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MONTHLY PRACTICE PROBLEMS (XI & XII)

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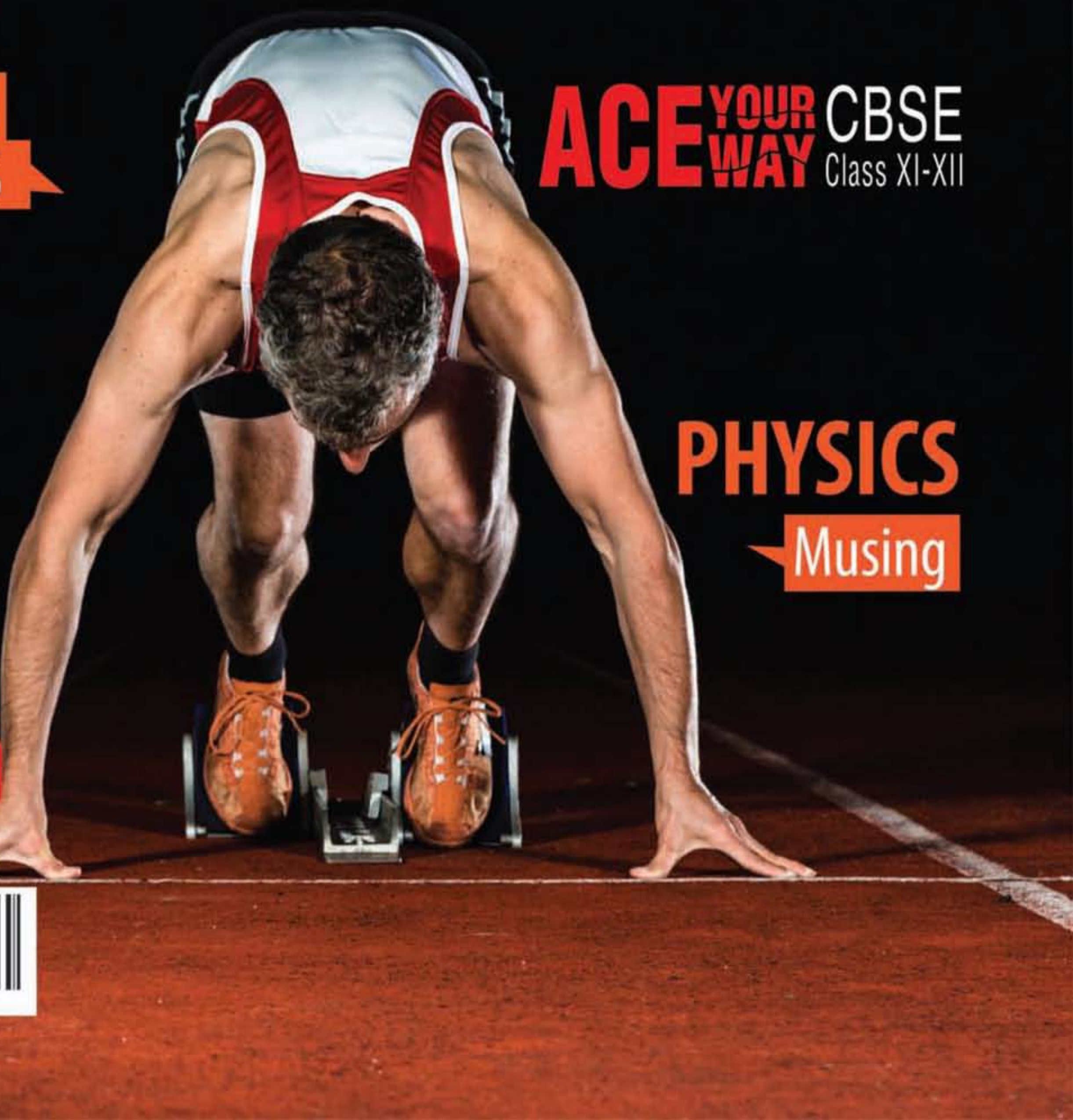
PHYSICS Musing



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PHYSICS for you

Volume 25 No. 2 February 2017

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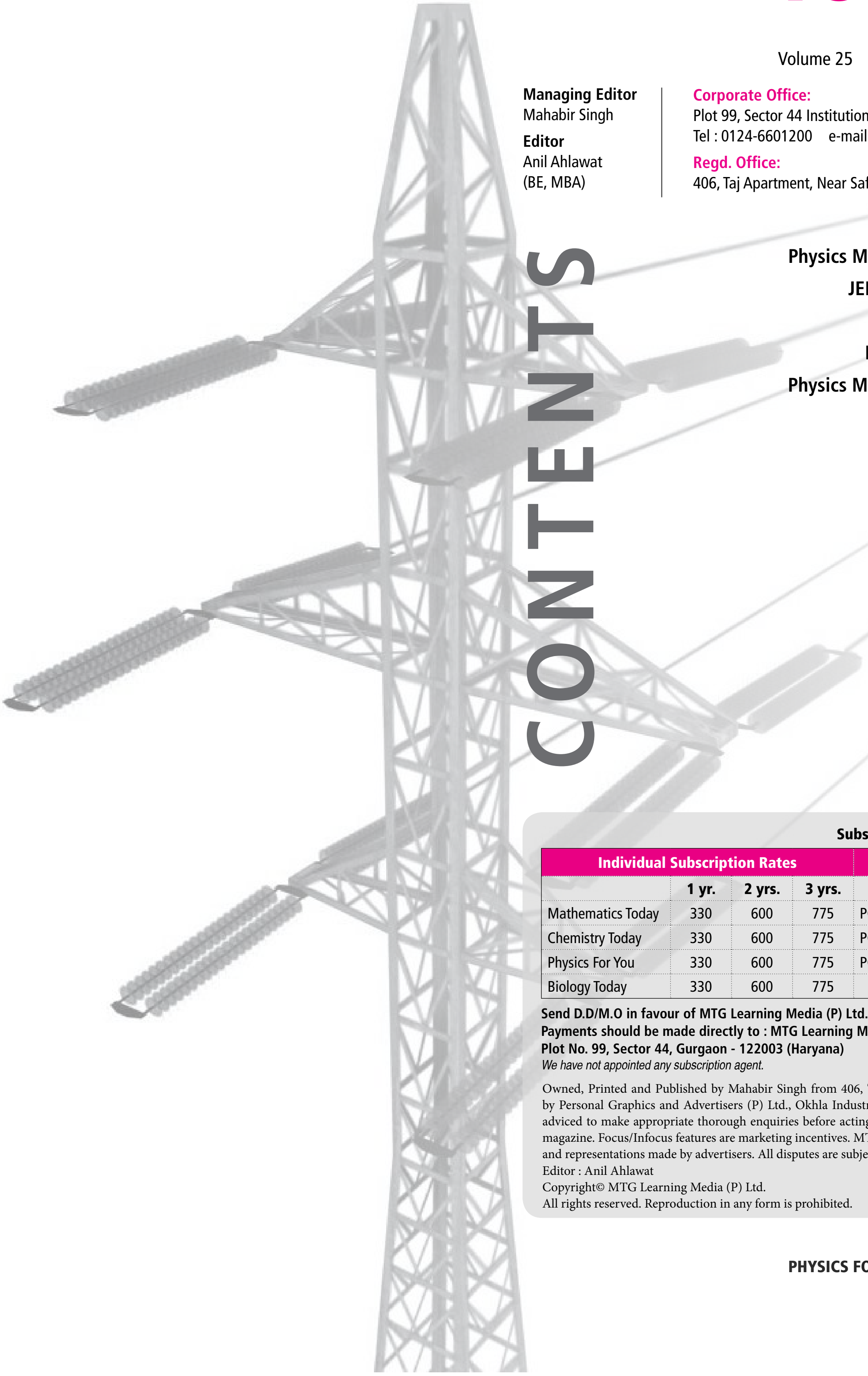

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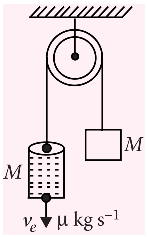
PHYSICS MUSING

Physics Musing was started in August 2013 issue of Physics For You with the suggestion of Shri Mahabir Singh. The aim of Physics Musing is to augment the chances of bright students preparing for JEE (Main and Advanced) / AIIMS / NEET / Other PMTs with additional study material.
In every issue of Physics For You, 10 challenging problems are proposed in various topics of JEE (Main and Advanced) / various PMTs. The detailed solutions of these problems will be published in next issue of Physics For You.
The readers who have solved five or more problems may send their detailed solutions with their names and complete address. The names of those who send atleast five correct solutions will be published in the next issue.
We hope that our readers will enrich their problem solving skills through "Physics Musing" and stand in better stead while facing the competitive exams.

PROBLEM Set 43

1. A block of mass M and cylindrical tank which contains water having small hole at bottom, which is closed initially (total mass of cylinder + water is also M), are attached at two ends of an ideal string which passes over an ideal pulley as shown. At t = 0 hole is is opened such that water starts coming out of the hole with a constant rate μ kg s^{-1} and constant velocity v_e relative to the cylinder. Then choose the correct option. Magnitude of acceleration of the block at any time t is
(Magnitude of v_e is such that string does not get slack.)

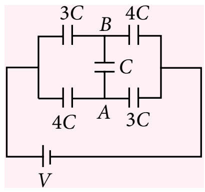


(a) $\frac{\mu(v_e+gt)}{(2M-\mu t)}$ (b) $\frac{\mu(v_e-gt)}{(2M-\mu t)}$
(c) $\frac{\mu gt}{2M}$ (d) μg

2. To measure the resistivity (ρ) of wire, the resistance (R) of the wire is measured with a tolerance ±1%. Percentage error in length (l) measurement is also 1%. To measure the diameter (D) of the wire, a screw gauge is used in which the least count of main scale is 0.5 mm and its pitch is also 0.5 mm. There are 50 divisions on the circular scale. When the wire is placed between the jaws, 4 main scale divisions are clearly visible, and 8th mark of circular scale match with the reference line. If the resistivity of the wire is given by $\rho = \frac{R\pi D^2}{4l}$, then the maximum percentage error in resistivity is
(a) 2 % (b) 3 % (c) 5 % (d) 8 %.

3. A convex lens of focal length f is cut along two perpendicular diameter of the aperture. Material of thickness δ is lost in cutting operation from every cut surface. All the four pieces are then pasted along the cut planes to make a lens. A point object is placed on the axis of new lens at a distance 1.5f. Number of images formed will be
(a) 1 (b) 2 (c) 3 (d) 4.

4. Consider the given circuit. Initially all capacitors were uncharged. In steady state if $V_A - V_B$ = 3 V, potential difference across the terminals of battery is



(a) 18 V (b) 9 V
(c) 27 V (d) None of these

5. A man crosses a river of width d. Speed of current flow is v and speed of swimmer relative to water is v. Man always heads towards the point exactly opposable to the starting point at the another bank (relative to water). Radius of curvature of the path followed by the swimmer just after he start swimming is
(a) d (b) $2\sqrt{2}d$ (c) $2d$ (d) $\sqrt{2}d$.

6. Consider a binary star system, constituent stars have masses M_1 and M_2 and separation between them is d. Choose the incorrect statement.
(a) Kinetic energy of the planets is in the ratio of inverse of their mass ratio.

Solution Senders of Physics Musing

SET-42

1. Suhas Sheikh, Mumbai
2. Baibhab Chakraborty, Assam
3. Souman Ghatak, Kolkata

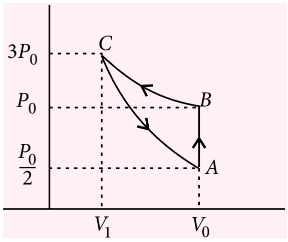
By Akhil Tewari, Author Foundation of Physics for JEE Main & Advanced, Professor, IITians PACE, Mumbai.

(b) Orbital radius of the planets is in the ratio of their mass ratio.

(c) Total energy of the binary star system is $-\dfrac{GM_1M_2}{2d}$.

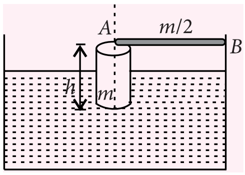
(d) Acceleration of stars is in the ratio of inverse of their mass ratio.

7. One mole of an ideal gas undergoes a thermodynamic cyclic process as shown in the figure. The cyclic process consists of an isochoric, an isothermal and an adiabatic process. Adiabatic exponent of gas is



(a) 1.5 (b) $\dfrac{\ln 5}{\ln 3}$ (c) 1.25 (d) $\dfrac{\ln 6}{\ln 3}$.

8. A cylindrical block of mass m and height h floats vertically in a liquid which is twice as dense as the block, as shown in the figure. A uniform rod of mass $m/2$ and length l is hinged to axis of the cylinder at A and to the wall of the vessel at B. The rod can rotate freely about the point B. It is observed that the rod is horizontal in its equilibrium position. Angular frequency of small vertical oscillations of the cylinder will be



(a) $\sqrt{\dfrac{12g}{7h}}$ (b) $\sqrt{\dfrac{3g}{2h}}$

(c) $\sqrt{\dfrac{4g}{3h}}$ (d) $\sqrt{\dfrac{13g}{6h}}$.

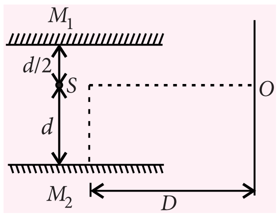
9. A particle undergoes from position $O(0, 0, 0)$ to A $(a, 2a, 0)$ via path $y = \dfrac{2x^2}{a}$ in x-y plane under the action of a force which varies with particle's coordinates (x, y, z) as $\vec{F} = x^2 y\,\hat{i} + yz^2 e^{2z}\,\hat{j} - \left(\dfrac{z}{x+2y}\right)\hat{k}$.

Work done by the force $\vec{F}$ is

(All symbols have their usual meaning and they are in SI unit)

(a) $\dfrac{4a^4}{5}$ (b) $\dfrac{a^4}{5}$ (c) $\dfrac{a^3}{4}$ (d) $\dfrac{2a^4}{5}$.

10. M_1 and M_2 are plane mirrors and kept parallel to each other. At point O, there will be a maxima for wavelength. Light from monochromatic source S of wavelength λ is not reaching directly on the screen. Then λ is (Assume, $D >> d$, $d >> \lambda$)



(a) $\dfrac{3d^2}{D}$ (b) $\dfrac{3d^2}{2D}$ (c) $\dfrac{d^2}{D}$ (d) $\dfrac{2d^2}{D}$.

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About the mentor:

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His superhit show **"IIT Made Easy by Sandip Sir"**, is a unique initiative which stressed on the importance of motivation along with the knowledge of the subject, as an essential raw material to crack the exams. The 35-episodes long show, which he recently wrapped used to be telecasted on **Taaza tv (Eastern India's only Hindi news channel)**, every Sunday. The show gained unprecedented popularity and viewership.

He is also a columnist of one of West Bengal's highest selling Hindi daily Prabhat Khabar ,where his career counseling articles are published every Saturday.(The e-paper of Kolkata Edition of Prabhat Khabar can be found at www.prabhatkhabar.com. You may also mail your career related queries to the given address).

An eminent speaker,he has conducted several motivational seminars in some of the most reputed schools of Kolkata. News about his seminars, results and contribution have also been printed in dailies like Sanmarg, Dainik Jagran, Chapte Chapte.

A man of absolute devotion, he leaves no stone unturned to help his students with his deep understanding of the subject and amazing problem-solving tricks. It is not surprising that the best and most brilliant of students hold him as their ideal.

Er. Sandip Prasad
Director of Sandip Physics Classes
Electrical Engineer (B.TECH) &
Motivational Speaker

You can subscribe to his channel "Sandip Physics Classes" on Youtube to watch his Physics lectures and Motivational Seminars by the name 'IIT Made Easy by Sandip Sir'. You can also like his Facebook page "Sandip Physics Classes" to stay informed about his latest updates.

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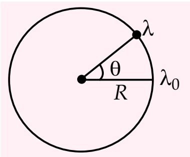
PRACTICE PAPER 2017

JEE MAIN

Exam Dates
OFFLINE : 2nd April
ONLINE : 8th & 9th April

1. A thin non-conduction ring of radius R has a linear charge density $\lambda = \lambda_0 \cos\theta$, where λ_0 is the value of λ at $\theta = 0$. Find the net electric dipole moment for this charge distribution.



(a) $\frac{\pi R^2}{\lambda_0}$ (b) $\pi R \lambda_0$ (c) $\pi R^2 \lambda_0$ (d) $\frac{\pi R}{\lambda_0}$

2. A short linear object of length b lies along the axis of a concave mirror of focal length f, at a distance u from the mirror. The size of the image is approximately (Assume $u >> b$)

(a) $b\left(\frac{u-f}{f}\right)^{1/2}$ (b) $b\left(\frac{f}{u-f}\right)$

(c) $b\left(\frac{u-f}{f}\right)$ (d) $b\left(\frac{f}{u-f}\right)^2$

3. A balloon starts rising from the ground with an acceleration of 1.25 m s^{-2}. After 8 s, a stone is released from the balloon. The stone will

(a) cover a distance of 55 m
(b) have a displacement of 50 m
(c) reach the ground in 4 s
(d) begin to move downward just after being released

4. Energy required to remove an electron from an aluminium surface is 4.2 eV. If light of wavelength 2000 Å falls on the surface, the velocity of fastest electrons ejected from the surface is

(a) 2.5×10^{18} m s^{-1} (b) 2.5×10^{13} m s^{-1}
(c) 6.7×10^{18} m s^{-1} (d) 8.3×10^{5} m s^{-1}

5 A copper bar of length L and area of cross-section A is placed in a chamber at atmospheric pressure. If the chamber is evacuated, the percentage change in its volume will be
(Compressibility of copper is 8×10^{-12} m^2 N^{-1} and 1 atm = 10^5 N m^{-2})

(a) 8×10^{-7} (b) 8×10^{-5}
(c) 1.25×10^{-4} (d) 1.25×10^{-5}

6. The equation of state of a gas is given by $\left(P + \frac{a}{V^3}\right)(V - b^2) = cT$, where P, V, T are pressure, volume and temperature respectively, and a, b, c are constants. The dimensions of a and b are respectively

(a) $[ML^8T^{-2}]$ and $[L^{3/2}]$
(b) $[ML^5T^{-2}]$ and $[L^3]$
(c) $[ML^5T^{-2}]$ and $[L^6]$
(d) $[ML^6T^{-2}]$ and $[L^{3/2}]$

7. An alpha particle (^{4}He) has a mass of 4.00300 amu. A proton has a mass of 1.00783 amu and a neutron has a mass of 1.00867 amu respectively. The binding energy of alpha particle estimated from these data is the closest to

(a) 27.9 MeV (b) 22.3 MeV
(c) 35.0 MeV (d) 20.4 MeV

8. In a biprism experiment, by using light of wavelength 5000 Å, 5 mm wide fringes are obtained on a screen 1.0 m away from the coherent sources. The separation between the two coherent sources is

(a) 1.0 mm (b) 0.1 mm
(c) 0.05 mm (d) 0.01 mm

9. In a series LCR circuit, the voltage across the resistance, capacitance and inductance is 10 V each. If the capacitance is short circuited, the voltage across the inductance will be

(a) 10 V (b) $10\sqrt{2}$ V
(c) $\frac{10}{\sqrt{2}}$ V (d) 20 V

10. A beam of monochromatic light reflects and refracts at point A, as shown in the diagram. Find the angle of refraction at point A.

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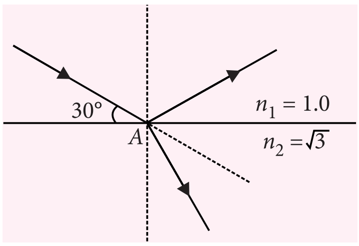


(a) 60° (b) 45°
(c) 30° (d) None of these

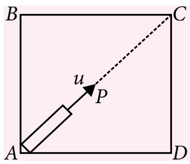
11. A paramagnetic gas at temperature 27 °C is placed in an external uniform magnetic field of magnitude 1.5 T. If the atoms of the gas have magnetic dipole moment $\mu = 2.0\mu_B$, then the energy difference between parallel alignment and antiparallel alignment of the atom's magnetic dipole moment with the magnetic field is
(a) 2.3×10^{-22} J (b) 5.6×10^{-23} J
(c) 1.9×10^{-24} J (d) 1.6×10^{-25} J

12. For the following fission reaction
$^{235}\mathrm{U} + n \rightarrow {}^{140}\mathrm{Ce} + {}^{94}\mathrm{Zr} + 2n$,
Find the disintegration energy.
($M_U = 235.02$ u, $M_n = 1.0$ u, $M_{Ce} = 139.9$ u, $M_{Zr} = 93.9$ u)
(a) 205 MeV (b) 198 MeV
(c) 123 MeV (d) 89 MeV

13. The primary winding of a transformer has 50 turns and its secondary has 500 turns. If primary is connected to ac supply of 20 V – 50 Hz, then secondary will have an
(a) 200 V – 50 Hz (b) 200 V – 500 Hz
(c) 2 V – 5 Hz (d) 2 V – 50 Hz

14. In optical communication system operating at 1200 nm, only 2% of the source frequency is available for TV transmission having a bandwidth of 5 MHz. The number of TV channels that can be transmitted is
(a) 2 million (b) 10 million
(c) 0.1 million (d) 1 million

15. A large rectangular box moves vertically downward with an acceleration a. A toy gun fixed at A and aimed towards C fires a particle P.



(a) P will hit C if $a = g$.
(b) P will hit the roof BC, if $a > g$.
(c) P will hit the wall CD if $a < g$.
(d) May be any of (a), (b) and (c), depending on the speed of projection of P.

16. An open pipe is in resonance in its 2[nd] harmonic with a tuning fork of frequency υ_1. Now it is closed at one end. If the frequency of the tuning fork is increased slowly from υ_1, then again a resonance is obtained with a frequency υ_2. If in this case the pipe vibrates in n^{th} harmonic, then
(a) $n = 3,\ \upsilon_2 = \frac{3}{4}\upsilon_1$ (b) $n = 3,\ \upsilon_2 = \frac{5}{4}\upsilon_1$
(c) $n = 5,\ \upsilon_2 = \frac{5}{4}\upsilon_1$ (d) $n = 5,\ \upsilon_2 = \frac{3}{4}\upsilon_1$

17. A cylindrical capacitor has radii a and b ($b > a$). The amount of energy stored in the cylindrical capacitor if its outer radius becomes $\sqrt{ab}$, is
(a) half of the total energy
(b) one-third of the total energy
(c) one-fourth of the total energy
(d) equal to the total energy

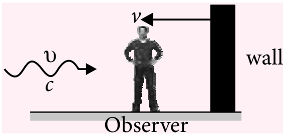
18. A particle starts with S.H.M. from the mean position. Its amplitude is A and time period is T. At one time, its speed is half that of the maximum speed, what is the displacement in this time?
(a) $\frac{2A}{\sqrt{3}}$ (b) $\frac{3A}{\sqrt{2}}$
(c) $\frac{\sqrt{2}A}{3}$ (d) $\frac{\sqrt{3}A}{2}$

19. A uniform horizontal metre scale of mass m is suspended by two vertical strings attached to its two ends. A body of mass $2m$ is placed on the 75 cm mark. The tensions in the two strings are in the ratio
(a) 1 : 2 (b) 1 : 3
(c) 2 : 3 (d) 3 : 4

20. A ball of mass m moving at speed v collides with another identical ball at rest. The kinetic energy of the balls after collision is three fourth of the original kinetic energy. The coefficient of restitution is
(a) $\sqrt{2}$ (b) $\frac{1}{\sqrt{2}}$ (c) $\frac{1}{\sqrt{3}}$ (d) $\frac{1}{2}$

21. A vessel containing 1 g of oxygen at a pressure of 10 atm and a temperature of 47 °C. It is found that because of a leak, the pressure drops to 5/8th of its original value and the temperature falls 27 °C. Find the mass of oxygen that is leaked out.
(a) $\frac{1}{3}$ g (b) $\frac{1}{2}$ g (c) $\frac{3}{4}$ g (d) $\frac{2}{3}$ g

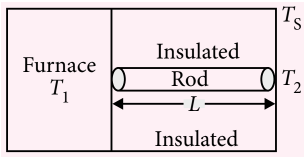
22. A sound wave of frequency υ travels horizontally to the right with speed c. It is reflected from a broad wall moving to the left with speed v. The number of beats heard by a stationary observer to the left of the wall is



(a) zero (b) $\frac{\upsilon(c+v)}{c-v}$

(c) $\frac{\upsilon v}{c-v}$ (d) $\frac{2\upsilon v}{c-v}$

23. One end of a rod of length L and cross sectional area A is kept in a furnace at temperature T_1. The other end of the rod is kept at a temperature T_2. The thermal conductivity of the material of the rod is K and emissivity of the rod is e. It is given that $T_2 = T_s + \Delta T$, where $\Delta T << T_s$, T_s is the temperature of the surroundings. If $\Delta T \propto (T_1 - T_2)$, find the proportional constant. Consider that heat is lost only by radiation at the end where the temperature of the rod is T_2.



(a) $\frac{K}{4e\sigma LT_s^3+1}$ (b) $\frac{K}{4e\sigma LT_s^3}$

(c) $\frac{K}{4e\sigma LT_s^2+K}$ (d) $\frac{K}{4e\sigma LT_s^3+K}$

24. Three identical thin rods, each of mass m and length l, are joined to form an equilateral triangular frame. Find the moment of inertia of the frame about an axis parallel to its one side and passing through the opposite vertex.

(a) $\frac{ml^2}{4}$ (b) $\frac{5}{4}ml^2$

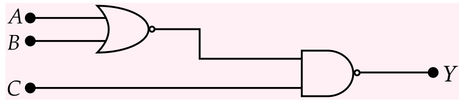
(c) $\frac{3}{2}ml^2$ (d) $\frac{3}{4}ml^2$

25. Two masses M_1 and M_2 at an infinite distance from each other and initially at rest, start interacting gravitationally. Find their velocity of approach when they are S distance apart.

(a) $\sqrt{\frac{2G(M_1+M_2)}{S}}$ (b) $\frac{2G}{S(M_1+M_2)}$

(c) $\sqrt{\frac{2G}{S(M_1+M_2)}}$ (d) $\sqrt{\frac{G(M_1+M_2)}{S}}$

26. A NOR gate and a NAND gate are connected as shown in the figure. Two different sets of inputs are given to this set up. In the first case, the inputs to the gates are $A = 0$, $B = 0$, $C = 0$. In the second case, the inputs are $A = 1$, $B = 0$, $C = 1$. The output Y in the first case and second case respectively are



(a) 0 and 0 (b) 0 and 1

(c) 1 and 0 (d) 1 and 1

27. The de Broglie wavelength of an electron (mass = 1×10^{-30} kg, charge = 1.6×10^{-19} C) with a kinetic energy of 200 eV is (Planck's constant = 6.6×10^{-34} J s)

(a) 9.60×10^{-11} m (b) 8.25×10^{-11} m

(c) 6.25×10^{-11} m (d) 5.00×10^{-11} m

28. A solenoid of 0.4 m length with 500 turns carries a current of 3 A. A coil of 10 turns and of radius 0.01 m carries a current of 0.4 A. The torque required to hold the coil with its axis at right angles to that of solenoid in the middle part of it, is

(a) $6\pi^2 \times 10^{-7}$ N m (b) $3\pi^2 \times 10^{-7}$ N m

(c) $9\pi^2 \times 10^{-7}$ N m (d) $12\pi^2 \times 10^{-7}$ N m

29. 12 identical cells were to be connected in series, some of them were wrongly connected. The emf of each cell is ε, internal resistance 0.5 Ω and current through an external resistance of 6 Ω is 1 A. When 2 more cells were added in series current through same external resistance is $\frac{15}{13}$ A. Find ε and number of cells wrongly connected.

(a) 1 V, 3 (b) 1.5 V, 2

(c) 2.0 V, 3 (d) 2.5 V, 2

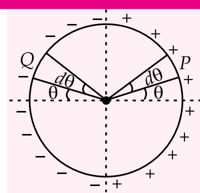
30. Water from a tap emerges vertically downwards with an initial speed of 1 m s–1. The cross-sectional area of the tap is 10–4 m2. Assuming pressure to be constant through out the stream of water and flow to be steady, the cross-sectional area 0.15 m below the tap is

(a) 10^{-4} m^2 (b) 10^{-5} m^2

(c) 0.5×10^{-4} m^2 (d) 0.2×10^{-4} m^2

SOLUTIONS

1. **(c):** Consider two small charge elements P and Q shown in figure.

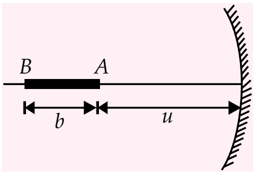


Dipole moment of this pair
$= [(\lambda_0\cos\theta)R\, d\theta]2R\cos\theta$

$= 2\lambda_0 R^2\cos^2\theta\, d\theta$

$\therefore$ Dipole moment of the charge distribution

$$= 2\lambda_0 R^2 \int_{-\pi/2}^{+\pi/2} \cos^2\theta\, d\theta = \pi R^2 \lambda_0$$

2. (d) : 

For the image of A, $\frac{1}{v_A} + \frac{1}{-u} = \frac{1}{-f} \Rightarrow v_A = \frac{uf}{f-u}$

For the image of B, $\frac{1}{v_B} + \frac{1}{-(u+b)} = \frac{1}{-f}$

$$\Rightarrow \quad v_B = \frac{f(u+b)}{(f-u-b)}$$

The image size is $v_B - v_A = \frac{f^2 b}{(f-u)(f-u-b)}$

$$= \frac{f^2 b}{(u-f)(u+b-f)}$$

$$= \frac{f^2 b}{(u-f)(u-f)} = b\left(\frac{f}{u-f}\right)^2 \quad (u >> b \text{ then } u+b = u)$$

3. (c) : When a particle separates from a moving body, it retains the velocity of the body but not its acceleration.

When the stone is released, the balloon is 40 m above the ground and has an upward velocity of 10 m s^{-1}. For the motion of the stone from the balloon to the ground,

$u = -10$ m s^{-1}, $s = 40$ m, $g = 10$ m s^{-2}

Distance covered in upward direction $v^2 - u^2 = 2gs$

$$\Rightarrow \quad s = \frac{u^2}{2g} \qquad (\because v = 0)$$

$$\therefore \quad s = \frac{100}{2\times 10} = 5 \text{ m}$$

$\therefore$ Total distance covered = 45 + 5 = 50 m

Displacement = 40 m

Now, $s = ut + \frac{1}{2}gt^2$

Putting the values, $40 = -10t + \frac{1}{2} \times 10 \times t^2$

$5t^2 - 10t - 40 = 0$

$t^2 - 2t - 8 = 0$; $t^2 - 4t + 2t - 8 = 0$

$t(t-4) + 2(t-4) = 0$; $(t-4)(t+2) = 0$

$t = 4, -2$

Taking positive value $t = 4$ s

4. (d) : According to Einstein's photoelectric equation,

$$\frac{1}{2}mv_{max}^2 = \frac{hc}{\lambda} - \phi_0$$

$$= \frac{6.6\times 10^{-34} \times 3\times 10^8}{2000\times 10^{-10} \times 1.6\times 10^{-19}} \text{ eV} - 4.2 \text{ eV}$$

≈ 2 eV $= 2 \times 1.6 \times 10^{-19}$ J

$$v_{max} = \sqrt{\frac{2\times 2\times 1.6\times 10^{-19}}{9.1\times 10^{-31}}} = \sqrt{\frac{6.4\times 10^{12}}{9.1}} \text{ m s}^{-1}$$

$= 0.83 \times 10^6$ m s^{-1} $= 8.3 \times 10^5$ m s^{-1}

5. (b) : Compressibility, $K = \frac{1}{B} = -\frac{1}{\Delta P}\left(\frac{\Delta V}{V}\right)$

$\frac{\Delta V}{V} = K\Delta P$

$\frac{\Delta V}{V} \times 100 = K\Delta P \times 100$

or $\frac{\Delta V}{V} \times 100 = 8 \times 10^{-12} \times 10^5 \times 100 = 8 \times 10^{-5}$

6. (a) : Given, $\left[P + \frac{a}{V^3}\right](V - b^2) = cT$

Dimensions of $[a]$ = dimensions of $[PV^3]$

$$= \left[\frac{F}{A}V^3\right] \qquad \left(\because P = \frac{F}{A}\right)$$

$$= \frac{[\text{MLT}^{-2}]}{[\text{L}^2]} \times [\text{L}^3]^3 = [\text{ML}^8\text{T}^{-2}]$$

Now, dimensions of $[b]^2$ = dimensions of $[V]$

$[b] = [\text{L}^3]^{1/2}$ or $[b] = [\text{L}^{3/2}]$

7. (a) : Binding energy $= \Delta Mc^2$

$= [2(m_p + m_N) - m_{He}] \times c^2$

$= [2(1.00783 + 1.00867) - 4.00300] \times 931$ MeV

B.E. = 27.9 MeV

8. (b) : As $\beta = \frac{D\lambda}{d}$

Here, $\beta = 5 \times 10^{-3}$ m, $\lambda = 5000 \times 10^{-10}$ m

and $D = 1$ m

$\therefore$ separation between two coherent sources

$$d = \frac{D\lambda}{\beta} = \frac{1\times 5000\times 10^{-10}}{5\times 10^{-3}} = 0.1 \text{ mm}$$

9. (c): As $V_R = V_L = V_C$ $\quad\therefore\ R = X_L = X_C$

$Z = R$, $V = IR = 10$ V

When capacitor is short circuited,

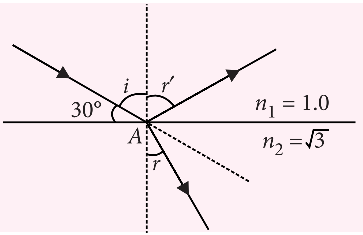
$$Z = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + R^2} = R\sqrt{2}$$

New current $I' = \frac{V}{Z} = \frac{V}{R\sqrt{2}} = \frac{10}{R\sqrt{2}}$

Potential drop across inductance

$$= I'X_L = I'R = \frac{10\times R}{R\sqrt{2}} = \frac{10}{\sqrt{2}} \text{ V}$$

10. (c): Angle of incidence, $i = 90° - 30° = 60°$
As angle of reflection = angle of incidence
$\therefore \quad r' = i = 60°$



Applying the Snell's law at point A on the interface,
$n_1 \sin i = n_2 \sin r$

$$\sin r = \frac{n_1}{n_2}\sin i = \frac{1}{\sqrt{3}}\sin 60° = \frac{1}{\sqrt{3}}\frac{\sqrt{3}}{2} = \frac{1}{2}$$

$$r = \sin^{-1}\left(\frac{1}{2}\right) = 30°$$

11. (b) : Here,
Magnetic dipole moment, $\mu = 2.0\mu_B$
$= 2.0 \times 9.27 \times 10^{-24}$ J T^{-1} = 18.54×10^{-24} J T^{-1}
Magnetic field, $B = 1.5$ T
The energy of a magnetic dipole in an external magnetic field is

$$U_B = -\vec{\mu}\cdot\vec{B} = -\mu B\cos\theta$$

where θ is the angle between the directions of $\vec{\mu}$ and $\vec{B}$.
The energy difference ΔU_B between parallel alignment ($\theta = 0°$) and antiparallel alignment ($\theta = 180°$) is
$\Delta U_B = -\mu B \cos 180° - (-\mu B \cos 0°)$
$= 2\mu B$
$= 2 \times (18.54 \times 10^{-24}$ J T^{-1}) (1.5 T)
$= 5.6 \times 10^{-23}$ J

12. (a) : ${}^{235}\text{U} + n \longrightarrow {}^{140}\text{Ce} + {}^{94}\text{Zr} + 2n$
The disintegration energy of the reaction is
$Q = (M_U + M_n - M_{Ce} - M_{Zr} - 2M_n)c^2$
$= (M_U - M_{Ce} - M_{Zr} - M_n)c^2$
$= (235.02 - 139.9 - 93.9 - 1.0)\text{u} \times c^2$
$= (0.22\ \text{u})c^2 \approx 205$ MeV

13. (a) : $V_s = \frac{N_s}{N_p}V_p = \frac{500}{50} \times 20 = 200$ V
Frequency remains unchanged.

14. (d) : Optical source frequency $\upsilon = \frac{c}{\lambda}$

$$\upsilon = \frac{3\times10^8 \text{ m s}^{-1}}{1200\times10^{-9}\text{m}} = 2.5\times10^{14} \text{ Hz}$$

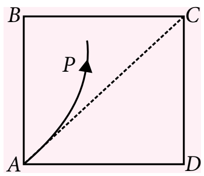
Total bandwidth of channel = 2% of the source frequency

$$= \frac{2}{100}\times 2.5\times10^{14} \text{ Hz} = 5\times10^{12} \text{ Hz}$$

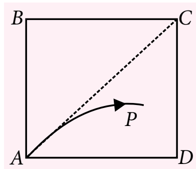
$$\text{Number of channels} = \frac{\text{Total bandwidth}}{\text{Bandwidth needed per channel}}$$

$$= \frac{5\times10^{12} \text{ Hz}}{5\times10^{6} \text{ Hz}} = 10^6 = 1 \text{ million}$$

15. (d) : Assuming box to be at rest.
(a) If $a = g$, then relative acceleration of P will be zero. so path is straight line along AC.
(b) If $a > g$, then relative acceleration of P is upwards. Therefore path of P with respect to box is as shown in figure.
So, particle may hit AB or BC depending on the speed of P.

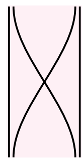


(c) If $a < g$, then relative acceleration of P is downwards. Therefore path of P with respect to box is as shown in figure.
So, the particle may hit CD or AD depending upon the speed of P.



16. (c): Fundamental harmonic of open organ pipe is given by

$$l = \frac{\lambda}{2} \text{ or } \lambda = 2l \text{ or, } \upsilon = \frac{v}{\lambda} = \frac{v}{2l}$$



As the tube vibrates in the second harmonic hence,

$$\upsilon_1 = 2\upsilon = \frac{2v}{2l} = \frac{v}{l} \qquad \text{...(i)}$$

If one end is closed, it gives only odd harmonics.
Fundamental frequency of closed organ pipe = $\frac{v}{4l}$

The other harmonics are $\frac{3v}{4l}, \frac{5v}{4l}$, etc.

Once, the frequency starts increasing, the first higher harmonic that is resonated = $\frac{3v}{4l}$.

If $n = 3$, $\upsilon_2 = \frac{3}{4}\cdot\frac{v}{l} = \frac{3}{4}\upsilon_1$

However, here is a snag. The frequency is increased from $\frac{v}{l}$. Here $\frac{3}{4}\upsilon_1$ is not greater than $\upsilon_1\left(=\frac{v}{l}\right)$.

Hence, $\frac{5}{4}\upsilon_1$ is the answer because this is greater than υ_1. So, $n = 5$, $\upsilon_2 = 5\times\frac{v}{4l} = \frac{5}{4}\upsilon_1$

17. (a) : Total energy, $E = \frac{Q^2}{2C} = \frac{Q^2}{2(2\pi\varepsilon_0 l)}\ln\frac{b}{a}$

Energy stored, $E' = \dfrac{Q^2}{2(2\pi\varepsilon_0 l)} \ln \dfrac{\sqrt{ab}}{a} = \dfrac{Q^2 \ln\left(\dfrac{b}{a}\right)^{1/2}}{2(2\pi\varepsilon_0 l)}$

$$= \frac{\frac{1}{2} Q^2 \ln \frac{b}{a}}{2(2\pi\varepsilon_0 l)} = \frac{E}{2}$$

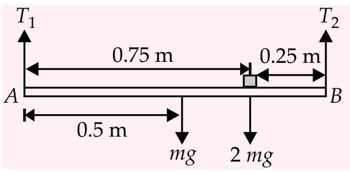
18. (d) : Maximum velocity, $v_{max} = A\omega$

According to question, $\dfrac{v_{max}}{2} = \dfrac{A\omega}{2} = \omega\sqrt{A^2 - y^2}$

$$\frac{A^2}{4} = A^2 - y^2$$

$$\Rightarrow \; y^2 = A^2 - \frac{A^2}{4} \;\Rightarrow\; y = \frac{\sqrt{3}A}{2}$$

19. (a) :



Here, $T_1 + T_2 = 2\,mg + 1\,mg = 3\,mg$

Taking torques about A, $0.5\,mg + 0.75 \times 2\,mg = 1 \times T_2$

$\therefore \quad T_2 = 2\,mg,\; T_1 = mg$

$$\frac{T_1}{T_2} = \frac{mg}{2mg} = \frac{1}{2}$$

20. (b) : By the principle of conservation of linear momentum,

$mv = mv_1 + mv_2 \quad \text{or} \quad v = v_1 + v_2$ ...(i)

The coefficient of restitution,

$e = \dfrac{v_2 - v_1}{v - 0} \quad \text{or } v_2 - v_1 = ev$ ...(ii)

Adding (i) and (ii) $v_2 = \dfrac{(v + ev)}{2}$ and $v_1 = \dfrac{(1-e)v}{2}$

$$\frac{3}{4}\frac{mv^2}{2} = \frac{m}{2}\left[\frac{v^2(1+e)^2}{4} + \frac{(1-e)^2 v^2}{4}\right]$$

or $\quad 3 = (1 + e)^2 + (1 - e)^2$ or $e^2 = \dfrac{1}{2}$ or $e = \dfrac{1}{\sqrt{2}}$

21. (a) : The pressure, temperature and the number of moles of oxygen in the vessel change due to leak while the volume remains fixed. Hence using $PV = nRT$, we

$$\frac{P_1}{n_1 T_1} = \frac{P_2}{n_2 T_2} \Rightarrow n_2 = \frac{T_1}{T_2} \times \frac{P_2}{P_1} \times n_1$$

Here, $n_2 = \dfrac{320}{300} \times \dfrac{5}{8} \times \dfrac{1}{32} = \dfrac{1}{48}$ moles

Mass leaking out $= 1 - n_2(32) = \dfrac{1}{3}$ g

22. (d) : Initially wall behaves as an approaching observer, so frequency of sound reaching the wall is

$$\upsilon_1 = \frac{c + v}{c}\upsilon$$

While reflecting, the wall behaves as an approaching source, so frequency received by stationary observer is

$$\upsilon_2 = \frac{c}{c - v}\upsilon_1 = \frac{c}{c - v} \times \frac{c + v}{c}\upsilon = \frac{c + v}{c - v}\upsilon$$

Direct frequency received by observer is υ, the number of beats is

$$x = \upsilon_2 - \upsilon = \frac{c + v}{c - v}\upsilon - \upsilon = \frac{2\upsilon v}{c - v}$$

23. (d) : Rate of heat conduction through rod = rate of the heat lost from right end of the rod.

$\dfrac{KA(T_1 - T_2)}{L} = eA\sigma(T_2^4 - T_s^4)$ ...(i)

Given that $T_2 = T_s + \Delta T$

$$T_2^4 = (T_s + \Delta T)^4 = T_S^4\left(1 + \frac{\Delta T}{T_S}\right)^4$$

Using binomial expansion, we have

$T_2^4 = T_S^4\left(1 + 4\dfrac{\Delta T}{T_S}\right)$ (as $\Delta T << T_S$)

$$T_2^4 - T_S^4 = 4(\Delta T)(T_S^3)$$

Substituting in eq. (i), we have

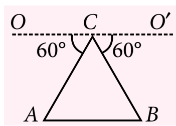
$$\frac{K(T_1 - T_S - \Delta T)}{L} = 4e\sigma T_S^3 \Delta T$$

$$\Rightarrow \frac{K(T_1 - T_S)}{L} = \left(4e\sigma T_S^3 + \frac{K}{L}\right)\Delta T$$

$$\Rightarrow \Delta T = \frac{K(T_1 - T_S)}{(4e\sigma L T_S^3 + K)}$$

Comparing with the given relation, proportionality constant $= \dfrac{K}{4e\sigma L T_S^3 + K}$

24. (b) : Moment of Inertia of each of rod AC and BC about the given axis OO' is



$$I_{AC} = I_{BC} = \frac{ml^2}{3}\sin^2 60° = \frac{ml^2}{4}$$

and moment of inertia of rod AB about the given axis OO' is

$$I_{AB} = m\left(\frac{l\sqrt{3}}{2}\right)^2 = \frac{3}{4}ml^2$$

Hence, $I = I_{AC} + I_{BC} + I_{AB} = \dfrac{ml^2}{4} + \dfrac{ml^2}{4} + \dfrac{3}{4}ml^2 = \dfrac{5}{4}ml^2$

25. (a) : Since they move under mutual attraction and no external force acts on them, their momentum and energy are conserved.
Therefore,

$$\therefore \quad 0 = \frac{1}{2}M_1v_1^2 + \frac{1}{2}M_2v_2^2 - \frac{GM_1M_2}{S}$$

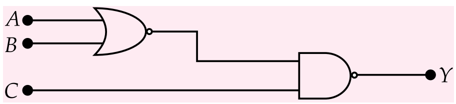
It is zero because in the beginning, both kinetic energy and potential energy are zero.
$0 = M_1v_1 + M_2v_2$
Solving the equations,

$$v_1^2 = \frac{2GM_2^2}{S(M_1+M_2)} \text{ and } v_2^2 = \frac{2GM_1^2}{S(M_1+M_2)}$$

v (velocity of approach) $= v_1 - (-v_2) = v_1 + v_2$

$$= \sqrt{\frac{2G(M_1+M_2)}{S}}$$

26. (d):



From given combination of gates, the output is

$$Y = \overline{\overline{A+B}\cdot C}$$

$$Y = \overline{\overline{A+B}} + \overline{C}$$

$$Y = (A + B + \overline{C})$$

Now, if $A = 0$, $B = 0$ and $C = 0$,
then output, $Y = (0 + 0 + \overline{0}) = 1 \quad (\because\ \overline{0} = 1)$
Now if $A = 1$, $B = 0$ and $C = 1$,
then output, $Y = (1 + 0 + \overline{1}) = 1 \quad (\because\ \overline{1} = 0)$

27. (b): de-Broglie wavelength associated with charged particle $\lambda = \dfrac{h}{\sqrt{2mE}}$

Here, $m = 1 \times 10^{-30}$ kg, $e = 1.6 \times 10^{-19}$ C
$E = 200$ eV $= 200 \times 1.6 \times 10^{-19}$ J
and $h = 6.6 \times 10^{-34}$ J s

$$\therefore \quad \lambda = \frac{6.6\times10^{-34}}{\sqrt{2\times1\times10^{-30}\times200\times1.6\times10^{-19}}} = \frac{6.6}{8}\times\frac{10^{-34}}{10^{-24}}$$

$\lambda = 8.25 \times 10^{-11}$ m

28. (a): Magnetic field, B for solenoid

$$= \mu_0 nI = 4\pi\times10^{-7}\times\frac{500}{0.4}\times3$$

Magnetic moment of the coil, $M = IAN$
$= 0.4 \times \pi \times (0.01)^2 \times 10 = 4\pi \times 0.0001$
$\tau = MB \sin 90°$

$$= 4\pi\times0.0001\times4\pi\times10^{-7}\times\frac{500}{0.4}\times3 = 6\pi^2\times10^{-7}\text{ N m}$$

29. (b): Let m be the number of cells wrongly connected. Then current,

$$I = \frac{n\varepsilon - 2m\varepsilon}{nr+R} \text{ or } \frac{12\varepsilon-2m\varepsilon}{6+6} = 1$$

or $\quad 12\varepsilon - 2m\varepsilon = 12 \qquad$ ...(i)

Also $\quad \dfrac{14\varepsilon - 2m\varepsilon}{7+6} = \dfrac{15}{13}$

or $14\varepsilon - 2m\varepsilon = 15 \qquad$ ...(ii)

Solving (i) and (ii) we get
$\varepsilon = 1.5$ V and $m = 2$

30. (c): By equation of continuity, $A_1v_1 = A_2v_2$

or $\quad v_2 = \dfrac{A_1}{A_2}v_1$

$v_2^2 = v_1^2 + 2gh$ and $A_2 = A_1\dfrac{v_1}{v_2}$

$$\text{or} \quad A_2 = \frac{A_1v_1}{\sqrt{v_1^2+2gh}} = \frac{10^{-4}\times1}{\sqrt{1+2\times10\times0.15}} = 0.5\times10^{-4}\text{ m}^2$$

SOLUTION OF JANUARY 2017 CROSSWORD

1 T		2 D	3 I	S	O	4 G	O	N	A	L		5 H	E	P	T	O	D	E		6 B
R		I				Y														A
A		U		7 P	E	R	I	H	E	L	I	O	N			8 M				L
N		R				A								9 M		E				L
S		N				T								A		G				I
D		10 A	N	E	M	O	M	E	T	E	R			11 G	R	A	Y			S
U		L				R		12 F	E	M	T	O		N		P		13 D		T
C	14 C	M		15 G	R	A	T	I	C	U	L	E		E		H		I		I
E	O	O						S						T		O		E		C
R	E	16 T	E	L	E	V	I	S	I	O	N			R		N		L		G
	R	I						I			17 M			O	18 C	E		E		A
	C	O		19 N	E	20 B	U	L	A		A			N	O			C		L
21 A	I	N				O		E			22 N	E	P	E	R			T		V
L	V					23 O	V	E	R	T	O	N	E		O			R		A
24 B	E	A	T	S		T			25 H	O	M	O	J	U	N	C	T	I	O	N
E	F					S					E				A			C		O
26 D	O	S	I	M	E	T	R	Y			T									M
O	R	27 L	I	D	A	R					28 E	X	O	S	P	H	E	R	E	E
	C					A					R									T
	E		29 D	A	M	P	I	N	G		30 R	E	S	I	L	I	E	N	C	E
31 B	I	T	T	E	R	P	A	T	T	E	R	N	S							R

Winner (January 2017)

- Adarsh Kalia, Hamirpur

Solution Senders (December 2016)

- Ashish Pandey, Mandsaur
- Swapnil Salve, Delhi

BOOST your NEET score

Practice Paper 2017

1. The rms speed of the molecules of a gas at 100 °C is v. The temperature at which the rms speed will be $\sqrt{3}v$ is
(a) 546 °C (b) 646 °C (c) 746 °C (d) 846 °C.

2. Two particles each of mass m and charge q, are attached to the two ends of a light rigid rod of length $2l$. The rod is rotated at constant angular speed about a perpendicular axis passing through its centre. The ratio of the magnitudes of the magnetic moment of the system and its angular momentum about the centre of the rod is
(a) $\frac{q}{\pi m}$ (b) $\frac{q}{m}$ (c) $\frac{2q}{m}$ (d) $\frac{q}{2m}$.

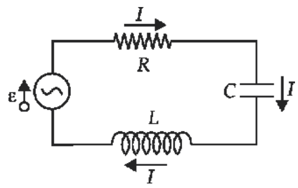
3. The equation for the vibration of a string fixed at both ends vibrating in its third harmonic is given by $y = 2\sin(0.6x)\cos(1500\pi t)$. The length of the string is
(a) 24.6 cm (b) 15.7 cm
(c) 20.6 cm (d) 12.5 cm.

4. There is some change in length when a 33000 N tensile force is applied on a steel rod of area of cross-section 10^{-3} m^2. The change in temperature required to produce the same elongation if the steel rod is heated is
(The modulus of elasticity is 3×10^{11} N m^{-2} and coefficient of linear expansion of steel is 1.1×10^{-5} °C^{-1})
(a) 20 °C (b) 15 °C (c) 10 °C (d) 0 °C

5. A and B are two points on a uniform ring of resistance R. The $\angle ACB = \theta$, where C is the centre of the ring. The equivalent resistance between A and B is
(a) $\frac{R}{4\pi^2}(2\pi - \theta)\theta$ (b) $R\left(1 - \frac{\theta}{2\pi}\right)$
(c) $R\frac{\theta}{2\pi}$ (d) $R\frac{2\pi - \theta}{4\pi}$.

6. A frictionless piston-cylinder based enclosure contains some amount of gas at a pressure of 400 kPa. Then heat is transferred to the gas at constant pressure in a quasi-static process. The piston moves up slowly through a height of 10 cm. If the piston has a cross-sectional area of 0.3 m^2, the work done by the gas in this process is
(a) 6 kJ (b) 12 kJ (c) 7.5 kJ (d) 24 kJ.

7. Figure shows a series LCR circuit with $R = 200\ \Omega$, $C = 15.0\ \mu$F and $L = 230$ mH. If $\varepsilon = 36.0 \sin 120\pi t$, the amplitude I_0 of the current I in the circuit is close to

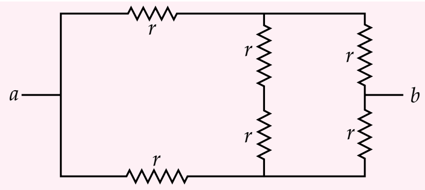


(a) 109 mA (b) 126 mA
(c) 150 mA (d) 164 mA.

8. A magnetising field of 1600 A m^{-1} produces a magnetic flux of 2.4×10^{-5} Wb in an iron bar of cross sectional area 0.2 cm^2. The susceptibility of an iron bar is
(a) 298 (b) 596 (c) 1192 (d) 1788.

9. A horizontal pipe line carries water in streamline flow. At a point along the pipe where cross-sectional area is 10 cm^2, the velocity of water is 1 m s^{-1} and pressure is 2000 Pa. The pressure of water at another point where cross-sectional area is 5 cm^2, is
(Density of water = 10^3 kg m^{-3})
(a) 250 Pa (b) 500 Pa
(c) 1000 Pa (d) 2000 Pa.

10. The equivalent resistance between the points a and b of the electrical network shown in the figure is



(a) $6r$ (b) $4r$ (c) $2r$ (d) r.

11. A bullet of mass m travelling with a speed v hits a block of mass M initially at rest and gets embedded in it. The combined system is free to move and there is no other force acting on the system. The heat generated in the process will be

(a) zero (b) $\frac{mv^2}{2}$

(c) $\frac{Mmv^2}{2(M-m)}$ (d) $\frac{mMv^2}{2(M+m)}$

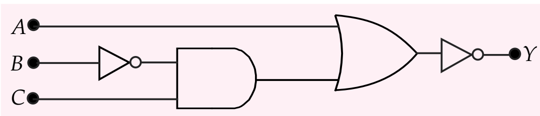
12. In an n-p-n transistor, 10^{10} electrons enter the emitter in 10^{-6} s. 2% of the electrons are lost in the base. The current transfer ratio is

(a) 0.88 (b) 0.78 (c) 0.98 (d) 0.68.

13. A sphere rolls down an inclined plane without slipping. What fraction of its total energy is rotational ?

(a) $\frac{2}{7}$ (b) $\frac{3}{7}$ (c) $\frac{4}{7}$ (d) $\frac{5}{7}$

14. The output Y of the logic circuit shown in figure is best represented as



(a) $\overline{A}+\overline{B\cdot C}$ (b) $A+\overline{B}\cdot C$

(c) $\overline{A+B\cdot C}$ (d) $\overline{A+\overline{B}\cdot C}$

15. A prism of refractive index 1.5 is placed in water of refractive index 1.33. The refracting angle of a prism is 60°. What is the angle of minimum deviation in water ? (Given sin 34° = 0.56)

(a) 4° (b) 8° (c) 12° (d) 16°

16. The binding energy of deuteron is 2.2 MeV and that of ${}^4_2$He is 28 MeV. If two deuterons are fused to form one ${}^4_2$He, then the energy released is

(a) 30.2 MeV (b) 25.8 MeV

(c) 23.6 MeV (d) 19.2 MeV.

17. A particle of mass M and charge q, initially at rest, is accelerated by a uniform electric field E through a distance D and is then allowed to approach a fixed static charge Q of the same sign. The distance of the closest approach of the charge q will then be

(a) $\frac{qQ}{4\pi\varepsilon_0 D}$ (b) $\frac{Q}{4\pi\varepsilon_0 ED}$

(c) $\frac{qQ}{2\pi\varepsilon_0 D^2}$ (d) $\frac{Q}{4\pi\varepsilon_0 E}$.

18. Which of the following statements are true ?

(I) All radioactive elements decay exponentially with time.

(II) Half life time of a radioactive element is the time required for one half of the radioactive atoms to distintegrate.

(III) Age of the earth can be determined by radioactive dating.

(IV) Half life time of a radioactive element is fifty percent of its average life period.

Select the correct answer using the codes given below.

(a) I and II (b) I, III and IV

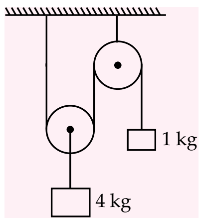
(c) I, II and III (d) II and III

19. The fundamental unit which has same power in the dimensional formula of surface tension and coefficient of viscosity is

(a) mass (b) length

(c) time (d) none of these.

20. In the system shown in the adjoining figure, the acceleration of 1 kg mass is



(a) $\frac{g}{4}$ downwards

(b) $\frac{g}{2}$ downwards

(c) $\frac{g}{2}$ upwards

(d) $\frac{g}{4}$ upwards.

21. A Carnot's reversible engine converts $\frac{1}{6}$ of heat input into work. When the temperature of the sink is reduced by 62 K, the efficiency of Carnot's cycle becomes (1/3). The temperatures of the source and the sink, (in kelvin) are respectively

(a) 372, 310 (b) 472, 410

(c) 310, 372 (d) 744, 682.

22. The moment of inertia of a uniform disc about an axis passing through its centre and perpendicular to its plane is 1 kg m^2. It is rotating with an angular velocity 100 rad s^{-1}. Another identical disc is gently placed on it so that their centres coincide. Now these two discs together continue to rotate about the same axis. Then the loss in kinetic energy (in kJ) is

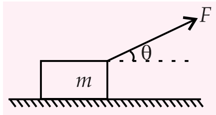
(a) 2.5 (b) 3.0 (c) 3.5 (d) 4.0.

23. A pendulum bob of mass m carrying a charge q is at rest with its string making an angle θ with the vertical in a uniform horizontal electric field E. The tension in the string is

(a) $\frac{mg}{\sin\theta}$ and $\frac{qE}{\cos\theta}$ (b) $\frac{mg}{\cos\theta}$ and $\frac{qE}{\sin\theta}$

(c) $\frac{qE}{mg}$ (d) $\frac{mg}{qE}$.

24. A wooden block of mass m resting on a rough horizontal table is pulled by a force F as shown in figure. If μ is the coefficient of friction between block and table, its acceleration will be



(a) $\frac{\mu F\cos\theta}{m}$ (b) $\frac{\mu F\sin\theta}{m}$

(c) $\frac{F}{m}(\cos\theta+\mu\sin\theta)-\mu g$

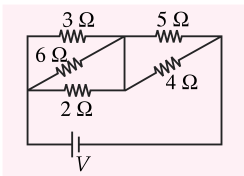
(d) $\frac{F}{m}(\cos\theta-\mu\sin\theta)$.

25. Two bodies of masses 1 kg and 3 kg have position vectors $(\hat{i}+2\hat{j}+\hat{k})$ and $(-3\hat{i}-2\hat{j}+\hat{k})$ respectively. The centre of mass of this system has a position vector

(a) $-\hat{i}+\hat{j}+\hat{k}$ (b) $-2\hat{i}+2\hat{k}$

(c) $-2\hat{i}-\hat{j}+\hat{k}$ (d) $2\hat{i}-\hat{j}-2\hat{k}$.

26. The resistor in which maximum heat will be produced is



(a) 6 Ω
(b) 2 Ω
(c) 5 Ω
(d) 4 Ω.

27. Two short bar magnets of magnetic moments M each are arranged at the opposite corners of a square of side d such that their centres coincide with the corners and their axes are parallel. If the like poles are in the same direction, the magnetic induction at any of the other corners of the square is

(a) $\frac{\mu_0}{4\pi}\frac{M}{d^3}$ (b) $\frac{\mu_0}{4\pi}\frac{2M}{d^3}$

(c) $\frac{\mu_0}{4\pi}\frac{M}{2d^3}$ (d) $\frac{\mu_0}{4\pi}\frac{M^3}{2d^3}$.

28. Suppose 4.0 mol of an ideal gas undergoes a reversible isothermal expansion from volume V_1 to volume $V_2 = 2.0V_1$ at temperature $T = 400$ K. Find the entropy change of the gas.
(Take ln 2 = 0.693)

(a) 23.0 J K^{-1} (b) 42.0 J K^{-1}
(c) 51.6 J K^{-1} (d) 56.9 J K^{-1}

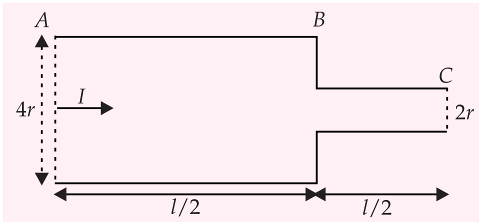
29. The ratio of radii of gyration of a circular disc and a circular ring of the same radii about a tangential axis perpendicular to plane of disc or ring is

(a) 1 : 2 (b) $\sqrt{5}:\sqrt{6}$ (c) 2 : 3 (d) $\sqrt{3}:2$.

30. A slab of material of dielectric constant K has the same area as the plates of a parallel plate capacitor but has a thickness $\left(\frac{3}{4}\right)d$, where d is the separation of the plates. The ratio of the capacitance C (in the presence of the dielectric) to the capacitance C_0 (in the absence of the dielectric) is

(a) $\frac{3K}{K+4}$ (b) $\frac{3}{4}K$ (c) $\frac{4K}{K+3}$ (d) $\frac{4}{3}K$.

31. Consider a cylindrical element as shown in figure. Current flowing through the element is I and resistivity of material of the cylinder is ρ. Choose the correct option out of the followings.

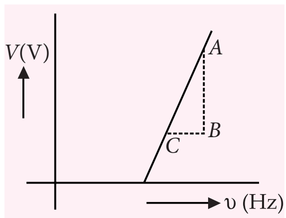


(a) Power loss in second half is four times the power loss in first half.
(b) Voltage drop in first half is twice of voltage drop in second half.
(c) Current density in both halves is equal.
(d) Electric field in both halves is equal.

32. A planet moves around the sun in an elliptical orbit with the sun at one of its foci. The physical quantity associated with the motion of the planet that remains constant with time is

(a) velocity (b) centripetal force
(c) linear momentum (d) angular momentum.

33. In a photoelectric experiment, the graph of frequency υ of incident light (in Hz) and stopping potential V (in V) is as shown in the figure. From figure, the value of the Planck's constant is (e is the elementary charge)



(a) $e\frac{AB}{CB}$

(b) $e\frac{CB}{AB}$

(c) $e\frac{AC}{BC}$

(d) $e\frac{AC}{AB}$.

34. A convex lens of focal length 20 cm made of glass of refractive index 1.5 is immersed in water having refractive index 1.33. The change in the focal length of lens is

(a) 62.2 cm (b) 5.82 cm
(c) 58.2 cm (d) 6.22 cm.

35. In a sonometer wire, the tension is maintained by suspending a 50.7 kg mass from the free end of the wire. The suspended mass has a volume of 0.0075 m^3. The fundamental frequency of the wire is 260 Hz. If the suspended mass is completely submerged in water, the fundamental frequency will become

(a) 200 Hz (b) 220 Hz (c) 230 Hz (d) 240 Hz.

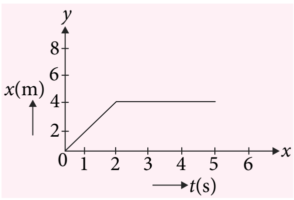
36. The period of oscillation of a simple pendulum is $T = 2\pi\sqrt{L/g}$. Measured value of L is 10 cm known to 1 mm accuracy and time for 100 oscillations of the pendulum is found to be 50 s using a wrist watch of 1 s resolution. What is the accuracy in the determination of g ?

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

37. A proton and an α-particle enter a uniform magnetic field perpendicularly with the same speed. If proton takes 25 μs to make 5 revolutions, then the periodic time for the α-particle would be

(a) 50 μs (b) 25 μs (c) 10 μs (d) 5 μs.

38. The position-time graph of a particle of mass 0.1 kg is as shown in the figure. The impulse at $t = 2$ s is



(a) 0.2 kg m s^{-1}
(b) 0.02 kg m s^{-1}
(c) 0.1 kg m s^{-1}
(d) 0.4 kg m s^{-1}.

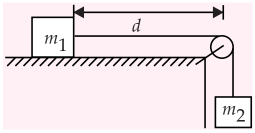
39. A magnet is suspended in such a way that it oscillates in the horizontal plane. It makes 20 oscillations per minute at a place where dip angle is 30° and 15 oscillations per minute at a place where dip angle is 60°. Ratio of the total earth's magnetic field at the two places is

(a) $3\sqrt{3}:8$ (b) $16:9\sqrt{3}$
(c) $4:9$ (d) $2\sqrt{3}:9$.

40. A glass plate of refractive index 1.5 is coated with a thin layer of thickness t and refractive index 1.8. Light of wavelength 648 nm travelling in air is incident normally on the layer. It is partly reflected at upper and lower surfaces of the layer and the two reflected rays interfere. The least value of t for which the rays interfere constructively is

(a) 30 nm (b) 60 nm (c) 90 nm (d) 120 nm.

41. A block of mass m_1 lies on a smooth horizontal table and is connected to another freely hanging block of mass m_2 by a light inextensible string passing over a smooth fixed pulley situated at the edge of the table as shown in the figure. Initially the system is at rest with m_1 at a distance d from the pulley. The time taken for m_1 to reach the pulley is



(a) $\dfrac{m_2 g}{m_1 + m_2}$ (b) $\sqrt{\dfrac{2d(m_1+m_2)}{m_2 g}}$

(c) $\sqrt{\dfrac{2m_2 d}{(m_1+m_2)g}}$ (d) None of these.

42. An 80 MHz carrier is modulated by 400 Hz sine wave. The carrier voltage is 5 V and the frequency deviation is 20 kHz. Find modulation index.

(a) 25 (b) 50 (c) 400 (d) 5

43. The absolute temperature of a body A is four times that of another body B. For two bodies, the difference in wavelength at which energy radiated is maximum, is 3.0 μm. Then the wavelength at which the body B radiates maximum energy in micrometer is

(a) 2.0 (b) 2.5 (c) 4.0 (d) 4.5.

44. A magnet of magnetic moment M is lying in a magnetic field of induction B. W_1 is the work done in turning it from 0° to 60° and W_2 is the work done in turning it from 30° to 90°. Then

(a) $W_1 = \dfrac{W_1}{2}$ (b) $W_2 = 2W_1$

(c) $W_2 = W_1$ (d) $W_2 = \sqrt{3}\,W_1$.

45. An object placed in front of a concave mirror at a distance of x cm from the pole gives a 3 times magnified real image. If it is moved to a distance of $(x + 5)$ cm, the magnification of the image becomes 2. The focal length of the mirror is

(a) 15 cm (b) 20 cm (c) 25 cm (d) 30 cm.

SOLUTIONS

1. (d) : The rms speed of a gas molecules is given by

$$v_{rms} = \sqrt{\frac{3RT}{M}} \text{ or } v_{rms} \propto \sqrt{T} \quad \therefore \quad \frac{v_{rms_1}}{v_{rms_2}} = \sqrt{\frac{T_1}{T_2}}$$

Here, $v_{rms_1} = v$, $v_{rms_2} = \sqrt{3}v$

and $T_1 = 100\ °C = 100 + 273 = 373$ K

$$\therefore \left(\frac{v}{\sqrt{3}v}\right)^2 = \left(\frac{373}{T_2}\right) \text{ or } \frac{1}{3} = \frac{373}{T_2}$$

$$\Rightarrow T_2 = 3 \times 373 = 1119 \text{ K}, T_2 = 1119 - 273 = 846\ °C$$

2. **(d):** Time of revolution, $T=\frac{2\pi l}{v}$

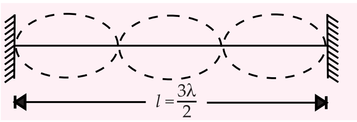
Total current due to the motion of charges,

$I=\frac{2q}{T}=\frac{2qv}{2\pi l}=\frac{qv}{\pi l}$

Magnetic moment of the system,

$M=IA=\frac{qv}{\pi l}\times\pi l^2=qvl$

Angular momentum of the system about the centre of rod, $L=mvl+mvl=2mvl$ $\therefore$ $\frac{M}{L}=\frac{qvl}{2mvl}=\frac{q}{2m}$

3. **(b):** 

As is clear from figure, while vibrating in 3rd harmonic, $l=\frac{3\lambda}{2}$

From the given equation, $\frac{2\pi}{\lambda}=0.6$

$\lambda=\frac{2\pi}{0.6}=\frac{10\pi}{3}$

$\therefore\quad l=\frac{3}{2}\lambda=\frac{3}{2}\times\frac{10\pi}{3}=5\pi=5\times3.14=15.7\text{ cm}$

4. **(c):** Young's modulus $Y=\frac{(F/A)}{\Delta l/l}$

or $\quad \Delta l=\frac{(F/A)l}{Y}$ ...(i)

Also, $\Delta l=\alpha l\,\Delta\theta$ ...(ii)

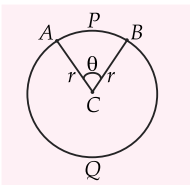
As per question

$\frac{(F/A)l}{Y}=\alpha l\Delta\theta$ or $\Delta\theta=\frac{F}{YA\alpha}$

$=\frac{33000}{(3\times10^{11})\times(10^{-3})\times(1.1\times10^{-5})}=10\text{ °C}$

5. **(a):** Resistance per unit length $=\rho=\frac{R}{2\pi r}$.

Lengths of sections APB and AQB are $r\theta$ and $r(2\pi-\theta)$ respectively.



Resistance of section APB and AQB are

$R_1=\frac{R}{2\pi r}r\theta=\frac{R\theta}{2\pi}$ and

$R_2=\frac{R}{2\pi r}r(2\pi-\theta)=\frac{R(2\pi-\theta)}{2\pi}$.

As R_1 and R_2 are in parallel between A and B,

$\therefore\quad R_{eq}=\frac{R_1R_2}{R_1+R_2}\Rightarrow R_{eq}=\frac{R}{4\pi^2}(2\pi-\theta)\theta$

6. **(b):** At constant pressure the work done by the gas to move the piston up is

$W=P\Delta V=P\Delta(lA)=400\times10^3\times10\times10^{-2}\times0.3=12\text{ kJ}$

7. **(d):** Given, $\varepsilon=36.0\sin120\pi t$

Compare it with standard equation,

$\varepsilon=\varepsilon_0\sin\omega t$

We get, $\varepsilon_0=36.0$, $\omega=120\pi$

The capacitive reactance is

$X_C=\frac{1}{\omega C}=\frac{1}{120\pi\times15\times10^{-6}}=177\ \Omega$

The inductive reactance is

$X_L=\omega L=120\pi\times230\times10^{-3}=87\ \Omega$

Impedance of the series LCR circuit is

$Z=\sqrt{R^2+(X_C-X_L)^2}=\sqrt{(200)^2+(177-87)^2}=219\ \Omega$

$\therefore\quad I_0=\frac{\varepsilon_0}{Z}=\frac{36\text{ V}}{219\ \Omega}=164\text{ mA}$

8. **(b):** Here, $H=1600\text{ A m}^{-1}$,

Magnetic flux $(\phi)=2.4\times10^{-5}$ Wb

$A=0.2\text{ cm}^2=0.2\times10^{-4}\text{ m}^2$

$\therefore\quad B=\frac{\phi}{A}=\frac{2.4\times10^{-5}}{0.2\times10^{-4}}=1.2\text{ Wb m}^{-2}$

$\therefore\quad \mu=\frac{B}{H}=\frac{1.2}{1600}=7.5\times10^{-4}\text{ N A}^{-2}$

Hence, susceptibility

$\chi=\frac{\mu}{\mu_0}-1=\frac{7.5\times10^{-4}}{4\pi\times10^{-7}}-1=596$

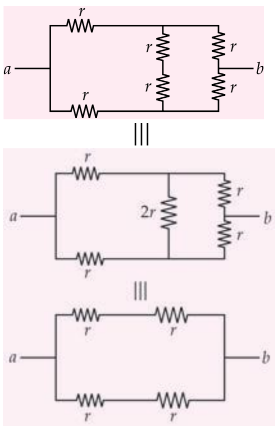
9. **(b):** According to equation of continuity,

$a_1v_1=a_2v_2$ or $v_2=\frac{a_1v_1}{a_2}=\frac{10\times1}{5}=2\text{ m s}^{-1}$

According to Bernoulli's theorem,

$P_1+\frac{1}{2}\rho v_1^2=P_2+\frac{1}{2}\rho v_2^2$; $P_2=P_1+\frac{1}{2}\rho\left(v_1^2-v_2^2\right)$

$=2000+\frac{1}{2}\times10^3\left(1^2-2^2\right)=500\text{ Pa}$

10. **(d):** 

Therefore, resultant resistance between a and b,

$$\frac{1}{R}=\frac{1}{2r}+\frac{1}{2r}=\frac{1}{r};\ R=r$$

11. (d)

12. (c) : The emitter current I_E is given by,

$$I_E=\frac{Ne}{t}=\frac{10^{10}\times(1.6\times10^{-19})}{10^{-6}}=1.6\times10^{-3}\text{ A}=1.6\text{ mA}$$

The base current I_B is given by,

$$I_B=\frac{2}{100}\times1.6\text{ mA}=0.032\text{ mA}$$

In a transistor, $I_E = I_B + I_C$

$\therefore$ $I_C = I_E - I_B = 1.6 - 0.032 = 1.568$ mA

Current transfer ratio $=\dfrac{I_C}{I_E}=\dfrac{1.568}{1.6}=0.98$

13. (a) : For solid sphere, total energy,

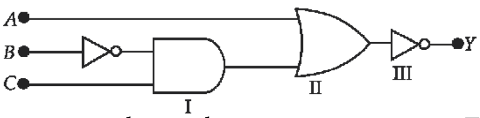
$$E=E_T+E_R=\frac{1}{2}Mv^2+\frac{1}{2}I\omega^2$$

$$=\frac{1}{2}Mv^2+\frac{1}{2}\left(\frac{2}{5}MR^2\right)\omega^2$$

$$=\frac{1}{2}Mv^2+\frac{1}{5}Mv^2=\frac{7}{10}Mv^2 \qquad (\because\ v=R\omega)$$

$$\therefore\ \frac{E_R}{E}=\frac{\left(\frac{1}{5}Mv^2\right)}{\left(\frac{7}{10}Mv^2\right)}=\frac{2}{7}$$

14. (d):



At logic gate I, the Boolean expression is $Y'=\overline{B}\cdot C$

At logic gate II, the Boolean expression is

$Y''=A+\overline{B}\cdot C$

At logic gate III, the Boolean expression is

$$Y=\overline{A+\overline{B}\cdot C}$$

15. (b): Here, ${}^a\mu_g=1.5=\frac{3}{2}$, ${}^a\mu_w=1.33=\frac{4}{3}$

$A = 60°$

As ${}^a\mu_w\times{}^w\mu_g={}^a\mu_g$

or $${}^w\mu_g=\frac{{}^a\mu_g}{{}^a\mu_w}=\frac{(3/2)}{(4/3)}=\frac{9}{8}$$

$${}^w\mu_g=\frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)};\ \frac{9}{8}=\frac{\sin\left(\frac{60°+\delta_m}{2}\right)}{\sin\left(\frac{60°}{2}\right)}$$

or $$\sin\left(\frac{60°+\delta_m}{2}\right)=\frac{9}{8}\times\sin30°=\frac{9}{8}\times\frac{1}{2}=\frac{9}{16}=0.56$$

or $\dfrac{60°+\delta_m}{2}=\sin^{-1}(0.56)$ or $\dfrac{60°+\delta_m}{2}=34°$

or $\delta_m = 68° - 60° = 8°$

16. (c) : ${}^2_1\text{H}+{}^2_1\text{H}\rightarrow{}^4_2\text{He}+\text{energy}$

$\therefore$ Energy released = B.E. of ${}^4_2$He – 2 × (B.E. of ${}^2_1$H)

= 28 – 2 × (2.2) = 28 – 4.4 = 23.6 MeV

17. (b): Force acting on charge q in uniform electric field E is, $F = qE$

$\therefore$ Work done on particle by electric field. $W = qED$

At distance of closest approach,

$$qED=\frac{1}{4\pi\varepsilon_0}\frac{qQ}{r_0}\quad\text{or}\quad r_0=\frac{Q}{4\pi\varepsilon_0 ED}$$

18. (c)

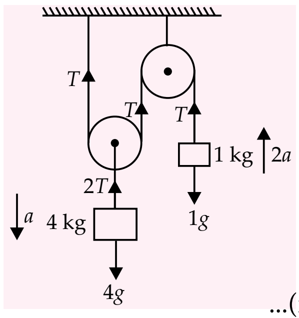
19. (a) : Surface tension $=\dfrac{\text{Force}}{\text{Length}}$

$$=\frac{[\text{MLT}^{-2}]}{[\text{L}]}=[\text{ML}^0\text{T}^{-2}]$$

Coefficient of viscosity $=\dfrac{\text{Force}}{\text{Area}\times\text{Velocity gradient}}$

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

20. (c) : If a is downward acceleration of 4 kg block, the upward acceleration of 1 kg block must be $2a$.



If T is tension in each part of string, then equations of motion of the two blocks are

$4a = 4g - 2T$ ...(i)

$1 \times 2a = T - 1g$ ...(ii)

or $4a = 2T - 2g$ ...(iii)

Adding eqns. (i) and (iii), we get

$$8a=2g,\ a=\frac{g}{4}$$

$\therefore$ Acceleration of 1 kg block $=2a=\dfrac{g}{2}$ upwards.

21. (a) : Efficiency of a Carnot's engine, $\eta=1-\dfrac{T_2}{T_1}$

where T_1 and T_2 are the temperatures of the source and the sink (in kelvin) respectively.

According to given question,

for the first case,

$$\frac{1}{6}=1-\frac{T_2}{T_1}\quad\text{or}\quad\frac{T_2}{T_1}=1-\frac{1}{6}=\frac{5}{6} \qquad \text{... (i)}$$

for the second case,

$$\frac{1}{3}=1-\frac{(T_2-62)}{T_1} \quad \text{or} \quad \frac{T_2-62}{T_1}=1-\frac{1}{3}=\frac{2}{3} \qquad \text{... (ii)}$$

Divide eqn. (i) by (ii), we get

$$\frac{T_2}{T_2-62}=\frac{5}{6}\times\frac{3}{2}=\frac{5}{4} \text{ or } 4T_2 = 5T_2 - 310 \text{ or } T_2 = 310 \text{ K}$$

Putting this value of T_2 in eqn. (i), we get

$$T_1=\frac{6}{5}T_2=\frac{6}{5}\times 310 = 372 \text{ K}$$

22. (a) : As no external torque is applied to the system, the angular momentum of the system remains conserved.

$\therefore \quad L_i = L_f$

where the subscripts represent initial and final.

or $\quad I_i\omega_i = I_f\omega_f$

Substituting the given values, we get

$\therefore \quad 1 \times 100 = 2 \times 1 \times \omega_f$

$\quad \omega_f = 50 \text{ rad s}^{-1} \qquad$ ...(i)

Initial kinetic energy, $K_i=\frac{1}{2}I_i\omega_i^2$

$$=\frac{1}{2}\times 1\times(100)^2 = 5\times 10^3 \text{ J}$$

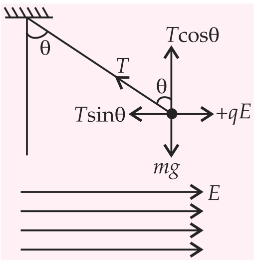
Final kinetic energy, $K_f=\frac{1}{2}I_f\omega_f^2$

$$=\frac{1}{2}\times 2\times 1\times(50)^2 = 2.5\times 10^3 \text{ J}$$

Loss in kinetic energy, $\Delta K = K_i - K_f$

$= 5 \times 10^3 - 2.5 \times 10^3 = 2.5 \times 10^3 \text{ J} = 2.5 \text{ kJ}$

23. (b) :

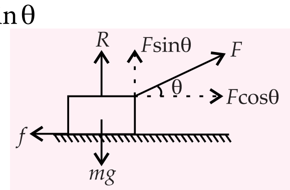


From figure,

$$T\cos\theta = mg \quad \text{or} \quad T=\frac{mg}{\cos\theta}$$

$$T\sin\theta = qE \quad \text{or} \quad T=\frac{qE}{\sin\theta}$$

24. (c) : Forces acting on the mass are shown in figure.



For vertical direction, no motion occurs.

$\therefore \quad R + F\sin\theta = mg$

Along horizontal

$F\cos\theta - f = ma$, where a is acceleration

or $\quad F\cos\theta - \mu R = ma \qquad [\because f = \mu R]$

$F\cos\theta - \mu(mg - F\sin\theta) = ma$

$$a=\frac{F}{m}(\cos\theta+\mu\sin\theta)-\mu g$$

25. (c) : Here, $m_1 = 1$ kg, $m_2 = 3$ kg

$x_1 = 1, y_1 = 2, z_1 = 1, x_2 = -3, y_2 = -2, z_2 = 1$

$$x_{cm}=\frac{m_1x_1+m_2x_2}{m_1+m_2}=\frac{1(1)+3(-3)}{1+3}=-2$$

$$y_{cm}=\frac{m_1y_1+m_2y_2}{m_1+m_2}=\frac{1(2)+3(-2)}{1+3}=-1$$

$$z_{cm}=\frac{m_1z_1+m_2z_2}{m_1+m_2}=\frac{1(1)+3(1)}{1+3}=1$$

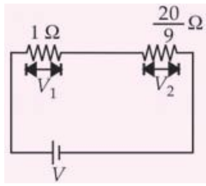
$\therefore$ Position vector of centre of mass is $(-2\hat{i}-\hat{j}+\hat{k})$.

26. (d): 3 Ω, 6 Ω and 2 Ω resistances are in parallel. So, potential drop across them will be equal. Of these three resistances, maximum heat will be generated across 2 Ω resistance.

$$\left(\because H=\frac{V^2}{R}t \text{ or } H\propto\frac{1}{R}\right)$$

Similarly, 5 Ω and 4 Ω resistances are also in parallel so, more heat will be generated across 4 Ω resistor. Now the given circuit can be redrawn as given.

$$\frac{V_1}{V_2}=\frac{1}{\frac{20}{9}}=\frac{9}{20}$$



$$\therefore \quad V_1=\left(\frac{9}{29}\right)V$$

and $V_2=\left(\frac{20}{29}\right)V$

Heat developed across 2 Ω resistor will be

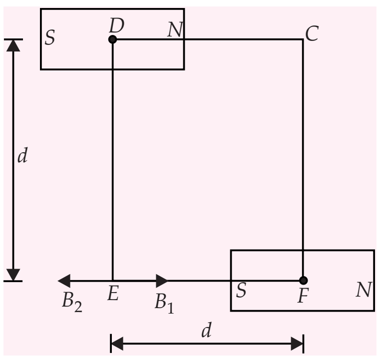
$$H_1=\frac{V_1^2t}{2}=\left(\frac{9}{29}\right)^2\frac{Vt}{2}$$

Heat developed across 4 Ω resistor,

$$H_2=\left(\frac{20}{29}\right)^2\frac{Vt}{4}$$

$\therefore \quad H_2 > H_1$

27. (a) :



Magnetic induction at point E due to magnet at F (axial point) is

$$B_1 = \frac{\mu_0}{4\pi}\frac{2M}{d^3} \text{ acts along } EF.$$

Magnetic induction at point E due to magnet at D (equatorial point) is

$$B_2 = \frac{\mu_0}{4\pi}\frac{M}{d^3} \text{ acts along } FE.$$

Resultant magnetic induction at point E is

$$B = B_1 - B_2 = \frac{\mu_0 M}{4\pi d^3}$$

28. (a) : Here, $n = 4$ mol, $R = 8.314$ J mol^{-1} K^{-1}
$T = 400$ K, $V_2 = 2.0\ V_1$
Work done by an ideal gas during isothermal expansion is $W = nRT\ln\left(\frac{V_2}{V_1}\right)$

For an isothermal expansion,

$$Q = W = nRT\ln\left(\frac{V_2}{V_1}\right) \quad \text{...(i)}$$

For reversible isothermal process, the change in entropy is $\Delta S = \frac{Q}{T}$

$$\Delta S = \frac{nRT\ln\left(\frac{V_2}{V_1}\right)}{T} = nR\ln\left(\frac{V_2}{V_1}\right) \quad \text{(Using (i))}$$

Substituting the given values, we get

$$\Delta S = 4\times 8.314\times \ln 2 = 4\times 8.314\times 0.693 = 23.0\ \text{J K}^{-1}$$

29. (d): Radius of gyration

$$K = \sqrt{\frac{I}{m}} \quad (I = \text{moment of inertia})$$

$$K_{disc} = \sqrt{\frac{\frac{1}{2}mR^2 + mR^2}{m}} = \sqrt{\frac{3}{2}}R$$

$$K_{ring} = \sqrt{\frac{mR^2 + mR^2}{m}} = \sqrt{2}R$$

$$\frac{K_{disc}}{K_{ring}} = \frac{\sqrt{\frac{3}{2}}}{\sqrt{2}} = \frac{\sqrt{3}}{2}$$

30. (c) : The capacitance of a parallel plate capacitor in the absence of the dielectric is

$$C_0 = \frac{\varepsilon_0 A}{d} \quad \text{...(i)}$$

where A is the area of each plate and d is the distance between them.

The capacitance of a parallel plate capacitor in the presence of dielectric slab of thickness t and dielectric constant K, is

$$C = \frac{\varepsilon_0 A}{(d-t)+\left(\frac{t}{K}\right)} = \frac{\varepsilon_0 A}{\left(d-\frac{3}{4}d\right)+\left(\frac{3d}{4K}\right)}$$

$$C = \frac{\varepsilon_0 A}{\frac{d}{4}+\frac{3d}{4K}} = \frac{4K\varepsilon_0 A}{d(K+3)} \quad \text{...(ii)}$$

Divide eqn. (ii) by (i), we get

$$\frac{C}{C_0} = \frac{4K\varepsilon_0 A}{d(K+3)}\times\frac{d}{\varepsilon_0 A} = \frac{4K}{K+3}$$

31. (a) : $R_1 = \frac{\rho(l/2)}{\pi(2r)^2} = \frac{\rho l}{8\pi r^2}$

$$R_2 = \frac{\rho(l/2)}{\pi r^2} = \frac{\rho l}{2\pi r^2} \qquad \therefore \frac{R_1}{R_2} = \frac{1}{4}$$

Power loss, $P = I^2R$ or $P \propto R$

$$\therefore \frac{P_1}{P_2} = \frac{I^2R_1}{I^2R_2} = \frac{1}{4} \text{ or } P_2 = 4P_1$$

Voltage drop, $V = IR$ or $V \propto R$

$$\therefore \frac{V_1}{V_2} = \frac{R_1}{R_2} = \frac{1}{4} \text{ or } V_2 = 4V_1$$

Current density, $J = \frac{I}{A} = \frac{I}{\pi r^2}$ or $J \propto \frac{1}{r^2}$

$$\therefore \frac{J_1}{J_2} = \frac{r^2}{(2r)^2} = \frac{1}{4} \text{ or } J_2 = 4J_1$$

Since the voltage drop is different for both halves, electric field is different.

32. (d): The angular momentum remains constant.

33. (a) : According to Einstein's photoelectric equation

$$h\upsilon = (\text{KE})_{max} + \phi_0$$

where ϕ_0 is the work function, υ is the incident frequency and h is the Planck's constant.
Also, $(\text{KE})_{max} = eV$
where e is the elementary charge, V is the stopping potential.

$$eV = h\upsilon - \phi_0$$

$$V = \frac{h}{e}\upsilon - \frac{\phi_0}{e}$$

Hence, the graph between V and υ is a straight line and slope of this graph is given by

$$\text{Slope} = \frac{h}{e} \quad \text{...(i)}$$

From the graph in the question,

$$\text{Slope} = \frac{AB}{BC} \quad \text{...(ii)}$$

From (i) and (ii), we get

$$h = e\frac{AB}{BC}$$

34. (c) : When the lens is in air

$$\frac{1}{f_a} = (\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{20} = (1.5-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{...(i)}$$

When lens is in water,

$$\frac{1}{f_w} = \left(\frac{\mu_g}{\mu_w} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

or $$\frac{1}{f_w} = \left(\frac{1.5-1.33}{1.33}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{...(ii)}$$

Dividing eqn. (i) by eqn. (ii), we get

$$\frac{f_w}{20} = (1.5-1)\left(\frac{1.33}{1.5-1.33}\right)$$

or $$f_w = 20 \times 0.5 \times \frac{1.33}{0.17} = 78.2 \text{ cm}$$

The change in focal length = 78.2 – 20 = 58.2 cm

35. (d): Initially, $260 = \frac{1}{2l}\sqrt{\frac{T_1}{\mu}}$, ...(i)

$T_1 = 50.7g = 507$ N $\quad (\because g = 10 \text{ ms}^{-1})$

When the mass is submerged, upthrust

$= (0.0075 \text{ m}^3)(10^3 \text{ kg m}^{-3})(10 \text{ m s}^{-2}) = 75$ N

New tension, $T_2 = (507 - 75)$ N = 432 N

New fundamental frequency

$$\upsilon = \frac{1}{2l}\sqrt{\frac{T_2}{\mu}} \quad \text{...(ii)}$$

Dividing eqn. (ii) by eqn. (i), we get

$$\frac{\upsilon}{260} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{432}{507}} = \sqrt{\frac{144}{169}} = \frac{12}{13}$$

or $\quad \upsilon = 240$ Hz

36. (d): Here, $T = 2\pi\sqrt{\frac{L}{g}}$

Squaring both sides, we get

$$T^2 = 4\pi^2\frac{L}{g} \quad \text{or} \quad g = 4\pi^2\frac{L}{T^2} \quad \text{...(i)}$$

Take log and differentiate both sides of equation (i),

we get $\frac{\Delta g}{g} = \frac{\Delta L}{L} - 2\left(\frac{\Delta T}{T}\right)$

For maximum relative error, the individual errors should be added.

$$\therefore \frac{\Delta g}{g} = \frac{\Delta L}{L} + 2\left(\frac{\Delta T}{T}\right)$$

Here, $T = \frac{t}{n}$ and $\Delta T = \frac{\Delta t}{n} \quad \therefore \frac{\Delta T}{T} = \frac{\Delta t}{t}$

As errors in both L and t are the least count errors.

$$\frac{\Delta g}{g} = \frac{0.1}{10} + 2\left(\frac{1}{50}\right) = 0.01 + 0.04 = 0.05$$

The percentage error in g is

$$\frac{\Delta g}{g}\times 100 = \frac{\Delta L}{L}\times 100 + 2\times\left(\frac{\Delta T}{T}\right)\times 100$$

$$= \left[\frac{\Delta L}{L} + 2\left(\frac{\Delta T}{T}\right)\right]\times 100 = 0.05\times 100 = 5\%$$

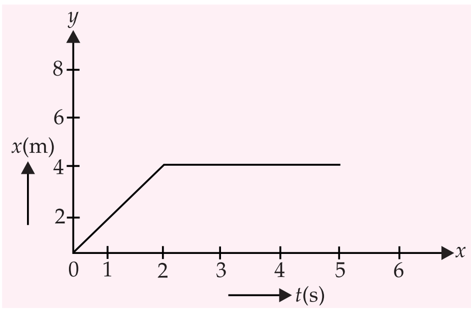
37. (c) : Time taken by proton to make one revolution

$$= \frac{25}{5} = 5\,\mu\text{s}$$

As $T = \frac{2\pi m}{qB} \quad \therefore \frac{T_\alpha}{T_p} = \frac{m_\alpha}{m_p}\times\frac{q_p}{q_\alpha}$

or $T_\alpha = T_p\frac{m_\alpha q_p}{m_p q_\alpha} = 5\times\frac{4m_p}{m_p}\times\frac{q}{2q} = 10\,\mu\text{s}$

38. (a) :



From the graph, it is clear that upto t = 2.0 s, the body moves with a constant velocity = slope of position time graph $= \frac{4}{2} = 2 \text{ m s}^{-1}$. After t = 2.0 s, position time graph is parallel to time axis, which means that the body comes to rest.

$\therefore$ Change in velocity = dv = 2 m s^{-1}

Impulse = change in momentum

= dp = mdv = 0.1 kg × 2 m s^{-1} = 0.2 kg m s^{-1}

39. (b): Here, υ_1 = 20 oscillations per minute

υ_2 = 15 oscillations per minute

$\delta_1 = 30°, \delta_2 = 60°$

$$\therefore \frac{\upsilon_1}{\upsilon_2} = \sqrt{\frac{B_{H_1}}{B_{H_2}}} = \sqrt{\frac{B_1\cos\delta_1}{B_2\cos\delta_2}}$$

Substituting the given values, we get

$$\frac{\upsilon_1}{\upsilon_2}=\sqrt{\frac{B_1\cos 30^\circ}{B_2\cos 60^\circ}}=\sqrt{\frac{B_1\times\frac{\sqrt{3}}{2}}{B_2\times\frac{1}{2}}}$$

$$\frac{20}{15}=\sqrt{\frac{\sqrt{3}B_1}{B_2}},\ \frac{B_1}{B_2}=\frac{16}{9\sqrt{3}}$$

40. (c) : Given

Refractive index of coating, $\mu = 1.8$

Wavelength of light, $\lambda = 648\text{ nm} = 648 \times 10^{-9}\text{ m}$

For constructive interference,

$$2\mu t=(2n+1)\frac{\lambda}{2}$$

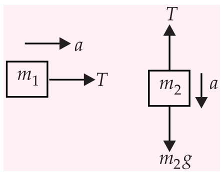
$$\therefore\quad 2\mu t=\frac{\lambda}{2}\qquad\text{(For } t \text{ to be minimum, } n = 0)$$

$$2\times 1.8\times t=\frac{648\times 10^{-9}}{2}$$

$$\therefore\quad t=\frac{648\times 10^{-9}}{2\times 2\times 1.8}=\frac{648}{7.2}\times 10^{-9}\text{ m}$$

$$= 90 \times 10^{-9}\text{ m} = 90\text{ nm}$$

41. (b): Let a be common acceleration of the system. The free body diagrams of two blocks is shown in the figure.



Their equations of motion are

$T = m_1 a$ ...(i) $\qquad m_2 g - T = m_2 a$ ...(ii)

From (i) and (ii), we get

$$a=\frac{m_2 g}{m_1+m_2}\qquad\text{...(iii)}$$

Using, $s=ut+\frac{1}{2}at^2$

$$\Rightarrow\quad d=0\times t+\frac{1}{2}\frac{m_2 g}{m_1+m_2}t^2\qquad\text{(Using(iii))}$$

$$\text{or}\quad t=\sqrt{\frac{2d(m_1+m_2)}{m_2 g}}$$

42. (b): Modulation index is the ratio of deviation to modulating frequency, $m_f=\frac{\delta}{\upsilon_m}=\frac{20000}{400}=50$

43. (c) : Given $T_A = 4T_B$ ...(i)

$\lambda_{m_B}-\lambda_{m_A}=3.0\ \mu\text{m}$ ...(ii)

According to Wien's law, $\lambda_m T$ = constant

$$\therefore\quad \lambda_{m_A}T_A=\lambda_{m_B}T_B\ \text{ or }\ \frac{\lambda_{m_A}}{\lambda_{m_B}}=\frac{T_B}{T_A}$$

$$\frac{\lambda_{m_A}}{\lambda_{m_B}}=\frac{T_B}{4T_B}\qquad\text{(Using (i))}$$

$$\text{or}\quad \lambda_{m_A}=\frac{\lambda_{m_B}}{4}$$

Substituting this value in eqn. (ii), we get

$$\lambda_{m_B}-\frac{\lambda_{m_B}}{4}=3.0\ \mu\text{m}\quad\text{or}\quad \lambda_{m_B}=4.0\ \mu\text{m}$$

44. (d): As $W = -MB(\cos\theta_2 - \cos\theta_1)$

$$W_1=-MB[\cos 60^\circ-\cos 0^\circ]$$

$$=-MB\left(\frac{1}{2}-1\right)=\frac{MB}{2}$$

$$W_2=-MB(\cos 90^\circ-\cos 30^\circ)$$

$$=-MB\left(0-\frac{\sqrt{3}}{2}\right)=\frac{\sqrt{3}MB}{2}=\sqrt{3}W_1$$

45. (d): For the first case, $m = -3$

$$\because\quad m=-\frac{v}{u}=-3\qquad\text{(As the image is real)}$$

$\therefore\quad v = 3u$

Here, $u = -x \quad \therefore\ v = -3x$

According to mirror formula $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$

$$\therefore\quad \frac{1}{(-x)}+\frac{1}{(-3x)}=\frac{1}{f}\qquad\text{...(i)}$$

For the second case, $m = -2$

$$\because\quad m=-\frac{v}{u}=-2\qquad\therefore\ v=2u$$

Here, $u = -(x + 5)\ \therefore\ v = -2(x + 5)$

Using mirror formula,

$$\frac{1}{-(x+5)}+\frac{1}{-2(x+5)}=\frac{1}{f}\qquad\text{...(ii)}$$

Solving (i) and (ii), we get $f = -30$ cm

EXAM DATES 2017	
SRMJEEE	1st April to 30th April (Online)
JEE MAIN	2nd April (Offline)
	8th & 9th April (Online)
VITEEE	5th April to 16th April (Online)
NATA	16th April
WBJEE	23rd April
Kerala PET	24th April (Physics & Chemistry)
	25th April (Mathematics)
Karnataka CET	2nd May (Biology & Mathematics)
	3rd May (Physics & Chemistry)
BITSAT	16th May to 30th May (Online)
JEE Advanced	21st May

PRACTICE PAPER

BITSAT

Exam date: 16^{th} to 30^{th} May 2017

1. The ratio of magnitude of electrostatic force and gravitational force between an electron and a proton is
(a) 6.6×10^{39} (b) 2.3×10^{39}
(c) 6.6×10^{29} (d) 2.3×10^{29}.

2. A man in a balloon rising vertically with an acceleration of 4.9 m s^{-2} releases a stone, 2 s after the balloon is let go from the ground. The greatest height above the ground reached by the stone is (Take $g = 9.8$ m s^{-2})
(a) 14.7 m (b) 19.6 m (c) 9.8 m (d) 24.5 m.

3. A body of mass 5 kg is moving with a momentum of 10 kg m s^{-1}. A force of 0.2 N acts on it in the direction of motion of body for 10 s. The increase in its kinetic energy is
(a) 2.8 J (b) 3.2 J (c) 3.8 J (d) 4.4 J.

4. A person at a distance R from the centre of the earth (where R is greater than the radius of the earth) is attracted towards the earth by a gravitational force of 400 N. How far away from the centre of the earth must the person be for the gravitational force to be 100 N ?
(a) $\frac{1}{4}R$ (b) $\frac{1}{2}R$ (c) $2R$ (d) $4R$

5. At a given plane on the earth's surface, the horizontal component of earth's magnetic field is 3×10^{-5} T and resultant magnetic field is 6×10^{-5} T. Angle of dip at this place is
(a) 30° (b) 40° (c) 50° (d) 60°.

6. A ball impinges directly on a similar ball at rest. The first ball is brought to rest by the impact. If half of the kinetic energy is lost by impact, the value of coefficient of restitution is
(a) $\frac{1}{2\sqrt{2}}$ (b) $\frac{1}{\sqrt{3}}$ (c) $\frac{1}{\sqrt{2}}$ (d) $\frac{\sqrt{3}}{2}$.

7. A body cools from 50 °C to 49 °C in 5 s. How long will it take to cool from 40 °C to 39 °C ? Assume temperature of surroundings to be 30 °C and Newton's law of cooling is valid.
(a) 2.5 s (b) 10 s (c) 20 s (d) 5 s

8. A ball is thrown from the ground with a velocity of $20\sqrt{3}$ m s^{-1} making an angle of 60° with the horizontal. The ball will be at a height of 40 m from the ground after a time t equal to (Take $g = 10$ m s^{-2})
(a) $\sqrt{2}$ s (b) $\sqrt{3}$ s (c) 2 s (d) $2\sqrt{3}$ s.

9. A solid sphere of volume V and density ρ floats at the interface of two immiscible liquids of densities ρ_1 and ρ_2 respectively. If $\rho_1 < \rho < \rho_2$, then the ratio of volume of the parts of the sphere in upper and lower liquid is
(a) $\frac{\rho-\rho_1}{\rho_2-\rho}$ (b) $\frac{\rho_2-\rho}{\rho-\rho_1}$ (c) $\frac{\rho+\rho_1}{\rho+\rho_2}$ (d) $\frac{\rho+\rho_2}{\rho+\rho_1}$.

10. A radioactive nucleus of mass number A, initially at rest, emits an α-particle with a speed v. What will be the recoil speed of the daughter nucleus ?
(a) $\frac{2v}{(A-4)}$ (b) $\frac{2v}{(A+4)}$
(c) $\frac{4v}{(A-4)}$ (d) $\frac{4v}{(A+4)}$

11. A force $\vec{F} = 5\hat{i}+2\hat{j}-5\hat{k}$ acts on a particle whose position vector is $\vec{r} = \hat{i}-2\hat{j}+\hat{k}$. What is the torque about the origin ?
(a) $8\hat{i}-10\hat{j}-8\hat{k}$ (b) $8\hat{i}+10\hat{j}+12\hat{k}$
(c) $10\hat{i}-10\hat{j}-\hat{k}$ (d) $8\hat{i}+10\hat{j}-12\hat{k}$

12. The mass of a planet is half that of the earth and the radius of the planet is one-fourth that of the earth. If we plan to send an artificial satellite from the planet, the escape velocity will be (Escape velocity on earth $v_e = 11$ km s^{-1})
(a) 11 km s^{-1} (b) 5.5 km s^{-1}
(c) 15.55 km s^{-1} (d) 7.78 km s^{-1}.

13. The flux linked with a circuit is given by $\phi = t^3 + 3t - 7$. The graph between time (x-axis) and induced emf (y-axis) will be
(a) a straight line through the origin
(b) straight line with positive intercept
(c) straight line with negative intercept
(d) parabola not through the origin.

14. Two simple harmonic motions are given by $x = A\sin(\omega t + \phi)$ and $y = A\sin\left(\omega t + \phi + \frac{\pi}{2}\right)$ act on a particle simultaneously, then the motion of particle will be
(a) circular anticlockwise
(b) elliptical anticlockwise
(c) elliptical clockwise
(d) circular clockwise.

15. The wavelength of an emission line obtained for Li^{2+} during an electronic transition from $n_2 = 2$ to $n_1 = 1$ is (R = Rydberg constant)
(a) $\frac{3R}{4}$ (b) $\frac{27R}{4}$ (c) $\frac{4}{3R}$ (d) $\frac{4}{27R}$.

16. A coin is placed on a horizontal platform which undergoes vertical simple harmonic motion of angular frequency ω. The amplitude of oscillation is gradually increased. The coin will leave contact with the platform for the first time
(a) at the mean position of the platform
(b) for an amplitude of g/ω^2
(c) for an amplitude g^2/ω^2
(d) for an amplitude ω/g.

17. Magnetic field at the centre of a circular loop of area A is B. The magnetic moment of the loop will be
(a) $\frac{BA^2}{\mu_0\pi}$ (b) $\frac{BA^{3/2}}{\mu_0\pi}$ (c) $\frac{BA^{3/2}}{\mu_0\pi^{1/2}}$ (d) $\frac{2BA^{3/2}}{\mu_0\pi^{1/2}}$.

18. A body is projected vertically upwards at time $t = 0$ and it is seen at a height H at time t_1 s and t_2 s during its flight. The maximum height attained is (g is acceleration due to gravity)
(a) $\frac{g(t_2 - t_1)^2}{8}$ (b) $\frac{g(t_1 + t_2)^2}{4}$
(c) $\frac{g(t_1 + t_2)^2}{8}$ (d) $\frac{g(t_2 - t_1)^2}{4}$.

19. A resistor has a colour code of green, blue, brown and silver. What is its resistance ?
(a) 56 Ω ± 5% (b) 560 Ω ± 10%
(c) 560 Ω ± 5% (d) 5600 Ω ± 10%

20. A transistor is operated in common-emitter configuration at constant collector voltage, $V_C = 1.5$ V such that a change in the base current from 100 μA to 150 μA produces a change in the collector current from 5 mA to 10 mA. The current gain is
(a) 67 (b) 75 (c) 100 (d) 50.

21. In a series LCR circuit the potential difference between the terminals of the inductance is 60 V, between the terminals of the capacitor is 30 V and between the terminals of resistance is 40 V. The supply voltage will be equal to
(a) 130 V (b) 10 V (c) 50 V (d) 70 V.

22. The equation of stationary wave along a stretched string is given by
$$y = 5\sin\frac{\pi x}{3}\cos 40\pi t$$
where x and y are in cm and t in second. The separation between two adjacent nodes is
(a) 1.5 cm (b) 3 cm (c) 6 cm (d) 4 cm.

23. A circular coil of radius 0.1 m has 80 turns of wire. If the magnetic field through the coil increases from 0 to 2 T in 0.4 s and the coil is connected to a 11 Ω resistor, what is the induced current through the resistor during the 0.4 s ?
(a) $\left(\frac{8}{7}\right)$ A (b) $\left(\frac{7}{8}\right)$ A (c) 8 A (d) 7 A

24. A wire has a mass of (0.3 ± 0.003) g, radius (0.5 ± 0.005) mm and length (6 ± 0.06) cm. The maximum percentage error in the measurement of density is
(a) 1 % (b) 2 % (c) 3 % (d) 4 %.

25. The acceleration due to gravity at the poles and the equator is g_p and g_e respectively. If the earth is a sphere of radius R and rotating about its axis with angular speed ω, then $g_p - g_e$ is given by
(a) $\frac{\omega^2}{R}$ (b) $\frac{\omega^2}{R^2}$ (c) ω^2R^2 (d) ω^2R.

26. In n type semiconductor, electrons are majority charge carriers but it does not show any negative charge. The reason is
(a) mobility of electrons is extremely small
(b) electrons are stationary
(c) atom is electrically neutral
(d) electrons neutralize with holes.

27. For a certain metal, incident frequency υ is five times of threshold frequency υ_0 and the maximum velocity of photoelectrons coming out is 8×10^6 m s^{-1}. If $\upsilon = 2\upsilon_0$, the maximum velocity of photoelectrons will be
(a) 4×10^6 m s^{-1} (b) 6×10^6 m s^{-1}
(c) 8×10^6 m s^{-1} (d) 1×10^6 m s^{-1}.

28. In a Young's double slit experiment, d = 0.5 mm and D = 100 cm. It is found that 9^{th} bright fringe is at a distance of 7.5 mm from the second dark fringe of fringe pattern. The wavelength of light used is (in Å)

(a) $\frac{2500}{7}$ (b) 2500 (c) 5000 (d) $\frac{5000}{7}$.

29. A body is hanging from a rigid support by an inextensible string of length l. It is struck inelastically by an identical body of mass m with horizontal velocity $u=\sqrt{2gl}$, the tension in the string increases just after striking by

(a) mg (b) $3mg$
(c) $2mg$ (d) None of these.

30. A microscope is focussed on a mark on a paper and then a slab of glass of thickness 3 cm and refractive index 1.5 is placed over the mark. How should the microscope be moved to get the mark in focus again?

(a) 2 cm upward (b) 1 cm upward
(c) 4.5 cm upward (d) 1 cm downward

31. In a field free region, two electrons are released to move on a line towards each other with velocities 10^6 m s^{-1}. The distance of their closest approach will be nearer to

(a) 1.28×10^{-10} m (b) 1.92×10^{-10} m
(c) 2.56×10^{-10} m (d) 3.84×10^{-10} m.

32. Potentiometer wire of length 1 m is connected in series with 490 Ω resistance and 2 V battery. If 0.2 mV cm^{-1} is the potential gradient, then resistance of the potentiometer wire is

(a) 4.9 Ω (b) 7.9 Ω (c) 5.9 Ω (d) 6.9 Ω.

33. An n-p-n transistor power amplifier in CE configuration gives

(a) voltage amplification only
(b) current amplification only
(c) both current and voltage amplifications
(d) only power gain of unity.

34. Which of the following statements is incorrect?

(a) In pure translation motion, every particle of the body moves with the same velocity at any instant of time.
(b) In rotation about a fixed axis, every particle of the rigid body moves in a circle which lies in a plane perpendicular to the axis and has its centre on the axis.
(c) The centre of gravity of a body coincides with its centre of mass only if the gravitational field does not vary from one part of the body to the other.
(d) The angular momentum $\vec{L}$ and the angular velocity $\vec{\omega}$ are necessarily parallel vectors.

35. Assuming that the mass m of the largest stone that can be moved by a flowing river depends upon the velocity v of the water, its density ρ and the acceleration due to gravity g. Then, m is directly proportional to

(a) v^3 (b) v^4 (c) v^5 (d) v^6

36. A wire of cross section 4 mm^2 is stretched by 0.1 mm by a certain weight. How far (length) will the wire of same material and length but of area 8 mm^2 stretch under the action of same force ?

(a) 0.05 mm (b) 0.10 mm
(c) 0.15 mm (d) 0.20 mm

37. A series resonant LCR circuit has a quality factor (Q-factor) 0.4 and a bandwidth of 1.3 kHz. If R = 2 kΩ, C = 0.1 μF, then the value of inductance is

(a) 0.1 H (b) 0.064 H (c) 2 H (d) 10 H.

38. The kinetic energy of 1 mole of a gas, at standard temperature and pressure is
(R = 8.31 J mol^{-1} K^{-1})

(a) 3.4×10^3 J (b) 2.97×10^3 J
(c) 1.2×10^2 J (d) 0.66×10^4 J.

39. A radioactive element X with a half life period of 2 hours decays giving a stable element Y. After a time t the ratio of X to Y atoms is 1 : 7. Then t is

(a) 6 hours (b) 4 hours
(c) between 4 and 6 hours
(d) 14 hours.

40. The stopping potential for photoelectrons emitted from a surface illuminated by light of wavelength 400 nm is 500 mV. When the incident wavelength is changed to a new value, the stopping potential is found to be 800 mV. New wavelength is about

(a) 365 nm (b) 250 nm
(c) 640 nm (d) 340 nm.

SOLUTIONS

1. (b) : Electrostatic force between an electron and a proton,

$$|F_e| = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

Gravitational force between an electron and a proton,

$$|F_g| = \frac{Gm_em_p}{r^2}$$

$$\therefore \frac{|F_e|}{|F_g|} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{Gm_em_p}$$

$$= \frac{9\times10^9 \times (1.6\times10^{-19})^2}{6.67\times10^{-11}\times 9\times10^{-31}\times1.66\times10^{-27}} = 2.3 \times 10^{39}$$

2. **(a)** : Here, $a = 4.9$ m s^{-2}, $t = 2$ s, $u = 0$,

$$s = ut + \frac{1}{2}at^2$$

$$s = 0 + \frac{1}{2} \times 4.9 \times (2)^2 = 9.8 \text{ m}$$

This is the height from where stone is dropped.
Upward velocity of stone when released,
$v = u + at = 0 + 4.9 \times 2 = 9.8$ m s^{-1}
The stone will move up till its velocity become zero.
From, $v^2 - u^2 = 2as$

$0 - (9.8)^2 = 2(-9.8)s' \quad \therefore \quad s' = 4.9$ m

Maximum height above the ground,

$s + s' = 9.8$ m $+ 4.9$ m $= 14.7$ m

3. **(d)** : Initial kinetic energy $= \frac{p_1^2}{2m} = \frac{10 \times 10}{2 \times 5} = 10 \text{ J}$

Impulse $= p_2 - p_1 = F \times t$
$p_2 - 10 = 0.2 \times 10$ or $p_2 = 12$ kg m s^{-1}

Final kinetic energy $= \frac{p_2^2}{2m} = \frac{12 \times 12}{2 \times 5} = 14.4 \text{ J}$

Increase in kinetic energy $= 14.4$ J $- 10$ J $= 4.4$ J

4. **(c)** : The force due to gravity is given by $F = \frac{GMm}{R^2}$.
As G, M and m do not change, one can write an equation for the first force $F_1 = \frac{GMm}{R_1^2}$ ...(i)

and the second force $F_2 = \frac{GMm}{R_2^2}$, ...(ii)

where R_1 and R_2 are the respective distances.
Dividing eqn. (i) by eqn. (ii), we get the ratio

$$\frac{F_1}{F_2} = \left(\frac{R_2}{R_1}\right)^2 = \frac{400 \text{ N}}{100 \text{ N}} = 4 = 2^2.$$

Thus, $R_2 = 2R_1 = 2R$

5. **(d)** : Horizontal component of earth's magnetic field, $B_H = B_e \cos\theta$

$$\cos\theta = \frac{B_H}{B_e} = \frac{3 \times 10^{-5}}{6 \times 10^{-5}} = \frac{1}{2}$$

$\therefore \quad \theta = 60°$

6. **(c)** : Let u_1 and v_1 be the initial and final velocities of ball 1 and u_2 and v_2 be the similar quantities for ball 2.

$\therefore$ Initial KE, $K_i = \frac{1}{2}mu_1^2 + \frac{1}{2}mu_2^2 = \frac{1}{2}mu_1^2 \quad (u_2 = 0)$

and final KE, $K_f = \frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2 = \frac{1}{2}mv_2^2 \quad (v_1 = 0)$

Loss of KE, $\Delta K = K_i - K_f = \frac{1}{2}mu_1^2 - \frac{1}{2}mv_2^2$

According to question,

$$\frac{1}{2}\left(\frac{1}{2}mu_1^2\right) = \frac{1}{2}mu_1^2 - \frac{1}{2}mv_2^2$$

($\because$ Half of its kinetic energy is lost by impact)

or $u_1^2 = 2v_2^2$ or $v_2 = \frac{u_1}{\sqrt{2}}$

$\therefore$ Coefficient of restitution,

$$e = \left(\frac{v_2 - v_1}{u_1 - u_2}\right) = \frac{v_2}{u_1} = \frac{1}{\sqrt{2}}$$

7. **(b)** : From Newton's law of cooling

$$\frac{T_1 - T_2}{t} \propto \left(\frac{T_1 + T_2}{2} - T_0\right)$$

where, T_0 = temperature of surroundings.

$$\therefore \quad \frac{50 - 49}{t_1} \propto \left(\frac{50 + 49}{2} - 30\right)$$

or $\frac{1}{t_1} = K(19.5)$ ... (i)

and $\frac{40 - 39}{t_2} \propto \left(\frac{40 + 39}{2} - 30\right)$

or $\frac{1}{t_2} = K(9.5)$ ... (ii)

Dividing equation (i) by (ii), we get

$$\frac{t_2}{t_1} = \frac{19.5}{9.5}$$

$$\Rightarrow \quad t_2 = \frac{19.5}{9.5} \times 5 \simeq 10 \text{ s}$$

8. **(c)**: As in projectile motion,

$s_g = u \sin\theta \, t - \frac{1}{2}gt^2$, ...(i)

Here, $u = 20\sqrt{3}$ m s^{-1}

$g = 10$ m s^{-2} and $\sin\theta = \sin 60° = \frac{\sqrt{3}}{2}$

Using eqn. (i) we get

$$40 = 20\sqrt{3} \times \frac{\sqrt{3}}{2}t - \frac{1}{2} \times 10 \times t^2$$

or $5t^2 - 30t + 40 = 0$ or $t^2 - 6t + 8 = 0$
$\Rightarrow$ $t = 2$ s or 4 s. Hence, the minimum time $t = 2$ s

9. **(b)** : Let V_1 = Volume of the part of the sphere immersed in a liquid of density ρ_1 and V_2 = Volume of the part of the sphere immersed in liquid of density ρ_2.
According to law of floatation,

$V\rho g = V_1\rho_1 g + V_2\rho_2 g$ ... (i)

and $V = V_1 + V_2$ ... (ii)

Hence from eqn. (i) and eqn. (ii),

$V_1\rho g + V_2\rho g = V_1\rho_1 g + V_2\rho_2 g$

or $V_1(\rho - \rho_1)g = V_2(\rho_2 - \rho)g$

or $\dfrac{V_1}{V_2} = \dfrac{\rho_2 - \rho}{\rho - \rho_1}$

10. (c) : As per law of conservation of momentum, $A \times 0 = 4v + (A - 4)v_r$

$\therefore$ Recoil speed, $|v_r| = \dfrac{4v}{(A-4)}$

11. (b) : Here, $\vec{r} = \hat{i} - 2\hat{j} + \hat{k}$

$$\vec{F} = 5\hat{i} + 2\hat{j} - 5\hat{k}$$

Torque, $\vec{\tau} = \vec{r} \times \vec{F}$

$$= \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & -2 & 1 \\ 5 & 2 & -5 \end{vmatrix}$$

$$= \hat{i}(10-2) - \hat{j}(-5-5) + \hat{k}(2-(-10))$$

$$= 8\hat{i} + 10\hat{j} + 12\hat{k}$$

12. (c): Escape velocity on planet, $v_p = \sqrt{\dfrac{2GM_p}{R_p}}$ ...(i)

Escape velocity on earth, $v_e = \sqrt{\dfrac{2GM_e}{R_e}}$ ... (ii)

where, subscripts p and e represent planet and earth respectively.

Given, $M_p = \dfrac{1}{2}M_e,\ R_p = \dfrac{1}{4}R_e$

Dividing eqn. (i) by eqn. (ii), we get

$$\frac{v_p}{v_e} = \sqrt{\frac{M_p}{M_e}\frac{R_e}{R_p}} = \sqrt{\left(\frac{1}{2}\right)\left(\frac{4}{1}\right)} = \sqrt{2}$$

or $v_p = \sqrt{2}v_e = \sqrt{2} \times 11 \text{ km s}^{-1} = 15.55 \text{ km s}^{-1}$

13. (d) : Given: $\phi = t^3 + 3t - 7$

Induced emf, $\varepsilon = -\dfrac{d\phi}{dt} = -\dfrac{d}{dt}(t^3 + 3t - 7) = -(3t^2 + 3)$

$= -3(t^2 + 1)$

Clearly, the graph between induced emf and time (along x-axis) will be parabola. At $t = 0$, $\varepsilon = -3 \neq 0$.

$\therefore$ The parabola would not pass through the origin.

14. (a) : Given: $x = A\sin(\omega t + \phi)$ ... (i)

and $y = A\sin\left(\omega t + \phi + \dfrac{\pi}{2}\right) = A\cos(\omega t + \phi)$ ... (ii)

Squaring and adding eqns. (i) and (ii), we get

$x^2 + y^2 = A^2[\sin^2(\omega t + \phi) + \cos^2(\omega t + \phi)]$

or $x^2 + y^2 = A^2$

which is the equation of a circle.

At $(\omega t + \phi) = 0$, $x = 0$, $y = A$

At $(\omega t + \phi) = \dfrac{\pi}{2}, x = A,\ y = 0$

From the above data, the motion of particle is circle traversed in anticlockwise direction.

15. (d) : For an electron transition from n_2^{th} level to n_1^{th} level of hydrogen like atom

$$\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

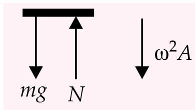
For Li^{2+}, $Z = 3$

Here $n_1 = 1$ and $n_2 = 2$

$$\frac{1}{\lambda} = R(3)^2\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = 9R\left(1 - \frac{1}{4}\right) = \frac{27}{4}R$$

or $\lambda = \dfrac{4}{27R}$

16. (b) : As the amplitude is increased, the maximum acceleration of the platform (along with coin as long as they does not get separated) increases.



If we draw the FBD for coin at one of the extreme positions as shown. Then from Newton's law, $mg - N = m\omega^2 A$

For loosing contact with the platform, $N = 0$

So, $A = \dfrac{g}{\omega^2}$

17. (d) : Magnetic field at the centre of circular loop

$$B = \frac{\mu_0}{4\pi}\frac{2\pi I}{r} = \frac{\mu_0 I}{2r} \Rightarrow I = \frac{2Br}{\mu_0}$$

Also, $A = \pi r^2$ or $r = \left(\dfrac{A}{\pi}\right)^{1/2}$

Magnetic moment, $M = IA$

$$= \frac{2Br}{\mu_0}A = \frac{2BA}{\mu_0} \times \left(\frac{A}{\pi}\right)^{1/2}$$

$$= \frac{2BA^{3/2}}{\mu_0 \pi^{1/2}}$$

18. (c) : Time taken for the body to reach the highest point is $\dfrac{t_1 + t_2}{2}$.

As $v = u - gt$

At highest point, $v = 0$

Therefore, initial velocity of the body is

$$u = \frac{g(t_1 + t_2)}{2}$$

Maximum height attained by the body is

$$H_{\max} = \frac{u^2}{2g} = \frac{1}{2g}\left(\frac{g(t_1 + t_2)}{2}\right)^2 = \frac{g(t_1 + t_2)^2}{8}$$

19. (b) : Numbers corresponding to green, blue, brown and silver are 5, 6, 1 and 10% respectively. Therefore, the resistance of given resistor

$= 56 \times 10^1\ \Omega \pm 10\% = 560\ \Omega \pm 10\%$

20. (c) : As $\Delta I_B = 150\ \mu A - 100\ \mu A = 50\ \mu A$;

and $\Delta I_C = 10$ mA – 5 mA = 5 mA,

Current gain,

$$\beta = \frac{\Delta I_C}{\Delta I_B} = \frac{5\text{ mA}}{50\ \mu\text{A}} = \frac{5\times10^{-3}\text{ A}}{50\times10^{-6}\text{ A}} = 100$$

21. (c) : In series *LCR* circuit,

$$V = \sqrt{{V_R}^2 + (V_L - V_C)^2}$$

$$= \sqrt{(40)^2 + (60-30)^2} = \sqrt{1600+900}$$

$$= \sqrt{2500} = 50\text{ V}.$$

22. (b) : Given : $y = 5\sin\frac{\pi x}{3}\cos 40\pi t$

Comparing with the standard equation of stationary wave

$y = 2A \sin kx \cos \omega t$, we get

$$k = \frac{\pi}{3} = \frac{2\pi}{\lambda}\quad \therefore\quad \lambda = 6\text{ cm}$$

Hence, the separation between two adjacent nodes $= \frac{\lambda}{2} = 3$ cm

23. (a) : Here, $r = 0.1$ m, $N = 80$,

$$\frac{dB}{dt} = \frac{2-0}{0.4} = 5\text{ T s}^{-1},\ R = 11\ \Omega$$

$$I = \frac{\varepsilon}{R} = \frac{NA}{R}\frac{dB}{dt} = \frac{N(\pi r^2)}{R}\times\frac{dB}{dt}$$

$$= 80\times\frac{22}{7}\frac{(0.1)^2}{11}\times5 = \frac{8}{7}\text{ A}$$

24. (d) : Since density $\rho = \frac{m}{\pi r^2 l}$

$\therefore$ Maximum percentage error in density,

$$\therefore\quad \left(\frac{\Delta\rho}{\rho}\right)\times100 = \left(\frac{\Delta m}{m} + \frac{2\Delta r}{r} + \frac{\Delta l}{l}\right)\times100$$

$$= \left(\frac{0.003}{0.3} + 2\times\frac{0.005}{0.5} + \frac{0.06}{6}\right)\times100$$

$= (0.01 + 0.02 + 0.01) \times 100 = 4\%$

25. (d) : Acceleration due to gravity at a place of latitude λ due to the rotation of earth is,

$g' = g - R\omega^2\cos^2\lambda$

At equator, $\lambda = 0°$, $\cos 0° = 1$

$\therefore\quad g' = g_e = g - R\omega^2$ ... (i)

At poles, $\lambda = 90°$, $\cos 90° = 0$

$\therefore\quad g' = g_p = g$ ...(ii)

From eqns. (i) and (ii)

$g_p - g_e = g - (g - R\omega^2) = R\omega^2$

26. (c) : The atom is electrically neutral.

27. (a) : According to Einstein's photoelectric equation

$$h\upsilon = h\upsilon_0 + \frac{1}{2}mv_{\max}^2\quad\text{or}\quad \frac{1}{2}mv_{\max}^2 = h\upsilon - h\upsilon_0$$

According to the given problem

$$\frac{1}{2}m(8\times10^6)^2 = h(5\upsilon_0 - \upsilon_0) \quad ...(i)$$

$$\frac{1}{2}mv_{\max}^2 = h(2\upsilon_0 - \upsilon_0) \quad ...(ii)$$

Dividing eqn. (i) by (ii), we get

$$\frac{(8\times10^6)^2}{v_{\max}^2} = \frac{4\upsilon_0}{\upsilon_0} \Rightarrow v_{\max}^2 = \frac{(8\times10^6)^2}{4}$$

$$v_{\max} = \frac{8\times10^6}{2} = 4\times10^6\text{ m s}^{-1}$$

28. (c) : For bright fringes, $x = \frac{n\lambda D}{d}$

where $n = 0, 1, 2, 3,$ ....

For dark fringes, $x = \frac{(2n-1)\lambda D}{2d}$

where $n = 1, 2, 3,$ ....

As per question

$$\frac{9\lambda D}{d} - \frac{3\lambda D}{2d} = 7.5\times10^{-3}$$

$$\text{or}\quad \frac{15\lambda D}{2d} = 7.5\times10^{-3}$$

$$\text{or}\quad \lambda = \frac{2\times7.5\times10^{-3}\times d}{15D}$$

Substituting the given values, we get

$$\lambda = \frac{2\times7.5\times10^{-3}\times0.5\times10^{-3}}{15\times1}$$

$= 0.5 \times 10^{-6}$ m = 5000 Å

29. (c): $mu = (m+m)v$ or $v = \frac{u}{2}$

$$T = \frac{2mv^2}{l} + 2mg = \frac{2mu^2}{4l} + 2mg$$

$$= \frac{m(2gl)}{2l} + 2mg = 3mg$$

Initially, the tension $T_0 = mg$

$\therefore$ Increase in tension = $2mg$

30. (b) : Here, real depth of mark, $x = 3$ cm

apparent depth of mark, $y = ?$

Refractive index, $\mu = 1.5$

$$\text{As}\quad \mu = \frac{x}{y}\quad \therefore\quad y = \frac{x}{\mu} = \frac{3}{1.5} = 2\text{ cm}$$

Distance through which mark appears to be raised $= x - y = 3 - 2 = 1$ cm

$\therefore$ To get the mark in focus again, distance through which microscope be moved upwards = 1 cm

31. (c): At the distance of closest approach (r)

KE = PE

$$\therefore \frac{1}{2}mv^2 + \frac{1}{2}mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

$$mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

$$r = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{mv^2} = \frac{9\times10^9\times(1.6\times10^{-19})^2}{9\times10^{-31}\times(10^6)^2}$$

$= 2.56 \times 10^{-10}$ m

32. (a) : Potential across potentiometer wire

$$\because \quad V = \frac{(0.2\times10^{-3})\text{ V}\times1\text{ m}}{10^{-2}\text{ m}} = 0.02\text{ V}$$

$$\because \quad V = \frac{R\varepsilon}{r+R}$$

$$\therefore \quad 0.02 = \frac{R}{r+R}\times2$$

(where R is resistance of potentiometer wire and r is resistance connected in series.)

or $\quad 0.02(490 + R) = 2R$

$\Rightarrow \quad R = 4.9\ \Omega$

33. (c)

34. (d) : The angular momentum $\vec{L}$ and the angular velocity $\vec{\omega}$ are not necessarily parallel vectors.

35. (d) : $m \propto v^a \rho^b g^c$

Writing the dimensions on both sides

$[M] = [LT^{-1}]^a [ML^{-3}]^b [LT^{-2}]^c$

$[M] = [M^b L^{a-3b+c} T^{-a-2c}]$

Applying principle of homogeneity of dimensions, we get

$b = 1$

$a - 3b + c = 0$

$-a - 2c = 0$

Solving these equations, we get

$a = 6, b = 1, c = -3$

Hence, $\quad m \propto v^6$

36. (a) : Given $A_1 = 4\ \text{mm}^2 = 4 \times 10^{-6}\ \text{m}^2$, $\Delta L_1 = 0.1 \times 10^{-3}$ m

$A_2 = 8 \times 10^{-6}$ m^2, $Y_2 = Y_1$, $L_2 = L_1$, $F_2 = F_1$

$$\Delta L_1 = \frac{F_1L_1}{A_1Y_1}, \Delta L_2 = \frac{F_2L_2}{A_2Y_2}$$

$$\frac{\Delta L_2}{\Delta L_1} = \frac{A_1}{A_2} = \frac{4\times10^{-6}}{8\times10^{-6}} = \frac{1}{2}$$

$$\therefore \quad \Delta L_2 = \frac{\Delta L_1}{2} = 0.05 \times 10^{-3}\text{ m} = 0.05\text{ mm}$$

37. (b) : $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$ or $\frac{L}{C} = (QR)^2$

$\therefore \quad L = (0.4 \times 2 \times 10^3)^2 \times 0.1 \times 10^{-6} = 0.064$ H

38. (a) : Kinetic energy,

$$E = \frac{3}{2}RT$$

where R is gas constant.

$$\therefore \quad E = \frac{3}{2}\times8.31\times273$$

$= 3.4 \times 10^3$ J

39. (a) : After a lapse of time t, let the number of atoms of X element and Y element be respectively N_X and N_Y.

Then, $\quad \frac{N_Y}{N_X} = 7$ or $\frac{N_Y}{N_X} + 1 = 7 + 1$

or $\quad \frac{N_Y + N_X}{N_X} = 8$ or $\frac{N_X}{N_Y + N_X} = \frac{1}{8}$

$$\therefore \quad \frac{N_X}{N_Y+N_X} = \frac{N}{N_0} = \frac{1}{8} = \left(\frac{1}{2}\right)^n$$

$$\therefore \quad n = 3 = \frac{t}{T_{1/2}}$$

But $T_{1/2} = 2$ hours, hence $t = 6$ hours.

40. (a) : According to Einstein's photoelectric equation

$$\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + eV_s$$

where λ = incident wavelength

λ_0 = threshold wavelength

V_s = stopping potential

As per question

$$\frac{hc}{400} = \frac{hc}{\lambda_0} + 500 \times 10^{-3}\text{ eV} \quad \ldots\text{(i)}$$

$$\frac{hc}{\lambda'} = \frac{hc}{\lambda_0} + 800 \times 10^{-3}\text{ eV} \quad \ldots\text{(ii)}$$

By subtracting eqn. (i) from (ii), we get

$$\frac{hc}{\lambda'} - \frac{hc}{400} = 300 \times 10^{-3}\text{ eV}$$

Take $hc = 1240$ eV nm

$$\therefore \quad \frac{1240}{\lambda'} = \frac{1240}{400} + 0.3$$

$$\frac{1240}{\lambda'} = 3.1 + 0.3 = 3.4\text{ eV}$$

or $\quad \lambda' = \frac{1240}{3.4} = 365$ nm

◆◆

CLASS XI

ACE YOUR WAY CBSE

Practice Paper 2017

Time Allowed : 3 hours
Maximum Marks : 70

GENERAL INSTRUCTIONS

(i) All questions are compulsory. There are 26 questions in all.
(ii) This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
(iii) Section A contains five questions of one mark each, Section B contains five questions of two marks each, Section C contains twelve questions of three marks each, Section D contains one value based question of four marks and Section E contains three questions of five marks each.
(iv) There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all the three questions of five marks weightage. You have to attempt only one of the choices in such questions.

SECTION-A

1. The distance travelled by a body is directly proportional to time. Is any external force acting on it?
2. Why are the bridges declared unsafe after long use?
3. Two vectors, both equal in magnitude, have their resultant equal in magnitude of the either. Find the angle between the two vectors.
4. Do water and ice have the same specific heats?
5. Is it possible for a body to be accelerated without speeding up or slowing down? If so, give an example.

SECTION-B

6. Explain
   (a) Why one can jump higher on the surface of the moon than that on the earth?
   (b) Why are spacecrafts usually launched from west to east in the equatorial plane?
7. What is an adiabatic process? What are the essential conditions for an adiabatic process to take place?
8. A balloon has 5 g mole of helium at 7 °C. Calculate,
   (a) the number of atoms of helium in the balloon,
   (b) the total internal energy of the system.
9. The amplitude of a simple harmonic oscillator is doubled. How does this affect:
   (a) the period
   (b) the total energy
   (c) the maximum velocity of the oscillator?

   OR

   What is the speed of the observer for whom a note is 10 percent lower than the emitted frequency?
10. A shell of mass 0.020 kg is fired by a gun of mass 100 kg. If the muzzle speed of the shell is 80 m s^{-1}, what is the recoil speed of the gun?

SECTION-C

11. A spring balance has a scale that reads from 0 to 50 kg. The length of the scale is 20 cm. A body suspended from this balance, when displaced and released, oscillates with a period of 0.6 s. What is the weight of the body?

12. A metal of mass 1 kg at constant atmospheric pressure and at initial temperature 20 °C is given a heat of 20000 J. Find (a) change in temperature, (b) work done and (c) change in internal energy. Given, specific heat, $c = 400\ \text{J kg}^{-1}\ °\text{C}^{-1}$, coefficient of cubical expansion, $\gamma = 9 \times 10^{-5}\ °\text{C}^{-1}$ density, $\rho = 9000\ \text{kg m}^{-3}$ atmospheric pressure, $P = 10^5\ \text{N m}^{-2}$.

13. Derive an expression for the variation of g with height from the surface of the earth.

14. There are N molecules of a gas in a container. If the number of molecules is increased to $2N$, what will be
(a) pressure of the gas,
(b) total energy of the gas and
(c) rms speed of the gas?

15. A physical quantity X is related to four measurable quantities a, b, c and d as follows:

$$X = a^2 b^3 c^{5/2} d^{-2}$$

The percentage error in the measurement of a, b, c and d are 1%, 2%, 3% and 4%, respectively. What is the percentage error in quantity X ? If the value of X calculated on the basis of the above relation is 2.763, to what value should you round off the result.

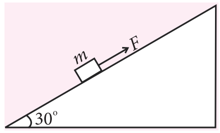
16. A liquid drop of diameter D breaks up into 27 tiny drops. Find the resulting change in energy. Take surface tension of the liquid as σ.

17. What do you mean by impulse of a force ? Show that impulse is equal to the product of average force and the time interval for which the force acts. Give the units and dimensions of impulse.

18. A cylinder of mass 10 kg and radius 15 cm is rolling perfectly on a plane of inclination 30°. The coefficient of static friction $\mu_s = 0.25$.
(a) How much is the force of friction acting on the cylinder?
(b) What is the work done against friction during rolling?
(c) If the inclination θ of the plane is increased, at what value of θ does the cylinder begin to skid, and not roll perfectly?

19. A car moving along a straight highway with speed of $126\ \text{km h}^{-1}$ is brought to a stop within a distance of 200 m. What is the retardation of the car (assumed uniform), and how long does it take for the car to stop?

20. A block of mass 1 kg is pushed up a surface inclined to horizontal at an angle of 30° by a force of 10 N parallel to the inclined surface as shown in figure. The coefficient of friction between block and the incline is 0.1. If the block is pushed up by 10 m along the incline, calculate
(a) work done against gravity
(b) work done against force of friction
(c) increase in potential energy



21. (a) A child stands at the centre of a turntable with his two arms outstretched. The turntable is set rotating with an angular speed of 40 revolutions per minute. How much is the angular speed of the child if he folds his hands back and thereby reduces his moment of inertia to 2/5 times the initial value? Assume that the turntable rotates without friction.
(b) Show that the child's new kinetic energy of rotation is more than the initial kinetic energy of rotation. How do you account for this increase in kinetic energy?

OR

From a uniform disc of radius R, a circular hole of radius $R/2$ is cut out. The centre of the hole is at $R/2$ from the centre of the original disc. Locate the centre of gravity of the resulting flat body.

22. A stone of mass 0.25 kg tied to the end of a string is whirled round in a circle of radius 1.5 m with a speed of 40 revolutions per minute in a horizontal plane. What is the tension in the string? What is the maximum speed with which the stone can be whirled around if the string can withstand a maximum tension of 200 N?

SECTION-D

23. One day Arvind went to super bazar to purchase some groceries. There he saw an old lady struggling with her shopping. He immediately showed her the lift and explained to her how she can carry her goods from one floor to the other. Even then the old lady showed hesitation to use the lift. On seeing this, Arvind took the lady into the lift and showed her how to operate the lift. The old lady was very happy and easily finished her shopping.
(a) What are the values shown by Arvind?
(b) An elevator which can carry a maximum load of 1800 kg is moving up with a constant speed of $2\ \text{m s}^{-1}$. The frictional force opposing the motion is 4000 N. Determine the maximum power delivered by the motor to the elevator in horse power.

SECTION-E

24. Explain why
(a) A body with large reflectivity is a poor emitter.
(b) A brass tumbler feels much colder than a wooden tray on a chilly day.

(c) An optical pyrometer (for measuring high temperatures) calibrated for an ideal black body radiation gives too low a value for the temperature of a red hot iron piece in the open, but gives a correct value for the temperature when the same piece is in the furnace.
(d) The earth without its atmosphere would be inhospitably cold.
(e) Heating systems based on circulation of steam are more efficient in warming a building than those based on circulation of hot water.

OR

Explain why
(a) To keep a piece of paper horizontal, you should blow over, not under, it.
(b) When we try to close a water tap with our fingers, fast jets of water gush through the openings between our fingers.
(c) The size of the needle of a syringe controls flow rate better than the thumb pressure exerted by a doctor while administering an injection.
(d) A fluid flowing out of a small hole in a vessel results in a backward thrust on the vessel.
(e) A spinning cricket ball in air does not follow a parabolic trajectory.

25. Show that for a particle in linear SHM the average kinetic energy over a period of oscillation equals the average potential energy over the same period.

OR

Explain why (or how) :
(a) In a sound wave, a displacement node is a pressure antinode and vice versa.
(b) Bats can ascertain distances, directions, nature and sizes of the obstacles without any eyes.
(c) A violin note and sitar note may have the same frequency, yet we can distinguish between the two notes.
(d) Solids can support both longitudinal and transverse waves, but only longitudinal waves can propagate in gases.
(e) The shape of a pulse gets distorted during propagation in a dispersive medium.

26. A cricket fielder can throw the cricket ball with a speed v_o. If he throws the ball while running with speed u at an angle θ to the horizontal,
(a) Find the effective angle to the horizontal at which the ball is projected in air as seen by a spectator.
(b) What will be the time of flight?
(c) What is the distance (horizontal range) from the point of projection at which the ball will land?
(d) Find θ at which he should throw the ball that would maximise the horizontal range as found in (c).

OR

A player throws a ball upwards with an initial speed of 29.4 m s^{-1}.
(a) What is the direction of acceleration during the upward motion of the ball?
(b) What are the velocity and acceleration of the ball at the highest point of its motion?
(c) Choose the $x = 0$ m and $t = 0$ s to be the location and time of the ball at its highest point, vertically downward direction to be the positive direction of x-axis, and give the signs of position, velocity and acceleration of the ball during its upward, and downward motion.
(d) To what height does the ball rise and after how long does the ball return to the player's hand? (Take $g = 9.8$ m s^{-2} and neglect air resistance).

SOLUTIONS

1. As $s \propto t$ or $s = kt$

$$\therefore \quad v = \frac{ds}{dt} = k, \quad \text{or} \quad a = \frac{dv}{dt} = 0$$

i.e., the body is moving with a uniform velocity and no external force is acting on it as the acceleration is zero.

2. On account of long use, a bridge develops elastic fatigue and there appears a permanent change in its structure. This permanent change may sometimes exceed elastic limit and the bridge may collapse.

3. Here, $P = Q = R$

As $R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

$\therefore \quad P = \sqrt{P^2 + P^2 + 2P.P\cos\theta}$

or $P^2 = 2P^2(1 + \cos\theta)$ or $1 + \cos\theta = \frac{1}{2}$

or $\cos\theta = -\frac{1}{2} = \cos 120°$ or $\theta = 120°$

4. No. Water and ice do not have the same specific heats. The specific heat of water is 1 cal g^{-1} °C^{-1} and that of ice is 0.5 cal g^{-1} °C^{-1}.

5. Yes. An object in uniform circular motion is accelerating but its speed neither decreases nor increases.

6. (a) The value of g on the surface of moon is about $(1/6)^{th}$ of its value on the surface of earth.

For the same gain of potential energy in both cases, we have

$mg_m h_m = mg_e h_e$

or $\quad h_m = \frac{g_e h_e}{g_m} = \frac{g_e h_e}{g_e/6} = 6\ h_e$

(b) Due to rotation of the earth about its polar axis, every particle on the earth has a linear velocity directed from west to east. This velocity ($v = R\omega$) is maximum at the equator. When a rocket is launched from west to east, this maximum velocity gets added to the launching velocity, so the launching becomes easier.

7. A process in which a thermally insulated system neither loses nor gains heat from the surroundings is called adiabatic process.
The essential conditions for an adiabatic process to take place are :
(a) The walls of the container must be perfectly nonconducting to prevent any exchange of heat between the gas and the surroundings.
(b) The process of compression or expansion should be rapid, so that there is no time for the heat exchange.

8. (a) Here, $n = 5$ gram mole, $T = 7\ °C = 280$ K
$\therefore$ Number of He atom, $N = n\,N_A$
$= 5 \times 6.023 \times 10^{23} = 30.115 \times 10^{23}$

(b) Average kinetic energy per molecule $= \frac{3}{2}kT$

Total internal energy $= \left(\frac{3}{2}kT\right)N$

$= \frac{3}{2} \times (1.38 \times 10^{-23}) \times 280 \times 30.115 \times 10^{23} = 1.74 \times 10^4$ J

9. (a) The time period of a simple harmonic oscillator is independent of its amplitude and as such remains unaffected.

(b) The total energy (E) of the oscillator is given by $E = \frac{1}{2}m\omega^2 A^2$, where A is the amplitude. Obviously, when A is doubled, E becomes four times its previous value.
(c) As $v_{max} = \omega A$, $\Rightarrow v_{max} \propto A$, *i.e.,* when A is doubled, v_{max} is also doubled.

OR

As the apparent frequency (υ') is less than the emitted frequency (υ), the observer must move away from the source.
If v is the speed of sound and v_o that of the observer, then

$$v' = \frac{v - v_o}{v}\upsilon$$

As the apparent frequency is 10% lower than the emitted frequency,

$$\therefore \quad \upsilon' = \upsilon - \frac{10}{100}\upsilon = \frac{90}{100}\upsilon = 0.9\ \upsilon$$

or $\quad 0.9\,\upsilon = \left(\frac{v - v_o}{v}\right)\upsilon$ $\quad$ or $\quad 0.9 = \left(\frac{v - v_o}{v}\right)$

or $\quad 0.9v = v - v_0$ $\qquad$ or $\quad v_0 = v - 0.9v = 0.1v$

Thus, speed of the observer is $(1/10)^{th}$ of the speed of sound.

10. Here, mass of the shell, $m_1 = 0.02$ kg ; mass of the gun, $m_2 = 100$ kg
Initial velocities of both the shell and the gun are zero, *i.e.,* $u_1 = u_2 = 0$
After firing, speed of the shell, $v_1 = 80$ m s^{-1}
Let v_2 be the recoil speed of the gun. According to the principle of conservation of momentum,

$$m_1 v_1 + m_2 v_2 = m_1 u_1 + m_2 u_2$$

$\therefore \quad 0.02 \times 80 + 100v_2 = 0.02 \times 0 + 100 \times 0$

or $\quad v_2 = -\frac{0.02 \times 80}{100} = -0.016$ m s^{-1}

11. Here, $m = 50$ kg,
Maximum extension, $y = 20 - 0 = 20$ cm $= 0.2$ m
Maximum force, $F = mg = 50 \times 9.8 = 490$ N
$\therefore$ Spring constant,

$$k = \frac{F}{y} = \frac{490}{0.2} = 2450\ \text{N m}^{-1}$$

When a body of mass M is suspended from the spring balance, it oscillates with a period of 0.6 s.

$\because$ Time period, $T = 2\pi\sqrt{\frac{M}{k}}$ or $T^2 = 4\pi^2\frac{M}{k}$

$\therefore \quad M = \frac{T^2 k}{4\pi^2} = \frac{(0.6)^2 \times 2450}{4 \times (3.14)^2}$

$M = 22.36$ kg

$\therefore$ Weight of the body, $W = Mg = 22.36 \times 9.8 = 219.1$ N

12. (a) As $\Delta Q = mc\Delta T$
$\therefore$ Rise in temperature,

$$\Delta T = \frac{\Delta Q}{mc} = \frac{20000\ \text{J}}{1\ \text{kg} \times 400\ \text{J kg}^{-1}\ °\text{C}^{-1}} = 50\ °\text{C}$$

(b) Density, $\rho = \frac{M}{V}$

$\therefore$ Volume, $V = \frac{M}{\rho} = \frac{1\ \text{kg}}{9000\ \text{kg m}^{-3}} = \frac{1}{9000}$ m^3

Change in volume,

$$\Delta V = \gamma V \Delta T = 9 \times 10^{-5} \times \frac{1}{9000} \times 50 = 5 \times 10^{-7}\ \text{m}^3$$

Work done, $W = P\Delta V = 10^5 \times 5 \times 10^{-7} = 0.05$ J

(c) The change in internal energy,
$\Delta U = \Delta Q - \Delta W = 20000 - 0.05 = 19999.95$ J

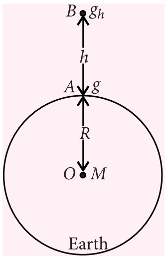
13. Consider the earth to be a sphere of mass M, radius R and centre O. Then the acceleration due to gravity at a point A on the surface of the earth will be

$$g = \frac{GM}{R^2} \qquad \ldots\text{(i)}$$

If g_h is the acceleration due to gravity at a point B at a height h from the earth's surface, then

$$g_h = \frac{GM}{(R+h)^2} \qquad \ldots\text{(ii)}$$

Dividing equation (ii) by (i), we get



$$\frac{g_h}{g} = \frac{GM}{(R+h)^2} \times \frac{R^2}{GM}$$

or $$\frac{g_h}{g} = \frac{R^2}{(R+h)^2}$$

or $$\frac{g_h}{g} = \frac{R^2}{R^2\left(1+\frac{h}{R}\right)^2} = \left(1+\frac{h}{R}\right)^{-2}$$

$$g_h = g\left(1-\frac{2h}{R}\right) \qquad \text{(using binomial theorem)}$$

14. $P = \frac{1}{3}mnv^2 = \frac{1}{3}\frac{mN}{V}v^2 \qquad \left[n = \frac{N}{V}\right]$

(a) As $P \propto N$, so the pressure of the gas is doubled when the number of molecules is increased from N to $2N$.

(b) Average kinetic energy per molecule,

$$\frac{1}{2}mv^2 = \frac{3}{2}k_BT$$

Total energy of N molecules

$$= \frac{1}{2}mNv^2 = \frac{3}{2}k_BNT$$

When the number of molecules is increased from N to $2N$, total energy of the gas is doubled, though the average kinetic energy per molecule remains same.

(c) The rms speed remains same because it depends only upon temperature.

15. Given, $X = a^2\, b^3\, c^{5/2}\, d^{-2}$

% error in $a = \frac{\Delta a}{a} \times 100 = 1\%$

% error in $b = \frac{\Delta b}{b} \times 100 = 2\%$

% error in $c = \frac{\Delta c}{c} \times 100 = 3\%$

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

$$\therefore \frac{\Delta X}{X} = \pm\left(2\frac{\Delta a}{a} + 3\frac{\Delta b}{b} + \frac{5}{2}\frac{\Delta c}{c} + 2\frac{\Delta d}{d}\right)$$

$$\Rightarrow \frac{\Delta X}{X} \times 100 = \pm\left(2\frac{\Delta a}{a} + 3\frac{\Delta b}{b} + \frac{5}{2}\frac{\Delta c}{c} + 2\frac{\Delta d}{d}\right) \times 100$$

$$= \pm\left[2(1\%) + 3(2\%) + \frac{5}{2}(3\%) + 2(4\%)\right] = \pm 23.5\%$$

$\therefore$ % error in $X = 23.5\%$

Mean absolute error in $X = \pm\, 0.235 = \pm\, 0.24$

Since errors are in two significant digits

On the basis of these values, value of X should have two significant digits only.

$\therefore \quad X = 2.763 \simeq 2.8$

16. Radius of larger drop $= D/2$

Let radius of each small drop $= r$

Now,

volume of 27 small drops = volume of the larger drop

$$27 \times \frac{4}{3} \times \pi r^3 = \frac{4}{3}\pi\left(\frac{D}{2}\right)^3 \quad \Rightarrow \quad r = \frac{D}{6}$$

Initial surface area of larger drop

$$= 4\pi R^2 = 4\pi\left(\frac{D}{2}\right)^2 = \pi D^2$$

Final surface area of 27 small drops $= 27 \times 4\pi r^2$

$$= 27 \times 4\pi\left(\frac{D}{6}\right)^2 = 3\pi D^2$$

$\therefore$ Increase in surface area $= 3\pi D^2 - \pi D^2 = 2\pi D^2$

Change in energy = Increase in surface area × surface tension $= 2\pi D^2\sigma$

17. Impulse is defined as the product of the force and the time for which it acts and is equal to the total change in momentum.

Impulse = force × time duration

= Total change in momentum

Impulse is a vector quantity denoted by $\vec{J}$. Its direction is same as that of force. The impulse of a force is positive, negative or zero depending on the momentum of the body increases, decreases or remains unchanged.

Suppose a force $\vec{F}$ acts for a small time dt. The impulse of the force is given by

$$d\vec{J} = \vec{F}dt$$

If we consider a finite interval of time from t_1 to t_2, then the impulse will be

$$\vec{J} = \int d\vec{J} = \int_{t_1}^{t_2} \vec{F}dt$$

If $\vec{F}_{av}$ is the average force, then

$$\vec{J} = \int_{t_1}^{t_2} \vec{F}_{av}dt = \vec{F}_{av}\int_{t_1}^{t_2} dt = \vec{F}_{av}[t]_{t_1}^{t_2} = \vec{F}_{av}(t_2 - t_1)$$

or $\quad \vec{J} = \vec{F}_{av} \times \Delta t$, where $\Delta t = t_2 - t_1$

Thus, the impulse of a force is equal to the product of the average force and the time interval for which it acts.
Dimensions of impulse are [MLT^{-1}].
SI unit of impulse is kg m s^{-1}.

18. Mass of cylinder, M = 10 kg
Radius of cylinder, R = 0.15 m
Angle of inclination, $\theta = 30°$
Coefficient of static friction, $\mu_s = 0.25$

(a) Force of friction on the cylinder is given by

$$F = \frac{1}{3} mg\sin\theta = \frac{1}{3} \times 10 \times 9.8 \times \sin 30°$$

$$= \frac{1}{3} \times 10 \times 9.8 \times \frac{1}{2} = 16.3 \text{ N}$$

(b) During rolling the point of contact is at rest. Therefore, work done against friction is zero.

(c) The cylinder skids (does not roll) when

$$\mu_s = \frac{1}{3}\tan\theta \,;\ \tan\theta = 3\mu_s = 3 \times 0.25 = 0.75$$

$$\theta = 36.87° \approx 37°$$

19. Here,

$$u = 126 \text{ km h}^{-1} = \frac{126 \times 1000}{60 \times 60} \text{ m s}^{-1} = 35 \text{ m s}^{-1};$$

v = 0, s = 200 m, a = ? and t = ?
We know, $v^2 = u^2 + 2as$

$\therefore \quad 0 = (35)^2 + 2 \times a \times 200$

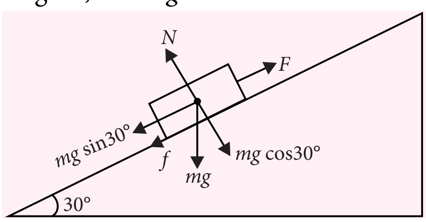
or $\quad a = \dfrac{-(35)^2}{2 \times 200} = \dfrac{-49}{16} = -3.06 \text{ m s}^{-2}$

As, $v = u + at$

$\therefore \quad 0 = 35 + (-3.06)t \quad$ or $\quad t = \dfrac{35}{3.06} = 11.43$ s

Negative sign shows that acceleration is negative, which is called retardation, *i.e.*, car is uniformly retarded at $a = 3.06$ m s^{-2}.

20. Given, m = 1 kg, F = 10 N, μ = 0.1, g = 10 m s^{-2}
From figure, $N = mg\cos 30°$



$\therefore \quad f = \mu N = \mu\, mg \cos 30° = 0.1 \times 1 \times 10 \times \dfrac{\sqrt{3}}{2}$

$= 0.866$ N

Distance travelled by block on incline, s = 10 m

(a) Work done against gravity

$$W_g = (mg\sin 30° \times s) \times \cos 0° + (mg\cos 30° \times s) \times \cos 90°$$
$$= 1 \times 10 \times \sin 30° \times 10 = 50 \text{ J}$$

(b) Work done against friction,

$$W_f = fs\cos 0° = \mu\, mg\cos 30° \times s \times \cos 0°$$
$$= 0.866 \times 10 = 8.66 \text{ J}$$

(c) Increase in potential energy = mgh

$= 1 \times 10 \times 5 = 50$ J $\qquad (\because\ h = 10 \sin 30° = 5)$

21. (a) Given that, initial angular speed,
ω_1 = 40 rpm, ω_2 = ?
Suppose that initial moment of inertia of the child is I_1. Then, final moment of inertia of the child

$$I_2 = \frac{2}{5} I_1$$

As no external torque acts in the process, therefore, according to the principle of conservation of angular momentum,

$$I_1\omega_1 = I_2\omega_2$$

$$\omega_2 = \frac{I_1}{I_2}\omega_1 = \frac{5}{2} \times 40 = 100 \text{ rpm}$$

(b) $\dfrac{\text{Final kinetic energy of rotation, } K_2}{\text{Initial kinetic energy of rotation, } K_1} = \dfrac{\frac{1}{2}I_2\omega_2^2}{\frac{1}{2}I_1\omega_1^2}$

$$\frac{K_2}{K_1} = \frac{I_2\omega_2^2}{I_1\omega_1^2} = \left(\frac{I_2}{I_1}\right)\left(\frac{\omega_2}{\omega_1}\right)^2 = \frac{2}{5} \times \left(\frac{100}{40}\right)^2 = \frac{5}{2} = 2.5$$

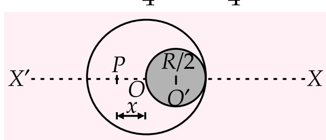
$$\frac{K_2}{K_1} = 2.5 \Rightarrow K_2 = 2.5\, K_1$$

The new kinetic energy is 2.5 times initial kinetic energy of rotation. The child uses his internal energy to increase his rotational kinetic energy.

OR

Suppose mass per unit area of the disc = m
$\therefore$ Mass of original disc $M = \pi R^2 \times m$
Mass of hole removed from the disc,

$$M' = \pi(R/2)^2 \times m = \frac{\pi R^2}{4} m = \frac{M}{4}$$



In figure, mass M is concentrated at O and mass M' is concentrated at O', where
$OO' = R/2$.
After the circular disc of mass M' is removed, the remaining portion can be considered as a system of two masses M at O and $-M'$ at O'.

If x is the distance of centre of mass (P) of the remaining part, then

$$x = \frac{M \times 0 - M' \times R/2}{M - M'} = \frac{-\frac{M}{4} \times \frac{R}{2}}{M - \frac{M}{4}}$$

$$= \frac{-MR}{8} \times \frac{4}{3M} = \frac{-R}{6}$$

Negative sign shows that P is to the left of O.

22. Frequency of revolution of stone, $\upsilon = 40$ rpm $= \frac{40}{60}$ rps

Mass of stone, $m = 0.25$ kg

Radius of circle, $r = 1.5$ m

Angular speed of the stone, $\omega = 2\pi\upsilon$

$$= 2\pi \times \frac{40}{60} = \frac{4\pi}{3} \text{ rad s}^{-1}$$

T = Tension in the string = ?

T_{max} = Maximum tension in the string = 200 N

v_{max} = Maximum speed of the stone = ?

The centripetal force is provided by the tension (T) in the string

$$T = \frac{mv^2}{r} = mr\omega^2 \qquad (\because \; v = r\omega)$$

$$= 0.25 \times 1.5 \times \left(\frac{4\pi}{3}\right)^2 \text{ N}$$

$$= 6.58 \text{ N} = 6.6 \text{ N} \qquad (\pi^2 = 9.87)$$

As the string can withstand a maximum tension of 200 N

$$\therefore \quad T_{max} = \frac{mv_{max}^2}{r}$$

$$\text{or} \quad v_{max} = \sqrt{\frac{rT_{max}}{m}} = \sqrt{\frac{1.5 \times 200}{0.25}} = \sqrt{1200}$$

$$= 34.64 \text{ m s}^{-1} \simeq 35.0 \text{ m s}^{-1}$$

$$\therefore \quad T = 6.6 \text{ N}, \; v_{max} = 35.0 \text{ m s}^{-1}$$

23. (a) Empathy, helping nature, social responsibility.

(b) The downward force on the elevator is

$F = mg + F_f = 1800 \times 10 + 4000 = 22000$ N

The motor must supply enough power to balance this force.

$$\therefore \quad P = Fv = (22000 \times 2)\text{ W} = \frac{44000}{746} \text{ hp} \simeq 59 \text{ hp}$$

24. (a) We know that $a + r + t = 1$

Where a, r and t are absorbance, reflectance and transmittance respectively of the surface of the body, t is also called emittance (e).

Also according to Krichhoff's law $e \propto a$, that is good absorber are good emitters and hence poor reflectors and vice-versa *i.e.*, if r is large (*i.e.*, large reflectively) a is smaller and hence e is smaller *i.e.*, poor emitter.

(b) The thermal conductivity of brass is high *i.e.* brass is a good conductor of heat. So when a brass tumbler is touched, heat quickly flows from human body to the tumbler. Consequently, the tumbler appears colder. On the other hand, wood is a bad conductor of heat. So heat does not flow from the human body to the wooden tray, thus it appears relatively hotter.

(c) Let T be the temperature of the hot iron in the furnace. Thus according to Stefan's law, heat radiated per second per unit area (E) is given by $E = \sigma T^4$. When the body is placed in open at temperature T_0, then the heat radiated per second per unit area (E') is given by

$$E' = \sigma(T^4 - T_0^4)$$

Clearly $E' < E$, so the optical pyrometer gives too low a value for the temperature of a red hot iron piece in open.

(d) Gases are generally insulators. The Earth's atmosphere acts like an insulating blanket around it and does not allow heat to escape out but reflects it back to the Earth. If this atmosphere is absent, then the Earth would naturally be colder as all its heat would have escaped out.

(e) This is because steam has much higher heat capacity (540 cal g^{-1}) than the heat capacity of water (80 cal g^{-1}) at the same temperature. Thus heating systems based on circulation of steam are more efficient than those based on circulation of hot water.

OR

(a) If we blow over a piece of paper, velocity of air above the paper becomes more than that below it. As kinetic energy of air above the paper increases, so in accordance with Bernoulli's theorem ($P + \frac{1}{2}\rho v^2$ = constant), its pressure energy and hence its pressure decreases. Due to greater value of pressure below the piece of paper = atmospheric pressure, it remains horizontal and does not fall.

On the other hand if we blow under the paper, the pressure on the lower side decreases. The atmospheric pressure above the paper will therefore bend the paper downwards. So the paper will not remain horizontal.

(b) This can be explained from the equation of continuity *i.e.* $a_1v_1 = a_2v_2$. As we try to close a water tap with our fingers, the area of cross-section of the outlet of water jet is reduced considerably as the openings between our fingers provide constriction (*i.e.*, regions of smaller area).

Thus velocity of water increases greatly and fast jets of water come through the openings between our fingers.

(c) According to Bernoulli's theorem, we know that,

$$P+\frac{1}{2}\rho v^2+\rho gh = \text{Constant} \quad ...(i)$$

Here, the size of the needle controls the velocity of flow and the thumb pressure controls pressure.

Now P occurs with power one and velocity v occurring with power two in equation (i), hence the velocity has more influence. That is why the needle of syringe has a better control over the flow rate.

(d) When a fluid is flowing out of a small hole in a vessel, it acquires a large velocity and hence possesses large momentum. Since no external force is acting on the system, a backward velocity must be attained by the vessel (according to the law of conservation of momentum). As a result of it, backward thrust is experienced by the vessel.

(e) This is due to Magnus effect. Let a ball moving to the right be given a spin at the top of the ball. The velocity of air at the top is higher than the velocity of air below the ball. So according to Bernoulli's theorem, the pressure above the ball is less than the pressure below the ball. Thus there is a net upward force on the spinning ball, so the ball follows a curved path. This dynamic lift due to spinning is known as Magnus effect.

25. Consider a particle of mass m executing SHM with period T. The displacement of the particle at an instant t, when time period is noted from the mean position is given by

$y = A\sin\omega t$

$\therefore$ Velocity, $v=\frac{dy}{dt}=A\,\omega\,\cos\omega t$

Kinetic energy, $E_k=\frac{1}{2}mv^2=\frac{1}{2}mA^2\omega^2\cos^2\omega t$

Potential energy, $E_p=\frac{1}{2}ky^2=\frac{1}{2}mA^2\omega^2\sin^2\omega t$

$(\because\ k=m\omega^2)$

$\therefore$ Average kinetic energy over one cycle

$$E_{k_{av}}=\frac{1}{T}\int_0^T E_k dt=\frac{1}{T}\int_0^T \frac{1}{2}m\,A^2\omega^2\cos^2\omega t\,dt$$

$$=\frac{1}{2T}m\,A^2\omega^2\int_0^T\frac{(1+\cos 2\omega t)}{2}dt$$

$$=\frac{1}{4T}m\,A^2\omega^2\left[t+\frac{\sin 2\omega t}{2\omega}\right]_0^T$$

$$=\frac{1}{4T}m\,A^2\omega^2(T)=\frac{1}{4}m\,A^2\omega^2 \quad ...(i)$$

Average potential energy over one cycle

$$E_{p_{av}}=\frac{1}{T}\int_0^T E_p dt=\frac{1}{T}\int_0^T \frac{1}{2}mA^2\omega^2\sin^2\omega t dt$$

$$=\frac{1}{2T}m\,\omega^2A^2\int_0^T\frac{(1-\cos 2\omega t)}{2}dt$$

$$=\frac{1}{4T}m\,\omega^2A^2\left[1-\frac{\sin 2\omega t}{2\omega}\right]_0^T$$

$$=\frac{1}{4T}m\,\omega^2A^2\,T=\frac{1}{4}mA^2\omega^2 \quad ...(ii)$$

From (i) and (ii), $E_{k_{av}}=E_{p_{av}}$

OR

(a) In a sound wave, a node is a point where the amplitude of oscillation *i.e.*, displacement is zero as here a compression and a rarefaction meet and the pressure is maximum, so it is called pressure antinode.

While an antinode is a point where the amplitude of oscillation is maximum *i.e.*, displacement is maximum but pressure is minimum. So this point is called pressure node.

Hence displacement node coincides with pressure antinode and displacement antinode with pressure node.

(b) Bats emit ultrasonic waves of large frequencies (small wavelength) when they fly. These ultrasonic waves are received by them after reflection from the obstacle. Their ears are so sensitive and trained that they not only get the information of the distance of the obstacle but also that of the nature of the reflecting surface.

(c) The quality of the sound produced by an instrument depends upon the number of overtones. Since the number of overtones is different in the cases of sounds produced by violin and sitar therefore we can distinguish through them.

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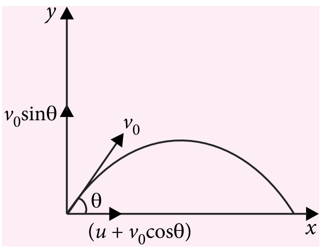
(d) Solids possess both the volume elasticity and the shear elasticity. Therefore they can support both longitudinal and transverse waves.
On the other hand, gases have only the volume elasticity and no shear elasticity, so only longitudinal waves can propagate in gases.

(e) A sound pulse is a combination of waves of different wavelengths. In a dispersive medium, the waves of different wavelengths travel with different speeds in different directions *i.e.*, with different velocities. So the shape of the pulse gets distorted *i.e.*, a plane wavefront in a non-dispersive medium does not remain a plane wavefront in a dispersive medium.

26. (a) Here, $u_y = v_0 \sin\theta$; $u_x = u + v_0 \cos\theta$

$$\tan\alpha = \frac{u_y}{u_x} = \frac{v_0 \sin\theta}{u + v_0 \cos\theta}$$

$$\Rightarrow \quad \alpha = \tan^{-1}\left(\frac{v_0 \sin\theta}{u + v_0 \cos\theta}\right)$$



(b) Along vertical axis, $y = u_y t + \frac{1}{2} a_y t^2$

$$\Rightarrow \quad 0 = v_0 \sin\theta T + \frac{1}{2}(-g)T^2$$

$$\Rightarrow \quad T = \frac{2v_0 \sin\theta}{g}$$

(c) Along horizontal axis, $x = u_x t + \frac{1}{2} a_x t^2$

$$\Rightarrow \quad R = u_x T + \frac{1}{2} 0 \times T^2$$

$$\Rightarrow \quad R = (u + v_0 \cos\theta)\frac{2v_0 \sin\theta}{g}$$

$$\Rightarrow \quad R = \frac{2(u + v_0 \cos\theta)v_0 \sin\theta}{g}$$

(d) For maximum R, $\frac{dR}{d\theta} = 0$

$$\Rightarrow \quad \frac{d}{d\theta}(uv_0 \sin\theta + v_0^2 \cos\theta \sin\theta) = 0$$

$$\Rightarrow \quad uv_0\cos\theta + v_0^2(\cos^2\theta - \sin^2\theta) = 0$$

$$\Rightarrow \quad 2v_0^2\cos^2\theta + uv_0\cos\theta - v_0^2 = 0$$

$$\Rightarrow \quad 2v_0\cos^2\theta + u\cos\theta - v_0 = 0$$

So, $\cos\theta = \frac{-u \pm \sqrt{u^2 + 8v_0^2}}{4v_0}$

$$\therefore \quad \theta = \theta_{max} = \cos^{-1}\left(\frac{-u + \sqrt{u^2 + 8v_0^2}}{4v_0}\right)$$

OR

(a) Since the ball is moving under the effect of gravity, the direction of acceleration due to gravity is always vertically downwards.

(b) When the ball is at the highest point of its motion, its velocity becomes zero and the acceleration is equal to the acceleration due to gravity = 9.8 m s^{-2} in vertically downward direction.

(c) When the highest point is chosen as the location for $x = 0$ and $t = 0$ and vertically downward direction to be the positive direction of x-axis.

During upward motion, sign of position is negative, sign of velocity is negative and the sign of acceleration is positive *i.e.*, $v < 0$, $a > 0$.

During downward motion, sign of position is positive, sign of velocity is positive and the sign of acceleration is also positive *i.e.*, $v > 0$, $a > 0$.

(d) Let t = Time taken by the ball to reach the highest point.

H = Height of the highest point from the ground.

$\therefore$ Initial velocity, $u = -29.4$ m s^{-1},
$a = g = 9.8$ m s^{-2},
Final velocity $v = 0$, $s = H = ?$, $t = ?$

Using the relation, $v^2 - u^2 = 2as$, we get

$$0^2 - (-29.4)^2 = 2 \times 9.8\, H$$

or $\quad H = \frac{-29.4 \times 29.4}{2 \times 9.8} = -44.1$ m

Where negative sign shows that the distance is covered in upward direction.

Using equation $v = u + at$, we get

$$0 = -29.4 + 9.8 \times t$$

$\therefore \quad t = \frac{29.4}{9.8} = 3$ s, *i.e.*, time of ascent = 3 s

Also we know that when the object moves under the effect of gravity alone, the time of ascent is always equal to the time of descent.

$\therefore$ Total time after which the ball returns to the player's hand = $2t = 2 \times 3 = 6$ s.

BRAIN MAP

CLASS XI

MECHANICAL PROPERTIES OF SOLIDS AND FLUIDS

PROPERTIES OF SOLIDS

STRESS AND STRAIN

- Stress $= \frac{\text{Restoring force}}{\text{Area}} = \frac{F}{A}$
- Strain $= \frac{\text{Change in configuration}}{\text{Original configuration}}$

HOOKE'S LAW

Stress ∝ Strain

or Stress $= E \times$ Strain,

(E = modulus of elasticity)

Young's modulus

$Y = \frac{\text{Normal stress}}{\text{Longitudinal strain}}$

Bulk modulus,

$B = \frac{\text{Normal stress}}{\text{Volumetric strain}}$

Compressibility, $k = 1/B$

Modulus of rigidity

$G = \frac{\text{Shearing stress}}{\text{Shearing strain}}$

Poisson's ratio

$\sigma = \frac{\text{Lateral strain}}{\text{Longitudinal strain}}$

RELATION BETWEEN Y, B, G AND σ

- $Y = 3B(1-2\sigma)$
- $Y = 2G(1+\sigma)$
- $\sigma = \frac{3B-2G}{2G+6B}$
- $\frac{9}{Y} = \frac{1}{B} + \frac{3}{G}$

ELASTIC POTENTIAL ENERGY

$U = \frac{1}{2}F \times \Delta L = \frac{1}{2} \times \text{stress} \times \text{strain} \times \text{volume}$

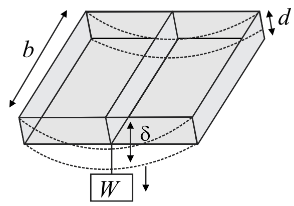
P.E. stored per unit volume of stretched wire,

$u = \frac{1}{2} \times \text{stress} \times \text{strain} = \frac{1}{2} \times Y \times (\text{strain})^2$

APPLICATION OF ELASTICITY

Designing beams for bridges

The depression in rectangular beam, $\delta = \frac{Wl^3}{4Ybd^3}$



ELASTICITY AND PLASTICITY

Elasticity : Ability of a body to regain its original shape, on removing deforming force.

Plasticity : The inability of a body to regain its original size and shape on the removal of the deforming forces.

PROPERTIES OF FLUIDS

FLUIDS IN MOTION | FLUIDS AT REST

VISCOSITY

Coefficient of viscosity:

$\eta = \frac{F}{A\left(-\frac{dv}{dx}\right)}$ where $-\frac{dv}{dx}$ is the velocity gradient between two layers of liquid.

BERNOULLI'S THEOREM

Bernoulli's theorem : For the streamline flow of an ideal liquid, the total energy per unit volume remains constant

$$P + \rho gh + \frac{1}{2}\rho v^2 = \text{constant}$$

Basic results on viscosity

Stoke's law : Backward dragging force on a spherical body, $F = 6\pi\eta rv$.

Poiseuille's formula

$Q = \frac{\pi}{8}\frac{Pr^4}{\eta l}$

Reynold's number : Determines nature of fluid flow $R = \frac{\rho vd}{\eta}$

PRESSURE

Pascal's law

The pressure is same at all points inside the liquid lying at the same depth in a horizontal plane.

Gauge pressure $= P - P_0 = h\rho g$.

ARCHIMEDE'S PRINCIPLE

When a body is immersed fully or partly in a liquid at rest, it loses some of its weight, which is equal to the weight of the liquid displaced by the immersed part of the body.

Apparent weight $= mg\left(1 - \frac{\rho'}{\rho}\right)$

(For fully immersed body)

SURFACE TENSION

Surface tension: The property by which the free surface of liquid at rest tends to have minimum surface area.

Surface energy: Work done against the force of surface tension in forming the liquid surface.

CAPILLARITY

The phenomenon of rise or fall of liquid in a capillary tube is called capillarity.

Height of the liquid within capillary tube

$h = \frac{2S\cos\theta}{a\rho g}$ Where, θ = angle of contact, ρ = density of liquid, a = radius of tube

Excess Pressure

In an air bubble

$\Delta P = \frac{2S}{R}$

Inside a soap bubble

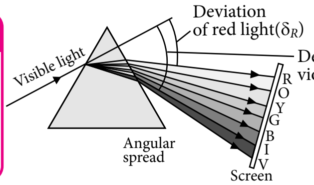
$\Delta P = \frac{4S}{R}$

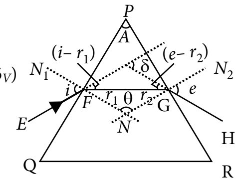
Inside a liquid drop

$\Delta P = \frac{2S}{R}$

RAY OPTICS AND OPTICAL INSTRUMENTS

BRAIN MAP
CLASS XII





APPLICATIONS OF TIR

- Fiber optics communication
- Medical endoscopy
- Periscope (Using prism)
- Sparkling of diamond

TOTAL INTERNAL REFLECTION

TIR conditions

- Light must travel from denser to rarer.
- Incident angle $i >$ critical angle i_c

Relation between μ and i_c: $\mu = \dfrac{1}{\sin i_c}$

REFRACTION OF LIGHT

Snell's law: When light travels from medium a to medium b, $\quad {}^a\mu_b = \dfrac{\mu_b}{\mu_a} = \dfrac{\sin i}{\sin r}$

Refractive index,

$$\mu = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in medium}} = \frac{c}{v}$$

Real and apparent depth

$$\mu = \frac{\text{real depth}(x)}{\text{apparent depth }(y)}$$

REFLECTION OF LIGHT

According to the laws of reflection, $\angle i = \angle r$

If a plane mirror is rotated by an angle θ, the reflected rays rotates by an angle 2θ.

SIMPLE MICROSCOPE

Magnifying power

For final image is formed at D (least distance) $M = 1 + \dfrac{D}{f}$

For final image formed at infinity

$$M = \frac{D}{f}$$

REFLECTING TELESCOPE

Magnifying power

$$M = \frac{f_o}{f_e} = \frac{R/2}{f_e}$$

REFRACTION THROUGH PRISM

Relation between μ and δ_m

$$\mu = \frac{\sin\dfrac{A+\delta_m}{2}}{\sin\dfrac{A}{2}}$$

where, δ_m = angle of minimum deviation
A = angle of prism

or $\delta = (\mu - 1)A$ (Prism of small angle)

Angular dispersion

$$= \delta_V - \delta_R = (\mu_V - \mu_R)A$$

Dispersive power,

$$\omega = \frac{\delta_V - \delta_R}{\delta} = \frac{\mu_V - \mu_R}{\mu - 1}$$

Mean deviation, $\delta = \dfrac{\delta_V + \delta_R}{2}$

RAY OPTICS

OPTICAL INSTRUMENTS

TELESCOPE

Astronomical telescope

For final image formed at D (least distance) $M = \dfrac{f_o}{f_e}\left(1 + \dfrac{f_e}{D}\right)$

In normal adjustment, image formed at infinity $\quad M = f_o / f_e$

POWER OF LENSES

Power of lens: $P = \dfrac{1}{f\text{ (in m)}}$

Combination of lenses:

Power: $P = P_1 + P_2 - dP_1P_2$

(d = small separation between the lenses)

For $d = 0$ (lenses in contact)

Power: $P = P_1 + P_2 + P_3 + \ldots$

THIN SPHERICAL LENS

Thin lens formula: $\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f}$

Magnification: $m = \dfrac{v}{u} = \dfrac{h_i}{h_o}$

REFRACTION BY SPHERICAL SURFACE

Relation between object distance (u), image distance (v) and refractive index (μ)

$$\frac{\mu_{\text{denser}}}{v} - \frac{\mu_{\text{rarer}}}{u} = \frac{\mu_{\text{denser}} - \mu_{\text{rarer}}}{R}$$

(Holds for any curved spherical surface.)

Lens maker's formula

$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

REFLECTION BY SPHERICAL MIRRORS

Mirror formula, $\dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f} = \dfrac{2}{R}$

Magnification, $m = -\dfrac{v}{u} = \dfrac{h_i}{h_o}$

COMPOUND MICROSCOPE

Magnifying power, $M = m_o \times m_e$

For final image formed at D (least distance) $M = \dfrac{L}{f_o}\left(1 + \dfrac{D}{f_e}\right)$

For final image formed at infinity

$$M = \frac{L}{f_o} \cdot \frac{D}{f_e}$$

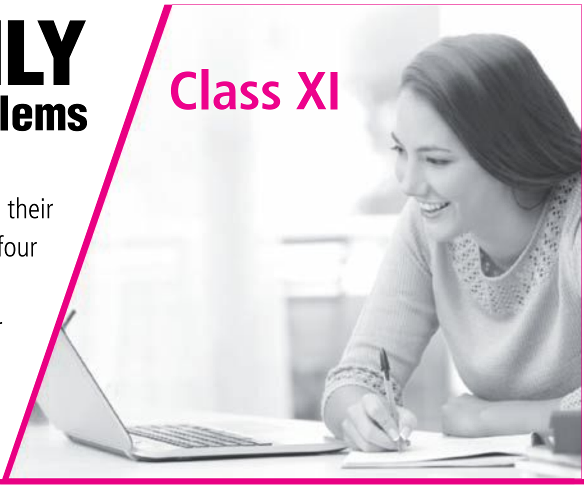
TERRESTRIAL TELESCOPE

For normal adjustment $M = \dfrac{f_o}{f_e}$

Distance between objective and eyepiece $d = f_o + 4f + f_e$

MPP-8 MONTHLY Practice Problems

Class XI



This specially designed column enables students to self analyse their extent of understanding of specified chapters. Give yourself four marks for correct answer and deduct one mark for wrong answer. Self check table given at the end will help you to check your readiness.

Waves and Oscillations

Total Marks : 120 **Time Taken : 60 min**

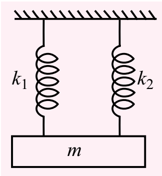
NEET / AIIMS / PMTs

Only One Option Correct Type

1. When an oscillator completes 100 oscillations its amplitude reduced to $\frac{1}{3}$ of initial value. What will be its amplitude, when it completes 200 oscillations ?

(a) $\frac{1}{8}$ (b) $\frac{2}{3}$ (c) $\frac{1}{6}$ (d) $\frac{1}{9}$

2. A mass is suspended separately by two different springs in successive order then time periods is t_1 and t_2 respectively. If it is connected by both springs as shown in figure then time period is t_0, the correct relation is



(a) $t_0^2 = t_1^2 + t_2^2$ (b) $t_0^{-2} = t_1^{-2} + t_2^{-2}$
(c) $t_0^{-1} = t_1^{-1} + t_2^{-1}$ (d) $t_0 = t_1 + t_2$.

3. Two trains move towards each other with the same speed. If the frequency when whistle of one of them heard on the other changes to 9/8 times, then the speed of each train should be
(The speed of sound is 340 m s^{-1}.)
(a) 20 m s^{-1} (b) 2 m s^{-1}
(c) 200 m s^{-1} (d) 2000 m s^{-1}.

4. Equation of progressive wave is given by $y = 4\sin\left[\pi\left(\frac{t}{5} - \frac{x}{9}\right) + \frac{\pi}{6}\right]$ where y, x are in cm and t is in seconds. Then which of the following is correct ?
(a) $v = 5$ cm (b) $\lambda = 18$ cm
(c) $a = 0.04$ cm (d) $\upsilon = 50$ Hz

5. In a simple harmonic motion, when the displacement is one-half the amplitude, what fraction of the total energy is kinetic ?
(a) 1/2 (b) 3/4 (c) Zero (d) 1/4

6. A body of mass 5 kg hangs from a spring and oscillates with a time period of 2π seconds. If the body is removed, the length of the spring will decrease by
(a) g/k m (b) k/g m
(c) 2π m (d) g m.

7. A simple harmonic oscillator has an amplitude A and time period T. The time required by it to travel from $x = A$ to $x = A/2$ is
(a) $T/6$ (b) $T/4$
(c) $T/3$ (d) $T/2$.

8. A body is executing simple harmonic motion. When the displacements from the mean position is 4 cm and 5 cm, the corresponding velocities of the body is 10 cm s^{-1} and 8 cm s^{-1}. Then the time period of the body is
(a) 2π s (b) $\pi/2$ s
(c) π s (d) $(3\pi/2)$ s.

9. Velocity of sound waves in air is 330 m s^{-1}. For a particular sound wave in air, a path difference of 40 cm is equivalent to phase difference of 1.6 π. The frequency of this wave is
(a) 165 Hz (b) 150 Hz
(c) 660 Hz (d) 330 Hz.

10. A source of frequency υ gives 5 beats per second when sounded with a source of frequency 200 Hz. The second harmonic of frequency 2υ of source gives 10 beats per second when sounded with a source of frequency 420 Hz. The value of υ is

(a) 205 Hz (b) 195 Hz
(c) 200 Hz (d) 210 Hz.

11. A closed organ pipe (closed at one end) is excited to support the third overtone. It is found that air in the pipe has

(a) three nodes and three antinodes
(b) three nodes and four antinodes
(c) four nodes and three antinodes
(d) four nodes and four antinodes.

12. A mass m is suspended from the two coupled springs connected in series. The force constant for springs are k_1 and k_2. The time period of the suspended mass will be

(a) $T = 2\pi\sqrt{\dfrac{m}{k_1 - k_2}}$ (b) $T = 2\pi\sqrt{\dfrac{mk_1k_2}{k_1 + k_2}}$

(c) $T = 2\pi\sqrt{\dfrac{m}{k_1 + k_2}}$ (d) $T = 2\pi\sqrt{\dfrac{m(k_1 + k_2)}{k_1k_2}}$.

Assertion & Reason Type

Directions : In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :

(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

13. Assertion : In simple harmonic motion, kinetic energy and potential energy become equal when the displacement is $(1/\sqrt{2})$ times the amplitude.

Reason : In simple harmonic motion, kinetic energy is zero when potential energy is maximum.

14. Assertion : The speed of sound in a gas is not affected by change in pressure provided the temperature of the gas remains constant.

Reason : The speed of sound is inversely proportional to the square root of the density of the gas.

15. Assertion : Resonance is a special case of forced vibrations in which the natural frequency of vibration of the body is the same as the impressed frequency of external periodic force and the amplitude of forced vibration is maximum.

Reason : The amplitude of forced vibrations of a body always increases with an increase in the frequency of the externally impressed periodic force.

JEE MAIN / JEE ADVANCED / PETS

Only One Option Correct Type

16. An object of specific gravity ρ is hung from a thin steel wire. The fundamental frequency for transverse standing waves in the wire is 300 Hz. The object is immersed in water so that one half of its volume is submerged. The new fundamental frequency (in Hz) is

(a) $300\left(\dfrac{2\rho - 1}{2\rho}\right)^{1/2}$ (b) $300\left(\dfrac{2\rho}{2\rho - 1}\right)^{1/2}$

(c) $300\left(\dfrac{2\rho}{2\rho - 1}\right)$ (d) $300\left(\dfrac{2\rho - 1}{2\rho}\right)$.

17. A wave represented by the equation $y = a\cos(kx - \omega t)$ is superposed with another wave to form a stationary wave such that point $x = 0$ is a node. The equation for the other wave is

(a) $a\cos(kx - \omega t)$ (b) $-a\cos(kx - \omega t)$
(c) $-a\cos(kx + \omega t)$ (d) $-a\sin(kx - \omega t)$.

18. Two bodies M and N of equal masses are suspended from two separate massless springs of spring constants k_1 and k_2 respectively. If the two bodies oscillate vertically such that their maximum velocities are equal, the ratio of the amplitude of vibration of M to that of N is

(a) $\dfrac{k_1}{k_2}$ (b) $\dfrac{k_2}{k_1}$

(c) $\sqrt{\dfrac{k_1}{k_2}}$ (d) $\sqrt{\dfrac{k_2}{k_1}}$.

19. A string of length 0.4 m and mass 10^{-2} kg is tightly clamped at its ends. The tension in the string is 1.6 N. Identical wave pulses are produced at one end at equal intervals of time, Δt. The minimum value of Δt which allows constructive interference between successive pulses is

(a) 0.05 s (b) 0.10 s
(c) 0.20 s (d) 0.40 s.

More than One Options Correct Type

20. Three simple harmonic motions in the same direction having the same amplitude a and same period are superposed. If each differs in phase from the next by 45°, then

(a) the resultant amplitude is $(1+\sqrt{2})a$

(b) the phase of the resultant motion relative to the first is 90°

(c) the energy associated with the resulting motion is $(3+2\sqrt{2})$ times the energy associated with any single motion

(d) the resulting motion is not simple harmonic.

21. A wire of 9.8×10^{-3} kg m^{-1} passes over a frictionless light pulley fixed on the top of a frictionless inclined plane which makes an angle of 30° with the horizontal. Masses m and M are tied at the two ends of wire such that m rests on the plane and M hangs freely vertically downwards. The entire system is in equilibrium and a transverse wave propagates along the wire with a velocity of 100 m s^{-1}. Which of the following are correct?

(a) $m = 20$ kg (b) $M = 5$ kg

(c) $\frac{m}{M}=\frac{1}{2}$ (d) $\frac{m}{M}=2$

22. A driver in a stationary car blows a horn which produces monochromatic sound waves of frequency 1000 Hz normally towards a reflecting wall. The wall approaches the car with a speed of 3.3 m s^{-1}. Then the

(a) frequency of sound reflected from wall and heard by the driver is 1020 Hz

(b) frequency of sound reflected from wall and heard by the driver is 980 Hz

(c) percentage increase in frequency of sound after reflection from wall is 2%

(d) percentage decrease in frequency of sound after reflection from wall is 2%.

23. If the tension in a stretched string fixed at both ends is changed by 21%, the fundamental frequency is found to increase by 15 Hz then the

(a) original frequency is 150 Hz

(b) velocity of propagation of the transverse wave along the string changes by 5%

(c) velocity of propagation of the transverse wave along the string changes by 10%

(d) fundamental wavelength on the string does not change.

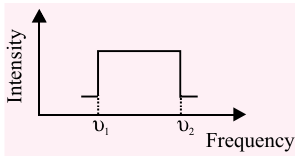
Integer Answer Type

24. An object of mass 0.2 kg executes simple harmonic motion along the x-axis with a frequency of $(25/\pi)$ Hz. At the position x = 0.04 m, the object has kinetic energy of 0.5 J and potential energy 0.4 J. The amplitude (in cm) of oscillations is

25. A bus is moving towards a huge wall with a velocity of 5 m s^{-1}. The driver sounds a horn of frequency 200 Hz. The frequency (in Hz) of the beats heard by a passenger of the bus will be (Speed of sound in air = 342 m s^{-1})

26. A uniform rod of length 1.5 m is suspended by an end and is made to undergo small oscillations. The length (in m) of the simple pendulum having the time period equal to that of the rod is

Comprehension Type



Two trains A and B are moving with speeds 20 m s^{-1} and 30 m s^{-1} respectively in the same direction on the same straight track, with B ahead of A. The engines are at the front ends. The engine of train A blows a long whistle. Assume that the sound of the whistle is composed of components varying in frequency from υ_1 = 800 Hz to υ_2 = 1120 Hz, as shown in the figure. The spread in the frequency (highest frequency – lowest frequency) is thus 320 Hz. The speed of sound in still air is 340 m s^{-1}.

27. The speed of sound of the whistle is

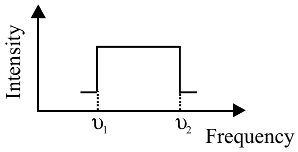
(a) 340 m s^{-1} for passengers in train A and 310 m s^{-1} for passengers in train B

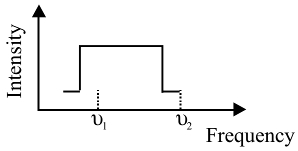
(b) 360 m s^{-1} for passengers in train A and 310 m s^{-1} for passengers in train B

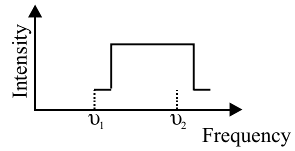
(c) 310 m s^{-1} for passengers in train A and 360 m s^{-1} for passengers in train B

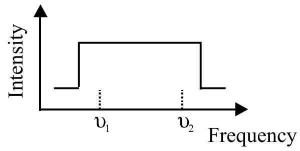
(d) 340 m s^{-1} for passengers in both the trains.

28. The distribution of the sound intensity of the whistle as observed by the passengers in train A is best represented by

(a) 

(b) 

(c) 

(d) 

Matrix Match Type

29. Match the following entries in Column I and Column II related to an oscillating spring-block system.

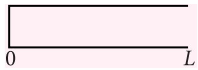
Column I	**Column II**
(A) Acceleration-displacement graph	(P) π
(B) Phase difference between velocity and acceleration	(Q) Parabola
(C) Phase difference between displacement and acceleration	(R) $\frac{\pi}{2}$
(D) Energy-displacement graph	(S) Straight line

	A	B	C	D
(a)	Q	R	S	P
(b)	P	Q	S	R
(c)	S	Q	P	R
(d)	S	R	P	Q

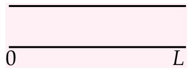
30. Column I shows four systems, each of the same length L, for producing standing waves. The lowest possible natural frequency of a system is called its fundamental frequency, whose wavelength is denoted as λ_f. Match each system in column I with quantities given in Column II.

Column I

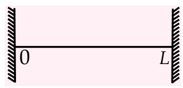
(A) Pipe closed at one end



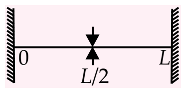
(B) Pipe opened at both ends



(C) Stretched wire clamped at both ends



(D) Stretched wire clamped at both ends and at mid-point



Column II

(P) Longitudinal waves

(Q) Transverse waves

(R) $\lambda_f = L$

(S) $\lambda_f = 2L$

(T) $\lambda_f = 4L$

	A	B	C	D
(a)	Q, T	Q, S	P, S	P, R
(b)	P, S	Q	R	Q, R
(c)	P, T	P, S	Q, S	Q, R
(d)	Q, R	R, P	P, S	Q

◈◈

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SELF CHECK

No. of questions attempted ……

No. of questions correct ……

Marks scored in percentage ……

Check your score! If your score is

> 90%	EXCELLENT WORK !	You are well prepared to take the challenge of final exam.
90-75%	GOOD WORK !	You can score good in the final exam.
74-60%	SATISFACTORY !	You need to score more next time.
< 60%	NOT SATISFACTORY!	Revise thoroughly and strengthen your concepts.

CLASS XII

ACE YOUR WAY CBSE

Exam date : 15th March 2017

Practice Paper

Time Allowed : 3 hours
Maximum Marks : 70

GENERAL INSTRUCTIONS

(i) All questions are compulsory. There are 26 questions in all.

(ii) This question paper has five sections: Section A, Section B, Section C, Section D and Section E.

(iii) Section A contains five questions of one mark each, Section B contains five questions of two marks each, Section C contains twelve questions of three marks each, Section D contains one value based question of four marks and Section E contains three questions of five marks each.

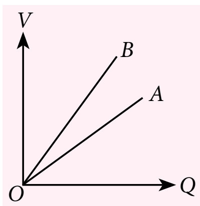
(iv) There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all the three questions of five marks weightage. You have to attempt only one of the choices in such questions.

SECTION-A

1. Two similar circular co-axial loops carry equal currents in the same direction. If the loops be brought nearer, what will happen to the currents in them?

2. A plane electromagnetic wave travels in vacuum along the y-direction. Write (a) the ratio of the magnitudes, and (b) the directions of its electric and magnetic field vectors.

3. The following graph depicts the variation of potential difference V between the plates of two capacitors A and B versus charge on the capacitors. Which of the two capacitors has higher capacitance and which has lower? Give reason too.



4. How will the magnetic field at the centre of a circular coil carrying current change, if the current through the coil is doubled and the radius of the coil is halved?

5. If the total charge enclosed by a surface is zero, does it imply that the electric field everywhere on the surface is zero? Conversely, if the electric field everywhere on a surface is zero, does it imply that net charge inside is zero?

SECTION-B

6. Show that when a ray of light is incident on the surface of a transparent medium at the polarising angle, the reflected and transmitted rays are perpendicular to each other.

7. What is the function of (a) square law device, and (b) band pass filter in an AM system?

8. Two conductors are made of the same material and have the same length. Conductor A is a solid wire of diameter 1 mm. Conductor B is a hollow tube of outer diameter 2 mm and inner diameter 1 mm. Find the ratio of resistance R_A to R_B.

9. Light of wavelength 488 nm is produced by an argon laser which is used in the photoelectric effect.

When light from this spectral line is incident on the emitter, the stopping potential of photoelectrons is 0.38 V. Find the work function of the material from which the emitter is made.

OR

A piece of wood from the ruins of an ancient building was found to have a ^{14}C activity of 12 disintegrations per minute per gram of its carbon content. The ^{14}C activity of the living wood is 16 disintegrations per minute per gram. How long ago did the tree, from which the wooden sample came, die? Given half-life of ^{14}C is 5760 years.

10. A cube of side b has a charge q at each of its vertices. Determine the potential and electric field due to this charge array at the centre of the cube.

SECTION-C

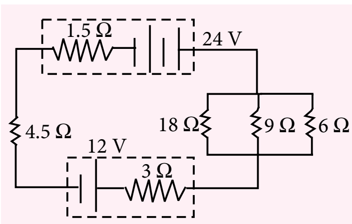
11. In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of 2.0×10^{10} Hz and amplitude 48 V m^{-1}.

(a) What is the wavelength of the wave?

(b) What is the amplitude of the oscillating magnetic field?

(c) Show that the average energy density of the $\vec{E}$ field equals the average energy density of the $\vec{B}$ field. ($c = 3 \times 10^8$ m s^{-1})

12. A 24 V battery of internal resistance 1.5 Ω is connected to three coils of 18 Ω, 9 Ω and 6 Ω in parallel, a resistor of 4.5 Ω and a reverse battery (emf = 12 V and internal resistance = 3 Ω) as shown in the figure. Calculate (a) the current in the circuit, (b) current in resistor of 18 Ω coil, and (c) potential difference across each battery.



13. A metallic rod of length l and resistance R is rotated with a frequency υ, with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius l, about an axis passing through the centre and perpendicular to the plane of the ring. A constant and uniform magnetic field B parallel to the axis is present everywhere.

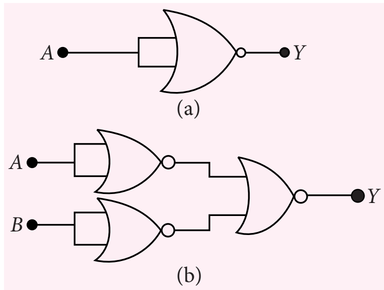
(a) Derive the expression for the induced emf and the current in the rod.

(b) Find the expression for the magnitude and direction of the force acting on this rod.

14. A point charge of +2 μC is kept fixed at the origin. Another point charge of +4 μC is brought from far off to a point distant 50 cm from the origin. Calculate the electrostatic potential energy of this two charge system. Another charge of +1 μC is brought to a point distant 100 cm from each of these two charges (assumed to be kept fixed). What is work done?

15. With the help of ray diagram derive an expression for magnifying power of compound microscope when final image is formed at least distance of distinct vision.

16. Write the truth table for the circuits given in figure consisting of NOR gates only. Identify the logic operations (OR, AND, NOT) performed by the two circuits.



17. The intensity of a light pulse travelling along a communication channel decreases exponentially with distance x according to the relation $I = I_0 e^{-\alpha x}$, where I_0 is the intensity at $x = 0$ and α is the attenuation constant.

(a) Show that the intensity reduces by 75 percent after a distance of $\left(\frac{\ln 4}{\alpha}\right)$.

(b) Attenuation of a signal can be expressed in decibel (dB) according to the relation $\text{dB} = 10 \log_{10}\left(\frac{I}{I_0}\right)$. What is the attenuation in dB km^{-1} for an optical fibre in which the intensity falls by 50 percent over a distance of 50 km?

18. A spherical capacitor consists of two concentric spherical conductors held in position by a suitable insulating support. Show that the capacitance of a spherical capacitor is given by $C = \frac{4\pi\varepsilon_0 r_1 r_2}{r_1 - r_2}$.

Where r_1 and r_2 are the radii of outer and inner spheres, respectively.

19. The total energy of an electron in the first excited state of the hydrogen atom is about – 3.4 eV.

(a) What is the kinetic energy of the electron in this state?

(b) What is the potential energy of the electron in this state?

(c) Which of the answers above would change if the choice of the zero of potential energy is changed?

20. What is photoelectric effect? Write Einstein's photoelectric equation. Explain how it enables us to understand the

(a) linear dependence of the maximum kinetic energy of the emitted electrons, on the frequency of the incident radiation.

(b) existence of a threshold frequency for a given photoemitter.

(c) independence of the maximum energy of emitted photoelectrons from the intensity of incident light.

21. Answer the following questions:

(a) Why does a paramagnetic sample display greater magnetisation for the same magnetising field when cooled?

(b) Why is diamagnetism, in contrast, almost independent of temperature?

(c) Is the permeability of a ferromagnetic material independent of the magnetic field? If not, is it more for lower or higher fields?

OR

Write the relation for the force F acting on a charge carrier q moving with a velocity v through a magnetic field B in vector notation.

Show that in the presence of this force

(a) the kinetic energy of the particle does not change.

(b) its instantaneous power is zero.

22. (a) In what way is diffraction from each slit related to the interference pattern in a double slit experiment?

(b) Two wavelengths of sodium light 590 nm and 596 nm are used, in turn to study the diffraction taking place at a single slit of aperture 2×10^{-4} m. The distance between the slit and the screen is 1.5 m. Calculate the separation between the positions of the first maxima of the diffraction pattern obtained in the two cases.

SECTION-D

23. Mr. Agrawal, a retired professor of physics was walking with his grandson. It was last week of December and so it was dark around 5:30 pm. The streetlights were on and the yellow light flooded the area around. The boy asked professor why yellow lights were used when white light were brighter. The professor answered that during foggy days the tiny droplets act as prisms splitting white light into its constituent colours and thus reducing the clarity.

(a) What phenomena was the professor referring to? Why does it happen?

(b) Give one application of prism.

(c) What values of the boy reflect from the conversation?

SECTION-E

24. State the working principle of a potentiometer. Draw a circuit diagram

(a) to compare the emfs of two primary cells.

(b) to find the internal resistance of a cell. Derive the formula used.

How can the sensitivity of a potentiometer be increased?

OR

(a) State with the help of a circuit diagram, the working principle of a metre bridge. Obtain the expression used for determining the unknown resistance.

(b) Why it is considered important to obtain the balance point near the midpoint of the wire?

(c) What happens if the galvanometer and cell are interchanged at the balance point of the bridge?

25. Draw the circuit diagram of an n-p-n transistor in common emitter configuration to study its (a) input and (b) output characteristics. Draw approximate shapes of these characteristics. Using these characteristics, explain how you would find the input and output resistance of the transistor.

OR

(a) State briefly the processes involved in the formation of p-n junction explaining clearly how the depletion region is formed.

(b) Using the necessary circuit diagrams, show how the V-I characteristics of a p-n junction are obtained in

(i) Forward biasing

(ii) Reverse biasing

26. (a) State Lenz's law. Give one example to illustrate this law. The Lenz's law is a consequence of the principle of conservation of energy. Justify this statement.

(b) Deduce an expression for the mutual inductance of two long coaxial solenoids but having different radii and different number of turns.

OR

(a) Draw a schematic sketch of an *ac* generator describing its basic elements. State briefly its working principle. Show a plot of variation of alternating emf versus time generated by a loop of wire rotating in a magnetic field.

(b) Why is choke coil needed in the use of fluorescent tubes with *ac* mains?

SOLUTIONS

1. As the loops are brought closer, the magnetic flux linked with them increases. An emf is induced in the each loop which opposes the change in flux. So the current in each loop decreases.

2. (a) $\frac{E}{B} = c$, speed of light.

(b) For an electromagnetic wave travelling along y-direction, its electric and magnetic field vectors are along z-axis and x-axis respectively. The direction of $\vec{E} \times \vec{B}$ is same as that of direction of wave propagation and $\hat{k} \times \hat{i} = \hat{j}$.

3. The capacitor A has higher value of capacitance and B has lower capacitance. We know that $C = Q/V$. Hence, slope of V-Q graph represents $1/C$.
As slope of graph for capacitor A is less, so its capacitance is more.

4. As per relation $B = \mu_0 I/2R$, if value of current is doubled ($I' = 2I$) and the radius of the coil is halved ($R' = R/2$) then new magnetic field

$$B' = \frac{\mu_0 I'}{2R'} = \frac{\mu_0 (2I)}{2\left(\frac{R}{2}\right)} = \frac{4\mu_0 I}{2R} = 4B$$

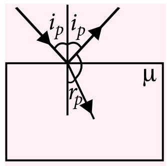
So, magnetic field will rise to become four times of its original value.

5. According to Gauss's law $\oint_S \vec{E} \cdot d\vec{S} = \frac{q}{\varepsilon_0}$. If the total charge enclosed by the surface is zero *i.e.*, $q = 0$, then $\oint \vec{E} \cdot d\vec{S} = 0$ which implies either $\vec{E} = 0$ or $\vec{E}$ is perpendicular to the surface. But if $\vec{E} = 0$, then $q = 0$ which implies that the net charge inside the surface is zero.

6. From Snell's law, $\frac{\sin i_p}{\sin r_p} = \mu$

From Brewster's law, $\tan i_p = \frac{\sin i_p}{\cos i_p} = \mu$

$\therefore \quad \frac{\sin i_p}{\sin r_p} = \frac{\sin i_p}{\cos i_p}$ or $\sin r_p = \cos i_p$



or $\quad \sin r_p = \sin (90° - i_p)$

$\therefore \quad r_p = 90° - i_p$ or $i_p + r_p = 90°$

Hence the reflected and transmitted rays are perpendicular to each other.

7. (a) The square law device transforms linear input signal into a nonlinear output signal. If input signal be $x(t)$, then the output signal $y(t)$ is of the form $y(t) = Bx(t) + Cx^2(t)$, where B and C are two constants.
(b) A band pass filter allows a certain band of frequencies to pass through and reject frequencies higher and lower than the band.

8. For a solid wire of resistance R_A

$l_1 = l, \rho_1 = \rho, D_1 = 1$ mm

$$A_1 = \frac{\pi D_1^2}{4} = \frac{\pi (1)^2}{4} \text{ mm}^2$$

$$R_A = \frac{\rho_1 l_1}{A_1} = \frac{\rho l}{\pi (1)^2/4} = \frac{4\rho l}{\pi}$$

For hollow tube of resistance R_B, $l_2 = l$, $\rho_2 = \rho$,

$$A_2 = \pi \frac{(D_2^2 - D_1^2)}{4} = \frac{\pi (2^2 - 1^2)}{4} = \frac{3\pi}{4} \text{ mm}^2$$

$$R_B = \frac{\rho_2 l_2}{A_2} = \frac{\rho l}{(3\pi/4)} = \frac{4\rho l}{3\pi}$$

$$\therefore \quad \frac{R_A}{R_B} = \frac{3}{1}$$

9. Energy of incident radiation

$$E=\frac{hc}{\lambda}=\frac{6.63\times10^{-34}\times3\times10^{8}}{488\times10^{-9}\times1.6\times10^{-19}}\text{ eV} = 2.55 \text{ eV}$$

Now using Einstein's relation

$E = \phi_0 + eV_0$, where V_0 is stopping potential

$2.55 \text{ eV} = \phi_0 + e \times 0.38 \text{ V}$

$\Rightarrow \quad \phi_0 = 2.55 - 0.38$

$\Rightarrow \quad \phi_0 = 2.17 \text{ eV} = 3.47 \times 10^{-19} \text{ J}$

OR

As per question, $T = 5760$ yrs, $t = ?$

$R_0 = 16$ disintegrations per minute per gram

$R = 12$ disintegrations per minute per gram

$$R = R_0\, e^{-\lambda t},\; e^{\lambda t}=\frac{R_0}{R}$$

$$t=\frac{\ln(R_0/R)}{\lambda}=\frac{\ln(16/12)}{0.693/5760} \qquad \left(\because\; T=\frac{0.693}{\lambda}\right)$$

$$=\frac{(2.303\log 1.333)(5760)}{0.693}$$

$= 2391.5$ yrs

10. The length of diagonal of the cube of each side b

$=b\sqrt{3}$

Distance of any of the vertices from the centre of cube,

$$r=\frac{\sqrt{3}}{2}b$$

$\therefore$ Total potential at the centre point,

$$V=8\times\frac{1}{4\pi\varepsilon_0}\frac{q}{r}=8\times\frac{1}{4\pi\varepsilon_0}\frac{q}{\sqrt{3}\frac{b}{2}}$$

or $$V=\frac{4q}{\sqrt{3}\pi\varepsilon_0 b}$$

$E = 0$, as electric field at the centre due to a charge at any corner of cube is just equal and opposite to that of another charge at diagonally opposite corner of the cube.

11. As per question, $E_0 = 48 \text{ V m}^{-1}$, $\upsilon = 2.0 \times 10^{10}$ Hz

(a) Wavelength of electromagnetic wave is

$$\lambda=\frac{c}{\upsilon}=\frac{3\times10^{8}}{2\times10^{10}}=1.5\times10^{-2}\text{ m}$$

(b) Amplitude of the oscillating magnetic field,

$$B_0=\frac{E_0}{c}=\frac{48}{3\times10^{8}}=16\times10^{-8}\text{ T}$$

(c) Average energy density of the electric field

$$\vec{E}=(u_E)_{av}=\frac{1}{2}\varepsilon_0 E_{rms}^2$$

and average energy density of the magnetic field

$$\vec{B}=(u_B)_{av}=\frac{B_{rms}^2}{2\mu_0}$$

We know that $\dfrac{E_0}{B_0}=\dfrac{E_{rms}}{B_{rms}}=c$ and $c=\dfrac{1}{\sqrt{\mu_0\varepsilon_0}}$

$$\therefore (u_E)_{av}=\frac{1}{2}\varepsilon_0E_{rms}^2=\frac{1}{2}\varepsilon_0c^2B_{rms}^2=\frac{1}{2}\varepsilon_0\cdot\frac{1}{(\mu_0\varepsilon_0)}\cdot B_{rms}^2$$

$$=\frac{B_{rms}^2}{2\mu_0}=(u_B)_{av}\text{, hence } (u_E)_{av}=(u_B)_{av}$$

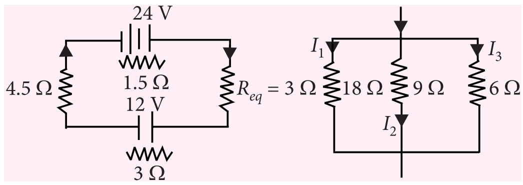
12. Equivalent resistance (R_{eq}) of three coils is given by

$$\frac{1}{R_{eq}}=\frac{1}{18}+\frac{1}{9}+\frac{1}{6}=\frac{1+2+3}{18}=\frac{1}{3}$$

$\Rightarrow \quad R_{eq} = 3\ \Omega$

(a) Current in the circuit

$$I=\frac{24-12}{3+3+4.5+1.5}=1\text{ A}$$



(b) Potential drop across 3 Ω

$V = IR_{eq} = 3$ V

$V = I_1R_1 = I_2R_2 = I_3R_3$

$3 = 18I_1 = 9I_2 = 6I_3$

$$I_1=\frac{3}{18}=\frac{1}{6}\text{ A}$$

(c) Potential difference across battery of 24 V

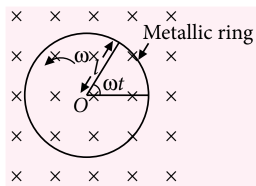
$V_1 = \varepsilon - Ir$

$V_1 = 24 - 1 \times 1.5 = 22.5$ V

Potential difference across battery of 12 V

$V_2 = \varepsilon + Ir = 12 + 1 \times 3 = 15$ V

13. (a) As the rod is rotated, free electrons in the rod move towards the outer end due to Lorentz force and get distributed over the ring. This separation of charges produces an emf across the ends of the rod.



The magnitude of the emf, generated across a length dl of the rod, as it moves at right angles to the magnetic field, is given by
$d\varepsilon = Bvdl$

$$\therefore \quad \varepsilon = \int d\varepsilon = \int_0^l Bvdl = \int_0^l B\omega l dl = \frac{B\omega l^2}{2} = \pi\upsilon B l^2$$

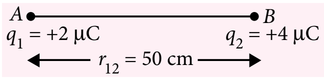
$$I = \frac{\varepsilon}{R} = \frac{\pi\upsilon B l^2}{R}$$

(b) $\quad F = IlB = \dfrac{\pi\upsilon B^2 l^3}{R}$

The external force required to rotate the rod must act in the direction opposite to that of Lorentz force acting on the rod.

14. Electric potential energy of two particle system is

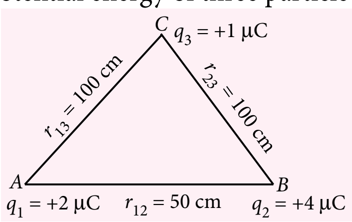
$$U_1 = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$$



or $\quad U_1 = 9\times 10^9 \times \dfrac{2\times10^{-6}\times4\times10^{-6}}{0.5}$

or $\quad U_1 = 144 \times 10^{-3}$ J $= 0.144$ J

Electric potential energy of three particle system is



$$U_2 = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_2}{r_{12}} + \frac{q_1q_3}{r_{13}} + \frac{q_2q_3}{r_{23}}\right]$$

$$= 9\times10^9\left[\frac{2\times4}{0.5} + \frac{2\times1}{1} + \frac{4\times1}{1}\right]\times10^{-12}$$

$$= 9\times10^9\,[16+2+4]\times10^{-12}$$

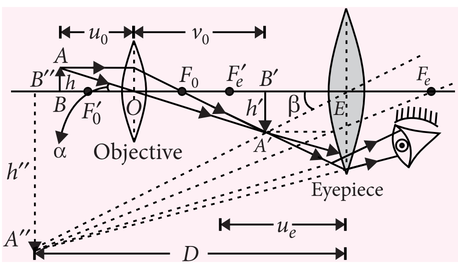
$$= 198\times10^{-3}\text{ J} = 0.198\text{ J}$$

Work done in bringing charge q_3 from infinity to point C is

$$W = U_2 - U_1 = 0.198 - 0.144$$

or $\quad W = 0.054$ J

15.



The magnifying power of a compound microscope is defined as the ratio of the angle subtended at the eye by the final image to the angle subtended at the eye by the object, when both are at the least distance of distinct vision from the eye.

$$\therefore \quad m = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha} = \frac{h'/u_e}{h/D} = \frac{h'}{h}\cdot\frac{D}{u_e} = m_0 m_e$$

Here, $m_0 = \dfrac{h'}{h} = \dfrac{v_0}{u_0}$

As the eyepiece acts as a simple microscope, so

$$m_e = \frac{D}{u_e} = 1 + \frac{D}{f_e} \quad \therefore\ m = \frac{v_0}{u_0}\left(1+\frac{D}{f_e}\right)$$

As the object AB is placed close to the focus F_0 of the objective, therefore,

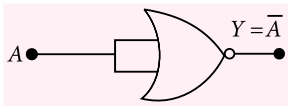
$$u_0 \simeq -f_0$$

Also image $A'B'$ is formed close to the eyelens whose focal length is short, therefore $v_0 \simeq L$ = the length of the microscope tube or the distance between the two lenses

$$\therefore \quad m_0 = \frac{v_0}{u_0} = \frac{L}{-f_0}$$

$$\therefore \quad m = -\frac{L}{f_0}\left(1+\frac{D}{f_e}\right) \qquad \text{[for final image at } D\text{]}$$

16. Boolean expression for logic circuit (a)

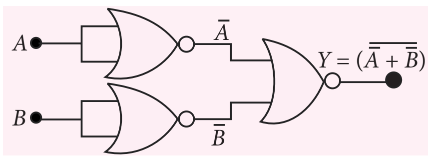


Here the given NOR gate with short circuit input is acting as NOT gate.

Its truth table is

A	Y
0	1
1	0

Boolean expression for logic circuit (b)



So, output

$$Y = \left(\overline{\overline{A} + \overline{B}}\right) = \overline{\overline{A}}\cdot\overline{\overline{B}} = AB$$

Hence, the logic circuit acts like AND gate.

Its truth table is

A	B	$\bar{A}$	$\bar{B}$	$\bar{A}+\bar{B}$	$Y=(\overline{\bar{A}+\bar{B}})$
0	0	1	1	1	0
0	1	1	0	1	0
1	0	0	1	1	0
1	1	0	0	0	1

17. (a) When intensity of light pulse reduces by 75%, Intensity after travelling distance x, *i.e.*,

$$I=\left(I_0-\frac{3}{4}I_0\right)\Rightarrow\frac{I}{I_0}=\frac{1}{4}$$

As $I=I_0\,e^{-\alpha x}$, $\frac{I}{I_0}=e^{-\alpha x}$; $\frac{1}{4}=e^{-\alpha x}$

or $4=e^{\alpha x}$

Taking logarithms both sides,

$\ln 4=\alpha x$

$$x=\frac{\ln 4}{\alpha}$$

(b) If attenuation of signal is expressed in dB, then

$$10\log_{10}\frac{I}{I_0}=-\alpha x$$

When intensity of the signal falls by 50%, intensity after travelling a distance x, $I=\left(I_0-\frac{I_0}{2}\right)=\frac{I_0}{2}$

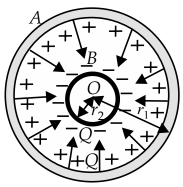
or $\frac{I}{I_0}=\frac{1}{2}$

$\therefore$ $10\log_{10}\left(\frac{1}{2}\right)=-\alpha x$

or $10\log_{10}2=50\alpha$ (as $x=50$ km)

or $\alpha=\frac{1}{5}\log_{10}2=\frac{0.3010}{5}=0.0602\text{ dB km}^{-1}$

18. Let $+Q$ be the charge on outer spherical shell A of radius r_1 and $-Q$ be the charge on inner spherical shell B of radius r_2. Then electric potential on shell A is



$$V_A=V_{AA}+V_{AB}=\frac{1}{4\pi\varepsilon_0}\left[\frac{+Q}{r_1}-\frac{Q}{r_1}\right]$$

or $V_A=0$

and electric potential on shell B is

$$V_B=V_{BA}+V_{BB}=\frac{1}{4\pi\varepsilon_0}\left[\frac{Q}{r_1}-\frac{Q}{r_2}\right]$$

or $V_B=\frac{Q}{4\pi\varepsilon_0}\left[\frac{r_2-r_1}{r_1r_2}\right]$

So, the potential difference between the two spherical shells A and B is

$$V=V_A-V_B=0-\frac{Q}{4\pi\varepsilon_0}\left[\frac{r_2-r_1}{r_1r_2}\right]$$

or $V=\frac{Q}{4\pi\varepsilon_0}\left[\frac{r_1-r_2}{r_1r_2}\right]$

$\therefore$ Capacitance of spherical capacitor,

$$C=\frac{Q}{V}=\frac{4\pi\varepsilon_0 r_1r_2}{r_1-r_2}\text{ or }C=\frac{4\pi\varepsilon_0 r_1r_2}{r_1-r_2}$$

This gives the capacitance of the spherical capacitor.

19. Kinetic energy of an electron in n^{th} orbit,

$$K=\frac{1}{2}\frac{kZe^2}{r}$$

Potential energy of an electron in n^{th} orbit,

$$U=-\frac{kZe^2}{r}=-2K$$

Total energy,

$E=K+U=K-2K=-K$

(a) Kinetic energy,

$K=E=-(-3.4)=3.4$ eV

(b) Potential energy,

$U=-2K=-2\times 3.4=-6.8$ eV

(c) If the zero of the potential energy is chosen differently, the kinetic energy does not change. Potential energy and hence total energy will be affected.

20. Photoelectric effect is the phenomenon of emission of electrons from the surface of metals, when light radiations of suitable frequency fall on them.

Einstein photoelectric equation is in accordance with the energy conservation law as applied to the photo-absorption by an electron in the metal. Thus

Energy of incident photon

= Maximum kinetic energy of photoelectron

+ Work function of metal

or $h\upsilon=\frac{1}{2}mv_{\max}^2+W_0$

or $K_{\max}=\frac{1}{2}mv_{\max}^2=h\upsilon-W_0$

At threshold frequency υ_0, no kinetic energy is given to the electron. So

$h\upsilon_0=W_0$

Hence $K_{\max}=h\upsilon-h\upsilon_0=h(\upsilon-\upsilon_0)$

This is Einstein's photoelectric equation.

(a) Clearly, above the threshold frequency υ_0, $K_{\max}\propto\upsilon$ *i.e.*, the maximum kinetic energy of the emitted electrons depends linearly on the frequency of incident radiation.

(b) When $\upsilon < \upsilon_0$, K_{max} becomes negative. The kinetic energy becomes negative which has no physical meaning. Hence there is no photoelectric emission below the threshold frequency υ_0.

(c) It is obvious from the photoelectric equation that the maximum kinetic energy of photoelectrons does not depend on the intensity of incident light.

21. (a) In paramagnetic sample, the tendency to disrupt the alignment of molecular dipoles with the external magnetising field arising from random thermal motion is reduced at lower temperatures.

(b) In diamagnetic sample, the molecular dipole moments always align in direction opposite to that of external magnetising field, inspite of the internal motion of atoms.

(c) No, the permeability of a ferromagnetic material is not independent of the magnetic field. It is more at higher fields.

OR

When a charged particle having a charge q moving with velocity v enters a magnetic field B, then it experiences a force $\vec{F} = q(\vec{v} \times \vec{B})$

(a) Rate of change of kinetic energy of a charged particle moving in a magnetic field is

$$\frac{d}{dt}(\text{KE}) = \frac{d}{dt}\left(\frac{1}{2}mv^2\right) = \frac{1}{2}m\frac{d}{dt}(\vec{v}.\vec{v})$$

$$= \frac{1}{2}m\left[\frac{d\vec{v}}{dt}\cdot\vec{v} + \vec{v}\cdot\frac{d\vec{v}}{dt}\right] = \frac{1}{2}m\left(\frac{2d\vec{v}}{dt}.\vec{v}\right)$$

$$= m\frac{d\vec{v}}{dt}.\vec{v} = m\vec{a}.\vec{v} = \vec{F}.\vec{v}$$

or $\quad \frac{d}{dt}(\text{KE}) = Fv\cos 90°$

[As $\vec{F}$ and $\vec{v}$ are perpendicular]

or $\quad \frac{d}{dt}(\text{KE}) = 0$

or $\quad$ KE = constant

So, kinetic energy of the particle does not change on moving in magnetic field.

(b) Instantaneous power of charged particle moving in magnetic field is

$$P = \vec{F}.\vec{v} = Fv\cos 90° = 0$$

22. (a) If the width of each slit is comparable to the wavelength of light used, the interference pattern thus obtained in the double-slit experiment is modified by diffraction from each of the two slits.

(b) Given, wavelength of the light beam,

$\lambda_1 = 590\text{ nm} = 5.9 \times 10^{-7}\text{ m}$

Wavelength of another light beam,

$\lambda_2 = 596\text{ nm} = 5.96 \times 10^{-7}\text{ m}$

Distance of the slits from the screen = D = 1.5 m

Distance between the two slits = $a = 2 \times 10^{-4}$ m

For the first secondary maxima,

$$\sin\theta = \frac{3\lambda_1}{2a} = \frac{x_1}{D}$$

$$x_1 = \frac{3\lambda_1 D}{2a} \text{ and } x_2 = \frac{3\lambda_2 D}{2a}$$

$\therefore$ Separation between the positions of first secondary maxima of two sodium lines

$$x_2 - x_1 = \frac{3D}{2a}(\lambda_2 - \lambda_1)$$

$$= \frac{3\times 1.5}{2\times 2\times 10^{-4}}(5.96\times 10^{-7} - 5.9\times 10^{-7})$$

$= 6.75 \times 10^{-5}$ m

23. (a) Dispersion, this is because the refractive index of the refracting medium is different for different wavelengths.

(b) Studying and analysing the spectrum of distant light sources.

(c) Curiosity, research mindedness, awareness.

24. **Refer to point 2.5 (7) page no. 101 (MTG Excel in Physics)**

OR

Refer to point 2.5 (6) page no. 100 (MTG Excel in Physics)

(c) There is no change in the position of the balance point of the bridge.

25. **Refer to point 9.4 (7) page no. 594 (MTG Excel in Physics)**

OR

Refer to point 9.3 (2, 4, 5) page no. 587 (MTG Excel in Physics)

26. **(a) Refer to point 4.1 (6) page no. 247 (MTG Excel in Physics)**

(b) Refer to point 4.2 (2) page no. 251 (MTG Excel in Physics)

OR

(a) Refer to point 4.8 (2) page no. 275 (MTG Excel in Physics)

(b) Refer to point 4.8 (3) page no. 276 (MTG Excel in Physics)

MPP-8 MONTHLY Practice Problems

Class XII

This specially designed column enables students to self analyse their extent of understanding of specified chapters. Give yourself four marks for correct answer and deduct one mark for wrong answer.

Self check table given at the end will help you to check your readiness.

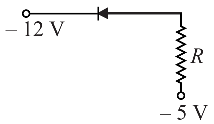
Semiconductor Electronics and Communication System

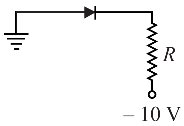
Total Marks : 120 **Time Taken : 60 min**

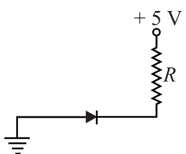
NEET / AIIMS / PMTs

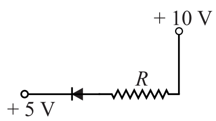
Only One Option Correct Type

1. Of the diodes shown in the following diagrams, which one is reverse biased ?

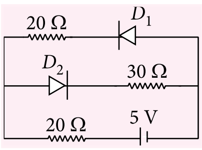
(a) 

(b) 

(c) 

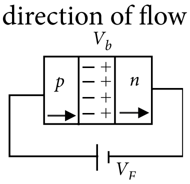
(d) 

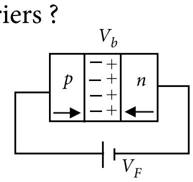
2. The current in the circuit will be

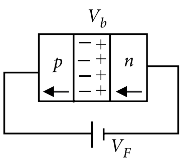


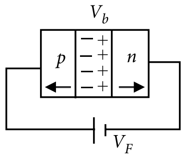
(a) 5/40 A
(b) 5/50 A
(c) 5/10 A
(d) 5/20 A.

3. In the case of forward biasing of p-n junction, which one of the following figures correctly depicts the direction of flow of carriers ?

(a) 

(b) 

(c) 

(d) 

4. p-n junction is said to be forward biased, when
(a) the positive pole of the battery is joined to the p-semiconductor and negative pole to the n-semiconductor
(b) the positive pole of the battery is connected to n-semiconductor and negative pole to the p-semiconductor
(c) a mechanical force is applied in the forward direction
(d) None of these.

5. The transfer ratio (β) of a transistor is 50. The input resistance of the transistor when used in the common emitter configuration is 1 kΩ. The peak value of the collector current for a peak value of AC input voltage of 0.01 V is
(a) 100 μA (b) 0.01 μA
(c) 0.25 μA (d) 500 μA.

6. When the emitter current of a transistor is changed by 1 mA, its collector current changes by 0.990 mA. In the common base circuit, current gain for the transistor is
(a) 0.099 (b) 1.01 (c) 1.001 (d) 0.990.

7. In a transistor the current amplification factor α is 0.9. The transistor is connected in common base configuration. The change in collector current when base current changes by 4 mA is
(a) 4 mA (b) 12 mA (c) 24 mA (d) 36 mA.

8. Mobilities of electrons and holes in a sample of intrinsic germanium at room temperature are 0.36 m^2 V^{-1} s^{-1} and 0.17 m^2 V^{-1} s^{-1}. The electron and hole densities are each equal to 2.5 $\times 10^{19}$ m^{-3}. The electrical conductivity of germanium is
(a) 0.47 S m^{-1} (b) 5.18 S m^{-1}
(c) 2.12 S m^{-1} (d) 1.09 S m^{-1}.

9. In short wave communication, waves of which of the following frequencies will be reflected back by the ionospheric layer having electron density 10^{11} m^{-3} ?

(a) 2 MHz (b) 10 MHz
(c) 12 MHz (d) 18 MHz.

10. In satellite communication
1. the frequency used lies between 5 MHz and 10 MHz.
2. the uplink and downlink frequencies are different.
3. the orbit of the geostationary satellite lies in the equatorial plane at an inclination of 0°.

In the above statements.
(a) only 2 and 3 are true (b) all are true
(c) only 2 is true (d) only 1 and 3 are true.

11. A signal wave of frequency 12 kHz is modulated with a carrier wave of frequency 2.51 MHz. The upper and lower sideband frequencies are respectively
(a) 2512 kHz and 2508 kHz
(b) 2522 kHz and 2488 kHz
(c) 2522 kHz and 2498 kHz
(d) 3512 kHz and 2488 kHz.

12. For a radio signal to travel 150 km from the transmitter to a receiving antenna, it takes
(a) 5×10^{-4} s (b) 4.5×10^{-3} s
(c) 5×10^{-8} s (d) 4.5×10^{-6} s.

Assertion & Reason Type

Directions : In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :
(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

13. Assertion : Sky wave signals are used for long distance radio communication. These signals are in general, less stable than ground wave signals.
Reason : The state of ionosphere varies from hour to hour, day to day and season to season.

14. Assertion : A pure semiconductor has negative temperature coefficient of resistance.
Reason : On raising the temperature, more charge carriers are released, conductance increases and resistance decreases.

15. Assertion : In a common emitter amplifier, the load resistance of the output circuit is 1000 times the load resistance of the input circuit. If $\alpha = 0.98$, then voltage gain is 49×10^3.

Reason : $\alpha = \dfrac{\beta}{1-\beta}$ (Symbols have their usual meaning).

JEE MAIN / PETs

Only One Option Correct Type

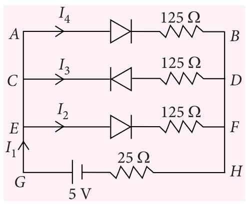
16. A common emitter amplifier has a voltage gain of 50, an input impedance of 100 Ω and an output impedance of 200 Ω. The power gain of the amplifier is
(a) 500 (b) 1000 (c) 1250 (d) 50.

17. If the highest modulating frequency of the wave is 5 kHz, the number of stations that can be accommodated in a 150 kHz bandwidth is
(a) 15 (b) 10
(c) 5 (d) None of these.

18. Digital signals
(i) do not provide a continuous set of values.
(ii) represent values as discrete steps.
(iii) can utilize binary system.
(iv) can utilize decimal as well as binary systems.

Which of the above statements are true ?
(a) (i) and (ii) only (b) (ii) and (iii) only
(c) (i), (ii) and (iii) but not (iv)
(d) All of (i), (ii), (iii) and (iv).

19. If each diode in figure has a forward bias resistance of 25 Ω and infinite resistance in reverse bias. The values of the current



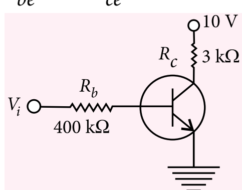
(a) $I_2 = 0.40$ A, $I_4 = 0.025$ A
(b) $I_2 = 0.25$ A, $I_4 = 0.20$ A
(c) $I_1 = 0.05$ A, $I_3 = 0.02$ A
(d) $I_2 = I_4 = 0.025$ A.

More than One Options Correct Type

20. A transistor is used in common emitter mode as an amplifier then
(a) the base emitter junction is forward biased
(b) the base emitter junction is reverse biased
(c) the input signal is connected in series with the voltage applied to the base emitter junction
(d) the input signal is connected in series with the voltage applied to the base collector junction.

21. In an *n-p-n* transistor circuit, the collector current is 10 mA. If 90% of the electrons emitted reach the collector
(a) the emitter current will be 9 mA
(b) the base current will be 1 mA
(c) the emitter current will be 11 mA
(d) the base current will be –1 mA.

22. In the circuit shown in figure, when the input voltage of the base resistance is 10 V, V_{be} and V_{ce} are zero.



Then, which of the following statements are correct ?
(a) The base current is 25 μA.
(b) The collector current is 3.33 mA.

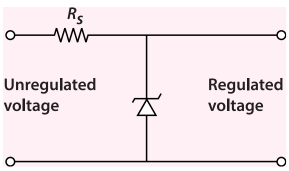
(c) Current gain is 133.
(d) The emitter current is less than 3 mA.

23. An audio signal of 15 kHz frequency cannot be transmitted over long distances without modulation because
(a) the size of the required antenna would be at least 5 km which is not convenient
(b) the audio signal can not be transmitted through sky waves
(c) the size of the required antenna would be at least 20 km, which is not convenient
(d) effective power transmitted would be very low, if the size of the antenna is less than 5 km.

Integer Answer Type

24. Audio sine waves of 3 kHz frequency are used to amplitude modulate a carrier signal of 1.5 MHz. The bandwidth required for amplitude modulation (in kHz) is

25. A Zener of power rating 2 W is to be used as a voltage regulator. If Zener has a breakdown of 5 V and it has to regulate voltage which fluctuates between 3 V and 7 V, then the value of R_s (in Ω) for safe operation is



26. A carrier wave of peak voltage 12 V is used to transmit a message signal. The peak voltage (in V) of the modulating signal in order to have a modulation index of 75% is

Comprehension Type

In a *p-n* junction diode, the current *I* can be expressed as

$$I = I_0\left[\exp\left(\frac{eV}{k_BT}\right)-1\right],$$ where I_0 is called the reverse saturation current, *V* is the voltage across the diode and is positive for forward bias and negative for reverse bias. *I* is current through the diode, k_B is the Boltzmann constant (8.6×10^{-5} eV K^{-1}) and *T* is the absolute temperature.

27. For a given diode $I_0 = 5 \times 10^{-12}$ A at $T = 300$ K, what will be the forward current at forward voltage of 0.6 ?
(a) 0.063 A (b) 0.126 A
(c) 0.032 A (d) 0.252 A

28. For a given diode $I_0 = 5$ nA at $T = 305$ K, what will be the current if reverse bias voltage changes from 1 V to 2 V ?
(a) 5 nA (b) –5 nA (c) – 4 nA (d) 4 nA

Matrix Match Type

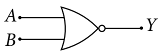
29. Column-II gives five uses/operational modes of different types of semiconductor diodes listed in Column-I.
Match each of these diode with the appropriate use (s)/operational mode (s).

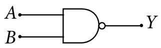
Column I	Column II
(A) Photodiode	(P) converts radiant energy into electrical energy
(B) Solar cell	(Q) operated under forward bias
(C) Light-emitting diode	(R) operated under reverse bias
(D) Zener diode	(S) based on inner photoelectric effect
	(T) used as a voltage regulator

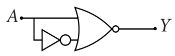
	A	B	C	D
(a)	R	P, Q	Q	T
(b)	P, R	Q	R	S, T
(c)	Q, R	P	R	T
(d)	R, S	P	Q	R, T

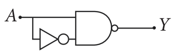
30. In column I we have the gates and in column II the output *Y*. Match the gate given in column I with its output given in column II.

Column I | **Column II**

(A)  (P) $\bar{A}.A$

(B)  (Q) $\bar{A}+A$

(C)  (R) $\bar{A}+\bar{B}$

(D)  (S) $\bar{A}.\bar{B}$

	A	B	C	D
(a)	P	Q	R	S
(b)	R	S	P	Q
(c)	S	R	P	Q
(d)	S	R	Q	P

Keys are published in this issue. Search now! ☺

SELF CHECK

No. of questions attempted ……
No. of questions correct ……
Marks scored in percentage ……

Check your score! If your score is

> 90%	EXCELLENT WORK !	You are well prepared to take the challenge of final exam.
90-75%	GOOD WORK !	You can score good in the final exam.
74-60%	SATISFACTORY !	You need to score more next time.
< 60%	NOT SATISFACTORY!	Revise thoroughly and strengthen your concepts.

PHYSICS MUSING

SOLUTION SET-42

1. (a) : Velocity of the particle, $\vec{v} = \alpha\hat{i} + \beta t\hat{j}$

Acceleration, $\vec{a} = \frac{d\vec{v}}{dt} = \beta\hat{j}$ So, total acceleration, $|\vec{a}| = \beta$

Speed of the particle, $v = \sqrt{\alpha^2 + \beta^2 t^2}$

So, tangential acceleration a_T is,

$$a_T = \frac{dv}{dt} = \frac{1}{2}(\alpha^2 + \beta^2 t^2)^{-1/2}(2\beta^2 t)$$

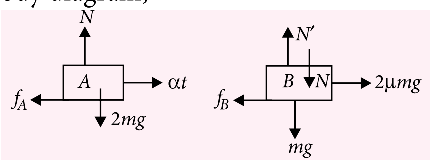
At $t = \frac{\sqrt{3}\alpha}{\beta}$, $a_T = \frac{\sqrt{3}\beta}{2}$ and $a_N = \sqrt{\beta^2 - \frac{3\beta^2}{4}} = \frac{\beta}{2}$

2. (c): Acceleration down the plane, $a = g(\sin\theta - \mu\cos\theta)$
Velocity of block at time t, $v = at = gt(\sin\theta - \mu\cos\theta)$
Force of friction, $f = \mu mg\cos\theta$
So, rate of work done by force of friction,
$P = f\cdot v = \mu mg^2 t\cos\theta(\sin\theta - \mu\cos\theta)$

3. (d) : Velocity of ball to reach the top of the tube should be given by law of conservation of energy.
$\therefore\ (U + K)_i = (U + K)_f$

$$\Rightarrow mgh + \frac{1}{2}mv^2 = mg(2R) + \frac{1}{2}m(0)^2 \Rightarrow v = \sqrt{2g(2R - h)}$$

4. (c): Mass of block $B = m$
$\therefore$ Mass of block $A = 2m$ [As $m_A : m_B = 2 : 1$]
Free body diagram,



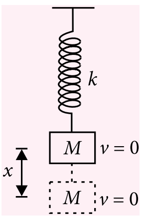
Since there is no vertical motion
$N = 2mg$, $N' = N + mg = 3\ mg$
$\therefore$ Frictional forces on the blocks are

$$f_A = \mu N = \mu(2mg) = 2\mu mg,\ f_B = \frac{\mu N'}{2} = \frac{3}{2}\mu mg$$

Acceleration, $a_A = a_B = \frac{2\mu mg - 3/2(\mu mg)}{m} = \frac{\mu g}{2}$

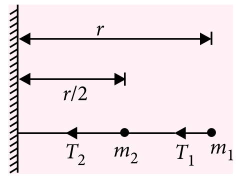
For A, $\alpha t - 2\mu mg = 2m \times \frac{\mu g}{2}$, $t = 3\ \mu mg/\alpha$

5. (b) : Let x be the maximum extension of the spring. From conservation of mechanical energy, decrease in gravitational potential energy = increase in elastic potential energy



$\therefore\ Mgx = \frac{1}{2}kx^2$ or $x = \frac{2Mg}{k}$

6. (c) : Since the particles describe horizontal circles, the angular velocity of two particles are same.



For mass m_1,
$T_1 = m_1\omega^2 r$ ... (i)
and for mass m_2, $T_2 - T_1 = m_2\omega^2\left(\frac{r}{2}\right)$ ... (ii)

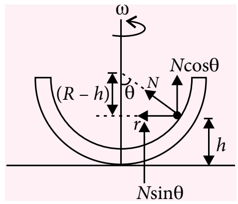
From eqns. (i) and (ii), $\frac{T_2}{T_1} = \frac{2m_1 + m_2}{2m_1}$

7. (b) : When total acceleration vector makes 45° with radial acceleration, then
$a_c = a_t = 2t$ .... (i)

$\because\ a_t = \frac{dv}{dt} = 2t \Rightarrow v = t^2$ and $a_c = \frac{v^2}{R} = \frac{t^4}{R}$ ... (ii)

From eqns. (i) and (ii), $2t = \frac{t^4}{R} \Rightarrow t^3 = 2R = 8 \Rightarrow t = 2$ s

8. (d) : Since, $N\cos\theta = mg$
and $N\sin\theta = m\omega^2 r$ ... (i)

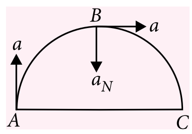


$\Rightarrow \tan\theta = \frac{\omega^2 r}{g}$

$\Rightarrow \frac{r}{R - h} = \frac{\omega^2 r}{g} \Rightarrow h = R - \frac{g}{\omega^2}$

9. (b) : Initially particle has tangential acceleration a only which is responsible for variation in velocity. Since this component of acceleration is constant throughout the motion, hence velocity of the particle at point B is given by, $v_B^2 = v_0^2 + 2a \times \frac{\pi R}{2}$
$v_B^2 = a\pi R$ $(\because\ v_0 = 0)$

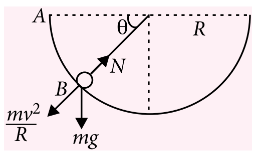
Normal acceleration of the particle at point B $a_N = \frac{v_B^2}{R} = a\pi$



Then, the resultant acceleration of the particle at point $B = \sqrt{a^2 + (a\pi)^2} = a\sqrt{1 + \pi^2}$

10. (a) : By conservation of energy
Energy at point A = Energy at point B

$$mgR = mgR(1 - \sin\theta) + \frac{1}{2}mv^2$$



$\frac{mv^2}{R} = 2mg\sin\theta$ ...(i)

Again, $N = \frac{mv^2}{R} + mg\sin\theta$ ...(ii)

From eqns. (i) and (ii), we get $N = 3mg\sin\theta$

Ratio, $x = \frac{mv^2}{R\cdot N} = \frac{2mg\sin\theta}{3mg\sin\theta} = \frac{2}{3}$ = constant

NEET | JEE ESSENTIALS

Class XI

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Unit 8 Waves and Oscillations

Periodic Motion and Oscillatory Motion

- When a particle repeats its motion after regular time interval is called periodic motion. The regular interval of time, after which the periodic motion is repeated is called its time period.
- Examples of periodic motion are
  - Motion of all planets around the sun.
  - Motion of the blade of electric fan.
- A periodic motion can be either rectilinear or closed or open curvilinear.
- When a particle moves back and forth about a fixed point after regular interval of time is called oscillatory motion.
- Examples of oscillatory motion are
  - Motion of the mass attached to a spring.
  - Motion of bob of the simple pendulum.
  - Vibration of the wire of sitar.
- Every oscillatory motion is periodic but every periodic motion is not oscillatory.

Simple Harmonic Motion

- Simple harmonic motion (SHM) is a special type of oscillatory motion in which particle oscillates on a straight line, the acceleration of the particle is always directed towards a fixed point on the line and its magnitude is proportional to the displacement of the particle from this point. This fixed point is called the centre of oscillation or mean position.
- **Necessary condition for SHM**
  - Motion of particle should be oscillatory.
  - Total mechanical energy of particle should be constant (kinetic energy + potential energy).
  - Extreme position should be well defined.
- **Comparison between linear and angular SHM**

Linear SHM	Angular SHM
$F \propto -x$ $F = -kx$ Where k is the restoring force constant.	$\tau \propto -\theta$ $\tau = -C\theta$ Where C is the restoring torque constant
$a = -\frac{k}{m}x$	$\alpha = -\frac{C}{I}\theta$
$\frac{d^2x}{dt^2} + \frac{k}{m}x = 0$ It is known as differential equation of linear SHM.	$\frac{d^2\theta}{dt^2} + \frac{C}{I}\theta = 0$ It is known as differential equation of angular SHM.
$x = A\sin\omega t,\ a = -\omega^2 x$	$\theta = \theta_0\sin\omega t,\ \alpha = -\omega^2\theta$
$\omega^2 = \frac{k}{m}$ $\omega = \sqrt{\frac{k}{m}} = \frac{2\pi}{T} = 2\pi\upsilon$	$\omega^2 = \frac{C}{I}$ $\omega = \sqrt{\frac{C}{I}} = \frac{2\pi}{T} = 2\pi\upsilon$
This concept is valid for all types of linear SHM.	This concept is valid for all types of angular SHM.

- **Some terms used in SHM**
  - **Amplitude** (A) **:** The maximum displacement of particle from mean position is defined as amplitude.
  - **Time period** (T) **:** The smallest time taken to complete one oscillation or vibration is also defined as time period. It is given by $T = \frac{2\pi}{\omega}$, where ω is angular frequency.

    Frequency (υ) **:** The number of oscillations per second is defined as frequency.

    $$\upsilon = \frac{1}{T}, \quad \upsilon = \frac{\omega}{2\pi}$$
  - **Phase :** Phase of vibrating particle at any instant is the state of the vibrating particle regarding its displacement and direction of vibration at that particular instant.

    In equation $x = A\,\sin(\omega t + \phi)$, the quantity $(\omega t + \phi)$ represents the phase angle at any instant.
    – The phase angle at time $t = 0$ is known as initial phase or epoch.
    – The difference of total phase angles of two particles executing SHM with respect to the mean position is known as phase difference.
  - **Angular frequency** (ω) **:** The rate of change of phase angle of a particle with respect to time is defined as its angular frequency.
  - Displacement can be given by relation $x = A\sin\omega t$ or $x = A\cos\omega t$.

    The first relation is valid when the time is measured from the mean position and the second relation is valid when the time is measured from the extreme position of the particle executing SHM along a straight line path.
  - Velocity of a particle in SHM is given by (Choose $x = A\sin(\omega t = \phi)$)

    $$v = \frac{dx}{dt} = A\omega\cos(\omega t + \phi) \;= \pm\,\omega\sqrt{(A^2 - x^2)}$$
  - Acceleration of a particle in SHM is given by

    $$a = \frac{dv}{dt} = \frac{d^2x}{dt^2} = -\omega^2 A\sin(\omega t + \phi) = -\omega^2 x$$

Energy in SHM

- If a particle executes SHM, its KE changes into potential energy and vice-versa keeping total energy constant (if friction of air is neglected).

  The kinetic energy in SHM is given by

  $$K = \frac{1}{2}mv^2 = \frac{1}{2}m\omega^2(A^2 - x^2)$$
  $$= \frac{1}{2}mA^2\omega^2\cos^2(\omega t + \phi)$$
  - Kinetic energy is maximum at mean position and zero at the extreme position.
- The potential energy in SHM is given by

  $$U = \frac{1}{2}m\omega^2 x^2 = \frac{1}{2}mA^2\omega^2\sin^2(\omega t + \phi)$$
  - Potential energy is minimum at mean position and increases as the particle approaches either extremes of oscillations.
- The total energy is given by,

  $$E = \frac{1}{2}m\omega^2 A^2$$
- The average value of kinetic energy or potential energy of a particle in SHM in one complete oscillation,

  $$\langle K\rangle = \langle U\rangle = \frac{1}{4}m\omega^2A^2$$
- The average value of total energy of a particle in SHM in one complete oscillation,

  $$\langle E\rangle = \frac{1}{2}m\omega^2A^2$$

Phase Relationship between Displacement, Velocity and Acceleration in SHM

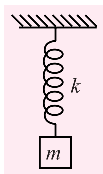
- The displacement of a particle executing SHM is given by $x = A\cos(\omega t + \phi)$

  $$\text{Velocity, } v = \frac{dx}{dt} = -\,\omega A\sin(\omega t + \phi)$$
  $$= \omega A\cos\left[(\omega t + \phi) + \frac{\pi}{2}\right]$$
  $$\text{Acceleration, } a = \frac{dv}{dt} = -\,\omega^2 A\cos(\omega t + \phi)$$
  $$= \omega^2 A\cos[(\omega t + \phi) + \pi]$$
- The velocity in SHM is leading the displacement by a phase π/2 radian.
- The acceleration in SHM is leading the displacement by a phase π radian.
- The acceleration in SHM is leading the velocity by a phase π/2 radian.

Spring Pendulum

- When a mass m is suspended from a massless spring of spring constant k, then its time period is given by

  $$T = 2\pi\sqrt{\frac{m}{k}}$$



- If M be the mass of the spring and mass m is suspended from it, then the time period is given by

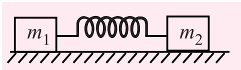
$$T = 2\pi\sqrt{\frac{m+(M/3)}{k}}$$

- If a spring of spring constant k is divided into N equal parts and one such part is attached to a mass m, then the time period is given by

$$T' = 2\pi\sqrt{\frac{m}{Nk}} = \frac{T}{\sqrt{N}}$$

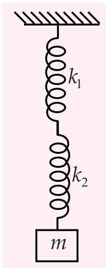
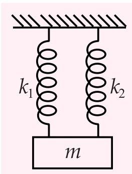
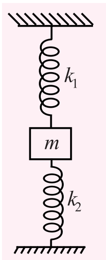
- If two masses m_1 and m_2 are connected by a spring of spring constant k, then the time period is given by

$$T = 2\pi\sqrt{\frac{\mu}{k}}$$



where μ = reduced mass = $\dfrac{m_1 m_2}{m_1 + m_2}$

- **Composite spring pendulum**

Series	Parallel	
 The effective spring constant is given by $k_s = \dfrac{k_1 k_2}{k_1 + k_2}$	 The effective spring constant is given by $k_p = k_1 + k_2$	 The effective spring constant is given by $k_p = k_1 + k_2$
$T = 2\pi\sqrt{\dfrac{m}{k_s}}$	$T = 2\pi\sqrt{\dfrac{m}{k_p}}$	$T = 2\pi\sqrt{\dfrac{m}{k_p}}$

- When a spring of length l and spring constant k, is cut into two pieces of lengths l_1 and l_2 of spring constants k_1 and k_2 such that $l_1 = nl_2$ (where n is an integer), then

$$k_1 = k\left(1+\frac{1}{n}\right) \text{ and } k_2 = (n+1)k$$

Simple Pendulum

- The time period of a simple pendulum is given by $T = 2\pi\sqrt{L/g}$.
  where L is the length of the pendulum and g is the acceleration due to gravity.
- Time period of a simple pendulum is independent of mass, shape and material of bob and it is also independent of the amplitude of oscillation provided it is small.
- The graph between T and L will be a parabola while between T^2 and L will be a straight line.
- If the length of a simple pendulum is comparable with the radius of earth (R_e), then time period T is given by

$$T = 2\pi\sqrt{\frac{1}{g\left(\frac{1}{L}+\frac{1}{R_e}\right)}}$$

where R_e is the radius of the earth.

  - If $L >> R_e$, then
  $$T = 2\pi\sqrt{\frac{R_e}{g}} \quad \text{or,} \quad T = 84.6 \text{ min}$$
  - If $L = R_e$, then $T = 2\pi\sqrt{\dfrac{R_e}{2g}} = 60$ min

- The simple pendulum having time period of 2 s is known as second pendulum.
- If a simple pendulum is suspended in a lift
  - Lift is accelerating downwards with an acceleration a, then
  $$T = 2\pi\sqrt{\frac{L}{g-a}}$$
  - Lift is accelerating upwards with an acceleration a, then
  $$T = 2\pi\sqrt{\frac{L}{g+a}}$$
  - Lift is moving upwards or downwards with constant velocity v, then
  $$T = 2\pi\sqrt{\frac{L}{g}}$$
  - Lift is freely falling with acceleration g, then
  $$T = 2\pi\sqrt{\frac{L}{g-g}} = \infty$$
- If a simple pendulum is suspended in a carriage which is accelerating horizontally with an acceleration a, then its time period is given by

$$T = 2\pi\sqrt{\frac{L}{(\sqrt{g^2+a^2})}}$$

- If a simple pendulum is suspended from the roof of a trolley which is moving down an inclined plane of inclination θ, then the time period is given by

$$T = 2\pi\sqrt{\frac{L}{g\cos\theta}}$$

- If a simple pendulum whose bob is of density ρ oscillates in a non-viscous liquid of density $\sigma(\sigma < \rho)$, then its time period is given by

$$T = 2\pi\sqrt{\frac{L}{\left(1-\frac{\sigma}{\rho}\right)g}}$$

- If the simple pendulum has charge q and is oscillating in a uniform electric field E, which is

Opposite to g	**In the direction of g**	**Perpendicular to g**
Electrostatic force qE is opposite to the force of gravity mg, then time period is given by $T = 2\pi\sqrt{\frac{L}{g-\frac{qE}{m}}}$	Electrostatic force qE is in the direction of force of gravity mg, then time period is given by $T = 2\pi\sqrt{\frac{L}{g+\frac{qE}{m}}}$	Electrostatic force qE is perpendicular to force of gravity mg, then time period is given by $T = 2\pi\sqrt{\frac{L}{\sqrt{g^2+\left(\frac{qE}{m}\right)^2}}}$

- **Conical pendulum :** The time period of a conical pendulum is given by

$$T = 2\pi\sqrt{\frac{L\cos\theta}{g}}$$

where L is the length of the string and θ is the angle which the string makes with the vertical.

- **Liquid in U-tube :** The time period of oscillation of a liquid in U-tube is given by

$$= 2\pi\sqrt{\frac{h}{g}}$$

where h = height of liquid column in each limb of U-tube

- **Floating cylinder in a liquid :** The time period of oscillation of floating cylinder in a liquid is given by

$$T = 2\pi\sqrt{\frac{m}{A\sigma g}}$$

where m is the mass of a cylinder, A is the area of cross section of a cylinder, σ is the density of a liquid

or $\quad T = 2\pi\sqrt{\frac{h\rho}{\sigma g}} = 2\pi\sqrt{\frac{h'}{g}}$

where h is the height of cylinder of density ρ and σ is the density of a liquid in which cylinder is floating, h' is the height of the cylinder inside the liquid.

- If a wire of length L, area of cross section A, Young's modulus Y is stretched by suspending a mass m, then the mass can oscillate with time period

$$T = 2\pi\sqrt{\frac{mL}{YA}}$$

- If a gas is enclosed in a cylinder of volume V fitted with piston of cross sectional area A and mass M and the piston is slightly depressed and released, the piston can oscillate with a time period

$$T = 2\pi\sqrt{\frac{MV}{BA^2}}$$

where B is the bulk modulus of elasticity of the gas.

Damped Oscillations

- When a simple harmonic system oscillates with a decreasing amplitude with time, its oscillations are known as damped oscillations.
- The energy of the system executing damped oscillations will go on decreasing with time.
- The differential equation of damped harmonic oscillator is given by

$$m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = 0$$

- The displacement of the damped oscillator at any instant t is given by

$$x(t) = Ae^{-bt/2m}\sin(\omega' t + \phi)$$

where ω' is the angular frequency of the damped oscillator is given by

$$\omega' = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}$$

  - If the damping constant b is small, then $\omega' \approx \omega$, where ω is the angular frequency of the undamped oscillator.

- The mechanical energy E of the damped oscillator at any instant t is given by

$$E(t) = \frac{1}{2}kA^2e^{-bt/m}$$

Forced Oscillations

- When a system oscillates with the help of an external periodic force, other than its own natural angular frequency, its oscillations are known as forced or driven oscillations.
- The differential equation of forced damped harmonic oscillator is given by

$$m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = F_0\sin\omega_d t$$

where ω_d is the angular frequency of the external force.

- The displacement of the forced damped harmonic oscillator at any instant t is given by

$x(t) = A \sin(\omega_d t - \phi)$

with amplitude $A = \dfrac{F_0}{\{m^2(\omega^2 - \omega_d^2)^2 + \omega_d^2 b^2\}^{1/2}}$

where ω is the natural frequency of the oscillator

and $\phi = \tan^{-1}\left[\dfrac{b\omega_d}{m(\omega^2 - \omega_d^2)}\right]$

- Condition for resonance is $\omega = \omega_d$.

Waves

- Wave is a disturbance which propagates energy and momentum from one place to the other place without the transport of matter.
- Waves moving along string are one dimensional, surface waves or ripples on water are two dimensional, while sound or light waves travelling out from a point source are three dimensional waves.
- **Types of waves:**
  - **Mechanical waves :** The waves which require material medium for their propagation are known as mechanical waves. Such waves can be seen or felt and include waves on a spring, water waves, waves on stretched strings, sound waves in air and in other materials.
  - **Non-mechanical waves :** The waves which do not essentially require any material medium for their propagation are known as non-mechanical waves. All electromagnetic waves such as γ-rays, X-rays, radio waves, light etc. are non-mechanical waves.
- Any wave whether mechanical or non-mechanical is of two type
  - **Transverse wave :** In transverse wave, the particle of the medium oscillates perpendicular to the direction in which the wave travels. Waves in strings are transverse waves.
  - **Longitudinal wave :** In longitudinal wave, the oscillation of the particle is parallel to the direction in which the wave travels. Disturbance travelling in a spring parallel to its length, a pressure variation propagating in a liquid, sound waves travelling in a medium are examples of longitudinal waves.
- All non-mechanical waves are transverse.
  - In solids mechanical waves can be either transverse or longitudinal depending on the mode of excitation.
- **Intensity of a wave :** It is defined as the amount of energy flow per unit area per unit time in a direction perpendicular to the propagation of wave.

  $I = 2\pi^2\upsilon^2A^2\rho v$

  where υ is the frequency, A is the amplitude, v is the velocity of the wave, ρ is the density of the medium.
- **Energy density :** It is defined as amount of energy flow per unit volume. It is denoted by symbol u and is given by

  $u = 2\pi^2A^2\upsilon^2\rho$

  where υ is the frequency, A is the amplitude and ρ is the density of the medium.

Plane Progressive Wave

- Equation of plane progressive wave travelling along the positive direction of x-axis is given by

  $y = A\sin(\omega t - kx + \phi)$

  where y = displacement of a particle at (x, t)

  A = amplitude of the wave

  ω = angular frequency = $2\pi\upsilon$ = $2\pi\dfrac{1}{T}$

  k = propagation constant or angular wave number $= \dfrac{2\pi}{\lambda}$

  ϕ = phase constant or initial phase of the wave.
- Phase of the wave is the argument $(\omega t - kx + \phi)$ of the oscillatory term $\sin(\omega t - kx + \phi)$.
- **Wave speed,** $v = \dfrac{\omega}{k}$

  It depends only on the nature of the medium in which the wave propagates.
- **Slope of the wave,** $\dfrac{dy}{dx} = -kA\cos(\omega t - kx + \phi)$
  - Particle speed,

    $v_{\text{particle}} = \dfrac{dy}{dt} = \omega A\cos(\omega t - kx + \phi) = -\left(\dfrac{\omega}{k}\right)\dfrac{dy}{dx}$

    or v_{particle} = −wave speed × slope of the wave
  - **Particle acceleration,** $a = \dfrac{d^2y}{dt^2} = -\omega^2 y$
- Equation of plane progressive wave travelling along negative direction of x-axis is given by

  $y = A\sin(\omega t + kx + \phi)$
- A plane progressive wave can be written in many forms such as
  - $y = A\sin(\omega t - kx)$
  - $y = A\sin 2\pi\left[\upsilon t - \dfrac{x}{\lambda}\right] = A\sin 2\pi\left[\dfrac{t}{T} - \dfrac{x}{\lambda}\right]$
  - $y = A\sin\dfrac{2\pi}{\lambda}(vt - x)$
  - $y = A\sin\dfrac{2\pi}{T}\left(t - \dfrac{x}{v}\right) = A\sin\omega\left(t - \dfrac{x}{v}\right)$

- The differential equation of one dimensional progressive wave is given by
$$\frac{\partial^2 y}{\partial t^2} = v^2 \frac{\partial^2 y}{\partial x^2}$$
- **Phase difference** ($\Delta\phi$) : $\Delta\phi$ between two particles which are separated by a path difference (Δx) is given by
$$\Delta\phi = \frac{2\pi}{\lambda}\Delta x$$
- $\Delta\phi$ of the same particle at two different times (time interval Δt) is $\Delta\phi = \frac{2\pi}{T}\Delta t$.

Sound Wave

- Sound wave is produced in a material medium by a vibrating body. Sound wave cannot propagate through vacuum.
- In solids, it can be transverse or longitudinal depending on the mode of excitation.
- **Velocity of sound :**
  - The velocity of sound in a medium of elasticity E and density ρ is given by,
  $$v = \sqrt{\frac{E}{\rho}}$$
  E is maximum for solids, than liquids and gases. Hence, v is maximum in solids, than in liquids and gases.
  - **Newton's formula:** Newton assumed that when sound propagates through air, temperature remains constant (*i.e.*, the process is isothermal). So, velocity of sound in gas is given by
  $$v = \sqrt{\frac{P}{\rho}}$$
  where P is the pressure of the gas and ρ is density of gas.
  At NTP,
  $$P = 1.0 \times 10^5 \text{ N m}^{-2} \text{ and } \rho = 1.3 \text{ kg m}^{-3}$$
  $$\Rightarrow \quad v_{air} = \sqrt{\frac{1.01\times10^5}{1.3}} = 279 \text{ m s}^{-1}$$
  The experimental value of v in air is 332 m s^{-1} at NTP.
  - **Laplace's correction:** Laplace assumed that the propagation of sound in air is an adiabatic process not the isothermal.
  Velocity of sound in a gas is given by
  $$v_{air} = \sqrt{\frac{\gamma P}{\rho}} \quad \text{where, } \gamma = \frac{C_P}{C_V} = 1.41$$
  $$v_{air} = \sqrt{\frac{1.0\times10^5\times1.41}{1.3}} = 331.3 \text{ m s}^{-1}$$
  Thus, sound waves propagate through gases adiabatically.
  - From kinetic theory of gases and thermodynamics
  $$v_{air} = \sqrt{\frac{\gamma RT}{M}} \qquad \left(\because \frac{P}{\rho} = \frac{RT}{M}\right)$$
  $$\because \quad v_{rms} = \sqrt{\frac{3RT}{M}}$$
  Hence, velocity of sound in a gas is of order of rms velocity of gas molecules.
- **Factors affecting the velocity of sound**
  - **Effect of temperature :** In a gas
  $$v \propto \sqrt{T}$$
  Thus, with increase in temperature velocity of sound also increases.
  At, $t = 0$ °C, $v_0 \propto \sqrt{273}$
  At, $t = t$ °C, $v_t \propto \sqrt{t + 273}$
  $$\frac{v_t}{v_0} = \sqrt{\frac{t+273}{273}} \text{ or } \frac{v_t}{v_0} = \left(1 + \frac{t}{273}\right)^{1/2}$$
  If $\frac{t}{273} << 1$
  $$\frac{v_t}{v_0} = \left(1 + \frac{t}{546}\right) \Rightarrow v_t = v_0\left(1 + \frac{t}{546}\right)$$
  - **Effect of pressure :** In a gas;
  $$v = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M}}$$
  Change in pressure has no effect on velocity of sound in a gas, as long as temperature remains constant; because, $\frac{P}{\rho}$ = constant.
  - **Effect of relative humidity:** When humidity increases, there is an increase in the relative number of water molecules and hence a decrease in the molar mass (avg. molecular weight), and the velocity of sound increases.
  - The velocity of sound in air is not affected by amplitude, frequency, phase, loudness, pitch, or quality.

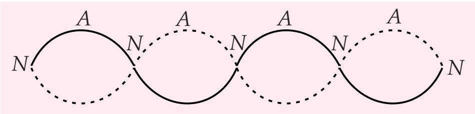
Reflection and Transmission of Waves

- When travelling waves are incident on a boundary separating two media, a part of it is reflected back into the same medium is called reflection of waves while the remaining is partly absorbed and partly transmitted into the other medium is called transmission of waves.

- **Characteristics**
  - In case of reflection and transmission of sound, the frequency of the wave remains unchanged.
  - The incident ray, the reflected ray, normal and the refracted ray always lie in the same plane.
  - In case of refraction of sound,
    Angle of incidence = Angle of reflection.
  - In case of refraction of sound
    $$\frac{\sin i}{\sin r}=\frac{v_i}{v_r}$$
  - In case of reflection from a denser medium or rigid support or fixed end there is inversion of the reflected displacement wave.
    i.e, if the incident wave is, $y = A_i \sin(\omega t - kx)$
    The reflected wave will be
    $$y = -A_r \sin(\omega t + kx) = A_r \sin(\omega t + kx + \pi)$$
    i.e., in case of reflection from a denser medium displacement wave changes in phase by π while in case of reflection from a rarer medium, no inversion of wave or phase change occurs. The transmitted wave is never inverted.
  - On reflection, the amplitude and intensity of wave may decrease.
  - When a transverse wave is reflected from a denser medium, the trough is reflected as crest and vice-versa.
  - When a transverse wave is reflected from a rarer medium, crest and trough do not invert after reflection.

Superposition of Waves

- If in any medium many sound waves propagate together then the existence of any sound wave will not be affected by the presence or absence of another, *i.e.*, these sound waves independently propagate in that medium.
- **Expression of superposition :** $\vec{y} = \vec{y}_1 + \vec{y}_2 + \vec{y}_3 ...$
  If superimposing waves give medium particles displacement along one line, the net displacement of medium particle is
  $$y = y_1 \pm y_2 \pm y_3 ...$$
- Three most important situations involving superposition are:
- **Interference:** In a region where wave trains from coherent sources cross, superposition occurs giving reinforcement of the waves at some points and cancellation at others. The resulting effect is called an interference pattern.
  - Coherent sources have a constant phase difference, which means they must have the same frequency, and for complete cancellation to occur the amplitudes of the superposing waves they produce must be about equal. In practice coherent sources are derived from a single source.
  - **Essential condition for interference**
    - Coherent waves
    - Identical frequency
    - Phase difference and path difference remain constant with respect to time.
  - **Condition for constructive interference**
    Phase difference = $2n\pi$, where n = 0, 1, 2, ...
    Path difference $= \frac{\lambda}{2\pi} \times$ phase difference $= n\lambda$,
    where n = 0, 1, 2,..
  - **Condition for destructive interference**
    Phase difference = $(2n + 1)\pi$, where n = 0, 1, 2, ...
    Path difference $= \frac{\lambda}{2\pi} \times$ phase difference
    $= \left(n+\frac{1}{2}\right)\lambda$, where n = 0, 1, 2 ....
  - The phenomenon of interference is based on conservation of energy.
- **Beats :** Beats are produced when two harmonic waves with equal amplitude but slightly different frequencies interfere.
  - The time between two consecutive minima or between two consecutive maxima is called period of beat T_{beat} and $\upsilon = \frac{1}{T_{beat}}$ is corresponding beat frequency.
  - **Important points related to beats :**
    - At frequency difference greater than about 6 or 7 Hz, we no longer hear individual beats. *e.g.*, if you listen to a whistle that produces sounds of 2000 Hz and 2100 Hz, you will hear not only these tones but also a much lower 100 Hz tone.
    - If the frequency of tuning fork is υ and it produces $\Delta\upsilon$ beats per second with a standard fork of frequency υ_0, then $\upsilon = \upsilon_0 \pm \Delta\upsilon$.
- **Standing waves :** When two waves of the same frequency and amplitude travel in opposite directions at the same speed their superposition gives rise to a new type of wave is called standing or stationary wave.



- In standing wave, the points for which the amplitude is zero are known as nodes whereas the points for which the amplitude is maximum are known as antinodes.
- Equation of a standing wave is given by
  $y = 2A\sin(kx)\cos\omega t$
- At antinodes, displacement and velocity is maximum but pressure is zero.
- At nodes, displacement and velocity is zero but pressure is maximum.
- Distance between two consecutive nodes or antinodes is $\frac{\lambda}{2}$. Distance between a node and adjoining antinode is $\frac{\lambda}{4}$.

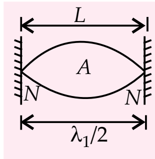
- **Difference between travelling and standing waves:**
  - In a travelling wave, the disturbance produced in a region propagates with a definite velocity but in a standing wave, it is confined to the region where it is produced.
  - In a travelling wave, the motion of all the particles are similar in nature. In a standing wave, different particles move with different amplitudes.
  - In a standing wave, the particles at nodes are always at rest. In travelling waves, there is no particle which always remains at rest.
  - In a standing wave, all the particles cross their mean positions simultaneously. In a travelling wave, there is no instant when all the particles are at the mean positions together.
  - In a standing wave, all the particles between two successive nodes reach their extreme positions together, thus moving in phase. In travelling wave, the phases of nearby particles are always different.
  - In a travelling wave, energy is transmitted from one region of space to other but in a standing wave, the energy of one region is always confined in that region.

Vibrations in a Stretched String

- Transverse stationary waves are formed on a stretched string fixed at both ends.
- Speed of waves in a stretched string is given by

  $v = \sqrt{\frac{T}{\mu}}$, where T is the tension of the string, μ is the mass per unit length of the string.

- Fundamental mode or first mode,
  $\lambda_1 = 2L$

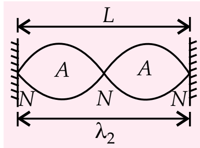


- Fundamental frequency

  $$\upsilon_1 = \frac{v}{\lambda_1} = \frac{v}{2L} = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$$

  This frequency is called first harmonic.
  - Second mode, $\lambda_2 = L$

    Frequency $\upsilon_2 = \frac{v}{\lambda_2} = \frac{v}{L} = 2\upsilon_1$



    This frequency is called second harmonic or first overtone.
  - For the n^{th} mode, $\lambda_n = \frac{2L}{n}$

    Frequency of n^{th} mode

    $$\upsilon_n = \frac{v}{\lambda_n} = \frac{nv}{2L} = n\upsilon_1 = \frac{n}{2L}\sqrt{\frac{T}{\mu}} \text{ where } n = 1, 2, 3, ...$$

    This frequency is called n^{th} harmonic or $(n-1)^{\text{th}}$ overtone.
- In general, $\upsilon_p = \frac{p}{2L}\sqrt{\frac{T}{\mu}} = p\upsilon_1$

  where p = number of loops.
- **Laws of vibrating stretched string :** The fundamental frequency of a stretched string is given by $\upsilon = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$.
  - Law of length, $\upsilon \propto \frac{1}{L}$

    when T and μ are constants.
  - Law of tension, $\upsilon \propto \sqrt{T}$

    when L and μ are constants
  - Law of mass, $\upsilon \propto \frac{1}{\sqrt{\mu}}$

    when L and T are constants.
- If ρ is the density of the material of the string and D is the diameter of string, then mass per unit length,

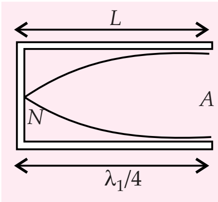
  $$\mu = \frac{\pi D^2 \rho}{4}$$

  $$\therefore \quad \upsilon = \frac{1}{2L}\sqrt{\frac{4T}{\pi D^2 \rho}} = \frac{1}{LD}\sqrt{\frac{T}{\pi\rho}}$$
- Laws of vibration of stretched string can be verified experimentally by using a sonometer.

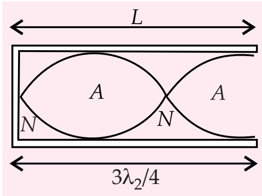
Vibrations in Air Column

- It is an example of standing longitudinal wave.
- **Closed pipe :** A long pipe (or tube) closed at one end is called closed pipe.

- Fundamental mode, or first mode $\lambda_1 = 4L$ where L is the length of the pipe.
  Fundamental frequency
  $$\upsilon_1 = \frac{v}{\lambda_1} = \frac{v}{4L}$$
  where v is the velocity of sound in air.
  This frequency is called first harmonic.

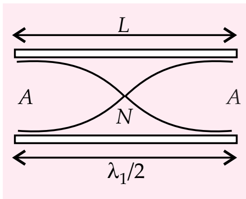


- Second mode, $\lambda_2 = \frac{4L}{3}$
  Frequency,
  $$\upsilon_2 = \frac{v}{\lambda_2} = \frac{3v}{4L} = 3\upsilon_1$$
  This frequency is called third harmonic or first overtone.

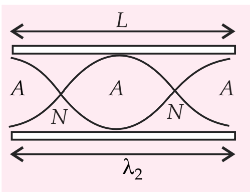


- For n^{th} mode, $\lambda_n = \frac{4L}{(2n-1)}$
  $$\text{Frequency, } \upsilon_n = \frac{v}{\lambda_n} = \frac{v(2n-1)}{4L} = (2n-1)\upsilon_1$$
  where $n = 1, 2, 3, ...$
  This frequency is called $(2n - 1)^{\text{th}}$ harmonic or $(n - 1)^{\text{th}}$ overtone.

- **Open pipe :** A pipe open at both ends is called an open pipe.
  - Fundamental mode or first mode, $\lambda_1 = 2L$ where L is the length of the pipe.
    Fundamental frequency
    $$\upsilon_1 = \frac{v}{\lambda_1} = \frac{v}{2L}$$
    where v is the velocity of sound in air.
    This frequency is called first harmonic or fundamental frequency.



  - Second mode, $\lambda_2 = L$
    Frequency,
    $$\upsilon_2 = \frac{v}{\lambda_2} = \frac{v}{L} = 2\upsilon_1$$
    This frequency is called second harmonic or first overtone.



  - For n^{th} mode, $\lambda_n = \frac{2L}{n}$
    $$\text{Frequency, } \upsilon_n = \frac{v}{\lambda_n} = \frac{nv}{2L} = n\upsilon_1, \text{ where } n = 1, 2, ...$$
    This frequency is called n^{th} harmonic or $(n - 1)^{\text{th}}$ overtone.

- **End correction :** The antinode at the open end of a pipe is not formed exactly at the open end but a little outside. This is called the end correction. This is denoted by e and its value is equal to $0.6r$ where r is the radius of the pipe. If L is the length of pipe then for closed pipe L is replaced by $L + e$ while for open pipe L is replaced by $L + 2e$.

Doppler Effect

- If there is motion of source and or observer relative to the medium (line of sight) the number of waves received per second is usually different from the emitted and frequency or pitch of the source appears to be different. This apparent change in frequency or pitch due to motion of source and observer relative to the medium along the line of sight is called Doppler effect.
- For the expressions for the apparent frequency of sound in different cases we make the following assumption.
  - The velocity of the source, the observer and medium are along the line joining the positions of the source and the observer.
  - The velocity of the source and the observer is less than the velocity of sound.
  - The velocity of sound is always positive
- **Special notation**
  υ = actual frequency, υ' = apparent frequency
  λ = actual wavelength, λ' = apparent wavelength
  v = velocity of sound, v_s = velocity of source
  v_0 = velocity of observer
- **Case I : Source in motion, observer at rest and medium at rest**
  - When source is moving towards stationary observer
    $$\upsilon' = \upsilon\left(\frac{v}{v - v_s}\right) \qquad \left(\because \lambda' = \frac{v - v_s}{\upsilon}\right)$$
  - When source moves away from stationary observer
    $$\upsilon' = \upsilon\left(\frac{v}{v + v_s}\right) \qquad \left(\because \lambda' = \frac{v + v_s}{\upsilon}\right)$$
- **Case II : Observer in motion, source at rest, medium at rest**
  - When observer moves towards stationary source
    $$\upsilon' = \upsilon\left(\frac{v + v_0}{v}\right)$$
  - When observer moves away from stationary source
    $$\upsilon' = \upsilon\left(\frac{v - v_0}{v}\right)$$

SPEED PRACTICE

1. If the displacement x and velocity v of a particle executing simple harmonic motion are related through the expression $4v^2 = 25 - x^2$, then its time period is
(a) π s (b) 2π s
(c) 4π s (d) 6π s.

2. A simple pendulum has time period T_1. When the point of suspension is moved upward according to the relation $y = kt^2 (k = 1 \text{ m s}^{-2})$, where y is the vertical displacement, the time period becomes T_2. The ratio of $\frac{T_1^2}{T_2^2}$ is (Take $g = 10 \text{ m s}^{-2}$)
(a) $\frac{6}{5}$ (b) $\frac{5}{6}$ (c) 1 (d) $\frac{4}{5}$.

3. A particle executing a simple harmonic motion has a period of 6 s. The time taken by the particle to move from the mean position to half the amplitude, starting from the mean position is
(a) $\frac{3}{2}$ s (b) $\frac{1}{2}$ s (c) $\frac{3}{4}$ s (d) $\frac{1}{4}$ s

4. A body performs simple harmonic motion with an amplitude A. At a distance $A/\sqrt{2}$ from the mean position, the correct relation between kinetic energy and potential energy is
(a) $\text{KE} = \frac{\text{PE}}{2}$ (b) $\text{KE} = \sqrt{2}\text{PE}$
(c) KE = PE (d) $\text{KE} = \frac{\text{PE}}{\sqrt{2}}$.

5. A string of mass 3 kg is under tension of 400 N. The length of the stretched string is 25 cm. If the transverse jerk is stuck at one end of the string how long does the disturbance take to reach the other end ?
(a) 0.043 s (b) 0.055 s (c) 0.034 s (d) 0.065 s

6. A mass m_1 connected to a horizontal spring performs simple harmonic motion with amplitude A. While mass m_1 is passing through mean position another mass m_2 is placed on it so that both the masses move together with amplitude A_1. The ratio of $\frac{A_1}{A}$ is $(m_2 < m_1)$
(a) $\left[\frac{m_1}{m_1+m_2}\right]^{\frac{1}{2}}$ (b) $\left[\frac{m_1+m_2}{m_1}\right]^{\frac{1}{2}}$
(c) $\left[\frac{m_2}{m_1+m_2}\right]^{\frac{1}{2}}$ (d) $\left[\frac{m_1+m_2}{m_2}\right]^{\frac{1}{2}}$.

7. An observer moves towards a stationary source of sound with a velocity one-fifth of the velocity of sound. The percentage change in the apparent frequency is
(a) zero (b) 5% (c) 10% (d) 20%.

8. The ratio of speed of sound in helium and hydrogen gases at the same temperature is
(a) $\sqrt{42} : \sqrt{25}$ (b) $\sqrt{25} : \sqrt{42}$
(c) 42 : 25 (d) 25 : 42.

9. The transverse displacement of a string fixed at both ends is given by $y = 0.06\sin\left(\frac{2\pi x}{3}\right)\cos(120\pi t)$ where y and x are in metres and t in seconds. The wavelength and frequency of the two superposing waves are
(a) 2 m, 120 Hz (b) $\frac{2}{3}$ m, 60 Hz
(c) $\frac{3}{2}$ m, 120 Hz (d) 3 m, 60 Hz.

10. A travelling acoustic wave of frequency 500 Hz is moving along the positive x-direction with a velocity of 300 m s^{-1}. The phase difference between two points x_1 and x_2 is 60°. Then the minimum separation between the two points is
(a) 1 mm (b) 1 cm (c) 10 cm (d) 1 m.

11. A uniform wire of length L, diameter D and density ρ is stretched under a tension T. The correct relation between its fundamental frequency υ, the length L and the diameter D is
(a) $\upsilon \propto \frac{1}{LD}$ (b) $\upsilon \propto \frac{1}{L\sqrt{D}}$
(c) $\upsilon \propto \frac{1}{D^2}$ (d) $\upsilon \propto \frac{1}{LD^2}$.

12. A sound absorber attenuates the sound level by 20 dB. The intensity decreases by a factor of
(a) 1000 (b) 10000 (c) 10 (d) 100.

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
(a) 150 cm (b) 200 cm (c) 66.7 cm (d) 100 cm.
[NEET Phase I 2016]

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

(a) $\sqrt{\dfrac{m_2}{m_1}}$ (b) $\sqrt{\dfrac{m_1+m_2}{m_1}}$

(c) $\sqrt{\dfrac{m_1}{m_2}}$ (d) $\sqrt{\dfrac{m_1+m_2}{m_2}}$.

[NEET Phase I 2016]

15. 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

(a) 10.5 Hz (b) 105 Hz (c) 155 Hz (d) 205 Hz.

[AIPMT 2015]

16. 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

(a) $\dfrac{\beta^2}{\alpha}$ (b) $\dfrac{2\pi\beta}{\alpha}$ (c) $\dfrac{\beta^2}{\alpha^2}$ (d) $\dfrac{\alpha}{\beta}$.

[AIPMT 2015]

17. A uniform string of length 20 m is suspended from a rigid support. A short wave pulse is introduced at its lowest end. It starts moving up the string. The time taken to reach the support is (Take $g = 10$ m s^{-2})

(a) $2\pi\sqrt{2}$ s (b) 2 s (c) $2\sqrt{2}$ s (d) $\sqrt{2}$ s.

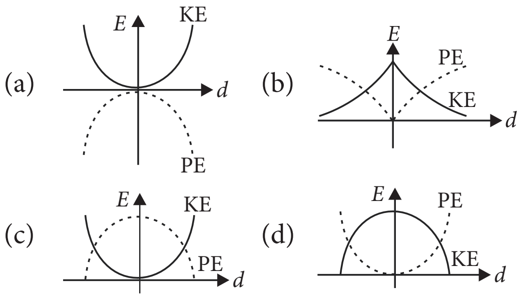
[JEE Main Offline 2016]

18. Two particles are performing simple harmonic motion in a straight line about the same equilibrium point. The amplitude and time period for both particles are same and equal to A and T respectively. At time $t = 0$ one particle has displacement A while the other one has displacement $-\dfrac{A}{2}$ and they are moving towards each other. If they cross each other at time t, then t is

(a) $\dfrac{5T}{6}$ (b) $\dfrac{T}{3}$ (c) $\dfrac{T}{4}$ (d) $\dfrac{T}{6}$.

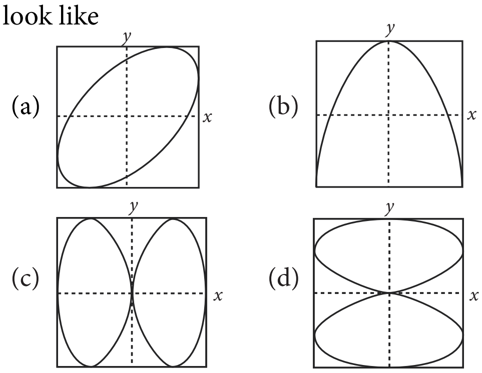
[JEE Main Online 2016]

19. For a simple pendulum, a graph is plotted between its kinetic energy (KE) and potential energy (PE) against its displacement d. Which one of the following represents these correctly ?
(Graphs are schematic and not drawn to scale)



[JEE Main Offline 2015]

20. x and y displacements of a particle are given as $x(t) = a \sin \omega t$ and $y(t) = a \sin 2\omega t$. Its trajectory will look like



[JEE Main Online 2015]

SOLUTIONS

1. **(c) :** Since, $4v^2 = 25 - x^2$

Differentiating both sides w.r.t. to t, we get

$$4\left(2v\frac{dv}{dt}\right) = -2x\frac{dx}{dt}$$

or $4\dfrac{dv}{dt} = -x$ or $4a = -x$ or $a = -\dfrac{1}{4}x$ ... (i)

For SHM, $a = -\omega^2 x$ ... (ii)

Comparing eqns. (i) and (ii), we get

$$\omega^2 = \frac{1}{4} \quad \text{or} \quad \omega = \frac{1}{2}$$

$\therefore$ Time period, $T = \dfrac{2\pi}{\omega} = \dfrac{2\pi}{1/2} = 4\pi$ s

2. **(a) :** Given, $y = kt^2$,

$\therefore \dfrac{dy}{dt} = 2kt$ and $\dfrac{d^2y}{dt^2} = 2k = 2\times 1 = 2$ m s^{-2}

So point of suspension of pendulum is moving upwards with acceleration, $a = 2$ m s^{-2}.

Then effective acceleration due to gravity on pendulum, $g' = (g + a) = 10 + 2 = 12$ m s^{-2}

$$T_1 = 2\pi\sqrt{\frac{l}{g}} \text{ and } T_2 = 2\pi\sqrt{\frac{l}{g'}}$$

$$\therefore \frac{T_1^2}{T_2^2} = \frac{g'}{g} = \frac{12}{10} = \frac{6}{5}$$

3. (b): Since the motion is started from the mean position, therefore displacement x of a particle executing SHM at any time t from its mean position is given by $x = A \sin \omega t$

At $x = \frac{A}{2}$,

$$\frac{A}{2} = A\sin\omega t \text{ or } \sin\left(\frac{\pi}{6}\right) = \sin\omega t \text{ or } \frac{\pi}{6} = \omega t$$

$$\text{or } t = \frac{\pi}{6\omega} = \frac{\pi}{6\left(\frac{2\pi}{T}\right)} \quad \left(\because \omega = \frac{2\pi}{T}\right)$$

$$= \frac{T}{12} = \frac{6}{12} = \frac{1}{2}\text{ s} \quad (\because T = 6\text{ s (Given)})$$

4. (c) : For SHM,

kinetic energy, KE = $\frac{1}{2}m\omega^2(A^2 - x^2)$

potential energy, PE = $\frac{1}{2}m\omega^2 x^2$

At $x = \frac{A}{\sqrt{2}}$,

$$KE = \frac{1}{2}m\omega^2\left(A^2 - \left(\frac{A}{\sqrt{2}}\right)^2\right) = \frac{1}{2}m\omega^2\frac{A^2}{2} = \frac{1}{4}m\omega^2A^2$$

$$PE = \frac{1}{2}m\omega^2\left(\frac{A}{\sqrt{2}}\right)^2 = \frac{1}{2}m\omega^2\frac{A^2}{2} = \frac{1}{4}m\omega^2A^2$$

$\therefore$ KE = PE

5. (a) : Here,
mass of the string, m = 3 kg
length of the string, L = 25 cm= 25×10^{-2}m
tension in the string, T = 400 N
Mass per unit length of the string,

$$\mu = \frac{m}{L} = \frac{3}{25\times10^{-2}} = 12 \text{ kg m}^{-1}$$

Speed of the wave on the string,

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{400}{12}} = 5.77 \text{ m s}^{-1}$$

Time taken by disturbance to reach the other end,

$$t = \frac{L}{v} = \frac{25\times10^{-2}}{5.77} = 0.043 \text{ s}$$

6. (a) : Applying principle of momentum conservation, at the mean position,

$$p_i = p_f$$
$$m_1 v = (m_1 + m_2)v_1$$
$$\frac{v}{v_1} = \frac{m_1+m_2}{m_1} \quad \text{...(i)}$$

Also, $\frac{v}{v_1} = \frac{\omega A}{\omega_1 A_1}$

$$\therefore \frac{A_1}{A} = \frac{\omega}{\omega_1}\times\frac{v_1}{v} \quad \text{...(ii)}$$

and $$\frac{\omega}{\omega_1} = \sqrt{\frac{k}{m_1}}\Big/\sqrt{\frac{k}{m_1+m_2}} = \sqrt{\frac{m_1+m_2}{m_1}} \quad \text{...(iii)}$$

From eqns. (i), (ii) and (iii)

$$\frac{A_1}{A} = \sqrt{\frac{m_1+m_2}{m_1}}\times\frac{m_1}{m_1+m_2} = \sqrt{\frac{m_1}{m_1+m_2}}$$

7. (d): When an observer moves towards a stationary source, the apparent frequency heard by the observer is

$$\upsilon' = \upsilon_0\left(\frac{v+v_0}{v}\right)$$

where, υ_0 = frequency of the source, v_o = velocity of the observer, v = velocity of the sound

$$\therefore \upsilon' = \upsilon_0\left(\frac{v+\frac{v}{5}}{v}\right) = \frac{6\upsilon_0}{5}$$

Percentage change in apparent frequency

$$= \frac{\upsilon'-\upsilon_0}{\upsilon_0}\times100$$

$$= \frac{\left(\frac{6\upsilon_0}{5}-\upsilon_0\right)}{\upsilon_0}\times100 = \frac{1}{5}\times100 = 20\%$$

8. (b): Speed of sound in gas is, $v = \sqrt{\frac{\gamma RT}{M}}$

For the same temperature, $v \propto \sqrt{\frac{\gamma}{M}}$

$$\therefore \frac{v_{He}}{v_{H_2}} = \sqrt{\frac{\gamma_{He}}{\gamma_{H_2}}\times\frac{M_{H_2}}{M_{He}}} = \sqrt{\frac{5}{3}\times\frac{5}{7}\times\frac{2}{4}} = \sqrt{\frac{25}{42}}$$

9. (d): The stationary wave is given as

$$y = 0.06\sin\left(\frac{2\pi x}{3}\right)\cos(120\pi t)$$

Compare this with standard form of stationary wave equation,

$$y = 2A\sin kx\cos\omega t$$

Here, $k = \frac{2\pi}{\lambda} = \frac{2\pi}{3}$ and $\omega = 120\pi$

$$\therefore \lambda = 3\text{ m and } \upsilon = \frac{120\pi}{2\pi} = 60\text{ Hz}$$

10. (c) **11. (a)**

12. (d): Let the intensity of sound be I_1 and I_2.
Given, $L_1 - L_2$ = 20 dB
Loudness of sound initially

$$L_1 = 10\log\left(\frac{I_1}{I_0}\right)$$

where I_0 is threshold intensity of sound.

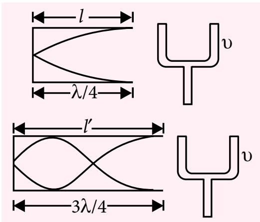
$$\text{Later, } L_2 = 10\log\left(\frac{I_2}{I_0}\right)$$

$\therefore \quad L_1 - L_2 = 10\log\left(\frac{I_1}{I_0}\right) - 10\log\left(\frac{I_2}{I_0}\right)$

or $\quad 20 = 10\log\left(\frac{I_1}{I_2}\right)$ or $10^2 = \left(\frac{I_1}{I_2}\right)$

or $\quad I_2 = \frac{I_1}{100}$

13. (a) : From figure,



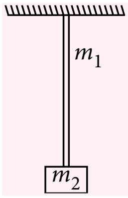
First harmonic is obtained at

$l = \frac{\lambda}{4} = 50$ cm

Third harmonic is obtained for resonance,

$l' = \frac{3\lambda}{4} = 150$ cm

14. (d) : Wavelength of pulse at the lower



end $\lambda_1 \propto$ velocity $v_1 = \sqrt{\frac{T_1}{\mu}}$

Similarly, $\lambda_2 \propto v_2 = \sqrt{\frac{T_2}{\mu}}$

$$\therefore \quad \frac{\lambda_2}{\lambda_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{(m_1+m_2)g}{m_2 g}} = \sqrt{\frac{m_1+m_2}{m_2}}$$

15. (b) : For a string fixed at both ends, the resonant frequencies are

$\upsilon_n = \frac{nv}{2L}$ where $n = 1, 2, 3, \ldots..$

The difference between two consecutive resonant frequencies is

$$\Delta\upsilon_n = \upsilon_{n+1} - \upsilon_n = \frac{(n+1)v}{2L} - \frac{nv}{2L} = \frac{v}{2L}$$

which is also the lowest resonant frequency ($n = 1$).

Thus the lowest resonant frequency for the given string = 420 Hz –315 Hz = 105 Hz

16. (b) : If A and ω be amplitude and angular frequency of vibration, then

$\alpha = \omega^2 A$ ...(i)

and $\beta = \omega A$ ...(ii)

Dividing eqn. (i) by eqn. (ii), we get

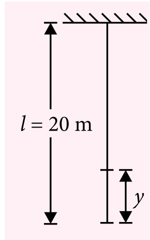
$$\frac{\alpha}{\beta} = \frac{\omega^2 A}{\omega A} = \omega$$

$\therefore$ Time period of vibration is

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{(\alpha/\beta)} = \frac{2\pi\beta}{\alpha}$$

17. (c) : Speed of the wave pulse (wave) in the string,

$$v = \sqrt{\frac{T}{\mu}}$$



Here, $T = \frac{m}{l} \times y \times g$ and $\mu = \frac{m}{l}$

$$\therefore \quad v = \sqrt{\frac{\frac{m}{l}\times y \times g}{m/l}} = \sqrt{gy}$$

Also, $v = \frac{dy}{dt} = \sqrt{gy}$ or $\int_0^{20}\frac{dy}{\sqrt{y}} = \int_0^t \sqrt{g}\,dt$

or $\left[\frac{y^{1/2}}{1/2}\right]_0^{20} = \sqrt{g}\,[t]_0^t \quad \therefore \quad t = 2\sqrt{2}$ s

18. (d) : Angular displacement (θ_1) of first particle from equilibrium point is given by $y_1 = A\sin\theta_1$

$\therefore \quad A = A\sin\theta_1$ or $\sin\theta_1 = 1$ or $\theta_1 = \frac{\pi}{2}$

Similarly, for second particle, $\theta_2 = \frac{-\pi}{6}$

Relative angular displacement between the two particles, $\theta = \theta_1 - \theta_2 = \frac{\pi}{2} - \left(\frac{-\pi}{6}\right) = \frac{2\pi}{3}$

Relative angular velocity between the two particles

$\omega' = \omega_1 - \omega_2 = \omega - (-\omega) = 2\omega$

$$\therefore \quad t = \frac{\theta}{\omega'} \quad \Rightarrow t = \frac{2\pi}{3\times 2\omega} = \frac{2\pi}{3\times 2\times\frac{2\pi}{T}} = \frac{T}{6}$$

19. (d) : For a simple pendulum, variation of kinetic energy and potential energy with displacement d is,

$\text{KE} = \frac{1}{2}m\omega^2(A^2 - d^2)$ and $\text{PE} = \frac{1}{2}m\omega^2 d^2$

where A is amplitude of oscillation.

When $d = 0$, $\text{KE} = \frac{1}{2}m\omega^2 A^2$, $\text{PE} = 0$

When $d = \pm A$, KE = 0, $\text{PE} = \frac{1}{2}m\omega^2 A^2$

Therefore, graph (d) represents the variation correctly.

20. (c) : Here, $x = a\sin\omega t$ and $y = a\sin 2\omega t$

$\therefore \quad y = 2a\sin\omega t\cos\omega t$

$$y = 2x\sqrt{1-\frac{x^2}{a^2}} = \frac{2}{a}x\sqrt{(a-x)(a+x)}$$

$y = 0$ at $x = 0, \pm a$

◈◈

MPP-8 CLASS XII ANSWER KEY

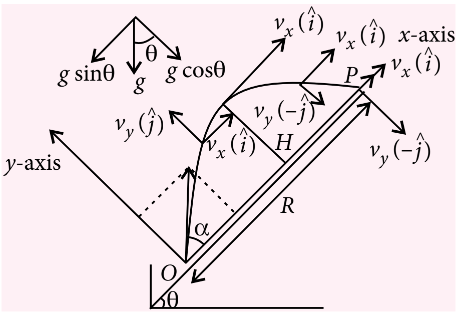
1.	(c)	2.	(b)	3.	(b)	4.	(a)	5.	(d)
6.	(d)	7.	(d)	8.	(c)	9 .	(a)	10.	(a)
11.	(c)	12.	(a)	13.	(a)	14.	(a)	15.	(c)
16.	(c)	17.	(a)	18.	(c)	19.	(d)	20.	(a, c)
21.	(b, c)	22.	(a, b, c)	23.	(a, b, d)	24.	(6)	25.	(5)
26.	(9)	27.	(a)	28.	(b)	29 .	(d)	30.	(c)

KEY CONCEPT on PROJECTILE MOTION ON INCLINED PLANE

Er. Sandip Prasad

Analysis of Motion of a Projectile Projected up the Plane

Let a particle be projected up with a speed v_0 at an angle α to the horizontal onto an inclined plane of inclination θ. Hence the component of initial velocity (velocity of projection) parallel and perpendicular to the plane are equal to $v_0 \cos\alpha$ and $v_0 \sin\alpha$ respectively. The component of g along the plane is $g \sin\theta$ and perpendicular to the plane is $g \cos\theta$ as shown in the figure.



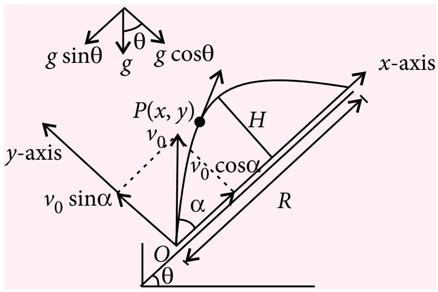
Let the particle hits at P after a time T from the instant of projection. During this time the particle moves up from O to P along the incline with a deceleration $g \sin\theta$ and moves up and down perpendicular to the incline. Considering the motion along y-axis, the displacement y of the particle during time t (= T) perpendicular to the plane is zero.

The horizontal component of velocity *i.e.* v_x will never be zero. If v_x would have been zero, the particle would never be able to complete its path. Although the vertical component of velocity v_y gradually decreases in magnitude during its upward motion and at the maximum height H, of the trajectory, v_y will attain a minimum value of zero and then its magnitude gradually increases in its downward of motion, such that just before striking the ground its magnitude again becomes equal to the initial vertical component of the projected velocity but in a direction opposite to it.

We study this two dimensional motion as a combination of two 1-D motions, since both horizontal and vertical motion are independent of each other. Thus we can analyse the motion along the individual axes.

Motion along x-axis	**Motion along y-axis**
$u_x = v_0 \cos\alpha$	$u_y = v_0 \sin\alpha$
$a_x = -g \sin\theta$	$a_y = -g \cos\theta$

- **Position :** Let the particle acquire a position P having the coordinates (x, y) just after time t from the instant of projection.



Motion along x-axis in the interval O-P :

Since there is an external force $m\,g \sin\theta$ acts upon the particle along x-axis, its horizontal acceleration will never be zero, that means, the particle moves with constant acceleration of magnitude $g \sin\theta$ along x-axis.

Hence the horizontal distance covered during time t is given as

$$s_x = u_x t + \frac{1}{2} a_x t^2$$

or $$x = v_0 \cos\alpha\, t - \frac{1}{2} g \sin\theta\, t^2$$

Motion along y-axis in the interval O-P :

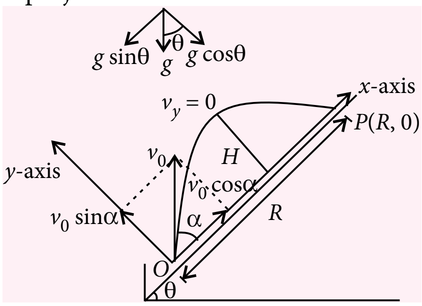
If we consider the motion of the particle along y-axis, the external force acting is gravitational force $m\,g \cos\theta$. Consequently the particle accelerates downwards (towards the centre of earth with an acceleration of magnitude $g \cos\theta$. In the other words we can say that the particle decelerates upward with $g \cos\theta$.

Hence the vertical distance covered during time t is given as

$$s_y = u_y t + \frac{1}{2} a_y t^2$$

or $\quad y = v_0 \sin\alpha \cdot t - \frac{1}{2} g \cos\theta \, t^2$

- **Time of flight (T):** It is the total time for which the projectile remains in its flight (from O-P). Let T be its time of flight. Consider the situation shown in figure. The particle is projected from the point O and reaches at point P (R, 0). The total time taken to reach at P is called time of flight (T) of the projectile.



For the motion along y-axis in the interval O-P

Here, the net displacement of the particle along y-axis covered during time of flight is zero.

i.e. $s_y = 0$

As $s_y = u_y t + \frac{1}{2} a_y t^2$

$$\therefore \quad 0 = t\left[v_0 \sin\alpha - \frac{1}{2} g \cos\theta t\right]$$

Either, $t = 0$

or, $\quad v_0 \sin\alpha - \frac{1}{2} g \cos\theta t = 0$

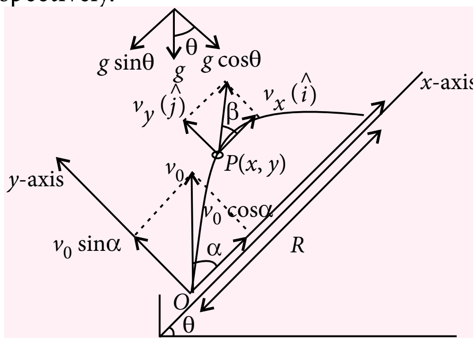
$$\therefore \quad t = \frac{2 v_0 \sin\alpha}{g \cos\theta} = T$$

The first value represents the initial time of projection. Hence, second expression gives us the time of flight as required.

In the generic form, we can express the formula of the time of flight as :

$$T = \frac{2 u_y}{|a_y|}$$

- **Velocity of the projectile at any instant :** At the instant t,(when the body is at point P), let the velocity of the projectile be V. The velocity has two rectangular components, one is along x-axis and other is along y-axis. Let v_x and v_y be the components of velocity along x-axis and y-axis respectively.



Motion along x-axis in the interval O-P

$u_x = v_0 \cos\alpha$, $a_x = -g \sin\theta$

$\therefore \quad v_x = u_x + a_x t$

$v_x = v_0 \cos\alpha - g \sin\theta \, t$

Motion along y-axis in the interval O-P

$u_y = v_0 \sin\alpha$, $a_y = -g \cos\theta$

As, $v_y = u_y + a_y t$

$\therefore \quad v_y = v_0 \sin\alpha - g \cos\theta \, t$

$\therefore \quad$ The resultant velocity at point P is

$$\vec{v} = v_x(\hat{i}) + v_y(\hat{j})$$

Hence, magnitude of the resultant velocity is,

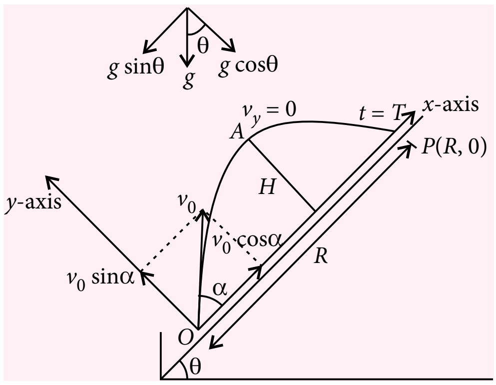
$$|\vec{v}| = \sqrt{v_x^2 + v_y^2}$$

If the velocity vector makes an angle β with the x-axis, then

$$\therefore \quad \tan\beta = \frac{v_y}{v_x}$$

- **Maximum height (H) :** It is the maximum displacement attained by the projectile along y-axis. It is denoted by H.

When the projectile is at the highest point, then $v_y = 0$ and vertical displacement, $y = H$. Thus putting these condition in following equation.



For the motion along y-axis in the interval O-A

$u_y = v_0 \sin\alpha$

$a_y = -g\cos\theta$

At the highest point A, the component of velocity along y-axis is zero.

i.e. $v_y = 0$

As, $v_y^2 = u_y^2 + 2a_y s$

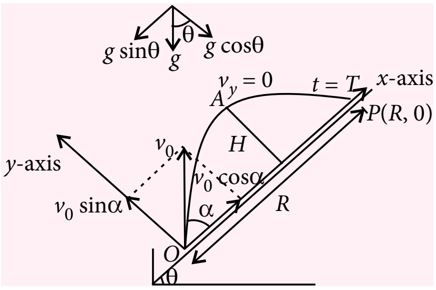
$\therefore \quad (0)^2 = (v_0 \sin\alpha)^2 + 2(-g\cos\theta)H$

$$\therefore \quad H = \frac{v_0^2 \sin^2\alpha}{2g\cos\theta}$$

In the generic form, we can express the formula of the maximum height as :

$$H = \frac{u_y^2}{2|a_y|}$$

- **Range (R) :** Displacement covered by the projectile along x-axis during its time of flight is called range. It is equal to $OP = R$.
  When $y = 0$, then $x = R$



For the motion along x-axis in the interval O-P

$$u_x = v_0\cos\alpha,\ a_x = -g\sin\theta,\quad t = T = \frac{2v_0\sin\alpha}{g\cos\theta}$$

Applying kinematics equations along the x-axis:

$$\text{As,}\quad s_x = u_x t + \frac{1}{2}a_x t^2$$

$$\therefore \quad R = v_0\cos\alpha T - \frac{1}{2}g\sin\theta T^2$$

$$\text{or}\quad R = T\left(v_0\cos\alpha - \frac{1}{2}g\sin\theta T\right)$$

$$R = \frac{2v_0\sin\alpha}{g\cos\theta}\left[v_0\cos\alpha - \frac{1}{2}g\sin\theta\frac{2v_0\sin\alpha}{g\cos\theta}\right]$$

$$R = \frac{2v_0^2\sin\alpha}{g\cos\theta}\left[\cos\alpha - \frac{\sin\theta\sin\alpha}{\cos\theta}\right]$$

$$= \frac{2v_0^2\sin\alpha}{g\cos\theta}\left[\frac{\cos\alpha\cos\theta - \sin\theta\sin\alpha}{\cos\theta}\right]$$

$$\therefore \quad R = \frac{2v_0^2\sin\alpha\cos(\alpha+\theta)}{g\cos^2\theta}$$

Condition for the maximum range(R_{max})

The range is given by

$$R = \frac{2v_0^2\sin\alpha\cos(\alpha+\theta)}{g\cos^2\theta}$$

For maximum value of R,

$$\textit{i.e.}\ \text{for}\ R_{max},\ \frac{dR}{d\alpha} = 0$$

$$\text{or}\quad \frac{d}{d\alpha}\left[\frac{2v_0^2\sin\alpha\cos(\alpha+\theta)}{g\cos^2\theta}\right] = 0$$

$$\text{or}\quad \frac{2v_0^2}{g\cos^2\theta}\frac{d}{d\alpha}[\sin\alpha\cos(\alpha+\theta)] = 0$$

$$\text{Since,}\quad \frac{2v_0^2}{g\cos^2\theta} \neq 0$$

$$\therefore \quad \frac{d}{d\alpha}[\sin\alpha\cdot\cos(\alpha+\theta)] = 0$$

or, $\cos(\alpha + \theta)\cos\alpha - \sin\alpha\sin(\alpha + \theta) = 0$

or, $\cos(\alpha + \theta + \alpha) = 0$

$$\text{or}\quad 2\alpha + \theta = \frac{\pi}{2}\quad \text{or}\quad 2\alpha = \frac{\pi}{2} - \theta$$

$$\therefore \quad \alpha = \frac{\pi}{4} - \frac{\theta}{2}$$

Hence, the range of the projectile is maximum when it is projected at an angle of $\alpha = \frac{\pi}{4} - \frac{\theta}{2}$ with the inclined plane.

The maximum value of the range is given by,

$$\therefore \quad R_{max} = \frac{2v_0^2\sin\left(\frac{\pi}{4} - \frac{\theta}{2}\right)\cos\left(\frac{\pi}{4} - \frac{\theta}{2} + \theta\right)}{g\cos^2\theta}$$

$$= \frac{v_0^2\left[2\sin\left(\frac{\pi}{4} - \frac{\theta}{2}\right)\cos\left(\frac{\pi}{4} + \frac{\theta}{2}\right)\right]}{g\cos^2\theta}$$

$$= \frac{v_0^2\left[\sin\left(\frac{\pi}{4} - \frac{\theta}{2} + \frac{\pi}{4} + \frac{\theta}{2}\right) + \sin\left(\frac{\pi}{4} - \frac{\theta}{2} - \frac{\pi}{4} - \frac{\theta}{2}\right)\right]}{g\cos^2\theta}$$

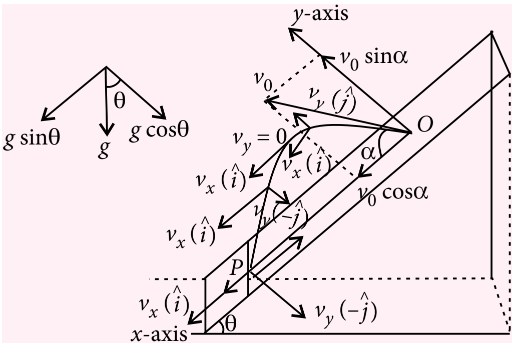
$$= \frac{v_0^2\left(\sin\frac{\pi}{2} + \sin(-\theta)\right)}{g\cos^2\theta} = \frac{v_0^2\left(\sin\frac{\pi}{2} - \sin\theta\right)}{g\cos^2\theta}$$

$$= \frac{v_0^2(1-\sin\theta)}{g(1-\sin^2\theta)} = \frac{v_0^2(1-\sin\theta)}{g(1-\sin\theta)(1+\sin\theta)}$$

$$\therefore \quad R_{max} = \frac{v_0^2}{g(1+\sin\theta)}$$

Analysis of Motion of a Projectile Projected down the Plane

Let a particle be projected down with a speed v_0 at an angle α to the horizontal onto an inclined plane of inclination θ. Hence the component of initial velocity (velocity of projection) parallel and perpendicular to the plane are equal to $v_0 \cos\alpha$ and $v_0 \sin\alpha$ respectively. The component of g along the plane is $g\sin\theta$ and perpendicular to the plane is $g\cos\theta$ as shown in the figure.



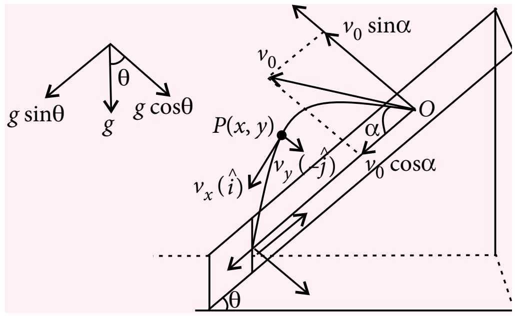
Let the particle hits at P after a time T from the instant of projection. During this time the particle moves down from O to P along the incline with an acceleration $g \sin\theta$ and moves down from O to P perpendicular to the incline with an acceleration $g \cos\theta$. Considering the motion along y-axis, the displacement y of the particle during time t (= T) perpendicular to the plane is zero.

The horizontal component of velocity *i.e.* v_x gradually increases in magnitude during its downward motion and becomes maximum at point P. Although the vertical component of velocity v_y gradually decreases in magnitude during its downward motion and at the maximum height H, of the trajectory, v_y will attain a minimum value of zero and then its magnitude gradually increases in its downward of motion, such that just before striking the plane its magnitude again becomes equal to the initial vertical component of the projected velocity but in a direction opposite to it.

We study this two dimensional motion as a combination of two 1-D motions, since both horizontal and vertical motion are independent of each other. Thus we can analyse the motion along the individual axis.

Motion along x-axis	**Motion along y-axis**
$u_x = v_0 \cos\alpha$	$u_y = v_0 \sin\alpha$
$a_x = g \sin\theta$	$a_y = -g \cos\theta$

- **Position :** After time t, suppose the body reaches the point $P(x, y)$ from the point of projection.



Motion along x-axis in the interval O-P

Since there is an external force $m\,g \sin\theta$ acts upon the particle along x-axis, its horizontal acceleration will never be zero, that means, the particle moves with constant acceleration of magnitude $g\sin\theta$ along x-axis.

The distance covered by the body along positive x-axis in time t is,

$$s_x = u_x t + \frac{1}{2}a_x t^2$$

$$\text{or} \quad x = v_0 \cos\alpha\, t + \frac{1}{2} g \sin\theta\, t^2$$

Motion along y-axis in the interval O-P

If we consider the motion of the particle along y-axis, the external force acting is gravitational force $m\,g\cos\theta$. Consequently the particle accelerates downwards (towards the centre of earth) with an acceleration of magnitude $g\cos\theta$. In the other words we can say that the particle decelerates upward with $g\cos\theta$.

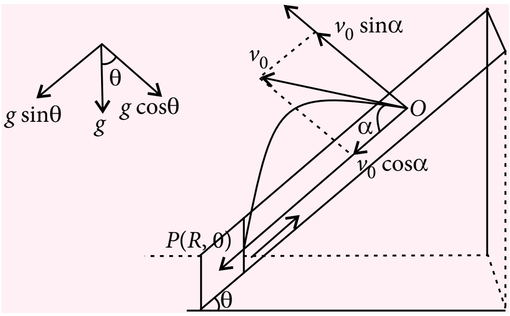
The distance covered by the body along positive y-axis in time t is,

$$s_y = u_y t + \frac{1}{2}a_y t^2$$

$$\text{or,} \quad y = v_0 \sin\alpha\, t - \frac{1}{2} g \cos\theta\, t^2$$

- **Time of flight (T) :** It is the total time for which the projectile remains in its flight(from O-P). Let T

be its time of flight. Consider the situation shown in figure. The particle is projected from the point O and reaches at point P $(R, 0)$. The total time taken to reach at P is called time of flight (T) of the projectile.



For the motion along y-axis in the interval O-P

Here, the net displacement of the particle along y-axis covered during time of flight is zero.

i.e. $s_y = 0$

As $s_y = u_y t + \frac{1}{2} a_y t^2$

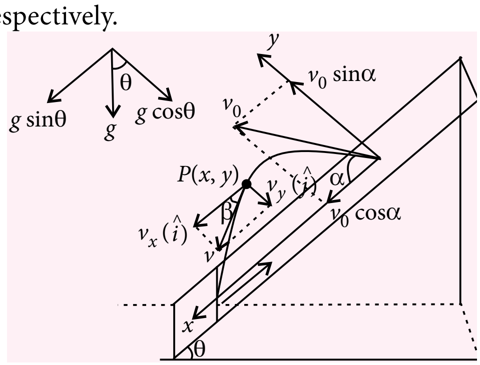
$\therefore \quad 0 = t\left(v_0 \sin\alpha - \frac{1}{2} g\cos\theta\, t\right)$

Either, $t = 0$; it is not possible.

or, $v_0 \sin\alpha - \frac{1}{2} g\cos\theta\, t = 0$

$\therefore \quad t = \dfrac{2v_0 \sin\alpha}{g\cos\theta} = T$

- **Velocity of the projectile at any instant:** At the instant t, (when the body is at point P), let the velocity of the projectile be v. The velocity has two rectangular components, one is along x-axis and other is along y-axis. Let v_x and v_y be the components of velocity along x-axis and y-axis respectively.



For the motion along x-axis in the interval O-P

As, $v_x = u_x + a_x t$

$\therefore \quad v_x = v_0 \cos\alpha + g\sin\theta\, t$

For the motion along y-axis in the interval O-P

As, $v_y = u_y + a_y t$

$\therefore \quad v_y = v_0 \sin\alpha - g\cos\theta\, t$

$\therefore$ The resultant velocity at point P is

$\vec{v} = v_x(\hat{i}) + v_y(\hat{j})$

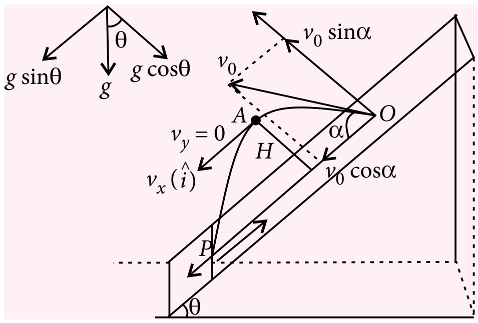
Hence, magnitude of the resultant velocity is,

$|\vec{v}| = \sqrt{v_x^2 + v_y^2}$

If the velocity vector makes an angle β with the x-axis, then

$\therefore \quad \tan\beta = \dfrac{v_y}{v_x}$

- **Maximum height (H):** It is the maximum displacement attained by the projectile along y-axis. It is denoted by H.
When the projectile is at the highest point, then $v_y = 0$ and vertical displacement, $y = H$. Thus putting these condition in following equation.



For the motion along y-axis in the interval O-A

$u_y = v_0 \sin\alpha$

$a_y = -g\cos\theta$

At the highest point A, the component of velocity along y-axis is zero.

i.e. $v_y = 0$

As, $v_y^2 = u_y^2 + 2a_y s$

$\therefore \quad (0)^2 = (v_0 \sin\alpha)^2 + 2(-g\cos\theta)H$

$\therefore \quad H = \dfrac{v_0^2 \sin^2\alpha}{2g\cos\theta}$

◈◈

MPP-8 CLASS XI ANSWER KEY

1.	(d)	**2.**	(b)	**3.**	(a)	**4.**	(b)	**5.**	(b)
6.	(d)	**7.**	(a)	**8.**	(c)	**9.**	(c)	**10.**	(a)
11.	(d)	**12.**	(d)	**13.**	(b)	**14.**	(b)	**15.**	(c)
16.	(a)	**17.**	(c)	**18.**	(d)	**19.**	(b)	**20.**	(a, c)
21.	(a, d)	**22.**	(a, c)	**23.**	(a,c,d)	**24.**	(6)	**25.**	(6)
26.	(1)	**27.**	(b)	**28.**	(a)	**29.**	(d)	**30.**	(c)

CROSSWORD

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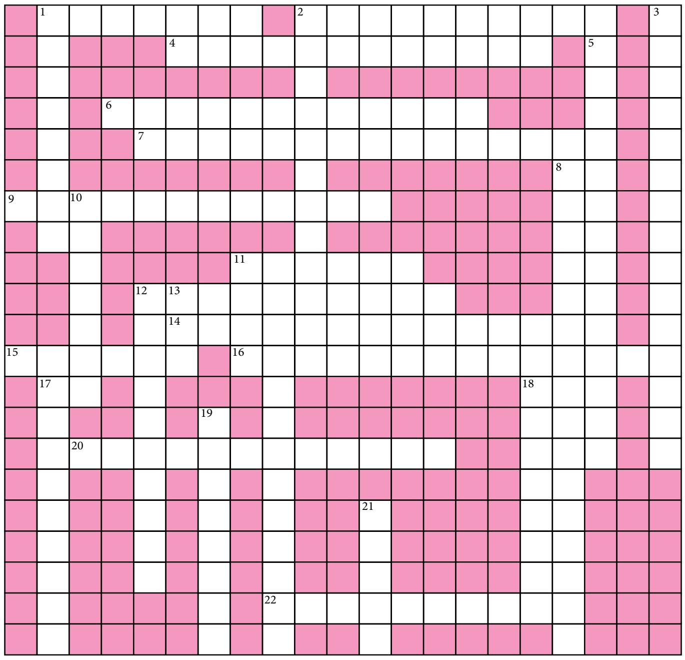

ACROSS

1. A hypothetical particle of time taken for a photon to traverse the diameter of an electron. (7)
2. The removal of any unwanted ac components from a circuit or circuit element. (10)
4. A small light disc suspended in the path of a sound wave, used to measure the intensity of the sound by analysing the resulting deflection of the disc. (8, 4)
6. The minimum mass of a fissile material that will sustain a chain reaction. (8, 4)
7. A measure of the intensity I of a sound with reference to the minimum audible intensity I_0. (9, 5)
9. Two or more nuclides that have the same difference in the number of neutrons and protons. (12)
11. A unit of radiant flux density that is used in astronomy especially for radio and infrared measurements. (6)
13. A highly luminous star of large dimensions in comparison with average stars. (5, 4)
14. A unit of energy extensively employed in atomic, nuclear and particle physics. (12)
15. A method for determining the age of archaeological and fossil remains rock etc. (6)
16. The plates used to investigate vibrations in solids. (7, 6)
20. The condition of near weightlessness induced by free fall or unpowered space flight. (12)
22. Any of a variety of alloys with a high magnetic permeability at low magnetic flux density. (9)

DOWN

1. The ratio of the difference in intensity between the lightest and darkest areas in a subject or its reproduction to the sum of these intensities. (8)
2. An isotope added to a fissile material to make it unsuitable for use in nuclear weapons. (10)
3. The ability of certain materials to generate a temporary voltage when they are heated or cooled. (15)
5. Any device or instrument designed to produce and study optical or radio wave interference. (14)
8. The radiant flux emitted per unit solid angle by a point source in a given direction. (7, 9)
10. The ratio of the radiant flux incident on an object to the flux transmitted. (7)
12. An instrument that gives an electrical indication of deviation from the vertical. (10)
17. The branch of applied mathematics dealing with motion and forces producing motion. (9)
18. A corrected pressure used in the thermodynamic equation of real gases to give them the same form as the equation of ideal gas. (8)
19. The energy loss due to magnetic hysteresis and eddy currents. (4, 4)
21. The sum of the initial kinetic energies of all charged particles produced by the indirect effect of ionizing radiation in a small volume of a given substance divided by the mass of substance in that volume. (5)

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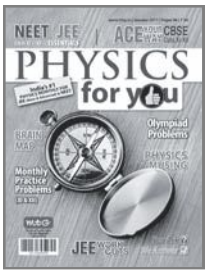

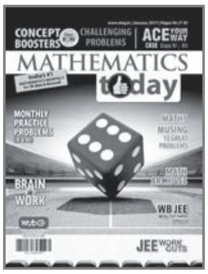

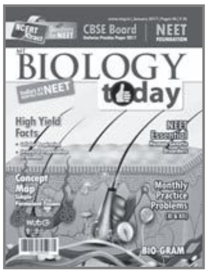

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