Crash Course for NEET

PHYSICS

Study Package-1

Aakash
Medical | IIT-JEE | Foundations
(Divisions of Aakash Educational Services Limited)

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Preface

Dear NEET Aspirant,

This book has been written specifically for the students who get themselves enrolled for the crash course for medical entrance exams. which is a limited days programme. It is meant for the quick brush-up of all the important topics. All the chapters have been written by the experienced faculties who have been preparing the students for qualifying various medical entrance exams. Each chapter covers all the important and must do topics and has been written in such a way that the student can grasp the contents easily.

After the theory portion in the study package, Try Yourself have been given to make the student practice the questions similar to those asked in entrance exams. The sequence of the questions has been kept same as the sequence of theory part so that a student can solve questions as per his/her coverage of theory part. The questions asked in previous AIPMT/NEET exam have also been included. This will help the students to assess the difficulty level in the actual medical entrance exams. We have also added a sample paper of 45 questions covering the entire content of this study package.

As the days are limited, the students should never miss a single class and must cover the syllabus in tandem with the coverage in the classroom. Once the topic is finished, you must do all the questions of same topic given in the form of Try Yourself. If there is any doubt, you can get it clarified from the faculties.

Finally, you are advised to remain focused on your target and must work hard and complete all the necessary work sincerely in a planned manner. You must stay away from all distractions including the mobile phone. All other things can wait but time never waits for anyone. So gear up your preparations to realise your dream of joining the most prestigious and respected profession.

Wishing you a brighter career!

J. C. CHAUDHRY
Managing Director

Analysis of NEET–2019

Subject-wise Report

Subject-wise Difficulty Level

S. No.	SUBJECT	EASY	MEDIUM	DIFFICULT	REMARKS
1	PHYSICS	18	25	2	Medium
2	CHEMISTRY	17	22	6	Medium
3	BOTANY	21	13	14	Easy
4	ZOOLOGY	9	25	8	Medium

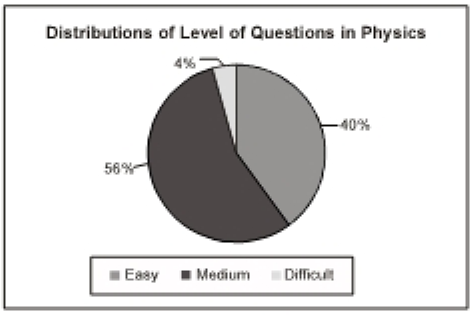
Topic-wise Credits & Difficulty Level

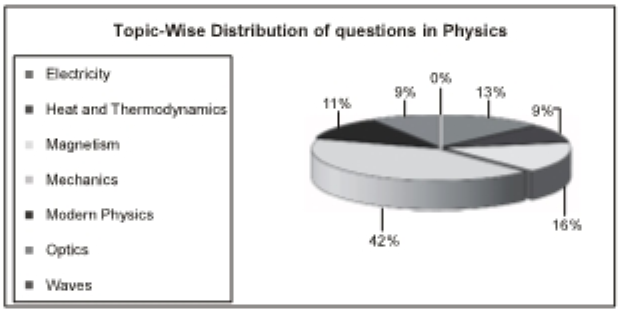
PHYSICS

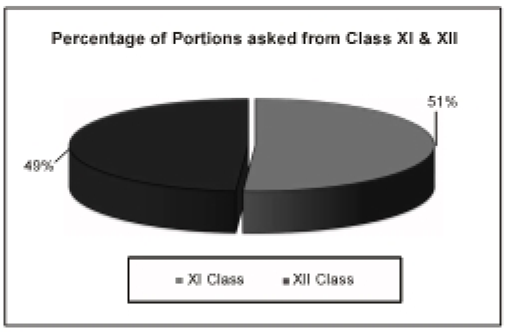
ANALYSIS OF PHYSICS PORTION OF NEET 2019

	XII	XI	XII	XI	XII	XII	XI	
	Electricity	Heat and Thermodynamics	Magnetism	Mechanics	Modern Physics	Optics	Waves	Total
Easy	3	3	2	6	2	2	0	18
Medium	3	1	5	11	3	2	0	25
Difficult	0	0	0	2	0	0	0	2
Total	6	4	7	19	5	4	0	45

XI Class	23	XII Class	22







Contents

Chapter 1

Physical World; Units and Measurements

Sub-topics *Scope and excitement; nature of physical laws; Physics, technology and society.· 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.*

Physics : It is the study of basic laws of nature and their manifestation in different natural phenomena.

There are two principal thrusts in physics.

Unification : It is an attempt to explain diverse physical phenomena in terms of a few concepts and laws.

Reductionism : It is an attempt to derive the properties of a bigger, more complex system from the properties and interaction of its constituent simpler parts.

Domains of Physics

(1) **Classical Physics :** It deals mainly with macroscopic phenomena. It includes mechanics, electrodynamics, optics and thermodynamics.

(2) **Quantum Physics :** It deals with microscopic phenomena and includes the study of constitution and structure of matter and interaction between elementry particles, such as electrons, photons, protons.

(3) **Mesoscopic Physics :** It deals with the domain between macroscopic and microscopic physics.

Fundamental Forces in Nature

They arise due to exchange of particles.

Gravitational Force

(1) It is the weakest force in nature. It is always attractive.

(2) The exchange particle is assumed to be graviton (Not yet discovered).

(3) It exists between any two particles having mass.

(4) Very long range (infinity)

Electromagnetic Force

(1) It is the force between charged particles.

(2) Tension, friction, normal force, spring force, Van der Waal's force are the common examples.

(3) The exchange particle is photon.

Weak Nuclear Force

(1) It is shortest range force.

(2) This force appears during beta-decay.

(3) Weak nuclear force is also a type of electromagnetic force which has very short range (10^{-16} m). This was shown by Abdus Salam.

Strong Nuclear Force

(1) It is the force between proton-proton, proton-neutron and neutron-neutron.

(2) The exchange particle is meson.

(3) Electrons and neutrino (Leptons) do not experience these forces. Recently it has been discovered that strong nuclear force is derived from **quark-quark interaction**, which is now regarded as fundamental force, instead of strong nuclear force.

(4) Short range (10^{-15} m)

Gravitational force : Weak nuclear force : Electromagnetic force : Strong nuclear force

10^{-39} : 10^{-13} : 10^{-2} : 1

SI Units

The International Bureau of Weights and Measures, located near Paris and established in 1875 is the fountainhead for selecting units. The 14th General Conference on Weights and Measures (1971) selected the seven quantities as base units and two quantities as supplementary units displayed in the following table :

TABLE - 1(a) FUNDAMENTAL UNITS

	Quantity	Name of the Unit	Symbol
1.	Length	metre	m
2.	Mass	kilogram	kg
3.	Time	second	s
4.	Electric current	ampere	A
5.	Thermodynamic temperature	kelvin	K
6.	Luminous Intensity	candela	cd
7.	Amount of substance	mole	mol

TABLE - 1(b) SUPPLEMENTARY UNITS

1.	Plane angle	radian	rad
2.	Solid angle	steradian	sr

Table : Derived SI Units and Dimensions of Some Important Physical Quantities

S.No.	Quantity	SI Unit	Dimensional Formula
1.	Volume	m^3	$[M^0L^3T^0]$
2.	Density	kg m^{-3}	$[ML^{-3}T^0]$
3.	Velocity	ms^{-1}	$[M^0L^1T^{-1}]$
4.	Acceleration	ms^{-2}	$[M^0L^1T^{-2}]$
5.	Angular Velocity	rad s^{-1}	$[M^0L^0T^{-1}]$
6.	Frequency	s^{-1} or hertz (Hz)	$[M^0L^0T^{-1}]$
7.	Momentum	kg ms^{-1}	$[MLT^{-1}]$
8.	Force	kg ms^{-2} or Newton (N)	$[MLT^{-2}]$
9.	Work, Energy	kg m^2s^{-2} or Joule (J)	$[ML^2T^{-2}]$
10.	Power	kg m^2 s^{-3} or Js^{-1} or watt (W)	$[ML^2T^{-3}]$

S.No.	Quantity	SI Unit	Dimensional Formula
11.	Pressure, Stress	Nm^{-2} or pascal (Pa)	$[ML^{-1}T^{-2}]$
12.	Modulus of Elasticity	Nm^{-2}	$[ML^{-1}T^{-2}]$
13.	Moment of Inertia	kg m^2	$[M^1L^2T^0]$
14.	Torque	Nm	$[ML^2T^{-2}]$
15.	Angular Momentum	kg m^2 s^{-1}	$[ML^2T^{-1}]$
16.	Impulse	Ns	$[MLT^{-1}]$
17.	Coefficient of Viscosity	kg m^{-1} s^{-1}	$[ML^{-1}T^{-1}]$
18.	Surface Tension	Nm^{-1}	$[M^1L^0T^{-2}]$
19.	Universal Gravitational Constant	Nm^2 kg^{-2}	$[M^{-1}L^3T^{-2}]$
20.	Latent Heat	J kg^{-1}	$[M^0L^2T^{-2}]$
21.	Specific Heat	J kg^{-1} K^{-1}	$[M^0L^2T^{-2}\theta^{-1}]$
22.	Thermal Conductivity	J m^{-1} s^{-1} K^{-1}	$[MLT^{-3}\theta^{-1}]$
23.	Electric Charge	As or coulomb (C)	$[M^0L^0T^1A^1]$
24.	Electric Potential	JC^{-1} or volt (V)	$[ML^2T^{-3}A^{-1}]$
25.	Electric Resistance	VA^{-1} or ohm (Ω)	$[ML^2T^{-3}A^{-2}]$
26.	Electric Resistivity	Ω m	$[ML^3T^{-3}A^{-2}]$
27.	Electric Conductance	Ω^{-1} or siemens (S)	$[M^{-1}L^{-2}T^3A^2]$
28.	Electric Conductivity	Ω^{-1} m^{-1} or S m^{-1}	$[M^{-1}L^{-3}T^3A^2]$
29.	Capacitance	CV^{-1} or farad (F)	$[M^{-1}L^{-2}T^4A^2]$
30.	Inductance	Vs A^{-1} or henry (H)	$[ML^2T^{-2}A^{-2}]$
31.	Electric field	NC^{-1} or Vm^{-1}	$[MLT^{-3}A^{-1}]$
32.	Magnetic Induction	NA^{-1} m^{-1} or tesla (T)	$[M^1L^0T^{-2}A^{-1}]$
33.	Magnetic Flux	Tm^2 or weber (Wb)	$[ML^2T^{-2}A^{-1}]$
34.	Permittivity	C^2 N^{-1} m^{-2}	$[M^{-1}L^{-3}T^4A^2]$
35.	Permeability	Tm A^{-1} or Wb A^{-1} m^{-1}	$[MLT^{-2}A^{-2}]$
36.	Planck's Constant	Js	$[ML^2T^{-1}]$
37.	Boltzmann's Constant	JK^{-1}	$[ML^2T^{-2}\theta^{-1}]$

Errors in Measurement

Some important cases of interest are given below

1. If a physical quantity Q is expressed as

   $Q = X^a Y^b Z^{-c}$

   and percentage error in the measurement of X, Y and Z be α, β and γ, then percentage error in Q is $(a\alpha + b\beta + c\gamma)\%$

   Note : *Errors are always added.*

2. If $x = a - b$ and error in the measurement of a and b are Δa and Δb, then % error in 'X'

$$\frac{\Delta x}{x} \times 100 = \left(\frac{\Delta a}{a-b} + \frac{\Delta b}{a-b}\right) \times 100$$

3. If an expression is represented by $Z = \frac{A}{A-B}$ and A and B are measured with error ΔA and ΔB respectively, then the percentage error in the measurement of Z is given by

$$\frac{\Delta Z}{Z} \times 100 = \left(\frac{\Delta A}{A} \times 100 + \frac{\Delta A + \Delta B}{A - B} \times 100\right)$$

4. For a simple pendulum, $T \propto l^{1/2}$ $\Rightarrow$ $\frac{\Delta T}{T} = \frac{1}{2}\frac{\Delta l}{l}$

5. For a sphere, $A = 4\pi r^2, V = \frac{4}{3}\pi r^3$ $\Rightarrow$ $\frac{\Delta A}{A} = 2.\frac{\Delta r}{r}$ and $\frac{\Delta V}{V} = 3.\frac{\Delta r}{r}$

6. For acceleration due to gravity,

$$g = \frac{GM}{R^2}$$

$$\frac{\Delta g}{g} = -2.\frac{\Delta R}{R} \text{ (where } M \text{ is constant)}$$

7. When two resistors R_1 and R_2 are connected

(a) In series, $R_s = R_1 + R_2$ $\Rightarrow$ $\Delta R_s = \Delta R_1 + \Delta R_2$

$$\therefore \frac{\Delta R_s}{R_s} = \frac{\Delta R_1 + \Delta R_2}{R_1 + R_2}$$

(b) In parallel $R_p = \frac{R_1 R_2}{R_1 + R_2}$ $\Rightarrow$ $\frac{dR_p}{R_p^2} = \frac{dR_1}{R_1^2} + \frac{dR_2}{R_2^2}$

Measuring Instruments : The error in the measurement by an instrument is equal to least count of the instrument.

Example :

A meter scale has smallest division 1 mm, this represents the least count or the absolute error in the measurement.

Let a length measured by the meter scale = 56.5 cm

This implies that x = 56.5 cm

Absolute error Δx = 1 mm = 0.1 cm

Relative error = $\frac{\Delta x}{x} = \frac{0.1}{56.5}$

Least count of two commonly used measuring instruments are given here.

(i) Least count of vernier callipers = 1 MSD – 1 VSD

(ii) Least count of spherometer = $\frac{\text{Pitch}}{\text{No. of CSD}}$

Significant Figures : The number of digits in the measured value about the correctness of which we are sure plus one more digit are called significant figures. Significant figures indicate the precision of measurement which depends on the least count of the measuring instrument.

Examples :

(i) 15678 has 5 significant figures

(ii) 108.006 has 6 significant figures

(iii) 0.00967 has 3 significant figures

(iv) 30.00 has 4 significant figures

(v) 0.007800 has 4 significant figures

(vi) 2020 has 3 significant figures

Note : *Length of an object may be represented in many ways such as 5 m, 5.0 m, 500 cm, 5.000 m, 5×10^2 cm. Here 5.000 m is most accurate as it contains 4 significant figures.*

Dimensions : Dimensions of some important quantities are given below

(1) $\frac{L}{R}, \sqrt{LC}, RC$ have the dimensions of time.

(2) $\frac{LdI}{dt}, IR, Edx, \frac{Q}{C}$ have the dimensions of potential or potential difference.

(3) $\frac{R}{V}, \frac{L}{RCV}, \frac{BL}{F}$ have same dimensions (I^{-1}).

(4) Boltzmann constant, thermal capacity, entropy, gas constant have same dimensional formula, $[ML^2T^{-2}K^{-1}]$.

(5) The following quantities are dimensionless :

$\sin\omega t, \cos kx, e^{-\alpha x}, \frac{1}{\varepsilon_0}\frac{e^2}{hc}$, strain, Poisson's ratio, refractive index, dielectric constant, relative permeability, relative density, distance gradient, relative humidity, phase, trigonometric ratio, exponential function, logarithmic function.

Principle of homogeneity : Only those quantities which have same dimensions and are of same nature can be added or subtracted.

Changing units : A new system of units is chosen, in which unit of mass is x kg, unit of length is y m and unit of time is z second.

(a) 1 Newton = F new units

where 'F' is calculated as follows

1 kg m $(s)^{-2} = F$ (x kg) (y m) (z s)$^{-2}$

$\Rightarrow F = \frac{z^2}{xy}$

(b) Speed of light $c = 3 \times 10^8$ m/s = c' New units

$\Rightarrow 3 \times 10^8$ ms^{-1} = c' (y m) (z s)$^{-1}$

$\Rightarrow c' = \frac{z}{y} \times 3 \times 10^8$

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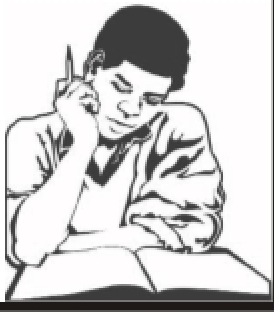

Try Yourself

SECTION - A

Objective Type Questions

1. Basic features of atomic phenomenon and photoelectric effect can be explained by
   (1) Newtonian mechanics
   (2) Quantum mechanics
   (3) Either of them
   (4) Mesoscopic physics
2. Who discovered radioactivity?
   (1) Newton (2) Curie
   (3) Becquerel (4) Einstein
3. Which of the following is not a fundamental force?
   (1) Gravitational force
   (2) Electrostatic force
   (3) Nuclear force
   (4) Quark-quark interaction force
4. Electromagnetic force between two electrons arise due to exchange of
   (1) Photon (2) π-meson
   (3) Gluon (4) Graviton
5. Ratio of strong nuclear force and weak nuclear force is
   (1) $1 : 10^{-38}$ (2) $1 : 10^{-2}$
   (3) $1 : 10^{-13}$ (4) $1 : 10^{-42}$
6. Which of the following forces is not of electromagnetic origin?
   (1) Tension in a taut string
   (2) van der Waal's force
   (3) Repulsion between two protons
   (4) Attraction between two protons
7. Which of the following laws is not a basic conservation law in physics?
   (1) Law of conservation of mechanical energy
   (2) Law of conservation of Linear momentum
   (3) Law of conservation of charge
   (4) Law of conservation of angular momentum
8. Which of the following expressions have same dimensions?
   (1) $\frac{1}{2}\varepsilon_0 E^2,\ mvr,\ \frac{1}{2}CV^2$
   (2) $\vec{F}.\vec{S},\ I\vec{\alpha},\ \frac{1}{2}QV$
   (3) $I\vec{\omega},\ \vec{r}\times\vec{p},\ m\vec{v}$
   (4) $\frac{L^2}{2I},\ \frac{B^2}{2\mu_0}$
9. The dimensional formula for impulse is
   (1) $[MLT^{-2}]$ (2) $[MLT^{-1}]$
   (3) $[LT^{-1}]$ (4) $[T^{-1}]$

10. A dimensionless quantity
    (1) Never has a unit (2) Always has a unit
    (3) May have a unit (4) Does not exist
11. If the formula $t = 2\pi\sqrt{\frac{Ax}{F}}$ is dimensionally correct, where t is time period, x is distance, F is force, then A has the dimensions of
    (1) Velocity (2) Acceleration
    (3) Mass (4) Length
12. If the velocity of light c, Planck's constant h and gravitational constant G are taken as the fundamental units of a system, the dimensional formula of force in the system would be
    (1) $[G^0 c^4 h^{-1}]$ (2) $[G^{-1} c^4 h^0]$
    (3) $[G^{-1} c^0 h^4]$ (4) $[G^4 c^{-1} h^0]$
13. If L, C, R represent the physical quantities inductance, capacitance and resistance respectively, the combination which does not have the dimension of frequency is
    (1) $\frac{1}{RC}$ (2) $\frac{R}{L}$
    (3) $\frac{1}{\sqrt{LC}}$ (4) $\left(\frac{C}{R}\right)$

14. N kg^{-1} is the unit of
    (1) Gravitational potential
    (2) Gravitational field intensity
    (3) Gravitational force
    (4) Impulse

15. In a new system of unit, unit of mass = 10 kg, length = 10 m and time = 1 min. Find the value of 1 joule in this system.
    (1) $\frac{10}{36}$ (2) $\frac{36}{10}$
    (3) 1 (4) None of these

16. In a hypothetical new system of measurement, the gravitational force between two particles, each of mass 1 kg, separated by 1 km is taken as a unit of force. Let this is called 'nuton'. How many 'Newton' will there be in one 'nuton'?
    (1) 6.67×10^{-11} (2) 6.67×10^{-17}
    (3) $\frac{1}{6.67 \times 10^{-11}}$ (4) $\frac{1}{6.67 \times 10^{-17}}$

17. Which of the following reading is most accurate?
    (1) 7.000 m (2) 7.0000×10^3 m
    (3) 7.00×10^3 m (4) 7×10^3 m

18. Two resistances (3 0.03) Ω and (6 0.06) Ω are connected in series. Find the equivalent resistance with error limits.
    (1) (2 0.09) Ω (2) (2 0.02) Ω
    (3) (2 0.06) Ω (4) (9 0.09) Ω

19. The time period of oscillations of a simple pendulum is $T = 2\pi\sqrt{\frac{L}{g}}$. L is about 10 cm and is known to 1mm accuracy. The time period of oscillations is about 0.5 s. The time of 100 oscillations is measured with a wrist watch of 1s resolution. What is the accuracy in determination of 'g'?
    (1) 1% (2) 3%
    (3) 5% (4) 7%

20. The pitch of a screw gauge is 0.5 mm. Its head scale contains 50 divisions. The least count of the screw gauge is
    (1) 0.001 mm (2) 0.01 mm
    (3) 0.02 mm (4) 0.025 mm

21. The damping force on an oscillator is directly proportional to the velocity. The units of the constant of proportionality are
    (1) kgs^{-1} (2) kgs
    (3) $kgms^{-1}$ (4) $kgms^{-2}$

22. The dimensional formula of $(\mu_0\varepsilon_0)^{-1/2}$ is
    (1) $[L^{1/2}T^{-1/2}]$ (2) $[L^{-1}T]$
    (3) $[LT^{-1}]$ (4) $[L^{1/2}T^{1/2}]$

23. What is the dimensional formula of surface tension?
    (1) $[ML^1T^0]$ (2) $[ML^1T^{-1}]$
    (3) $[ML^0T^{-2}]$ (4) $[M^2L^0T^{-2}]$

24. Which of the following five physical parameters have the same dimensional formula?
    (a) Energy density (b) Refractive index
    (c) Dielectric constant (d) Young's modulus
    (e) Magnetic field
    (1) (a) and (e) (2) (b) and (d)
    (3) (c) and (e) (4) (a) and (d)

25. If the error in the measurement of radius of a sphere is 2%, then the error in the determination of volume of the sphere will be
    (1) 2% (2) 4%
    (3) 6% (4) 8%

26. The dimensional formula of pressure is
    (1) $[MLT^{-2}]$ (2) $[ML^{-1}T^{-2}]$
    (3) $[ML^{-2}T^{-2}]$ (4) $[M^{-1}L^{-1}]$

27. Percentage errors in the measurement of mass and speed are 2% and 3% respectively. The error in the measurement of kinetic energy obtained by measuring mass and speed will be
    (1) 8% (2) 2%
    (3) 12% (4) 10%

28. Which of the following is a dimensional constant?
    (1) Relative density
    (2) Gravitational constant
    (3) Refractive index
    (4) Poisson's ratio

29. The density of a cube is measured by measuring its mass and length of its sides. If the maximum error in the measurement of mass and lengths are 3% and 2% respectively, the maximum error in the measurement of density would be
    (1) 12% (2) 14%
    (3) 7% (4) 9%

30. An equation is given here $\left(P+\frac{a}{V^2}\right)=b\frac{\theta}{V}$ where P = Pressure, V = Volume and θ = Absolute temperature. If a and b are constants, the dimensions of a will be

(1) $[ML^{-5}T^{-1}]$ (2) $[ML^5T^1]$

(3) $[ML^5T^{-2}]$ (4) $[M^{-1}L^5T^2]$

31. The dimensional formula of magnetic flux is

(1) $[M^0L^{-2}T^2A^{-2}]$ (2) $[ML^0T^{-2}A^{-2}]$

(3) $[ML^2T^{-2}A^{-1}]$ (4) $[ML^2T^{-1}A^3]$

32. The dimensions of Planck's constant equals to that of

(1) Energy (2) Momentum

(3) Angular momentum (4) Power

33. The velocity v of a particle at time t is given by $v=at+\frac{b}{t+c}$, where a, b and c are constants. The dimensions of a, b and c are

(1) [L], [LT] and $[LT^{-2}]$ (2) $[LT^{-2}]$, [L] and [T]

(3) $[L^2]$, [T] and $[LT^2]$ (4) $[LT^2]$, [LT] and [L]

34. Dimensional formula of resistance in an electrical circuit, in terms of mass M, length L, time T and current I, would be

(1) $[ML^2T^{-2}]$ (2) $[ML^2T^{-1}I^{-1}]$

(3) $[ML^2T^{-3}I^{-2}]$ (4) $[ML^2T^{-3}I^{-1}]$

35. The dimensional formula of $\frac{1}{2}\varepsilon_0E^2$, where ε_0 is permittivity of free space and E is electric field, is

(1) $[MLT^{-1}]$ (2) $[ML^2T^{-2}]$

(3) $[ML^{-1}T^{-2}]$ (4) $[ML^2T^{-1}]$

SECTION - B

Previous Years Questions

1. The damping force on an oscillator is directly proportional to the velocity. The units of the constant of proportionality are **[AIPMT 2012]**

(1) kgs^{-1} (2) kgs

(3) $kgms^{-1}$ (4) $kgms^{-2}$

2. 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: $P=\frac{a^3b^2}{cd}$.% error in P is **[NEET-2013]**

(1) 10%

(2) 7%

(3) 4%

(4) 14%

3. If force (F), velocity (V) and time (T) are taken as fundamental units, then the dimensions of mass are **[AIPMT 2014]**

(1) $[F\ V\ T^{-1}]$ (2) $[F\ V\ T^{-2}]$

(3) $[F\ V^{-1}\ T^{-1}]$ (4) $[F\ V^{-1}\ T]$

4. If energy (E), velocity (V) and time (T) are chosen as the fundamental quantities, the dimensional formula of surface tension will be **[AIPMT-2015]**

(1) $[E^{-2}V^{-1}T^{-3}]$ (2) $[E\ V^{-2}T^{-1}]$

(3) $[E\ V^{-1}T^{-2}]$ (4) $[E\ V^{-2}T^{-2}]$

5. If dimensions of critical velocity v_c of a liquid flowing through a tube are expressed as $[\eta^x\rho^yr^z]$ 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 **[Re-AIPMT-2015]**

(1) 1, 1, 1 (2) 1, – 1, –1

(3) – 1, – 1, 1 (4) –1, – 1, – 1

6. Planck's constant (h), speed of light in vacuum (c) and Newton's gravitational constant (G) are three fundamental constants. Which of the following combinations of these has the dimension of length? **[NEET (Phase-2) 2016]**

(1) $\frac{\sqrt{hG}}{c^{3/2}}$ (2) $\frac{\sqrt{hG}}{c^{5/2}}$

(3) $\sqrt{\frac{hc}{G}}$ (4) $\sqrt{\frac{Gc}{h^{3/2}}}$

7. A physical quantity of the dimensions of length that can be formed out of c, G and $\frac{e^2}{4\pi\varepsilon_0}$ is [c is velocity of light, G is universal constant of gravitation and e is charge] **[NEET-2017]**

(1) $\frac{1}{c^2}\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{\frac{1}{2}}$ (2) $c^2\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{\frac{1}{2}}$

(3) $\frac{1}{c^2}\left[\frac{e^2}{G4\pi\varepsilon_0}\right]^{\frac{1}{2}}$ (4) $\frac{1}{c}G\frac{e^2}{4\pi\varepsilon_0}$

8. A student measured the diameter of a small steel ball using a screw gauge of least count 0.001 cm. The main scale reading is 5 mm and zero of circular scale division coincides with 25 divisions above the reference level. If screw gauge has a zero error of –0.004 cm, the correct diameter of the ball is **[NEET-2018]**

(1) 0.521 cm (2) 0.525 cm

(3) 0.529 cm (4) 0.053 cm

9. In an experiment, the percentage of error occurred in the measurement of physical quantities A, B, C and D are 1%, 2%, 3% and 4% respectively. Then the maximum percentage of error in the measurement X, where $X = \frac{A^2 B^{1/2}}{C^{1/3} D^3}$, will be **[NEET-2019]**

(1) $\left(\frac{3}{13}\right)\%$

(2) 16%

(3) – 10%

(4) 10%

10. The main scale of a vernier callipers has n divisions/cm. n divisions of the vernier scale coincide with (n – 1) divisions of main scale. The least count of the vernier callipers is **[NEET-2019 (Odisha)]**

(1) $\frac{1}{(n+1)(n-1)}$ cm (2) $\frac{1}{n}$ cm

(3) $\frac{1}{n^2}$ cm (4) $\frac{1}{n(n+1)}$ cm

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Chapter 2

Motion in a Straight Line

Sub-topics *Frame of reference, Motion in a straight line; Position-time graph, speed and velocity. Uniform and non-uniform motion, average speed and instantaneous velocity. Uniformly accelerated motion, velocity-time and position-time graphs, for uniformly accelerated motion (graphical treatment). Elementary concepts of differentiation and integration for describing motion.*

Reference Frame

It is a system to which set of coordinate axes are attached and with respect to that an observer describes the position of an object.

Motion in Straight Line

When a particle moves as a point object, it is said to be in translatory motion.

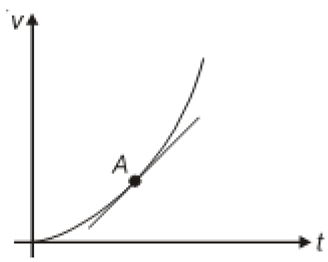
(i) |Displacement| = distance, if body moves in a straight line without changing direction.

(ii) |Displacement| < distance, in all other cases.

(iii) Distance and speed are always > 0. They can be zero only when body does not move at all.

(iv) Average speed can be the magnitude of average velocity only when body moves in a straight line without change in direction.

Formulae for Motion



Acceleration at $A = \frac{dv}{dt}$ = Slope of tangent at A.

(i) Acceleration $a = \frac{dv}{dt}$ or $v = \int a dt$ also $a = v\frac{dv}{dx}$

(ii) Velocity $v = \frac{dx}{dt}$ or $x = \int v dt$

Uniformly Accelerated Motion

Let a body starts from origin ($x = 0$) at $t = 0$ with initial velocity u and acceleration 'a'.

(i) Displacement x at time t is given by

$$x = ut + \frac{1}{2}at^2 = \frac{u+v}{2}t = vt - \frac{1}{2}at^2$$

(ii) $v = u + at$

(iii) $(v)^2 - (u)^2 = 2ax$.

(iv) Displacement in n^{th} second is given by, $\vec{x}_n = \vec{u}(1) + \frac{1}{2}\vec{a}(2n-1)(1)$.

Average Velocity

Average velocity is equal to total displacement over total time.

Average Speed

It is equal to total distance travelled over total time.

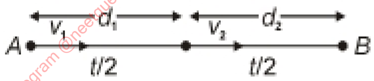
Case - I :

Let a body cover a journey in two equal time intervals with different speeds. Then

$$v_{avg.} = \frac{d_1 + d_2}{t/2 + t/2}$$

$$= \frac{v_1 t/2 + v_2 t/2}{t}$$

$$= \frac{v_1 + v_2}{2}$$



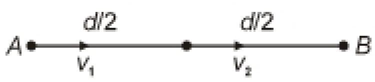
Note : *If there are n equal time intervals, then*

$$v_{avg.} = \frac{v_1 + v_2 + \dots\dots\dots + v_n}{n}$$

Case - II :

Let a body cover two equal distances with different speeds. Then

$$v_{avg.} = \frac{\frac{d}{2} + \frac{d}{2}}{t_1 + t_2} = \frac{\frac{d}{2} + \frac{d}{2}}{\frac{d/2}{v_1} + \frac{d/2}{v_2}} = \frac{2v_1v_2}{v_1 + v_2}$$



or $$\frac{2}{v_{avg.}} = \frac{1}{v_1} + \frac{1}{v_2}$$

Note : *If there are n equal parts of journey, then*

$$\frac{n}{v_{avg.}} = \frac{1}{v_1} + \frac{1}{v_2} + \dots\dots\dots + \frac{1}{v_n}$$

Case - III :

Let a particle covers first half of the journey with speeds v_1 and v_2 in two equal time intervals and remaining half with speed v_3. The average speed is given by,

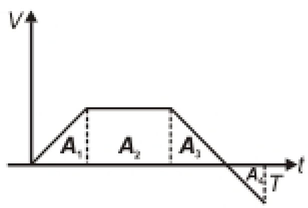
$$\frac{2}{v_{avg.}} = \frac{1}{\frac{(v_1 + v_2)}{2}} + \frac{1}{v_3}$$

or $$v_{avg.} = \frac{2(v_1 + v_2)v_3}{v_1 + v_2 + 2v_3}$$

GRAPHS FOR MOTION

Properties of graphs :

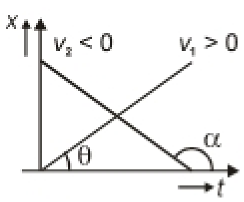
1. Slope of x-t graph gives instantaneous velocity $\left(\frac{dx}{dt}\right)$.
2. Slope of v-t graph gives instantaneous acceleration $\left(\frac{dv}{dt}\right)$.
3. Slope of a-t graph gives instantaneous rate of change of acceleration $\left(\frac{da}{dt}\right)$.
4. Area of a-t graph gives change in velocity (Δv).
5. Area of v-t graph gives change in position (Δx).

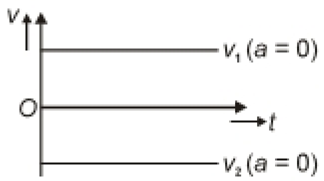


(i) Distance covered by the particle in time T is $A_1 + A_2 + A_3 + A_4$.

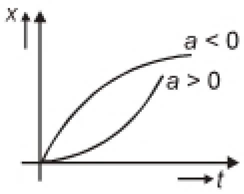
(ii) Displacement of the particle in time T is $A_1 + A_2 + A_3 - A_4$.

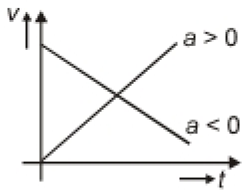
1. Uniform Motion





2. Uniformly Accelerated Motion

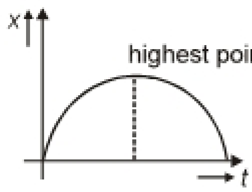




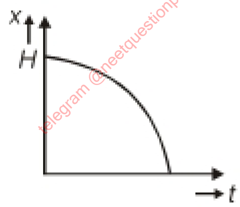
3. Motion Under Gravity (Neglecting air friction)

(a) **Position-Time Graph for a body :**

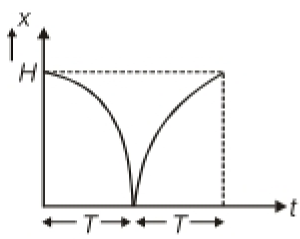
(i) Thrown from ground, vertically upwards



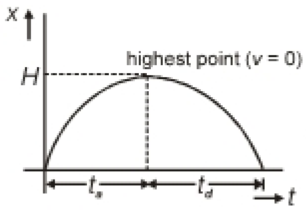
(ii) Dropped from a height



(iii) Dropped from a height such that it rebounds elastically



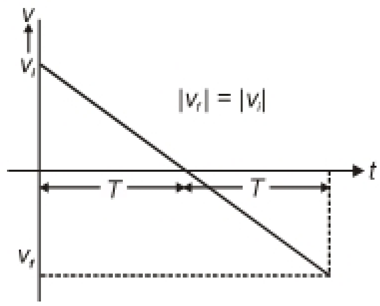
(iv) Thrown upward, considering constant air friction acting on it.



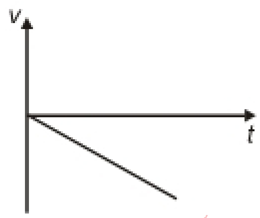
$t_a < t_d$

(b) **Velocity-Time Graph for a body :**

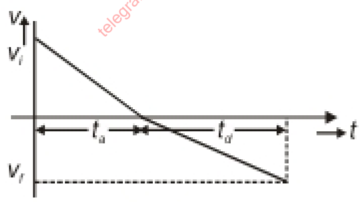
(i) Thrown vertically upward (taking upward direction as +ve)



(ii) Dropped from a height



(iii) Thrown upward, considering constant air friction acting on it.



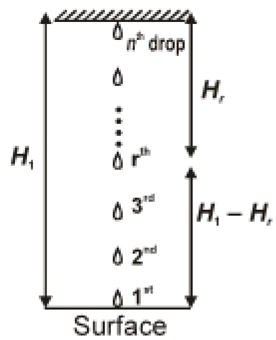
Important Problems

(1) If water drops are falling at regular time intervals from ceiling, then position of any drop is given by

From ceiling for r^{th} drop

$$H_r = \frac{(n-r)^2}{(n-1)^2}.H_1$$

n is total number of drops



***Note :** Distance between consecutive drops starting from above are in the ratio 1 : 3 : 5 : 7: 9 ....*

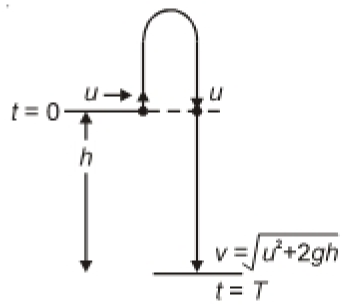
(2) A particle is dropped and another particle is thrown downward with initial velocity u, then

(a) Relative acceleration is always zero

(b) Relative velocity is always u.

(c) Time after which their separation becomes x, is $\frac{x}{u}$.

(3) If a body is projected upward from certain height h with initial velocity u, then



(a) Its speed at same level is u.

(b) Its speed at the ground level is

$$v = \sqrt{u^2 + 2gh}$$

(c) Time required by it to attain same level is,

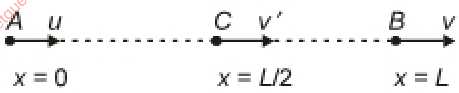
$$t = \frac{2u}{g}$$

(d) Total time of flight is obtained by solving the quadratic equation

$$-h = uT - \frac{1}{2}gT^2$$

(4) If body is moving with constant acceleration, then velocity midway between A and B is

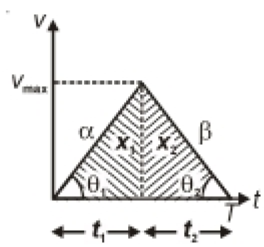
$$v' = \sqrt{\frac{u^2 + v^2}{2}}$$



(5) If a body starts from rest with acceleration α and then retards to rest with retardation β, such that total time of journey is T, then

(a) Its maximum velocity during the trip is given by, $v_{max.} = \left(\frac{\alpha\beta}{\alpha + \beta}\right)T$

(b) Length of the journey is, $L = \frac{1}{2}\left(\frac{\alpha\beta}{\alpha + \beta}\right)T^2$.



(c) Average velocity of the trip = $\frac{v_{max.}}{2}$.

(d) $\frac{x_1}{x_2} = \frac{\beta}{\alpha} = \frac{t_1}{t_2}$.

(6) When a body is thrown upward such that it takes t seconds to reach its highest point, then

(a) Distance travelled in $(t)^{th}$ s = distance travelled in $(t + 1)^{th}$ s.

(b) Distance travelled in $(t - 1)^{th}$ s = distance travelled in $(t + 2)^{th}$ s.

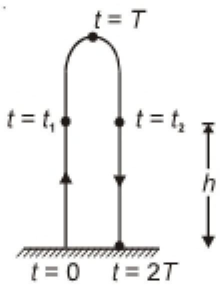
(c) Distance travelled in $(t - r)^{th}$ s = distance travelled in $(t + r + 1)^{th}$ s.

(7) A body thrown vertically upward reaches its maximum height in time T. The body will be at a height h (< maximum height) at two instants of time given by,

$$t = T \pm \sqrt{T^2 - \frac{2h}{g}} \quad i.e., \; t_1 = T - \sqrt{T^2 - \frac{2h}{g}}, \; t_2 = T + \sqrt{T^2 - \frac{2h}{g}}.$$

Also, $t_1 + t_2 = 2T$ = total time of flight and $t_1 t_2 = \frac{2h}{g}$

Special case : $h = \frac{H}{2} \Rightarrow t = T\left(1 \pm \frac{1}{\sqrt{2}}\right)$, where H is maximum height.



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Try Yourself

SECTION - A

Objective Type Questions

1. What is the displacement of a point on the rim of a wheel hinged at its centre as the wheel rotates half a revolution? (radius of wheel = R)

   (1) $2R$ (2) πR

   (3) $R\sqrt{\pi^2+4}$ (4) Zero

2. A person starts from his home on a straight road in his car at a speed of 50 m/s for half an hour. Then the fuel in his car finishes. So he stops, walks to a petrol pump some distance ahead on the same road. He gets the fuel from the pump and gets back to his car in 20 min. Then he again starts moving in initial direction of motion with same speed of 50m/s. What is the average velocity of the man in 1 hour, after he started from his home?

   (1) Zero (2) 120 km/hr

   (3) 180 km/hr (4) 50 m/s

3. A particle travels first 'x' metre with speed 'v'm/s, next '2x'm with speed '2v'm/s, next '3x'm with speed '3v'm/s. The average speed of the particle is

   (1) v (2) $4v$

   (3) $2v$ (4) $9v$

4. A ball is thrown vertically up with speed 'u'. At the same instant another ball B is released from rest from height 'h'. After time 't', the speed of A relative to B is

   (1) u (2) $u - 2gt$

   (3) $\sqrt{u^2-2gh}$ (4) $u - gt$

5. The velocity of a body depends on time according to the equation $v = 20 + 0.1t^2$. The body is undergoing

   (1) Uniform retardation

   (2) Uniform acceleration

   (3) Non-uniform acceleration

   (4) Zero acceleration

6. A car starts from rest and moves with constant acceleration. The ratio of distance covered by the car in n^{th} second to that covered in n seconds is

   (1) $\frac{2n-1}{2n^2}$ (2) $\frac{n^2}{2n-1}$

   (3) $\frac{2n-1}{n^2}$ (4) $1 : n$

7. A particle starts with initial velocity u and retardation a. It will reach the point of start in time

   (1) $\frac{u}{a}$ (2) $\frac{u}{a^2}$

   (3) $\frac{u^2}{a}$ (4) $\frac{2u}{a}$

8. A ball thrown vertically up with a speed v comes back to the starting point with speed v. The ratio of distance covered and displacement is

   (1) Zero (2) 1

   (3) –1 (4) Infinite

9. A toy car travels from A to B at a constant speed of 20 km/h and immediately returns to A at a constant speed v. If the average speed of the car is 24 km/h, then v is

   (1) 24 km/h (2) 28 km/h

   (3) 30 km/h (4) 32 km/h

10. Which of the following four statements is false?

    (1) A car can have a constant velocity and still have a varying speed

    (2) The body can have zero velocity and still be accelerated

    (3) The direction of the velocity of a body can change when its acceleration is constant in magnitude

    (4) A body can have a constant speed and still have a varying velocity

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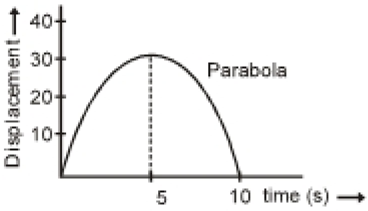
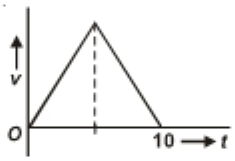
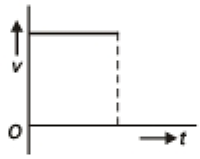
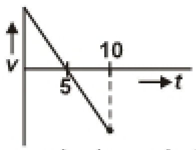
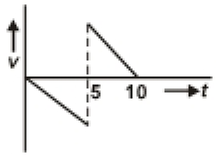
11. The displacement-time graph of a moving object is shown in the figure. Which of the velocity time graphs could represent the motion of the same body?



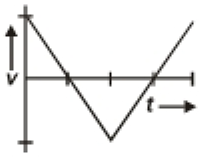
(1) 

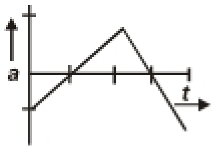
(2) 

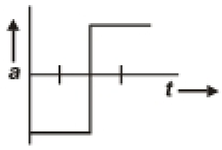
(3) 

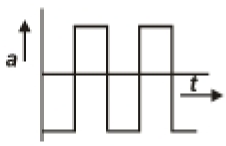
(4) 

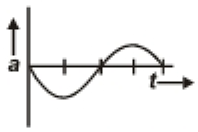
12. The graph shown in the figure is velocity v versus time t graph for a body. Which of the graphs shown in figure represents the corresponding acceleration versus time graph?



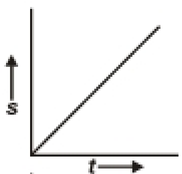
(1) 

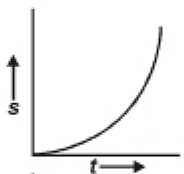
(2) 

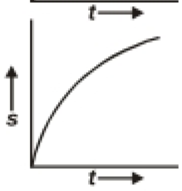
(3) 

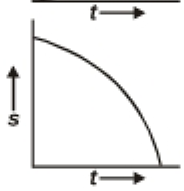
(4) 

13. Which of the following graphs represents the distance-time variation of a body released from the top of a building?

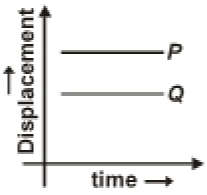
(1) 

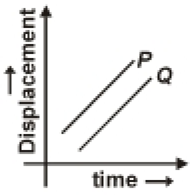
(2) 

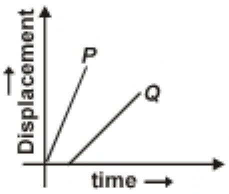
(3) 

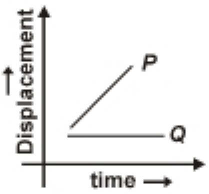
(4) 

14. Which one of the following represents the displacement-time graph of two moving objects *P* and *Q* moving with zero relative speed?

(1) 

(2) 

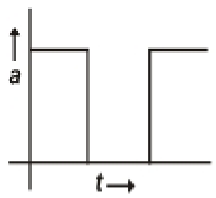
(3) 

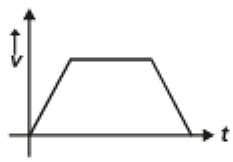
(4) 

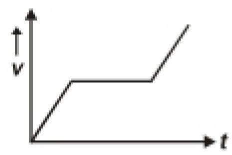
15. A body starts with initial velocity 30 m/s and a retardation of 4 m/s^2. Find the distance travelled by the body in 8th second

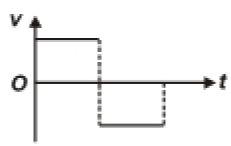
(1) Zero (2) 1 m
(3) 2 m (4) 112 m

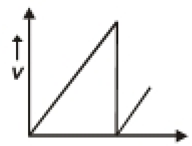
16. Figure shows the acceleration-time graph of a particle. Which of the following represents the corresponding velocity-time graph?



(1) 

(2) 

(3) 

(4) 

17. A body travelling with uniform acceleration crosses two points *A* and *B* with velocities 20 m/s and 30 m/s respectively. The speed of the body at the mid-point of *A* and *B* is

(1) 24 m/s (2) 25 m/s
(3) 25.5 m/s (4) $10\sqrt{6}$ m/s

18. A train is moving with a velocity of 30 m/s. When brakes are applied, it is found that the velocity reduces to 10 m/s in 240 m. When the velocity of the train becomes zero, the total distance travelled is

(1) 220 m (2) 240 m

(3) 250 m (4) 270 m

19. Two bodies begin a free fall from rest, from the same height, 1 second apart. How long after the first body begins to fall, will the two bodies be 10 m apart?

(1) 2 s (2) 3.5 s

(3) 0.5 s (4) 1.5 s

20. A body covers 26 m, 28 m, 30 m, 32 m in 10^{th} s, 11^{th} s, 12^{th} s and 13^{th} s respectively. The body starts

(1) From rest and moves with uniform acceleration

(2) From rest and moves with uniform velocity

(3) With a certain initial velocity and moves with uniform acceleration

(4) With an initial velocity and moves with uniform velocity

21. If a particle is thrown up with some velocity (more than 10 m/s) then distance travelled by the particle in first second of its descent will be

(1) g (2) $\frac{g}{4}$

(3) $\frac{g}{2}$ (4) Zero

SECTION - B

Previous Years Questions

1. The motion of a particle along a straight line is described by equation

$x = 8 + 12t - t^3$

where x is in metre and t in second. The retardation of the particle when its velocity becomes zero, is **[AIPMT 2012]**

(1) 6 ms^{-2} (2) 12 ms^{-2}

(3) 24 ms^{-2} (4) Zero

2. A stone falls freely under gravity. It covers distances h_1, h_2 and h_3 in the first 5 seconds, the next 5 seconds and the next 5 seconds respectively. The relation between h_1, h_2 and h_3 is **[NEET-2013]**

(1) $h_1 = \frac{h_2}{3} = \frac{h_3}{5}$

(2) $h_2 = 3h_1$ and $h_3 = 3h_2$

(3) $h_1 = h_2 = h_3$

(4) $h_1 = 2h_2 = 3h_3$

3. A particle of unit mass undergoes one-dimensional motion such that its velocity varies according to $v(x) = \beta x^{-2n}$, where β and n are constants and x is the position of the particle. The acceleration of the particle as a function of x, is given by **[AIPMT-2015]**

(1) $-2n\beta^2 e^{-4n+1}$ (2) $-2n\beta^2 x^{-2n-1}$

(3) $-2n\beta^2 x^{-4n-1}$ (4) $-2\beta^2 x^{-2n+1}$

4. If the velocity of a particle is $v = At + Bt^2$, where A and B are constants, then the distance travelled by it between 1 s and 2 s is **[NEET-2016]**

(1) $\frac{A}{2}+\frac{B}{3}$ (2) $\frac{3}{2}A+4B$

(3) $3A + 7B$ (4) $\frac{3}{2}A+\frac{7}{3}B$

5. Two cars P and Q start from a point at the same time in a straight line and their positions are represented by $x_P(t) = at + bt^2$ and $x_Q(t) = ft - t^2$. At what time do the cars have the same velocity? **[NEET (Phase-2) 2016]**

(1) $\frac{a-f}{1+b}$ (2) $\frac{a+f}{2(b-1)}$

(3) $\frac{a+f}{2(1+b)}$ (4) $\frac{f-a}{2(1+b)}$

6. Preeti reached the metro station and found that the escalator was not working. She walked up the stationary escalator in time t_1. On other days, if she remains stationary on the moving escalator, then the escalator takes her up in time t_2. The time taken by her to walk up on the moving escalator will be **[NEET-2017]**

(1) $\frac{t_1+t_2}{2}$ (2) $\frac{t_1t_2}{t_2-t_1}$

(3) $\frac{t_1t_2}{t_2+t_1}$ (4) $t_1 - t_2$

7. A person travelling in a straight line moves with a constant velocity v_1 for certain distance 'x' and with a constant velocity v_2 for next equal distance. The average velocity v is given by the relation **[NEET-2019 (Odisha)]**

(1) $\frac{1}{v}=\frac{1}{v_1}+\frac{1}{v_2}$ (2) $\frac{2}{v}=\frac{1}{v_1}+\frac{1}{v_2}$

(3) $\frac{v}{2}=\frac{v_1+v_2}{2}$ (4) $v=\sqrt{v_1v_2}$

❑ ❑ ❑

Chapter 3

Motion in a Plane

Sub-topics *Scalar and vector quantities: Position and displacement vectors, general vectors, general vectors and notation, equality of vectors, multiplication of vectors by a real number; addition and subtraction of vectors. Relative velocity. Unit vectors. Resolution of a vector in a plane-rectangular components. Scalar and Vector products of Vectors. Motion in a plane. Cases of uniform velocity and uniform acceleration- projectile motion. Uniform circular motion.*

Vectors

It is a physical quantity, which has magnitude as well as direction, and which obeys vector laws of addition *e.g.* Force, Torque.

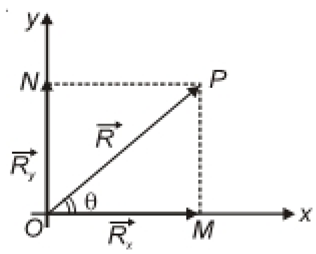
Note : *Current, Pressure, time have direction but they are not vectors because they do not obey vector laws of addition*

Resolution of a vector into plane rectangular components

In ΔOPM,

$$\cos\theta = \frac{R_x}{R}$$

$$\boxed{R_x = R\cos\theta}$$



In ΔOPM,

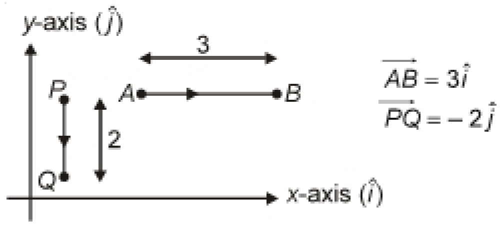
$MP = ON = R_y$

$$\sin\theta = \frac{PM}{OP} = \frac{ON}{OP} = \frac{R_y}{OP}$$

$$\boxed{R_y = R\sin\theta}$$

Unit Vector

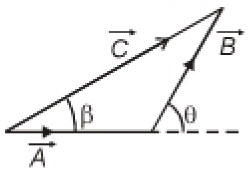
A standard of measurement with which a given vector is compared for its measurement.



Here $\overrightarrow{AB} = 3\hat{i}$ indicates that its length or magnitude is 3 and it is parallel to *x*-axis.

Addition of Vectors

When $\theta < 90°$

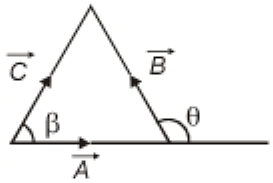


$|\vec{C}| > |\vec{A}|, |\vec{C}| > |\vec{B}|$

$|\vec{C}| = \sqrt{A^2 + B^2 + 2AB\cos\theta}$

$\tan\beta = \dfrac{B\sin\theta}{A + B\cos\theta}$

When $\theta > 90°$



Here $|\vec{C}|$ can be >, < or = $|\vec{A}|$ or $|\vec{B}|$

Case - I :

$\theta = 0°,\ |\vec{C}|_{max} = |\vec{A}| + |\vec{B}|$

Case - II :

$\theta = 180°,\ |\vec{C}|_{min} = |\vec{A}| - |\vec{B}|$

Case - III :

$|\vec{A}| = |\vec{B}|, |\vec{C}| = 2|\vec{A}|\cos\dfrac{\theta}{2}, \beta = \dfrac{\theta}{2}$

Case - IV :

$|\vec{C}| = |\vec{A}| = |\vec{B}| \Rightarrow \theta = 120°$

Case - V :

$A^2 + C^2 = B^2 \Rightarrow \vec{C} \perp \vec{A}, \cos\theta = -\dfrac{A}{B}$

Case - VI :

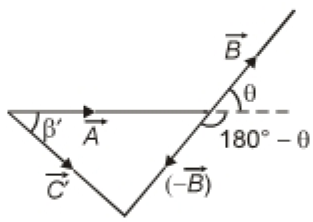
$A^2 + B^2 = C^2 \Rightarrow \vec{A} \perp \vec{B}$ *i.e.* $\theta = 90°,\ \tan\beta = \dfrac{A}{B}$

Subtraction of Vectors

$\vec{C}' = \vec{A} - \vec{B}$

$|\vec{C}'| = \sqrt{A^2 + B^2 - 2AB\cos\theta}$

$\tan\beta' = \dfrac{B\sin\theta}{A - B\cos\theta}$



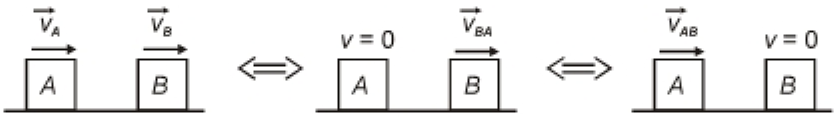
Note :

If $|\vec{A}+\vec{B}| = |\vec{A}-\vec{B}|$, *then*

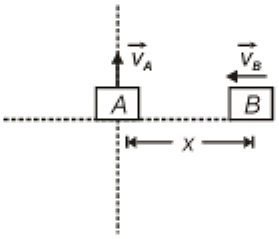
$\vec{A} \perp \vec{B}$ *and* $|\vec{A}+\vec{B}| = |\vec{A}-\vec{B}| = \sqrt{A^2+B^2}$

Applications

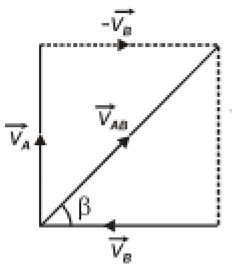
(1) **Relative velocity :** Velocity of object *A* w.r.t. object *B* is $\vec{v}_{AB} = \vec{v}_A - \vec{v}_B, \vec{v}_{BA} = \vec{v}_B - \vec{v}_A$



(2) **Closest Approach:**



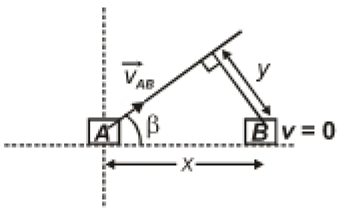
Calculation of Relative Velocity



$\tan\beta = \dfrac{v_A}{v_B}$

The above situation is similar to figure given below.

'*y*' is the distance of closest approach.

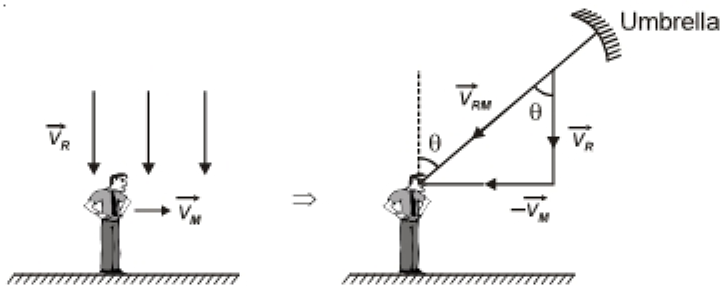


Now $\sin\beta = \dfrac{y}{x}$

$\Rightarrow y = x\sin\beta$

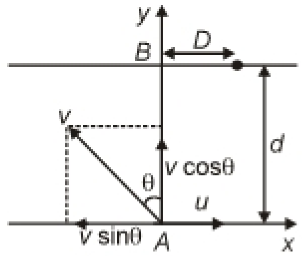
$$y = \frac{x\tan\beta}{\sqrt{1+\tan^2\beta}}$$

(3) **Direction of Umbrella :** It is the direction of relative velocity of rain.



$\boxed{\tan\theta = \dfrac{v_M}{v_R}}$ with vertical in forward direction.

(4) **Crossing a River**



v = velocity of the man in still water,

u = velocity of river flow

θ = angle at which man swims w.r.t. normal to bank

$v_x = -v\sin\theta,\ v_y = v\cos\theta$

Time taken to cross the river $t = \dfrac{d}{v_y} = \dfrac{d}{v\cos\theta}$

Velocity along the river = drift velocity along the river

$v'_x = u - v\sin\theta$

Distance drifted along the river $D = t\,v_x'$

$$\boxed{D = \frac{d}{v\cos\theta}(u - v\sin\theta)}$$

Case - I :

Minimum time to cross the river

$t_{min} = \dfrac{d}{v}$ (⇒ $\cos\theta = 1,\ \theta = 0°,\ u \perp v$)

Distance drifted

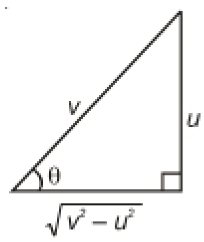
$$\boxed{D = \frac{ud}{v}}$$

Case - II :

Shortest path = AB will be obtained when

$D = 0 \quad \Rightarrow\ u - v\sin\theta = 0$

$\Rightarrow\ \boxed{\sin\theta = \dfrac{u}{v}} \quad \Rightarrow (v > u)$

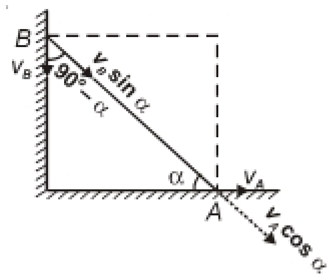


Time to cross the river straight across

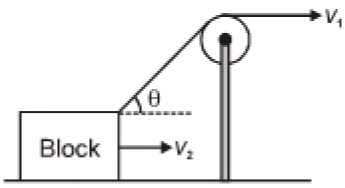
$$t = \frac{d}{v\cos\theta} = \frac{d}{\sqrt{v^2 - u^2}}$$

(5) A rod of length AB slides down a smooth vertical wall as shown. At the instant when it makes angle α with horizontal, the speed v_A and v_B are related as,

$\therefore \quad v_A \cos\alpha = v_B \sin\alpha$ (As length of rod is constant)



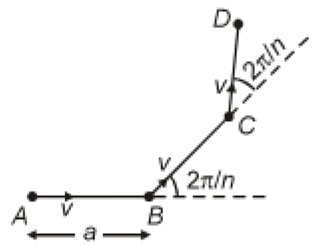
(6) If the block shown in figure, is constrained to move horizontally, then velocity of block is given by $v_2 = \dfrac{v_1}{\cos\theta}$



(7) n persons are standing at the vertices of a regular n-sided polygon of side a. Each person starts moving towards the person standing at the adjacent corner with same speed v.

(i) The persons will meet at the centre of the polygon after a time,

$$t = \frac{a}{v - v\cos\frac{2\pi}{n}}$$



(ii) In this time each person will cover a distance of

$$d = v \times t = \frac{a}{1 - \cos\frac{2\pi}{n}}$$

Case - I :

If the polygon is an equilateral triangle, put $n = 3$

$$t = \frac{a}{v - v\cos\frac{2\pi}{3}} = \frac{a}{v + \frac{v}{2}} = \frac{2a}{3v}$$

$$\therefore \quad d = \frac{2a}{3}$$

Case - II :

If the polygon is a square, put $n = 4$

$$t = \frac{a}{v - v\cos\frac{2\pi}{4}} = \frac{a}{v}$$

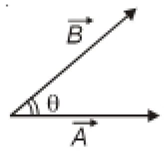
$d = a$

Case - III :

If the polygon is a hexagon, put $n = 6$

$$t = \frac{a}{v - \frac{v}{2}} = \frac{2a}{v},\ d = 2a$$

Scalar Product



(i) $R = \vec{A}\cdot\vec{B} = AB\cos\theta$

(ii) $\vec{A}\cdot\vec{B} = \vec{B}\cdot\vec{A}$

(iii) $\cos\theta = \frac{\vec{A}\cdot\vec{B}}{AB}$

(iv) $\vec{A}\cdot\vec{B} = A_xB_x + A_yB_y + A_zB_z$

(v) $\vec{A}\cdot\vec{B} = 0$ if $\vec{A}$ is $\perp$ to $\vec{B}$

(vi) $\vec{A}\cdot\vec{A} = A^2$

(vii) *e.g.* work, power, flux and current..

Vector Product

(i) $\vec{R} = \vec{A}\times\vec{B} = AB\sin\theta\ \hat{n}$

(ii) $\vec{A}\times\vec{B} \neq \vec{B}\times\vec{A}$

(iii) $|\vec{A}\times\vec{B}| = AB\sin\theta$

(iv) $\vec{A}\times(\vec{B}+\vec{C}) = \vec{A}\times\vec{B} + \vec{A}\times\vec{C}$

(v) $\vec{A}\times\vec{B} = 0$ if $\vec{A}$ and $\vec{B}$ are collinear.

(vi) $\hat{i}\times\hat{j} = \hat{k}$, $\hat{j}\times\hat{k} = \hat{i}$, $\hat{k}\times\hat{i} = \hat{j}$

(vii) *e.g.* torque, $\vec{\tau} = \vec{r}\times\vec{F}$, angular momentum $\vec{L} = \vec{r}\times\vec{p}$.

General Motion in three dimensions

Displacement $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k} = (x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j} + (z_2 - z_1)\hat{k}$

Initial velocity $\vec{u} = u_x\hat{i} + u_y\hat{j} + u_z\hat{k}$

Velocity after time t is $\vec{V} = V_x\hat{i} + V_y\hat{j} + V_z\hat{k}$

Acceleration $\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$

- A person moves x m along north, y m along east and z m vertically up a staircase, then

  (a) Position vector from starting point = $x\hat{i} + y\hat{j} + z\hat{k}$

  (b) Displacement from starting point = $\sqrt{x^2 + y^2 + z^2}$

Uniformly accelerated motion in two dimensions

Let a particle is at O at $t = 0$

At time t, it reaches P.

The various formulae are as given below

(i) $x = u_x t + \frac{1}{2} a_x t^2$

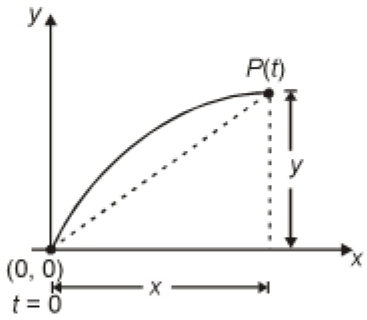
(ii) $v_x = u_x + a_x t$

(iii) $v_x^2 - u_x^2 = 2a_x x$

(iv) $y = u_y t + \frac{1}{2} a_y t^2$

(v) $v_y = u_y + a_y t$

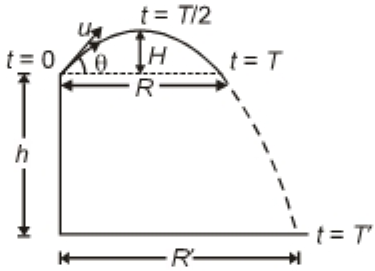
(vi) $v_y^2 - u_y^2 = 2a_y y$



PROJECTILE MOTION

A projectile is an object moving in space under the influence of gravity alone. It describes a parabola.

The important results are given below



(1) (a) $T = \frac{2u\sin\theta}{g}$

(b) $H = \frac{u^2 \sin^2\theta}{2g}$

(c) $R = \frac{u^2 \sin 2\theta}{g}$

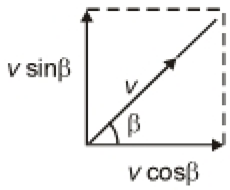
(d) For calculation of T' use $h = -u\sin\theta T' + \frac{1}{2} g T'^2$

(e) For calculation of R' use $R' = (u\cos\theta)T'$

(2) Equation of trajectory : $y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}$

or $y = x\tan\theta\left(1 - \frac{x}{R}\right)$

(3) (a) Instantaneous velocity is $v = \sqrt{u^2 + (gt)^2 - 2u(gt)\sin\theta}$



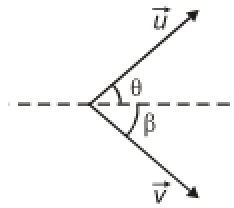
(b) Direction of motion is 'β' such that $\tan\beta = \tan\theta - \frac{gt}{u\cos\theta}$

(c) $v = \frac{u\cos\theta}{\cos\beta}$ [∵ Horizontal component is same everywhere]

(d) $v\sin\beta = u\sin\theta - gt$

(4) When $\vec{v}$ (velocity at any instant 't') is ⊥ to $\vec{u}$ (initial velocity)

$\Rightarrow \beta = 90° - \theta$



(a) $v = \dfrac{u\cos\theta}{\cos(90° - \theta)} = u\cot\theta$

(b) $t = \dfrac{u}{g\sin\theta}$

(5) The height attained by the particle is largest when θ = 90°. In this situation, time of flight is maximum, range is minimum (zero).

(6) The horizontal range is same for complimentary angles like (θ, 90° – θ) or (45° + θ, 45° – θ). It is maximum for θ = 45°.

(7) When horizontal range is maximum, $H = \dfrac{R_{max}}{4}$

(8) When R is range, T is time of flight and H is maximum height, then

(a) $\tan\theta = \dfrac{gT^2}{2R}$

(b) $\tan\theta = \dfrac{4H}{R}$

(9) Radius of curvature, when direction of motion (or velocity) is α, is $\rho = \dfrac{v^2}{g\cos\alpha}$, where v is instantaneous velocity and α is the angle with horizontal at initial moment.

(a) For vertical projection, α = 90° ⇒ ρ = ∞.

(b) At the highest point, $\rho = \dfrac{u^2\cos^2\theta}{g}$ (minimum).

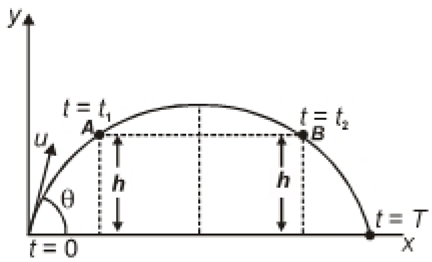
(10) A body is thrown with speed u so that range is n times height. Then

(a) $\tan\theta = \dfrac{4}{n}$, where 'θ' is the angle of projection.

(b) $R = \dfrac{u^2}{g}\dfrac{8n}{n^2+16}$

(c) $H = \dfrac{u^2}{g}\dfrac{8}{n^2+16}$

(11) If A and B are two points at same level, then



(a) $T = \dfrac{2u\sin\theta}{g} = t_1 + t_2$

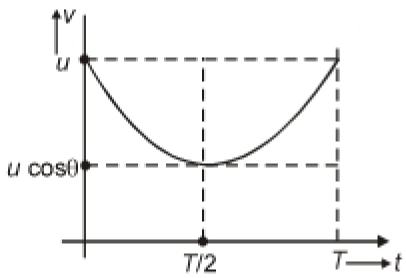
(b) $h = \dfrac{1}{2}gt_1t_2$

(c) Average velocity in the interval *AB* is

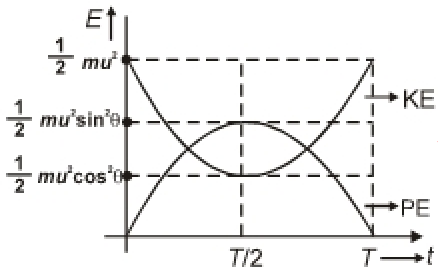
$v_{av} = u\cos\theta$ [$\because$ vertical displacement is zero]

Graphs for Projectile Motion

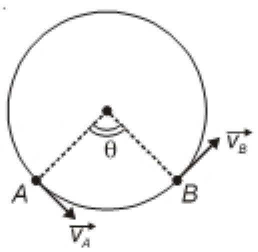
(1) Speed-time graph



(2) Energy-time graph (θ > 45°)



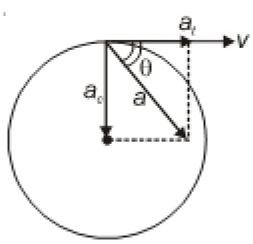
CIRCULAR MOTION

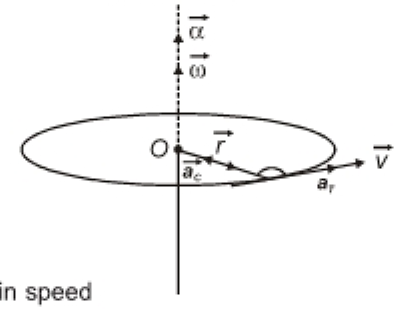


$|\Delta\vec{v}| = 2v\sin\dfrac{\theta}{2}$

- $a = \sqrt{a_c^2 + a_t^2}$

- $\tan\theta = \dfrac{|\vec{a}_c|}{|\vec{a}_t|}$





$\vec{v} = \vec{\omega} \times \vec{r}$

$\frac{d\vec{v}}{dt} = \frac{d\vec{\omega}}{dt} \times \vec{r} + \vec{\omega} \times \frac{d\vec{r}}{dt}$

$\frac{d\vec{v}}{dt} = \vec{\alpha} \times \vec{r} + \vec{\omega} \times \vec{v}$

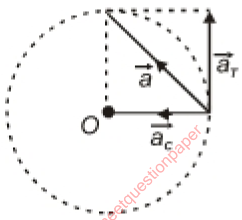
$\vec{a} = \vec{a}_T + \vec{a}_C$

$\vec{a}_T = \vec{\alpha} \times \vec{r}$ (tangential acceleration). It is responsible for change in speed

$\vec{a}_C = \vec{\omega} \times \vec{v}$ $|\vec{a}_C| = \frac{v^2}{r} = \omega^2 r$. It is responsible for change in direction

$|a| = \sqrt{a_C^2 + a_T^2}$ as $\vec{a}_C \perp \vec{a}_T$

Note : *Both $\vec{a}_C$ and $\vec{a}_T$ continuously change in direction*



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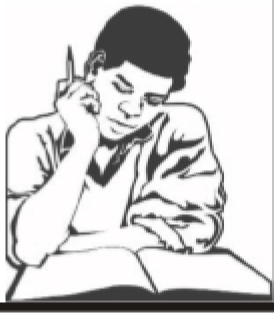


Try Yourself

SECTION - A

Objective Type Questions

1. The vector $\overrightarrow{OA}$ where O is origin is given by $\overrightarrow{OA} = 2\hat{i} + 2\hat{j}$. Now it is rotated by 45° anticlockwise about O. What will be the new vector?

(1) $2\hat{j}$ (2) $2\hat{i}$

(3) $2\sqrt{2}\,\hat{i}$ (4) $2\sqrt{2}\,\hat{j}$

2. The resultant $|\vec{R}|$ of $\vec{a}$ and $\vec{b}$ is inclined at $\frac{\pi}{3}$ to both of them. Which of the following is true?

(1) $|\vec{a}| \neq |\vec{b}|$ (2) $|\vec{R}| = |\vec{a}|$

(3) $|\vec{a}| = |\vec{b}| \neq |\vec{R}|$ (4) $\vec{R} = \vec{a} = \vec{b}$

3. If $|\vec{a} - \vec{b}| = \frac{1}{2}|\vec{b}|$ and $(\vec{a} - \vec{b})$ is $\perp$ to $\vec{a}$, then what is the angle between $\vec{a}$ and $\vec{b}$?

(1) 120° (2) 150°

(3) 60° (4) 30°

4. A car moves north with speed 15 m/s for 1 hour. Then it moves eastwards with same speed for another 1 hour. Then the average speed and average velocity of car for $t = 0$ to $t = 2$ hours is

(1) 0, 54 m/s (2) 15 m/s, $\frac{15}{\sqrt{2}}$ m/s

(3) 0, $\frac{54}{\sqrt{2}}$ km/hr (4) 0, 0

5. A particle, with an initial velocity v_0 in a plane, is subjected to a constant acceleration in the same plane. Then in general, the path of the particle would be

(1) A circle (2) An ellipse

(3) A parabola (4) A hyperbola

6. A body starts from rest from the origin with an acceleration of 6 m/s^2 along the x-axis and 8 m/s^2 along the y-axis. Its displacement from the origin after 4 second will be

(1) 56 m (2) 64 m

(3) 80 m (4) 128 m

7. The position of a particle moving in the XY-plane at any time t is given by $X = (3t^2 - 6t)$ metre and $Y = (t^2 - 2t)$ metre. Select the correct statement about the moving particle from the following

(1) The velocity of the particle is zero at $t = 0$

(2) The acceleration of the particle is zero at $t = 0$

(3) The velocity and acceleration of the particle are never zero

(4) The velocity of the particle is zero at $t = 1$ unit

8. A bomb is dropped on an enemy post by an aeroplane flying horizontally with a velocity of 60km/h and at a height of 490m. At the time of dropping the bomb, how far the aeroplane should be from the enemy post so that the bomb may directly hit the target?

(1) $\frac{400}{3}$ m (2) $\frac{500}{3}$ m

(3) $\frac{1700}{3}$ m (4) 498 m

9. A marble is to be thrown horizontally from a height of 19.6 cm above the ground so that it hits another marble on the ground, 2m away. The velocity of throw should be

(1) 5 m/s (2) 10 m/s

(3) 15 m/s (4) 20 m/s

10. A stone of mass m is thrown vertically upwards. Another stone of mass $2m$ is thrown at an angle θ with vertical. Both of them stay in air for same period of time. The heights attained by the two stones are in the ratio

(1) 1 : 1 (2) 2 : 1

(3) 1 : cos θ (4) cos θ : 1

11. In the case of an oblique projectile, the velocity is perpendicular to acceleration

(1) Once (2) Twice

(3) Thrice (4) Four times

12. An oblique projectile has the smallest speed on its trajectory when

(1) It is at its highest point

(2) It is at the point of projection

(3) It hits the ground

(4) The horizontal distance travelled by it is one-eight of the maximum height

13. A projectile is thrown with velocity v at an angle θ with horizontal. When the projectile is at a height equal to half of the maximum height, then the vertical component of the velocity of projectile is

(1) $v \sin\theta \times 3$ (2) $v \sin\theta + 3$

(3) $\frac{v\sin\theta}{\sqrt{2}}$ (4) $\frac{v\sin\theta}{\sqrt{3}}$

14. A stone is thrown with a velocity v at an angle θ with the horizontal. Its speed, when it makes an angle β with the horizontal, is

(1) $v \cos\theta$

(2) $\frac{v}{\cos\beta}$

(3) $v \cos\theta \cos\beta$

(4) $\frac{v\cos\theta}{\cos\beta}$

15. A stone is thrown with a velocity v making an angle θ with the horizontal. At some instant, its velocity V is perpendicular to the initial velocity v. Then, V is

(1) $v \sin\theta$ (2) $v \cos\theta$

(3) $v \tan\theta$ (4) $v \cot\theta$

16. If the range of a projectile is R, then its K.E. is maximum after (from start) a displacement equal to

(1) $\frac{R}{4}$ (2) R

(3) $\frac{R}{2}$ (4) $\frac{3R}{4}$

17. Two projectiles, one fired from earth with 5 m/s and the other fired from a planet with 3 m/s trace identical trajectories. If acceleration due to gravity on earth is 9.8 m/s², then the acceleration due to gravity on the planet is (assume same angle of projection)

(1) 1.5 m/s² (2) 3.5 m/s²

(3) 7.5 m/s² (4) 9.5 m/s²

18. Two stones are projected from the same point with same speed making angles 45° + θ and 45° – θ with the horizontal respectively. If $\theta \leq 45°$, then the horizontal ranges of the two stones are in ratio

(1) 1 : 1 (2) 1 : 2

(3) 1 : 3 (4) 1 : 4

19. A large number of bullets are fired in all directions with the same speed v. What is the maximum area on the ground on which these bullets will spread?

(1) $\frac{\pi v^2}{g}$ (2) $\frac{\pi v^4}{g^2}$

(3) $\frac{\pi^2 v^4}{g^2}$ (4) $\frac{\pi^2 v^2}{g^2}$

20. If angle of projection is 30°, then how many times the horizontal range is to the maximum height?

(1) 2 (2) 3

(3) $3\sqrt{4}$ (4) $4\sqrt{3}$

21. A ball is projected with a velocity v so that its range on a horizontal plane is twice the greatest height attained. Then its range is

(1) $\frac{5}{4}\frac{v^2}{g}$ (2) $\frac{v^2}{g}$

(3) $\frac{4v^2}{5g}$ (4) $\frac{2v^2}{g}$

22. If the time of flight of a bullet over a horizontal range R is T, then the angle of projection with the horizontal is

(1) $\tan^{-1}\left[\frac{gT^2}{2R}\right]$ (2) $\tan^{-1}\left[\frac{2R^2}{gT}\right]$

(3) $\tan^{-1}\left[\frac{2R}{g^2T}\right]$ (4) $\tan^{-1}\left[\frac{2R}{gT}\right]$

SECTION - B

Previous Years Questions

1. The horizontal range and the maximum height of a projectile are equal. The angle of projection of the projectile is **[AIPMT 2012]**

   (1) $\theta = \tan^{-1}(2)$ (2) $\theta = 45°$

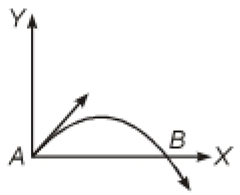
   (3) $\theta = \tan^{-1}\left(\frac{1}{4}\right)$ (4) $\theta = \tan^{-1}(4)$

2. A particle has initial velocity $(2\vec{i} + 3\vec{j})$ and acceleration $(0.3\vec{i} + 0.2\vec{j})$. The magnitude of velocity after 10 seconds will be **[AIPMT 2012]**

   (1) 5 units (2) 9 units

   (3) $9\sqrt{2}$ units (4) $5\sqrt{2}$ units

3. The velocity of a projectile at the initial point *A* is $(2\hat{i} + 3\hat{j})$ m/s. Its velocity (in m/s) at point *B* is **[NEET-2013]**



   (1) $-2\hat{i} + 3\hat{j}$ (2) $2\hat{i} - 3\hat{j}$

   (3) $2\hat{i} + 3\hat{j}$ (4) $-2\hat{i} - 3\hat{j}$

4. A projectile is fired from the surface of the earth with a velocity of 5 ms^{-1} and angle θ with the horizontal. Another projectile fired from another planet with a velocity of 3 ms^{-1} at the same angle follows a trajectory which is identical with the trajectory of the projectile fired from the earth. The value of the acceleration due to gravity on the planet is (in ms^{-2}) is (given g = 9.8 ms^{-2}) **[AIPMT 2014]**

   (1) 3.5 (2) 5.9

   (3) 16.3 (4) 110.8

5. A particle is moving such that its position coordinates (*x*, *y*) are

   (2m, 3m) at time *t* = 0,

   (6m, 7m) at time *t* = 2 s and

   (13m, 14m) at time *t* = 5 s

   Average velocity vector $(\vec{V}_{av})$ from *t* = 0 to *t* = 5 s is **[AIPMT 2014]**

   (1) $\frac{1}{5}(13\hat{i} + 14\hat{j})$ (2) $\frac{7}{3}(\hat{i} + \hat{j})$

   (3) $2(\hat{i} + \hat{j})$ (4) $\frac{11}{5}(\hat{i} + \hat{j})$

6. A ship *A* is moving Westwards with a speed of 10 km h^{-1} and a ship *B* 100 km South of *A*, is moving Northwards with a speed of 10 km h^{-1}. The time after which the distance between them becomes shortest, is **[AIPMT-2015]**

   (1) $10\sqrt{2}$ h

   (2) 0 h

   (3) 5 h

   (4) $5\sqrt{2}$ h

7. The position vector of a particle $\vec{R}$ as a function of time is given by :

   $$\vec{R} = 4\sin(2\pi t)\hat{i} + 4\cos(2\pi t)\hat{j}$$

   where *R* is in meters, *t* is in seconds and $\hat{i}$ and $\hat{j}$ denote unit vectors along *x*-and *y*-directions, respectively. Which one of the following statements is wrong for the motion of particle? **[Re-AIPMT-2015]**

   (1) Path of the particle is a circle of radius 4 meter

   (2) Acceleration vector is along $-\vec{R}$

   (3) Magnitude of acceleration vector is $\frac{v^2}{R}$, where *v* is the velocity of particle

   (4) Magnitude of the velocity of particle is 8 meter/second

8. Two particles *A* and *B*, move with constant velocities $\vec{v}_1$ and $\vec{v}_2$. At the initial moment their position vectors are $\vec{r}_1$ and $\vec{r}_2$ respectively. The condition for particles *A* and *B* for their collision is: **[Re-AIPMT-2015]**

   (1) $\vec{r}_1 - \vec{r}_2 = \vec{v}_1 - \vec{v}_2$

   (2) $\frac{\vec{r}_1 - \vec{r}_2}{|\vec{r}_1 - \vec{r}_2|} = \frac{\vec{v}_2 - \vec{v}_1}{|\vec{v}_2 - \vec{v}_1|}$

   (3) $\vec{r}_1 \cdot \vec{v}_1 = \vec{r}_2 \cdot \vec{v}_2$

   (4) $\vec{r}_1 \times \vec{v}_1 = \vec{r}_2 \times \vec{v}_2$

9. If the magnitude of sum of two vectors is equal to the magnitude of difference of the two vectors, the angle between these vectors is **[NEET-2016]**

(1) 180° (2) 0°

(3) 90° (4) 45°

10. A particle moves so that its position vector is given by $\vec{r} = \cos\omega t\,\hat{x} + \sin\omega t\,\hat{y}$, where ω is a constant. Which of the following is true? **[NEET-2016]**

(1) Velocity is perpendicular to $\vec{r}$ and acceleration is directed away from the origin

(2) Velocity and acceleration both are perpendicular to $\vec{r}$

(3) Velocity and acceleration both are parallel to $\vec{r}$

(4) Velocity is perpendicular to $\vec{r}$ and acceleration is directed towards the origin

11. A particle of mass 10 g moves along a circle of radius 6.4 cm with a constant tangential acceleration. What is the magnitude of this acceleration if the kinetic energy of the particle becomes equal to 8×10^{-4} J by the end of the second revolution after the beginning of the motion? **[NEET-2016]**

(1) 0.2 m/s^2

(2) 0.1 m/s^2

(3) 0.15 m/s^2

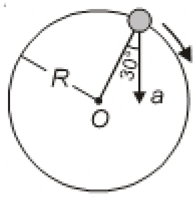
(4) 0.18 m/s^2

12. A uniform circular disc of radius 50 cm at rest is free to turn about an axis which is perpendicular to its plane and passes through its centre. It is subjected to a torque which produces a constant angular acceleration of 2.0 rad s^{-2}. Its net acceleration in ms^{-2} at the end of 2.0 s is approximately **[NEET-2016]**

(1) 3.0 (2) 8.0

(3) 7.0 (4) 6.0

13. In the given figure, a = 15 m/s^2 represents the total acceleration of a particle moving in the clockwise direction in a circle of radius R = 2.5 m at a given instant of time. The speed of the particle is **[NEET (Phase-2) 2016]**



(1) 4.5 m/s (2) 5.0 m/s

(3) 5.7 m/s (4) 6.2 m/s

14. The x and y coordinates of the particle at any time are $x = 5t - 2t^2$ and $y = 10t$ respectively, where x and y are in meters and t in seconds. The acceleration of the particle at t = 2 s is **[NEET-2017]**

(1) Zero (2) 5 m/s^2

(3) –4 m/s^2 (4) –8 m/s^2

15. When an object is shot from the bottom of a long smooth inclined plane kept at an angle 60° with horizontal, it can travel a distance x_1 along the plane. But when the inclination is decreased to 30° and the same object is shot with the same velocity, it can travel x_2 distance. Then $x_1 : x_2$ will be: **[NEET-2019]**

(1) $1:\sqrt{2}$ (2) $\sqrt{2}:1$

(3) $1:\sqrt{3}$ (4) $1:2\sqrt{3}$

16. The speed of a swimmer in still water is 20 m/s. The speed of river water is 10 m/s and is flowing due east. If he is standing on the south bank and wishes to cross the river along the shortest path the angle at which he should make his strokes w.r.t. north is given by : **[NEET-2019]**

(1) 30° west (2) 0°

(3) 60° west (4) 45° west

17. Two bullets are fired horizontally and simultaneously towards each other from roof tops of two buildings 100 m apart and of same height of 200 m, with the same velocity of 25 m/s. When and where will the two bullets collide? (g = 10 m/s^2) **[NEET-2019 (Odisha)]**

(1) After 2 s at a height of 180 m

(2) After 2 s at a height of 20 m

(3) After 4 s at a height of 120 m

(4) They will not collide

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Chapter 4

Laws of Motion

Sub-topics *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. 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 level circular road, vehicle on banked road).*

Intuitive concept of force:

Force is a push or a pull which changes or tends to change the state of rest or uniform motion or the direction of motion of the body.

Inertia:

It is the property of the body by virtue of which it is unable to change its state of rest or uniform motion along a straight line unless and until it is acted upon by an external force.

Newton's first law of motion:

Every body continues to be at rest or uniform motion along a straight line unless and until it is acted upon by an external force.

Momentum $\vec{p} = m\vec{v}$

Momentum and Newton's 2nd law : $\vec{F}_{net} = \frac{d\vec{p}}{dt}$

Law of conservation of momentum $\vec{F}_{ext} = 0 \Rightarrow \frac{d\vec{p}}{dt} = 0 \Rightarrow \vec{p} = \text{constant}$

$$\vec{F}_{ext} = \frac{d}{dt}(m\vec{v}) = \frac{md\vec{v}}{dt} + \frac{\vec{v}dm}{dt}$$

As mass = constant, $\Rightarrow \frac{dm}{dt} = 0$

$$\therefore \quad \vec{F}_{ext} = m\frac{d\vec{v}}{dt} = m\vec{a}$$

Impulse: $\vec{J} = \vec{p}_2 - \vec{p}_1 = m(\vec{v}_2 - \vec{v}_1)$

Variable mass system : Given below are common problems based on a variable mass system.

(a) A machine gun fires n bullets per second with speed v and mass of each bullet is m.

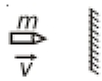
Force required on gun to keep it stationary

$F = nmv$

(b) The bullets hit a wall and

(i) Come to rest in wall

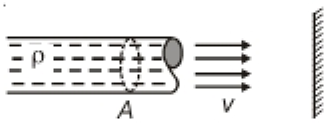
Force on wall $F_{wall} = nmv$



(ii) Rebound elastically

$F_{wall} = 2nmv$

(c) A liquid jet of area A hits a wall with a speed v



(i) Force required to move the liquid with this speed

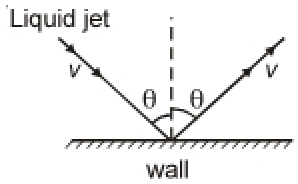
$$F = \frac{dp}{dt} = \frac{vdm}{dt} = v \times \rho A v = \rho A v^2$$

(ii) Power delivered $P = F.v = \rho A v^3 \Rightarrow P \propto v^3$

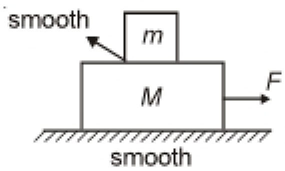
(iii) Jet hits a vertical wall and does not rebound. The force exerted on the wall is given by, $F_{wall} = \rho A v^2$

(iv) Water rebounds elastically $\Rightarrow F_{wall} = 2\rho A v^2$

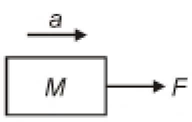
(v) $F_{wall} = 2\rho A v^2 \cos\theta$, along the normal shown by dotted line



Pseudo Force :

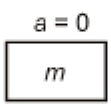


FBD of M w.r.t. ground



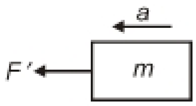
$F = Ma \Rightarrow a = \frac{F}{M}$

FBD of m w.r.t. ground



$\Rightarrow F = 0$

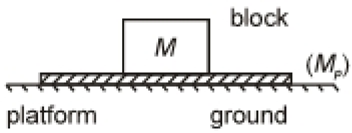
FBD of m w.r.t. M



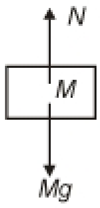
$\Rightarrow F' = ma$ (Pseudo force)

Application of Newton's third Law

(1) Due to weight of block, a normal reaction develops between block and platform.

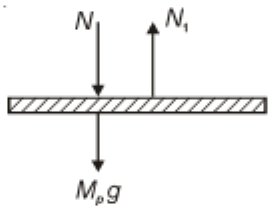


FBD of block w.r.t. ground



N = contact force between block M and platform

FBD of platform



N_1 is normal reaction between platform and ground

(a) If the platform is stationary

$\Rightarrow$ Net force is zero

$\therefore$ $N = Mg$ and $N + M_p g = N_1$

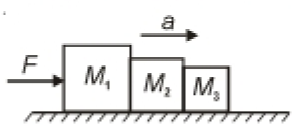
(b) System accelerates upward with acceleration 'a'

$\Rightarrow$ $N > Mg$ i.e. $N - Mg = Ma$

(c) System accelerates downward with acceleration 'a'

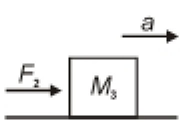
$\Rightarrow$ $N < Mg$ i.e. $Mg - N = Ma$

(2) F_1, F_2 are contact forces between M_1, M_2 and M_2, M_3 respectively in the figure shown below.

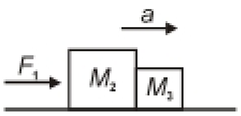


$$a = \frac{F}{M_1 + M_2 + M_3}$$

FBD of M_3



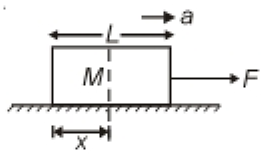
$F_2 = M_3 a$

FBD of M_2 and M_3  $F_1 = (M_2 + M_3)a$

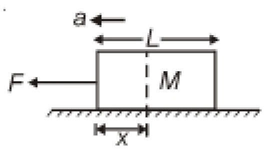
$$\Rightarrow \quad F_2 = \frac{M_3}{M_1 + M_2 + M_3}F,\ F_1 = \left(\frac{M_2 + M_3}{M_1 + M_2 + M_3}\right)F$$

(3) Tension in the block at a distance '*x*' from left end is given by

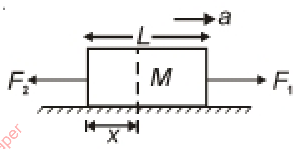
$$T_x = \frac{Mx}{L} \times \frac{F}{M} = \frac{Fx}{L};\quad a = \frac{F}{M}$$



(4) $T_x = \dfrac{F(L-x)}{L};\quad a = \dfrac{F}{M}$

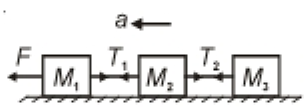


(5) $T_x = \dfrac{F_1 x}{L} + \dfrac{F_2(L-x)}{L};\quad a = \dfrac{F_1 - F_2}{M}$

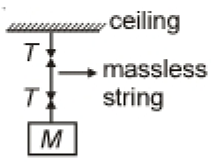


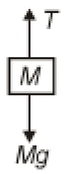
(6) The string shown in the figure is massless.

$$a = \frac{F}{M_1 + M_2 + M_3},\ T_1 = \frac{(M_2 + M_3)F}{M_1 + M_2 + M_3},\ T_2 = \frac{M_3 F}{M_1 + M_2 + M_3}$$



(7)





FBD of *M* w.r.t. ground

(a) When system is stationary

$T = Mg$

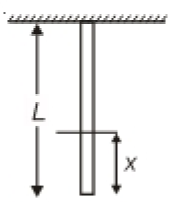
(b) System moves up with acceleration '*a*'

$T = Mg + Ma$

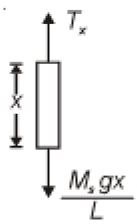
(c) System moves down with acceleration '*a*'

$T = Mg - Ma$

(8) Uniform rope of mass M_s.



FBD of lower portion



(a) Stationary system $T_x = \frac{M_s g x}{L}$

(b) Accelerating upwards $T_x = \frac{M_s x}{L}(g + a)$

(c) Accelerating downwards $T_x = \frac{M_s x}{L}(g - a)$

(d) For freely falling system, tension is zero.

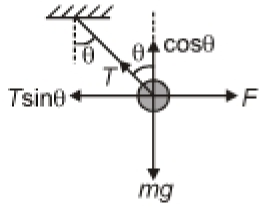
(9) A block suspended from a light rope, is held at the position shown by applying a horizontal force F

$T\sin\theta = F$ ...(i)

$T\cos\theta = mg$ ...(ii)

$\tan\theta = \frac{F}{mg}$ ...(iii)

$T = \sqrt{F^2 + m^2g^2}$



Note : *If rope falls freely, T = 0 everywhere*

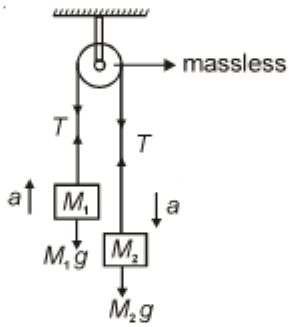
Important Problems

(1) Pulley mass systems

(a) Stationary pulley

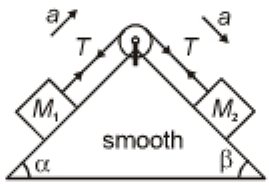
$a = \frac{M_2 - M_1}{M_2 + M_1} g$

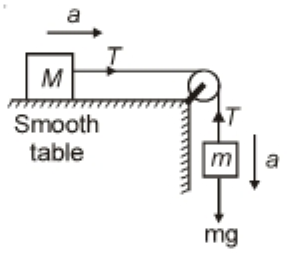
$T = 2\left(\frac{M_1 M_2}{M_1 + M_2}\right) g$



(b) $T = \frac{M_1 M_2 g}{M_1 + M_2}(\sin\alpha + \sin\beta)$

$a = \left(\frac{M_2\sin\beta - M_1\sin\alpha}{M_2 + M_1}\right) g$



(c) 

$mg - T = ma$ ...(i)

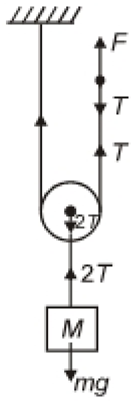
$T = Ma$ ...(ii)

$$\Rightarrow \quad a = \frac{mg}{M+m}$$

$$T = \left(\frac{mM}{M+m}\right)g$$

***Note:** If the table is smooth as in this case, any possible value of m will be able to accelerate M.*

(d) The force F needed to lift the block is $\frac{mg}{2}$



(2) Two block system

Case - I :

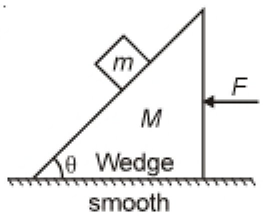
When 'm' does not slide down relative to wedge 'M'

$F = (M + m)g \tan\theta$

$a = g\tan\theta$ in horizontal direction w.r.t. ground

Contact force R between m and M is

$$R = \frac{Mg}{\cos\theta}$$



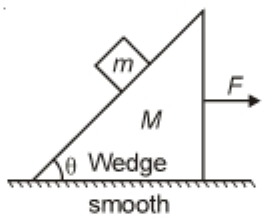
Case - II :

Minimum value of F so that 'm' falls freely

$F = Mg\cot\theta$

Wedge M moves with acceleration = $g\cot\theta$

Contact force between M and m is zero.

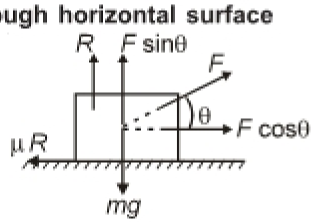


(3) Minimum force required to move a body on a rough horizontal surface

$F\cos\theta > \mu R$

$$F \geq \frac{\mu mg}{\cos\theta + \mu\sin\theta}$$

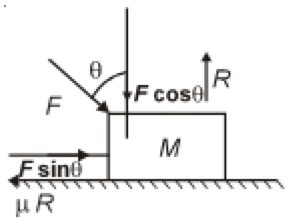
$$F_{min} = \frac{\mu mg}{\sqrt{1+\mu^2}} \text{ at } \theta = \tan^{-1}(\mu)$$



***Note:** If a horizontal force is to be applied, then F_{min} = μmg.*

(4) Minimum angle at which a pushing force should be applied so that it can move a body

$$F \geq \frac{\mu mg}{\sin\theta - \mu\cos\theta}$$



Now $\sin\theta - \mu\cos\theta > 0$

$\mu < \tan\theta$

or $\boxed{\theta > \tan^{-1}\mu}$

i.e., θ must be greater than angle of friction.

(5) Angle of Repose : It is the maximum inclination of a rough inclined plane at which a block placed on it is in a state of limiting equilibrium. $\alpha = \tan^{-1}(\mu)$

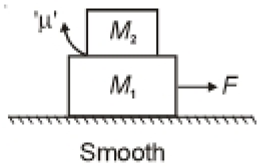
Let a body of mass m is kept on a rough inclined plane with inclination θ.

(i) When $\theta < \tan^{-1}\mu$; body remains stationary and force of friction is $mg\sin\theta$.

(ii) When $\theta > \tan^{-1}\mu$; body slides down and force of friction is $\mu mg\cos\theta$.

(6) Two block system on a smooth horizontal surface

(a) $F \leq \mu(M_1 + M_2)g$



⇒ both blocks move together with same acceleration $a = \dfrac{F}{M_1 + M_2}$

$a_{max} = \mu g$

In this case, the force of friction of m_2 is $m_2 a$. (static)

(b) $F > \mu(M_1 + M_2)g$

⇒ Sliding between M_1 and M_2 starts.

M_2 moves with constant acceleration $a_2 = \mu g$

M_1 moves with acceleration $a_1 = \dfrac{F - \mu M_2 g}{M_1}$

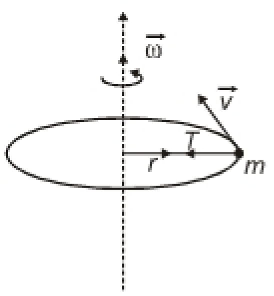
In this case, the force of friction acting on M_2 is

$f = \mu M_2 g$ (kinetic)

DYNAMICS OF UNIFORM CIRCULAR MOTION

Case - I :

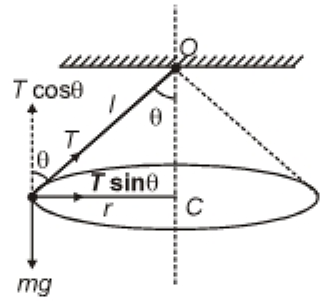
Neglecting Gravity (uniform circular motion)



T = Centripetal force = $\dfrac{mv^2}{r} = m\omega^2 r$

Case - II :

Considering gravity (Conical pendulum)



$T\sin\theta$ = Centripetal force

$T\sin\theta = m\omega^2 r$ ...(i)

$T\cos\theta = mg$

$T = \dfrac{mg}{\cos\theta}$ ...(ii)

(a) For θ to be 90° (*i.e.*, string to be horizontal)

$T = \infty$

∴ It is not possible.

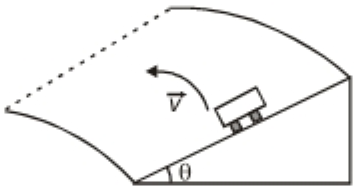
(b) $T\sin\theta = m\omega^2 r = m\omega^2 l\sin\theta$

$\Rightarrow \boxed{T = m\omega^2 l}$

(c) Time period = $2\pi\sqrt{\dfrac{l\cos\theta}{g}}$

Banking of roads : The maximum velocity with which a vehicle can safely negotiate a curve of radius *r* on a rough inclined road is

$$v^2 = \frac{rg(\mu + \tan\theta)}{1 - \mu\tan\theta}$$

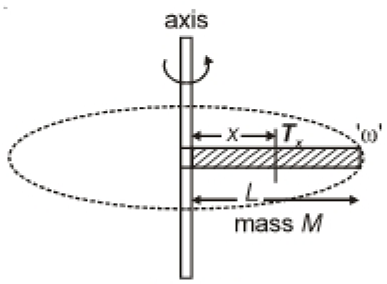


(a) For a smooth surface, $v^2 = rg\tan\theta$ [$\mu = 0$]

(b) For a horizontal surface, $\theta = 0$ $v^2 = \mu rg$

Applications :

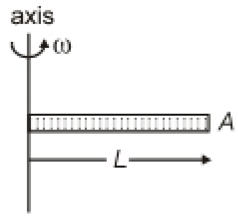
1. A rod of length *L* and mass *m* is rotating in a circle about one end as shown.



(a) Force exerted on the support by rod = $\dfrac{1}{2}M\omega^2 L$

(b) Tension in the rod at a distance '*x*' from the support is $\dfrac{1}{2}\dfrac{M\omega^2}{L}[L^2 - x^2]$

2. A liquid of mass *M* is enclosed in a tube of length *L* and the tube is rotating about one end. Force exerted by the liquid at end *A* of the pipe = $\dfrac{1}{2}M\omega^2 L$



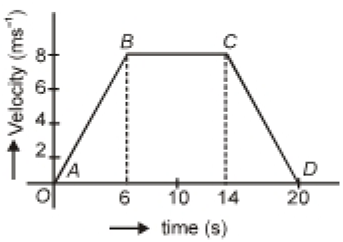
❑ ❑ ❑

Try Yourself

SECTION - A

Objective Type Questions

1. Figure shows velocity-time graph for a body of mass 1kg. Which of the following statements is true?



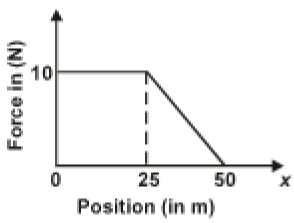
(1) Force between *A* and *B* ≠ Force between *C* and *D*

(2) Force between *B* and *C* = 1 N

(3) Force between *A* and *B* = Force between *C* and *D*

(4) Data is insufficient to calculate the force

2. An object of mass 5 kg is acted upon by a force that varies with the position of the object as in the figure. If the object starts from rest at x = 0, then its speed at x = 25 m is



(1) 5 m/s (2) 10 m/s

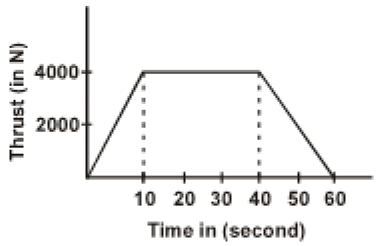
(3) 20 m/s (4) 28 m/s

3. A horizontal jet of water of cross-sectional area 10 cm^2 hits a vertical wall with a velocity of 10 m/s. After having hit the wall, water moves parallel to the wall. The force exerted by water on the wall is

(1) 10^2 N (2) 10^3 N

(3) 10^4 N (4) 10^5 N

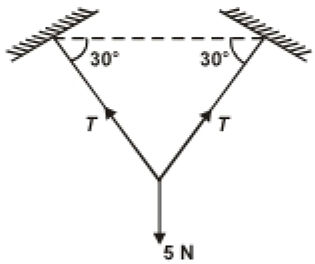
4. Figure shows the thrust-time graph of a rocket. If the mass of the rocket is 1 ton, then the velocity of the rocket 1 minute after starting from rest is



(1) 18 m/s (2) 180 m/s

(3) 1800 m/s (4) 360 m/s

5. A bird of weight 5N sits at the mid point of a clothesline. The line is so distorted that it makes 30° angles with the horizontal at each end as shown in figure. The tension in the clothesline is



(1) 5 N (2) 5 cos 30° N

(3) 5 sin 30° N (4) 5.98 N

6. A block of mass *m* is pulled along a horizontal surface by a horizontal rope of mass 1 kg. A force of 15N is applied at the free end of the rope. The force exerted by the block on the rope is 13.5N. The mass *m* of the block is

(1) 1.5 kg (2) 3 kg

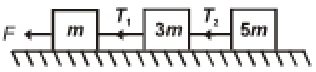
(3) 6 kg (4) 9 kg

7. A triangular block of mass M with angles 30°, 60° and 90° rests with its 30° – 90° side on a horizontal table. A cubical block of mass m rests on the 60° – 30° side. The acceleration, which M must have relative to the table, to keep m stationary relative to the triangular block, (assuming frictionless contact) is

(1) g (2) $\frac{g}{\sqrt{2}}$

(3) $\frac{g}{\sqrt{3}}$ (4) $\frac{g}{\sqrt{5}}$

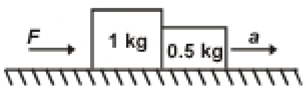
8. Figure shows a system of three masses being pulled with a force F. The masses are connected to each other by strings. The horizontal surface is frictionless. The tension T_1 in the first string is 16 N. The acceleration of the system is



(1) $\frac{1}{m}$ (2) $\frac{2}{m}$

(3) $\frac{3}{m}$ (4) $\frac{4}{m}$

9. A 1 kg block and a 0.5 kg block move together on a horizontal frictionless surface. Each block exerts a force of 6 N on the other. The blocks move with a uniform acceleration of



(1) 3 m/s² (2) 6 m/s²

(3) 9 m/s² (4) 12 m/s²

10. A balloon has 5 g of air. A small hole is pierced into it. The air escapes at a uniform rate with a velocity of 4 cm/s. If the balloon shrinks completely in 2.5 second, then the average force acting on the balloon is

(1) 2 dyne (2) 50 dyne

(3) 8 dyne (4) 8 N

11. A body of mass 10 kg moves with a constant velocity of 10 m/s. Now a constant force acts for 4s on the body and gives it a speed of 2 m/s in the opposite direction. The impulse imparted to the object is

(1) 120 N-s (2) –120 N-s

(3) 60 N-s (4) – 60 N-s

12. A man of mass 50 kg carries a bag of weight 500 N on his shoulder. The force with which the floor pushes up his feet will be (g = 9.8 m/s²)

(1) 1000 N (2) 490 N

(3) 500 N (4) 990 N

13. A frame of reference which moves with constant velocity with respect to a stationary frame of reference is called

(1) Inertial frame of reference

(2) Non-inertial frame of reference

(3) Rotating frame of reference

(4) Absolute frame of reference

14. A block of mass m is placed on a smooth inclined plane of inclination θ with the horizontal. The force exerted by the plane on the block has a magnitude

(1) mg (2) $\frac{mg}{\cos\theta}$

(3) $mg \cos\theta$ (4) $mg \tan\theta$

15. A woman of mass 50 kg is standing in an elevator. Suddenly, the cable of the elevator breaks and the elevator begins to fall freely. The force exerted by the floor of the elevator on the woman is

(1) 0 (2) 50 kgf

(3) 100 kgf (4) 50 × 9.8 kgf

16. A block of mass 2 kg is sliding with a constant velocity of 8 m/s on a frictionless horizontal surface. The force exerted on the horizontal surface is nearly

(1) 20 N (2) 10 N

(3) 40 N (4) 16 N

17. Nine five-rupee coins are put on top of each other on a table. Each coin has a mass m kg. The reaction of the 5th coin (counted from bottom) on 6th coin is

(1) 0 mg (2) 2 mg

(3) 4 mg (4) 5 mg

18. A weighing machine records 35 kg when a boy stands on it. The reaction of the machine on the boy is

(1) 0 kgf (2) 35 kgf

(3) 70 kgf (4) 350 kgf

19. Gravel is dropped on to a conveyor belt at the rate of 0.5 kg/s. The extra force in newton required to keep the belt moving at 2 m/s is

(1) 1 (2) 2

(3) 4 (4) 5

20. A ball of mass m is thrown vertically upwards. What is rate at which the momentum of the ball changes?

(1) Zero (2) mg

(3) Infinity (4) Data is not sufficient

21. Two bodies of masses m_1 and m_2 are connected by a light, inextensible string which passes over a frictionless pulley. If the pulley is moving upward with uniform acceleration g, then the tension in the string is

(1) $\frac{4m_1m_2}{m_1+m_2}g$ (2) $\frac{m_1+m_2}{4m_1m_2}g$

(3) $\frac{m_1m_2}{m_1+m_2}g$ (4) $\frac{m_1-m_2}{m_1+m_2}g^2$

22. A machine gun mounted on a 2000 kg car on a horizontal frictionless surface fires 10 bullets per second. If the mass of each bullet is 10 g and the velocity of each bullet is 500 m/s, then the acceleration of the car will be

(1) $\frac{1}{10}\text{m/s}^2$ (2) $\frac{1}{20}\text{m/s}^2$

(3) $\frac{1}{40}\text{m/s}^2$ (4) $\frac{1}{60}\text{m/s}^2$

23. A body of mass 32 kg is suspended by a spring balance from the roof of a vertically operating lift, going downward from rest. At the instant the lift has covered 20 m and 50 m, the spring balance showed 30 kg and 36 kg respectively. Then the velocity of lift is

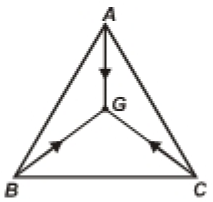
(1) Decreasing at 20 m and increasing at 50 m

(2) Increasing at 20 m and decreasing at 50 m

(3) Continuously decreasing at a steady rate throughout the journey

(4) Constantly increasing at constant rate throughout the journey

24. Three particles A, B and C of equal mass, move with equal speed v along the medians of an equilateral triangle as shown in figure. They collide at the centroid G of the triangle. After collision A comes to rest and B retraces its path with speed v. What is the speed of C after collision?



(1) 0 (2) $\frac{v}{2}$

(3) v (4) $2v$

25. A man slides down a light rope whose breaking strength is η times his weight ($\eta < 1$). The acceleration of the man so that the rope just breaks is

(1) $g(1-\eta)$ (2) $g(1+\eta)$

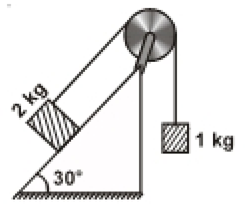
(3) $g\eta$ (4) $\frac{g}{\eta}$

26. Two masses 3 kg and 5 kg are suspended from the ends of an unstretchable massless cord passing over a frictionless pulley. When the masses are released, the downward force on the pulley is

(1) 2 kgf (2) 7.5 kgf

(3) 8 kgf (4) 15 kgf

27. Refer to the system shown in the figure. Assume that the inclined plane is smooth. Which of the following is correct?



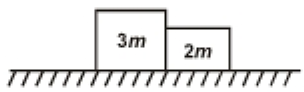
(1) 1 kg body moves downward with some acceleration

(2) 2 kg body moves down the inclined plane with acceleration $g \sin 30°$

(3) The system is in equilibrium

(4) All of these

28. Two blocks of masses 3 m and 2 m are in contact on a smooth table. A force P is first applied horizontally on block of mass 3 m and then on mass 2 m. The contact forces between the two blocks in the two cases are in the ratio



(1) 1 : 2 (2) 2 : 3

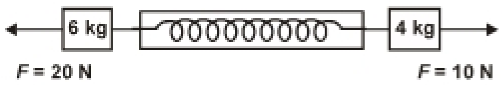
(3) 3 : 2 (4) 5 : 3

29. A block of wood is kept on the floor of a stationary elevator. The elevator begins to descend with an acceleration of 12 m/s². If g = 10 m/s², then the displacement of the block w.r.t. ground during the first 0.2 second after the start is

(1) 0.02 m (2) 0.1 m

(3) 0.2 m (4) 0.4 m

30. A dynamometer D is attached to two blocks of masses 6 kg and 4 kg. Forces of 20 N and 10 N are applied on the blocks as in the figure. The dynamometer reads

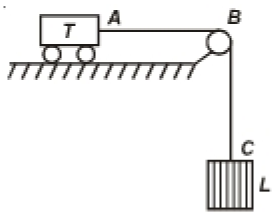


(1) 10 N (2) 20 N

(3) 6 N (4) 14 N

31. A trolley T (mass 5 kg) on a horizontal smooth surface is pulled by a load L (2 kg) through a uniform rope ABC of length 2 m and mass 1 kg. As the load falls from $BC = 0$ to $BC = 2$ m, its acceleration (in m/s^2) changes from

(Take $g = 10$ m/s^2)



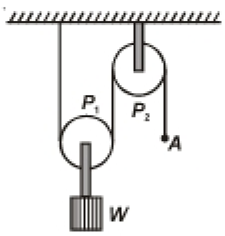
(1) $\frac{20}{6}$ to $\frac{20}{5}$

(2) $\frac{20}{8}$ to $\frac{30}{8}$

(3) $\frac{20}{5}$ to $\frac{30}{6}$

(4) Its acceleration remains constant

32. A system of frictionless pulleys P_1 and P_2 are shown in the figure. Neglecting the weights of the pulleys, the minimum pull needed at A to lift a load W will be



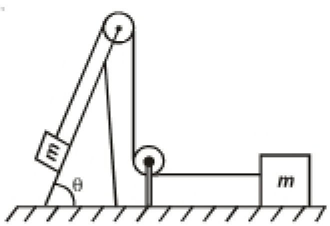
(1) $\frac{W}{2}$

(2) $\frac{W}{3}$

(3) W

(4) Below $\frac{W}{3}$

33. For the system shown in the figure the pulleys are light and frictionless. The tension in the string will be



(1) $\frac{2}{3}mg\sin\theta$

(2) $\frac{3}{2}mg\sin\theta$

(3) $\frac{1}{2}mg\sin\theta$

(4) $2\,mg\sin\theta$

34. A one kg mass suspended by a thread is first lifted up with an acceleration $\frac{g}{2}$ and then lowered downward with an acceleration $\frac{g}{2}$. The ratio of tensions in the first and second case is

(1) 1 : 2 (2) 2 : 1

(3) 1 : 3 (4) 3 : 1

35. A car accelerates on a horizontal road due to the force exerted by

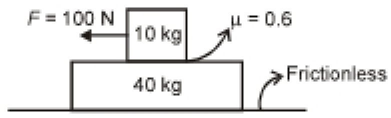
(1) The engine of the car

(2) The driver of the car

(3) Normal reaction between ground and car

(4) Friction between ground and car

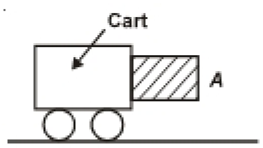
36. In the situation shown in the figure, the acceleration of 10 kg block will be



(1) 4 m/s^2 (2) 2 m/s^2

(3) 10 m/s^2 (4) Zero

37. What acceleration must the cart in the figure have in order that the block A will not fall?



(μ is coefficient of friction between the cart and the block)

(1) μg (2) $\frac{g}{\mu}$

(3) $\frac{\mu}{g}$ (4) $\mu + g$

38. A truck moving at $\frac{250}{9}$ m/s carries a steel girder which rests on its wooden floor. The minimum time in which the truck can come to a stop, without the girder moving forward, is (given $\mu_s = 0.5$)

(1) 3 s (2) 4 s

(3) 5 s (4) 5.7 s

39. A block of mass 'm' is placed on a rough inclined plane. When the inclination of the plane is θ, the block just begins to slide down the plane under its own weight. The minimum force applied parallel to the plane, to move the block up the plane is

(1) $mg \sin\theta$ (2) $2\ mg \sin\theta$

(3) $mg \cos\theta$ (4) $mg \tan\theta$

40. A block of mass m is kept on the floor of a freely falling lift. During the free fall of the lift, the block is pulled horizontally with a force of 2 N, $\mu_s = 0.1$. The frictional force on the block will be

(1) Zero (2) 2 N

(3) 1 N (4) 10 N

41. In uniform circular motion, the factor that remains constant is

(1) Linear velocity (2) Centripetal force

(3) Acceleration (4) Speed

42. When the road is dry and the coefficient of friction is μ, the maximum speed of a car in a circular path is 10m/s. If the road becomes wet and $\mu' = \frac{\mu}{2}$, what is the maximum speed permitted?

(1) 5 m/s (2) 10 m/s

(3) $10\sqrt{2}$ m/s (4) $5\sqrt{2}$ m/s

43. A stone is whirled in a vertical plane. The stone has

(1) Radial acceleration only

(2) Tangential acceleration only

(3) Both radial and tangential accelerations

(4) Neither radial nor tangential acceleration

44. A curved road of radius r is perfectly banked for a speed v. When a car of weight W goes round the curve with speed v (friction neglected), the normal reaction of the road is N. Then

(1) The centripetal force is the resultant of W and N

(2) Normal reaction is W

(3) The centripetal force is zero

(4) The centripetal force is W

45. Three identical cars A, B and C are moving at the same speed on three bridges. The car A goes on a plane bridge, B on a bridge convex upward and C goes on a bridge concave upward. Let F_A, F_B and F_C be the normal forces exerted by the cars on the bridges when they are at the middle of bridges. Then

(1) F_A is maximum of the three forces

(2) F_B is maximum of the three forces

(3) F_C is maximum of the three forces

(4) $F_A = F_B = F_C$

SECTION - B

Previous Years Questions

1. A car of mass 1000 kg negotiates a banked curve of radius 90 m on a frictionless road. If the banking angle is 45°, the speed of the car is **[AIPMT 2012]**

(1) 5 ms^{-1} (2) 10 ms^{-1}

(3) 20 ms^{-1} (4) 30 ms^{-1}

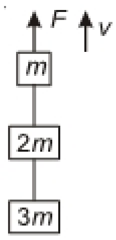
2. The upper half of an inclined plane of inclination θ is perfectly smooth while lower half is rough. A block starting from rest at the top of the plane will again come to rest at the bottom, if the coefficient of friction between the block and lower half of the plane is given by **[NEET-2013]**

(1) $\mu = \frac{2}{\tan\theta}$ (2) $\mu = 2\tan\theta$

(3) $\mu = \tan\theta$ (4) $\mu = \frac{1}{\tan\theta}$

3. 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 2 m?

(g is the acceleration due to gravity) **[NEET-2013]**



(1) 2 mg (2) 3 mg

(3) 6 mg (4) Zero

4. 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 **[NEET-2013]**

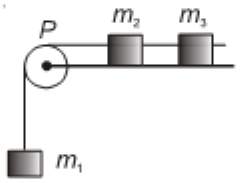
(1) 5 kg (2) 7 kg

(3) 17 kg (4) 3 kg

5. 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

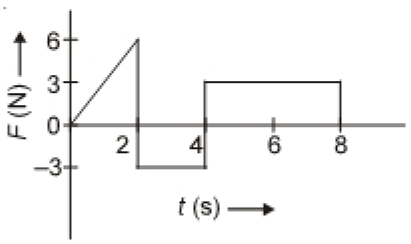
(Assume $m_1 = m_2 = m_3 = m$) **[AIPMT 2014]**



(1) $\frac{g(1-g\mu)}{9}$ (2) $\frac{2g\mu}{3}$

(3) $\frac{g(1-2\mu)}{3}$ (4) $\frac{g(1-2\mu)}{2}$

6. 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 zero to 8 s is **[AIPMT 2014]**



(1) 24 Ns (2) 20 Ns

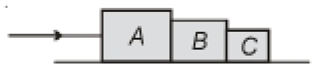
(3) 12 Ns (4) 6 Ns

7. A balloon with mass *m* is descending down with an acceleration *a* (where $a < g$). How much mass should be removed from it so that it starts moving up with an acceleration *a*? **[AIPMT 2014]**

(1) $\frac{2ma}{g+a}$ (2) $\frac{2ma}{g-a}$

(3) $\frac{ma}{g+a}$ (4) $\frac{ma}{g-a}$

8. 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. If a force of 14 N is applied on the 4 kg block, then the contact force between *A* and *B* is **[AIPMT-2015]**



(1) 18 N (2) 2 N

(3) 6 N (4) 8 N

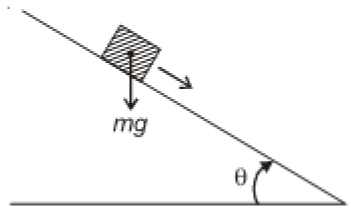
9. A block *A* of mass m_1 rests on a horizontal table. A light string connected to it passes over a frictionless pulley at the edge of table and from its other end another block *B* of mass m_2 is suspended. The coefficient of kinetic friction between the block and table is μ_k. When the block *A* is sliding on the table, the tension in the string is **[AIPMT-2015]**

(1) $\frac{m_1 m_2(1-\mu_k)g}{(m_1+m_2)}$ (2) $\frac{(m_2+\mu_k m_1)g}{(m_1+m_2)}$

(3) $\frac{(m_2-\mu_k m_1)g}{(m_1+m_2)}$ (4) $\frac{m_1 m_2(1+\mu_k)g}{(m_1+m_2)}$

10. A plank with a box on it at one end is gradually raised about the other end. As the angle of inclination with the horizontal reaches 30°, the box starts to slip and slides 4.0 m down the plank in 4.0 s. The coefficients of static and kinetic friction between the box and the plank will be, respectively

[Re-AIPMT-2015]



(1) 0.4 and 0.3 (2) 0.6 and 0.6

(3) 0.6 and 0.5 (4) 0.5 and 0.6

11. Two stones of masses *m* and 2 *m* are whirled in horizontal circles, the heavier one in a radius $\frac{r}{2}$ and lighter one in 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 **[Re-AIPMT-2015]**

(1) 1 (2) 2

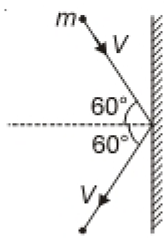
(3) 3 (4) 4

12. A car is negotiating a curved road of radius *R*. The road is banked at an angle θ. The coefficient of friction between the tyres of the car and the road is μ_s. The maximum safe velocity on this road is **[NEET-2016]**

(1) $\sqrt{\frac{g}{R^2}\frac{\mu_s+\tan\theta}{1-\mu_s\tan\theta}}$ (2) $\sqrt{gR^2\frac{\mu_s+\tan\theta}{1-\mu_s\tan\theta}}$

(3) $\sqrt{gR\frac{\mu_s+\tan\theta}{1-\mu_s\tan\theta}}$ (4) $\sqrt{\frac{g}{R}\frac{\mu_s+\tan\theta}{1-\mu_s\tan\theta}}$

13. A rigid ball of mass *m* strikes a rigid wall at 60° and gets reflected without loss of speed as shown in the figure below. The value of impulse imparted by the wall on the ball will be



[NEET (Phase-2) 2016]

(1) mV (2) $2mV$

(3) $\frac{mV}{2}$ (4) $\frac{mV}{3}$

14. One end of string of length *l* is connected to a particle of mass *m* and the other end is connected to a small peg on a smooth horizontal table. If the particle moves in circle with speed *v*, the net force on the particle (directed towards center) will be (*T* represents the tension in the string) **[NEET-2017]**

(1) T (2) $T+\frac{mv^2}{l}$

(3) $T-\frac{mv^2}{l}$ (4) Zero

15. Which one of the following statements is incorrect? **[NEET-2018]**

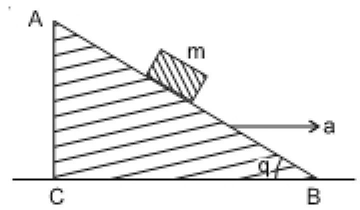
(1) Rolling friction is smaller than sliding friction.

(2) Limiting value of static friction is directly proportional to normal reaction.

(3) Coefficient of sliding friction has dimensions of length.

(4) Frictional force opposes the relative motion.

16. A block of mass m is placed on a smooth inclined wedge ABC of inclination θ as shown in the figure. The wedge is given an acceleration 'a' towards the right. The relation between a and θ for the block to remain stationary on the wedge is **[NEET-2018]**



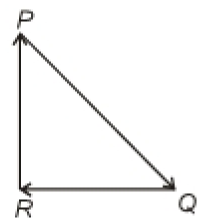
(1) $a=\frac{g}{\text{cosec}\,\theta}$

(2) $a=\frac{g}{\sin\theta}$

(3) $a = g\tan\theta$

(4) $a = g\cos\theta$

17. A particle moving with velocity $\vec{V}$ is acted by three forces shown by the vector triangle *PQR*. The velocity of the particle will : **[NEET-2019]**



(1) Increase

(2) Decrease

(3) Remain constant

(4) Change according to the smallest force $\overrightarrow{QR}$

18. A block of mass 10 kg is in contact against the inner wall of a hollow cylindrical drum of radius 1 m. The coefficient of friction between the block and the inner wall of the cylinder is 0.1. The minimum angular velocity needed for the cylinder to keep the block stationary when the cylinder is vertical and rotating about its axis, will be : ($g = 10\ m/s^2$) **[NEET-2019]**

(1) $\sqrt{10}$ rad/s

(2) $\frac{10}{2\pi}$ rad/s

(3) 10 rad/s

(4) 10π rad/s

19. A person standing on the floor of an elevator drops a coin. The coin reaches the floor in time t_1 if the elevator is at rest and in time t_2 if the elevator is moving uniformly. Then **[NEET-2019 (Odisha)]**

(1) $t_1 < t_2$ or $t_1 > t_2$ depending upon whether the lift is going up or down

(2) $t_1 < t_2$

(3) $t_1 > t_2$

(4) $t_1 = t_2$

20. A truck is stationary and has a bob suspended by a light string, in a frame attached to the truck. The truck suddenly moves to the right with an acceleration of *a*. The pendulum will tilt **[NEET-2019 (Odisha)]**

(1) to the left and angle of inclination of the pendulum with the vertical is $\sin^{-1}\left(\frac{g}{a}\right)$

(2) to the left and angle of inclination of the pendulum with the vertical is $\tan^{-1}\left(\frac{a}{g}\right)$

(3) to the left and angle of inclination of the pendulum with the vertical is $\sin^{-1}\left(\frac{a}{g}\right)$

(4) to the left and angle of inclination of the pendulum with the vertical is $\tan^{-1}\left(\frac{g}{a}\right)$

21. A body of mass m is kept on a rough horizontal surface (coefficient of friction = μ). A horizontal force is applied on the body, but it does not move. The resultant of normal reaction and the frictional force acting on the object is given by *F*, where *F* is **[NEET-2019 (Odisha)]**

(1) $|\vec{F}| = mg + \mu mg$

(2) $|\vec{F}| = \mu mg$

(3) $|\vec{F}| \le mg\sqrt{1+\mu^2}$

(4) $|\vec{F}| = mg$

❑ ❑ ❑

Chapter 5

Work, Energy and Power

Sub-topics *Work done by a constant force and 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); nonconservative forces; motion in a vertical circle, elastic and inelastic collisions in one and two dimensions.*

Work Done by a Constant Force and Variable Force

Work done by a constant force = $\vec{F}.\vec{s}$

Work done by a variable force = $\int \vec{F} \cdot d\vec{s}$

Work done by a force = Area of *F*-*s* graph

Work done by a conservative force is independent of the path followed. *e.g.* gravitational, electrostatic forces.

Kinetic Energy

Kinetic energy = $\frac{1}{2}mv^2$

Work-Energy Theorem

(i) Work done by all the forces (internal or external, conservative or non conservative)

= change in KE of the body

$W_{cons} + W_{non\text{-}cons} + W_{ext} = \Delta KE$

(ii) $W_{conservative} = -\Delta PE$

$\Rightarrow \Delta U = -\int_{x_1}^{x_2} F_{cons}\,dx \Rightarrow U = -\int_{0}^{x} F_{cons}\,dx$

$\Rightarrow W_{ext} + W_{non\text{-}cons} = \Delta KE + \Delta PE$

$\Rightarrow$ If there is no external or non-conservative force,

$\Delta KE + \Delta PE = 0$

$\Rightarrow$ Total mechanical energy = Constant

Applications :

(1) Consider a car and a bus of mass M_1 and M_2 respectively.

(a) If they are moving with same velocity, then the ratio of their stopping distances, by the application of same retarding force can be calculated as shown.

$$\frac{1}{2}M_1v^2 = F.x_1; \frac{1}{2}M_2v^2 = Fx_2$$

$$\therefore \quad \frac{x_1}{x_2} = \frac{M_1}{M_2}$$

(b) If they are moving with same kinetic energy, then ratio of their stopping distances, by the application of same retarding force can be calculated as shown.

$$\frac{1}{2}Mv^2 = F.x$$

$$x_1 = x_2$$

(c) If they are moving with same momentum, then ratio of their stopping distances, by the application of same retarding force can be calculated as shown.

$$\frac{P^2}{2m} = F.x$$

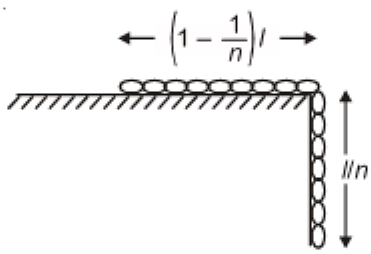
$$\therefore \quad \frac{x_1}{x_2} = \frac{m_2}{m_1}$$

(2) If a body moving with speed v is stopped in time 't' by delivering constant braking power, then

$$P.t = \frac{1}{2}mv^2$$

or $t \propto v^2$

(3) Let $\left(\frac{1}{n}\right)^{th}$ part of a chain is hanging at the edge of a table

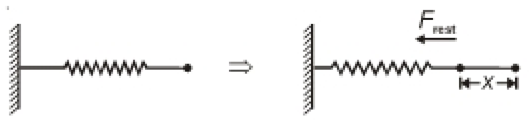


(a) If table surface is taken as reference, the potential energy of chain = $-\frac{mgl}{2n^2}$

(b) Work done against gravity to pull the hanging part on the table = $\frac{mgl}{2n^2}$

Potential Energy

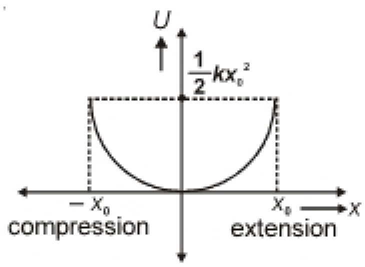
(1) Potential energy of a spring



$F_{rest} \propto -x$

$\Rightarrow$ $F = -kx$, where k = spring constant

$$U = -\int_0^x F dx = -\int_0^x (-kx)dx = \frac{1}{2}kx^2 = \text{PE inside the spring}$$



$U \propto x^2$ i.e. potential energy varies parabolically with extension

(2) Two springs having spring constants k_1 and k_2

(a) are pulled by same force $\Rightarrow F = k_1x_1 = k_2x_2$

$$U_1 = \frac{1}{2}k_1x_1^2 = \frac{1}{2}Fx_1, \; U_2 = \frac{1}{2}Fx_2$$

$$\Rightarrow \frac{U_1}{U_2} = \frac{x_1}{x_2} = \frac{k_2}{k_1}$$

(b) are pulled by same distance 'x'

$$F_1 = k_1x \qquad F_2 = k_2x \quad \Rightarrow \frac{F_1}{F_2} = \frac{k_1}{k_2}$$

$$U_1 = \frac{1}{2}k_1x^2 \quad U_2 = \frac{1}{2}k_2x^2$$

$$\Rightarrow \frac{U_1}{U_2} = \frac{k_1}{k_2} = \frac{F_1}{F_2}$$

Power

Instantaneous power, $P = \frac{dW}{dt} = \frac{\vec{F}.d\vec{s}}{dt} = \vec{F}.\vec{v}$

$$P_{average} = \frac{W}{t}$$

Conservation of Mechanical Energy

Applicable only for a conservative force

$W_{\text{con. }F} + W_{\text{Non-con. }F} = KE_f - KE_i$

$W_{\text{Non-con. }F} = ME_f - ME_i$

If $W_{\text{Non-con. }F} = 0$

$\boxed{ME_f = ME_i}$

Power : It is the rate of doing work.

$$P_{av} = \frac{\Delta W}{\Delta t} \qquad P_{\text{inst}} = \frac{dW}{dt} = \vec{F}\cdot\vec{v}$$

Vertical Circle (under gravity alone)

$a_T = g\sin\theta$ ...(i)

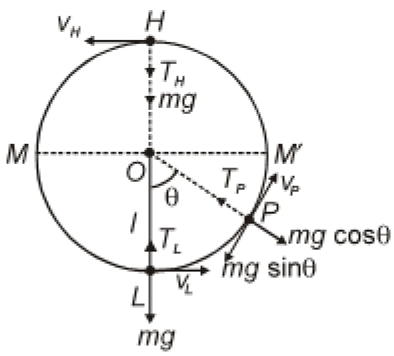
$$a_C = \frac{T_p - mg\cos\theta}{m} = \frac{v_p^2}{l}$$

$$\Rightarrow T_p = \frac{mv_p^2}{l} + mg\cos\theta \quad \text{...(ii)}$$

$$T_L = mg + \frac{mv_L^2}{l}$$

$$T_H = -mg + \frac{mv_H^2}{l}$$

$T_L - T_H = 6\ mg$ (always)



(a) When $v_L \geq \sqrt{5gl}$, it completes vertical circle (Also $v_H \geq \sqrt{gl}$)

(b) $v_L \leq \sqrt{2gl}$, it oscillates between M and M'

(c) $\sqrt{2gl} < v_L < \sqrt{5gl}$, it will leave the circular path somewhere between M and H.

Collisions

In one dimension

($u_1 > u_2$ and $v_2 > v_1$)

(1) Conservation of linear momentum

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ ...(i)

(2) Coefficient of restitution

$$e = \frac{v_2 - v_1}{u_1 - u_2}$$

Loss of kinetic energy $\Delta KE = \dfrac{1}{2}\dfrac{m_1m_2}{m_1 + m_2}(u_1 - u_2)^2(1 - e^2)$

(3) For an elastic collision $e = 1$

$\Rightarrow v_2 - v_1 = u_1 - u_2$ ...(ii)

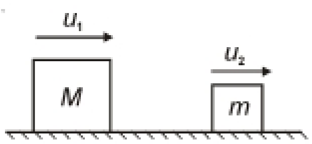
From (i) and (ii)

$$v_1 = \frac{m_1 - m_2}{m_1 + m_2}u_1 + \frac{2m_2u_2}{m_1 + m_2}$$

$$v_2 = \frac{m_2 - m_1}{m_2 + m_1}u_2 + \frac{2m_1u_1}{m_2 + m_1}$$

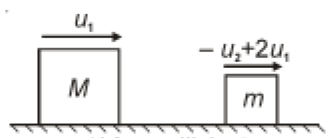
$\Delta KE = 0 \Rightarrow$ Final KE = Initial KE

(4) In an elastic collision, kinetic energy during the collision is not conserved. It is converted into elastic potential energy. But KE before collision = KE after collision.

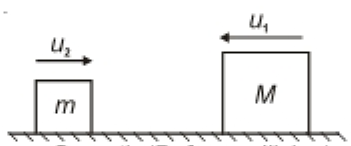
(5) 

Smooth (Before collision)

$M >> m$ $\Rightarrow$

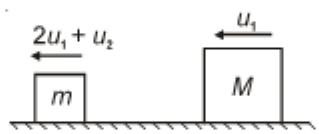


(After collision)

(6) 

Smooth (Before collision)

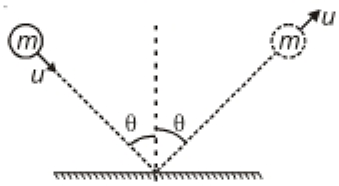
$M >> m$ $\Rightarrow$



(7) 

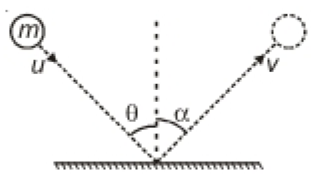
elastic collision

e = coefficient of restitution

(8) 

Elastic collision

(9) If coefficient of restitution = e



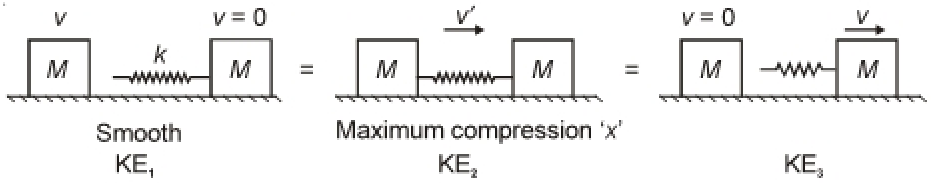
$u\sin\theta = v\sin\alpha$ ...(i)

$eu\cos\theta = v\cos\alpha$ ...(ii)

$$\Rightarrow v = u\sqrt{\sin^2\theta + e^2\cos^2\theta}$$

$$\tan\alpha = \frac{\tan\theta}{e}$$

(10)



$KE_1 = KE_3 > KE_2$ ...(i)

$\frac{1}{2}kx^2 + \frac{1}{2}2Mv'^2 = \frac{1}{2}Mv^2$ ...(ii)

$Mv = (M + M)v'$ ...(iii)

(11) A moving body of mass m_1 collides head-on elastically with a body of mass m_2 at rest. The speed of m_1 is u before collision.

(a) Initial kinetic energy $K_0 = \frac{1}{2}m_1u^2$

(b) Final velocity of m_1 is $v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1$

(c) Final velocity of m_2 is $v_2 = \left(\frac{2m_1}{m_1 + m_2}\right)u_1$

(d) Fraction of kinetic energy of m_1 transferred to m_2 is given by

$$\frac{K_2}{K_0} = \frac{4m_1m_2}{(m_1 + m_2)^2}$$

(e) Fraction of kinetic energy of m_1 retained by m_1 is

$$\frac{K_1}{K_0} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2$$

Collision in two dimensions

When $m_1 = m_2 = m$ and $u_2 = 0$

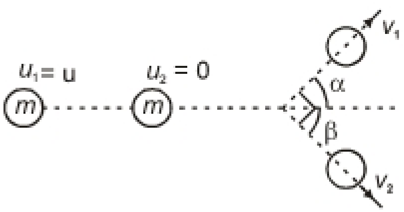
If $e = 1$ (elastic collision)

$\alpha + \beta = \frac{\pi}{2}$ ...(i)

$v_1\cos\alpha + v_2\cos\beta = u$ ...(ii)

$v_1\sin\alpha = v_2\sin\beta$ ...(iii)

$u^2 = v_1^2 + v_2^2$ ...(iv)



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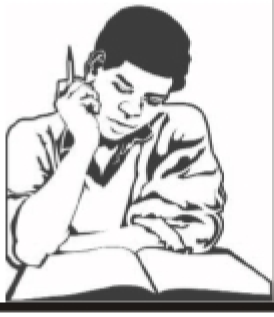


Try Yourself

SECTION - A

Objective Type Questions

1. In the non-relativistic regime, if the momentum of a particle is increased by 100%, the percentage increase in its kinetic energy is

   (1) 100 (2) 200

   (3) 300 (4) 400

2. A train weighing 1000 ton is moving on a horizontal track with a uniform velocity of 10 m/s. The total resistance to the motion of the train is 5 kgf per ton. If g = 10 m/s^2, then the power of the engine is

   (1) 200 kW (2) 400 kW

   (3) 500 kW (4) 800 kW

3. The kinetic energy acquired by a body of mass M after travelling a fixed distance from rest under the action of a constant force is

   (1) $\propto M$ (2) $\propto \sqrt{M}$

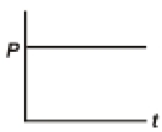
   (3) $\propto \frac{1}{\sqrt{M}}$ (4) Independent of M

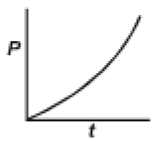
4. A body of mass 2 kg is thrown vertically upward with kinetic energy 245 J. The acceleration due to gravity is 9.8 m/s^2. The kinetic energy of the body will become half at a height of

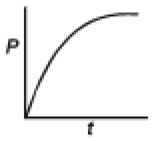
   (1) 25 m (2) 12.5 m

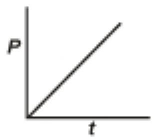
   (3) 6.25 m (4) 5 m

5. A motor drives a body along a straight line with a constant force. The power P developed by the motor must vary with time t according to

   (1) 

   (2) 

   (3) 

   (4) 

6. The energy required to accelerate a car from rest to 10 m/s is E. What energy will be required to accelerate the car from 10 m/s to 20 m/s?

   (1) E (2) $3E$

   (3) $5E$ (4) $7E$

7. If the force acting on a body is inversely proportional to its velocity, then the kinetic energy acquired by the body in time t is proportional to

   (1) t^0 (2) t^1

   (3) t^2 (4) t^4

8. A moving car encounters air resistance which is proportional to the square of the speed of the car. The ratio of the power required at 40 km/h to that required at 80 km/h, to move at constant speed

   (1) 1 : 6 (2) 1 : 8

   (3) 1 : 16 (4) 16 : 1

9. A 10 m long chain of linear mass density 0.8 kg/m is hanging freely from a rigid support. If g = 10 m/s^2, then power required to lift the chain upto the point of support in 10 second is

   (1) 10 W (2) 20 W

   (3) 30 W (4) 40 W

10. If distance is plotted against x-axis and kinetic energy against y-axis for an object moving along x-axis, then the slope of the graph so obtained is proportional to

    (1) Distance (2) Kinetic energy

    (3) Velocity (4) Acceleration

11. A stone is falling freely in free space. Its velocity is x when it has lost y units of potential energy in the gravitational field of earth. The mass of the stone is

    (1) xy (2) $\frac{2y}{x^2}$

    (3) $x + y$ (4) $\frac{2y}{x} + 9.8$

12. If two electrons are forced to come closer to each other, then the potential energy of the electrons
    (1) Becomes zero
    (2) Increases
    (3) Decreases
    (4) Becomes infinity
13. A ball is thrown vertically upward in free space. Its total mechanical energy
    (1) Remains constant throughout the motion
    (2) Increases during ascent and decreases during descent
    (3) Is zero at maximum height
    (4) Is equal to kinetic energy at a point just below the maximum height
14. The displacement x of a body of mass 1 kg on a horizontal smooth surface as a function of time t is given by $x = \frac{t^3}{3}$. The work done by the external agent in the first one second is
    (1) 0.25 J (2) 0.5 J
    (3) 0.75 J (4) 1 J
15. A car of mass m has an engine which can deliver power P. The minimum time in which the car can be accelerated from rest to a speed v is
    (1) $\frac{mv^2}{2P}$ (2) Pmv^2
    (3) $2Pmv^2$ (4) $\frac{mv^2P}{2}$
16. A pendulum bob has been pulled aside from the equilibrium position through an angle α and then released. If l is the length of the pendulum, then the bob will reach the equilibrium position with a speed of
    (1) $\sqrt{2gl}$ (2) $\sqrt{2gl}\cos\alpha$
    (3) $\sqrt{2gl(1-\cos\alpha)}$ (4) $\sqrt{2gl(1-\sin\alpha)}$
17. A ball is projected with kinetic energy K at an angle of 45° with the horizontal. At the highest point during its flight, its kinetic energy will be
    (1) K (2) $\frac{K}{\sqrt{2}}$
    (3) $\frac{K}{2}$ (4) Zero
18. The work done by all the forces on a system is equal to the change in
    (1) Total energy (2) Kinetic energy
    (3) Potential energy (4) Mechanical energy
19. A bomb of mass M at rest explodes into two fragments of masses m_1 and m_2. The total energy released in the explosion is E. If E_1 and E_2 represent the energies carried by masses m_1 and m_2 respectively, then which of the following is correct?
    (1) $E_1 = \frac{m_2}{M}E$ (2) $E_1 = \frac{m_1}{m_2}E$
    (3) $E_1 = \frac{m_1}{M}E$ (4) $E_1 = \frac{m_2}{m_1}E$
20. A body of mass 1 kg collides with a wall with speed 8 m/s and rebounds on the same line with the same speed. If mass of the wall is taken as infinite, the work done by the ball on the wall is
    (1) 6 J (2) 8 J
    (3) 9 J (4) Zero
21. A nucleus ruptures into two nuclear parts, which have their velocity ratio equal to 2 : 1. The ratio of their respective nuclear sizes (nuclear radii) is
    (1) 1 : 2 (2) $1:\sqrt{2}$
    (3) $1 : 2^{1/3}$ (4) 1 : 8
22. Ordinarily, the value of coefficient of restitution varies from
    (1) 0 to 1 (2) 0 to 0.5
    (3) –1 to +1 (4) –0.5 to +5.0
23. A ball of mass m approaches a moving wall of infinite mass with speed v along the normal to the wall. The speed of the wall is u towards the ball. The speed of the ball after an elastic collision with the wall is
    (1) $v - 2u$ away from the wall
    (2) $2u + v$ away from the wall
    (3) $u - v$ away from the wall
    (4) $u + v$ away from the wall
24. A 1 kg block moving with a velocity of 4m/s collides with a stationary 2 kg block. The lighter block comes to rest after the collision. The loss of kinetic energy of the system is
    (1) 1 J (2) 2 J
    (3) 3 J (4) 4 J

25. A body of mass 5 kg collides elastically with a stationary body of mass 2.5 kg. After the collision the 2.5 kg body begins to move with a kinetic energy of 8 J. Assuming the collision to be one dimensional, the kinetic energy of the 5 kg body before collision is

(1) 3 J (2) 6 J

(3) 9 J (4) 11 J

26. A metal ball of mass 2 kg moving with a velocity of 10 m/s undergoes a head on collision with a stationary ball of mass 3 kg. If after the collision both the balls move together, then loss in kinetic energy due to collision is

(1) 60 J (2) 80 J

(3) 120 J (4) 160 J

27. Consider an oblique elastic collision between a moving ball and a stationary ball of the same mass. Both the balls move with the same speed after the collision. After the collision the angle between the direction of motion of two balls is

(1) 0° (2) 30°

(3) 60° (4) 90°

28. Two springs have force constants K_1 and K_2. Both are stretched till their elastic energies are equal. If the stretching forces are F_1 and F_2, then $F_1 : F_2$ is

(1) $K_1 : K_2$ (2) $K_2 : K_1$

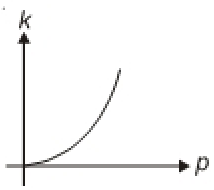
(3) $\sqrt{K_1} : \sqrt{K_2}$ (4) $K_1^2 : K_2^2$

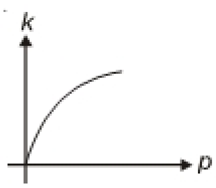
29. A block of mass 1 kg is lowered by 1 m using string from rest. Its speed at lowest point is 2 m/s. Work done by tension in string is

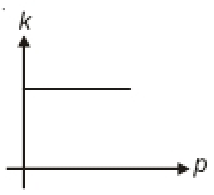
(1) 8 J (2) –8 J

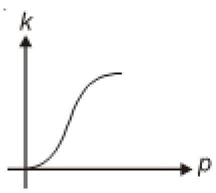
(3) 18 J (4) –18 J

30. Which graph represents correct relation between kinetic energy and momentum of a body?

(1) 

(2) 

(3) 

(4) 

SECTION - B

Previous Years Questions

1. The potential energy of a particle in a force field is $U = \frac{A}{r^2} - \frac{B}{r}$, where A and B are positive constants and r is the distance of particle from the centre of the field. For stable equilibrium, the distance of the particle is **[AIPMT 2012]**

(1) $\frac{A}{B}$ (2) $\frac{B}{A}$

(3) $\frac{B}{2A}$ (4) $\frac{2A}{B}$

2. Two spheres A and B of masses m_1 and m_2 respectively collide. A is at rest initially and B is moving with velocity v along x-axis. After collision B has a velocity $\frac{v}{2}$ in a direction perpendicular to the original direction. The mass A moves after collision in the direction **[AIPMT 2012]**

(1) $\theta = \tan^{-1}\left(\frac{1}{2}\right)$ to the x-axis

(2) $\theta = \tan^{-1}\left(-\frac{1}{2}\right)$ to the x-axis

(3) Same as that of B

(4) Opposite to that of B

3. A uniform force of $\left(3\hat{i}+\hat{j}\right)$ newton acts on a particle of mass 2 kg. Hence the particle is displaced from position $\left(2\hat{i}+\hat{k}\right)$ metre to position $\left(4\hat{i}+3\hat{j}-\hat{k}\right)$ metre. The work done by the force on the particle is **[NEET-2013]**

(1) 6 J (2) 13 J

(3) 15 J (4) 9 J

4. A body of mass ($4m$) is lying in x-y plane at rest. It suddenly explodes into three pieces. Two pieces each of mass (m) move perpendicular to each other with equal speeds (v). The total kinetic energy generated due to explosion is **[AIPMT 2014]**

(1) mv^2 (2) $\frac{3}{2}mv^2$

(3) $2\ mv^2$ (4) $4\ mv^2$

5. Two particles of masses m_1, m_2 move with initial velocities u_1 and u_2. On collision, one of the particles get excited to higher level, after absorbing energy ε. If final velocities of particles be v_1 and v_2 then we must have **[AIPMT-2015]**

(1) $\frac{1}{2}m_1^2u_1^2+\frac{1}{2}m_2^2u_2^2+\varepsilon=\frac{1}{2}m_1^2v_1^2+\frac{1}{2}m_2^2v_2^2$

(2) $m_1^2u_1+m_2^2u_2-\varepsilon=m_1^2v_1+m_2^2v_2$

(3) $\frac{1}{2}m_1u_1^2+\frac{1}{2}m_2u_2^2=\frac{1}{2}m_1v_1^2+\frac{1}{2}m_2v_2^2-\varepsilon$

(4) $\frac{1}{2}m_1u_1^2+\frac{1}{2}m_2u_2^2-\varepsilon=\frac{1}{2}m_1v_1^2+\frac{1}{2}m_2v_2^2$

6. Two similar springs P and Q have spring constants K_P and K_Q such that $K_P > K_Q$. They stretched first by the same amount (case a), then by the same force (case b). The work done by the springs W_P and W_Q are related as in case (a) and case (b), respectively **[AIPMT-2015]**

(1) $W_P < W_Q$; $W_Q < W_P$

(2) $W_P = W_Q$; $W_P > W_Q$

(3) $W_P = W_Q$; $W_P = W_Q$

(4) $W_P > W_Q$; $W_Q > W_P$

7. A particle of mass m is driven by a machine that delivers a constant power k watts. If the particle starts from rest, the force on the particle at time t is **[AIPMT-2015]**

(1) $\frac{1}{2}\sqrt{mk}\,t^{\frac{-1}{2}}$

(2) $\sqrt{\frac{mk}{2}}\,t^{\frac{-1}{2}}$

(3) $\sqrt{mk}\,t^{\frac{-1}{2}}$

(4) $\sqrt{2mk}\,t^{\frac{-1}{2}}$

8. A block of mass 10 kg moving in x direction with a constant speed of 10 ms^{-1}, is subjected to a retarding force $F = 0.1x$ J/m during its travel from x = 20 m to 30 m. Its final KE will be **[AIPMT-2015]**

(1) 250 J (2) 475 J

(3) 450 J (4) 275 J

9. If vectors $\vec{A}=\cos\omega t\,\hat{i}+\sin\omega t\,\hat{j}$ and $\vec{B}=\cos\frac{\omega t}{2}\hat{i}+\sin\frac{\omega t}{2}\hat{j}$ are functions of time, then the value of t at which they are orthogonal to each other is **[Re-AIPMT-2015]**

(1) $t = 0$ (2) $t=\frac{\pi}{4\omega}$

(3) $t=\frac{\pi}{2\omega}$ (4) $t=\frac{\pi}{\omega}$

10. A ball is thrown vertically downwards from a height of 20 m with an initial velocity v_0. It collides with the ground, loses 50 percent of its energy in collision and rebounds to the same height. The initial velocity v_0 is (Take g = 10 ms^{-2})

[Re-AIPMT-2015]

(1) 10 ms^{-1} (2) 14 ms^{-1}

(3) 20 ms^{-1} (4) 28 ms^{-1}

11. On a frictionless surface, a block of mass M moving at speed v collides elastically with another block of same mass M which is initially at rest. After collision the first block moves at an angle θ to its initial direction and has a speed $\frac{v}{3}$. The second blocks speed after the collision is

[Re-AIPMT-2015]

(1) $\frac{\sqrt{3}}{2}v$ (2) $\frac{2\sqrt{2}}{3}v$

(3) $\frac{3}{4}v$ (4) $\frac{3}{\sqrt{2}}v$

12. The heart of a man pumps 5 litres of blood through the arteries per minute at a pressure of 150 mm of mercury. If the density of mercury be 13.6 × 10^3 kg/m^3 and g = 10 m/s^2 then the power of heart in watt is **[Re-AIPMT-2015]**

(1) 1.50

(2) 1.70

(3) 2.35

(4) 3.0

13. What is the minimum velocity with which a body of mass m must enter a vertical loop of radius R so that it can complete the loop? **[NEET-2016]**

(1) $\sqrt{5gR}$ (2) $\sqrt{gR}$

(3) $\sqrt{2gR}$ (4) $\sqrt{3gR}$

14. A body of mass 1 kg begins to move under the action of a time dependent force $F = (2t\hat{i} + 3t^2\hat{j})$N, where $\hat{i}$ and $\hat{j}$ are unit vectors along *x* and *y* axis. What power will be developed by the force at the time *t*? **[NEET-2016]**

(1) $(2t^3 + 3t^5)$ W (2) $(2t^2 + 3t^2)$ W

(3) $(2t^2 + 4t^4)$ W (4) $(2t^3 + 3t^4)$ W

15. A particle moves from a point $(-2\hat{i} + 5\hat{j})$ to $(4\hat{j} + 3\hat{k})$ when a force of $(4\hat{i} + 3\hat{j})$ N is applied. How much work has been done by the force? **[NEET (Phase-2) 2016]**

(1) 8 J (2) 11 J

(3) 5 J (4) 2 J

16. A bullet of mass 10 g moving horizontally with a velocity of 400 ms^{-1} strikes a wood block of mass 2 kg which is suspended by light inextensible string of length 5 m. As a result, the centre of gravity of the block found to rise a vertical distance of 10 cm. The speed of the bullet after it emerges out horizontally from the block will be **[NEET (Phase-2) 2016]**

(1) 100 ms^{-1} (2) 80 ms^{-1}

(3) 120 ms^{-1} (4) 160 ms^{-1}

17. Two identical balls *A* and *B* having velocities of 0.5 m/s and –0.3 m/s respectively collide elastically in one dimension. The velocities of *B* and *A* after the collision respectively will be **[NEET (Phase-2) 2016]**

(1) –0.5 m/s and 0.3 m/s

(2) 0.5 m/s and –0.3 m/s

(3) –0.3 m/s and 0.5 m/s

(4) 0.3 m/s and 0.5 m/s

18. Consider a drop of rain water having mass 1 g falling from a height of 1 km. It hits the ground with a speed of 50 m/s. Take *g* constant with a value 10 m/s^2. The work done by the (i) gravitational force and the (ii) resistive force of air is **[NEET-2017]**

(1) (i) – 10 J (ii) –8.25 J

(2) (i) 1.25 J (ii) –8.25 J

(3) (i) 100 J (ii) 8.75 J

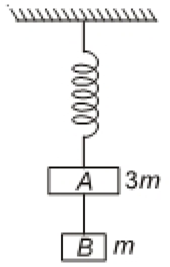
(4) (i) 10 J (ii) –8.75 J

19. A spring of force constant *k* is cut into lengths of ratio 1 : 2 : 3. They are connected in series and the new force constant is *k*′. Then they are connected in parallel and force constant is *k*″. Then *k*′ : *k*″ is **[NEET-2017]**

(1) 1 : 6 (2) 1 : 9

(3) 1 : 11 (4) 1 : 14

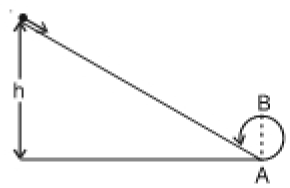
20. Two blocks *A* and *B* of masses 3*m* and *m* respectively are connected by a massless and inextensible string. The whole system is suspended by a massless spring as shown in figure. The magnitudes of acceleration of *A* and *B* immediately after the string is cut, are respectively **[NEET-2017]**



(1) $g, \frac{g}{3}$ (2) $\frac{g}{3}, g$

(3) g, g (4) $\frac{g}{3}, \frac{g}{3}$

21. A body initially at rest and sliding along a frictionless track from a height h (as shown in the figure) just completes a vertical circle of diameter AB = D. The height h is equal to **[NEET-2018]**



(1) $\frac{3}{2}$D (2) D

(3) $\frac{5}{4}$D (4) $\frac{7}{5}$D

22. A moving block having mass m, collides with another stationary block having mass 4m. The lighter block comes to rest after collision. When the initial velocity of the lighter block is v, then the value of coefficient of restitution (e) will be **[NEET-2018]**

(1) 0.5 (2) 0.25

(3) 0.4 (4) 0.8

23. A mass m is attached to a thin wire and whirled in a vertical circle. The wire is most likely to break when: **[NEET-2019]**

(1) The mass is at the highest point

(2) The wire is horizontal

(3) The mass is at the lowest point

(4) Inclined at an angle of 60° from vertical

24. Body A of mass $4m$ moving with speed u collides with another body B of mass $2m$, at rest. The collision is head on and elastic in nature. After the collision the fraction of energy lost by the colliding body A is : **[NEET-2019]**

(1) $\frac{1}{9}$

(2) $\frac{8}{9}$

(3) $\frac{4}{9}$

(4) $\frac{5}{9}$

25. A force $F = 20 + 10y$ acts on a particle in y-direction where F is in newton and y in meter. Work done by this force to move the particle from $y = 0$ to $y = 1$ m is **[NEET-2019]**

(1) 30 J (2) 5 J

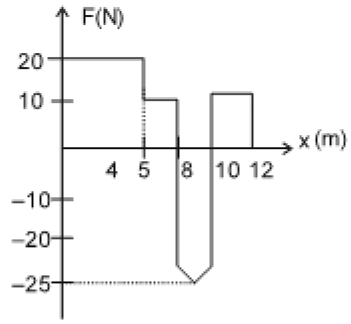
(3) 25 J (4) 20 J

26. A particle of mass 5m at rest suddenly breaks on its own into three fragments. Two fragments of mass m each move along mutually perpendicular direction with speed v each. The energy released during the process is **[NEET-2019 (Odisha)]**

(1) $\frac{3}{5}mv^2$ (2) $\frac{5}{3}mv^2$

(3) $\frac{3}{2}mv^2$ (4) $\frac{4}{3}mv^2$

27. An object of mass 500 g, initially at rest, is acted upon by a variable force whose X-component varies with x in the manner shown. The velocities of the object at the points x = 8 m and x = 12 m, would have the respective values of (nearly) **[NEET-2019 (Odisha)]**



(1) 18 m/s and 24.4 m/s

(2) 23 m/s and 24.4 m/s

(3) 23 m/s and 20.6 m/s

(4) 18 m/s and 20.6 m/s

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Chapter 6

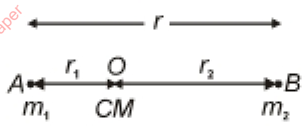
System of Particles and Rotational Motion

Sub-topics *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 uniform rod. Moment of a force,-torque, angular momentum, conservation of angular momentum with some examples. Equilibrium of rigid bodies, rigid body rotation and equation of rotational motion, comparison of linear and rotational motions; moment of inertia, radius of gyration. Values of M.I. for simple geometrical objects (no derivation). Statement of parallel and perpendicular axes theorems and their applications.*

Centre of Mass of a two particle system

(1) $m_1r_1 = m_2r_2$ ...(i)

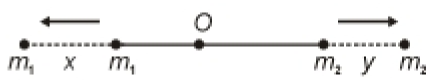
$r_1 + r_2 = r$ ...(ii)



$$r_1 = \frac{m_2 r}{m_1 + m_2},\ r_2 = \frac{m_1 r}{m_1 + m_2}$$

(2) If m_1 is moved by x due to internal forces then m_2 has to move by $y = \frac{-m_1 x}{m_2}$ to keep the position of centre of mass undisturbed.

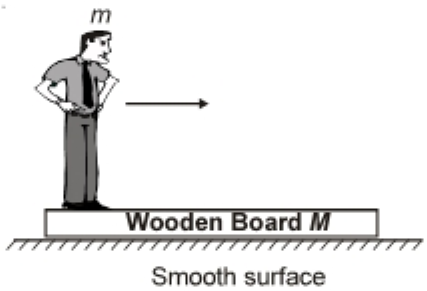
$$|y| = \frac{m_1 x}{m_2}$$



(3) If the person moves '*x*' relative to board, then

(a) Board + man will move in opposite direction by $\frac{mx}{M + m} = y$.

(b) Net displacement of person with respect to ground = $x - y$.



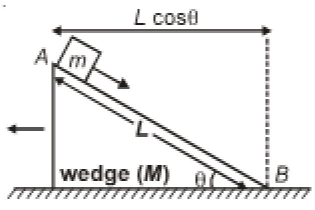
Momentum Conservation and Centre of Mass Motion

(1) If the person starts walking with velocity v_r relative to board then

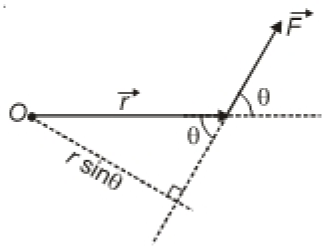
(a) Board starts moving backward with velocity $\frac{mv_r}{M + m} = v$

(b) Velocity of man w.r.t. ground = $v_r - v$

(2) As m slides from A to B relative to wedge, the wedge (+ block) will move towards left by $\dfrac{mL\cos\theta}{M+m}$



Moment of force- Torque:

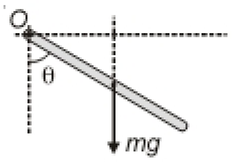


$$\left|\vec{\tau}\right| = \left|\vec{F}\right| \times r \times \sin\theta$$

$$\vec{\tau} = \vec{r} \times \vec{F}$$

Example:

(a) Torque of weight of a rod about O at an instant shown is given by

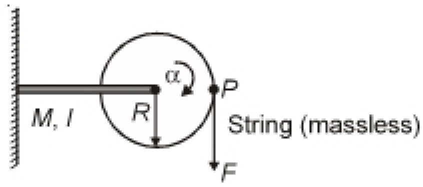


$$\tau = mg\frac{l}{2}\sin\theta$$

(b) $\tau = F \times R = I_c\alpha$

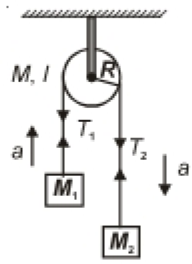
$$\alpha = \frac{FR}{I_c}$$

$$a_p = R\alpha = \frac{FR^2}{I_c}$$



(c) $T_2 > T_1$

$M_2 > M_1$

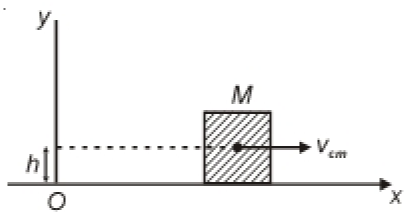


Angular Momentum

$L = Mv_{cm}R + I\omega$

Case - I :

$|\vec{L}_O| = MV_{cm}h$

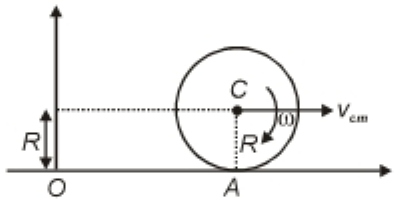


Case - II :

$L_c = I_c\omega$

$L_O = L_A = I_C\omega + Mv_{cm}R$

I_c = M.I. about '*C*'

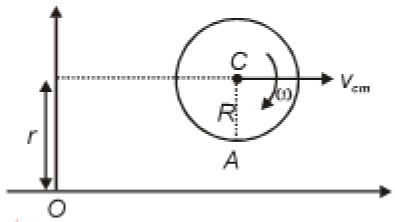


Case - III :

$L_c = I_c\omega$

$L_A = I_c\omega + Mv_{cm}R$

$L_O = I_c\omega + Mv_{cm}r$

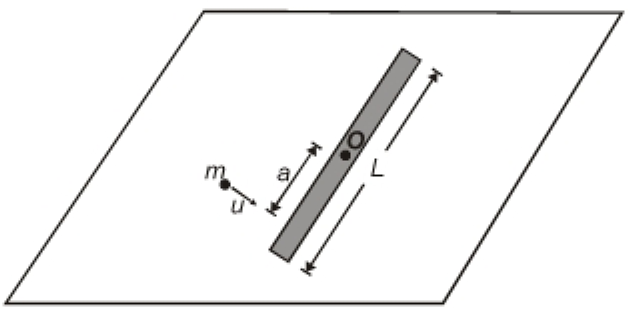


Case - IV :

For pure rotational motion, put $v_{cm} = 0$

Conservation of Angular Momentum

1. A rod of mass *M* and length *L* is resting on a smooth horizontal table. A point mass *m* moving with speed *u* hits the rod perpendicular to its length. After collision, the rod rotates as well as translates.



If the particle stops after collision, then

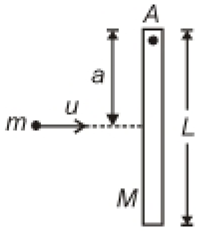
By conservation of linear momentum $mu = Mv_{cm}$ ...(i)

By conservation of angular momentum $mua = I\omega$ ...(ii)

$\left[\text{where } I = \dfrac{ML^2}{12}\right]$

2. The rod is hinged at *A* and can rotate freely in a vertical plane.

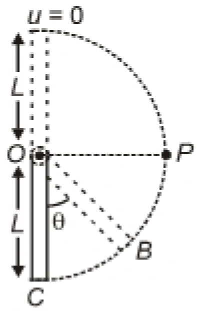
   Only conservation of angular momentum can be applied as the rod is fixed at *A*.



   If the particle sticks to the rod, then

$$mua = \left[\frac{ML^2}{3} + ma^2\right]\omega$$

3. The rod is released from unstable equilibrium position



   (i) When at *B*, $mg\frac{L}{2}(1+\cos\theta) = \frac{1}{2}\left(\frac{ML^2}{3}\right)\omega^2$

$$\omega = \sqrt{\frac{6g}{L}}\cos\frac{\theta}{2}$$

   (ii) at *C*, $\theta = 0°$

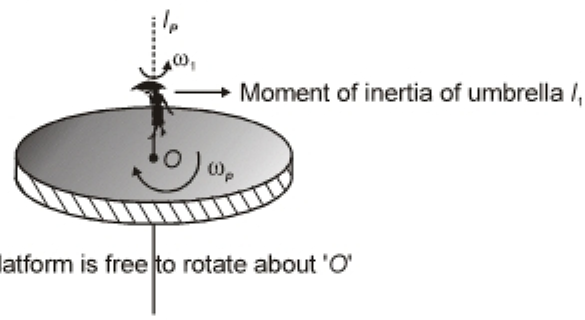
$$\omega = \sqrt{\frac{6g}{l}}$$

   (iii) at *P*, $\theta = 90°$, $\omega = \sqrt{\frac{3g}{l}}$

4. The boy starts rotating umbrella with angular velocity w_1 relative to platform, then platform will start revolving in opposite direction

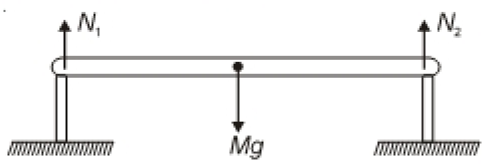
$$\omega_p = \frac{I_1\omega_1}{I_p + I_1}$$

   I_p = Moment of inertia of (boy + platform)



Platform is free to rotate about '*O*'

Equilibrium of rigid body



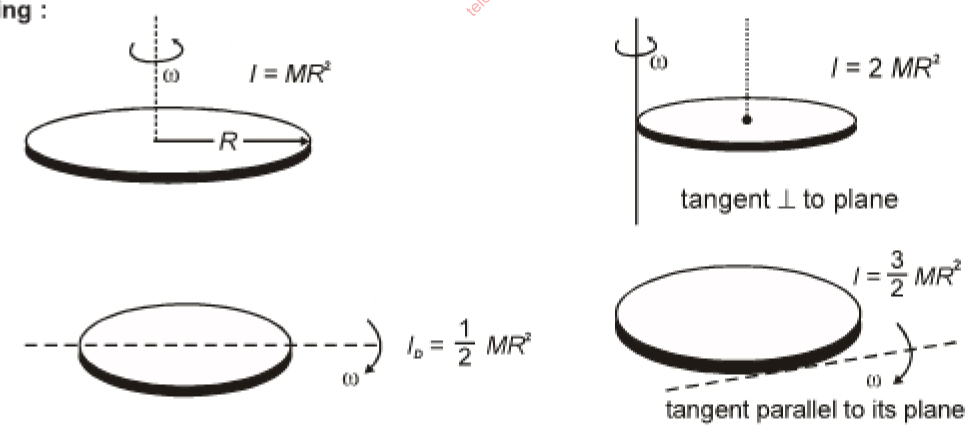
For equilibrium, $\vec{F}_{net} = 0, \vec{\tau}_{net} = 0$

Comparison of Linear and Rotational Motion

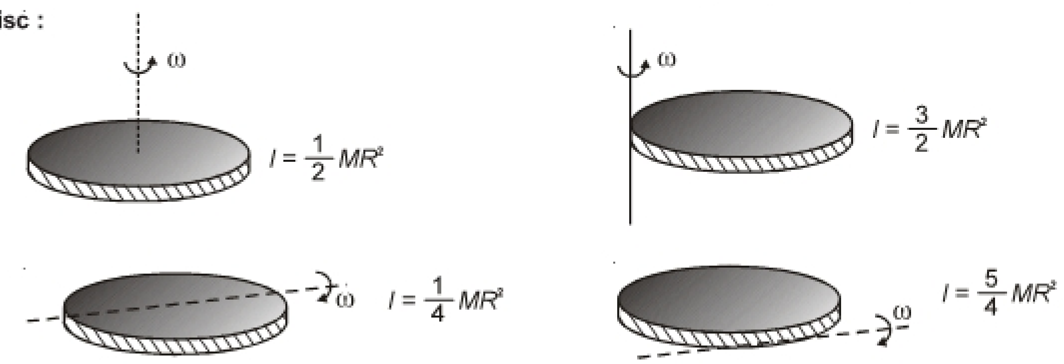
	Linear Motion	Rotational Motion
(A)	If acceleration $a = 0$ and velocity v = constant, then $x = vt$	If angular acceleration $\alpha = 0$ and angular velocity ω is constant, then $\boxed{\theta = \omega t}$
(B)	If acceleration a = constant, then (i) $v = v_0 + at$ (ii) $x = v_0 t + \frac{1}{2}at^2$ (iii) $v^2 = v_0^2 + 2ax$ (iv) $x_{n^{th}} = v_0 + \frac{2n-1}{2}a$ (v) $x = \frac{v_0 + v}{2}t$	If angular acceleration α = constant then (i) $\omega = \omega_0 + \alpha t$ (ii) $\theta = \omega_0 t + \frac{1}{2}\alpha t^2$ (iii) $\omega^2 = \omega_0^2 + 2\alpha\theta$ (iv) $\theta_{n^{th}} = \omega_0 + \frac{2n-1}{2}\alpha$ (v) $\theta = \frac{\omega_0 + \omega}{2}t$
(C)	If acceleration a is not constant, then (i) $\frac{dv}{dt} = a \Rightarrow v = v_0 + \int_0^t a\,dt$ (ii) $\frac{dx}{dt} = v \Rightarrow x - x_0 = \int_0^t v\,dt$ (iii) $v\frac{dv}{dx} = a \Rightarrow \int_{v_0}^{v} v\,dv = \int_0^x a\,dx$	If angular acceleration α is not constant, then (i) $\frac{d\omega}{dt} = \alpha \Rightarrow \omega = \omega_0 + \int_0^t \alpha\,dt$ (ii) $\frac{d\theta}{dt} = \omega \Rightarrow \theta - \theta_0 = \int_0^t \omega\,dt$ (iii) $\omega.\frac{d\omega}{d\theta} = \alpha \Rightarrow \int_{\omega_0}^{\omega} \omega\,d\omega = \int_0^{\theta} \alpha\,d\theta$

Moment of Inertia

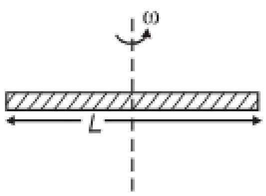
Ring :



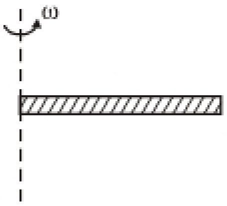
Disc :



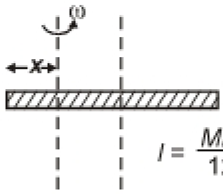
Thin Rod :



$I = \frac{ML^2}{12}$

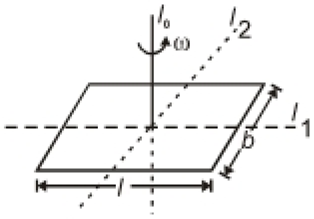


$I = \frac{ML^2}{3}$



$I = \frac{ML^2}{12} + M\,(L/2 - x)^2$

Rectangular Lamina

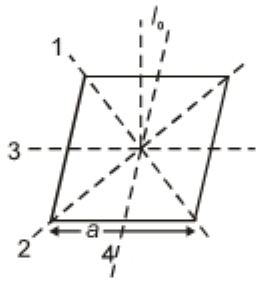


$$I_0 = \frac{M(l^2 + b^2)}{12}$$

$$I_1 = \frac{Mb^2}{12}$$

$$I_2 = \frac{Ml^2}{12}$$

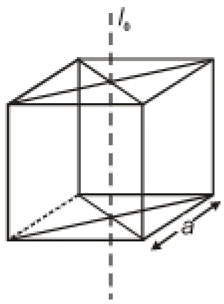
Square Lamina



$$I_1 = I_2 = I_3 = I_4 = \frac{ma^2}{12}$$

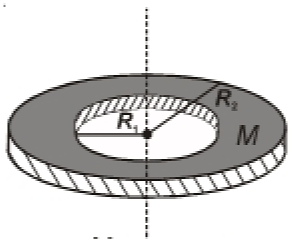
$$I_0 = I_1 + I_2 = I_3 + I_4 = \frac{ma^2}{6}$$

Cube



$$I_0 = \frac{ma^2}{6}$$

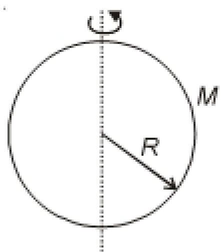
Annular Disc



$$I_0 = \frac{M}{2}(R_1^2 + R_2^2)$$

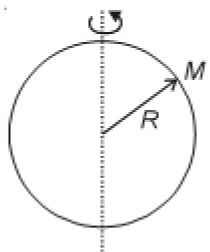
Solid sphere

$$I_D = \frac{2}{5}MR^2$$



Hollow sphere

$$I_D = \frac{2}{3}MR^2$$



Rolling on inclined plane

(a) Velocity of centre of mass

$$V_{cm} = \sqrt{\frac{2gh}{1+\frac{K^2}{R^2}}}$$

(b) Acceleration of centre of mass

$$a_{cm} = \frac{g\sin\theta}{1+\frac{K^2}{R^2}}$$

(c) Time of descent

$$t = \frac{1}{\sin\theta}\sqrt{\frac{2h\left(1+\frac{K^2}{R^2}\right)}{g}}$$

Pure rolling on horizontal plane

$$a_{cm} = \frac{\left(1+\frac{h}{R}\right)F}{\left(1+\frac{K^2}{R^2}\right)M}$$

❑ ❑ ❑

Try Yourself

SECTION - A

Objective Type Questions

1. A point on the rim of a rotating wheel 4 m in diameter has a velocity of 1600 cm/s. The angular velocity of the wheel is

   (1) 2 rad/s (2) 4 rad/s

   (3) 6 rad/s (4) 8 rad/s

2. For the same total mass which of the following bodies will have the largest moment of inertia about an axis passing through their centre of gravity and perpendicular to the plane of the body?

   (1) A ring of radius l

   (2) A disc of radius l

   (3) A square lamina of side $2l$

   (4) Four rods forming square of side $2l$

3. Two rings of same mass and radius are placed such that their centres are at a common point and their planes are perpendicular to each other. The moment of inertia of the system about an axis passing through the centre and perpendicular to the plane of one of the rings is (Take M = mass of each ring and R = radius of each ring)

   (1) MR^2 (2) $\frac{3}{2}MR^2$

   (3) $2MR^2$ (4) $\frac{5}{2}MR^2$

4. Let I_A and I_B be moments of inertia of a body about two axes A and B respectively. The axis A passes through the centre of mass of the body but B does not then

   (1) $I_A < I_B$ always

   (2) If the axes are parallel, $I_A < I_B$

   (3) If the axes are parallel, $I_A = I_B$

   (4) If the axes are not parallel, then $I_A \geq I_B$

5. A wheel whose moment of inertia is 12 kg m^2 has an initial angular velocity of 40 rad/s. A constant torque of 20 N-m acts on the wheel. The time in which the wheel is accelerated to 100 rad/s is

   (1) 72 second (2) 16 second

   (3) 8 second (4) 36 second

6. A 5 N weight is balanced on the top of a vertical wheel of radius 1 m. The torque, exerted by the weight about the axis of rotation of the wheel is

   (1) 5 Nm (2) 6 Nm

   (3) 1 Nm (4) Zero

7. A disc like reel on massless thread unrolls itself while falling vertically downwards. The acceleration of its fall is

   (1) Zero (2) g

   (3) $\frac{2}{3}g$ (4) $\frac{g}{2}$

8. The density of a rod continuously increases from A to B. It is easier to set it into rotation by

   (1) Clamping the rod at A and applying a force F at B, perpendicular to the rod

   (2) Clamping the rod at B and applying a force F at A, perpendicular to rod

   (3) Clamping the rod at mid-point of AB and applying a force F at A, perpendicular to the rod

   (4) Clamping the rod at mid-point of AB and applying a force F at B, perpendicular to the rod

9. A body of mass m crosses the topmost point of a vertical circle with critical speed. Torque about centre at this instant is (l = length of string)

   (1) mgl (2) 0

   (3) $\frac{mgl}{2}$ (4) $\frac{mg\sqrt{3}l}{2}$

10. A sphere of mass 2000 g and radius 5 cm is rotating at the rate of 300 rpm. Then the torque required to stop it in 2π revolution is

(1) 1.6×10^2 dyne cm (2) 1.6×10^3 dyne cm

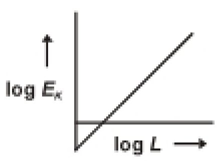
(3) 2.5×10^4 dyne cm (4) 2.5×10^5 dyne cm

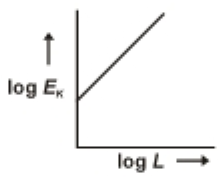
11. A particle of mass m is moving in a plane along a circle of radius r. Its angular momentum about the axis of rotation is L. What is the centripetal force acting on the particle?

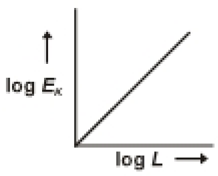
(1) $\frac{L^2}{mr}$ (2) $\frac{L^2}{mr^3}$

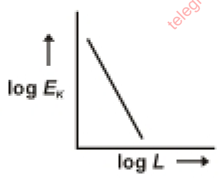
(3) $\frac{L^2 m}{r}$ (4) $\frac{L^2}{mr^2}$

12. Which of the following correctly represents the relation between log L and log E_K? (L : angular momentum; E_K : Rotational Kinetic Energy)

(1) 

(2) 

(3) 

(4) 

13. A horizontal disc rotating freely about a vertical axis makes 90 revolutions per second. A small piece of wax of mass m falls vertically on the disc and sticks to it at a distance r cm from the axis. If the number of revolutions per second reduce to 60, then the moment of inertia of the disc is

(1) mr^2 (2) $\frac{3}{2} mr^2$

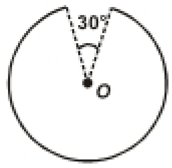
(3) $2 mr^2$ (4) $3 mr^2$

14. Two bodies of mass 4 kg and 2 kg are tied to the ends of a string which passes over a light frictionless pulley. The masses are initially at rest and released. If $g = 9$ m/s^2 then the acceleration of their centre of mass is

(1) 0 m/s^2 (2) 1 m/s^2

(3) 2 m/s^2 (4) 3 m/s^2

15. From a complete ring of mass M and radius R a 30° arc is removed. The moment of inertia of the incomplete ring about an axis passing through the centre of the ring and perpendicular to the plane of ring is



(1) $\frac{9}{12}MR^2$ (2) $\frac{11}{12}MR^2$

(3) $\frac{11.3}{12}MR^2$ (4) MR^2

16. What is the moment of inertia of a wheel of mass m and radius R having two spokes each of mass m? (The axis of rotation is perpendicular to the plane and passing through centre)

(1) $\frac{1}{2}mR^2$ (2) mR^2

(3) $\frac{2m}{3}R^2$ (4) $\frac{5}{3}mR^2$

17. A particle performs uniform circular motion with an angular momentum L. If the frequency of motion of the particle is doubled and its kinetic energy is halved, then the angular momentum becomes

(1) $\frac{L}{2}$ (2) $\frac{L}{4}$

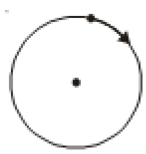
(3) $\frac{L}{6}$ (4) $\frac{L}{8}$

18. The radius of gyration of a circular plate of radius R, about an axis perpendicular to its plane and bisecting a radius is

(1) R (2) $\frac{R}{2}$

(3) $\frac{\sqrt{3}}{2}R$ (4) $\frac{\sqrt{5}}{2}R$

19. In the circular motion shown, the speed of the particle is increasing. The direction of the angular acceleration vector is



(1) Opposite to that of angular velocity vector

(2) "Going into" the plane of the figure

(3) "Coming out of" the plane of the figure

(4) Changing continuously

20. A disc of mass M radius R lies in the xy plane with its centre at a distance a from origin on the x-axis. Which of the following is correct?

    (1) Moment of inertia of the disc about x-axis is $\frac{MR^2}{4}$

    (2) Moment of inertia of the disc about y-axis is $\frac{MR^2}{4} + Ma^2$

    (3) Moment of inertia of the disc about z-axis is $\frac{MR^2}{2} + Ma^2$

    (4) All of these

21. Two wheels are mounted side by side and each is marked with a dot on its rim. The two dots are aligned with the wheels at rest. Now, one wheel is given a constant angular acceleration of $\frac{\pi}{2}$ rad/s^2, and the other is given $\frac{\pi}{4}$ rad/s^2. The two dots would become aligned again for the first time after

    (1) 2 s (2) 4 s

    (3) 1 s (4) 8 s

22. An initial momentum is imparted to a solid cylinder as a result of which it begins to roll without slipping up an inclined plane at a speed of 4 m/s. The plane makes an angle 30° with the horizontal. To what height h will the cylinder rise?

    (Take g = 10 m/s^2)

    (1) 0.8 m

    (2) 1.2 m

    (3) 1 m

    (4) 1.6 m

23. Two masses of 20 kg and 30 kg are suspended from the ends of a light rod 5 m long. At which point the rod must be suspended by means of a string to keep it horizontal?

    (1) At 3m from the first

    (2) At 3m from the second

    (3) At 4m from the first

    (4) At 4m from the second

24. A disc of mass M and radius R is rotating in a horizontal plane with angular velocity ω_0. An insect of mass m moves from centre to the circumference of the disc. The new angular velocity of the disc will be

    (1) $\frac{M}{M+2m}\omega_0$ (2) $\frac{2M}{2M+m}\omega_0$

    (3) $\frac{M}{M+m}\omega_0$ (4) Zero

25. A string of length l is used to whirl a particle in a vertical plane. The ratio of the maximum speed to the minimum speed in the circle when it just goes through a complete revolution is

    (1) 4 : 1 (2) $\sqrt{3}:1$

    (3) $\sqrt{5}:2$ (4) $\sqrt{5}:1$

26. A boy of mass 20 kg is standing at one end of a boat of length 8 m and mass 180 kg in a river. What would be the displacement of the boat relative to water if the boy moves to the other end of the boat? (Assume the river water to be non-viscous)

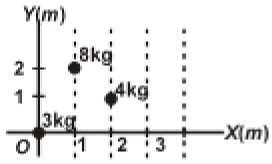
    (1) 0.12 m

    (2) 0.36 m

    (3) 0.80 m

    (4) 0.96 m

27. What are the co-ordinates of the centre of mass of the three particle system shown in the figure?



    (1) x = 1.1 m, y = 1.3 m

    (2) x = 0.7 m, y = 0.8 m

    (3) x = 0.5 m, y = 0.6 m

    (4) x = 0 m, y = 3 m

28. The kinetic energy of a body rotating with an angular speed ω depends on

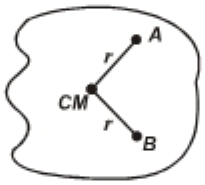
    (1) ω only

    (2) Its mass only

    (3) The distribution of mass and angular speed

    (4) ω^2 only

29. Figure shows the centre of mass of a body. Two points *A* and *B* which are equidistant from the centre of mass are also shown. If I, I_A and I_B represent the moment of inertia of the body about perpendicular axis through centre of mass, through *A* and through *B* respectively, then



(1) $I = I_A = I_B$ (2) $I_A = I_B > I$

(3) $I_A < I_B < I$ (4) $I_A > I_B > I$

30. A uniform metre stick of mass *M* hinged at one end is supported in a horizontal direction by a string attached to the other end. What would be the initial acceleration of the free end of the stick if the string is cut?

(1) $\frac{3}{2}g$ m/s² (2) g m/s²

(3) 3 g m/s² (4) 4 g m/s²

31. Which of the following is not correct?

(1) The radius of gyration of a body is independent of mass of the body

(2) Mass in linear motion is analogous to torque in rotational motion

(3) The moment of inertia of a semicircular disc of mass *M* and radius *R* about an axis passing through the centre of the disc and perpendicular to the plane of it is $\frac{1}{2}MR^2$

(4) All of these

32. A ring-type flywheel of mass 100 kg and diameter 2m is rotating at the rate of $\frac{300}{\pi}$ revolutions per minute then

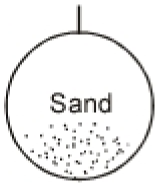
(1) The moment of inertia of the flywheel is 100 kg m²

(2) The kinetic energy of rotation of the flywheel is 5 kJ

(3) The flywheel, if subjected to a retarding torque of 200 Nm will come to rest in 5 s

(4) All of these

33. A hollow sphere is completely filled with sand. Sand leaks out through a hole at the bottom. The centre of gravity of the system with the leakage of sand



(1) Rises continuously

(2) Remains unchanged in the process

(3) First rises and then falls to the original position

(4) First falls and then rises to the original position

SECTION - B

Previous Years Questions

1. A solid cylinder of mass 3 kg is rolling on a horizontal surface with velocity 4 ms^{-1}. It collides with a horizontal spring of force constant 200 Nm^{-1}. The maximum compression produced in the spring will be **[AIPMT 2012]**

(1) 0.7 m (2) 0.2 m

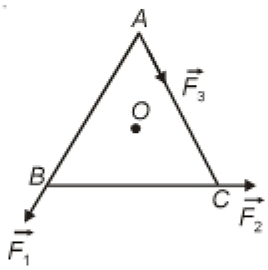
(3) 0.5 m (4) 0.6 m

2. Two persons of masses 55 kg and 65 kg respectively, are at the opposite ends of a boat. The length of the boat is 3.0 m and weighs 100 kg. The 55 kg man walks up to the 65 kg man and sits with him. If the boat is in still water the center of mass of the system shifts by **[AIPMT 2012]**

(1) Zero (2) 0.75 m

(3) 3.0 m (4) 2.3 m

3. *ABC* is an equilateral triangle with *O* as its centre. $\vec{F}_1$, $\vec{F}_2$ and $\vec{F}_3$ represent three forces acting along the sides *AB*, *BC* and *AC* respectively. If the total torque about *O* is zero then the magnitude of $\vec{F}_3$ is **[AIPMT 2012]**



(1) $\frac{F_1 + F_2}{2}$ (2) $2(F_1 + F_2)$

(3) $F_1 + F_2$ (4) $F_1 - F_2$

4. When a mass is rotating in a plane about a fixed point, its angular momentum is directed along **[AIPMT 2012]**

(1) The radius

(2) The tangent to the orbit

(3) A line perpendicular to the plane of rotation

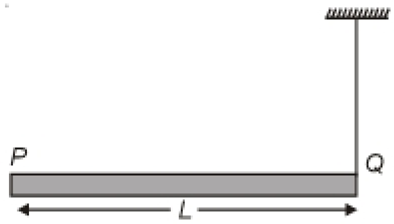
(4) The line making an angle of 45° to the plane of rotation

5. A small object of uniform density rolls up a curved surface with an initial velocity v'. It reaches up to a maximum height of $\frac{3v^2}{4g}s$ with respect to the initial position. The object is **[NEET-2013]**

(1) Solid sphere (2) Hollow sphere

(3) Disc (4) Ring

6. A rod PQ of mass M and length L is hinged at end P. The rod is kept horizontal by a massless string tied to point Q as shown in figure. When string is cut, the initial angular acceleration of the rod is **[NEET-2013]**



(1) $\frac{g}{L}$ (2) $\frac{2g}{L}$

(3) $\frac{2g}{3L}$ (4) $\frac{3g}{2L}$

7. A solid cylinder of mass 50 kg and radius 0.5 m is free to rotate about the horizontal axis. A massless string is wound round the cylinder with one end attached to it and other hanging freely. Tension in the string required to produce an angular acceleration of 2 revolutions s^{-2} is **[AIPMT 2014]**

(1) 25 N (2) 50 N

(3) 78.5 N (4) 157 N

8. The ratio of the accelerations for a solid sphere (mass m and radius R) rolling down an incline of angle 'θ' without slipping and slipping down the incline without rolling is **[AIPMT 2014]**

(1) 5 : 7 (2) 2 : 3

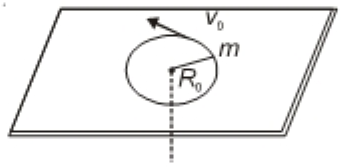
(3) 2 : 5 (4) 7 : 5

9. A rod of weight W is supported by two parallel knife edges A and B and is in equilibrium in a horizontal position. The knives are at a distance d from each other. The centre of mass of the rod is at distance x from A. The normal reaction on A is **[AIPMT-2015]**

(1) $\frac{W(d-x)}{d}$ (2) $\frac{Wx}{d}$

(3) $\frac{Wd}{x}$ (4) $\frac{W(d-x)}{x}$

10. A mass m moves in a circle on a smooth horizontal plane with velocity v_0 at a radius R_0. The mass is attached to a string which passes through a smooth hole in the plane as shown.



The tension in the string is increased gradually and finally m moves in a circle of radius $\frac{R_0}{2}$. The final value of the kinetic energy is **[AIPMT-2015]**

(1) $\frac{1}{2}mv_0^2$ (2) mv_0^2

(3) $\frac{1}{4}mv_0^2$ (4) $2mv_0^2$

11. Three identical spherical shells, each of mass m and radius r are placed as shown in figure. Consider an axis XX' which is touching to two shells and passing through diameter to third shell.

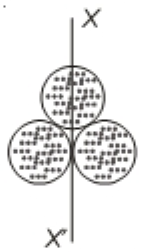
Moment of inertia of the system consisting of these three spherical shells about XX' axis is **[AIPMT-2015]**

(1) $4mr^2$

(2) $\frac{11}{5}mr^2$

(3) $3mr^2$

(4) $\frac{16}{5}mr^2$



12. Two spherical bodies of mass M and $5M$ and radii R and $2R$ are released in free space with initial separation between their centres equal to $12R$. If they attract each other due to gravitational force only, then the distance covered by the smaller body before collision is **[AIPMT-2015]**

(1) $1.5R$ (2) $2.5R$

(3) $4.5R$ (4) $7.5R$

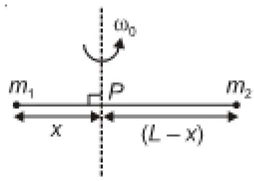
13. An automobile moves on a road with a speed of 54 km h^{-1}. The radius of its wheels is 0.45 m and the moment of inertia of the wheel about its axis of rotation is 3 kg m^2. If the vehicle is brought to rest in 15 s, the magnitude of average torque transmitted by its brakes to the wheel is

[Re-AIPMT-2015]

(1) 2.86 kg m^2s^{-2} (2) 6.66 kg m^2s^{-2}

(3) 8.58 kg m^2s^{-2} (4) 10.86 kg m^2s^{-2}

14. Point masses m_1 and m_2 are placed at the opposite ends of a rigid rod of length L, and negligible mass. The rod is to be set rotating about an axis perpendicular to it. The position of point P on this rod through which the axis should pass so that the work required to set the rod rotating with angular velocity ω_0 is minimum, is given by



[Re-AIPMT-2015]

(1) $x = \frac{m_2 L}{m_1 + m_2}$

(2) $x = \frac{m_1 L}{m_1 + m_2}$

(3) $x = \frac{m_1}{m_2} L$

(4) $x = \frac{m_2}{m_1} L$

15. A force $\vec{F} = \alpha\hat{i} + 3\hat{j} + 6\hat{k}$ is acting at a point $\vec{r} = 2\hat{i} - 6\hat{j} - 12\hat{k}$. The value of α for which angular momentum about origin is conserved is

[Re-AIPMT-2015]

(1) 1 (2) –1

(3) 2 (4) Zero

16. From a disc of radius R and mass M, a circular hole of diameter R, whose rim passes through the centre is cut. What is the moment of inertia of the remaining part of the disc about a perpendicular axis, passing through the centre? **[NEET-2016]**

(1) $9MR^2/32$ (2) $15MR^2/32$

(3) $13MR^2/32$ (4) $11MR^2/32$

17. A disk and a sphere of same radius but different masses roll off on two inclined planes of the same altitude and length. Which one of the two objects gets to the bottom of the plane first? **[NEET-2016]**

(1) Depends on their masses

(2) Disk

(3) Sphere

(4) Both reach at the same time

18. Two rotating bodies A and B of masses m and $2m$ with moments of inertia I_A and I_B ($I_B > I_A$) have equal kinetic energy of rotation. If L_A and L_B be their angular momenta respectively, then

[NEET (Phase-2) 2016]

(1) $L_A = \frac{L_B}{2}$ (2) $L_A = 2L_B$

(3) $L_B > L_A$ (4) $L_A > L_B$

19. A solid sphere of mass m and radius R is rotating about its diameter. A solid cylinder of the same mass and same radius is also rotating about its geometrical axis with an angular speed twice that of the sphere. The ratio of their kinetic energies of rotation (E_{sphere} / $E_{cylinder}$) will be

[NEET (Phase-2) 2016]

(1) 2 : 3 (2) 1 : 5

(3) 1 : 4 (4) 3 : 1

20. A light rod of length l has two masses m_1 and m_2 attached to its two ends. The moment of inertia of the system about an axis perpendicular to the rod and passing through the centre of mass is

[NEET (Phase-2) 2016]

(1) $\frac{m_1 m_2}{m_1 + m_2} l^2$ (2) $\frac{m_1 + m_2}{m_1 m_2} l^2$

(3) $(m_1 + m_2)l^2$ (4) $\sqrt{m_1 m_2} l^2$

21. 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? **[NEET-2017]**

(1) 25 m/s^2

(2) 0.25 rad/s^2

(3) 25 rad/s^2

(4) 5 m/s^2

22. Which of the following statements are correct?

    (a) Centre of mass of a body always coincides with the centre of gravity of the body.

    (b) Centre of mass of a body is the point at which the total gravitational torque on the body is zero

    (c) A couple on a body produce both translational and rotational motion in a body.

    (d) Mechanical advantage greater than one means that small effort can be used to lift a large load. **[NEET-2017]**

    (1) (b) and (d) (2) (a) and (b)

    (3) (b) and (c) (4) (c) and (d)

23. Two discs of same moment of inertia rotating about their regular axis passing through centre and perpendicular to the plane of disc with angular velocities ω_1 and ω_2. They are brought into contact face to face coinciding the axis of rotation. The expression for loss of energy during this process is **[NEET-2017]**

    (1) $\frac{1}{2}I(\omega_1+\omega_2)^2$ (2) $\frac{1}{4}I(\omega_1-\omega_2)^2$

    (3) $I(\omega_1-\omega_2)^2$ (4) $\frac{I}{8}(\omega_1-\omega_2)^2$

24. 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? **[NEET-2018]**

    (1) Angular velocity

    (2) Moment of inertia

    (3) Angular momentum

    (4) Rotational kinetic energy

25. A solid sphere is in rolling motion. In rolling motion a body possesses translational kinetic energy (K_t) as well as rotational kinetic energy (K_r) simultaneously. The ratio $K_t : (K_t + K_r)$ for the sphere is **[NEET-2018]**

    (1) 7 : 10 (2) 5 : 7

    (3) 2 : 5 (4) 10 : 7

26. Three objects, A : (a solid sphere), B : (a thin circular disk) and C : (a circular ring), each have the same mass M and radius R. They all spin with the same angular speed ω about their own symmetry axes. The amounts of work (W) required to bring them to rest, would satisfy the relation **[NEET-2018]**

    (1) $W_C > W_B > W_A$ (2) $W_A > W_B > W_C$

    (3) $W_A > W_C > W_B$ (4) $W_B > W_A > W_C$

27. The moment of the force, $\vec{F}=4\hat{i}+5\hat{j}-6\hat{k}$ at (2, 0, –3), about the point (2, –2, –2), is given by **[NEET-2018]**

    (1) $-8\hat{i}-4\hat{j}-7\hat{k}$ (2) $-4\hat{i}-\hat{j}-8\hat{k}$

    (3) $-7\hat{i}-4\hat{j}-8\hat{k}$ (4) $-7\hat{i}-8\hat{j}-4\hat{k}$

28. A disc of radius 2 m and mass 100 kg rolls on a horizontal floor. Its centre of mass has speed of 20 cm/s. How much work is needed to stop it? **[NEET-2019]**

    (1) 3 J (2) 30 kJ

    (3) 2 J (4) 1 J

29. A solid cylinder of mass 2 kg and radius 4 cm is rotating about its axis at the rate of 3 rpm. The torque required to stop after 2π revolutions is **[NEET-2019]**

    (1) 2×10^{-6} N m (2) 2×10^{-3} N m

    (3) 12×10^{-4} N m (4) 2×10^{6} N m

30. An object flying in air with velocity $(20\hat{i}+25\hat{j}-12\hat{k})$ suddenly breaks into two pieces whose masses are in the ratio 1 : 5. The smaller mass flies off with a velocity $(100\hat{i}+35\hat{j}+8\hat{k})$. The velocity of the larger piece will be **[NEET-2019 (Odisha)]**

    (1) $4\hat{i}+23\hat{j}-16\hat{k}$ (2) $-100\hat{i}-35\hat{j}-8\hat{k}$

    (3) $20\hat{i}+15\hat{j}-80\hat{k}$ (4) $-20\hat{i}-15\hat{j}-80\hat{k}$

31. A particle starting from rest, moves in a circle of radius 'r'. It attains a velocity of V_0 m/s in the n[th] round. Its angular acceleration will be **[NEET-2019 (Odisha)]**

    (1) $\frac{V_0}{n}\text{rad/s}^2$ (2) $\frac{V_0^2}{2\pi nr^2}\text{rad/s}^2$

    (3) $\frac{V_0^2}{4\pi nr^2}\text{rad/s}^2$ (4) $\frac{V_0^2}{4\pi nr}\text{rad/s}^2$

32. A solid cylinder of mass 2 kg and radius 50 cm rolls up an inclined plane of angle of inclination 30°. The centre of mass of the cylinder has speed of 4 m/s. The distance travelled by the cylinder on the inclined surface will be, [take g = 10 m/s^2] **[NEET-2019 (Odisha)]**

    (1) 2.2 m (2) 1.6 m

    (3) 1.2 m (4) 2.4 m

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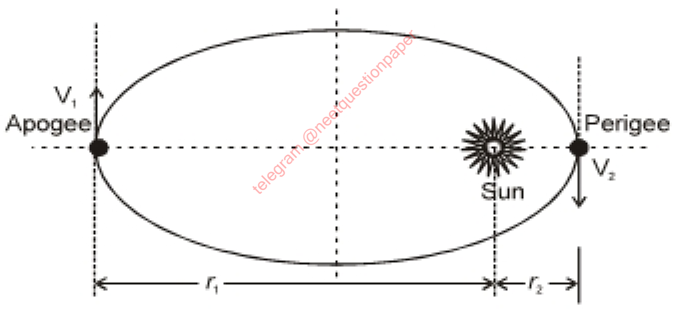
Chapter 7

Gravitation

Sub-topics *Kepler's laws of planetary motion. The universal law of gravitation. Acceleration due to gravity and its variation with altitude and depth. Gravitational potential energy; gravitational potential. Escape velocity, orbital velocity of a satellite. Geostationary satellites.*

Kepler's Laws

(1) All planets revolve around the sun in elliptical orbit having sun at one focus.



(2) A planet sweeps out equal area in equal time interval *i.e.* Areal speed of the planet is constant

$$\frac{dA}{dt} = \frac{L}{2m} = \text{constant}$$

$$\boxed{v_1 r_1 = v_2 r_2}$$

Angular momentum '*L*' of all planets and satellites is constant if external torque = 0

(3) Square of time period is proportional to cube of semi-major axis

i.e., $T^2 \propto r^3$ (Also applicable for electrons motion in orbits).

Universal Law of Gravitation

$$F = G.\frac{m_1 m_2}{r^2} \text{ (always attractive)}$$

G → universal gravitational constant = 6.67×10^{-11} Nm^2/kg^2 (*G* is independent of the medium in which the masses are kept)

Relation between g and G

$$g = \frac{GM}{R^2} = \frac{G \times \frac{4}{3}\pi R^3 \rho}{R^2} = \frac{4}{3}\pi G R \rho$$

$\rho \rightarrow$ density of earth = 5.5×10^3 kg/m^3

Variation in the value of g

1. **at height 'h'**

$$g' = \frac{g}{\left[1 + \frac{h}{R_e}\right]^2} \text{ and } g' = g\left[1 - \frac{2h}{R_e}\right] \text{ if } h << R_e$$

Example : If $h = R_e$, $g' = \frac{g}{4}$

2. **at depth 'x'**

$$g' = g\left\{1 - \frac{x}{R_e}\right\}$$, at the centre of earth $g' = 0$, weight = 0

Note : *Mass is intrinsic property and it is not affected by variation of gravity.*

Gravitational Potential Energy

(i) At earth's surface $U = -\frac{GM_e m}{R_e}$

(ii) If a projectile is projected with speed v (order km/s) then maximum height is given by

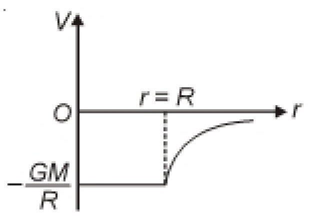
$$\frac{mgh}{(1 + h/R_e)} = \frac{1}{2}mv^2$$

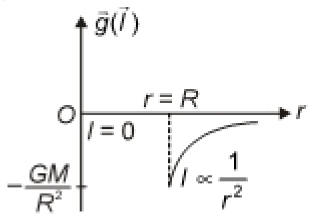
If $h << R_e$, $\Delta U = mgh \Rightarrow v = \sqrt{2gh}$

(iii) Escape energy = $+\frac{GM_e m}{R_e} = -\left[\frac{-GM_e m}{R_e}\right]$ *i.e.*, – GPE at earth's surface.

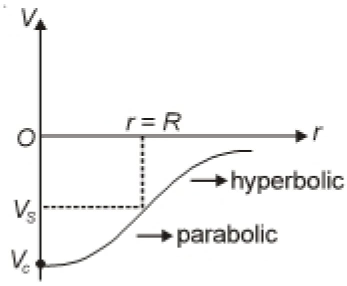
Variation of Field and Potential

(i) For a shell of mass M and radius R





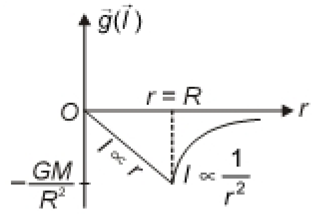
(ii) For Uniform Sphere (say earth)



Inside uniform sphere

$V_i = -\frac{GM}{2R^3}(3R^2 - r^2)$

$V_c = \frac{3}{2} V_s$



Escape velocity

$$v_e = \sqrt{\frac{2GM_e}{R_e}} = \sqrt{\frac{8}{3}\pi G R_e{}^2 \rho} = \sqrt{2gR_e}$$

At earth surface v_e = 11.2 km/s

***Note :** Escape velocity is independent of mass of object and direction of projection.*

(i) If a body is projected with velocity greater than escape velocity, the interstellar speed is given by

$$v_{I.S} = \sqrt{v_{\text{given}}^2 - v_e^2}$$

(ii) If a body is projected upwards with velocity $v = Kv_e$, where $K < 1$, maximum height attained from centre of earth is 'r' $= \frac{R}{1-K^2}$ and hence

from surface of the earth the altitude $h = r - R = \frac{RK^2}{1-K^2}$

Type of path acquired by a projected body

(i) If $v < v_0$ (Elliptical)

(ii) If $v = v_0$ (Circular)

(iii) If $v_0 < v < v_e$ (Elliptical)

(iv) If $v = v_e$ (Parabolic)

(v) If $v > v_e$ (Hyperbolic)

Motion of Satellites

(i) Orbital velocity $v_0 = \sqrt{\frac{GM_e}{r}} = \sqrt{\frac{gR_e^2}{R_e + h}} = R_e\sqrt{\frac{g}{R_e + h}} \simeq \sqrt{gR_e}$ {Only when $h << R_e$}

(ii) $T = 2\pi\sqrt{\frac{(R_e + h)^3}{GM_e}}$

(iii) $T = 2\pi\sqrt{\frac{R_e}{g}}$ ⇒ 1.4 hour or 84.6 min. ($h << R_e$)

(iv) $PE = -\frac{GMm}{r}$, $KE = \frac{GMm}{2r}$, $TE = -\frac{GMm}{2r}$

Geostationary Satellites

(i) The plane of the orbit lies in equatorial plane of earth.

(ii) Height from the earth surface is 36000 km, this orbit is called parking orbit.

(iii) Orbital speed is nearly 3 km/s.

(iv) Time period is equal to that of earth's rotation *i.e.*, 24 hours.

(v) Used for communication purposes

Polar Satellites

(i) It goes around poles of the earth in north-south direction.

(ii) It is at low altitude (500-800 km).

(iii) It's time period is around 100 minute.

(iv) It gathers information useful for remote sensing, meteorology as well as environmental studies.

Gravitational Potential

Amount of work done in bringing a unit mass from infinity to a point in the gravitational field.

$$V = -\frac{W}{m} = -\frac{GM}{r} \text{ J/kg}$$

Some important points

1. Time period of a satellite is independent of mass of the satellite.
2. Atmosphere on a planet is possible only if $v_{rms} < v_e$, where v_{rms} = rms speed of gas molecules. v_e = escape speed
3. If angular velocity of earth is made 17 times, objects placed at equator will fly off.
4. As we move from pole to equator, gravity decreases by 0.35%.
5. If orbital velocity of any satellite increases by 41.4%, the satellite escapes to infinity.
6. If gravitational force ∝ r^n, time period for an orbiting object ∝ $r^{(1-n)/2}$.

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Try Yourself

SECTION - A

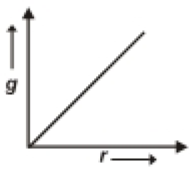
Objective Type Questions

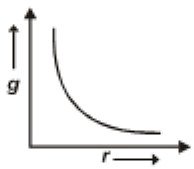
1. What is the value of $10^{11}G$ in S.I. units?

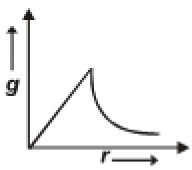
   (1) 6.67×10^{-22} (2) 6.67×10^{-11}

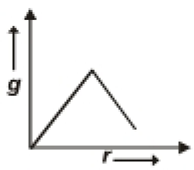
   (3) 6.67 (4) 6.67×10^{11}

2. Which graph best represents the variation of acceleration due to gravity with distance from the centre of the earth?

   (1) 

   (2) 

   (3) 

   (4) 

3. A body has a mass of 1kg on the surface of Earth. What is the mass at the centre of Earth?

   (1) 0 kg (2) 1 kg

   (3) 9.8 kg (4) ∞

4. The unit of the quantity $\frac{G}{g}$ is

   (1) kg m^{-2} (2) m^2 kg^{-1}

   (3) kg m^{-1} (4) kg m^2

5. Two planets have radii in the ratio $x : y$ and density in the ratio $m : n$. The acceleration due to gravity 'g' is in the ratio

   (1) $nx : my$ (2) $ny : mx$

   (3) $mx : ny$ (4) $my : nx$

6. If mass of a planet is 10% less than that of the Earth and radius 20% greater than that of the Earth, then the acceleration due to gravity on the planet will be

   (1) $\frac{5}{8}$ times that on the surface of the Earth

   (2) $\frac{3}{4}$ times that on the surface of the Earth

   (3) $\frac{1}{2}$ times that on the surface of the Earth

   (4) $\frac{9}{10}$ times that on the surface of the Earth

7. Choose the incorrect statement

   (1) Acceleration due to gravity decreases with increasing altitude

   (2) Acceleration due to gravity decreases with increasing depth

   (3) Acceleration due to gravity is independent of mass of body

   (4) Effect of rotation on the effective value of 'g' is greatest at the poles

8. A tunnel is dug along a diameter of the Earth. If M_e and R_e, are the mass and radius respectively of Earth, then the force on a particle of mass m placed in the tunnel at a distance r from the centre is

   (1) $\frac{GM_e m}{R_e^3}r$ (2) $\frac{GM_e m}{R_e^3 r}$

   (3) $\frac{GM_e m R_e^3}{r}$ (4) $\frac{GM_e m}{R_e^2}r$

9. A satellite of mass m is revolving at a height R above the surface of Earth. Here R is the radius of the Earth. The gravitational potential energy of the satellite is

   (1) $-mgR$ (2) $\frac{-mgR}{2}$

   (3) $\frac{-mgR}{3}$ (4) $\frac{-mgR}{7}$

10. A projectile is fired vertically from the Earth with a velocity $k V_e$ where V_e is the escape velocity and k is a constant less than unity. The maximum height to which projectiles rises, as measured from the centre of Earth is

(1) $\frac{R}{k}$ (2) $\frac{R}{k-1}$

(3) $\frac{R}{1-k^2}$ (4) $\frac{R}{1+k^2}$

11. What amount of energy is required for making a 500 kg body escape from the Earth?

(Given g = 10 m/s² and radius of Earth = 6 × 10⁶m)

(1) 3 × 10⁹ J (2) 1.5 × 10⁹ J

(3) 3 × 10¹⁰ J (4) 6 × 10¹⁰ J

12. Earth is compressed to such a small-sized sphere that the escape velocity becomes equal to the velocity of light. What is the approximate radius of this small-sized sphere?

(Given : mass of Earth = 6 × 10²⁴ kg)

(1) 4.5 mm (2) 9 mm

(3) 12 mm (4) 24 mm

13. A body is projected from the surface of earth with a velocity 2 V_e, where V_e is the escape velocity. The velocity of the body when it escapes the gravitational field of earth is

(1) $\sqrt{2}\,V_e$ (2) $\sqrt{3}\,V_e$

(3) $\sqrt{7}\,V_e$ (4) $\sqrt{11}\,V_e$

14. Suppose the acceleration of free fall at the surface of a distant planet were found to be equal to that at the surface of the earth, if the diameter of the planet were twice the diameter of Earth. Then the ratio of mean density of the planet to that of the Earth would be

(1) 4 : 1 (2) 2 : 1

(3) 1 : 1 (4) 1 : 2

15. If both the mass and radius of Earth decrease by 1%, the value of escape velocity will decrease by nearly

(1) 1 % (2) 1.5 %

(3) 2 % (4) 0 %

16. A satellite is orbiting close to surface of the Earth. Its time period is

(1) $2\pi\sqrt{\frac{R}{g}}$ (2) $2\pi\sqrt{\frac{2R}{g}}$

(3) $2\pi\sqrt{\frac{R}{2g}}$ (4) $2\pi\sqrt{\frac{4R}{g}}$

17. If the orbital speed of moon is increased by 41.4%, then moon will

(1) Leave its orbit and will escape out

(2) Fall on Earth

(3) Attract all the bodies on the Earth towards it

(4) Have time period equal to 27 days

18. V_e and V_p denote the escape velocities from the Earth and another planet having twice the radius and the same density as the Earth, then

(1) $V_e = V_p$ (2) $V_e = \frac{V_p}{2}$

(3) $V_e = 2\,V_p$ (4) $V_e = \frac{V_p}{4}$

19. The orbital velocity of a satellite at a height R above the surface of Earth is v. The escape velocity from the location is

(1) $\sqrt{2}\,v$ (2) $2\,v$

(3) $4\,v$ (4) $(\sqrt{2}-1)v$

20. A satellite is moving round the Earth in a circular orbit. The force acting on the satellite is

(1) Centripetal only, provided by Earth's gravitational pull

(2) Centrifugal only, due to orbital motion

(3) Zero, because centripetal and centrifugal forces balance out

(4) The sum of centripetal and gravitational forces

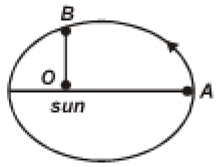
21. A satellite of mass m is circulating around the Earth with constant angular velocity. If radius of the orbit is R_0 and mass of the Earth is M, then the angular momentum about the centre of the Earth is

(1) $m\sqrt{GMR_0}$ (2) $M\sqrt{GmR_0}$

(3) $m\sqrt{\frac{GM}{R_0}}$ (4) $M\sqrt{\frac{Gm}{R_0}}$

22. Select the correct statement from the following
    (1) The orbital velocity of a satellite increases with the radius of the orbit
    (2) Escape velocity of a particle from the surface of the Earth depends on the angle at which it is fired
    (3) The time period of a satellite does not depend on the radius of the orbit
    (4) The orbital velocity is inversely proportional to the square root of the radius of the orbit

23. The Earth moves around the sun in an elliptical orbit as shown in figure. The ratio $\frac{OA}{OB} = x$. The ratio of the speed of the Earth at B and at A is nearly



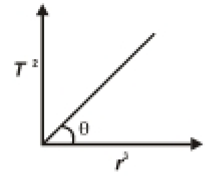
    (1) $\sqrt{x}$ (2) x
    (3) $x\sqrt{x}$ (4) x^2

24. If the Earth were at one-fourth of its present distance from the sun, the duration of the year would be
    (1) Half the present year
    (2) One-eight the present year
    (3) One-fourth the present year
    (4) One-sixth the present year

25. An Earth satellite is moved from one stable circular orbit to a farther stable circular orbit. Which of the following increases?
    (1) Gravitational potential energy
    (2) Linear orbital speed
    (3) Gravitational force
    (4) Centripetal acceleration

26. A satellite of mass m is revolving round the Earth at a height R above the surface of the Earth. If g is the gravitational intensity at the earth's surface and R is the radius of Earth, then the kinetic energy of the satellite will be
    (1) $\frac{mgR}{4}$ (2) $\frac{mgR}{2}$
    (3) mgR (4) $2\ mgR$

27. If a graph is plotted between T^2 and r^3 for a planet, then the slope of the graph will be (Letters have usual meanings)



    (1) $\frac{4\pi^2}{GM}$ (2) $\frac{GM}{4}$
    (3) $4\pi GM$ (4) $\frac{GM}{4\pi}$

28. A satellite is revolving in an orbit close to surface of the earth with kinetic energy K. When the kinetic energy is increased to nK, the satellite escapes. What is the minimum value of n?
    (1) 2 (2) 2.5
    (3) 4 (4) 5

29. Assume that the time period of a satellite close to surface of the Earth is 80 minutes. What is the time period of another Earth satellite in an orbit of radius equal to four times the Earth's radius?
    (1) 640 minute (2) 660 minute
    (3) 680 minute (4) 720 minute

30. A research satellite of mass 200 kg circles the earth in an orbit of average radius $3R/2$, where R is the radius of the Earth. Assuming the gravitational pull on a mass 1 kg on Earth's surface to be 10N, the pull on the satellite will be
    (1) 880 N (2) 889 N
    (3) 890 N (4) 892 N

31. The K.E. of a satellite is 2MJ. What is the total energy of the satellite?
    (1) –2 MJ (2) –1 MJ
    (3) $-\frac{1}{2}$ MJ (4) –4 MJ

32. The time period T of revolution of a satellite is related to its orbital radius as
    (1) $T \propto r^2$ (2) $T^2 \propto r^3$
    (3) $T^3 \propto r^2$ (4) $T^2 \propto r^6$

33. If the time period of a satellite orbiting close to earth's surface is T, the time period of a geostationary satellite is nearly equal to
    (1) $2T$ (2) $24T$
    (3) $7\sqrt{7}T$ (4) T

34. The height at which weight of a person changes by 1% is (R is radius of earth)

(1) $\frac{R}{200}$ (2) $\frac{R}{100}$

(3) $\frac{R}{50}$ (4) $\frac{R}{1000}$

35. At what depth from the earth's surface the value of acceleration due to gravity reduces by 1% of its value on the earth's surface? (R is radius of the earth)

(1) $\frac{R}{200}$ (2) $\frac{R}{100}$

(3) $\frac{R}{10}$ (4) $9R$

SECTION - B

Previous Years Questions

1. A spherical planet has a mass M_p and diameter D_p. A particle of mass m falling freely near the surface of this planet will experience an acceleration due to gravity, equal to **[AIPMT 2012]**

(1) GM_p / D_p^2 (2) $4\ GM_p m / D_p^2$

(3) $4\ GM_p / D_p^2$ (4) $GM_p m / D_p^2$

2. A geostationary satellite is orbiting the earth at a height of $5R$ above that surface of the earth, R being the radius of the earth. The time period of another satellite in hours at a height of $2R$ from the surface of the earth is **[AIPMT 2012]**

(1) $6\sqrt{2}$

(2) $\frac{6}{\sqrt{2}}$

(3) 5

(4) 10

3. The height at which the weight of a body becomes $\frac{1}{16}^{th}$, its weight on the surface of earth (radius R), is **[AIPMT 2012]**

(1) 3 R

(2) 4 R

(3) 5 R

(4) 15 R

4. A body of mass 'm' taken from the earth's surface to the height equal to twice the radius (R) of the earth. The change in potential energy of body will be **[NEET-2013]**

(1) $\frac{2}{3}mgR$ (2) $3mgR$

(3) $\frac{1}{3}mgR$ (4) $mg2R$

5. Infinite number of bodies, each of mass 2 kg are situated on x-axis at distance 1 m, 2 m, 4 m, 8 m, ... respectively, from the origin. The resulting gravitational potential due to this system at the origin will be **[NEET-2013]**

(1) $-\frac{8}{3}G$ (2) $-\frac{4}{3}G$

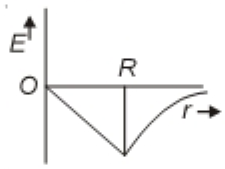
(3) $-4G$ (4) $-G$

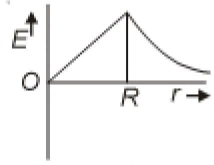
6. A black hole is an object whose gravitational field is so strong that even light cannot escape from it. To what approximate radius would earth (mass = 5.98×10^{24} kg) have to be compressed to be a black hole? **[AIPMT 2014]**

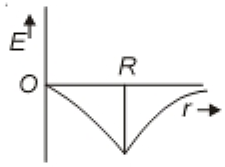
(1) 10^{-9} m (2) 10^{-6} m

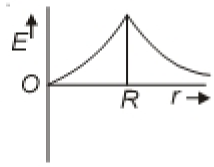
(3) 10^{-2} m (4) 100 m

7. Dependence of intensity of gravitational field (E) of earth with distance (r) from centre of earth is correctly represented by **[AIPMT 2014]**

(1) 

(2) 

(3) 

(4) 

8. A satellite S is moving in an elliptical orbit around the earth. The mass of the satellite is very small compared to the mass of the earth. Then, **[Re-AIPMT-2015]**

(1) The acceleration of S is always directed towards the centre of the earth

(2) The angular momentum of S about the centre of the earth changes in direction, but its magnitude remains constant

(3) The total mechanical energy of S varies periodically with time

(4) The linear momentum of S remains constant in magnitude

9. A remote-sensing satellite of earth revolves in a circular orbit at a height of 0.25×10^6 m above the surface of earth. If earth's radius is 6.38×10^6 m and $g = 9.8$ ms^{-2}, then the orbital speed of the satellite is **[Re-AIPMT-2015]**

(1) 6.67 km s^{-1}

(2) 7.76 km s^{-1}

(3) 8.56 km s^{-1}

(4) 9.13 km s^{-1}

10. Kepler's third law states that square of period of revolution (T) of a planet around the sun, is proportional to third power of average distance r between sun and planet, *i.e.*, $T^2 = Kr^3$, here K is constant. If the masses of sun and planet are M and m respectively then as per Newton's law of gravitation force of attraction between them is $F = \frac{GMm}{r^2}$, here G is gravitational constant. The relation between G and K is described as

[AIPMT-2015]

(1) $K = \frac{1}{G}$

(2) $GK = 4\pi^2$

(3) $GMK = 4\pi^2$

(4) $K = G$

11. At what height from the surface of earth the gravitation potential and the value of g are -5.4×10^7 J kg^{-2} and 6.0 ms^{-2} respectively? Take the radius of earth as 6400 km **[NEET-2016]**

(1) 2000 km

(2) 2600 km

(3) 1600 km

(4) 1400 km

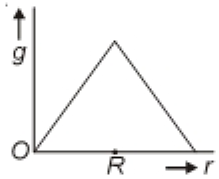
12. The ratio of escape velocity at earth (v_e) to the escape velocity at a planet (v_p) whose radius and mean density are twice as that of earth is

[NEET-2016]

(1) $1 : \sqrt{2}$ (2) 1 : 2

(3) $1 : 2\sqrt{2}$ (4) 1 : 4

13. Starting from the centre of the earth having radius R, the variation of g (acceleration due to gravity) is shown by **[NEET (Phase-2) 2016]**

(1)


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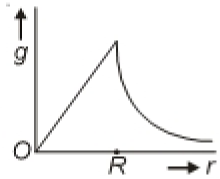

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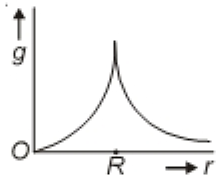

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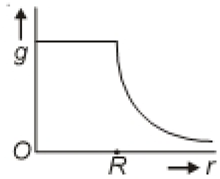


14. A satellite of mass m is orbiting the earth (of radius R) at a height h from its surface. The total energy of the satellite in terms of g_0, the value of acceleration due to gravity at the earth's surface, is **[NEET (Phase-2) 2016]**

(1) $\frac{mg_0R^2}{2(R+h)}$

(2) $-\frac{mg_0R^2}{2(R+h)}$

(3) $\frac{2mg_0R^2}{R+h}$

(4) $-\frac{2mg_0R^2}{R+h}$

15. The acceleration due to gravity at a height 1 km above the earth is the same as at a depth d below the surface of earth. Then **[NEET-2017]**

(1) $d = \frac{1}{2}$ km

(2) $d = 1$ km

(3) $d = \frac{3}{2}$ km

(4) $d = 2$ km

16. Two astronauts are floating in gravitational free space after having lost contact with their spaceship. The two will **[NEET-2017]**

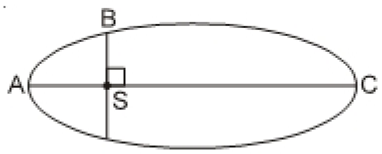
(1) Keep floating at the same distance between them

(2) Move towards each other

(3) Move away from each other

(4) Will become stationary

17. The kinetic energies of a planet in an elliptical orbit about the Sun, at positions A, B and C are K_A, K_B and K_C, respectively. AC is the major axis and SB is perpendicular to AC at the position of the Sun S as shown in the figure. Then **[NEET-2018]**



(1) $K_A < K_B < K_C$ (2) $K_A > K_B > K_C$

(3) $K_B > K_A > K_C$ (4) $K_B < K_A < K_C$

18. If the mass of the Sun were ten times smaller and the universal gravitational constant were ten times larger in magnitude, which of the following is not correct? **[NEET-2018]**

(1) Raindrops will fall faster

(2) Walking on the ground would become more difficult

(3) 'g' on the Earth will not change

(4) Time period of a simple pendulum on the Earth would decrease

19. A body weighs 200 N on the surface of the earth. How much will it weigh half way down to the centre of the earth? **[NEET-2019]**

(1) 150 N (2) 200 N

(3) 250 N (4) 100 N

20. The work done to raise a mass m from the surface of the earth to a height h, which is equal to the radius of the earth, is **[NEET-2019]**

(1) mgR (2) $2mgR$

(3) $\frac{1}{2}mgR$ (4) $\frac{3}{2}mgR$

21. Assuming that the gravitational potential energy of an object at infinity is zero, the change in potential energy (final – initial) of an object of mass m, when taken to a height h from the surface of earth (of radius R), is given by **[NEET-2019 (Odisha)]**

(1) $\frac{GMm}{R+h}$

(2) $-\frac{GMm}{R+h}$

(3) $\frac{GMmh}{R(R+h)}$

(4) mgh

22. The time period of a geostationary satellite is 24 h, at a height $6R_E$(R_E is radius of earth) from surface of earth. The time period of another satellite whose height is 2.5 R_E from surface will be **[NEET-2019 (Odisha)]**

(1) $\frac{12}{2.5}$ h (2) $6\sqrt{2}$ h

(3) $12\sqrt{2}$ h (4) $\frac{24}{2.5}$ h

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Chapter 8

Mechanical Properties of Solids

Sub-topics *Elastic behaviour, Stress-strain relationship. Hooke's law, Young's modulus, bulk modulus, shear, modulus of rigidity, Poisson's ratio; elastic energy.*

Elasticity

It is the property of a solid, by which it tries to restore its original shape and size, by developing a restoring force in it.

Stress

Restoring force developed/Area.

Strain

Change in dimension/original dimension.

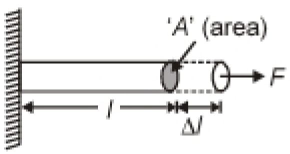
Modulus of Elasticity = $\frac{\text{Stress}}{\text{Strain}}$

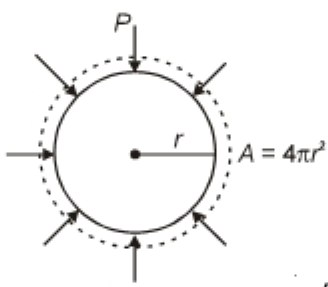
Hooke's law: Stress $\propto$ Strain (within elastic limit)

Steel is considered more elastic than rubber, because its modulus of elasticity is more than that of rubber.

Types of Stress

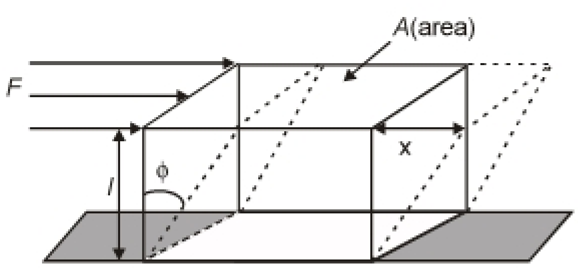
1.





(a) Axial Stress (Tensile) = F/A (b) Normal Stress (Compressive) = $\frac{F}{4\pi r^2} = P$ (pressure)

2.



Tangential Stress or shear stress = $\frac{F}{A}$

Types of Strain

(1) Longitudinal strain = $\frac{\Delta l}{l}$

(2) Volumetric strain = $-\frac{\Delta V}{V}$

(3) Shear strain = $\phi = \frac{x}{l}$ = Shear angle

(i) Young's modulus of elasticity $Y = \frac{\text{Longitudinal stress}}{\text{Longitudinal strain}} = \frac{Fl}{A\Delta l}$

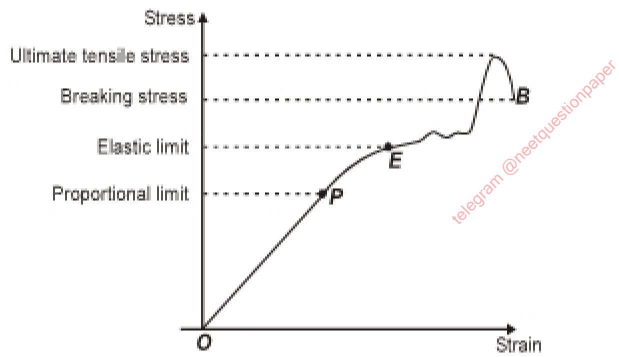
(ii) Bulk modulus of elasticity (K or B) = $\frac{\text{Normal or compressive stress}}{\text{Volumetric strain}}$

$$K = \frac{-PV}{\Delta V} \text{ or } \frac{-dP}{dV}V$$

Compressibility = $\frac{1}{K}$

(iii) Modulus of rigidity η or $G = \frac{\text{Shear stress}}{\text{Shear strain}} = \frac{F}{A\phi} = \frac{Fl}{Ax}$

Stress - Strain curve for a wire :



(1) Stress ∝ strain till point P.

(2) In region OE, material returns to original position after removal of deforming force.

(3) For deformation beyond E, material does not return to original size.

(4) At B, fracture of the solid occurs.

(5) For the wire $Y = \frac{Fl}{A\Delta l} \Rightarrow F = \frac{YA}{l}\Delta l$

i.e. a wire behaves like a spring with spring constant

$$k = \frac{YA}{l} \qquad \left(i.e.\ k \propto \frac{1}{l}\right)$$

When this wire is stretched by applying constant external force F, and Δl is extension produced, then

(i) Work done by external force = $F\Delta l$

(ii) Work done by restoring force = $\frac{1}{2}F\Delta l$

(iii) Elastic potential energy stored = $\frac{1}{2}F\Delta l$

$$\text{Energy density } U = \frac{1}{2}\frac{F\Delta l}{\text{volume}} = \frac{1}{2}\frac{F\Delta l}{Al}$$

$$= \frac{1}{2}\text{ stress} \times \text{strain}$$

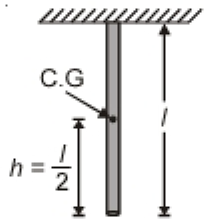
$$= \frac{1}{2}\frac{(\text{stress})^2}{Y} = \frac{1}{2}Y(\text{strain})^2$$

(6) A wire of mass m and length l hangs from a support

Area of cross-section = A

Extension produced due to its own weight

$$\Delta l = \frac{Mgl}{2AY}$$



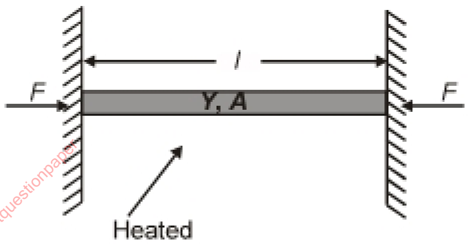
Thermal Stress

$\Delta\theta$ = Rise in temperature

Compressive strain = $\frac{\Delta l}{l} = \alpha\Delta\theta$

Compressive stress = Y × strain = $Y\alpha\Delta\theta$

$F = Y\alpha\Delta\theta \times A$

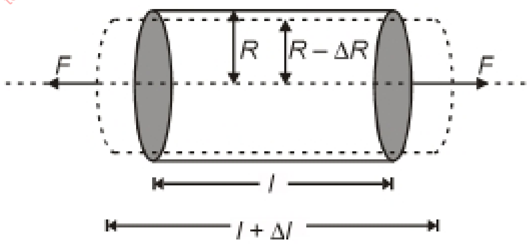


Poisson's Ratio

Longitudinal strain = $\frac{\Delta l}{l}$

Lateral strain = $-\frac{\Delta R}{R}$

Poisson's ratio $\sigma = -\frac{\Delta R / R}{\Delta l / l}$



(i) Theoretically $-1 \le \sigma \le 0.5$

(ii) Practically $0 \le \sigma \le 0.5$

(iii) When density of material is constant $\Rightarrow \sigma = 0.5$

(iv) $\frac{9}{Y} = \frac{3}{\eta} + \frac{1}{K}$

(v) $K = \frac{Y}{3(1-2\sigma)}$

(vi) $\eta = \frac{Y}{2(1+\sigma)}$

(vii) $\sigma = \frac{3K - 2\eta}{2\eta + 6K}$

Some important points

1. Young's modulus of a wire is numerically equal to stress required to double the length of wire.
2. When a pressure dP is applied on a substance, its density changes from ρ to ρ' so that

   $$\rho' = \rho\left(1+\frac{dP}{B}\right)$$

   $\Rightarrow \dfrac{\Delta\rho}{\rho} = \dfrac{dP}{B}$, where B is Bulk modulus.
3. The energy density of water in a lake h metre deep is

   $U = \dfrac{1}{2}\dfrac{(h\rho g)^2}{B}$ where ρ is density of water, B is Bulk modulus.
4. A solid possesses all the three modulii of elasticity Y, K or η.
5. A liquid or gas possesses a finite value of only K out of the three modulii of elasticity.
6. For a gas, K depends on the processes by which gas expands/compresses.

   For a process PV^N = constant

   $$K = -\frac{dP}{dV/V} = NP$$

   (i) For isothermal process $N = 1$ $\therefore K = P$

   (ii) For adiabatic process $N = \gamma$ $\therefore K = \gamma P$

   (iii) For isobaric process $N = 0$ $\therefore K = 0$

   (iv) For isochoric process $N = \infty$ $\therefore K = \infty$

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Try Yourself

SECTION - A

Objective Type Questions

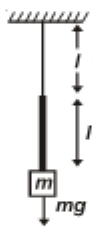
1. The depth at which density of water becomes 1% greater than that at the surface, (compressibility of water is 50×10^{-11}/Pa) is

   (1) 1000 m (2) 500 m
   (3) 2000 m (4) 4000 m

2. A solid sphere made of a material of bulk modulus B is surrounded by a liquid in a cylindrical container. A massless piston of area A floats on the surface of liquid. The fractional change in the radius of the sphere (dR/R), when a mass M is placed on the piston to compress the liquid, is given by

   (1) $\frac{Mg}{AB}$ (2) $\frac{Mg}{2AB}$
   (3) $\frac{Mg}{3AB}$ (4) Zero

3. A light wire of length 'l' and radius 'r' is welded to another light wire of length 'l' and radius '$2r$'. Taking the modulus of elasticity of each wire as Y, the ratio of extension produced in first wire to 2nd wire is



   (1) 1/4 (2) 4
   (3) 1/2 (4) 2

4. The ratio of diameters of two wires of same material is n : 1. The length of each wire is 4m. On applying the same load, the increase in the length of thin wire will be (n > 1)

   (1) n^2 times (2) n times
   (3) $2n$ times (4) $(2n + 1)$ times

5. The elasticity limit for a gas

   (1) Exists
   (2) Exists only at absolute zero
   (3) Exists for a prefect gas
   (4) Does not exist

6. A wire of area of cross-section 10^{-6} m^2 is increased in length by 0.1 %. The tension produced is 1000 N. The Young's modulus of wire is

   (1) 10^{12} Nm^{-2} (2) 10^{11} Nm^{-2}
   (3) 10^{10} Nm^{-2} (4) 10^{9} Nm^{-2}

7. An iron bar of length l having cross-section area A is heated from 0°C to 100°C. If this bar is so held that it is not permitted to expand or bend, the elastic force F that is developed in the bar is proportional to

   (1) l (2) l^{-1}
   (3) l^0 (4) A^{-1}

8. A cable that can support a load of 800 N is cut into two equal parts. The maximum load that can be suspended by either part is

   (1) 100 N (2) 400 N
   (3) 800 N (4) 1600 N

9. The breaking stress of a wire of length l and radius r is 5 kg wt m^{-2}. A wire of length $2l$ and radius $2r$ of the same material will have breaking stress (in kg wt m^{-2}) equal to

   (1) 5 (2) 10
   (3) 20 (4) 80

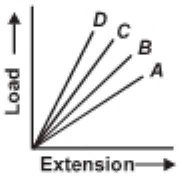
10. Consider the following pairs of quantities

    (a) Young's modulus; pressure
    (b) Torque; energy
    (c) Linear momentum; work
    (d) Solar day; light year

    In which cases are the dimensions, within a pair are same?

    (1) (a) & (c) (2) (a) & (d)
    (3) (a) & (b) (4) (b) & (d)

11. Figure shows the load extension curves for four wires *A*, *B*, *C* and *D*. The dimensions of all the four wires are identical but materials of wire are different. Which wire has largest value of Young's modulus of elasticity?



(1) *A* (2) *B*
(3) *C* (4) *D*

12. If E_θ and E_ϕ denote the isothermal and adiabatic elasticities respectively, of a diatomic gas, then $\frac{E_\theta}{E_\phi}$

(1) < 1 (2) > 1
(3) = 1 (4) < 0.7

13. Two wires of same material and same mass are stretched by the same force. Their lengths are in the ratio 2 : 3. Their elongations are in the ratio

(1) 3 : 2 (2) 2 : 3
(3) 4 : 9 (4) 9 : 4

14. An aluminium rod of Young's modulus 7.0×10^9 N m^{-2}, has a breaking strain of 0.2%. The minimum cross-section area of the rod (in m^2) in order to support a load of 10^4 N, is

(1) 1×10^{-2} (2) 1.4×10^{-3}
(3) 1×10^{-3} (4) 7.1×10^{-4}

15. If 3×10^{-3} J of work is done in stretching a wire through 1 mm, the work done in stretching it through 3 mm is

(1) 9×10^{-3} J (2) 8×10^{-3} J
(3) 27×10^{-3} J (4) Data is not complete

SECTION - B

Previous Years Questions

1. The following four wires are made of the same material. Which of these will have the largest extension when the same tension is applied? **[NEET-2013]**

(1) Length = 100 cm, diameter = 1 mm
(2) Length = 200 cm, diameter = 2 mm
(3) Length = 300 cm, diameter = 3 mm
(4) Length = 50 cm, diameter = 0.5 mm

2. Copper of fixed volume *V* is drawn into wire of length *l*. When this wire is subjected to a constant force *F*, the extension produced in the wire is Δl. Which of the following graphs is a straight line? **[AIPMT 2014]**

(1) Δl versus $\frac{1}{l}$ (2) Δl versus l^2
(3) Δl versus $\frac{1}{l^2}$ (4) Δl versus l

3. The Young's modulus of steel is twice that of brass. Two wires of same length and of same area of cross section, one of steel and another of brass are suspended from the same roof. If we want the lower ends of the wires to be at the same level, then the weights added to the steel and brass wires must be in the ratio of **[Re-AIPMT-2015]**

(1) 1 : 1 (2) 1 : 2
(3) 2 : 1 (4) 4 : 1

4. The approximate depth of an ocean is 2700 m. The compressibility of water is 45.4×10^{-11} Pa^{-1} and density of water is 10^3 kg/m^3. What fractional compression of water will be obtained at the bottom of the ocean? **[AIPMT-2015]**

(1) 1.4×10^{-2} (2) 0.8×10^{-2}
(3) 1.0×10^{-2} (4) 1.2×10^{-2}

5. The bulk modulus of a spherical object is *B*. If it is subjected to uniform pressure *p*, the fractional decrease in radius is **[NEET-2017]**

(1) $\frac{p}{B}$ (2) $\frac{B}{3p}$
(3) $\frac{3p}{B}$ (4) $\frac{p}{3B}$

6. Two wires are made of the same material and have the same volume. The first wire has cross-sectional area A and the second wire has cross-sectional area 3A. If the length of the first wire is increased by Δl on applying a force F, how much force is needed to stretch the socond wire by the same amount? **[NEET-2018]**

(1) 9 F (2) 6 F
(3) F (4) 4 F

7. When a block of mass M is suspended by a long wire of length L, the length of the wire becomes $(L + l)$. The elastic potential energy stored in the extended wire is **[NEET-2019]**

(1) Mgl

(2) MgL

(3) $\frac{1}{2}Mgl$

(4) $\frac{1}{2}MgL$

8. The stress-strain curves are drawn for two different materials X and Y. It is observed that the ultimate strength point and the fracture point are close to each other for material X but are far apart for material Y.

We can say that materials X and Y are likely to be (respectively) **[NEET-2019 (Odisha)]**

(1) Plastic and ductile

(2) Ductile and brittle

(3) Brittle and ductile

(4) Brittle and plastic

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Chapter 9

Mechanical Properties of Fluids

Sub-topics *Viscosity, Stokes' law, terminal velocity, Reynold's number, streamline and turbulent flow. Critical velocity, Bernoulli's theorem and its applications. Surface energy and surface tension, angle of contact, excess of pressure, application of surface tension ideas to drops, bubbles and capillary rise.*

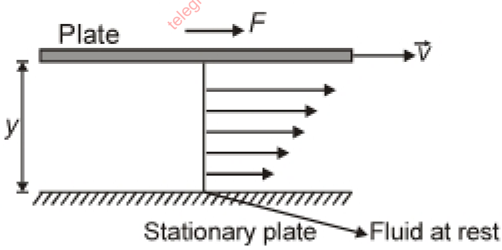
Pressure Exerted by a Fluid : $P = \frac{F}{A}$ (N/m^2 or Pa)

Viscosity : It is the name given to fluid friction.

Coefficient of viscosity

Let a thickness y of a fluid is trapped between two plates.

The fluid in contact with the plate is moving with velocity v and fluid in contact with stationary plate is at rest.



$F \propto A\frac{dv}{dy}$ $\qquad F = -\eta A\frac{dv}{dy}$

F = frictional force acting on upper plate = $-\eta A\frac{v}{y}$

η = coefficient of viscosity

Units : SI $\rightarrow$ 1 Pa - s = 10 poise = 1 decapoise

C.G.S $\rightarrow$ 1 dyne/cm^2 - s = 1 poise

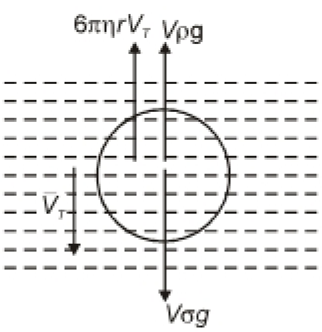
Terminal Velocity

(1) A body of radius r is released from rest in a fluid

σ = density of body

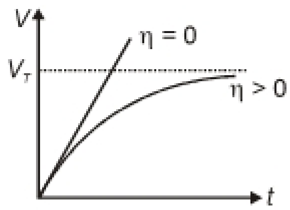
ρ = density of liquid or fluid

terminal velocity

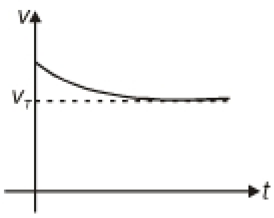


$$V_T = \frac{2}{9}\frac{r^2 g}{\eta}(\sigma - \rho)$$

velocity increases from 0 to V_T



(2) A body is thrown downwards with speed greater than v_T then its speed decreases and becomes equal to V_T.



(3) Two rain drops of radius r falling with terminal speed v_T each merge to form a single drop then radius of new drop is given by

$R = 2^{1/3}r$

$v_T \propto r^2$

$v_T' \propto R^2 \quad \Rightarrow \quad v_T' = 2^{2/3}\, v_T$

$$\boxed{v' = 1.587 v_T}$$

(4) With increase in temperature of water η decreases, terminal velocity increases.

(5) When σ < ρ body will move upward with terminal speed.

(6) When water is replaced by glycerine, terminal speed decreases.

Steady flow (Stream Line)

The velocity of fluid particles at any point does not vary with time. $\vec{v}_1, \vec{v}_2$ and $\vec{v}_3$ are constant. It is **NOT** necessary that $\vec{v}_1 = \vec{v}_2 = \vec{v}_3$.

Reynold's Number $N_R = \dfrac{\rho v D}{\eta} = \dfrac{\text{Inertial Forces}}{\text{Viscous forces}}$

For cylindrical pipe

(1) $N_R < 1000$, flow is streamline

(2) $N_R > 2000$, flow is turbulent

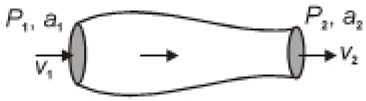
(3) $1000 < N_R < 2000$, flow is unstable (transition flow)

(4) when N_R = 1000, flow is critical

$$\frac{\rho v_c D}{\eta} = 1000$$

$\Rightarrow$ $$v_c = 1000\frac{\eta}{\rho D} \text{ (Critical velocity)}$$

Equation of continuity



$\rho_1 a_1 v_1 = \rho_2 a_2 v_2$

mass entering per second = mass leaving per second

For incompressible liquid $\rho_1 = \rho_2 \Rightarrow a_1 v_1 = a_2 v_2 \Rightarrow v \propto \frac{1}{a}$

Energy of a liquid

(1) Potential energy/mass = gh

(2) Kinetic energy/mass = $\frac{1}{2}v^2$

(3) Pressure energy/mass = $\frac{P}{\rho}$

Energy head

(1) Gravitational head = h

(2) Kinetic head = $\frac{v^2}{2g}$

(3) Pressure head = $\frac{P}{\rho g}$

Bernoulli's Equation

For an ideal, non-viscous and incompressible liquid

$$\frac{P_1}{\rho} + \frac{v_1^2}{2} + gh_1 = \frac{P_2}{\rho} + \frac{v_2^2}{2} + gh_2 = \text{constant}$$

Applications

1. To find rate of flow of liquid Q by venturimeter

Applying Bernoulli's theorem

$$\frac{P_1}{\rho} + \frac{v_1^2}{2} = \frac{P_2}{\rho} + \frac{v_2^2}{2}$$

Applying equation of continuity

$a_1v_1 = a_2v_2 = Q$

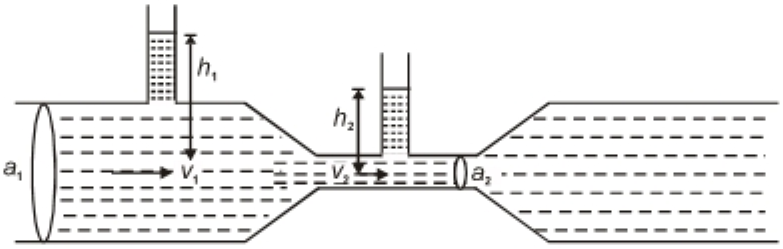
From (1) $v_2^2 - v_1^2 = \frac{2(P_1 - P_2)}{\rho}$

$\Rightarrow \quad Q = a_1a_2\sqrt{\frac{2(P_1 - P_2)}{\rho(a_1^2 - a_2^2)}}$

$P_1 = \rho gh_1$

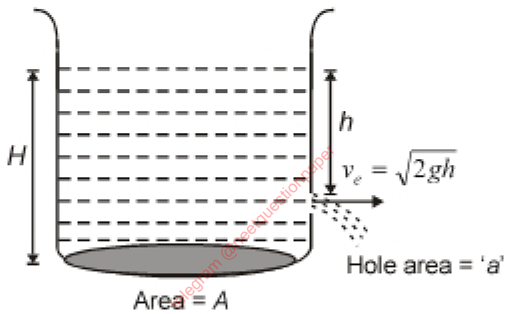
$P_2 = \rho gh_2$

$\Rightarrow \quad Q = a_1a_2\sqrt{\frac{2g(h_1 - h_2)}{a_1^2 - a_2^2}}$



2. Speed of efflux :

$v_e = \sqrt{2gh}$



(a) Time taken by water level to fall from h_1 to h_2 = $t = \frac{A}{a}\sqrt{\frac{2}{g}}\left[\sqrt{h_1} - \sqrt{h_2}\right]$

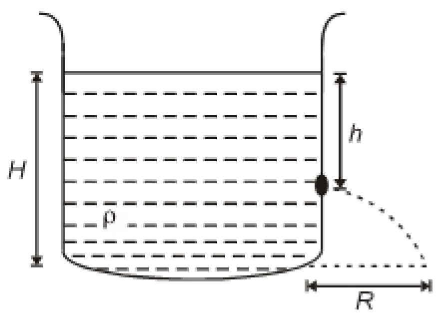
(b) Time taken to completely empty the container by a hole at bottom

$t \propto \sqrt{H}$ [Put $h_1 = H$, $h_2 = 0$]

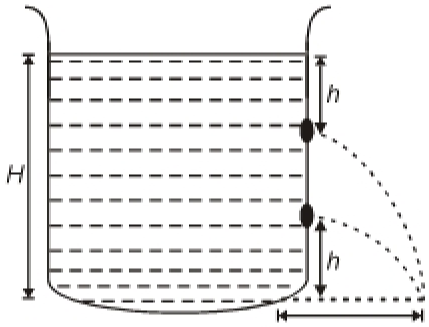
(c) Range of liquid

$R = 2\sqrt{h(H - h)}$

$R_{max} = H$ when $h = \frac{H}{2}$



(d)



$R = 2\sqrt{h(H-h)}$ for both holes

Surface Tension

It is the property of a liquid due to which it behaves like a stretched elastic membrane.

Due to the property of surface tension a free liquid drop tries to acquire spherical shape (minimum surface area).

Surface tension is mathematically given as force/length. $T = \frac{F}{l}$ (N/m)

Surface energy: It is the energy of a surface due to surface tension. So S.E. = S.T. × Surface area

(i) For liquid drop of radius R $\Rightarrow$ S.E. = $T \times 4\pi R^2$

(ii) For soap bubble of radius $R \Rightarrow$ S.E. = $2 \times T \times 4\pi R^2$

Applications

(1) Work done to blow a soap bubble of radius $r = 2 \times T \times 4\pi r^2$

(2) If a drop of radius R breaks up into n identical drops

then work done = ΔS.E. = $[n \times 4\pi r^2 - 4\pi R^2]T$ ...(i)

$R^3 = nr^3$ ...(ii)

$\Rightarrow$ work done = $4\pi R^2 T\,[n^{1/3} - 1]$

(3) n identical drops coalesce to form a single drop of radius R

Heat produced = $4\pi R^2 T\,[n^{1/3} - 1] = mc\,\Delta\theta$

c = sp. heat, m = mass = $\frac{4}{3}\pi R^3 \rho$, $\Delta\theta$ = Rise in temperature.

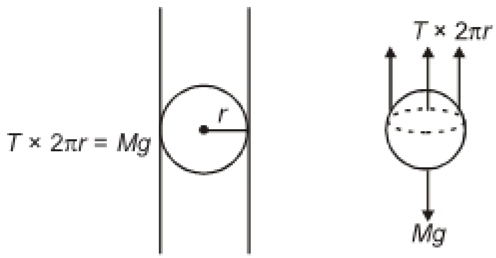
(4) A needle floats on the surface of a liquid due to surface tension.

(5) Surface tension decreases with rise in temperature.

(6) S.T. decreases by adding sparingly soluble impurities like detergents.

(7) S.T. increases by adding soluble impurities like NaCl, sugar.

(8) A drop of liquid is balanced in a capillary tube then

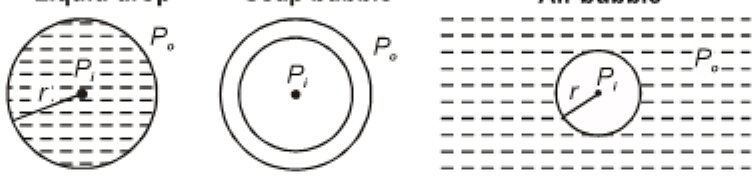


Excess Pressure

P_o = Atmospheric pressure

P_i = Inside pressure

$P_i - P_o$ = Excess pressure

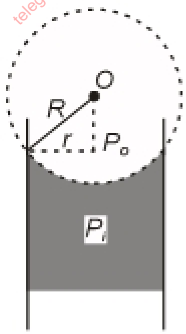


$P_i = P_o + \frac{2T}{r}$ $\quad P_i - P_o = \frac{4T}{r}$ $\quad P_i = P_o + \frac{2T}{r}$

Applications

1. $P_i = P_o - \frac{2T}{r}$

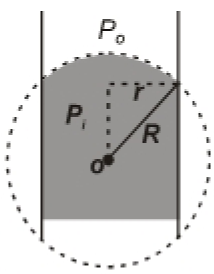
   $F_a > \frac{F_c}{\sqrt{2}}$



Capillary tube, Concave Meniscus

2. $P_i = P_o + \frac{2T}{R}$

   $F_a < \frac{F_c}{\sqrt{2}}$

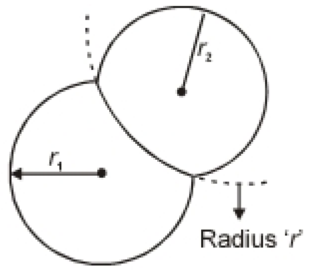


Convex Meniscus

3. (i) If two soap bubbles coalesce in vacuum, then $P_o = 0$

$\Rightarrow \; r^2 = r_1^2 + r_2^2$

(ii) Two soap bubbles come in contact to form a double bubble then



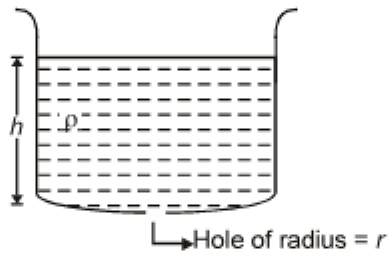
r = radius of interface, $r_1 > r_2$

$$\frac{1}{r} = \frac{1}{r_2} - \frac{1}{r_1}$$

The interface will be convex towards larger bubble and concave towards smaller bubble.

4. $\frac{2T}{r} = h\rho g$, for no leakage of liquid through the hole

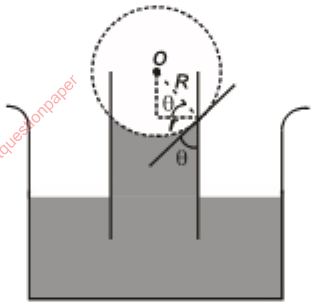
$$h = \frac{2T}{r\rho g}$$



Capillary action

The rise or fall of liquid in a tube of fine diameter is known as capillary action.

Ascent formula



$$h = \frac{2T}{R\rho g} = \frac{2T\cos\theta}{r\rho g}$$

θ = angle of contact

Applications:

(1) hR = constant

$h > 0$ for concave meniscus ($\theta < 90°$) *i.e.* rise

$h < 0$ for convex meniscus ($\theta > 90°$) *i.e.* fall

(2) For water glass interface $\theta = 0°$ *i.e.*, meniscus is nearly hemispherical.

(3) For mercury glass interface $\theta = 135°$.

(4) Two capillary tubes of radius r_1 and r_2 ($r_2 > r_1$) are joined to form a U-tube opened at both ends. This U-tube is filled with water. The level in the two limbs will not be same due to capillary action.

(i) Difference in level $h = \frac{2T\cos\theta}{\rho g}\left(\frac{r_2 - r_1}{r_1 r_2}\right)$

(ii) Liquid in tube of smaller radius will be at higher level.

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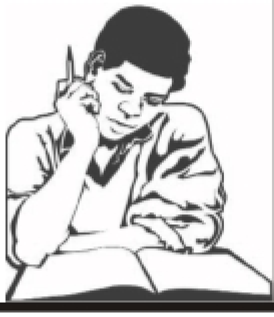


Try Yourself

SECTION - A

Objective Type Questions

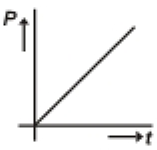
1. In a laminar flow, the velocity of flow at any point in the liquid
   (1) Does not vary with time
   (2) May vary in magnitude but not in direction
   (3) May vary in direction but not in magnitude
   (4) May vary both in magnitude and direction

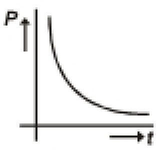
2. Why does a steel ball fall slower through water than through air?
   (1) Density of air is low
   (2) Upthrust of air is low
   (3) Viscosity of air is low
   (4) There is no surface tension

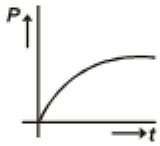
3. A liquid is stirred, when stirring is stopped, the liquid comes to rest due to
   (1) Surface tension (2) Gravity
   (3) Viscosity (4) Buoyancy

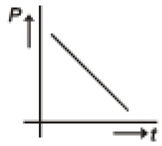
4. Liquid is flowing steadily through a cylindrical tube. Velocity of the liquid in the streamline along the axis of the cylinder is 4 cm/s. The velocity of the liquid layer in contact with the tube is
   (1) 4 cm/s (2) 2 cm/s
   (3) 1 cm/s (4) Zero

5. A soap bubble is blown slowly at the end of a tube by a pump supplying air at a constant rate. Which one of the following graphs represents the correct variation of the excess pressure inside the bubble with time?

   (1) 

   (2) 

   (3) 

   (4) 

6. Liquid flows through a horizontal tube of variable diameter. The pressure is lowest where
   (1) Velocity is lowest
   (2) Velocity is highest
   (3) Diameter is largest
   (4) Both velocity and diameter are largest

7. Rate of flow of water through a tube of radius 2 mm is 8 cm^3/s. Under similar conditions, the rate of flow of water through a tube of radius 1 mm will be
   (1) 4 cm^3/s
   (2) 2 cm^3/s
   (3) 1 cm^3/s
   (4) 0.5 cm^3/s

8. An inflated balloon rises to a certain height and then can't rise any further. This is because at that height,
   (1) The atmospheric pressure is zero
   (2) The gravity disappears
   (3) The apparent weight of balloon is zero
   (4) Density of balloon is zero

9. A capillary tube of radius r is dipped in a liquid of density ρ and surface tension S. If the angle of contact is θ, the pressure difference between the two surfaces in the beaker and the capillary is
   (1) $\frac{S}{r}\cos\theta$ (2) $\frac{2S}{r}\cos\theta$
   (3) $\frac{S}{r\cos\theta}$ (4) $\frac{2S}{r\cos\theta}$

10. The height upto which water will rise in a capillary tube will be
    (1) Maximum when water temperature is 4°C
    (2) Maximum when water temperature is 0°C
    (3) Minimum when water temperature is 4°C
    (4) Same at all temperatures

11. The surface tension of a liquid is 5 N m^{-1}. If a thin film is formed on a loop of area 0.02 m^2. Then its surface energy will be
    (1) 5×10^{-2} J (2) 2.5×10^{-2} J
    (3) 2×10^{-1} J (4) 3×10^{-1} J

12. If two identical mercury drops are combined to form a single drop, then its temperature will
    (1) Decrease
    (2) Increase
    (3) Remain same
    (4) May increase or decrease

13. Let F_C and F_A denote cohesive and adhesive force on a liquid molecule near the surface of a solid. The surface of liquid is convex, if
    (1) $F_A > \frac{F_C}{\sqrt{2}}$ (2) $F_A = \frac{F_C}{\sqrt{2}}$
    (3) $F_A < \frac{F_C}{\sqrt{2}}$ (4) $F_A < F_C$

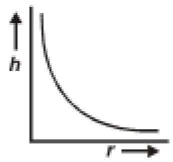
14. At the boiling point of a liquid, surface tension
    (1) Is zero
    (2) Is infinite
    (3) Is same as that at any other temperature
    (4) Can't be determined

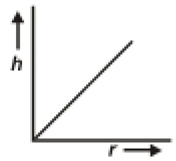
15. The change in surface energy when a drop of radius R splits up into 1000 droplets, each of radius 'r' is (Surface tension is T)
    (1) $4\pi R^2 T$ (2) $7\pi R^2 T$
    (3) $16\pi R^2 T$ (4) $36\pi R^2 T$

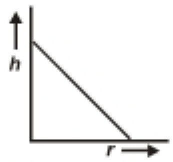
16. In a satellite moving around any planet, an ice cube exists. As it melts with passage of time, its shape will
    (1) Remain unchanged
    (2) Change to spherical
    (3) Become oval-shaped with long axis along the orbit plane
    (4) Become oval-shaped with long axis perpendicular to orbit plane

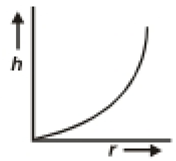
17. A drop of water breaks into two droplets of equal size. In this process which of the following statements is correct?
    (1) The sum of the temperatures of the two droplets together is equal to the original temperature of the drop
    (2) The sum of the masses of the two droplets is equal to the original mass of the drop
    (3) The sum of the radii of the two droplets is equal to the radius of the original drop
    (4) The sum of the surface areas of the two droplets is equal to the surface area of the original drop

18. Which of the following graphs correctly represents the variation of height h of liquid in a capillary with the radius r of the tube?

(1) 

(2) 

(3) 

(4) 

19. Some air is drained out of a soap bubble. The pressure inside
    (1) Increases
    (2) Decreases
    (3) Remains unchanged
    (4) Becomes equal to atmospheric pressure

20. If work W is done in blowing a bubble of radius R from a soap solution, then the work done in blowing a bubble of radius $2R$ from the same solution is
    (1) $W/2$
    (2) $2W$
    (3) $4W$
    (4) $2^{\frac{1}{3}} W$

21. If two soap bubbles of different radii are in communication with each other,

(1) Air flows from larger bubble into smaller one until the two bubbles are of equal size

(2) The size of the bubbles remains unchanged

(3) Air flows from smaller bubble into larger bubble and the larger bubble grows at the expense of the smaller one

(4) Air flows from larger bubble into smaller until the radius of the smaller one becomes equal to that of larger one and of the larger one equal to that of the smaller one

22. The energy E supplied to a soap bubble of radius r and surface tension σ doubles the radius of the soap bubble under isothermal conditions. The value of E is

(1) $8\pi r^2\sigma$ (2) $12\pi r^2\sigma$

(3) $16\pi r^2\sigma$ (4) $24\pi r^2\sigma$

23. A capillary tube of radius r is immersed in a liquid. The liquid rises to a height h. The corresponding mass is 'm'. What mass of the liquid shall rise in the capillary if the radius of the tube is doubled?

(1) m (2) 2 m

(3) 3 m (4) 4 m

24. 1 centipoise is equal to

(1) 1 kg m^{-1} s^{-1} (2) 1000 kg m^{-1} s^{-1}

(3) 0.1 kg m^{-1} s^{-1} (4) 0.001 kg m^{-1} s^{-1}

25. When a liquid flows through a horizontal capillary tube, the fall in pressure P and rate of flow Q are related as

(1) $P \propto Q$ (2) $P \propto \frac{1}{Q}$

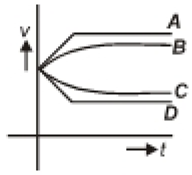
(3) $P \propto Q^2$ (4) $P \propto \frac{1}{Q^2}$

26. Liquid flows through two capillary tubes connected in series. Their length are L and $2L$ and radius r and $2r$ respectively. The pressure difference across the first and second tube are in the ratio

(1) 8 (2) 2

(3) 4 (4) 1/8

27. A small spherical solid ball is dropped from a great height into a viscous liquid. Its journey in the liquid is best described in the figure by the curve



(1) A (2) B

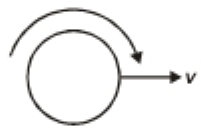
(3) C (4) D

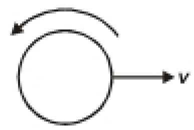
28. Water from a tap emerges vertically downwards with an initial speed of 1 m/s. The cross-sectional area of the tap is 10^{-4}m^2. Assume that the pressure is constant throughout the stream of water, and the flow is steady. The cross-sectional area of the stream 0.15 m below the tap is

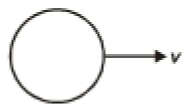
(1) 5×10^{-4} m^2 (2) 1.0×10^{-5} m^2

(3) 5×10^{-5} m^2 (4) 10^{-4} m^2

29. To keep a ball low (prevent from rising), it must be thrown as

(1) 

(2) 

(3) 

(4) None of these

30. A water tank of height 10 m, completely filled with water is placed on a level ground. It has two holes one at 3 m and the other at 7 m from its base. The water ejecting from

(1) Both the holes will fall at the same spot

(2) Upper hole will fall farther than that from lower hole

(3) Upper hole will fall closer than that from lower hole

(4) More information is required

31. A cylindrical vessel is filled with non viscous liquid of density d to a height h_0 and a hole is made at a height h_1 from the bottom of the cylinder. The velocity of liquid rushing out of the hole is

(1) $\sqrt{2gh_0}$ (2) $\sqrt{2g(h_0 - h_1)}$

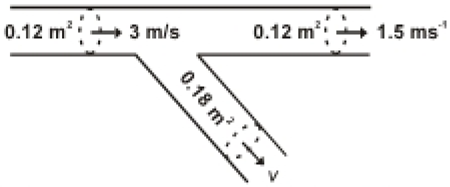
(3) $\sqrt{dgh_1}$ (4) $\sqrt{dgh_0}$

32. A marble of mass x and diameter $2r$ is gently released in a tall cylinder containing honey. If the marble displaces mass y ($< x$) of the liquid, then the terminal velocity is proportional to

(1) $x + y$ (2) $x - y$

(3) $\frac{x+y}{r}$ (4) $\frac{x-y}{r}$

33. An incompressible liquid travels as in figure. The speed of the fluid in the lower branch will be



(1) 1 m/s (2) 1.5 m/s

(3) 2.25 m/s (4) 3 m/s

34. Reynolds number is low for

(1) High viscosity (2) Low velocity

(3) Low density (4) All of these

35. A copper ball of radius r is moving with a uniform velocity v in the mustard oil. The dragging force acting on the ball is F. The dragging force on the copper ball of radius $2r$ moving with uniform velocity $2v$ in the mustard oil is

(1) F (2) $2F$

(3) $4F$ (4) $8F$

36. A tank has a hole at its bottom. The time needed to empty the tank from level h_1 to h_2 is proportional to

(1) $h_1 - h_2$ (2) $h_1 + h_2$

(3) $\sqrt{h_1} - \sqrt{h_2}$ (4) $\sqrt{h_1} + \sqrt{h_2}$

37. Water flows in a streamline manner through a capillary tube of radius a, the pressure difference being P and the rate of flow is Q. If the radius is reduced to $\frac{a}{2}$ and the pressure is increased to $2P$, the rate of flow becomes

(1) $4Q$ (2) Q

(3) $\frac{Q}{2}$ (4) $\frac{Q}{8}$

38. A horizontal pipeline carries water in streamline flow. At a point where the cross-sectional area is 10 cm², the water velocity is 1 m/s and pressure is 2000 Pa. The pressure of water at another point where the cross-sectional area is 5 cm² is

(1) 200 Pa (2) 400 Pa

(3) 500 Pa (4) 800 Pa

SECTION - B

Previous Years Questions

1. The wettability of a surface by a liquid depends primarily on **[NEET-2013]**

(1) Surface tension

(2) Density

(3) Angle of contact between the surface and the liquid

(4) Viscosity

2. A certain number of spherical drops of a liquid of radius r coalesce to form a single drop of radius R and volume V. If 'T' is the surface tension of the liquid, then **[AIPMT 2014]**

(1) Energy = $4VT\left(\frac{1}{r}-\frac{1}{R}\right)$ is released

(2) Energy = $3VT\left(\frac{1}{r}+\frac{1}{R}\right)$ is absorbed

(3) Energy = $3VT\left(\frac{1}{r}-\frac{1}{R}\right)$ is released

(4) Energy is neither released nor absorbed

3. The cylindrical tube of a spray pump has radius R, one end of which has n fine holes, each of radius r. If the speed of the liquid in the tube is V, the speed of the ejection of the liquid through the holes is **[Re-AIPMT-2015]**

(1) $\frac{V^2R}{nr}$ (2) $\frac{VR^2}{n^2r^2}$

(3) $\frac{VR^2}{nr^2}$ (4) $\frac{VR^2}{n^3r^2}$

4. Water rises to a height h in capillary tube. If the length of capillary tube above the surface of water is made less than h, then **[Re-AIPMT-2015]**

(1) Water does not rise at all

(2) Water rises upto the tip of capillary tube and then starts overflowing like a fountain

(3) Water rises upto the top of capillary tube and stays there without overflowing

(4) Water rises upto a point a little below the top and stays there

5. A wind with speed 40 m/s blows parallel to the roof of a house. The area of the roof is 250 m². Assuming that the pressure inside the house is atmospheric pressure, the force exerted by the wind on the roof and the direction of the force will be (P_{air} = 1.2 kg/m³) **[AIPMT-2015]**

(1) 2.4×10^5 N, downwards

(2) 4.8×10^5 N, downwards

(3) 4.8×10^5 N, upwards

(4) 2.4×10^5 N, upwards

6. Two non-mixing liquids of densities ρ and $n\rho$ ($n > 1$) are put in a container. The height of each liquid is h. A solid cylinder of length L and density d is put in this container. The cylinder floats with its axis vertical and length pL ($p < 1$) in the denser liquid. The density d is equal to **[NEET-2016]**

(1) $\{1 + (n - 1)p\}\rho$ (2) $\{1 + (n + 1)p\}\rho$

(3) $\{2 + (n + 1)p\}\rho$ (4) $\{2 + (n - 1)p\}\rho$

7. A rectangular film of liquid is extended from (4 cm × 2 cm) to (5 cm × 4 cm). If the work done is 3×10^{-4} J, the value of the surface tension of the liquid is **[NEET (Phase-2) 2016]**

(1) 0.250 Nm^{-1} (2) 0.125 Nm^{-1}

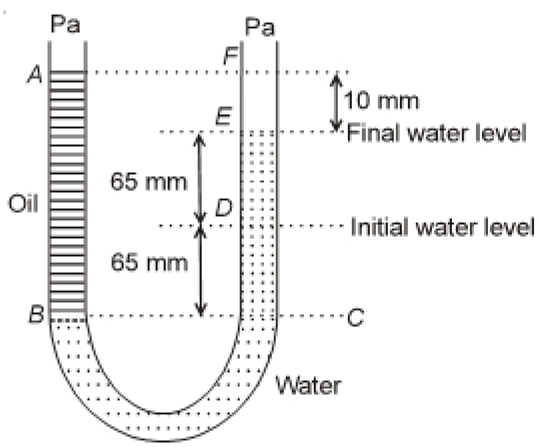
(3) 0.2 Nm^{-1} (4) 8.0 Nm^{-1}

8. Three liquids of densities ρ_1, ρ_2 and ρ_3 (with $\rho_1 > \rho_2 > \rho_3$), having the same value of surface tension T, rise to the same height in three identical capillaries. The angles of contact θ_1, θ_2 and θ_3 obey **[NEET (Phase-2) 2016]**

(1) $\frac{\pi}{2} > \theta_1 > \theta_2 > \theta_3 \geq 0$ (2) $0 \leq \theta_1 < \theta_2 < \theta_3 < \frac{\pi}{2}$

(3) $\frac{\pi}{2} < \theta_1 < \theta_2 < \theta_3 < \pi$ (4) $\pi > \theta_1 > \theta_2 > \theta_3 > \frac{\pi}{2}$

9. A U-tube with both ends open to the atmosphere, is partially filled with water. Oil, which is immiscible with water, is poured into one side until it stands at a distance of 10 mm above the water level on the other side. Meanwhile the water rises by 65 mm from its original level (see diagram). The density of the oil is **[NEET- 2017]**



(1) 650 kg m^{-3} (2) 425 kg m^{-3}

(3) 800 kg m^{-3} (4) 928 kg m^{-3}

10. A small sphere of radius 'r' falls from rest in a viscous liquid. As a result, heat is produced due to viscous force. The rate of production of heat when the sphere attains its terminal velocity, is proportional to **[NEET-2018]**

(1) r^3 (2) r^2

(3) r^4 (4) r^5

11. A soap bubble, having radius of 1 mm, is blown from a detergent solution having a surface tension of 2.5×10^{-2} N/m. The pressure inside the bubble equals at a point Z_0 below the free surface of water in a container. Taking g = 10 m/s^2, density of water = 10^3 kg/m^3, the value of Z_0 is : **[NEET-2019]**

(1) 100 cm (2) 10 cm

(3) 1 cm (4) 0.5 cm

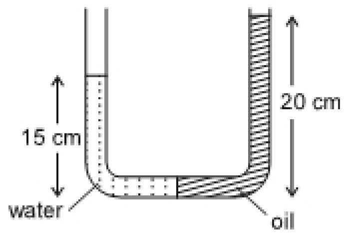
12. A small hole of area of cross-section 2 mm^2 is present near the bottom of a fully filled open tank of height 2 m. Taking g = 10 m/s^2, the rate of flow of water through the open hole would be nearly **[NEET-2019]**

(1) 12.6×10^{-6} m^3/s (2) 8.9×10^{-6} m^3/s

(3) 2.23×10^{-6} m^3/s (4) 6.4×10^{-6} m^3/s

13. In a U-tube as shown in the fig. water and oil are in the left side and right side of the tube respectively. The heights from the bottom for water and oil columns are 15 cm and 20 cm respectively. The density of the oil is

[take ρ_{water} = 1000 kg/m^3] **[NEET-2019 (Odisha)]**



(1) 1333 kg/m^3 (2) 1200 kg/m^3

(3) 750 kg/m^3 (4) 1000 kg/m^3

14. Two small spherical metal balls, having equal masses, are made from materials of densities ρ_1 and ρ_2 ($\rho_1 = 8\rho_2$) and have radii of 1 mm and 2 mm, respectively, they are made to fall vertically (from rest) in a viscous medium whose coefficient of viscosity equals η and whose density is $0.1\rho_2$. The ratio of their terminal velocities would be **[NEET-2019 (Odisha)]**

(1) $\frac{79}{36}$ (2) $\frac{79}{72}$

(3) $\frac{19}{36}$ (4) $\frac{39}{72}$

❑ ❑ ❑

Chapter 10

Thermal Properties of Matter and Thermodynamics

Sub-topics *Heat, temperature, thermal expansion; thermal expansion of solids, liquids, and gases. Anomalous expansion. Specific heat capacity: C_p, C_v- calorimetry; change of state – latent heat. Heat transfer-conduction and thermal conductivity, convection and radiation. Qualitative ideas of Black Body Radiation, Wein's displacement law, and Green House effect. Newton's law of cooling and Stefan's law. Thermal equilibrium and definition of temperature (zeroth law of Thermodynamics). Heat, work and internal energy. First law of thermodynamics. Isothermal and adiabatic processes. Second law of the thermodynamics: Reversible and irreversible processes. Heat engines and refrigerators.*

Heat and Temperature

A hot body has more internal energy than another identical cold body. When a hot body is kept in contact with a cold body, "There is a transfer of energy from hot body to cold body. The energy transferred is called heat".

Zeroth Law of Thermodynamics : If two bodies *A* and *B* are in thermal equilibrium, *A* and *C* are in thermal equilibrium then *B* and *C* are also in the thermal equilibrium.

"Two bodies which are in thermal equilibrium are said to have equal temperatures".

Scales of Temperature :

Name of scale	Celsius	Fahrenheit	Kelvin	New
F.P. of H_2O	0°C	32°F	273° K	FP°T
B.P. of H_2O	100°C	212°F	373° K	BP°T

$$\frac{°C - 0}{100 - 0} = \frac{°F - 32}{212 - 32} = \frac{K - 273}{373 - 273} = \frac{T - FP}{BP - FP}$$

(1) A temperature of – 40°C is also equal to a temperature of – 40°F.

(2) 1.8 ΔT°C = ΔT°F.

i.e. a change of 1°C = change of 1.8°F.

(3) ΔT°C = ΔT°K.

Celsius and kelvin can never give equal numerical values of temperature.

Thermal Expansion : When the temperature of a body increases, its size increases.

(1) Average coefficient of linear expansion

$$\alpha = \frac{\Delta L}{L\Delta\theta} \quad \text{or} \quad \Delta L = \alpha L \Delta\theta$$

$$L' = L_0 (1 + \alpha\Delta\theta)$$

(2) Coefficient of superficial expansion

$$\beta = \frac{\Delta A}{A\Delta\theta} \quad \text{or} \quad A' = A_0 (1 + \beta\Delta\theta)$$

(3) Coefficient of cubical expansion

$$\gamma = \frac{\Delta V}{V\Delta\theta} \quad \text{or} \quad V' = V_0 (1 + \gamma\Delta\theta)$$

(4) If a body expands equally in all directions then

$\gamma = 3\alpha$, $\beta = 2\alpha$

(5) If α_x, α_y, α_z are coefficient of linear expansion along *x*-axis, *y*-axis and *z*-axis, then $\gamma = \alpha_x + \alpha_y + \alpha_z$.

(6) For water γ is negative between 0°C and 4°C

Also $C_P < C_V$ during this temperature range.

(7) Density of water is maximum at 4°C. Therefore water at the bottom of lake (is at 4°C) is warmer than that at the surface

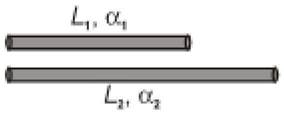
(8) $V_\theta = V_0 (1 + \gamma\theta)$

$$\frac{m}{\rho_\theta} = \frac{m}{\rho_0}(1 + \gamma\theta) \Rightarrow \rho_\theta = \rho_0(1 - \gamma\theta)$$

(9) Two rods of length L_1 and L_2 are kept side by side. If with increase in temperature, the difference in their lengths does not change then $L_1\alpha_1 = L_2\alpha_2$ or $\frac{L_1}{L_1 - L_2} = \frac{\alpha_2}{\alpha_2 - \alpha_1}$

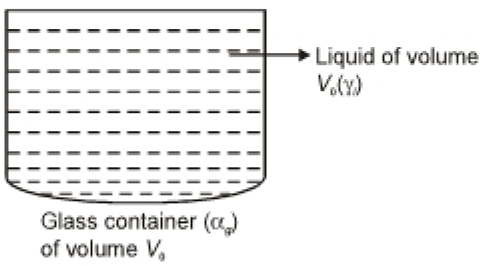
$$\Rightarrow L_1 - L_2 = L_1' - L_2'$$

$$= L_1(1 + \alpha_1\Delta\theta) - L_2(1 + \alpha_2\Delta\theta)$$



(10) α_g = coefficient of linear expansion of glass

γ_l = coefficient of cubical expansion of liquid



With increase in temperature, the volume of liquid flown out

$= V_0[1 + (\gamma_l - \gamma_g)\Delta\theta] = V_0[1 + (\gamma_l - 3\alpha_g)\Delta\theta]$

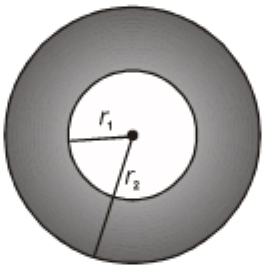
$= V_0[1 + \gamma_a\Delta\theta]$

γ_a = coefficient of apparent expansion = $\gamma_l - \gamma_g$.

(11) As the disc is heated all the dimensions (including cavity) increase.

i.e., $r_1' = r_1(1 + \alpha\Delta\theta)$

$r_2' = r_2(1 + \alpha\Delta\theta)$



Annular disc

(12) Coefficient of volume expansion of an ideal gas at constant pressure

$$\gamma = \frac{1}{T}$$

(13) A meter scale callibrated at T_1°C is used for measurement at T_2°C, α = coefficient of linear expansion for scale. If it gives a reading L, then error in the reading is $\Delta L = \alpha L(T_2 - T_1)$.

Calorimetry

Calorie : The amount of heat needed to increase the temperature of 1 g of water from 14.5°C to 15.5°C at a pressure of 1 atm is called **1 calorie**.

Specific heat capacity : $c = \frac{Q}{m\Delta T}$ cal g^{-1}°C^{-1}

Molar heat capacity : $C = \frac{Q}{n\Delta T}$ cal mol^{-1}°C^{-1}

Relation : If M is mass of 1 mole substance, then

$C = Mc$

(i) Latent heat of fusion $L_f = \frac{Q}{m}$ ⇒ Amount of heat absorbed by unit mass of a substance at its melting point to change its state

(ii) Latent heat of vaporisation $L_v = \frac{Q}{m}$ ⇒ Amount of heat absorbed by unit mass of a substance at its boiling point to change its state.

For water

Specific heat c = 1 cal g^{-1}°C^{-1} = 4.2 J g^{-1}°C^{-1} = 4200 J $kg^{-1}K^{-1}$

L_f = 80 cal/g = 336 J/g

L_v = 540 cal/g = 2268 J/g

(1) To convert *m* mass of ice at 0°C into steam at 100°C, amount of heat required is

80 m + 100 m + 540 m = 720 m cal

$(mL_f) + (mc\Delta T) + (mL_v)$

(2) 1 kg ice at 0°C is mixed with 1 kg of steam at 100°C. At equilibrium, Temperature = 100°C, 665 g of steam left 1.335 kg of water will be present.

(3) *w* g of water at T°C is mixed with *m* g of ice at 0°C.

(i) $w = \frac{80m}{T}$ ⇒ Whole of ice melts. Final temperature = 0°C.

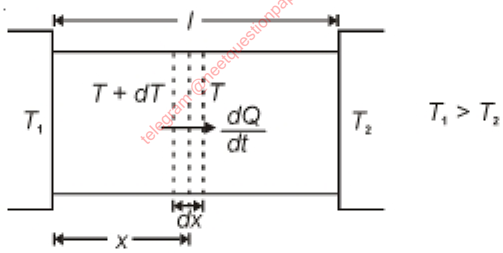
(ii) $w < \frac{80m}{T}$ ⇒ Whole of ice will not melt. Final temperature = 0°C

Amount of ice melted, $m' = \frac{wT}{80}$

Amount of ice left = $m - m'$

(iii) $w > \frac{80m}{T}$ ⇒ Whole of ice melts. Final temperature = $\frac{wT - 80m}{w + m} > 0°C$

Heat Transfer



Rate of heat flow across any section

$$\frac{dQ}{dt} = kA\left(\frac{-dT}{dx}\right)$$

k = Thermal conductivity $\left[\frac{\text{watt}}{mK}\right]$

In steady state, rate of heat flow is same across any section and is given by

$$\frac{dQ}{dt} = kA\left(\frac{T_1 - T_2}{l}\right)$$

Temperature at every section remains constant. Temperature at a distance x from T_1 end is

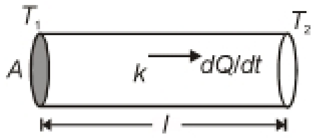
$$T_x = T_1 - \left(\frac{T_1 - T_2}{l}\right)x$$

or $$T_x = T_2 + \left[\frac{T_1 - T_2}{l}\right](l - x)$$

Thermal Resistance of a Rod :

In steady state $\frac{dQ}{dt} = kA\frac{(T_1 - T_2)}{l}$

$R = \frac{l}{kA}$ $\left[\text{Analogous to current electricity } R = \frac{\rho l}{A} = \frac{l}{\sigma A}\right]$



k = thermal conductivity

σ = electrical conductivity $\frac{k}{\sigma T}$ = constant [Weidman – Frenz Law]

T = absolute temperature

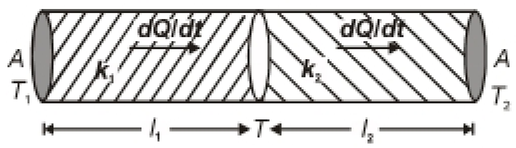
Composite Rod

(1) **In series**

In steady state

$$R = \frac{l_1}{k_1 A} + \frac{l_2}{k_2 A} = \frac{l_1 + l_2}{kA}$$

[k = effective thermal conductivity]

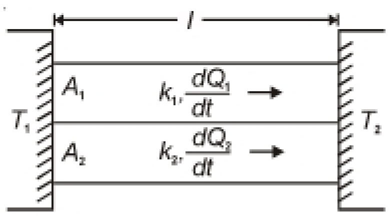


Temperature of junction $T = \dfrac{\frac{k_1}{l_1}T_1 + \frac{k_2}{l_2}T_2}{\frac{k_1}{l_1} + \frac{k_2}{l_2}}$

(2) **In parallel**

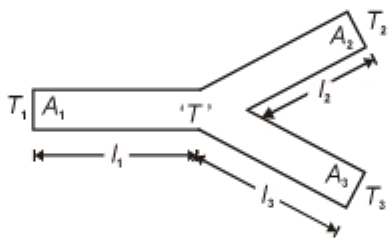
$$\frac{dQ}{dt} = \frac{dQ_1}{dt} + \frac{dQ_2}{dt}$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow \frac{k(A_1 + A_2)}{l} = \frac{k_1 A_1}{l} + \frac{k_2 A_2}{l}$$



Other Applications

(1) $T = \dfrac{\frac{k_1A_1}{l_1}T_1 + \frac{k_2A_2}{l_2}T_2 + \frac{k_3A_3}{l_3}T_3}{\frac{k_1A_1}{l_1} + \frac{k_2A_2}{l_2} + \frac{k_3A_3}{l_3}}$



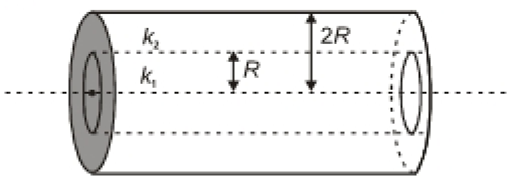
$T = \dfrac{k_1T_1 + k_2T_2 + k_3T_3}{k_1 + k_2 + k_3}$ [$l_1 = l_2 = l_3$, $A_1 = A_2 = A_3$]

(2) $\frac{kA\Delta\theta}{l} = \frac{k_1A_1\Delta\theta}{l} + \frac{k_2A_2\Delta\theta}{l}$ $A_1 = \pi R^2$

$\Rightarrow kA = k_1A_1 + k_2A_2$ $A_2 = \pi[4R^2 - R^2]$

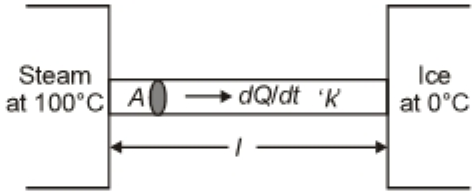
$\Rightarrow k = \frac{k_1 + 3k_2}{4}$ $= 3\pi R^2$

$A = \pi(2R^2) = 4\pi R^2$



(3) $\dfrac{dQ}{dt} = \dfrac{kA(100-0)}{l}$ = Rate of flow of heat

$\dfrac{dQ}{dt} = \dfrac{dm}{dt}L$



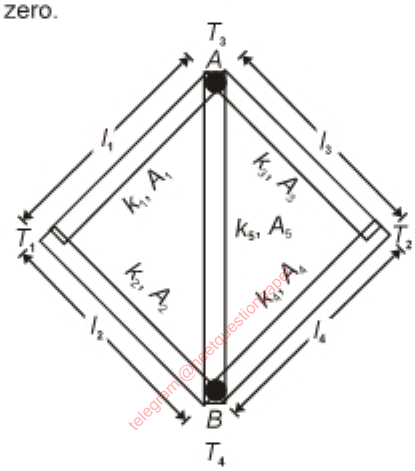
Rate of condensation of steam $\dfrac{dm}{dt} = \dfrac{kA100}{lL_v}$

Rate of melting of ice $\dfrac{dm}{dt} = \dfrac{kA100}{lL_f}$

(4) If $\dfrac{l_1}{k_1A_1} : \dfrac{l_2}{k_2A_2} :: \dfrac{l_3}{k_3A_3} : \dfrac{l_4}{k_4A_4}$

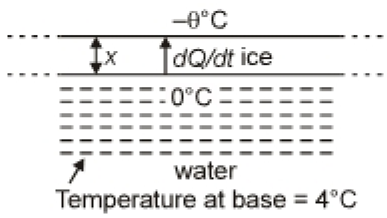
then $T_3 = T_4$

Also, $\dfrac{dQ}{dt}$ across AB is zero.



(5) Formation of ice

$\dfrac{dQ}{dt} = \dfrac{kA}{x}\theta = \dfrac{dm}{dt}L$



$\Rightarrow \quad dm = \dfrac{kA\theta}{xL}dt$

$\rho A dx = \dfrac{kA\theta}{xL}dt$

$\dfrac{\rho L}{k\theta}\dfrac{x^2}{2} = t$ (time taken to deposite x thickness)

$\Rightarrow \quad t \propto x^2$

Formation of ice from x_1 and x_2

$t = \dfrac{\rho L}{2k\theta}(x_2^2 - x_1^2)$

Radiation

All objects with temperature above 0 K radiate energy continuously in the form of electromagnetic waves.

Stefan's Law

Rate at which an object radiates energy

$P = \sigma A \varepsilon T^4$

where P is power in watt, A is surface area in m^2, ε = emissivity (lies between 0 and 1) and σ is Stefan's constant

(i) $\sigma = 5.67 \times 10^{-8}$ W/m^2-K^4.

(ii) $\varepsilon = 1$ for a perfectly black body.

(iii) $\varepsilon < 1$ for all other bodies

Kirchhoff's Law

Ratio of emissive power to absorptive power is same for all surfaces at the same temperature.

(1) Good absorbers for a particular wavelength are also good emitters of the same wavelength.

(2) If a polished metal plate has a black spot then when the plate is heated strongly and taken to a dark room, spot will appear brighter than the plate.

(3) If a black body is heated from 27°C to 927°C, or (300 K to 1200 K), radiations emitted by it becomes 256 times.

Wein's Displacement Law

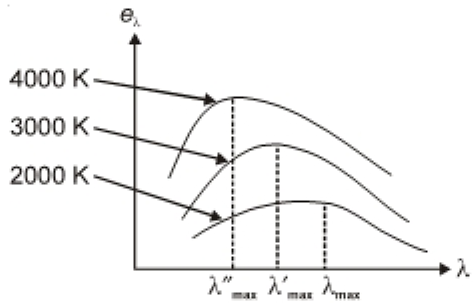
(1) $\lambda_{max.} T = b$

(2) $b = 2.898 \times 10^{-3}$ mK

(3) Area under $e_\lambda \sim \lambda$ graph $= \sigma T^4$

(4) Area $\propto T^4$

(5) If the temperature of the black body is made two fold, λ_{max} becomes half,while area becomes 16 times.



Newton's Law of Cooling

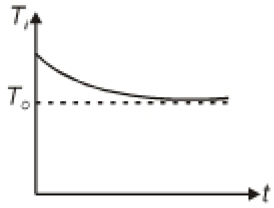
If the temperature T of a body is not much different from surrounding temperature T_0, then

Rate of cooling $-\dfrac{dT}{dt} \propto (T - T_0)$

(1) $T_f = T_0 + (T_i - T_0)e^{-\alpha t}$, where T_i is initial temperature, T_t is temperature after time t.

(2) Another form: $\alpha t = \log\left|\dfrac{T_i - T_0}{T_f - T_0}\right|$

(3) $\alpha = \dfrac{4\varepsilon A\sigma T_0^3}{mc}$, $\left[\begin{array}{l} m = \text{mass of body} \\ c = \text{specific heat} \\ A = \text{surface area} \\ \varepsilon = \text{emissivity} \end{array}\right]$



(4) $t \propto \dfrac{1}{\alpha}$

(5) Another approximate formula is

$$\frac{T_1 - T_2}{t} = \alpha\left(\frac{T_1 + T_2}{2} - T_0\right)$$

Above formula gives time 't' taken by the body to cool from T_1 to T_2. T_0 is temperature of surroundings.

Solar Constant $(S) = \dfrac{H}{4\pi r^2} = \dfrac{\sigma 4\pi R^2 T^4}{4\pi r^2} = \left(\dfrac{R}{r}\right)^2 \sigma T^4 = 1360$ W/m^2

Temperature of the Sun $(T) = \left[\dfrac{r^2 S}{R^2 \sigma}\right]^{1/4} = 5800$ K

Thermodynamics

Ist Law of Thermodynamics : Let Q heat is supplied to gas. It is used in two ways.

(1) Increasing internal energy ($\Rightarrow$ increasing temperature).

(2) Work done by the gas during expansion

$$Q = \Delta E + W$$

or $dQ = dE + dW$ $[dW = PdV]$

$$\Delta E = Q - W$$

(3) Q and W are path functions. They depend on the type of process.

(4) ΔE is state function. It depends only on initial and final states of the system.

$\Delta E = nC_V\Delta T$ (Always applicable, whatever may be the process. C_V = Molar heat capacity at constant volume)

$\Rightarrow$ $Q = nC_V\Delta T + W$

Now $\boldsymbol{Q = nC\Delta T}$

$\Rightarrow$ $nC\Delta T = nC_V\Delta T + W$

$$C = C_V + \frac{W}{n\Delta T}$$

i.e. C (molar heat capacity of a gas for the process) depends on C_V and W.

As W can have different value for different processes, C of a gas is variable. It may have any value between $-\infty$ to ∞.

Thermodynamic Process

(1) **Melting process :**

$$Q = \Delta E + W$$

$mL_f = \Delta E + 0$ [$W = 0$ as volume remains nearly constant]

(2) **Boiling process :**

$$mL_v = \Delta E + P[V_2 - V_1]$$

V_2 = volume of vapours

V_1 = volume of liquid

When 1 g of water vapourises isobarically at atmospheric pressure. $P = 1.013 \times 10^5$ Pa, $\Delta E = 2086.8$ J , and $\Delta W = 169.2$J
$V_1 = 1\text{ cm}^3$, $V_2 = 1671\text{ cm}^3$. (For steam)

(3) **Isochoric process :**

$$dV = 0 \Rightarrow W = 0$$

$$Q = nC_V\Delta T = \Delta E$$

$$\Rightarrow C_V = \frac{\Delta E}{n\Delta T}$$

(4) **Isobaric process :**

P = constant, $dW = PdV$

$\Rightarrow W = P\Delta V = nR\Delta T$

$Q = nC_P\Delta T = \Delta E + W$

$nC_P\Delta T = nC_V\Delta T + nR\Delta T$

$\Rightarrow C_P = C_V + R$

(5) **Isothermal process :**

$PV = K \Rightarrow \Delta T = 0 \Rightarrow \Delta E = 0,\ C = \infty$

$$Q = W = 2.303\ nRT \log\left(\frac{V_2}{V_1}\right)$$

V_2 = final volume

V_1 = initial volume

(6) **Adiabatic process :**

$PV^\gamma = K$

$Q = 0$ [$\therefore nC\Delta T = 0$ or $C = 0$]

$0 = nC_V\Delta T + W$

$$W = \frac{P_1V_1 - P_2V_2}{\gamma - 1} = \frac{nR(T_1 - T_2)}{\gamma - 1} = \frac{-nR\Delta T}{\gamma - 1}$$

$$0 = nC_V\Delta T - \frac{nR\Delta T}{\gamma - 1}$$

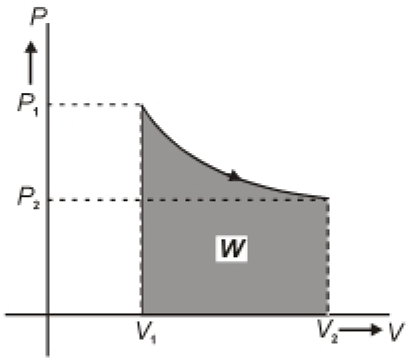
$$\Rightarrow C_V = \frac{R}{\gamma - 1}$$

$$\Rightarrow C_P = \frac{\gamma R}{\gamma - 1}\ [\because C_P = C_V + R]$$

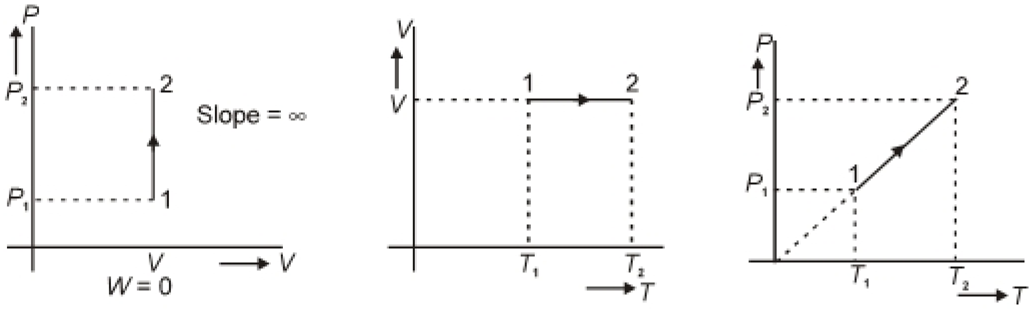
$$\Rightarrow \frac{C_P}{C_V} = \gamma$$

Indicator Diagram

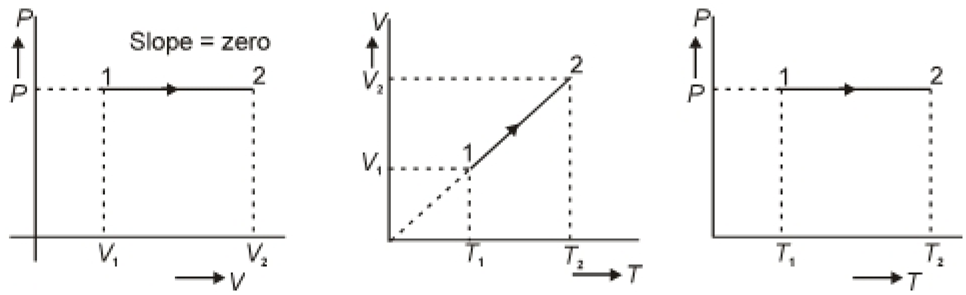
P-V graph of a process is called indicator diagram. Area under P-V graph = Work done in a process.



Isochoric Process :

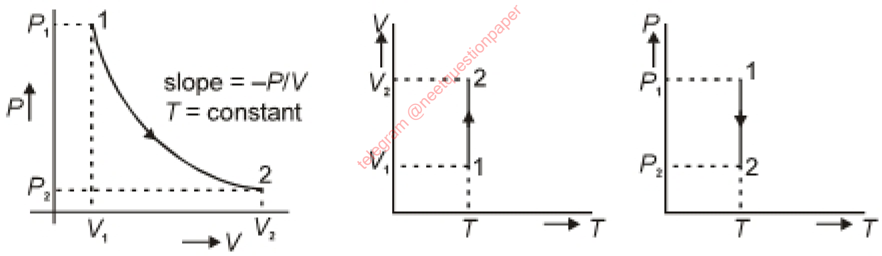


Isobaric :



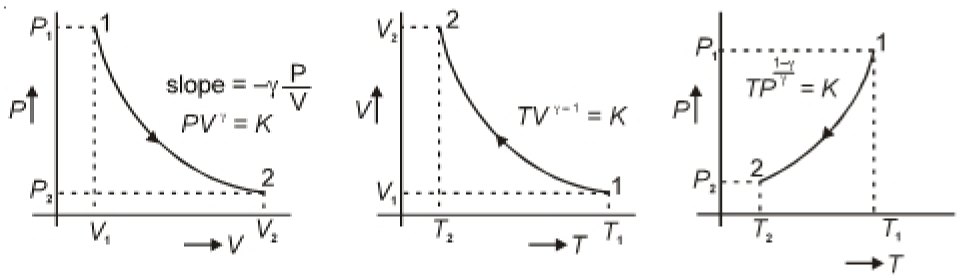
$W = P(V_2 - V_1) = P\Delta V = nR\Delta T$

Isothermal process :



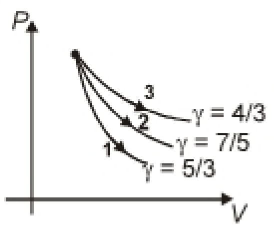
$W = 2.303nRT \log\left(\frac{V_2}{V_1}\right)$

Adiabatic process :



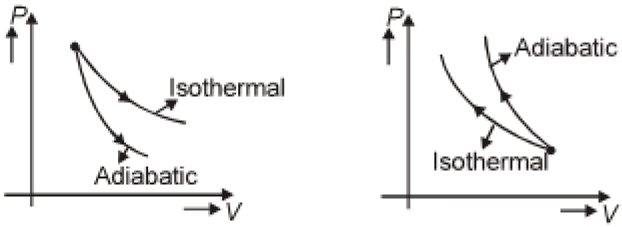
P-V graph for different gases

(1)

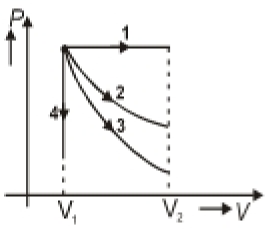


1 → monatomic
2 → diatomic
3 → polyatomic

(2)



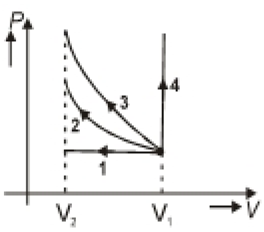
(3) **Expansion**



$1 \rightarrow$ Isobaric
$2 \rightarrow$ Isothermal
$3 \rightarrow$ Adiabatic
$4 \rightarrow$ Isochoric

$|W_1| > |W_2| > |W_3|$

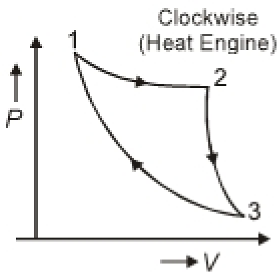
(4) **Compression**



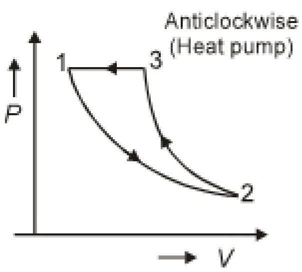
$1 \rightarrow$ Isobaric
$2 \rightarrow$ Isothermal
$3 \rightarrow$ Adiabatic
$4 \rightarrow$ Isochoric

$|W_3| > |W_2| > |W_1|$

Cyclic Process



or



$\Delta E = 0$

$Q_{net} = W_{total} > 0$

$\Delta E = 0$

$Q_{net} = W_{total} < 0$

Efficiency of a cycle : $\eta = \dfrac{\text{Work done during complete cycle}}{\text{Heat supplied to gas}} \times 100$

(1) For heat engine : $\eta = \dfrac{W_{total}}{|Q_{+ve}|} \times 100 = \dfrac{Q_{supplied} - Q_{rejected}}{Q_{supplied}} \times 100$

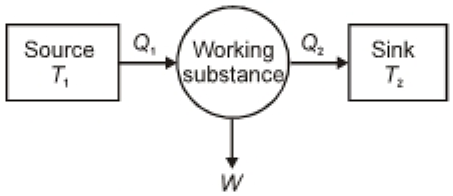
Heat is rejected during compression.

(2) For refrigerator

Coefficient of performance $\beta = \dfrac{Q_{\text{extracted from sink}}}{W_{\text{total}}} \times 100$

(3) For a heat pump coefficient of performance $\beta = \dfrac{Q_{\text{supplied to source}}}{W_{\text{total}}} \times 100$

Heat Engine



Heat supplied = Q_1 $\quad Q_1 = Q_2 + W$

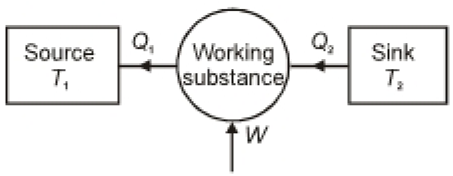
Heat rejected = Q_2 $\quad \Rightarrow Q_1 - Q_2 = W$

$$\eta = \frac{W_{\text{total}}}{Q_{\text{supplied}}} \times 100 = \frac{Q_1 - Q_2}{Q_1} \times 100$$

$$= \left(1 - \frac{Q_2}{Q_1}\right) \times 100$$

$$= \left(1 - \frac{T_2}{T_1}\right) \times 100 \quad \text{(for ideal engine)}$$

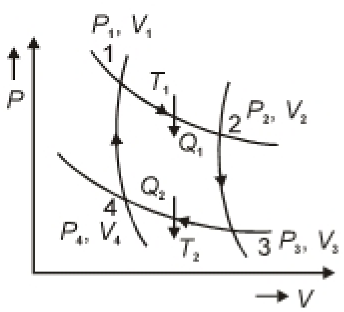
Refrigerator and Heat Pump :



(1) Refrigerator : $\beta = \dfrac{\text{Heat extracted}}{W_{\text{total}}} \times 100 = \dfrac{Q_2}{W} \times 100 = \dfrac{Q_2}{Q_1 - Q_2} \times 100 = \dfrac{T_2}{T_1 - T_2} \times 100$

(2) Heat pump : $\beta = \dfrac{\text{Heat rejected}}{W_{\text{total}}} = \dfrac{Q_1}{W} \times 100 = \dfrac{T_1}{T_1 - T_2} \times 100$ (for ideal pump)

Carnot Cycle : Efficiency of carnot engine is independent of the nature of the working substance



$1 \rightarrow 2$ Isothermal expansion process $|Q_1| = W = 2.303\ nRT_1 \log\left(\frac{V_2}{V_1}\right)$ [supplied]

$2 \rightarrow 3$ Adiabatic expansion process $Q = 0;\ W = \frac{(P_2V_2 - P_3V_3)}{(\gamma - 1)}$

$3 \rightarrow 4$ Isothermal compression process $Q_2 = W = 2.303\ nRT_2 \log\left(\frac{V_3}{V_4}\right)$ [rejected]

$4 \rightarrow 1$ Adiabatic compression process $Q = 0;\ W = \frac{(P_4V_4 - P_1V_1)}{(\gamma - 1)}$ $\left[\textit{Note}: \frac{V_2}{V_1} = \frac{V_3}{V_4}\right]$

Note : *The efficiency of Carnot engine is maximum (<100%) for given temperatures T_1 and T_2. No engine can have efficiency more than that of the Carnot engine. This statement is called "Carnot's Theorem"*

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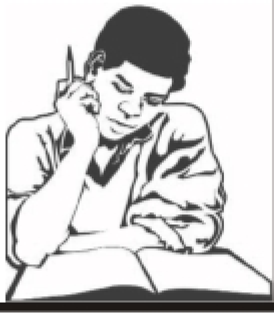


Try Yourself

SECTION - A

Objective Type Questions

1. On a hot day in Delhi, a diesel truck was loaded with 1000 litre of fuel. This truck delivered the fuel to the station in Siachen glacier where temperature was 60°C lower than that in Delhi. What is the volume of diesel delivered there? The coefficient of volume expansion for diesel fuel is 9.5×10^{-4} / °C

(1) 1057 litre (2) 943 litre

(3) 1000 litre (4) Cannot be calculated

2. At what temperature is the Fahrenheit scale reading equals twice that of Celsius scale?

(1) 320°F (2) 80°F

(3) 0°F (4) 160°F

3. A certain substance has a mass per mole of 50g/mol. When 300 J of heat is added to a 30.0 g sample of this material, its temperature rises from 25°C to 45°C. What is the molar specific heat of this substance?

(1) 50 J $mol^{-1}K^{-1}$ (2) 25 J $mol^{-1}K^{-1}$

(3) 0.5 J $mol^{-1}K^{-1}$ (4) 0.25 J $mol^{-1}K^{-1}$

4. If the coefficient of real expansion of a liquid is γ, its coefficient of apparent expansion γ' and the coefficient of linear expansion of the container vessel is α, then

(1) $\gamma = \gamma' + 3\alpha$ (2) $\gamma = \gamma' - 3\alpha$

(3) $\gamma = \gamma' - 2\alpha$ (4) $\gamma = \gamma' - \alpha$

5. Melting point of ice

(1) Increases with increasing pressure

(2) Decreases with increasing pressure

(3) Is independent of pressure

(4) Is proportional to pressure

6. A small amount of mass m of water at a temperature θ (in °C) is poured on to a large mass M of ice which is at its melting point. If c is the specific heat capacity of water and L is the specific latent heat of fusion of ice, then the mass of ice that melts, is given by

(1) $\frac{ML}{mc\theta}$ (2) $\frac{Mc\theta}{L}$

(3) $\frac{mc\theta}{ML}$ (4) $\frac{mc\theta}{L}$

7. What mass of steam at 100°C must be mixed with 150 g of ice at melting point, in a thermally insulated container, to produce liquid water at 40°C?

(1) 40 g (2) 150 gm

(3) 30 gm (4) 100 gm

8. By what percentage should the pressure of a given mass of a gas be increased so as to decrease its volume by 10% at a constant temperature?

(1) 8.1 %

(2) 9.1 %

(3) 10.1 %

(4) 11.1 %

9. When an ideal diatomic gas is heated at constant pressure, the fraction of the heat energy supplied which increases the internal energy of the gas is

(1) $\frac{2}{5}$ (2) $\frac{3}{5}$

(3) $\frac{3}{7}$ (4) $\frac{5}{7}$

10. An ideal gas having pressure P, volume V and temperature T is allowed to expand adiabatically until its volume becomes $4\sqrt{2}V$ while its temperature falls to $\frac{T}{2}$. The degrees of freedom of gas molecules are

(1) 3 (2) 5

(3) 6 (4) 7

11. A gas mixture consists of 3 moles of N_2, 2 mole of He and 1 mole of H_2. Neglecting all vibrational modes, the total internal energy of the system is

(1) 4 RT (2) 15 RT

(3) 9 RT (4) 13 RT

12. Starting with some initial conditions if an ideal gas expands from volume V_1 to V_2 in three different ways. The work done by gas is W_1 if the process is purely isothermal, W_2 if purely isobaric and W_3 if purely adiabatic, then

(1) $W_1 > W_2 > W_3$

(2) $W_2 > W_1 > W_3$

(3) $W_2 > W_3 > W_1$

(4) $W_1 > W_3 > W_2$

13. In a given process of an ideal gas, if $\Delta U = 0$ and $dQ < 0$, then for the gas

(1) The volume will increase

(2) The temperature will decrease

(3) The volume will decrease

(4) The temperature will increase

14. An ideal gas has an initial pressure of 3 pressure units and an initial volume of 4 volume units. Which of the following values of final pressure and volume corresponds to an isothermal change?

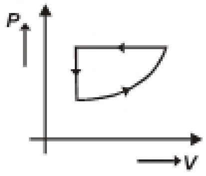
(1) 12, 1

(2) 6, 2

(3) 4, 3

(4) All of these

15. For one complete cycle as shown in the P–V diagram



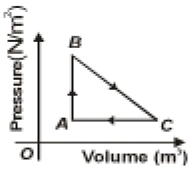
(1) $\Delta U = 0, \Delta Q > 0$

(2) $\Delta U > 0, \Delta Q = 0$

(3) $\Delta U < 0, \Delta Q < 0$

(4) $\Delta U = 0, \Delta Q < 0$

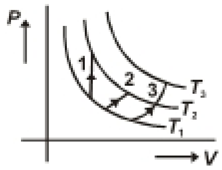
16. A gas enclosed in a chamber passes through the cycle as shown. Determine the net heat added to the system during process CA if the heat Q_{AB} added during process AB = 20.0 J. No heat is transferred during process BC and the net work done during the cycle is 15.0 J



(1) 5 J (2) 0 J

(3) 20 J (4) –5 J

17. The figure shows three paths traversed by a gas on P-V diagram. Let U_1, U_2 and U_3 are the changes in internal energy of the gas, then



(1) $U_1 > U_2 > U_3$ (2) $U_3 > U_2 > U_1$

(3) $U_1 = U_2 = U_3$ (4) $U_3 > U_2 = U_1$

18. What is the internal energy of 16 g of oxygen at STP?

(1) 177 J (2) 2832 J

(3) 28.32 J (4) None of these

19. What is the molar heat capacity of a diatomic gas in a process when the pressure changes with volume as $P = KV$?

(1) $\frac{R}{2}$ (2) R

(3) $3R$ (4) $2R$

20. The ratio of the mean translational K.E. of chlorine and oxygen molecules at the same temperature is

(1) 16 : 35.5 (2) 35.5 : 16

(3) $(35.5)^2 : 16^2$ (4) 1 : 1

21. A fixed mass of a gas expands at constant temperature. Which property of the gas molecules increases?

(1) Average number of molecules per unit volume

(2) Average kinetic energy

(3) Average separation

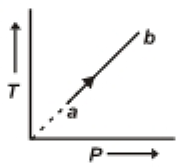
(4) Average number of collisions per unit time

22. A carnot engine operates between temperature range 300 K and T_1 (T_1 > 300 K). It takes 200 J of heat and rejects 120 J of heat. Which of the following may be the value of T_1?

(1) 350 K (2) 500 K

(3) 600 K (4) 900 K

23. An ideal gas changes from state *a* to state *b* as in figure. What is the work done by the gas in the process?



(1) Zero (2) Positive

(3) Negative (4) Infinite

24. For an ideal gas, the heat capacity at constant pressure is larger than that at constant volume because

(1) Work is done during expansion of the gas by external pressure

(2) Work is done during expansion by the gas against external pressure

(3) Work is done during expansion of the gas against intermolecular force of attraction

(4) More collisions occur per unit time when volume is kept constant

25. The specific heat of a gas

(1) Has only two values C_P and C_V

(2) Has a unique value at a given temperature

(3) Can have any value between 0 and ∞

(4) Depends on the mass of the gas

26. The slopes of isothermal and adiabatic curves are related as

(1) Isothermal curve slope = adiabatic curve slope

(2) Isothermal curve slope = γ × adiabatic curve slope

(3) Adiabatic curve slope = γ × isothermal curve slope

(4) Adiabatic curve slope = $\frac{1}{2}$ × isothermal curve slope

27. In changing the state of a thermodynamical system from *A* to *B*, the heat required is *Q* and work done by the system is *W*. The change in its internal energy is

(1) $Q + W$ (2) $Q - W$

(3) Q (4) $\frac{Q-W}{2}$

28. The work done in an adiabatic change in a particular gas depends upon only change in

(1) Specific heat (2) Volume

(3) Pressure (4) Temperature

29. The internal energy *U* is a unique function of any state because change in *U*

(1) Depends upon path

(2) Doesn't depend upon path

(3) Corresponds to an adiabatic process

(4) Corresponds to an isothermal process

30. The isothermal bulk modulus of a prefect gas at normal pressure is

(1) 1.013×10^5 N/m^2 (2) 1.013×10^6 N/m^2

(3) 1.013×10^{-11} N/m^2 (4) 1.013×10^{11} N/m^2

31. A given system undergoes a change in which the work done by the system equals the decrease in its internal energy. The system must have undergone an

(1) Isothermal change (2) Adiabatic change

(3) Isobaric change (4) Isochoric change

32. When heat is given to a gas in an isothermal change, the result will be

(1) External work done

(2) Rise in temperature

(3) Increase in internal energy

(4) External work done and also rise in temperature

33. When a gas expands adiabatically

(1) No energy is required for expansion

(2) Energy is required and it comes from the wall of the container of the gas

(3) Internal energy of the gas is used in doing work

(4) Law of conservation of energy does not hold

34. Entropy of a system decreases

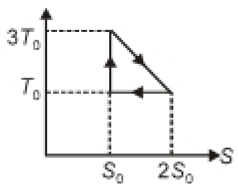
(1) When heat is supplied to a system at constant temperature

(2) When heat is taken out from the system at constant temperature

(3) At equilibrium

(4) In any spontaneous process

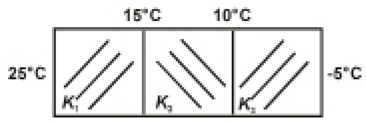
35. The temperature-entropy diagram of a reversible engine cycle is given in the figure. Its efficiency is



(1) 33% (2) 67%

(3) 50% (4) 25%

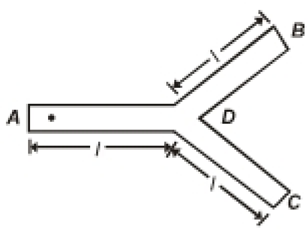
36. The figure shows the face and interface temperature of a composite slab consisting of three different materials of equal thickness, through which heat transfer is steady. If K_1, K_2 and K_3 are the thermal conductivities of the materials then



(1) $K_1 > K_2 > K_3$ (2) $K_2 > K_1 > K_3$

(3) $K_3 > K_1 > K_2$ (4) $K_3 > K_2 > K_1$

37. The end A of the composite rod shown is immersed in steam bath and other two ends B & C are kept in ice. What will be the temperature of junction D? Assume 'area' of cross-section to be uniform.



(1) 50° C (2) 33.33° C

(3) 66.66° C (4) 75° C

38. If K, σ and T stand for thermal conductivity, electrical conductivity and absolute temperature of a metal, then

(1) $K + \sigma = T$ (2) $K - \sigma = T$

(3) $\frac{K}{\sigma} \propto T$ (4) $\frac{K}{\sigma} = T^2$

39. Two rods of the same length and area of cross-section A_1 and A_2 have their ends at the same temperature. K_1 and K_2 are the thermal conductivities of the two rods. The rate of flow of heat is same in both the rods if

(1) $\frac{A_1}{A_2} = \frac{K_1}{K_2}$ (2) $\frac{A_1}{A_2} = \frac{K_2}{K_1}$

(3) $A_1 A_2 = K_1 K_2$ (4) Placed in hot oil

40. On heating one end of rod, the temperature of the whole rod will be uniform when

(1) $K = 1$ (2) $K = 0$

(3) $K = 100$ (4) $K = \infty$

41. Under steady state, the temperature of a body

(1) Increases with time

(2) Decreases with time

(3) Does not change with time and is same at all points of body

(4) Does not change with time but is different at different points of the body

42. The most suitable material for cooking utensils is the one having

(1) High specific heat and low conductivity

(2) Low specific heat and low conductivity

(3) Low specific heat and high conductivity

(4) High specific heat and high conductivity

43. A blue glass heated strongly appears

(1) Red (2) Yellow

(3) Blue (4) White

44. If r, a and t represent the reflection coefficient, absorption coefficient and transmission coefficient respectively, then for a perfectly black body

(1) $r = 0$, $a = 1$, $t = 0$

(2) $r = 1$, $a = 0$, and $t = 0$

(3) $r = 0$, $a = 0$, $t = 1$

(4) $r = 0$, $a = 0$, and $t = 0$

45. The wavelength corresponding to maximum radiation emitted at 2000 K is 4 μm. What will be the wavelength corresponding to maximum radiation emitted at 2400 K?

(1) 3.33 μm (2) 0.66 μm

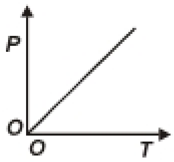
(3) 1 μm (4) 1 m

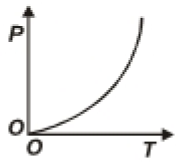
46. A hot body is placed in a room. After a time, its temperature becomes constant. At constant temperature
    (1) The body does not radiate
    (2) The body does not receive heat by radiation from surroundings
    (3) Body is radiating heat and also takes heat from the surroundings
    (4) The radiations from the body and heat received by the body from the surroundings are not possible

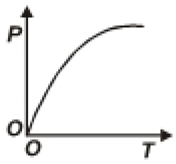
47. Woollen clothes are used in winter season because woollen clothes
    (1) Are good sources for producing heat
    (2) Absorb heat from surrounding
    (3) Are bad conductor of heat
    (4) Provide heat to body continuously

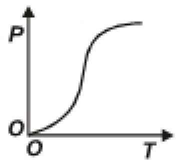
48. Ice formed over lakes
    (1) Helps in further ice formation
    (2) Retards further formation of ice
    (3) Permits quick convection and retards further formation of ice
    (4) Is very good radiator

49. Which one of the following graphs best represents the way in which the total power P radiated by a black body depends upon the thermodynamic temperature T of the body?

(1) 

(2) 

(3) 

(4) 

50. Only a very small fraction of the energy supplied to a domestic light bulb is emitted as light. This is because
    (1) The filament is not a black body
    (2) The filament surface area is too small to emit light efficiently
    (3) Most of the energy is given out at longer wavelength
    (4) Most of the energy is given out at shorter wavelength

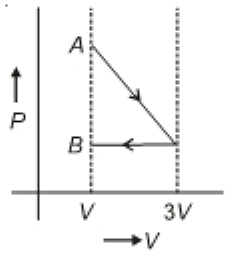
51. If temperature of sun is decreased by 60 K the value of solar constant will change by
    (1) 2% (2) –4%
    (3) –2% (4) 4%

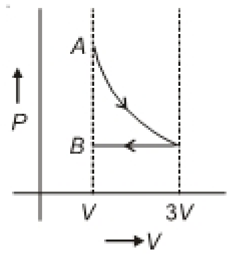
52. The value of solar constant is
    (1) 2 kcal m^{-2} min^{-1} (2) 20 kcal m^{-2} min^{-1}
    (3) 2 kWm^{-2} (4) 200 Wm^{-2}

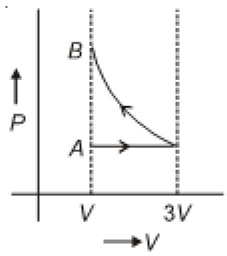
SECTION - B

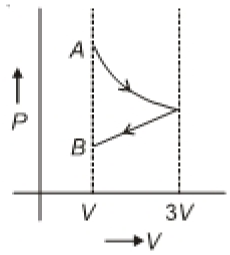
Previous Years Questions

1. One mole of an ideal gas goes from an initial state A to final state B via two processes: It first undergoes isothermal expansion from volume V to $3V$ and then its volume is reduced from $3V$ to V at constant pressure. The correct P-V diagram representing the two processes is **[AIPMT 2012]**

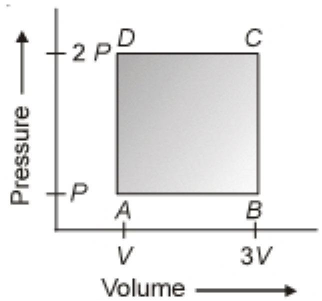
(1) 

(2) 

(3) 

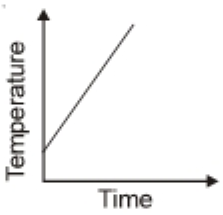
(4) 

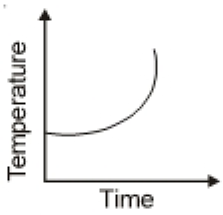
2. A thermodynamic system is taken through the cycle $ABCD$ as shown in figure. Heat rejected by the gas during the cycle is **[AIPMT 2012]**

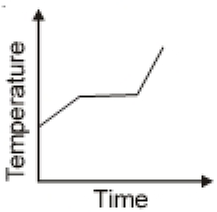


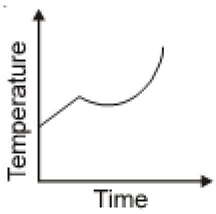
(1) $\frac{1}{2}PV$ (2) PV
(3) $2\,PV$ (4) $4\,PV$

3. Liquid oxygen at 50 K is heated to 300 K at constant pressure of 1 atm. The rate of heating is constant. Which one of the following graphs represents the variation of temperature with time? **[AIPMT 2012]**

(1) 

(2) 

(3) 

(4) 

4. If the radius of a star is R and it acts as a black body, what would be the temperature of the star, in which the rate of energy production is Q? **[AIPMT 2012]**

(1) $\left(\dfrac{4\pi R^2 Q}{\sigma}\right)^{1/4}$ (2) $\left(\dfrac{Q}{4\pi R^2\sigma}\right)^{1/4}$

(3) $\dfrac{Q}{4\pi R^2\sigma}$ (4) $\left(\dfrac{Q}{4\pi R^2\sigma}\right)^{-1/2}$

(σ stands for Stefan's constant.)

5. A piece of iron is heated in a flame. It first becomes dull red then becomes reddish yellow and finally turns to white hot. The correct explanation for the above observation is possible by using **[NEET-2013]**

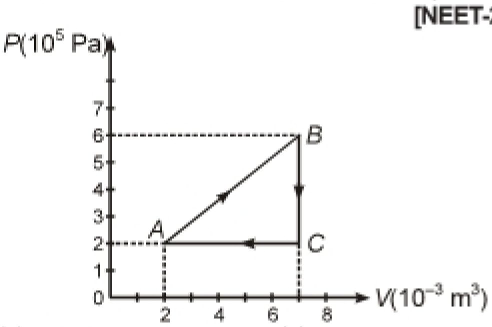
(1) Wien's displacement Law

(2) Kirchoff's Law

(3) Newton's Law of cooling

(4) Stefan's Law

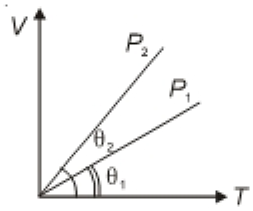
6. A gas is taken through the cycle $A \to B \to C \to A$, as shown. What is the net work done by the gas? **[NEET-2013]**



(1) 1000 J (2) Zero

(3) –2000 J (4) 2000 J

7. In the given ($V - T$) diagram, what is the relation between pressures P_1 and P_2? **[NEET-2013]**



(1) $P_2 > P_1$ (2) $P_2 < P_1$

(3) Cannot be predicted (4) $P_2 = P_1$

8. During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its temperature. The ratio of $\dfrac{C_p}{C_v}$ for the gas is **[NEET-2013]**

(1) 2 (2) $\dfrac{5}{3}$

(3) $\dfrac{3}{2}$ (4) $\dfrac{4}{3}$

9. Steam at 100°C is passed into 20 g of water at 10°C. When water acquires a temperature of 80°C, the mass of water present will be: [Take specific heat of water = 1 cal g^{-1} °C^{-1} and latent heat of steam = 540 cal g^{-1}] **[AIPMT 2014]**

(1) 24 g (2) 31.5 g

(3) 42.5 g (4) 22.5 g

10. Certain quantity of water cools from 70°C to 60°C in the first 5 minutes and to 54°C in the next 5 minutes. The temperature of the surroundings is **[AIPMT 2014]**

(1) 45°C

(2) 20°C

(3) 42°C

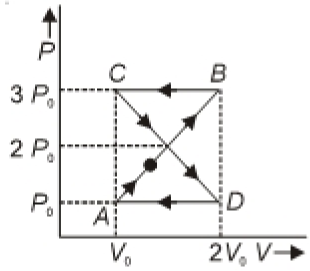
(4) 10°C

11. A monatomic gas at a pressure P, having a volume V expands isothermally to a volume 2 V and then adiabatically to a volume 16 V. The final pressure of the gas is (take $\gamma = \dfrac{5}{3}$) **[AIPMT 2014]**

(1) 64 P (2) 32 P

(3) $\dfrac{P}{64}$ (4) 16 P

12. A thermodynamic system undergoes cyclic process *ABCDA* as shown in figure. The work done by the system in the cycle is **[AIPMT 2014]**



(1) $P_0 V_0$ (2) $2P_0 V_0$

(3) $\frac{P_0 V_0}{2}$ (4) Zero

13. The value of coefficient of volume expansion of glycerin is 5×10^{-4} K^{-1}. The fractional change in the density of glycerin for a rise of 40°C in its temperature is **[Re-AIPMT-2015]**

(1) 0.010 (2) 0.015

(3) 0.020 (4) 0.025

14. The two ends of a metal rod are maintained at temperatures 100°C and 110°C. The rate of heat flow in the rod is found to be 4.0 J/s. If the ends are maintained at temperatures 200°C and 210°C, the rate of heat flow will be **[AIPMT-2015]**

(1) 4.0 J/s (2) 44.0 J/s

(3) 16.8 J/s (4) 8.0 J/s

15. On observing light from three different stars *P*, *Q* and *R*, it was found that intensity of violet colour is maximum in the spectrum of *P*, the intensity of green colour is maximum in the spectrum of *R* and the intensity of red colour is maximum in the spectrum of *Q*. If T_P, T_Q and T_R are the respective absolute temperatures of *P*, *Q* and *R* then it can be concluded from the above observations that

[AIPMT-2015]

(1) $T_P < T_Q < T_R$ (2) $T_P > T_Q > T_R$

(3) $T_P > T_R > T_Q$ (4) $T_P < T_R < T_Q$

16. 4.0 g of a gas occupies 22.4 litres at NTP. The specific heat capacity of the gas at constant volume is 5.0 JK^{-1} mol^{-1}. If the speed of sound in this gas at NTP is 952 ms^{-1}, then the heat capacity at constant pressure is (Take gas constant R = 8.3 JK^{-1} mol^{-1}) **[Re-AIPMT-2015]**

(1) 8.5 JK^{-1} mol^{-1} (2) 8.0 JK^{-1} mol^{-1}

(3) 7.5 JK^{-1} mol^{-1} (4) 7.0 JK^{-1} mol^{-1}

17. The coefficient of performance of a refrigerator is 5. If the temperature inside freezer is –20°C, the temperature of the surroundings to which it rejects heat is **[Re-AIPMT-2015]**

(1) 21°C (2) 31°C

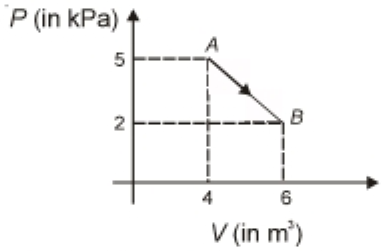
(3) 41°C (4) 11°C

18. An ideal gas is compressed to half its initial volume by means of several processes. Which of the process results in the maximum work done on the gas? **[Re-AIPMT-2015]**

(1) Isothermal (2) Adiabatic

(3) Isobaric (4) Isochoric

19. One mole of an ideal diatomic gas undergoes a transition from *A* to *B* along a path *AB* as shown in the figure



The change in internal energy of the gas during the transition is **[AIPMT-2015]**

(1) –12 kJ (2) 20 kJ

(3) –20 kJ (4) 20 J

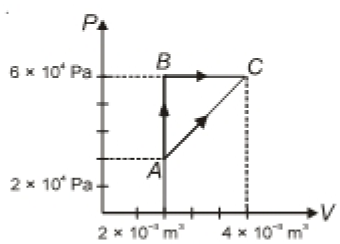
20. A Carnot engine, having an efficiency of $\eta = \frac{1}{10}$ as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the amount of energy absorbed from the reservoir at lower temperature is

[AIPMT-2015]

(1) 1 J (2) 100 J

(3) 99 J (4) 90 J

21. Figure below shows two paths that may be taken by a gas to go from a state *A* to a state *C*. In process *AB*, 400 J of heat is added to the system and in process *BC*, 100 J of heat is added to the system. The heat absorbed by the system in the process *AC* will be **[AIPMT-2015]**



(1) 300 J (2) 380 J

(3) 500 J (4) 460 J

22. Coefficient of linear expansion of brass and steel rods are α_1 and α_2. Lengths of brass and steel rods are l_1 and l_2 respectively. If $(l_2 - l_1)$ is maintained same at all temperatures, which one of the following relations holds good? **[NEET-2016]**
(1) $\alpha_1 l_1 = \alpha_2 l_2$ (2) $\alpha_1 l_2 = \alpha_2 l_1$
(3) $\alpha_1 l_2^2 = \alpha_2 l_1^2$ (4) $\alpha_1^2 l_2 = \alpha_2^2 l_1$

23. A piece of ice falls from a height h so that it melts completely. Only one-quarter of the heat produced is absorbed by the ice and all energy of ice gets converted into heat during its fall. The value of h is
[Latent heat of ice is 3.4×10^5 J/kg and $g = 10$ N/kg]
[NEET-2016]
(1) 68 km (2) 34 km
(3) 544 km (4) 136 km

24. A black body is at a temperature of 5760 K. The energy of radiation emitted by the body at wavelength 250 nm is U_1, at wavelength 500 nm is U_2 and that at 1000 nm is U_3. Wien's constant, $b = 2.88 \times 10^6$ nmK. Which of the following is correct? **[NEET-2016]**
(1) $U_2 > U_1$ (2) $U_1 = 0$
(3) $U_3 = 0$ (4) $U_1 > U_2$

25. Two identical bodies are made of a material for which the heat capacity increases with temperature. One of these is at 100°C, while the other one is at 0°C. If the two bodies are brought into contact, then assuming no heat loss, the final common temperature is **[NEET (Phase-2) 2016]**
(1) 50°C
(2) More than 50°C
(3) Less than 50°C but greater than 0°C
(4) 0°C

26. A body cools from a temperature $3T$ to $2T$ in 10 minutes. The room temperature is T. Assume that Newton's law of cooling is applicable. The temperature of the body at the end of next 10 minutes will be **[NEET (Phase-2) 2016]**
(1) $\frac{7}{4}T$ (2) $\frac{3}{2}T$
(3) $\frac{4}{3}T$ (4) T

27. A refrigerator works between 4°C and 30°C. It is required to remove 600 calories of heat every second in order to keep the temperature of the refrigerated space constant. The power required is [Take 1 cal = 4.2 joules) **[NEET-2016]**
(1) 2365 W (2) 2.365 W
(3) 23.65 W (4) 236.5 W

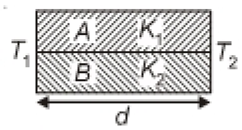
28. A gas is compressed isothermally to half its initial volume. The same gas is compressed separately through an adiabatic process until its volume is again reduced to half. Then **[NEET-2016]**
(1) Which of the case (whether compression through isothermal or through adiabatic process) requires more work will depend upon the atomicity of the gas
(2) Compressing the gas isothermally will require more work to be done
(3) Compressing the gas through adiabatic process will require more work to be done
(4) Compressing the gas isothermally or adiabatically will require the same amount of work

29. One mole of an ideal monatomic gas undergoes a process described by the equation PV^3 = constant. The heat capacity of the gas during this process is **[NEET (Phase-2) 2016]**
(1) $\frac{3}{2}R$ (2) $\frac{5}{2}R$
(3) $2R$ (4) R

30. The temperature inside a refrigerator is t_2°C and the room temperature is t_1°C. The amount of heat delivered to the room for each joule of electrical energy consumed ideally will be
[NEET (Phase-2) 2016]
(1) $\frac{t_1}{t_1 - t_2}$ (2) $\frac{t_1 + 273}{t_1 - t_2}$
(3) $\frac{t_2 + 273}{t_1 - t_2}$ (4) $\frac{t_1 + t_2}{t_1 + 273}$

31. A spherical black body with a radius of 12 cm radiates 450 watt power at 500 K. If the radius were halved and the temperature doubled, the power radiated (in watt) would be **[NEET-2017]**
(1) 225
(2) 450
(3) 1000
(4) 1800

32. Two rods A and B of different materials are welded together as shown in figure. Their thermal conductivities are K_1 and K_2. The thermal conductivity of the composite rod will be **[NEET-2017]**



(1) $\frac{K_1+K_2}{2}$ (2) $\frac{3(K_1+K_2)}{2}$

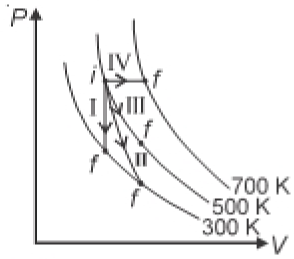
(3) $K_1 + K_2$ (4) $2(K_1 + K_2)$

33. A Carnot engine having an efficiency of $\frac{1}{10}$ as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the amount of energy absorbed from the reservoir at lower temperature is **[NEET-2017]**

(1) 1 J (2) 90 J

(3) 99 J (4) 100 J

34. Thermodynamic processes are indicated in the following diagram.



Match the following

	Column-I		Column-II
P.	Process I	a.	Adiabatic
Q.	Process II	b.	Isobaric
R.	Process III	c.	Isochoric
S.	Process IV	d.	Isothermal

[NEET-2017]

(1) P → a, Q → c, R → d, S → b

(2) P → c, Q → a, R → d, S → b

(3) P → c, Q → d, R → b, S → a

(4) P → d, Q → b, R → a, S → c

35. A sample of 0.1 g of water at 100°C and normal pressure (1.013×10^5 Nm^{-2}) requires 54 cal of heat energy to convert to steam at 100°C. If the volume of the steam produced is 167.1 cc, the change in internal energy of the sample, is **[NEET-2018]**

(1) 104.3 J (2) 208.7 J

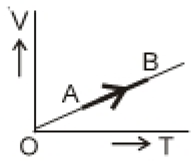
(3) 84.5 J (4) 42.2 J

36. The power radiated by a black body is P and it radiates maximum energy at wavelength, λ_0. If the temperature of the black body is now changed so that it radiates maximum energy at wavelength $\frac{3}{4}\lambda_0$, the power radiated by it becomes nP. The value of n is **[NEET-2018]**

(1) $\frac{3}{4}$ (2) $\frac{4}{3}$

(3) $\frac{81}{256}$ (4) $\frac{256}{81}$

37. The volume (V) of a monatomic gas varies with its temperature (T), as shown in the graph. The ratio of work done by the gas, to the heat absorbed by it, when it undergoes a change from state A to state B, is **[NEET-2018]**



(1) $\frac{2}{5}$

(2) $\frac{2}{3}$

(3) $\frac{2}{7}$

(4) $\frac{1}{3}$

38. The efficiency of an ideal heat engine working between the freezing point and boiling point of water, is **[NEET-2018]**

(1) 26.8% (2) 20%

(3) 12.5% (4) 6.25%

39. A copper rod of 88 cm and an aluminium rod of unknown length have their increase in length independent of increase in temperature. The length of aluminium rod is : ($\alpha_{Cu} = 1.7 \times 10^{-5}$ K^{-1} and $\alpha_{Al} = 2.2 \times 10^{-5}$ K^{-1}) **[NEET-2019]**

(1) 6.8 cm (2) 113.9 cm

(3) 88 cm (4) 68 cm

40. The unit of thermal conductivity is :

[NEET-2019]

(1) J m K^{-1} (2) J m^{-1} K^{-1}

(3) W m K^{-1} (4) W m^{-1} K^{-1}

41. In which of the following processes, heat is neither absorbed nor released by a system?

[NEET-2019]

(1) Isothermal (2) Adiabatic

(3) Isobaric (4) Isochoric

42. A deep rectangular pond of surface area A, containing water (density = ρ), specific heat capacity = s), is located in a region where the outside air temperature is at a steady value of –26°C. The thickness of the frozen ice layer in this pond, at a certain instant is x. **[NEET-2019 (Odisha)]**

Taking the thermal conductivity of ice as K, and its specific latent heat of fusion as L, the rate of increase of the thickness of ice layer, at this instant, would be given by

(1) $26K/\rho x(L + 4s)$ (2) $26K/\rho x(L - 4s)$

(3) $26K/(\rho x^2 L)$ (4) $26K/(\rho x L)$

43. An object kept in a large room having air temperature of 25°C takes 12 minutes to cool from 80°C to 70°C. **[NEET-2019 (Odisha)]**

The time taken to cool for the same object from 70°C to 60°C would be nearly,

(1) 15 min (2) 10 min

(3) 12 min (4) 20 min

44. 1 g of water, of volume 1 cm^3 at 100°C, is converted into steam at same temperature under normal atmospheric pressure ($\simeq 1\times 10^5$ Pa). The volume of steam formed equals 1671 cm^3. If the specific latent heat of vaporisation of water is 2256 J/g, the change in internal energy is

[NEET-2019 (Odisha)]

(1) 2256 J (2) 2423 J

(3) 2089 J (4) 167 J

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Chapter 11

Kinetic Theory

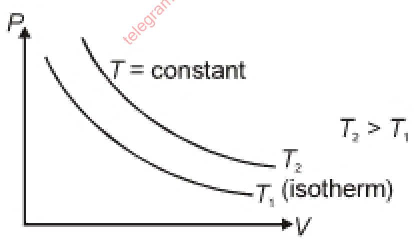
Sub-topics *Equation of state of a perfect gas, work done on compressing a gas. Kinetic theory of gases: Assumptions, concept of pressure. Kinetic energy and temperature; degrees of freedom, law of equipartition of energy (statement only) and application to specific heat capacities of gases; concept of mean free path.*

Equation of State of a Perfect Gas

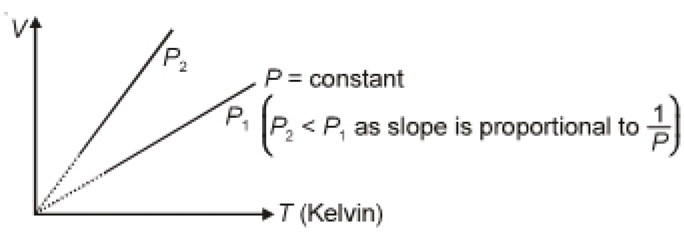
Ideal Gas : A real gas behaves as ideal gas at low pressure and high temperature.

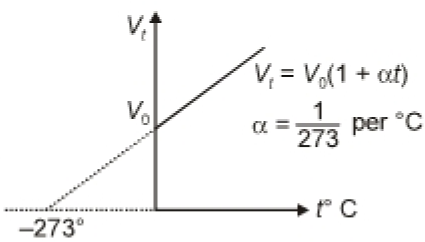
Gas Laws

(1) **Boyle's Law :** $P_1V_1 = P_2V_2$ [when mass and temperature are fixed].

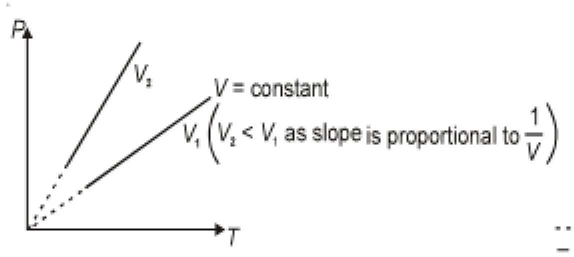


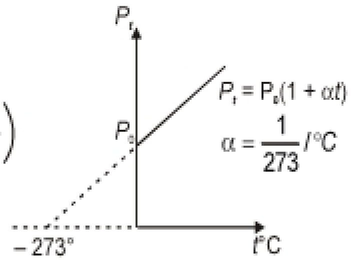
(2) **Charle's Law :** $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ [when mass and pressure are fixed].





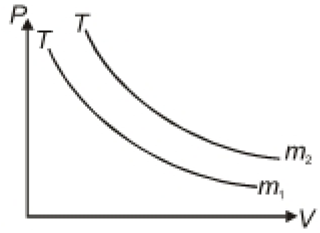
(3) **Gay Lussac's Law :** $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ [when mass and volume are fixed].





Case - 1 :

$m_2 > m_1$

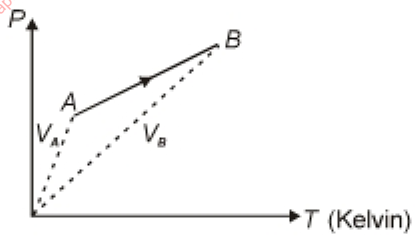


Case - 2 :

V_A = volume at A

V_B = volume at B

$V_A < V_B$ $\left(\because \text{slope} \propto \frac{1}{\text{volume}}\right)$

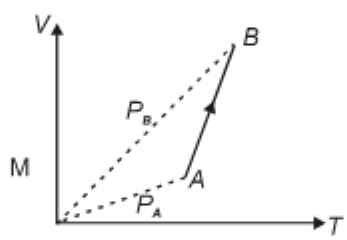


Case - 3 :

P_A = pressure at A

P_B = pressure at B

$P_B < P_A$ $\left(\because \text{slope} \propto \frac{1}{\text{pressure}}\right)$



Pressure Exerted by an Ideal Gas

It is due to elastic collisions between walls of container and gas molecules.

$$P = \frac{1}{3}\frac{mN}{V}C^2$$

m = Mass of one gas molecule

N = Total number of molecules

V = Volume of container

C = Root mean square velocity

Kinetic Energy and Temperature

(1) Average translational kinetic energy per molecule

$$\frac{1}{2}mv^2 = \frac{3}{2}kT \quad \text{where } k = \text{Boltzmann constant}$$

(2) Average translational kinetic energy per mole

$$\text{KE} = \frac{3}{2}RT$$

(3) Root mean square speed C or $v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3P}{\rho}}$

(4) Mean or average speed $v_{mean} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8P}{\pi\rho}}$

(5) Most probable speed $v_{MP} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2P}{\rho}}$

(i) $v_{rms} > v_{av} > v_{MP}$

(ii) $v_{rms} : v_{av} : v_{MP} = \sqrt{3} : \sqrt{\frac{8}{\pi}} : \sqrt{2}$

Degree of Freedom

The number of independent terms in the expression of energy of a molecule is called its degree of freedom.

(1) **For a monatomic gas :** $E = \frac{1}{2}mv_x^2 + \frac{1}{2}mv_y^2 + \frac{1}{2}mv_z^2$

degree of freedom = 3

(2) **For a diatomic gas :** $E = \frac{1}{2}mv_x^2 + \frac{1}{2}mv_y^2 + \frac{1}{2}mv_z^2 + \frac{1}{2}I_x\omega_x^2 + \frac{1}{2}I_y\omega_y^2$

degree of freedom = 5

At high temperature, if vibrational mode of energy is also considered then degree of freedom = 7

Law of Equipartition of Energy

Average energy associated with each degree of freedom of a gas molecule is $\frac{1}{2}kT$, where k is Boltzmann constant and T is absolute temperature.

⇒ If a molecule has f degrees of freedom

Total energy of 1 molecule = $f \times \frac{1}{2}kT$

Total energy of 1 mole = $N_a \times f \times \frac{1}{2}kT$ (N_a = Avogadro number)

$$= \frac{f}{2}RT \qquad [R = N_a \times k]$$

$\Rightarrow$ Internal energy of n moles of gas = $\frac{nf}{2}RT$

$\Rightarrow$ $\Delta E = n\frac{f}{2}R\Delta T$

as $\Delta E = nC_V\Delta T \Rightarrow C_V = \frac{f}{2}R$

$$C_P = C_V + R = \frac{(f+2)}{2}R$$

$$\gamma = \frac{C_P}{C_V} = 1 + \frac{2}{f}$$

(1) For monatomic, $f = 3$, $C_V = \frac{3}{2}R, C_P = \frac{5}{2}R, \gamma = \frac{5}{3}$

(2) For diatomic $f = 5$, $C_V = \frac{5}{2}R, C_P = \frac{7}{2}R, \gamma = \frac{7}{5}$

(3) For polyatomic $f = 6$, $C_V = \frac{6}{2}R, C_P = \frac{8}{2}R, \gamma = \frac{4}{3}$

(4) For a mixture of gases containing n_1 moles of monatomic gas and n_2 moles of diatomic gas

$$C_v = \frac{3n_1 + 5n_2}{2(n_1 + n_2)}R$$

$$C_P = \frac{5n_1 + 7n_2}{2(n_1 + n_2)}R$$

$$\gamma = \frac{C_P}{C_V} = \frac{5n_1 + 7n_2}{3n_1 + 5n_2}$$

Concept of Mean Free Path

The average distance between two successive collisions is called mean free path

$$\bar{\lambda} = \bar{v} \times t_{mean}$$

$$\bar{\lambda} = \frac{1}{4\pi\sqrt{2}r^2 n}$$ (r = Radius of molecule, n = number density)

$$PV = Nk_BT$$

$$\bar{\lambda} = \frac{k_BT}{4\pi\sqrt{2}r^2 P}$$

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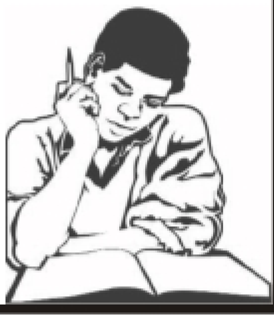


Try Yourself

SECTION - A

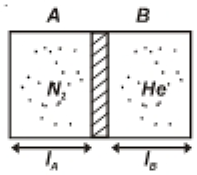
Objective Type Questions

1. The average translational kinetic energy per gram mole of a gas is given by

(1) $\frac{3}{2}RT$ (2) $\frac{1}{2}RT$

(3) $\frac{2}{3}RT$ (4) $\frac{2}{3RT}$

2. A piston separates a closed chamber into two sections *A* and *B*. Chamber *A* has 28 mg of nitrogen gas and chamber *B* has 40 mg of helium gas. At equilibrium, $\frac{l_A}{l_B}$ is



(1) 0.15 (2) 0.20

(3) 0.10 (4) 4

3. The ratio of most probable speed and rms speed for a gas molecule is

(1) $\sqrt{\frac{3}{2}}$ (2) 1

(3) $\sqrt{\frac{2}{3}}$ (4) $\frac{3}{2}$

4. Diffusion of gases is mainly due to

(1) Newton's law of cooling

(2) Pressure difference

(3) Joule-Kelvin effect

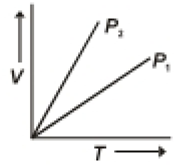
(4) A concentration gradient of the molecules

5. If *P* is the pressure of the gas, then the kinetic energy per unit volume of the gas is

(1) $\frac{P}{2}$ (2) P

(3) $\frac{3P}{2}$ (4) $2P$

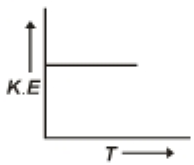
6. *V* versus *T* curves at constant pressure P_1 and P_2 for a given mass of an ideal gas is shown in figure. Here

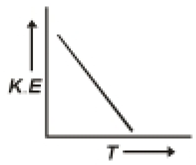


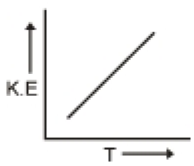
(1) $P_1 > P_2$ (2) $P_1 < P_2$

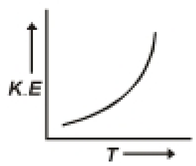
(3) $P_1 = P_2$ (4) $P_1 \geq P_2$

7. Which of the following graphs best represents the relationship between absolute temperature of a gas and the average kinetic energy of the gas molecules?

(1)


(2)


(3)


(4)


8. Two perfect diatomic gases at absolute temperature T_1 and T_2 are mixed. There is no loss of energy. The masses of the molecules are m_1 and m_2. The number of molecules in the gases are n_1 and n_2. The temperature of the mixture is

(1) $T_1 + T_2$

(2) $\frac{T_1+T_2}{2}$

(3) $\frac{n_1T_1+n_2T_2}{n_1+n_2}$

(4) $\frac{n_1T_1-n_2T_2}{n_1+n_2}$

9. An electric fan is switched on in a closed room. The air in the room is
   (1) Cooled
   (2) Heated
   (3) At 273 K
   (4) Heated or cooled depending on the atmospheric pressure

10. At 10°C the value of the density of a fixed mass of an ideal gas divided by its pressure is x. At 110°C this ratio is
   (1) $\frac{283}{383}x$ (2) x
   (3) $\frac{383}{283}x$ (4) $\frac{10}{110}x$

11. At 0 K, which of the following properties of a gas will be zero?
   (1) Mass (2) Density
   (3) Kinetic energy (4) Potential energy

12. The value of critical temperature in terms of van der Waals' constants a and b is given by
   (1) $T_C = \frac{8a}{27Rb}$ (2) $T_C = \frac{27a}{8Rb}$
   (3) $T_C = \frac{a}{2Rb}$ (4) $T_C = \frac{a}{27Rb}$

13. The degrees of freedom of a triatomic gas is
   (Consider moderate temperature)
   (1) 6 (2) 4
   (3) 2 (4) 8

14. To find out degree of freedom, the expression is
   (1) $f = \frac{2}{\gamma - 1}$ (2) $f = \frac{\gamma + 1}{2}$
   (3) $f = \frac{2}{\gamma + 1}$ (4) $f = \frac{1}{\gamma + 1}$

15. The equation of state for 5 g of oxygen at a pressure P and temperature T, when occupying a volume V, will be (where R is the gas constant)
   (1) $PV = (5/32)RT$
   (2) $PV = 5RT$
   (3) $PV = (5/2)RT$
   (4) $PV = (5/16)RT$

16. The molar specific heat at constant pressure of an ideal gas is $(7/2)R$. The ratio of specific heat at constant pressure to that at constant volume is
   (1) $\frac{9}{7}$ (2) $\frac{7}{5}$
   (3) $\frac{8}{7}$ (4) $\frac{5}{7}$

17. A closed cylindrical vessel contains N moles of an ideal diatomic gas at a temperature T. On supplying heat, temperature remains same, but n moles get dissociated into atoms. The heat supplied is
   (1) $\frac{5}{2}(N-n)RT$ (2) $\frac{5}{2}nRT$
   (3) $\frac{1}{2}nRT$ (4) $\frac{3}{2}nRT$

18. 105 calories of heat is required to raise the temperature of 3 moles of an ideal gas at constant pressure from 30°C to 35°C. The amount of heat required in calories to raise the temperature of the gas through the range (60°C to 65°C) at constant volume is $\left(\gamma = \frac{C_p}{C_v} = 1.4\right)$
   (1) 50 cal (2) 75 cal
   (3) 70 cal (4) 90 cal

19. A diatomic gas of molecular mass 40 g/mol is filled in a rigid container at temperature 30°C. It is moving with velocity 200 m/s. If it is suddenly stopped, the rise in the temperature of the gas is
   (1) $\frac{32}{R}$°C (2) $\frac{320}{R}$°C
   (3) $\frac{3200}{R}$°C (4) $\frac{3.2}{R}$°C

20. The ratio of average translatory kinetic energy of He gas molecules to O_2 gas molecules at the same temperature is
   (1) $\frac{25}{21}$ (2) $\frac{21}{25}$
   (3) $\frac{3}{2}$ (4) 1

SECTION - B

Previous Years Questions

1. The molar specific heats of an ideal gas at constant pressure and volume are denoted by C_p and C_v respectively. If $\gamma = \frac{C_p}{C_v}$ and R is the universal gas constant, then C_v is equal to **[NEET-2013]**

(1) $\frac{R}{(\gamma - 1)}$ (2) $\frac{(\gamma - 1)}{R}$

(3) γR (4) $\frac{1+\gamma}{1-\gamma}$

2. The amount of heat energy required to raise the temperature of 1 g of Helium at NTP, from T_1K to T_2K is **[NEET-2013]**

(1) $\frac{3}{2}N_a k_B(T_2 - T_1)$ (2) $\frac{3}{4}N_a k_B(T_2 - T_1)$

(3) $\frac{3}{4}N_a k_B\left(\frac{T_2}{T_1}\right)$ (4) $\frac{3}{8}N_a k_B(T_2 - T_1)$

3. The mean free path of molecules of a gas, (radius r) is inversely proportional to **[AIPMT 2014]**

(1) r^3 (2) r^2

(3) r (4) $\sqrt{r}$

4. Two vessels separately contain two ideal gases A and B at the same temperature, the pressure of A being twice that of B. Under such conditions, the density of A is found to be 1.5 times the density of B. The ratio of molecular weight of A and B is **[Re-AIPMT-2015]**

(1) $\frac{1}{2}$ (2) $\frac{2}{3}$

(3) $\frac{3}{4}$ (4) 2

5. The ratio of the specific heats $\frac{C_P}{C_v} = \gamma$ in terms of degrees of freedom (n) is given by **[AIPMT-2015]**

(1) $\left(1+\frac{n}{2}\right)$ (2) $\left(1+\frac{1}{n}\right)$

(3) $\left(1+\frac{n}{3}\right)$ (4) $\left(1+\frac{2}{n}\right)$

6. The molecules of a given mass of a gas have r.m.s. velocity of 200 ms^{-1} at 27°C and 1.0 × 10^5 Nm^{-2} pressure. When the temperature and pressure of the gas are respectively, 127°C and 0.05 × 10^5 Nm^{-2}, the r.m.s. velocity of its molecules in ms^{-1} is **[NEET-2016]**

(1) $\frac{100}{3}$ (2) $100\sqrt{2}$

(3) $\frac{400}{\sqrt{3}}$ (4) $\frac{100\sqrt{2}}{3}$

7. A given sample of an ideal gas occupies a volume V at a pressure P and absolute temperature T. The mass of each molecule of the gas is m. Which of the following gives the density of the gas? **[NEET (Phase-2) 2016]**

(1) $\frac{P}{(kT)}$ (2) $\frac{Pm}{(kT)}$

(3) $\frac{P}{(kTV)}$ (4) mkT

8. A gas mixture consists of 2 moles of O_2 and 4 moles of Ar at temperature T. Neglecting all vibrational modes, the total internal energy of the system is **[NEET-2017]**

(1) $4RT$ (2) $15RT$

(3) $9RT$ (4) $11RT$

9. At what temperature will the rms speed of oxygen molecules become just sufficient for escaping from the Earth's atmosphere?

(Given :

Mass of oxygen molecule (m) = 2.76 × 10^{-26} kg

Boltzmann's constant k_B = 1.38 × 10^{-23} JK^{-1}) **[NEET-2018]**

(1) 2.508 × 10^4 K (2) 8.360 × 10^4 K

(3) 1.254 × 10^4 K (4) 5.016 × 10^4 K

10. Increase in temperature of a gas filled in a container would lead to **[NEET-2019]**

(1) Increase in its mass

(2) Increase in its kinetic energy

(3) Decrease in its pressure

(4) Decrease in intermolecular distance

11. The value of $\gamma\left(=\frac{C_p}{C_v}\right)$, for hydrogen, helium and another ideal diatomic gas X (whose molecules are not rigid but have an additional vibrational mode), are respectively equal to **[NEET-2019 (Odisha)]**

(1) $\frac{7}{5}, \frac{5}{3}, \frac{7}{5}$ (2) $\frac{7}{5}, \frac{5}{3}, \frac{9}{7}$

(3) $\frac{5}{3}, \frac{7}{5}, \frac{9}{7}$ (4) $\frac{5}{3}, \frac{7}{5}, \frac{7}{5}$

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Chapter 12

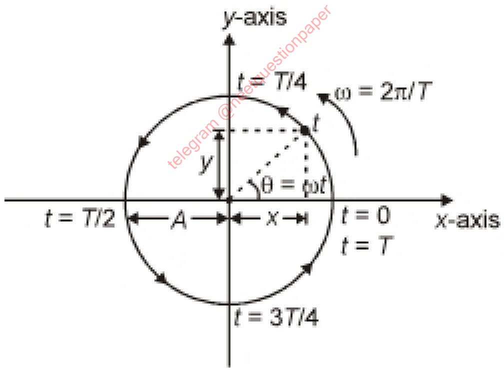
Oscillations

Sub-topics

Periodic motion-period, frequency, displacement as a function of time. Periodic functions. Simple harmonic motion(SHM) and its equation; phase; oscillations of a spring-restoring force and force constant; energy in SHM –Kinetic and potential energies; simple pendulum-derivation of expression for its time period; free, forced and damped oscillations (qualitative ideas only), resonance.

Periodic Motion, Period and Frequency

Consider a body under uniform circular motion with angular velocity ω and time period T, radius of circle is A



At any time '*t*'

$x = A\cos\omega t$

At $t = 0$, $x = A$

i.e. motion starts from extreme position

At $t = \frac{T}{6}$, $x = A\cos\left(\frac{2\pi}{T}\times\frac{T}{6}\right)$

$x = A\cos\frac{\pi}{3} = \frac{A}{2}$

i.e. particle takes $\frac{T}{6}$ time to move from extreme position to half way between extreme and mean position

$y = A\sin\omega t$

At $t = 0$, $y = 0$

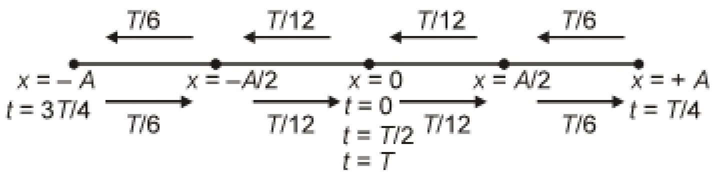
i.e. motion starts from mean position

At $t = \frac{T}{12}$, $y = A\sin\left(\frac{2\pi}{T}\times\frac{T}{12}\right)$

$y = \frac{A}{2}$

i.e. particle takes $\frac{T}{12}$ time to move from mean position to midway between mean and extreme position

$x = A\sin\omega t$



Simple Harmonic Motion

$F \propto -x$

$F = -kx$

$a = -\dfrac{k}{m}x$

$\dfrac{d^2x}{dt^2} + \dfrac{k}{m}x = 0$ or $\boxed{\dfrac{d^2x}{dt^2} + \omega^2 x = 0}$

This equation represents S.H.M.

(1) $x = A\sin\omega t$, $x = A\cos\omega t$, $x = A\sin\omega t + B\cos\omega t$ all satisfy the above differential equation. Therefore they all represent S.H.M.

(2) $x = A\sin^2\omega t$, $x = A\cos\omega t + B\sin 2\omega t$ do not satisfy above differential equation. Therefore they do not represent S.H.M.

(3) Two particles executing S.H.M. with time periods T_1 and T_2 ($T_1 > T_2$) start at the same time. The particles will be in phase after n oscillations of T_2 and $(n - 1)$ oscillations of T_1 so that $nT_2 = (n - 1)T_1$.

Velocity and acceleration of a particle executing S.H.M.

$x = A\sin\omega t$

$v = \dfrac{dx}{dt} = A\omega\cos\omega t$

$v = A\omega\sin\left(\omega t + \dfrac{\pi}{2}\right)$ *i.e.*, velocity leads displacement by 90°.

$v_{max} = A\omega$ at $x = 0$ (mean position)

$v_{min} = 0$ at $x = \quad A$ (extreme positions)

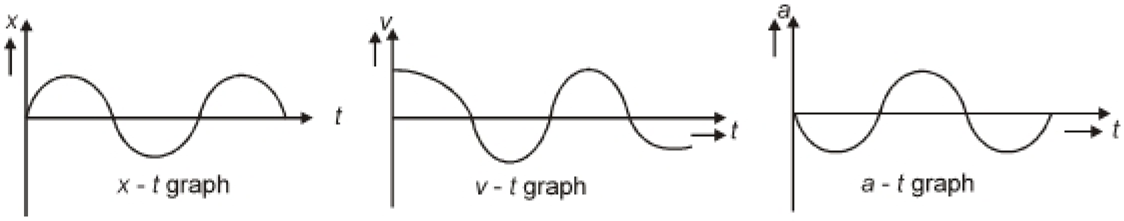
$v = \omega\sqrt{A^2 - x^2}$ (at any position)

$a = \dfrac{dv}{dt} = -A\omega^2\sin\omega t = -\omega^2 x$ [*i.e.* $a \propto -x$]

$a = A\omega^2\sin(\omega t + \pi)$ *i.e.* acceleration leads displacement by 180° / velocity by 90°

$|a_{max}| = A\omega^2$ [at extreme positions]

$a_{min} = 0$ [at mean position]

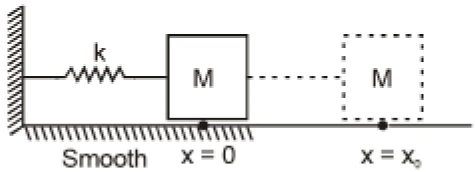


Spring Mass System

Horizontal Oscillations :

The spring is pulled/pushed from $x = 0$ to $x = x_0$ and released.

The block executes SHM

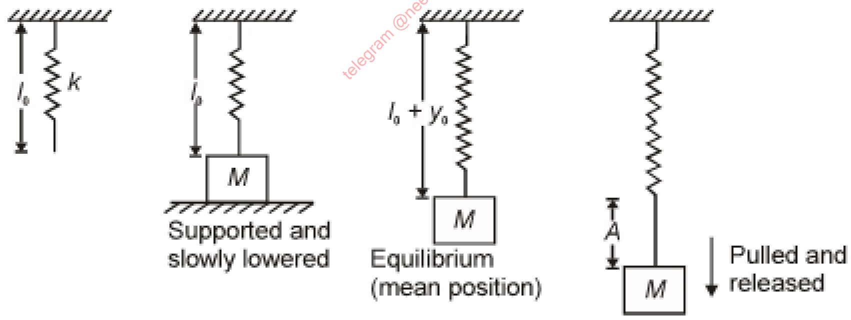


(i) Amplitude of oscillation = x_0

(ii) Time period $T = 2\pi\sqrt{\frac{M}{k}}$

Vertical Oscillations :

Case - I :



$y_0 = \frac{mg}{k}$

Now the spring is pulled by A and released.

(i) Amplitude of oscillation = A

(ii) Time period $T = 2\pi\sqrt{\frac{M}{k}}$

(iii) If mass (M_s) of the spring is also given

$$T = 2\pi\sqrt{\frac{M + \frac{M_s}{3}}{k}}$$

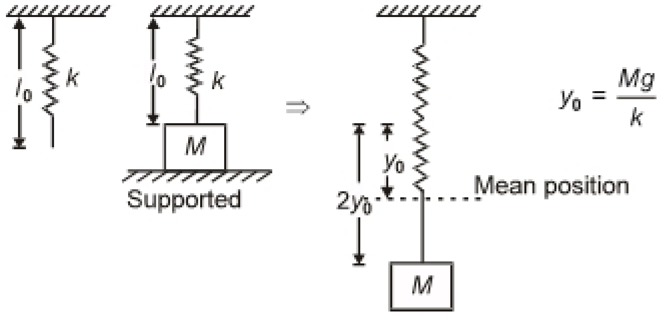
Case - II :

Support is suddenly removed

(i) Maximum extension = $\frac{2Mg}{k}$

(ii) Amplitude of oscillation = $\frac{Mg}{k}$

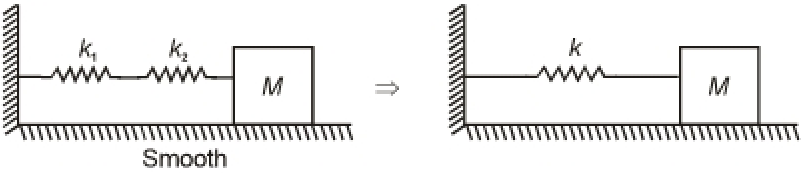
(iii) $T = 2\pi\sqrt{\frac{M}{k}}$



Combination of Springs

Series Combination :

(1)

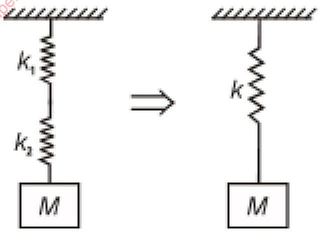


$\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2}$ or $k = \frac{k_1 k_2}{k_1 + k_2}$, $T = 2\pi\sqrt{\frac{M}{k}}$

(2) $\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2}$

$k = \frac{k_1 k_2}{k_1 + k_2}$

$T = 2\pi\sqrt{\frac{M}{k}}$



(i) Force developed in both the springs will be same.

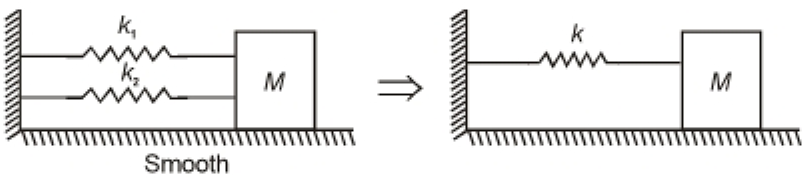
(ii) Extensions in the two springs will be different $\frac{x_1}{x_2} = \frac{k_2}{k_1}$

(iii) Energy stored will be different $\frac{U_1}{U_2} = \frac{x_1}{x_2} = \frac{k_2}{k_1}$.

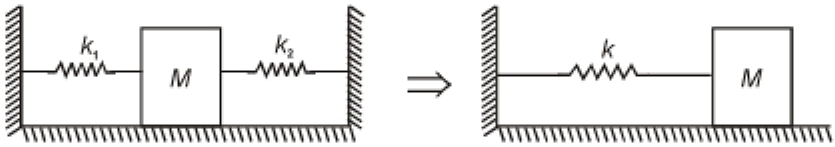
(iv) Total extension $x = x_1 + x_2$.

Parallel Combination :

(1) $k = k_1 + k_2$ $T = 2\pi\sqrt{\frac{M}{k}}$



(2) $k = k_1 + k_2$ $\quad T = 2\pi\sqrt{\frac{M}{k}}$



Smooth

(i) Force developed in two springs is different.

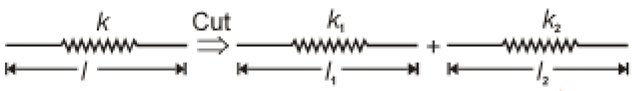
(ii) Extensions in the spring are same.

(iii) Energy stored is different.

$$\frac{F_1}{F_2} = \frac{k_1}{k_2} = \frac{U_1}{U_2}$$

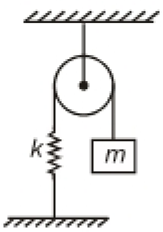
Spring constant $k \propto \frac{1}{\text{length of spring}}$

$\Rightarrow \quad k \propto \frac{1}{l}$ or kl = constant

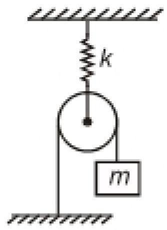


$kl = k_1 l_1 = k_2 l_2$ $\qquad l = l_1 + l_2$

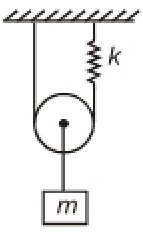
Various cases of spring mass system

(1) 

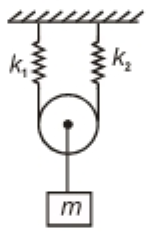
$T = 2\pi\sqrt{\frac{m}{k}}$

(2) 

$T = 2\pi\sqrt{\frac{4m}{k}}$

(3) 

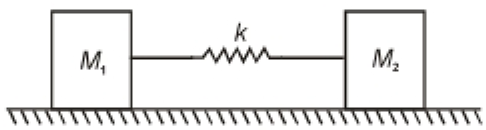
$T = 2\pi\sqrt{\frac{m}{4k}}$

(4) 

$T = 2\pi\sqrt{\frac{m(k_1 + k_2)}{4k_1 k_2}}$

(5) $T = 2\pi\sqrt{\frac{\mu}{k}}$

$\frac{1}{\mu} = \frac{1}{M_1} + \frac{1}{M_2}$ or $\mu = \frac{M_1 M_2}{M_1 + M_2}$ = reduced mass



Smooth

Energy of oscillating particle

(1) $KE = \frac{1}{2}mv^2 = \frac{1}{2}m\omega^2A^2\cos^2\omega t = \frac{1}{4}m\omega^2A^2(1+\cos 2\omega t)$

(2) Average value of $\cos^2\omega t = \frac{1}{2}$ for 1 complete cycle.

(3) $KE_{avg} = \frac{1}{4}m\omega^2A^2$.

(4) KE oscillates with frequency 2ω.

(5) $KE_{max} = \frac{1}{2}m\omega^2A^2$ at mean position.

(6) KE_{min} = zero at extreme position.

(7) $PE = \frac{1}{2}m\omega^2x^2 = \frac{1}{2}m\omega^2A^2\sin^2\omega t = \frac{1}{4}m\omega^2A^2(1-\cos 2\omega t)$

(8) Average value of $\sin^2\omega t = \frac{1}{2}$ for 1 complete cycle.

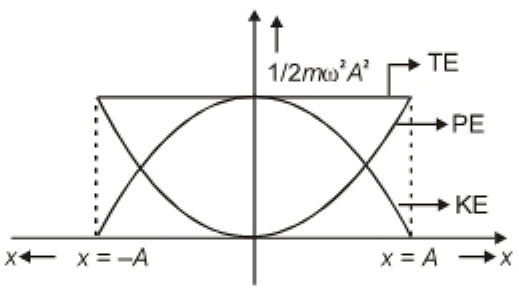
(9) $PE_{avg} = \frac{1}{4}m\omega^2A^2$.

(10) PE oscillates with frequency 2ω.

(11) $PE_{max} = \frac{1}{2}m\omega^2A^2$ at extreme position.

(12) PE_{min} = zero at mean position.

Both kinetic and potential energy vary parabolically with x.



TE = Constant

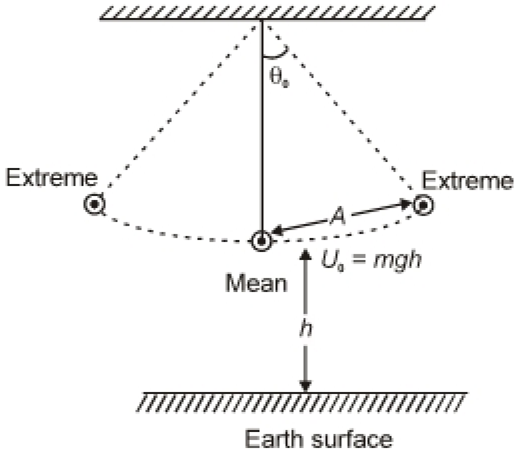
TE = $1/2m\omega^2A^2$

(13) PE = KE at $x = \frac{A}{\sqrt{2}}$ and $t = \frac{T}{8}$. (Starting from mean position).

***Note:** This graph is valid only when there is no potential energy other than the potential energy of SHM*

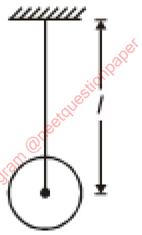
Simple Pendulum

$$T = 2\pi\sqrt{\frac{l}{g}}$$



(1) At mean position, PE = mgh instead of being zero.

(2) l is the length from point of suspension to centre of mass of bob.



At mean position

$y = 0$, $v = A\omega$ (max.), KE $= \frac{1}{2}m\omega^2A^2$, PE $= U_0$ (zero point energy)

$F = 0$, $a = 0$

At extreme position

$y = A$, $v = 0$, PE $= \frac{1}{2}m\omega^2A^2 + U_0$, KE $= 0$

$F = $ max., $a = \omega^2 A$ (max.)

Variation in Time Period

(1) If length 'l' is changed

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

(2) If gravity 'g' is changed

$$\frac{\Delta T}{T} = -\frac{1}{2}.\frac{\Delta g}{g}$$

Oscillating	Time period	Frequency
Displacement	T	f
KE	T/2	$2f$
PE	T/2	$2f$
KE ~ PE	T/4	$4f$
Total Energy	∞	0

(3) If length of pendulum changes due to temperature,

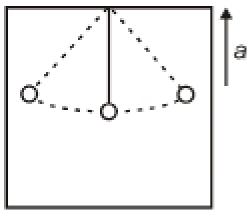
time loss per day = $\frac{1}{2}\alpha\Delta\theta \times 86400$ seconds, where 'α' is coefficient of thermal expansion.

(4) If a simple pendulum is taken to height h above the earth surface, loss of time per day ($h << R$).

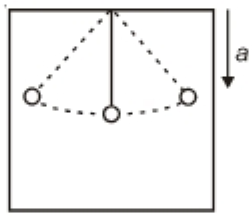
$$= \frac{h}{R} \times 86400 \text{ sec.}$$

(5) If h = 1 km, loss of time = 13.6 sec/day.

Simple Pendulum in Lift

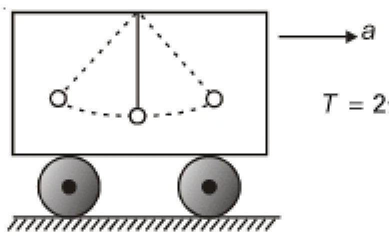


$T = 2\pi\sqrt{\frac{l}{g+a}}$

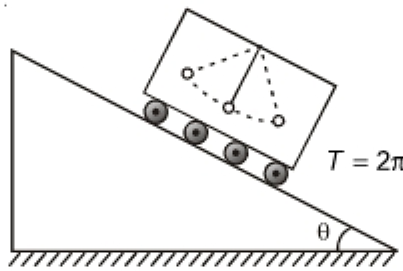


$T = 2\pi\sqrt{\frac{l}{g-a}}$

in case of free fall
$a = g$
$T \to \infty$, $f = 0$



$T = 2\pi\sqrt{\frac{l}{\sqrt{g^2+a^2}}}$

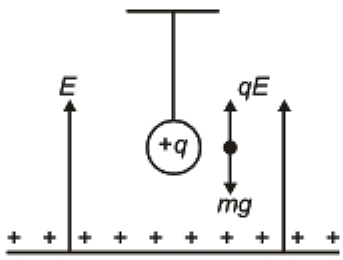


$T = 2\pi\sqrt{\frac{l}{g\cos\theta}}$

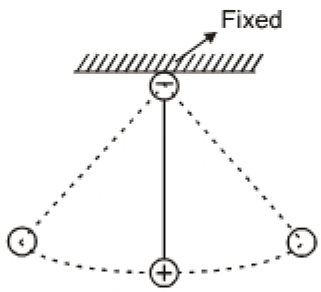
Bob is charged and placed in electric field *E*

(1) $g' = g - \frac{qE}{m}$

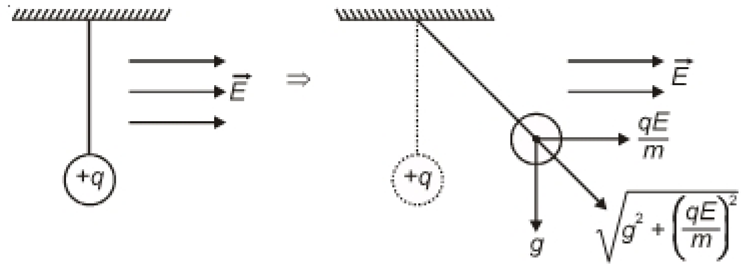
$$T = 2\pi\sqrt{\frac{l}{g - \frac{qE}{m}}}$$



(2) $T = 2\pi\sqrt{\frac{l}{g}}$



(3) $T = 2\pi\sqrt{\dfrac{l}{\sqrt{g^2 + \left(\dfrac{qE}{m}\right)^2}}}$



Seconds Pendulum

T = 2 sec

$T = 2\pi\sqrt{\dfrac{l}{g}}$

l = 99 cm $\simeq$ 1 m

$T \propto \sqrt{l}$ if l is very large then (comparable to R_e)

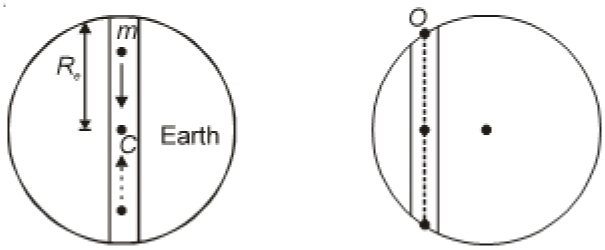
$T = 2\pi\sqrt{\dfrac{R_e}{\left(1+\dfrac{R_e}{l}\right)g}}$

Case - I : $l = R_e \Rightarrow T = 2\pi\sqrt{\dfrac{R_e}{2g}}$ = 60 min. ⇒ 1 hour

Case - II : $l >> R_e$ $T = 2\pi\sqrt{\dfrac{R_e}{g}} = 60\sqrt{2}$ min ⇒ 1.4 hour

Some Other Systems Executing S.H.M.

(1) **A body is released in a tunnel along the diameter of earth**



also $T = 2\pi\sqrt{\dfrac{R_e}{g}}$

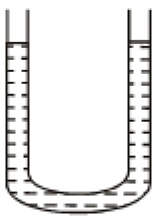
(i) $T = 2\pi\sqrt{\dfrac{R_e}{g}}$ = 84.6 min.

(ii) Amplitude of oscillation $\le R_e$.

(2) **Oscillation of a liquid in U tube**

If l = total length of liquid column, then

$T = 2\pi\sqrt{\dfrac{l}{2g}}$



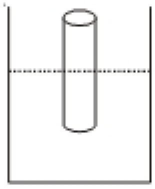
(3) **Oscillation of a Floating Cylinder**

$$T = 2\pi\sqrt{\frac{L\sigma}{\rho g}}$$

where σ : density of cylinder

ρ : density of liquid

L : length of cylinder

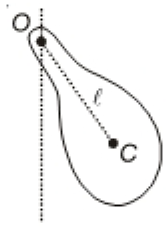


(4) **Compound Pendulum**

$$T = 2\pi\sqrt{\frac{I}{mg\ell}}$$

where ℓ : distance between point of oscillation and CM

I : moment of inertia about point of oscillation

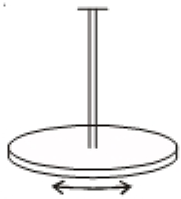


(5) **Torsional Pendulum**

$$T = 2\pi\sqrt{\frac{I}{C}}$$

where I : moment of inertia

C : torsional constant (torque per unit twist)



Damped Oscillations

There is a continuous loss of energy of the oscillating particle due to presence of dissipative forces. Let the dissipative or resistive force $F \propto v$

i.e. $F = -bv$

Total force $= ma = F_{resistive} + F_{dissipative}$

$$\Rightarrow \frac{d^2x}{dt} + \frac{b}{m}\frac{dx}{dt} + \frac{k}{m}x = 0$$

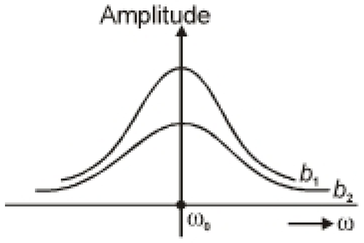
These oscillation are given by $x = A_0 e^{-\frac{b}{2m}t}\cos(\omega' t + \phi)$, where, $A_0 e^{-\frac{b}{2m}t}$ = Amplitude of damped oscillation which decreases exponentially and $\omega' = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}$ is the angular frequency of damped oscillation.

i.e. after T second, if $A = \frac{A_0}{N}$, then after $2T$ second, $A = \frac{A_0}{N^2}$ and so on.

Forced Oscillations

A body oscillates under the action of external force $F = F_0\sin\omega t$. After some time, body starts oscillating with frequency ω. Let ω_0 = natural frequency of body then

When $\omega = \omega_0$, Velocity amplitude of oscillations is maximum. This state is resonance. Energy of the oscillations is also maximum in this state.



$b_1 < b_2 \Rightarrow$ less resistive forces means sharp resonance.

❑ ❑ ❑

Try Yourself

SECTION - A

Objective Type Questions

1. What is the minimum time taken by a particle in SHM of time period T from the point of maximum displacement to that at which the displacement is half the amplitude?

   (1) $\frac{T}{4}$ (2) $\frac{T}{8}$

   (3) $\frac{T}{12}$ (4) $\frac{T}{6}$

2. The force on a body executing SHM is 2N, when the displacement is 3 cm. When the displacement is 5 cm the force on the body is

   (1) 1.2 N (2) 3.33 N

   (3) 2 N (4) 0.36 N

3. When a mass undergoes simple harmonic motion, there is always a constant ratio between its displacement and

   (1) Period (2) Mass

   (3) Acceleration (4) Velocity

4. A particle moves according to the equation $x = a\cos\pi t$. The distance covered by it in 2.5 s is

   (1) 3 a (2) 5 a

   (3) 2 a (4) 9 a

5. If the displacement equation of a particle be represented by $y = A \sin \pi t + B \cos \pi t$, the particle executes

   (1) Uniform circular motion

   (2) SHM

   (3) A uniform elliptical motion

   (4) A rectilinear motion

6. The velocity and acceleration of a particle executing SHM have a steady phase relationship. The acceleration leads velocity in phase by

   (1) $+\pi$ (2) $\frac{+\pi}{2}$

   (3) $\frac{-\pi}{2}$ (4) $-\pi$

7. What fraction of the total energy is potential when the displacement is one-half of the amplitude?

   (1) $\frac{1}{4}$ (2) $\frac{2}{4}$

   (3) $\frac{3}{4}$ (4) $\frac{3.5}{4}$

8. Which of the following quantities are always positive in a simple harmonic motion? [Letters have usual meanings]

   (1) $\vec{F}.\vec{a}$ (2) $\vec{V}.\vec{r}$

   (3) $\vec{a}.\vec{r}$ (4) $\vec{F}.\vec{r}$

9. A particle executes SHM of amplitude 5 cm and period 3 s. The velocity of the particle at a distance 4 cm from the mean position (taken $\pi = 3$) is

   (1) 8 cm/s (2) 12 cm/s

   (3) 4 cm/s (4) 6 cm/s

10. The maximum energy of a body executing SHM of amplitude 2 cm is E. If the same body executes SHM of amplitude 3 cm but same period, the maximum energy will be

    (1) E

    (2) $\frac{2}{3}E$

    (3) $\frac{3}{2}E$

    (4) $\frac{9}{4}E$

11. Two pendula have time periods T and $\frac{5T}{4}$. They start SHM at the same time from the mean position. What will be the phase difference between them after the bigger pendulum has completed one oscillation?

    (1) 45° (2) 90°

    (3) 60° (4) 80°

12. A simple pendulum of length l_1 has a time period of 4s and another simple pendulum of length l_2 has a time period of 3s. Then the time period of another pendulum of length $(l_1 - l_2)$ is

    (1) $\sqrt{3}$ s (2) 1 s

    (3) $\sqrt{\frac{3}{4}}$ s (4) $\sqrt{7}$ s

13. The length of the seconds pendulum on the surface of earth is 1 m. Its length on the surface of Moon, where g is $\frac{1}{6}$th the value of g on the surface of earth is

    (1) $\frac{1}{6}$ m (2) 6 m

    (3) $\frac{1}{36}$ m (4) 36 m

14. A simple pendulum has a period T. What will be the percentage change in the period if the amplitude is decreased by 6%?

    (1) 6 % (2) 3 %

    (3) 1.5 % (4) No change

15. For a simple pendulum, the graph between l and T is

    (1) Hyperbola (2) Curved line

    (3) Straight line (4) Parabola

16. The tension in the string of a simple pendulum is

    (1) Constant

    (2) Maximum in the extreme position

    (3) Zero in the mean position

    (4) Maximum at mean position

17. Which of the following represents simple harmonic motion?

    (1) $y = a\sin\omega t + b\sin 2\omega t$

    (2) $y = a\sin\omega t + b\cos 2\omega t$

    (3) $y = a\sin\omega t$

    (4) $y = \sin^2\omega t + \cos^2\omega t$

18. A second's pendulum is placed in a space laboratory orbiting around the earth at a height of $3R$, where R is the radius of earth. The time period of the pendulum is

    (1) Infinite (2) Zero

    (3) 4 s (4) $2\sqrt{3}$ s

19. A pendulum suspended from the ceiling of a train has a period T when the train is at rest. When the train is accelerating with a uniform acceleration, the period of oscillation will

    (1) Increase

    (2) Decrease

    (3) Remain unaffected

    (4) Become infinite

20. The time period of a simple pendulum measured inside a stationary lift is T. If the lift starts moving upward with an acceleration of $g/3$, what will be its time period?

    (1) $\frac{T}{3}$

    (2) $3T$

    (3) $\frac{\sqrt{3}}{2}T$

    (4) $\sqrt{\frac{3}{2}}T$

21. A clock P is based on oscillation of a spring and another clock Q is based on pendulum motion. Both the clocks run at the same rate on Earth. Both the clocks are then taken to a planet having same density as Earth but twice the radius. Then

    (1) P will run faster than Q

    (2) Q will run faster than P

    (3) Both will run at the same rates as on Earth

    (4) Both will run at equal rates but faster than on earth

22. If acceleration due to gravity is halved, then the frequency f of oscillation of a spring becomes

    (1) $2f$ (2) $4f$

    (3) $\frac{f}{2}$ (4) No effect

23. A uniform spring of force constant k is cut into two pieces, the lengths of which are in the ratio 1 : 2. The ratio of the force constants of the shorter and the longer pieces is

    (1) 1 : 2 (2) 2 : 3

    (3) 2 : 1 (4) 1 : 3

24. A mass on the end of a spring undergoes simple harmonic motion with a frequency of 0.5 Hz. If the attached mass is reduced to one quarter of its value, then the new frequency in Hz is

    (1) 4.5 (2) 2.0

    (3) 0.25 (4) 1.0

25. If the mass of an oscillator is numerically equal to its force constat, then the frequency is

(1) π (2) 2π

(3) $\frac{1}{\pi}$ (4) $\frac{1}{2\pi}$

26. What change in mass is required to double the frequency of a spring-mass harmonic oscillator?

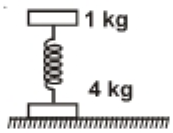
(1) The mass must be reduced to one-forth of its original value

(2) The mass must be reduced to half its original value

(3) The mass must be doubled

(4) The mass must be increased to four-times its original value

27. Refer to figure. One kg block performs vertical harmonic oscillation with amplitude 1.6 cm and frequency 25 rad/s. The maximum value of force that the system exerts on the surface is



(1) 20 N (2) 30 N

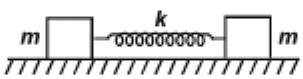
(3) 40 N (4) 60 N

28. The equation of an SHM of amplitude *a* and angular frequency ω in which all the distances are measured from one mean position and time is taken to be zero at other extreme position is

(1) $x = a \sin \omega t$ (2) $x = a \cos \omega t$

(3) $x = a - a \sin \omega t$ (4) $x = a + a \cos \omega t$

29. Consider the situation as in figure. If the blocks are pressed slightly in opposite directions and released, they will execute simple harmonic motion. The time period is



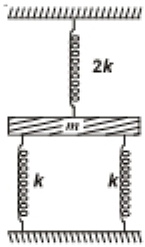
(1) $2\pi\sqrt{\frac{m}{k}}$

(2) $2\pi\sqrt{\frac{m}{2k}}$

(3) $2\pi\sqrt{\frac{m}{5k}}$

(4) $2\pi\sqrt{\frac{m}{9k}}$

30. What is the spring constant for the combination of spring as in figure?



(1) k (2) $2k$

(3) $4k$ (4) $\frac{5k}{2}$

31. A mass attached to a vertical spring produce elongation Δ in equilibrium. The time period of oscillation will be

(1) $\frac{1}{\pi}\sqrt{\frac{g}{\Delta}}$ (2) $2\pi\sqrt{\frac{\Delta}{g}}$

(3) $\frac{1}{2\pi}\sqrt{\frac{g}{\Delta}}$ (4) Data insufficient

32. A second's pendulum gives correct time on the surface of moon. What will be its time period on the earth's surface?

(1) 2 s (2) $2\sqrt{6}$ s

(3) $\frac{2}{\sqrt{6}}$ s (4) $6\sqrt{2}$ s

33. Which of the following function of time is periodic?

(1) $\sin \omega t + \cos \omega t$ (2) $e^{-\omega t}$

(3) $\log \omega t$ (4) All of these

34. A simple pendulum of effective length *l* is hanging from a ceiling of a trolley which is coming down an inclined plane of an angle θ with a constant velocity. The time period of simple pendulum is given by

(1) $2\pi\sqrt{\frac{l}{g\cos\theta}}$ (2) $2\pi\sqrt{\frac{l}{g\sin\theta}}$

(3) $2\pi\sqrt{\frac{l}{g\tan\theta}}$ (4) $2\pi\sqrt{\frac{l}{g}}$

35. Which of the following equation does not represent SHM?

(1) $y = A \sin \omega t + B \sin 2\omega t + C \sin 3\omega t$

(2) $y = a \sin \omega t + b \cos \omega t$

(3) $y = a \sin 2\omega t$

(4) $y = b \cos 4\omega t$

36. A uniform spring having force constant k is cut into two parts having lengths in the ratio 2 : 3. If identical blocks are attached to them and made to oscillate, ratio of their time period is

(1) $\sqrt{\frac{2}{5}}$

(2) $\sqrt{\frac{3}{5}}$

(3) $\sqrt{\frac{2}{3}}$

(4) $\sqrt{\frac{3}{2}}$

37. If the velocity of particle performing S.H.M. are 4 m/s and 2 m/s at its displacement 2 cm and 4 cm respectively, then its angular frequency in rad/s is

(1) 1 (2) 10

(3) 100 (4) 0.1

38. The displacement of a particle executing S.H.M. is given by $y = 0.04 \sin\left(10t - \frac{\pi}{4}\right)$, where y is in metre and t is in second. The maximum speed of the particle will be (in ms^{-1})

(1) 0.04 (2) 0.4

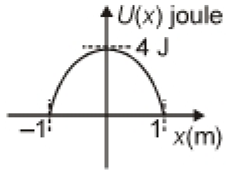
(3) 4.0 (4) 0.1

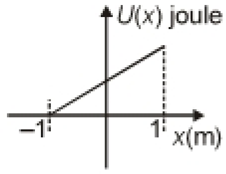
39. The time period of oscillations of a mass attached to spring is T. The spring is now cut into four equal parts and the same mass is oscillated with one part. The new time period will be

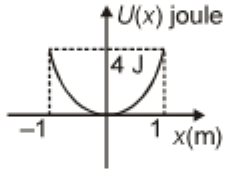
(1) $2T$ (2) $\frac{T}{2}$

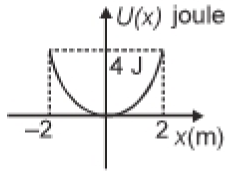
(3) $\frac{T}{4}$ (4) T

40. A particle of mass 2 kg moves simple harmonically such that its maximum speed is 2 m/s. The period of oscillation is π. Then the correct variation of potential energy with position is as

(1) 

(2) 

(3) 

(4) 

41. The time period of oscillation of a simple pendulum of length $2R$ on the surface of earth is about [where R is radius of earth]

(1) 1.4 h (2) 1.14 h

(3) 1.2 h (4) 14.4 h

42. The value of acceleration averaged over one time period in a SHM will be

(1) Non-zero but cannot be specified

(2) Zero

(3) Half of the maximum acceleration

(4) One fourth of maximum acceleration

43. S.H.M of a particle is described by an equation $y = P \cos\omega t + Q$. The amplitude of S.H.M is

(1) P (2) $\sqrt{P^2 + Q^2}$

(3) $P + Q$ (4) Q

44. Amplitude of oscillations of a particle decreases to half in 5 minute. The percentage decrease in its maximum kinetic energy in 10 minute is

(1) 6.25% (2) 93.75%

(3) 12.5% (4) 87.5%

45. A block of mass 8 kg is suspended from a spring of force constant 200 N/m. The time period (in second) of vertical oscillations is

(1) $\frac{2\pi}{5}$ (2) $\frac{\pi}{10}$

(3) $\frac{5\pi}{10}$ (4) $\frac{7\pi}{10}$

46. Equation of damped oscillation is given by $\frac{md^2x}{dt^2} + \frac{bdx}{dt} + kx = 0$ (Notation have their usual meaning). With time, frequency of oscillations will
   (1) Decrease
   (2) Increase
   (3) Remain unchanged
   (4) Uncertain behaviour

SECTION - B

Previous Years Questions

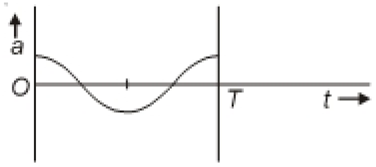
1. The oscillation of a body on a smooth horizontal surface is represented by the equation,

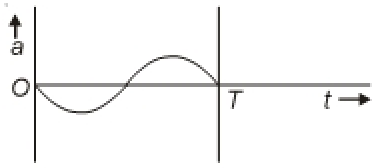
   $X = A\cos(\omega t)$

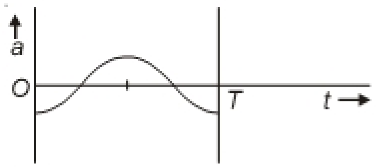
   where X = displacement at time t

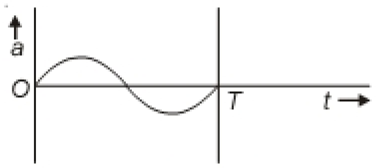
   ω = frequency of oscillation

   Which one of the following graphs shows correctly the variation acceleration a with t? **[AIPMT 2014]**

   (1) 

   (2) 

   (3) 

   (4) 

   Here, a = acceleration at time t, T = time period

2. A particle is executing a simple harmonic motion. Its maximum acceleration is α and maximum velocity is β. Then, its time period of vibration will be **[Re-AIPMT - 2015]**
   (1) $\frac{2\pi\beta}{\alpha}$
   (2) $\frac{\beta^2}{\alpha^2}$
   (3) $\frac{\alpha}{\beta}$
   (4) $\frac{\beta^2}{\alpha}$

3. A particle is executing SHM along a straight line. Its velocities at distances x_1 and x_2 from the mean position are V_1 and V_2 respectively. Its time period is **[AIPMT - 2015]**
   (1) $2\pi\sqrt{\frac{V_1^2 - V_2^2}{x_1^2 - x_2^2}}$
   (2) $2\pi\sqrt{\frac{x_1^2 + x_2^2}{V_1^2 + V_2^2}}$
   (3) $2\pi\sqrt{\frac{x_2^2 - x_1^2}{V_1^2 - V_2^2}}$
   (4) $2\pi\sqrt{\frac{V_1^2 + V_2^2}{x_1^2 + x_2^2}}$

4. When two displacements represented by $y_1 = a\sin(\omega t)$ and $y_2 = b\cos(\omega t)$ are superimposed the motion is **[AIPMT - 2015]**
   (1) Simple harmonic with amplitude $\frac{(a+b)}{2}$
   (2) Not a simple harmonic
   (3) Simple harmonic with amplitude $\frac{a}{b}$
   (4) Simple harmonic with amplitude $\sqrt{a^2+b^2}$

5. A body of mass m is attached to the lower end of a spring whose upper end is fixed. The spring has negligible mass. When the mass m is slightly pulled down and released, it oscillates with a time period of 3 s. When the mass m is increased by 1 kg, the time period of oscillations becomes 5 s. The value of m in kg is **[NEET (Phase-2) 2016]**
   (1) $\frac{3}{4}$
   (2) $\frac{4}{3}$
   (3) $\frac{16}{9}$
   (4) $\frac{9}{16}$

6. A particle executes linear simple harmonic motion with an amplitude of 3 cm. When the particle is at 2 cm from the mean position, the magnitude of its velocity is equal to that of its acceleration. Then its time period in seconds is **[NEET-2017]**
   (1) $\frac{\sqrt{5}}{\pi}$
   (2) $\frac{\sqrt{5}}{2\pi}$
   (3) $\frac{4\pi}{\sqrt{5}}$
   (4) $\frac{2\pi}{\sqrt{3}}$

7. A pendulum is hung from the roof of a sufficiently high building and is moving freely to and fro like a simple harmonic oscillator. The acceleration of the bob of the pendulum is 20 m/s^2 at a distance of 5 m from the mean position. The time period of oscillation is **[NEET-2018]**
   (1) 2π s
   (2) π s
   (3) 1 s
   (4) 2 s

8. The displacement of a particle executing simple harmonic motion is given by

$y = A_0 + A\sin\omega t + B\cos\omega t$

Then the amplitude of its oscillation is given by **[NEET-2019]**

(1) $A_0 + \sqrt{A^2 + B^2}$ (2) $\sqrt{A^2 + B^2}$

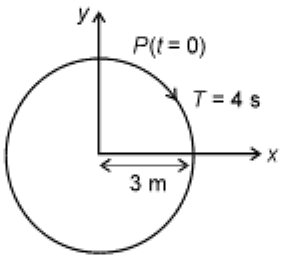
(3) $\sqrt{A_0^2 + (A + B)^2}$ (4) $A + B$

9. Average velocity of a particle executing SHM in one complete vibration is **[NEET-2019]**

(1) $\frac{A\omega}{2}$ (2) $A\omega$

(3) $\frac{A\omega^2}{2}$ (4) Zero

10. The radius of circle, the period of revolution, initial position and sense of revolution are indicated in the figure



y - projection of the radius vector of rotating particle P is **[NEET-2019]**

(1) $y(t) = -3\cos 2\pi t$, where y in m

(2) $y(t) = 4\sin\left(\frac{\pi t}{2}\right)$, where y in m

(3) $y(t) = 3\cos\left(\frac{3\pi t}{2}\right)$, where y in m

(4) $y(t) = 3\cos\left(\frac{\pi t}{2}\right)$, where y in m

11. The distance covered by a particle undergoing SHM in one time period is (amplitude = A),

[NEET-2019 (Odisha)]

(1) 4A (2) Zero

(3) A (4) 2A

12. A mass falls from a height 'h' and its time of fall 't' is recorded in terms of time period T of a simple pendulum. On the surface of earth it is found that $t = 2T$. The entire set up is taken on the surface of another planet whose mass is half of that of earth and radius the same. Same experiment is repeated and corresponding times noted as t' and T'. Then we can say **[NEET-2019 (Odisha)]**

(1) $t' = 2T'$ (2) $t' = \sqrt{2}T'$

(3) $t' > 2T'$ (4) $t' < 2T'$

❑ ❑ ❑

Chapter 13

Waves

Sub-topics *Wave motion. Longitudinal and transverse waves, speed of wave motion. Displacement relation for a progressive wave. Principle of superposition of waves, reflection of waves, standing waves in strings and organ pipes, fundamental mode and harmonics. Beats. Doppler effect.*

Wave Motion

A disturbance which propagates energy and momentum without transport of matter.

Longitudinal and Transverse Waves

Mechanical waves or elastic waves

(1) They require a medium for their propagation.

(2) A medium requires elasticity and inertia (density) for propagation of mechanical waves.

(3) They are of two types

S. No.	Transverse	Longitudinal
1	Particles of the medium vibrate at right angles to the direction of wave motion	Particles of the medium vibrate in the direction of wave motion
2	Particle velocity is always perpendicular to wave velocity	Particle velocity is parallel or antiparallel to wave velocity
3	Waves on strings are always transverse	Cannot be produced on stretched strings
4	They can be polarised	Cannot be polarised
5	Do not exist in gases/liquids as they do not possess shear modulus or modulus of rigidity	Can exist in a solid, liquid or gas

(4) Type of mechanical wave depends on nature of medium and mode of excitation.

Non-Mechanical Waves

(1) They do not require material medium for their propagation.

(2) Electromagnetic waves are non-mechanical.

(3) Elasticity or inertia do not affect their propagation.

(4) They are always transverse in nature.

Velocity of wave motion

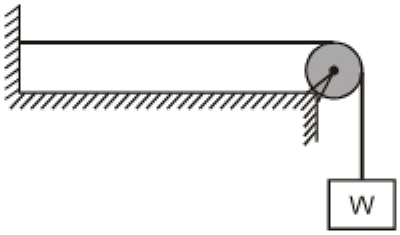
(1) Velocity of non-mechanical *i.e.* electromagnetic wave

is $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

where μ_0 = absolute permeability

ε_0 = absolute permittivity

(2) Velocity of mechanical waves



(a) Transverse wave in a stretched string

T = tension in the string

μ = mass per unit length

D = diameter of the string

ρ = density

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{\text{stress}}{\text{density}}} = \frac{2}{D}\sqrt{\frac{T}{\pi\rho}}$$

(b) Longitudinal waves in a long bar $v = \sqrt{\frac{Y}{\rho}}$ Y = Young's modulus

(c) Longitudinal Waves in liquid $v = \sqrt{\frac{K}{\rho}}$ K = Bulk modulus of elasticity

ρ = Density

(d) Longitudinal Waves in gases $v = \sqrt{\frac{K}{\rho}}$. For gases, K depends upon the process.

Case - I :

As per Newton, by taking propagation of longitudinal wave as isothermal process $K = P \Rightarrow \sqrt{\frac{P}{\rho}}$

Put P = 1 atm = 1.01×10^5 Nm^{-2}, ρ = 1.29 kg/m^3 $\Rightarrow$ v = 280 m/s, experimentally proved to be wrong

Case - II :

Corrected by Laplace by taking propagation of longitudinal wave as adiabatic process

$K = \gamma P$

$$v = \sqrt{\frac{\gamma P}{\rho}} \qquad (\gamma = 1.4)$$

$\Rightarrow$ v = 331.3 ms$^{-1,}$ which agress with the measured speed

Factors affecting velocity of sound

(1) v is independent of pressure

(2) $v \propto \frac{1}{\sqrt{\rho}}$ or $v \propto \frac{1}{\sqrt{M}}$

For a mixture of gases containing n_1 moles of molecular mass M_1 and n_2 moles of molecular mass M_2

$$M_{mix} = \frac{n_1M_1 + n_2M_2}{n_1 + n_2}, \quad \frac{n_1 + n_2}{\gamma_{mix} - 1} = \frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1}$$

where γ_1, γ_2 are adiabatic exponent of gases

(3) $v \propto \sqrt{T}$

(4) Velocity of sound in humid air is more because its density is very less.

(5) Velocity of sound in humid hydrogen is less than in dry hydrogen due to similar reason.

Velocity of a wave depends on medium.

Now $v = \nu\lambda$

ν = frequency of wave, which is a constant.

λ = wavelength

$\lambda \propto v$

As a wave changes medium its speed and wavelength change but frequency remains same.

Principle of Superposition of Waves

When two or more than two waves propagate in a medium simultaneously, the displacement of a medium particle is algebraic sum of displacement produced by individual waves.

Displacement relation for a progressive wave.

$y = A\sin k(x - vt) = A\sin(kx - \omega t)$, where, $v = \frac{\omega}{k}$ = wave velocity

y = displacement of particle at a time 't' which is situated at a distance x from origin.

The particle executes SHM about its mean position

v_p = particle velocity = $\frac{dy}{dt} = A\omega\cos(kx - \omega t)$

Maximum particle velocity = $A\omega$

$y = A\sin(kx - \omega t + \phi)$ is travelling towards + x-axis

$y = A\sin(\omega t - kx + \phi)$ is travelling towards + x-axis

$y = A\sin(\omega t + kx + \phi)$ is travelling towards – x-axis

$v = \frac{\omega}{k}$ = wave velocity

$k = \frac{2\pi}{\lambda}$ = angular wave number or propagation constant

λ = wavelength

$\omega = 2\pi\nu = \frac{2\pi}{T}$

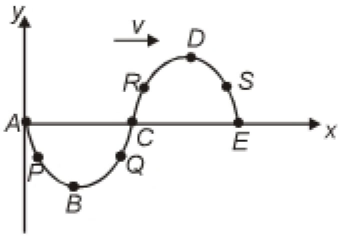
ν = frequency of wave

T = time period of oscillation of particle

= time taken by the wave to cover a distance 'λ'

***y* = *A* sin(ω*t* – *kx*)**

at $t = 0$, photograph of the wave is



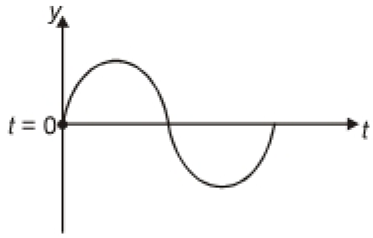
$y = A\sin(-kx)$

Particles at *A*, *P*, *S*, *E* are moving upwards

Particles at *Q*, *C*, *R* are moving downwards

Particles at *B* and *D* are at rest

For the particle at $x = 0$

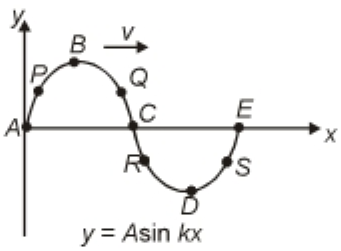


$y = A\sin\omega t$

This particle is moving upward at $t = 0$

***y* = *A* sin(*kx* – ω*t*)**

at $t = 0$, photograph of the wave is

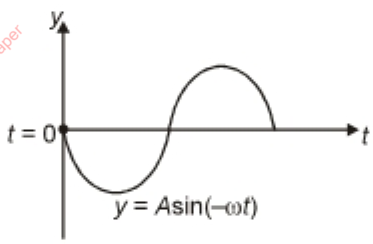


Particles at *A*, *P*, *S*, *E* are moving downwards

Particles at *Q*, *C*, *R* are moving upwards

Particles at *B* and *D* are at rest

For the particle at $x = 0$



This particle is moving downward at $t = 0$

(i) In general, points with positive slope $\left(\frac{dy}{dx}\right)$ move downward.

(ii) The points with negative slope move upward.

(iii) The points with maximum slope (*A*, *C*, *E*) have maximum velocity.

(iv) The points with zero slope are at rest.

Sound Waves

They are mechanical, longitudinal waves. They propagate in the form of compressions and rarefactions. Particle displacements can be represented by wave function

$y = A\sin(\omega t - kx)$

As particles oscillate, pressure variation takes place according to the wave function.

$\Delta P = \Delta P_0 \cos(\omega t - kx)$, ΔP_0 = maximum pressure variation

(i) Points where displacement is maximum, pressure variation is zero *i.e.* there is a phase difference of 90° between pressure wave and displacement wave.

(ii) **Infrasonic Waves :**

Sound below 20 Hz. (produced during earthquakes)

(iii) **Audible Waves :**

20 to 20,000 Hz

(iv) **Ultrasonic Waves :**

Frequency > 20,000 Hz

(v) **Shock Waves :**

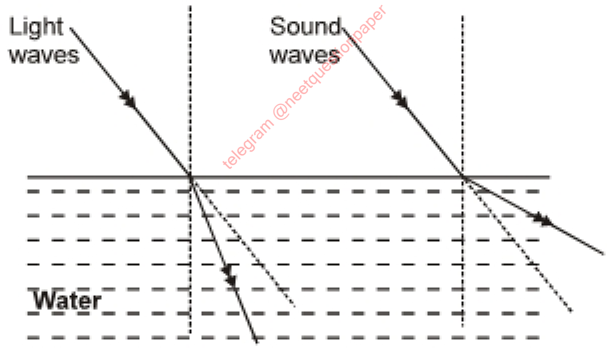
A body moving with speed greater than speed of sound (supersonic speed) produces a conical disturbance called a shock wave.

Refraction of Waves

Rarer Medium : A medium in which speed of wave is greater.

Denser Medium : A medium in which speed of wave is smaller.

For example, in case of light, air is rare medium and water is denser medium as speed of light is more in air than in water.

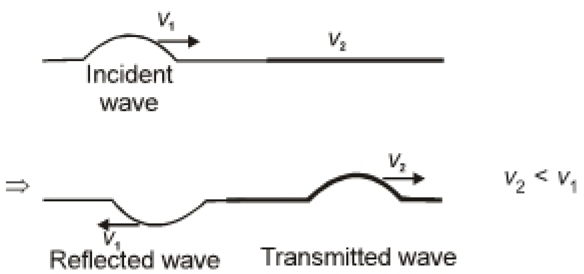


In case of sound air is denser medium and water is rare medium as speed of sound in air is less than that in water.

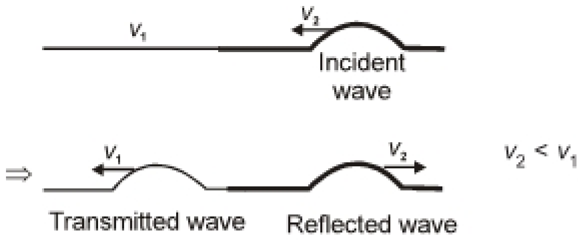
Reflection of Waves

At the interface of a rarer and denser medium.

(a) Wave is moving from rarer to denser medium.



(b) Wave is moving from denser to rarer medium

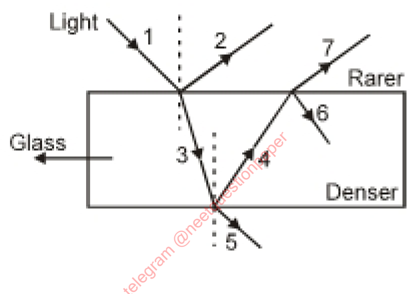


(i) The transmitted wave is always in phase with incident wave.

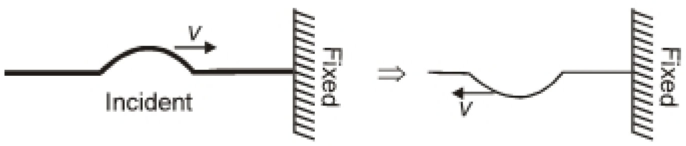
(ii) When the reflected wave is in rarer medium as in case (a), it is 180° out of phase with incident wave.

(iii) Ray 1 and 2 have a phase difference of 180°.

(iv) Ray 1, 3, 5, 4, 6, 7 are all in phase with each other.



Reflection from fixed end :



Reflection from free end :

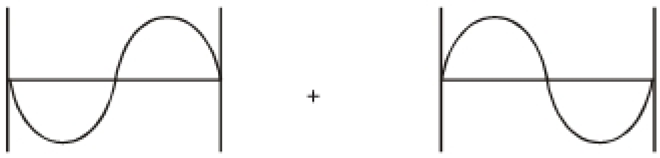
Standing Waves

When two waves identical in all respects, but travelling in opposite direction along a straight line, superimpose each other, standing waves are produced.

(i) Longitudinal stationary waves are formed in organ pipes.

(ii) Transverse stationary waves are formed in sonometer wire.

Let $y_1 = A\sin(\omega t - kx)$ and $y_2 = A\sin(\omega t + kx)$



$\Rightarrow$ $y = y_1 + y_2 = 2A\cos kx \sin\omega t$

$2A\cos kx$ represents the amplitude of the particle located at 'x'.

(iii) For $x = 0$, $x = \frac{\lambda}{2}, \lambda$ and so on, amplitude is maximum *i.e.*, $2A$. These points are called antinodes.

(iv) For $x = \frac{\lambda}{4}, \frac{3\lambda}{4}$, ... and so on amplitude is minimum *i.e.*, *O*. These points are called nodes.

(v) Distance between consecutive nodes = distance between consecutive antinodes = $\frac{\lambda}{2}$.

(vi) Distance between adjacent node and antinodes = $\frac{\lambda}{4}$.

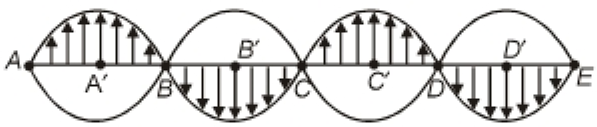
(vii) All the particles in same loop *i.e.*, between two adjacent nodes vibrate in same phase.

(viii) Particles on the opposite side of a node vibrate in opposite phase.

(ix) Node is always at rest. There is no transfer of energy across a node.

(x) In longitudinal stationary waves, a point where displacement node is formed, pressure is maximum *i.e.*, pressure antinode is formed.

(xi) All the particles of medium pass through their mean position simultaneously twice in each time period.

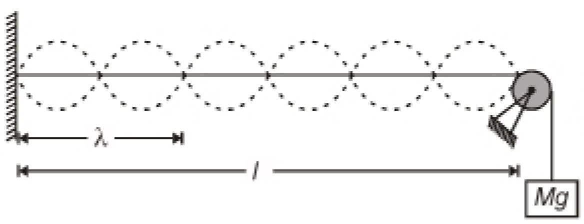


A, *B*, *C*, *D*, *E* are nodes.

A′, *B*′, *C* ′, *D*′ are antinodes.

Standing Waves in a String

Sonometer :



The wire vibrates in n loops, then

$$l = \frac{n\lambda}{2} \text{ or } \lambda = \frac{2l}{n}$$

velocity $v = \sqrt{\frac{T}{\mu}}$ where 'μ' is mass per unit length of wire.

$$\nu_n = \frac{v}{\lambda} = \frac{nv}{2l} = \frac{n}{2l}\sqrt{\frac{T}{\mu}}$$

$$\nu_1 = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$ [Fundamental mode, Ist harmonic]

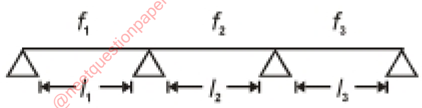
$$\nu_n = \frac{n}{2l}\sqrt{\frac{T}{\mu}}$$ [$(n-1)^{th}$ overtone, n^{th} harmonic]

A wire is divided in three parts whose fundamental frequencies are f_1, f_2 and f_3.

$$l_1 + l_2 + l_3 = l \quad ...(1)$$

$$l_1 : l_2 : l_3 :: \frac{1}{f_1} : \frac{1}{f_2} : \frac{1}{f_3}$$

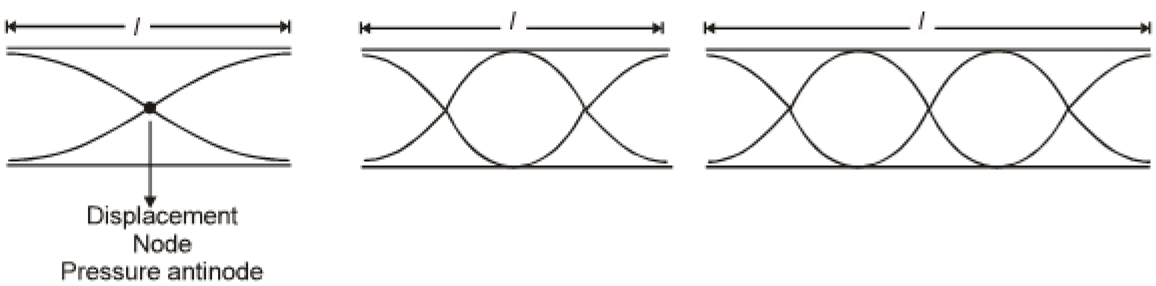
$$\Rightarrow \quad l_1 = \frac{f_2 f_3}{f_1 f_2 + f_2 f_3 + f_1 f_3} l$$



$$l_2 = \frac{f_1 f_3 l}{\Sigma f_1 f_2}, \; l_3 = \frac{f_1 f_2}{\Sigma f_1 f_2} l$$

Organ Pipe

Open organ Pipe :



$l = \frac{\lambda}{2}$ or $\lambda = 2l$

$\nu_1 = \frac{v}{\lambda} = \frac{v}{2l}$

1st harmonic or

Fundamental mode

$l = \lambda$

$\nu_2 = \frac{v}{l} = 2\nu_1$

2nd harmonic

Ist overtone

$l = \frac{3\lambda}{2}$

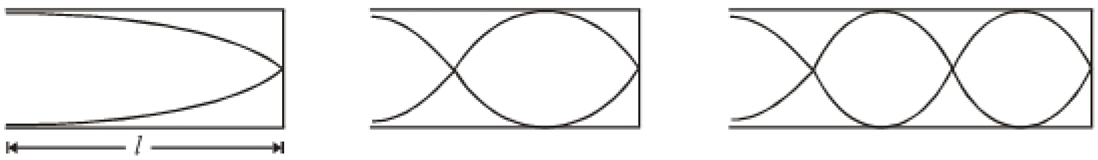
$\lambda = \frac{2l}{3}$

$\nu_3 = \frac{3v}{2l} = 3\nu_1$

3rd harmonic

2nd overtone

Closed organ pipe :



$l = \frac{\lambda}{4} \Rightarrow \lambda = 4l$

$\nu_1 = \frac{v}{4l}$

Fundametal mode

1st harmonic

$l = \frac{3\lambda}{4} \Rightarrow \lambda = \frac{4l}{3}$

$\nu_2 = \frac{3v}{4l}$

1st overtone

3rd harmonic

$l = \frac{5\lambda}{4}$ $\lambda = \frac{4l}{5}$

$\nu_3 = \frac{5v}{4l}$

2nd overtone

5th harmonic

Pipe length 'l'	Fundamental Mode	Ist Overtone	n^{th} overtone	Ratio of Successive frequencies
Open	$\nu_1 = \frac{v}{2l}$ Ist Harmonic	$\nu_2 = \frac{v}{l}$ 2nd Harmonic	$\nu_n = (n+1)\frac{v}{2l}$ $(n+1)^{th}$ Harmonic	1 : 2 : 3 : 4
Close	$\nu_1 = \frac{v}{4l}$ Ist Harmonic	$\nu_2 = \frac{3v}{4l}$ 3rd Harmonic	$\nu_n = (2n+1)\frac{v}{4l}$ $(2n+1)^{th}$ Harmonic	1 : 3 : 5 : 7

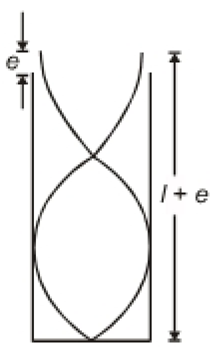
***Note :** Even numbered (i.e. 2nd, 4th .....) harmonics do not exist in close organ pipe.*

End correction :

The antinodes are formed slightly outside the open end.

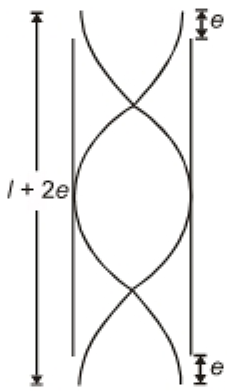
$e = 0.6r$ = end correction

For closed organ pipe



$\nu = \frac{(2n-1)V}{4(l+e)}$

For open organ pipe



$\nu = \frac{nV}{2(l+2e)}$

Resonance Tube :

Resonance is obtained first at length l_1. Then at length l_2.

As v and ν remain same

$\therefore$ λ is same for both

first case $\frac{\lambda}{4} = l_1$

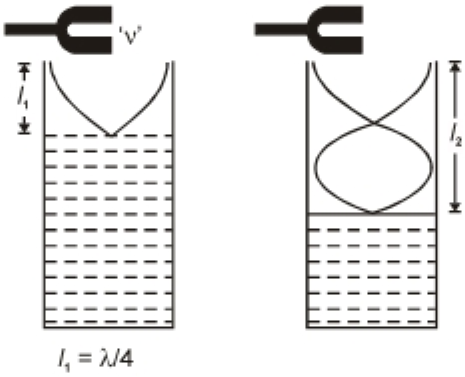
For 2[nd] case $\frac{3\lambda}{4} = l_2$

$l_2 - l_1 = \frac{\lambda}{2}$

$\Rightarrow \lambda = 2(l_2 - l_1)$

$\Rightarrow$ distance between two successive lengths is $\frac{\lambda}{2}$

$v = \nu\lambda = 2\nu(l_2 - l_1)$



Beats

It is the phenomenon of periodic variation in intensity at a particular position on account of superposition of waves of nearly equal frequencies.

When two waves of same amplitude and nearly equal frequencies ν_1 and ν_2 superimpose on each other,

(a) The amplitude at a given position varies with frequency $\left|\frac{\nu_1 - \nu_2}{2}\right|$.

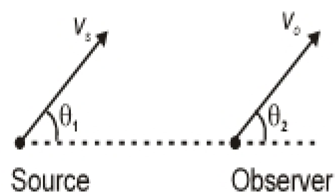
(b) The intensity at a given position varies with frequency $|\nu_1 - \nu_2|$. This frequency of variation of intensity is called beats frequency.

To observe the phenomenon of beats, beats frequency should be less than 10 Hz.

Doppler Effect

In Sound :

$$\nu' = \left(\frac{v - v_o \cos\theta_2}{v - v_s \cos\theta_1}\right)\nu \quad (v = \text{velocity of sound})$$



The direction from source to observer is taken as positive.

The direction from observer to source is taken as negative

In Light :

$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$

v = velocity of separation of source and observer. If source and observer move towards each other, v is negative.

telegram @neetquestionpaper

Application of beats and Doppler effect :

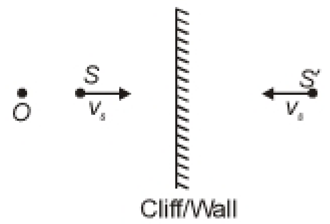
Case - I :

Observer at rest, source moving towards the wall

f = frequency of source v_s = velocity of source

f' = frequency of direct sound v = velocity of sound

f'' = frequency of reflected sound



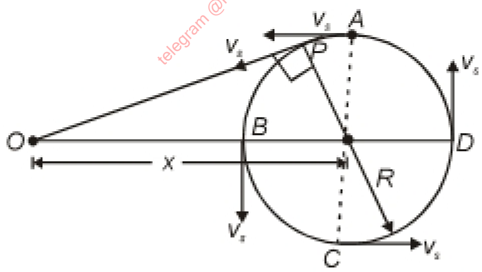
$$f' = \left(\frac{v}{v+v_s}\right)f \qquad \text{(source moving away)}$$

$$f'' = \left(\frac{v}{v-v_s}\right)f \qquad \text{(source moving towards)}$$

$$\text{beats} = f'' - f' = \left(\frac{v}{v-v_s} - \frac{v}{v+v_s}\right)f = \left(\frac{v \times 2v_s}{v^2 - v_s^2}\right)f$$

Case - II :

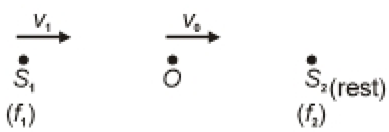
A source of frequency 'f' is revolving in a circle of radius R with speed v_s. An observer is standing at a distance x from the centre in the same plane.



At B and D, observed frequency is 'f' but at 'P' frequency is maximum as $OP \perp PR$.

$$f' = \left(\frac{v}{v-v_s}\right)f \qquad OP = \sqrt{OR^2 - PR^2} = \sqrt{x^2 - R^2}$$

Case - III :

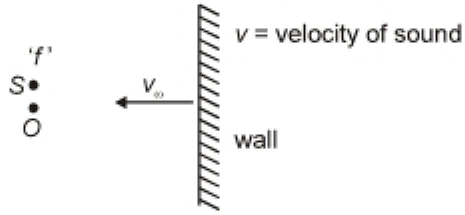


v = velocity of sound

$$f_1' = \left(\frac{v - v_0}{v - v_1}\right)f_1 \qquad \text{beat frequency} = f_1' - f_2'$$

$$f_2' = \left(\frac{v + v_0}{v}\right)f_2$$

Case - IV :



Direct frequency = f

Reflected frequency = $\left(\dfrac{v + v_\omega}{v - v_\omega}\right)f$

Beats frequency = $-f\left(\dfrac{v + v_\omega}{v - v_\omega} - 1\right) = f\left(\dfrac{2v_\omega}{v - v_\omega}\right)$

Case - V :

Two notes of wavelengths λ_1 and λ_2 gives n beats/s with a third note. Then

Let $\lambda_2 > \lambda_1$, $\dfrac{v}{\lambda_1} - \nu_0 = n$

$$\nu_0 - \frac{v}{\lambda_2} = n$$

$$\frac{v}{\lambda_1} - \frac{v}{\lambda_2} = 2n$$

Velocity of sound, $v = \dfrac{2n\,\lambda_1\lambda_2}{(\lambda_2 - \lambda_1)}$

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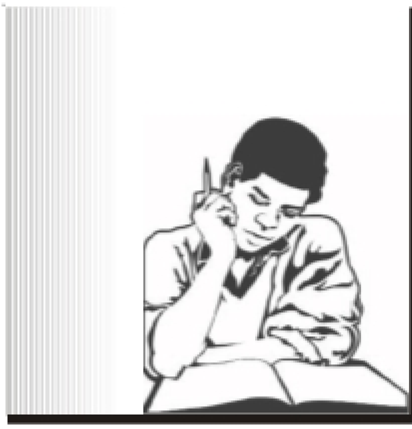


Try Yourself

SECTION - A

Objective Type Questions

1. Velocity of sound in vacuum is
   (1) Zero (2) 330 m/s
   (3) 660 m/s (4) 165 m/s

2. A sound wave travels from air to water. The angle of incidence is α_1 and the angle of refraction is α_2. Assuming Snell's law to be valid,
   (1) $\alpha_2 < \alpha_1$ (2) $\alpha_2 > \alpha_1$
   (3) $\alpha_2 = \alpha_1$ (4) $\alpha_2 = 90°$

3. Which of the following is a mechanical wave?
   (1) Radio wave (2) X-rays
   (3) Light wave (4) Sound wave

4. The rms velocity of the molecules of a gas is c and the velocity of sound in this gas is v. The ratio $\frac{v}{c}$ is
   (1) $\sqrt{\frac{\gamma}{3}}$ (2) $\sqrt{\frac{\gamma}{6}}$
   (3) $\sqrt{\frac{2\gamma}{3}}$ (4) $\sqrt{\gamma}$

5. If T be the tension in a wire, then speed of transverse wave in it is proportional to
   (1) $\sqrt{T}$ (2) T^2
   (3) $T^{3/2}$ (4) T^{-1}

6. The equation $y = 0.02 \sin (500 \pi t) \cos (4.5\, x)$ represents
   (1) A progressive wave of frequency 250 Hz along x-axis
   (2) A stationary wave of wavelength 1.4 m
   (3) A transverse progressive wave of amplitude 0.02 m
   (4) Progressive wave of speed of about 350 m/s

7. A closed organ pipe has a frequency 'n'. If its length is doubled and radius is halved, its frequency will nearly be
   (1) Halved (2) Doubled
   (3) Tripled (4) Quadrupled

8. In open end pipe, first overtone is produced, when the length of pipe is
   (1) $\lambda/4$ (2) $\lambda/3$
   (3) $\lambda/2$ (4) λ

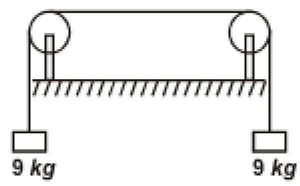
9. Two organ pipes produce 7 beats per second at 5°C. When the temperature rises to 10°C, the number of beats is
   (1) = 7 (2) < 7
   (3) > 7 (4) Data is inadequate

10. Two sound waves travelling in the same direction in a medium superimpose. The amplitude of each wave is A and the phase difference between the two waves is 90°. The resultant amplitude will be
    (1) A (2) $2A$
    (3) $4A$ (4) $\sqrt{2}A$

11. A sonometer wire supports a 4 kg load and vibrates in a fundamental mode with a tuning fork of frequency 416 Hz. The length of the wire between the bridges is now doubled. In order to maintain fundamental mode, the load should be changed to
    (1) 1 kg (2) 2 kg
    (3) 8 kg (4) 16 kg

12. If the wavelengths of a note in two media are in the ratio 3 : 8, the velocities of sound in the two media will be in the ratio
    (1) 3 : 8 (2) 8 : 3
    (3) 9 : 64 (4) 64 : 9

13. The length of the wire as in figure between the pulley is 1.5 m and its mass is 12 g. The frequency of vibration with which the wire vibrates in two loops leaving the middle point of the wire between the pulley at rest is



    (1) 10 Hz (2) 30 Hz
    (3) 40 Hz (4) 70 Hz

14. The beats can't be heard separately, owing to persistence of hearing when the number of beats is more than

(1) 10 per second (2) 12 per second
(3) 11 per second (4) 16 per second

15. A 2 kHz siren and a person are both at rest with respect to earth. What frequency does the person hear if the wind is blowing at 12 m/s from source to observer?

(1) 2 kHz (2) > 2 kHz
(3) < 24 kHz (4) > 24 kHz

16. A tuning fork P of frequency 256 Hz produce 4 beats/s with another tuning fork Q. When a small amount of wax is attached to Q, the number of beats heard per second is 2. The original frequency of the fork Q is

(1) 258 Hz (2) 262 Hz
(3) 260 Hz (4) 256 Hz

17. In expressing sound intensity we take 10^{-12} W m^{-2} as the reference level. For ordinary conversation, the intensity level is about 10^{-6} W m^{-2}. Expressed in decibel, this is

(1) 10^6 (2) 6
(3) 60 (4) $\log_e(10^6)$

18. What is the minimum length of a tube open at both ends, that resonates with a tuning fork of frequency 350 Hz? (Given : Velocity of sound in air = 350 m/s)

(1) 50 cm (2) = 50 cm
(3) 100 cm (4) = 100 cm

19. Given below are some functions of x and t to represent the displacement of an elastic wave. Which function represents a travelling harmonic wave?

(1) $y = 2\cos 3x \sin 10t$
(2) $y = 2\sqrt{x - Vt}$
(3) $y = 3\sin(5x - 0.5t) + 4\cos(5x - 0.5t)$
(4) $y = \cos x \sin t + \cos 2x \sin 2t$

20. A bat's sound emission frequency is 40 kHz. During one fast swoop directly towards a flat wall surface, the bat is moving at a speed 0.03 times the speed of sound in air. The frequency of the reflected sound heard by the bat is

(1) 21.2 kHz (2) 42.47 kHz
(3) 80 kHz (4) 40 kHz

21. In a stretched string equation of a transverse wave is $y = 2\sin\left[2\pi\left(\frac{x}{10} - \frac{t}{0.01}\right)\right]$, where x and y are in m and t in second. The wave velocity is

(1) 1000 m/s (2) 10 m/s
(3) 100 m/s (4) 30 m/s

22. A longitudinal wave is described by the equation $S = S_0 \sin(at + bx)$, then it is propagating towards

(1) Positive x axis with speed $\frac{a}{b}$
(2) Positive x axis with speed $\frac{b}{a}$
(3) Negative x axis with speed $\frac{a}{b}$
(4) Negative x axis with speed $\frac{b}{a}$

23. Decibel is a

(1) Measure of sound level
(2) Musical instrument
(3) Musical note
(4) Measure of intensity

24. Which of the following is minimum audible wavelength (approximately) at room temperature?

(1) 20 mm (2) 20 cm
(3) 20 m (4) 20 km

25. In equation of wave motion $y = a\sin(\omega t - kx)$ the term y can represent

(1) Velocity (2) Pressure
(3) Displacement (4) All of these

26. The transverse displacement of a string (clamped at its both ends) is given by $y(x, t) = 0.06 \sin\left(\frac{2\pi}{3}x\right)\cos(120\pi t)$, where x, y are in m and t is in second. The length of the string is 1.5 m and its mass is 3×10^{-2} kg. The tension in the string is

(1) 320 N (2) 248 N
(3) 648 N (4) 120 N

27. Which one of the following equation cannot represent travelling wave?

(1) $x = A\sin[\omega t - kx]$
(2) $y = A\cos[\omega t - kx]$
(3) $y = A\sin\omega t \cdot \sin kx$
(4) $y = A e^{-[t - 20x]}$

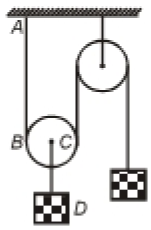
28. A uniform string of mass *m* hangs vertically from a rigid support. A transverse wave is sent from its free end towards fixed end. As the wave moves upward
    (1) Its speed and wavelength increase
    (2) Its speed increases but wavelength decreases
    (3) Its speed decreases but wavelength increases
    (4) Its speed and wavelength decrease

29. Propagation of sound wave in a medium results in the formation of pressure wave. The phase difference between pressure waves and sound wave is
    (1) Zero (2) $\frac{\pi}{2}$
    (3) π (4) 2π

30. A siren emitting sound of frequency 800 Hz is going away from a static listener with speed 60 m/s. Frequency of sound to be heard by the listener is (Take speed of sound to 340 m/s)
    (1) 680 Hz (2) 800 Hz
    (3) 860 Hz (4) 600 Hz

31. The longitudinal waves having frequency above 20 kHz are called
    (1) Infrasonic waves (2) Audible waves
    (3) Ultrasonic waves (4) Shock waves

32. In the situation shown, both the string are made of same material and have same radii. The pulleys are light. If the wave speed of a transverse wave in the string *AB* is '*v*' then in the string *CD* is
    (1) 2 *v*
    (2) *v*
    (3) $\sqrt{2}v$
    (4) $\frac{v}{\sqrt{2}}$



33. A wave of frequency 300 Hz has velocity 600 ms^{-1}. The distance between two nearest points 45° out of phase is
    (1) 50 cm (2) 25 cm
    (3) 75 cm (4) 100 cm

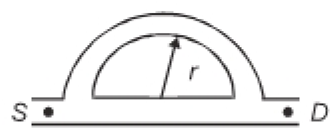
34. The displacement of a particle executing SHM is given by $x = (10\text{m})\sin\left(\frac{\pi t}{30}+\alpha\right)$. If displacement of the particle at t = 0 be $5\sqrt{3}$ m, the phase of the particle (in radians) at t = 5 s will be
    (1) π (2) $\frac{\pi}{3}$
    (3) $\frac{\pi}{2}$ (4) $\frac{2\pi}{3}$

35. Two wires *x* and *y* are in unison. Now tension in wire *x* is increase by 4% then 3 beats are produced. The frequency of wire *y* is
    (1) 150 Hz (2) 50 Hz
    (3) 250 Hz (4) 300 Hz

36. Phase difference between two particles of the medium in consecutive loops of stationary wave in that medium is
    (1) Zero (2) π
    (3) 2π (4) $\frac{L_1+L_2}{10}$

37. Two persons talking inside a room can be identified without seeing them. The characteristics of sound which helps us to identify them is
    (1) Loudness (2) Pitch
    (3) Amplitude (4) Quality

38. A sound wave of wavelength 48 cm enters at *S* in the tube as shown in the figure. Then, the smallest radius *r* of the semicircular part so that a minimum of sound is observed at *D* is



    (1) 14 cm (2) 20 cm
    (3) 21 cm (4) 15 cm

SECTION - B

Previous Years Questions

1. Two sources of sound placed close to each other, are emitting progressive waves given by $y_1 = 4\sin 600\pi t$ and $y_2 = 5\sin 608\pi t$. An observer located near these two sources of sound will hear **[AIPMT 2012]**
    (1) 8 beats per second with intensity ratio 81 : 1 between waxing and waning
    (2) 4 beats per second with intensity ratio 81 : 1 between waxing and waning
    (3) 4 beats per second with intensity ratio 25 : 16 between waxing and waning
    (4) 8 beats per second with intensity ratio 25 : 16 between waxing and waning

2. When a string is divided into three segments of length l_1, l_2 and l_3, the fundamental frequencies of these three segments are ν_1, ν_2 and ν_3 respectively. The original fundamental frequency (ν) of the string is **[AIPMT 2012]**

(1) $\frac{1}{\nu}=\frac{1}{\nu_1}+\frac{1}{\nu_2}+\frac{1}{\nu_3}$

(2) $\frac{1}{\sqrt{\nu}}=\frac{1}{\sqrt{\nu_1}}+\frac{1}{\sqrt{\nu_2}}+\frac{1}{\sqrt{\nu_3}}$

(3) $\sqrt{\nu}=\sqrt{\nu_1}+\sqrt{\nu_2}+\sqrt{\nu_3}$

(4) $\nu = \nu_1 + \nu_2 + \nu_3$

3. If we study the vibration of a pipe open at both ends, then the following statement is not true **[NEET-2013]**

(1) Odd harmonics of the fundamental frequency will be generated

(2) All harmonics of the fundamental frequency will be generated

(3) Pressure change will be maximum at both ends

(4) Open end will be anti-node

4. A source of unknown fundamental frequency gives 4 beat/s, when sounded with a source of known frequency 250 Hz. The second harmonic of the source of unknown frequency gives five beats per second, when sounded with a source of frequency 513 Hz. The unknown frequency is **[NEET-2013]**

(1) 246 Hz (2) 240 Hz

(3) 260 Hz (4) 254 Hz

5. A wave travelling in the +ve x-direction having displacement along y-direction as 1 m, wavelength 2π m and frequency of $\frac{1}{\pi}$ Hz is represented by **[NEET-2013]**

(1) $y = \sin(2\pi x - 2\pi t)$ (2) $y = \sin(10\pi x - 20\pi t)$

(3) $y = \sin(2\pi x + 2\pi t)$ (4) $y = \sin(x - 2t)$

6. If n_1, n_2 and n_3 are the fundamental frequencies of three segments into which a string is divided, then the original fundamental frequency n of the string is given by **[AIPMT 2014]**

(1) $\frac{1}{n}=\frac{1}{n_1}+\frac{1}{n_2}+\frac{1}{n_3}$

(2) $\frac{1}{\sqrt{n}}=\frac{1}{\sqrt{n_1}}+\frac{1}{\sqrt{n_2}}+\frac{1}{\sqrt{n_3}}$

(3) $\sqrt{n}=\sqrt{n_1}+\sqrt{n_2}+\sqrt{n_3}$

(4) $n = n_1 + n_2 + n_3$

7. The number of possible natural oscillations of air column in a pipe closed at one end of length 85 cm whose frequencies lie below 1250 Hz are (velocity of sound = 340 ms^{-1}) **[AIPMT 2014]**

(1) 4 (2) 5

(3) 7 (4) 6

8. A speeding motorcyclist sees traffic jam ahead of him. He slows down to 36 km/hour. He finds that traffic has eased and a car moving ahead of him at 18 km/hour is honking at a frequency of 1392 Hz. If the speed of sound is 343 m/s, the frequency of the honk as heard by him will be **[AIPMT 2014]**

(1) 1332 Hz

(2) 1372 Hz

(3) 1412 Hz

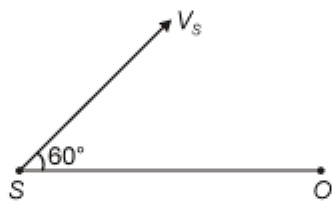
(4) 1454 Hz

9. A string is stretched between fixed points separated by 75.0 cm. It is observed to have resonant frequencies of 420 Hz and 315 Hz. There are no other resonant frequencies between these two. The lowest resonant frequency for this string is **[Re-AIPMT-2015]**

(1) 105 Hz (2) 155 Hz

(3) 205 Hz (4) 10.5 Hz

10. A source of sound S emitting waves of frequency 100 Hz and an observer O are located at some distance from each other. The source is moving with a speed of 19.4 ms^{-1} at an angle of 60° with the source observer line as shown in the figure. The observer is at rest. The apparent frequency observed by the observer (velocity of sound in air 330 ms^{-1}), is **[Re-AIPMT-2015]**



(1) 97 Hz (2) 100 Hz

(3) 103 Hz (4) 106 Hz

11. The fundamental frequency of a closed organ pipe of length 20 cm is equal to the second overtone of an organ pipe open at both the ends. The length of organ pipe open at both the ends is **[AIPMT-2015]**

(1) 140 cm (2) 80 cm

(3) 100 cm (4) 120 cm

12. A siren emitting a sound of frequency 800 Hz moves away from an observer towards a cliff at a speed of 15 ms^{-1}. Then, the frequency of sound that the observer hears in the echo reflected from the cliff is (Take velocity of sound in air = 330 ms^{-1}) **[NEET-2016]**

(1) 885 Hz (2) 765 Hz
(3) 800 Hz (4) 838 Hz

13. An air column, closed at one end and open at the other, resonates with a tuning fork when the smallest length of the column is 50 cm. The next larger length of the column resonating with the same tuning fork is **[NEET-2016]**

(1) 200 cm (2) 66.7 cm
(3) 100 cm (4) 150 cm

14. A uniform rope of length L and mass m_1 hangs vertically from a rigid support. A block of mass m_2 is attached to the free end of the rope. A transverse pulse of wavelength λ_1 is produced at the lower end of the rope. The wavelength of the pulse when it reaches the top of the rope is λ_2. The ratio λ_2/λ_1 is **[NEET-2016]**

(1) $\sqrt{\frac{m_1+m_2}{m_1}}$ (2) $\sqrt{\frac{m_1}{m_2}}$
(3) $\sqrt{\frac{m_1+m_2}{m_2}}$ (4) $\sqrt{\frac{m_2}{m_1}}$

15. The second overtone of an open organ pipe has the same frequency as the first overtone of a closed pipe L metre long. The length of the open pipe will be **[NEET (Phase-2) 2016]**

(1) L (2) $2L$
(3) $\frac{L}{2}$ (4) $4L$

16. Three sound waves of equal amplitudes have frequencies $(n - 1)$, n, $(n + 1)$. They superimpose to give beats. The number of beats produced per second will be **[NEET (Phase-2) 2016]**

(1) 1 (2) 4
(3) 3 (4) 2

17. Two cars moving in opposite directions approach each other with speed of 22 m/s and 16.5 m/s respectively. The driver of the first car blows a horn having a frequency 400 Hz. The frequency heard by the driver of the second car is [Velocity of sound 340 m/s] **[NEET-2017]**

(1) 350 Hz (2) 361 Hz
(3) 411 Hz (4) 448 Hz

18. The two nearest harmonics of a tube closed at one end and open at other end are 220 Hz and 260 Hz. What is the fundamental frequency of the system? **[NEET-2017]**

(1) 10 Hz (2) 20 Hz
(3) 30 Hz (4) 40 Hz

19. A tuning fork is used to produce resonance in a glass tube. The length of the air column in this tube can be adjusted by a variable piston. At room temperature of 27°C two successive resonances are produced at 20 cm and 73 cm of column length. If the frequency of the tuning fork is 320 Hz, the velocity of sound in air at 27°C is **[NEET-2018]**

(1) 330 m/s (2) 339 m/s
(3) 300 m/s (4) 350 m/s

20. The fundamental frequency in an open organ pipe is equal to the third harmonic of a closed organ pipe. If the length of the closed organ pipe is 20 cm, the length of the open organ pipe is **[NEET-2018]**

(1) 13.2 cm (2) 8 cm
(3) 16 cm (4) 12.5 cm

21. A tuning fork with frequency 800 Hz produces resonance in a resonance column tube with upper end open and lower end closed by water surface. Successive resonance are observed at lengths 9.75 cm, 31.25 cm and 52.75 cm. The speed of sound in air is **[NEET-2019 (Odisha)]**

(1) 172 m/s (2) 500 m/s
(3) 156 m/s (4) 344 m/s

❑ ❑ ❑

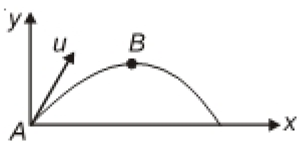
Sample Question Paper

Choose the correct answer :

1. If force (F), velocity (V) and Time (T) are taken as fundamental units, then the dimensions of length are
   (1) $[FVT^{-2}]$ (2) $[FVT^{-1}]$
   (3) $[F^0VT]$ (4) $[F^0VT^{-1}]$

2. In an experiment four quantities *a*, *b*, *c* and *d* are measured with percentage error 2%, 3%, 4% and 1% respectively. Quantity *P* is calculated as follows: $P = \frac{a^3b^2}{cd}$. Percentage error in *P* is
   (1) 14% (2) 15%
   (3) 8% (4) 17%

3. The velocity of a projectile at the initial point *A* is $(3\hat{i}+4\hat{j})$ m/s. Its velocity (in m/s) at point *B* is



   (1) $-4\hat{j}$ (2) $-3\hat{i}+4\hat{j}$
   (3) $3\hat{i}-4\hat{j}$ (4) $3\hat{i}$

4. A ball is thrown upwards with a speed *v* from a height *h* above the ground. The time taken by the ball to hit the ground is
   (1) $\sqrt{\frac{2h}{g}}$ (2) $\sqrt{\frac{8h}{g}}$
   (3) $\frac{v}{g}+\sqrt{\frac{2h}{g}}$ (4) $\frac{\sqrt{v^2+2gh}}{g}+\frac{v}{g}$

5. A particle starts from the origin of coordinates at time $t = 0$ and moves in the *x*-*y* plane with a constant acceleration α in the *y*-direction. Its equation of motion is $y = \beta x^2$. Its velocity component in the *x*-direction is
   (1) $\frac{\alpha}{2\beta}$ (2) $\sqrt{\frac{\alpha}{2\beta}}$
   (3) $\sqrt{\frac{2\alpha}{\beta}}$ (4) Variable

6. A particle has an initial velocity $3\hat{i}+4\hat{j}$ and acceleration of $0.3\hat{i}+0.4\hat{j}$. Its speed after 10 s is
   (1) 10 units (2) 8.5 units
   (3) $7\sqrt{2}$ units (4) 7 units

7. The vertical height of the projectile at time *t* is given by $y = 4t - t^2$ and the horizontal distance covered is given by $x = 3t$. The angle of projection with the horizontal is
   (1) $\tan^{-1}\left(\frac{3}{4}\right)$ (2) $\tan^{-1}\left(\frac{3}{5}\right)$
   (3) $\tan^{-1}\left(\frac{4}{3}\right)$ (4) $\tan^{-1}\left(\frac{4}{5}\right)$

8. A man crosses a river in a boat. If he crosses the boat in minimum time he takes 10 minute with a drift of 120 m. If he crosses the river taking shortest path, he takes 12.5 minute. The velocity of boat w.r.t. water is
   (1) 10 m/min (2) 12 m/min
   (3) 18 m/min (4) 20 m/min

9. Points *P*, *Q* and *R* are in vertical line such that *PQ* = *QR*. A ball at *P* is allowed to fall freely. What is the ratio of the times of descent through *PQ* and *QR*?
   (1) 1 : 1 (2) $1:\sqrt{3}$
   (3) $1:\sqrt{2}$ (4) $1:(\sqrt{2}-1)$

10. Gravitational potential at the surface of a uniform isolated solid sphere is *V*. Gravitational potential at its centre is
    (1) *V* (2) Zero
    (3) $\frac{3V}{2}$ (4) 2*V*

11. A body is thrown with speed *v* vertically upward from the surface to earth to just escape. If the body is thrown at the same speed at an angle 45° above horizontal, then the body
    (1) Orbit around earth in circular orbit
    (2) Orbit around earth in elliptical orbit
    (3) Just escape
    (4) Follows parabolic path to return to earth

12. Orbital speed of a satellite at height R (R = radius of earth) from the surface of earth is v. Orbital speed of another satellite at height $3R$ from earth surface is

(1) v (2) $\frac{v}{\sqrt{2}}$

(3) $\frac{v}{2}$ (4) $\frac{v}{4}$

13. If gravitational force by earth on moon is $\vec{F}$, then the gravitational force by moon on earth is

(1) $\vec{F}$ (2) $-\vec{F}$

(3) $-\frac{\vec{F}}{81}$ (4) $\frac{\vec{F}}{81}$

14. If ice at the polar caps of earth will melt, then the duration of day will

(1) Decrease (2) Increase

(3) Remain constant (4) Data insufficient

15. A body is moving in air at 20 m/s is exploded into two parts of mass in the ratio 2 : 3. If heavier part moves at 30 m/s, then the speed of the centre of mass is

(1) 5 m/s (2) 20 m/s

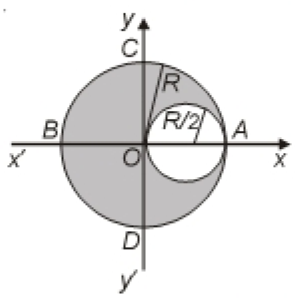
(3) 30 m/s (4) 15 m/s

16. A uniform solid sphere of mass m and radius r is rolling without slipping on horizontal floor such that speed of its centre of mass is v. Its kinetic energy is

(1) $\frac{1}{2}mv^2$ (2) $\frac{7}{10}mv^2$

(3) $\frac{1}{5}mv^2$ (4) $\frac{7}{5}mv^2$

17. A disk of radius $R/2$ is scooped out from a uniform disk of radius R as shown in figure. Centre of mass of the remaining system will lie



(1) At O (2) On OB

(3) On OA (4) On CD

18. Moment of inertia of a uniform rod about an axis normally through one end is I. Moment of inertia about an axis through centre normal to the plane is

(1) I (2) $\frac{I}{4}$

(3) $\frac{I}{3}$ (4) $\frac{I}{2}$

19. A body A moving at a speed 10 m/s collides head-on elastically with another identical body B at rest. Which of the following is incorrect?

(1) Linear momentum of system of A and B is conserved

(2) Kinetic energy of system of A and B is conserved

(3) Total energy of system of A and B is conserved

(4) Both (1) & (3)

20. Linear momentum of a body is increased by 50%. Percentage increase in its kinetic energy is

(1) 50% (2) 100%

(3) 125% (4) 75%

21. Work done in increasing the length of a spring by 2 mm from its natural length is 20 J. Work done in increasing its length 2 mm further is

(1) 20 J (2) 40 J

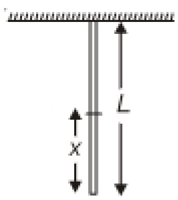
(3) 60 J (4) 80 J

22. A body of mass m is moving on a flat horizontal circular road with constant speed v. If radius of curvature of the road is r then minimum coefficient of friction (μ) between road and body such that body will not slip is

(1) $\mu = \frac{v^2}{rg}$ (2) $\mu = \frac{v^2 r}{g}$

(3) $\mu = \frac{v^2 g}{r}$ (4) $\mu = v^2 rg$

23. A uniform string of mass M and length L is suspended freely from the ceiling as shown in figure. Tension in the string at distance x from its lower end is



(1) $\frac{M}{L}x\,g$ (2) $\frac{M}{L}(L-x)\,g$

(3) Mg (4) Zero

24. A body of mass 10 kg is kept on a horizontal floor. If g = 10 m/s^2, then net force acting on the body is

(1) Zero (2) 100 N

(3) 50 N (4) $100\sqrt{2}$ N

25. Which of the following is correct about static friction?

(1) It is self adjusting

(2) Maximum value of static friction is limiting friction

(3) It may be greater than kinetic friction

(4) All of these

26. A river having parallel banks has width 200 m. Flow of water parallel to banks is at 5 km/h. A man can swim at 4 km/h in still water. Minimum time taken by the man to cross the river is

(1) $\frac{1}{10}$ h (2) $\frac{1}{20}$ h

(3) $\frac{1}{40}$ h (4) $\frac{1}{5}$ h

27. Rain is pouring vertically downward at 4 m/s. Velocity of the rain with respect to a man running along east at 3 m/s is

(1) 7 m/s (2) 1 m/s

(3) 5 m/s (4) Zero

28. If a graph is plotted by taking translational kinetic energy and y-axis and speed of body along x-axis, then slope of the graph represents

(1) Speed (2) Momentum

(3) Force (4) Mass

29. Two sources 1000 Hz and 1005 Hz are sounded together. Number of beats heard per minute is

(1) 300 (2) 5

(3) 100 (4) 200

30. A source sounding a sound of frequency 660 Hz is at rest. Speed of sound in air is 330 m/s. An observer is approaching the source at 30 m/s. Wavelength of sound observed by the observer is

(1) 1 m (2) 0.5 m

(3) 0.4 m (4) 0.2 m

31. Consecutive frequencies from an organ pipe are 75 Hz, 125 Hz, 175 Hz, fundamental frequency of the organ pipe is

(1) 50 Hz (2) 75 Hz

(3) 125 Hz (4) 25 Hz

32. Equation of a wave is given by
y = (0.4m) sin (314t – 3.14x),

where x is in metre and t is in second. Speed of the wave is

(1) 314 m/s (2) 3.14 m/s

(3) 100 m/s (4) Zero

33. If a graph is plotted by taking velocity along y-axis and displacement of particle in SHM along x-axis, then the nature of the graph is

(1) Straight line (2) Ellipse

(3) Parabola (4) Hyperbola

34. A body is dropped into a bottomless frictionless well through earth. Assuming earth as a uniform solid sphere, the motion of the body is

(1) Uniform motion

(2) Simple harmonic

(3) Oscillation but not simple harmonic

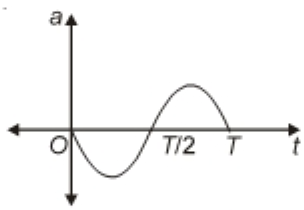
(4) Uniformly accelerated motion

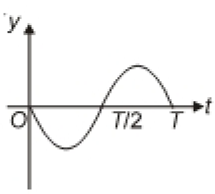
35. A spring mass system has time period T. If the spring is cut into four identical parts and same mass is loaded to one of them, then new time period of vibration is

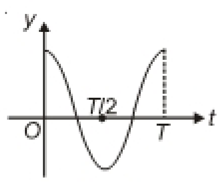
(1) T (2) $\frac{T}{2}$

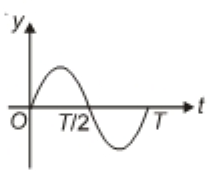
(3) $\frac{T}{4}$ (4) $2T$

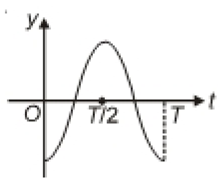
36. A body is executing simple harmonic motion whose acceleration (a) versus time (t) graph is as shown in figure. Its corresponding position (y) versus time (t) graph is



(1) 

(2) 

(3) 

(4) 

37. N mole ideal gas is heated at constant temperature T K to double its volume. Work done by the gas is (R = gas constant)

(1) $NRT \ln 2$ (2) NRT

(3) $NRT \log_{10} 2$ (4) Zero

38. Colour of a star is indication of its

(1) Atmosphere (2) Temperature

(3) Its distance (4) All of these

39. A body is cooling under Newtons law of cooling. Temperature of the body falls from 60°C to 50°C in 10 minutes. Time in which its temperature falls from 50°C to 40°C is

(1) Equal to 10 minutes

(2) Less than 10 minutes

(3) More than 10 minutes

(4) Less than or equal to 10 minutes

40. Radiant emittance of a black body at temperature T is E. Radiant emittance of the same body at temperature $2T$ is

(1) $4E$ (2) $8E$

(3) $16E$ (4) $64E$

41. Two rods of identical dimension and thermal conductivities $2k$ and $3k$ are connected in series between two reservoirs at different temperature. Effective thermal conductivity of the series combination is

(1) $2.5k$ (2) $2.4k$

(3) $2k$ (4) $3k$

42. Maximum efficiency of a heat engine working between 327°C and 27°C is

(1) 0.5 (2) 0.2

(3) 0.4 (4) 1

43. A monatomic gas absorbs 30 cal at constant volume to raise its temperature by t°C. Amount of heat used by it to increase its internal energy is

(1) 50 cal (2) 70 cal

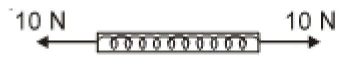
(3) 30 cal (4) Zero

44. Ratio of rms speed of hydrogen molecules to the oxygen molecules at room temperature 27°C is

(1) 4 : 1 (2) 2 : 1

(3) 8 : 1 (4) 16 : 1

45. A spring balance is equally pulled by two equal forces of 10 N each as shown in figure. Find reading shown by spring balance



(1) 10 N

(2) 20 N

(3) Zero

(4) $\sqrt{10}$ N

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ANSWERS

Chapter 1 : Physical World; Units and Measurements

Section A : Objective Type Questions

1.	(2)	2.	(3)	3.	(3)	4.	(1)	5.	(3)	6.	(4)	7.	(1)
8.	(2)	9.	(2)	10.	(3)	11.	(3)	12.	(2)	13.	(4)	14.	(2)
15.	(2)	16.	(2)	17.	(2)	18.	(4)	19.	(3)	20.	(2)	21.	(1)
22.	(3)	23.	(3)	24.	(4)	25.	(3)	26.	(2)	27.	(1)	28.	(2)
29.	(4)	30.	(3)	31.	(3)	32.	(3)	33.	(2)	34.	(3)	35.	(3)

Section B : Previous Years Questions

1.	(1)	2.	(4)	3.	(4)	4.	(4)	5.	(2)	6.	(1)	7.	(1)
8.	(3)	9.	(2)	10.	(3)								

Chapter 2 : Motion in a Straight Line

Section A : Objective Type Questions

1.	(1)	2.	(2)	3.	(3)	4.	(1)	5.	(3)	6.	(3)	7.	(4)
8.	(4)	9.	(3)	10.	(1)	11.	(3)	12.	(2)	13.	(2)	14.	(2)
15.	(2)	16.	(2)	17.	(3)	18.	(4)	19.	(4)	20.	(3)	21.	(3)

Section B : Previous Years Questions

1.	(2)	2.	(1)	3.	(3)	4.	(4)	5.	(4)	6.	(3)	7.	(2)

Chapter 3 : Motion in a Plane

Section A : Objective Type Questions

1.	(4)	2.	(2)	3.	(4)	4.	(2)	5.	(3)	6.	(3)	7.	(4)
8.	(2)	9.	(2)	10.	(1)	11.	(1)	12.	(1)	13.	(3)	14.	(4)
15.	(4)	16.	(2)	17.	(2)	18.	(1)	19.	(2)	20.	(4)	21.	(3)
22.	(1)												

Section B : Previous Years Questions

1.	(4)	2.	(4)	3.	(2)	4.	(1)	5.	(4)	6.	(3)	7.	(4)
8.	(2)	9.	(3)	10.	(4)	11.	(2)	12.	(2)	13.	(3)	14.	(3)
15.	(3)	16.	(1)	17.	(1)								

Chapter 4 : Laws of Motion

Section A : Objective Type Questions

1.	(1)	2.	(2)	3.	(1)	4.	(2)	5.	(1)	6.	(4)	7.	(3)
8.	(2)	9.	(4)	10.	(3)	11.	(2)	12.	(4)	13.	(1)	14.	(3)
15.	(1)	16.	(1)	17.	(3)	18.	(2)	19.	(1)	20.	(2)	21.	(1)
22.	(3)	23.	(2)	24.	(3)	25.	(1)	26.	(2)	27.	(3)	28.	(2)

29.	(3)	30.	(4)	31.	(2)	32.	(1)	33.	(3)	34.	(4)	35.	(4)
36.	(1)	37.	(2)	38.	(4)	39.	(2)	40.	(1)	41.	(4)	42.	(4)
43.	(3)	44.	(1)	45.	(3)								

Section B : Previous Years Questions

1.	(4)	2.	(2)	3.	(4)	4.	(1)	5.	(3)	6.	(3)	7.	(1)
8.	(3)	9.	(4)	10.	(3)	11.	(2)	12.	(3)	13.	(1)	14.	(1)
15.	(3)	16.	(3)	17.	(3)	18.	(3)	19.	(4)	20.	(2)	21.	(3)

Chapter 5 : Work, Energy and Power

Section A : Objective Type Questions

1.	(3)	2.	(3)	3.	(4)	4.	(3)	5.	(4)	6.	(2)	7.	(2)
8.	(2)	9.	(4)	10.	(4)	11.	(2)	12.	(2)	13.	(1)	14.	(2)
15.	(1)	16.	(3)	17.	(3)	18.	(2)	19.	(1)	20.	(4)	21.	(3)
22.	(1)	23.	(2)	24.	(4)	25.	(3)	26.	(1)	27.	(4)	28.	(3)
29.	(2)	30.	(1)										

Section B : Previous Years Questions

1.	(4)	2.	(1)	3.	(4)	4.	(2)	5.	(4)	6.	(4)	7.	(2)
8.	(2)	9.	(4)	10.	(3)	11.	(2)	12.	(2)	13.	(1)	14.	(1)
15.	(3)	16.	(3)	17.	(2)	18.	(4)	19.	(3)	20.	(2)	21.	(3)
22.	(2)	23.	(3)	24.	(2)	25.	(3)	26.	(4)	27.	(3)		

Chapter 6 : System of Particles and Rotational Motion

Section A : Objective Type Questions

1.	(4)	2.	(4)	3.	(2)	4.	(2)	5.	(4)	6.	(4)	7.	(3)
8.	(2)	9.	(2)	10.	(4)	11.	(2)	12.	(1)	13.	(3)	14.	(2)
15.	(2)	16.	(4)	17.	(2)	18.	(3)	19.	(2)	20.	(4)	21.	(2)
22.	(2)	23.	(1)	24.	(1)	25.	(4)	26.	(3)	27.	(1)	28.	(3)
29.	(2)	30.	(1)	31.	(2)	32.	(4)	33.	(4)				

Section B : Previous Years Questions

1.	(4)	2.	(1)	3.	(3)	4.	(3)	5.	(3)	6.	(4)	7.	(4)
8.	(1)	9.	(1)	10.	(3)	11.	(1)	12.	(4)	13.	(2)	14.	(1)
15.	(2)	16.	(3)	17.	(3)	18.	(3)	19.	(2)	20.	(1)	21.	(3)
22.	(1)	23.	(2)	24.	(3)	25.	(2)	26.	(1)	27.	(3)	28.	(1)
29.	(1)	30.	(1)	31.	(3)	32.	(4)						

Chapter 7 : Gravitation

Section A : Objective Type Questions

1.	(3)	2.	(3)	3.	(2)	4.	(2)	5.	(3)	6.	(1)	7.	(4)
8.	(1)	9.	(2)	10.	(3)	11.	(3)	12.	(2)	13.	(2)	14.	(4)

15. (4)	16. (1)	17. (1)	18. (2)	19. (1)	20. (1)	21. (1)
22. (4)	23. (2)	24. (2)	25. (1)	26. (1)	27. (1)	28. (1)
29. (1)	30. (2)	31. (1)	32. (2)	33. (3)	34. (1)	35. (2)

Section B : Previous Years Questions

1. (3)	2. (1)	3. (1)	4. (1)	5. (3)	6. (3)	7. (1)
8. (1)	9. (2)	10. (3)	11. (2)	12. (3)	13. (2)	14. (2)
15. (4)	16. (2)	17. (2)	18. (3)	19. (4)	20. (3)	21. (3)
22. (2)						

Chapter 8 : Mechanical Properties of Solids

Section A : Objective Type Questions

1. (3)	2. (3)	3. (2)	4. (1)	5. (4)	6. (1)	7. (3)
8. (3)	9. (1)	10. (3)	11. (4)	12. (1)	13. (3)	14. (4)
15. (3)						

Section B : Previous Years Questions

1. (4)	2. (2)	3. (3)	4. (4)	5. (4)	6. (1)	7. (3)
8. (3)						

Chapter 9 : Mechanical Properties of Fluids

Section A : Objective Type Questions

1. (1)	2. (3)	3. (3)	4. (4)	5. (2)	6. (2)	7. (4)
8. (3)	9. (2)	10. (3)	11. (3)	12. (2)	13. (3)	14. (1)
15. (4)	16. (2)	17. (2)	18. (1)	19. (1)	20. (3)	21. (3)
22. (4)	23. (2)	24. (4)	25. (1)	26. (1)	27. (3)	28. (3)
29. (1)	30. (1)	31. (2)	32. (4)	33. (1)	34. (4)	35. (3)
36. (3)	37. (4)	38. (3)				

Section B : Previous Years Questions

1. (3)	2. (3)	3. (3)	4. (3)	5. (4)	6. (1)	7. (2)
8. (2)	9. (4)	10. (4)	11. (3)	12. (1)	13. (3)	14. (1)

Chapter 10 : Thermal Properties of Matter and Thermodynamics

Section A : Objective Type Questions

1. (2)	2. (1)	3. (2)	4. (1)	5. (2)	6. (4)	7. (3)
8. (4)	9. (4)	10. (2)	11. (4)	12. (2)	13. (3)	14. (4)
15. (4)	16. (4)	17. (4)	18. (2)	19. (3)	20. (4)	21. (3)
22. (2)	23. (1)	24. (2)	25. (3)	26. (3)	27. (2)	28. (4)
29. (2)	30. (1)	31. (2)	32. (1)	33. (3)	34. (2)	35. (3)
36. (2)	37. (2)	38. (3)	39. (2)	40. (4)	41. (4)	42. (3)
43. (1)	44. (1)	45. (1)	46. (3)	47. (3)	48. (2)	49. (2)
50. (3)	51. (2)	52. (2)				

Section B : Previous Years Questions

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

Chapter 11 : Kinetic Theory

Section A : Objective Type Questions

1.	(1)	2.	(3)	3.	(3)	4.	(4)	5.	(3)	6.	(1)	7.	(3)
8.	(3)	9.	(2)	10.	(1)	11.	(3)	12.	(1)	13.	(1)	14.	(1)
15.	(1)	16.	(2)	17.	(3)	18.	(2)	19.	(2)	20.	(4)		

Section B : Previous Years Questions

1.	(1)	2.	(4)	3.	(2)	4.	(3)	5.	(4)	6.	(3)	7.	(2)
8.	(4)	9.	(2)	10.	(2)	11.	(2)						

Chapter 12 : Oscillations

Section A : Objective Type Questions

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

Section B : Previous Years Questions

1.	(3)	2.	(1)	3.	(3)	4.	(4)	5.	(4)	6.	(3)	7.	(2)
8.	(2)	9.	(4)	10.	(4)	11.	(1)	12.	(1)				

Chapter 13 : Waves

Section A : Objective Type Questions

1.	(1)	2.	(2)	3.	(4)	4.	(1)	5.	(1)	6.	(2)	7.	(1)
8.	(4)	9.	(3)	10.	(4)	11.	(4)	12.	(1)	13.	(4)	14.	(1)
15.	(1)	16.	(3)	17.	(3)	18.	(2)	19.	(3)	20.	(2)	21.	(1)
22.	(3)	23.	(1)	24.	(1)	25.	(4)	26.	(3)	27.	(3)	28.	(1)
29.	(2)	30.	(1)	31.	(3)	32.	(3)	33.	(2)	34.	(3)	35.	(1)
36.	(2)	37.	(4)	38.	(3)								

Section B : Previous Years Questions

1.	(2)	2.	(1)	3.	(3)	4.	(4)	5.	(4)	6.	(1)	7.	(4)
8.	(3)	9.	(1)	10.	(3)	11.	(4)	12.	(4)	13.	(4)	14.	(3)
15.	(2)	16.	(4)	17.	(4)	18.	(2)	19.	(2)	20.	(1)	21.	(4)

Sample Question Paper

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

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