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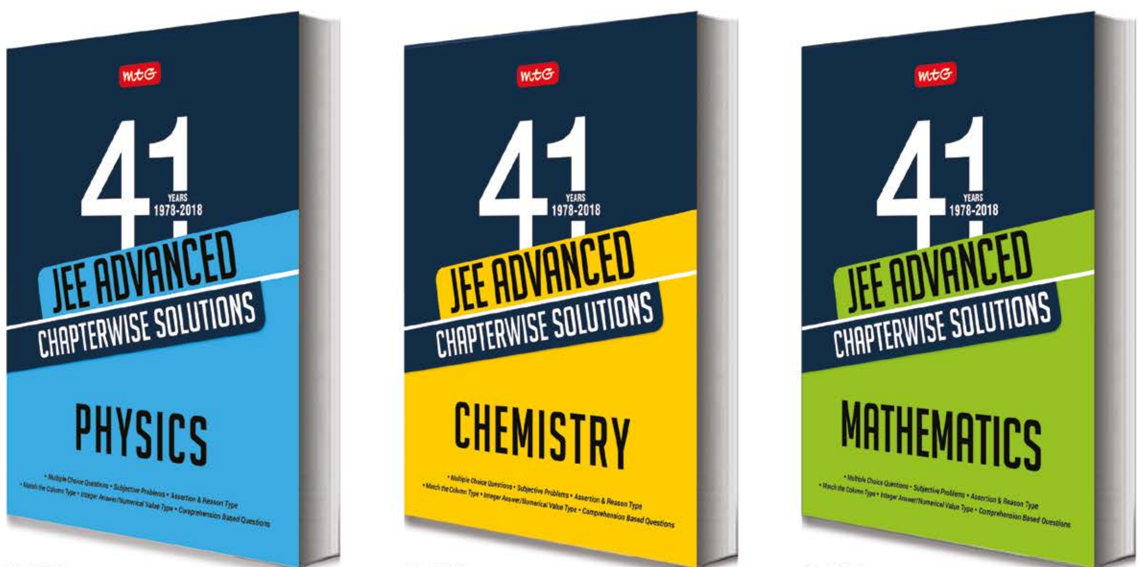

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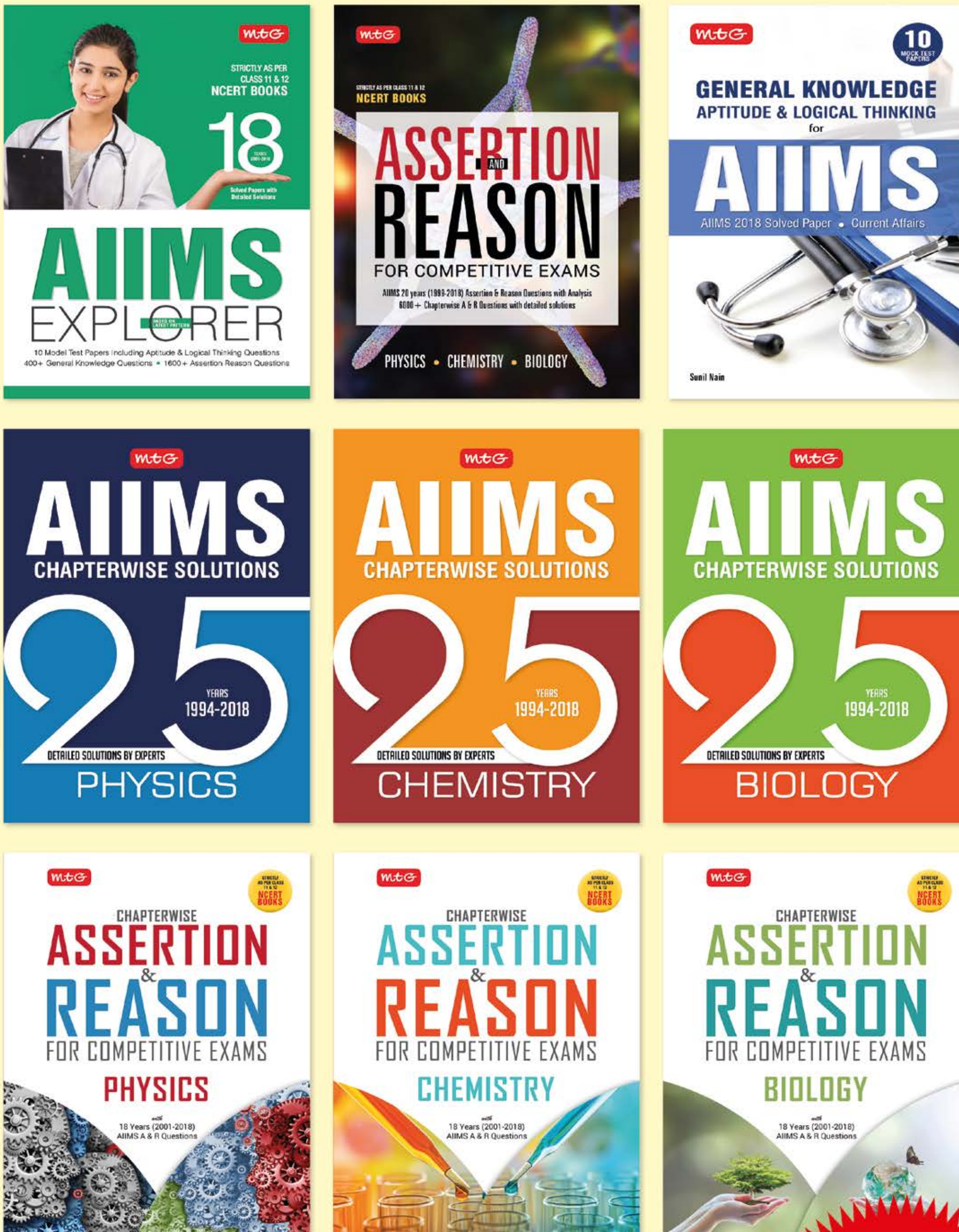

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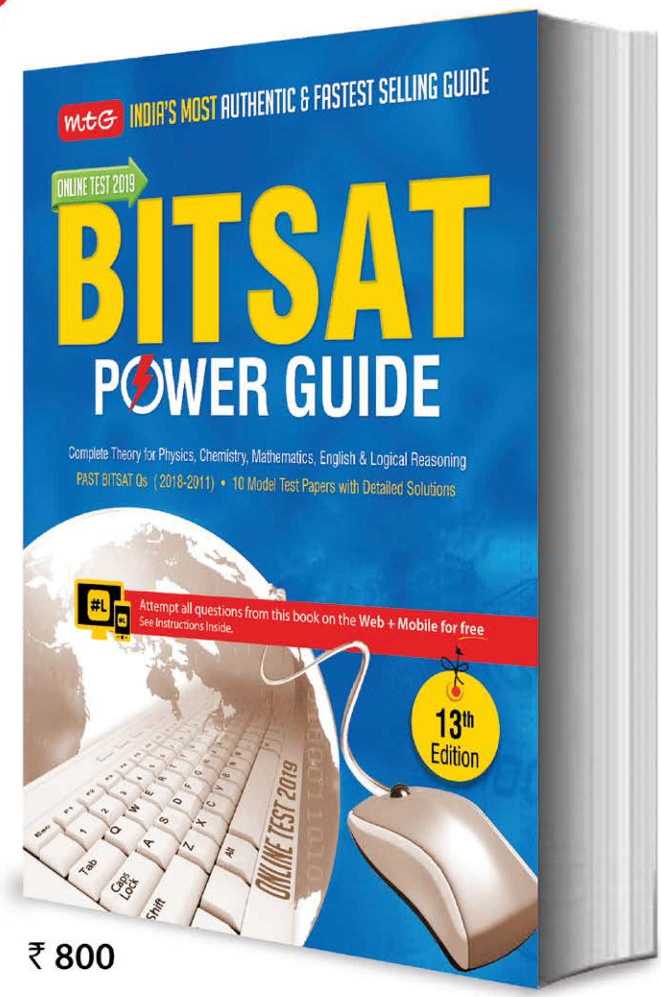

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PHYSICS for you

Volume 27 No. 5 May 2019

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Physics Musing was started in August 2013 issue of Physics For You. The aim of Physics Musing is to augment the chances of bright students preparing for JEE (Main and Advanced) / NEET / AIIMS / JIPMER with additional study material.
In every issue of Physics For You, 10 challenging problems are proposed in various topics of JEE (Main and Advanced) / NEET. The detailed solutions of these problems will be published in next issue of Physics For You.
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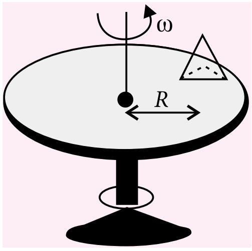
We hope that our readers will enrich their problem solving skills through "Physics Musing" and stand in better stead while facing the competitive exams.

PROBLEM Set 70

SINGLE OPTION CORRECT TYPE

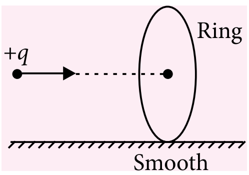
1. A solid cone of radius r and height h is kept on a turntable rotating with an angular velocity ω. The friction between the table and the cone is sufficient so that the cone does not slide. The distance between the axis of the cone and the axis of turntable is R ($R >> r$). The maximum value of ω for which the cone does not topple is



(a) $\sqrt{\frac{4}{3}\frac{gr}{Rh}}$ (b) $\sqrt{\frac{gr}{Rh}}$

(c) $\sqrt{\frac{4gr}{Rh}}$ (d) $\sqrt{\frac{3gr}{4Rh}}$

2. A particle of mass m and charge $+q$ approaches from a very large distance towards a uniformly charged ring of radius R and charge $+q$, mass same as that of particle, with initial velocity v_0 along the axis of the ring as shown in the figure. What is the closest distance of approach between the ring and the particle? Assume the space to be gravity free and frictionless.



(a) $\sqrt{\frac{q^4}{\pi^2\varepsilon_0^2 m^2 v_0^4} - R^2}$

(b) $\sqrt{\frac{3q^4}{2\pi^2\varepsilon_0^2 m^2 v_0^4} + R^2}$

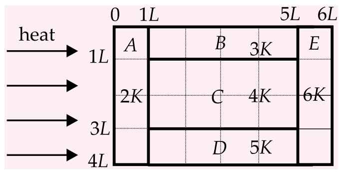
(c) $\sqrt{\frac{m^2 v_0^4}{2\pi^2 q^4 \varepsilon_0^2} - R^2}$ (d) $\sqrt{\frac{q^4}{4\pi^2\varepsilon_0^2 m^2 v_0^4} - R^2}$

3. A light ray incident along vector $2\hat{i} + 4\hat{j} + \sqrt{5}\hat{k}$ strikes on the x-z plane from medium I of refractive index $\sqrt{3}$ and medium II of refractive index is μ_2. The value of μ_2 for which the value of angle of refraction becomes 90° is

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

MULTIPLE CORRECT OPTIONS TYPE

4. A composite block is made of slabs A, B, C, D and E of different thermal conductivities (given in terms of a constant K) and sizes (given in terms of length, L) as shown in the figure. All slabs are of same width. Heat Q flows only from left to right through the blocks. Then in steady state



(a) heat flow through A and E slabs are same.
(b) heat flow through slab E is maximum.
(c) temperature difference across slab E is smallest.
(d) heat flow through C = heat flow through B + heat flow through D

5. A particle which constraints to move along the x-axis is subjected to a force in the same direction which varies with distance x of the particle from the origin as $F(x) = -kx + \alpha x^3$. Here, k and α are positive constants. Then, the correct options are
(a) potential energy is zero at $x = 0$
(b) kinetic energy is maximum at $x = 0$
(c) kinetic energy is not maximum at $x = 0$
(d) none of these

By Akhil Tewari, Author of Rank up Physics (JEE Main & Advanced), Director of School Toppers, Thane, Maharashtra, Ph.: +917900025559

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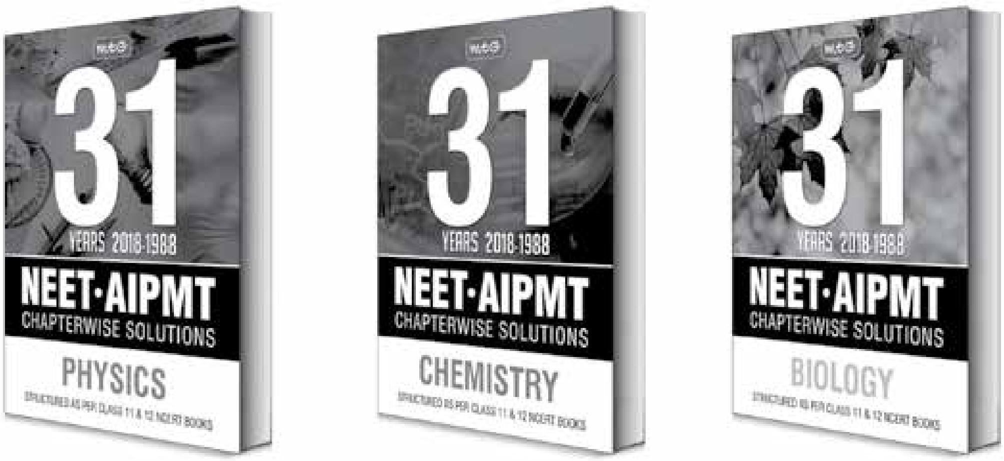

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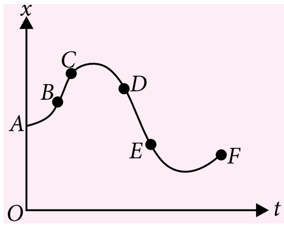
6. For a particle moving along x-axis, x-t graph is given. Mark the correct statement(s).



(a) Initial velocity of the particle is zero.
(b) For BC acceleration is positive and DE acceleration is negative.
(c) For EF acceleration is positive.
(d) Velocity is getting zero, three times in the motion.

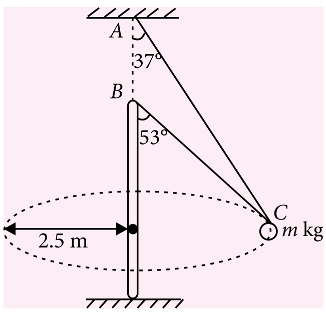
7. Two lenses, one concave and the other convex of same power are placed such that their principal axes coincide, the separation between the lenses is x, then
(a) real image is formed for $x = 0$ only
(b) real image is formed for all values of x
(c) system will behave like a glass plate for $x = 0$
(d) virtual image is formed for all values of x other than zero

NUMERICAL VALUE TYPE

8. A radioactive sample has decay constant λ. The rate of production of nuclei in the given sample as $\frac{9\lambda N_0^2}{N}$, where N_0 is the number of radioactive nuclei in the sample at $t = 0$ and N is the number of radioactive nuclei in the sample at time $t = t$ sec. If the number of nuclei present in the radioactive sample at $t \to \infty$ is $m \times 10^6$ nuclei then find the value of m. (Given $N_0 = 10^6$ nuclei).

9. Two cylinders A and B fitted with pistons contain equal amounts of an ideal diatomic gas at 300 K. The piston A is free to move, while that of B is held fixed. The same amount of heat is given slowly to the gas in each cylinder. If the rise in temperature of the gas in A is 30 K, and rise in temperature of the gas in B is T kelvin then find the value of T.

10. An ideal string ACB passes through a smooth ring of mass m as shown in the figure. The radius of circle in which the ring moves is 2.5 m. The speed of the ring (in m s^{-1}) will be



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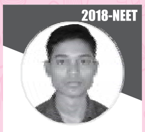

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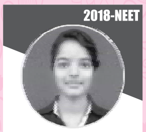

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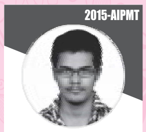

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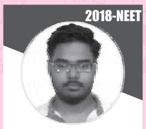

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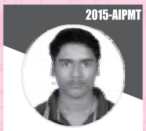

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JEE MAIN 2019

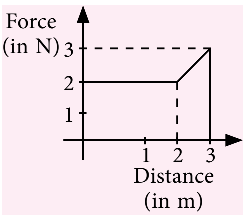
Held on 8^{th} April (Morning Shift)

SOLVED PAPER

1. A boy's catapult is made of rubber cord which is 42 cm long, with 6 mm diameter of cross-section and of negligible mass. The boy keeps a stone weighing 0.02 kg on it and stretches the cord by 20 cm by applying a constant force. When released, the stone flies off with a velocity of 20 m s^{-1}. Neglect the change in the area of cross-section of the cord while stretched. The Young's modulus of rubber is closest to

(a) 10^3 N m^{-2} (b) 10^4 N m^{-2}
(c) 10^8 N m^{-2} (d) 10^6 N m^{-2}

2. A particle moves in one dimension from rest under the influence of a force that varies with the distance travelled by the particle as shown in the figure. The kinetic energy of the particle after it has travelled 3 m is



(a) 2.5 J (b) 6.5 J (c) 5 J (d) 4 J

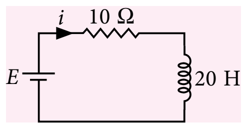
3. In an interference experiment the ratio of amplitudes of coherent waves is $\frac{a_1}{a_2} = \frac{1}{3}$. The ratio of maximum and minimum intensities of fringes will be

(a) 4 (b) 9 (c) 2 (d) 18

4. If 10^{22} gas molecules each of mass 10^{-26} kg collide with a surface (perpendicular to it) elastically per second over an area 1 m^2 with a speed 10^4 m s^{-1}, the pressure exerted by the gas molecules will be of the order of

(a) 10^{16} N m^{-2} (b) 10^4 N m^{-2}
(c) 10^3 N m^{-2} (d) 10^8 N m^{-2}

5. A 20 Henry inductor coil is connected to a 10 ohm resistance in series as shown in figure. The time at which rate of dissipation of energy (Joule's heat) across resistance is equal to the rate at which magnetic energy is stored in the inductor, is



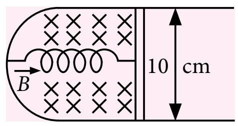
(a) $\frac{1}{2}\ln 2$ (b) ln 2 (c) $\frac{2}{\ln 2}$ (d) 2 ln 2

6. A thermally insulated vessel contains 150 g of water at 0°C. Then the air from the vessel is pumped out adiabatically. A fraction of water turns into ice and the rest evaporates at 0°C itself. The mass of evaporated water will be closest to

(Latent heat of vaporization of water = 2.10×10^6 J kg^{-1} and latent heat of fusion of water = 3.36×10^5 J kg^{-1})

(a) 20 g (b) 35 g (c) 130 g (d) 150 g

7. A thin strip 10 cm long is on a U shaped wire of negligible resistance and it is connected to a spring of spring constant 0.5 N m^{-1} (see figure).



The assembly is kept in a uniform magnetic field of 0.1 T. If the strip is pulled from its equilibrium position and released, the number of oscillations it performs before its amplitude decreases by a factor of e is N. If the mass of the strip is 50 grams, its resistance 10 Ω and air drag negligible, N will be close to

(a) 10000 (b) 1000 (c) 5000 (d) 50000

8. Ship A is sailing towards north-east with velocity $\vec{v} = 30\hat{i} + 50\hat{j}$ km h^{-1} where $\hat{i}$ points east and $\hat{j}$, north. Ship B is at a distance of 80 km east and 150 km north of ship A and is sailing towards west at 10 km h^{-1}. A will be at minimum distance from B in

(a) 2.2 h (b) 3.2 h (c) 4.2 h (d) 2.6 h

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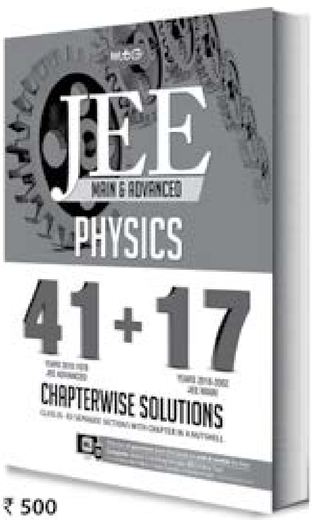

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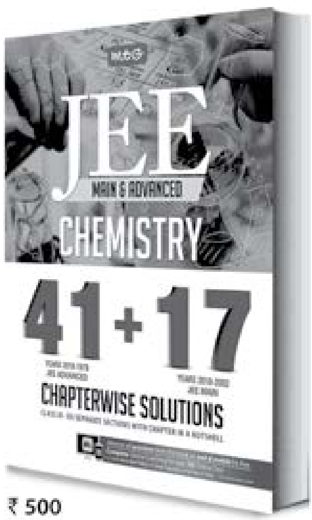

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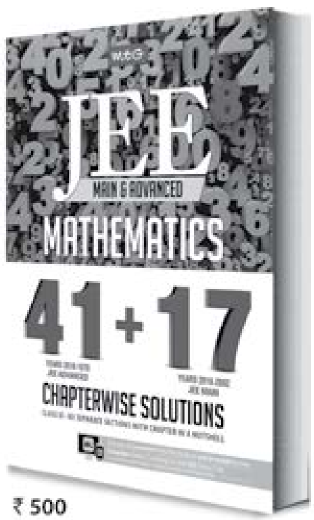

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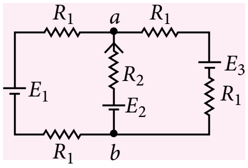
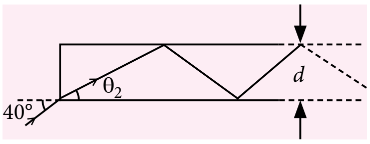
9. For the circuit shown, with $R_1 = 1.0\ \Omega$, $R_2 = 2.0\ \Omega$, $E_1 = 2$ V and $E_2 = E_3 = 4$ V, the potential difference between the points a and b is approximately (in V)



(a) 2.7 (b) 3.7 (c) 2.3 (d) 3.3

10. In figure, the optical fiber is $l = 2$ m long and has a diameter of $d = 20\ \mu$m. If a ray of light is incident on one end of the fiber at angle $\theta_1 = 40°$, the number of reflections it makes before emerging from the other end is close to :

(refractive index of fiber is 1.31 and sin 40° = 0.64)



(a) 55000 (b) 66000 (c) 57000 (d) 45000

11. Water from a pipe is coming at a rate of 100 liters per minute. If the radius of the pipe is 5 cm, the Reynolds number for the flow is of the order of (density of water = 1000 kg m^{-3}, coefficient of viscosity of water = 1 mPa s.)

(a) 10^2 (b) 10^4 (c) 10^3 (d) 10^6

12. A solid conducting sphere, having a charge Q, is surrounded by an uncharged conducting hollow spherical shell. Let the potential difference between the surface of the solid sphere and that of the outer surface of the hollow shell be V. If the shell is now given a charge of $-4\ Q$, the new potential difference between the same two surfaces is

(a) $4\ V$ (b) V (c) $2\ V$ (d) $-2\ V$

13. An upright object is placed at a distance of 40 cm in front of a convergent lens of focal length 20 cm. A convergent mirror of focal length 10 cm is placed at a distance of 60 cm on the other side of the lens. The position and size of the final image will be

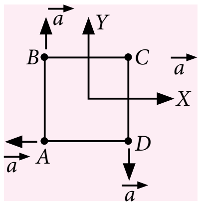
(a) 40 cm from the convergent mirror, same size as the object

(b) 20 cm from the convergent mirror, twice the size of the object

(c) 20 cm from the convergent mirror, same size as the object

(d) 40 cm from the convergent lens, twice the size of the object.

14. Four particles A, B, C and D with masses $m_A = m$, $m_B = 2m$, $m_C = 3m$ and $m_D = 4m$ are at the corners of a square. They have accelerations of equal magnitude with directions as shown. The acceleration of the centre of mass of the particles is

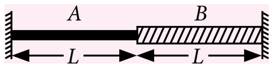


(a) $\frac{a}{5}(\hat{i}+\hat{j})$ (b) $a(\hat{i}+\hat{j})$ (c) zero (d) $\frac{a}{5}(\hat{i}-\hat{j})$

15. A circular coil having N turns and radius r carries a current I. It is held in the XZ plane in a magnetic field $B\hat{i}$. The torque on the coil due to the magnetic field is

(a) $\frac{B\pi r^2 I}{N}$ (b) $\frac{Br^2 I}{\pi N}$ (c) $B\pi r^2 IN$ (d) Zero

16. A wire of length $2L$, is made by joining two wires A and B of same length but different radii r and $2r$ and made of the same material. It is vibrating at a frequency such that the joint of the two wires forms a node. If the number of antinodes in wire A is p and that in B is q, then the ratio $p : q$ is



(a) 3 : 5 (b) 4 : 9 (c) 1 : 2 (d) 1 : 4

17. Voltage rating of a parallel plate capacitor is 500 V. Its dielectric can withstand a maximum electric field of 10^6 V m^{-1}. The plate area is 10^{-4} m^2. What is the dielectric constant if the capacitance is 15 pF ?

(given $\varepsilon_0 = 8.86 \times 10^{-12}$ C^2 N^{-1} m^{-2})

(a) 3.8 (b) 8.5 (c) 6.2 (d) 4.5

18. A plane electromagnetic wave travels in free space along the x-direction. The electric field component of the wave at a particular point of space and time is $E = 6$ V m^{-1} along y-direction. Its corresponding magnetic field component, B would be

(a) 6×10^{-8} T along x-direction

(b) 2×10^{-8} T along y-direction

(c) 2×10^{-8} T along z-direction

(d) 6×10^{-8} T along z-direction

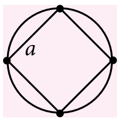
19. A thin circular plate of mass M and radius R has its density varying as $\rho(r) = \rho_0 r$ with ρ_0 as constant and r is the distance from its center. The moment of inertia of the circular plate about an axis perpendicular to the plate and passing through its edge is $I = a\ MR^2$. The value of the coefficient a is

(a) 3/5 (b) 3/2 (c) 1/2 (d) 8/5

20. A steel wire having a radius of 2.0 mm, carrying a load of 4 kg, is hanging from a ceiling. Given that $g = 3.1\ \pi$ m s^{-2}, what will be the tensile stress that would be developed in the wire?
(a) 4.8×10^6 N m^{-2} (b) 3.1×10^6 N m^{-2}
(c) 6.2×10^6 N m^{-2} (d) 5.2×10^6 N m^{-2}

21. In SI units, the dimensions of $\sqrt{\frac{\varepsilon_0}{\mu_0}}$ is
(a) $A^2T^3M^{-1}L^{-2}$ (b) $AT^2M^{-1}L^{-1}$
(c) $AT^{-3}ML^{3/2}$ (d) $A^{-1}TML^3$

22. Four identical particles of mass M are located at the corners of a square of side 'a'. What should be their speed if each of them revolves under the influence of others gravitational field in a circular orbit circumscribing the square ?



(a) $1.35\sqrt{\frac{GM}{a}}$ (b) $1.21\sqrt{\frac{GM}{a}}$
(c) $1.41\sqrt{\frac{GM}{a}}$ (d) $1.16\sqrt{\frac{GM}{a}}$

23. A 200 Ω resistor has a certain color code. If one replaces the red color by green in the code, the new resistance will be
(a) 100 Ω (b) 500 Ω (c) 300 Ω (d) 400 Ω

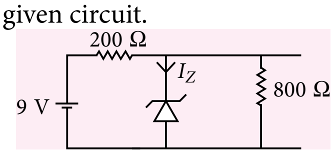
24. Two particles move at right angle to each other. Their de Broglie wavelengths are λ_1 and λ_2 respectively. The particles suffer perfectly inelastic collision. The de Broglie wavelength λ, of the final particle, is given by
(a) $\frac{2}{\lambda} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$ (b) $\lambda = \sqrt{\lambda_1\lambda_2}$
(c) $\frac{1}{\lambda^2} = \frac{1}{\lambda_1^2} + \frac{1}{\lambda_2^2}$ (d) $\lambda = \frac{\lambda_1 + \lambda_2}{2}$

25. Radiation coming from transitions $n = 2$ to $n = 1$ of hydrogen atoms fall on He^+ ions in $n = 1$ and $n = 2$ states. The possible transition of helium ions as they absorb energy from the radiation is
(a) $n = 2 \rightarrow n = 3$ (b) $n = 2 \rightarrow n = 5$
(c) $n = 1 \rightarrow n = 4$ (d) $n = 2 \rightarrow n = 4$

26. An alternating voltage $v(t) = 220 \sin 100\pi t$ volt is applied to a purely resistive load of 50 Ω. The time taken for the current to rise from half of the peak value to the peak value is
(a) 3.3 ms (b) 5 ms (c) 2.2 ms (d) 7.2 ms

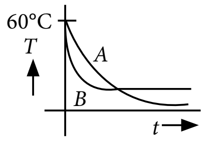
27. The bob of a simple pendulum has mass 2 g and a charge of 5.0 μC. It is at rest in a uniform horizontal electric field of intensity 2000 V m^{-1}. At equilibrium, the angle that the pendulum makes with the vertical is (take $g = 10$ m s^{-2})
(a) $\tan^{-1}(0.2)$ (b) $\tan^{-1}(0.5)$
(c) $\tan^{-1}(2.0)$ (d) $\tan^{-1}(5.0)$

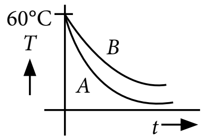
28. The reverse breakdown voltage of a Zener diode is 5.6 V in the given circuit.

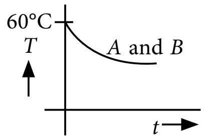


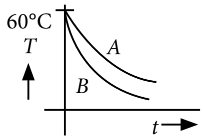
The current I_Z through the Zener is
(a) 17 mA (b) 7 mA (c) 10 mA (d) 15 mA

29. Two identical beakers A and B contain equal volumes of two different liquids at 60°C each and left to cool down. Liquid in A has density of 8×10^2 kg m^{-3} and specific heat of 2000 J kg^{-1} K^{-1} while liquid in B has density of 10^3 kg m^{-3} and specific heat of 4000 J kg^{-1} K^{-1}. Which of the following best describes their temperature versus time graph schematically ? (assume the emissivity of both the beakers to be the same)

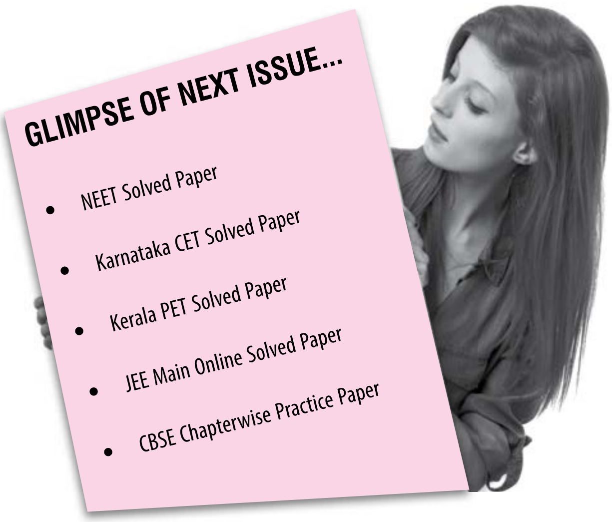
(a)


(b)


(c)


(d)


30. The wavelength of the carrier waves in a modern optical fiber communication network is close to
(a) 600 nm (b) 2400 nm
(c) 1500 nm (d) 900 nm



SOLUTIONS

1. (d) : $\frac{1}{2}mv^2 = \frac{1}{2}\times Y\times(\text{strain})^2\times V$

$$mv^2 = Y\times\left(\frac{\Delta l}{l}\right)^2\times V \Rightarrow Y = \frac{mv^2}{\left(\frac{\Delta l}{l}\right)^2\times V}$$

$$= \frac{(0.02)(20)^2}{\left(\frac{20}{42}\right)^2\times\pi(3\times10^{-3})^2(42\times10^{-2})}$$

$\Rightarrow$ $Y = 2.97\times10^6$ N m^{-2}

2. (b) : As work done by force = change in K.E. of the particle

From the graph,

When distance = 2 m, Force = 2 N

When distance = 3 m, Force = 3 N

Work done = Area enclosed by graph

$$W = 2\times2+\frac{1}{2}(2+3)\times(3-2) = 6.5 \text{ J}$$

$W = \Delta K = K_f - K_i$ (Here $K_i = 0$)

$\therefore$ $K_f = 6.5$ J

3. (a) : $\frac{I_{\max}}{I_{\min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} = \frac{(1+3)^2}{(1-3)^2} = \frac{16}{4} = \frac{4}{1}$

$$\frac{I_{\max}}{I_{\min}} = 4$$

4. (*) : Magnitude of change in moment per collision $= |-mv - mv|N = 2mvN$

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{2mvN}{t\times A} = \frac{2\times10^{-26}\times10^{22}\times10^4}{1\times1}$$

$= 2$ N m^{-2}

* None of the given option is correct.

5. (d) : $L = 20$ H, $R = 10\ \Omega$

As $I^2R = \frac{d}{dt}\left(\frac{1}{2}L\,I^2\right)$ (Given)

or $I^2R = \frac{1}{2}L(2I)\frac{dI}{dt}$

or $RI_o(1-e^{-t/\tau}) = L\,I_o(-e^{-t/\tau})\left(-\frac{1}{\tau}\right)$

or $e^{t/\tau} = \frac{L}{\tau R}+1 = 1+1$ [$\because$ $\tau = L/R$]

or $t = \tau\ln 2 = 2\ln 2$

6. (a) : Latent heat of vaporization of water, $L_1 = 2.10\times10^6$ J kg^{-1}

Latent heat of fusion of water, $L_2 = 3.36\times10^{-5}$ J kg^{-1}

Let the mass of ice formed = m g

Mass of water evaporated = $(150 - m)$ g

Heat gained by water in evaporation = Heat lost by water in freezing

$(150 - m)\times2.10\times10^3 = m\times3.36\times10^2$

$m = 129.31$ g $\simeq 130$ g

So, the water evaporated = 150 – 130 = 20 g

7. (c) : Total force on the rod of any instant is

$$-kx - ilB = m\frac{d^2x}{dt^2}$$

$$\Rightarrow\ -kx - \frac{B^2l^2}{R}.\frac{dx}{dt} - m\frac{d^2x}{dt^2} = 0 \quad ...(i)$$

Differential equation for damped oscillations

$$-kx - b\frac{dx}{dt} - m\frac{d^2x}{dt^2} = 0 \quad ...(ii)$$

Also amplitude in case of damped oscillation is

$$A = A_o e^{-\frac{b}{2m}t} \quad ...(iii)$$

According to question $A = \frac{A_0}{e}$

$$\therefore\ \frac{1}{e} = e^{-\frac{b}{2m}t} \Rightarrow \frac{b}{2m}t = 1$$

Comparing (i) and (ii), we get, $b = \frac{B^2l^2}{R}$

$$\therefore\ \frac{B^2l^2}{2mR}t = 1 \Rightarrow t = \frac{2mR}{B^2l^2}$$

$$\Rightarrow\ t = \frac{2\times0.05\times10}{(0.1)^2\times(.1)^2} = 10000 \text{ s}$$

$$\text{Number of oscillations} = \frac{t}{T_o} = \frac{t}{2\pi\sqrt{\frac{m}{k}}}$$

$$= \frac{10^4}{2\pi\sqrt{50\times10^{-3}/0.5}} = 5000$$

8. (d) : At any time t, the position of ship A, $\vec{x}_A = (30\hat{i}+50\hat{j})t$

The position of ship B, $\vec{x}_B = (-10t+80)\hat{i}+150\hat{j}$.

Distance between ship A and B, $\vec{x}_{AB} = \vec{x}_B - \vec{x}_A$

EXAM ALERT 2019

Exam	Date
NEET	5th May
COMEDK (Engg.)	12th May
MHT-CET	2nd to 13th May
BITSAT	16th to 26th May
AIIMS	25th & 26th May
AMU (Engg.)	26th May **(Revised)**
WB JEE	26th May
JEE Advanced	27th May **(Revised)**
JIPMER	2nd June

$$|\vec{x}_{AB}| = \sqrt{(-10t+80-30t)^2+(150-50t)^2}$$

For $|\vec{x}_{AB}|$ to be minimum, $\frac{d}{dt}x_{AB}=0$

$\Rightarrow \quad \frac{d}{dt}(16t^2 + 64 - 64t + 225 + 25t^2 - 150t) = 0$

$\Rightarrow \quad 32t - 64 + 50t - 150 = 0 \quad \Rightarrow \quad t = \frac{214}{82} = 2.6$ s

9. (d) : Applying KVL for loop I

$-E_1 + 2I_1R_1 + (I_1 - I_2)R_2 + E_2 = 0$

$-2 + 2I_1 + (I_1 - I_2)2 + 4 = 0$

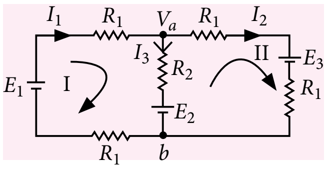
$\Rightarrow \quad 4I_1 - 2I_2 = -2$ ...(i)

Applying KVL for loop II

$E_3 + 2I_2R_1 + R_2(-I_1 + I_2) + E_2 = 0$

$-4 + 2I_2 + 2(-I_1 + I_2) + 4 = 0$

$\Rightarrow \quad -2I_1 + 4I_2 = 0$ ...(ii)



On solving (i) and (ii),

$I_1 = 2/3$ A, $I_2 = -1/3$ A

So $I_3 = I_1 - I_2 = -\frac{2}{3} - \left(-\frac{1}{3}\right) = -\frac{1}{3}$ A

For branch ab, $V_a - I_3R_2 - E_2 = V_b$

or $\quad V_a - V_b = I_3R_2 + E_2 = \left(-\frac{1}{3}\right)(2) + 4$

$= 4 - \frac{2}{3} = \frac{10}{3} = 3.3$ V

10. (c) : Required number of reflection

$$n = \frac{l}{d\cot\theta_2}$$

Also, $\sin 40° = \mu \sin\theta_2$

$$\sin\theta_2 = \frac{\sin 40°}{1.31} = \frac{0.64}{1.31} = \frac{64}{131}$$

$$\cot\theta_2 = \frac{\sqrt{(131)^2-(64)^2}}{64} = \frac{114}{64}$$

$$n = \frac{2\times 64}{20\times 10^{-6}\times 114} \approx 56140$$

11. (b) : The rate of flow $\frac{dV}{dt} = \pi r^2 \frac{dx}{dt} = \pi r^2 v$

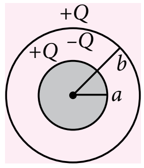
$$\Rightarrow \quad v = \frac{1}{\pi r^2}\frac{dV}{dt}$$

So, the Reynolds number, $R_e = \frac{1}{\pi r^2}\frac{dV}{dt}\frac{\rho D}{\eta}$

$$= \frac{1}{(3.14)(5\times 10^{-2})}\left(\frac{10^{-1}}{60}\right)\frac{(10^3)}{10^{-3}}$$

$= 10615.71 = 1.06 \times 10^4$

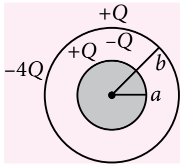
12. (b) : Case I.



$$V_a - V_b = k\left(\frac{Q}{a} - \frac{Q}{b}\right)$$

$= V \quad$ (Given)

Case II.



$$V_a' = \frac{kQ}{a} + \frac{k(-4Q)}{b}$$

$$V_b' = \frac{kQ}{b} + \frac{k(-4Q)}{b}$$

$$V_a' - V_b' = \frac{kQ}{a} - \frac{kQ}{b} = V_a - V_b = V.$$

13. (*) : For first refraction

$u = -40$ cm, $f = 20$ cm, $v = ?$

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad$ or $\quad \frac{1}{v} = \frac{1}{20} - \frac{1}{40} = \frac{1}{40}$

$v = 40$ cm ; $m_1 = \frac{v}{u} = -1$

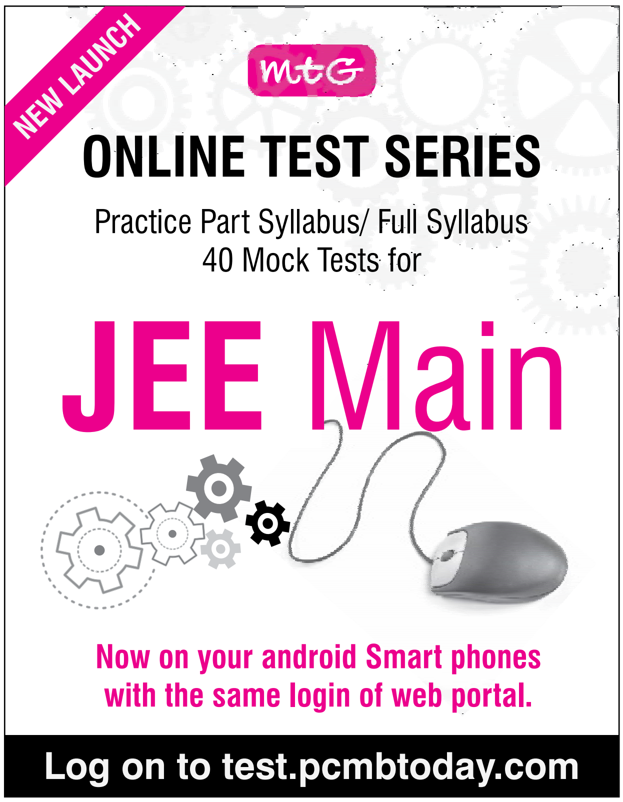
Now for first reflection

$u = -(60 - 40) = -20$ cm, $f = -10$ cm, $v = ?$

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \quad$ or $\quad \frac{1}{v} = \frac{1}{-10} + \frac{1}{20} = -\frac{1}{20}$

$v = -20$ cm

$m_2 = -\frac{v}{u} = -1$



For final refraction,
$u = -40$ cm, $f = 20$ cm, $v = ?$
$v = 40$ cm

$$m_3 = -\frac{v}{u} = -1$$

Net magnification = $m_1 \times m_2 \times m_3 = -1$
Hence final image is formed at 40 cm from the convergent lens with magnification 1.
* None of the given option is correct.

14. (d) : $\vec{a}_{cm} = \dfrac{m_1\vec{a}_1 + m_2\vec{a}_2 + m_3\vec{a}_3 + m_4\vec{a}_4}{m_1 + m_2 + m_2 + m_4}$

$$= \frac{m(-a\hat{i}) + 2m(a\hat{j}) + 3m(a\hat{i}) + 4m(-a\hat{j})}{m + 2m + 3m + 4m}$$

$$\Rightarrow \vec{a}_{cm} = \frac{a(2\hat{i} - 2\hat{j})}{10} = \frac{a}{5}(\hat{i} - \hat{j})$$

15. (c) : $\tau = NIAB \sin\theta = NI\,\pi r^2 B \sin 90° = B\pi r^2 IN$

16. (c)

17. (b) : $C = \dfrac{K\varepsilon_0 A}{d}$ or $K = \dfrac{CV}{\varepsilon_0 A E_{max}}$

$$K = \frac{15\times10^{-12}\times500}{8.86\times10^{-12}\times10^{-4}\times10^{6}} = 8.5$$

18. (c) : The direction of electromagnetic wave travelling is given by $\hat{k} = \vec{E}\times\vec{B}$.
As, the wave is travelling along x-direction and $\vec{E}$ is along y-direction. So $\vec{B}$ must point toward z-direction.

Magnetic field, $B = \dfrac{E}{c} = \dfrac{6}{3\times10^8} = 2\times10^{-8}\,\text{T}$

19. (d) : $M = \displaystyle\int_0^R \rho_0 r(2\pi r\,dr) = \frac{2}{3}\pi\rho_0 R^3$

The moment of inertia about the centre of the plate is $= \int dmr^2$

$$= \int_0^R \rho_0 r(2\pi r dr) r^2 = 2\pi\rho_0\frac{R^5}{5} = \frac{3}{5}MR^2$$

So, the moment of inertia about an axis perpendicular to the plate and passing through its edge is

$$= MR^2 + \frac{3}{5}MR^2 = \frac{8}{5}MR^2$$

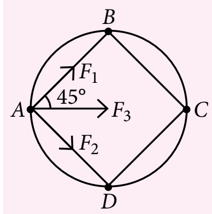
20. (b) : Tensile stress = $\dfrac{\text{Force}}{\text{Area}}$

$$= \frac{(4)(3.1\pi)}{\pi(2\times10^{-3})^2} = 3.1\times10^6\ \text{N m}^{-2}$$

21. (a) : $[\varepsilon_0] = [M^{-1}L^{-3}T^4A^2]$, $[\mu_0] = [MLT^{-2}A^{-2}]$

So, the dimensional formula for $\sqrt{\dfrac{\varepsilon_0}{\mu_0}}$ is $[M^{-1}L^{-2}T^3A^2]$.

22. (d) : Let F_1, F_2 and F_3 be the forces acting on particle at A due to particles at B, C and D respectively.



The net gravitational force acting on particle A,
$F_A = F_1\cos 45° + F_2\cos 45° + F_3$
[along x-direction]
The y-components of F_1 and F_2 cancels each other.
Net force on A provides the centripetal force

$$\therefore \frac{Mv^2}{r} = 2F_1\cos 45° + F_3 \quad \text{...(i)}$$

Let r be the radius of the circle. So, $r^2 + r^2 = a^2$.

$$\Rightarrow r = \frac{a}{\sqrt{2}}$$

Using it in equation (i), $\dfrac{Mv^2}{a/\sqrt{2}} = \dfrac{2GMM}{a^2}\dfrac{1}{\sqrt{2}} + \dfrac{GMM}{2a^2}$

$$\Rightarrow v^2 = \frac{GM}{a}\left(1 + \frac{1}{2\sqrt{2}}\right) \Rightarrow v = 1.16\sqrt{\frac{GM}{a}}$$

23. (b) : The resistance 200 Ω = 20×10^1 Ω
Here digit 2 corresponds to red colour.
So, if red is replaced by green, new resistance would be 50×10^1 Ω = 500 Ω

24. (c) : Let the two particles be moving along x-direction and y-direction.

Top 10 educational institutions in India, NIRF Ranking 2019

Indian Institute of Technology Madras (IIT Madras) is the best institutions in India according to NIRF ranking 2019. IIT-Madras topped the NIRF ranking 2019 this year in the overall category with 83.88 percent score. The Indian Institute of Science (IISc), that was number 1 last year, has slipped to number 2 this year. The top sixth spot hold by the Indian Institute of Technologies (IITs) — Indian Institute of Technology-Delhi (Rank 3), Indian Institute of Technology-Bombay (Rank 4), Indian Institute of Technology-Kharagpur (Rank 5), Indian Institute of Technology-Kanpur (Rank 6).

The President of India, Ram Nath Kovind announced the NIRF ranking on 8th April. Jawaharlal Nehru University has secured the seventh spot, while Banaras Hindu University clinched the 10th position.

States that dominated Top 100 rankings

State	No. of institutes
Tamil Nadu	21
Maharashtra	12
West Bengal	8
Delhi	7
UP	7
Karnataka	6

So, the net momentum initially is $\sqrt{\frac{h^2}{\lambda_1^2}+\frac{h^2}{\lambda_2^2}}$.

and final momentum will be $\frac{h}{\lambda}$.

Applying momentum conservation, $\frac{h}{\lambda}=\sqrt{\frac{h^2}{\lambda_1^2}+\frac{h^2}{\lambda_2^2}}$

$$\Rightarrow \quad \frac{1}{\lambda^2}=\frac{1}{\lambda_1^2}+\frac{1}{\lambda_2^2}$$

25. (d)

26. (a) : The current is given as $I=\frac{220}{50}\sin(100\pi t)$ A.

For the peak value of current (I_0), $\sin(100\pi t_1)=1$

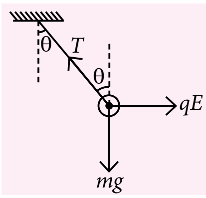
$$\Rightarrow \quad 100\pi t_1=\frac{\pi}{2}\Rightarrow t_1=\frac{1}{200}\text{ s}$$

For half of peak value of current *i.e.*, $I=\frac{I_0}{2}$,

$$\sin(100\pi t_2)=\frac{1}{2} \quad \text{or} \quad 100\pi t_2=\frac{\pi}{6} \quad \text{or} \quad t_2=\frac{1}{600}\text{ s}$$

Time taken $=\frac{1}{200}-\frac{1}{600}=3.33\times10^{-3}\text{ s}=3.33\text{ ms}$

27. (b) : The forces acting on the bob are its weight and the force due to field.



At equilibrium, $T\cos\theta = mg$ ...(i)

and $T\sin\theta = qE$ ...(ii)

Dividing (ii) by (i), $\tan\theta=\frac{qE}{mg}$

$$\Rightarrow \quad \theta=\tan^{-1}\left(\frac{5\times10^{-6}\times2\times10^{3}}{2\times10^{-3}\times10}\right)=\tan^{-1}(0.5)$$

28. (c) : The current through 200 Ω resistor is, $\frac{9-5.6}{200}=\frac{3.4}{200}$ A

So, the current through diode $I_2=\frac{3.4}{200}-\frac{5.6}{800}$

$= 0.01$ A $= 10$ mA

29. (b) : From Newton's law of cooling, rate of fall of temperature $\frac{d\theta}{dt}\propto\frac{1}{mc}$.

So, when two liquids are cooled under indentical conditions, rate of fall of temperature is lower for liquid with higher specific heat.

For liquid A, $mc = (8\times10^2\times2\times10^3)V$

For liquid B, $mc = (10^3\times4\times10^3)V$

where V is the volume of liquids taken.

So, $\frac{d\theta}{dt}$ is greater for B.

30. (c) : Fiber optics communication is mainly conducted in wavelength range from 1260 nm to 1625 nm.

MtG

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5 MIND BLOWING FACTS

1. 3-D Printed Rubber Material That can Self-Repair is Made

Researchers at the University of Southern California have made a new material that can be manufactured quickly and is able to repair itself if it becomes fractured or punctured. The material is manufactured using a 3-D printing method that uses photopolymerization. This process uses light to solidify a liquid resin in a desired shape or geometry. Photopolymerization is achieved through a reaction with a certain chemical group called thiols. By adding an oxidizer to the equation, thiols transform into another group called disulfides. It is the disulfide group that is able to reform when broken, leading to the self-healing ability. On being cut in half and heated at 60°C, the material healed completely in two hours, researchers said. This material could be game-changing for industries like shoes, tires, soft robotics, and even electronics, decreasing manufacturing time while increasing product durability and longevity.

2. Two-thirds of Himalayan glaciers could melt away by 2100

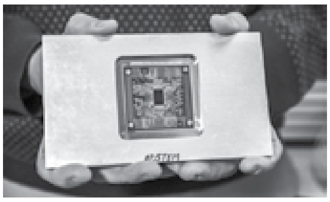
Atleast a third of the ice cover in the Hindu Kush Himalayan mountain range will definitely melt even if carbon emission will be slashed immediately, says a new study of Hindu Kush Himalaya Assessment. Due to global warming, the after-effect is occurring at a pace that even if the world limits global warming to 1.50 C, 36% of Himalayan Glacier will disappear by 2100. Glacier are the source of water for rivers that flow to India, Pakistan, China, Nepal. From 2060s the river flow will go into decline, and the region could face a shortage of water. The researchers of Hindu Kush Himalaya Assessment also considered the fraught geopolitics of the region as threat as a war could worsen the crisis. On the other hand, changing in the river flow or water level could also trigger a political crisis between India and Pakistan.

3. Bow Riding

BOW RIDING is a behaviour in which some species of dolphins or porpoises "surf' in the waves generated by the front (bow) of an advancing vessel.

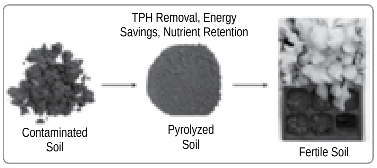
The animals are able to position themselves to be lifted up and propelled forward by the waves as they glide through the water.

4. Electron Microscope can find defects at atomic level



A team of scientists at Berkeley National laboratory designed the superfast electron detector called "4D Camera", that can capture images at the atomic level. It is 60-times faster than the conventional electron microscope, captures images at a faster rate at 100,000 times per second. This innovation allows scientists to see and record all reactions during experiments. The 4D Camera outputs a huge amount of data-about 4TB per minute. "The amount of data is equivalent to watching about 60,000 HD movies simultaneously," said a staff.

5. New Method that turns oily soil into fertile soil developed



Scientists at America's Rice University have 'fine tuned' a method to restore the fertility of soil that is contaminated by oil spills. Scientists heated contaminated soil samples in the absence of oxygen, a process named pyrolysis, and successfully reduced petroleum hydrocarbons to below regulatory mandates.

Samples heated at 420°C for 15 minutes reduced 99.9% hydrocarbons, scientists said.

JEE ADVANCED 2019 PRACTICE PAPER

Exam on 27^{th} May

PAPER - I

Section 1 (Maximum Marks : 24)

- *This section contains SIX (06) questions.*
- *Each question has FOUR options for correct answer(s). ONE OR MORE THAN ONE of these four option(s) is (are) correct option(s).*
- *For each question, choose the correct option(s) to answer the question.*
- *Answer to each question will be evaluated according to the following marking scheme:*

Full Marks : +4 If only (all) the correct option(s) is (are) chosen.

Partial Marks : +3 If all the four options are correct but ONLY three options are chosen.

Partial Marks : +2 If three or more options are correct but ONLY two options are chosen, both of which are correct options.

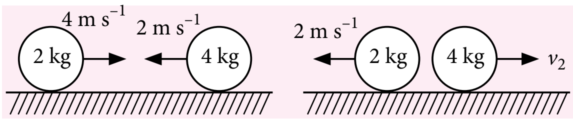
Partial Marks : +1 If two or more options are correct but ONLY one option is chosen and it is a correct option.

Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered).

Negative Marks : –2 In all other cases.

- *For Example : If first, third and fourth are the ONLY three correct options for a question with second option being an incorrect option; selecting only all the three correct options will result in +4 marks. Selecting only two of the three correct options (e.g. the first and fourth options), without selecting any incorrect option (second option in this case), will result in +2 marks. Selecting only one of the three correct options (either first or third or fourth option), without selecting any incorrect option (second option in this case), will result in +1 marks. Selecting any incorrect option(s) (second option in this case), with or without selection of any correct option(s) will result in -2 marks.*

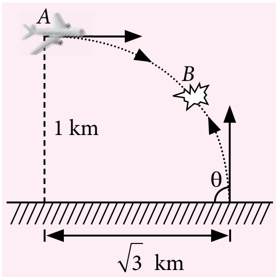
1. Two balls of masses 2 kg and 4 kg are moved towards each other with velocities 4 m s^{-1} and 2 m s^{-1} respectively on a frictionless surface. After colliding, the 2 kg ball returns back with velocity 2 m s^{-1}. Then



(a) velocity of 4 kg ball after collision is 1 m s^{-1}.
(b) coefficient of restitution e is 0.8.
(c) maximum potential energy of deformation is 24 J.
(d) impulse of reformation J_R is –4 N s.

2. An aircraft (say A) is flying horizontally with a constant velocity = 200 m s^{-1}, at a height = 1 km above the ground.

At the moment shown, a bomb (Say B) is released from the aircraft and the cannon-gun below fires a shell with initial speed = 200 m s^{-1}, at some angle θ. Take sin 53° = 4/5. Then,



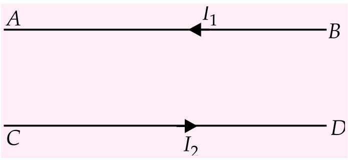
(a) for θ = 60°, the projectile shall destroy the bomb in mid-air.
(b) for θ = 53°, the minimum distance between the bomb and the shell as they fly past each other is $\dfrac{2-\sqrt{3}}{\sqrt{5}}$ km.
(c) for θ = 45°, projectile will destroy the bomb in mid-air.
(d) all of these.

3. n drops of a liquid each with surface energy E join to form a single drop. Then
(a) some energy will be released in the process
(b) some energy will be absorbed in the process
(c) the energy released or absorbed will be $E(n - n^{2/3})$
(d) the energy released or absorbed will be $nE(2^{2/3} - 1)$.

4. A charged particle carrying charge q = 10 μC moves in a uniform magnetic field with velocity $v_1 = 10^6$ m s^{-1} at angle 45° with the x-axis in the xy plane and experiences a force $F_1 = 5\sqrt{2}$ m N along the negative z-axis. When the same particle moves with velocity $v_2 = 10^6$ m s^{-1} along the z-axis, it experiences a force F_2 in the y-direction. Find
(i) the magnitude and direction of the magnetic field.
(ii) the magnitude of the force F_2.

(a) $10^{-5}\,\hat{i}$ T, 10^{-2} N
(b) $10^{-3}\hat{i}$ T, 10^{-3} N
(c) $10^{-3}\,\hat{i}$ T, 10^{-2} N
(d) $10^{-2}\,\hat{i}$ T, 10 N

5. A long horizontal wire AB which is free to move in a vertical plane and carries a steady current of 20 A, is in equilibrium at a height of 0.01 m over another parallel long wire CD, which is fixed in a horizontal plane and carries a steady current of 30 A as shown in figure. Find the period of oscillations.



(a) 0.5 s (b) 0.3 s (c) 0.2 s (d) 0.10 s

6. A partition divides a container having insulated walls into two compartments I and II. The same gas fills the two compartments whose initial parameters are given. The partition is a conducting wall which can move freely without friction. Which of the following statements is/are correct, with reference to the final equilibrium position?

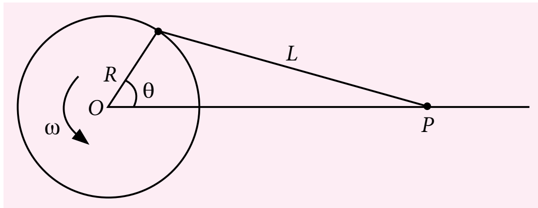
P, V, T I	$2P, 2V, T$ II

(a) The pressure in the two compartments are equal.
(b) Volume of compartment I is $\frac{3}{5}V$.
(c) Volume of compartment II is $\frac{12}{5}V$.
(d) Final pressure in compartment I is $\frac{5}{3}P$.

Section 2 (Maximum Marks : 24)

- ***This section contains EIGHT (08) questions. The answer to each question is a NUMERICAL VALUE.***
- ***For each question, enter the correct numerical value (in decimal notation, truncated/rounded-off to the second decimal place; e.g. 6.25, 7.00, –0.33, –.30, 30.27, –127.30) using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.***
- ***Answer to each question will be evaluated according to the following marking scheme:***
  Full Marks : +3 If ONLY the correct numerical value is entered as answer.
  Zero Marks : 0 In all other cases.

7. One end of a rod of length L = 1 m is fixed to a point on the circumference of a wheel of radius $R = 1/\sqrt{3}$ m. The other end is sliding freely along a straight channel passing through the center O of the wheel as shown in the figure below. The wheel is rotating with a constant angular velocity 3 rad s^{-1} about O.

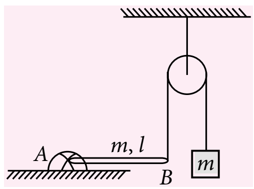


Find the speed (in m s^{-1}) of the sliding end P when θ = 60°.

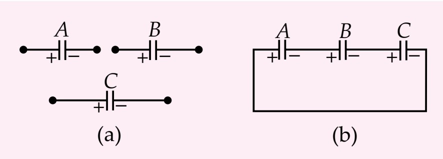
8. A whistle emitting a loud sound of frequency 540 Hz is whirled in a horizontal circle of radius 2 m and at a constant angular speed of 15 rad s^{-1}. The speed of sound is 330 m s^{-1}. Then find the ratio of the highest to the lowest frequency heard by a listener standing at rest at a large distance from the center of the circle.

9. During a heavy rain, hailstones of average size 1 cm in diameter fall with an average speed of 20 m s^{-1}. Suppose 2000 hailstones strike every square meter of 10 m × 10 m roof perpendicularly in one second and assume that the hailstones do not rebound. Calculate the average force (in N) exerted by the falling hailstones on the roof. Density of a hailstone is 900 kg m^{-3}.

10. Uniform rod AB is hinged at the end A in a horizontal position as shown in the figure. The other end is connected to a block through a massless string as shown. The pulley is smooth and massless. Masses of the block and the rod are same and are equal to m. Find the acceleration (in m s^{-2}) of the block just after release from this position (Take g = 10 m s^{-2}).



11. Given that $C_A = 1$ μF, $C_B = 2$ μF and $C_C = 2$ μF. Initially, each capacitor was charged to potential differences of $V_A = 10$ V, $V_B = 40$ V and $V_C = 60$ V separately and are kept as shown in figure (a). Now they are connected as shown in figure (b). The + and – ve sign shown in figure (b) represent initial polarities. Find total amount of heat produced (in μJ) by the time steady state is reached.



12. A body at temperature 40°C is kept in a surrounding of constant temperature 20°C. It is observed that its temperature falls to 35°C in 10 minutes. Find how much time (in min) will it take for the body to attain a temperature of 30°C by approximate method.

13. In a Young's double slit experiment using monochromatic light, the fringe pattern shifts by a certain distance on the screen when a mica sheet of refractive index 1.6 and thickness 1.964 micron (1 micron = 10^{-6} m) is introduced in the path of one of the interfering waves. The mica sheet is then removed and the distance between the screen and the slits is doubled. It is found that the distance between the successive maxima now is the same as the observed fringe-shift upon the introduction of the mica sheet. Calculate the wavelength (in nm) of the monochromatic light used in the experiment.

14. A charge of 3.14×10^{-6} C is distributed uniformly over a circular ring of radius 20.0 cm. The ring rotates about its axis with an angular velocity of 60.0 rad s^{-1}. The ratio of the electric field to the magnetic field at a point on the axis at a distance of 5.00 cm from the centre is $x \times 10^{15}$ m s^{-1}. Find x.

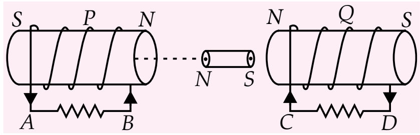
Section 3 (Maximum Marks : 12)

- ***This section contains TWO (02) paragraphs. Based on each paragraph, there are TWO (02) questions.***
- ***Each question has FOUR options. ONLY ONE of these four options corresponds to the correct answer.***
- ***For each question, choose the option corresponding to the correct answer.***
- ***Answer to each question will be evaluated according to the following marking scheme:***

Full Marks :	***+3***	***If ONLY the correct option is chosen.***
Zero Marks :	***0***	***If none of the options is chosen (i.e. the question is unanswered).***
Negative Marks :	***–1***	***In all other cases.***

PARAGRAPH 1

In the given figure, NS is a permanent magnet with its poles N and S as shown. P and Q are two coils with iron core, connected to resistors AB (for P) and CD (for Q) respectively lying on the common axis of the magnet to its left and right respectively as in the figure. The windings on the coil are similar as shown.



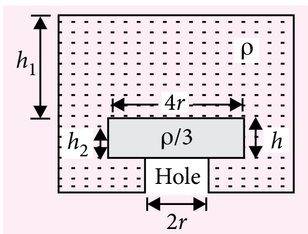
15. If the magnet is now moved to the left, then during its motion, a current will flow from

(a) A to B in P and from C to D in Q.
(b) A to B in P and from D to C in Q.
(c) B to A in P and from C to D in Q.
(d) B to A in P and from D to C in Q.

16. If the magnet is kept fixed, and the coil P is moved to the left with coil Q fixed, then during its motion, a current will flow from

(a) B to A in P and no current will flow in Q.
(b) B to A in P and from C to D in Q.
(c) B to A in P and from D to C in Q.
(d) A to B in P and no current will flow in Q.

PARAGRAPH 2



A cylindrical tank has a hole of diameter $2r$ in the bottom. The hole is covered by wooden cylindrical block of diameter $4r$, height h and density $\rho/3$.

Situation 1 : Initially, the tank is filled with water of density ρ to a height such that the height of water above the top of block is h_1 (measured from the top of the block).

Situation 2 : The water is removed from the tank to a height h_2 (measured from the bottom of the block) as shown in figure. The height h_2 is smaller than h (height of the block) and thus the block is exposed to the atmosphere.

17. In situation-2, if h_2 is further decreased, then

(a) block will not move up and remains at its original position.

(b) for $h_2 = \frac{h}{3}$, block starts moving up.

(c) for $h_2 = \frac{h}{4}$, block starts moving up.

(d) for $h_2 = \frac{h}{5}$, block starts moving up.

18. Find the minimum height h_1 (in situation-1), for which the block just starts to move up.

(a) $\frac{2h}{3}$ (b) $\frac{5h}{4}$

(c) $\frac{5h}{3}$ (d) $\frac{5h}{2}$

PAPER - II

Section 1 (Maximum Marks : 24)

- *This section contains SIX (06) questions.*
- *Each question has FOUR options for correct answer(s). ONE OR MORE THAN ONE of these four option(s) is (are) correct option(s).*
- *For each question, choose the correct option(s) to answer the question.*
- *Answer to each question will be evaluated according to the following marking scheme:*

Full Marks :	*+4*	*If only (all) the correct option(s) is (are) chosen.*
Partial Marks :	*+3*	*If all the four options are correct but ONLY three options are chosen.*
Partial Marks :	*+2*	*If three or more options are correct but ONLY two options are chosen, both of which are correct options.*
Partial Marks :	*+1*	*If two or more options are correct but ONLY one option is chosen and it is a correct option.*
Zero Marks :	*0*	*If none of the options is chosen (i.e. the question is unanswered).*
Negative Marks :	*–2*	*In all other cases.*

- *For Example: If first, third and fourth are the ONLY three correct options for a question with second option being an incorrect option; selecting only all the three correct options will result in +4 marks. Selecting only two of the three correct options (e.g. the first and fourth options), without selecting any incorrect option (second option in this case), will result in +2 marks. Selecting only one of the three correct options (either first or third or fourth option), without selecting any incorrect option (second option in this case), will result in +1 marks. Selecting any incorrect option(s) (second option in this case), with or without selection of any correct option(s) will result in -2 marks.*

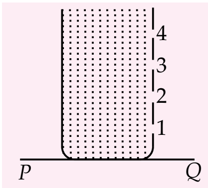
1. A particle of mass m (starting from rest) moves vertically upwards from the surface of earth under an external force $\vec{F}$ which varies with height z as, $\vec{F} = (2 - \alpha z)m\vec{g}$, where α is a positive constant. If H is the maximum height to which particle rises, then

(a) $H = \frac{1}{\alpha}$ (b) $H = \frac{2}{\alpha}$

(c) work done by $\vec{F}$ during motion upto $\frac{H}{2}$ is $\frac{3mg}{2\alpha}$.

(d) velocity of particle at $\frac{H}{2}$ is $\sqrt{\frac{g}{\alpha}}$.

2. A cylindrical vessel of 90 cm height is kept filled upto the brim. It has four holes 1, 2, 3, 4 which are respectively at heights of 20 cm, 30 cm, 40 cm and 50 cm from the horizontal floor PQ. The water falling at the maximum horizontal distance from the vessel comes from



(a) hole number 4

(b) hole number 3

(c) hole number 2

(d) hole number 1.

3. A heavy particle is tied to the end A of a string of length 1.6 m. Its other end O is fixed. It revolves as a conical pendulum with the string making 60° with the vertical. Then

(a) its period of revolution is $\frac{4\pi}{7}$ s.

(b) the tension in the string is double the weight of the particle.

(c) the velocity of the particle is $2.8\sqrt{3}$ m s^{-1}

(d) the centripetal acceleration of the particle is $9.8\sqrt{3}$ m s^{-2}.

4. In displacement method, the distance between object and screen is 96 cm. The ratio of length of two images formed by a convex lens placed between them is 4.84.

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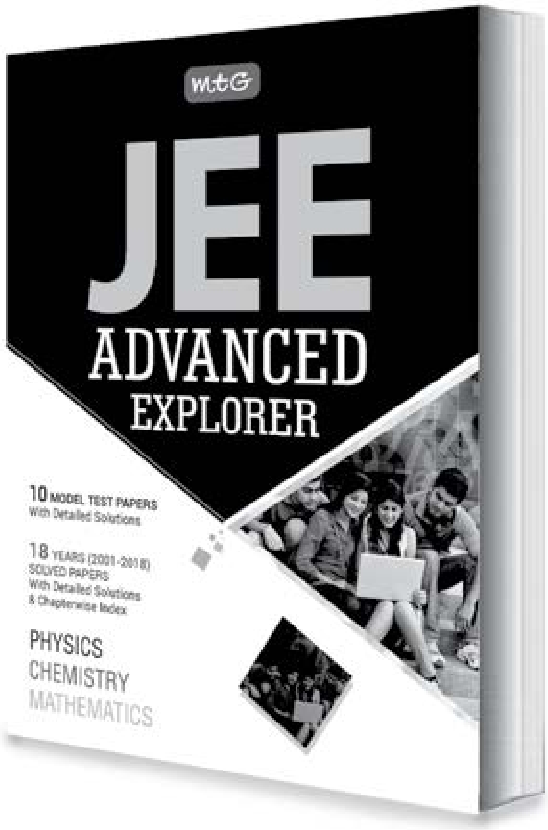

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(a) ratio of the length of object to the length of shorter image is $\frac{11}{5}$.
(b) distance between the two positions of the lens is 36 cm.
(c) focal length of the lens is 22.5 cm.
(d) distance of the lens from the shorter image is 30 cm.

5. It is observed that only 0.39% of the original radioactive sample remains undecayed after eight hours. Select the correct options.
(a) The half-life of that substance is 1 hour.
(b) The mean life of the substance is $\frac{1}{\ln 2}$ hour.
(c) Decay constant of the substance is ln 2 per hour.
(d) If the number of radioactive nuclei of this substance at a given instant is 10^8, then the number left after 30 min would be $\sqrt{2}\times 10^7$.

6. Three SHMs 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 $A(1+\sqrt{2})$.
(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 resultant motion is not simple harmonic.

Section 2 (Maximum Marks : 24)

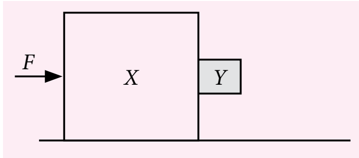
- ***This section contains EIGHT (08) questions. The answer to each question is a NUMERICAL VALUE.***
- ***For each question, enter the correct numerical value (in decimal notation, truncated/rounded-off to the second decimal place; e.g., 6.25, 7.00, –0.33, –.30, 30.27, –127.30) using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.***
- ***Answer to each question will be evaluated according to the following marking scheme:***

Full Marks : +3 *If ONLY the correct numerical value is entered as answer.*

Zero Marks :0 *In all other cases.*

7. A boy is standing on top of a tower of height 85 m and throws a ball in the vertically upward direction with a certain speed. If 5.25 seconds later he hears the ball hitting the ground, then find the speed (in m s^{-1}) with with which the boy threw the ball. (Take g = 10 m s^{-2}, speed of sound in air = 340 m s^{-1})

8. Consider the system shown below.

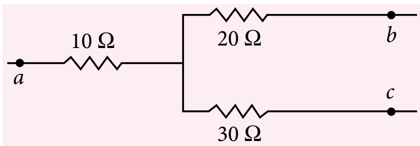


A horizontal force F is applied to a block X of mass 8 kg such that the block Y of mass 2 kg adjacent to it does not slip downwards under gravity. There is no friction between the horizontal plane and the base of the block X. The coefficient of friction between the surfaces of blocks X and Y is 0.5. Take acceleration due to gravity to be 10 m s^{-2}. Find the minimum value of F (in N).

9. A hollow sphere of radius 2 cm is attached to an 18 cm long thread to make a pendulum. Find the time period of oscillation of this pendulum. Find the time period (in s) of the pendulum.

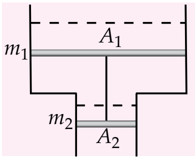
10. A sphere of mass 20 kg is suspended by a metal wire of unstretched length 4 m and diameter 1 mm. When in equilibrium, there is a clear gap of 2 mm between the sphere and the floor. The sphere is gently pushed aside so that the wire makes an angle θ with the vertical and is released. Find the maximum value of θ (in degree) so that the sphere does not rub the floor. Young's modulus of the metal of the wire is 2.0×10^{11} N m^{-2}. Make appropriate approximations.

11. Figure given here shows a part of an electric circuit. The potentials at the points a, b and c are 30 V, 12 V and 2 V respectively. Find the current (in A) through 10 Ω resistor.



12. Consider a vertical tube open at both ends. The tube consists of two parts, each of different cross-sections and each part having a piston which can move smoothly in respective tubes. The two pistons are joined together by an inextensible wire. The combined mass of the two piston is 5 kg and area of cross-section of the upper piston is 10 cm^2 greater than that of the lower piston. Amount of gas enclosed by the pistons is one mole. When the gas is heated slowly, pistons move by

50 cm. Rise in the temperature of the gas, is $\frac{X}{R}$ K where R is universal gas constant.



Find the value of X. (Use g = 10 m s^{-2} and outside pressure = 10^5 N m^{-2})

13. Photons of energy 7 eV are incident on two metals A and B with work functions 6 eV and 3 eV respectively. The minimum de Broglie wavelength of the emitted photoelectrons with maximum energies are λ_A and λ_B, respectively. Find λ_A/λ_B.

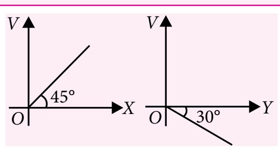
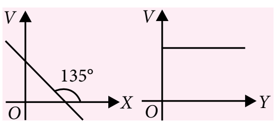
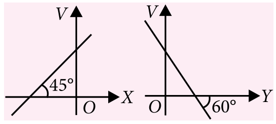
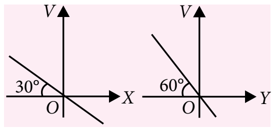
14. In the Bohr model of a π-mesic atom, a π-meson of mass m_π and of the same charge as the electron is in a circular orbit of radius r about the nucleus with an orbital angular momentum $h/2\pi$. If the radius of a nucleus of atomic number Z is given by $R = 1.6 \times 10^{-15} Z^{1/3}$m, then the limit on Z for which π-mesic atoms might exist is
(Given $\varepsilon_0 h^2/\pi m_e e^2 = 0.53$ Å and $m_\pi/m_e = 264$)

Section 3 (Maximum Marks : 12)

- ***This section contains FOUR (04) questions.***
- ***Each question has TWO (02) matching lists: List-I and List-II.***
- ***FOUR options are given representing matching of elements from List-I and List-II. ONLY ONE of these four options corresponds to a correct matching.***
- ***For each question, choose the option corresponding to the correct matching.***
- ***For each question, marks will be awarded according to the following marking scheme:***

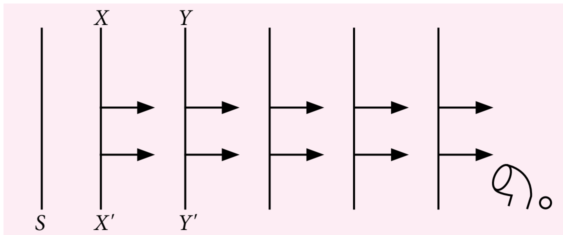
Full Marks : ***+3*** ***If ONLY the option corresponding to the correct matching is chosen.***
Zero Marks : ***0*** ***If none of the options is chosen (i.e. the question is unanswered).***
Negative Marks : ***-1*** ***In all other cases.***

15. List-I shows graphs of electric potential V versus X and Y in a certain region for four situations. List-II gives angle which the electric field vector makes with positive X-direction.

List I		List II	
(A)		(P)	0°
(B)		(Q)	$\tan^{-1}(3)$
(C)		(R)	120°
(D)		(S)	150°

	A	B	C	D
(a)	R	P	S	Q
(b)	S	P	R	Q
(c)	Q	R	Q	P
(d)	P	S	Q	S

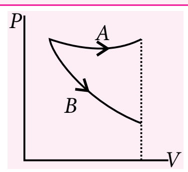
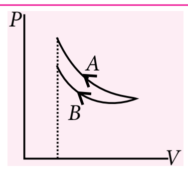
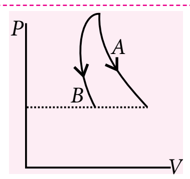
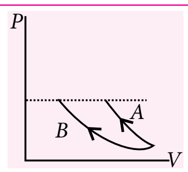
16. Consider a large plane diaphragm 'S' emitting sound and a detector 'O'. The diagram shows plane wavefronts for the sound wave travelling in air towards right when source, observer and medium are at rest. XX' and YY' are fixed imaginary planes. List-I describes about the motion of source, observer or medium and List-II describes various effects. Match them correctly.



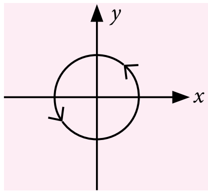
List I		List II	
(A)	Source starts moving towards right.	(P)	Distance between any two wavefronts will increase.
(B)	Air starts moving towards right.	(Q)	Distance between any two wavefronts will decrease.
(C)	Observer and source both move towards left with same speed.	(R)	The time needed by sound to move from plane XX' to YY' will increase.
(D)	Source and medium (air) both move towards right with same speed.	(S)	The time needed by sound to move from plane XX' to YY' will decrease.
		(T)	Frequency received by observer increases.

	A	B	C	D
(a)	R, S	T, P	Q, S	R
(b)	T, P	Q, R	S	T, S
(c)	Q, S, T	P, S	P, R	S, T
(d)	P	Q	S	T

17. An ideal gas undergoes two processes A and B. One of these is isothermal and the other is adiabatic.

	List I		List II
(A)		(P)	Heat supplied during curve A is positive
(B)		(Q)	Work done by gas in both processes positive
(C)		(R)	Internal energy increases in adiabatic process
(D)		(S)	Temperature of gas in process B is constant

18. A circular current carrying loop of 100 turns and radius 10 cm is placed in x-y plane as shown in figure.



A uniform magnetic field $\vec{B} = (-\hat{i} + \hat{k})$ tesla is present in the region. If current in the loop is 5 A, then match the List I with List II.

	List I		List II
(A)	Magnitude and direction of moment (in Am) of the loop are	(P)	Zero
(B)	Magnitude and direction of torque (in Nm) on the loop are	(Q)	5π
(C)	Magnitude and direction of net force (in N) on the current loop are	(R)	along positive z-axis
(D)	Direction of magnetic field of loop at the center is	(S)	along negative y-axis

	A	B	C	D
(a)	S	R	P, Q	P
(b)	Q, R	Q, R	P	R
(c)	Q, S	P, R	S	R
(d)	P	Q	R	S

SOLUTIONS

PAPER - I

1. (a,c,d) : By momentum conservation,

$2(4) - 4(2) = 2(-2) + 4(v_2)$

$\Rightarrow v_2 = 1 \text{ m s}^{-1}$

(b) $e = \dfrac{\text{velocity of separation}}{\text{velocity of approach}} = \dfrac{1-(-2)}{4-(-2)} = \dfrac{3}{6} = 0.5$

(c) At maximum deformed state, by conservation of momentum, common velocity is $v = 0$.

Potential energy at maximum deformed state

U = loss in kinetic energy during deformation

or $U = \left(\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2h_2^2\right) - \frac{1}{2}(m_1 + m_2)v^2$

$= \left(\frac{1}{2}2(4)^2 + \frac{1}{2}4(2)^2\right) - \frac{1}{2}(2+4)(0)^2$

or $U = 24$ J

(d) $J_0 = m_1(v - u_1) = m_2(v - u_2)$

$= 2(0 - 4) = -8$ N s

$= 4(0 - 2) = -8$ N s

or $= 4(0 - 2) = -8$ N s

$J_R = m_1(v_1 - v) = m_2(v - v_2)$

$= 2(-2 - 0) = -4$ N s

or $= 4(0 - 1) = -4$ N s

or $e = \dfrac{J_R}{J_0} \Rightarrow J_R = eJ_0 = (0.5)(-8) = -4$ N s

2. (a, b) : Suppose shell destroy the bomb at time t.

Then for horizontal motion,

$t(200 + 200\cos\theta) = \sqrt{3} \times 1000$

$t(1 + \cos\theta) = 5\sqrt{3}$ ...(i)

For vertical motion,

$\frac{1}{2}gt^2 + (200\sin\theta)t - \frac{1}{2}gt^2 = 1000$

$\therefore \sin\theta\, t = 5$

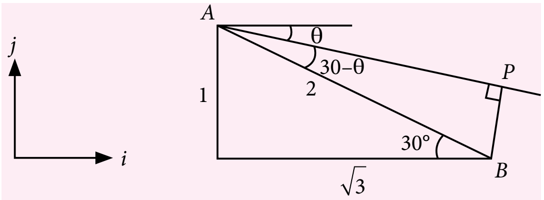
From eqn. (i) and (ii), we get

$$\frac{\sin\theta}{1+\cos\theta}=\frac{1}{\sqrt{3}}$$

On solving, $\theta = 60°$

(b) $\vec{v}_A = 200\,\hat{i}$

$\vec{v}_B = -200\cos 53°\,\hat{i} + 200\sin 53°\,\hat{j}$



$$= -200 \times \frac{3}{5}\hat{i} + 200\times\frac{4}{5}\hat{j} \;=\; -120\,\hat{i} + 160\,\hat{j}$$

$$\vec{v}_{A/B} = \vec{v}_A - \vec{v}_B \;= (200+120)\,\hat{i} - 160\,\hat{j}$$

$$\tan\theta = \left|-\frac{160}{320}\right| = \frac{1}{2}$$

$AB = 2$ km

BP = minimum distance = $AB\sin(30° - \theta)$

$= 2[\sin 30° \cos\theta - \cos 30° \sin\theta]$

$$= 2\left[\frac{1}{2}\times\frac{2}{\sqrt{5}} - \frac{\sqrt{3}}{2}\times\frac{1}{\sqrt{5}}\right] = \frac{2-\sqrt{3}}{\sqrt{5}}\text{km}$$

3. (a,c) : Surface tension = Surface energy per unit area

r = Radius of each small drop

R = Radius of big drop

$$n\times\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3 \text{ or } R = n^{1/3}\times r$$

Initial surface energy, $E_i = n \times 4\pi r^2 \times T = nE$

Final surface energy, $E_f = 4\pi R^2 \times T = 4\pi r^2 n^{2/3} T = n^{2/3}E$

Energy released = $E_i - E_f = E(n - n^{2/3})$

4. (c) : The magnetic force on a moving charge is given by $\vec{F} = q(\vec{v}\times\vec{B})$

Case I : $\vec{F} = -5\sqrt{2}\times 10^{-3}\,\hat{k}$ N, $\vec{v} = \dfrac{10^6}{\sqrt{2}}(\hat{i}+\hat{j})$ m s^{-1}

Let $\vec{B} = B_x\,\hat{i} + B_y\,\hat{j} + B_z\,\hat{k}$

Hence, $-5\sqrt{2}\times 10^{-3}\,\hat{k}$

$$= (10^{-5})\left(\frac{10^6}{\sqrt{2}}\right)(\hat{i}+\hat{j})\times\left(B_x\,\hat{i} + B_y\,\hat{j} + B_z\,\hat{k}\right)$$

$$= \frac{10}{\sqrt{2}}\left[B_z\,\hat{i} - B_z\,\hat{j} + (B_y - B_x)\,\hat{k}\right]$$

Comparing the coefficients of $\hat{i}, \hat{j}$ and $\hat{k}$,

$B_z = 0$ and $B_y - B_x = -10^{-3}$ T ...(i)

Case II : $\vec{F} = F_2\,\hat{j}, \vec{v} = 10^6\,\hat{k}$ m s^{-1}, $\vec{B} = B_x\,\hat{i} + B_y\,\hat{j} + 0\,\hat{k}$

$$F_2\,\hat{j} = (10^{-5})(10^6)\,\hat{k}\times[B_x\,\hat{i} + B_y\,\hat{j}] \;= 10B_x\,\hat{j} - 10B_y\,\hat{i}$$

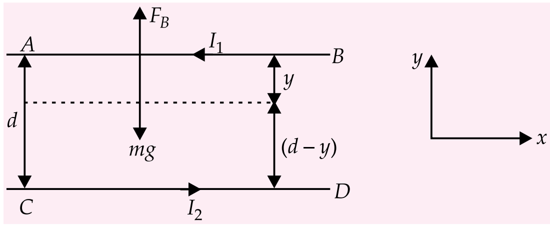
We get, $B_y = 0$,

$\therefore$ $B_x = 10^{-3}$ tesla and $F_2 = 10B_x = 10^{-2}$ N [using (i)]

Hence, (i) $\vec{B} = 10^{-3}$ T $\hat{i}$ (ii) $F_2 = 10^{-2}$ N

5. (c) : The force per unit length between two parallel wires is given by $\dfrac{F}{L} = \dfrac{\mu_0 I_1 I_2}{2\pi d}$

For antiparallel currents, force is repulsive.



In equilibrium position, $\dfrac{mg}{L}(-\hat{j}) + \dfrac{\mu_0 I_1 I_2}{2\pi d}(\hat{j}) = 0$

or $\dfrac{\mu_0 I_1 I_2}{2\pi d} = \dfrac{mg}{L}$ ...(i)

If upper wire is displaced downward from its equilibrium position, the resultant force on it,

$$\vec{F}_R = \frac{\mu_0 I_1 I_2 L}{2\pi(d-y)}\hat{j} - mg\,\hat{j} \quad ...(ii)$$

Put equation (i) in equation (ii), we get

$$\vec{F}_R = \frac{\mu_0 I_1 I_2 L}{2\pi}\left[\frac{1}{d-y} - \frac{1}{d}\right]\hat{j}\;;\; \vec{F}_R = \frac{\mu_0 I_1 I_2 L}{2\pi}\frac{y}{(d-y)d}\hat{j}$$

For small displacement, If $y << d$, $\vec{F}_R = \dfrac{\mu_0}{2\pi}\dfrac{I_1 I_2 L}{d^2}\,y\,\hat{j}$

Note that displacement of wire is along negative y-direction and resultant magnetic force is along positive y-direction. Thus the motion is simple harmonic.

From equation (i), $m = \dfrac{(\mu_0 I_1 I_2)L}{2\pi d g}$

Acceleration of wire, $a = \dfrac{F_R}{m} = -\dfrac{g}{d}y$

(As y is opposite to a)

Thus, $\omega = \sqrt{\dfrac{g}{d}} = \dfrac{2\pi}{T}$ or $T = 2\pi\sqrt{\dfrac{d}{g}}$

$$T = 2\times 3.14\sqrt{\frac{0.01}{9.8}} = 0.2 \text{ s}$$

6. (a,b,c,d) : In the equilibrium position, the net force on the partition will be zero.

Hence, pressure on both sides are same.

Hence, (a) is correct.

Initially, $PV = nRT$

$$n_1 = \frac{P_1V_1}{RT_1} = \frac{PV}{RT} \text{ and } n_2 = \frac{(2P)(2V)}{RT} = 4\frac{PV}{RT}$$

$\Rightarrow \; n_2 = 4n_1$

Moles remain conserved.

Finally, pressure becomes equal in both parts.

$\therefore \; P_1 = P_2$

Using, $P_1V_1 = n_1RT_1$

$P_2V_2 = n_2RT_2 \Rightarrow T_1 = T_2 = T$

$$\therefore \; \frac{V_1}{V_2} = \frac{n_1}{n_2} = \frac{1}{4} \;\Rightarrow\; V_2 = 4V_1$$

Also, $V_1 + V_2 = 3V$

$$\Rightarrow \; V_1 + 4V_1 = 3V \;\Rightarrow\; V_1 = \frac{3}{5}V \text{ And } V_2 = \frac{12}{5}V$$

Hence, (b) and (c) are correct.

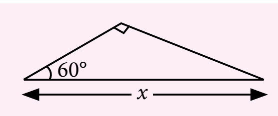
In compartment (I)

$P_1'V_1 = n_1RT_1$

$$P_1'\left(\frac{3V}{5}\right) = \left(\frac{PV}{RT}\right)RT \;;\; P_1' = \frac{5PV}{3V} = \frac{5}{3}P$$

Hence, (d) is also correct.

7. (2):



$$\cos\theta = \frac{R^2 + x^2 - L^2}{2Rx} \Rightarrow R^2 + x^2 - L^2 = 2Rx\cos\theta \quad \text{...(i)}$$

$$R^2 + x^2 - L^2 = 2Rx\cdot\frac{1}{2} \;;\; x^2 - Rx + (R^2 - L^2) = 0$$

$$x = \frac{R \pm \sqrt{R^2 - 4(R^2 - L^2)}}{2}$$

Putting $R = \frac{1}{\sqrt{3}}$ m and $L = 1$ m, we get $x = \frac{2}{\sqrt{3}}$ m

Again differentiating eqn. (i)

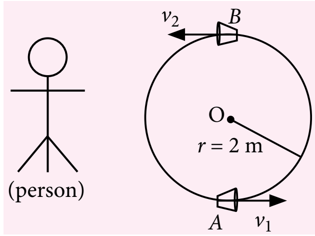
$$\Rightarrow \; 2x\frac{dx}{dt} = 2R\left[\frac{d\theta}{dt}x(-\sin\theta) + \cos\theta\frac{dx}{dt}\right]$$

$$\frac{dx}{dt}[x - R\cos\theta] = -Rx\sin\theta\frac{d\theta}{dt}$$

$$\therefore \; -\frac{dx}{dt} = v \text{ and } \frac{d\theta}{dt} = \omega \;\Rightarrow\; v = \frac{Rx\sin\theta\omega}{x - R\cos\theta}$$

$$= \frac{\frac{1}{\sqrt{3}}\frac{2}{\sqrt{3}}\cdot\frac{\sqrt{3}}{2}.\omega}{\frac{2}{\sqrt{3}} - \frac{1}{\sqrt{3}}\cdot\frac{1}{2}} = \frac{\frac{\omega}{\sqrt{3}}}{\frac{1}{\sqrt{3}}\frac{3}{2}} = \frac{2\omega}{3} = \frac{2}{3}(3) \;= 2 \text{ m s}^{-1}$$

8. (1.2) : Let v_1 and v_2 be the speed of whistle



$v_s = |v_1| = |v_2| = \omega r$

$= 15 \times 2 = 30 \text{ m s}^{-1}$

Here,

$$f_{max} = f\left[\frac{v}{v - v_s}\right]$$

$$f_{min} = f\left[\frac{v}{v + v_s}\right]; \frac{f_{max}}{f_{min}} = \frac{v + v_s}{v - v_s} = \frac{330 + 30}{330 - 30} = \frac{360}{300}$$

$$\frac{f_{max}}{f_{min}} = \frac{6}{5} = 1.2$$

Technology can kill/transform 45m jobs globally by '25: Report

Advent of digital technologies will have an impact on jobs, and up to 45 million jobs can get displaced or transformed by 2025, a report has warned.

Productivity gains through digital technologies will help create upto 65 million new jobs during the same timeframe, a McKinsey Global Institute report said on 29th March.

"Retraining and redeployment will be essential to help some 10-45 million workers whose jobs could be displaced or transformed," the report said.

It can be noted that the report comes amid tech industry leaders raising question marks over the skillsets of Indian techies and wondering whether they will be helpful in the future.

According to the report, core digital sectors like IT/software and business process management, digital communication and electronics manufacturing can double their GDP contributions upto USD 435 billion by 2025.

"All stakeholders will need to respond effectively if India is to achieve its digital potential," it added.

Companies will have to invest in building capabilities, including through partnering with universities, governments will have to invest in digital infrastructure and public data that can be used by organisations, it said.

To capture the gains, we will require more ease in creating, scaling and exiting startups as well as policies to facilitate retraining, it said.

Individuals will have to keep abreast of the changes and keep themselves informed on how the digital economy can impact their work, it recommended.

The study said up to USD 150 billion each of benefits can be accrued in sectors, including agriculture, education, energy, financial services, healthcare, logistics and retail if they embrace digital technologies.

It, however, added while domestic businesses are digitising "rapidly", it is not an even growth as there are laggards everywhere.

Courtesy : The Times of India

9. (1885.6) : $d = 1$ cm, $v = 20$ m s^{-1},
$u = 0$, $\rho = 900$ kg m^{-3} = 0.9 g cm^{-3}

Volume = $\left(\frac{4}{3}\right)\pi r^3 = \frac{4}{3}\pi(0.5)^3 = 0.5238$ cm^3

$\therefore$ Mass = $V\rho = 0.5238 \times 0.9 = 0.4714258$ g

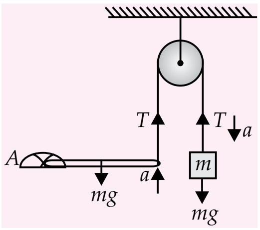
$\therefore$ Mass of 2000 halistones
= $2000 \times 0.4714 = 942.8$ g

$\therefore$ Rate of change of momentum per unit area
= $942.8 \times 20 \times 10^{-3} = 18.856$ N m^{-2}

$\therefore$ Total force exerted
= $18.856 \times 100 \simeq 1885.6$ N

10. (3.75) : For the rod :

$$T(l) - mg\left(\frac{l}{2}\right) = \frac{ml^2}{3} \times \frac{a}{l} \quad \ldots(i)$$



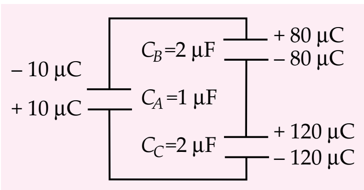
For the block :

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

Solving (i) and (ii) we get,

$$a = \frac{3g}{8} = 3.75 \text{ m s}^{-2}$$

11. (3025) : Initial state



In final state, applying conservation of charge

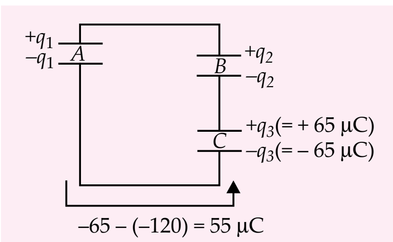
$-q_1 - q_3 = 10 - 120 = -110$ μC ...(i)

$-q_2 + q_3 = -80 + 120 = +40$ μC ...(ii)

In the final state

$$\frac{q_1}{C_A} = \frac{q_2}{C_B} + \frac{q_3}{C_C}$$

$$\Rightarrow \frac{q_1}{1} = \frac{q_2}{2} + \frac{q_3}{2}$$



$\Rightarrow q_2 + q_3 = 2q_1$

Solving, we get

$q_3 = 65$ μC

The charge on lower plate of capacitor C_C changes from – 120 μC to – 65 μC.

Hence, the charge flowing through shown connecting wire is (120 – 65) = 55 μC.

Final charges, $q_3 = 65$ μC, $q_2 = 25$ μC, $q_1 = 45$ μC

Heat produced = $U_i - U_f$

$$= \left[\frac{(120\ \mu C)^2}{2\times 2\ \mu F} + \frac{(80\ \mu C)^2}{2\times 2\ \mu F} + \frac{(10\ \mu C)^2}{2\times 1\ \mu F}\right] - \left[\frac{(65\ \mu C)^2}{2\times 2\ \mu F} + \frac{(25\ \mu C)^2}{2\times 2\ \mu F} + \frac{(45\ \mu C)^2}{2\times 1\ \mu F}\right]$$

= 3025 μJ

12. (14) : By approximate method

For the interval in which temperature falls from 40°C to 35°C

$$\langle T \rangle = \frac{40+35}{2} = 37.5°\text{C}$$

From equation, $\left\langle \frac{dT}{dt} \right\rangle = -k(\langle T \rangle - T_0)$ ...(i)

$$\Rightarrow \frac{(35°\text{C} - 40°\text{C})}{10\,\text{min}} = -k(37.5°\text{C} - 20°\text{C})$$

$$\Rightarrow k = \frac{1}{35}\text{min}^{-1}$$

For the interval in which temperature falls from 35°C to 30°C

$$\langle T \rangle = \frac{35+30}{2} = 32.5°\text{C}$$

Using equation (i), required time,

$$t = \frac{5}{12.5} \times 35 \text{ min} = 14 \text{ min}.$$

13. (589.2) : In the given Young's double slit experiment, $\mu = 1.6$, $t = 1.964$ micron = 1.964×10^{-6} m

We know, number of fringes shifted = $\frac{(\mu-1)t}{\lambda}$

So, the corresponding shift

= No. of fringes shifted × fringe width

$$= \frac{(\mu-1)t}{\lambda} \times \frac{\lambda D}{d} = \frac{(\mu-1)tD}{d} \quad \ldots(i)$$

Again, when the distance between the screen and the slits is doubled,

fringe width = $\frac{\lambda}{d}(2D)$ ...(ii)

From eqn. (i) and (ii), we get

$$\frac{(\mu-1)tD}{d} = \frac{\lambda \times 2D}{d}$$

$$\Rightarrow \lambda = \frac{(\mu-1)t}{2} = \frac{(1.6-1)\times(1.964)\times 10^{-6}}{2} = 589.2 \text{ nm}$$

14. (1.88) : Given $q = 3.14 \times 10^{-6}$ C,
$r = 20$ cm $= 20 \times 10^{-2}$ m ; $\omega = 60$ rad s^{-1}.

So, time take for 1 revolution = $\frac{2\pi}{60}$

$$\therefore \text{ Current } i = \frac{q}{t} = \frac{3.14\times 10^{-6} \times 60}{2\pi} = 30\times 10^{-6} \text{ A}$$

Then electric field, $E = \dfrac{1}{4\pi\varepsilon_0}\dfrac{qx}{(x^2+r^2)^{3/2}}$

Magnetic field, $B = \dfrac{\mu_0}{4\pi}\cdot\dfrac{2\pi r^2 i}{(x^2+r^2)^{3/2}}$

$$\therefore \quad \frac{E}{B} = \frac{qx}{\mu\varepsilon_0 2\pi r^2 i} = \frac{qxc^2}{2\pi r^2 i}$$

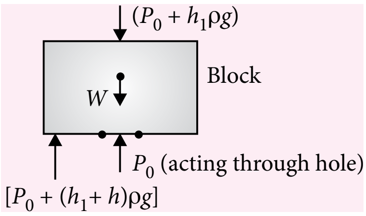
Putting the given values, we get $\dfrac{E}{B} = 1.88 \times 10^{15}$ m s^{-1}

15. (b) : The magnet moving to the left increases the flux entering into coil P and decreases the flux leaving coil Q. Hence the near end of coil P must develop north pole to compensate the increasing flux (Lenz law). Similarly the near end of coil Q must develop north pole to compensate the decreasing flux. Hence current must flow from A to B in P and D to C in Q.

16. (a) : Both magnet and coil Q are fixed. Hence flux through Q does not change. Hence no induced current will flow in Q. When P is moved away, the flux entering it decreases, hence the nearer face must develop south pole. Hence current must flow from B to A in P.

17. (a) : When h_2 is decreased, the upward force (buoyancy) on the block decreases while the downward force (weight) remains the same. Thus, the block does not move up and remains at its original position.

18. (c) :



For the equilibrium of the block,

$(P_0 + h_1\rho g)\,[\pi(2r)^2] + \pi(2r)^2\;h(\rho/3)g$

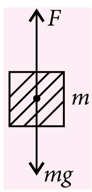
$= [P_0 + (h_1 + h)\,\rho g]\,[\pi(2r)^2 - \pi r^2] + P_0(\pi r^2)$

On solving, we get $h_1 = \dfrac{5h}{3}$

PAPER - II

1. (b, c, d) : Resultant force on particle = $F - mg$

$= (2 - \alpha z)mg - mg = (1 - \alpha z)mg$



$$mv\frac{dv}{dz} = (1-\alpha z)\,mg$$

$$\Rightarrow \quad \frac{v^2}{2} = \left(z - \frac{\alpha z^2}{2}\right)g$$

For maximum height, $v = 0 \Rightarrow \quad z = H = \dfrac{2}{\alpha}$

Velocity at $\dfrac{H}{2}\left(=\dfrac{1}{\alpha}\right)$

$$v = \sqrt{2\left(z - \frac{\alpha z^2}{2}\right)g} = \sqrt{2\left(\frac{1}{\alpha} - \frac{1}{2\alpha}\right)g} = \sqrt{\frac{g}{\alpha}}$$

$$W = \int_0^{1/\alpha}(2-\alpha z)\,mg\,dz$$

$$= mg\left[2z - \frac{\alpha z^2}{2}\right]_0^{1/\alpha} = mg\left[\frac{2}{\alpha} - \frac{1}{2\alpha}\right] = \frac{3mg}{2\alpha}$$

2. (a, b) : The maximum horizontal distance from the vessel comes from hole number 3 and 4

$v = \sqrt{2gh}$ where h is height of hole from top.

Horizontal distance, $x = vt = \sqrt{2gh}\sqrt{\dfrac{2(H-h)}{g}}$

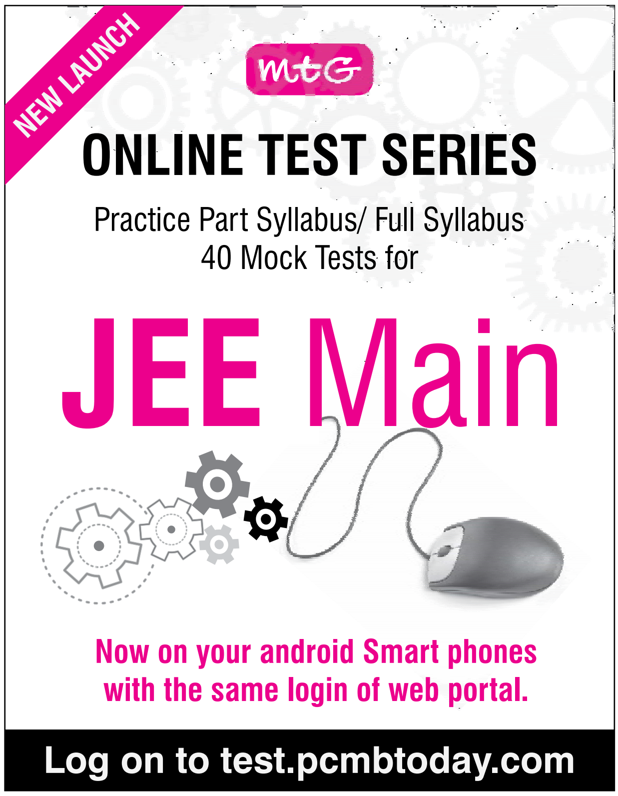
$x = 2\sqrt{h(H-h)}$

3. (b, c, d) : As $T\sin 60° = \dfrac{mv^2}{r}$ ...(i)

$T\cos 60° = mg$ ...(ii)

$\therefore \quad \tan 60° = \dfrac{v^2}{rg}$

$v = \sqrt{rg\tan 60°}$; Also, $r = l\sin 60°$



Time period $= \frac{2\pi r}{v} = \frac{2\pi r}{\sqrt{rg\tan 60°}}$

$= 2\pi\sqrt{\frac{r}{g\tan 60°}} = 2\pi\sqrt{\frac{l\cos 60°}{g}} \simeq \frac{4\sqrt{2}}{10}\pi$

From equation (ii) $T = 2mg$

$v = \sqrt{l\, g\sin 60° \tan 60°} = 2.8\sqrt{3}\ \text{m s}^{-1}$

$\therefore$ Centripetal acceleration $a_c = \frac{v^2}{r} = \frac{rg\tan 60°}{r}$

$= g\tan 60° = 9.8\sqrt{3}\ \text{m s}^{-2}$

4. (a, b, d) : Given, $D = 96$ cm, $\frac{I_2}{I_1} = 4.84$

Let $I_1 = a$ and $I_2 = 4.84\,a$

$\therefore\ O = \sqrt{I_1 I_2} = 2.2\,a$

(a) Required ratio $= \frac{2.2a}{a} = \frac{11}{5}$

(b) Also, $\frac{v_1}{u_1} = \frac{11}{5}$ ...(i)

$v_1 + u_1 = 96$ ...(ii)

$\therefore\ v_1 + \frac{5v_1}{11} = 96 \Rightarrow \frac{16v_1}{11} = 96$ or $v_1 = 66$ cm

$\therefore\ u_1 = 30$ cm

Distance between two positions

$= v_1 - v_2 = 66 - 30 = 36$ cm $(\because\ u_1 = v_2)$

(c) $\frac{1}{f} = \frac{1}{66} + \frac{1}{30} = \frac{30+66}{30\times 66}$

$\Rightarrow\ f = \frac{30\times 66}{96} = \frac{330}{16} = 20.625$ cm

(d) $u_1 = 30$ cm

5. (a, b, c) : Here, $t = 8$ hours

As $N = N_0 e^{-\lambda t}$

$\frac{N}{N_0} = e^{-\lambda t}$; $0.0039 = e^{-\lambda 8}$

$e^{\lambda 8} = \frac{1}{0.0039} \simeq 256$ or $e^{\lambda 8} = 2^8$

Taking natural logarithm on both sides, we get

$8\lambda = 8\ln 2$; $\lambda = \ln 2$ per hour

Option (c) is correct.

$T_{1/2} = \frac{\ln 2}{\lambda} = 1$ hour . Option (a) is correct.

Mean time, $\tau = \frac{1}{\lambda} = \frac{1}{\ln 2}$ hour . Option (b) is correct.

$N = (10)^8\left(\frac{1}{2}\right)^{\left(\frac{1}{2}\right)} = \frac{1}{\sqrt{2}}\times 10^8$ or $N = 5\sqrt{2}\times 10^7$

Option (d) is incorrect.

6. (a, c) : According to the principle of superposition, the resultant displacement is

$x = x_1 + x_2 + x_3$

$= A\sin\omega t + A\sin\left(\omega t + \frac{\pi}{4}\right) + A\sin\left(\omega t + \frac{\pi}{2}\right)$

$= A\left[\left\{\sin\omega t + \sin\left(\omega t + \frac{\pi}{2}\right)\right\} + \sin\left(\omega t + \frac{\pi}{4}\right)\right]$

$= A\left[2\sin\left(\omega t + \frac{\pi}{4}\right)\cos\frac{\pi}{4} + \sin\left(\omega t + \frac{\pi}{4}\right)\right]$

$= A\left[\frac{2}{\sqrt{2}}\sin\left(\omega t + \frac{\pi}{4}\right) + \sin\left(\omega t + \frac{\pi}{4}\right)\right]$

$= A(\sqrt{2}+1)\sin\left(\omega t + \frac{\pi}{4}\right)$

Thus, resultant motion is SHM with an amplitude $A(\sqrt{2}+1)$.

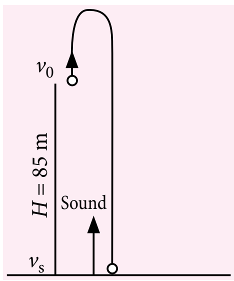
Again energy of resultant motion

$= \frac{1}{2}m\omega^2\left[A(\sqrt{2}+1)\right]^2 = \frac{1}{2}m\omega^2 A^2(3+2\sqrt{2})$

$= (3+2\sqrt{2})$ times energy of any one motion.

7. (8) : Time taken to reach sound after hit $t_s = \frac{H}{v_s}$

$t_s = \left(\frac{85}{340}\right)$ s ; $t_s = 0.25$ s



If for the ball, time of flight T_f is,

$T_f + t_s = 5.25$ s ;

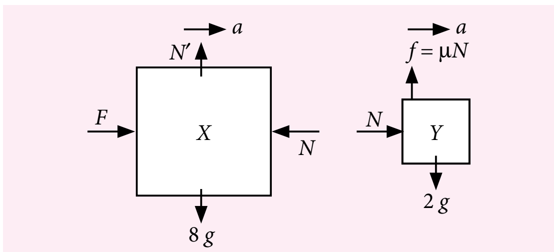
$T_f = 5.25 - 0.25 = 5$ s

For ball, $v_0 t - \frac{1}{2}gt^2 = -H$

$\Rightarrow\ v_0(5) - \frac{1}{2}10(5)^2 = -85$

$5v_0 = 40$ or $v_0 = 8\ \text{m s}^{-1}$

8. (200) : According to free body diagram



$F - N = 8a$ ...(i)

$N = 2a$ ...(ii)

$f = 2g = 20$

$\Rightarrow\ \mu N = 20$ or $N = \frac{20}{\mu} = \frac{20}{0.5} = 40$

$\Rightarrow \quad a = \dfrac{N}{2} = \dfrac{40}{2} = 20 \text{ m s}^{-2}$ [Using (ii)]

$F = N + 8a = 10\, a$ [From equation (i)]

$\quad = 10 \times 20 = 200\, N$

9. (0.89) : According to energy conservation,

$$mg\,(0.2)\,(1 - \cos\theta) + \frac{1}{2} I\omega^2 = C \qquad \ldots\text{(i)}$$

Again, $I = \dfrac{2}{3} m(r)^2 + m\,(0.18 + 0.02)^2$

$= \dfrac{2}{3} m\,(0.0004) + m\,(0.04) = m\left(\dfrac{0.1208}{3}\right)$

where I is the moment of inertia about the point of suspension A. From equation (i), differentiating and putting the value of I in equation

$$\frac{d}{dt}\left[mg(0.2)(1-\cos\theta)+\frac{1}{2}\frac{0.1208}{3}m\omega^2\right] = \frac{d}{dt}(C)$$

$$\Rightarrow \quad mg\,(0.2)\sin\theta\frac{d\theta}{dt}+\frac{1}{2}\left(\frac{0.1208}{3}\right)m2\omega\frac{d\omega}{dt}=0$$

$\Rightarrow \quad 2\sin\theta = -\dfrac{0.1208}{3}\alpha$ [because, $g = 10 \text{ m s}^{-2}$]

$\Rightarrow \quad \dfrac{\alpha}{\theta} = -\dfrac{6}{0.1208}$ [For S.H.M $\sin\theta \simeq \theta$]

$\quad \omega^2 = 49.669 \Rightarrow \omega = 7.05$

So, $T = \dfrac{2\pi}{\omega} = 0.89$ s

10. (77.6) : $m = 20$ kg, $L = 4$ m,

$2r = 1$ mm, $r = 5 \times 10^{-4}$ m.

At equilibrium, $T = mg$

When it moves at an angle θ and released, the tension T at lowest point is

$$\Rightarrow \quad T = mg + \frac{mv^2}{r}$$

The change in tension is due to centrifugal force

$$\Delta T = \frac{mv^2}{r}$$

Again, by work energy principle

$\dfrac{1}{2}mv^2 - 0 = mgr\,(1 - \cos\theta) \Rightarrow v^2 = 2gr\,(1 - \cos\theta)$

So, $\Delta T = \dfrac{m[2gr(1-\cos\theta)]}{r} = 2mg - 2\,mg\cos\theta$

$\Rightarrow \quad 2mg\cos\theta = 2mg - \dfrac{YA\Delta L}{L} \Rightarrow \cos\theta = 1 - \dfrac{YA\Delta L}{L(2mg)}$

$$\Rightarrow \quad \cos\theta = 1-\left[\frac{2\times10^{11}\times4\times3.14\times(5)^2\times10^{-8}\times2\times10^{-3}}{4\times2\times20\times10}\right]$$

$\Rightarrow \quad \cos\theta = 0.215 \Rightarrow \theta = 77.6°$

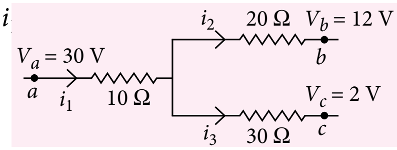
11. (1) : Let potential at the point common to three resistors be x V. i_1, i_2 and i_3 be the currents through the resistors as shown in figure.

Then, $(30 - x) = 10\, i$

$\quad (x - 12) = 20\, i_2$

$\quad (x - 2) = 30\, i_3$

Since, $\quad i_1 = i_2 + i_3$



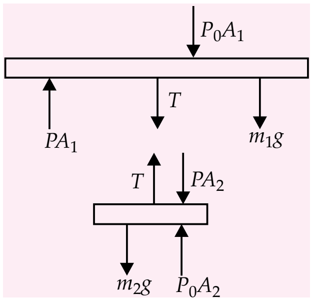
$\Rightarrow \quad \dfrac{30-x}{10} = \dfrac{x-12}{20} + \dfrac{x-2}{30} \Rightarrow 30 - x = \dfrac{x-12}{2} + \dfrac{x-2}{3}$

$\Rightarrow \quad 30 - x = \dfrac{3x-36+2x-4}{6} \Rightarrow 180 - 6x = 5x - 40$

$\Rightarrow \quad 11x = 220 \Rightarrow x = \dfrac{220}{11} = 20$ V

$\quad i_1 = \dfrac{30-20}{10} = 1$ A

12. (75) : Due to the heating, pressure inside is not changed. Let inside pressure be P.



Then for the equilibrium of the system,

$P(A_1 - A_2) = P_0(A_1 - A_2) + (m_1 + m_2)g$

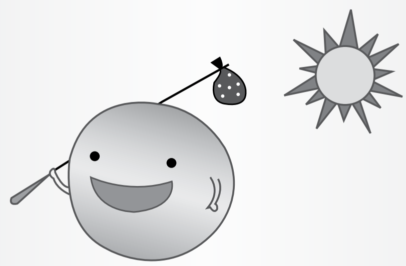
$\Rightarrow \quad P\Delta V = (P_0\,\Delta A + mg)l$

$\quad l$ is displacement of the piston.

$\quad P\Delta V = nR\Delta T$

COMIC CAPSULE

A PHOTON CHECKS INTO A HOTEL AND IS ASKED IF HE NEEDS ANY HELP WITH HIS LUGGAGE



"NO THANKS, I'M TRAVELLING LIGHT."

$$\Delta T = \frac{P\Delta V}{nR} = \frac{(P_0 \Delta A + mg)l}{nR}$$

$$= \frac{(10^5 \times 10^{-3} + 5 \times 10)(50 \times 10^{-2})}{1 \times R} \Rightarrow \Delta T = \frac{75}{R} \text{ K}$$

$\therefore \quad X = 75$

13. (2) : de-Broglie wavelength $\lambda = \dfrac{h}{\sqrt{2mKE}}$

When KE is maximum the λ is minimum.

$KE_{max} = hf - \phi$

In case of A, $KE_A \Rightarrow 7 - 6 = 1$ eV

In case of B, $KE_B \Rightarrow 7 - 3 = 4$ eV

$$\frac{\lambda_A}{\lambda_B} = \sqrt{\frac{KE_B}{KE_A}} \Rightarrow \sqrt{\frac{4}{1}} = \frac{2}{1}$$

14. (37) : Angular momentum, $mvr = \dfrac{nh}{2\pi}$ ...(i)

Centripetal force, $\dfrac{mv^2}{r} = \dfrac{Ze^2}{4\pi\varepsilon_0 r^2}$ ...(ii)

From eqns (i) and (ii)

$$r = \frac{\varepsilon_0 n^2 h^2}{\pi m_\pi e^2 Z} = \left(\frac{\varepsilon_0 h^2}{\pi m_e e^2}\right)\left(\frac{m_e}{m_\pi}\right)\frac{1}{Z}$$

$$= \frac{0.53 \times 10^{-10}}{264 Z} = \frac{200 \times 10^{-15}}{Z} \quad \left[\because \frac{m_\pi}{m_e} = 264\right]$$

Since r cannot be less than nuclear radius,

$$r > 1.6 Z^{\frac{1}{3}} \times 10^{-15} \text{ m}$$

or $$\frac{200 \times 10^{-15}}{Z} > 1.6 \times 10^{-15} Z^{\frac{1}{3}}$$

$$\Rightarrow \quad Z < \left(\frac{200}{1.6}\right)^{\frac{3}{4}} \approx 37$$

15. (b) **16. (c)**

17. A $\rightarrow$ (P, Q); B $\rightarrow$ (R, S); C $\rightarrow$ (P, Q); D $\rightarrow$ (R, S)

18. (b) : $M = NIA = 100 \times 5 \times \pi(0.1)^2 = 5\pi$ A m

As the current in xy plane is along anticlockwise direction, so moment will be along z-axis by right hand thumb rule.

$$\vec{M} = 5\pi \hat{k}$$

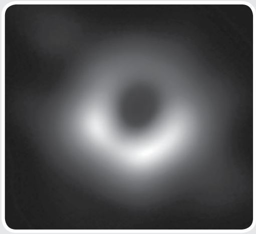
$$\vec{\tau} = \vec{M} \times \vec{B} = 5\pi \hat{k} \times (-\hat{i} + \hat{k}) = -5\hat{j}$$

Net force on a closed current carrying loop in a uniform magnetic field is zero.

Magnetic field at center of loop due to current in loop will be along +ve z-axis from right hand thumb rule.

☺☺

Black Hole Image Makes History; NASA Telescopes Coordinated Observations



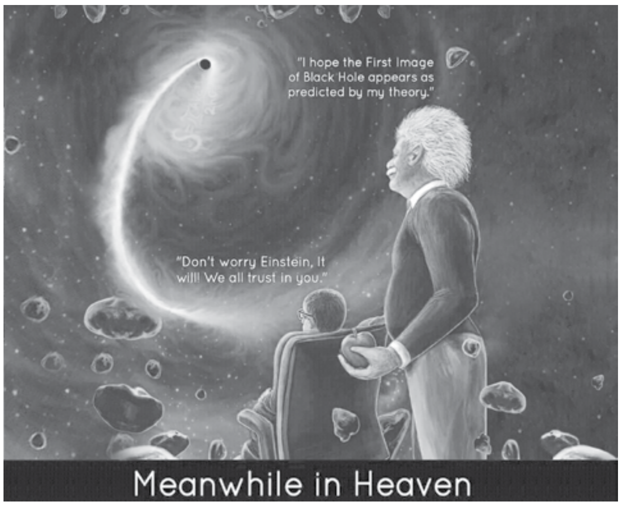
A black hole and its shadow have been captured in an image for the first time, a historic feat by an international network of radio telescopes called the Event Horizon Telescope (EHT). EHT is an international collaboration whose support in the U.S. includes the National Science Foundation. Using the Event Horizon Telescope, scientists obtained an image of the black hole at the center of galaxy M87, outlined by emission from hot gas swirling around it under the influence of strong gravity near its event horizon.

The stunning new image shows the shadow of the supermassive black hole in the center of Messier 87 (M87), an elliptical galaxy some 55 million light-years from Earth. This black hole is 6.5 billion times the mass of the Sun. Catching its shadow involved eight ground-based radio telescopes around the globe, operating together as if they were one telescope of the size of our entire planet.

To complement the EHT findings, several NASA spacecraft were part of a large effort, coordinated by the EHT's Multiwavelength Working Group, to observe the black hole using different wavelengths of light. As a part of this effort, NASA's Chandra X-ray Observatory, Nuclear Spectroscopic Telescope Array (NuSTAR) and Neil Gehrels Swift Observatory space telescope missions, all attuned to different varieties of X-ray light, turned their gaze to the M87 black hole around the same time as the EHT in April 2017. NASA's Fermi Gamma-ray Space Telescope was also watching for changes in gamma-ray light from M87 during the EHT observations. If EHT observed changes in the structure of the black hole's environment, data from these missions and other telescopes could be used to help figure out what was going on.

While NASA observations did not directly trace out the historic image, astronomers used data from NASA's Chandra and NuSTAR satellites to measure the X-ray brightness of M87's jet. Scientists used this information to compare their models of the jet and disk around the black hole with the EHT observations. NASA space telescopes have previously studied a jet extending more than 1,000 light-years away from the center of M87. The jet is made of particles traveling near the speed of light, shooting out at high energies from close to the event horizon. The EHT was designed in part to study the origin of this jet and others like it.

Source: NASA Website

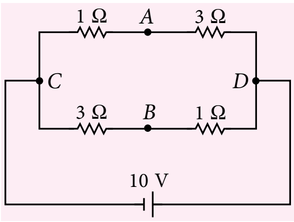


PRACTICE PAPER

AIIMS

Exam on
25^{th} & 26^{th} May 2019

1. A battery of emf 10 V is connected to resistances as shown in figure. Find the potential difference between the points A and B.

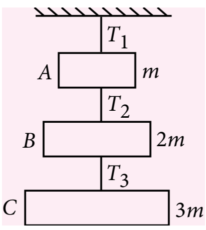


(a) 2.0 V (b) 5.0 V (c) 7.5 V (d) 9.5 V

2. Find the temperature at which the rms speed of an atom of argon gas is equal to the rms speed of helium at –20°C. The atomic mass of argon is 39.9 u and that of helium is 4.0 u.
(a) 2000 K (b) 2523.68 K
(c) 1723 K (d) 1500 K

3. The electric field in a region is given by $\vec{E} = \frac{3}{5}E_0\hat{i} + \frac{4}{5}E_0\hat{j}$ with $E_0 = 2.0 \times 10^3$ N C^{-1}. Find the flux of this field through a rectangular surface of area 0.2 m^2 parallel to the Y-Z plane.
(a) 50 N m^2 C^{-1} (b) 240 N m^2 C^{-1}
(c) 110 N m^2 C^{-1} (d) 105 N m^2 C^{-1}

4. For the system shown in figure, find $T_1 : T_2 : T_3$. The connecting string are light inextensible and the system is stationary with respect to ground.



(a) 3 : 2 : 1 (b) 5 : 3 : 2 (c) 1 : 4 : 7 (d) 6 : 5 : 3

5. A point moves along a circle with a velocity $v = kt$, where $k = 0.5$ m s^{-2}. What is the magnitude of the total acceleration of the point at the instant when it covered the n^{th} ($n = 0.10$) fraction of the circle after the beginning of motion?
(a) 2.0 m s^{-2} (b) 4.0 m s^{-2}
(c) 2.5 m s^{-2} (d) 0.8 m s^{-2}

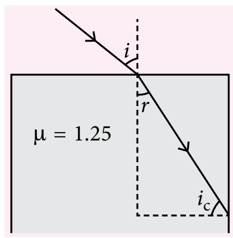
6. A solenoid of length 0.4 m and having 500 turns of wire carries a current of 3 A. A thin coil having 10 turns of wire and of radius 0.01 m carries a current of 0.4 A. Calculate the torque required to hold the coil in the middle of the solenoid with its axis perpendicular to the axis of the solenoid. ($\mu_0 = 4\pi \times 10^{-7}$ V s A^{-1} m^{-1}).
(a) 6×10^{-7} N m (b) 5×10^{-5} N m
(c) 5.92×10^{-7} N m (d) 7.5×10^{-6} N m

7. A satellite is placed in a circular orbit around earth at such a height that it always remains stationary with respect to earth surface. In such case, its height from the earth surface is
(a) 32000 km (b) 36000 km
(c) 3400 km (d) 4800 km

8. Young's modulus of steel is 19×10^{10} N m^{-2}. Find its value in dyn cm^{-2}.
(a) 1.9 (b) 190
(c) 1.9×10^{11} (d) 19×10^{11}

9. The wave described by $y = 0.25 \sin(10\pi x - 2\pi t)$, where x and y are in metre and t in seconds, is a wave travelling along the
(a) – ve x direction with amplitude 0.25 m and wavelength $\lambda = 0.2$ m.
(b) – ve x direction with frequency 1 Hz.
(c) + ve x direction with frequency π Hz and wavelength $\lambda = 0.2$ m.
(d) + ve x direction with frequency 1 Hz and wavelength $\lambda = 0.2$ m.

10. For a situation shown in figure, find the maximum angle i for which the light suffers total internal reflection at the vertical surface.

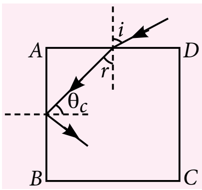


(a) 48.6° (b) 50° (c) 52.5° (d) 37.5°

11. A ball of mass m is thrown vertically upwards. Another ball of mass 2 m is thrown at an angle θ with the vertical. Both of them remain in air for the same period of time. What is the ratio of the heights attained by the two balls?
(a) 1 : 3 (b) 2 : 1 (c) 1 : 1 (d) 2 : 3

12. What is the capacitance of a 1 m long hi-fi cable where the central conductor is 1 mm in diameter and the shield is 5 mm in diameter?
(a) 34.5 pF (b) 36 pF (c) 40 pF (d) 15 pF

13. A ray of light falling on a glass slab makes an angle of 45° with the vertical, as shown in figure. Find the refractive index of glass if total internal reflection takes place at the vertical face AB.



(a) 2.5 (b) 2.0 (c) 1.22 (d) 3.2

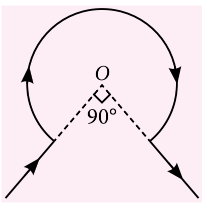
14. A 10 V zener diode along with a series resistance is connected across a 40 V supply. Calculate the minimum value of the resistance required, if the maximum zener current is 50 mA.
(a) 500 Ω (b) 71 Ω (c) 600 Ω (d) 200 Ω

15. If the unit of mass is 1 kg, the unit of length is 1 m and the unit of time is 1 minute, the unit of pressure in N m^{-2} is
(a) $\frac{1}{60}$ (b) 3600 (c) 60 (d) $\frac{1}{3600}$

16. A particle is dropped vertically from rest from a height. The time taken by it to fall through successive distances of 1 m each will then be
(a) all equal, being equal to $\sqrt{2/g}$ second
(b) in the ratio of the square roots of the integers 1, 2, 3, ...
(c) in the ratio of the difference in the square roots of the integers *i.e.*, $\sqrt{1}, (\sqrt{2}-\sqrt{1}), (\sqrt{3}-\sqrt{2}), (\sqrt{4}-\sqrt{3}) \ldots$
(d) in the ratio of the reciprocal of the square roots of the integers, *i.e.*, $\frac{1}{\sqrt{1}}, \frac{1}{\sqrt{2}}, \frac{1}{\sqrt{3}}, \frac{1}{\sqrt{4}}$.

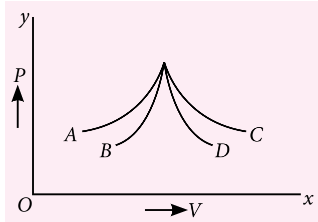
17. The length of a simple pendulum is increased by 45%. What is the percentage increase in its time period ?
(a) 44% (b) $\sqrt{44}$% (c) 10% (d) 20%

18. The wire shown in figure carries a current of 10 A. Determine the magnitude of the magnetic field at the centre O. Given radius of the bent coil is 3 cm.



(a) 2.2×10^{-5} T (b) 3×10^{-6} T
(c) 1.57×10^{-4} T (d) 4.5×10^{-2} T

19. Figure shows four PV diagrams. Which of these curves represent isothermal and adiabatic processes?



(a) C and D (b) A and C
(c) A and B (d) B and D

20. A simple pendulum with a metal bob has a time period of oscillation T. Now the bob is immersed into a liquid which is non viscous. This time, the time period is $3T$. Then the ratio of densities of metal bob and that of the liquid is
(a) 4 : 3 (b) 8 : 3 (c) 9 : 4 (d) 9 : 8

21. A wire has a resistance of 16 Ω. It is melted and drawn into a wire of half its length. Calculate the resistance of the new wire. What is the percentage change in its resistance?
(a) 25% (b) 40% (c) 50% (d) 75%

22. When an automobile moving with a speed of 36 km h^{-1} reaches an upward inclined road of angle 30°, its engine is switched off. If the coefficient of friction is 0.1, how much distance will the automobile move before coming to rest? Take $g = 10$ m s^{-2}.
(a) 8.53 m (b) 10.23 m (c) 4.5 m (d) 20.2 m

23. An electric bulb rated for 500 W at 100 V is used in circuit having a 200 V supply. Calculate the resistance R that must be put in series with the bulb, so that the bulb delivers 500 W.
(a) 15 Ω (b) 5.2 Ω (c) 7.5 Ω (d) 20 Ω

24. A mass m attached to a spring oscillates with a period 2 s. If the mass is increased by 2 kg, the period increases by 1 s. Find the initial mass m, assuming that Hooke's law is obeyed.
(a) 2.0 kg (b) 1.6 kg (c) 5.0 kg (d) 2.7 kg

25. A bar magnet of length 10 cm is placed in the magnetic meridian with its north pole pointing towards the geographical north. A neutral point is obtained at a distance of 12 cm from the centre of the magnet. Find the magnetic moment of the magnet, if $B_H = 0.34$ G.
(a) 0.747 J T^{-1} (b) 4.5 J T^{-1}
(c) 5.2 J T^{-1} (d) 5.2 J T^{-1}

26. A coil of mean area 500 cm^2 and having 1000 turns is held perpendicular to a uniform field of 0.4 gauss. The coil is turned through 180° in 1/10 second. Calculate the average induced emf.
(a) 5.2 V (b) 0.04 V (c) 7.5 V (d) 2.04 V

27. A solid cylinder rolls down an inclined plane. Its mass is 2 kg and radius 0.1 m. If the height of the inclined plane is 4 m, what is its rotational kinetic energy when it reaches foot of the plane ? Assume that the surfaces are smooth. Take moment of inertia of solid cylinder about its axis = $mr^2/2$.
(a) 26.13 J (b) 22 J (c) 15.01 J (d) 17.23 J

28. A step down transformer converts transmission line voltage from 2200 V to 220 V. Primary coil is having 5000 turns. Efficiency of transformer is 90% and output power is 8 kW. Evaluate number of turns in secondary coil and input power.
(a) 500, 7.5 kW (b) 200, 8.2 kW
(c) 500, 8.88 kW (d) 450, 7.5 kW

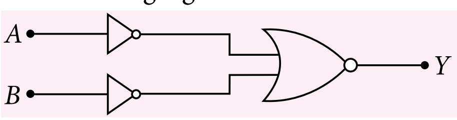
29. A particle is moving three times as fast as an electron. The ratio of the de Broglie wavelength of the particle to that of the electron is 1.813×10^{-4}. Calculate the mass of the particle. Mass of electron = 9.11×10^{-31} kg.
(a) 2.5×10^{-26} kg (b) 4×10^{17} kg
(c) 5.25×10^{25} kg (d) 1.675×10^{-27} kg

30. The number of particles scattered at 60° is 100 per minute in an α-particle scattering experiment, using gold foil. Calculate the number of particles per minute scattered at 90° angle.
(a) 25 particles min^{-1} (b) 15 particles min^{-1}
(c) 10 particles min^{-1} (d) 12 particles min^{-1}

31. A wire loaded by a weight of density 7.8 g cc^{-1} is found to be of length 100 cm. On immersing the weight in water, the length decreases by 0.20 cm. Find the original length of the wire.
(a) 98.44 cm (b) 22.23 cm
(c) 12 cm (d) 70.5 cm

32. A Carnot engine whose heat sink is at 27°C has an efficiency of 40%. By how many degrees should the temperature of source be changed to increase the efficiency by 10% of the original efficiency?
(a) 35.7°C (b) 39°C (c) 45°C (d) 40°C

33. Which logic gate is represented by the following combination of logic gates?



(a) OR (b) NAND (c) AND (d) NOR

34. The frequency band of a radio station is 5 MHz to 10 MHz. Determine the corresponding wavelength band.
(a) 10 m - 30 m (b) 30 m - 50 m
(c) 20 m - 60 m (d) 30 m - 60 m

35. A solid cylinder rolls up an inclined plane of angle of inclination 30°. At the bottom of the inclined plane the centre of mass of the cylinder has a speed of 5 m s^{-1}. How far will the cylinder go up the plane?
(a) 3.8 m (b) 4.2 m (c) 1.2 m (d) 5.0 m

36. Two slits are separated by a distance of 0.03 cm. An interference pattern is produced on a screen 1.5 m away. The fourth bright fringe is at a distance of 1 cm from the central maximum. Determine the wavelength of the light used.
(a) 2000 Å (b) 5200 Å (c) 5000 Å (d) 5500 Å

37. A uniform rod has a mass attached to one end to make it float upright in liquid. If 3.0 cm of the rod is immersed when floats in water and 3.5 cm when it floats in a liquid of specific gravity 0.9, what length of it will be immersed, when it floats in a liquid of specific gravity 1.2 ?
(a) 2.25 cm (b) 4.00 cm (c) 5.25 cm (d) 3.75 cm

38. Find the time taken by a given sample of bismuth to decay to $1/8^{th}$ of its initial value. The half-life of bismuth is 5 days.
(a) 7 days (b) 15 days (c) 10 days (d) 25 days

39. The rates of heat radiation from two patches of skin each of area *A*, on a patient's chest differ by 10%. If the patch of the lower temperature is at 300 K and emissivity of both the patches is assumed to be unity,the temperature of other patch would be
(a) 306 K (b) 312 K (c) 308.5 K (d) 307.5 K

40. What should be the height of a transmitting antenna if the TV telecast is to cover an area of radius 128 km ?
(a) 1200 m (b) 1280 m (c) 2200 m (d) 1500 m

Directions : In the following questions (41-60), 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.

41. **Assertion :** When two positive point charges move away from each other, then their electrostatic potential energy decreases.

Reason : Change in potential energy between two points is equal to the work done by electrostatic forces.

42. Assertion : During discharging of a battery potential difference across the terminals of a battery is

$V = E - ir$

$\therefore \ V < E$

Reason: Potential difference across the terminals of a battery is always less than the emf of the battery.

43. Assertion : If amplitude of simple pendulum increases, its time period also increases.
Reason : The motion of simple pendulum is simple harmonic when its amplitude is large.

44. Assertion : The surface charge densities of two spherical conductors of differential radii are equal. Then, the electric field intensities near their surface are also equal.
Reason : Surface charge density is equal to charge per unit area.

45. Assertion : In the relation $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$, where symbols have their standard meanings, μ represents linear mass density.
Reason : The frequency has the dimensions of inverse of time.

46. Assertion : The time period of revolution of a satellite close to surface of earth is smaller than that revolving away from surface of earth.
Reason : The square of time period of revolution of a satellite is directly proportional to cube of its orbital radius.

47. Assertion : If a magnet is brought closer to a current carrying loop along its axis, then current always decreases in the loop.
Reason : Magnet is always repelled by the loop.

48. Assertion : At frequency greater than resonance frequency, circuit is inductive in nature.
Reason : $X_L \propto \omega$.

49. Assertion : When a wave travels from a denser to a rarer medium, its amplitude increases.
Reason : In a rarer medium, speed of wave is more.

50. Assertion : In javelin throw, the athlete throws the projectile at an angle slightly more than 45°.
Reason : The maximum range does not depend upon angle of projection.

51. Assertion : A rocket works on the principle of conservation of linear momentum.
Reason : Whenever there is a change in momentum of one body, the same change occurs in the momentum of the second body of the same system but in the opposite direction.

52. Assertion : Magnetic field $(\vec{B})$ and electric field $(\vec{E})$ are present in a region. Net force on a charged particle in this region is zero, if $\vec{E} = \vec{B} \times \vec{v}$.
Reason : $\frac{E}{B}$ has the dimensions of velocity.

53. Assertion : If one arm of a U-tube containing a diamagnetic solution is placed in between the poles of a strong magnet with the level in line with the field, the level of the solution falls.
Reason : Diamagnetic substances are repelled by the magnetic field.

54. Assertion : The power of a pump which raises 100 kg of water in 10 s to a height of 100 m is 10 kW.
Reason : The practical unit of power is horse power.

55. Assertion : Torque due to force is maximum when angle is 90°.
Reason : The unit of torque is newton-metre.

56. Assertion : Second orbit circumference of hydrogen atom is two times the de-Broglie wavelength of electrons in that orbit.
Reason : de-Broglie wavelength of electron in ground state is minimum.

57. Assertion : A transistor amplifier in common emitter configuration has a low input impedance.
Reason : The base to emitter region is forward biased.

58. Assertion : Young's modulus for a perfectly plastic body is zero.
Reason : For a perfectly plastic body, restoring force is zero.

59. Assertion : Sound produced by an open organ pipe is richer than the sound produced by a closed organ pipe.
Reason : Outside air can enter the pipe from both ends, in case of open organ pipe.

60. Assertion : In Young's double slit experiment, ratio $\frac{I_{max}}{I_{min}}$ is infinite.
Reason : If width of any one of the slits is slightly increased, then this ratio will decrease.

SOLUTIONS

1. **(b) :** Total resistance, $R = \frac{4\times 4}{4+4} = 2\,\Omega$

Current, $I = \frac{V}{R} = \frac{10\text{ V}}{2\,\Omega} = 5\text{ A}$

As each of the two parallel branches has same resistance ($4\,\Omega$), so the current of 5 A is divided equally through them.
Current through each branch = 5/2 = 2.5 A
Now $V_C - V_A = 2.5 \times 1 = 2.5$ V
and $V_C - V_B = 2.5 \times 3 = 7.5$ V
$\therefore \quad V_A - V_B = (V_C - V_B) - (V_C - V_A) = 5.0$ V

2. **(b) :** Let the molecules of argon gas at temperature T_{Ar} and that of helium gas at temperature T_{He} have the same *rms* speed. The *rms* speed of a gaseous molecule is given by

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

Then, according to the question, we have

$$v_{rms} = \sqrt{\frac{3RT_{Ar}}{M_{Ar}}} = \sqrt{\frac{3RT_{He}}{M_{He}}} \;;\; T_{Ar} = \left(\frac{M_{Ar}}{M_{He}}\right)T_{He} \quad \ldots\text{(i)}$$

where M_{Ar} and M_{He} are the molecular weights of argon and helium respectively.
Here, $M_{Ar} = 39.9$ u, $M_{He} = 4.0$ u, $T_{He} = (273 - 20)$ K $= 253$ K
Putting these values in equation (i), we get

$$T_{Ar} = \left(\frac{39.9\text{ u}}{4.0\text{ u}}\right)\times 253\text{ K} = 2523.68\text{ K}$$

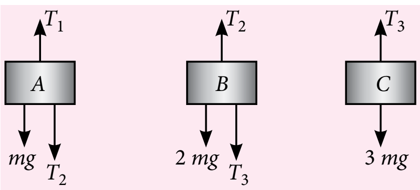
3. **(b) :** Here, $\vec{E} = \frac{3}{5}E_0\hat{i} + \frac{4}{5}E_0\hat{j} \;;\; \phi = ?$

$\therefore \quad E_x = \frac{3}{5}E_0$ and $E_y = \frac{4}{5}E_0$ where,

$E_0 = 2.0 \times 10^3$ N C^{-1}, $A = 0.2$ m^2 parallel to Y-Z plane
Normal to the area will be along X - axis.

$\therefore \quad \phi = E_x \times A = \frac{3}{5}E_0 \times 0.2 = 240$ N m^2 C^{-1}

4. **(d) :** Let us identify the forces acting on the blocks A, B and C and draw their *FBD* (free-body diagram) as shown in figure.



Since the system is stationary, the net force on each block will be zero.
Thus, for block A : $T_1 - (mg + T_2) = 0$ ...(i)
for block B : $T_2 - (2mg + T_3) = 0$ ...(ii)
for block C : $T_3 - 3\,mg = 0$ ...(iii)
Adding equations (i), (ii) and (iii), we get
$T_1 - 6\,mg = 0 \Rightarrow T_1 = 6\,mg$
Substituting the value of T_1 in eq. (i), we get $T_2 = 5\,mg$
From equation (iii), we get $T_3 = 3\,mg$
Thus, $T_1 : T_2 : T_3 = 6 : 5 : 3$.

5. **(d) :** Given : $v = kt$. Hence, tangential acceleration is

$$a_t = \frac{dv}{dt} = k \quad \ldots\text{(i)}$$

and radial acceleration is, $a_r = \frac{v^2}{r} = \frac{k^2t^2}{r}$ ...(ii)

Since the velocity v of the point is not constant, but changes with time, the distance covered by it in t seconds is $\int_0^t v\,dt$. If during this time t, the point covers the n^{th} fraction of the circle, then the distance covered is $2\pi rn$.
Hence,

$$2\pi rn = \int_0^t v\,dt = \int_0^t kt\,dt \;\Rightarrow\; 2\pi rn = \frac{kt^2}{2} \;\Rightarrow\; t^2 = \frac{4\pi rn}{k} \quad \ldots\text{(iii)}$$

From equations (ii) and (iii), we get

$$a_r = \frac{k^2}{r}\cdot\frac{4\pi rn}{k} = 4\pi nrk$$

The magnitude of the net acceleration is, therefore,

$$a = \sqrt{a_t^2 + a_r^2} = \sqrt{k^2 + 16\pi^2 n^2 k^2} \;\Rightarrow\; a = 0.8\text{ m s}^{-2}.$$

6. **(c) :** For solenoid, $l = 0.4$ m, $N_1 = 500$, $I_1 = 3$ A
For coil, $N_2 = 10$, $r = 0.01$ m, $I_2 = 0.4$ A
Field inside the solenoid,
$B = \frac{\mu_0 N_1 I_1}{l}$, along the axis of solenoid.
Magnetic moment of coil,
$m = N_2 I_2 A = N_2 I_2 \pi r^2$, along the axis of coil.
As the axis of the coil is perpendicular to the axis of solenoid, $\vec{m}$ and $\vec{B}$ will be perpendicular to each other.
Required torque,

$$\tau = mB\sin\theta = N_2 I_2 \pi r^2 \cdot \frac{\mu_0 N_1 I_1}{l} \cdot \sin 90°$$

On solving, we get $\tau = 5.92 \times 10^{-6}$ N m

7. **(b)** 8. **(d)**

9. **(d) :** The given equation is
$y = 0.25\sin(10\pi x - 2\pi t)$
As terms containing x and t have opposite signs, therefore, the wave is travelling along positive x- direction.
Compare with standard equation, $y = r\sin\left[\frac{2\pi}{\lambda}x - \frac{2\pi}{T}t\right]$

We have, $\frac{2\pi}{\lambda} = 10\pi \;\therefore\; \lambda = \frac{2\pi}{10\pi} = 0.2$ m

and $\frac{2\pi}{T} = 2\pi \;\therefore\; T = 1$ s, $\upsilon = \frac{1}{T} = 1$ Hz

10. (a) : The critical angle i_c is given by

$$\sin i_c = \frac{1}{\mu} = \frac{1}{1.25} = \frac{4}{5}$$

As $i_c + r = 90°$, therefore

$$\sin r = \sin(90° - i_c) = \cos i_c = \sqrt{1 - \left(\frac{4}{5}\right)^2} = \frac{3}{5}$$

From Snell's law, $\dfrac{\sin i}{\sin r} = 1.25$

or $\sin i = 1.25 \times \sin r = 1.25 \times \dfrac{3}{5} = 0.75$ or $i = 48.6°$

If the angle of incidence at vertical surface is greater than i_c, then i will be less than 48.6°. Hence the maximum value of i, for which total internal reflection occurs at the vertical surface, is 48.6°.

11. (c) : Time of flight of the ball thrown vertically upwards, $T_1 = \dfrac{2u_1}{g}$

Time of flight of the ball thrown at an angle θ with vertical,

$$T_2 = \frac{2u_2 \cos\theta}{g}$$

As $T_1 = T_2$

$$\therefore \quad \frac{2u_1}{g} = \frac{2u_2\cos\theta}{g} \quad \text{or} \quad u_1 = u_2 \cos\theta$$

Now $H_1 = \dfrac{u_1^2}{2g}$ and $H_2 = \dfrac{u_2^2\cos^2\theta}{2g}$

$$\therefore \quad \frac{H_1}{H_2} = \frac{u_1^2}{u_2^2\cos^2\theta} = \frac{u_2^2\cos^2\theta}{u_2^2\cos^2\theta} = 1:1$$

12. (a) : Here, $C = ?$, $L = 1$ m

$r_a = \dfrac{1}{2}$ mm = 0.5 mm = 5×10^{-4} m

$r_b = \dfrac{5}{2}$ mm = 2.5 mm = 2.5×10^{-3} m

For a cylindrical capacitor,

$$C = \frac{2\pi\varepsilon_0 L}{\log_e\left(\frac{r_b}{r_a}\right)} = \frac{4\pi\varepsilon_0 L}{2\log_e(r_b/r_a)} = \frac{1\times1}{9\times10^9\times2\log_e\left(\frac{2.5\times10^{-3}}{5\times10^{-4}}\right)}$$

$$C = \frac{1}{18\times10^9\log_e 5} = \frac{10^{-9}}{18\times1.609} = 3.45\times10^{-11}\ \text{F}$$

$= 34.5 \times 10^{-12}$ F = 34.5 pF

13. (c) : For total internal reflection of the light ray at the face AB of the slab, the angle of incidence must be equal to or greater than the critical angle θ_c for the glass-air interface. From the given figure,

$$\frac{\sin i}{\sin r} = n \Rightarrow \frac{\sin 45°}{\sin r} = n \Rightarrow \sin r = \frac{1}{\sqrt{2}n} \qquad \ldots\text{(i)}$$

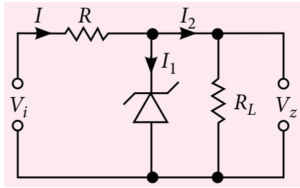
The critical angle is given by

$$\sin\theta_c = \frac{1}{n} \Rightarrow \sin(90° - r) = \frac{1}{n} \Rightarrow \cos r = \frac{1}{n} \qquad \ldots\text{(ii)}$$

Squaring and adding equations (i) and (ii),

$$1 = \frac{1}{2n^2} + \frac{1}{n^2} = \frac{3}{2n^2} \Rightarrow n^2 = \frac{3}{2} \Rightarrow n = \sqrt{\frac{3}{2}} = 1.22.$$

14. (c) : In figure $V_i = 40$ V, $I_1 = 50$ mA



∴ Maximum current,

$I = I_1 + I_2 = 50 + 0$

$= 50$ mA $= 50 \times 10^{-3}$A

This is because maximum current flows through zener diode, so $I_2 = 0$.

V_z = Voltage drop across zener diode = 10 V

As I is maximum, so maximum value of R is

$$R = \frac{V_i - V_z}{I} = \frac{40 - 10}{50\times10^{-3}} = 600\ \Omega$$

15. (d) : As pressure = $[\text{ML}^{-1}\text{T}^{-2}]$

$$\therefore \quad \frac{u_2}{u_1} = \frac{[\text{M}_2\text{L}_2^{-1}\text{T}_2^{-2}]}{[\text{M}_1\text{L}_1^{-1}\text{T}_1^{-2}]}$$

$$= \left(\frac{1\,\text{kg}}{1\,\text{kg}}\right)^1\left(\frac{1\,\text{m}}{1\,\text{m}}\right)^{-1}\left(\frac{60\,\text{sec}}{1\,\text{sec}}\right)^{-2} = \frac{1}{3600}$$

$$\therefore \quad u_2 = \frac{1}{3600}u_1 = \frac{1}{3600}\,\text{N m}^{-2}$$

16. (c) : Using the relation, $s = ut + \frac{1}{2}at^2$, time taken to fall a distance s, when $u = 0$, $a = g$ will be $t = \sqrt{2s/g}$.

Let t_1, t_2, t_3 ... be the time taken to fall 1 m, 2 m, 3 m ... respectively. Then

$$t_1 = \sqrt{\frac{2\times1}{g}}; t_2 = \sqrt{\frac{2\times2}{g}}; t_3 = \sqrt{\frac{2\times3}{g}}$$

So the time taken to fall 1 m

$= t_1 - 0 = \sqrt{2/g}(\sqrt{1} - 0)$

time taken to fall 2nd metre

$= (t_2 - t_1) = \sqrt{2/g}(\sqrt{2} - \sqrt{1})$

time taken to fall 3rd metre

$= (t_3 - t_1) = \sqrt{2/g}(\sqrt{3} - \sqrt{2})$

∴ ratio of successive 1 m distance

$= \sqrt{1} : (\sqrt{2} - \sqrt{1}) : (\sqrt{3} - \sqrt{2}) : \ldots.$

17. (d) : As $T = 2\pi\sqrt{l/g}$ or $T \propto \sqrt{l}$

$$l' = l + \frac{45}{100}l = 1.45l$$

$$\frac{T'}{T}=\sqrt{\frac{l'}{l}}=\sqrt{\frac{1.45\,l}{l}}=1.2$$

% increase in time period = $\left(\frac{T'-T}{T}\right)\times 100$ = 20%

18. (c) : As θ (rad) = $\frac{\text{Arc}}{\text{Radius}}$

$\therefore \quad \frac{3\pi}{2}=\frac{l}{r}$ or $l=\frac{3\pi r}{2}$

According to Biot-Savart law, magnetic field at the centre O is

$$B=\frac{\mu_0}{4\pi}\frac{Il}{r^2}=\frac{\mu_0}{4\pi}\cdot\frac{I}{r^2}\cdot\frac{3\pi r}{2}=\frac{\mu_0}{4\pi}\cdot\frac{3}{2}\cdot\frac{\pi I}{r} = 1.57\times 10^{-4}\text{ T.}$$

19. (a) : In curves A and B, pressure and volume both increase. Therefore, temperature must rise and heat must be supplied or work is done. Therefore, A and B cannot be the required curves. Out of C and D, slope of C is smaller. Therefore, C is isothermal curve and D is adiabatic curve.

20. (d) : Let ρ_1 , ρ_2 be the density of bob and liquid respectively. When simple pendulum is oscillating in air, then $T=2\pi\sqrt{\frac{l}{g}}$

When bob of pendulum is in liquid, the period of oscillation is

$$3T=2\pi\sqrt{\frac{l}{g(1-\rho_2/\rho_1)}}$$

or $\frac{1}{3}=\sqrt{1-\rho_2/\rho_1}$ or $1-\frac{\rho_2}{\rho_1}=\frac{1}{9}$

or $\frac{\rho_2}{\rho_1}=1-\frac{1}{9}=\frac{8}{9}$ or $\frac{\rho_1}{\rho_2}=\frac{9}{8}$

21. (d) : In both cases, volume of the wire is same.

$\therefore \quad V = A'l' = Al$

or $\quad \frac{A'}{A}=\frac{l}{l'}=\frac{l}{\frac{1}{2}l}=\frac{2}{1}$

$\therefore \quad \frac{R'}{R}=\frac{\rho\frac{l'}{A'}}{\rho\frac{l}{A}}=\frac{1}{4}$ or $R'=\frac{1}{4}\times 16=4\,\Omega$

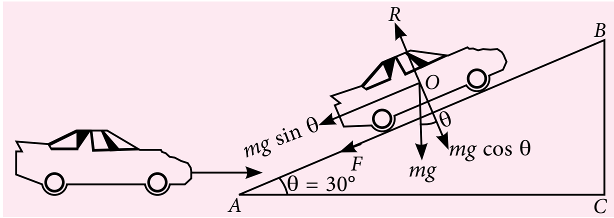
Percentage change in resistance

$$=\frac{R-R'}{R}\times 100=\frac{12}{16}\times 100=75\%.$$

22. (a) : Here, initial speed,

$$u = 36\text{ km h}^{-1} = \frac{36\times 1000}{60\times 60}\text{m s}^{-1}=10\text{ m s}^{-1}$$

$\theta = 30°$, $\mu = 0.1$, s = ?



Final velocity, $v = 0$

Work done in moving up the inclined road = K.E. of the vehicle

$(mg\sin\theta + F)\times s = \frac{1}{2}mu^2$

$(mg\sin\theta + \mu R)\times s = \frac{1}{2}mu^2$

$(mg\sin\theta + \mu mg\cos\theta)\,s = \frac{1}{2}mu^2$

$$s=\frac{\frac{1}{2}mu^2}{mg(\sin\theta+\mu\cos\theta)}=\frac{u^2}{2g(\sin\theta+\mu\cos\theta)}$$

$$=\frac{10\times 10}{2\times 10(\sin 30°+0.1\cos 30°)}=8.53\text{ m}$$

23. (d) : Resistance of the bulb,

$$R=\frac{V^2}{P}=\frac{100\times 100}{500}=20\,\Omega$$

Current through the bulb, $I=\frac{V}{R}=\frac{100}{20}=5\text{ A}$

For the same power dissipation, the current through bulb must be 5 A.

When the bulb is connected to 200 V supply, the safe resistance of the circuit should be

$$R'=\frac{V'}{I}=\frac{200}{5}=40\,\Omega$$

$\therefore$ Resistance required to be put in series with the bulb is $R' - R = 40 - 20 = 20\ \Omega$.

24. (b) : As, $T=2\pi\sqrt{\frac{m}{k}}$

where m is the mass of the oscillating body.

Case (i), T = 2 s, oscillating mass = m

Then $2=2\pi\sqrt{\frac{m}{k}}$ or $k=\frac{4\pi^2 m}{4}=\pi^2 m$

Case (ii), $T = (2 + 1) = 3$ s ; oscillating mass = $(m + 2)$

Then $3=2\pi\sqrt{\frac{m+2}{k}}=2\pi\sqrt{\frac{m+2}{\pi^2 m}}=2\sqrt{\frac{m+2}{m}}$

or $\quad 9m = 4m + 8$ or $5m = 8$ or $m = 8/5 = 1.6$ kg

25. (a) : Here, $2l$ = 10 cm, l = 5 cm = 5×10^{-2}m

r = 12 cm = 12×10^{-2} m, B_H = 0.34 G = 0.34×10^{-4} T

In this case, the neutral points lie on the equatorial line of the magnet so that at any neutral point,

$B_{equa} = B_H$ or $\frac{\mu_0}{4\pi}.\frac{m}{(r^2+l^2)^{3/2}} = B_H$

$\therefore$ Magnetic moment, $m = B_H.\frac{4\pi}{\mu_0}.(r^2+l^2)^{3/2}$

$= 0.34\times10^{-4}\times\frac{1}{10^{-7}}[5^2+12^2]^{3/2}(10^{-4})^{3/2}$

$= 0.747$ J T^{-1}.

26. (b) : Here A = 500 cm^2 = 500 × 10^{-4} m^2, N = 1000, B = 0.4 G = 0.4 × 10^{-4} T, t = 1/10 s

When the coil is held perpendicular to the field, the normal to the plane of the coil makes an angle of 0° with the field B.

$\therefore$ Initial flux, $\phi_1 = BA\cos 0° = BA$

Final flux, $\phi_2 = BA\cos 180° = -BA$

Average induced emf,

$$e = -N\left(\frac{\phi_2-\phi_1}{t}\right) = -N\left(\frac{-BA-BA}{t}\right)$$

$$= \frac{2NBA}{t} = \frac{2\times1000\times0.4\times10^{-4}\times500\times10^{-4}}{1/10}\text{V} = 0.04\text{ V}$$

27. (a) : Here, m = 2 kg, r = 0.1 m

Height of inclined plane, h = 4 m

Rotational K.E. = ?

At the top of inclined plane, the cylinder has P.E. = mgh

At the bottom of inclined plane, the cylinder has K.E. of translation $\left(\frac{1}{2}mv^2\right)$ and K.E. of rotation $\left(\frac{1}{2}I\omega^2\right)$.

$$\therefore \frac{1}{2}mv^2+\frac{1}{2}I\omega^2 = mgh$$

Now, $v = r\omega$, $I = \frac{1}{2}mr^2$

$$\therefore \frac{1}{2}m(r\omega)^2+\frac{1}{2}\times\left(\frac{1}{2}mr^2\right)\omega^2 = mgh$$

$$\frac{3}{4}mr^2\omega^2 = mgh \Rightarrow \omega^2 = \frac{4mgh}{3mr^2} = \frac{4gh}{3r^2}$$

K.E. of rotation $= \frac{1}{2}I\omega^2 = \frac{1}{2}\left(\frac{1}{2}mr^2\right)\times\frac{4gh}{3r^2}$ = 26.13 J

28. (c) : Here, E_p = 2200 V, E_s = 220 V, n_p = 5000

η = 90%, $P_0 = E_sI_s$ = 8 kW = 8000 W

n_s = ? and $P_i = E_pI_p$ = ?

As $\eta = \frac{P_0}{P_i}$ $\therefore P_i = \frac{P_0}{\eta} = \frac{8\text{ kW}}{90/100} = 8.88$ kW

As $\frac{E_s}{E_p} = \frac{n_s}{n_p}$ $\therefore n_s = \frac{E_s}{E_p}\times n_p = \frac{220}{2200}\times5000 = 500$

29. (d) : de-Broglie wavelengths of the particle and the electron are

$\lambda_p = \frac{h}{m_pv_p}$ and $\lambda_e = \frac{h}{m_ev_e}$

$\therefore \frac{\lambda_p}{\lambda_e} = \frac{m_ev_e}{m_pv_p}$ or $\frac{m_p}{m_e} = \frac{\lambda_e}{\lambda_p}.\frac{v_e}{v_p}$

Given $v_p = 3v_e$ and $\frac{\lambda_p}{\lambda_e} = 1.813\times10^{-4}$

$\therefore \frac{m_p}{m_e} = \frac{1}{1.813\times10^{-4}}\times\frac{1}{3}$

or $m_p = \frac{m_e}{3\times1.813\times10^{-4}}$ = 1.675 × 10^{-27} kg

30. (a) : Number of α-particles scattered at an angle θ,

$N \propto \frac{1}{\sin^4(\theta/2)}$ *i.e.*, $N = \frac{K}{\sin^4(\theta/2)}$,

where K is a proportionality constant.

$$\therefore \frac{N_{90°}}{N_{60°}} = \frac{\sin^4(60°/2)}{\sin^4(90°/2)}$$

or $N_{90°} = \frac{\sin^4 30°}{\sin^4 45°}\times N_{60°} = \left[\frac{1/2}{1/\sqrt{2}}\right]^4\times100$

$= \frac{100}{4} = 25$ particles min^{-1}.

31. (a) : Let l be the length and A be the area of cross section of the wire. Let V be the volume of the weight attached to the wire.

Then, $F = Mg = V\rho g = V\times7.8\times980$ dyne

Extension in wire, Δl = (100 – l) cm

Now $Y = \frac{F}{A}\times\frac{l}{\Delta l} = \frac{(V\times7.8\times980)\times l}{A\times(100-l)}$ ...(i)

When weight is immersed in water, then

apparent weight, F' = true weight – upthrust of water

$= V\rho g - V\rho_w g = V(\rho-\rho_w)g$

$= V$ (7.8 – 1) × 980 dyne = V × 6.8 × 980 dyne

Length of wire, l' = 100 – 0.20 = 99.80 cm

Extension in wire, $\Delta l'$ = (99.80 – l)

Now $Y = \frac{F'}{A}\times\frac{l}{\Delta l'} = \frac{(V\times6.8\times980)\times l}{A\times(99.80-l)}$ ...(ii)

Equating equation (i) and (ii), we have

$$\frac{V\times7.8\times980\times l}{A(100-l)} = \frac{V\times6.8\times980\times l}{A\times(99.80-l)} \Rightarrow l = 98.44\text{ cm}$$

32. (a) : Here, T_2 = 27°C = 27 + 273 = 300 K,

η = 40 %, T_1 = ?

From $\eta = 1-\frac{T_2}{T_1} \Rightarrow \frac{T_2}{T_1} = 1-\eta = 1-\frac{40}{100} = \frac{60}{100} = \frac{3}{5}$

$$T_1 = \frac{5}{3}T_2 = \frac{5}{3}\times300 = 500\text{ K}$$

Increase in efficiency = 10% of 40 = 4%

$\therefore$ New efficiency $\eta' = 40 + 4 = 44\%$

Let T_1' be the new temperature of the source.

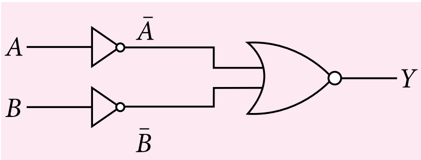
As $\eta' = 1 - \dfrac{T_2}{T_1'}$

$\therefore \quad \dfrac{T_2}{T_1'} = 1 - \eta' = 1 - \dfrac{44}{100} = \dfrac{56}{100}$

$T_1' = \dfrac{100}{56} T_2 = \dfrac{100}{56} \times 300 = 535.7\,\text{K}$

$\therefore$ Increase in temperature of source = 535.7 – 500 = 35.7 K or 35.7°C

33. (c) :



The Boolean expression for the given logic gate is $Y = \overline{\bar{A} + \bar{B}}$

Applying De Morgan's theorem $Y = \bar{\bar{A}} \cdot \bar{\bar{B}} = A \cdot B$

This is the Boolean expression for the AND gate.

34. (d) : The wavelength of electromagnetic wave is given by $\lambda = \dfrac{c}{\upsilon}$

where c is the speed of light and υ is the frequency of the wave.

When υ = 5 MHz, $\lambda = \dfrac{3 \times 10^8\ \text{m s}^{-1}}{5 \times 10^6\ \text{Hz}} = 60\,\text{m}.$

When υ = 10 MHz, $\lambda = \dfrac{3 \times 10^8\ \text{m s}^{-1}}{10 \times 10^6\ \text{Hz}} = 30\,\text{m}.$

Hence, the corresponding wavelength band is 30 m to 60 m.

35. (a) : Total initial kinetic energy of the cylinder,

$$K_i = \frac{1}{2} M v_{CM}^2 + \frac{1}{2} I_{CM} \omega^2$$

$$= \frac{1}{2} M v_{CM}^2 + \frac{1}{2} \times \frac{1}{2} M R^2 \times \frac{v_{CM}^2}{R^2}$$

$$= \frac{1}{2} M v_{CM}^2 + \frac{1}{4} M v_{CM}^2 = \frac{3}{4} M v_{CM}^2$$

Initial potential energy, $U_i = 0$

Final kinetic energy, $K_f = 0$

Final potential energy, $U_f = Mgh = Mgs \sin 30° = \dfrac{1}{2} Mgs$

where s is the distance travelled up the inclined plane and h is the vertical height covered above the bottom.

Gain in P.E. = Loss in K.E.

$$\frac{1}{2} Mgs = \frac{3}{4} M v_{CM}^2$$

$$s = \frac{3 v_{CM}^2}{2g} = \frac{3 \times (5)^2}{2 \times 9.8} = 3.8\,\text{m}.$$

36. (c) : The fringe width is given by

$$\beta = \frac{\lambda D}{d}$$

Hence, the total width of four fringes will be

$$\beta' = 4\beta = \frac{4\lambda D}{d}$$

Substituting d = 0.03 cm, D = 1.5 m = 150 cm, 4β = 1 cm,

$$1\,\text{cm} = \frac{4 \times \lambda \times 150\,\text{cm}}{0.03\,\text{cm}} = \frac{600\,\lambda}{0.03} \Rightarrow \lambda = 5000\ \text{Å}$$

37. (a) : Let a be the area of cross section of the rod and V be the volume of the mass attached.

When rod is floating in water, then

weight of float = weight of water displaced

= $(a \times 3 + V) \times 1 \times g$ ...(i)

When rod is floating in a liquid of specific gravity 0.9, weight of liquid displaced = $(a \times 3.5 + V)\ 0.9 \times g$ ...(ii)

From equation (i) and (ii),

$(a \times 3 + V) \times 1 \times g = (a \times 3.5 + V) \times 0.9 \times g$

or $3a + V = 3.15\,a + 0.9\,V$ or $V = 1.5\,a$

Let x be the depth of the rod immersed in a liquid of specific gravity 1.2.

Then weight of liquid displaced = $(x\,a + V) \times 1.2 \times g$

$\therefore$ $(xa + V) \times 1.2 \times g = (a \times 3 + V)\,g$ (Using eqn (i))

or $(x\,a + 1.5\,a) \times 1.2 = 3\,a + 1.5\,a = 4.5\,a$

or $1.2\,x + 1.8 = 4.5$ or $x = 2.25$ cm

38. (b) : $N = N_0 e^{-\lambda t}$

$$\Rightarrow \frac{N_0}{8} = N_0 e^{-\lambda t} \Rightarrow \left(\frac{1}{2}\right)^3 = e^{-\lambda t} \Rightarrow e^{\lambda t} = 2^3$$

Taking the logarithms of both sides of the preceding equation,

$\ln(e^{\lambda t}) = \ln(2^3) \Rightarrow \lambda t = 3 \ln 2$

$$\Rightarrow \left(\frac{\ln 2}{T}\right) t = 3 \ln 2 \Rightarrow t = 3T$$

Inserting T = 5 days in the preceding equation,

t = 3 × 5 days = 15 days.

39. (d) : According to stefan's law, $E_1 = \sigma T^4$

and $E_2 = \sigma (T + \Delta T)^4$

$$\therefore \frac{E_2 - E_1}{E_1} = \frac{\sigma[(T + \Delta T)^4 - T^4]}{\sigma T^4} = 4 \frac{\Delta T}{T}$$

$$\text{Now, } \frac{E_2 - E_1}{E_1} = \frac{10}{100} = 4 \frac{\Delta T}{300}$$

$$\therefore \quad \Delta T = \frac{300 \times 10}{4 \times 100} = 7.5\,\text{K}$$

$\therefore$ Temperature of other patch = $T + \Delta T$ = 300 + 7.5 = 307.5 K

40. (b) : The distance upto which the signal can be received is

$$d=\sqrt{2h_tR} \Rightarrow h_t=\frac{d^2}{2R}$$

Substituting $d = 128$ km $= 128 \times 10^3$ m and $R = 6400$ km $= 6400 \times 10^3$ m,

$$h_t=\frac{(128\times10^3)^2\ \text{m}^2}{2\times6400\times10^3\ \text{m}} = 1280\ \text{m}.$$

41. (b) : Potential energy of a system of two charges, $U=K\dfrac{q_1q_2}{r}$.

$\therefore$ When two positive point charges move away from each other then their potential energy decreases and work done by electrostatic forces can always be expressed in terms of potential energy, when the particle moves from a point.

42. (d) : During charging of battery,

$V = E + iR \ \therefore\ V > E$

43. (d)

44. (b) : As $\sigma_1 = \sigma_2$

$$\therefore \quad \frac{q_1}{4\pi r_1^2}=\frac{q_2}{4\pi r_2^2}, \text{ or } \frac{q_1}{q_2}=\frac{r_1^2}{r_2^2}$$

[let r_1 and r_2 be two different radii]

Then, the ratio of electric field intensities near the surface of spherical conductor,

$$\frac{E_1}{E_2}=\frac{q_1}{4\pi\varepsilon_0 r_1^2}\times\frac{4\pi\varepsilon_0 r_2^2}{q_2}=\frac{q_1}{q_2}\times\frac{r_2^2}{r_1^2}=1 \ \textit{i.e.}, E_1=E_2$$

45. (b) : From, $f=\dfrac{1}{2l}\sqrt{\dfrac{T}{\mu}}$ or $f^2=\dfrac{T}{4l^2\mu}$

$$\text{or,}\quad \mu=\frac{T}{4l^2f^2}=\frac{[\text{MLT}^{-2}]}{\text{L}^2\text{T}^{-2}}=\frac{\text{M}}{\text{L}}$$

$$=\frac{\text{Mass}}{\text{Length}} = \text{Linear mass density.}$$

46. (a) : The time period of satellite, $T \propto r^{3/2}$

or, $T \propto (R_e + h)^{3/2}$

For a satellite revolving close to surface of earth, $h \approx 0$

$\therefore \quad T \propto R_e^{3/2}$.

It is evident that the period of revolution of a satellite depends upon its height above the earth's surface. Greater is the height of a satellite above the earth's surface, greater is its period of revolution.

47. (d)

48. (a) : At $\omega = \omega_r$, $X_L = X_C$

At $\omega > \omega_r$, $X_L > X_C$ as, $X_L \propto \omega$ and $X_C \propto \dfrac{1}{\omega}$.

49. (a)

50. (d) : If a body is projected from a place above the surface of earth, then for the maximum range, the angle of projection should be slightly less than 45°.

51. (a)

52. (b) : As, $qE + q(v \times B) = 0$

$\therefore \quad E = -(v \times B) = (B \times v)$

53. (a) : Diamagnetic substances are repelled by a magnet. The level of a solution falls when one arm of a U-tube containing a diamagnetic solution is placed in between the poles of a strong magnet.

54. (b) : The power of the pump is the work done by it per second.

$$\therefore \quad \text{Power} = \frac{\text{work}}{\text{time}}=\frac{mgh}{t}=\frac{100\times10\times100}{10}$$

$= 10^4$ W $= 10$ kW

55. (b)

56. (b) : $mv_2r_2 = 2\left(\dfrac{h}{2\pi}\right) \ \therefore\ 2\pi r_2 = 2\left(\dfrac{h}{mv_2}\right)=2\lambda_2$

Further, $\lambda = h/p$

Speed of momentum of electron is maximum in ground state. Hence, λ is minimum.

57. (a)

58. (a) : Young's modulus of a material, $Y=\dfrac{\text{Stress}}{\text{Strain}}$

Here, stress $=\dfrac{\text{Restoring force}}{\text{Area}} \ \therefore\ Y = 0.$

59. (b) **60. (a)**

NEET mandatory to study MBBS from abroad, current students exempted

"MCI informed that the regulations prescribe that the Indian citizens or Overseas Citizen of India intending to obtain primary medical qualification from any medical institution outside India, on or after May 2018, shall have to mandatorily qualify the National Eligibility-cum-Entrance Test (NEET), for admission to MBBS course abroad.

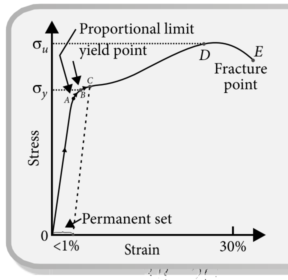
After making the decision public, the Ministry received grievances of the students requesting that those who have already gone abroad may be exempted from the requirement of qualifying NEET.

Clearing the confusion, the Union Health Ministry has said students who have already taken admission under present regulations to pursue primary medical courses by taking eligibility certificate from Medical Council of India (MCI) were "exempted" from qualifying NEET.

Every year, around 7,000 students go outside India to study medicine. Most of the students go to China and Russia. "As per the data, the percentage of graduates who have studied abroad and have cleared the FMGE has ranged between 13 and 26.9 per cent in the last five years. This is really a matter of concern as they go out, spend lot of money of their parents and are not able to contribute to the healthcare in India once they come back," an official said.

BRAIN MAP

MECHANICAL PROPERTIES OF SOLIDS AND FLUIDS



Yield strength:
Stress at which material begins to deform plastically.

Tensile strength:
Maximum load that a material can support without fracture.

Permanent set:
When stress is zero the strain is not zero.

MODULUS OF ELASTICITY — A Proportionality Constant

Stress-strain curve — STRESS = K × STRAIN

STRESS ∝ STRAIN

- Stress $= \dfrac{\text{Restoring force}}{\text{Area}} = \dfrac{F}{A}$
- Strain $= \dfrac{\text{Change in configuration}}{\text{Original configuration}}$

Young's modulus

$$Y = \frac{\text{Normal stress}}{\text{Longitudinal strain}} = \frac{F/A}{\Delta l/l} = \frac{Fl}{A\Delta l}$$

Bulk modulus

$$B = \frac{\text{Normal stress}}{\text{Volumetric strain}} = \frac{-F/A}{\Delta V/V} = \frac{-PV}{\Delta V}$$

Modulus of rigidity

$$G = \frac{\text{Shearing stress}}{\text{Shearing strain}} = \frac{\sigma_s}{\theta} = \frac{F/A}{\Delta x/L} = \frac{FL}{A\Delta x}$$

Poisson's ratio

$$\sigma = \frac{\text{Lateral strain}}{\text{Longitudinal strain}} = \frac{-\Delta R/R}{\Delta L/L} = \frac{-L\Delta R}{R\Delta L}$$

Relation between Y, B, G and σ

- $Y = 3B(1 - 2\sigma)$
- $Y = 2G(1 + \sigma)$
- $\sigma = \dfrac{3B - 2G}{2G + 6B}$
- $\dfrac{9}{Y} = \dfrac{1}{B} + \dfrac{3}{G}$

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, $u = \frac{1}{2} \times \text{stress} \times \text{strain} = \frac{1}{2} \times Y \times (\text{strain})^2$

HOOKE'S LAW

Within the elastic limit, for small deformation, stress is directly proportional to the strain for many materials.

PLASTICITY

The inability of a body to regain its original size and shape on the removal of the deforming forces.

MECHANICS OF SOLIDS

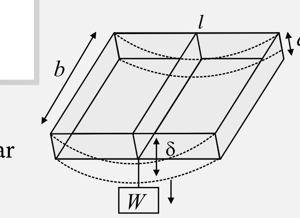
ELASTICITY

Ability of a body to regain its original shape, on removing deforming force.

APPLICATIONS OF ELASTICITY

Designing beams for bridges

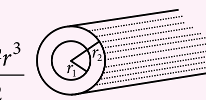
The depression in rectangular beam, $\delta = \dfrac{Wl^3}{4Ybd^3}$



Designing circular shaft

For solid shaft (bar), $\tau_{solid} = \dfrac{\pi G r^3}{2}$

For hollow shaft, $\tau_{hollow} = \dfrac{\pi G(r_2^4 - r_1^4)}{2r_2}$



MECHANICS OF FLUIDS

FLUIDS IN MOTION — FLUIDS AT REST

VISCOSITY

Coefficient of viscosity:

$$\eta = \frac{F}{A\left(-\dfrac{dv}{dx}\right)}$$ where $-\dfrac{dv}{dx}$ is the velocity gradient between two layers of liquid.

Basic results on viscosity

Terminal velocity

$$v_T = \frac{2r^2(\rho - \rho_0)g}{9\eta}$$

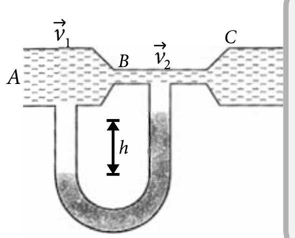
Poiseuille's formula

$$Q = \frac{\pi}{8}\frac{Pr^4}{\eta l}$$

Reynold's number : Determines nature of fluid flow

$$R = \frac{\rho v r}{\eta}$$

Stoke's law : Backward dragging force on a spherical body falling in a medium $F = 6\pi\eta r v$.



Venturimeter

A device used to measure the flow speed of incompressible fluid.

Rate of flow of liquid through the venturimeter

$$V = A_1 A_2 \sqrt{\frac{2\rho_m g h}{\rho(A_1^2 - A_2^2)}}$$

BERNOULLI'S THEOREM

Bernoulli's theorem : For the streamline flow of an ideal liquid, the total energy per unit volume remains constant.

$$P + \rho g h + \frac{1}{2}\rho v^2 = \text{constant}$$

Applications

Torricelli's law

Velocity of efflux:

$$v = \sqrt{2gh + \frac{2(P - P_0)}{\rho}}$$

Dynamic lift

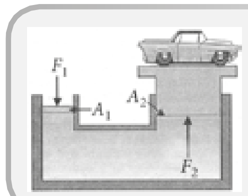
- Magnus effect
- Lift on aircraft wing

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 $= P - P_0 = h\rho g$.



Hydraulic lift

It is a force multiplying device used to support or lift heavy objects.

$$F_2 = \frac{A_2}{A_1}F_1$$

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 $W' = \left(1 - \dfrac{\rho'}{\rho}\right)$ (For fully immersed body)

SURFACE TENSION

Surface tension: The property by virtue of 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.

Excess Pressure

- In an air bubble, $\Delta P = \dfrac{2S}{R}$
- Inside a soap bubble $\Delta P = \dfrac{4S}{R}$
- Inside a liquid drop $\Delta P = \dfrac{2S}{R}$

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

Half immersed liquid drop

Drop of liquid half immersed in another liquid has radius,

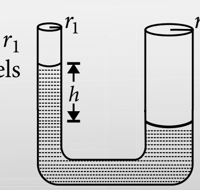
$$r = \sqrt{\frac{3S}{2(\rho_2 - \rho_1)g}}$$

where, ρ_1 = density of drop, ρ_2 = density of liquid, S = surface tension

U-tube

If the radii of two limbs of U-tube are r_1 and r_2, then difference between the levels of a liquid inserted in a U-tube is

$$h = \frac{2S}{\rho g}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$ where $(r_2 > r_1)$



FULL LENGTH PRACTICE PAPER

BITSAT

Exam date: 16^{th} to 26^{th} May 2019

SECTION-I (PHYSICS)

1. A potential difference of 200 V is applied to a coil at a temperature of 15°C and the current is 10 A. What will be the mean temperature of the coil when the current has fallen to 5 A, the applied voltage being same as before? Given $\alpha = \frac{1}{234}\,°C^{-1}$ at 0°C

(a) 150°C (b) 225°C (c) 50°C (d) 264°C

2. A cubical body (side 0.1 m and mass 0.002 kg) floats in water. It is pressed and then released so that it executes SHM. Find the time period. ($g = 10$ m s^{-2})

(a) 2.0 s (b) 2.2 s (c) 0.028 s (d) 1.2 s

3. The electrostatic force of repulsion between two positively charged ions carrying equal charge is 3.7×10^{-9} N, when they are separated by a distance of 5 Å. How many electrons are missing from each ion?

(a) 1 (b) 2 (c) 3 (d) 4

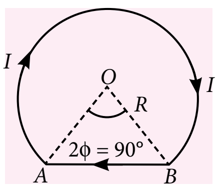
4. If voltage $V = (100 \pm 5)$ V and current $I = (10 \pm 0.2)$ A, the percentage error in resistance R is

(a) 5.2 % (b) 25 % (c) 7 % (d) 2.5 %

5. Drops of water fall from the roof of a building 20 m high at regular intervals of time. When the first drop reaches the ground at the same instant fifth drop starts its fall. What will be the distance of second and third drops from roof? ($g = 10$ m s^{-2})

(a) 5.0 m and 1.25 m (b) 5.0 m and 2.25 m
(c) 11.25 m and 5.0 m (d) 11.25 m and 1.25 m

6. A current I = 5.0 A flows along a thin wire, shaped as shown in figure. The radius of the curved part of the wire is equal to R = 120 mm, the angle $2\phi = 90°$. Find the magnetic induction of the field at the point O.



(a) 2.8×10^{-5} T (b) 4×10^{-6} T
(c) 2.2×10^{-4} T (d) 3×10^{5} T

7. A body A of mass m is thrown with velocity v at an angle 30° to the horizontal and another body B of the same mass is thrown with velocity v at an angle of 60° to the horizontal, find the ratio of the horizontal range and maximum height of A and B.

(a) 1 : 3, 1 : 4 (b) 1 : 1, 1 : 3
(c) 1 : 3, 2 : 1 (d) 1 : 2, 2 : 5

8. A 5.0 MeV proton is falling vertically downward through a region of magnetic field 1.5 T acting horizontally from south to north. Find the magnitude of the magnetic force exerted on the proton. Take mass of the proton as 1.6×10^{-27} kg.

(a) 4×10^{-10} N (b) 2.5×10^{5} N
(c) 4×10^{-5} N (d) 7.58×10^{-12} N

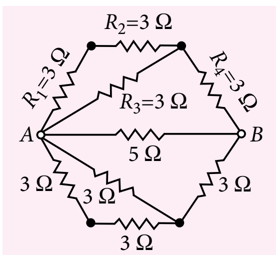
9. The electric field in an electromagnetic wave is given by $E = 10 \sin(\omega t - kx)$ V m^{-1}. Calculate the intensity of the wave and the *rms* value of the field.

(a) 1.33×10^{-2} W m^{-2}, 7.07 V m^{-1}
(b) 2×10^{-5} W m^{-2}, 7 V m^{-1}
(c) 3.2×10^{-5} W m^{-2}, 5.02 V m^{-1}
(d) 5×10^{-2} W m^{-2}, 5.02 V m^{-1}

10. A hot liquid kept in a beaker cools from 80°C to 70°C in two minutes. If the surrounding temperature is 30°C, then the time of cooling of the same liquid from 60°C to 50°C is

(a) 240 s (b) 360 s (c) 480 s (d) 216 s

11. Find the equivalent resistance between the points A and B of the network of resistors shown in figure.



(a) 2/5 Ω
(b) 1/5 Ω
(c) 5/3 Ω
(d) 3/5 Ω

12. If 5% of the energy supplied to an incandescent light bulb is radiated as visible light, how many visible light photons are emitted by 100 watt bulb? Assume wavelength of all visible photons to be 5600 Å. Given $h = 6.625 \times 10^{-34}$ J s.
(a) 1.43×10^{19} (b) 3×10^{6}
(c) 2.5×10^{15} (d) 4.5×10^{12}

13. The muzzle velocity of a bullet of mass 0.02 kg, fired from a gun of mass 100 kg, is 80 m s^{-1}. Find the recoil speed of the gun.
(a) 1.6 cm s^{-1} (b) 2 m s^{-1}
(c) 2.5 cm s^{-1} (d) 0.5 m s^{-1}

14. Find the dimensions of a and b in the equation
$$\left(p+\frac{a}{V^2}\right)(V-b)=RT,$$
where p is the pressure, V is the volume, R is the universal gas constant and T is the temperature.
(a) $[ML^6T^{-2}]$, $[L^3]$ (b) $[ML^5T^{-2}]$, $[L^2]$
(c) $[ML^5T^{-2}]$, $[L^3]$ (d) $[ML^{-5}T^{-2}]$, $[L^3]$

15. 1.4 g of nitrogen is contained in a vessel of volume 5.0 litres at a temperature of 1800 K. Assuming that 30% of the molecules are dissociated at this temperature, find the pressure of the gas.
(a) 1.92 atm (b) 2.5 atm
(c) 7 atm (d) 5 atm

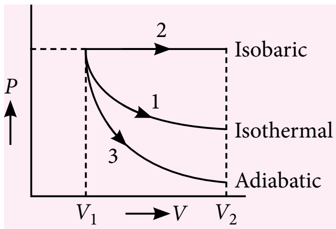
16. A solenoid of length 50 cm with 20 turns per cm and area of cross-section 40 cm^2 completely surrounds another co-axial solenoid of the same length, area of cross-section 25 cm^2 with 25 turns per cm. Calculate the mutual-inductance of the system.
(a) 7.85 mH (b) 4.50 mH
(c) 2.55 mH (d) 3.00 mH

17. A student cannot see beyond 15 cm. Find the power of the lens that he should use to read a book placed at the least distance of distinct vision.
(a) –2.67 D (b) 4.00 D
(c) –12.5 D (d) 3.2 D

18. A ball moving with a speed of 9 m s^{-1} strikes an identical ball at rest, such that after the collision, the direction of each ball makes an angle of 30° with the original line of motion. Find the speeds of the two balls after collision.
(a) $3\sqrt{3}$ m s^{-1} (b) $9\sqrt{3}$ m s^{-1}
(c) 3 m s^{-1} (d) 9 m s^{-1}

19. The input resistance of a silicon transistor is 665 Ω. When its base current is changed by 15 μA, its collector current changes by 2 mA. This transistor is used as a CE amplifier with a load resistance of 5 kΩ. What is the voltage gain of the amplifier?
(a) –1002.5 (b) 100.5
(c) –505.7 (d) 202.5

20. Starting with the same initial conditions, an ideal gas expands from volume V_1 to V_2 in three different ways. The work done by the gas is W_1 if the process is purely isothermal, W_2 if purely isobaric and W_3 if purely adiabatic. Then



(a) $W_2 > W_1 > W_3$ (b) $W_2 > W_3 > W_1$
(c) $W_1 > W_2 > W_3$ (d) $W_1 > W_3 > W_2$

21. The phase difference between two waves represented by
$$y_1 = 10^{-6}\sin\left[100\,t+\frac{x}{50}+0.5\right] \text{ m and}$$
$$y_2 = 10^{-6}\cos\left[100\,t+\frac{x}{50}\right] \text{ m}$$
where x is in metre and t in seconds, is
(a) 0.5 radian (b) 1.5 radian
(c) 1.07 radian (d) 2.07 radian

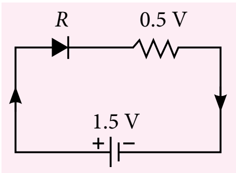
22. It has been experimentally observed that the electric field in a large region of the earth's atmosphere is directed vertically down. At an altitude of 300 m, the electric field is 60 V m^{-1}. At an altitude of 200 m, the field is 100 V m^{-1}. Calculate the net amount of charge contained in a cube 100 m on edge located between 200 m and 300 m altitude.
(a) 5×10^{-5} C (b) 2.5×10^{-6} C
(c) 3.54×10^{-6} C (d) 3×10^{7} C

23. A solid sphere is rolling on a frictionless plane surface about the axis of symmetry. Find the ratio of rotational K.E. to its total energy.
(a) 4 : 5 (b) 1 : 4 (c) 2 : 7 (d) 2 : 3

24. An iron rod of volume 10^{-4} m^3 and relative permeability 1000 is placed inside a long solenoid wound with 5 turns per cm. If a current of 0.5 A is passed through the solenoid, find the magnetic moment of the rod.
(a) 15 A m^2 (b) 20 A m^2
(c) 12.5 A m^2 (d) 25 A m^2

25. A rectangular glass slab rests in the bottom of a trough of water. A ray of light incident on water surface at an angle of 50° passes through water into glass. Calculate the angle of refraction in glass. Given that μ for water is 4/3 and that for glass is 3/2.
(a) 40.5° (b) 30.7° (c) 35° (d) 30.2°

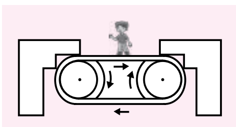
26. A *p-n* junction diode when forward biased has a drop of 0.5 V which is assumed to be independent of current. The current in excess of 10 mA through the diode produces a large Joule heating which damages (burns) the diode. If we want to use a 1.5 V battery to forward bias the diode, what should be the value of resistor used in series with the diode so that the maximum current does not exceed 5 mA?



(a) 150 Ω (b) 200 Ω (c) 100 Ω (d) 115 Ω

27. Find the acceleration due to gravity on the surface of the moon, if its radius is $\frac{1}{4}$ of the radius of the earth and its mass is $\frac{1}{80}$ of the mass of the earth. The acceleration due to gravity on the surface of the earth is 9.8 m s^{-2}.
(a) 1.96 m s^{-2} (b) 2.5 m s^{-2}
(c) 4.2 m s^{-2} (d) 0.5 m s^{-2}

28. A man of mass m = 65 kg is stationary with respect to a horizontal moving conveyor belt. The conveyor belt has an acceleration of 1 m s^{-2}. Find the net force acting on the man. Assuming that the coefficient of static friction between the conveyor belt and the man's shoes is 0.2, find up to what acceleration of the belt the man can remain stationary relative to the belt.



(a) 7 m s^{-2} (b) 5 m s^{-2}
(c) 1.96 m s^{-2} (d) 3 m s^{-2}

29. A series *R-C* combination is connected to an *AC* voltage of angular frequency ω = 500 radian s^{-1}. If the impedance of the *R-C* circuit is $R\sqrt{1.25}$, the time constant (in millisecond) of the circuit is
(a) 2 (b) 3 (c) 4 (d) 5

30. Two wires made of same material are subjected to forces in the ratio 1 : 4. Their lengths are in the ratio 2 : 1 and diameters in the ratio 1 : 3. What is the ratio of their extensions?
(a) 1 : 9 (b) 2 : 9
(c) 9 : 2 (d) 2 : 5

31. A Carnot engine having a perfect gas as the working substance is driven backwards and is used for freezing water already at 0°C. If the engine is driven by 500 W electric motor with an efficiency of 60%, how long will it take to freeze 15 kg of water? The working temps of the engine are 15°C and 0°C. The system involves no energy losses. Given latent heat of ice = 333 × 10^3 J kg^{-1}.
(a) 800 s (b) 900 s
(c) 914.8 s (d) 15.6 s

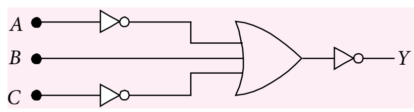
32. The equations of simple harmonic motion is given by $y = 3 \sin 5\pi t + 4 \cos 5\pi t$, where y is in cm and t in second. Determine the amplitude and time period

	Amplitude	Time Period
(a)	5 cm	0.4 s
(b)	3 cm	1 s
(c)	12 cm	0.4 s
(d)	9 cm	1 s

33. A change of 6.29 mA in the emitter current of a transistor produces a change of 6.25 mA in the collector current. What change in the base current would be necessary to produce an equivalent change in the collector current?
(a) 20 × 10^{-2} mA (b) 14.5 × 10^{-5} mA
(c) 12.2 × 10^{-3} mA (d) 40.26 × 10^{-3} mA

34. A parallel beam of light of wavelength 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m away. It is observed that the first minima is at a distance of 2.5 mm from the centre of the screen. The width of the slit is
(a) 0.2 mm (b) 1 mm
(c) 2 mm (d) 1.5 mm

35. The logic circuit given in the figure performs the logic operation



(a) ABC (b) $AB\bar{C}$ (c) $A\bar{B}C$ (d) $\bar{A}B\bar{C}$.

36. A bullet of mass 10 g and speed 500 m s^{-1} is fired into a door and gets embedded exactly at the centre of the door. The door is 1.0 m wide and weighs 12 kg. It is hinged at one end and rotates about a vertical axis practically without friction. Find the angular speed of the door just after the bullet embeds into it.
(a) 0.625 rad s^{-1} (b) 2.2 rad s^{-1}
(c) 5.7 rad s^{-1} (d) 1.5 rad s^{-1}

37. By what percentage will the transmission range of a TV tower be affected when the height of the tower is increased by 21%?
(a) 20% (b) 5% (c) 10% (d) 15%

38. Liquid rises to a height of 5.0 cm in a capillary tube and mercury falls to a depth of 2.0 cm in the same capillary tube. If the density of liquid is 1.2 g cm^{-3} and of mercury is 13.6 g cm^{-3} and angles of contact of liquid and mercury with capillary tube are 0° and 135° respectively, find the ratio of the surface tension for mercury and liquid.
(a) 2.52 (b) 6.41 (c) 3.71 (d) 2.41

39. Springs of spring constants k, $2k$, $4k$, $8k$, ... are connected in series. A mass m kg is attached to the lower end of the last spring and the system is allowed to vibrate. What is the time period of oscillations? Given m = 40 g ; k = 2.0 N cm^{-1}.
(a) 0.22 s (b) 0.126 s (c) 0.311 s (d) 0.24 s

40. The half-life of radium is 1600 years. After how many years will 12.5% of a radium sample remain undecayed?
(a) 4800 years (b) 5200 years
(c) 2000 years (d) 2200 years

SECTION-II (CHEMISTRY)

41. The correct order of basicity of the following compounds is

$CH_3-C(=NH)-NH_2$ (I) $CH_3-CH_2-NH_2$ (II)

$(CH_3)_2NH$ (III) $CH_3-C(=O)-NH_2$ (IV)

(a) II > I > III > IV (b) I > III > II > IV
(c) III > I > II > IV (d) I > II > III > IV

42. All the following substances react with water. The pair that gives the same gaseous product is
(a) K and KO_2 (b) Na and Na_2O_2
(c) Ca and CaH_2 (d) Ba and BaO_2

43. Under two different conditions an element could be made to exist in *bcc* and *fcc* arrangements with exactly same interatomic distance. The ratio of the densities in the two forms is
(a) 1 : 1 (b) 0.919 : 1
(c) 1 : 0.919 (d) 0.2 : 1

44. $AgNO_3$ reacts with $Na_2S_2O_3$ with a colour change
(a) white $\longrightarrow$ yellow $\longrightarrow$ brown $\longrightarrow$ black
(b) white $\longrightarrow$ red $\longrightarrow$ brown
(c) white $\longrightarrow$ brown $\longrightarrow$ red
(d) white $\longrightarrow$ green $\longrightarrow$ orange $\longrightarrow$ red.

45. The atomic masses of He and Ne are 4 and 20 amu respectively. The value of the de Broglie wavelength of He gas at –73°C is 'M' times that of the de Broglie wavelength of Ne at 727°C. 'M' is
(a) 2 (b) 3 (c) 4 (d) 5

46. Which of the following solutions will have pH close to 1.0?
(a) 100 mL of M/100 HCl + 100 mL of M/100 NaOH
(b) 55 mL of M/10 HCl + 45 mL of M/10 NaOH
(c) 10 mL of M/10 HCl + 90 mL of M/10 NaOH
(d) 75 mL of M/5 HCl + 25 mL of M/5 NaOH

47. In the following reaction :

$$M^{x+} + MnO_4^- \longrightarrow MO_3^- + Mn^{2+} + \frac{1}{2}O_2,$$

if one mole of MnO_4^- oxidises 2.5 moles of M^{x+}, then the value of x is
(a) 5 (b) 3 (c) 4 (d) 2

48. How many grams of sucrose (mol. wt. = 342) should be dissolved in 100 g water in order to produce a solution with a 105.0°C difference between the freezing and the boiling temperatures?
(K_f = 1.86° C/m, K_b = 0.51° C/m)
(a) 34.2 g (b) 72 g (c) 342 g (d) 460 g

49. Which one of the following shows highest magnetic moment?
(a) V^{3+} (b) Cr^{3+} (c) Fe^{3+} (d) Co^{3+}

50. When chlorine water is added to an aqueous solution of potassium halide in presence of chloroform, a violet colour is obtained. On adding more of chlorine water, the violet colour disappears, and a colourless solution is obtained. This test confirms the presence of ______ in aqueous solution.
(a) iodide (b) bromide
(c) chloride (d) iodide and bromide

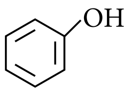
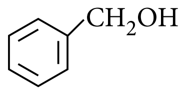
51. Elements X, Y and Z have atomic numbers 19, 37 and 55 respectively. Which of the following statements is true about them?
(a) Their ionization potential would increase with increasing atomic number.

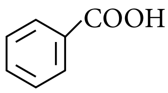
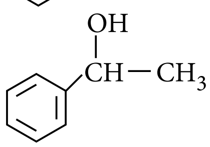
(b) 'Y' would have an ionization potential between those of 'X' and 'Z'.
(c) 'Z' would have the highest ionization potential.
(d) 'Y' would have the highest ionization potential.

52. Which of the following complexes will give maximum number of isomers?
(a) $[Co(NH_3)_4Cl_2]$ (b) $[Ni(en)(NH_3)_4]^{2+}$
(c) $[Ni(C_2O_4)(en)_2]^{2-}$ (d) $[Cr(SCN)_2(NH_3)_4]^+$

53. N_2 and O_2 are converted into monocations, N_2^+ and O_2^+ respectively. Which of the following is wrong?
(a) In N_2^+, N – N bond weakens.
(b) In O_2^+, the O – O bond order increases.
(c) In O_2^+, paramagnetism decreases.
(d) N_2^+ becomes diamagnetic.

54. Arrange the given compounds in order of increasing acidic character.

(I)  (II) 

(III)  (IV) 

(a) III > II > I > IV (b) III > IV > II > I
(c) III > I > II > IV (d) I > III > II > IV

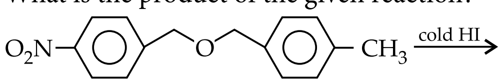
55. The enthalpy changes for the following processes are listed below :

$Cl_{2(g)} \longrightarrow 2Cl_{(g)}$; 242.3 kJ mol^{-1}
$I_{2(g)} \longrightarrow 2I_{(g)}$; 151.0 kJ mol^{-1}
$I_{2(s)} \longrightarrow I_{2(g)}$; 62.76 kJ mol^{-1}
$ICl_{(g)} \longrightarrow I_{(g)} + Cl_{(g)}$; 211.3 kJ mol^{-1}

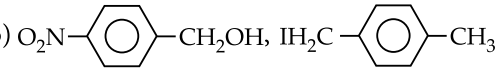
Given that the standard states for iodine and chlorine are $I_{2(s)}$ and $Cl_{2(g)}$, standard enthalpy of formation of $ICl_{(g)}$ is
(a) –16.8 kJ mol^{-1} (b) +16.8 kJ mol^{-1}
(c) + 244.8 kJ mol^{-1} (d) –14.6 kJ mol^{-1}

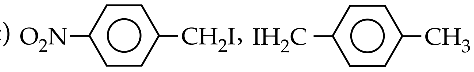
56. Polyphosphates are used as water softening agents because they
(a) form soluble complexes with anionic species
(b) precipitate anionic species
(c) form soluble complexes with cationic species
(d) precipitate cationic species.

57. What is the product of the given reaction?

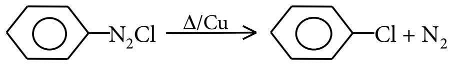


(a) 

(b) 

(c) 

(d) No reaction

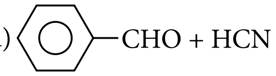
58. 

(A)

Half-life is independent of concentration of A. After 10 minutes volume of N_2 gas is 10 L and after complete reaction 50 L. Hence, rate constant is
(a) $\frac{2.303}{10}\log 5\ \text{min}^{-1}$ (b) $\frac{2.303}{10}\log 1.25\ \text{min}^{-1}$
(c) $\frac{2.303}{10}\log 2\ \text{min}^{-1}$ (d) $\frac{2.303}{10}\log 4\ \text{min}^{-1}$

59. Identify x, y, z for the following metallurgical process.
Metal sulphide $\xrightarrow{x}$ Metal oxide $\xrightarrow{y}$ Impure metal $\xrightarrow{z}$ Pure metal
x, y and z are respectively
(a) roasting, smelting, electrolysis
(b) roasting, calcination, smelting
(c) calcination, auto-reduction, bessemerisation
(d) none of the above is correct.

60. The bactericidal and bacteriostatic antibiotics respectively are
(a) penicillin, ofloxacin
(b) erythromycin, tetracycline
(c) penicillin, chloramphenicol
(d) tetracycline and penicillin

61. In which case, chiral carbon is not generated?
(a) $CH_3COCH_3 + HCN \xrightarrow{H_3O^+}$
(b) $CH_3CHO + HCN \xrightarrow{H_3O^+}$
(c) $CH_3COCOOH + HCN \xrightarrow{H_3O^+}$
(d)  $+ HCN \xrightarrow{H_3O^+}$

62. In the reaction,
$2Al_{(s)} + 6HCl_{(aq)} \longrightarrow 2Al^{3+}_{(aq)} + 6Cl^-_{(aq)} + 3H_{2(g)}$
(a) 6 L $HCl_{(aq)}$ is consumed for every 3 L $H_{2(g)}$ produced
(b) 33.6 L $H_{2(g)}$ is produced regardless of temperature and pressure for every mole of Al reacted
(c) 67.2 L $H_{2(g)}$ at STP is produced for every mole of Al reacted
(d) 11.2 L $H_{2(g)}$ at STP is produced for every mole of $HCl_{(aq)}$ consumed.

63. What products are expected from the disproportionation reaction of hypochlorous acid?
(a) $HClO_3$ and Cl_2O (b) $HClO_2$ and $HClO_4$
(c) HCl and Cl_2O (d) HCl and $HClO_3$

64. On passing a current of 1.0 ampere for 16 min and 5 sec through one litre solution of $CuCl_2$, all copper of the solution is deposited at cathode. The strength of $CuCl_2$ solution is (Molar mass of Cu = 63.5, Faraday constant = 96500 C mol^{-1})
(a) 0.07 M (b) 0.2 N
(c) 0.005 M (d) 0.02 N

65. Which of the following compounds decolourises cold alkaline $KMnO_4$ but cannot give a red precipitate with ammoniacal Cu_2Cl_2?
(a) $CH_3C\equiv CH$ (b) $CH_3CH=CH_2$
(c)  (d) $CH_3CH_2CH_3$

66. The following equilibrium constants are given
$N_2 + 3H_2 \rightleftharpoons 2NH_3;\ K_1$
$N_2 + O_2 \rightleftharpoons 2NO;\ K_2$
$H_2 + \frac{1}{2}O_2 \rightleftharpoons H_2O;\ K_3$
The equilibrium constant for the oxidation of NH_3 by oxygen to give NO :
$2NH_3 + \frac{5}{2}O_2 \rightleftharpoons 2NO + 3H_2O$, is
(a) $\frac{K_2K_3^2}{K_1}$ (b) $\frac{K_2^2K_3^6}{K_1^2}$ (c) $\frac{K_1K_2}{K_3}$ (d) $\frac{K_2K_3^3}{K_1}$

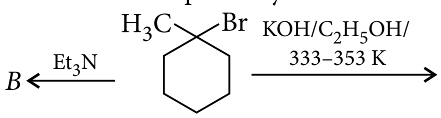
67. An ester (A) with molecular formula, $C_9H_{10}O_2$ was treated with excess of CH_3MgBr and the complex so formed was treated with H_2SO_4 to give an olefin (B). Ozonolysis of (B) gave a ketone with molecular formula C_8H_8O which shows positive iodoform test. The structure of (A) is
(a) $C_6H_5COOC_2H_5$ (b) $C_6H_5COOC_6H_5$
(c) $CH_3OCH_2COC_6H_5$
(d) p-$CH_3OCOC_6H_4COCH_3$

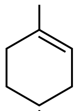
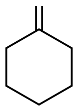
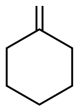
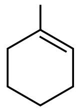
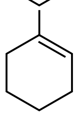
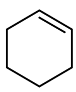
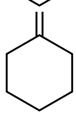
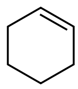
68. Which among the following statements is false?
(a) Adsorption may be monolayered or multilayered.
(b) Particle size of adsorbent will not affect the amount of adsorption.
(c) Increase of pressure increases the amount of adsorption.
(d) Increase of temperature may decrease the amount of adsorption.

69. Assume that a particular amino acid has an isoelectric point of 6.0. In a solution of pH 1.0, which of the following species will predominate?
(a) $H_3\overset{+}{N}CH(R)CO_2H$ (b) $H_2NCH(R)CO_2H$
(c) $H_3\overset{+}{N}CH(R)CO_2^-$ (d) $H_2NCH(R)CO_2^-$

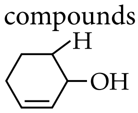
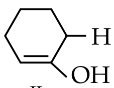
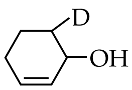
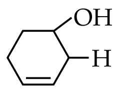
70. Two liquids A and B have vapour pressures in the ratio $p_A^\circ : p_B^\circ = 1 : 2$ at a certain temperature. Suppose that we have an ideal solutions of A and B in the mole fractions ratio $A : B = 1 : 2$, the mole fraction of A in the vapour in equilibrium with the solution at the given temperature is
(a) 0.25 (b) 0.2 (c) 0.5 (d) 0.33

71. PbF_4, $PbCl_4$ exist but $PbBr_4$ and PbI_4 do not exist because of
(a) large size of Br^- and I^-
(b) strong oxidising character of Pb^{4+}
(c) strong reducing character of Pb^{4+}
(d) low electronegativity of Br^- and I^-.

72. The major organic products A and B in the given reactions are respectively


(a)  and  (b)  and 
(c)  and  (d)  and 

73. An organic compound 'X' on treatment with NH_3 gives 'Y' which on heating gives 'Z'. 'Z' when treated with Br_2 in the presence of KOH produces ethylamine. Compound 'X' is
(a) CH_3COOH (b) $CH_3CH_2CH_2COOH$
(c) $CH_3-CH(CH_3)COOH$ (d) CH_3CH_2COOH

74. The ease of dehydration in the following compounds is
   

(a) I > III > IV > II (b) II > I > III > IV
(c) IV > I > III > II (d) III > I > II > IV

75. A cylinder contains 100 g of an ideal gas (mol. wt. 40 g mol^{-1}) at 27°C and 2 atm pressure. In transference process, the cylinder fell and a dent was created, *i.e.*, there was a decrease in the volume

of cylinder. But valve attached to the cylinder cannot keep the pressure greater than 2 atm, so 10 g of gas leaked out. Calculate the volume of the cylinder after dent.
(a) 3.08 L (b) 30.8 L (c) 2.770 L (d) 27.71 L

76. Which of the following statements is false?
(a) Lower the concentration of DO, more polluted is the water sample.
(b) The tolerable limit of lead in drinking water is 50 ppb.
(c) Water is considered pure if it has BOD less than 5 ppm.
(d) In COD determination, the pollutants resistant to microbial oxidation are not oxidised by oxidising agent like $K_2Cr_2O_7$.

77. Which of the following alkenes is most reactive towards cationic polymerization?
(a) $CH_2{=}CHCH_3$ (b) $CH_2{=}CHCl$
(c) $CH_2{=}CHC_6H_5$ (d) $CH_2{=}CHCOOCH_3$

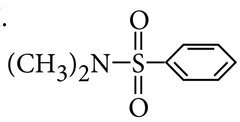
78. Which of the following is isostructural to I_3^-?
(a) ICl_2^-, XeF_2, N_3^- (b) NO_2^-, XeF_2, N_3^-
(c) NH_2^-, NO_2^-, ICl_2^- (d) BH_3, CO_2, ICl_2^-

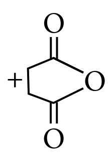
79. An alkyl halide with molecular formula, $C_6H_{13}Br$ on treatment with alcoholic KOH gave two isomeric alkenes, *A* and *B*. Reductive ozonolysis of the mixture gave the following compounds : CH_3COCH_3, CH_3CHO, CH_3CH_2CHO and $(CH_3)_2CHCHO$. The alkyl halide is
(a) 2-bromohexane
(b) 3-bromo-2-methylpentane
(c) 2,2-dimethyl-1-bromobutane
(d) 2-bromo-2, 3-dimethylbutane.

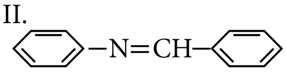
80. Match list I with list II and select the correct answer using the codes given below :

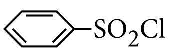
List I (Reactions) / **List II (Products)**

(P) $(CH_3)_2NH$ $+C_6H_5COCl$

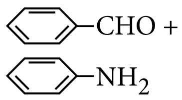
I. 

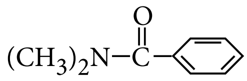
(Q) $2CH_3CH_2NH_2$ + 

II. 

(R) $(CH_3)_2NH$ + 

III. $C_2H_5NHCO(CH_2)_2COO^- + C_2H_5\overset{+}{N}H_3$

(S) 

IV. 

Codes :

	P	Q	R	S
(a)	III	IV	I	II
(b)	IV	III	II	I
(c)	I	II	III	IV
(d)	IV	III	I	II

SECTION-III (ENGLISH AND LOGICAL REASONING)

Direction (Questions 81 to 84): Read the passage and answer the following questions.

Democratic societies from the earliest times have expected their governments to protect the weak against the strong. No 'era of good feeling' can justify discharging the police force or giving up the idea of public control over concentrated private wealth. On the other hand, it is obvious that a spirit of self-denial and moderation on the part of those who hold economic power will greatly soften the demand for absolute equality. Men are more interested in freedom and security than in an equal distribution of wealth. The extent to which the government must interfere with business, therefore, is not exactly measured by the extent to which economic power is concentrated into a few hands. The required degree of government interference depends mainly on whether economic powers are oppressively used, and on the necessity of keeping economic factors in a tolerable state of balance.

But with the necessity of meeting all these dangers and threats to liberty, the powers of the government are unavoidably increased, whichever political party may be in office. The growth of government is a necessary result of the growth of technology and of the problems that go with the use of machines and science. Since the government in our nation, must take on more powers to meet its problems, there is no way to preserve freedom except by making democracy more powerful.

81. The advent of science and technology has increased the ______.
(a) powers of the governments
(b) chances of economic inequality
(c) freedom of people
(d) tyranny of the political parties

82. A spirit of moderation on the economically sound people would make the less privileged ______.
(a) unhappy with their lot
(b) clamour less for absolute equality

(c) unhappy with the rich people
(d) more interested in freedom and security

83. The growth of government is necessitated to _____.
(a) monitor science and technology
(b) deploy the police force wisely
(c) make the rich and the poor happy
(d) curb the accumulation of wealth in a few hands

84. 'Era of good feeling' in sentence 2 refers to _____.
(a) time without government
(b) time of police atrocities
(c) time of prosperity (d) time of adversity

Direction (Questions 85 and 86): Choose the correct antonym for each of the following words.

85. **Autonomy**
(a) Subordination (b) Slavery
(c) Submissiveness (d) Dependence

86. **Laconic**
(a) Prolific (b) Bucolic
(c) Prolix (d) Profligate

Direction (Questions 87 to 89): In each of the following questions. Find out which part of the sentence has an error. If there is no mistake, the answer is 'No error'.

87. (a) Having deprived from their homes
(b) in the recent earthquake
(c) they had no other option but
(d) to take shelter in a school.

88. (a) The Ahujas
(b) are living in this colony
(c) for the last eight years.
(d) No error.

89. (a) She sang (b) very well
(c) isn't it? (d) No error.

Direction (Questions 90 to 93): Rearrange the given five sentences A, B, C, D, E in the proper sequence so as to form a meaningful paragraph and then answer the given questions.

A. Many consider it wrong to blight youngsters by recruiting them into armed forces at a young age.
B. It is very difficult to have an agreement on an issue when emotions run high.
C. The debate has again come up whether this is right or wrong.
D. In many countries military service is compulsory for all.
E. Some of these detractors of compulsory draft are even very angry.

90. Which sentence should come fourth in the paragraph?
(a) A (b) B (c) C (d) D

91. Which sentence should come first in the paragraph?
(a) A (b) B (c) C (d) D

92. Which sentence should come last in the paragraph?
(a) A (b) B (c) C (d) D

93. Which sentence should come third in the paragraph?
(a) A (b) B (c) C (d) E

Direction (Questions 94 to 95): In each of the following questions, a word has been written in four different ways out of which only one is correctly spelt. Choose the correctly spelt word.

94. (a) Sepalchral (b) Sepulchrle
(c) Sepulchral (d) Sepalchrle

95. (a) Overleped (b) Overelaped
(c) Overlapped (d) Overlaped

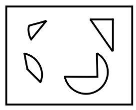
96. Complete the given series.
1, 5, 14, 30, 55, …
(a) 97 (b) 95 (c) 91 (d) 55

97. Find the missing number, if certain rule is followed row-wise or column-wise.
(a) 9 (b) 10
(c) 12 (d) 15

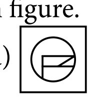
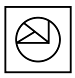
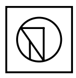
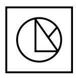
5	9	8	7
8	6	9	10
7	13	?	19
5	7	8	9

98. In the given letter sequence, some letters are missing which are given in that order as one of the four alternatives under it.
Find out the correct option.
ab — d — aaba — na — badna — b
(a) andaa (b) babda
(c) badna (d) dbanb

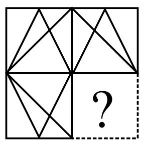
99. In the following question, find out which of the figures (a), (b), (c) and (d) can be formed from the pieces given in figure.

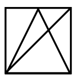
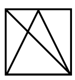
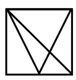
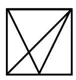


(X)

(a)  (b)  (c)  (d) 

100. Select a figure from the options which when placed in the blank space of the given figure would complete the pattern.



(a)  (b)  (c)  (d) 

101. Which of the following forms the mirror image of given word, if the mirror is placed vertically to the left?

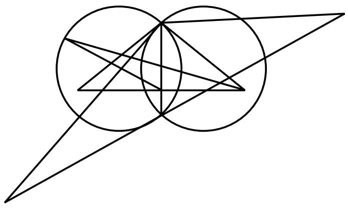
1 B F 9 8 l 6 i F

(a) I B Ɐ ∂ 8 I ɘ ! Ɐ (b) ꟻ i ∂ l 8 ɘ ꟻ B I
(c) I i ∂ l 8 ɘ ꟻ B ꟻ (d) I ! 9 l 8 6 Ⅎ B Ⅎ

102. In a certain code language,
I. 'she likes apples' is written as 'pic sip dip'.
II. 'parrot likes apples lots' is written as 'dip pic tif nif'.
III. 'she likes parrot' is written as 'tif sip dip'.
How is 'parrot' written in that code language?
(a) pic (b) dip (c) tif (d) nif

103. X's mother is the mother-in-law of the father of Z. Z is the brother of Y while X is the father of M. How is X related to Z?
(a) Paternal uncle (b) Maternal uncle
(c) Cousin (d) Grandfather

104. How many straight lines are required to draw the given figure?



(a) 8
(b) 9
(c) 10
(d) 11

105. Select a figure from the options which forms the water image of the given combination of letters/numbers.

8C185e2F9

(a) 6ℲZɘƧ8IƆ8 (b) 8CI8Ƨ^eZⱯ∂
(c) 8ƆI 8Ƨ^eZⱯ∂ (d) ɘꟻZɘƧ8IƆ8

SECTION-IV (MATHEMATICS)

106. The inverse of the function $f(x) = \log_2(x+\sqrt{x^2+1})$ is
(a) $2^x + 2^{-x}$ (b) $\dfrac{2^x+2^{-x}}{2}$
(c) $\dfrac{2^{-x}-2^x}{2}$ (d) $\dfrac{2^x-2^{-x}}{2}$

107. If cube roots of unity are 1, ω, ω^2 then the roots of the equation $x^3 - 3x^2 + 3x + 63 = 0$ are
(a) $-3, 1-3\omega, 1+3\omega^2$ (b) $-4, 1-4\omega, 1-4\omega^2$
(c) $-3, 1-4\omega, 1-4\omega^2$ (d) $-3, 1+4\omega, 1+4\omega^2$

108. If $3^{50}(x+iy) = \left(\dfrac{3}{2}+\dfrac{i\sqrt{3}}{2}\right)^{100}$ $\forall\ x, y \in R$, then ordered pair (x, y) is given by
(a) $\left(-\dfrac{1}{2},\dfrac{\sqrt{3}}{2}\right)$ (b) $\left(\dfrac{1}{2},\dfrac{\sqrt{3}}{2}\right)$
(c) $\left(-\dfrac{1}{2},-\dfrac{\sqrt{3}}{2}\right)$ (d) $\left(-\dfrac{3}{2},-\dfrac{1}{2}\right)$

109. If α, β are roots of the equation $6x^2 - x - 2 = 0$ then the equation whose roots are $\alpha^2 + 2$, $\beta^2 + 2$ is
(a) $36x^2 - 169x + 198 = 0$
(b) $36x^2 + 169x + 198 = 0$
(c) $36x^2 - 169x - 198 = 0$
(d) $x^2 - 169x + 198 = 0$

110. $2^{1/4}\cdot 4^{1/8}\cdot 8^{1/16}\cdot 16^{1/32}$ ... is equal to
(a) 1 (b) 2 (c) 3/2 (d) 5/2

111. The sixth term in the expansion of

$$\left[2^{\log_2\sqrt{9^{x-1}+7}}+\frac{1}{2^{\frac{1}{5}\log_2(3^{x-1}+1)}}\right]^7 \text{ is } 84.$$

Then the number of values of x is
(a) 0 (b) 1 (c) 2 (d) 3

112. If ω is cube root of unity and $x + y + z = a$, $x + \omega y + \omega^2 z = b$, $x + \omega^2 y + \omega z = c$, then which of the following is not correct?
(a) $x = \dfrac{a+b+c}{3}$ (b) $y = \dfrac{a+b\omega^2+\omega c}{3}$
(c) $z = \dfrac{a+b\omega+\omega^2 c}{3}$ (d) none of these

113. The number of ways in which the letters $x_1, x_2, ..., x_{10}, y_1, y_2, ..., y_{15}$ can be arranged in a line such that the suffixes of x and those of y are in ascending order of magnitude, is
(a) ${}^{25}C_{10}10!15!$ (b) ${}^{25}C_{15}$
(c) ${}^{25}C_5$ (d) none of these

114. Let $f(x) = e^{\cos^{-1}\sin\left(x+\frac{\pi}{3}\right)}$, then $f\left(\dfrac{8\pi}{9}\right)$ equals
(a) $e^{\frac{7\pi}{12}}$ (b) $e^{\frac{13\pi}{18}}$ (c) $e^{\frac{5\pi}{18}}$ (d) $e^{\frac{\pi}{12}}$

115. If $\sin^{-1}a + \sin^{-1}b + \sin^{-1}c = \dfrac{3\pi}{2}$ and $f(2) = 2$, $f(x + y) = f(x)\,f(y)\ \forall\ x, y \in R$
then $a^{f(2)} + b^{f(4)} + c^{f(6)} - \dfrac{3\left(a^{f(2)}\cdot b^{f(4)}\cdot c^{f(6)}\right)}{a^{f(2)}+b^{f(4)}+c^{f(6)}}$ equals
(a) 2 (b) 4 (c) 6 (d) 8

116. The light ray emerging from the point source placed at $P(2, 3)$ is reflected at a point Q on the y-axis and then passes through the point $R(5, 10)$. So coordinates of Q are
(a) (0, 1) (b) (0, 5) (c) (0, 2) (d) (0, 4)

117. The equation of the plane through the intersection of the planes $x + 2y + 3z - 4 = 0$ and $4x + 3y + 2z + 1 = 0$ and passing through the origin is
(a) $17x + 14y + 11z = 0$ (b) $7x + 4y + z = 0$
(c) $x + 14y + 11z = 0$ (d) $x + y + 11z = 0$

118. Let the function $f(x)=\dfrac{3-(243-5x)^{1/5}}{(5x+27)^{1/3}-3}$, $(x \neq 0)$ is continuous everywhere. Then the value of $f(0)$ equals
(a) $\frac{1}{15}$ (b) $\frac{2}{15}$ (c) $\frac{4}{15}$ (d) $\frac{1}{45}$

119. $\displaystyle\int \frac{\cos^3 x+\cos^5 x}{\sin^2 x+\sin^4 x}dx =$
(a) $\sin x - 6\tan^{-1}(\sin x) + c$
(b) $\sin x - 2\operatorname{cosec} x + c$
(c) $\sin x - 2\operatorname{cosec} x - 6\tan^{-1}(\sin x) + c$
(d) $\sin x - 2\operatorname{cosec} x + 5\tan^{-1}(\sin x) + c$

120. The solution of the differential equation
$$\frac{dy}{dx}=\frac{y}{x}+\frac{\phi\left(\frac{y}{x}\right)}{\phi'\left(\frac{y}{x}\right)}$$ is
(a) $x\phi\left(\frac{y}{x}\right)=k$ (b) $\phi\left(\frac{y}{x}\right)=kx$
(c) $y\phi\left(\frac{y}{x}\right)=k$ (d) $\phi\left(\frac{y}{x}\right)=ky$

121. The abscissae of two points A and B are the roots of the equation $x^2 + 2ax - b^2 = 0$ and their ordinates are the roots of the equation $x^2 + 2px - q^2 = 0$. The radius of the circle with AB as diameter, is
(a) $\sqrt{a^2+p^2}$ (b) $\sqrt{b^2+q^2}$
(c) $\sqrt{a^2+b^2+p^2+q^2}$ (d) none of these

122. A person goes to office either by car, scooter, bus or train. The probabilities of which being $\frac{1}{7},\frac{3}{7},\frac{2}{7},\frac{1}{7}$ respectively. The probability that he reaches office late, if he takes car, scooter, bus or train is $\frac{2}{9},\frac{1}{9},\frac{4}{9},\frac{1}{9}$ respectively. If he reached office in time, the probability that he travelled by car is
(a) $\frac{1}{5}$ (b) $\frac{1}{9}$ (c) $\frac{2}{11}$ (d) $\frac{1}{7}$

123. The standard deviation of n observations $x_1, x_2, ..., x_n$ is 2. If $\sum_{i=1}^{n} x_i = 20$ and $\sum_{i=1}^{n} x_i^2 = 100$, then n is
(a) 10 or 20 (b) 5 or 10 (c) 5 or 20 (d) 5 or 15

124. Equation of the plane parallel to the planes $x+2y+3z-5=0, x+2y+3z-7=0$ and equidistant from them is
(a) $x + 2y + 3z - 6 = 0$ (b) $x + 2y + 3z - 1 = 0$
(c) $x + 2y + 3z - 8 = 0$ (d) $x + 2y + 3z - 3 = 0$

125. Three numbers, the third of which being 12, form a decreasing G.P. If the third term were 9 instead of 12, the three numbers would have formed an A.P. Then the common ratio of the original G.P., is
(a) $\frac{3}{7}$ (b) $\frac{2}{3}$ (c) $\frac{3}{5}$ (d) $\frac{4}{5}$

126. The value of x for which $\sin(\cot^{-1}(1 + x)) = \cos(\tan^{-1}x)$ is
(a) 1/2 (b) 1 (c) 0 (d) –1/2

127. If the eccentricity of the hyperbola $x^2 - y^2\sec^2\theta = 4$ is $\sqrt{3}$ times the eccentricity of the ellipse $x^2\sec^2\theta + y^2 = 16$, then the value of θ equals
(a) $\frac{\pi}{6}$ (b) $\frac{3\pi}{4}$ (c) $\frac{\pi}{3}$ (d) $\frac{\pi}{2}$

128. The value of x for which the matrix
$$A=\begin{bmatrix} x+a & b & c \\ a & x+b & c \\ a & b & x+c \end{bmatrix}$$ is non-singular, is
(a) $R - \{0, -(a + b + c)\}$ (b) $R - \{0\}$
(c) $R - \{-(a + b + c)\}$ (d) none of these

129. If $\vec{a},\vec{b},\vec{c}$ are non-coplanar unit vectors such that $\vec{a}\times(\vec{b}\times\vec{c})=\dfrac{\vec{b}+\vec{c}}{\sqrt{2}}$ then the angle between $\vec{a}$ and $\vec{b}$ is
(a) $\frac{8\pi}{2}$ (b) $\frac{\pi}{4}$ (c) $\frac{\pi}{2}$ (d) π

130. The maximum value of $f = 4x + 3y$
Subject to constraints :
$x \geq 0$, $y \geq 0$, $2x + 3y \leq 18$, $x + y \geq 10$ is
(a) 35 (b) 36
(c) 34 (d) none of these

131. The shortest distance between the parabolas $y^2 = 4x$ and $y^2 - 2x + 6 = 0$ is
(a) $\sqrt{2}$ (b) $\sqrt{5}$ (c) $\sqrt{3}$
(d) none of these

132. Identify the false statement.
(a) $\sim[p\vee(\sim q)]\equiv(\sim p)\wedge q$
(b) $[p \vee q] \vee (\sim p)$ is a tautology
(c) $\sim(p\vee q)\equiv(\sim p)\vee(\sim q)$
(d) $\sim[p\wedge(\sim p)]$ is a tautology

133. $\int_0^{\frac{\pi}{4}}\left(\frac{x}{x\sin x+\cos x}\right)^2 dx=$

(a) $\frac{5-\pi}{5+\pi}$ (b) $\frac{2}{4+\pi}$ (c) $\frac{4-\pi}{4+\pi}$ (d) $\frac{4+\pi}{4-\pi}$

134. If vectors $\alpha\hat{i}+\hat{j}+\hat{k}, \hat{i}+\beta\hat{j}+\hat{k}, \hat{i}+\hat{j}+\gamma\hat{k}$ ($\alpha \neq 1$, $\beta \neq 1$, $\gamma \neq 1$) are coplanar, then the value of $\frac{1}{1-\alpha}+\frac{1}{1-\beta}+\frac{1}{1-\gamma}$ is

(a) 0 (b) – 1 (c) 1 (d) 2

135. $\int\frac{dx}{\cos^3 x\sqrt{2\sin 2x}}=$

(a) $\sqrt{\tan x}-\frac{(\tan x)^{\frac{3}{2}}}{3}+c$ (b) $\sqrt{\tan x}+\frac{(\tan x)^{\frac{3}{2}}}{3}+c$

(c) $\sqrt{\tan x}-\frac{(\tan x)^{\frac{5}{2}}}{5}+c$ (d) $\sqrt{\tan x}+\frac{(\tan x)^{\frac{5}{2}}}{5}+c$

136. If $f'(x) = \sin(\log x)$ and $y=f\left(\frac{2x+3}{3-2x}\right)$, then $\frac{dy}{dx}$ at $x = 1$ is equal to

(a) 6 sin log (5) (b) 5 sin log (6)
(c) 12 sin log (5) (d) 5 sin log (12)

137. The straight lines whose d.c.'s are given by $al + bm + cn = 0$ and $fmn + gnl + hlm = 0$ are perpendicular if

(a) $\frac{f}{a}+\frac{g}{b}+\frac{h}{c}=0$ (b) $\frac{a}{f}+\frac{b}{g}+\frac{c}{h}=0$

(c) $\frac{f}{a^2}+\frac{g}{b^2}+\frac{h}{c^2}=0$ (d) $\frac{a^2}{f}+\frac{b^2}{g}+\frac{c^2}{h}=0$

138. Find the new coordinates of point (3, – 4) if the origin is shifted to (1, 2) by a translation.

(a) (–2, –6) (b) (2, 6) (c) (–2, 6) (d) (2, –6)

139. Let $f(x)=\begin{cases}\cos\frac{\pi}{2}x & \forall\ 0\le x<1\\ 5x+3 & \forall\ x\ge 1\end{cases}$, then

(a) $f(x)$ has local minimum at $x = 1$
(b) $f(x)$ has local maximum at $x = 1$
(c) $f(x)$ does not have any local maximum or local minimum at $x = 1$
(d) $f(x)$ has a global minimum at $x = 1$

140. The mean and variance of n observations $x_1, x_2, x_3, \ldots, x_n$ are 5 and 0 respectively. If $\sum_{i=1}^{n} x_i^2 = 400$, then the value of n is equal to

(a) 80 (b) 25 (c) 20 (d) 16

141. The number of critical points of $f(x)=\frac{|x-1|}{x^2}$, is

(a) 1 (b) 2 (c) 3 (d) 4

142. If $f(x)=\frac{\cos 3x}{\cos x}$ $\forall\ x \neq (2n\pm 1)\frac{\pi}{2}$, then the range of $f(x)\ \forall\ x \in R$ is

(a) [–3, 1] (b) (–∞, 1]
(c) (–∞, 1) (d) (–3, 1]

143. The range of the function $f(x) = 9^x - 3^x + 1$ is

(a) (– ∞, ∞) (b) (– ∞, 0)
(c) (0, ∞) (d) $\left[\frac{3}{4},\infty\right)$

144. The parametric representation of a point on the ellipse whose foci are (3, 0) and (–1, 0) and eccentricity 2/3 is

(a) $(1+3\cos\theta,\ \sqrt{3}\sin\theta)$
(b) $(1+3\cos\theta,\ 5\sin\theta)$
(c) $(1+3\cos\theta,\ 1+\sqrt{5}\sin\theta)$
(d) $(1+3\cos\theta,\ \sqrt{5}\sin\theta)$

145. The ratio in which the area bounded by the curves $y^2 = 12x$ and $x^2 = 12y$ is divided by the line $x = 3$ is

(a) 15 : 49 (b) 13 : 37 (c) 15 : 23 (d) 17 : 50

146. The expression $\cos A \cos 2A \cos 4A \cos 8A \ldots \cos 2^{n-1}A$ equals

(a) $\frac{2^n\sin A}{\sin 2^n A}$ (b) $\frac{\sin 2^n A}{2^n \sin A}$

(c) $\frac{2^n \sin 2^n A}{\sin A}$ (d) $\frac{\sin A}{2^n \sin 2^n A}$

147. If $\vec{p}\times\vec{q}=\vec{r}$ and $\vec{q}\times\vec{r}=\vec{p}$, then

(a) $r = 1, p = q$ (b) $p = 1, q = 1$
(c) $r = 2p, q = 2$ (d) $q = 1, p = r$

148. The volume of the largest cylinder which can be inscribed in a sphere of unit radius is

(a) $2\sqrt{2}\frac{\pi}{3}$ (b) $\frac{4\pi}{3\sqrt{3}}$ (c) $\frac{8\pi}{9\sqrt{3}}$ (d) $2\sqrt{\frac{2}{3}}\pi$

149. In how many ways can the letters of the word DAUGHTER can be arranged so that the vowels may never be separated ?

(a) 4320 (b) 4520 (c) 4145 (d) 6545

150. If $y=(x+\sqrt{1+x^2})^n$, then $(1+x^2)\frac{d^2y}{dx^2}+x\frac{dy}{dx}$ is

(a) n^2y (b) $-n^2y$ (c) $-y$ (d) $2x^2y$

SOLUTIONS

1. (d) : According to the questions,

$$R_{15} = \frac{V}{I} = \frac{200}{10} = 20\,\Omega$$

Let t be the temperature at which current falls to 5 A.
In the second case, it is clear that the current decreases due to the increase in resistance on heating..
Then

$$R_t = \frac{200}{5} = 40\,\Omega$$

As $R_t = R_0\,(1 + \alpha\, t)$

$$R_{15} = R_0\left(1+\frac{15}{234}\right) \quad \text{or} \quad 20 = \frac{R_0 \times 249}{234} \qquad \text{...(i)}$$

$$R_t = R_0\left(1+\frac{t}{234}\right) \quad \text{or} \quad 40 = R_0\left(\frac{234+t}{234}\right) \qquad \text{...(ii)}$$

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

$$2 = \frac{234+t}{249} \quad \text{or} \quad t = 498 - 234 = 264°\text{C}.$$

2. (c) : Let cubical body be floating in water of density σ with length l inside the water. Then
weight of body = upward thrust due to water
so $\quad mg = A\, l\, \sigma\, g \quad$ or $\quad m = A\, l\, \sigma \qquad$ ...(i)
If the cubical body is depressed through distance y, then effective restoring force on the body is
$F = -[A\,(l + y)\,\sigma\, g - A\, l\, \sigma\, g] = -(A\,\sigma\, g)\, y \qquad$ ...(ii)
As, $F \propto y$ and this F is directed towards equilibrium position of body, so the body when released will execute linear SHM.
Here, spring factor = $A\,\sigma\, g$; inertia factor = m

$$\text{Time period, } T = 2\pi\sqrt{\frac{\text{inertia factor}}{\text{spring factor}}} = 2\times\frac{22}{7}\sqrt{\frac{m}{A\sigma g}}$$

$$= 2\times\frac{22}{7}\sqrt{\frac{0.002}{(0.1)^2\times 10^3\times 10}} = 0.028 \text{ s}$$

3. (b)

4. (c) : $V = (100 \pm 5)$ V ; $I = (10 \pm 0.2)$ A

$$R = \frac{V}{I} = \frac{100}{10} = 10\,\Omega$$

$$\frac{\Delta R}{R} = \pm\left(\frac{\Delta V}{V}+\frac{\Delta I}{I}\right) = \pm\left(\frac{5}{100}+\frac{0.2}{10}\right) = \pm\frac{7}{100}$$

$$\%\text{ error in } R = \frac{\Delta R}{R}\times 100 = \pm\frac{7}{100}\times 100 = \pm 7\,\%.$$

5. (c) : Time taken by first drop to reach the ground

$$t' = \sqrt{\frac{2s}{g}} = \sqrt{\frac{2\times 20}{10}} = 2 \text{ s}$$

Time interval between successive drops,

$$t = t'/4 = \frac{2}{4} = \frac{1}{2}\text{ s}$$

For second drop, time = $3\,t = 3 \times \frac{1}{2} = 1.5$ s
Distance of second drop,

$$S_2 = \frac{1}{2}\times 10\times(1.5)^2 = 11.25 \text{ m}$$

For third drop, time = $2\,t = 2 \times \frac{1}{2} = 1$ s

$$\text{Distance of third drop, } S_3 = \frac{1}{2}\times 10\times(1)^2 = 5 \text{ m}$$

6. (a) : Magnetic induction at O due to the linear segment AB is

$$B_1 = \frac{\mu_0}{4\pi}\times\frac{I}{R\cos\phi}[\sin\phi+\sin\phi] = \frac{\mu_0}{4\pi}\cdot\frac{2I}{R}\tan\phi, \text{ acting}$$

normally downwards
Magnetic field at O due to the current through arc segment is

$$B_2 = \frac{\mu_0}{4\pi}\times\frac{I}{R}(2\pi - 2\phi), \text{ acting normally downwards}$$

Total magnetic induction at O,

$$B = B_1 + B_2 = \frac{\mu_0}{2\pi}\cdot\frac{I}{R}[\pi - \phi + \tan\phi]$$

$$= \frac{4\pi\times 10^{-7}\times 5}{2\pi\times 0.120}\left[\pi-\frac{\pi}{4}+\tan\frac{\pi}{4}\right] = \frac{2\times 10^{-7}\times 5\times 3.356}{0.120}$$

$= 2.8 \times 10^{-5}$ T.

7. (b) : For body A : $\theta = 30°$

$$\text{Horizontal range, } R_A = \frac{u^2\sin(2\times 30°)}{g} = \frac{u^2}{g}\times\frac{\sqrt{3}}{2}$$

$$\text{Maximum height, } H_A = \frac{u^2\sin^2 30°}{2g} = \frac{u^2}{2g}\times\frac{1}{4}$$

For body B : $\theta = 60°$

$$\therefore \quad R_B = \frac{u^2\sin(2\times 60°)}{g} = \frac{u^2}{g}\times\frac{\sqrt{3}}{2}$$

$$\text{and} \quad H_B = \frac{u^2\sin^2 60°}{2g} = \frac{u^2}{2g}\times\frac{3}{4}$$

Hence $R_A : R_B = 1 : 1$ and $H_A : H_B = 1 : 3$.

8. (d)

9. (a) : Comparing the given equation with the standard wave equation, $E = E_0 \sin(\omega\, t - kx)$, for the electric field,
$E_0 = 10$ V m^{-1}

The intensity of the wave is given by $I = \frac{1}{2}\epsilon_0\, cE_0^2$

Substituting the appropriate values in the preceding equation,

$$I = \frac{1}{2}(8.85\times 10^{-12}\text{ C}^2\text{ N}^{-1}\text{ m}^{-2})(3\times 10^8\text{ m s}^{-1})(10\text{ V m}^{-1})^2$$

$= 1.33 \times 10^{-2}$ W m^{-2}
The rms value of the field is given by

$$E = \frac{E_0}{\sqrt{2}} = \frac{10}{\sqrt{2}}\text{ V m}^{-1} = 7.07\text{ V m}^{-1}.$$

10. (d) : Average temperature of liquid in 1st case

$$\theta_1 = \frac{80+70}{2} = 75°C$$

Also, $\theta_1 - \theta_0 = 75 - 30 = 45°C$; $\frac{d\theta_1}{dt} = \frac{80-70}{2} = 5°C \text{ min}^{-1}$

As $\frac{d\theta_1}{dt} = k(\theta_1 - \theta_0)$; $\therefore$ $5 = k\,(45)$; $k = \frac{1}{9}$

Similarly, in 2nd case,

$$\frac{d\theta_2}{dt} = k(\theta_2 - \theta_0) \quad \text{or} \quad \frac{60-50}{t} = \frac{1}{9}\left(\frac{60+50}{2} - 30\right)$$

$t = 216$ s

11. (c)

12. (a) : Here $\lambda = 5600$ Å $= 5600 \times 10^{-10}$ m

Energy of one photon

$$= \frac{hc}{\lambda} = \frac{6.625\times10^{-34}\times3\times10^{8}}{5600\times10^{-10}} = 3.5\times10^{-19}\text{ J}$$

A 100 W bulb supplies 100 J of energy per second.

$\therefore$ Energy released per second as visible photons

$$= \frac{100\times5}{100} = 5\text{ J}$$

$\therefore$ Number of photons emitted per second as visible light

$$= \frac{5}{3.5\times10^{-19}} = 1.43\times10^{19}.$$

13. (a) : As no external force acts on the system (gun plus bullet), the total linear momentum of the system will remain conserved. As the initial momentum of the system is zero, we must have

$$M\vec{V} + m\vec{v} = 0 \quad \Rightarrow \quad M\vec{V} = -m\vec{v} \quad \Rightarrow \quad \vec{V} = -\left(\frac{m}{M}\right)\vec{v}.$$

The negative sign shows that the gun will recoil in a direction opposite to that of the bullet. The magnitude of the recoil speed of the gun is

$$V = \left(\frac{0.02\text{ kg}}{100\text{ kg}}\right)\times 80\text{ m s}^{-1} = 0.016\text{ m s}^{-1} = 1.6\text{ cm s}^{-1}.$$

The gun will recoil with a speed of 1.6 cm s^{-1}.

14. (c) : In the given expression, $\frac{a}{V^2}$ is added to the pressure p. Hence, $\frac{a}{V^2}$ must have the dimension of pressure. This is so because only like quantities can be added or subtracted. Therefore, $\left[\frac{a}{V^2}\right] = [p]$

$\Rightarrow$ $[a] = [p]\,[V^2] = [ML^{-1}T^{-2}].[L^3]^2 = [ML^5T^{-2}]$.

Again, in the given expression, b is subtracted from the volume V. Hence, b must have the dimension of volume. Therefore, $[b] = [V] = [L^3]$.

15. (a) : As nitrogen is diatomic, every nitrogen molecule when dissociated give two nitrogen atoms. If η is the fraction of molecules dissociated, then the number of molecules after dissociation will be $n(1+\eta)$, where $n = \frac{m}{M}$ is the number of molecules before dissociation.

Using the gas law, we have

$$pV = n(1+\eta)\,RT \quad \Rightarrow \quad p = \frac{m(1+\eta)RT}{MV} \qquad ...(i)$$

Substitute the given values in equation (i), we get

$$p = \frac{1.4\times1.3\times8.3\times1800}{28\times5.0\times10^{-3}} = 1.94\times10^{5}\text{ N m}^{-2}$$

$$= \frac{1.94\times10^5}{1.01\times10^5}\text{ atm} = 1.92\text{ atm}$$

16. (a) : Here $l = 50$ cm $= 0.50$ m

Total number of turns in outer-solenoid,

$N_1 = n_1 l = 20 \times 50 = 1000$

Area of cross-section of outer solenoid,

$A_1 = 40\text{ cm}^2 = 40 \times 10^{-4}\text{ m}^2$

Total number of turns in inner solenoid,

$N_2 = n_2 l = 25 \times 50 = 1250$

Area of cross-section of inner solenoid,

$A_2 = 25\text{ cm}^2 = 25 \times 10^{-4}\text{ m}^2$

To determine mutual inductance, we take area of cross-section of inner solenoid.

$$\therefore \quad M = \frac{\mu_0 N_1 N_2 A_2}{l}$$

$$= \frac{4\pi\times10^{-7}\times1000\times1250\times25\times10^{-4}}{0.50} = 7.85\text{ mH}.$$

17. (a) : For the student to read a book placed at a distance of 25 cm, its image should be formed at a distance of 15 cm. Using the lens formula,

$$\frac{1}{-15\text{ cm}} - \frac{1}{-25\text{ cm}} = \frac{1}{f} \quad \Rightarrow \quad f = \frac{-75}{2}\text{ cm}$$

The power of the required lens is

$$P = \frac{100}{f(\text{cm})} = -\frac{100}{-75/2} = \frac{-200}{75} = -2.67\text{ D}.$$

18. (a) : Applying principle of conservation of linear momentum

(i) along the direction of motion (X-axis)

$m_1 u_1 + m_2 u_2 = m_1 v_1 \cos\theta_1 + m_2 v_2 \cos\theta_2$

$m \times 9 + 0 = m\, v_1 \cos 30° + m\, v_2 \cos 30°$

$$v_1 + v_2 = \frac{18}{\sqrt{3}} \qquad ...(i)$$

(ii) along the direction perpendicular to the direction of motion (Y-axis)

$0 + 0 = m_1 v_1 \sin\theta_1 - m_2 v_2 \sin\theta_2$

$\therefore$ $m_1 v_1 \sin\theta_1 = m_2 v_2 \sin\theta_2$

$m\, v_1 \sin 30° = m\, v_2 \sin 30°$

$\therefore$ $v_1 = v_2$ ...(ii)

Using eqn. (ii) in eqn. (i), we get

$$2v_1 = \frac{18}{\sqrt{3}} \quad \text{or} \quad v_1 = 3\sqrt{3}\text{ m s}^{-1}$$

Hence, the two balls move with the same velocity $= 3\sqrt{3}$ m s^{-1} after collision.

19. (a) : The *ac* current gain of the transistor,

$$\beta_{\text{a.c.}} = \frac{\Delta I_C}{\Delta I_B} = \frac{2\times10^{-3}\,\text{A}}{15\times10^{-6}\,\text{A}} = \frac{400}{3}.$$

The transconductance of the transistor,

$$g_m = \frac{\beta_{\text{a.c.}}}{R_i} = \frac{400}{3\times665\,\Omega}.$$

The voltage gain of the amplifier,

$$A_v = -g_m \times R_L = -\frac{400}{3\times665\,\Omega}\times5\times10^3\,\Omega = -1002.5$$

20. (a) : As work done by the gas = area under the graph (between the graph and V axis) and

$(\text{Area})_2 > (\text{Area})_1 > (\text{Area})_3$

$\therefore\ W_2 > W_1 > W_3$

21. (c) : The equations of two waves are

$$y_1 = 10^{-6}\sin\left[100\,t + \frac{x}{50} + 0.5\right]$$

$$y_2 = 10^{-6}\cos\left[100\,t + \frac{x}{50}\right] = 10^{-6}\sin\left[\frac{\pi}{2} + 100\,t + \frac{x}{50}\right]$$

Comparing the two equations, we get phase difference

$$= \left(\frac{\pi}{2} - 0.5\right) = \frac{3.14}{2} - 0.5 = 1.57 - 0.5 = 1.07 \text{ rad}$$

22. (c)

23. (c) : $\dfrac{\text{Rotational energy}}{\text{Total energy}} = \dfrac{\frac{1}{5}mv^2}{\frac{7}{10}mv^2} = \dfrac{2}{7}$

24. (d) : The relation between magnetic induction B, magnetising field intensity H and the magnetisation M is given by

$B = \mu_0 (H + M)$

$$\therefore\quad M = \frac{B}{\mu_0} - H = \frac{\mu H}{\mu_0} - H \qquad [\because B = \mu H]$$

$$= \mu_r H - H = (\mu_r - 1)H \qquad \left[\because \mu_r = \frac{\mu}{\mu_0}\right]$$

But for a long solenoid, we have

$H = nI$

where n is the number of turns per metre.

$\therefore\ M = (\mu_r - 1)\,nI$

Here $\mu_r = 1000,\ I = 0.5$ A

$$n = \frac{5}{0.01}\text{ turns / m} = 500 \text{ turns / m}$$

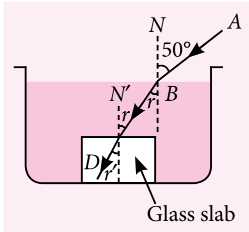
$\therefore\ M = (1000 - 1)\times500\times0.5 = 2.5\times10^5$ A m^{-1}

Magnetic moment,

$m = M\times V = 2.5\times10^5\times10^{-4}$ A m^2 = 25 A m^2.

25. (b) : Here ${}^a\mu_w = \dfrac{4}{3},\ {}^a\mu_g = \dfrac{3}{2}$

$$\therefore\quad {}^w\mu_g = \frac{{}^a\mu_g}{{}^a\mu_w} = \frac{3/2}{4/3} = \frac{9}{8}$$



Angle of incidence on water surface, $i = 50°$

$$\therefore\quad \frac{\sin 50°}{\sin r} = \frac{4}{3}$$

$$\sin r = \frac{3}{4}\times0.766 = 0.5745$$

$\therefore$ Angle of refraction, $r = 35.06°$

For refraction at water-glass interface, we have

$$\frac{\sin 35.06°}{\sin r'} = \frac{9}{8}$$

or $\quad \sin r' = \dfrac{8}{9}\times0.5745 = 0.5107 \quad \therefore\ r' = 30.7°$

26. (b) : Here $V_D = 0.5$ V, $V = 1.5$ V, $I = 5$ mA $= 5\times10^{-3}$A, $R = ?$

The voltage equation for the diode circuit is

$IR + V_D = V$

or $\quad 5\times10^{-3}\times R + 0.5 = 1.5 \quad$ or $\quad R = 200\ \Omega$.

27. (a)

28. (c) : As the man is stationary with respect to the conveyor belt, the acceleration of the man with respect to ground is equal to the acceleration of the conveyor belt. Hence, acceleration of the man = a = 1 m s^{-2}

and therefore, the net force on the man is

$F = ma$ = (65 kg) × 1 m s^{-2} = 65 N.

Let R be the normal reaction of the belt on the man. As there is no motion of the man in a direction normal to the belt, we must have

$R = mg$.

The force of limiting friction on the man is

$\mu R = \mu mg$.

Let us assume that the man can remain stationary relative to the belt up to an acceleration a'. Then the force acting on the man will be

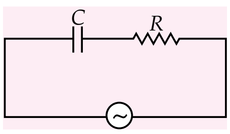
$F' = ma'$.

and this must be provided by the force of limiting friction. Hence,

$F' = ma' = \mu R = \mu mg$

$\Rightarrow\quad a' = \mu g = 0.2\times9.8$ m s^{-2} = 1.96 m s^{-2}.

29. (c) : Here, $\omega = 500$ radian s^{-1}



The capacitive reactance is

$$X_C = \frac{1}{\omega C}$$

The impedance of the circuit is

$$Z = \sqrt{R^2 + (X_C)^2} = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$$

$$R\sqrt{\frac{5}{4}} = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2} \quad\text{or}\quad RC = \frac{2}{\omega} = \frac{2}{500}\text{ s} = 4 \text{ ms}$$

$\therefore$ The time constant of RC circuit, $\tau = RC = 4$ ms

30. (c) : Young's modulus $Y = \frac{F}{\pi r^2} \times \frac{l}{\Delta l}$

or $\Delta l = \frac{Fl}{\pi r^2 Y}$ or $\Delta l \propto \frac{Fl}{r^2}$

$\therefore \frac{\Delta l_1}{\Delta l_2} = \frac{F_1}{F_2} \times \frac{l_1}{l_2} \times \frac{r_2^2}{r_1^2} = \frac{1}{4} \times \frac{2}{1} \times \left(\frac{3}{1}\right)^2 = \frac{9}{2}$

31. (c) : Here, $T_1 = 0°C = (0 + 273)$ K $= 273$ K, $m = 15$ kg
$T_2 = 15°C = (15 + 273) = 288$ K, $P = 500$ watt, $\eta = 60\%$, $L = 333 \times 10^3$ J kg^{-1}.
Useful power of motor = 60% of (500) watt = 300 W
The net work done per second *i.e.*, $W = 300$ J s^{-1}
Coefficient of performance of refrigerator (reversed engine)

$$\beta = \frac{Q_2}{W} = \frac{T_2}{T_1 - T_2}$$

$$\therefore \quad Q_2 = \frac{T_2 W}{T_1 - T_2} = \frac{273 \times 300}{288 - 273} = 5460 \text{ J s}^{-1}$$

Total heat to be drawn from 15 kg water to freeze it
$Q = mL = 15 \times 333 \times 10^3$ J

$$\therefore \quad \text{Time taken} = \frac{Q}{Q_2} = \frac{15 \times 333 \times 10^3}{5460} = 914.8 \text{ s}$$

32. (a) : Given, $y = 3 \sin 5\pi t + 4 \cos 5\pi t$ ...(i)
Let, $A \cos\phi = 3$ and $A \sin\phi = 4$
Then
$A^2 (\cos^2\phi + \sin^2\phi) = 3^2 + 4^2 = 25$ or $A = 5$ cm
From (i), $y = A \cos\phi \sin 5\pi t + A \sin\phi \cos 5\pi t$
$= A \sin(5\pi t + \phi)$ ...(ii)
It is a SHM with amplitude $A = 5$ cm
Comparing (ii) with $y = A \sin(\omega t + \phi)$, we have

$$\omega = 5\pi \text{ or } \frac{2\pi}{T} = 5\pi \text{ or } T = \frac{2\pi}{5\pi} = 0.4 \text{ s}$$

33. (d) : For the given transistor,

$$\alpha_{\text{a.c.}} = \frac{\Delta I_C}{\Delta I_E} = \frac{6.25 \text{ mA}}{6.29 \text{ mA}} = 0.9936$$

and $\beta_{\text{a.c.}} = \frac{\alpha}{1-\alpha} = \frac{0.9936}{1 - 0.9936} = \frac{0.9936}{0.0064} = 155.25$

But $\beta_{\text{a.c.}} = \frac{\Delta I_C}{\Delta I_B}$

$$\Rightarrow \quad \Delta I_B = \frac{\Delta I_C}{\beta_{\text{a.c.}}} = \frac{6.25 \text{ mA}}{155.25} = 40.26 \times 10^{-3} \text{ mA.}$$

34. (a) : Width of slit, $d = \frac{n\lambda D}{x}$

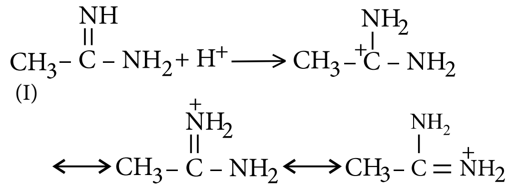
Here, $n = 1$, $D = 1$ m, $x = 2.5$ mm $= 2.5 \times 10^{-3}$ m
$\lambda = 500$ nm $= 500 \times 10^{-9}$ m

$$\therefore \quad d = \frac{1 \times 500 \times 10^{-9} \times 1}{2.5 \times 10^{-3}} = 2 \times 10^{-4} \text{ m} = 0.2 \text{ mm}$$

When the distance between the slits and the screen is doubled, the fringe width is

35. (c) **36. (a)** **37. (c)** **38. (b)** **39. (b)**
40. (a)

41. (b) :



The conjugate acid obtained by addition of a proton to I is stabilised by two equivalent resonance structures and hence, compound I is the most basic. Further 2° amines are more basic than 1° amines while amides are least basic due to delocalization of lone pair of electrons of N over the CO group. Thus the order is : I > III > II > IV

42. (c)

43. (b) : For *bcc*, $4r = \sqrt{3}\, a_1$ and $Z_1 = 2$
For *fcc*, $4r = \sqrt{2}\, a_2$ and $Z_2 = 4$
For equal interatomic distance, $\sqrt{3}\, a_1 = \sqrt{2}\, a_2$

$$\frac{a_2}{a_1} = \frac{\sqrt{3}}{\sqrt{2}}$$

$$\frac{d_1}{d_2} = \frac{\frac{MZ_1}{a_1^3 N_0}}{\frac{MZ_2}{a_2^3 N_0}} = \frac{a_2^3 Z_1}{a_1^3 Z_2} = \left(\sqrt{\frac{3}{2}}\right)^3 \times \frac{2}{4} = 0.919 : 1$$

44. (a) : A dilute solution of sodium thiosulphate ($Na_2S_2O_3$) when treated with $AgNO_3$ solution, first gives a white ppt. of silver thiosulphate ($Ag_2S_2O_3$) which readily changes to yellow, orange, brown and finally black due to formation of silver sulphide, Ag_2S.

$$2AgNO_3 + Na_2S_2O_3 \longrightarrow \underset{\text{white ppt.}}{Ag_2S_2O_3\downarrow} + 2NaNO_3$$

$$Ag_2S_2O_3 + H_2O \longrightarrow \underset{\text{black ppt.}}{Ag_2S\downarrow} + H_2SO_4$$

45. (d) : $\lambda = \frac{h}{\sqrt{2m(KE)}}$

$$\frac{\lambda_{He}}{\lambda_{Ne}} = \sqrt{\frac{m_{Ne}(KE)_{Ne}}{m_{He}(KE)_{He}}} \quad \text{...(i)}$$

$$\Rightarrow \quad \frac{m_{Ne}}{m_{He}} = \frac{20}{4} = 5 \quad \text{...(ii)}$$

$KE \propto T$

$$\frac{(KE)_{Ne}}{(KE)_{He}} = \frac{727 + 273}{-73 + 273} = \frac{1000}{200} = 5 \quad \text{...(iii)}$$

Put values from eqns. (ii) and (iii) in eqn. (i)

$$\frac{\lambda_{He}}{\lambda_{Ne}} = \sqrt{5 \times 5} = 5$$

46. (d)

47. (b) :

$$\overset{\text{Oxidation}}{\overbrace{\text{Change in oxidation state} = 2}}$$

$$M^{x+} + \overset{+7}{MnO_4^-} \longrightarrow \overset{+5}{MO_3^-} + Mn^{2+} + \frac{1}{2}O_2$$

$$\underset{\text{Reduction}}{\underbrace{\text{Change in oxidation state} = 5}}$$

$x + 2 = 5$

$x = 5 - 2 = +3$

48. (b) : Boiling point $(T_b) = 100 + \Delta T_b = 100 + K_b m$

Freezing point $(T_f) = 0 - \Delta T_f = -K_f m$

$T_b - T_f = (100 + K_b m) - (-K_f m)$

$105 = 100 + 0.51\ m + 1.86\ m$

$2.37\ m = 5$ or, $m = \dfrac{5}{2.37} = 2.11\ \text{m}$

$\therefore$ Wt. of sucrose to be dissolved in 100 g water

$$= \frac{2.11 \times 342}{1000} \times 100 \approx 72\ \text{g}$$

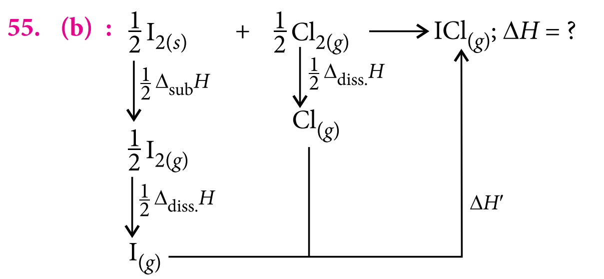
49. (c) **50. (a)**

51. (b) : Elements *X*, *Y*, *Z* with atomic numbers 19, 37, 55 lie in group 1 (alkali metals). Within a group, *IE* decreases from top to bottom. Therefore, *IE* of *Y* could be between those of *X* and *Z*.

52. (d) : $[Cr(SCN)_2(NH_3)_4]^+$ shows linkage, geometrical and optical isomerisms.

53. (d) **54. (c)**

55. (b) :



$$\Delta H = \left(\frac{1}{2}\Delta_{sub}H + \frac{1}{2}\Delta_{diss.}H\right)_{I_2} + \frac{1}{2}(\Delta_{diss.}H)_{Cl_2} + \Delta H'$$

$$= \frac{1}{2} \times 62.76 + \frac{1}{2} \times 151 + \frac{1}{2} \times 242.3 - 211.3$$

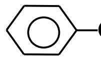
$= 75.5 + 31.38 + 121.15 - 211.3$

$= 228.03 - 211.3 = 16.73\ \text{kJ mol}^{-1}$

56. (c) : Polyphosphates like sodium hexametaphosphate [calgon, $(NaPO_3)_6$] form soluble complexes with cationic species like Ca^{2+} and Mg^{2+} present in hard water.

57. (b)

58. (b) : It follows first order kinetics since half-life is independent of concentration.

$A \xrightarrow{\Delta/Cu}$ –Cl + N_2

$t = 0$	a	0	0
$t = 10$ min	$(a - x)$	x	x
Complete	$(a - a)$	a	a

Hence, $x = 10$ L, $a = 50$ L ; $\therefore$ $k = \dfrac{2.303}{10}\log\dfrac{50}{40}\ \text{min}^{-1}$

$$k = \frac{2.303}{10}\log 1.25\ \text{min}^{-1}$$

59. (a) : The conversion of metal sulphide to metal oxide involves the process of roasting.

The metal oxides can then be converted to impure metal by reduction process called smelting.

The conversion of impure metal to pure metal involves a process called electrolysis.

60. (c) **61. (a)**

62. (d) : $2Al_{(s)} + \underset{6\ \text{mol}}{6HCl_{(aq)}} \longrightarrow 2Al^{3+}_{(aq)} + 6Cl^-_{(aq)} + \underset{3 \times 22.4\ \text{L}}{3H_{2(g)}}$

3×22.4 L $H_{2(g)}$ at STP are produced from 6 moles HCl. Hence, 11.2 L $H_{2(g)}$ at STP are produced from 1 mole HCl.

63. (d)

64. (c) : Weight $= \dfrac{\text{Eq.wt.} \times It}{96500}$ [16 min 5 sec = 965 sec]

Eq. wt. $= \dfrac{63.5}{2} = 31.75$

Mass deposited $= \dfrac{31.75 \times 1 \times 965}{96500} = 0.3175$ g

Moles in one litre $= \dfrac{0.3175}{63.5} = 0.005$ M

65. (b)

66. (d) : $N_2 + 3H_2 \rightleftharpoons 2NH_3; K_1$

$\Rightarrow\ 2NH_3 \rightleftharpoons N_2 + 3H_2; K' = \dfrac{1}{K_1}$ ...(i)

$N_2 + O_2 \rightleftharpoons 2NO; K_2$ ...(ii)

$H_2 + \dfrac{1}{2}O_2 \rightleftharpoons H_2O; K_3$

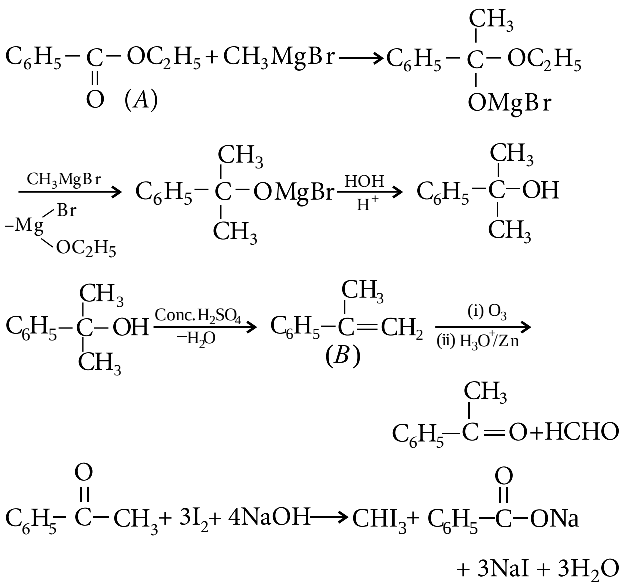
$\Rightarrow\ 3H_2 + \dfrac{3}{2}O_2 \rightleftharpoons 3H_2O;\ K'' = K_3^3$ ...(iii)

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

$2NH_3 + \dfrac{5}{2}O_2 \rightleftharpoons 2NO + 3H_2O; K = ?$

$K = K' \times K_2 \times K'' = \dfrac{K_2 \cdot K_3^3}{K_1}$

67. (a) : Since ketone with molecular formula C_8H_8O shows positive iodoform test, therefore, it must be a methyl ketone *i.e.*, $C_6H_5COCH_3$. Since this ketone is obtained by the ozonolysis of an olefin (*B*) which is obtained by the addition of excess of CH_3MgBr to an ester (*A*) with molecular formula $C_9H_{10}O_2$, therefore, ester (*A*) is $C_6H_5COOC_2H_5$ and the olefin (*B*) is $C_6H_5C(CH_3){=}CH_2$ as explained here :



68. (b) : Adsorption increases with increase in surface area.

69. (a) : In acidic medium $-COO^-$ group acts as a base and accepts a proton.

70. (b) : Since the ratio of $p_A°$ and $p_B°$ is 1 : 2 and mole fraction is 1 : 2 therefore, partial pressure of A $(p_A') = p_A° \, x_A$ and partial pressure of B $(p_B') = p_B° \, x_B$ are related as

$p_B' = 4p_A'$

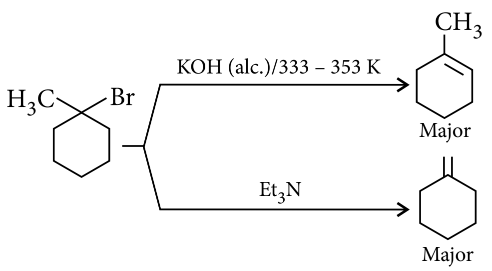
$P = p_A' + p_B' = p_A' + 4p_A' = 5p_A'$

The mole fraction of A in the vapour in equilibrium with solution (according to Dalton's law of partial pressure) is

$$x_A' = \frac{p_A'}{P} = \frac{p_A'}{5p_A'} = \frac{1}{5} = 0.2$$

71. (b) : F_2 and Cl_2 are more oxidising in nature hence, they can form Pb in + 4 oxidation state but Br_2 and I_2 cannot. Secondly, Pb^{4+} is strong oxidising agent and in its presence Br^- and I^- cannot exist.

72. (a) : Dehydrohalogenation using KOH/C_2H_5OH produces Saytzeff product as the major product while the strong bases like Et_3N or $(CH_3)_3COH/KOH$ produce Hofmann product as the major product.



73. (d) : $\underset{\text{Propionic acid (X)}}{CH_3CH_2COOH} \xrightarrow{NH_3} \underset{\text{Ammonium propanoate (Y)}}{CH_3CH_2COONH_4}$

$\underset{\text{Ethylamine}}{CH_3CH_2NH_2} \xleftarrow{Br_2/KOH} \underset{\text{Propanamide (Z)}}{CH_3CH_2CONH_2} \xleftarrow[-H_2O]{\Delta}$

74. (a) : Allylic carbocation is more stable and C—H bond is easily broken compared to C—D bond. Hence, the order is I > III > IV >II.

75. (d) : As 10 g of gas leaked out after the dent, 90 g of the gas must occupy the volume of the cylinder at 2 atm and 27°C.

$$PV = \frac{w}{M}RT, \; 2 \times V = \frac{90}{40} \times 0.0821 \times 300 \Rightarrow V = 27.7 \text{ L}$$

76. (d)	**77. (c)**	**78. (a)**	**79. (b)**	**80. (d)**
81. (b)	**82. (b)**	**83. (c)**	**84. (c)**	**85. (d)**
86. (c)	**87. (a)**	**88. (b)**	**89. (c)**	**90. (c)**
91. (d)	**92. (b)**	**93. (d)**	**94. (c)**	**95. (c)**
96. (c)	**97. (d)**	**98. (a)**	**99. (c)**	**100. (d)**
101. (b)	**102. (c)**	**103. (b)**	**104. (b)**	**105. (c)**
106. (d)				

107. (c) : Given equation $(x^3 - 3x^2 + 3x - 1) + 64 = 0$

$\Rightarrow \; (x-1)^3 = (-4)^3 \; \Rightarrow \; x - 1 = -4, -4\omega, -4\omega^2$

$\therefore \; x = -3, 1 - 4\omega, 1 - 4\omega^2$

108. (a) : $\left(\frac{3}{2} + \frac{i\sqrt{3}}{2}\right)^{100} = 3^{50}(x + iy)$

$\Rightarrow \; (i\sqrt{3})^{100}\left(\frac{1}{2} - \frac{i\sqrt{3}}{2}\right)^{100} = 3^{50}(x + iy)$

$\Rightarrow \; (-\omega)^{100} = x + iy \; \Rightarrow \; \omega = x + iy$

$\Rightarrow \; \frac{-1 + i\sqrt{3}}{2} = x + iy \; \Rightarrow \; x = -1/2, y = \frac{\sqrt{3}}{2}$

109. (a)

110. (b) : Let $S = 2^{1/4} \cdot 4^{1/8} \cdot 8^{1/16} \cdot 16^{1/32} \ldots\infty$

$= 2^{1/4} \cdot 2^{2/8} \cdot 2^{3/16} \cdot 2^{4/32} \ldots = 2^{1/4 + 2/8 + 3/16 + 4/32} \ldots = 2^x$,

where $x = \frac{1}{4} + \frac{2}{8} + \frac{3}{16} + \frac{4}{32} + \ldots$ ...(i)

$\Rightarrow \; \frac{x}{2} = \frac{1}{8} + \frac{2}{16} + \frac{3}{32} + \frac{4}{64} + \ldots$ ...(ii)

(i) – (ii) gives $\frac{x}{2} = \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \frac{1}{32} + \ldots = \frac{\frac{1}{4}}{1 - \frac{1}{2}}$

$\Rightarrow \; x = 1 \; \Rightarrow \; S = 2$

111. (c) : $2^{\log_2\sqrt{9^{x-1}+7}} = \sqrt{9^{x-1}+7}$

$2^{\frac{1}{5}\log_2(3^{x-1}+1)} = (3^{x-1} + 1)^{1/5}$

The sixth term in the expansion is

$$\binom{7}{5}\left(\sqrt{9^{x-1}+7}\right)^2 \cdot \frac{1}{3^{x-1}+1} = 84$$

$\Rightarrow \quad \dfrac{9^{x-1}+7}{3^{x-1}+1}=\dfrac{84}{21}=4 \Rightarrow (3^{x-1})^2 - 4(3^{x-1}) + 3 = 0$

$\Rightarrow \quad (3^{x-1} - 1)(3^{x-1} - 3) = 0 \;\Rightarrow\; x = 1, 2.$

112. (d) : Given $x + y + z = a$ ...(i)

$x + \omega y + \omega^2 z = b$ ...(ii) $x + \omega^2 y + \omega z = c$ ...(iii)

By adding (i), (ii) and (iii) we get $x = \dfrac{a+b+c}{3}$

Hence, (a) is correct.

Again (i) + (ii) × ω^2 + (iii) × ω, we get $3y = a + b\omega^2 + c\omega$

$y = \dfrac{a+b\omega^2+c\omega}{3} \Rightarrow$ (b) is correct

Similarly, (i) + (ii) × ω + (iii) × ω^2 gives $z = \dfrac{a+b\omega+c\omega^2}{3}$

$\Rightarrow$ (c) is correct.

113. (b) : Since order of $x_1, x_2, ..., x_{10}$ and that of $y_1, y_2, ..., y_{15}$ is not to change. $x_1, x_2, x_3 ..., x_{10}$ may be considered identical and so $y_1, y_2 ..., y_{15}$. Hence, total number of required arrangements is $\dfrac{25!}{10!15!} = {}^{25}C_{15}$

114. (b) : $f(x) = e^{\cos^{-1}\sin\left(x+\frac{\pi}{3}\right)}$

$\therefore \quad f\left(\dfrac{8\pi}{9}\right)=e^{\cos^{-1}\sin\left(\frac{8\pi}{9}+\frac{\pi}{3}\right)}=e^{\cos^{-1}\sin\left(\frac{11\pi}{9}\right)}$

$=e^{\cos^{-1}\sin\left(\frac{22\pi}{18}\right)}=e^{\cos^{-1}\sin\left(\frac{9\pi}{18}+\frac{13\pi}{18}\right)}$

$=e^{\cos^{-1}\sin\left(\frac{\pi}{2}+\frac{13\pi}{18}\right)}=e^{\cos^{-1}\left(\cos\left(\frac{13\pi}{18}\right)\right)}=e^{\frac{13\pi}{18}}$

115. (a) : Given $\sin^{-1}a + \sin^{-1}b + \sin^{-1}c = \dfrac{3\pi}{2}$

$\Leftrightarrow \quad \sin^{-1}a = \dfrac{\pi}{2} = \sin^{-1}b = \sin^{-1}c \quad \Leftrightarrow \quad a = b = c = 1$

Again $f(x + y) = f(x)f(y)\ \forall x, y \in R$

$\therefore \quad f(2 + 2) = f(2)f(2) = (f(2))^2 = 2^2 \qquad [\because f(2) = 2]$

$\therefore \quad f(4) = 4$

Again, $f(4 + 2) = f(4)f(2) \;\therefore f(6) = 4 \times 2 = 8$

Now given expression yields $3 - \dfrac{3(1)}{3} = 2$

116. (b)

117. (a) : Required equation of plane is

$(x + 2y + 3z - 4) + k(4x + 3y + 2z + 1) = 0$ ... (i)

It passes through (0,0,0) $-4 + k = 0$ or $k = 4$

Substituting $k = 4$ in (i), we get

$(x + 2y + 3z - 4) + 4(4x + 3y + 2z + 1) = 0$

or $\quad 17x + 14y + 11z = 0$

118. (a) : As $f(x)$ is continuous $\forall\ x \in R-\{0\}$

$\therefore \quad f(0)=\underset{x\to 0^+}{\mathrm{Lt}}\, f(x)=\underset{x\to 0^-}{\mathrm{Lt}}\, f(x)$

$\therefore \quad f(0)=\underset{x\to 0^+}{\mathrm{Lt}}\, f(x)=\underset{h\to 0}{\mathrm{Lt}}\, f(0+h)$

$=\underset{h\to 0}{\mathrm{Lt}}\dfrac{3-(243-5h)^{1/5}}{(5h+27)^{1/3}-3}=-\underset{h\to 0}{\mathrm{Lt}}\dfrac{(243-5h)^{1/5}-(243)^{1/5}}{(5h+27)^{1/3}-(27)^{1/3}}$

$$=-\frac{\underset{h\to 0}{\mathrm{Lt}}\dfrac{(243-5h)^{1/5}-(243)^{1/5}}{(243-5h)-243}\times(-5h)}{\underset{h\to 0}{\mathrm{Lt}}\dfrac{(5h+27)^{1/3}-(27)^{1/3}}{(5h+27)-27}\times(5h)}=\frac{1}{15}$$

119. (c) : $\displaystyle\int\frac{\cos^3 x+\cos^5 x}{\sin^2 x+\sin^4 x}dx=\int\frac{(\cos^2 x+\cos^4 x)\cos x\,dx}{\sin^2 x+\sin^4 x}$

Let $t = \sin x \;\Rightarrow\; dt = \cos x\, dx$

$=\displaystyle\int\frac{1-t^2+(1-t^2)^2}{t^2+t^4}dt=\int\frac{2-3t^2+t^4}{t^2+t^4}dt$

$=\displaystyle\int\left(1+\frac{2-4t^2}{t^2(1+t^2)}\right)dt=\int\left(1+\frac{2}{t^2}-\frac{6}{t^2+1}\right)dt$

$= t - \dfrac{2}{t} - 6\tan^{-1} t + c$

$= \sin x - 2\operatorname{cosec} x - 6\tan^{-1}(\sin x) + c.$

120. (b)

121. (c) : Let A and B be (α, β) and (γ, δ) respectively, then ;

$\alpha + \gamma = -2a, \alpha\gamma = -b^2$ and $\beta + \delta = -2p, \beta\delta = -q^2$.

Equation of circle on AB as diameter is

$(x - \alpha)(x - \gamma) + (y - \beta)(y - \delta) = 0$

i.e. $x^2 + y^2 - (\alpha + \gamma)x - (\beta + \delta)y + \alpha\gamma + \beta\delta = 0$

or $\quad x^2 + y^2 + 2ax + 2py - b^2 - q^2 = 0$

Its radius = $\sqrt{a^2+p^2+b^2+q^2}$.

122. (d) : Let C, S, B, T be the events that the person goes by car, scooter, bus, train respectively.

$P(C) = \dfrac{1}{7}, P(S) = \dfrac{3}{7}, P(B) = \dfrac{2}{7}, P(T) = \dfrac{1}{7}$.

Let $\bar{L}$ be the event that the person reaches the office in time.

$P(\bar{L}/C)=\dfrac{7}{9},\ P(\bar{L}/S)=\dfrac{8}{9},\ P(\bar{L}/B)=\dfrac{5}{9},\ P(\bar{L}/T)=\dfrac{8}{9}$

$\therefore \quad P(C/\bar{L})=\dfrac{P(C)P(\bar{L}/C)}{P(\bar{L})}=\dfrac{1}{7}$

123. (c) : Since, variance $(\sigma^2)=\dfrac{1}{n}\sum(x_i-\bar{x})^2$

$=\dfrac{1}{n}\sum x_i^2-\left(\dfrac{1}{n}\sum x_i\right)^2$

Since, S.D. = 2, variance = $(2)^2 = 4$

$\Rightarrow \quad 4=\dfrac{100}{n}-\dfrac{1}{n^2}(20)^2 \quad \Rightarrow \quad \dfrac{4}{100}=\dfrac{1}{n}-\dfrac{4}{n^2}$

$\Rightarrow \quad n^2 - 25n + 100 = 0$

$\Rightarrow \quad n^2 - 20n - 5n + 100 = 0 \quad \Rightarrow \quad n = 20, 5$

124. (a) : Let equation of plane be $x + 2y + 3z = c$

$\dfrac{|c-5|}{\sqrt{1+4+9}}=\dfrac{|c-7|}{\sqrt{1+4+9}}$

Squaring on both sides, we get

$c^2 + 25 - 10c = c^2 + 49 - 14c$

$\Rightarrow \quad 4c = 24 \quad \Rightarrow \quad c = 6$

So, required equation is $x + 2y + 3z - 6 = 0$

125. (b) : Let $\frac{12}{r^2}, \frac{12}{r}, 12$ be a decreasing G.P.

$\therefore$ According to question, $\frac{12}{r^2}, \frac{12}{r}, 9$ are in A.P.

$\Rightarrow \frac{24}{r} = 9 + \frac{12}{r^2} \Rightarrow 3r^2 - 8r + 4 = 0$

$\Rightarrow r = 2 \text{ or } \frac{2}{3} \Rightarrow r = \frac{2}{3}$ only

($\because$ The given G.P. is a decreasing one).

126. (d) : $\sin(\cot^{-1}(x+1)) = \sin\left(\sin^{-1}\frac{1}{\sqrt{x^2+2x+2}}\right)$

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

$\cos(\tan^{-1}x) = \cos\left(\cos^{-1}\left(\frac{1}{\sqrt{1+x^2}}\right)\right) = \frac{1}{\sqrt{1+x^2}}$

Thus, $\frac{1}{\sqrt{x^2+2x+2}} = \frac{1}{\sqrt{1+x^2}}$

$\Rightarrow x^2 + 2x + 2 = x^2 + 1 \Rightarrow x = -\frac{1}{2}$

127. (b) : Given $x^2 - y^2\sec^2\theta = 4$ and $x^2\sec^2\theta + y^2 = 16$

$\Rightarrow \frac{x^2}{4} - \frac{y^2}{4\cos^2\theta} = 1$ and $\frac{x^2}{16\cos^2\theta} + \frac{y^2}{16} = 1$

According to problem $\frac{4+4\cos^2\theta}{4} = 3\left(\frac{16-16\cos^2\theta}{16}\right)$

$\Rightarrow 1 + \cos^2\theta = 3(1 - \cos^2\theta) \Rightarrow 4\cos^2\theta = 2$

$\Rightarrow \cos\theta = \pm\frac{1}{\sqrt{2}} \Rightarrow \theta = \frac{\pi}{4}, \frac{3\pi}{4}$

128. (a) : Given A is non-singular $\therefore |A| \neq 0$

$$\Rightarrow \begin{vmatrix} x+a+b+c & b & c \\ x+a+b+c & x+b & c \\ x+a+b+c & b & x+c \end{vmatrix} \neq 0 \quad [C_1 \to C_1 + C_2 + C_3]$$

Taking out $x + a + b + c$ common from C_1 and applying $R_2 \to R_2 - R_1$

$$\Rightarrow (x+a+b+c)\begin{vmatrix} 1 & b & c \\ 0 & x & 0 \\ 1 & b & x+c \end{vmatrix} \neq 0$$

$\Rightarrow (x + a + b + c) \neq 0$ and $x(x) \neq 0$

$\therefore$ Required choice $= R - \{0, -(a + b + c)\}$

129. (b) : Given $\vec{a}\times(\vec{b}\times\vec{c}) = \frac{\vec{b}+\vec{c}}{\sqrt{2}}$

$\Rightarrow (\vec{a}\cdot\vec{c})\vec{b} - (\vec{a}\cdot\vec{b})\vec{c} = \frac{\vec{b}+\vec{c}}{\sqrt{2}}$

$\Rightarrow \left(\vec{a}\cdot\vec{c} - \frac{1}{\sqrt{2}}\right)\vec{b} - \left(\vec{a}\cdot\vec{b} + \frac{1}{\sqrt{2}}\right)\vec{c} = \vec{0}$

$\Rightarrow \vec{a}\cdot\vec{c} = \frac{1}{\sqrt{2}}$ and $\vec{a}\cdot\vec{b} = -\frac{1}{\sqrt{2}}$

[$\because \vec{a}, \vec{b}, \vec{c}$ are non-coplanar]

$\cos\theta = \frac{\vec{a}\cdot\vec{b}}{|\vec{a}||\vec{b}|} = \frac{(-1/\sqrt{2})}{1\cdot 1} = \frac{-1}{\sqrt{2}} \quad \therefore \theta = \pi - \frac{\pi}{4} = \frac{3\pi}{4}$

$\therefore$ Angle between $\vec{a}$ and $\vec{b}$ is $\frac{\pi}{4}$

130. (d)

131. (b) : Shortest distance between two curves exist along the common normal. We need the equation of normals to both the curve.

Now normal equation to the curve $y^2 = 4x$ at $(m^2, 2m)$ is taken as

$y - y_1 = -\left(\frac{1}{\frac{dy}{dx}}\right)_{(x,y)=(m^2,2m)}(x - x_1) \quad \therefore (y - 2m) = -m(x - m^2)$

$\Rightarrow y + mx - 2m - m^3 = 0$ ...(A)

Similarly normal to $y^2 - 2x + 6 = 0$ at $\left(\frac{1}{2}t^2 + 3, t\right)$ is

$y + t(x - 1) - 3 - \frac{1}{2}t^3 = 0$ ...(B)

(A) and (B) represents same line.

$\Rightarrow -2m - m^3 = -4m - \frac{1}{2}m^3$

$\Rightarrow 2m = m^3 - \frac{1}{2}m^3 \Rightarrow 2m = \frac{1}{2}m^3$

$\Rightarrow m\left(2 - \frac{1}{2}m^2\right) = 0 \Rightarrow m = 0, m = \pm 2$

$\therefore$ Points on the parabolas $(m^2, 2m) = (4, 4)$

and $\left(\frac{1}{2}m^2 + 3, m\right) = (5, 2)$

$\therefore$ Shortest distance $= \sqrt{(5-4)^2 + (4-2)^2} = \sqrt{5}$

132. (c) : Since $\sim(p \vee q) \equiv \sim p \wedge \sim q$

(By De - Morgan's law)

$\therefore \sim(p \vee q) \equiv \sim p \vee \sim q$ is false.

133. (c) : $\int_0^{\pi/4} \frac{x^2 dx}{(x\sin x + \cos x)^2} = \int_0^{\pi/4} x\sec x \cdot \frac{x\cos x\, dx}{(x\sin x + \cos x)^2}$

$= \int_0^{\pi/4} x\sec x \frac{d}{dx}\left(\frac{-1}{x\sin x + \cos x}\right)dx$

$= \left.\frac{-x\sec x}{x\sin x + \cos x}\right|_0^{\pi/4} + \int_0^{\pi/4} \frac{\sec x + x\sec x\tan x}{x\sin x + \cos x}dx$

$= -\frac{2\pi}{\pi+4} + \int_0^{\pi/4} \sec^2 x\, dx = \frac{-2\pi}{\pi+4} + 1 = \frac{4-\pi}{4+\pi}.$

134. (c) : Since given vectors are coplanar

$$\therefore \begin{vmatrix} \alpha & 1 & 1 \\ 1 & \beta & 1 \\ 1 & 1 & \gamma \end{vmatrix} = 0 \Rightarrow \alpha\beta\gamma - (\alpha + \beta + \gamma) + 2 = 0$$

Now, $\frac{1}{1-\alpha} + \frac{1}{1-\beta} + \frac{1}{1-\gamma}$

$$=\frac{3-2(\alpha+\beta+\gamma)+(\alpha\beta+\beta\gamma+\gamma\alpha)}{1-(\alpha+\beta+\gamma)+(\alpha\beta+\beta\gamma+\gamma\alpha)-\alpha\beta\gamma}$$
$$=\frac{-1-2\alpha\beta\gamma+(\alpha\beta+\beta\gamma+\gamma\alpha)}{-1-2\alpha\beta\gamma+(\alpha\beta+\beta\gamma+\gamma\alpha)}=1$$

135. (d) : Let $I=\int\frac{dx}{\cos^3 x\sqrt{2\sin 2x}}=\frac{1}{2}\int\frac{dx}{(\cos x)^{\frac{7}{2}}\sqrt{\sin x}}$

$=\frac{1}{2}\int\frac{dx}{\cos^4 x\sqrt{\tan x}}$. Put $t=\tan x \Rightarrow dt=\sec^2 x\,dx$

$$\therefore\quad I=\frac{1}{2}\int\frac{1+t^2}{\sqrt{t}}dt=\frac{1}{2}\int\left(t^{-\frac{1}{2}}+t^{\frac{3}{2}}\right)dt$$
$$=\sqrt{t}+\frac{t^{\frac{5}{2}}}{5}+c=\sqrt{\tan x}+\frac{(\tan x)^{\frac{5}{2}}}{5}+c$$

136. (c)

137. (a) : Eliminating n, we get

$ag\,l^2+(af+bg-ch)\,lm+bf\,m^2=0$

$$\Rightarrow\quad ag\left(\frac{l}{m}\right)^2+(af+bg-ch)\left(\frac{l}{m}\right)+bf=0$$

It is quadratic in $\left(\frac{l}{m}\right)$

Let two values of $\frac{l}{m}$ are $\frac{l_1}{m_1}$ and $\frac{l_2}{m_2}$

$\therefore$ Product of roots $=\frac{l_1l_2}{m_1m_2}=\frac{bf}{ag}$

$\therefore\quad \frac{l_1l_2}{\frac{f}{a}}=\frac{m_1m_2}{\frac{g}{b}}=\frac{n_1n_2}{\frac{h}{c}}$ using symmetry

If the lines are perpendicular, then

$l_1l_2+m_1m_2+n_1n_2=0$

$$\frac{l_1l_2}{m_1m_2}+1+\frac{n_1n_2}{m_1m_2}=0\quad\Rightarrow\quad\frac{bf}{ag}+1+\frac{bh}{cg}=0$$
$$\Rightarrow\quad\frac{f}{a}+\frac{g}{b}+\frac{h}{c}=0$$

138. (d) : The coordinates of the new origin are $h=1$, $k=2$, and the original coordinates of the point are given to be $x=3$, $y=-4$.

The transformation relation between the old coordinates (x, y) and the new coordinates (x', y') are given by

$x=x'+h$ i.e., $x'=x-h$

and $y=y'+k$ i.e., $y'=y-k$

Substituting the values, we have

$x'=3-1=2$ and $y'=-4-2=-6$

Hence, the coordinates of the point$(3, -4)$ in the new system are $(2, -6)$.

139. (a) : $f(x)=\begin{cases}\cos\frac{\pi}{2}x, & \forall\ 0\le x<1\\ 5x+3, & \forall\ x\ge 1\end{cases}$

$$\therefore\quad f'(x)=\begin{cases}-\frac{\pi}{2}\sin\frac{\pi}{2}x, & \forall\ 0\le x<1\\ 5, & \forall\ x\ge 1\end{cases}$$

$\Rightarrow$ $f'(x)$ changes its sign from –ve to +ve in the immediate neighbourhood of $x=1$.

$\Rightarrow$ $f(x)$ changes from decreasing function to increasing function.

$\Rightarrow$ $f(x)$ has local minimum value at $x=1$.

140. (d)

141. (c) : We have, $f(x)=\frac{|x-1|}{x^2}$

$$f(x)=\begin{cases}\frac{x-1}{x^2}, x\ge 1\\ \frac{1-x}{x^2}, x<1\end{cases}$$

Clearly, $f(x)$ is not differentiable at $x=0$ and $x=1$

$\therefore$ By definition there are two critical points.

For points other than these two, we have

$$f'(x)=\begin{cases}\frac{x^2(1)-(x-1)2x}{x^4}\ i.e., \frac{2-x}{x^3}, x>1\\ \frac{x^2(-1)-(1-x)2x}{x^4}, i.e., \frac{x-2}{x^3}, x<1\end{cases}$$

$\Rightarrow$ $f'(x)=0$ at $x=2$. $\therefore$ $x=2$ is also a critical point.

Hence, $f(x)$ has three critical points 0, 1, 2.

142. (d)

143. (d) : Let $f(x)=y=3^{2x}-3^x+1=(3^x)^2-3^x+1$

$$=\left(3^x-\frac{1}{2}\right)^2+1-\frac{1}{4}=\left(3^x-\frac{1}{2}\right)^2+\frac{3}{4}$$

Now $\left(3^x-\frac{1}{2}\right)^2\ge 0\quad\therefore\quad\left(3^x-\frac{1}{2}\right)^2+\frac{3}{4}\ge 3/4$

$\Rightarrow$ $f(x)\ge 3/4$

Required range is $\left[\frac{3}{4},\infty\right)$

144. (d) : Foci are $(3, 0)$ and $(-1, 0)$, $e=2/3$ (given)

$$2ae=3-(-1)=4\ \Rightarrow a=\frac{4}{2e}=\frac{4}{2\times\frac{2}{3}}=3$$

$$\text{Now,}\ e=\frac{\sqrt{a^2-b^2}}{a}=\frac{\sqrt{9-b^2}}{3}$$

$$\Rightarrow\ \frac{2}{3}=\frac{\sqrt{9-b^2}}{3}\Rightarrow\sqrt{9-b^2}=2\Rightarrow b=\sqrt{5}$$

$\therefore$ Parametric representation of a point is

$(1+3\cos\theta, \sqrt{5}\sin\theta)$

145. (a) **146. (b)** **147. (d)** **148. (b)** **149. (a)**

150. (a)

◈◈

5 MOST FREQUENTLY ASKED CHAPTERS IN JEE ADVANCED

1. Units, Measurements and Errors
2. Rotational Motion
3. Heat and Thermodynamics
4. Electrostatics
5. Magnetism

Last 3 years (2018-2016) questions along with important formula/concepts are covered here to give you an idea of the pattern of questions asked.

Units, Measurements and Errors

If $x = A \pm B$, then $\Delta x = \Delta A + \Delta B$

Percentage error in value of $x = \left(\frac{\Delta A + \Delta B}{A \pm B}\right) \times 100\%$

If $x = AB$ or $x = \frac{A}{B}$, then percentage error =

$\frac{\Delta x}{x} \times 100\% = \frac{\Delta A}{A} \times 100\% + \frac{\Delta B}{B} \times 100\%$

If $x = \frac{kA^l B^m}{C^n}$ then $\frac{\Delta x}{x} = l\left(\frac{\Delta A}{A}\right) + m\left(\frac{\Delta B}{B}\right) + n\left(\frac{\Delta C}{C}\right)$

Paragraph for Questions 1 and 2

In electromagnetic theory, the electric and magnetic phenomena are related to each other. Therefore, the dimensions of electric and magnetic quantities must also be related to each other. In the questions below, [E] and [B] stand for dimensions of electric and magnetic fields respectively, while $[\varepsilon_0]$ and $[\mu_0]$ stand for dimensions of the permittivity and permeability of free space respectively. [L] and [T] are dimensions of length and time respectively. All the quantities are given in SI units.

1. The relation between [E] and [B] is

(a) $[E] = [B][L][T]$ (b) $[E] = [B][L]^{-1}[T]$
(c) $[E] = [B][L][T]^{-1}$ (d) $[E] = [B][L]^{-1}[T]^{-1}$

(2018)

2. The relation between $[\varepsilon_0]$ and $[\mu_0]$ is

(a) $[\mu_0] = [\varepsilon_0][L]^2[T]^{-2}$ (b) $[\mu_0] = [\varepsilon_0][L]^{-2}[T]^2$
(c) $[\mu_0] = [\varepsilon_0]^{-1}[L]^2[T]^{-2}$ (d) $[\mu_0] = [\varepsilon_0]^{-1}[L]^{-2}[T]^2$

(2018)

Paragraph for Questions 3 and 4

If the measurement errors in all the independent quantities are known, then it is possible to determine the error in any dependent quantity. This is done by the use of series expansion and truncating the expansion at the first power of the error. For example, consider the relation $z = x/y$. If the errors in x, y and z are Δx, Δy and Δz, respectively, then

$$z \pm \Delta z = \frac{x \pm \Delta x}{y \pm \Delta y} = \frac{x}{y}\left(1 \pm \frac{\Delta x}{x}\right)\left(1 \pm \frac{\Delta y}{y}\right)^{-1}$$

The series expansion for $\left(1 \pm \frac{\Delta y}{y}\right)^{-1}$, to first power in $\Delta y/y$, is $1 \mp (\Delta y/y)$. The relative errors in independent variables are always added. So the error in z will be

$$\Delta z = z\left(\frac{\Delta x}{x} + \frac{\Delta y}{y}\right)$$

The above derivation makes the assumption that $\Delta x/x << 1$, $\Delta y/y << 1$. Therefore, the higher powers of these quantities are neglected.

3. Consider the ratio $r = \frac{(1-a)}{(1+a)}$ to be determined by measuring a dimensionless quantity a. If the error in the measurement of a is Δa $(\Delta a/a << 1)$, then what is the error Δr in determining r?

(a) $\frac{\Delta a}{(1+a)^2}$ (b) $\frac{2\Delta a}{(1+a)^2}$
(c) $\frac{2\Delta a}{(1-a^2)}$ (d) $\frac{2a\Delta a}{(1-a^2)}$

(2018)

4. In an experiment the initial number of radioactive nuclei is 3000. It is found that 1000±40 nuclei decayed in the first 1.0 s. For $|x|<<1$, $\ln(1 + x) = x$ up to first power in x. The error $\Delta\lambda$, in the determination of the decay constant λ, in s^{-1}, is
(a) 0.04 (b) 0.03
(c) 0.02 (d) 0.01 *(2018)*

5. A person measures the depth of a well by measuring the time interval between dropping a stone and receiving the sound of impact with the bottom of the well. The error in his measurement of time is $\delta T = 0.01$ seconds and he measures the depth of the well to be $L = 20$ metres. Take the acceleration due to gravity $g = 10$ m s^{-2} and the velocity of sound is 300 m s^{-1}. Then the fractional error in the measurement, $\delta L/L$, is closest to
(a) 5% (b) 1% (c) 3% (d) 0.2% *(2017)*

6. Consider an expanding sphere of instantaneous radius R whose total mass remains constant. The expansion is such that the instantaneous density ρ remains uniform throughout the volume. The rate of fractional change in density $\left(\frac{1}{\rho}\frac{d\rho}{dt}\right)$ is constant. The velocity v of any point on the surface of the expanding sphere is proportional to
(a) R (b) $1/R$ (c) $R^{2/3}$ (d) R^3 *(2017)*

7. A length-scale (l) depends on the permittivity (ε) of a dielectric material, Boltzmann constant (k_B), the absolute temperature (T), the number per unit volume (n) of certain charged particles, and the charge (q) carried by each of the particles. Which of the following expression(s) for l is(are) dimensionally correct?
(a) $l=\sqrt{\left(\frac{nq^2}{\varepsilon k_B T}\right)}$ (b) $l=\sqrt{\left(\frac{\varepsilon k_B T}{nq^2}\right)}$
(c) $l=\sqrt{\left(\frac{q^2}{\varepsilon n^{2/3} k_B T}\right)}$ (d) $l=\sqrt{\left(\frac{q^2}{\varepsilon n^{1/3} k_B T}\right)}$
(2016)

8. In an experiment to determine the acceleration due to gravity g, the formula used for the time period of a periodic motion is $T=2\pi\sqrt{\frac{7(R-r)}{5g}}$. The value of R and r are measured to be (60 ± 1) mm and (10 ± 1) mm, respectively. In five successive measurements, the time period is found to be 0.52 s, 0.56 s, 0.57 s, 0.54 s and 0.59 s. The least count of the watch used for the measurement of time period is 0.01 s. Which of the following statement(s) is(are) true?
(a) The error in the measurement of r is 10%
(b) The error in the measurement of T is 3.57%
(c) The error in the measurement of T is 2%
(d) The error in the determined value of g is 11%
(2016)

Rotational Motion

For a continuous distribution of mass, the coordinates of centre of mass are given by

$$X_{CM}=\frac{1}{M}\int x\,dm\,;Y_{CM}=\frac{1}{M}\int y\,dm;Z_{CM}=\frac{1}{M}\int z\,dm$$

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

Angular momentum $\vec{L}=\vec{r}\times\vec{P}$; $L = r\,p\sin\theta$

Relation between torque and angular momentum

i.e., $\vec{\tau}_{ext}=\frac{d\vec{L}}{dt}$

Torque $\tau = I\alpha$

Kinetic energy of a rolling body = Translational kinetic energy (K_T) + Rotational kinetic energy (K_R)

$$=\frac{1}{2}Mv^2+\frac{1}{2}I\omega^2=\frac{1}{2}Mv^2\left[1+\frac{K^2}{R^2}\right]$$

9. The potential energy of a particle of mass m at a distance r from a fixed point O is given by $V(r) = kr^2/2$, where k is a positive constant of appropriate dimensions. This particle is moving in a circular orbit of radius R about the point O. If v is the speed of the particle and L is the magnitude of its angular momentum about O, which of the following statements is (are) true?
(a) $v=\sqrt{\frac{k}{2m}}R$ (b) $v=\sqrt{\frac{k}{m}}R$
(c) $L=\sqrt{mk}R^2$ (d) $L=\sqrt{\frac{mk}{2}}R^2$ *(2018)*

10. Consider a body of mass 1.0 kg at rest at the origin at time $t = 0$. A force $\vec{F}=(\alpha t\hat{i}+\beta\hat{j})$ is applied on the body, where $\alpha = 1.0$ N s^{-1} and $\beta = 1.0$ N. The torque acting on the body about the origin at time $t = 1.0$ s is $\vec{\tau}$. Which of the following statements is (are) true?

(a) $|\vec{\tau}| = \frac{1}{3}$ N m

(b) The torque $\vec{\tau}$ is in the direction of the unit vector $+\hat{k}$

(c) The velocity of the body at t = 1 s is $\vec{v} = \frac{1}{2}(\hat{i} + 2\hat{j})$ m s^{-1}

(d) The magnitude of displacement of the body at t = 1 s is $\frac{1}{6}$ m *(2018)*

11. A ring and a disc are initially at rest, side by side, at the top of an inclined plane which makes an angle 60° with the horizontal. They start to roll without slipping at the same instant of time along the shortest path. If the time difference between their reaching the ground is $(2-\sqrt{3})/\sqrt{10}$ s, then the height of the top of the inclined plane, in metres, is _______ . Take g = 10 m s^{-2}. *(2018)*

12. In the List-I below, four different paths of a particle are given as functions of time. In these functions, α and β are positive constants of appropriate dimensions and $\alpha \neq \beta$. In each case, the force acting on the particle is either zero or conservative. In List-II, five physical quantities of the particle are mentioned: $\vec{p}$ is the linear momentum, $\vec{L}$ is the angular momentum about the origin, K is the kinetic energy, U is the potential energy and E is the total energy. Match each path in List-I with those quantities in List-II, which are conserved for that path.

List-I		List-II	
P.	$\vec{r}(t) = \alpha t\hat{i} + \beta t\hat{j}$	1.	$\vec{p}$
Q.	$\vec{r}(t) = \alpha\cos\omega t\hat{i} + \beta\sin\omega t\hat{j}$	2.	$\vec{L}$
R.	$\vec{r}(t) = \alpha(\cos\omega t\,\hat{i} + \sin\omega t\,\hat{j})$	3.	K
S.	$\vec{r}(t) = \alpha t\,\hat{i} + \frac{\beta}{2}t^2\,\hat{j}$	4.	U
		5.	E

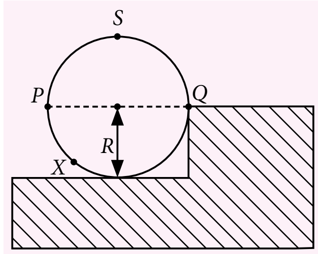
(a) P → 1, 2, 3, 4, 5; Q → 2, 5; R → 2, 3, 4, 5; S → 5

(b) P → 1, 2, 3, 4, 5; Q → 3, 5; R → 2, 3, 4, 5; S → 2, 5

(c) P → 2, 3, 4; Q → 5; R → 1, 2, 4; S → 2, 5

(d) P → 1, 2, 3, 5; Q → 2, 5; R →2, 3, 4, 5; S → 2, 5 *(2018)*

13. A wheel of radius R and mass M is placed at the bottom of a fixed step of height R as shown in the figure. A constant force is continuously applied on the surface of the wheel so that it just climbs the step without slipping. Consider the torque τ about an axis normal to the plane of the paper passing through the point Q. Which of the following options is/are correct?



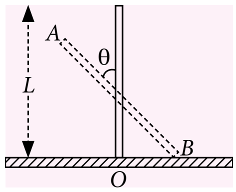
(a) If the force is applied at point P tangentially then τ decreases continuously as the wheel climbs.

(b) If the force is applied tangentially at point S then $\tau \neq 0$ but the wheel never climbs the step.

(c) If the force is applied normal to the circumference at point P then τ is zero.

(d) If the force is applied normal to the circumference at point X then τ is constant. *(2017)*

14. A rigid uniform bar AB of length L is slipping from its vertical position on a frictionless floor (as shown in the figure). At some instant of time, the angle made by the bar with the vertical is θ. Which of the following statements about its motion is/are correct?



(a) When the bar makes an angle θ with the vertical, the displacement of its midpoint from the initial position is proportional to $(1 - \cos\theta)$.

(b) The midpoint of the bar will fall vertically downward.

(c) Instantaneous torque about the point in contact with the floor is proportional to $\sin\theta$.

(d) The trajectory of the point A is a parabola. *(2017)*

Paragraph for Questions 15 and 16

One twirls a circular ring (of mass M and radius R) near the tip of one's finger as shown in figure 1. In the process the finger never loses contact with the inner rim of the ring. The finger traces out the surface of a cone, shown by the dotted line. The radius of the path traced out by the point where the ring and the finger is in contact is r. The finger rotates with an angular velocity ω_0. The rotating ring rolls without slipping on the outside of a smaller circle described by the point where the ring and the finger is in contact (figure 2). The coefficient of friction between the ring and the finger is μ and the acceleration due to gravity is g.

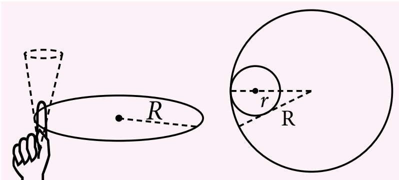


Figure 1 Figure 2

15. The minimum value of ω_0 below which the ring will drop down is

(a) $\sqrt{\dfrac{3g}{2\mu(R-r)}}$ (b) $\sqrt{\dfrac{g}{\mu(R-r)}}$

(c) $\sqrt{\dfrac{g}{2\mu(R-r)}}$ (d) $\sqrt{\dfrac{2g}{\mu(R-r)}}$

16. The total kinetic energy of the ring is

(a) $M\omega_0^2(R-r)^2$ (b) $\frac{1}{2}M\omega_0^2(R-r)^2$

(c) $\frac{3}{2}M\omega_0^2(R-r)^2$ (d) $M\omega_0^2R^2$ *(2017)*

17. A uniform wooden stick of mass 1.6 kg and length l rests in an inclined manner on a smooth, vertical wall of height $h(< l)$ such that a small portion of the stick extends beyond the wall. The reaction force of the wall on the stick is perpendicular to the stick. The stick makes an angle of 30° with the wall and the bottom of the stick is on a rough floor. The reaction of the wall on the stick is equal in magnitude to the reaction of the floor on the stick. The ratio h/l and the frictional force f at the bottom of the stick are ($g = 10$ m s^{-2})

(a) $\frac{h}{l}=\frac{\sqrt{3}}{16},\ f=\frac{16\sqrt{3}}{3}$ N

(b) $\frac{h}{l}=\frac{3}{16},\ f=\frac{16\sqrt{3}}{3}$ N

(c) $\frac{h}{l}=\frac{3\sqrt{3}}{16},\ f=\frac{8\sqrt{3}}{3}$ N

(d) $\frac{h}{l}=\frac{3\sqrt{3}}{16},\ f=\frac{16\sqrt{3}}{3}$ N *(2016)*

18. The position vector $\vec{r}$ of a particle of mass m is given by the following equation

$\vec{r}(t)=\alpha t^3\,\hat{i}+\beta t^2\,\hat{j},$

where $\alpha = 10/3$ m s^{-3}, $\beta = 5$ m s^{-2} and $m = 0.1$ kg. At $t = 1$ s, which of the following statement(s) is (are) true about the particle?

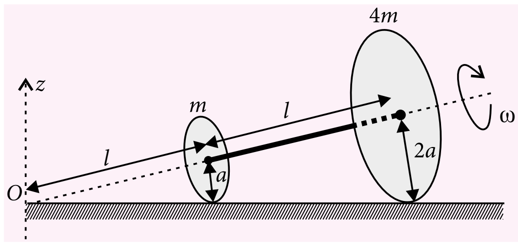
(a) The velocity $\vec{v}$ is given by $\vec{v}=(10\,\hat{i}+10\,\hat{j})$ m s^{-1}

(b) The angular momentum $\vec{L}$ with respect to the origin is given by $\vec{L}=-(5/3)\,\hat{k}$ N m s

(c) The force $\vec{F}$ is given by $\vec{F}=(\hat{i}+2\,\hat{j})$ N

(d) The torque $\vec{\tau}$ with respect to the origin is given by $\vec{\tau}=-(20/3)\,\hat{k}$ N m *(2016)*

19. Two thin circular discs of mass m and $4m$, having radii of a and $2a$, respectively, are rigidly fixed by a massless, rigid rod of length $l=\sqrt{24}a$ through their centers. This assembly is laid on a firm and flat surface, and set rolling without slipping on the surface so that the angular speed about the axis of the rod is ω. The angular momentum of the entire assembly about the point O is $\vec{L}$ (see the figure). Which of the following statement(s) is (are) true?



(a) The magnitude of angular momentum of the assembly about its center of mass is $17ma^2\omega/2$

(b) The center of mass of the assembly rotates about the z-axis with an angular speed of $\omega/5$

(c) The magnitude of the z-component of $\vec{L}$ is $55ma^2\omega$

(d) The magnitude of angular momentum of center of mass of the assembly about the point O is $81ma^2\omega$ *(2016)*

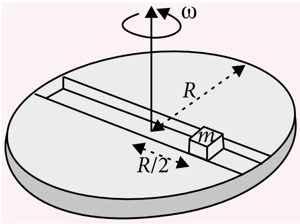
Paragraph for Questions 20 and 21

A frame of reference that is accelerated with respect to an inertial frame of reference is called a non-inertial frame of reference. A coordinate system fixed on a circular disc rotating about a fixed axis with a constant angular velocity ω is an example of a non-inertial frame of reference. The relationship between the force $\vec{F}_{rot}$ experienced by a particle of mass m moving on the rotating disc and the force $\vec{F}_{in}$ experienced by the particle in an inertial frame of reference is

$$\vec{F}_{rot}=\vec{F}_{in}+2m(\vec{v}_{rot}\times\vec{\omega})+m(\vec{\omega}\times\vec{r})\times\vec{\omega},$$

where $\vec{v}_{rot}$ is the velocity of the particle in the rotating frame of reference and $\vec{r}$ is the position vector of the particle with respect to the centre of the disc.

Now consider a smooth slot along a diameter of a disc of radius R rotating counter-clockwise with a constant angular speed ω about its vertical axis through its center. We assign a coordinate system with the origin at the center of the disc, the x-axis along the slot, the y-axis perpendicular to the slot and the z-axis along the rotation axis $(\vec{\omega} = \omega\hat{k})$. A small block of mass m is gently placed in the slot at $\vec{r} = (R/2)\hat{i}$ at t = 0 and is constrained to move only along the slot.



20. The distance r of the block at time t is

(a) $\frac{R}{4}(e^{2\omega t} + e^{-2\omega t})$ (b) $\frac{R}{4}(e^{\omega t} + e^{-\omega t})$

(c) $\frac{R}{2}\cos 2\omega t$ (d) $\frac{R}{2}\cos \omega t$

21. The net reaction of the disc on the block is

(a) $-m\omega^2 R\cos\omega t\,\hat{j} - mg\,\hat{k}$

(b) $\frac{1}{2}m\omega^2 R(e^{2\omega t} - e^{-2\omega t})\hat{j} + mg\,\hat{k}$

(c) $m\omega^2 R\sin\omega t\,\hat{j} - mg\,\hat{k}$

(d) $\frac{1}{2}m\omega^2 R(e^{\omega t} - e^{-\omega t})\hat{j} + mg\,\hat{k}$ *(2016)*

Heat and Thermodynamics

Coefficient of linear expansion of a solid, $\alpha = \frac{\Delta L}{L\Delta T}$

Principle of calorimetry :

heat lost by one body = heat gained by the other.

The rate of flow of heat (or heat current) H is given by

$$H = \frac{KA(T_1 - T_2)}{L}$$

Stefan Boltzmann law : $E = \sigma T^4$

The energy radiated per second by a body of area $A = eA\sigma T^4$

Newton's law of cooling : $\frac{dQ}{dt} = -k(T - T_S)$

Wien's displacement law : $\lambda_m T$ = constant

First law of thermodynamics : $\Delta Q = \Delta U + \Delta W$

Equation of isothermal process PV = constant.

Work done during isothermal process,

$$W = \mu RT\ln\left(\frac{V_f}{V_i}\right) = \mu RT\ln\left(\frac{P_i}{P_f}\right)$$

Equation of adiabatic process,

PV^γ = constant, where $\gamma = C_P/C_V$.

Work done during adiabatic process,

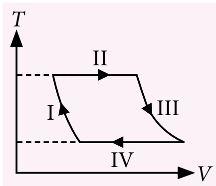
$$W = \frac{(P_iV_i - P_fV_f)}{(\gamma-1)} = \frac{\mu R(T_i - T_f)}{\gamma - 1}$$

Equation of isobaric process $\frac{V}{T}$ = constant.

Work done during isobaric process,

$W = P(V_f - V_i) = \mu R(T_f - T_i)$

22. One mole of a monatomic ideal gas undergoes a cyclic process as shown in the figure (where V is the volume and T is the temperature). Which of the following statements is (are) true?



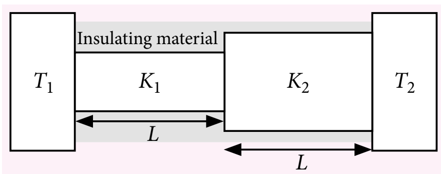
(a) Process I is an isochoric process

(b) In process II, gas absorbs heat

(c) In process IV, gas releases heat

(d) Processes I and III are not isobaric *(2018)*

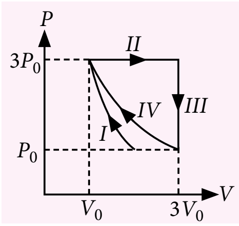
23. Two conducting cylinders of equal length but different radii are connected in series between two heat baths kept at temperatures T_1 = 300 K and T_2 = 100 K, as shown in the figure. The radius of the bigger cylinder is twice that of the smaller one and the thermal conductivities of the materials of the smaller and the larger cylinders are K_1 and K_2 respectively. If the temperature at the junction of the two cylinders in the steady state is 200 K, then K_1/K_2 = ______.



(2018)

24. One mole of a monatomic ideal gas undergoes an adiabatic expansion in which its volume becomes eight times its initial value. If the initial temperature of the gas is 100 K and the universal gas constant R = 8.0 J mol^{-1}K^{-1}, the decrease in its internal energy, in joule, is ______ . *(2018)*

25. One mole of a monatomic ideal gas undergoes four thermodynamic processes as shown schematically in the PV-diagram. Among these four processes, one is isobaric, one is isochoric, one is isothermal and one is adiabatic. Match the processes mentioned in List-I with the corresponding statements in List-II.



List-I		List-II	
P.	In process I	1.	Work done by the gas is zero
Q.	In process II	2.	Temperature of the gas remains unchanged
R.	In process III	3.	No heat is exchanged between the gas and its surroundings
S.	In process IV	4.	Work done by the gas is $6P_0V_0$

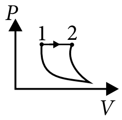
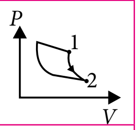
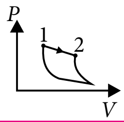
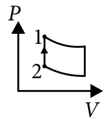
(a) $P \to 4$; $Q \to 3$; $R \to 1$; $S \to 2$
(b) $P \to 1$; $Q \to 3$; $R \to 2$; $S \to 4$
(c) $P \to 3$; $Q \to 4$; $R \to 1$; $S \to 2$
(d) $P \to 3$; $Q \to 4$; $R \to 2$; $S \to 1$ *(2018)*

26. A human body has a surface area of approximately 1 m^2. The normal body temperature is 10 K above the surrounding room temperature T_0. Take the room temperature to be T_0 = 300 K. For T_0 = 300 K, the value of σT_0^4 = 460 W m^{-2} (where σ is the Stefan Boltzmann constant). Which of the following options is/are correct?

(a) If the body temperature rises significantly then the peak in the spectrum of electromagnetic radiation emitted by the body would shift to longer wavelengths
(b) If the surrounding temperature reduces by a small amount $\Delta T_0 << T_0$, then to maintain the same body temperature the same (living) human being needs to radiate $\Delta W = 4\sigma T_0^3 \Delta T_0$ more energy per unit time
(c) The amount of energy radiated by the body in 1 second is close to 60 Joules
(d) Reducing the exposed surface area of the body (e.g. by curling up) allows humans to maintain the same body temperature while reducing the energy lost by radiation. *(2017)*

Answer Q. 27, Q. 28 and Q. 29 by appropriately matching the information given in the three columns of the following table.

An ideal gas is undergoing a cyclic thermodynamic process in different ways as shown in the corresponding P – V diagrams in column 3 of the table. Consider only the path from state 1 to state 2. W denotes the corresponding work done on the system. The equations and plots in the table have standard notations as used in thermodynamic processes. Here γ is the ratio of heat capacities at constant pressure and constant volume. The number of moles in the gas is n.

Column 1	Column 2	Column 3
(I) $W_{1\to 2} = \frac{1}{\gamma - 1}(P_2V_2 - P_1V_1)$	(i) Isothermal	(P) 
(II) $W_{1\to 2} = -PV_2 + PV_1$	(ii) Isochoric	(Q) 
(III) $W_{1\to 2} = 0$	(iii) Isobaric	(R) 
(IV) $W_{1\to 2} = -nRT\ln\left(\frac{V_2}{V_1}\right)$	(iv) Adiabatic	(S) 

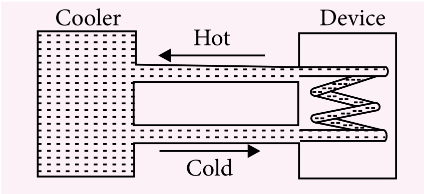
27. Which one of the following options correctly represents a thermodynamic process that is used as a correction in the determination of the speed of sound in an ideal gas?
(a) (IV) (ii) (R) (b) (I) (ii) (Q)
(c) (I) (iv) (Q) (d) (III) (iv) (R)

28. Which of the following options is the only correct representation of a process in which $\Delta U = \Delta Q - P\Delta V$?
(a) (II) (iii) (S) (b) (II) (iii) (P)
(c) (III) (iii) (P) (d) (II) (iv) (R)

29. Which one of the following options is the correct combination?
(a) (II) (iv) (P) (b) (III) (ii) (S)
(c) (II) (iv) (R) (d) (IV) (ii) (S) *(2017)*

30. A water cooler of storage capacity 120 litres can cool water at a constant rate of P watts. In a closed circulation system (as shown schematically in the figure), the water from the cooler is used to cool an external device that generates constantly 3 kW of heat (thermal load). The temperature of water fed into the device cannot exceed 30 °C and the entire stored 120 litres of water is initially cooled to 10°C. The entire system is thermally insulated.

The minimum value of P (in watts) for which the device can be operated for 3 hours is



(Specific heat of water is 4.2 kJ kg^{-1} K^{-1} and the density of water is 1000 kg m^{-3})

(a) 1600 (b) 2067 (c) 2533 (d) 3933 *(2016)*

31. The ends Q and R of two thin wires, PQ and RS, are soldered (joined) together. Initially each of the wires has a length of 1 m at 10 °C. Now the end P is maintained at 10 °C, while the end S is heated and maintained at 400 °C. The system is thermally insulated from its surroundings. If the thermal conductivity of wire PQ is twice that of the wire RS and the coefficient of linear thermal expansion of PQ is 1.2×10^{-5} K^{-1}, the change in length of the wire PQ is

(a) 0.78 mm (b) 0.90 mm
(c) 1.56 mm (d) 2.34 mm *(2016)*

32. A gas is enclosed in a cylinder with a movable frictionless piston. Its initial thermodynamic state at pressure $P_i = 10^5$ Pa and volume $V_i = 10^{-3}$ m^3 changes to a final state at $P_f = (1/32) \times 10^5$ Pa and $V_f = 8 \times 10^{-3}$ m^3 in an adiabatic quasi-static process, such that P^3V^5 = constant. Consider another thermodynamic process that brings the system from the same initial state to the same final state in two steps : an isobaric expansion at P_i followed by an isochoric (isovolumetric) process at volume V_f. The amount of heat supplied to the system in the two-step process is approximately

(a) 112 J (b) 294 J (c) 588 J (d) 813 J *(2016)*

33. A metal is heated in a furnace where a sensor is kept above the metal surface to read the power radiated (P) by the metal. The sensor has a scale that displays $\log_2 (P/P_0)$, where P_0 is a constant. When the metal surface is at a temperature of 487 °C, the sensor shows a value 1. Assume that the emissivity of the metallic surface remains constant. What is the value displayed by the sensor when the temperature of the metal surface is raised to 2767 °C ? *(2016)*

Electrostatics

Electric field intensity at any point due to an electric dipole, $E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}\sqrt{1+3\cos^2\theta}$

Electric flux, $\phi = \vec{E}\cdot d\vec{S}$; Gauss's law : $\oint \vec{E}\cdot d\vec{S} = \frac{q}{\varepsilon_0}$

Electric field due to thin infinitely long straight wire of uniform linear charge density λ, $E = \frac{\lambda}{2\pi\varepsilon_0 r}$

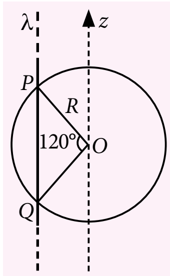
Electric potential, $V = W/q$

Electric field at the surface of a charged conductor

$\vec{E} = \frac{\sigma}{\varepsilon_0}\hat{n}$

Energy density : $U = \frac{1}{2}\varepsilon_0 E^2$

34. An infinitely long thin non-conducting wire is parallel to the z-axis and carries a uniform line charge density λ. It pierces a thin non-conducting spherical shell of radius R in such a way that the arc PQ subtends an angle 120° at the centre O of the spherical shell, as shown in the figure.



The permittivity of free space is ε_0. Which of the following statements is (are) true?

(a) The electric flux through the shell is $\sqrt{3}R\lambda/\varepsilon_0$
(b) The z-component of the electric field is zero at all the points on the surface of the shell
(c) The electric flux through the shell is $\sqrt{2}R\lambda/\varepsilon_0$
(d) The electric field is normal to the surface of the shell at all points *(2018)*

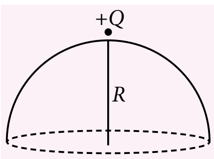
35. A particle, of mass 10^{-3} kg and charge 1.0 C, is initially at rest. At time t = 0, the particle comes under the influence of an electric field $\vec{E}(t) = E_0 \sin \omega t\,\hat{i}$, where E_0 = 1.0 N C^{-1} and $\omega = 10^3$ rad s^{-1}. Consider the effect of only the electrical force on the particle. Then the maximum speed, in m s^{-1}, attained by the particle at subsequent times is ______. *(2018)*

36. The electric field E is measured at a point $P(0, 0, d)$ generated due to various charge distributions and the dependence of E on d is found to be different for different charge distributions. List-I contains different relations between E and d. List-II describes different electric charge distributions, along with their locations. Match the functions in List-I with the related charge distributions in List-II.

List-I		List-II	
P	E is independent of d	1.	A point charge Q at the origin
Q.	$E \propto \frac{1}{d}$	2.	A small dipole with point charges Q at(0, 0, l) and $-Q$ at (0, 0, $-l$). Take $2l << d$
R.	$E \propto \frac{1}{d^2}$	3.	An infinite line charge coincident with the x-axis, with uniform linear charge density λ
S.	$E \propto \frac{1}{d^3}$	4.	Two infinite wires carrying uniform linear charge density parallel to the x- axis. The one along ($y = 0, z = l$) has a charge density + λ and the one along ($y = 0, z = -l$) has a charge density $-\lambda$. Take $2l << d$
		5.	Infinite plane charge coincident with the xy-plane with uniform surface charge density

(a) P $\rightarrow$ 5; Q $\rightarrow$ 3, 4; R $\rightarrow$ 1; S $\rightarrow$ 2
(b) P $\rightarrow$ 5; Q $\rightarrow$ 3; R $\rightarrow$ 1, 4; S $\rightarrow$ 2
(c) P $\rightarrow$ 5; Q $\rightarrow$ 3; R $\rightarrow$ 1, 2; S $\rightarrow$ 4
(d) P $\rightarrow$ 4; Q $\rightarrow$ 2, 3; R $\rightarrow$ 1; S $\rightarrow$ 5 *(2018)*

37. A point charge $+Q$ is placed just outside an imaginary hemispherical surface of radius R as shown in the figure. Which of the following statements is/are correct ?



(a) The circumference of the flat surface is an equipotential.
(b) The component of the electric field normal to the flat surface is constant over the surface.
(c) Total flux through the curved and the flat surfaces is Q/ε_0.
(d) The electric flux passing through the curved surface of the hemisphere is $-\frac{Q}{2\varepsilon_0}\left(1-\frac{1}{\sqrt{2}}\right)$.

(2017)

Paragraph for Questions 38 and 39

Consider a simple RC circuit as shown in figure 1.
Process 1 : In the circuit the switch S is closed at $t = 0$ and the capacitor is fully charged to voltage V_0 (*i.e.*, charging continues for time $T >> RC$). In the process some dissipation (E_D) occurs across the resistance R. The amount of energy finally stored in the fully charged capacitor is E_C.

Process 2 : In a different process the voltage is first set to $\frac{V_0}{3}$ and maintained for a charging time $T >> RC$. Then the voltage is raised to $\frac{2V_0}{3}$ without discharging the capacitor and again maintained for a time $T >> RC$. The process is repeated one more time by raising the voltage to V_0 and the capacitor is charged to the same final voltage V_0 as in Process 1.
These two processes are depicted in figure 2.

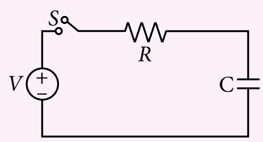


Figure 1

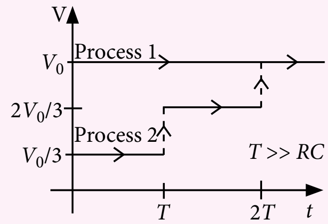


Figure 2

38. In Process 2, total energy dissipated across the resistance E_D is

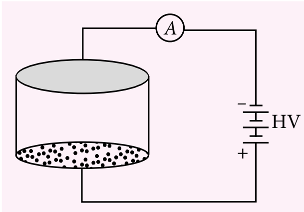
(a) $E_D = 3\left(\frac{1}{2}CV_0^2\right)$ (b) $E_D = \frac{1}{3}\left(\frac{1}{2}CV_0^2\right)$

(c) $E_D = 3CV_0^2$ (d) $E_D = \frac{1}{2}CV_0^2$

39. In Process 1, the energy stored in the capacitor E_C and heat dissipated across resistance E_D are related by

(a) $E_C = E_D$ (b) $E_C = E_D \ln 2$
(c) $E_C = 2\,E_D$ (d) $E_C = (1/2)E_D$ *(2017)*

Paragraph for Questions 40 and 41



Consider an evacuated cylindrical chamber of height h having rigid conducting plates at the ends and an insulating curved surface as shown in the figure. A number of spherical balls made of a light weight and soft material and coated with a conducting material are placed on the bottom plate. The balls have a radius $r << h$. Now a high voltage source (HV) is connected across the conducting plates such that the bottom plate is at $+V_0$ and the top plate at $-V_0$. Due to their conducting surface, the balls will get charged, will become equipotential with the plate and are repelled by it. The balls will eventually collide with the top plate, where the coefficient of restitution can be taken to be zero due to the soft nature of the material of the balls. The electric field in the chamber can be considered to be that of a parallel plate capacitor. Assume that there are no collisions between the balls and the interaction between them is negligible. (Ignore gravity)

40. Which one of the following statements is correct?
(a) The balls will bounce back to the bottom plate carrying the opposite charge they went up with
(b) The balls will stick to the top plate and remain there
(c) The balls will execute simple harmonic motion between the two plates
(d) The balls will bounce back to the bottom plate carrying the same charge they went up with

41. The average current in the steady state registered by the ammeter in the circuit will be
(a) proportional to $V_0^{1/2}$
(b) zero
(c) proportional to V_0^2
(d) proportional to the potential V_0 *(2016)*

Magnetism

Biot Savart's law, $dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$; $d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,(d\vec{l}\times\vec{r})}{r^3}$

Ampere's circuital law $\oint \vec{B}\cdot d\vec{l} = \mu_0 I$.

Radius of circular path is

$$R = \frac{mv}{Bq} = \frac{\sqrt{2mK}}{qB}$$

Time period of revolution is $T = \frac{2\pi R}{v} = \frac{2\pi m}{qB}$

Force on a current carrying conductor in a uniform magnetic field

$\vec{F} = I\,(\vec{l}\times\vec{B})$; $F = IlB\sin\theta$

Torque on a current carrying coil placed in a uniform magnetic field

$\tau = NIAB\sin\theta = MB\sin\theta$

Conversion of galvanometer into a ammeter

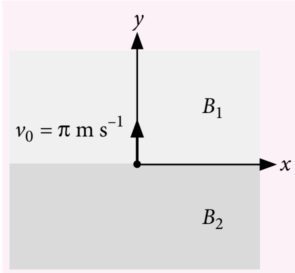
$$S = \left(\frac{I_g}{I - I_g}\right)G$$

Conversion of galvanometer into voltmeter

$$R = \frac{V}{I_g} - G$$

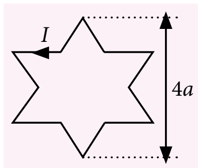
42. Two infinitely long straight wires lie in the xy-plane along the lines $x = \pm R$. The wire located at $x = +R$ carries a constant current I_1 and the wire located at $x = -R$ carries a constant current I_2. A circular loop of radius R is suspended with its centre at $(0, 0, \sqrt{3}R)$ and in a plane parallel to the xy-plane. This loop carries a constant current I in the clockwise direction as seen from above the loop. The current in the wire is taken to be positive if it is in the $+\hat{j}$ direction. Which of the following statements regarding the magnetic field $\vec{B}$ is (are) true?
(a) If $I_1 = I_2$, then $\vec{B}$ cannot be equal to zero at the origin (0, 0, 0)
(b) If $I_1 > 0$ and $I_2 < 0$, then $\vec{B}$ can be equal to zero at the origin (0, 0, 0)
(c) If $I_1 < 0$ and $I_2 > 0$, then $\vec{B}$ can be equal to zero at the origin (0, 0, 0)
(d) If $I_1 = I_2$, then the z-component of the magnetic field at the centre of the loop is $\left(-\frac{\mu_0 I}{2R}\right)$ *(2018)*

43. In the xy-plane, the region $y > 0$ has a uniform magnetic field $B_1\hat{k}$ and the region $y < 0$ has another uniform magnetic field $B_2\hat{k}$. A positively charged particle is projected from the origin along the positive y-axis with speed $v_0 = \pi$ m s^{-1} at $t = 0$, as shown in the figure. Neglect gravity in this problem. Let $t = T$ be the time when the particle crosses the x-axis from below for the first time. If $B_2 = 4B_1$, the average speed of the particle, in m s^{-1}, along the x-axis in the time interval T is ______ . *(2018)*



44. A moving coil galvanometer has 50 turns and each turn has an area 2×10^{-4} m^2. The magnetic field produced by the magnet inside the galvanometer is 0.02 T. The torsional constant of the suspension wire is 10^{-4} N m rad^{-1}. When a current flows through the galvanometer, a full scale deflection occurs if the coil rotates by 0.2 rad. The resistance of the coil of the galvanometer is 50 Ω. This galvanometer is to be converted into an ammeter capable of measuring current in the range 0 - 1.0 A. For this purpose, a shunt resistance is to be added in parallel to the galvanometer. The value of this shunt resistance, in ohm, is _______. *(2018)*

45. A symmetric star shaped conducting wire loop is carrying a steady state current I as shown in the figure. The distance between the diametrically opposite vertices

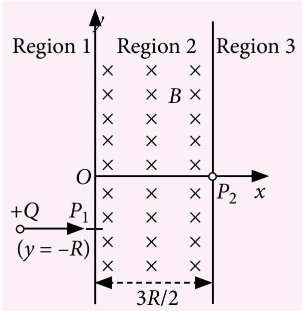


of the star is $4a$. The magnitude of the magnetic field at the center of the loop is

(a) $\frac{\mu_0 I}{4\pi a}3[2-\sqrt{3}]$ (b) $\frac{\mu_0 I}{4\pi a}6[\sqrt{3}-1]$

(c) $\frac{\mu_0 I}{4\pi a}3[\sqrt{3}-1]$ (d) $\frac{\mu_0 I}{4\pi a}6[\sqrt{3}+1]$ *(2017)*

46. A uniform magnetic field B exists in the region between $x = 0$ and $x = \frac{3R}{2}$ (region 2 in the figure) pointing normally into the plane of the paper. A particle with charge $+Q$ and momentum p directed along x-axis enters region 2 from region 1 at point $P_1(y = -R)$. Which of the following option(s) is/are correct?



(a) For $B > \frac{2}{3}\frac{p}{QR}$, the particle will re-enter region 1.

(b) For $B = \frac{8}{13}\frac{p}{QR}$, the particle will enter region 3 through the point P_2 on x-axis.

(c) For a fixed B, particles of same charge Q and same velocity v, the distance between the point P_1 and the point of re-entry into region 1 is inversely proportional to the mass of the particle.

(d) When the particle re-enters region 1 through the longest possible path in region 2, the magnitude of the change in its linear momentum between point P_1 and the farthest point from y-axis is $p/\sqrt{2}$. *(2017)*

Answer Q. 47, Q. 48 and Q. 49 by appropriately matching the information given in the three columns of the following table.

A charged particle (electron or proton) is introduced at the origin $(x = 0, y = 0, z = 0)$ with a given initial velocity $\vec{v}$. A uniform electric field $\vec{E}$ and a uniform magnetic field $\vec{B}$ exist everywhere. The velocity $\vec{v}$, electric field $\vec{E}$ and magnetic field $\vec{B}$ are given in columns 1, 2 and 3, respectively. The quantities E_0, B_0 are positive in magnitude.

Column 1	Column 2	Column 3
(I) Electron with $\vec{v} = 2\frac{E_0}{B_0}\hat{x}$	(i) $\vec{E} = E_0\hat{z}$	(P) $\vec{B} = -B_0\hat{x}$
(II) Electron with $\vec{v} = \frac{E_0}{B_0}\hat{y}$	(ii) $\vec{E} = -E_0\hat{y}$	(Q) $\vec{B} = B_0\hat{x}$
(III) Proton with $\vec{v} = 0$	(iii) $\vec{E} = -E_0\hat{x}$	(R) $\vec{B} = B_0\hat{y}$
(IV) Proton with $\vec{v} = 2\frac{E_0}{B_0}\hat{x}$	(iv) $\vec{E} = E_0\hat{x}$	(S) $\vec{B} = B_0\hat{z}$

47. In which case would the particle move in a straight line along the negative direction of y-axis (*i.e.*, move along $-\hat{y}$)?

(a) (IV) (ii) (S) (b) (II) (iii) (Q)

(c) (III) (ii) (R) (d) (III) (ii) (P)

48. In which case will the particle move in a straight line with constant velocity?

(a) (II) (iii) (S) (b) (III) (iii) (P)

(c) (IV) (i) (S) (d) (III) (ii) (R)

49. In which case will the particle describe a helical path with axis along the positive z direction?

(a) (II) (ii) (R) (b) (III) (iii) (P)

(c) (IV) (i) (S) (d) (IV) (ii) (R) *(2017)*

50. Consider two identical galvanometers and two identical resistors with resistance R. If the internal resistance of the galvanometers $R_C < R/2$, which of the following statement(s) about any one of the galvanometers is(are) true?

(a) The maximum voltage range is obtained when all the components are connected in series

(b) The maximum voltage range is obtained when the two resistors and one galvanometer are connected in series, and the second galvanometer is connected in parallel to the first galvanometer

(c) The maximum current range is obtained when all the components are connected in parallel

(d) The maximum current range is obtained when the two galvanometers are connected in series and the combination is connected in parallel with both the resistors. *(2016)*

ANSWER KEY

1.	(c)	**2.**	(d)	**3.**	(b)	**4.**	(c)	**5.**	(b)
6.	(a)	**7.**	(b)	**8.**	(a,b,d)	**9.**	(b,c)	**10.**	(a,c)
11.	(0.75)	**12.**	(a)	**13.**	(a)	**14.**	(a,b,c)	**15.**	(b)
16.	(d)	**17.**	(d)	**18.**	(a,b,d)	**19.**	(a,b)	**20.**	(b)
21.	(d)	**22.**	(b,c,d)	**23.**	(4.00)	**24.**	(900)	**25.**	(c)
26.	(b,c,d)	**27.**	(c)	**28.**	(b)	**29.**	(b)	**30.**	(b)
31.	(a)	**32.**	(c)	**33.**	(9)	**34.**	(a,b)	**35.**	(2.00)
36.	(b)	**37.**	(a,d)	**38.**	(b)	**39.**	(a)	**40.**	(a)
41.	(c)	**42.**	(a,b,d)	**43.**	(2.00)	**44.**	(5.56)	**45.**	(b)
46.	(a,b)	**47.**	(c)	**48.**	(a)	**49.**	(c)	**50.**	(a,c)

The ABC of ASAT

Why shooting down a satellite, apart from being a technology stride, gives India a new strategic weapon

India announced to the world on 27th March that it had carried out a successful anti-satellite missile test, becoming only the fourth country to do so. With Prime Minister Narendra Modi coming on television himself to make the announcement, the test is being described as a giant technological and strategic development for the country.

What is an anti-satellite missile test ?

Called ASAT in short, it is the technological capability to hit and destroy satellites in space through missiles launched from the ground. Early March 27, scientists and engineers at Defence Research and Development Organisation (DRDO) launched a missile from the Dr A P J Abdul Kalam Island launch complex near Balasore in Odisha that struck a predetermined target: a redundant Indian satellite that was orbiting at a distance of 300 km from the Earth's surface.

But why would one want to hit and destroy a satellite?

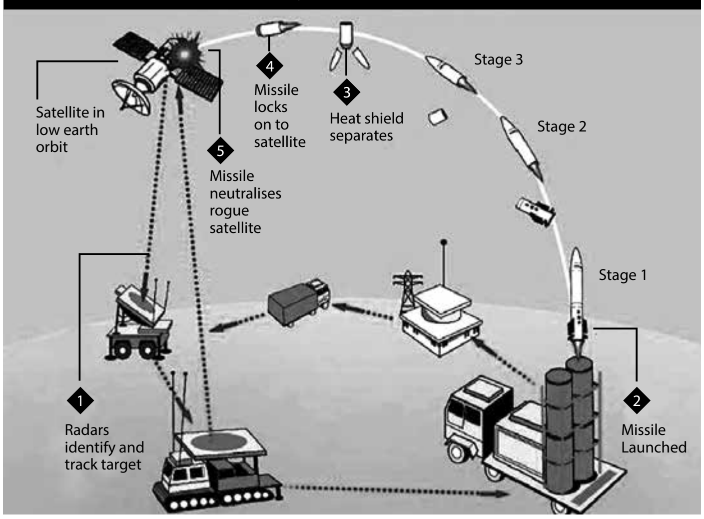
The technology is aimed at destroying, if necessary, satellites owned by enemy countries. The test, however, can be carried out only on one's own satellite. There are a large number of satellites currently in space, many of which have outlived their utility and orbiting aimlessly. One such satellite was chosen for the test. India did not identify the satellite it had chosen to hit for the test. But official sources said the satellite that had been knocked out was Microsat R, a micro-satellite launched by ISRO on January 24 this year. The satellite was manufactured by DRDO.

Satellites are extremely critical infrastructure of any country these days. A large number of crucial applications are now satellite-based. These include navigation systems, communication networks, broadcasting, banking systems, stock markets, weather forecasting, disaster management, land and ocean mapping and monitoring tools, and military applications etc. Destroying a satellite would render these applications useless. It can cripple enemy infrastructure, and bring it down on knees, without causing any threat to human lives.

If it is so potent, why do only few countries have it ?

It requires very advanced capabilities in both space and missile technologies that not many countries possess. But more than that, destroying space infrastructure like satellites is also taboo in the international community — at least till now — just like the use of a nuclear weapon. Almost every country agrees that space must not be used for wars and has spoken against weaponisation of space. There are international treaties governing the use of space, that mandate that outer space, and celestial bodies like the Moon, must only be exploited for peaceful purposes.

SENT UP, BROUGHT DOWN



There is a Outer Space Treaty of 1967, to which India is a signatory, that prohibits countries from placing into orbit around the Earth "any objects carrying nuclear weapons or any other kinds of weapons of mass destruction". It also prohibits the stationing of such weapons on celestial bodies, like the moon, or in outer space. "The moon and other celestial bodies shall be used by all state parties to the treaty exclusively for peaceful purposes," it says.

There are at least four more multilateral treaties that deal with specific concepts agreed to in the Outer Space Treaty. None of these, however, prohibits the kind of test that India carried out on March 27.

But there is a more compelling, practical and selfish reason for countries not wanting to destroy each other's satellites — the problem of space debris.

Why is space debris such a big problem?

Anything launched into the space remains in space, almost forever, unless it is specifically brought down or slowly disintegrate over decades or centuries. Satellites that are past their life and are no longer required also remain in space, orbiting aimlessly in some orbit. According to the September 2018 issue of Orbital Debris Quarterly News, published by NASA, there were 19,137 man-made objects in space that were large enough to be tracked. These included active and inactive satellites, rockets and their parts, and other small fragments. Over a thousand of them are operational satellites. Besides these, there are estimated to be millions of other smaller objects that have disintegrated from these and keep floating around in space. According to the European Space Agency, there were an estimated 7,50,000 objects of size one cm or above in space.

A satellite that is destroyed by a missile disintegrates into small pieces, and adds to the space debris. The threat from the space debris is that it could collide with the operational satellites and render them dysfunctional. According to the ESA, space debris is one of the principal threats to satellites.

When China carried out its first anti-satellite missile test in 2007, destroying its Fengyun-1C weather satellite, it created more than 2,300 large pieces of space debris, and an estimated 1.5 lakh pieces of objects that were larger than 1 cm in size. Each of them could render a satellite useless on collision.

With countries launching more and more satellites, each one of them being a strategic or commercial asset, avoiding collisions could become a challenge in the future. Countries do not want to complicate matters by creating more debris in space.

Didn't Indian test add to the debris?

It did, but it is too early to say by how much. The Ministry of External Affairs said the Indian test was done in the lower atmosphere to ensure that there was no space debris. "Whatever debris that is generated will decay and fall back on to the earth within weeks," it said. The satellite hit during the Indian test, as stated, was orbiting at 300 km from Earth's surface. Several analysis of the Chinese test of 2007, which had targeted the satellite placed at more than 800 km from Earth's surface, said that the debris created in that test would remain in space for several decades, possibly centuries.

What signal does the test send to the world?

While the government has conceded that India has long had ASAT capabilities, this is the country's first demonstration to the world. It has shown that it is capable of bringing down a satellite, and disrupting communication. Because the test was carried out on a satellite placed in the low-earth orbit, one might question whether India can hit any satellite. Targeting satellites in the higher orbits, however, is only a matter of scale — of powering the rockets enough to go deeper in the space. Many of the most strategic satellites are placed in orbits that 30,000 km from earth's surface or even higher. DRDO scientists claim India has the technology to target these as well.

But could this trigger similar tests by other countries?

Unlikely. The countries that have the capability, and intended to carry out the tests, have already done so. The first anti-satellite test (ASAT) was carried out by the US military way back in 1959. The then Soviet Union followed a year later. Thereafter, the two countries carried out a series of such tests up till early 1980s. After that there was a lull, broken only by the Chinese test in 2007. A year later, US brought down a non-functional spy satellite. Other countries which could have the capability, like Israel, have not shown an intention to test.

How does the world generally react to such tests?

Technically, if the Prime Minister had not announced it himself, the world would not have known, at least immediately, of the test since only India's own satellite was affected. As is mandatory for any missile test, India did issue a Notice to Airmen (NOTAM) to airline authorities across the world informing them about an impending missile test. This notice does not have to specify the kind of missile being tested, only the flight path and the region affected, so that airborne systems are able to avoid it.

The Chinese had withheld the information about their 2007 test for 12 days before announcing it. It had triggered an international outcry, but that was also because of the very large amount of debris created.

Is this the only way to target enemy satellites?

In the last few years, countries have explored alternative options of making enemy satellites dysfunctional, options which do not involve direct destruction of the target or creation of the debris. For example, technologies have been developed to jam the communication from the satellites by interfering with its radio signals. This can be attempted during the uplink or the downlink.

Another option that has been explored is the possibility of sending satellites that could just approach a target close enough to deviate it from its selected orbit, without destroying it. Several countries and organisations including China, Japan, Russia and the European Space Agency are said to be working on developing these 'close proximity' anti-satellite technologies.

The third option is the possible use of ground-based lasers to 'dazzle' the sensors of the satellites and make them at least "partially blind" so that they are unable to work efficiently.

None of these technologies is mature enough to be deployed or tested.

Courtesy: The Indian Express

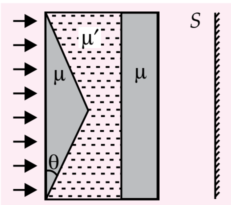
9 MIND BLOWING PROBLEMS OLYMPIAD CORNER

1. A uniform metal plate shaped like a triangle ABC has a mass of 540 gm, the length of the sides AB, BC and CA are 3 cm, 5 cm and 4 cm, respectively. The plate is pivoted freely about the point A. What mass must be added to a vertex, so that the plate can hang with the long edge horizontal?

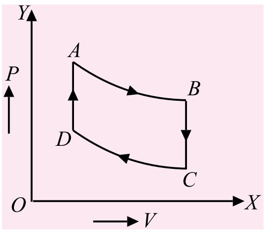
2. A body is allowed to slide on an inclined frictionless track from rest position under earth's gravity. The track ends in a circular loop of radius R. Find the minimum height h of the body so that it successfully complete the loop.

3. A hollow equiconvex lens made of a very thin glass sheet has one of its curved surface silvered. It converges a parallel beam of light at a distance of 0.2 m infront of it. Where will it converge the same rays if filled with water, ($\mu_{water} = 4/3$)?

4. A plane light wave with wavelength $\lambda = 0.70\ \mu$m falls normally on the base of a biprism made of glass ($\mu = 1.52$) with refracting angle $\theta = 5.0°$. Behind the biprism as shown in figure, there is a plane-parallel plate, with the space between them filled up with benzene ($\mu' = 1.5$). Find the width of a fringe on the screen S placed behind the system.



5. One mole of a monatomic ideal gas is taken through the cycle shown in figure.



$A \to B$: adiabatic expansion
$B \to C$: cooling at constant volume
$C \to D$: adiabatic compression
$D \to A$: heating at constant volume

The pressure and temperature at A, B etc. are denoted by P_A, T_A, P_B, T_B etc. respectively.
Given that $T_A = 1000$ K, $P_B = (2/3)P_A$ and $P_C = (1/3)P_A$.
Calculate the following quantities
(i) The work done by the gas in the process $A \to B$
(ii) The heat lost by the gas in process $B \to C$
Given that $(2/3)^{2/5} = 0.85$.

6. The landing speed of a particular type of aircraft is 216 km h^{-1} and from the moment its wheels touch the ground its motion is resisted by a force F given

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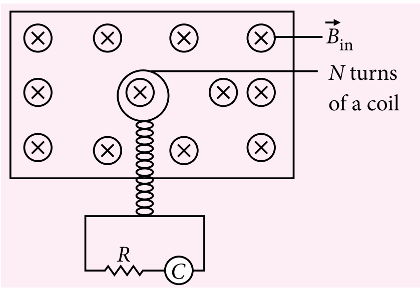
by, $F = (500 + 3v^2)$ N per tonne of aircraft. Find the minimum length of runway required by this aircraft to ensure a safe-landing.

7. How many head-on, elastic collision must a neutron have with deuterium nuclei to reduce its energy from 1 MeV to 0.025 eV ?

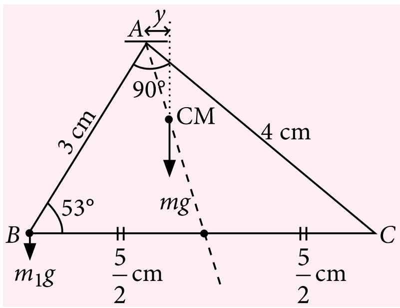
8. A flip coil consists of N turns of circular coils which lie in a uniform magnetic field. Plane of the coils is perpendicular to the magnetic field as shown in figure. The coil is connected to a current integrator which measures the total charge passing through it. The coil is turned through 180° about the diameter. Find the charge passing through the coil.



9. A short magnet makes 40 oscillations per minute when used in a vibration magnetometer at a place where Earth's horizontal components of magnetic field is 25 μT. Another short magnet of magnetic moment 1.6 A m^2 is placed north-south and 20 cm east of the oscillation magnet. Find the new frequency of oscillation in oscillation per minute if the magnet has its north pole towards north and towards south.

SOLUTIONS

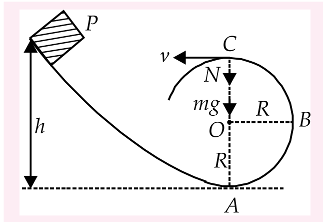
1.



Centre of mass of triangular plate is on the median. If we put a mass say m_1 on B it will produce torque about A which balance the torque produced mg about A. Thus plate will be in equilibrium position, $m_1\, g \times 3 \cos 53° = mg \times y$

$$m_1\, g \times 3 \times \frac{3}{5} = mg \times y \Rightarrow m_1 = m \times y \times \frac{5}{9} = \frac{5ym}{9}$$

2.



Suppose v be the velocity of the body at the highest point C.
According to law of conservation of energy
Energy at point P = Energy at point C

$$mgh = mg(2R) + \frac{1}{2}mv^2$$

$$\therefore \frac{1}{2}mv^2 = mg(h - 2R) \text{ or } v^2 = 2g(h - 2R) \quad \text{...(i)}$$

At point C, downward force = $mg + N$

Hence, for circular motion at point C : $mg + N = \left(\frac{mv^2}{R}\right)$

Since N cannot be negative, the velocity of the body at C must correspond to $N = 0$ if the body describes a circle *i.e.*

$$mg = \frac{mv_{\min}^2}{R} \text{ or } v_{\min} = \sqrt{(gR)}$$

For minimum velocity, equation. (i) becomes

$$v_{\min}^2 = 2g(h_{\min} - 2R) \Rightarrow h_{\min} = \frac{5R}{2}$$

3. If R is the radius of curvature of the curved surfaces,

$$\frac{1}{f_m} = \frac{2}{R}, f_m = \frac{R}{2}$$

With air inside, the system will behave as a concave mirror of focal length $\frac{R}{2}$. For parallel incoming rays, from mirror equation we have

$$\frac{1}{-0.2} + \frac{1}{-\infty} = \frac{1}{f_m}, f_m = -0.2 \text{ m}$$

Hence $R = -2f_m = 0.4$ m,
When water is filled in the lens,

$$\frac{1}{f_l} = \left(\frac{4}{3} - 1\right)\left[\frac{1}{0.4} - \frac{1}{(-0.4)}\right] = \frac{1}{0.6}$$

Power of composite system,

$$\frac{1}{F} = \frac{1}{f_l} + \frac{1}{f_m} + \frac{1}{f_l} \Rightarrow F = -12 \text{ cm}$$

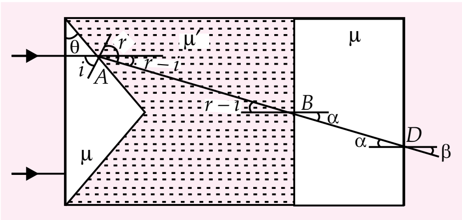
For parallel rays, we have

$$\frac{1}{v} - \frac{1}{-\infty} = \frac{1}{-12} \Rightarrow v = -12 \text{ cm}$$

The final image is formed at 12 cm in front of the lens.

4. Applying Snell's law at point A,

$\mu \sin i = \mu' \sin r$



or $\mu \sin\theta = \mu' \sin r$ $\quad (\because i = \theta)$

But θ is very small, $\sin\theta \approx \theta$ $\therefore \mu\theta = \mu' r$; $r = \dfrac{\mu\theta}{\mu'}$ ... (i)

Applying Snell's law at point B,

$\mu' \sin(r - i) = \mu \sin\alpha$

or $\mu'(r - i) = \mu\alpha$ or $\alpha = \left(\dfrac{\mu - \mu'}{\mu}\right)\theta$ ... (ii)

Applying Snell's law at point D,

$\mu \sin\alpha = 1 \times \sin\beta$ or $\mu\alpha = \beta$

$$\therefore \quad \beta = \mu\left(\frac{\mu - \mu'}{\mu}\right)\theta = (\mu - \mu')\theta \qquad \text{[Using (ii)]}$$

$$\Delta x = \frac{(a+b)\lambda}{2a\beta}$$

Since, rays are incident on prism as parallel beam. So, real source S is situated at infinity.

$\therefore \quad a \to \infty$

$$\therefore \quad \Delta x = \left(\frac{a+b}{a}\right)\frac{\lambda}{2\beta} = \left(1 + \frac{b}{\infty}\right)\frac{\lambda}{2\beta}$$

$$\therefore \quad \Delta x = \frac{\lambda}{2\beta} = \frac{\lambda}{2(\mu - \mu')\theta} = 0.20 \text{ mm}$$

5. (i) Work done during adiabatic expansion $A \to B$ is given by

$$W = \frac{nR}{\gamma - 1}(T_i - T_f) = \frac{3}{2}R(T_A - T_B) \qquad \text{...(i)}$$

For adiabatic process $P^{1-\gamma}\,T^{\gamma}$ = constant

$$\therefore \quad P_A^{1-\gamma}\,T_A^{\gamma} = P_B^{1-\gamma}T_B^{\gamma} \quad \text{or} \quad \frac{T_B}{T_A} = \left(\frac{P_B}{P_A}\right)^{(\gamma-1)/\gamma}$$

For monatomic ideal gas, $\gamma = \dfrac{5}{3}$

$$\frac{\gamma - 1}{\gamma} = \frac{2}{5} \Rightarrow \frac{T_B}{T_A} = \left(\frac{2}{3}\right)^{2/5} = 0.85 \quad [\because P_B = (2/3)P_A]$$

or $T_B = 0.85T_A = 0.85 \times 1000$ K $= 850$ K ...(ii)

$$\therefore \quad W = \left(\frac{3}{2}\right) \times 8.31 \times (1000 - 850) = 1869.75 \text{ J}$$

(ii) Process BC is isochoric, therefore heat lost by the gas in process $B \to C$ is given by

$$\Delta Q = nC_V\Delta T = nC_V(T_B - T_C) = 1 \times \frac{R}{\gamma - 1}(T_B - T_C)$$

$$= \left(\frac{3}{2}\right)R(T_B - T_C) \qquad \text{...(iii)}$$

Now, at constant volume, $\dfrac{P}{T}$ = constant

$$\therefore \quad \frac{P_B}{T_B} = \frac{P_C}{T_C} \text{ or } T_C = \left(\frac{P_C}{P_B}\right)T_B = \frac{(P_A/3)}{(2P_A/3)}T_B = \frac{T_B}{2}$$

$$T_C = \frac{850 \text{ K}}{2} = 425 \text{ K} \qquad \text{...(iv)}$$

From (iii), $\Delta Q = \left(\dfrac{3}{2}\right) \times 8.31 \times (850 - 425) = 5297.62$ J

6. Since the force resists the motion, it is negative.

$$\Rightarrow \quad a = -\left(\frac{500 + 3v^2}{1000}\right)\text{N kg}^{-1} = \frac{dv}{dt}$$

Where a is acceleration of aircraft

$$\Rightarrow \quad 500 + 3v^2 = -1000v\frac{dv}{dx}$$

$$\Rightarrow \quad \int dx = -1000\int \frac{v}{500 + 3v^2}dv$$

$$\Rightarrow \quad x = -\frac{1000}{6}\int_{60}^{0} \frac{6v}{500 + 3v^2}dv$$

$$= -\frac{1000}{6}\left[\log_e(500 + 3v^2)\right]_{60}^{0}$$

(At the moment the wheels touch the ground,

$$v = 216 \text{ km h}^{-1} = \frac{216}{3.6} = 60 \text{ m s}^{-1})$$

$$\therefore \quad x = \frac{1000}{6}\log_e\left\{\frac{11300}{500}\right\}$$

7. Mass of neutron, m_1 = 1 u; mass of deuterium, $m_2 = 2$ u

$$\frac{\Delta E}{E_0} = \frac{4m_1m_2}{(m_1 + m_2)^2} \approx \frac{4(1)(2)}{(1+2)^2} = \frac{8}{9}$$

Where E_0 is the K.E. of the neutron and ΔE is the energy loss.

After 1st collision, $\Delta E_1 = \dfrac{8}{9}E_0$

After 2nd collision, $\Delta E_2 = \dfrac{8}{9}E_1$

Solution Senders of Physics Musing

SET-69

1. Kunal Mukherjee, Barasat, Kolkata
2. Pritam Mishra
3. Vivekanand Jha, Faridabad, Haryana

After n^{th} collision, $\Delta E_n = \frac{8}{9}E_{n-1}$

Adding all the loses, we get

$$\Delta E = \Delta E_1 + \Delta E_2 + ... + \Delta E_n$$

$$= \frac{8}{9}(E_0 + E_1 + ... + E_{n-1})$$

Since $E_1 = E_0 - \Delta E_1 = \frac{1}{9}E_0$ and $E_2 = \frac{1}{9}E_1 = \left(\frac{1}{9}\right)^2 E_0$

So, $E_{n-1} = \left(\frac{1}{9}\right)^{n-1} E_0$

$$\Delta E = \frac{8}{9}E_0\left[1 + \frac{1}{9} + \left(\frac{1}{9}\right)^2 + ... \left(\frac{1}{9}\right)^{n-1}\right]$$

$$\frac{\Delta E}{E_0} = \frac{8}{9}\left[\frac{1 - \frac{1}{9^n}}{1 - \frac{1}{9}}\right] = 1 - \frac{1}{9^n}$$

Here, $E_0 = 1 \times 10^6$ eV

$\Delta E = 1 \times 10^6 - 0.025$ eV

$\therefore \quad \frac{1}{9^n} = 1 - \frac{\Delta E}{E_0} = \frac{E_0 - \Delta E}{E_0} = \frac{0.025}{10^6}$ or $9^n = 4 \times 10^7$

Taking log both sides and solving, we get, $n = 8$

8. When the flip coil is rotated, the magnetic flux through it changes, resulting in an induced e.m.f. ε and induced current $I = \varepsilon/R$, where R is the total resistance of the circuit.

As $I = \frac{dQ}{dt}$; $Q = \int dQ = \int I dt$

From Faraday's law, induced e.m.f.

$$|\varepsilon| = \frac{d\phi_B}{dt}$$

$$Q = \int I dt = \int \frac{\varepsilon}{R} dt = \frac{1}{R}\int \frac{d\phi_B}{dt} dt$$

$$= \frac{1}{R}\int d\phi_B = \frac{d\phi_B}{R}$$

Initial flux through the coil, $\phi_{Bi} = +NBA$

When the coil is turned through 180° its flux reverses, the angle between magnetic field and area vector is reversed.

Final flux through the coil, $\phi_{Bf} = -NBA$

$|\Delta\phi_B| = |\phi_{Bf} - \phi_{Bi}| = |(-NBA) - NBA| = 2NBA$

$$\therefore \quad Q = \frac{2NBA}{R}$$

9. Magnetic induction due to the short magnet at the centre of oscillating magnet will be

$$B_I = \frac{\mu_0}{4\pi} \times \frac{M}{d^3} = \frac{10^{-7} \times 1.6}{8 \times 10^{-3}} = 2 \times 10^{-5}\ \text{T} = 20\ \mu\text{T}$$

$$T_1 = 2\pi\sqrt{\frac{I}{MB_H}} \quad \therefore \quad T_1^2 = \frac{1}{\upsilon_1^2} = \frac{4\pi^2 I}{MB_H}$$

When new magnet is placed and points towards north.

$$T_2^2 = \frac{1}{\upsilon_2^2} = \frac{4\pi^2 I}{M(B_H - B_I)}$$

Dividing, $\frac{\upsilon_2^2}{\upsilon_1^2} = \frac{B_H - B_I}{B_H} = \frac{25 - 20}{25} = \frac{1}{5}$

$\therefore \quad \upsilon_2 = \frac{\upsilon_1}{\sqrt{5}} = \frac{40}{\sqrt{5}} = 17.9$ oscillations per minute

When new magnet points towards south

$$T_3^2 = \frac{1}{\upsilon_3^2} = \frac{4\pi^2 I}{M(B_H + B_I)}$$

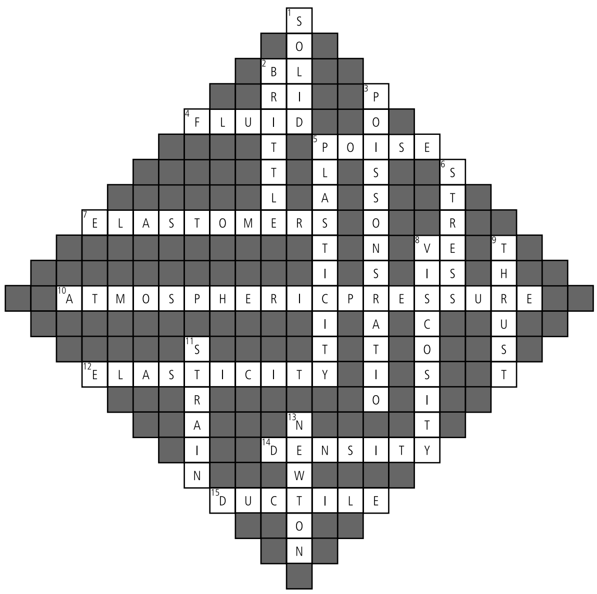
$$\therefore \quad \frac{\upsilon_3^2}{\upsilon_1^2} = \frac{(B_H + B_I)}{B_H} = \frac{25 + 20}{25} = \frac{9}{5}$$

$$\therefore \quad \upsilon_3 = \sqrt{\frac{9}{5}}\, n_1 = 40\sqrt{1.8}$$

$= 53.7$ oscillations per minute.

☺☺

CROSSWORD SOLUTION APRIL 2019



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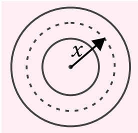
PHYSICS MUSING

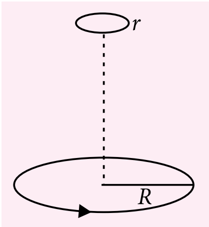
SOLUTION SET-69

1. **(c) :** $B \times 2\pi x = \mu_0 J\pi(x^2 - a^2)$



$$B = \frac{\mu_0 J}{2}\left(x - \frac{a^2}{x}\right)$$

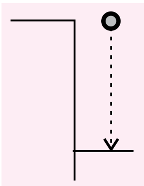
2. **(d) :** $B = \frac{\mu_0 i R^2}{2(R^2 + x^2)^{3/2}}$



$$\phi = B\pi r^2 = \frac{\mu_0 i \pi r^2 R^2}{2(R^2 + x^2)^{3/2}}$$

$$M = \frac{\phi}{i} = \frac{\mu_0 \pi R^2 r^2}{2(R^2 + x^2)^{3/2}}$$

3. **(a) :** $S_1 = \frac{1}{2}\times 10(3+t)^2$



$$S_2 = 40t + \frac{1}{2}\times 10t^2$$

or $5t^2 + 40t = 5(9 + t^2 + 6t)$

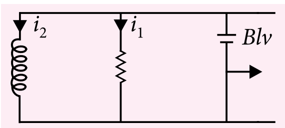
or $40t = 45 + 30t$

or $t = 4.5$ s

$$S_2 = 40(4.5) + 5\times(4.5)^2 = \frac{1125}{4}\text{ m}$$

4. **(a) :** $MR^2 = \frac{2}{5}MR^2 + Mx^2 \Rightarrow x = \sqrt{\frac{3}{5}}R = \sqrt{0.6}\,R$

5. **(b) :**



$$i_1 = \frac{Blv}{R} \qquad \text{...(i)}$$

$$Blv = \frac{Ldi}{dt}$$

$$i_2 = \frac{Blvt}{L} \qquad \text{....(ii)}$$

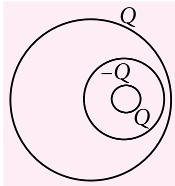
$i = i_1 + i_2$

$$F = \left(\frac{Blv}{R} + \frac{Blvt}{L}\right)Bl \qquad \text{[Using (i) and (ii)]}$$

$$P = Fv = \frac{B^2l^2v^2}{R} + \frac{B^2l^2v^2t}{L}$$

$$W = \int_0^2 Pdt = \frac{B^2l^2v^2}{R}\times 2 + \frac{B^2l^2v^2}{L}\times\frac{2^2}{2} = 32\text{ J}$$

6. **(a) :** $U = \frac{Q^2}{\frac{2\times 4\pi\varepsilon_0 r r_1}{r_1 - r}} + \frac{Q^2}{4\pi\varepsilon_0 r_2}\times\frac{1}{2}$



$$= kQ^2\left(\frac{1}{2r_2} - \frac{1}{2r_1} + \frac{1}{2r}\right)$$

7. **(a,c,d):** $\omega_1 = \frac{1}{2}\times(-2\alpha)\times T = -\text{ve}$

$$\omega_{3T/2} = \frac{1}{2}\times(-2\alpha)\times T + \frac{1}{2}\times\alpha\times\frac{T}{2} = -\text{ve}$$

$$\omega_{5T/2} = \frac{1}{2}\times(-2\alpha)\times T + \frac{1}{2}\times\alpha\times\frac{T}{2} + \alpha\times T = +\text{ve}$$

$$\omega_{3T} = \frac{1}{2}\times(-2\alpha)\times T + \frac{1}{2}\alpha\times\frac{T}{2} + \alpha T + \frac{1}{2}\times\alpha\times\frac{T}{2} = +\text{ve}$$

$$\omega_{7T/2} = \frac{1}{2}\times(-2\alpha)\times T + \frac{1}{2}\times\alpha\times\frac{T}{2} + \alpha T + \frac{1}{2}\alpha\frac{T}{2} + \frac{1}{2}\times(-\alpha)\times\frac{T}{2} = +\text{ve}$$

8. **(a,b,d) :** (a) To keep intensity same, number of photons must be increased and hence change in photo current.

(b) $(K_{max})_1 = h\upsilon - \phi$ ...(i)

$$(K_{max})_2 = \frac{h\upsilon}{2} - \phi \qquad \text{...(ii)}$$

$2(K_{max})_2 = h\upsilon - 2\phi$ ...(iii)

Using (i) and (ii)

$(K_{max})_1 - 2(K_{max})_2 = \phi$

$$(K_{max})_2 = \frac{(K_{max})_1}{2} - \frac{\phi}{2}$$

(c) and (d)

If $E_{incidence} < h\upsilon$, no current is there.

If $E_{incident} > h\upsilon$, option (a).

9. **(2) :** $V_A - iR + 2 - \frac{Ldi}{dt} = V_B$

$$V_A - V_B = 8 = iR - 2 + L\frac{di}{dt} = 2R - 2 + L\times 1 \qquad \text{...(i)}$$

$V_A - V_B = 4 = 2R - 2 - L \times 1$ ...(ii)

From (i) and (ii)

$$L = 2\text{ H},\ R = 4\ \Omega \Rightarrow \frac{R}{L} = 2$$

10. **(1) :** $F = u_{rel}\frac{dm}{dt} = 5\times\rho\frac{dV}{dt}$

$= 10^3 \times 5 \times 200 \times 10^{-6}$ N = 1 N

CROSSWORD

Modern Physics

CLASS XII

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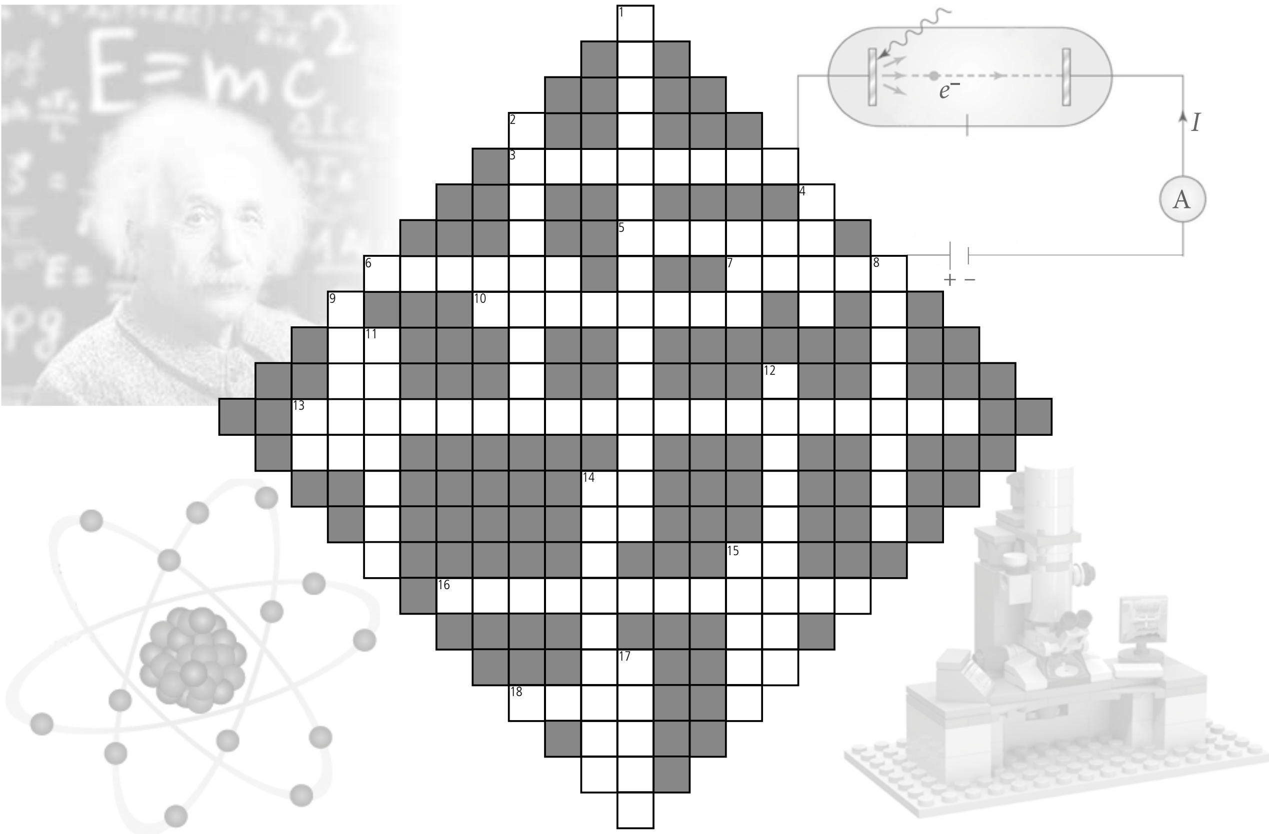

DOWN

1. The value of retarding potential at which the photoelectric current becomes zero **(6,9)**
2. An arrangement which converts light energy into electric energy **(9)**
4. The density of nuclei of all the elements is **(4)**
8. Protons and neutrons which are present in the nuclei of the atoms are collectively known as **(8)**
9. The particles which produce heating effect and have least penetrating power **(5)**
11. The material used to cool the fuel rod and moderator **(7)**
12. S.I. unit of radioactivity **(9)**
14. The substance which is used to slow down fast moving neutrons **(9)**
15. Unit of binding energy **(5)**
17. The rays which have minimum ionising power **(5)**

ACROSS

3. The time interval in which one-half of the radioactive nuclei originally present in radioactive sample disintegrate **(4,4)**
5. A material consisting of moving charged particles with equal number of positive and negative charges **(6)**
6. The particle which have zero rest mass and always moves with speed of light in a vacuum **(6)**
7. The spectrum series which belong to the ultraviolet region **(5)**
10. A process in which a nucleus rich in protons captures an electron from the inner most shell **(1,7)**
13. The phenomenon of emission of electrons from a metal surface, when electromagnetic radiations of sufficiently high frequency are incident on it **(13,6)**
16. The strong attractive force that binds the protons and neutrons together inside nucleus **(7,5)**
18. The particles emission which results in formation of Isobars **(4)**

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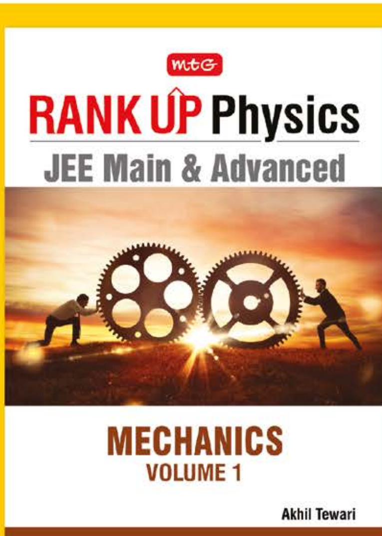

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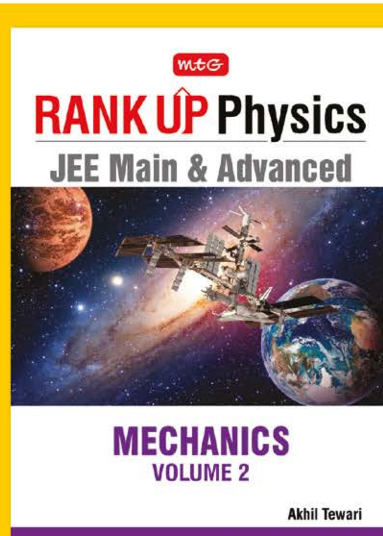

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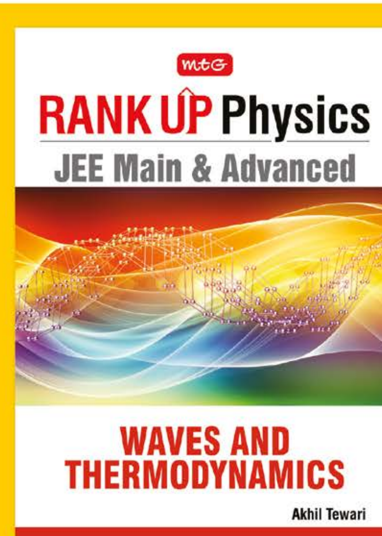

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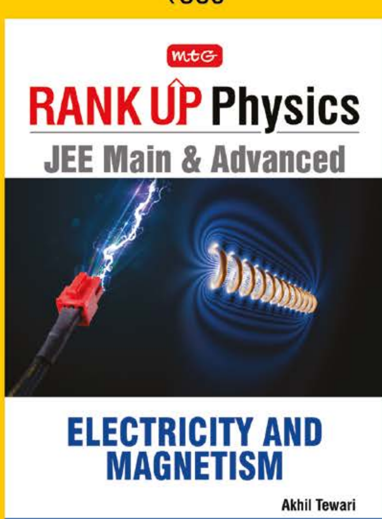

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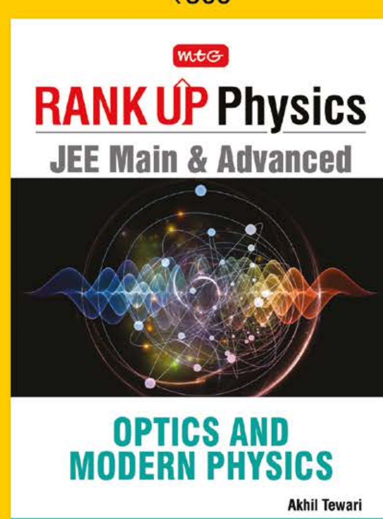

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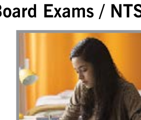

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