = -F_1 r - F_2 r + F_3 r$

$\Rightarrow \quad F_3 = F_1 + F_2$

15. Angular momentum (L) can be defined as moment of linear momentum about a point. It is given by,

$\mathbf{L} = \mathbf{r} \times \mathbf{p}$

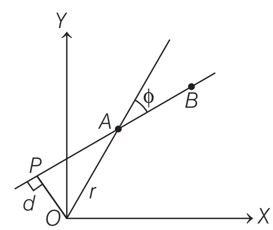
L can also be represented as, $L = rp \sin\theta\hat{n}$.

16. According to Newton's second law of rotational motion, the rate of the total angular momentum of a system of particles about a point is equal to the sum of the external torques acting on the system taken about the same point.

i.e. $\tau_{ext} = \frac{dL}{dt}$

17. From the definition of angular momentum,

$\mathbf{L} = \mathbf{r} \times \mathbf{p} = rmv \sin\phi\,(-\hat{\mathbf{k}})$

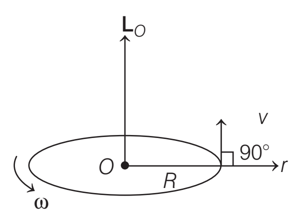


Therefore, the magnitude of L is $L = mvr, \sin\phi = mvd$, where $d = r\sin\phi$ is the distance of closest approach of the particle to the origin. As d is same for both the particles, hence $L_A = L_B$.

18. Angular momentum of a particle about a point is given by

$\mathbf{L} = \mathbf{r} \times \mathbf{p} = m\,(\mathbf{r} \times \mathbf{v})$

For $\mathbf{L}_O$,

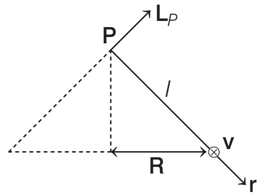


$|\mathbf{L}| = (mvr \sin\theta) = m\,(R\omega)(R) \sin 90° = mR^2\omega$
$= \text{constant}$

Direction of $\mathbf{L}_O$ is always upwards, therefore $\mathbf{L}_O$ is constant, both in magnitude as well as direction.

For $\mathbf{L}_P$, $|\mathbf{L}_P| = (mvr \sin\theta)$

$$= (m)(R\omega)(l)\sin 90° = mRl\omega$$



Magnitude of $\mathbf{L}_P$ will remains constant but direction of $\mathbf{L}_P$ keeps on changing, i.e. it varies with time.

19. From law of conservation of angular momentum,

$$L_1 = L_2$$

$$\Rightarrow \quad I_1\omega_1 = I_2\omega_2 \Rightarrow \omega_2 = \frac{I_1\omega_1}{I_2}$$

$$\Rightarrow \quad \omega_2 = \frac{I_1 \times 40}{\frac{2}{5}I_1} = \frac{200}{2} = 100 \text{ rpm}$$

20. As, torque, $\tau = \dfrac{dL}{dt}$

If $\tau = 0$, then L = constant.

Hence, option (a) is correct.

21. The initial velocity is $\mathbf{v}_i = v\hat{\mathbf{e}}_y$ and after reflection from the wall, the final velocity is $\mathbf{v}_f = -v\hat{\mathbf{e}}_y$. The trajectory is described as position vector $\mathbf{r} = y\hat{\mathbf{e}}_y + a\hat{\mathbf{e}}_z$.

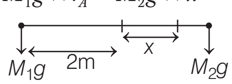
Hence, the change in angular momentum is $\mathbf{r} \times m(\mathbf{v}_f - \mathbf{v}_j) = 2mva\hat{\mathbf{e}}_x$.

22. As the slope of θ-t graph is positive and positive slope indicates anti-clockwise rotation.

23. A body may remain in partial equilibrium means that body may remain only in translational equilibrium or only in rotational equilibrium.

24. Let x be the distance from centre, then for rotational equilibrium,

$$M_1 g \times r_A = M_2 g \times x$$



$$(40 \times 10) \times 2 = (60 \times 10)\,x$$

$$\Rightarrow \quad x = \frac{8}{6} = \frac{4}{3} \text{ m}$$

So, 60 kg boy has to be displaced to

$$= 2 - \frac{4}{3} = \frac{2}{3} \text{ m}$$

25. The centre of gravity of a homogeneous body is the point at which the whole weight of the body is assumed to be concentrated.

26. Let mass and outer radii of solid sphere and hollow sphere be M and R, respectively. The moment of inertia of solid sphere A about its diameter,

$$I_A = \frac{2}{5}MR^2 \qquad \ldots\text{(i)}$$

The moment of inertia of hollow sphere (spherical shell) B about its diameter,

$$I_B = \frac{2}{3}MR^2 \qquad \ldots\text{(ii)}$$

It is clear from Eqs. (i) and (ii), that

$$I_A < I_B$$

27. I_{disc} about the axis along its diameter

$$= \frac{MR^2}{4} \qquad \ldots\text{(i)}$$

Using radius of gyration, $I = Mk^2$ ...(ii)

Comparing Eqs. (i) and (ii), we get $k = \dfrac{R}{2}$.

28. As, moment of inertia of rod,

$$I_{\text{rod}} = \frac{ML^2}{12} \qquad \ldots\text{(i)}$$

Using radius of gyration, $I = Mk^2$ ...(ii)

Comparing Eqs. (i) and (ii), we get

Radius of gyration, $k = L/\sqrt{12}$

29. Angular retardation,

$$\alpha = \frac{\omega_f - \omega_i}{\Delta t} = \frac{0 - 900 \times \frac{2\pi}{60}}{60} \text{ rad s}^{-2}$$

$$= -\frac{900 \times 2 \times \pi}{3600} = -\frac{\pi}{2} \text{ rad s}^{-2}$$

30. Given, initial angular velocity of object, $\omega_0 = 0$

Angular displacement, $\theta = 60$ rad

and $\Delta t = 10$ s

From equation of rotational motion,

$$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$$

$$60 = 0 \times t + \frac{1}{2} \times \alpha \times 10^2$$

$$\Rightarrow \quad \alpha = \frac{60}{50}$$

$$\Rightarrow \quad \alpha = 1.2 \text{ rads}^{-2}$$

31. Total angular displacement in 36 rotation,

$$\theta = 36 \times 2\pi$$

Using $\omega_2^2 - \omega_1^2 = 2\alpha\theta$, we get

$$(\omega/2)^2 - \omega^2 = 2\alpha(36 \times 2\pi) \quad \ldots\text{(i)}$$

Similarly, $0^2 - (\omega/2)^2 = 2\alpha\,(n \times 2\pi)$ ...(ii)

Dividing Eq. (i) by Eq. (ii), we get

$$\frac{-\frac{3}{4}\omega^2}{-\omega^2/4} = \frac{36}{n} \Rightarrow n = 12$$

Hence, ceiling fan will make 12 more rotations before coming to rest.

32. Power, $P = \tau\omega$

$$P = (\mathbf{r} \times \mathbf{F}) \cdot \omega$$

33. Given, moment of inertia of flywheel,

$$I = 0.4 \text{ kg-m}^2$$

Radius, $r = 0.2$ m

Force, $F = 10$ N

$$\because \; F \times r = I\alpha = I\frac{(\omega_2 - \omega_1)}{t}$$

$$\Rightarrow \quad \omega_2 - \omega_1 = \frac{F \times r \times t}{I}$$

(from $\tau = F \times r$ and $\tau = I\alpha$)

$$= \frac{10 \times 0.2 \times 4}{0.4}$$

$$= 20 \text{ rads}^{-1}$$

34. Given, mass ratio of two discs,

$m_1 : m_2 = 1:2$, i.e. $\frac{m_1}{m_2} = \frac{1}{2}$

and diameter ratio, $\frac{d_1}{d_2} = \frac{2}{1}$

$$\Rightarrow \quad \frac{r_1}{r_2} = \frac{d_1/2}{d_2/2} = \frac{d_1}{d_2} = \frac{2}{1}$$

$\therefore$ Ratio of their moment of inertia,

$$\frac{I_1}{I_2} = \frac{\frac{m_1 r_1^2}{2}}{\frac{m_2 r_2^2}{2}} = \frac{m_1}{m_2} \cdot \left(\frac{r_1}{r_2}\right)^2 = \frac{1}{2}\left(\frac{2}{1}\right)^2 = \frac{2}{1}$$

$$\therefore \quad I_1 : I_2 = 2:1$$

35. As, we know that external torque, $\tau_{ext} = \frac{dL}{dt}$

where, L is the angular momentum.

Since, in the given condition,

$$\tau_{ext} = 0 \Rightarrow \frac{dL}{dt} = 0$$

or $\quad L =$ constant

Hence, when the radius of the sphere is increased keeping its mass same, only the angular momentum remains constant. But other quantities like moment of inertia, rotational kinetic energy and angular velocity changes.

36. We know that, kinetic energy,

$$K = \frac{1}{2}mv^2 = \frac{1}{2}I\omega^2$$

Given, $m = 27$ kg (mass of the body),

$\omega = 3 \text{ rads}^{-1}$ (angular velocity)

and $\quad I = 3 \text{ kg-m}^2$ (moment of inertia)

$$\Rightarrow \quad mv^2 = I\omega^2 \quad \Rightarrow v^2 = \frac{I\omega^2}{m}$$

$$v^2 = \frac{3 \times 3^2}{27} \Rightarrow v^2 = \frac{27}{27} = 1$$

$$\Rightarrow \quad v = \sqrt{1} = 1 \text{ ms}^{-1}$$

37. Before being brought in contact with the table, the disc was in pure rotational motion, hence $v_{CM} = 0$.

38. Rotational kinetic energy remains same.

i.e. $\quad \frac{1}{2}I_1\omega_1^2 = \frac{1}{2}I_2\,\omega_2^2$

or $\frac{1}{2I_1}(I_1\omega_1)^2 = \frac{1}{2I_2}(I_2\,\omega_2)^2$

$$\Rightarrow \quad \frac{L_1^2}{I_1} = \frac{L_2^2}{I_2} \quad \text{or} \quad \frac{L_1}{L_2} = \sqrt{\frac{I_1}{I_2}}$$

But $\quad I_1 = I,\; I_2 = 2I$

$$\Rightarrow \quad \frac{L_1}{L_2} = \sqrt{\frac{I}{2I}} = \frac{1}{\sqrt{2}} \Rightarrow L_1 : L_2 = 1 : \sqrt{2}$$

39. We know that, angular momentum of the body is given by

$$L = I\omega \text{ or } L = I \times \frac{2\pi}{T} \text{ or } L \propto \frac{1}{T} \Rightarrow \frac{L_1}{L_2} = \frac{T_2}{T_1}$$

$$\Rightarrow \frac{L}{L_2} = \frac{2T}{T} \quad \text{(as, } T_2 = 2T \text{ and } L_1 = L\text{)}$$

So, $L_2 = \frac{L}{2}$. Thus, on doubling the time period, angular momentum of body becomes half.

40. As there is no external torque, so if the girl bends her hands, her moment of inertia about the rotational axis will decrease. By conservation of angular momentum,

$L = I\omega =$ constant. So, in order to keep L constant, if I is decreasing, then ω will increase.

41. As no external torque acts on the system, angular momentum should be conserved.

Hence, $I\,\omega =$ constant. ...(i)

where, I is moment of inertia of the system and ω is angular velocity of the system.

From Eq. (i) $I_1\omega_1 = I_2\,\omega_2$

where, ω_1 and ω_2 are angular velocities before and after jumping)

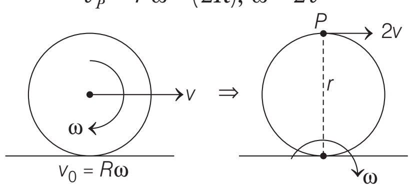
$\Rightarrow \quad I\omega = \frac{I}{2} \times \omega_2$

(as mass reduced to half, hence moment of inertia also reduced to half)

$\Rightarrow \omega_2 = 2\omega$

42. Velocity of the particle,

$v_P = r\,\omega = (2R),\ \omega = 2\,v$



43. Work done = ΔK = Change in rotational kinetic energy + Change in linear kinetic energy

$$= \frac{1}{2}mv_{CM}^2 + \frac{1}{2}I\omega^2$$

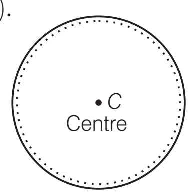
$(\because I = mr^2 \text{ and } v_{CM} = r\omega)$

$$= mv_{CM}^2 = 100 \times (20 \times 10^{-2})^2 = 4\text{ J}$$

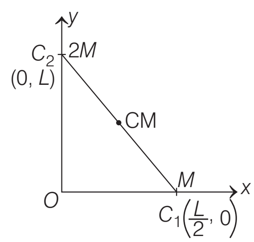
44. When a body rolls down without slipping along an inclined plane of inclination θ, it rotates about a horizontal axis through its centre of mass and its centre of mass also moves.

As it rolls down, it suffers loss in gravitational potential energy which provides translational energy and due to frictional force, it gets converted into rotational energy.

45. A bangle is in the form of a ring as shown in the adjacent diagram. The centre of mass lies at the centre, which is outside the body (boundary).



46. As rods are uniform, therefore centre of mass of both rods will be at their geometrical centres. The coordinates of CM of first rod C_1 are $\left(\frac{L}{2}, 0\right)$ and second rod C_2 are $(0, L)$.



$$\therefore\ x_{CM} = \frac{M\left(\frac{L}{2}\right) + 2M(0)}{M + 2M} = \frac{L}{6}$$

$$y_{CM} = \frac{M(0) + 2M(L)}{M + 2M} = \frac{2L}{3}$$

Hence, coordinates of CM are $\left(\frac{L}{6}, \frac{2L}{3}\right)$.

47. The role of moment of inertia in the study of rotational motion is analogous to that of mass in study of linear motion.

48. As, $\tau = I\alpha = Mk^2\alpha$

$$\Rightarrow \alpha = \frac{\tau}{Mk^2}$$

$$\Rightarrow \alpha = \frac{10}{5 \times 0.5 \times 0.5} = 8 \text{ rad s}^{-2}$$

49. We know that, angular acceleration,

$\alpha = \frac{d\omega}{dt}$, given $\omega =$ constant

where, ω is angular velocity of the disc.

$$\Rightarrow \alpha = \frac{d\omega}{dt} = \frac{0}{dt} = 0$$

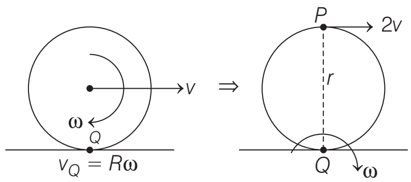
Hence, angular acceleration is zero.

50. Velocity of the particle at Q,

$$v_Q = r\omega = R\omega$$

Velocity of the particle at P,

$$v_P = r\,\omega = (2R)\,\omega = 2v_Q$$



Hence, points near the top move faster than points near the bottom.

51. $L_1 = I\omega = \frac{2}{5}MR^2\omega$

$$L_2 = \frac{2}{5}M\left(\frac{R}{2}\right)^2\omega'$$

As $L_1 = L_2 \Rightarrow \omega' = 4\omega$

$$\therefore \quad \frac{2\pi}{T'} = 4\left(\frac{2\pi}{T}\right)$$

$$\Rightarrow \quad T' = \frac{T}{4}$$

Time period will become $\left(\frac{1}{4}\right)$th.

Further, $K = \frac{L^2}{2I}$

Since, angular momentum is constant and I has become (1/4)th.

Therefore, kinetic energy will become 4 times.

Hence, A → r, B → p and C → q.

52. If v is the velocity of centre of mass of the body of radius r, then

velocity at point A, $v_A = 0$

velocity at point B, $v_B = v\sqrt{2}$

velocity at point C, $v_C = v + r\omega = 2v$

velocity of point D , $v_D = r\omega = v$

Hence, A → q, B → p, C → s and D → r.

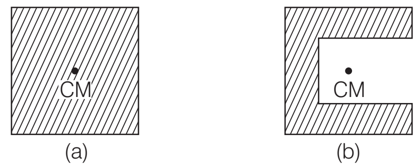
53. The motion of centre of mass describes the translational part of the motion.

In translational motion, all points of a moving body move along a straight line, i.e. the relative velocities between any two particles, must be zero.

But it is not necessary that, translational motion of body is always in straight line. A parabolic motion of an object without rotation is also translational motion.

Therefore, A is true but R is false.

54. The centre of mass of a body may lie on or outside the body.



Hence, in Fig. (a), centre of mass is on the body and in Fig. (b), centre of mass does not lie on the body.

The centre of mass of an object is the average position of all the parts of the system, weighted according to their masses. Therefore, centre of mass of a body lie at the geometric centre of body.

Therefore, A is false and R is also false.

55. We know that, centre of mass of half disc depends only on radius and not only the density of the material of disc similarly in this case centre of mass of half filled sphere will depends only on radius and not on density of liquid inside. Since, both sphere are of same radius so both have CM at the same level.

Therefore, A is true and R is false.

56. $L = mvr\sin\theta$ or $mvr_\perp$

In case of constant velocity m, v and $r_\perp$ all are constant.

Therefore, angular momentum is constant.

Further, $L = n\frac{h}{2\pi}$ (in Bohr's theory)

Hence, L and h have same units.

Therefore, A is true but R is false.

57. Angular momentum remains constant as particle is moving in a straight line. The angular momentum is constant, when particle moves with a uniform velocity.

Therefore, both A and R are true but R is not the correct explanation of A.

58. When $\tau_{ext} = 0$, then $\mathbf{L}$ = constant.

So, for a system of particles under central force field, the total angular momentum on the system is conserved because torque acting on such a system is zero.

Therefore, both A and R are true and R is the correct explanation of A.

59. There is a difference between inertia and moment of inertia of a body. The inertia of a body depends only upon the mass of the body but the moment of inertia of a body about an axis not only depend upon the mass of the body but also upon the distribution of mass about the axis of rotation.
Inertia represents the capacity (ability) of a body to oppose its state of motion or rest.

Therefore, A is true but R is false.

60. Moment of inertia changes with axis chosen. It is because moment of inertia of a particle depends on its mass and its distance from axis of rotation.

Therefore, A is true but R is false.

61. Angular velocity for a rigid body can be described as the rate of change at which the object rotates about an axis. It is defined for the whole body.

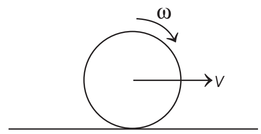
Angular velocity of particle of rigid body is same in rotational motion.

Therefore, both A and R are true but R is not the correct explanation of A.

62. Friction force between sliding body and inclined plane depends upon the nature of surfaces of both the body and inclined plane, hence if bodies slide down an inclined plane without rolling, then it is not necessary that all bodies reach the bottom simultaneously. Acceleration of all bodies are also not equal due to different values of friction between the surfaces of body and inclined plane.

Therefore, A is true but R is false.

63. Sphere can roll without slipping on surface, if $v = r\,\omega$ on an inclined plane, it is friction which creates rotation on sphere. So, smooth surface cannot create rotation.



Therefore, A is false and R is also false.

64. The work done on a body is given by

$W = \int F \cdot v dt$, where F is force of friction.

For the rolling disc without slipping down an inclined plane, the velocity of the particle on which the friction force is acting, is zero. Hence, work done is zero, i.e. when the disc rolls without slipping, the friction force is required because for rolling condition, velocity of point of contact is zero.

Therefore, both A and R are true and R is the correct explanation of A.

65. Centre of mass of a system of two particles is

Then, $r_{CM} = \dfrac{m_1 r_1 + m_2 r_2}{m_1 + m_2}$

If $m_1 + m_2 = M$ = total mass of the particles,

then $r_{CM} = \dfrac{m_1 r_1 + m_2 r_2}{M}$

$\therefore \quad r_{CM} \propto 1/M$

So, the above relation clearly shows that the centre of mass of a system of two particles divide the distance between them in inverse ratio of masses of particles.

66. Let the coordinates of the centre of mass be (x, y).

$$\therefore \quad x = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$$

$$= \frac{1 \times (-1) + 2 \times 2}{3} = \frac{-1 + 4}{3} = 1$$

$$y = \frac{m_1 y_1 + m_2 y_2}{m_1 + m_2}$$

$$= \frac{1 \times 2 + 2 \times 4}{3} = \frac{2 + 8}{3} = \frac{10}{3}$$

Therefore, the coordinates of centre of mass be $\left(1, \dfrac{10}{3}\right)$.

67. As the balls were initially at rest and the forces of attraction are internal, then their centre of mass (CM) will always remain at rest.

So, $v_{CM} = 0$

As CM is at rest, they will meet at CM. Hence, they will meet at $l/2$ from any initial positions.

68. For a single particle, distance of centre of mass from origin is R. For more than one particles, distance $\leq R$.

69. As per the question, two particles A and B are initially at rest, move towards each other under a mutual force of attraction. It means that, no external force is applied on the system. Therefore, $F_{ext} = 0$.

So, there is no acceleration of CM. This means velocity of the CM remain constant.

As, initial velocity of CM, $v_i = 0$ and final velocity of CM, $v_f = 0$.

So, the speed of centre of mass of the system will be zero.

70. The tip of the pencil provides a vertically upward force due to which the cardboard is in equilibrium. As shown in given figure, the reaction of the tip is equal and opposite to Mg, the total weight of the cardboard, i.e. $R = Mg$.

71. Net τ due to all the forces of gravity $m_1 g, m_2 g, \cdots, m_n g$ about CG is zero.

τ of reaction $\mathbf{R}$ about CG is also zero as it is at CG.

Point G is the centre of gravity of the cardboard and it is so located that the total torque on it due to forces $m_1\mathbf{g}, m_2\mathbf{g}, \ldots, m_n\mathbf{g}$ is zero.

It means, $\tau_g = \Sigma \tau_i$

$$= \Sigma \mathbf{r}_i \times m_i \mathbf{g} = 0.$$

72. As, $\tau_g = \Sigma \mathbf{r}_i \times m_i \mathbf{g}$

(τ_g = total gravitational torque)

$\Sigma \mathbf{r}_i \times m_i \mathbf{g} = 0$

If g is constant,

$$(\Sigma m_i \mathbf{r}_i) \times \mathbf{g} = \mathbf{g}\, \Sigma m_i \mathbf{r}_i$$

As $\mathbf{g} \neq 0$, so $\Sigma m_i \mathbf{r}_i = 0$

It is the condition where the centre of mass (CM) of the body lies at origin and here origin is considered at centre of gravity (CG), when g is constant.

73. If the value of g varies, then CM and CG will not coincide. Keep in mind that, CG and CM both are two different concepts. CM has nothing to do with CG.

74. A body in a gravitational field will be in stable equilibrium, if the vertical line through CG passes from the base of the body.

75. Moment of inertia of a body depends on position and orientation of the axis of rotation with respect to the body.

76. Perpendicular distance from Z-axis would be

$\sqrt{(1)^2 + (1)^2} = \sqrt{2}$ m

$\therefore\ I = Mr^2 = (1)(\sqrt{2})^2 = 2$ kg-m^2

77. Initial moment of inertia, $I = \dfrac{ml^2}{3}$

New moment of inertia,

$$I' = \frac{(3m/4)(3l/4)^2}{3} = \frac{27}{64}\left(\frac{ml^2}{3}\right) = \frac{27}{64} I$$

78. A circular disc is made up of larger number of circular rings.

Moment of inertia of a circular ring in given by

$$I = MR^2$$

$$\Rightarrow \quad I \propto M$$

Since, mass is proportional to the density of material. The density of iron is more than that of aluminium. Hence to get maximum value of I, the less dense material should be used at interior and denser at the surrounding.

Therefore, using aluminium at the interior and iron at its surrounding will maximise the moment of inertia.

79. Moment of inertia of the rod lying along Z-axis will be zero. Moment of inertia of the rods along X and Y-axes will be $\dfrac{ML^2}{3}$ each.

Hence, total moment of inertia is $\dfrac{2}{3} ML^2$.

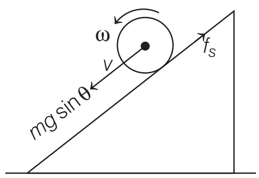
80. The frictional force will reduce v_0, hence translational KE will also decrease.

It will increases ω, which increases its rotational kinetic energy.

There is no torque about the line of contact, angular momentum will remain constant. The frictional force will decrease the mechanical energy.

81. $a = \dfrac{g \sin \theta}{1 + \dfrac{k^2}{R^2}} = \dfrac{g \sin 30^\circ}{1 + \dfrac{1}{2}} \Rightarrow a = \dfrac{g/2}{3/2} = g/3$

82. As we know that,



The direction of f_s will be upwards to provide torque for rolling of sphere.

83. KE of a rolling body = Rotational KE + Translational KE

$$= \frac{1}{2} I\omega^2 + \frac{1}{2} mv_{CM}^2 \qquad \left(\because I = mk^2 \text{ and } v_{CM} = R\omega\right)$$

$$= \frac{1}{2} \frac{m\,k^2 v_{CM}^2}{R^2} + \frac{1}{2} mv_{CM}^2$$

where, k is the corresponding radius of gyration of the body.

$$= \frac{1}{2} mv_{CM}^2 \left(1 + \frac{k^2}{R^2}\right)$$

It applies for any rolling body.

84. When a body rolls down on inclined plane, it is accompanied by rotational and translational kinetic energies.

Rotational kinetic energy $= \dfrac{1}{2} I\omega^2 = K_R$

where, I is the moment of inertia and ω is the angular velocity.

Translational kinetic energy for pure rolling,

$$v_{CM} = r\omega$$

$$= \frac{1}{2} mv_{CM}^2 = K_T = \frac{1}{2} m(r\omega)^2$$

where, m is mass of the body, v_{CM} is the velocity and ω is the angular velocity.

Given,

Translational KE = Rotational KE

$$\therefore \quad \frac{1}{2} m(r^2\omega^2) = \frac{1}{2} I\omega^2$$

$$\Rightarrow \quad I = mr^2$$

We know that, mr^2 is the moment of inertia of hollow cylinder about its axis, where m is the mass of hollow cylindrical body and r is the radius of the cylinder.

08

Gravitation

Quick Revision

1. **Universal Law of Gravitation** It states that, every body in this universe attracts every other body with a force whose magnitude is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

   Gravitational force, $F = G\dfrac{m_1 m_2}{r^2}$

   where, G is a constant of proportionality and is known as **universal gravitational constant**.

   In CGS system, the value of G is 6.67×10^{-8} dyne $cm^2 g^{-2}$ and its SI value is 6.67×10^{-11} $N\text{-}m^2 kg^{-2}$.

   Dimensional formula for G is $[M^{-1}L^3T^{-2}]$.

2. **Vector Form of Newton's Law of Gravitation** In vector notation, Newton's law of gravitation is written as follows

   $$\mathbf{F}_{12} = -G\frac{m_1 m_2}{r_{21}^2}\hat{\mathbf{r}}_{21} \qquad \ldots\text{(i)}$$

   where, $\mathbf{F}_{12}$ = gravitational force exerted on A by B and $\hat{\mathbf{r}}_{21}$ is a unit vector pointing towards A. Negative sign shows that the gravitational force is attractive in nature.

   Similarly, $$\mathbf{F}_{21} = -G\frac{m_1 m_2}{r_{12}^2}\hat{\mathbf{r}}_{12} \qquad \ldots\text{(ii)}$$

   where, $\hat{\mathbf{r}}_{12}$ is a unit vector pointing towards B.

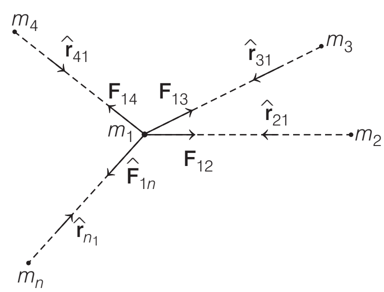
   Equating Eqs. (i) and (ii), we have

   $$\mathbf{F}_{12} = -\mathbf{F}_{21}$$

   As, $\mathbf{F}_{12}$ and $\mathbf{F}_{21}$ are directed towards the centres of the two particles, so gravitational force is a central force.

3. **Principle of Superposition** According to this principle, the resultant gravitational force $\mathbf{F}$ can be expressed in vector addition of all forces, at a point (as shown below).

   i.e. $\mathbf{F} = \mathbf{F}_{12} + \mathbf{F}_{13} + \mathbf{F}_{14} + \ldots + \mathbf{F}_{1n}$



   Resultant force,

   $$\mathbf{F} = -Gm_1\left(\frac{m_2}{r_{21}^2}\hat{\mathbf{r}}_{21} + \frac{m_3}{r_{31}^2}\hat{\mathbf{r}}_{31} + \ldots + \frac{m_n}{r_{n1}^2}\hat{\mathbf{r}}_{n1}\right)$$

4. **Acceleration due to gravity** The acceleration produced in the motion of a body under the effect of gravity is called acceleration due to gravity (g).

   At the surface of the earth, $g = \dfrac{GM}{R^2}$

5. **Weight of a body** It is the gravitational force with which a body is attracted towards the centre of the earth $w = mg$

   It is a vector quantity and its SI unit is newton (N).

6. **Factors Affecting Acceleration Due to Gravity**
   - **Shape of Earth** Acceleration due to gravity,
   $$g \propto \frac{1}{R^2}$$
   Therefore, g is minimum at equator and maximum at poles.
   - **Rotation of Earth about Its Own Axis** If ω is the angular velocity of rotation of earth about its own axis, then acceleration due to gravity at a place having latitude λ is given by
   $$g' = g - R\omega^2 \cos^2 \lambda$$
   At poles, $\lambda = 90°$ and $g' = g$.

     Therefore, there is no effect of rotation of earth about its own axis at poles.

     At equator, $\lambda = 0°$ and $g' = g - R\omega^2$

     The value of g is minimum at equator.

     If earth stops its rotation about its own axis, then g will remain unchanged at poles but increases by $R\omega^2$ at equator.
   - **Effect of Altitude** The value of g at height h from earth's surface,
   $$g' = \frac{g}{\left(1 + \frac{h}{R}\right)^2}$$
   Therefore, g decreases with altitude.
   - **Effect of Depth** The value of g at depth h from earth's surface,
   $$g' = g\left(1 - \frac{h}{R}\right)$$
   Therefore, g decreases with depth from earth's surface.

     The value of g becomes zero at earth's centre.

7. **Intensity of Gravitational Field at a Point** The gravitational force acting per unit mass at any point in gravitational field is called intensity of gravitational field at that point. Intensity of gravitational field at a distance r, from a body of mass M is given as
$$E = \frac{F}{m} = \frac{GM}{r^2}$$
   It is a vector quantity and its direction is towards the centre of gravity.

8. **Gravitational Potential** Gravitational potential at a point in the gravitational field is defined as the amount of work done per unit mass in bringing a body of unit mass from infinity to that point without acceleration.

   i.e. $$V = -\frac{W}{m}$$
$$= -\int \frac{\mathbf{F} \cdot d\mathbf{r}}{m} = -\int \mathbf{E} \cdot d\mathbf{r} = \frac{-GM}{r}$$
   It is a scalar quantity. The unit of gravitational potential in SI system is Jkg^{-1} and in CGS system is erg-g^{-1} .

   Dimensional formula for gravitational potential is $[M^0L^2T^{-2}]$.

   Special Cases
   - When $r = \infty$, then $V = 0$, hence gravitational potential is maximum (zero) at infinity.
   - At surface of the earth $r = R$, then
   $$V = \frac{-GM}{R}$$

9. **Gravitational Potential Energy** Gravitational potential energy of a body at a point is defined as the amount of work done in bringing the given body from infinity to that point against the gravitational force.

   Gravitational potential energy,
$$U = \left(-\frac{GM}{r}\right) \times m$$

10. **Escape Speed** Escape speed on the earth (or any other planet) is defined as the minimum speed with which a body should be projected vertically upwards from the surface

of the earth, so that it just escapes out from gravitational field of the earth and never returns on its own.

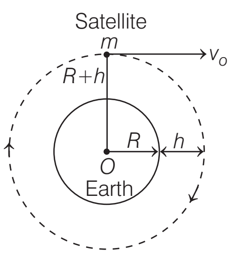
$\therefore$ Escape velocity, $v_e = \sqrt{2gR}$

where, R is the radius of the earth.

Also, escape velocity, $v_e = R\sqrt{\frac{8}{3}\pi G\rho}$

where, ρ is the mean density of the earth.

11. **Earth's Satellites** A satellite is a body which is constantly revolving in an orbit around a comparatively much larger body. e.g. The moon is a natural satellite while INSAT-1B is an artificial satellite of the earth. Condition for establishment of satellite is that the centre of orbit of satellite must coincide with centre of the earth or satellite must move around in greater circle of the earth.
12. **Orbital Velocity of a Satellite** Orbital velocity is the velocity required to put the satellite into its orbit around the earth or a planet.



Mathematically, it is given by $v_o = \sqrt{\frac{GM}{R+h}}$

13. **Energy of an Orbiting Satellite** When a satellite revolves around a planet in its orbit, it possesses both potential energy (due to its position against gravitational pull of the earth) and kinetic energy (due to orbital motion). If m is the mass of the satellite and v is its orbital velocity, then KE of the satellite,

$$K = \frac{1}{2}mv^2 = \frac{1}{2}m\frac{GM}{r} \qquad (\because v = \sqrt{GM/r})$$

$$K = \frac{GMm}{2(R+h)} \qquad (\because r = R+h)$$

PE of the satellite, $U = -mv^2 = -\frac{GMm}{R+h}$

Total mechanical energy of satellite,

$$E = K + U$$

$$E = -\frac{GMm}{2(R+h)}$$

Satellites are always at finite distance from the earth and hence their energies cannot be positive or zero.

14. **Geo-stationary Satellite** These satellites revolves in a circular orbits around the earth in the equatorial plane with period of revolution same as that of earth, i.e. $T = 24$ h and also known as geo-synchronous satellites.
    - It should revolve in an orbit concentric and coplanar with the equatorial plane of earth.
    - These satellites appears stationary due to its law relative velocity w.r.t. that place on earth.
    - It should be at a height around 36000 km.
    - These satellites are used for communication purpose like radio broadcast, TV broadcast, etc.
15. **Polar Satellite** They are low-altitude satellites ($h \approx 500$ to 800 km) which circle in a North-South orbit passing over the North and South poles. It is also known as sun synchronous satellite.
    - The time period is about 100 min.
    - These satellites are used for military purpose.
16. **Weightlessness** A body is said to be in a state of weightlessness when the relation of the supporting surface is zero or its apparent weight is zero. At one particular position, the two gravitational pulls may be equal & opposite and the net pull on the body becomes zero. This is zero gravity region or the null point where the body is said to be weightless.

    The state of weightlessness can be observed in the following situations
    - When objects fall freely under gravity.
    - When a satellite revolves in its orbit around the earth.
    - When bodies are at null points in outer space.

Objective Questions

Multiple Choice Questions

1. The force of gravitation is

(a) repulsive (b) electrostatic
(c) conservative (d) non-conservative

2. Newton's law of gravitation is universal because

(a) it acts on all bodies in the universe
(b) it acts on all the masses at all distances and not affected by the medium
(c) it is a attractive force
(d) it acts only when bodies are in contact

3. Both the earth and the moon are subject to the gravitational force of the sun. As observed from the sun, the orbit of the moon *(NCERT Exemplar)*

(a) will be elliptical
(b) will not be strictly elliptical because the total gravitational force on it is not central
(c) is not elliptical but will necessarily be a closed curve
(d) deviates considerably from being elliptical due to influence of planets other than the earth

4. Two sphere of masses m and M are situated in air and the gravitational force between them is F. The space around the masses is now filled with a liquid of specific gravity. The gravitational force will now be

(a) F (b) $\frac{F}{3}$
(c) $\frac{F}{9}$ (d) $3F$

5. A mass of 1g is separated from another mass of 1g by a distance of 1 cm. How many force (in g-wt) exists between them?

(a) 7×10^{-11} g-wt (b) 7×10^{11} g-wt
(c) 9×10^{-11} g-wt (d) 9×10^{11} g-wt

6. If the distance between the sun and the earth is increased by three times, then attraction between two will

(a) remain constant (b) decrease by 63%
(c) increase by 63% (d) decrease by 89%

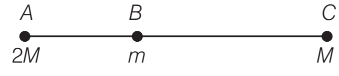
7. If the gravitation force on body 1 due to 2 is given by $\mathbf{F}_{12}$ and on body 2 due to 1 is given as $\mathbf{F}_{21}$, then

(a) $F_{12} = F_{21}$
(b) $F_{12} = -F_{21}$
(c) $F_{12} = \frac{F_{21}}{4}$
(d) None of the above

8. Two equal point masses are separated by a distance d_1. The force of gravitation acting between them is F_1. If the separation is decreased to d_2, then the new force of gravitation F_2 is given by

(a) $F_2 = F_1$ (b) $F_2 = F_1\left(\frac{d_1}{d_2}\right)^2$
(c) $F_2 = F_1\left(\frac{d_2}{d_1}\right)^2$ (d) $F_2 = F_1\left(\frac{d_1}{d_2}\right)$

9. Particles of masses $2M$, m and M are respectively at points A, B and C with $AB = \frac{1}{2}(BC)$, m is much-much smaller than M and at time $t = 0$, they are all at rest as given in figure. At subsequent times before any collision takes place. *(NCERT Exemplar)*



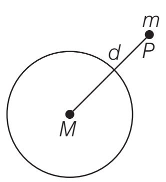
(a) m will remain at rest
(b) m will move towards M
(c) m will move towards $2M$
(d) m will have oscillatory motion

10. Two particles of equal masses go round a circle of radius R under the action of their mutual gravitational attraction. The speed v of each particle is

(a) $\sqrt{\left(\frac{GM}{2R}\right)}$ (b) $\frac{1}{2R}\sqrt{\left(\frac{1}{GM}\right)}$

(c) $\frac{1}{2}\sqrt{\left(\frac{GM}{R}\right)}$ (d) $\sqrt{\left(\frac{4GM}{R}\right)}$

11. A point mass m is placed outside a hollow spherical shell of mass M and uniform density at a distance d from centre of the sphere as shown in figure. Gravitational force on point mass m at P is



(a) $\frac{GmM}{d^2}$ (b) zero

(c) $\frac{2\,GmM}{d^2}$ (d) Data insufficient

12. Three equal masses of 2 kg each are placed at the vertices of an equilateral triangle and a mass of 4 kg is placed at the centroid of the triangle which is at a distance of $\sqrt{2}$ m from each of the vertices of the triangle. The force (in newton) acting on the mass of 4 kg is

(a) 2 (b) $\sqrt{2}$ (c) 1 (d) zero

13. During the free fall of an object,

(a) acceleration due to gravity is zero
(b) force on object is zero
(c) force on object decreases with height
(d) acceleration due to gravity is 9.8 m/s^2

14. What will happen to the weight of the body at the south-pole, if the earth stops rotating about its polar axis?

(a) No change
(b) Increases
(c) Decreases but not become zero
(d) Reduces to zero

15. If G is universal gravitational constant and g is acceleration due to gravity, then the unit of the quantity $\frac{G}{g}$ is

(a) kg-m^2 (b) kgm^{-1}
(c) kgm^{-2} (d) $m^2\ kg^{-1}$

16. The earth is an approximate sphere. If the interior contained matter which is not of the same density everywhere, then on the surface of the earth, the acceleration due to gravity *(NCERT Exemplar)*

(a) will be directed towards the centre but not the same everywhere
(b) will have the same value everywhere but not directed towards the centre
(c) will be same everywhere in magnitude directed towards the centre
(d) cannot be zero at any point

17. The height at which the weight of a body becomes 1/16th of its weight, on the surface of the earth (radius R), is

(a) 5R (b) 15 R
(c) 3 R (d) 4 R

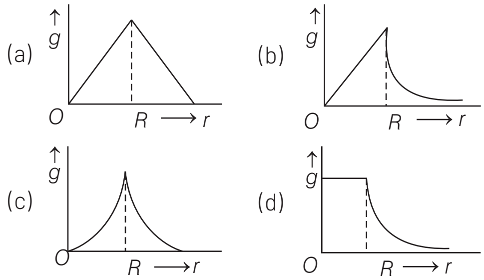
18. The radius of earth is R. Height of a point vertically above the earth's surface at which acceleration due to gravity becomes 1% of its value at the surface is

(a) 8 R (b) 9 R
(c) 10 R (d) 20 R

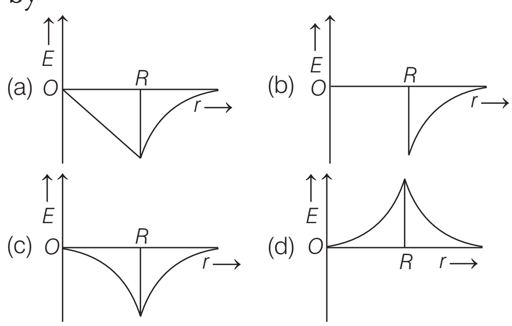
19. What will be the value of g at the bottom of sea 7 km deep? Diameter of the earth is 12800 km and g on the surface of the earth is 9.8 ms^{-2}.

(a) 9.789 m/s^2 (b) 9.259 m/s^2
(c) 97.89 m/s^2 (d) 0.987 m/s^2

20. Starting from the centre of the earth having radius R, the variation of g (acceleration due to gravity) is shown by which of the following option ?



21. Dependence of intensity of gravitational field (E) of earth with distance (r) from centre of earth is correctly represented by



22. A thin rod of length L is bent to form a semicircle. The mass of rod is M. What will be the gravitational potential at the centre of the circle?

(a) $-\frac{GM}{L}$ (b) $-\frac{GM}{2\pi L}$
(c) $-\frac{\pi GM}{2L}$ (d) $-\frac{\pi GM}{L}$

23. A particle is kept on the surface of a uniform sphere of mass 100 kg and radius 10 cm. Find the work to be done per unit mass against the gravitational force between them, to take the particle far away from the sphere (you may take $h = 6.67 \times 10^{-11}$ $\text{Nm}^2\text{kg}^{-2}$).

(a) 13.34×10^{-10} J (b) 3.33×10^{-10} J
(c) 6.67×10^{-9} J (d) 6.67×10^{-8} J

24. The gravitational potential energy of a system consisting two particles separated by a distance r is

(a) directly proportional to product of the masses of particles
(b) inversely proportional to the separation between them
(c) independent of distance r
(d) Both (a) and (b)

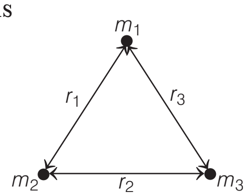
25. The mass of the earth is 6.00×10^{24} kg and that of the moon is 7.40×10^{22} kg. The constant of gravitation $G = 6.67 \times 10^{-11}$ N-m^{2}kg^{-2}. The potential energy of the system is -7.79×10^{28} J. The mean distance between the earth and the moon is

(a) 3.80×10^8 m (b) 3.37×10^6 m
(c) 7.60×10^4 m (d) 1.90×10^2 m

26. Two point masses m_1 and m_2 are separated by a distance r. The gravitational potential energy of the system is G_1. When the separation between the particles is doubled, the gravitational potential energy is G_2. Then, the ratio of $\frac{G_1}{G_2}$ is

(a) 1 (b) 2 (c) 3 (d) 4

27. Gravitational potential energy of a system of particles as shown in the figure is



(a) $\frac{Gm_1m_2}{r_1} + \frac{Gm_2m_3}{r_3} + \frac{Gm_1m_3}{r_3}$

(b) $\left(\frac{-Gm_1m_2}{r_1}\right) + \left(\frac{-Gm_2m_3}{r_2}\right) + \left(\frac{-Gm_1m_3}{r_3}\right)$

(c) $\frac{-Gm_1m_2}{r_1} - \frac{Gm_2m_3}{r_2} + \frac{Gm_1m_3}{r_3}$

(d) $\frac{Gm_1m_2}{r_1} + \frac{Gm_2m_3}{r_2} - \frac{Gm_1m_3}{r_3}$

28. Escape velocity of a body on the surface of earth is independent of

(a) mass
(b) radius of earth
(c) direction of projection of body
(d) Both (a) and (c)

29. An object is thrown from the surface of the moon. The escape speed for the object is

(a) $\sqrt{2g' R_m}$, where g' = acceleration due to gravity on the moon and R_m = radius of the moon
(b) $\sqrt{2g' R_e}$, where g' = acceleration due to gravity on the moon and R_e = radius of the earth
(c) $\sqrt{2gR_m}$, where g = acceleration due to gravity on the earth and R_m = radius of the moon
(d) None of the above

30. A body is projected vertically upwards from the surface of a planet of radius R with a velocity equal to 1/3rd of the escape velocity for the planet. The maximum height attained by the body is

(a) $R/2$ (b) $R/3$
(c) $R/5$ (d) $R/9$

31. Two planets A and B have the same material density. If the radius of A is twice that of B, then the ratio of escape velocity $\frac{v_A}{v_B}$ is

(a) 2 (b) $\sqrt{2}$
(c) $\frac{1}{\sqrt{2}}$ (d) $\frac{1}{2}$

32. Escape velocity on earth is 11.2 kms^{-1}, what would be the escape velocity on a planet whose mass is 1000 times and radius is 10 times that of earth?

(a) 112 kms^{-1} (b) 11.2 kms^{-1}
(c) 1.12 kms^{-1} (d) 3.7 kms^{-1}

33. The time period of a satellite in a circular orbit around a planet is independent of

(a) the mass of the planet
(b) the radius of the planet
(c) the mass of the satellite
(d) All the three parameters (a), (b) and (c)

34. Satellites orbiting the earth have finite life and sometimes debris of satellites fall to the earth. This is because *(NCERT Exemplar)*

(a) the solar cells and batteries in satellites run out
(b) the laws of gravitation predict a trajectory spiralling inwards
(c) of viscous forces causing the speed of satellite and hence height to gradually decrease
(d) of collisions with other satellites

35. An artificial satellite is revolving around the earth, close to its surface. Find the orbital velocity of artificial satellite? (Take, radius of earth = 6400 km)

(a) 7.2 km/s (b) 7.9 km/s
(c) 11.2 km/s (d) 9.5 km/s

36. Two satellites A and B go around a planet P in circular orbits having radius $4R$ and R, respectively. If the speed of satellite A is $3v$, then the speed of satellite B will be

(a) $6v$
(b) $9v$
(c) $3v$
(d) None of the above

37. An artificial satellite moving in a circular orbit around the earth has a total (kinetic + potential) energy E_0. Its potential energy and kinetic energy respectively are

(a) $2E_0$ and $-2E_0$ (b) $-2E_0$ and E_0
(c) $2E_0$ and $-E_0$ (d) $-2E_0$ and $-E_0$

38. The kinetic energy of the satellite in a circular orbit with speed v is given as

(a) $KE = \frac{-GmM_e}{2(R_e + h)}$ (b) $KE = \frac{GmM_e}{(R_e + h)}$

(c) $KE = \frac{GmM_e}{2(R_e + h)}$ (d) $KE = -\frac{1}{2}mv^2$

39. The time period of geo-stationary satellite is

(a) 6 h (b) 12 h (c) 24 h (d) 48 h

40. Geo-stationary satellites are placed in equatorial orbits at the height approximately

(a) 1000 km (b) 15000 km
(c) 25000 km (d) 36000 km

41. An astronaut experiences weightlessness in a space satellite. It is because

(a) the gravitational force is small at that location in space.
(b) the gravitational force is large at that location in space.
(c) the astronaut experiences no gravity
(d) the gravitational force is infinitely large at that location in space.

42. A pendulum beats sounds on the earth. Its time period on a stationary satellite of the earth will be

(a) zero (b) 1s
(c) 2s (d) infinity

43. …… is defined to be numerically equal to the force of attraction between two bodies each of mass 1 kg and separated by a distance of 1 m.

(a) Universal gravitational constant (G)
(b) Gravity (g)
(c) Force (F)
(d) Magnetic field (B)

44. Weight of a body is maximum at ……… .

(a) poles (b) equator
(c) centre of earth (d) at latitude 45°

45. The ratio of the magnitude of potential energy and kinetic energy of a satellite is ……… .

(a) 1:2 (b) 2:1
(c) 3:1 (d) 1:3

46. Weightlessness experienced while orbiting the earth in spaceship, is the result of ……… .

(a) inertia
(b) acceleration
(c) zero gravity
(d) centre of gravity

47. Which of the following statement is incorrect? *(NCERT Exemplar)*

(a) Acceleration due to gravity decreases with increasing altitude.
(b) Acceleration due to gravity increases with increasing depth (assume the earth to be a sphere of uniform density).
(c) Acceleration due to gravity increases with increasing altitude.
(d) None of the above

48. If the gravitational attraction of earth suddenly disappears, then which of the following statement is correct?

(a) Both masses as well as the weight will be zero.
(b) Weight of the body will become zero but the mass will remain unchanged.
(c) Weight of the body will remain unchanged but the mass will become zero.
(d) Neither mass nor weight will be zero.

49. Study the following statements and choose the incorrect option.

I. G is not equal to $6.67 \times 10^{-11} \text{Nm}^{-2}\text{kg}^{-2}$ on the surface of earth.

II. The escape velocity on the surface of earth is lesser than the escape velocity from moon's surface.

III. The angular momentum of a satellite going around the earth remains conserved.

IV. The relation, $g = \frac{GM}{r^2}$ holds good for all the celestial bodies.

(a) Only I (b) Only III
(c) Both I and II (d) Both II and IV

50. Which of the following statement is correct? *(NCERT Exemplar)*

(a) A polar satellite goes around the earth's pole in north-south direction.
(b) A geo-stationary satellite goes around the earth in east-west direction.
(c) A geo-stationary satellite goes around the earth in north-south direction.
(d) A polar satellite goes around the earth in east-west direction.

51. Match the Column I (quantities) with Column II (approximate values) and select the correct answer from the codes given below.

	Column I		Column II
A.	Escape velocity of earth	p.	$1.6\ m/s^2$
B.	Gravitational acceleration at moon's surface	q.	6400 km
C.	Radius of earth	r.	11.2 km/s

Codes

	A	B	C
(a)	p	q	r
(b)	r	q	p
(c)	q	p	r
(d)	r	p	q

52. A satellite of mass m revolving with a velocity v around the earth. With reference to the above situation, match the Column I (types of energy) with Column II (expression) and select the correct answer from the codes given below.

	Column I		Column II
A.	Kinetic energy of the satellite	p.	$-\frac{1}{2}mv^2$
B.	Potential energy of the satellite	q.	$\frac{1}{2}mv^2$
C.	Total energy of the satellite	r.	$-mv^2$

Codes

	A	B	C
(a)	p	q	r
(b)	q	r	p
(c)	r	q	p
(d)	r	p	q

Assertion-Reasoning MCQs

For question numbers 53 to 66, two statements are given-one labelled ***Assertion*** *(A) and the other labelled* ***Reason*** *(R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

53. **Assertion** Newton's law of universal gravitation states that a particle attracts every other particle in the universe using a force of attraction that is directly proportional to the product of their masses and inversely proportional to the square of distance between them.

Reason Law of gravitation is analogous to magnetic force between the moving charges.

54. **Assertion** The value of acceleration due to gravity does not depend upon mass of the body on which force is applied.

Reason Acceleration due to gravity is a variable quantity.

55. **Assertion** As we go up the surface of the earth, we feel light weighed than on the surface of the earth.

Reason The acceleration due to gravity decreases on going up above the surface of the earth.

56. **Assertion** Work done by or against gravitational force in moving a body from one point to another is independent of the actual path followed between the two points.

Reason This is because gravitational forces are conservative in nature.

57. **Assertion** If gravitational potential at some point is positive, then the gravitational field strength at that point will also be zero.

Reason Except at infinity gravitational potential due to a system of point masses at some finite distance cannot be negative.

58. **Assertion** The force of attraction between a hollow spherical shell of uniform density and a point mass situated inside it, is zero.

Reason The value of G does not depend on the nature and size of the masses.

59. **Assertion** Moon has no atmosphere.

Reason The escape speed for the moon is much smaller.

60. **Assertion** The escape velocity for a planet is $v_e = \sqrt{2gR}$. If the radius of the planet is four times, the escape velocity becomes half (i.e. $v_e' = \frac{v_e}{2}$).

Reason In the relation for escape velocity, $v_e = \sqrt{2gR}$, the acceleration due to gravity g is inversely proportional to radius of the planet. Thus, $v_e \propto \frac{1}{\sqrt{R}}$.

61. **Assertion** The velocity of the satellite increases as its height above earth's surface increases and is minimum near the surface of the earth.

Reason The velocity of the satellite is directly proportional to square root of its height above earth's surface.

62. **Assertion** A satellite moves around the earth in a circular orbit under the action of gravity. A person in the satellite experience zero gravity field in the satellite.

Reason The contact force by the surface on the person is not zero.

63. **Assertion** The total energy of the satellite is always negative irrespective of the nature of its orbit, i.e. elliptical or circular and it cannot be positive or zero.

Reason If the total energy is negative the satellite would leave its orbit.

64. **Assertion** The geo-stationary satellite goes around the earth in west-east direction.

Reason Geo-stationary satellites orbits around the earth in the equatorial plane with $T = 24$ h same as that of the rotation of the earth around its axis.

65. **Assertion** In the satellite, everything inside it is in a state of free fall.

Reason Every part and parcel of the satellite has zero acceleration.

66. **Assertion** An object is weightless when it is in free fall and this phenomenon is called weightlessness.

Reason In free fall, there is upward force acting on the object.

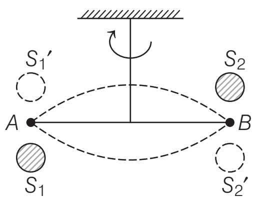
Case Based MCQs

Direction *Answer the questions from 67-71 on the following case.*

Cavendish's Experiment

The figure shows the schematic drawing of Cavendish's experiment to determine the value of the gravitational constant. The bar *AB* has two small lead spheres attached at its ends. The bar is suspended from a rigid support by a fine wire.

Two large lead spheres are brought close to the small ones but on opposite sides as shown. The value of *G* from this experiment came to be $6.67 \times 10^{-11} \text{ N-m}^2/\text{kg}^2$.



67. The big spheres attract the nearby small ones by a force which is
(a) equal and opposite
(b) equal but in same direction
(c) unequal and opposite
(d) None of the above

68. The net force on the bar is
(a) non-zero (b) zero
(c) Data insufficient (d) None of these

69. The net torque on the bar is
(a) zero
(b) non-zero
(c) *F* times the length of the bar, where *F* is the force of attraction between a big sphere and its neighbouring
(d) Both (b) and (c)

70. The torque produces twist in the suspended wire. The twisting stops when
(a) restoring torque of the wire equals the gravitational torque
(b) restoring torque of the wire exceeds the gravitational torque
(c) the gravitational torque exceeds the restoring torque of the wire
(d) None of the above

71. After Cavendish's experiment, there have been given suggestions that the value of the gravitational constant *G* becomes smaller when considered over very large time period (in billions of years) in the future. If that happens, for our earth,
(a) nothing will change
(b) we will become hotter after billions of years
(c) we will be going around but not strictly in closed orbits
(d) None of the above

Direction *Answer the questions from 72-76 on the following case.*

Acceleration due to gravity

The acceleration for any object moving under the sole influence of gravity is known as acceleration due to gravity. So, for an object of mass *m*, the acceleration experienced by it is usually denoted by the symbol *g* which is related to *F* by Newton's second law by relation $F = mg$. Thus,

$$g = \frac{F}{m} = \frac{GM_e}{R_e^2}$$

Acceleration *g* is readily measurable as R_e is a known quantity. The measurement of *G* by Cavendish's experiment (or otherwise), combined with knowledge of *g* and R_e enables one to estimate M_e from the above equation. This is the reason why there is a popular statement regarding Cavendish "Cavendish weighed the earth". The value of *g* decrease as we go upwards from the earth's surface or downwards, but it is maximum at its surface.

72. If g is the acceleration due to gravity at the surface of the earth, the force acting on the particle of mass m placed at the surface is

(a) mg (b) $\frac{GmM_e}{R_e^2}$

(c) Data insufficient (d) Both (a) and (b)

73. The weight of a body at the centre of earth is

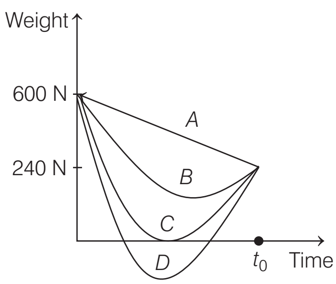
(a) same as on the surface of earth
(b) same as on the poles
(c) same as on the equator
(d) None of the above

74. If the mass of the sun is ten times smaller and gravitational constant G is ten times larger in magnitude, then for earth,

(a) walking on ground would become more easy
(b) acceleration due to gravity on the earth will not change
(c) raindrops will fall much slower
(d) airplanes will have to travel much faster

75. Suppose, the acceleration due to gravity at the earth's surface is 10 ms^{-2} and at the surface of mars, it is 4.0 ms^{-2}. A 60 kg passenger goes from the earth to the mars in a spaceship moving with a constant velocity. Neglect all other objects in the sky.

Which curve best represents the weight (net gravitational force) of the passenger as a function of time?



(a) A (b) B (c) C (d) D

76. If the mass of the earth is doubled and its radius halved, then new acceleration due to the gravity g' is

(a) $g' = 4g$ (b) $g' = 8g$
(c) $g' = g$ (d) $g' = 16g$

Direction *Answer the questions from 77-81 on the following case.*

Earth's Satellite

Earth satellites are objects which revolve around the earth. Their motion is very similar to the motion of planets around the Sun. In particular, their orbits around the earth are circular or elliptic. Moon is the only natural satellite of the earth with a near circular orbit with a time period of approximately 27.3 days which is also roughly equal to the rotational period of the moon about its own axis. Also, the speed that a satellite needs to be travelling to break free of a planet or moon's gravity well and leave it without further propulsion is known as escape velocity. For example, a spacecraft leaving the surface of earth needs to be going 7 miles per second or nearly 25000 miles per hour to leave without falling back to the surface or falling into orbit.

77. Gas escapes from the surface of a planet because it acquires an escape velocity. The escape velocity will depend on which of the following factors?

(a) Mass of the planet
(b) Mass of the particle escaping
(c) Temperature of the planet
(d) None of the above

78. The escape velocity of a satellite from the earth is v_e. If the radius of earth contracts to $(1/4)$th of its value, keeping the mass of the earth constant, escape velocity will be

(a) doubled
(b) halved
(c) tripled
(d) unaltered

79. The ratio of escape velocity at earth (v_e) to the escape velocity at a planet (v_p), whose radius and mean density are twice as that of earth is

(a) $1:2\sqrt{2}$ (b) 1: 4
(c) $1:\sqrt{2}$ (d) 1: 2

80. A satellite S is moving in an elliptical orbit around the earth. The mass of the satellite is very small as compared to the mass of the earth, then

(a) the angular momentum of S about the centre of the earth changes in direction, but its magnitude remains constant
(b) the total mechanical energy of S varies periodically with time
(c) the linear momentum of S remains constant in magnitude
(d) the acceleration of S is always directed towards the centre of the earth

81. The orbital velocity of an artificial satellite in a circular orbit just above the earth's surface is v_o. The orbital velocity of a satellite orbiting at an altitude of half of the radius, is

(a) $\frac{3}{2}v_o$ (b) $\frac{2}{3}v_o$ (c) $\sqrt{\frac{3}{2}}v_o$ (d) $\sqrt{\frac{2}{3}}v_o$

ANSWERS

Multiple Choice Questions

1. (c)	2. (b)	3. (b)	4. (a)	5. (a)	6. (d)	7. (b)	8. (b)	9. (c)	10. (c)
11. (a)	12. (d)	13. (d)	14. (a)	15. (d)	16. (d)	17. (c)	18. (b)	19. (a)	20. (b)
21. (a)	22. (d)	23. (d)	24. (d)	25. (a)	26. (b)	27. (b)	28. (d)	29. (a)	30. (d)
31. (a)	32. (a)	33. (c)	34. (c)	35. (b)	36. (a)	37. (c)	38. (c)	39. (c)	40. (d)
41. (c)	42. (d)	43. (a)	44. (a)	45. (b)	46. (c)	47. (b)	48. (b)	49. (c)	50. (a)
51. (d)	52. (b)								

Assertion-Reasoning MCQs

53. (c)	54. (a)	55. (a)	56. (a)	57. (d)	58. (b)	59. (a)	60. (a)	61. (d)	62. (c)
63. (c)	64. (a)	65. (c)	66. (c)						

Case Based MCQs

67. (a)	68. (b)	69. (d)	70. (a)	71. (c)	72. (d)	73. (d)	74. (d)	75. (c)	76. (b)
77. (a)	78. (a)	79. (a)	80 (d)	81. (d)					

SOLUTIONS

1. As the work done by the gravitational force F in closed path is zero. So, it is conservative in nature, i.e. work done by the body is independent of path followed.

2. According to universal law of gravitation, gravitational force is given by

$$F = \frac{Gm_1m_2}{r^2}$$

It depends on all the masses at all distances but does not depend on medium between them.

3. As observed from the sun, two types of forces are acting on the moon one is due to gravitational attraction between the sun and the moon and the other is due to gravitational attraction between the earth and the moon. Therefore, total force on the moon is not central.
Hence, the orbit of the moon will not be strictly elliptical.

4. Gravitational force does not depend on the medium between masses.

So, it will remains same, i.e. F.

5. Gravitational force is given by

$$F = G\frac{m_1 m_2}{r^2}$$

$$= (6.67\times 10^{-8})\left(\frac{1\times 1}{1^2}\right) \text{ dyne}$$

$$= 6.67\times 10^{-8} \text{ dyne} = \frac{6.67\times 10^{-8}}{980} \text{ g-wt}$$

$$\left(\because 1 \text{ dyne} = \frac{1}{980} \text{ g-wt}\right)$$

$$= 7\times 10^{-11} \text{ g-wt}$$

6. As we know, $F = \frac{Gm_1 m_2}{r^2}$

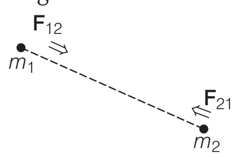
If distance increased by 3 times, then gravitational force is given by

$$F' = \frac{Gm_1 m_2}{(3r)^2} = \frac{F}{9}$$

Per cent decrease in force $= \left(\frac{F - F'}{F}\right)\times 100$

$$= \frac{8}{9}\times 100 = 88.88\% \simeq 89\%$$

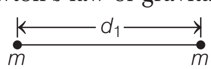
7. Since, gravitational forces are attractive, $\mathbf{F}_{12}$ is directed opposite to $\mathbf{F}_{21}$ and they are also equal in magnitude.



Hence, $\mathbf{F}_{21} = -\mathbf{F}_{12}$

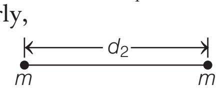
or $\mathbf{F}_{12} = -\mathbf{F}_{21}$

8. From Newton's law of gravitation,



$$F_1 = \frac{Gm\cdot m}{d_1^2} = \frac{Gm^2}{d_1^2} \quad \ldots\text{(i)}$$

Similarly,



$$F_2 = \frac{Gm^2}{d_2^2} \quad \ldots\text{(ii)}$$

From Eqs. (i) and (ii), we get

$$\frac{F_1}{F_2} = \left(\frac{d_2}{d_1}\right)^2$$

$$\therefore \quad F_2 = F_1\left(\frac{d_1}{d_2}\right)^2$$

9. Force on B due to A, $F_{BA} = \frac{G(2Mm)}{(AB)^2}$ (towards BA)

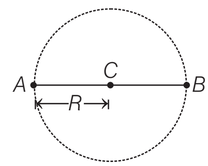
Force on B due to C, $F_{BC} = \frac{GMm}{(BC)^2}$ (towards BC)

As, $BC = 2AB$ (given)

$$\Rightarrow \quad F_{BC} = \frac{GMm}{(2AB)^2} = \frac{GMm}{4(AB)^2} < F_{BA}$$

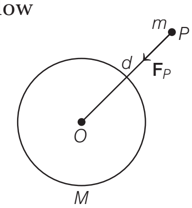
Hence, m will move towards BA, i.e. $2M$.

10. Two particles A and B each of mass m move in a circular path of radius R. Then, gravitational force between them provides the necessary centripetal force,



i.e. $\frac{mv^2}{R} = \frac{GMm}{(2R)^2} \Rightarrow v = \frac{1}{2}\sqrt{\left(\frac{GM}{R}\right)}$

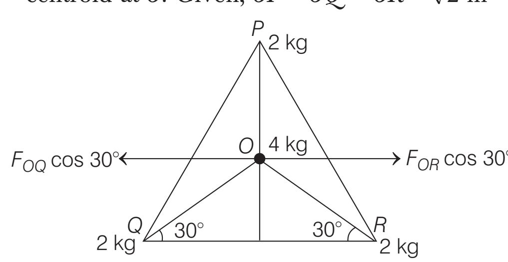
11. For a point outside the spherical shell as shown below



According to Newton's gravitational law, gravitational force on point mass m at P is

$$|\mathbf{F}_P| = \frac{GmM}{d^2}$$

12. Consider the equilateral triangle as PQR with centroid at O. Given, $OP = OQ = OR = \sqrt{2}$ m



The gravitational force on mass 4 kg due to mass 2 kg at point P is

$$F_{OP} = G\frac{4\times 2}{(\sqrt{2})^2} = 4\,G, \text{ along } OP$$

Similarly, $F_{OQ} = G\frac{4\times 2}{(\sqrt{2})^2} = 4\,G$, along OQ

and $F_{OR} = G\frac{4\times 2}{(\sqrt{2})^2} = 4\,G$, along OR

$F_{OQ}\cos 30^\circ$ and $F_{OR}\cos 30^\circ$ are equal and acting in opposite directions, hence cancel out each other. Then, the resultant force on the mass 4 kg at point O, $F = 0$ (zero).

13. Force on the object is given by $F = \frac{Gm_1m_2}{r^2}$

It is not zero under free fall. As, the height decreases, force will increases on object. The acceleration due to gravity is constant and equal to 9.8 m/s^2 during the free fall.

14. As, weight of the body at pole is mg and g is not affected by the rotation of earth at poles. So, there is no change in weight of body.

15. As, we know, $g = \frac{GM}{R^2}$ or $\frac{G}{g} = \frac{R^2}{M}$

Hence, the unit of the quantity $\frac{G}{g} = \frac{\text{m}^2}{\text{kg}}$

16. If we assume the earth as a sphere of uniform density, then it can be treated as point mass placed at its centre. In this case, acceleration due to gravity $g = 0$, at the centre.

It is not so, if the earth is considered as a sphere of non-uniform density, in that case value of g will be different at different points and cannot be zero at any point.

17. According to the question,

$$\frac{GMm}{(R+h)^2} = \frac{1}{16}\frac{GMm}{R^2}$$

where, m = mass of the body

and $\frac{GM}{R^2}$ = gravitational acceleration.

So, $\frac{1}{(R+h)^2} = \frac{1}{16R^2}$

or $\frac{R}{R+h} = \frac{1}{4}$ or $\frac{R+h}{R} = 4$

$$h = 3R$$

18. Given, $g' = \left(\frac{1}{100}\right)g$ or $g'/g = \frac{1}{100}$

For height h above the surface of the earth,

$$g' = g\left(\frac{R}{R+h}\right)^2 \Rightarrow \frac{g'}{g} = \left(\frac{R}{R+h}\right)^2$$

$$\Rightarrow \left(\frac{1}{100}\right) = \left(\frac{R}{R+h}\right)^2 \Rightarrow \frac{R}{R+h} = \frac{1}{10}$$

$$\therefore \quad h = 10R - R = 9\,R$$

19. Given, depth of sea, $d = 7$ km and $g = 9.8$ ms^{-2}

Radius of the earth,

$$R = \frac{D}{2} = \frac{12800}{2}\text{ km} = 6400\text{ km}$$

Value of g at bottom of sea, $g_d = g\left(1-\frac{d}{R}\right)$

$$= 9.8\left(1-\frac{7}{6400}\right) = \frac{9.8\times 6393}{6400}$$

$$= 9.789\text{ m/s}^2$$

20. Acceleration due to gravity at a depth d below the surface of the earth is given by

$$g_{\text{depth}} = g_{\text{surface}}\left(1-\frac{d}{R}\right)$$

$$= g_{\text{surface}}\left(\frac{R-d}{R}\right) = g_{\text{surface}}\left(\frac{r}{R}\right)$$

Also, for a point at height h above surface,

$$g_{\text{height}} = g_{\text{surface}}\left[\frac{R^2}{(R+h)^2}\right]$$

Therefore, we can say that value of g increases from centre to maximum at the surface and then decreases as depicted in graph (b).

21. Dependence of gravitational field (E) with distance is depicted properly in option (a) because at centre $r = 0$,

$$\therefore \quad E = 0$$

For a point outside the earth $(r > R)$,

$$E = -\frac{GM}{r^2} \Rightarrow E \propto \frac{1}{r^2}$$

and at the surface of earth $(r = R)$,

$$E = -\frac{GM}{R^2}$$

Inside the earth $(r < R)$,

$$E = -\frac{GMr}{R^3} \Rightarrow E \propto r$$

22. Since, length if rod is equal to the circumference of semicircle

$$\pi R = L \Rightarrow R = \frac{L}{\pi}$$

Therefore, the gravitational at the centre of circle will be

$$V = -\frac{GM}{R} = -\frac{\pi GM}{L}$$

23. Gravitational potential, $V_i = -\frac{GM}{r}$

$$V_i = -\frac{6.67 \times 10^{-11} \times 100}{0.1}$$

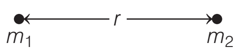
$$V_i = -\frac{6.67 \times 10^{-9}}{0.1} = -6.67 \times 10^{-8} \text{ J}$$

$\because \quad V_f = 0$

$\therefore$ Work done per unit mass,

$$W = \Delta V = (V_f - V_i) = 6.67 \times 10^{-8} \text{ J}$$

24. Two point masses m_1 and m_2 are separated by a distance r is shown as



Gravitational potential energy (U) of the above system is given as

$$U = -\frac{Gm_1m_2}{r}$$

i.e. $U \propto m_1m_2$ and $U \propto \frac{1}{r}$ or gravitational potential energy is directly proportional to the product of the masses of particles and inversely proportional to the separation between them.

25. Given, $U = -7.79 \times 10^{28}$ J

$G = 6.67 \times 10^{-11}$ N-m^{2}kg^{-2}

$m = 6 \times 10^{24}$ kg

and $M = 7.40 \times 10^{22}$ kg

Potential energy of the system,

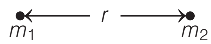
$$U = \frac{-GMm}{R}$$

$$\Rightarrow -7.79 \times 10^{28} = \frac{-6.67 \times 10^{-11} \times 7.4 \times 10^{22} \times 6 \times 10^{24}}{R}$$

$$\Rightarrow R = \frac{-6.67 \times 10^{-11} \times 7.4 \times 10^{22} \times 6 \times 10^{24}}{-7.79 \times 10^{28}}$$

$$\Rightarrow R = 3.8 \times 10^8 \text{ m}$$

26. As we know, $G_1 = \frac{-Gm_1m_2}{r}$ ...(i)



and $G_2 = -\frac{Gm_1m_2}{2r}$ ...(ii)

$\therefore \quad \frac{G_1}{G_2} = 2$ [dividing Eq. (i) by Eq. (ii)]

27. For a system of particles, all possible pairs are taken and total gravitational potential energy is the algebraic sum of the potential energies due to each pair, applying the principle of superposition.

Total gravitational potential energy

$$= U_{12} + U_{23} + U_{31}$$

$$= \frac{-Gm_1m_2}{r_1} - \frac{Gm_2m_3}{r_2} - \frac{Gm_1m_3}{r_3}$$

$$= \left(\frac{-Gm_1m_2}{r_1}\right) + \left(\frac{-Gm_2m_3}{r_2}\right) + \left(\frac{-Gm_1m_3}{r_3}\right)$$

28. Escape velocity on the surface of earth is given by

$$v = \sqrt{2gR_e}$$

i.e. $\quad v \propto \sqrt{R_e}$

Hence, escape velocity does not depend on the mass and direction of projection of body, it depends on the radius of earth.

29. Escape speed from the moon $= \sqrt{2g'R_m}$

where, g' = acceleration due to gravity on the surface of moon

and R_m = radius of the moon.

30. Let h be the maximum height attained. Then from equation of the motion $v^2 = u^2 + 2gh$

When $u = 0$, $v = \sqrt{2gh}$

Given, $\quad v = \frac{v_e}{3}$, where $v_e = \sqrt{2gR}$

$$\Rightarrow \sqrt{2gh} = \frac{1}{3}\sqrt{2gR}$$

On squaring both sides, we get

$$h = \frac{R}{9}$$

31. Escape velocity is given by

$$v_e = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2G}{R} \times \frac{4}{3}\pi R^3 \rho}$$

$\Rightarrow \quad v_e = R\sqrt{\frac{8}{3}\pi G\rho}$

$\Rightarrow \quad v \propto R \qquad [\because \rho$ is same for A and $B]$

$\therefore \quad \frac{v_A}{v_B} = \frac{R_A}{R_B} = 2 \qquad [\because R_A = 2R_B$, given$]$

32. $v_e = \sqrt{2gR} = \sqrt{2\frac{GM}{R^2}\cdot R}$ or $v_e \propto \sqrt{\frac{M}{R}}$

Mass is 1000 times and radius is 10 times.

$\therefore \quad v'_e = \sqrt{\frac{(1000M)G}{10R}}$

$\Rightarrow \quad v'_e = 10\sqrt{\frac{GM}{R}} \Rightarrow v'_e = 10v_e$

$\Rightarrow \quad v'_e = 10\times 11.2 \Rightarrow v'_e = 112 \text{ kms}^{-1}$

33. The time period of satellite in a circular orbit around a planet is independent of the mass of satellite.

34. As the total energy of the earth satellite bounded system is negative $\left(\text{i.e.} \frac{-GM}{2a}\right)$,

where a is radius of the satellite and M is mass of the earth.

Due to the viscous force acting on satellite, energy decreases continuously and radius of the orbit or height decreases gradually.

35. Here, $R_e = 6400$ km $= 6.4\times 10^6$ m, $g = 9.8$ m/s^2

Hence, orbital velocity of artificial satellite near the earth's surface,

$$v_o = \sqrt{gR_e} = \sqrt{9.8\times 6.4\times 10^6}$$

$$= 7.9\times 10^3 \text{ m/s} = 7.9 \text{ km/s}$$

36. Velocity of satellite varies inversely as the square root of the orbit of radius R,

$$v \propto \frac{1}{\sqrt{R}}$$

$\therefore \quad \frac{v_A}{v_B} = \sqrt{\frac{R_B}{R_A}} = \sqrt{\frac{R}{4R}}$

$\Rightarrow \quad \frac{3v}{v_B} = \frac{1}{2} \Rightarrow v_B = 6v$

37. $\because$ Total energy, $E_0 = -\frac{GMm}{2r}$

Potential energy, $U = -\frac{GMm}{r} = 2E_0$

Kinetic energy, $K = +\frac{GMm}{2r} = -E_0$

38. KE of satellite $= \frac{1}{2}mv^2 = \frac{1}{2}m\left(\sqrt{\frac{GM_e}{(R_e+h)}}\right)^2$

$$= \frac{1}{2}\frac{GmM_e}{(R_e+h)}$$

39. Geo-stationary satellite has an orbital period equal to earth's rotational period of 23 h and 56 min, i.e. approx. 24 h.

40. A geo-stationary satellite is an earth's orbiting satellite. It is placed at an altitude of approximately 36000 km directly over the equator and it revolves in the same direction the earth rotates.

41. An astronaut experiences weightlessness in a space satellite. It is because the astronaut experiences no gravity.

42. Inside a satellite, every object experiences weightlessness. Therefore, time period of a pendulum inside a satellite is $T = 2\pi\sqrt{\frac{L}{g}}$

As, $\quad g = 0$

$\therefore \quad T = \infty$ (infinity)

43. According to universal law of gravitation,

$$F = \frac{Gm_1m_2}{r^2} \Rightarrow G = \frac{Fr^2}{m_1m_2}$$

Here, $m_1 = m_2 = 1$ kg and $r = 1$ m

$\therefore \quad G = F$

44. At poles, value of g is maximum. So, there is no effect of rotation of earth.

45. The ratio of magnitude of PE and KE of a satellite is 2 : 1.

$\because \quad \left|\frac{\text{PE}}{\text{KE}}\right| = \left|\frac{-mv^2}{\frac{1}{2}mv^2}\right| = \left|\frac{2}{1}\right| = 2:1$

46. Weightlessness experienced while orbiting the earth in spaceship is the result of zero gravity because the surface does not exert any force on the body.

By Newton's law, $\frac{GMm}{r^2} - R = ma$

$\Rightarrow \quad \frac{GMm}{r^2} - R = m\left(\frac{GM}{r^2}\right) \Rightarrow R = 0$

Since, reaction force by the surface of spaceship is zero, so body will experience weightlessness. This happens in zero gravity region and also from, $w = mg$, when $g = 0$, then $w = 0$.

47. Acceleration due to gravity at altitude h,

$$g_h = \frac{g}{(1 + h/R)^2} \approx g\left(1 - \frac{2h}{R}\right)$$

At depth d, $g_d = g\left(1 - \frac{d}{R}\right)$

In both cases, with increase in h and d, g decreases.

At latitude ϕ, $g_\phi = g - \omega^2 R\cos^2\phi$

As ϕ increases g_ϕ increases.

So, option (b) is incorrect.

48. As, $w = mg$ and $g = 0$.

So, weight of the body will become zero but the mass will remain unchanged.

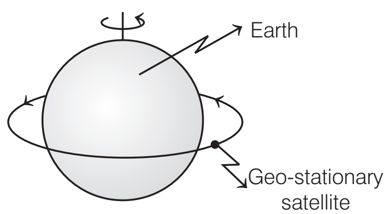
49. The statements I and II are incorrect and these can be corrected as,

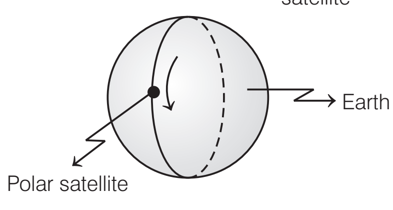
As, $G = 6.67 \times 10^{-11}$ N-m^{2}kg^{-2} on the surface of earth.

The escape velocity on the surface of earth is greater than the escape velocity from moon's surface because the moon has no atmosphere while earth has a very draws one.

50. A geo-stationary satellite is having same sense of rotation as that of earth, i.e. west-east direction.

A polar satellite goes around the earth's pole in north-south direction.





51. A. Escape velocity of earth is 11.2 km/s while for moon is 2.4 km/s.

B. Gravitational acceleration of earth is 9.8 ms^2 while for moon's surface is 1.6 m/s^2.

C. Radius of moon is 1740 km while radius of earth is 6400 km.

Hence, A $\rightarrow$ r, B $\rightarrow$ p and C $\rightarrow$ q.

52. A. If the velocity of satellite is v and mass m, then

$$\text{KE} = \frac{1}{2}mv^2$$

B. Since, potential energy of the satellite

$= -2$ kinetic energy of satellite

$\Rightarrow$ $\text{PE} = -mv^2)$

C. Also, total energy = KE + PE

$$= \frac{1}{2}mv^2 - mv^2 = -\frac{1}{2}mv^2$$

Hence, A $\rightarrow$ q, B $\rightarrow$ r and C $\rightarrow$ p.

53. According to universal law of gravitation,

$$F = \frac{Gm_1m_2}{r^2}$$

This force of attraction between two bodies is directly proportional to products of their masses and inversely proportional to the square of distance between them.

Law of gravitation is not analogous to magnetic force between the moving charges.

Therefore, A is true but R is false.

54. Acceleration due to gravity is given by

$$g = \frac{GM}{R^2}$$

Thus, it doesn't depend on mass of the body on which it is acting. Also, it is a variable quantity, it changes with change in value of both M and R.

Therefore, both A and R are true and R is the correct explanation of A.

55. Variation of acceleration due to gravity at height is given by

$$g_h = \left(1 - \frac{2h}{R}\right)$$

Since, acceleration due to gravity decreases above the surface of the earth and weight is directly proportional to the acceleration due to gravity, so as we go up, we feel light weighted than on the surface of the earth.

Therefore, both A and R are true and R is the correct explanation of A.

56. As, work done by or against gravitational force in moving a body from one point to another is independent of the actual path followed because it is conservative force of nature which only depends on the initial and final positions.

Therefore, both A and R are true and R is the correct explanation of A.

57. Gravitational potential due to a point mass at some finite distance is always negative.

Gravitational potential at infinity is zero.

Therefore, A is false and R is also false.

58. The force of attraction due to a hollow spherical shell of uniform density on a point mass situated inside it, is zero because gravitational force possesses spherical symmetry.

Gravitational force is conservative in nature and the value of G does not depend on the nature and size of the masses.

Therefore, both A and R are true but R is not the correct explanation of A.

59. The escape speed for the moon is much smaller and hence any gas molecule formed having thermal velocity larger than escape speed will escape from the gravitational pull of the moon.
So, moon has no atmosphere.

Therefore, both A and R are true and R is the correct explanation of A.

60. Escape velocity, $v_e = \sqrt{2gR}$

where, $g = \frac{GM}{R^2} \Rightarrow v_e = \sqrt{\frac{2\,GM}{R}}$

i.e. $v_e \propto \frac{1}{\sqrt{R}}$

So, if radius is four times, i.e. $R' = 4R$

$$v'_e = \sqrt{\frac{2\,GM}{(4R)}} = \frac{1}{2}\sqrt{\frac{2\,GM}{R}} = \frac{v_e}{2}$$

Therefore, both A and R are true and R is the correct explanation of A.

61. Orbital velocity of satellite, $v_o = \sqrt{\frac{GM_e}{(R_e + h)}}$

$$\Rightarrow \quad v_o \propto \frac{1}{\sqrt{R_e + h}}$$

Thus, v_o is maximum near the surface of the earth for $h = 0$.

$$(v_o)_{\max} = \sqrt{\frac{GM_e}{R_e}}$$

Therefore, A is false and R is also false.

62. The person experiences zero net force as the force of gravity is balanced by the centrifugal force inside the satellite. So, person experience no gravity.

The contact force by the surface on the person is zero.

Therefore, A is true but R is false.

63. Total energy of a satellite is always negative irrespective of the nature of its orbit. It indicates that the satellite is bound to the earth. At infinity, the potential energy and kinetic energy of satellite is zero.
Hence, total energy at infinity is zero, therefore only negative energy of satellite is possible when it is revolved around the earth.
If it is positive or zero, the satellite would leave its definite orbit and escape to infinity.

Therefore, A is true but R is false.

64. The geo-stationary satellite goes around the earth in west-east direction.

It is because it orbits around earth in the equatorial plane with a time period of 24 h same as that of rotation of the earth around its axis.

Therefore, both A and R are true and R is the correct explanation of A.

65. In a satellite around the earth, every part and parcel of the satellite has an acceleration towards the centre of the earth which is exactly the value of earth's acceleration due to gravity at that position.

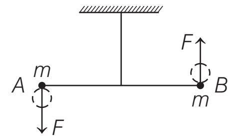
Thus, in the satellite, everything inside it is in a state of free fall.

Therefore, A is true but R is false.

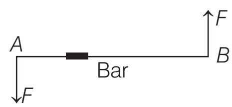
66. An object is weightless when it is in free fall as during free fall, there is no upward force acting on the body and this phenomenon is called weightlessness.

Therefore, A is true but R is false.

67. The force of attraction on small spheres due to big sphere are equal and opposite in direction. Hence, equal and opposite force separated by a fixed distance forms a couple.



68. $|\mathbf{F}_{net}|$ = zero



Since, the force are equal and opposite, net force on the bar is zero.

69. Magnitude of torque due to a couple

= (Either Force) × (Distance between of forces)

$= F \times l$

where, l = length of the bar

and F = force of attraction between a big sphere and its neighbouring small sphere.

70. The torque produces a twist in the suspended wire. The twisting stops when the restoring torque of the wire equal the gravitational torque.

71. We know that, gravitational force between the earth and the sun.

$F_G = \frac{GMm}{r^2}$, where M is mass of the sun and m is mass of the earth.

When G decreases with time, the gravitational force F_G will become weaker with time. As F_G is changing with time. Due to it, the earth will be going around the sun not strictly in closed orbit and radius also increases, since the attraction force is getting weaker. Hence, after long time the earth will leave the solar system.

72. The force acting on the particle of mass m at surface of the earth,

$$F = mg \quad \ldots(i)$$

where, g = acceleration due to gravity at the earth's surface.

Also, $$g = \frac{GM_e}{R_e^2} \quad \ldots(ii)$$

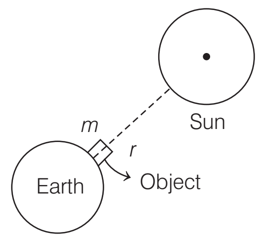
Then, from Eqs. (i) and (ii), we get

$$\Rightarrow \quad F = mg = \frac{GmM_e}{R_e^2}$$

Hence, options (a) and (b) are correct.

73. Gravitational acceleration (g) at the centre of earth is zero, hence weight of body ($w = mg$) at the centre of earth becomes zero.

74. Consider the given diagram



Force on the object due to the earth,

$$F = \frac{G' M_e m}{R^2} = \frac{10\, GM_e m}{R^2} \quad (\because G' = 10\, G)$$

$$= 10\left(\frac{GM_e m}{R^2}\right) = (10\, g)\, m = 10\, mg \quad \ldots(i)$$

$$\left(\because g = \frac{GM_e}{R^2}\right)$$

Now, force on the object due to the sun ,

$$F' = \frac{GM_s' m}{r^2}$$

$$= \frac{G\,(M_s)\,m}{10\, r^2} \quad \left(\because M_s' = \frac{M_s}{10}\right)$$

As, $r >> R$ (radius of the earth)

$\Rightarrow$ F' will be very small, so the effect of the sun will be neglected.

Now, as $g' = 10\, g$

Hence, weight of person $= mg' = 10\, mg$ [from Eq. (i)]

i.e. Gravity pull on the person will increase.

Due to it, walking on ground would become more difficult.

Escape velocity v_e is proportional to g, i.e. $v_e \propto g$.

As, $g' > g \Rightarrow v_e' > v_e$

Hence, rain drops will fall much faster.

To overcome the increased gravitational force of the earth, the airplanes will have to travel much faster.

75. Initially, the weight of the passenger at the earth's surface, $w = mg = 60 \times 10 = 600$ N.

Finally, the weight of the passenger at the surface of the mars $= 60 \times 4 = 240$ N and during the flight in between somewhere its weight will be zero because at that point, gravitational pull of earth and mars will be equal.

Only the curve (c) represents the weight = 0.

So, (c) is correct option.

76. As we know that, acceleration due to gravity,

$$g = \frac{GM}{R^2}$$

Given, $M' = 2M$ ($\because$ mass gets doubled)

$\Rightarrow$ $R' = (R/2)$ ($\because$ radius gets halved)

Then, acceleration becomes

$$\Rightarrow \quad g' = \frac{GM'}{R'^2} = \frac{G\,(2M)}{(R/2)^2} = \frac{8\,GM}{R^2}$$

$\therefore$ $g' = 8\,g$

Thus, the new acceleration due to gravity g' is 8 times that of g.

77. As we know that, escape velocity,

$$v_e = \sqrt{\frac{2GM}{R}} \qquad \ldots\text{(i)}$$

where, M is mass of planet.

So, on the basis of Eq. (i), it can be said that escape velocity will depend upon the mass of the planet (M).

78. Given, escape velocity on the surface of earth,

$$v_e = \sqrt{\frac{2GM_e}{R_e}}$$

where, M_e = mass of the earth

and R_e = radius of the earth.

Now, according to the question, radius of earth,

$$R' = R_e/4$$

$$\Rightarrow \quad v'_e = \sqrt{\frac{2GM_e}{R'}} = \sqrt{4\left(\frac{2\,GM_e}{R_e}\right)}$$

$$= 2\sqrt{\frac{2GM_e}{R_e}}$$

or $v'_e = 2\,v_e$

Hence, the escape velocity will be doubled.

79. Since, the escape velocity of earth can be given as

$$v_e = \sqrt{2gR}$$

$$\Rightarrow \quad v_e = R\sqrt{\frac{8}{3}\pi G\rho} \quad (\rho = \text{ density of earth}) \ldots\text{(i)}$$

As it is given that, the radius and mean density of planet are twice as that of earth. So, escape velocity at planet will be

$$v_p = 2R\sqrt{\frac{8}{3}\pi G 2\rho} \qquad \ldots\text{(ii)}$$

Dividing Eq. (i) by Eq. (ii), we get

$$\frac{v_e}{v_p} = \frac{R\sqrt{\frac{8}{3}\pi G\rho}}{2R\sqrt{\frac{8}{3}\pi G 2\rho}}$$

$$\Rightarrow \quad \frac{v_e}{v_p} = \frac{1}{2\sqrt{2}} = 1 : 2\sqrt{2}$$

80. As, we know that, force on satellite is only gravitational force which will always be towards the centre of earth. Thus, the acceleration of S is always directed towards the centre of the earth.

81. Orbital velocity is given by $v_o = \sqrt{\frac{GM}{r}}$

where, $r = R + h$.

If $h = \frac{R}{2}$, then $r = R + \frac{R}{2} = \frac{3}{2}R$

Then orbital velocity of satellite orbiting at half altitude becomes,

$$\therefore \quad v = \sqrt{\frac{GM \times 2}{3R}} = \sqrt{\frac{2}{3}}v_o$$

PRACTICE PAPER 1

Physics Class 11th (Term I)

Instructions

1. *This paper has 35 questions.*
2. *All questions are compulsory.*
3. *Each question carry 1 mark.*
4. *Answer the questions as per given instructions.*

Time : 90 Minutes **Max. Marks : 35**

Multiple Choice Questions

1. A cyclist is travelling with velocity v on a banked curved road of radius R. The angle θ through which the cyclist lean inwards is given by

(a) $\tan\theta = \frac{Rg}{v^2}$ (b) $\tan\theta = v^2\ Rg$

(c) $\tan\theta = \frac{v^2 R}{g}$ (d) $\tan\theta = \frac{v^2}{Rg}$

2. Three particles each of mass m are kept at vertices of an equilateral triangle of side L. The gravitational potential at the centre due to these particles is

(a) $-\frac{3Gm}{L}$

(b) $\frac{-9\ Gm}{\sqrt{3}\ L}$

(c) $-\frac{3\sqrt{3}\ Gm}{L}$

(d) Both (b) and (c)

3. Two bodies having masses m_1 & m_2 and velocities v_1 & v_2 collide and form a composite system. If $m_1v_1 + m_2v_2 = 0\ (m_1 \neq m_2)$, then the velocity of composite system will be

(a) $v_1 - v_2$ (b) $v_1 + v_2$

(c) $\frac{v_1 + v_2}{2}$ (d) zero

4. What is the maximum height attained by a body projected with a velocity equal to one-third of the escape velocity from the surface of the earth? (Take, radius of the earth = R)

(a) $R/2$ (b) $R/3$ (c) $R/5$ (d) $R/8$

5. A body of mass 2 kg is thrown up vertically with kinetic energy of 490 J. The height at which the kinetic energy of the body becomes half of its original value is

(a) 50 m (b) 12.25 m

(c) 25 m (d) 10 m

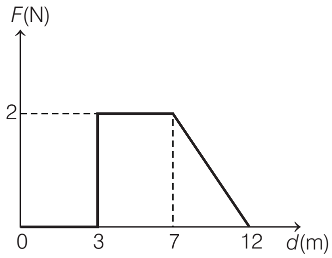
6. A rocket is fired vertically from the surface of mars with a speed of 2 kms^{-1}. If 20% of its initial energy is lost due to martian atmospheric resistance, how far will the rocket go from the surface of mars before returning to it? (Take, mass of mars = 6.4×10^{23} kg, radius of mars = 3395 km and $G = 6.67 \times 10^{-11}$ N-m^2 kg^{-2})

(a) 685 km (b) 785 km

(c) 495 km (d) 500 km

7. Force F on a particle moving in a straight line varies with distance d as shown in figure.

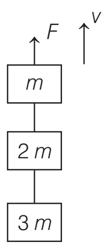
The work done on the particle during its displacement of 12 m is



(a) 18 J (b) 21 J (c) 26 J (d) 13 J

8. Weak nuclear forces operates among
(a) all charged particles
(b) electrons and neutrino
(c) all objects in universe
(d) Both (a) and (b)

9. Three blocks with masses m, $2m$ and $3m$ are connected by strings, as shown in the figure. After an upward force F is applied on block m, the masses move upward at constant speed v. What is the net force on the block of mass $2m$?



(a) Zero (b) 2 mg
(c) 3 mg (d) 6 mg
Here, g is the acceleration due to gravity.

10. If the unit of force is 1 kN, unit of length 1 km and the unit of time is 100s, what will be the unit of mass?
(a) 10^{-4} kg (b) 10^3 kg (c) 10^2 kg (d) 10^4 kg

11. A rope is wound around a hollow cylinder of mass 3 kg and radius 40 cm. What is the angular acceleration of the cylinder, if the rope is pulled with a force of 30 N?
(a) 25 ms^{-2} (b) 0.25 rad s^{-2}
(c) 25 rad s^{-2} (d) 5 ms^{-2}

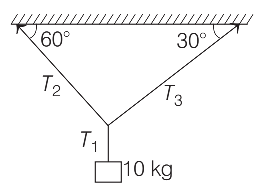
12. A body of mass 2kg travels according to the law $x(t) = pt + qt^2 + rt^3$, where $q = 4ms^{-2}$, $p = 3ms^{-1}$ and $r = 5ms^{-3}$. The force acting on the body at $t = 2$s is
(a) 136 N (b) 134 N
(c) 158 N (d) 68 N

13. The orbital velocity of a body close to the earth's surface is
(a) 8 kms^{-1} (b) 11.2 kms^{-1}
(c) 3×10^8 ms^{-1} (d) 2.2×10^3 kms^{-1}

14. A force of 20 N is applied on a body of mass 5 kg resting on a horizontal plane. The body gains a kinetic energy of 10 J after it moves a distance 2 m. The frictional force is
(a) 10 N (b) 15 N
(c) 20 N (d) 30 N

15. If E energy is required to project a body with speed v, what is the energy required to give an initial speed of $2v$ to the body?
(a) E (b) $2E$
(c) $4E$ (d) $E/2$

16. A block of mass 10 kg is suspended by three strings as shown in the figure. The tension T_2 is



(a) 100 N (b) $\frac{100}{\sqrt{3}}$ N
(c) $\sqrt{3} \times 100$ N (d) $50\sqrt{3}$ N

17. A smooth sphere of mass M moving with velocity u directly collides elastically with another sphere of mass m at rest. After collision, their final velocities are v' and v, respectively. The value of v is

(a) $\frac{2uM}{m}$ (b) $\frac{2um}{M}$

(c) $\frac{2u}{1+\frac{m}{M}}$ (d) $\frac{2u}{1+\frac{M}{m}}$

18. A solid cylinder rolls down an inclined plane of height 3 m and reaches the bottom of plane with angular velocity, of $2\sqrt{2}$ rad s^{-1}. The radius of cylinder must be (take, $g = 10$ ms^{-2})

(a) 5 cm (b) 0.5 cm

(c) $\sqrt{10}$ cm (d) $\sqrt{5}$ m

19. The displacement of a particle is given by $x = (t-2)^2$ m, where x is in metre and t is in second. The distance covered by the particle in first 4 s is

(a) 4 m (b) 8 m (c) 12 m (d) 16 m

20. A projectile can have same range for two angles of projection with same initial speed. If h_1 and h_2 be the maximum heights attained by them, then

(a) $R = \sqrt{h_1 h_2}$

(b) $R = \sqrt{2h_1 h_2}$

(c) $R = 4\sqrt{h_1 h_2}$

(d) $R = 2\sqrt{h_1 h_2}$

21. The radius of gyration of a thin ring about any diameter is ……… .

(a) $\frac{R}{\sqrt{2}}$ (b) $\frac{R}{2}$

(c) $2R$ (d) R

22. The SI unit of intensity of gravitational field is ……… .

(a) N kg^{-1}

(b) N kg

(c) N-m kg^{-1}

(d) N $m^{-1}kg^{-1}$

Assertion-Reasoning MCQs

For question numbers 23 to 27, two statements are given-one labelled ***Assertion*** *(A) and the other labelled* ***Reason*** *(R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true but R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false and R is also false.

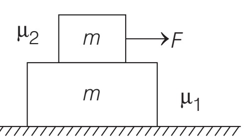
23. **Assertion** For a system of particles under central force field, the total angular momentum is conserved.

Reason The torque acting on such a system is zero.

24. **Assertion** Mass and energy are not conserved separately, but are conserved as a single entity called mass-energy.

Reason Mass and energy are inter-convertible in accordance with Einstein's relation, $E = mc^2$.

25. **Assertion** In the system of two blocks of equal masses as shown, the coefficient of friction between the blocks (μ_2) is less than coefficient of friction (μ_1) between lower block and ground.



For all values of force F applied on upper block, lower block remains at rest.

Reason Frictional force on lower block due to upper block is not sufficient to overcome the frictional force on lower block due to ground.

26. **Assertion** Spring force, friction force, normal force, tension in rope, etc., are similar forces.

Reason They arise out of the gravitational force between the particles.

27. **Assertion** The light year and wavelength consist of dimensions of length.

Reason Both light year and wavelength represent time.

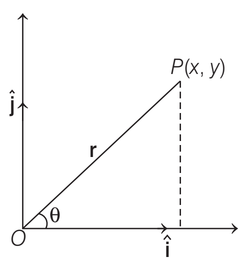
Case Based MCQs

Direction *Answer the questions from 28-31 on the following case.*

Resolution of Vectors

The process of splitting a single vector into two or more vectors are known as resolution of vectors. These vectors are in different directions which collectively has same effect as that of by the single vector alone.

With the help of graph shown below



Any vector **r** can be expressed as a linear combination of two unit vectors $\hat{i}$ and $\hat{j}$ at right angle, i.e. $\mathbf{r} = x\hat{i} + y\hat{j}$ in two-dimension and $\mathbf{r} = x\hat{i} + y\hat{j} + z\hat{k}$ in three-dimension.

28. Two vectors are given by $A = \hat{i} + 2\hat{j} + 2\hat{k}$ and $B = 3\hat{i} + 6\hat{j} + 2\hat{k}$. Another vector **C** has the same magnitude as that of B but has the same direction as that of A. Then, which of the following vectors represents C?

(a) $\frac{7}{3}(\hat{i}+2\hat{j}+2\hat{k})$ (b) $\frac{3}{7}(\hat{i}-2\hat{j}+2\hat{k})$

(c) $\frac{7}{9}(\hat{i}-2\hat{j}+2\hat{k})$ (d) $\frac{9}{7}(\hat{i}+2\hat{j}+2\hat{k})$

29. The X and Y-components of a force F acting at 30° to X-axis are respectively

(a) $\frac{F}{\sqrt{2}}, F$ (b) $\frac{F}{2}, \frac{\sqrt{3}}{2}F$

(c) $\frac{\sqrt{3}}{2}F, \frac{1}{2}F$ (d) $F, \frac{F}{\sqrt{2}}$

30. A person walks in the following pattern 3.1 km north, then 2.4 km west and finally 5.2 km south. How far the person will be from its initial point?

(a) 4.2 km (b) 3.2 km

(c) 3.0 km (d) 8.0 km

31. A unit radial vector $\hat{r}$ makes angles of $\alpha = 30°$ relative to the X-axis, $\beta = 60°$ relative to the Y-axis and $\gamma = 90°$ relative to the Z-axis. The vector $\hat{r}$ can be written as

(a) $\frac{1}{2}\hat{i}+\frac{\sqrt{3}}{2}\hat{j}$ (b) $\frac{\sqrt{3}}{2}\hat{i}+\frac{1}{2}\hat{j}$

(c) $\sqrt{\frac{2}{3}}\hat{i}+\frac{1}{\sqrt{3}}\hat{j}$ (d) None of these

Direction *Answer the questions from 32-35 on the following case.*

Acceleration

Acceleration is defined as the rate of change of velocity with time. Since, velocity is a quantity having both magnitude and direction, a change in velocity may involve either or both of these factors.

Acceleration, therefore may result from a change in speed (magnitude), a change in direction or changes in both.

For motion with constant acceleration, the average acceleration equals the constant value of acceleration during the interval.

32. The acceleration of a moving car is found from

(a) area under velocity-time graph
(b) area under displacement-time graph
(c) slope of distance-time graph
(d) slope of velocity-time graph

33. The motion of a car along a straight line is described by equation $x = 8 + 12t - t^3$, where x is in metre and t is in second. The retardation of the particle, when its velocity becomes zero, is

(a) 24 ms^{-2} (b) zero
(c) 6 ms^{-2} (d) 12 ms^{-2}

34. The graph between displacement and time for a particle moving with uniform acceleration is

(a) straight line with a positive slope
(b) parabola
(c) ellipse
(d) straight line parallel to time axis

35. At a certain time, a car has a speed of 18 m/s in positive x-direction and 2.4 s later its speed was 30 m/s in the opposite direction.

What is the magnitude of the average acceleration of the particle during the 2.4 s interval?

(a) 20 m/s^2 (b) 10 m/s^2
(c) 5 m/s^2 (d) 2.5 m/s^2

PRACTICE PAPER 1

OMRSHEET

Instructions

- Use black or blue ball point pens and avoid gel pens and fountain pens for filling the sheets
- Darken the bubbles completely. Don't put a tick mark or a cross mark half-filled or over-filled bubbles will not be read by the software.

Incorrect Incorrect Incorrect Correct

- Do not write anything on the OMR Sheet
- Multiple markings are invalid

1	a	b	c	d
2	a	b	c	d
3	a	b	c	d
4	a	b	c	d
5	a	b	c	d
6	a	b	c	d
7	a	b	c	d
8	a	b	c	d
9	a	b	c	d
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25	a	b	c	d
26	a	b	c	d
27	a	b	c	d
28	a	b	c	d
29	a	b	c	d
30	a	b	c	d
31	a	b	c	d
32	a	b	c	d
33	a	b	c	d
34	a	b	c	d
35	a	b	c	d

Students should not write anything below this line

SIGNATURE OF EXAMINER WITH DATE	MARKS SCORED

PRACTICE PAPER 2

Physics Class 11th (Term I)

Instructions

1. *This paper has 35 questions.*
2. *All questions are compulsory.*
3. *Each question carry 1 mark.*
4. *Answer the questions as per given instructions.*

Time : 90 Minutes **Max. Marks : 35**

Multiple Choice Questions

1. If the length and time period of an oscillating pendulum have errors 1% and 3% respectively, then the error in measurement of acceleration due to gravity is

(a) 4% (b) 5% (c) 6% (d) 7%

2. A ball is travelling with uniform translatory motion. This means that

(a) it is at rest
(b) the path can be a straight line or circular and the ball travels with uniform speed
(c) all parts of the ball have the same velocity (magnitude and direction) and the velocity is constant
(d) the centre of the ball moves with constant velocity and the ball spins about its centre uniformly

3. The equation of state for a real gas is given by $\left(P + \frac{a}{v^2}\right)(v - b) = RT$

The dimensions of the constant a is

(a) $[ML^5T^{-2}]$ (b) $[M^{-1}L^5T^2]$
(c) $[ML^{-5}T^{-1}]$ (d) $[ML^5T^{-1}]$

4. The acceleration due to gravity g and mean density of earth ρ are related by which of the following relations?

(Take, G = gravitational constant and R = radius of earth)

(a) $\rho = \frac{4\pi gR^2}{3G}$ (b) $\rho = \frac{4\pi gR^3}{3G}$
(c) $\rho = \frac{3g}{4\pi GR}$ (d) $\rho = \frac{3g}{4\pi GR^3}$

5. A body is rolling down an inclined plane. Its translational and rotational kinetic energies are equal. The body is a

(a) solid sphere (b) hollow sphere
(c) solid cylinder (d) hollow cylinder

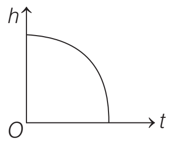
6. A person is moving with a velocity of 10 m s^{-1} towards north. A car moving with a velocity of 20 ms^{-1} towards south crosses the person.
The velocity of car relative to the person is

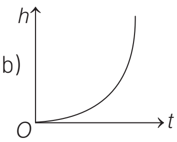
(a) $-30\, ms^{-1}$ (b) $+20\, ms^{-1}$
(c) $10\, ms^{-1}$ (d) $-10\, ms^{-1}$

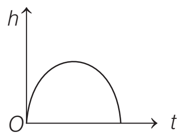
7. Which of the following does not specify the correct link between technology and physics?

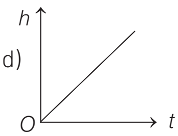
(a) Optical fibres ↔ total internal reflection
(b) Nuclear reactor ↔ nuclear fusion
(c) Electron microscope ↔ wave nature of electrons
(d) Electric generator ↔ laws of electromagnetic induction

8. Amongst the following graphs, which graph represents the correct relation between the height of projectile h and time t, when a particle (projectile) is thrown from the ground obliquely?

(a) 

(b) 

(c) 

(d) 

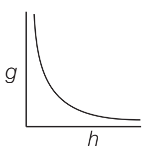
9. A stone of mass 0.05 kg is thrown vertically upwards. What is the magnitude and direction of net force on the stone during its upward motion?

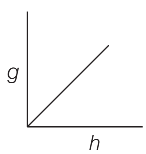
(a) 0.98 N, vertically downwards
(b) 0.49 N, vertically downwards
(c) 9.8 N, vertically downwards
(d) 0.49 N, vertically upwards

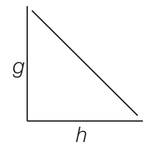
10. Three particles A, B and C projected from the same point with the same initial speeds making angle 30°, 45° and 60°, respectively with the horizontally. Which of the following statement is correct?

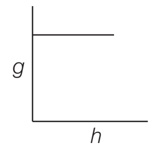
(a) A, B and C have unequal ranges.
(b) Ranges of A and C are less than that of B.
(c) Ranges of A and C are equal and greater than that of B.
(d) A, B and C have equal ranges.

11. Which of the following graph shows the variation of acceleration due to gravity g with depth h from the surface of the earth?

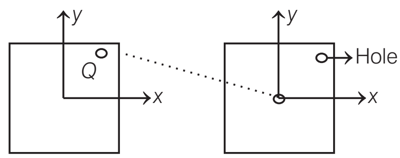
(a) 

(b) 

(c) 

(d) 

12. A uniform square plate has a small piece Q of an irregular shape removed and glued to the centre of the plate leaving a hole behind in figure. The moment of inertia about the Z-axis is



(a) increased
(b) decreased
(c) the same
(d) changed in unpredicted manner

13. The object is released from rest under gravity at $y = 0$. The equation of motion which correctly expresses the above situation is

(a) $v = -9.8\ t\ \text{ms}^{-1}$
(b) $v = (9.8 - 9.8\ t)$ m/s
(c) $v^2 = -19.6\ y^2\ \text{m}^2\text{s}^{-2}$
(d) $v^2 = (v_0^2 + 29.6\ y)\ \text{m}^2\ \text{s}^{-2}$

14. The unification of electromagnetism and optics leads to the

(a) celestial and terrestrial mechanics
(b) discovery of uncertainty principle
(c) discovery of optical fibres
(d) discovery of light as an electromagnetic wave

15. A body falling from the rest has a velocity v after it falls through a height h. The distance it has to fall down further for its velocity to become double, will be

(a) $8h$
(b) $6h$
(c) $4h$
(d) $5h$

16. An aircraft executes a horizontal loop of radius 1 km with a speed of 900 kmh^{-1}. What is the ratio of its centripetal acceleration with the acceleration due to gravity?

(a) 6.38 (b) 3.19
(c) 12.76 (d) 5.38

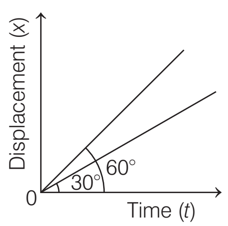
17. A body possessing kinetic energy T moving on a rough horizontal surface is stopped in a distance y. The frictional force exerted on the body is

(a) Ty (b) $\frac{\sqrt{T}}{y}$
(c) $\frac{T}{y}$ (d) $\frac{T}{\sqrt{y}}$

18. A particle moves from a point $(-2\hat{\mathbf{i}}+5\hat{\mathbf{j}})$ to $(4\hat{\mathbf{j}}+3\hat{\mathbf{k}})$ when a force of $(4\hat{\mathbf{i}}+3\hat{\mathbf{j}})$ N is applied. How much work has been done by the force?

(a) 8 J (b) 11 J
(c) 5 J (d) 2 J

19. The displacement-time graph of two moving particles make angles of 30° and 60° with the X-axis. The ratio of their velocities is



(a) 1:3 (b) 1:2
(c) 1:1 (d) $\sqrt{3}$:2

20. The ceiling of a long hall is 25 m high. What is the maximum horizontal distance that a ball thrown with a speed of 40 ms^{-1} can go without hitting the ceiling of the hall?

(a) 150.5 m (b) 250.5 m
(c) 130.2 m (d) 100.5 m

21. The sign (+ ve or – ve) of the average velocity depends only upon ……… .

(a) the sign of displacement
(b) the initial position of the object
(c) the final position of the object
(d) None of the above

22. In projectile motion, both the magnitude and direction of acceleration ……… .

(a) decreases with the height
(b) increases with the height
(c) remains constant
(d) increases with the range

Assertion-Reasoning MCQs

*For question numbers 23 to 27, two statements are given-one labelled **Assertion** (A) and the other labelled **Reason** (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

23. **Assertion** The time-period of pendulum on a satellite orbiting the earth is infinity.

Reason Time-period of a pendulum is inversely proportional to $\sqrt{g}$.

24. **Assertion** In case of pure rolling, the force of friction becomes zero.

Reason The speed at the point of contact is non-zero.

25. **Assertion** A lift is ascending with decreasing speed means acceleration of lift is downwards.

Reason A body always moves in the direction of its acceleration.

26. **Assertion** The centripetal and centrifugal forces never cancel out.

Reason They do not act at the same time.

27. **Assertion** In universe, gravitational force dominates in long distance and electric force dominates in short distance.

Reason For gravitational force $\propto \frac{\text{mass}^2}{\text{distance}^2}$ and electric force $\propto \frac{\text{charge}^2}{\text{distance}^2}$

Case Based MCQs

Direction *Answer the questions from 28-31 on the following case.*

Equilibrium of a Particle

Equilibrium of a particle in mechanics refers to the situation when the net external force on the particle is zero. According to the first law, the particle is either at rest or in uniform motion.

If two forces $\mathbf{F}_1$ and $\mathbf{F}_2$ act on a particle, equilibrium requires

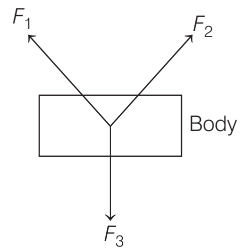
$$\mathbf{F}_1 = -\mathbf{F}_2$$

i.e. The two forces on the particle must be equal and opposite. Equilibrium under three concurrent forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ requires that the vector sum of three forces is zero.

$$\mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3 = 0$$

In other words, the resultant of any two forces say $\mathbf{F}_1$ and $\mathbf{F}_2$, obtained by the parallelogram law of forces must be equal and opposite to the third force $\mathbf{F}_3$.

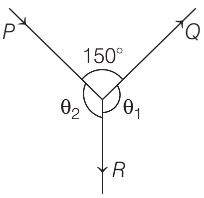
28. Three forces F_1, F_2 and F_3 together keep a body in equilibrium. If $F_1 = 3\text{N}$ along the positive X-axis, $F_2 = 4\text{N}$ along the positive Y-axis, then the third force F_3 is



(a) 5 N making an angle $\theta = \tan^{-1}\left(\frac{3}{4}\right)$ with negative Y-axis
(b) 5N making an angle $\theta = \tan^{-1}\left(\frac{4}{3}\right)$ with negative Y-axis
(c) 7N making an angle $\theta = \tan^{-1}\left(\frac{3}{4}\right)$ with negative Y-axis
(d) 7N making an angle $\theta = \tan^{-1}\left(\frac{4}{3}\right)$ with negative Y-axis

29. Three concurrent coplanar forces 1N, 2N and 3N acting along different directions on a body
(a) can keep the body in equilibrium, if 2N and 3N act at right angle
(b) can keep the body in equilibrium, if 1N and 2N act at right angle
(c) cannot keep the body in equilibrium
(d) can keep the body in equilibrium, if 1N and 3N act at an acute angle

30. P, Q and R are three coplanar forces acting at a point and are in equilibrium. Given, $P = 1.9318$ kg-wt and $\sin\theta_1 = 0.9659$, find the value of R (in kg-wt).



(a) 0.9659 (b) 2 (c) 1 (d) $\frac{1}{2}$

31. A mass of 10 kg is suspended from a spring balance. It is pulled aside by a horizontal string, so that it makes an angle of 60° with the vertical. The new reading of the balance is

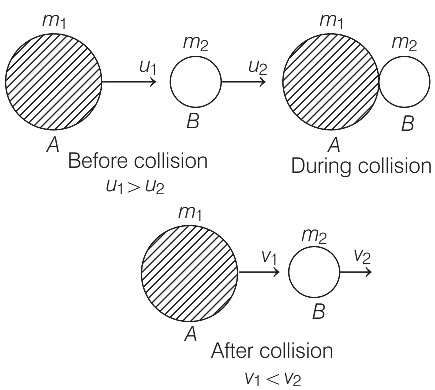
(a) $10\sqrt{3}$ kg-wt (b) $20\sqrt{3}$ kg-wt
(c) 20 kg-wt (d) 10 kg-wt

Direction *Answer the questions from 32-35 on the following case.*

Collision

A collision is an isolated event in which two or more colliding bodies exert strong forces on each other for a relatively short time. For a collision to take place, the actual physical contact is not necessary.

At the time of collision, the two colliding objects are deformed and may be momentarily at rest with respect to each other. If the initial and final velocities of both the bodies are along the same straight line, then it is called a one-dimensional collision or head-on collision.



32. In elastic collision,

I. initial kinetic energy is equal to the final kinetic energy.
II. kinetic energy during the collision time Δt is constant.

Which of the following option is correct?

(a) Only I (b) Only II
(c) Both I and II (d) None of these

33. A particle of mass m_1 moves with velocity v_1 collides with another particle at rest of equal mass. The velocity of second particle after the elastic collision is

(a) $2v_1$ (b) v_1 (c) $-v_1$ (d) zero

34. A molecule in a gas container hits a horizontal wall with speed 200 ms^{-1} at an angle 30° with the normal and rebounds with the same speed. Which statement is correct?

(a) Momentum is conserved
(b) Elastic collision
(c) Inelastic collision
(d) Both (a) and (b)

35. A particle of mass 1g moving with a velocity $\mathbf{v}_1 = 3\hat{\mathbf{i}} - 2\hat{\mathbf{j}}$ ms^{-1} experiences a perfectly elastic collision with another particle of mass 2 g and velocity $\mathbf{v}_2 = 4\hat{\mathbf{j}} - 6\hat{\mathbf{k}}$ ms^{-1}. The velocity of the particle is

(a) 2.3 ms^{-1} (b) 4.6 ms^{-1}
(c) 9.2 ms^{-1} (d) 6 ms^{-1}

PRACTICE PAPER 2

OMRSHEET

Instructions

- Use black or blue ball point pens and avoid gel pens and fountain pens for filling the sheets
- Darken the bubbles completely. Don't put a tick mark or a cross mark half-filled or over-filled bubbles will not be read by the software.

✓	✗	◓	●
Incorrect	Incorrect	Incorrect	Correct

- Do not write anything on the OMR Sheet
- Multiple markings are invalid

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34	a	b	c	d
35	a	b	c	d

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PRACTICE PAPER 3

Physics Class 11th (Term I)

Instructions

1. *This paper has 35 questions.*
2. *All questions are compulsory.*
3. *Each question carry 1 mark.*
4. *Answer the questions as per given instructions.*

Time : 90 Minutes **Max. Marks : 35**

Multiple Choice Questions

1. At a metro station, a girl walks up a stationary escalator in time t_1. If she remains stationary on the escalator, then the escalator take her up in time t_2. The time taken by her to walk up on the moving escalator will be

(a) $(t_1 + t_2)/2$ (b) $t_1 t_2/(t_2 - t_1)$
(c) $t_1 t_2/(t_2 + t_1)$ (d) $t_1 - t_2$

2. Force of 4N is applied on a body of mass 20 kg. The work done in 3 s is

(a) 3 J (b) 2 J (c) 4 J (d) 1 J

3. Weight of a body on surface of earth is 63 N. When this object is taken below earth surface at a height equals to half the radius, its weight becomes

(a) 28 N (b) 10 N
(c) 0 (d) 63 N

4. The three initial and final positions of a man on the X-axis are given as

(i) $(-8\text{ m}, 7\text{ m})$
(ii) $(7\text{ m}, -3\text{ m})$
(iii) $(-7\text{ m}, 3\text{ m})$

Which pair gives the negative displacement?

(a) (i) (b) (ii)
(c) (iii) (d) (i) and (iii)

5. Two solid spheres A and B are made of metals of different densities ρ_A and ρ_B, respectively. If their masses are equal,then the ratio of their moments of inertia (I_B/I_A) about their respective diameters is

(a) $\left(\frac{\rho_B}{\rho_A}\right)^{2/3}$ (b) $\left(\frac{\rho_A}{\rho_B}\right)^{2/3}$ (c) $\frac{\rho_A}{\rho_B}$ (d) $\frac{\rho_B}{\rho_A}$

6. A body of mass 1 kg is moving in a vertical circular path of radius 1 m. The difference between the kinetic energies at the highest and the lowest positions is

(a) 20 J (b) 10 J
(c) $4\sqrt{5}$ J (d) $10(\sqrt{5}-1)$ J

7. A particle moves along a circle of radius r with constant tangential acceleration. If the velocity of the particle is v at the end of second revolution, after the revolution has started, then the tangential acceleration is

(a) $\frac{v^2}{8\pi r}$ (b) $\frac{v^2}{6\pi r}$ (c) $\frac{v^2}{4\pi r}$ (d) $\frac{v^2}{2\pi r}$

8. If K_i and K_f are the initial and final values of kinetic energy of a body respectively, then the work done by the net force on the body is equal to

(a) $\frac{K_f K_i}{K_f - K_i}$ (b) $K_f + K_i$ (c) $K_f - K_i$ (d) $\frac{K_f + K_i}{2}$

9. Conservation of momentum in a collision between particles can be understood from

(a) law of conservation of energy
(b) Newton's first law only
(c) Newton's second law only
(d) Both Newton's second and third laws

10. Electromagnetic force is

(a) the force between charged particles
(b) charges in motion
(c) 10^{36} times the gravitational force between two protons for any fixed distance
(d) All of the above

11. The respective number of significant figures for numbers 23.023, 0.0003 and 2.1×10^{-3} are

(a) 4, 4, 2 (b) 5, 1, 5
(c) 5, 1, 2 (d) 5, 5, 2

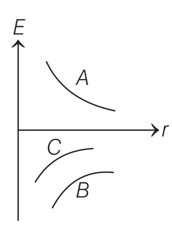
12. If the mass of the earth is doubled and its radius halved, then new acceleration due to the gravity g' is

(a) $g' = 4g$ (b) $g' = 8g$
(c) $g' = g$ (d) $g' = 16g$

13. A bob of mass m attached to an inextensible string of length l is suspended from a vertical support. The bob rotates in a horizontal circle with an angular speed ω rads^{-1} about the vertical support. About the point of suspension,

(a) angular momentum is conserved
(b) angular momentum changes in magnitude but not in direction
(c) angular momentum changes in direction but not in magnitude
(d) angular momentum changes both in direction and magnitude

14. Figure shows the variation of energy E with the orbital radius r of a satellite in a circular motion. Select the correct statement.



(a) A shows the kinetic energy, B shows the total energy and C shows the potential energy of the satellite.
(b) A and B are the kinetic energy and potential energy respectively and C is the total energy of the satellite.
(c) A and B are the potential energy and kinetic energy respectively and C is the total energy of the satellite.
(d) C and A are the kinetic energy and potential energy respectively and B is the total energy of the satellite.

15. A projectile, thrown with velocity v_0 at an angle α to the horizontal, has a range R. It will strike a vertical wall at a distance $R/2$ from the point of projection with a speed of

(a) v_0 (b) $v_0 \sin\alpha$
(c) $v_0 \cos\alpha$ (d) $\sqrt{\frac{gR}{2}}$

16. A solid sphere of mass 1 kg and radius 10 cm rolls down an inclined plane of height 7 m. The velocity of its centre as it reaches the ground level is

(a) 7 ms^{-1} (b) 10 ms^{-1}
(c) 15 ms^{-1} (d) 20 ms^{-1}

17. In a two dimensional motion, instantaneous speed v_0 is a positive constant. Then, which of the following are necessarily true?

(a) The average velocity is not zero at any time.
(b) Average acceleration must always vanish.
(c) Displacements in equal time intervals are equal.
(d) Equal path lengths are traversed in equal intervals.

18. A cyclist moving on a circular track of radius 40 m completes half a revolution in 40 s. Its average velocity is

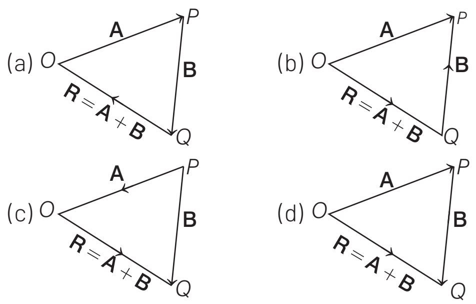
(a) zero (b) 2 ms^{-1}
(c) 4π ms^{-1} (d) 8π ms^{-1}

19. An explosion breaks a rock into three parts in a horizontal plane. Two of them go off at right angles to each other. The first part of mass 1 kg moves with a speed of $12\,ms^{-1}$ and the second part of mass 2 kg moves with $8\,ms^{-1}$ speed. If the third part flies off with $4\,ms^{-1}$ speed, then its mass is

(a) 3 kg (b) 5 kg (c) 7 kg (d) 17 kg

20. **A** and **B** are two inclined vectors and **R** is their sum.

Choose the correct figure for the given description.



21. In vernier callipers, 10 vernier scale divisions is equal to ……… main scale divisions.

(a) 10 (b) 9
(c) 11 (d) 0

22. In a rotating frame of reference, the pseudo force is called ……… , when applied for centripetal acceleration.

(a) gravitational force
(b) centrifugal force
(c) centripetal force
(d) dynamic force

Assertion-Reasoning MCQs

For question numbers 23 to 27, two statements are given-one labelled ***Assertion*** *(A) and the other labelled* ***Reason*** *(R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

23. **Assertion** When the objects A and B move in the same direction, then relative velocity of object A w.r.t. object B is $v_{AB} = v_A - v_B$.

Reason When the objects A and B move in opposite direction, then relative velocity of object B w.r.t. object A is $v_{BA} = v_B - v_A$.

24. **Assertion** In an elastic collision between two bodies, the energy of each body is conserved.

Reason The total energy of an isolated system is not conserved.

25. **Assertion** An astronaut experiences weightlessness in a space satellite.

Reason When a body falls freely, it does not experience gravity.

26. **Assertion** Static friction acting on a body is always greater than the kinetic friction acting on this body.

Reason Coefficient of static friction is more than the coefficient of kinetic friction.

27. **Assertion** In projectile motion, if time of flight is made two times, then maximum height will become four times.

Reason $T \propto \sin\theta$ and $H \propto \sin^2\theta$, where θ is angle of projection.

Case Based MCQs

Direction *Answer the questions from 28-31 on the following case.*

Universal Law of Gravitation

In a school, teacher is explaining an experiment to the students. He tells them about the law of gravitation by taking two bodies having masses m_1 and m_2, respectively. Both the bodies are mutually separated by a distance r. The teacher explains that there is a force of gravitational attraction between two bodies. This force depends on both the masses and also on the separation distance between them.

28. Two particles of masses m_1 and m_2, approach each other due to their mutual gravitational attraction only. Then,

(a) acceleration of both the particles are equal
(b) acceleration of the particle of mass m_1 is directly proportional to m_1
(c) acceleration of the particle of mass m_1 is directly proportional to m_2
(d) acceleration of the particle of mass m_1 is inversely proportional to m_1

29. A body of mass M is divided into two parts m and $M - m$. The gravitational force between them is maximum, if $\frac{m}{M}$ is

(a) 1 : 1 (b) 1 : 2 (c) 1 : 3 (d) 1 : 4

30. Apple falls towards the earth but the earth does not move towards the apple because

(a) acceleration is inversely proportional to mass, so acceleration of earth is negligible
(b) only earth exerts force on apple, apple does not exert force on earth
(c) apple experience greater force than the earth
(d) only apple exerts force on earth, earth does not exert force on apple

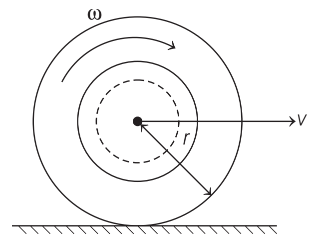
31. What is the mass of a body whose weight is 59 N? (Take, $g = 9.8\ \text{m/s}^2$)

(a) 5 kg (b) 9 kg (c) 6 kg (d) 50 kg

Direction *Answer the questions from 32-35 on the following case.*

Angular Velocity and its Relation with Linear Velocity

Shyam is playing football in his society and suddenly a car passes near him. He thought about the dynamics of the tyre of a car. He was curious to know the reason behind the rotation of a tyre. He went to his teacher and asked the same. Teacher explains him, suppose there is a car moving with velocity v in a straight line. The tyre of a car rotates with an angular velocity ω. Linear velocity depends on the angular velocity of the tyre and on the radius r of the tyre as shown in the figure below



Tyre of a car

32. Angular speed of hour hand of a clock (in degree per second) is

(a) $\frac{1}{30}$ (b) $\frac{1}{60}$
(c) $\frac{1}{120}$ (d) $\frac{1}{720}$

33. Given, $\omega = 2\hat{k}$ and $r = 2\hat{i} + 2\hat{j}$. Find the linear velocity.

(a) $4\hat{i} + 4\hat{j}$ (b) $4\hat{i} - 4\hat{j}$
(c) $-4\hat{i} + 4\hat{j}$ (d) $-4\hat{i} - 4\hat{j}$

34. What is the value of linear velocity, if $r = 3\hat{i} + 4\hat{j} + 6\hat{k}$ and $\omega = -5\hat{i} + 3\hat{j} + 5\hat{k}$?

(a) $-2\hat{i} + 45\hat{j} - 29\hat{k}$
(b) $2\hat{i} - 45\hat{j} + 29\hat{k}$
(c) $3\hat{i} - 29\hat{j} + 45\hat{k}$
(d) $5\hat{i} - 6\hat{j} + 4\hat{k}$

35. The correct vector relation between linear velocity v and angular velocity ω in rigid body dynamics is

(a) $\omega = v \times r$ (b) $v = r \times \omega$
(c) $v = \omega \times r$ (d) $r = v \times \omega$

Here, r is the position vector.

PRACTICE PAPER 3

OMRSHEET

Instructions

- Use black or blue ball point pens and avoid gel pens and fountain pens for filling the sheets
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Incorrect Incorrect Incorrect Correct

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ANSWERS

Practice Paper 1

1. (d)	*2. (c)*	*3. (d)*	*4. (d)*	*5. (b)*	*6. (c)*	*7. (d)*	*8. (b)*	*9. (a)*	*10. (d)*
11. (c)	*12. (a)*	*13. (a)*	*14. (b)*	*15. (c)*	*16. (d)*	*17. (c)*	*18. (d)*	*19. (b)*	*20. (c)*
21. (a)	*22. (a)*	*23. (a)*	*24. (a)*	*25. (a)*	*26. (c)*	*27. (c)*	*28. (a)*	*29. (c)*	*30. (b)*
31. (b)	*32. (d)*	*33. (d)*	*34. (b)*	*35. (a)*					

Practice Paper 2

1. (d)	*2. (c)*	*3. (a)*	*4. (c)*	*5. (d)*	*6. (a)*	*7. (b)*	*8. (c)*	*9. (b)*	*10. (b)*
11. (c)	*12. (b)*	*13. (a)*	*14. (d)*	*15. (c)*	*16. (a)*	*17. (c)*	*18. (c)*	*19. (a)*	*20. (a)*
21. (a)	*22. (c)*	*23. (a)*	*24. (d)*	*25. (c)*	*26. (c)*	*27. (a)*	*28. (a)*	*29. (c)*	*30. (c)*
31. (c)	*32. (a)*	*33. (b)*	*34. (d)*	*35. (b)*					

Practice Paper 3

1. (c)	*2. (b)*	*3. (a)*	*4. (b)*	*5. (b)*	*6. (a)*	*7. (a)*	*8. (c)*	*9. (d)*	*10. (a)*
11. (c)	*12. (b)*	*13. (c)*	*14. (b)*	*15. (c)*	*16. (b)*	*17. (d)*	*18. (b)*	*19. (b)*	*20. (d)*
21. (b)	*22. (b)*	*23. (b)*	*24. (d)*	*25. (b)*	*26. (a)*	*27. (b)*	*28. (c)*	*29. (b)*	*30. (a)*
31. (c)	*32. (c)*	*33. (c)*	*34. (a)*	*35. (c)*					