Get Set Go for NEET | JEE

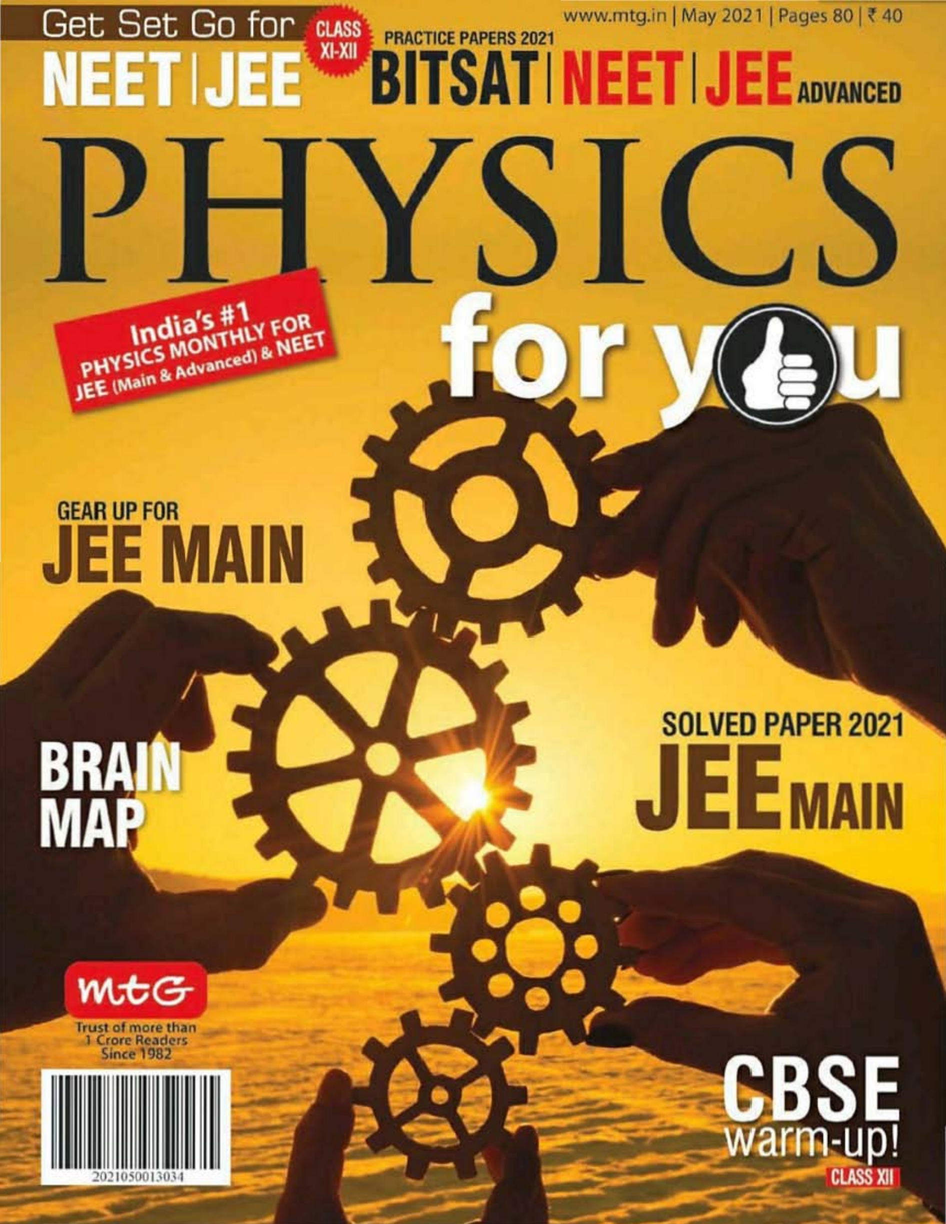
CLASS XI-XII

PRACTICE PAPERS 2021 BITSAT | NEET | JEE ADVANCED

www.mtg.in | May 2021 | Pages 80 | ₹ 40

PHYSICS for you

India's #1 PHYSICS MONTHLY FOR JEE (Main & Advanced) & NEET



GEAR UP FOR JEE MAIN

BRAIN MAP

SOLVED PAPER 2021 JEE MAIN

CBSE warm-up! CLASS XII

mtG

Trust of more than 1 Crore Readers Since 1982

2021050013034

PHYSICS for you

Volume 29 No. 5 May 2021

Managing Editor
Mahabir Singh
Editor
Anil Ahlawat

Corporate Office:
Plot 99, Sector 44 Institutional area, Gurugram -122 003 (HR).
Tel : 0124-6601200 e-mail : info@mtg.in website : www.mtg.in
Regd. Office:
406, Taj Apartment, Near Safdarjung Hospital, New Delhi - 110029.

CONTENTS

Competition Edge

Printed and Published by Mahabir Singh on behalf of MTG Learning Media Pvt. Ltd. Printed at HT Media Ltd., B-2, Sector-63, Noida, UP-201307 and published at 406, Taj Apartment, Ring Road, Near Safdarjung Hospital, New Delhi - 110029.
Editor : Anil Ahlawat

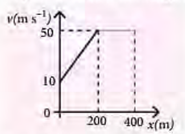
SOLVED PAPER

Held on 16^{th} March, Morning Shift

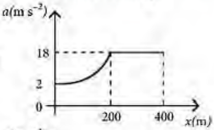
JEE MAIN 2021

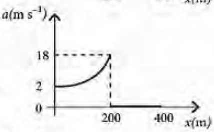
SECTION A (MULTIPLE CHOICE QUESTIONS)

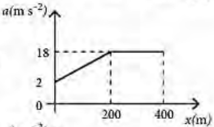
1. The velocity-displacement graph describing the motion of a bicycle is shown in the figure.

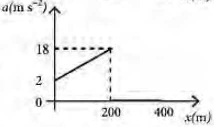


The acceleration-displacement graph of the bicycle's motion is best described by

(a)


(b)


(c)


(d)


2. For an electromagnetic wave travelling in free space, the relation between average energy densities due to electric (U_e) and magnetic (U_m) field is

(a) $U_e < U_m$ (b) $U_e \neq U_m$
(c) $U_e > U_m$ (d) $U_e = U_m$

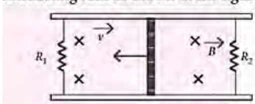
3. The volume V of an enclosure contains a mixture of three gases, 16 g of oxygen, 28 g of nitrogen and 44 g of carbon dioxide at absolute temperature T. Consider R as universal gas constant. The pressure of the mixture of gases is

(a) $\frac{4RT}{V}$ (b) $\frac{3RT}{V}$
(c) $\frac{88RT}{V}$ (d) $\frac{5}{2}\frac{RT}{V}$

4. One main scale division of a vernier callipers is 'a' cm and n^{th} division of the vernier scale coincide with $(n-1)^{th}$ division of the main scale. The least count of the callipers in mm is

(a) $\left(\frac{n-1}{10n}\right)a$ (b) $\frac{10na}{(n-1)}$
(c) $\frac{10a}{n}$ (d) $\frac{10a}{(n-1)}$

5. A conducting bar of length L is free to slide on two parallel conducting rails as shown in the figure.



Two resistors R_1 and R_2 are connected across the ends of the rails. There is a uniform magnetic field $\vec{B}$ pointing into the page. An external agent pulls the bar to the left at a constant speed v.

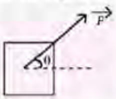
The correct statement about the directions of induced currents I_1 and I_2 flowing through R_1 and R_2 respectively is

(a) both I_1 and I_2 are in clockwise direction
(b) both I_1 and I_2 are in anticlockwise direction
(c) I_1 is in clockwise direction and I_2 is in anticlockwise direction
(d) I_1 is in anticlockwise direction and I_2 is in clockwise direction.

6. The maximum and minimum distances of a comet from the Sun are 1.6×10^{12} m and 8.0×10^{10} m respectively. If the speed of the comet at the nearest point is 6×10^4 m s^{-1}, the speed at the farthest point is

(a) 3.0×10^3 m s^{-1} (b) 4.5×10^3 m s^{-1}
(c) 1.5×10^3 m s^{-1} (d) 6.0×10^3 m s^{-1}

7. A block of mass m slides along a floor while a force of magnitude F is applied to it at an angle θ as shown in figure. The coefficient of kinetic friction is μ_K. Then the block's acceleration 'a' is given by (g is acceleration due to gravity)



(a) $\frac{F}{m}\cos\theta - \mu_K\left(g + \frac{F}{m}\sin\theta\right)$

(b) $\frac{F}{m}\cos\theta - \mu_K\left(g - \frac{F}{m}\sin\theta\right)$

(c) $-\frac{F}{m}\cos\theta - \mu_K\left(g - \frac{F}{m}\sin\theta\right)$

(d) $\frac{F}{m}\cos\theta + \mu_K\left(g - \frac{F}{m}\sin\theta\right)$

8. A block of 200 g mass moves with a uniform speed in a horizontal circular groove, with vertical side walls of radius 20 cm. If the block takes 40 s to complete one round, the normal force by the side walls of the groove is

(a) 9.859×10^{-4} N (b) 6.28×10^{-3} N
(c) 9.859×10^{-2} N (d) 0.0314 N

9. A conducting wire of length 'l', area of cross-section A and electric resistivity ρ is connected between the terminals of a battery. A potential difference V is developed between its ends, causing an electric current.

If the length of the wire of the same material is doubled and the area of cross-section is halved, the resultant current would be

(a) $\frac{1}{4}\frac{VA}{\rho l}$ (b) $4\frac{VA}{\rho l}$

(c) $\frac{1}{4}\frac{\rho l}{VA}$ (d) $\frac{3}{4}\frac{VA}{\rho l}$

10. A plane electromagnetic wave of frequency 500 MHz is travelling in vacuum along y-direction. At a particular point in space and time, $\vec{B} = 8.0 \times 10^{-8}\,\hat{z}$ T. The value of electric field at this point is (speed of light = 3×10^8 m s^{-1})

$\hat{x}, \hat{y}, \hat{z}$ are unit vectors along x, y and z directions.

(a) $-2.6\,\hat{y}$ Vm^{-1} (b) $24\hat{x}$ Vm^{-1}
(c) $2.6\hat{x}$ Vm^{-1} (d) $-24\hat{x}$ Vm^{-1}

11. A bar magnet of length 14 cm is placed in the magnetic meridian with its north pole pointing towards the geographic north pole. A neutral point is obtained at a distance of 18 cm from the center of the magnet. If $B_H = 0.4$ G, the magnetic moment of the magnet is ($1\text{ G} = 10^{-4}$ T)

(a) 28.80 J T^{-1} (b) 2.880 J T^{-1}
(c) 2.880×10^3 J T^{-1} (d) 2.880×10^2 J T^{-1}

12. Time period of a simple pendulum is T inside a lift when the lift is stationary. If the lift moves upwards with an acceleration $\frac{g}{2}$, the time period of pendulum will be

(a) $\sqrt{3}T$ (b) $\frac{T}{\sqrt{3}}$

(c) $\sqrt{\frac{3}{2}}T$ (d) $\sqrt{\frac{2}{3}}T$

13. In thermodynamics, heat and work are

(a) extensive thermodynamic state variables
(b) point functions
(c) path functions
(d) intensive thermodynamic state variables.

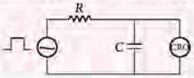
14. The pressure acting on a submarine is 3×10^5 Pa at a certain depth. If the depth is doubled, the percentage increase in the pressure acting on the submarine would be

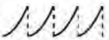
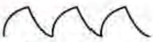
(Assume that atmospheric pressure is 1×10^5 Pa, density of water is 10^3 kg m^{-3}, $g = 10$ m s^{-2})

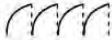
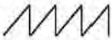
(a) $\frac{3}{200}\%$ (b) $\frac{200}{3}\%$

(c) $\frac{200}{5}\%$ (d) $\frac{5}{200}\%$

15. An RC circuit as shown in the figure is driven by a AC source generating a square wave. The output wave pattern monitored by CRO would look close to



(a)  (b) 

(c)  (d) 

16. For changing the capacitance of a given parallel plate capacitor, a dielectric material of dielectric constant K is used, which has the same area as the plates of the capacitor. The thickness of the dielectric slab is $\frac{3}{4}d$, where 'd' is the separation between the plates of parallel plate capacitor. The new capacitance (C') in terms of original capacitance (C_0) is given by the following relation.

(a) $C' = \frac{3+K}{4K}C_0$ (b) $C' = \frac{4}{3+K}C_0$

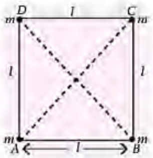
(c) $C' = \frac{4+K}{3}C_0$ (d) $C' = \frac{4K}{K+3}C_0$

17. A 25 m long antenna is mounted on an antenna tower. The height of the antenna tower is 75 m. The wavelength (in meter) of the signal transmitted by this antenna would be

(a) 100 (b) 300

(c) 200 (d) 400

18. For equal masses, m each are placed at the corners of a square of length (l) as shown in the figure. The moment of inertia of the system about an axis passing through A and parallel to DB would be



(a) $2\,ml^2$ (b) $\sqrt{3}\,ml^2$

(c) ml^2 (d) $3\,ml^2$

19. The stopping potential in the context of photoelectric effect depends on the following property of incident electromagnetic radiation

(a) phase (b) frequency

(c) intensity (d) amplitude.

20. The angle of deviation through a prism is minimum when

(A) incident ray and emergent ray are symmetric to the prism

(B) the refracted ray inside the prism becomes parallel to its base

(C) angle of incidence is equal to that of the angle of emergence

(D) when angle of emergence is double the angle of incidence.

(a) Only statements (A) and (B) are true.

(b) Statements (B) and (C) are true.

(c) Statements (A), (B) and (C) are true.

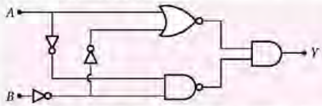
(d) Only statement (D) is true.

SECTION B (NUMERICAL VALUE TYPE)

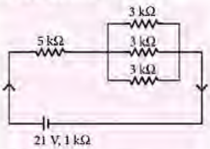
21. A fringe width of 6 mm was produced for two slits separated by 1 mm apart. The screen is placed 10 m away. The wavelength of light used is 'x' nm. The value of 'x' to the nearest integer is ______.

22. The first three spectral lines of H-atom in the Balmer series are given λ_1, λ_2, λ_3 considering the Bohr atomic model, the wavelengths of first and third spectral lines $\left(\frac{\lambda_1}{\lambda_3}\right)$ are related by a factor of approximately 'x' $\times 10^{-1}$. The value of x, to the nearest integer, is ______.

23. In the logic circuit shown in the figure, if input A and B are 0 to 1 respectively, the output at Y would be 'x'. The value of x is ____.

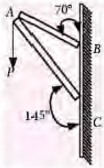


24. In the figure given, the electric current flowing through the 5 kΩ resistor is 'x' mA.



The value of x to nearest integer is ____.

25. Consider a frame that is made up of two thin massless rods AB and AC as shown in the figure. A vertical force $\vec{P}$ of magnitude 100 N is applied at point A of the frame. Suppose the force $\vec{P}$ is resolved parallel to the arms AB and AC of the frame. The magnitude of the resolved component along the arm AC is x N. The value of x, to the nearest integer, is _____.

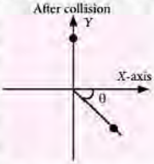


[Given : $\sin(35°) = 0.573$, $\cos(35°) = 0.819$, $\sin(110°) = 0.939$, $\cos(110°) = -0.342$]

26. Consider a 20 kg uniform circular disk of radius 0.2 m. It is pin supported at its center and is at rest initially. The disk is acted upon by a constant force F = 20 N through a massless string wrapped around its periphery as shown in figure. Suppose the disk makes n number of revolutions to attain an angular speed of 50 rad s^{-1}. The value of n, to the nearest integer, is ____.

[Given : In one complete revolution the disk rotates by 6.28 rad]

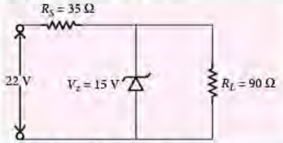
27. A ball of mass 10 kg moving with a velocity $10\sqrt{3}$ m s^{-1} along X-axis, hits another ball of mass 20 kg which is at rest. After collision, the first ball comes to rest and the second one disintegrates into two equal pieces. One of the pieces starts moving along Y-axis at a speed of 10 m s^{-1}. The second piece starts moving at a speed of 20 m s^{-1} at an angle θ (degree) with respect to the X-axis. The configuration of pieces after collision is shown in the figure. The value of θ to the nearest integer is _______.



28. The resistance $R = \frac{V}{I}$, where $V = (50 \pm 2)$ V and $I = (20 \pm 0.2)$A. The percentage error in R is 'x' %. The value of 'x' to the nearest integer is _____.

29. A sinusoidal voltage of peak value 250 V is applied to a series LCR circuit, in which $R = 8\ \Omega$, $L = 24$ mH and $C = 60\ \mu$F. The value of power dissipated at resonant condition is 'x' kW. The value of x to the nearest integer is _____.

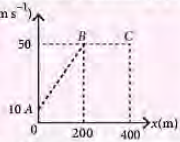
30. The value of power dissipated across the zener diode (V_z = 15 V) connected in the circuit as shown in the figure is $x \times 10^{-1}$ watt.



The value of x, to the nearest integer, is _____.

SOLUTIONS

1. **(d)**: Given velocity - displacement graph



Equation of line AB

$$v = \frac{(50-10)}{(200-0)} \times (x-0) + 10 \qquad (0 \le x \le 200)$$

$$\Rightarrow \quad v = \frac{40}{200} \times x + 10 \Rightarrow \quad v = \frac{x}{5} + 10 \qquad ...(i)$$

Differentiate equation (i) w.r.t. x

$$\frac{dv}{dx} = \frac{1}{5} \qquad ...(ii)$$

$$\text{Acceleration, } a = \frac{dv}{dt} = \frac{dv}{dx} \times \frac{dx}{dt} = v\frac{dv}{dx}$$

$$a = \left(\frac{x}{5} + 10\right) \times \frac{1}{5} \qquad \text{(Using (i) and (ii))}$$

$$a = \left(\frac{x}{25} + 2\right) \text{m s}^{-2}, \quad \text{At } x = 0, a = 2 \text{ m s}^{-2}.$$

It is straight line till $x = 200$.

For $x > 200$, v = constant, $a = 0$.

Therefore, most appropriate option will be (d).

2. **(d)**: For an electromagnetic wave the average energy density for electric and magnetic fields are equal.

$\therefore \quad U_e = U_m$

3. **(d)**: Number of moles of O_2, $n_1 = \frac{16}{32} = 0.5$ mole

Number of moles of N_2, $n_2 = \frac{28}{28} = 1$ mole

Number of moles of CO_2, $n_3 = \frac{44}{44} = 1$ mole

Total number of moles, $n = n_1 + n_2 + n_3$

$\therefore$ Now $n = 0.5 + 1 + 1 = \frac{5}{2}$ moles

Now, $PV = nRT$

$$P = \frac{(nRT)}{V} = \left(\frac{5}{2}\right)\left(\frac{RT}{V}\right)$$

4. (c) : One main scale division, 1 M.S.D. = a cm

n^{th} division of the vernier scale division are equal to $(n-1)^{th}$ division of main scale,

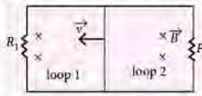
We get 1 V.S.D. $= \frac{(n-1)^{th}}{n^{th}}$ mm

The least count is given by = 1 MSD − 1 VSD

$$= \left(a - \frac{(n-1)}{(n)} \times a\right) \text{cm} = \frac{na - (n-1)a}{n} \text{ cm}$$

$$= \frac{a}{n} \text{cm} = 10\frac{a}{n} \text{mm}$$

5. (c) : An external agent pulls the bar, area of loop 1, decreases and that of loop 2 increases. Magnetic flux decreases in loop 1 and increases in loop 2. As a result magnetic field should be increase in loop 1 and decrease in loop 2. So the induced current I_1, should be clockwise and I_2, anticlockwise.



6. (a) : Here : $r_{max} = 1.6 \times 10^{12}$ m

$r_{min} = 8.0 \times 10^{10}$ m, $v_{max} = 6 \times 10^4$ m s^{-1}

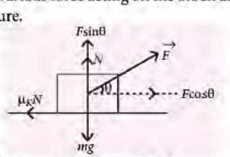
By conservation of angular momentum,

mvr = constant

$v_{min} \times r_{max} = v_{max} \times r_{min}$

$$\therefore v_{min} = \frac{6 \times 10^4 \times 8.0 \times 10^{10}}{1.6 \times 10^{12}} = 3.0 \times 10^3 \text{ m s}^{-1}$$

7. (b): The various force acting on the block as shown in the figure.



$N + F\sin\theta = mg$ or $N = mg - F\sin\theta$

and $f = \mu_K N = \mu_K(mg - F\sin\theta)$

Also, $F\cos\theta - f = ma$ or $a = \frac{1}{m}\left[F\cos\theta - f\right]$

or $a = \frac{1}{m}[F\cos\theta - \mu_K(mg - F\sin\theta)]$

or $a = \frac{F}{m}\cos\theta - \mu_K\left(g - \frac{F}{m}\sin\theta\right)$

8. (a) : Given, $m = 200$ g = 0.2 kg, $T = 40$ s, $r = 20$ cm = 0.2 m

$$N = m\left(\frac{2\pi}{T}\right)^2 r = m \times \frac{4\pi^2}{T^2} \times r$$

$$= \frac{0.2 \times 4 \times (3.14)^2 \times 0.2}{(40)^2} = 9.859 \times 10^{-4} \text{ N}$$

9. (a) : We know that, $R = \rho\frac{l}{A}$ ...(i)

Given, new length $l' = 2l$

New area of cross section $= \frac{A}{2}$

New resistance, $R' = \rho \cdot \frac{2l}{A/2}$ ...(ii)

$$\text{Current, } I = \frac{V}{\rho \cdot \frac{2l}{(A/2)}} = \frac{V}{4\frac{\rho l}{A}} = \frac{1}{4}\frac{VA}{\rho l}$$

10. (d): Given , frequency $\upsilon = 500$ MHz $= 5 \times 10^8$ Hz

$\vec{B} = 8.0 \times 10^{-8}\,\hat{z}\,T$

EM wave travelling towards $+\hat{j}$

$\vec{E} = \vec{B} \times \vec{C} = (8 \times 10^{-8}\,\hat{z}) \times (3 \times 10^8\,\hat{y}) = -24\,\hat{x}\,\text{Vm}^{-1}$

11. (b): Given, length $(2l) = 14$ cm, $l = 7$ cm

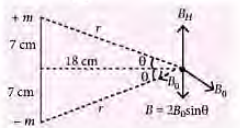
$B_H = 0.4\text{G} = 0.4 \times 10^{-4}\text{T}$

Magnetic field at a point on axial line, of bar magnet of length $(2l)$ and magnetic moment m is

$$\frac{2\mu_0 m}{4\pi r^2} \times \frac{7}{r} = 0.4 \times 10^{-4}$$

$$2 \times 10^{-7} \times \frac{m \times 7}{(7^2 + 18^2)^{3/2}} \times 10^4 = 0.4 \times 10^{-4}$$

$$\Rightarrow m = \frac{4 \times 10^{-2} \times (373)^{3/2}}{14}$$



$$M = m \times 14 \text{ cm} = m \times \frac{14}{100} = \frac{0.04 \times (373)^{3/2}}{14} \times \frac{14}{100}$$

$= 4 \times 10^{-4} \times 7203.82 = 2.88$ J T^{-1}

12. **(d)**: Time period of a simple pendulum,

$T = 2\pi\sqrt{\frac{l}{g_{eff}}}$

When lift is stationary,

$T = 2\pi\sqrt{\frac{l}{g}} \qquad (\because\ g_{eff} = g)$

When lift is moving upward with an acceleration g/2, then effective acceleration

$g_{eff} = g + \frac{g}{2} = \frac{3g}{2} \quad \therefore \quad T' = 2\pi\sqrt{\frac{2l}{3g}};$

$T' = \sqrt{\frac{2}{3}}\,T$

13. **(c)**: Heat and work depends on the path taken to reach the final state from initial state.

14. **(b)**: The pressure acting on a submarine,

$P = P_o + h\rho g = 3 \times 10^5$ Pa ...(i)

$h\rho g = 3 \times 10^5 - 1 \times 10^5 = 2 \times 10^5$ Pa

If depth is doubled,

$2h\rho g = 4 \times 10^5$ Pa

Now, $P' = P_o + 4 \times 10^5$

$= 1 \times 10^5 + 4 \times 10^5 = 5 \times 10^5$ Pa ...(ii)

% increase in pressure $= \frac{P' - P}{P} \times 100$

$= \frac{(5-3) \times 10^5}{3 \times 10^5} \times 100$ (Using (i) and (ii))

$= 66.66\% = \frac{200}{3}\%$

15. **(b)**: During the +ve cycle of input the capacitor starts charging exponentially and attains maximum value. During the negative cycle it starts discharging and voltage across capacitance decreases exponentially from the maximum value. It is represented by graph (b).

16. **(d)**: If A be area of each plate and d is the distance between the plates, then capacitance

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

For dielectric slab,

$C' = \frac{\varepsilon_0 A}{\left(d - t + \frac{t}{K}\right)} \Rightarrow C' = \frac{\varepsilon_0 A}{\left(d - \frac{3d}{4} + \frac{3d}{4K}\right)}$

$\Rightarrow C' = \frac{4K\varepsilon_0 A}{(3+K)d} = \frac{4KC_0}{3+K}$ (Using (i))

17. **(a)**: Length of Antenna = 25 m $= \frac{\lambda}{4}$

$\Rightarrow \lambda = 100$ m

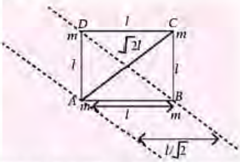
18. **(d)**: Moment of inertia of point mass

= mass × (perpendicular distance from axis)^2

Moment of inertia,

$I = m\left(\frac{l}{\sqrt{2}}\right)^2 + m(l\sqrt{2})^2 + m\left(\frac{l}{\sqrt{2}}\right)^2$

$I = 3ml^2$



19. **(b)**: Stopping potential charges linearly with frequency of incident radiation.

20. **(b)**: Deviation is minimum in prism when $i = e$, $r_1 = r_2$ and ray inside prism is parallel to the base of the prism.

Hence statement (B) and (C) are true.

21. **(600)** :Given, $\beta = 6$ mm $= 6 \times 10^{-3}$ m

$d = 1$ mm $= 1 \times 10^{-3}$ m, $D = 10$ m

Fringe width, $\beta = \frac{\lambda D}{d}$

$6 \times 10^{-3} = \frac{\lambda \times 10}{1 \times 10^{-3}}$

$\lambda = \frac{6 \times 10^{-3} \times 1 \times 10^{-3}}{10}$

$\lambda = 600 \times 10^{-9}$ m $= 600$ nm

22. **(15)** : The wavelength of the spectral lines in the Balmer series is given by,

$\frac{1}{\lambda} = RZ^2\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$ where $n = 3, 4, 5, 6$

For first line

$\frac{1}{\lambda_1} = RZ^2\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{5}{36}RZ^2$ ...(i)

For third line $\frac{1}{\lambda_3} = RZ^2\left(\frac{1}{2^2} - \frac{1}{5^2}\right)$

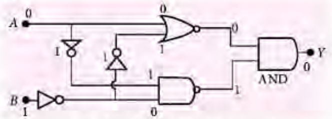
$\Rightarrow \frac{1}{\lambda_3} = \left(\frac{21}{100}\right)RZ^2$ ...(ii)

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

$\frac{\lambda_1}{\lambda_3} = \frac{21}{100} \times \frac{36}{5} = 1.512 = 15.12 \times 10^{-1}$

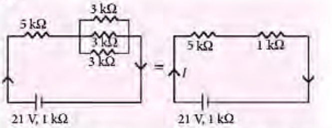
$\therefore \quad x = 15$

23. (0) :



The output Y of the logic circuit is zero.

24. (3) :



In the circuit the resistance 3 kΩ, 3 kΩ, 3 kΩ are connected in parallel. Their effective resistance will be

$\frac{1}{R_P} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = \frac{3}{3}$ or $R_P = 1\,\text{k}\Omega$

The equivalent circuit is as shown in the figure.

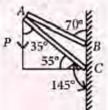
The equivalent resistance of the circuit is

$R_{eq} = 1 + 1 + 5 = 7\,\text{k}\Omega$

Current in the circuit, $I = \frac{21}{7} = 3\,\text{mA}$

$\therefore \quad I = 3\,\text{mA}$

25. (82) : Component along AC,



$= 100 \cos 35°\ \text{N} = 100 \times 0.819\ \text{N} = 81.9\ \text{N} = 82\ \text{N}$

26. (20) : Given : $m = 20$ kg, $R = 0.2$ m

$F = 20$ N, $\omega = 50$ rad s^{-1}

We know that, anglar acceleration $\alpha = \frac{\tau}{I} = \frac{FR}{mR^2/2}$

$\alpha = \frac{2F}{mR} = \frac{2 \times 20}{20 \times 0.2} = 10$

As $\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

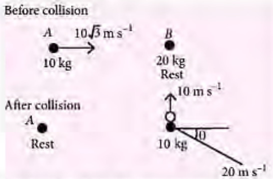
$(50)^2 = 0^2 + 2(10)\Delta\theta$

$\Delta\theta = 125$ rad

In one complete revolution the disk rotates by 6.28 rad.

Then the disk rotates by 125 rad, the number of revolution = 20

27. (30) :



According to the law of conservation of linear momentum, we get

$10 \times 10\sqrt{3} = 10 \times 20 \cos\theta$

$\cos\theta = \sqrt{3}/2 \quad \therefore \theta = 30°$

28. (5) : Here $V = (50 \pm 2)$ V and $I = (20 \pm 0.2)$ A

$R = I/V$

The percentage error in R is

$$\frac{\Delta R}{R} \times 100 = \frac{\Delta V}{V} \times 100 + \frac{\Delta I}{I} \times 100$$

$$\frac{\Delta R}{R} \times 100 = \frac{2}{50} \times 100 + \frac{0.2}{20} \times 100$$

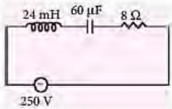
$$\frac{\Delta R}{R} \times 100 = 4 + 1$$

% error in R = 5%

29. (4) : Given : $R = 8\ \Omega$, $L = 24$ mH

$C = 60\ \mu$F

$V = 250$ V



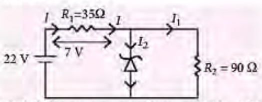
At resonance,

Power $P = \frac{(V_{rms})^2}{R}$

$$\therefore \quad P = \frac{\left(\frac{250}{\sqrt{2}}\right)^2}{8} \quad (\because V = \sqrt{2}\, V_{rms})$$

$P = 3906.25$ W = 4 kW

30. (5) :



Potential difference across R_1 is = 22 V − 15 V = 7 V

Current, $I = \frac{7}{35} = \frac{1}{5}$ A

Current, $I_1 = \frac{15}{90} = \frac{1}{6}$ A, $I_2 = I - I_1 = \frac{1}{30}$ A

Power across diode, $P_2 = V_2 I_2 = 15 \times \left(\frac{1}{30}\right) = 0.5$ W

$\therefore \quad P = 5 \times 10^{-1}$ W

$\therefore \quad x = 5$

unacademy

Tips and tricks to score maximum marks in exams (IIT-JEE/NEET)

Praveen Kumar

Dear students, this is Praveen Kumar your own PKR sir, your mentor and your friend.

I know many of you will be preparing for IIT-JEE/NEET exams 2021. So, at this point of time what should be the strategy to crack IIT-JEE/NEET with maximum score?

Here in this article, I am going to give some tips to crack IIT-JEE/NEET in very efficient manner. At this point of time many students feel that they have wasted their time. So dear students, first you need to change your mindset. You have not wasted your time, you have invested your time. Only thing is that you are not able to recall your concepts properly. So, first and very important thing is that just believe in yourself. YOU CAN DO IT.

Now I know many of you might not have confidence in your preparation. So how to gain confidence in your exam? So here are the tips to crack JEE Mains/NEET.

<Step 1>: Solve any previous year question paper under time limit as per your exam schedule of JEE Main/NEET. Say for example, exam timing for JEE mains is from 9.00 am to 12.00 pm. So just take any previous year paper say of year 2020 and take test under examination condition. After taking test evaluate your answer key and identify your mistakes and weak areas. Let's say you were not able to solve questions of Polarization, Earth magnetism, Modern Physics etc., in your paper. So now you know your weak areas in all subjects (Physics, Chemistry, Mathematics).

<Step 2>: Now you have to revise your concepts of your weak areas found in step 1 and solve few problems to gain confidence. Once you have revised your all the concepts then again move to step 1 and take another test. Some students take too many tests without reviewing their mistakes. It is the biggest blunder. So don't commit such mistakes. Review each test properly. Work on your weak areas before taking next test. I am sure with this technique, your score will improve tremendously. The above technique is equally applicable for NEET also. Remember that the road to success is already built by you, only you need to identify holes and fill it. I hope you will follow the above steps.

So this was all about JEE Mains/NEET examination. Now comes to JEE Advanced.

To crack JEE Advanced with good rank, it is not only width but depth of concepts matters a lot.

You should have a crystal-clear conceptual clarity. Now what to do to achieve crystal-clear conceptual clarity?

You need to practice good quality of questions. For this you can solve selective questions of H.C. Verma (specially last 20 questions of each chapter) and I. E. Irodov. Questions based on multiple concepts will boost your preparation tremendously. Also, one needs to keep in mind that there are plenty of material in market. So don't get distracted. Just solve authentic material to avoid wastage of time on unnecessary questions. At last, solve PYQs of advance level problem to have practice. Keep in mind the paper pattern of JEE Advanced while your preparation.

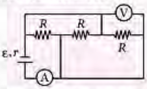
At last, I can say that " IIT KO AAPKI 10 BOOKS SE KHATRA NAHIN HAI JO AAPNE EK BAAR PRACTICE KI HAI, IIT KO AAPKI US EK AUTHENTIC BOOK SE KHATRA HAI JO AAPNE 10 BAAR PRACTICE KI HAI". So don't follow too many books , just focus on 2 or 3 authentic books/study material and master them with sincerity.

I wish you all the best for your upcoming examination. God bless you. Jai Sri Krishna..

PRACTICE PAPER

NEET 2021

1. In the circuit shown in the figure, ammeter and voltmeter are ideal. If $\varepsilon = 4$ V, $R = 9\ \Omega$ and $r = 1\ \Omega$, then readings of ammeter and voltmeter are
   (a) 1 A, 3 V
   (b) 2 A, 3 V
   (c) 1 A, 4 V
   (d) 4 A, 4 V



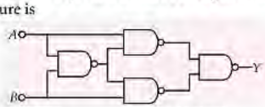
2. Which one of the following statements regarding photo-emission of electrons is correct?
   (a) Kinetic energy of electrons increases with the intensity of incident light.
   (b) Electrons are emitted when the wavelength of the incident light is above a certain threshold wavelength.
   (c) Photoelectric emission is instantaneous with the incidence of light.
   (d) Photo electrons are emitted whenever a gas is irradiated with ultraviolet light.

3. A certain body weighs 22.42 g and has a measured volume of 4.7cc. The possible error in the measurement of mass and volume are 0.01 g and 0.1 cc. Then maximum error in the density will be
   (a) 22% (b) 2% (c) 0.2% (d) 0.02%.

4. A car of mass m starts from rest and acquires a velocity along east $\vec{v} = v\hat{i}$ $(v > 0)$ in two seconds. Assuming the car moves with uniform acceleration, the force exerted on the car is
   (a) $\frac{mv}{2}$ eastward and is exerted by the car engine.
   (b) $\frac{mv}{2}$ eastward and is due to the friction on the tyres exerted by the road.
   (c) more than $\frac{mv}{2}$ eastward exerted due to the engine and overcomes the friction of the road.
   (d) $\frac{mv}{2}$ exerted by the engine.

5. The density of a non-uniform rod of length 1 m is given by $\rho(x) = a(1 + bx^2)$ where a and b are constants and $0 \le x \le 1$.
   The centre of mass of the rod will be at
   (a) $\frac{3(2+b)}{4(3+b)}$ (b) $\frac{4(2+b)}{3(3+b)}$
   (c) $\frac{3(3+b)}{4(2+b)}$ (d) $\frac{4(3+b)}{3(2+b)}$

6. Truth table for system of four NAND gates as shown in figure is



(a)

A	B	Y
0	0	0
0	1	0
1	0	1
1	1	1

(b)

A	B	Y
0	0	1
0	1	1
1	0	0
1	1	0

(c)

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

(d)

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

7. An ideal gas goes from state A to state B via three different processes as indicated in the P-V diagram. If Q_1, Q_2, Q_3 indicate the heat absorbed by the gas along the three processes and ΔU_1, ΔU_2, ΔU_3 indicate the change in internal energy along the three processes respectively, then

   (a) $Q_1 > Q_2 > Q_3$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$
   (b) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$
   (c) $Q_1 = Q_2 = Q_3$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$
   (d) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$

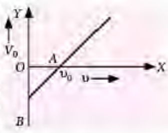
8. In SHM, potential energy of a particle at mean position is E_1 and kinetic energy is E_2, then
(a) $E_1 = E_2$
(b) total potential energy at $x = \frac{\sqrt{3}A}{2}$ is $E_1 + \frac{3E_2}{4}$
(c) total kinetic energy at $x = \frac{\sqrt{3}A}{2}$ is $\frac{3E_2}{4}$
(d) total kinetic energy at $x = \frac{A}{\sqrt{2}}$ is $\frac{E_2}{4}$.

9. The kinetic energy K of a particle moving along a circle of radius R depends upon the distance s as $K = as^2$, where a is a constant. The force acting on the particle is
(a) $2a\frac{s^2}{R}$
(b) $2as\left[1+\frac{s^2}{R^2}\right]^{1/2}$
(c) $2as$
(d) $2a$

10. Calculate the highest frequency of the emitted photon in the Paschen series of spectral lines of the Hydrogen atom.
(a) 3.7×10^{14} Hz
(b) 9.1×10^{15} Hz
(c) 10.23×10^{14} Hz
(d) 29.7×10^{15} Hz

11. A wave disturbance in a medium is described by $y(x, t) = 0.02 \cos\left(50\pi t + \frac{\pi}{2}\right)\cos(10\pi x)$, where x and y are in metre and t in second. Choose the correct option.
(a) a node occurs at $x = 0.15$ m
(b) an antinode occurs at $x = 0.3$ m
(c) the wavelength of the constituent wave is 0.2 m
(d) all of the above.

12. In an experiment on photoelectric effect the frequency υ of the incident light is plotted against the stopping potential V_0. The work function of the photoelectric surface is given by (e is electronic charge)



(a) $OB \times e$ in eV
(b) OB in volt
(c) OA in eV
(d) the slope of the line AB.

13. Two rods A and B have identical length and have circular cross sections of radius R_1 and R_2 ($R_1 = 2R_2$) for the same temperature difference, both the rods conduct heat at the same rate. The relation between the thermal conductivities is given by
(a) $K_1 = \frac{K_2}{4}$
(b) $K_1 = 2K_2$
(c) $K_1 = 4K_2$
(d) $K_1 = \frac{K_2}{2}$

14. A cup of tea cools from 80°C to 60°C in one minute. The ambient temperature is 30°C. In cooling from 60°C to 50°C, it will take
(a) 50 s (b) 90 s (c) 60 s (d) 48 s

15. The surface tension and vapour pressure of water at 20°C is 7.28×10^{-2} N m^{-1} and 2.33×10^3 Pa, respectively. What is the radius of the smallest spherical water droplet which can form without evaporating at 20°C?
(a) 6.25×10^{-5} m
(b) 3.12×10^{-2} m
(c) 4.21×10^{-2} m
(d) 7.12×10^{-5} m

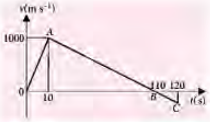
16. A body of mass 1 kg is projected with velocity 50 m s^{-1} at an angle of 30° with the horizontal. At the highest point of its path a force of 10 N acts on body for 5 s vertically upward besides gravitational force. What is the horizontal range of the body? ($g = 10$ m s^{-2})
(a) $125\sqrt{3}$ m
(b) $200\sqrt{3}$ m
(c) 500 m
(d) $250\sqrt{3}$ m

17. A block of mass 500 g is connected to a spring of spring constant $k = 312.5$ N m^{-1} on a frictionless table. The spring is held firmly at the other end. The block is pulled a distance of 5 cm and then released to make SHM. Calculate the time period of its oscillations.
(a) 2.0 s (b) 1.75 s (c) 0.5 s (d) 0.25 s

18. A closed vessel contains a mixture of two diatomic gases A and B. Molar mass of A is 16 times that of B and mass of gas A contained in the vessel is 2 times that of B. Which of the following statement is incorrect?
(a) Average kinetic energy per molecule of A is equal to that of B.
(b) Root mean square value of translational velocity of B is four times that of A.
(c) Pressure exerted by B is four times that of exerted by A.
(d) Number of molecules of B in the cylinder is eight times that of A.

19. A bar magnet having a magnetic moment of 2.0×10^{-4} J T^{-1} is free to rotate in a horizontal plane. A horizontal magnetic field $B = 5 \times 10^{-5}$ T exists in the space. The work done in rotating the magnet slowly from a direction parallel to the field to a direction 60° from the field is
(a) 2.1 J (b) 0.5 J (c) 0.9 J (d) 2.7 J

20. The given graph shows the variation of velocity of a rocket with time. Find the time of burning of fuel from the graph.

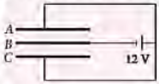


(a) 10 s
(b) 110 s
(c) 120 s
(d) cannot be estimated from the graph.

21. A stone tied at the end of a string 80 cm long is whirled in a horizontal circle with a constant speed. If the stone makes 25 revolutions in 14 s, what is the magnitude of acceleration of the stone ?
(a) 90 m s^{-2} (b) 100 m s^{-2}
(c) 110 m s^{-2} (d) 120 m s^{-2}

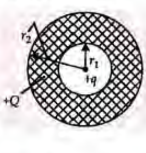
22. Two identical circular coils A and B are placed parallel to each other with their centres on the same axis. The coil B carries a current I in the clock wise direction as seen from A. What would be the direction of the induced current in A seen from B when (i) The current in B is increased (ii) The coil B is moved towards A keeping the current in B constant
(a) clockwise, clockwise
(b) clockwise, anti clockwise
(c) anti clockwise, clockwise
(d) anti clockwise, anti clockwise.

23. Three plates A, B, C each of area 50 cm^2 have separation 3 mm between A and B and 3 mm between B and C. The energy stored when the plates are fully charged is



(a) 1.6×10^{-9} J (b) 2.1×10^{-9} J
(c) 5×10^{-9} J (d) 7×10^{-9} J

24. A thick metallic spherical shell of inner radius r_1 and outer radius r_2 has a charge +Q. A charge $+q$ is placed at the centre of the shell. The charge per unit area on the outer surface is



(a) $\dfrac{(Q-q)}{4\pi(r_2^2-r_1^2)}$ (b) $\dfrac{(Q-q)}{4\pi r_2^2}$

(c) $\dfrac{(Q+q)}{4\pi r_2^2}$ (d) $\dfrac{(Q+q)}{4\pi(r_2^2+r_1^2)}$

25. The electric current in an AC circuit is given by $I = I_0 \sin \omega t$. What is the time taken by the current to change from its maximum value to the rms value?
(a) $\dfrac{T}{4}$ (b) $\dfrac{T}{6}$ (c) $\dfrac{T}{8}$ (d) $\dfrac{T}{10}$

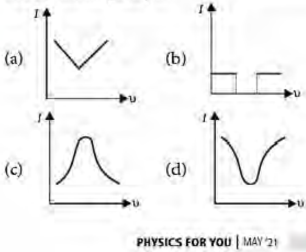
26. An infinitely long rod lies along the axis of a concave mirror of focal length f. The near end of the rod is at distance $u > f$ from the mirror. Its image will have a length
(a) $\dfrac{uf}{u-f}$ (b) $\dfrac{uf}{u+f}$ (c) $\dfrac{f^2}{u+f}$ (d) $\dfrac{f^2}{u-f}$

27. In a uranium reactor whose thermal power is P = 100 MW, if the average number of neutrons liberated in each nuclear splitting is 2.5. Each splitting is assumed to release an energy E = 200 MeV. The number of neutrons generated per unit time is
(a) 4×10^{18} s^{-1} (b) 8×10^{23} s^{-1}
(c) 8×10^{19} s^{-1} (d) $\dfrac{125}{16} \times 10^{18}$ s^{-1}

28. A beam of protons with velocity 4×10^5 m s^{-1} enters a uniform magnetic field of 0.3 tesla at an angle of 60° to the magnetic field. Find the radius of the helical path taken by the proton beam.
Mass of proton = 1.67×10^{-27} kg.
(a) 1.7 cm (b) 1.4 m (c) 1.3 m (d) 1.2 cm

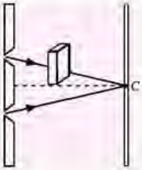
29. Two identical magnetic dipoles of magnetic moment 2 A m^2 are placed at a separation of 2 m with their axes perpendicular to each other in air. The resultant magnetic field at a midpoint between the dipoles is
(a) $4\sqrt{5} \times 10^{-5}$ T (b) $2\sqrt{5} \times 10^{-5}$ T
(c) $4\sqrt{5} \times 10^{-7}$ T (d) $2\sqrt{5} \times 10^{-7}$ T

30. An AC source of variable frequency υ is connected to an L-C-R series circuit. Which one of the graphs in figure represents the variation of current I in the circuit with frequency υ ?



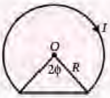
31. A glass plate of refractive index 1.5 is coated with a thin layer of thickness t and refractive index 1.8. Light of wavelength λ travelling in air is incident normally on the layer. It is partly reflected at the upper and lower surfaces of the layer and the two reflected rays interfere. If $\lambda = 648$ nm, obtain the least value of t for which rays interfere constructively.
(a) 45 mm (b) 90 mm
(c) 45 nm (d) 90 nm

32. In Young's experiment, monochromatic light is used to illuminate the two slits A and B. Interference fringes are observed on a screen placed in front of the slits. Now if a thin glass plate is placed normally in the path of the beam coming from the slit



(a) the fringes will disappear
(b) the fringe width will increase
(c) the fringe width will increase
(d) there will be no change in the fringe width but the pattern shifts.

33. A current $I = 5.0$ A flows along a thin wire shaped as shown in figure. The radius of a curved part of the wire is equal to R = 120 mm, the angle $2\phi = 90°$. Find the magnetic field at the point O.



(a) 20 μT (b) 18 μT (c) 15 μT (d) 28 μT

34. A 2.5 dioptre lens forms a virtual image which is 4 times the object placed perpendicularly on the principal axis of the lens. Find the required distance of the object from the lens.
(a) 30 cm (b) 40 cm (c) 10 cm (d) 20 cm

35. A cylinder rolls up an inclined plane, reaches some height and them rolls down (without slipping throughout these motions). The directions of the frictional force acting on the cylinder are
(a) up the incline while ascending and down the incline while descending
(b) up the incline while ascending as well as descending
(c) down the incline while ascending and up the incline while descending
(d) down the incline while ascending as well as descending.

36. A liquid is allowed into a tube of truncated cone shape. Identify the correct statement from the following.
(a) The speed is high at the wider end and low at the narrow end.
(b) The speed is low at the wider end and high at the narrow end.
(c) The speed is same at both ends in a streamline flow.
(d) The liquid flows with uniform velocity in the tube.

37. A truck is pulling a car out of a ditch by means of a steel cable that is 9.1 m long and has a radius of 5 mm. When the car just begins to move, the tension in the cable is 800 N. How much has the cable stretched? (Young's modulus for steel is 2×10^{11} N m^{-2}.)
(a) 1.79×10^{-3} m (b) 4.64×10^{-4} m
(c) 3.42×10^{-6} m (d) 2.11×10^{-3} m

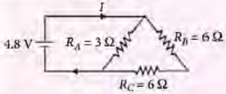
38. A telescope with objective of focal length 60 cm and eyepiece of focal length 5 cm is focussed on a far off distant object such that parallel rays emerge from the eyepiece. If object subtends an angle of 2° on the objective, angular width of the image will be
(a) 10° (b) 30° (c) 24° (d) 60°

39. The heat evolved for the rise of water when one of the capillary tube of radius r is immersed vertical water is (Assume surface tension = T and density water = ρ)
(a) $\frac{2\pi T}{\rho g}$ (b) $\frac{\pi T^2}{\rho g}$
(c) $\frac{2\pi T^2}{\rho g}$ (d) none of these.

40. A transverse mechanical harmonic wave is travelling on a string. Maximum velocity and maximum acceleration of a particle on the string are 3 m s^{-1} and 90 m s^{-2} respectively. If the wave is travelling with a speed of 20 m s^{-1} on the string. The amplitude and the phase of the wave respectively be
(a) 0.2 and $(30t \pm 0.5x)$
(b) 0.1 and $(30t \pm 1.5x)$
(c) 0.05 and $(1.5t \pm 30x)$
(d) 0.02 and $(1.5t \pm 30x)$

41. In a meter bridge experiment null point is obtained at 20 cm from one end of the wire when resistance X is balanced against another resistance Y. If $X < Y$, then where will be the new position of the null point from the same end, if one decides to balance a resistance of $4X$ against Y?
(a) 50 cm (b) 80 cm
(c) 40 cm (d) 70 cm

42. The current in the given circuit is



(a) 4.9 A (b) 6.8 A
(c) 8.3 A (d) 2.0 A

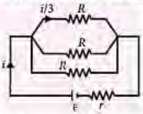
43. Two 220 volt, 100 watt bulbs are connected first in series and then in parallel. Each time the combination is connected to a 220 volt a.c. supply line. The power drawn by the combination in each case respectively will be
(a) 50 watt, 100 watt (b) 100 watt, 50 watt
(c) 200 watt, 150 watt (d) 50 watt, 200 watt

44. We consider the radiation emitted by the human body. Which one of the following statements is true?
(a) The radiation emitted is in the infra-red region.
(b) The radiation is emitted only during the day.
(c) The radiation is emitted during the summers and absorbed during the winters.
(d) The radiation emitted lies in the ultraviolet region and hence is not visible.

45. The peak voltage in the output of a half wave diode rectifier fed with a sinusoidal signal without filter is 10 V. The d.c. component of the output voltage is
(a) $10/\sqrt{2}$ V (b) $10/\pi$ V
(c) 10 V (d) $20/\pi$ V

SOLUTIONS

1. (a) : The given three resistors are in parallel



$$\therefore\ i = \frac{\varepsilon}{r + R/3} = \frac{4}{1+3} = 1\text{ A}$$

$$V = \frac{i}{3}R = \left(\frac{1}{3}\right)(9) = 3\text{ V}$$

2. (c)

3. (b) : Density $\rho = \dfrac{\text{mass } m}{\text{volume } V}$ ...(i)

Take logarithm on the both sides of eqn (i), we get
$\ln\rho = \ln m - \ln V$ ...(ii)

Differentiate eqn (ii), on both sides, we get

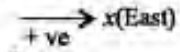
$$\frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} - \frac{\Delta V}{V}$$

Errors are always added, error in the density ρ will be

$$= \left[\frac{\Delta m}{m} + \frac{\Delta V}{V}\right] \times 100\%$$

$$= \left[\frac{0.01}{22.42} + \frac{0.1}{4.7}\right] \times 100\% = 2\%$$

4. (b) : Here,
Mass of the car = m
Initial velocity, $u = 0$ (As the car starts from rest)
Final velocity $\vec{v} = v\hat{i}$ along east



$t = 2$ s
Using, $v = u + at$

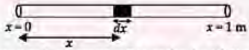
$$v\hat{i} = 0 + \vec{a} \times 2 \quad \text{or} \quad \vec{a} = \frac{v}{2}\hat{i}$$

Force exerted on the car is

$$\vec{F} = m\vec{a} = \frac{mv}{2}\hat{i} = \frac{mv}{2} \text{ eastward}$$

This is due to the friction on the tyres exerted by the road.

5. (a) :

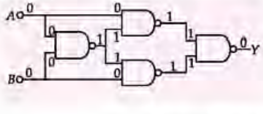


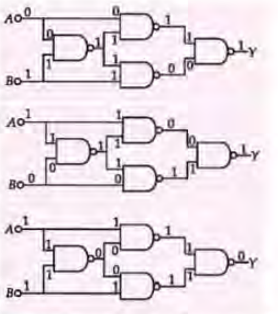
Mass of a small element of length dx of the rod at a distance x from the one end of the rod is
$dm = \rho dx = a(1 + bx^2)dx$
The centre of mass of the rod is

$$X_{CM} = \frac{\int_0^1 x\,dm}{\int_0^1 dm} = \frac{\int_0^1 xa(1+bx^2)dx}{\int_0^1 a(1+bx^2)dx}$$

$$= \frac{\int_0^1 (x+bx^3)dx}{\int_0^1 (1+bx^2)dx} = \frac{\left[\frac{x^2}{2} + \frac{bx^4}{4}\right]_0^1}{\left[x + \frac{bx^3}{3}\right]_0^1} = \frac{3(2+b)}{4(3+b)}$$

6. (d) :





7. **(a)** : Change in internal energy is path independent and depends only on the initial and final states.
As the initial and final states in the three processes are same. Therefore,

$\Delta U_1 = \Delta U_2 = \Delta U_3$

Work done, W = Area under P-V graph
As area under curve 1 > area under curve 2 > area under curve 3

$\therefore \; W_1 > W_2 > W_3$

According to first law of thermodynamics,

$Q = W + \Delta U$

As $W_1 > W_2 > W_3$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$

$\therefore \; Q_1 > Q_2 > Q_3$

8. **(b)** : $U = U_{mean} + \frac{1}{2}kx^2$

Given, $U_{mean} = E_1$ and $\frac{1}{2}kA^2 = E_2$ = maximum kinetic energy at mean position

$\therefore \; x = \frac{\sqrt{3}A}{2}, U = E_1 + \frac{1}{2}k\left(\frac{\sqrt{3}A}{2}\right)^2 = E_1 + \frac{3}{4}E_2$

9. **(b)** : Here, $K = \frac{1}{2}mv^2 = as^2 \; \therefore \; mv^2 = 2as^2$

Differentiating with respect to time t

$2mv\frac{dv}{dt} = 4as\frac{ds}{dt} = 4asv \Rightarrow m\frac{dv}{dt} = 2as$

$\therefore$ Tangential force, $F_t = 2as$

Centripetal force, $F_c = \frac{mv^2}{R} = \frac{2as^2}{R}$

$\therefore$ Net force acting on the particle

$$F = \sqrt{F_t^2 + F_c^2} = \sqrt{(2as)^2 + \left(\frac{2as^2}{R}\right)^2} = 2as\sqrt{1 + s^2/R^2}$$

10. **(a)** : The frequencies of the emitted photon in the Paschen series are given by

$$\upsilon = Rc\left(\frac{1}{3^2} - \frac{1}{n^2}\right)$$

where $n = 4, 5, 6, \ldots\ldots$
The highest frequency corresponds to $n = \infty$

$$\therefore \; \upsilon_{highest} = \frac{Rc}{9} = \frac{1.097 \times 10^7 \text{ m}^{-1} \times 3 \times 10^8 \text{ m s}^{-1}}{9} = 0.37 \times 10^{15} \text{ s}^{-1} = 3.7 \times 10^{14} \text{ Hz}$$

11. **(d)** : A wave disturbance,

$y = 0.02\cos(10\pi x)\cos\left(50\pi t + \frac{\pi}{2}\right)$

At node, amplitude $= 0 \Rightarrow \cos(10\pi x) = 0$

$\Rightarrow \; 10\pi x = \frac{\pi}{2}, \frac{3\pi}{2} \Rightarrow x = \frac{1}{20} = 0.05 \text{ m}, 0.15 \text{ m}$

At antinode, amplitude is maximum

$\Rightarrow \; \cos(10\pi x) = \pm 1 \; \Rightarrow \; 10\pi x = 0, \pi, 2\pi \ldots$

$\Rightarrow \; x = 0, 0.1 \text{ m}, 0.2 \text{ m}, 0.3 \text{ m} \ldots$

$v = \frac{50\pi}{10\pi} = 5 \text{ m s}^{-1}$

Wavelength, $\lambda = \frac{2\pi}{k} = \frac{2\pi}{10\pi} = \frac{1}{5} \text{ m} = 0.2 \text{ m}$

12. **(a)** : Using Einstein's equation, $V_0 = \left(\frac{h}{e}\right)\upsilon - \frac{W_0}{e}$

Comparing this equation with $y = mx + c$

We get intercept on $-V_0$ axis $= \frac{W_0}{e}$

$\Rightarrow \; OB = \frac{W_0}{e} \Rightarrow W_0 = OB \times e$

13. **(a)** : $H = \frac{\Delta T}{R}$

Since H and ΔT are same.

$\frac{L}{K_1 \pi R_1^2} = \frac{L}{K_2 \pi R_2^2}; \; \frac{K_1}{K_2} = \frac{R_2^2}{R_1^2} = \frac{R_2^2}{4R_2^2} = \frac{1}{4}$

14. **(d)** : Newton's law of cooling $\frac{\Delta T}{\Delta t} = k(T - T_0)$

T_0 = surrounding's temperature

$\Rightarrow \frac{80-60}{60} = k\left[\frac{80+60}{2} - 30\right]$ ...(i)

and $\frac{60-50}{t} = k\left[\frac{60+50}{2} - 30\right]$ ...(ii)

Using (i) and (ii), $t = 48$ s

15. **(a)** : Let r = radius of drop,

$T = 7.28 \times 10^{-2} \text{ N m}^{-1}$

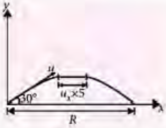
$P = 2.33 \times 10^3$ Pa

If the excess pressure is more than the vapour pressure then the drop will evaporate.

So, minimum radius of drop, for not to evaporate,

$$\frac{2T}{r} = P \Rightarrow r = \frac{2T}{P} \Rightarrow r = \frac{2\times 7.28\times 10^{-2}}{2.33\times 10^{3}} = 6.25\times 10^{-5}\ \text{m}$$

16. (d) : For 5 s, weight of the body is balanced by the given force. Hence, it will move in a straight line as shown in the figure.

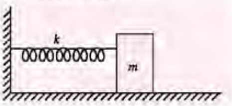


$$R = \frac{u^2 \sin 2\theta}{g} + (u\cos\theta)(t)$$

$$= \frac{(50)^2 \cdot \sin 60^\circ}{10} + (50\times \cos 30^\circ)(5) = 250\sqrt{3}\ \text{m}$$

17. (d) : Here, $m = 500\ \text{g} = 500 \times 10^{-3}$ kg

$k = 312.5\ \text{N m}^{-1}$



The time period of oscillations is $T = 2\pi\sqrt{\frac{m}{k}}$

$$= 2\pi\sqrt{\frac{500\times 10^{-3}}{312.5}} = 2\times 3.14\times 0.04\ \text{s} = 0.25\ \text{s}$$

18. (c) : Average KE per molecule in A and $B = \frac{3}{2}kT$

$(v_{rms})_A = \sqrt{\frac{3RT}{M_A}}$ and $(v_{rms})_B = \sqrt{\frac{3RT}{M_B}}$

$$\Rightarrow \frac{(v_{rms})_A}{(v_{rms})_B} = \sqrt{\frac{M_B}{M_A}} = \sqrt{\frac{M_B}{16M_B}} = \frac{1}{4}$$

No. of mole of $A = \frac{m_A}{M_A}$

No. of mole of $B = \frac{m_B}{M_B} = \frac{m_A/2}{M_A/16} = 8n_A$

Pressure exerted by a gas in the vessel depends on the number of molecules present inside.

19. (b) : The work done by the external agent = change in potential energy

$= (-MB\cos\theta_2) - (-MB\cos\theta_1)$

$= -MB(\cos 60^\circ - \cos 0^\circ)$

$= \frac{1}{2}MB = \frac{1}{2}\times (2.0\times 10^4\ \text{J/T})\ (5\times 10^{-5}\ \text{T}) = 0.5\ \text{J}$

20. (a) : When the fuel is burning, velocity of the rocket is increasing. After the fuel is exhausted, velocity starts decreasing. From the graph, time of burning of fuel = 10 s.

21. (b) : Length of a string, $l = 80$ cm = 0.8 m

Number of revolutions = 25

Time taken = 14 s

$\therefore\ \upsilon = \frac{25}{14} = 1.78\ \text{s}^{-1}$

$\therefore\ \omega = 2\pi\upsilon = 2\pi\times 1.78 = 11.18\ \text{rad s}^{-1}$

$a = \omega^2 l = (11.18)^2 \times (0.8)$

$= 99.99\ \text{m s}^{-2} \approx 100\ \text{m s}^{-2}$

22. (a) :

I increases B_1 increases.

So from Lenz's law, current in A is clockwise.

I same and flux linked with A increases.

So from Lenz's law current in A clockwise.

23. (b) : Here circuit is equivalent to two capacitors in parallel.

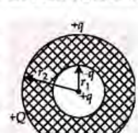
$$\therefore\ C_{eq} = C_1 + C_2 = \frac{\varepsilon_0 A}{d} + \frac{\varepsilon_0 A}{d} = \frac{2\varepsilon_0 A}{d}$$

$$\therefore\ \text{Energy stored} = \frac{1}{2}C_{eq}V^2 = \frac{1}{2}\left(\frac{2\varepsilon_0 A}{d}\right)V^2$$

$$= \frac{8.86\times 10^{-12}\times 50\times 10^{-4}\times 12\times 12}{3\times 10^{-3}} = 2.1\times 10^{-9}\ \text{J}$$

24. (c) : The charge $+Q$ resides on the outer surface of the shell.

When a charge $+q$ is placed at the centre of the shell, it will induce a charge $-q$ on the inner surface of the shell of radius r_1 and the charge $+q$ on the outer surface of the shell of radius r_2 as shown in figure.



Total charge on the outer surface of the shell

$= Q + q$

The charge per unit area on the outer surface $= \frac{Q+q}{4\pi r_2^2}$

25. (c) : Since $I_1 = I_0 \sin \omega t_1$

$\because \quad I_1 = I_0$, so, $I_0 = I_0 \sin \omega t_1$

$t_1 = \frac{\pi/2}{2\pi/T} = \frac{T}{4}$ and $I_2 = \frac{I_0}{\sqrt{2}}$, hence $\frac{I_0}{\sqrt{2}} = I_0 \sin (\omega t_2)$

$t_2 = \frac{\pi/4}{2\pi/T} = \frac{T}{8}$

$\Delta t = t_1 - t_2 = \frac{T}{4} - \frac{T}{8} = \frac{T}{8}$

26. (d) : $u = -u, f = -f, v_A = -\frac{uf}{u-f}$

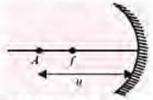


Image of last end of rod $v_B = -f$

Length $= |v_B| - |v_A|$

$= \frac{uf}{f-u} - f = \frac{+f^2 + uf - uf}{f-u}$

Length $= \frac{f^2}{u-f}$.

27. (d) : Number of nuclear splitting per second is

$N = \frac{100\text{ MW}}{200\text{ MeV}} = \frac{100}{200 \times 1.6 \times 10^{-19}}\ \text{s}^{-1}$

Number of neutrons liberated

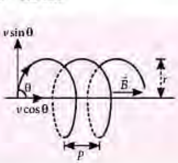
$= \frac{100}{200} \times \frac{1}{1.6 \times 10^{-19}} \times 2.5\ \text{s}^{-1}$

$= \frac{125}{16} \times 10^{18}\ \text{s}^{-1}$

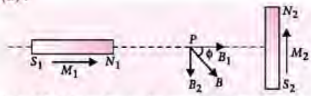
28. (d) : Radius of helix

$$r = \frac{mv\sin\theta}{qB} = \frac{(1.67\times10^{-27})(4\times10^5)\frac{\sqrt{3}}{2}}{(1.6\times10^{-19})0.3}$$

$= \frac{2}{\sqrt{3}} \times 10^{-2}\,\text{m} = 1.2\,\text{cm}$



29. (d) :



Let point P be the midpoint between the dipoles. The point P will be in end-on position with respect to one dipole and in broad-side on position with respect to the other.

$\therefore \quad B_1 = \frac{\mu_0}{4\pi}\frac{2M_1}{r_1^3} = \frac{10^{-7}\times2\times2}{(1)^3} = 4\times10^{-7}\ \text{T}$

and $B_2 = \frac{\mu_0}{4\pi}\frac{M_2}{r_2^3} = \frac{10^{-7}\times2}{(1)^3} = 2\times10^{-7}\ \text{T}$

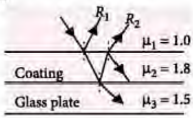
As B_1 and B_2 are perpendicular to each other, therefore the resultant magnetic field at point P is

$B = \sqrt{B_1^2 + B_2^2} = \sqrt{(4\times10^{-7})^2 + (2\times10^{-7})^2}$

$= 10^{-7}\sqrt{16+4} = 10^{-7}\sqrt{20} = 2\sqrt{5}\times10^{-7}\ \text{T}$

30. (c)

31. (d) : R_1 and R_2 are the two rays considered for interference. R_1 is the result of reflection at denser medium. Hence, it suffers an additional path difference $\lambda/2$ and phase difference π. Ray R_2 originates after reflection at lower surface, this reflection takes place at rarer medium.



Net path difference,

$2\mu t + \frac{\lambda}{2} = n\lambda$ [for constructive interference]

or $\quad 2\mu t = \frac{(2n-1)\lambda}{2}$

t will be minimum for $n = 1$.

$t_{min} = \frac{\lambda}{4\mu} = \frac{648}{4\times1.8}\ \text{nm} = 90\ \text{nm}$

32. (d) : In the presence of thin glass plate, the fringe pattern shifts, but no change in fringe width.

33. (d) : Magnetic induction due to the arc segment at O,

$B_1 = \frac{\mu_0}{4\pi}\frac{i}{R}(2\pi - 2\phi)$

Magnetic induction due to the line segment at O,

$B_2 = \frac{\mu_0}{4\pi}\frac{i}{R\cos\phi}[2\sin\phi]$

B_1 and B_2 both are directed into the plane of page so total magnetic induction at O

$$B = B_1 + B_2 = \frac{\mu_0}{2\pi}\frac{i}{R}[\pi - \phi + \tan\phi] = 28\,\mu\text{T}$$

34. (a) : Focal length,

$$f = \frac{1}{P} = \frac{1}{2.5}\text{ m} = 40\text{ cm}, m = \frac{v}{u} = 4, v = 4u$$

Using lens formula

$$\frac{1}{40} = \frac{1}{4u} - \frac{1}{u} = \frac{1-4}{4u}, \frac{1}{40} = \frac{-3}{4u} \Rightarrow u = -30\text{ cm}$$

So, required distance = 30 cm

35. (b) : $mg\sin\theta$ component is always down the plane whether it is rolling up or rolling down. Therefore, for no slipping, sense of angular acceleration should also be same in both the cases. Therefore, force of friction f always act upwards.

36. (b) : For an incompressible liquid equation of continuity

$$Av = \text{constant or } A \propto \frac{1}{v}$$

Therefore, at the wider end speed will be low and at narrow end speed will be high.

37. (b) : Given, $L = 9.1$ m, $r = 5$ mm $= 5 \times 10^{-3}$ m

$T = F = 800$ N, $\Delta L = ?$

$Y = 2 \times 10^{11}$ N m^{-2}

$$Y = \frac{F/A}{\Delta L/L} \Rightarrow \Delta L = \frac{FL}{Y(\pi r^2)}$$

$$\Delta L = \frac{800 \times 9.1}{(2\times10^{11})(3.14\times25\times10^{-6})} = 4.64\times10^{-4}\text{ m}$$

38. (c) : $M = \dfrac{\beta}{\alpha} = \dfrac{f_0}{f_e} = \dfrac{60\text{ cm}}{5\text{ cm}} = 12,$

$\beta = 12\alpha = 12 \times 2° = 24°$

39. (c) : Water rise to height, $h = \dfrac{2T}{\rho g r}$

Mass of water in capillary tube, $m = pV = P\pi r^2 h$

Potential energy of water column

$$U = \frac{mgh}{2}, \therefore U = \frac{2\pi T^2}{\rho g}$$

The work performed by force of surface tension is $W = 2\pi r T h = \dfrac{4\pi T^2}{\rho g}$. From conservation of energy the heat evolved $Q = W - U = \dfrac{2\pi T^2}{\rho g}$

40. (b) : Given, $v_{max} = \omega A = 3$ ...(i)

and $a_{max} = \omega^2 A = 90$ ...(ii)

From equations (i) and (ii), we have

$\omega = 30$ rad s^{-1} and $A = 0.1$ m

The propagation constant, $k = \dfrac{\omega}{A} = \dfrac{30}{20} = 1.5$

Thus wave functions can be written as

$y = A\sin(\omega t \pm kx) = 0.1\sin(30t \pm 1.5x)$.

41. (a) : In balancing condition, $\dfrac{R_1}{R_2} = \dfrac{l_1}{l_2} = \dfrac{l_1}{100 - l_1}$

$$\Rightarrow \frac{X}{Y} = \frac{20}{80} = \frac{1}{4}$$

and $\dfrac{4X}{Y} = \dfrac{l}{100-l} = \dfrac{1}{4}$

$$\Rightarrow \frac{4}{4} = \frac{l}{100-l} \Rightarrow l = 50\text{ cm}$$

42. (d) : In given circuit R_B and R_C are in series.

$\therefore R_{BC} = 6 + 6 = 12\ \Omega$.

Now, R_A and R_{BC} are in parallel.

Therefore, equivalent resistance of circuit,

$$R_{eq} = \frac{12\times3}{12+3} = \frac{36}{15}.$$

Using Ohm's law, $I = \dfrac{V}{R_{eq}} = \dfrac{4.8}{36/15} = 2$ A.

43. (d) : $R = \dfrac{V^2}{P} = \dfrac{220\times220}{100} = 484\ \Omega$

In series, $R_{eq} = 484 + 484 = 968\ \Omega$

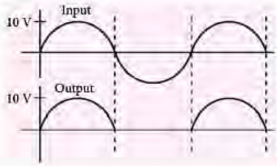
$\therefore P_{eq} = \dfrac{V^2}{968} = \dfrac{220\times220}{968} = 50$ watt

In parallel, $R_{eq} = 242\ \Omega$

$\therefore P_{eq} = \dfrac{V^2}{242} = \dfrac{220\times220}{242} = 200$ watt.

44. (a) : Every body at all time, at all temperatures emit radiation (except at $T = 0$), which fall in the infrared region.

45. (b) : $V_{dc} = \dfrac{V_m}{\pi} = \dfrac{10}{\pi}$ V.



JEE 2021 PRACTICE PAPER ADVANCED

PAPER - I

SECTION 1 (Maximum Marks : 18)

- *This section contains SIX (06) questions.*
- *Each question has FOUR options. ONLY ONE of these four options is the correct answer.*
- *For each question, choose the correct 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.*

1. A ball of radius r rolls inside a hemispherical shell of radius R. It is released from rest from point A as shown in figure. The angular velocity of centre of the ball in position B about the centre of the shell is

(a) $2\sqrt{\frac{g}{5(R-r)}}$ (b) $\sqrt{\frac{10g}{7(R-r)}}$

(c) $\sqrt{\frac{2g}{5(R-r)}}$ (d) $\sqrt{\frac{5g}{2(R-r)}}$

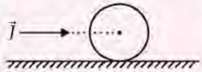
2. For the situation described in figure the magnetic field changes with time according to $B = (2t^3 - 4t^2 + 0.8)$T and $r_1 = 2R = 5.0$ cm

The force on an electron located at P_1 at $t = 2.00$ s is

(a) 2.5×10^{-20} N (b) 3.0×10^{-17} N

(c) 8.0×10^{-21} N (d) 1.6×10^{-19} N

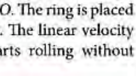
3. An impulse J is applied on a ring of mass m along a line passing through its centre O. The ring is placed on a rough horizontal surface. The linear velocity of centre of ring once it starts rolling without slipping is



(a) J/m (b) $J/2m$

(c) $J/4m$ (d) $J/3m$

4. Three rods of the same cross section and made of the same material form the sides of a triangle ABC as shown. The points A and B are maintained at temperatures T and $\sqrt{2}T$ respectively in the steady state. Assuming that only heat conduction takes place, the temperature at point C is



(a) $\left[\frac{(2\sqrt{2}+\sqrt{3})}{(2+\sqrt{3})}\right]T$ (b) $\left[\frac{3\sqrt{2}}{(2+\sqrt{3})}\right]T$

(c) $\left[\frac{2}{\sqrt{3}}\right]T$ (d) $\left[\frac{\sqrt{5}}{2}\right]T$

5. You are studying for an exam on the eight floor of your luxurious apartment building. You look out from the window and notice that one of your neighbours is giving a party on the ground-floor terrace and has placed a huge punch bowl full of an interesting looking beverage (specific gravity = 1) directly below your window. You quickly string together 80 drinking straws to form a giant straw that can reach the punch bowl 80 feet below. You dip the straw into the punch and begin to suck. When you use a single drinking straw to

drink something, it takes you 0.1 seconds to raise the liquid to your lips. But when you use this giant drinking straw

(a) you find that you can't raise the liquid to your lips no matter how hard you try.

(b) it takes you 8 seconds (80 times 0.1 second) to raise the liquid to your lips.

(c) it takes you 800 seconds (80 divided by 0.1 second) to raise the liquid to your lips.

(d) it takes you 640 seconds (80 times 80 times 0.1 second) to raise the liquid to your lips.

6. 0.2 moles of an ideal gas is taken round the cycle ABC. The path $B \to C$ is an adiabatic process, $A \to B$ is an isochoric process and $C \to A$ is an isobaric process. The temperature at A and B are $T_A = 300$ K and $T_B = 500$ K and pressure at A is 1 atm and volume at A is 4.9 L. The volume at C is

(Given : $\gamma = \frac{C_P}{C_V} = \frac{5}{3}$,

$R = 8.205 \times 10^{-2}$ L atm mol^{-1} K^{-1},

$\left(\frac{3}{5}\right)^{2/5} = 0.81$)

(a) 7.9 L (b) 6.6 L

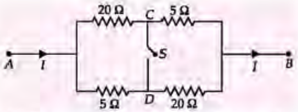
(c) 5.5 L (d) 5.8 L

Section 2 (Maximum Marks : 24)

- *This section contains SIX (06) questions.*
- *Each question has FOUR options. ONE OR MORE THAN ONE of these four option(s) is (are) correct answer(s).*
- *For each question, choose the option(s) corresponding to (all) the correct answer(s).*
- *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 and both of which are correct.*
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.*

7. When some potential difference is maintained between A and B current I enters the network at A and leaves at B. When switch S is closed



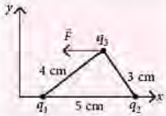
(a) the equivalent resistance between A and B is 8 Ω

(b) C and D are at same potential

(c) no current flows between C and D

(d) current $\frac{3}{5}I$ flows from D to C.

8. Three charges q_1, q_2 and q_3 are placed as shown. The magnitude of q_1, is 2μC, but its sign and the value of the charge q_2 are not known. Charge q_3 is +4μC and the net force $\vec{F}$ on q_3 is in the negative x direction, then



(a) charge q_1 is negative

(b) charge q_2 is positive

(c) the magnitude of charge q_2 is $\frac{27}{32}$μC

(d) the magnitude of net force $\vec{F}$ on charge q_3 is $\frac{45}{22}$mN.

9. Physical quantities A and B have the same dimensions. Then,

(a) $A \pm B$ must be a meaningful physical quantity

(b) $A \pm B$ may not be a meaningful physical quantity

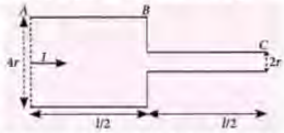
(c) $\frac{A}{B}$ must be a dimensionless quantity

(d) both must be either scalar or vector quantities.

10. An electron is at $t = 0$. It is circulating in anticlockwise direction with a constant angular speed ω along the shown circular path. Magnetic field at $Q(CQ = 2R$, where R is radius of the circle) will be recorded as zero at times

(a) $\frac{\pi}{3\omega}$ (b) $\frac{5\pi}{3\omega}$ (c) $\frac{7\pi}{3\omega}$ (d) $\frac{8\pi}{3\omega}$

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



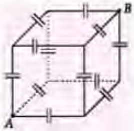
(a) Electric field in both halves is equal.
(b) Voltage drop in first half is twice of voltage drop in second half.
(c) Current density in both halves is equal.
(d) Power loss in second half is four times the power loss in first half.

12. It is observed that only 0.39% of the original radioactive sample remains undecayed after eight hours. Hence
(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 ln2 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 $\sqrt{2}\times10^7$.

SECTION 3 (Maximum Marks : 24)

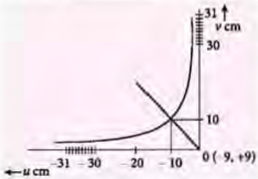
- *This section contains SIX (06) questions. The answer to each question is a NUMERICAL VALUE.*
- *For each question, enter the correct numerical value of the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer. If the numerical value has more than two decimal places, truncate/round-off the value to TWO decimal places.*
- *Answer to each question will be evaluated according to the following marking scheme:*
  Full Marks : +4 *If ONLY the correct numerical value is entered.*
  Zero Marks : 0 *In all other cases.*

13. Twelve capacitors, each having a capacitance C, are connected to form a cube as shown. If equivalent capacitance between the diagonally opposite corners such as A and B is $\frac{nC}{5}$, the value of n is ________.



14. Image of an object approaching a convex mirror of radius of curvature 20 m along its optical axis is observed to move from $\frac{25}{3}$ m to $\frac{50}{7}$ m in 30 seconds. The speed of the object (in km per hour) is ________.

15. The graph shows relationship between object distance and image distance for an equiconvex lens. Then, maximum error in focal length of the lens (in cm) is ________.



16. Electrons in hydrogen like atoms (Z = 3) make transitions from the fifth to the fourth orbit and from the fourth to the third orbit. The resulting radiations are incident normally on a metal plate and eject photoelectrons. The stopping potential for the photoelectrons ejected by the shorter wavelength is 3.95 volt. The stopping potential for the photoelectrons ejected by the longer wavelength (in volt) is ________.
(Rydberg constant = 1.094×10^7 m^{-1})

17. In hydrogen spectrum the wavelength of H_α line is 656 nm, whereas in the spectrum of a distant galaxy, H_α line wavelength is 706 nm. Speed of the galaxy with respect to earth (in m s^{-1}) is $n\times10^7$. The value of n is ________.

18. A series RC combination is connected to an AC voltage of angular frequency ω = 500 radian/s. If the impedance of the RC circuit is $R\sqrt{1.25}$, the time constant (in millisecond) of the circuit is ________.

PAPER-II

SECTION 1 (Maximum Marks : 18)

- ***This section contains SIX (06) questions.***
- ***The answer to each question is a SINGLE DIGIT INTEGER ranging from 0 to 9, both inclusive.***
- ***For each question, enter the correct integer corresponding to the answer using the mouse and the on-screen virtual numerical 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 integer is chosen;***

Zero Marks : ***0 If the question is unanswered;***

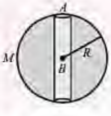
Negative Marks : –1 In all other cases.

1. A steady current I goes through a wire loop PQR having shape of a right angle triangle with $PQ = 3x$, $PR = 4x$ and $QR = 5x$. If the magnitude of the magnetic field at P due to this loop is $k\left(\frac{\mu_0 I}{48\pi x}\right)$, the value of k will be ______.

2. A stone tied to a string of length L is whirled in a vertical circle with the other end of the string at the centre. At a certain instant of time, the stone is at its lowest position, and has a speed u. The magnitude of the change in its velocity as it reaches a postion where the string is horizontal is $\{2(u^2 + ngL)^{-x}\}$. The value of ratio $\frac{n}{x}$ is ______.

3. A thin rod of length L is lying along the x-axis with its ends at $x = 0$ and $x = L$. Its linear density (mass/length) varies with x as $k(x/L)^n$, where n can be zero or any positive number. If the position x_{CM} of the centre of mass of the rod is plotted against n, the slope of dependence curve of x_{CM} on n is $\frac{L}{(n+\phi)^2}$. The value of ϕ is ______.

4. A smooth tunnel is dug along the diameter of the earth. A point mass m is released from the surface of earth in the tunnel. The velocity of the point mass when it crosses the centre of the earth is $\left(\frac{GM^a}{R^b}\right)^c$. The ratio $\frac{ab}{c}$ is ______.



(Mass of earth is M and radius is R)

5. A rod of length 1 m and uniform cross section is hinged at one end to the bottom of a tank. The tank is filled with water upto a height of 0.5 m. The specific gravity of the plank is 0.5. Angle that the plank makes with the vertical in the equilibrium position (in degrees) is 9 n. The value of n is ______.

6. In a Young's double slit experiment, two slits are illuminated by a mixture of two wavelengths 12000 Å and 10000 Å. At 6.0 mm from the common central bright fringe on a screen 2 m away from the slits, a bright fringe of one interference pattern coincides with the bright fringe of other. The distance (in mm) between the slits is ______.

Section 2 (Maximum Marks : 24)

- ***This section contains SIX (06) questions.***
- ***Each question has FOUR options. ONE OR MORE THAN ONE of these four option(s) is (are) correct answer(s).***
- ***For each question, choose the option(s) corresponding to (all) the correct answer(s).***
- ***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 and both of which are correct;***

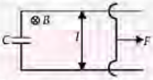
Partial Marks : ***+ 1 If two or more options are correct but ONLY one option is chosen and it is a correct option;***

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

Negative Marks : –2 In all other cases.

7. Two rays of light A and B with wavelength 5000 Å travel parallel to each other in air. Ray A encounters a 1 mm thick layer of glass with refractive index $n = 1.5$. Then :
   (a) ray B will complete more oscillation than ray A
   (b) both rays will complete same number of oscillations.
   (c) ray A will complete more oscillations than ray B
   (d) the actual difference in number of oscillation made by two waves over the 1 mm distance is 1000.

8. A conducting wire of length l and mass m can slide without friction on two parallel rails and is connected to capacitance C. The whole system lies in a magnetic field B and a constant force F is applied to the rod. Then



(a) the rod moves with constant velocity
(b) the rod moves with an acceleration of $\dfrac{F}{m+B^2l^2C}$
(c) there is constant charge on the capacitor.
(d) charge on the capacitor increases with time.

9. Which of the following statements are correct?
(a) A ray of light is incident on a plane mirror and gets reflected. If the mirror is rotated through an angle θ, then the reflected ray gets deviated through angle 2θ.
(b) A ray of light gets reflected successively from two mirrors which are mutually inclined. Angular deviation suffered by the ray does not depend upon angle of incidence on first mirror.
(c) A plane mirror cannot form real image of a real object.
(d) If an object approaches toward a plane mirror with velocity v, then the image approaches the object with velocity $2v$.

10. The given infinite grid consists of hexagonal cells of six resistors each of resistance R. Then R_{12} is equal to

(a) $\dfrac{R}{3}$ (b) $\dfrac{2R}{3}$ (c) $\dfrac{4R}{3}$ (d) $\dfrac{3R}{4}$

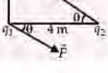
11. A spherical body of radius R consists of a fluid of constant density and is in equilibrium under its own gravity. If $P(r)$ is the pressure at $r(r < R)$, then the correct option(s) is (are)
(a) $P(r = 0) = 0$ (b) $\dfrac{P(r=3R/4)}{P(r=2R/3)}=\dfrac{63}{80}$
(c) $\dfrac{P(r=3R/5)}{P(r=2R/5)}=\dfrac{16}{21}$ (d) $\dfrac{P(r=R/2)}{P(r=R/3)}=\dfrac{20}{27}$

12. A sound wave of frequency f travels horizontally to the right. It is reflected from a large vertical plane surface moving to left with a speed v. The speed of sound in medium is C
(a) The number of wave striking the surface per second is $f\dfrac{(C+v)}{C}$
(b) The wavelength of reflected wave is $\dfrac{C(C-v)}{f(C+v)}$
(c) The frequency of the reflected wave is $f\dfrac{(C+v)}{(C-v)}$
(d) The number of beats heard by a stationary listener to the left of the reflecting surface is $\dfrac{vf}{C-v}$

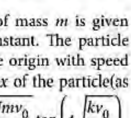
Section 3 (Maximum Marks : 24)

- *This section contains SIX (06) questions. The answer to each question is a NUMERICAL VALUE.*
- *For each question, enter the correct numerical value of the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer. If the numerical value has more than two decimal places, truncate/round-off the value to TWO decimal places.*
- *Answer to each question will be evaluated according to the following marking scheme:*
Full Marks : +4 If ONLY the correct numerical value is entered;
Zero Marks : 0 In all other cases.

13. A current $I = 5.0$ A flows along a thin wire shaped as shown in figure. The radius of a curved part of the wire is equal to $R = 120$ mm, the angle $2\varphi = 90°$. The magnetic field at the point O is ______ μT.



14. Three charges $q_1 = 3$ μC, $q_2 = -3$ μC and q_3 are kept at the vertices of a triangle as shown in the figure. If the net force acting on q_1 is $\vec{F}$, the charge q_3 is then given as $\left(1+\dfrac{2}{n}\right)^2$ μC. The value of n is ________.



15. A force acting on a particle of mass m is given by $F = k\dot{x}x$ where k is a constant. The particle is injected into this field at the origin with speed v_0 at time $t = 0$. The position x of the particle(as a function of t) is given by $\sqrt{\dfrac{Nmv_0}{5k}}\tan\left(t\sqrt{\dfrac{kv_0}{2m}}\right)$. The value of N is ________.

16. One end of a string of length l is tied to the ceiling of a lift accelerating upwards with an acceleration $g/2$. The linear mass density of the string is $\mu(x) = \mu_0 x^{1/2}$ where, x is measured from the bottom. The time taken by a pulse to reach from bottom to top is $\sqrt{\frac{x \times l}{3g}}$. The value of x is ________.

17. Diameter of a plano-convex lens is 6 cm and thickness at the centre is 3 mm. If the speed of light in the material of the lens is 2×10^8 metre per sec, the focal length of the lens is ______ cm.

18. Two identical coherent sources placed on a diameter of a circle of radius R at separation x ($<< R$) symmetrically about the centre of the circle. The sources emit identical wavelength λ each. The number of points on the circle with maximum intensity is ($x = 5\lambda$) ________.

SOLUTIONS

PAPER-I

1. **(b)** : KE of ball in position $B = mg(R - r)$
Here, m = mass of ball.
Since, it rolls without slipping the ratio of rotational to translational kinetic energy will be $\frac{2}{5}$ or $\frac{K_R}{K_T} = \frac{2}{5}$

$$\therefore \quad K_T = \frac{5}{7}mg(R-r)$$

$$\text{or} \quad \frac{1}{2}mv^2 = \frac{5}{7}mg(R-r)$$

$$\text{or} \quad v = \sqrt{\frac{10g(R-r)}{7}}$$

$$\therefore \quad \omega = \frac{v}{R-r} = \sqrt{\frac{10g}{7(R-r)}}$$

2. **(c)** : $E\ell = A\left|\frac{dB}{dt}\right|$

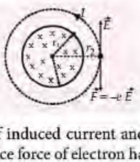
$$\Rightarrow \quad E = \frac{\pi R^2}{2\pi r_2}\frac{d}{dt}(2t^3 - 4t^2 + 0.8)$$

Force on electron at P_2 is $F = eE$
$\therefore$ At $t = 2$ s

$$F = \frac{1.6\times10^{-19}\times(2.5\times10^{-2})^2}{2\times5\times10^{-2}}\times[6(2)^2 - 8(2)]$$

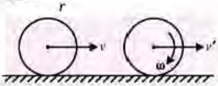
$$= \frac{1.6}{4}\times2.5\times10^{-21}\times(24-16) = 8\times10^{-21}\text{ N}$$

$\frac{dB}{dt}$ is positive so it is increasing.



$\therefore$ Direction of induced current and E are as shown in figure and hence force of electron having charge $-e$ is right perpendicular to r_2 downwards.

3. **(b)** : Let v be the velocity of COM of ring just after the impulse is applied and v' be its velocity when pure rolling starts. Angular velocity ω of the ring at this instant will be $\omega = \frac{v'}{r}$



From impulse = change in linear momentum
we have $J = mv$
or $\quad v = J/m$ ...(i)
Between the two positions shown in figure, force of friction on the ring acts backwards. Angular momentum of the ring about bottommost point will remain conserved

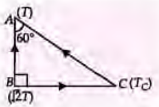
$\therefore \quad L_i = L_f$

or $\quad mvr = mv'r + I\omega$

$= mv'r + (mr^2)\frac{v'}{r} = 2mv'r$

$\therefore \quad v' = \frac{v}{2} = J/2m$ [from Eq. (i)]

4. **(a)** : Let T_C be temperature at point C.
As $T_B > T_A$, heat flows B to A through both path BA and BCA.



From figure,

$$BC = AC\sin60° = \frac{\sqrt{3}}{2}AC$$

In steady state,
Rate of flow of heat in BC = Rate of flow of heat in AC

$\therefore \quad \frac{KA\left(\sqrt{2}T - T_C\right)}{BC} = \frac{KA(T_C - T)}{AC}$

$$\frac{\sqrt{2}T - T_C}{\frac{\sqrt{3}}{2}AC} = \frac{T_C - T}{AC}$$

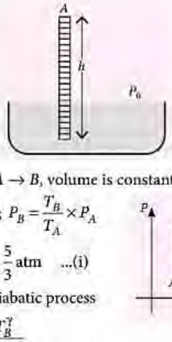
$$\sqrt{2}T - T_C = \frac{\sqrt{3}}{2}(T_C - T)$$

$$2\sqrt{2}T - 2T_C = \sqrt{3}T_C - \sqrt{3}T$$

$$T_C\left(2+\sqrt{3}\right) = \left(\sqrt{3}+2\sqrt{2}\right)T$$

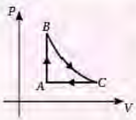
$$T_C = \frac{\left(\sqrt{3}+2\sqrt{2}\right)}{\left(2+\sqrt{3}\right)}$$

5. **(a)** : The liquid will rise up to 80 feet height only if the pressure at that point is less than P_0 by an amount ρgh so pressure at point A should be $P_A = P_0 - \rho gh < 0$ (As $\rho gh = 10^3 \times 10 \times 80 \times 0.305 > 10^5$ (P_0))



6. **(b)** : For $A \rightarrow B$, volume is constant.

$\therefore \quad \frac{P_A}{T_A} = \frac{P_B}{T_B}$; $P_B = \frac{T_B}{T_A} \times P_A$



$P_B = \frac{500}{300} \times 1 = \frac{5}{3}$ atm ...(i)

For $B \rightarrow C$, adiabatic process

$\therefore \quad \frac{T_C^{\gamma}}{P_C^{\gamma-1}} = \frac{T_B^{\gamma}}{P_B^{\gamma-1}}$

$$T_C = \left(\frac{P_C}{P_B}\right)^{\frac{\gamma-1}{\gamma}} \times T_B$$

$$= \left[\frac{1}{5/3}\right]^{\frac{(5/3)-1}{(5/3)}} \times 500 \qquad \text{(Using (i))}$$

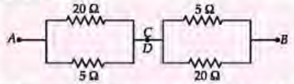
or $T_C = \left(\frac{3}{5}\right)^{2/5} \times 500$ ...(ii)

For $C \rightarrow A$, pressure is constant.

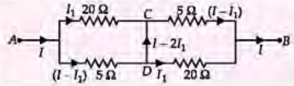
$\therefore \quad \frac{V_C}{T_C} = \frac{V_A}{T_A}$; $V_C = V_A \times \frac{T_C}{T_A}$

$$= 4.9 \times \left(\frac{3}{5}\right)^{2/5} \times 500 \times \frac{1}{300} = 6.6 \text{ L} \qquad \text{(Using (ii))}$$

7. **(a, b, d)** : When the switch S is closed, C and D are at same potential. The equivalent circuit diagram is as shown in the figure.



Hence, the equivalent resistance between A and B is 8 Ω. Using symmetry, the current distribution in the network is as shown in the figure.



$V_A - V_D = V_A - V_C$ or $5(I - I_1) = 20I_1$

$\therefore \quad I_1 = \frac{I}{5}$

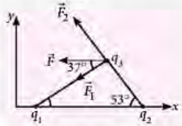
Current flows D to $C = I - 2I_1 = I - \frac{2}{5}I = \frac{3}{5}I$

8. **(a, b, c)** : For F to be along negative x-axis, q_1 has to be negative while q_2 has to be positive.

Also $F_1 \cos 53° = F_2 \cos 37°$

where $F_1 = \frac{k \cdot q_1 q_3}{(4 \text{ cm})^2}$ and $F_2 = \frac{k \cdot q_2 q_3}{(3 \text{ cm})}$

On putting values, $q_2 = \frac{27}{32} \mu$C



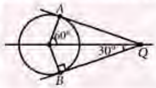
So, net force, $F = F_1 \cos 37° + F_2 \cos 53°$

On putting the values,

$F = 56.25$ N

9. **(b, c)** : The ratio of two quantities having the same dimensions must necessarily be a dimensionless quantity. However, two quantities having the same dimensions may not add to necessarily give a meaningful quantity; for example, work and torque have the same dimensions but their addition is meaningless.

10. (a, b, c) : Zero magnetic field will be recorded at Q when particle is at A and B such that AQ and BQ are tangent to circle.



$\therefore$ Zero magnetic field will be recorded at Q at time

$\frac{T}{6}, T-\frac{T}{6}, T+\frac{T}{6}, 2T-\frac{T}{6}$...... where $T=\frac{2\pi}{\omega}$

$\therefore \quad t=\frac{\pi}{3\omega}, \frac{5\pi}{3\omega}, \frac{7\pi}{3\omega}, \frac{11\pi}{3\omega}, ...$

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

$R_2=\frac{\rho(l/2)}{\pi r^2}=\frac{\rho l}{2\pi r^2}$

$\therefore \quad \frac{R_1}{R_2}=\frac{1}{4}$

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

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

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

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

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

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

Now, $J=\sigma E$

So, $\frac{E_1}{E_2}=\frac{J_1}{J_2}=\frac{1}{4}$

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

As $N=N_0e^{-\lambda t}$

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

$0.0039=e^{-\lambda 8}$

$e^{8\lambda}=\frac{1}{0.0039}$

$e^{8\lambda}\simeq 256$ 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

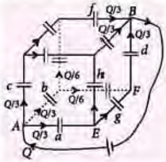
Option (b) is correct.

$N=(10)^8\left(\frac{1}{2}\right)^{\left(\frac{1}{2}\right)}=\frac{1}{\sqrt{2}}\times10^8$

$N=5\sqrt{2}\times10^7$

Option (d) is incorrect.

13. (6) : By symmetry, the capacitors a, g and d have charges $Q/3$, $Q/6$ and $Q/3$ respectively as shown.



We have,

$V_A-V_B=(V_A-V_E)+(V_E-V_F)+(V_F-V_B)$

$=\frac{Q/3}{C}+\frac{Q/6}{C}+\frac{Q/3}{C}=\frac{5Q}{6C}$ or $C_{eq}=\frac{Q}{V_A-V_B}=\frac{6}{5}C.$

14. (3) : Focal length of a convex mirror,

$f=\frac{R}{2}=\frac{20}{2}$ m = 10 m

Now, $v_1=+\frac{25}{3}$ m, $f=+10$ m

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

$\therefore \quad \frac{1}{(25/3)}+\frac{1}{u_1}=\frac{1}{10}$ or $\frac{1}{u_1}=\frac{1}{10}-\frac{3}{25}$

or $u_1=-50$ m

For second position,

$v_2=+\frac{50}{7}$ m, $f=+10$ m

$\frac{1}{v_2}+\frac{1}{u_2}=\frac{1}{f}$

$\therefore \frac{1}{(50/7)}+\frac{1}{u_2}=\frac{1}{10}$ or $\frac{1}{u_2}=\frac{1}{10}-\frac{7}{50}$

or $u_2=-25$ m

Speed of the object $=\frac{25}{30}$ m s^{-1}

$=\frac{25}{30}\times\frac{18}{5}$ km h^{-1} = 3 km h^{-1}

15. (0.05) : Using lens formula

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u} \text{ or } \frac{1}{f}=\frac{1}{10}-\frac{1}{-10} \text{ or } \frac{1}{f}=\frac{2}{10}=\frac{1}{5}$$

or $f = +5$ cm

From graph $\Delta u = 0.1$ and $\Delta v = 0.1$

$$\because \quad \frac{1}{f}=\frac{1}{v}-\frac{1}{u}$$

For maximum error in f, errors are added.

$$\frac{\Delta f}{f^2}=\frac{\Delta v}{v^2}+\frac{\Delta u}{u^2} \text{ or } \frac{\Delta f}{(5)^2}=\frac{0.1}{(10)^2}+\frac{0.1}{(10)^2}$$

$$\text{or } \Delta f=\frac{25\times2\times0.1}{100} \text{ or } \Delta f = 0.05$$

$\therefore$ Focal length of lens $= f \pm \Delta f = 5.00 \pm 0.05$ cm.

16. (0.74) : The stopping potential for shorter wavelength is 3.95 volt *i.e.*, maximum kinetic energy of photoelectrons corresponding to shorter wavelength will be 3.95 eV. Further energy of incident photons corresponding to shorter wavelength will be in transition from $n = 4$ to $n = 3$.

$$E_{4\to3}=E_4-E_3=\frac{-(13.6)(3)^2}{(4)^2}-\left[\frac{-(13.6)(3)^2}{(3)^2}\right]=5.95 \text{ eV}$$

Now from the equation, $K_{max} = E - W$

We have, $W = E - K_{max} = E_{4\to3} - K_{max}$

$= (5.95 - 3.95)$ eV $= 2$ eV

Longer wavelength will correspond to transition from $n = 5$ to $n = 4$.

From the relation $\frac{1}{\lambda}=RZ^2\left(\frac{1}{n_f^2}-\frac{1}{n_i^2}\right)$

the longer wavelength, $\frac{1}{\lambda}=(1.094\times10^7)(3)^2\left(\frac{1}{16}-\frac{1}{25}\right)$

or $\lambda = 4.514 \times 10^{-7}$ m $= 4514$ Å

Energy corresponding to this wavelength,

$$E=\frac{12375 \text{ eV–Å}}{4514\text{Å}}=2.74 \text{ eV}$$

$\therefore$ Maximum kinetic energy of photoelectrons

$K_{max} = E - W = (2.74 - 2)$ eV $= 0.74$ eV

or the stoping potential is 0.74 volt.

17. (2.3) : Since the wavelength increases from 656 nm to 706 nm in respect of H_α line, let the galaxy recedes with speed v w.r.t. earth.

$$\Delta\lambda=\frac{v}{c}\lambda \text{ or } v=\frac{\Delta\lambda}{\lambda}c$$

$$\therefore \quad v=\frac{(706-656)\times10^{-9}}{656\times10^{-9}}\times(3\times10^8)$$

$$\text{or } v=\frac{50\times3\times10^8}{656} \text{ m s}^{-1} \text{ or } v=2.3\times10^7 \text{ m s}^{-1}.$$

18. (4) : Here, $\omega = 500$ rad s^{-1}

The capacitive reactance is

$$X_C=\frac{1}{\omega C}$$

The impedance of the circuit is

$$Z=\sqrt{R^2+(X_C)^2}=\sqrt{R^2+\left(\frac{1}{\omega C}\right)^2}$$

$$R\sqrt{\frac{5}{4}}=\sqrt{R^2+\left(\frac{1}{\omega C}\right)^2}$$

$$\frac{5}{4}R^2=R^2+\left(\frac{1}{\omega C}\right)^2 \text{ or } \frac{1}{4}R^2=\left(\frac{1}{\omega C}\right)^2$$

$$R^2C^2=4\left(\frac{1}{\omega}\right)^2$$

$$\text{or } RC=\frac{2}{\omega}=\frac{2}{500}\text{s} = 0.4\times10^{-2}\text{ s}=4\times10^{-3}\text{ s}=4 \text{ ms}$$

The time constant of RC circuit,

$\tau = RC = 4$ ms

PAPER-II

1. (7) :

Using the concept of area of triangle

$$\frac{1}{2}\times PD\times5x=\frac{1}{2}\times3x\times4x$$

$$\therefore \quad PD=\frac{12x}{5}$$

$$QD=\sqrt{(PQ)^2-(PD)^2}=\sqrt{9x^2-\frac{144x^2}{25}}=\frac{9x}{5}$$

$$\text{and } DR=5x-\frac{9x}{5}=\frac{16x}{5}$$

Magnetic field at P due to current elements PQ and PR is zero as the point P is on the conductor. Hence, magnetic field at P is due to current element QR only.

$$\therefore \quad B=\frac{\mu_0 I}{4\pi PD}(\sin\phi_1+\sin\phi_2)$$

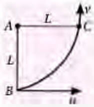
$$B=\frac{\mu_0 I\times5}{4\pi\times12x}\left(\frac{(9x/5)}{3x}+\frac{(16x/5)}{4x}\right)$$

$$=\frac{5\mu_0 I}{48\pi x}\left(\frac{3}{5}+\frac{4}{5}\right)=\frac{7\mu_0 I}{48\pi x}$$

$$\therefore \quad k=7$$

2. **(2)** : At lowest position B, $P.E. = 0$

$K.E. = \frac{1}{2}mu^2$



$\therefore$ Total energy $= \frac{1}{2}mu^2$

At C, when string is horizontal,

$P.E. = mgL$

$K.E. = \frac{1}{2}mv^2$

$\therefore$ Total energy $= \frac{1}{2}mv^2 + mgL$

Since energy is conserved,

$\frac{1}{2}mv^2 + mgL = \frac{1}{2}mu^2$ or $v^2 = u^2 - 2gL$

Since v is in vertical direction and u is in horizontal direction, they are mutually perpendicular to each other.

$\therefore$ Change in velocity $= \sqrt{u^2 + v^2}$

or $|\Delta\vec{v}| = \sqrt{u^2 + (u^2 - 2gL)}$ or $|\Delta\vec{v}| = \sqrt{2(u^2 - gL)}$.

So, $n = -1$ and $x = -\frac{1}{2}$

$\therefore \quad \frac{n}{x} = 2$

3. **(2)** : $$x_{C.M} = \frac{\int_0^L \left(\frac{k}{L^n} \cdot x^n dx\right)x}{\int_0^L \frac{k}{L^n} \cdot x^n dx}$$

$$\Rightarrow x_{C.M} = \frac{\int_0^L x^{n+1} dx}{\int_0^L x^n dx} = \frac{L^{n+2}}{n+2} \cdot \frac{(n+1)}{L^{n+1}} \Rightarrow x_{C.M} = \frac{L(n+1)}{(n+2)}$$

The slope of variation of the centre of mass with x is given by

$$\frac{dx}{dn} = L\left\{\frac{(n+2) \times 1 - (n+1)}{(n+2)^2}\right\} = \frac{L}{(n+2)^2}$$

$$= \frac{L}{(n+\phi)^2}$$

$\therefore \quad \phi = 2$

4. **(2)** : Potential due to earth (solid sphere) at a point inside the earth is given by

$$V = \frac{-GM(3R^2 - r^2)}{2R^3},$$

At surface, $V_A = \frac{-GM}{R}$

At centre, $V_B = \frac{-3}{2}\frac{GM}{R}$

Applying conservation of energy

$K_A + U_A = K_B + U_B$

$0 + mV_A = \frac{1}{2}mv^2 + mV_B$

$-m\frac{GM}{R} = \frac{1}{2}mv^2 - m\frac{3}{2}\frac{GM}{R}$

$\frac{1}{2}mv^2 = \frac{GMm}{R}\left(\frac{3}{2} - 1\right)$

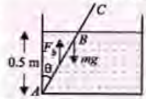
$v^2 = \frac{GM}{R}, \; v = \sqrt{\frac{GM}{R}}$

5. **(5)** : From the figure shown here,

$AC = 1$ m, $AB = 0.5 \sec\theta$,

Force of buoyancy acts in the middle of AB,

$F_b = A(0.5 \sec\theta)\rho_{H_2O}\, g$, ... (i)



where A is the cross sectional area of the rod.

Balancing torque about A since rod is in rotational equilibrium

$F_b \frac{(0.5 \sec\theta)}{2} \sin\theta = mg\left(\frac{1}{2}\right)\sin\theta$

$\Rightarrow \quad 0.5 \sec\theta\, F_b = mg$ ... (ii)

Using (i) and (ii),

$0.5\sec\theta\, A(0.5\sec\theta)\rho_{H_2O}g = A(1)\rho_{rod}\, g$

$(0.5)^2 \sec^2\theta = \frac{\rho_{rod}}{\rho_{H_2O}}$

Since, specific gravity $\frac{\rho_{rod}}{\rho_{water}} = 0.5$ (given)

$\sec^2\theta = 2$, $\sec\theta = \sqrt{2}$, $\theta = 45°$.

6. **(2)** : $x = n\lambda\frac{D}{d} = (n+1)\lambda'\frac{D}{d}$

$\therefore \quad n \times 12000 = (n+1) \times 10000$

or $\quad n = 5$

$\therefore \quad d = \frac{n\lambda D}{x} = \frac{5 \times 12000 \times 10^{-10} \times 2}{6 \times 10^{-3}}$ m

$= 2 \times 10^{-3}$ m $= 2$ mm

7. **(c, d)** : For ray A, t_1 = time taken by the ray to travel through the glass

$= \frac{d}{v_g}$ [$d = 1$ mm and v_g = velocity of light in glass $= c/n$]

$$\frac{nd}{c}=\frac{1.5\times10^{-3}}{3\times10^{8}}=5\times10^{-12}\ \text{s}$$

For ray B, $t_2=\frac{d}{c}=\frac{10^{-3}}{3\times10^{8}}=\frac{10}{3}\times10^{-12}\ \text{s}$

$$\Delta t=t_1-t_2=\left(5-\frac{10}{3}\right)\times10^{-12}=\frac{5}{3}\times10^{-12}\ \text{s}$$

The frequency of the light (oscillation per second) does not change inside the glass.

$t_1 > t_2 \Rightarrow$ ray A will make more oscillations

n_1 = number of oscillations for ray $A = f\,t_1$

similarly, n_2 = number of oscillations for ray $B = f\,t_2$

$$\Delta n = n_1 - n_2 = f(t_1 - t_2) = \left(\frac{c}{\lambda}\right)(\Delta t)$$

$$=\frac{3\times10^{8}}{5000\times10^{-10}}\left(\frac{5}{3}\times10^{-12}\right)=10^{3}$$

8. **(b, d)** : Current, $i=\frac{dq}{dt}=\frac{d}{dt}(CvBl)=CBl\frac{dv}{dt}=CBla$

$\therefore\quad F-CB^2l^2a=ma$

$\Rightarrow\quad a=\frac{F}{m+B^2l^2C}$

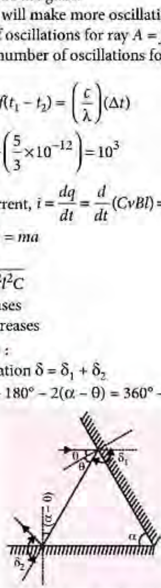
$\Rightarrow$ emf increases

$\Rightarrow$ charge increases

9. **(a, b, c, d)** :

b. Total deviation $\delta=\delta_1+\delta_2$

$=(180°-2\theta)+180°-2(\alpha-\theta)=360°-2\alpha$



Which is independent of angle of incidence.

c. Power of a plane mirror is zero.

d. Velocity of the image toward the object $=v+v=2v$.

10. **(b)** : Here we will apply superposition principle.

(i) Let us feed a current I to point 1, but do not draw the current from 2 and allow the current to spread to infinity. Then current in branch 12 will be $I/3$.

(ii) Secondary feed current I to point 1 and take it out from 2, now again current through branch 12 will be $I/3$.

(iii) Now carry out both the above steps (i) and (ii) simultaneously.

Then current in branch 12 will be sum of above two currents,

i.e., $\frac{I}{3}+\frac{I}{3}=\frac{2I}{3}$

Resistance between 1 and 2 is R.

Let remaining resistance is R_1. Then

$$R_1\frac{I}{3}=R\frac{2I}{3}\ \text{ or }\ R_1=2R$$

$$R_{eq}=\frac{RR_1}{R+R_1}=\frac{R(2R)}{R+2R}=\frac{2R}{3}$$

11. **(b, c)** : Let the density of fluid be ρ.

Pressure at a distance $r(r<R)$ from centre is given by

$$P(r)=\frac{2\pi}{3}\rho^2G(R^2-r^2)$$

where G is gravitational constant.

Now, $P(r=0)=\frac{2\pi}{3}\rho^2GR^2\neq0$

$$\frac{P(r=3R/4)}{P(r=2R/3)}=\frac{R^2-(3R/4)^2}{R^2-(2R/3)^2}=\frac{7}{16}\times\frac{9}{5}=\frac{63}{80}$$

$$\frac{P(r=3R/5)}{P(r=2R/5)}=\frac{R^2-(3R/5)^2}{R^2-(2R/5)^2}=\frac{16}{25}\times\frac{25}{21}=\frac{16}{21}$$

$$\frac{P(r=R/2)}{P(r=R/3)}=\frac{R^2-(R/2)^2}{R^2-(R/3)^2}=\frac{3}{4}\times\frac{9}{8}=\frac{27}{32}\neq\frac{20}{27}$$

12. **(a, b, c)** : A large vertical plane surface reflects incident waves. Sound travels to right while the reflecting plane travels to left.

(a) $\frac{\text{No. of waves}}{\text{sec}}=\frac{\text{distance travelled}}{\text{wavelength}}$

$$=\frac{C+v}{\lambda}=\frac{f(C+v)}{C}\quad\text{.....(i)}$$

(c) Frequency of reflected wave $=f''$

According to Doppler's effect.

or $f''=f\frac{(C+v)}{(C-v)}$ ......(ii)

(b) Wavelength of reflected wave $=\lambda''$

$$\lambda''=\frac{C}{f''},\ \lambda''=\frac{C(C-v)}{f(C+v)}\ \text{.....(iii)}$$

(d) Beat frequency $=f''-f$

$= f\frac{(C+v)}{(C-v)} - f = \frac{2vf}{C-v}$

Options (a), (b), (c) are correct.

Option (d) is not correct.

13. (28): Magnetic induction due to the arc segment at O,

$$B_1 = \frac{\mu_0}{4\pi}\frac{i}{R}(2\pi - 2\varphi)$$

Magnetic induction due to the line segment at O,

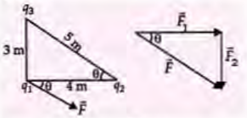
$$B_2 = \frac{\mu_0}{4\pi}\frac{i}{R\cos\phi}[2\sin\varphi]$$

B_1 and B_2 both are directed into the plane of page so total magnetic induction at O

$$B = B_1 + B_2 = \frac{\mu_0}{2\pi}\frac{i}{R}[\pi - \varphi + \tan\varphi] = 28\ \mu\text{T}$$

14. (16): Let $\vec{F}_1$ be the force on q_1 due to q_2 and $\vec{F}_2$ be that due to q_3.

As $q_1 > 0$, $q_2 < 0$, the charge q_3 should be + ve to get the net force $\vec{F}$.



$$\tan\theta = \frac{F_2}{F_1},\ F_1 = \frac{Kq_1q_2}{16},\ F_2 = \frac{Kq_1q_3}{9} \text{ and } K = \frac{1}{4\pi\varepsilon_0}$$

$$\therefore\ \frac{3}{4} = \frac{q_3}{9}\times\frac{16}{q_2}$$

$$\therefore\ q_3 = \frac{27}{64}\times q_2 = \frac{81}{64} = \left(\frac{9}{8}\right)^2 \mu\text{C}$$

$$= \left(1+\frac{1}{8}\right)^2 \mu\text{C} = \left(1+\frac{2}{16}\right)^2 \mu\text{C}$$

Hence $n = 16$

15. (10): $F = k\dot{x}x = \frac{1}{2}k\frac{d}{dt}(x^2)$

$$m\ddot{x} = \frac{1}{2}k\frac{d}{dt}(x^2)$$

$$m\frac{d\dot{x}}{dt} = \frac{1}{2}k\frac{d}{dt}(x^2)$$

Integrating the above equation, we get

$$(m\dot{x}) = \left(\frac{k}{2}\right)x^2 + C$$

where C is a constant of integration.

Applying initial condition,

$\dot{x} = v_0, x = 0$ so $C = mv_0$

$$\therefore\ m\dot{x} = m\frac{dx}{dt} = \frac{kx^2}{2} + mv_0$$

Rearranging above equation

$$\frac{2m\,dx}{kx^2 + 2mv_0} = dt$$

$$\Rightarrow\ \frac{dx}{v_0 + \left(\frac{kx^2}{2m}\right)} = dt$$

Integrating both sides, we get

$$\sqrt{\frac{2m}{kv_0}}\tan^{-1}\sqrt{\frac{kx^2}{2mv_0}} = t + C'$$

where C' is a constant of integration

Applying initial condition, $x = 0$, $t = 0$ so $C' = 0$

$$\therefore\ \tan^{-1}\sqrt{\frac{kx^2}{2mv_0}} = \sqrt{\frac{kv_0}{2m}}t$$

$$\text{or } \sqrt{\left(\frac{k}{2mv_0}\right)}x = \tan\left[\sqrt{\left(\frac{kv_0}{2m}\right)}t\right]$$

$$\Rightarrow\ x = \sqrt{\frac{2mv_0}{k}}\tan\left(\sqrt{\frac{kv_0}{2m}}t\right)$$

$$= \sqrt{\frac{10mv_0}{5k}}\tan\left(t\sqrt{\frac{kv_0}{2m}}\right)$$

$\therefore\ N = 10$

16. (12): Consider a small element dx at a distance x from the bottom of string.

Weight of this element $= [\mu(x)dx](g + \frac{g}{2})$

Tension at this element $T_x = \int_0^x \frac{3}{2}\mu(x)g\,dx$

$$T_x = \frac{3}{2} g \int_0^x \mu_0 x^{1/2} dx = \frac{3g\mu_0}{2} \frac{x^{3/2}}{(3/2)} = g\mu_0 x^{3/2}$$

Velocity of transverse wave at this element

$$v = \sqrt{\frac{T}{\mu}}$$

$$v = \frac{dx}{dt} = \sqrt{\frac{g\mu_0 x^{3/2}}{\mu_0 x^{1/2}}} = \sqrt{gx}$$

$$dt = \frac{dx}{\sqrt{gx}}$$

Integrate both sides, we get

$$\int_0^t dt = \int_0^l \frac{dx}{\sqrt{gx}}$$

$$t = \frac{1}{\sqrt{g}} \int_0^l x^{-1/2} dx \Rightarrow t = 2\sqrt{\frac{l}{g}}$$

$$= \sqrt{\frac{12l}{3g}} = \sqrt{\frac{xl}{3g}}$$

$\therefore \quad x = 12$

17. (30) : Here, $r = \frac{6}{2} = 3$ cm, $t = 3$ mm $= 0.3$ cm

If R is radius of curvature of convex surface, then $2Rt = r^2$

$$R = \frac{r^2}{2t} = \frac{3 \times 3}{2 \times 0.3} = 15 \text{ cm}$$

As $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ and $\mu = \frac{c}{v} = \frac{3 \times 10^8}{2 \times 10^8} = \frac{3}{2}$

$$\therefore \quad \frac{1}{f} = \left(\frac{3}{2} - 1\right)\left(\frac{1}{\infty} - \frac{1}{-15}\right) = \frac{1}{30}$$

$f = 30$ cm

18. (20) : As is clear from figure, path difference between the light waves reaching P from S_1 and S_2 is

$$\Delta x = 2\left(\frac{x}{2}\cos\theta\right) = x\cos\theta$$

For intensity to be maximum at P,
path difference $\Delta x = n\lambda$, where $n = 0, 1, 2, ...$

$$x\cos\theta = n\lambda \text{ or } \cos\theta = \frac{n\lambda}{x}$$

As $\cos\theta$ cannot be greater than one, therefore,

$$\frac{n\lambda}{x} \ngtr 1 \text{ or } n \ngtr \frac{x}{\lambda}$$

As $x = 5\lambda$, therefore, $n \ngtr \frac{5\lambda}{\lambda}$

i.e., $n \ngtr 5$ or $n = 1, 2, 3, 4, 5.$

Therefore, in all the four quadrants, there can be 20 maxima.

BRAIN MAP

RAY OPTICS AND OPTICAL INSTRUMEN

THIN SPHERICAL LENS

Thin lens formula: $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

Magnification: $m=\frac{v}{u}=\frac{h_i}{h_0}$

REFLECTION FROM PLANE SURFACE

- The image formed by a plane mirror is laterally inverted.
- The image formed by a plane mirror is virtual, erect w.r.t. object and of the same size as the object.
- If keeping the incident ray fixed, the plane mirror is rotated through an angle θ, the reflected ray turns through double the angle *i.e.*, 2θ in that direction.
- Deviation suffered by a light ray incident at an angle i is given by $\delta=(180^\circ-2i)$

POWER OF LENSES

Power of lens : $P=\frac{1}{f\text{ (in cm)}}$

- The SI unit of power of lens is dioptre (D).
- For a convex lens, P is positive.
- For a concave lens, P is negative.
- When focal length (f) of lens is in cm, then $P=\frac{100}{f\text{ (in cm)}}$ dioptre.

COMBINATION OF LENSES

- Power: $P=P_1+P_2-dP_1P_2$ (d = small separation between the lenses)
- For $d=0$ (lenses in contact) Power: $P=P_1+P_2+P_3+\ldots$

COMMON DEFECTS OF EYES ↔ CORRECTING LENSES

- Myopia (short-sightedness) ↔ Concave lens
- Hypermetropia (long-sightedness) ↔ Convex lens
- Presbyopia ↔ Bifocal lens
- Astigmatism ↔ Cylindrical lens

REFRACTION BY SPHERICAL SURFACE

Relation between object distance (u), image distance (v) and refractive index (μ)

$$\frac{\mu_{\text{denser}}}{v}-\frac{\mu_{\text{rarer}}}{u}=\frac{\mu_{\text{denser}}-\mu_{\text{rarer}}}{R}$$

(Holds for any curved spherical surface)

Lens maker's formula

$$\frac{1}{f}=\left(\frac{\mu_{\text{denser}}-\mu_{\text{rarer}}}{\mu_{\text{rarer}}}\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

for the lens placed in air

$$\frac{1}{f}=(\mu-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

REFLECTION OF LIGHT

Laws of reflection:

- The angle of incidence i equals the angle of reflection r.

$$\angle i=\angle r$$

- Incident ray, the normal and the reflected ray lie in the same plane.

SIMPLE MICROSCOPE

Magnifying power

For final image formed at D (least distance),

$$m=\frac{\text{Angle subtended by the image at } D}{\text{Angle subtended by the object at infinity}}=\frac{\beta}{\alpha}=1+\frac{D}{f}$$

For final image formed at infinity, $m=\frac{D}{f}$

TERRESTRIAL TELESCOPE

For final image formed at D, $m=\frac{f_o}{f_e}\left(1+\frac{f_e}{D}\right)$

For final image formed at infinity, $m=\frac{f_o}{f_e}$

Distance between objective and eyepiece $d=f_o+4f+f_e$

REFRACTION TH

Relation between μ and δ

where, δ_m = a... d...

A = a...

or $\delta=(\mu-1)A$ (Prism of ...

Angular dispersion $=\delta_V-$ ...

Dispersive power, $\omega=\frac{\delta_V-}{\delta}$ ...

Mean deviation, $\delta=\frac{\delta_V+}{2}$ ...

RAY O AN OPTI INSTRU

ASTRON

Magnifying pow

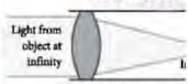
- For final image ...

$m=\frac{\text{Angle sub}}{\text{Angle s}}$ ...

$=\frac{\beta}{\alpha}=\frac{-f_0}{f_e}\Big(1$ ...

- In normal adju ... $m=-f_o/f_e$

A terrestrial t



Objective lens

TS

ROUGH PRISM

gle of minimum
viation
gle of prism

nall angle)

$_R = (\mu_V - \mu_R)A$

$\frac{\delta_R}{} = \frac{\mu_V - \mu_R}{\mu - 1}$

PTICS
D
CAL
MENTS

OMICAL TELESCOPE

formed at D (least distance),

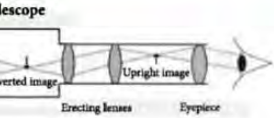
ended by the image at D

btended by the object
at infinity

$\frac{f_e}{D}\Big)$

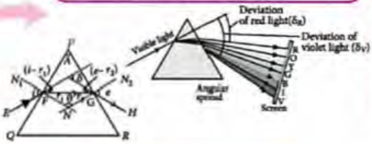
tment, image formed at infinity

lescope



DISPERSION OF LIGHT

The phenomenon of splitting of white light into its constituent colours on passing through a prism.



RELATION BETWEEN μ AND i_C

The angle of incidence in the optically denser medium for which the angle of refraction is 90°. It is denoted by i_c.

$$\mu = \frac{1}{\sin i_c}$$

- If $i < i_c$, then refraction takes place.
- If $i = i_c$, then grazing emergence takes place.
- If $i > i_c$, then total internal reflection takes place.

REFLECTION BY SPHERICAL MIRRORS

Mirror formula, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} = \frac{2}{R}$

Magnification, $m = -\frac{v}{u} = \frac{h_i}{h_o}$

If the image is upright or erect with respect to the object then m is positive and m is negative if the image is inverted with respect to the object.

TOTAL INTERNAL REFLECTION

The phenomenon in which a ray of light travelling from an optically denser into an optically rarer medium at an angle of incidence greater than the critical angle for the two media is totally reflected back into the same medium.

TIR conditions

- Light must travel from denser to rarer.
- Angle of incidence is greater than critical angle.

REFRACTION OF LIGHT

Laws of refraction :

- The incident ray, the normal to the interface at the point of incidence and the refracted ray all lie in the same plane.
- Snell's law: $\frac{\sin i}{\sin r} = \text{constant} = {}^1\mu_2$

(${}^1\mu_2$ = refractive index of medium 2 w.r.t. 1)

APPLICATIONS OF TIR

- Fiber optics communication
- Medical endoscopy
- Periscope (Using prism)
- Sparkling of diamond
- Mirage
- Totally reflecting glass prisms

COMPOUND MICROSCOPE

Magnifying power, $m = m_o \times m_e$

For final image formed at D (least distance)

$$m = \frac{\beta}{\alpha} = \frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right) = \frac{L}{f_0}\left(1 + \frac{D}{f_e}\right)$$

For final image formed at infinity

$$m = \frac{L}{f_0} \cdot \frac{D}{f_e}$$

REFRACTIVE INDEX

$$\mu = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in medium}} = \frac{c}{v}$$

Real and apparent depth

$$\mu = \frac{\text{real depth } (x)}{\text{apparent depth } (y)}$$

REFLECTING TELESCOPE

Magnifying power

When the final image is formed at D,

$$m = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$$

When the final image is formed at infinity

$$m = \frac{f_0}{f_e} = \frac{R/2}{f_e}$$

Newtonian reflecting telescope

PRACTICE PAPER

BITSAT

Exam date: 24th to 30th June 2021

1. When the angle of projection is 75°, a ball falls 10 m shorter of the target. When the angle of projection is 45°, it falls 10 m ahead of the target. Both are projected from the same point with the same speed in the same direction, the distance of the target from the point of projection is
   (a) 15 m (b) 30 m (c) 45 m (d) 10 m

2. The expression for centripetal force (F) depends upon mass of body (m), speed of the body (v) and the radius of circular path (r). What will be the expression for centripetal force?
   (a) $F=\frac{mv^2}{2r^3}$ (b) $F=\frac{mv^2}{r}$
   (c) $F=\frac{mv^2}{r^2}$ (d) $F=\frac{m^2v^2}{2r}$

3. A coil of 100 turns is pulled in 0.04 sec from between the poles of a magnet, where its area includes flux of 40×10^{-6} weber per turn to a place where it includes a flux of 10^{-5} weber per turn. The average e.m.f. induced in the coil is
   (a) 0.012 V (b) 0.035 V
   (c) 0.075 V (d) 0.121 V

4. A free pith ball of mass 6 g carries a positive charge of $(1/3)\times10^{-7}$ C. What is the magnitude of charge that should be given to a second pith ball fixed 5 cm vertically below the former pith ball so that the upper pith ball is stationary.
   (a) 1.41×10^{-4} C (b) 2.31×10^{-4} C
   (c) 3.21×10^{-4} C (d) 4.90×10^{-7} C

5. The ratio of de Broglie wavelength of a proton and an α particle accelerated through the same potential difference is
   (a) $3\sqrt{2}$ (b) $2\sqrt{2}$ (c) $2\sqrt{3}$ (d) $2\sqrt{5}$

6. A ray of light is incident on a glass sphere of refractive index 3/2. What should be an angle of incident so that the ray which enters the sphere does not come out of the sphere?
   (a) $\tan^{-1}(2/3)$ (b) 60°
   (c) 90° (d) 30°

7. The magnetic flux through a coil perpendicular to its plane and directed into paper is varying according to the relation $\phi = (5t^2 + 10t + 5)$ milliweber. Calculate the e.m.f. induced in the loop at $t = 5$ s.
   (a) 0.06 V (b) 1.2 V
   (c) 1.45 V (d) 0.09 V

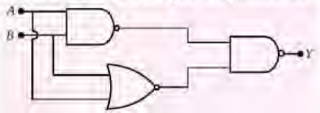
8. Velocity of light in a liquid is 1.5×10^8 m s^{-1} and in air, it is 3×10^8 m s^{-1}. If a ray of light passes from liquid into the air, The value of critical angle is
   (a) 30° (b) 45°
   (c) 60° (d) 90°

9. How much below the surface does the acceleration due to gravity become 70 % of its value on the surface of earth. Radius of earth = 6.4×10^6 m.
   (a) 1.82×10^6 m (b) 1.92×10^6 m
   (c) 1.82×10^8 m (d) 1.92×10^8 m

10. Calculate the escape speed for an atmospheric particle 1600 km above the earth's surface, given that the radius of the earth is 6400 km and acceleration due to gravity on the surface of earth is 9.8 m s^{-2}.
    (a) 9.1 m s^{-1} (b) 9.2×10^3 m s^{-1}
    (c) 10.02×10^3 m s^{-1} (d) 7.9 m s^{-1}

11. A compound microscope has an eye piece of focal length 10 cm and an objective of focal length 4 cm. Calculate the magnification, if an object is kept at a distance of 5 cm from the objective, so that the final image is formed at the least distance of distinct vision 20 cm.
    (a) 12 (b) 11
    (c) 10 (d) 13

12. The circuit as shown in figure is equivalent to



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

13. Suppose an electron is attracted towards the origin by a force k/r, where k is a constant and r is the distance of the electron from the origin. By applying Bohr model to this system, the radius of n^{th} orbit of the electron is found to be r_n and the kinetic energy of the electron is found to be T_n. Then which of the following is true?

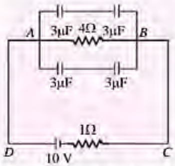
(a) $T_n \propto \frac{1}{n^2}$

(b) T_n is independent of n; $r_n \propto n$

(c) $T_n \propto \frac{1}{n}$; $r_n \propto n$

(d) $T_n \propto \frac{1}{n}$ and $r_n \propto n^2$

14. In the circuit shown each capacitor has a capacity of 3μF. The quantity of charge on each capacitor is



(a) 12 μC
(b) 8 μC
(c) 6 μC
(d) 10 μC

15. A copper wire is stretched to make it 0.2% longer. What is the percentage change in its resistance?
(a) 1.2 % (b) 0.4 % (c) 3.2 % (d) 0.9 %

16. Two wires A and B are of the same material. Their lengths are in the ratio 1 : 2 and the diameters are in the ratio 2 : 1. If they are pulled by the same force, increase in their lengths will be in the ratio
(a) 2 : 1 (b) 1 : 4 (c) 1 : 8 (d) 8 : 1

17. A body is thrown horizontally from the top of a tower of 5 m height. It touches the ground at a distance of 10 m from the foot of the tower. The initial velocity of the body is (Take g = 10 m s^{-2})
(a) 2.5 m s^{-1} (b) 5 m s^{-1}
(c) 10 m s^{-1} (d) 20 m s^{-1}

18. A uniform chain of mass m and length l is lying on a table with $\frac{l}{4}$ of its length hanging freely from the edge of the table. The amount of work done in dragging the chain on the table completely is

(a) $\frac{mgl}{4}$ (b) $\frac{mgl}{8}$ (c) $\frac{mgl}{32}$ (d) $\frac{mgl}{16}$

19. An object floats in water with 10% of its volume outside and in oil 30% of its volume outside. The specific gravity of the oil is
(a) 1.3 (b) 0.33 (c) 2 (d) 7

20. When two resistance wires are in the two gaps of a meter bridge, the balance point was found to be 1/3 m from the zero end. When a 6 Ω coil is connected in series with the smaller of the two resistances, the balance point is shifted to 2/3 m from the same end. The resistance of the two wires.
(a) 6 Ω, 8 Ω (b) 4 Ω, 6 Ω
(c) 6 Ω, 10 Ω (d) 2 Ω, 4 Ω

21. A proton, a deutron and α-particle, whose kinetic energies are same, enter perpendicularly a uniform magnetic field. The ratio of radii of their circular paths is
(a) $1:\sqrt{2}:1$ (b) 2 : 1 : 1
(c) $\sqrt{2}:2:1$ (d) $\sqrt{2}:\sqrt{3}:1$

22. A magnet suspended at 30° with magnetic meridian makes an angle of 45° with the horizontal. What shall be the actual value of the angle of dip?
(a) 40.9° (b) 60.1° (c) 50.6° (d) 45.2°

23. In a hydrogen atom, the electron moves in an orbit of radius 0.5 Å, making 10^{16} rps. The magnetic moment associated with the orbital motion of electron is
(a) 2.121×10^{-21} A m^2 (b) 1.214×10^{-18} A m^2
(c) 2.14×10^{-18} A m^2 (d) 1.256×10^{-23} A m^2

24. A gas expands with temperature according to the relation $V = KT^{2/3}$. Then the work done when the temperature changes by 60 K will be
(a) 10R (b) 30R (c) 40R (d) 20R

25. A thin uniform rod of mass m moves translationally with acceleration a due to two antiparallel forces of lever arm l. One force is of magnitude F and acts at one extreme end. The length of the rod is

(a) $\frac{mal}{ma+F}$ (b) $\frac{2(F+ma)l}{ma}$

(c) $l\left(1+\frac{F}{ma}\right)$ (d) $\frac{(F+ma)l}{2ma}$

26. A body of mass m strikes another body at rest of mass $\frac{m}{9}$. Assuming the impact to be inelastic, the fraction of the initial kinetic energy transformed into heat during the contact is
(a) 0.1 (b) 0.2 (c) 0.5 (d) 0.64

27. A ball rolls of the top of a stair way with a horizontal velocity u m s^{-1}. If the steps are h metre high and b metre wide, the time taken by the ball to hit the edge of n^{th} step, is
(a) $\frac{hu}{gb}$ (b) $\frac{2hu}{gb}$ (c) $\frac{2hu^2}{gb}$ (d) $\frac{hu^2}{2gb}$

28. An electron of energy 2000 eV describes a circular path in magnetic field of flux density 0.2 T. What is the radius of the path? Take $e = 1.6 \times 10^{-19}$ C, $m = 9 \times 10^{-31}$ kg.
(a) 7.5×10^{-4} m (b) 5.4×10^{3} m
(c) 6.4×10^{2} m (d) 3.1×10^{4} m

29. Find the maximum value of current when inductance of two henry is connected to 150 volt, 50 cycle supply.
(a) 0.912 A (b) 0.423 A
(c) 0.337 A (d) 0.121 A

30. An e.m.f. of 250 microvolt is induced in a coil when current in it changes from 10 ampere to 6 ampere in 0.4 sec. The self inductance of the coil is
(a) 17×10^{-4} H (b) 25×10^{-6} H
(c) 21×10^{-3} H (d) 13×10^{-2} H

31. Which of the following electromagnetic waves will cause heating?
1. Radio waves
2. Infrared radiation
3. X-rays
(a) 2 only (b) 1 and 2 only
(c) 2 and 3 only (d) 1, 2 and 3

32. The intensity at a point where the path difference is $\frac{\lambda}{6}$ (λ = wavelength of light) is I. If I_0 is the maximum intensity, then I/I_0 is equal to
(a) $\sqrt{3}/2$ (b) 1/2 (c) 3/4 (d) $1/\sqrt{2}$

33. A football is kicked 20 m s^{-1} at a projection angle of 45°. A receiver on the goal line 25 metres away in the direction of the kick runs the same instant to meet the ball. What must be his speed, if he is to catch the ball before it hits the ground?
(a) 5.483 m s^{-1} (b) 2.121 m s^{-1}
(c) 4.213 m s^{-1} (d) 7.412 m s^{-1}

34. The power and type of lens by which a person can see clearly the distant objects, if the person cannot see objects beyond 40 cm, are
(a) −2.5 D and concave lens
(b) −2.5 D and convex lens
(c) −3.5 D and concave lens
(d) −3.5 D and convex lens.

35. Three identical spherical balls A, B and C are placed on a table as shown in the figure along a straight line.

B and C are at rest initially. The ball A hits B head on with a speed of 10 m s^{-1}. Then after all collisions (assumed to be elastic) A and B come to rest and C takes off with a velocity of
(a) 5 m s^{-1} (b) 10 m s^{-1}
(c) 2.5 m s^{-1} (d) 7.5 m s^{-1}

36. At room temperature, the rms speed of the molecules of a certain diatomic gas is found to be 1930 m s^{-1}. The gas is
(a) H_2 (b) F_2 (c) O_2 (d) Cl_2.

37. A man weighing 60 kg runs along the rails with a velocity of 18 km h^{-1} and jumps into a car of mass 1 quintal standing on the rails. The velocity with which the car will start travelling along the rails is.
(a) 2.12 m s^{-1} (b) 3.14 m s^{-1}
(c) 1.88 m s^{-1} (d) 1.27 m s^{-1}

38. A closed organ pipe and an open organ pipe of same length produce 2 beats s^{-1} while vibrating in their fundamental modes. The length of the open organ pipe is halved and that of closed pipe is doubled. Then, the number of beats produced per second while vibrating in the fundamental mode is
(a) 2 (b) 6 (c) 8 (d) 7

39. A screen in placed 2 m away from the single narow slit. Calculate the slit width if the first minimum lies 5 mm on either side of the central maximum. Incident plane waves have a wavelength of 5000 Å.
(a) 2×10^{-4} m (b) 10^{-5} m
(c) 1×10^{4} m (d) 10^{6} m

40. A new unit of length is so chosen that the speed of light in vacuum is unity. Calculate the distance (in this new unit) between sun and the earth if light takes 8 min and 20 seconds to reach earth from sun.
(a) 300 (b) 400 (c) 500 (d) 600

SOLUTIONS

1. (b) : If range of target is R then,

$$\frac{u^2\sin(2\times75)^\circ}{g}=R-10 \quad ...(i)$$

and $\frac{u^2\sin(2\times45)^\circ}{g}=R+10$ or $\frac{u^2}{g}=R+10$

Putting in eqn. (i), $(R + 10)\sin 150^\circ = R - 10$

or $(R+10)\frac{1}{2}=R-10$ or $R = 30$ m

2. (b) : According to question,

$F \propto m^a v^b r^c$

or $F = km^a v^b r^c$

k, being a dimensionless constant.

From homogeneity of dimensions,

$[MLT^{-2}] = [M]^a [LT^{-1}]^b [L]^c$

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

Comparing the powers, we obtain

$a = 1$

$b + c = 1$

$-b = -2 \Rightarrow b = 2$

$\therefore\ 2 + c = 1 \Rightarrow c = -1$

Therefore, $F = kmv^2r^{-1}=\frac{kmv^2}{r}$

The experimental value of k is found to be 1 here.

$\therefore\ F=\frac{mv^2}{r}$

3. (c) : Here, $N = 100$, $t = 0.04$ sec. e = ?

$\phi_1 = 100 \times 40 \times 10^{-6}$ Wb $= 4 \times 10^{-3}$ Wb

$\phi_2 = 100 \times 10^{-5}$ Wb $= 10^{-3}$ Wb

As $e=\frac{-[\phi_2-\phi_1]}{t}$

$\therefore\ e=-\frac{[10^{-3}-4\times10^{-3}]}{0.04}=\frac{3\times10^{-3}}{0.04}=0.075$ V

4. (d) : The upper pith ball will becomes stationary only when its weight acting downwards is balanced by the upward force of repulsion between the two pith balls. Let $+q_2$ be the charge given to lower pith ball.

Now, $q_1=\frac{1}{3}\times10^{-7}$ C, $r = 5$ cm $= 5\times10^{-2}$ m

$m = 6$ g $= 6 \times 10^{-3}$ kg

When upper pith ball is stationary, $F = mg$

$\therefore\ \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}=mg$

$$\frac{9\times10^9\times\frac{1}{3}\times10^{-7}q_2}{(5\times10^{-2})^2}=6\times10^{-3}\times9.8$$

$$\frac{3\times10^2}{25\times10^{-4}}q_2=58.8\times10^{-3}$$

$$q_2=\frac{58.8\times25}{3}\times10^{-9}=4.90\times10^{-7}\text{ C.}$$

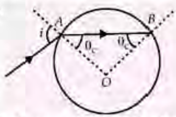
5. (b) : de Broglie wavelength associated with charged particle is given by,

or $\lambda=\frac{h}{\sqrt{2mqV}}, \frac{\lambda_p}{\lambda_\alpha}=\sqrt{\frac{2m_\alpha q_\alpha V}{2m_p q_p V}}$

where subscripts, p and α represent for proton and α particle respectively.

As $\frac{m_p}{m_\alpha}=\frac{1}{4}$ and $\frac{q_\alpha}{q_p}=\frac{2}{1}$ $\Rightarrow \frac{\lambda_p}{\lambda_\alpha}=\sqrt{4\times2}=2\sqrt{2}$

6. (c) :



From figure, $\angle ABO = \angle OAB = \theta_c$

$$\sin\theta_c=\frac{1}{\mu}=\frac{2}{3} \quad ...(i)$$

Applying Snell's law at A

$\frac{\sin i}{\sin\theta_c}=\frac{3}{2}$; $\sin i=\left(\frac{3}{2}\right)\left(\frac{2}{3}\right)=1$ (Using (i))

$\Rightarrow \sin i = \sin 90^\circ \Rightarrow i = 90^\circ$

7. (a) : Here, $\phi = (5t^2 + 10t + 5)$ milliweber

$\phi = (5t^2 + 10t + 5) \times 10^{-3}$ Wb

As $e=\frac{d\phi}{dt}$ (in magnitude)

$\therefore\ e=\frac{d}{dt}(5t^2+10t+5)\times10^{-3}$ Wb s^{-1}

$= (10t + 10) \times 10^{-3}$ volt

At $t = 5$ s

$e = (10 \times 5 + 10) \times 10^{-3}$ volt $= 0.06$ volt.

8. (a) : Here, $v = 1.5 \times 10^8$ m s^{-1}

$c = 3 \times 10^8$ m s^{-1}, C = ?

As $\mu=\frac{c}{v}=\frac{1}{\sin C}$

$\therefore\ \sin C=\frac{v}{c}=\frac{1.5\times10^8}{3\times10^8}=0.5$

$C = \sin^{-1}(0.5) = 30^\circ$

9. **(b)**: Here $g'/g = 70/100 = 7/10$
and $d = ?$
Now $g' = g(1 - d/R)$;

$$\therefore \frac{g'}{g} = 1 - \frac{d}{R} \text{ or } \frac{7}{10} = 1 - \frac{d}{R} \text{ or } \frac{d}{R} = 1 - \frac{7}{10} = \frac{3}{10}$$

$$\text{or } d = \frac{3R}{10} = \frac{3 \times 6.4 \times 10^6}{10} = 1.92 \times 10^6 \text{ m}$$

10. **(c)**: Here, $h = 1600$ km;
$R = 6400 \text{ km} = 6.4 \times 10^6$ m;
$\therefore \quad r = R + h = 6400 + 1600$
$= 8000 \text{ km} = 8.0 \times 10^6$ m.

$$\text{Now, } v_e = \sqrt{2g'r} = \sqrt{2\left(\frac{gR^2}{r^2}\right)r} \quad \left(\because g' = g\frac{R^2}{r^2}\right)$$

$$= \sqrt{\frac{2gR^2}{r}} = \sqrt{\frac{2 \times 9.8 \times (6.4 \times 10^6)^2}{8 \times 10^6}}$$

$= 10.02 \times 10^3$ m s^{-1}

11. **(a)**: Here, $u_o = -5$ cm, $f_o = 4$ cm,
$f_e = 10$ cm, $D = 20$ cm
According to lens formula

$$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o} \text{ or } \frac{1}{v_o} = \frac{1}{f_o} + \frac{1}{u_o}$$

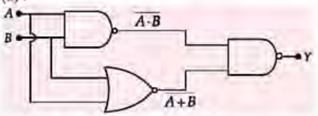
Substituting the given values, we get

$$\frac{1}{v_o} = \frac{1}{4} + \frac{1}{-5} = \frac{1}{4} - \frac{1}{5} = \frac{1}{20}$$

$v_o = 20$ cm

$$\text{Magnification, } M = \frac{v_o}{|u_o|}\left(1 + \frac{D}{f_e}\right) = \frac{20}{5}\left(1 + \frac{20}{10}\right) = 12$$

12. **(a)**:



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

$= A \cdot B + A + B = A(B + 1) + B$
$Y = A + B$
It is the Boolean expression of the OR gate.

13. **(b)**: Applying Bohr model to the given system,

$$\frac{mv^2}{r_n} = \frac{k}{r_n} \quad \text{...(i)}$$

$$\text{and } mvr_n = \frac{nh}{2\pi} \text{ or } v = \frac{nh}{2\pi m r_n}$$

Put the values in equations (i), we get

$$\frac{m}{r_n} \times \frac{n^2h^2}{4\pi^2 m^2 r_n^2} = \frac{k}{r_n}$$

$$r_n^2 = \frac{n^2h^2}{4\pi^2 mk} \quad \text{...(ii)}$$

$\therefore \quad r_n^2 \propto n^2$ or $r_n \propto n$

K.E. of the electron, $T_n = \frac{1}{2}mv^2$

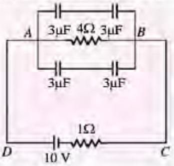
$$= \frac{1}{2}m\frac{n^2h^2}{4\pi^2 m^2 r_n^2} = \frac{n^2h^2}{8\pi^2 m r_n^2}$$

Using (ii), we get

$$T_n = \frac{n^2h^2 4\pi^2 mk}{8\pi^2 m n^2 h^2} = \frac{k}{2}$$

$\therefore \quad T_n$ is independent of n.

14. **(a)**: Total resistance in the circuit $ABCD$,



$R = 4 + 1 = 5\Omega$

$$\therefore \quad \text{Current } I = \frac{V}{R} = \frac{10}{5} = 2\text{A}$$

Potential diff. across A and $B = I \times 4 = 2 \times 4 = 8$ V
As two capacitors of 3 μF each are in series,

$$\therefore \quad \text{pot. diff. across each condenser} = \frac{8}{2} = 4 \text{ V}$$

Charge on each condenser, $q = CV = 3 \times 4 = 12$ μC

15. **(b)**: The mass m of the wire of length l, area of cross section A and density d is given by

$$m = Ald \text{ or } A = \frac{m}{ld}$$

The resistance R of the wire of resistivity ρ is given by

$$R = \frac{\rho l}{A} = \frac{\rho l^2 d}{m} = kl^2$$

where $k = \rho\, d/m$ is a constant of the wire.

$$\therefore \quad \frac{dR}{R} = \frac{2dl}{l};$$

% increase in resistance

$$= \frac{dR}{R} \times 100 = \frac{2 \times 0.2}{100} \times 100 = 0.4\%$$

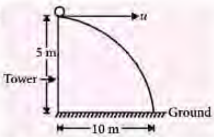
16. **(c)**: $Y = \frac{F}{\pi r^2} \times \frac{L}{\Delta L}$

Since Y and F are same for both the wires, we have

$$\frac{L_1}{r_1^2\Delta L_1}=\frac{L_2}{r_2^2\Delta L_2} \text{ or } \frac{\Delta L_1}{\Delta L_2}=\frac{r_2^2L_1}{r_1^2L_2}=\frac{(D_2/2)^2L_1}{(D_1/2)^2L_2}$$

or $$\frac{\Delta L_1}{\Delta L_2}=\frac{D_2^2L_1}{D_1^2L_2}=\frac{D_2^2}{(2D_2)^2}\times\frac{L_1}{2L_1}=\frac{1}{8}$$

17. **(c) :**



Let t be time taken by the body to reach the ground.

$\therefore \quad H=\frac{1}{2}gt^2$ or $t=\sqrt{\frac{2H}{g}}=\sqrt{\frac{2\times5}{10}}=1$ s

$R = ut$ or $10 = u\times 1$ or $u = 10$ m s^{-1}

18. **(c) :** Mass of $\left(\frac{l}{4}\right)$ length of the chain = $\frac{m}{4}$

The weight of this part of the chain acts as its CG which is at a distance $\left(\frac{l}{8}\right)$ from the edge of the table.

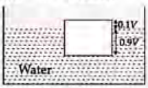
Work done = $\left(\frac{m}{4}\right)g\left(\frac{l}{8}\right)=\frac{mgl}{32}$

19. **(a) :** Let V be the volume of an object. When the object is floating in the liquid, then

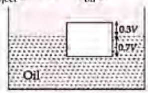
Weight of the object = Weight of the liquid displaced

In water, $V\rho_{\text{object}}\,g = V_{\text{inside}}\,\rho_{\text{liquid}}\,g$

$$V\rho_{\text{object}}\,g = 0.9V\rho_{\text{water}}\,g \quad \text{...(i)}$$



In oil, $V\rho_{\text{object}}\,g = 0.7V\rho_{\text{oil}}\,g$ ...(ii)



Divide (i) by (ii), we get

$$1=\frac{0.9\,\rho_{\text{water}}}{0.7\rho_{\text{oil}}} \text{ or } \frac{\rho_{\text{oil}}}{\rho_{\text{water}}}=\frac{0.9}{0.7}=\frac{9}{7}$$

Specific gravity of the oil = $\frac{\rho_{\text{oil}}}{\rho_{\text{water}}}=\frac{9}{7}=1.3$

20. **(d):** Refer to meter bridge circuit, let the resistance of wire in left gap be R_1 and resistance of wire in right gap be R_2.

Then, $R = R_1$; $S = R_2$, $l=\frac{1}{3}$ m

and $(100 - l) = 1 - \frac{1}{3}=\frac{2}{3}$ m.

$\therefore \quad \frac{R_1}{R_2}=\frac{l}{(100-l)}=\frac{1/3}{2/3}=\frac{1}{2}$;

or $\quad R_2 = 2R_1$.

So, $\quad R_1 < R_2$

As 6 Ω coil is connected in series with the smaller resistance R_1, so resistance of the left gap becomes, $R'_1 = R_1 + 6$. Resistance of right gap is R_2.

Now, $l'=\frac{2}{3}$ m and $(100-l')=1-\frac{2}{3}=\frac{1}{3}$ m.

$\therefore \quad \frac{R'_1}{R_2}=\frac{l'}{(100-l')}$; or $\frac{R_1+6}{R_2}=\frac{2/3}{1/3}=2$

or $\quad R_1 + 6 = 2R_2 = 2\times 2R_1 = 4R_1$ or $R_1 = 2\,\Omega$.

and $R_2 = 2R_1 = 2\times 2 = 4\,\Omega$

21. **(a) :** Here, mass of proton, $m_p = m$; mass of deutron, $m_d = 2m$ and mass of α-particle $m_\alpha = 4m$; charge on proton, $q_p = e$; charge on deutron, $q_d = e$ and charge on α-particle, $q_\alpha = 2e$.

K.E. of charged particle, $E=\frac{1}{2}mv^2$ or $v=\sqrt{2E/m}$

Radius of the circular path of a charged particle in the magnetic field is given by

$$r=\frac{mv}{Bq}=\frac{m}{Bq}\sqrt{\frac{2E}{m}}=\sqrt{\frac{2mE}{Bq}}; \text{so } r\propto\frac{\sqrt{m}}{q}$$

$$\therefore r_p : r_d : r_\alpha = \frac{\sqrt{m_p}}{q_p}:\frac{\sqrt{m_d}}{q_d}:\frac{\sqrt{m_\alpha}}{q_\alpha}$$

$$=\frac{\sqrt{m}}{e}:\frac{\sqrt{2m}}{e}:\frac{\sqrt{4m}}{2e}=1:\sqrt{2}:1$$

22. **(a) :** Here, θ = 30°

Apparent value of dip, $\delta_1 = 45°$

Actual value of dip, δ = ?

If H is horizontal component of earth's magnetic field in magnetic meridian, then

$$\tan\delta=\frac{V}{H}$$

Let H_1 be component of H at 30° to magnetic meridian, then

$$\tan\delta_1 = \frac{V}{H_1} = \frac{V}{H\cos\theta} = \frac{\tan\delta}{\cos\theta}$$

or $\tan\delta = \tan\delta_1 \times \cos\theta = \tan 45° \times \cos 30°$

$$= 1\times\frac{\sqrt{3}}{2} = \frac{1.732}{2} = 0.866$$

$\therefore$ $\delta = \tan^{-1}(0.866) = 40.9°$

23. (d): Here, $r = 0.5\,\text{Å} = 0.5\times10^{-10}\,\text{m}; \upsilon = 10^{16}\,\text{rps}, M = ?$

Charge on electron, $e = 1.6\times10^{-19}$ C

Equivalent current, $I = \frac{e}{T} = e\upsilon$

Area of the orbit, $A = \pi r^2$

As $M = IA$

$\therefore M = e\upsilon(\pi r^2) = 1.6\times10^{-19}\times10^{16}\times3.14\times(0.5\times10^{-10})^2$

$= 1.256\times10^{-23}\,\text{A m}^2$

24. (c) : $dW = PdV = \frac{RT}{V}dV$ ...(i)

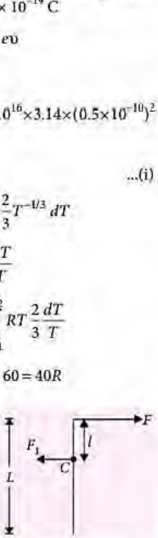
As $V = KT^{2/3}$ $\therefore$ $dV = K\frac{2}{3}T^{-1/3}\,dT$

$$\therefore \frac{dV}{V} = \frac{K\frac{2}{3}T^{-1/3}dT}{KT^{2/3}} = \frac{2}{3}\frac{dT}{T}$$

From (i), $W = \int_{T_1}^{T_2} RT\frac{dV}{V} = \int_{T_1}^{T_2} RT\frac{2}{3}\frac{dT}{T}$

$$\therefore W = \frac{2}{3}R(T_2 - T_1) = \frac{2}{3}R\times60 = 40R$$

25. (b): Let L be the length of the rod of mass m, with centre of mass at C. Suppose F_1 is the magnitude of other force. Let $F_1 > F$.



$\therefore$ $F_1 - F = ma$

or $F_1 = F + ma$

As the rod moves translationally and there is no rotation, therefore, net torque about C must be zero.

$$\therefore \quad F\left(\frac{L}{2}\right) = F_1\left(\frac{L}{2} - l\right) = (F + ma)\left(\frac{L}{2} - l\right)$$

$$F\left(\frac{L}{2}\right) = F\left(\frac{L}{2}\right) - Fl + ma\frac{L}{2} - mal$$

$$ma\frac{L}{2} = l(F + ma) \therefore L = \frac{2(F + ma)l}{ma}$$

26. (a) : Applying the law of conservation of linear momentum, we get

$$m\times u + \frac{m}{9}\times0 = \left(m + \frac{m}{9}\right)v$$

$$v = \frac{u}{\left(\frac{10}{9}\right)} = \frac{9}{10}u$$

Initial kinetic energy,

$$K_i = \frac{1}{2}mu^2$$

Final kinetic energy,

$$K_f = \frac{1}{2}\left(m + \frac{m}{9}\right)v^2$$

$$= \frac{1}{2}\left(\frac{10}{9}m\right)\left(\frac{9u}{10}\right)^2 = \frac{1}{2}\left(\frac{9}{10}\right)mu^2$$

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

$$\Delta K = \frac{1}{2}mu^2 - \frac{1}{2}\left(\frac{9}{10}mu^2\right) = \frac{1}{2}\left(\frac{1}{10}\right)mu^2$$

Fraction of initial kinetic energy transformed into heat is

$$\frac{\text{Loss in kinetic energy}}{\text{Initial kinetic energy}} = \frac{\Delta K}{K_i} = \frac{\frac{1}{2}\left(\frac{1}{10}\right)mu^2}{\frac{1}{2}mu^2} = 0.1$$

27. (b): The ball reaches n^{th} step in time t, then $bn = ut$ or $t = bn/u$,

Also, $nh = \frac{1}{2}gt^2 = \frac{1}{2}g\times\frac{b^2n^2}{u^2}$, $\therefore n = \frac{2u^2h}{gb^2}$

Time taken to travel vertical distance nh is

$$t = \sqrt{\frac{2nh}{g}} = \sqrt{\frac{2h}{g}\times\frac{2u^2h}{gb^2}} = \frac{2uh}{gb}$$

28. (a) : Here, energy of electron,

$E' = 2000\,\text{eV} = 2000\times1.6\times10^{-19}\,\text{J} = 3.2\times10^{-16}\,\text{J}$.

$B = 0.2\,\text{T}$; $r = ?$

As, $E' = \frac{1}{2}mv^2$ $\therefore v = \sqrt{\frac{2E'}{m}}$

Also, $Bev = \frac{mv^2}{r}$

or $r = \frac{mv}{Be} = \frac{m}{Be}\sqrt{\frac{2E'}{m}}$

$$= \frac{\sqrt{2\times3.2\times10^{-16}\times9\times10^{-31}}}{0.2\times1.6\times10^{-19}} = 7.5\times10^{-4}\,\text{m}$$

29. (c) : Here, inductance, $L = 2$ H

r.m.s. voltage, $E_v = 150$ V

Frequency of A.C. supply, $\upsilon = 50$ cycle s^{-1}.

$\therefore$ Inductive reactance, $X_L = \omega L = 2\pi\upsilon\ L$

$= 2\times\frac{22}{7}\times 50\times 2 = \frac{4400}{7}$ ohm

If E_0 is the peak value of the alternating voltage, then maximum value of current (I_0) is given by

$$I_0 = \frac{E_0}{X_L} \text{ or } I_0 = \frac{\sqrt{2}\times E_v}{X_L} = \frac{\sqrt{2}\times 150}{4400/7} = 0.337\text{A}$$

30. (b) : Here, $e = 250$ microvolt $= 250\times 10^{-6}$ V

$dI = 10 - 6 = 4$ A

$dt = 0.4$ s, $L = ?$

As $e = L\frac{dI}{dt}$

$\therefore L = \frac{e(dt)}{dI} = \frac{250\times 10^{-6}\times 0.4}{4} = 25\times 10^{-6}$ henry

31. (a)

32. (c)

33. (a) : Here, $u = 20$ m s^{-1} ; $\theta = 45°$, $d = 25$ m.

Horizontal range ; $R = \frac{u^2}{g}\sin 2\theta$

$= \frac{(20)^2}{9.8}\sin(2\times 45°) = 40.82$ m

Time of flight, $T = \frac{2u\sin\theta}{g} = \frac{(20)^2}{9.8}\times\sin 45° = 2.886$ s

Since the goal man is already 25 m away in the direction of the ball, so to catch the ball, he is to cover a distance = 40.82 – 25 = 15.82 m, in time 2.886 s. Therefore, the velocity of goal man to catch the ball is $v = \frac{15.82}{2.886} = 5.483$ m s^{-1}

34. (a) : Here, in this case lens used by person should form the image of distant object at a distance of 40 cm in front of it.

$\therefore$ $u = -\infty$, $v = -40$ cm

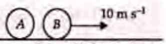
and $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ or $\frac{1}{f} = \frac{1}{-40} - \frac{1}{-\infty}$

or $\frac{1}{f} = \frac{1}{-40}$ or $f = -40$ cm

Power $= \frac{100}{f\text{ (cm)}} = \frac{100}{-40} = -2.5$ D

Negative sign shows that lens used is concave lens.

35. (b) : Since A, B and C are identical balls, if any of the two balls undergo elastic collision, they will exchange their velocities.



Thus, when A and B collide, A comes to rest, and B starts moving ahead with 10 m s^{-1}.

Similarly, when B collides with C, B comes to rest and C starts moving ahead with a speed of 10 m s^{-1}.

36. (a) : Mass of the gas molecule,

$m = \frac{3KT}{v^2} = \frac{3RT}{Nv^2}$

$= \frac{3\times 8.31\times 300}{6.023\times 10^{23}\times(1930)^2} = 3.3\times 10^{-27}$ kg

Mass of H_2 molecule $= 1.66\times 10^{-27}\times 2$

$= 3.32\times 10^{-27}$ kg

Thus the gas is hydrogen.

37. (c) : Here $m_1 = 60$ kg,

$v_1 = 18\text{ km h}^{-1} = \frac{18\times 1000}{60\times 60}\text{ m s}^{-1} = 5\text{ m s}^{-1}$

$m_2 = 1$ quintal = 100 kg,

$v_2 = 0$, $v = ?$

Applying the principle of conservation of linear momentum.

$(m_1 + m_2)v = m_1v_1 + m_2v_2 = m_1v_1$

$v = \frac{m_1v_1}{m_1 + m_2}$

$v = \frac{60\times 5}{60 + 100} = 1.88\text{ m s}^{-1}$

38. (d)

39. (a) : Here, distance of the screen from the slit, $D = 2$ m,

$a = ?$ $x = 5$ mm $= 5\times 10^{-3}$ m,

$\lambda = 5000$ Å $= 5000\times 10^{-10}$ m

For the first secondary minima,

$\sin\theta = \frac{\lambda}{a} = \frac{x}{D}$

$\therefore a = \frac{D\lambda}{x} = \frac{2\times 5000\times 10^{-10}}{5\times 10^{-3}} = 2\times 10^{-4}$ m.

40. (c) : Here,

Speed of light in vacuum, $c = 1$ new unit of length s^{-1}

Time taken by light of sun to reach the earth

$t = 8$ min and 20 seconds

$= (8\times 60 + 20)$ s $= 500$ s

$\therefore$ Distance between sun and the earth

$S = ct = 1$ new unit of length $s^{-1}\times 500$ s

= 500 new units of length

GEAR UP for JEE MAIN 2021

Exam Dates 2021
24^{th} to 28^{th} May

Section A will be of Multiple Choice Questions (MCQs). Section B will contain questions whose answers are to be filled in as a Numerical Value. In Section B candidates have to attempt any five questions out of 10.

SECTION A (MULTIPLE CHOICE QUESTIONS)

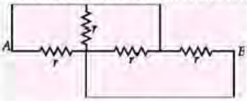
1. A bob is attached to a long, light string. The string is deflected by 30° initially with respect to vertical. The length of the string is 1 m. The value of θ at any time t after the bob has been released is (Use $g = \pi^2$)
   (a) $30°\cos\pi t$ (b) $30°\sin\pi t$
   (c) $30°\sin(\pi t + 30°)$ (d) none of these.

2. An ideal monoatomic gas initially at 300 K undergoes an isobaric expansion at a pressure of 2.5 kPa. If the volume increases from 1 m^3 to 3 m^3, then heat added to the gas and its final temperature respectively are
   (a) 12500 J, 450 K (b) 12500 J, 600 K
   (c) 12500 J, 900 K (d) 25000 J, 1200 K.

3. Two vectors $\vec{A}$ and $\vec{B}$ have equal magnitudes. If magnitude of $\vec{A}+\vec{B}$ is equal to n times the magnitude of $\vec{A}-\vec{B}$, then the angle between $\vec{A}$ and $\vec{B}$ is
   (a) $\cos^{-1}\left(\frac{n-1}{n+1}\right)$ (b) $\cos^{-1}\left(\frac{n^2-1}{n^2+1}\right)$
   (c) $\sin^{-1}\left(\frac{n-1}{n+1}\right)$ (d) $\sin^{-1}\left(\frac{n^2-1}{n^2+1}\right)$

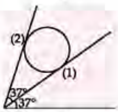
4. Two identical thin rings, each of radius 10 cm carrying charges 10 C and 5 C are coaxially placed at a distance 10 cm apart. The work done in moving a charge q from the centre of the first ring to that of the second is
   (a) $\frac{q}{8\pi\varepsilon_0}\left(\frac{\sqrt{2}+1}{\sqrt{2}}\right)$ (b) $\frac{q}{8\pi\varepsilon_0}\left(\frac{\sqrt{2}-1}{\sqrt{2}}\right)$
   (c) $\frac{q}{4\pi\varepsilon_0}\left(\frac{\sqrt{2}+1}{\sqrt{2}}\right)$ (d) $\frac{q}{4\pi\varepsilon_0}\left(\frac{\sqrt{2}-1}{\sqrt{2}}\right)$

5. The effective resistance between A and B is



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

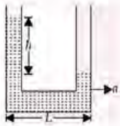
6. A sphere of mass m is held between two smooth inclined walls. For $\sin 37° = 3/5$, the normal reaction of the wall (2) is equal to



   (a) $\frac{16}{25}mg$ (b) $\frac{25}{21}mg$ (c) $\frac{25}{39}mg$ (d) $\frac{40}{13}mg$

7. A capacitor of capacitance 1 μF is charged to a potential of 1 V. It is connected in parallel to an inductor of inductance 10^{-3} H. The maximum current that will flow in the circuit has the value
   (a) $\sqrt{1000}$ mA (b) 1 mA
   (c) 1 μA (d) 1000 mA

8. When at rest, a liquid stands at the same level in the tubes shown in figure. But as indicated, a height difference h occurs when the system is given an acceleration a towards the right. Here h is equal to



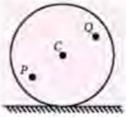
   (a) $\frac{aL}{2g}$ (b) $\frac{gL}{2a}$ (c) $\frac{gL}{a}$ (d) $\frac{aL}{g}$

9. An ideal gas is taken through a cyclic thermodynamical process through four steps. The amounts of heat involved in these steps are: Q_1 = 5960 J, Q_2 = –5585 J, Q_3 = –2980 J, Q_4 = 3645 J;

respectively. The corresponding works involved are: $W_1 = 2200$ J, $W_2 = -825$ J, $W_3 = -1100$ J and W_4 respectively. The value of W_4 is

(a) 1315 J (b) 275 J (c) 765 J (d) 675 J

10. A disc is rolling (without slipping) on a horizontal surface. C is its center and Q and P are two points equidistant from C. Let V_P, V_Q and V_C be the magnitude of velocities of points P, Q and C respectively, then



(a) $V_Q > V_C > V_P$ (b) $V_Q < V_C < V_P$
(c) $V_Q = V_P, V_C = V_P$ (d) $V_Q < V_C > V_P$

11. Which of the following statements is false for the properties of electromagnetic waves?
    (a) Both electric and magnetic field vectors attain the maxima and minima at the same place and same time.
    (b) The energy in electromagnetic wave is divided equally between electric and magnetic vectors.
    (c) Both electric and magnetic field vectors are parallel to each other and perpendicular to the direction of propagation of wave.
    (d) These waves do not require any material medium for propagation.

12. Four identical mirrors are made to stand vertically to form a square arrangement as shown in a top view. A ray starts from the midpoint M of mirror AD and after two reflections reaches corner D. Then, angle θ must be

(a) $\tan^{-1}(0.75)$ (b) $\cot^{-1}(0.75)$
(c) $\sin^{-1}(0.75)$ (d) $\cos^{-1}(0.75)$

13. A parallel plate capacitor is charged to a potential difference of 50 volts. It is then dicharged through a resistance for 2 seconds and its potential drops by 10 volts. Calculate the fraction of energy stored in the capacitance.

(a) 0.14 (b) 0.25 (c) 0.50 (d) 0.64

14. A charged particle of mass 10^{-3} kg and charge 10^{-5} C enters a magnetic field of induction 1 T. If $g = 10$ m s^{-2}, for what value of velocity will it pass straight through the field without deflection?

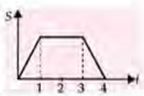
(a) 10^{-3} m s^{-1} (b) 10^3 m s^{-1}
(c) 10^6 m s^{-1} (b) 1 m s^{-1}

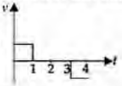
15. A uniform magnetic field of induction B is confined to a cylindrical region of radius R. The magnetic field is increasing at a constant rate of $\frac{dB}{dt}$.

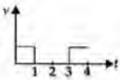
An electron of charge q, placed at the point P on the periphery of the field experiences an acceleration

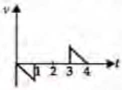
(a) $\frac{1}{2}\frac{eR}{m}\frac{dB}{dt}$ towards left
(b) $\frac{1}{2}\frac{eR}{m}\frac{dB}{dt}$ toward right
(c) $\frac{eR}{m}\frac{dB}{dt}$ toward left
(d) 0

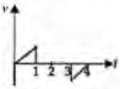
16. The displacement-time graph of a body moving along a straight line is as shown in figure. Which of the following graphs represents the velocity-time graph for the motion of that body?



(a)


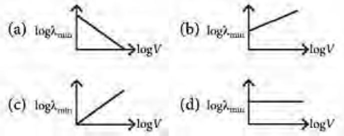
(b)


(c)


(d)


17. **Statement 1 :** Not gate is also called invertor circuit.
Statement 2 : NOT gate inverts the input order.
    (a) Statement-1 is true, Statement-2 is false
    (b) Statement-1 is false, Statement-2 is true
    (c) Statement-1 is true, Statement-2 is true and Statement-2 is a correct explanation for Statement-1.
    (d) Statement-1 is true, Statement-2 is true but Statement-2 is not a correct explanation for Statement-1.

18. An electron beam is accelerated by a potential difference V to hit a metallic target to produce X-rays. It produces continuous as well as characteristic X-rays. If λ_{min} is the smallest possible wavelength of X-ray in the spectrum, the variation of $\log\lambda_{min}$ with $\log V$ is correctly represented in



19. A mark is made on the bottom of a vessel and over this mark, a glass slab of thickness 3.5 cm and refractive index 7/4 is placed. Now water (refractive index, 4/3) is poured into the vessel so that the surface of water is 8 cm above the upper surface of the slab. Looking down normally through the water, the apparent depth of the mark below the surface of water will be
(a) 6.33 cm (b) 7.5 cm
(c) 8 cm (d) 10 cm

20. **Statement 1 :** Nuclear energy is due to difference in sum of masses of component nucleons and the nucleus.
Statement 2 : Mass of nucleus is more than the sum of masses of component nucleons.
(a) Statement-1 is true, Statement-2 is false
(b) Statement-1 is false, Statement-2 is true
(c) Statement-1 is true, Statement-2 is true and Statement-2 is a correct explanation for Statement-1.
(d) Statement-1 is true, Statement-2 is true but Statement-2 is not a correct explanation for Statement-1.

SECTION B (NUMERICAL VALUE TYPE)

21. Electric potential in a particular region of space is $V = 12x - 3x^2y + 2yz^2$. The magnitude of electric field at point $P(1\text{ m}, 0, 0)$ is ______ NC^{-1}.

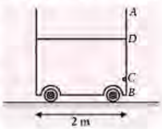
22. A parallel air film is formed between two glass plates. If the film thickness is 0.45×10^{-6} m, the film will be best reflector for visible light in the neighbourhood of 6×10^x Å, where the value of x is ______.

23. The gravitational acceleration on the surface of a planet is $\frac{\sqrt{2}}{11}g$, where g is the acceleration due to gravity on the surface of earth. The average mass density of the planet is $\frac{2}{3}$ times that of the earth. If the escape speed on the surface of the earth is taken as 11 km s^{-1}, the escape speed from the surface of the planet is $\sqrt{x}\text{ km s}^{-1}$, where the value of x is ______.

24. Two bodies are executing SHM such that their amplitude is A and time period T, when one of the blocks is at extreme right and another block is at $+\frac{A}{2}$ moving toward left. The time after which both the blocks will have same position from equilibrium position is $5T/x$, where x is ______.

25. A double convex thin lens made of glass (refractive index $\mu = 1.5$) has both radii of curvature of magnitude 20 cm. Incident light rays parallel to the axis of the lens will converge at a distance $L =$ ______ cm.

26. A cubical container with side 2 m has a small hole with a cap at point C as shown in the figure. The water level is upto point D. (BC = 0.5 m and BD = 1.5 m). If container is given an acceleration of 8 m s^{-2} and the hole is opened simultaneously. The amount of water that will spill out of the container is 200 α L. The value of α is ______.



27. A lift of mass 2000 kg is supported by the steel ropes. If maximum upward acceleration of the lift be 1.2 m s^{-2} and the breaking stress for the ropes be 2.8×10^8 N m^{-2}. The minimum diameter of the rope (in cm) is ______.

28. The length and breadth of a metal sheet are 2.214 m and 2.002 m respectively. The area of this sheet (in m^2) upto four correct significant figures is ______.

29. On heating a glass block of 10,000 cm^3, from 25°C to 40°C, its volume increases by 4 cm^3. The coefficient of linear expansion of glass is $x \times 10^{-6}$ °C^{-1}, where the value of x is ______.

30. A transmitting antenna of height 20 m and the receiving antenna of height h are separated by a distance of 40 km for satisfactory communication in line of sight mode. Then the value of h (in m) is ______.
(Given radius of the earth is 6400 km)

SOLUTIONS

1. **(d)**: For large angle like this (30°), the bob's motion is oscillating and not simple harmonic. In option (a), (b), (c) the equations written are of simple harmonic motion. So the answer is (d).

2. **(c)**: $\Delta Q = nC_P(T_2 - T_1)$

$$= n\frac{\gamma R}{\gamma-1}(T_2 - T_1) = \frac{\gamma}{\gamma-1}(V_2 - V_1)P$$

$$= \frac{5/3}{(5/3)-1}\times 2.5\times10^3\times(3-1) = 12500 \text{ J}.$$

$V \propto T$

$1 \text{ m}^3 \propto 300 \text{ K} \quad \therefore \quad 3 \text{ m}^3 \propto 900 \text{ K}$

3. **(b)**: Let θ be angle between vectors $\vec{A}$ and $\vec{B}$.

$|\vec{A}+\vec{B}| = n|\vec{A}-\vec{B}|$ (Given)

Then, $|\vec{A}+\vec{B}|^2 = n^2|\vec{A}-\vec{B}|^2$

$A^2 + B^2 + 2AB\cos\theta = n^2[A^2 + B^2 - 2AB\cos\theta]$

$A^2 + A^2 + 2A^2\cos\theta = n^2[A^2 + A^2 - 2A^2\cos\theta]$

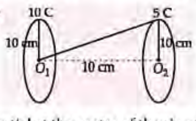
$[\because |\vec{A}| = |\vec{B}|]$

$2A^2 + 2A^2\cos\theta = n^2[2A^2 - 2A^2\cos\theta]$

$(n^2+1)\cos\theta = (n^2-1)$

$$\cos\theta = \left(\frac{n^2-1}{n^2+1}\right) \text{ or } \theta = \cos^{-1}\left(\frac{n^2-1}{n^2+1}\right)$$

4. **(b)**:



Potential at the centre of the ring 1 is

$$V_1 = \frac{1}{4\pi\varepsilon_0}\left[\frac{10}{10} + \frac{5}{\sqrt{(10)^2+(10)^2}}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{10}{10} + \frac{5}{10\sqrt{2}}\right]$$

Potential at the centre of the ring 2 is

$$V_2 = \frac{1}{4\pi\varepsilon_0}\left[\frac{5}{10} + \frac{10}{\sqrt{(10)^2+(10)^2}}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{5}{10} + \frac{10}{10\sqrt{2}}\right]$$

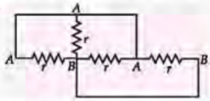
Work done, $W = q(V_1 - V_2)$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{10}{10} + \frac{5}{10\sqrt{2}} - \frac{5}{10} - \frac{10}{10\sqrt{2}}\right]$$

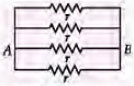
$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{5}{10} - \frac{5}{10\sqrt{2}}\right] = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{2} - \frac{1}{2\sqrt{2}}\right]$$

$$= \frac{q}{8\pi\varepsilon_0}\left[1 - \frac{1}{\sqrt{2}}\right] = \frac{q}{8\pi\varepsilon_0}\left(\frac{\sqrt{2}-1}{\sqrt{2}}\right)$$

5. **(b)**:



The equivalent circuit diagram is as shown in the figure.



Here, all the resistances are connected in parallel.

Hence, the equivalent between A and B is

$$\frac{1}{R_{AB}} = \frac{1}{r} + \frac{1}{r} + \frac{1}{r} + \frac{1}{r} = \frac{4}{r}\;;\; R_{AB} = \frac{r}{4}$$

6. **(c)**: $N_1\sin37° = N_2\sin74°$

or $N_1 = 2N_2\cos37°$

$N_1\cos37° + N_2\cos74° = mg$

or $2N_2\cos^2 37°$

$+ N_2(2\cos^2 37° - 1) = mg$

or

$$2N_2\left(\frac{16}{25}\right) + N_2\left(\frac{32}{25} - 1\right) = mg$$

or $\frac{39}{25}N_2 = mg \quad \therefore \quad N_2 = \frac{25}{39}mg$

7. **(a)**: Charge on the capacitor,

$q_0 = CV = 1\times10^{-6}\times1 = 10^{-6}$ C

$LC = 10^{-3}\times10^{-6} = 10^{-9}$

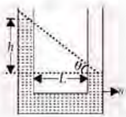
$I_0 = \omega q_0$ = maximum current

Now $\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{10^{-9}}} = (10^9)^{1/2}$

$\therefore \quad I_0 = (10^9)^{1/2}\times(1\times10^{-6})$

$= \sqrt{10^{-3}}\text{ A} = \sqrt{1000}\text{ mA}$

8. **(d)**: Let P_1 and P_2 be the pressures at the bottom of the left end and right end of the tube respectively. Then



$F = (P_1 - P_2)A = \rho ghA$

where A is the area of cross-section of the tube.

The mass of the liquid in the horizontal portion is

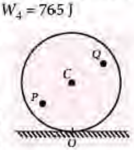
$m = \rho LA$

As $F = ma$

$\therefore$ $\rho ghA = \rho LAa$ or $h = \frac{aL}{g}$

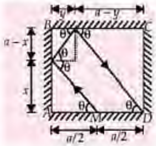
9. (c) : $\Delta Q = Q_1 + Q_2 + Q_3 + Q_4$
$= 5960 \text{ J} - 5585 \text{ J} - 2980 \text{ J} + 3645 \text{ J} = 1040 \text{ J}$
$\Delta W = W_1 + W_2 + W_3 + W_4$
$= 2200 \text{ J} - 825 \text{ J} - 1100 \text{ J} + W_4 = 275 \text{ J} + W_4$
For a cyclic process, $U_f = U_i$
$\Delta U = U_f - U_i = 0$
From first law of thermodynamics, $\Delta Q = \Delta U + \Delta W$
$1040 \text{ J} = 0 + 275 \text{ J} + W_4$ or $W_4 = 765 \text{ J}$

10. (a) : About instantaneous axis of rotation
i.e., point of contact,
$v = r\omega$ ...(i)
Distance $OP < OC < OQ$ ...(ii)
From (i) and (ii) $V_P < V_C < V_Q$.



11. (c) : In an electromagnetic wave both electric and magnetic vectors are perpendicular to each other as well as perpendicular to the direction of propagation of wave.

12. (b): The ray starting from point M at an angle θ reaches the corner D at the right along a parallel path. Let a be the length of the side.
From figure,



$\tan\theta = \frac{x}{(a/2)}$ ...(i)

$\tan\theta = \frac{a-x}{y}$ ...(ii)

$\tan\theta = \frac{a}{a-y}$ ...(iii)

From (i) and (ii), we get

$\frac{2x}{a} = \frac{a-x}{y}$

$2xy = a^2 - xa$ ...(iv)

From (ii) and (iii), we get

$\frac{a-x}{y} = \frac{a}{a-y}$

$a^2 - ya - xa + xy = ya;\ a^2 - xa - ya + xy = ya$

$3xy = 2ay \ \therefore\ x = \frac{2}{3}a$ (Using (iv))

Substituting this value of x in equation (i), we get

$\tan\theta = \frac{(2a/3)}{(a/2)} = \frac{4}{3}$ $\therefore\ \cot\theta = \frac{1}{\tan\theta} = \frac{3}{4}$

or $\theta = \cot^{-1}(0.75)$

13. (d): Initial energy stored in the capacitor,

$U_i = \frac{1}{2}CV^2 = \frac{1}{2}\times C\times(50)^2 = \frac{1}{2}C(50)^2$ ...(i)

After 2 s, when the potential drops by 10 V, the final potential is 40 V.
Final energy stored in the capacitor,

$U_f = \frac{1}{2}C(40)^2$ ...(ii)

Fraction of energy stored

$= \frac{U_f}{U_i} = \frac{\frac{1}{2}C(40)^2}{\frac{1}{2}C(50)^2} = \left(\frac{40}{50}\right)^2 = 0.64$

14. (b): Since the charged particle passes straight without deflection, therefore

$Bqv = mg$

or $v = \frac{mg}{Bq} = \frac{10^{-3}\times 10}{1\times 10^{-5}} = 10^3 \text{ m s}^{-1}$

15. (a) : The electric field force due to variable magnetic field $E = \frac{1}{2}R\frac{d\vec{B}}{dt}$

Force $= qE = \frac{1}{2}eR\frac{dB}{dt}$

The induced electric field is directed towards right at point P. The direction of force on electron is towards left.

$\therefore$ Acceleration $= \frac{1}{2m}eR\frac{dB}{dt}$

16. (a): In displacement-time graph, between time interval 0 to 1 s, $S \propto t$, so velocity is constant. Between time interval 1 s to 3 s, S is constant, so velocity is zero. Between time interval 3 s to 4 s, S decreases with t, *i.e.*, velocity is constant but opposite to the previous direction. Hence the option (a) is correct.

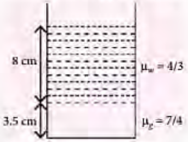
17. (c) : A NOT gate puts the input condition in the opposite order, means for high input it give low output and for low input it gives high output. For this reason NOT gate is known as invertor circuit.

18. (a): Minimum possible wavelength of X-rays is $\lambda_{min} = \frac{hc}{eV}$

$\log(\lambda_{min}) = \log\left(\frac{hc}{e}\right) - \log V$

This is the equation of a straight line with negative slope and positive intercept on the y-axis ($\log\lambda_{min}$).

19. (c) : Apparent depth = $\sum\left(\frac{t_i}{\mu_i}\right) = \frac{t_w}{\mu_w} + \frac{t_g}{\mu_g}$



$= \frac{8}{4/3} + \frac{3.5}{7/4} = \frac{24}{4} + \frac{14}{7} = 6 + 2 = 8$ cm.

20. (c) : Statement-1 is true, Statement-2 is true, and Statement-2 is a correct explanation for Statement-1.

$1 \text{ amu} = \frac{1}{6.023\times10^{26}} \text{ kg}$

$E = \left(\frac{1}{6.023\times10^{26}} \text{kg}\right)\left(3\times10^8 \frac{\text{m}}{\text{s}}\right)^2 = 931 \text{ MeV.}$

21. (5) : $V = 4x - 3x^2y + 2yz^2$

$\therefore \quad E_x = -\frac{\partial V}{\partial x} = -4 + 6xy$

$E_y = -\frac{\partial V}{\partial y} = 3x^2 - 2z^2 \,;\; E_z = -\frac{\partial V}{\partial y} = -4zy$

At point P (1, 0, 0)

$E_x = -4 - 0 = -4; E_y = 3 + 0 = 3; E_z = 0$

$\therefore \quad \vec{E}\text{at}(1,0,0) = -4\hat{i} + 3\hat{j} + 0\hat{k}$

$\therefore \quad |\vec{E}| = 5 \text{ N/C}$

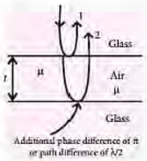
22. (3) : For maxima, $2\mu t + \frac{\lambda}{2} = n\lambda$

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

$\lambda = \frac{4\mu t}{(2n-1)}$

$= \frac{4\times1\times0.45\times10^{-6}}{(2n-1)}$

$\lambda = \frac{18000}{(2n-1)}$ Å



Among the choices for $n = 2$, $\lambda = = 6000$ Å $= 6 \times 10^3$Å is valid.

23. (3) : Acceleration due to gravity at surface of earth,

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

where mass of the earth can be expressed as $M = \left(\frac{4}{3}\pi R^3\right)\rho$

So, $g = \frac{G\left(\frac{4}{3}\pi R^3\right)\rho}{R^2} = \frac{4\pi G\rho R}{3}$

So, $g \propto \rho R$ or $R \propto \frac{g}{\rho}$

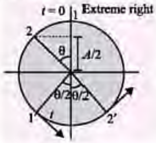
$\therefore$ Escape velocity, $v_e = \sqrt{\frac{2GM}{R}} = \sqrt{2gR}$

$v_e \propto \sqrt{g\left(g/\rho\right)} = \sqrt{\frac{g^2}{\rho}} \Rightarrow \frac{v_e'}{v_e} = \sqrt{\left(\frac{g'}{g}\right)^2\frac{\rho}{\rho'}}$

$\Rightarrow \quad \frac{v_e'}{v_e} = \sqrt{\left(\frac{2}{121}\right)\left(\frac{3}{2}\right)} = \frac{\sqrt{3}}{11}$

$\Rightarrow \quad v_e' = \frac{\sqrt{3}}{11}v_e = \frac{\sqrt{3}}{11}(11 \text{ km s}^{-1}) = \sqrt{3} \text{ km s}^{-1}$

24. (12) : At $t = 0$, position of particle is 1 and 2 and at time t, positions are 1′ and 2′, respectively.



$A\cos\theta = \frac{A}{2} \quad \therefore \theta = \frac{\pi}{3}$

Initial phase difference,

$\theta = \frac{\pi}{3}$. Since time period is same for both, the initial phase difference of $\frac{\pi}{3}$ remains unchanged.

When blocks have same position, 1 has turned by

$\pi - \frac{\pi}{6}\,;\; \pi - \frac{\pi}{6} = \omega t \Rightarrow t = \frac{5T}{12}$

25. (20) : $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

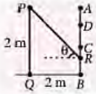
For double convex lens,

$\mu = 1.5, R_1 = +20$ cm, $R_2 = -20$

$\frac{1}{f} = (1.5 - 1)\left(\frac{1}{(+20)} - \frac{1}{(-20)}\right)$

$\frac{1}{f} = 0.5 \Rightarrow L = f = +20$ cm.

26. **(6)** : $\tan\theta = a/g = 4/5$



$\Rightarrow \quad BR = PQ - QB\tan\theta$

$= 2 - (2 \times 4/5) = 0.4$ m

Volume of water contained, V_{fin}

$$= \left(\frac{PQ + BR}{2}\right) \times 4 \text{ m}^2$$

Initial volume of water, $V_{in} = BD \times 4$ m^2

Amount of spill $= V_{in} - V_{fin}$

$= 2(2BD - PQ - BR) \times 1000$ L

$= 2(3 - 2 - 0.4) \times 1000 = 1200$ L

$\therefore \quad \alpha = 6$

27. **(1)** : Here $m = 2000$ kg, $a = 1.2$ m s^{-2}

Breaking stress $= 2.8 \times 10^8$ N m^{-2}

As the lift moves upwards, the tension in the rope is

$T = m(g + a) = 2000(9.8 + 1.2) = 22{,}000$ N

$$\text{Now, breaking stress} = \frac{\text{Force}}{\text{Area}} = \frac{T}{\pi D^2/4} = \frac{4T}{\pi D^2}$$

$$\text{or} \quad 2.8 \times 10^8 = \frac{4 \times 22{,}000 \times 7}{22 \times D^2}$$

$$\text{or} \quad D^2 = \frac{4 \times 22{,}000 \times 7}{22 \times 2.8 \times 10^8} = 10^{-4}$$

or $\quad D = 10^{-2}$ m $= 1$ cm

28. **(4.432)** : As, area = length × breadth

$\therefore$ Area of metal $= 2.214 \times 2.002 = 4.432428$ m^2

As per of rule numerical value of area has four significant digits.

So, area of metal sheet = 4.432 m^2

29. **(8.89)** : Here $V = 10{,}000$ cm^3

$\Delta T = (40 - 25) = 15$°C, $\Delta V = 4$ cm^3

The coefficient of cubical expansion is given by

$$\Rightarrow \quad \gamma = \frac{\Delta V}{V\Delta T} = \frac{4}{10000 \times 15} = 26.67 \times 10^{-6}\ °\text{C}^{-1}$$

We known that, coefficient of linear expansion,

$$\alpha = \frac{\gamma}{3} = \frac{26.67 \times 10^{-6}}{3} = 8.89 \times 10^{-6}\ °\text{C}^{-1}$$

30. **(45)** : $d_M = \sqrt{2Rh_R} + \sqrt{2Rh_T}$

where h_R and h_T are the heights of receiving and transmitting antenna and R is the radius of the earth.

$$\therefore \quad 40 \times 10^3 = \sqrt{2 \times 6400 \times 10^3 \times h} + \sqrt{2 \times 6400 \times 10^3 \times 20}$$

$$\Rightarrow \quad 40 \times 10^3 = \sqrt{2 \times 6400 \times 10^3 \times h} + 16 \times 10^3$$

$$\Rightarrow \quad h = \frac{[(40 - 16) \times 10^3]^2}{2 \times 6.4 \times 10^6} = 45 \text{ m}$$

◆◆

GET SET GO *for* JEE

Class XI

with exclusive and brain storming MCQs

Practicing these MCQs help to strengthen your concepts and give you extra edge in your JEE preparation

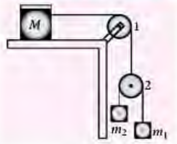
Only One Option Correct Type

1. The velocities of two bodies having masses 5 kg and 10 kg are 4 ms^{-1} and 2 ms^{-1} respectively along x and y axes. They collide and stick together. The compound body moves with velocity v at angle θ with x-axis. The value of θ is
   (a) 30° (b) 45° (c) 60° (d) – 75°

2. Two parallel glass plates are held vertically at a small separation d and dipped in a liquid of surface tension T, angle of contact $\theta = 0$ and density ρ. The height of water that climbs up in the gap between the plates is given by
   (a) $2T/d\rho g$ (b) $T/2\ d\rho g$
   (c) $T/d\rho g$ (d) None of these

3. Four wires of the same material are stretched by the same load. The dimensions are given below. Which of them will elongate the most ?
   (a) Length 100 cm, diameter 1 cm
   (b) Length 200 cm, diameter 2 cm
   (c) Length 300 cm, diameter 3 cm
   (d) Length 400 cm, diameter 0.5 cm

4. In the arrangement shown in figure, m_1 = 1 kg, m_2 = 2 kg. Pulleys are massless and strings are light. For what value of M, the mass m_1 moves with constant velocity ?



   (a) 5 kg (b) 6 kg
   (c) 8 kg (d) 7 kg

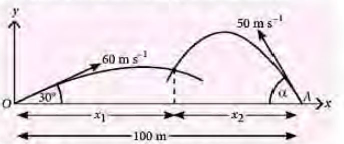
5. **Statement 1:** Equal volumes of monoatomic and polyatomic gases are adiabatically compressed separately to equal compression ratio $\left(\frac{P_2}{P_1}\right)$. Then monoatomic gas will have greater final volume.
   Statement 2 : Among ideal gases, a molecule of a monoatomic gas has the smallest number of degrees of freedom.
   (a) Statement-1 is true, Statement-2 is false
   (b) Statement-1 is false, Statement-2 is true
   (c) Statement-1 is true, Statement-2 is true and Statement-2 is a correct explanation for Statement-1.
   (d) Statement-1 is true, Statement-2 is true but Statement-2 is not a correct explanation for Statement-1.

6. A satellite of mass m revolves around the earth of radius R at a height x from its surface. If g is acceleration due to gravity on the surface of the earth, the orbital speed of the satellite is

(a) $\frac{gR^2}{R+x}$ (b) $\frac{gR}{R-x}$

(c) gx (d) $\left(\frac{gR^2}{R+x}\right)^{1/2}$

7. A particle P is projected from a point O with an initial velocity of 60 m s^{-1} at an angle 30° to the horizontal. At the same instant a second particle Q is projected in the opposite direction with initial speed 50 m s^{-1} from a point level with O and 100 m from O. The time after which the particles collide.



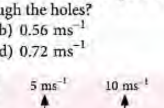
(a) 2.11 s (b) 0.51 s
(c) 1.52 s (d) 1.09 s

8. The molecules of a given mass of a gas have root mean square speed of 100 m s^{-1} at 27°C and 1 atmospheric pressure. The root mean square speed (in m s^{-1}) of the molecules of the gas at 127°C and 2 atmospheric pressure is

(a) $\frac{200}{\sqrt{3}}$ (b) $\frac{100}{\sqrt{3}}$ (c) $\frac{400}{3}$ (d) $\frac{200}{3}$

9. The cylindrical tube of a spray pump has a cross-section of 8 cm^2 one end of which has 40 fine holes each of diameter 1.0 mm. If the liquid flow rate inside the tube is 1.5 m min^{-1}, what is the speed of ejection of the liquid through the holes?
(a) 0.48 ms^{-1} (b) 0.56 ms^{-1}
(c) 0.64 ms^{-1} (d) 0.72 ms^{-1}

10. Two particles A and B are thrown vertically upward with velocity, 5 ms^{-1} and 10 ms^{-1}, respectively (g = 10 ms^{-2}). Find separation between them after 1 s.



(a) 20 m (b) 0
(c) 10 m (d) 5 m

11. The collision frequency of nitrogen molecule in a cylinder containing nitrogen molecule at 2.0 atm pressure and temperature 17°C (Take radius of a nitrogen molecule as 1.0 Å.) is
(a) 3.2×10^5 s^{-1} (b) 4.6×10^9 s^{-1}
(c) 4.6×10^{-9} s^{-1} (d) 3.2×10^{-5} s^{-1}

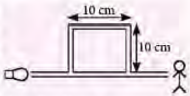
12. A chain of length l is placed on a smooth spherical surface of radius R with one of its ends fixed at the top of the sphere. What will be acceleration a of each element of the chain when its upper end is released? It is assumed that the length of chain $l < \left(\pi \frac{R}{2}\right)$.

(a) $\frac{g}{l}\left(1-\cos\frac{l}{R}\right)$ (b) $\frac{gR}{l}\left(1+\cos\frac{l}{R}\right)$

(c) $\frac{g}{l}\left(1+\cos\frac{l}{R}\right)$ (d) $\frac{gR}{l}\left(1-\cos\frac{l}{R}\right)$

13. A source of wavelength 60 cm is moving towards the north with a speed of $\frac{1}{5}$ of the velocity of sound in air. The wavelength observed by an observer in the north and another in the south are
(a) 72 cm and 48 cm
(b) 48 cm and 72 cm
(c) they will be the same
(d) none of these

14. Figure shows a tube having sound source at one end and observer at the other end. Source produces frequencies upto 10000 Hz. Find the frequencies at which person hears maximum intensity. Speed of sound is 400 m s^{-1}.



(a) 3000 Hz (b) 2500 Hz
(c) 4000 Hz (d) 4500 Hz

15. A car starting from rest, accelerates at the rate of f through a distance S, then continues at constant speed for time t and then decelerates at the rate $\frac{f}{2}$ to come to rest. If the total distance traversed is 15S, then

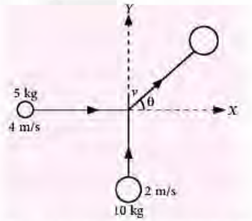
(a) $S = \frac{1}{4}ft^2$ (b) $S = \frac{1}{72}ft^2$

(c) $S = \frac{1}{6}ft^2$ (d) $S = ft$

SOLUTIONS

1. (b) : $\vec{p}_{\text{initial}} = (5\text{ kg})\left(4\frac{\text{m}}{\text{s}}\right)\hat{i} + (10\text{ kg})\left(2\frac{\text{m}}{\text{s}}\right)\hat{j}$

$= (20\hat{i} + 20\hat{j})\frac{\text{kg m}}{\text{s}}$



$\vec{p}_{\text{final}} = (15\text{ kg})(v\cos\theta)\hat{i} + (15\text{ kg})(v\sin\theta)\hat{j}$

$= (15v\cos\theta)\hat{i} + (15v\sin\theta)\hat{j}$

For collision, $\vec{p}_{\text{initial}} = \vec{p}_{\text{final}}$

$$(20\hat{i} + 20\hat{j}) = (15v\cos\theta)\hat{i} + (15v\sin\theta)\hat{j}$$

$\Rightarrow\ 15v\sin\theta = 20$ and $15v\cos\theta = 20$

Dividing the two equations, $\tan\theta = 1 \Rightarrow \theta = 45°$.

2. (a) : The meniscus between the plates has cylindrical shape with radius $r = \frac{d}{2}$. The pressure just inside the meniscus is

$P_0 - T\left(\frac{1}{r} + \frac{1}{\infty}\right) = P_0 - \frac{2T}{d}$

Now, $P_A = P_B$

or, $P_0 = \left(P_0 - \frac{2T}{d}\right) + h\rho g \Rightarrow h = \frac{2T}{d\rho g}$

3. (d) : We know, young's Modules,

$Y = \frac{F/A}{\Delta L/L} = \frac{4FL}{\pi D^2 \Delta L}$

So, $\Delta L = \frac{4FL}{\pi D^2 Y}$ or $\Delta l \propto \frac{L}{D^2}$

For wire 1, $\frac{L}{D^2} = \frac{100}{1^2} = 100$

For wire 2, $\frac{L}{D^2} = \frac{200}{2^2} = 50$

For wire 3, $\frac{L}{D^2} = \frac{300}{3^2} = \frac{100}{3}$

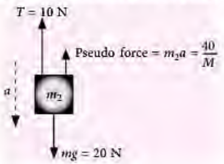
For wire 4, $\frac{L}{D^2} = \frac{400}{(0.5)^2} = 1600$ (largest)

So, wire described in option (d) will elongate the most.

4. (c) : Mass m_1 moves with constant velocity if tension in the lower string.
$T_1 = m_1 g = (1)(10) = 10$ N
Tension in the upper string,
$T_2 = 2T_1 = 20$ N
Acceleration of block M is, therefore,

$$a = \frac{T_2}{M} = \frac{20}{M} \quad \text{...(i)}$$

This is also the acceleration of pulley 2.
The absolute acceleration of mass m_1 is zero. Thus, the acceleration of m_1 relative to pulley 2 is in upward or acceleration of m_2 with respect to pulley 2 is in downward direction. Drawing free-body diagram of m_2 with respect to pulley 2.



Equation of motion gives

$$20 - \frac{40}{M} - 10 = 2a = \frac{40}{M} \quad \text{[Using (i)]}$$

Solving this, we get, $M = 8$ kg

5. (b) : Statement-1 is false, Statement-2 is true.
For a monoatomic gas,

$$P_1V_1^{\gamma} = P_2V_2^{\gamma}$$

$$\Rightarrow \left(\frac{P_2}{P_1}\right) = \left(\frac{V_1}{V_2}\right)^{\gamma} \Rightarrow V_2 = V_1\left[\frac{P_1}{P_2}\right]^{\frac{1}{\gamma}} = V_1C^{1/\gamma}\ (C > 1)$$

Similarly, for a diatomic gas,

$$\Rightarrow\ V_2' = V_1\left[\frac{P_1}{P_2}\right]^{\frac{1}{\gamma'}} = V_1C^{1/\gamma'}$$

$\because\ \gamma > \gamma'$

$\therefore\ V_2' > V_2$.

A molecule of monoatomic gas has degree of freedom due to translation motion only.

6. (d): As $\frac{mv^2}{(R+x)} = \frac{GmM}{(R+x)^2}$

$\therefore \frac{mv^2}{(R+x)} = m\left(\frac{GM}{R^2}\right)\frac{R^2}{(R+x)^2} \quad \left[\because g = \frac{GM}{R^2}\right]$

or $\frac{mv^2}{(R+x)} = mg\frac{R^2}{(R+x)^2}$

or $v^2 = \frac{gR^2}{R+x} \Rightarrow v = \left(\frac{gR^2}{R+x}\right)^{1/2}$

7. (d): If the particles collide they must be at the same point at the same time.

Let t be the time between projection and collision.

For P, we use O as origin and the x-axis along OA is given,

$x_P = (60\cos 30°)\,t;\ y_P = (60\sin 30°)\ t - \frac{1}{2}gt^2$

For Q, we use A as origin and the x-axis along AO given

$x_Q = (50\cos\alpha)\,t,\ y_Q = (50\sin\alpha)\ t - \frac{1}{2}gt^2$

During collision

$x_P + x_Q = 100 \Rightarrow t(30\sqrt{3} + 50\cos\alpha) = 100$ ...(i)

Also, $y_P = y_Q \Rightarrow 30 = 50\sin\alpha \Rightarrow \sin\alpha = \frac{3}{5}$ ...(ii)

Hence, from equation (ii), $\cos\alpha = \frac{4}{5} \Rightarrow \alpha = 36.9°$

Therefore Q is projected at 36.9° to the horizontal.

Then equation (i) gives,

$t(30\sqrt{3} + 40) = 100 \Rightarrow t = 1.09\text{ s}$

Therefore the particles collide 1.09 seconds after projection.

8. (a): Here, let v_{rms_1} = 100 m s^{-1} at temperature $T_1 = 27\,°C = (27 + 273)\text{ K} = 300\text{ K}$

and Pressure P_1 = 1 atm.

Now for the same gas at temperature

$T_2 = 127°C = (127 + 273)\text{ K} = 400\text{ K}$,

$P_2 = 2\text{ atm}, v_{rms_2} = ?$,

Using $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}, \frac{V_1}{V_2} = \frac{P_2}{P_1}\cdot\frac{T_1}{T_2} = 2\times\frac{300}{400} = \frac{3}{2}$

Again $P_1 = \frac{1}{3}\frac{M}{V_1}v_{rms_1}^2$ and $P_2 = \frac{1}{3}\frac{M}{V_2}v_{rms_2}^2$

$\therefore \frac{v_{rms_2}^2}{v_{rms_1}^2}\times\frac{V_1}{V_2} = \frac{P_2}{P_1}$

$v_{rms_2}^2 = v_{rms_1}^2\times\frac{P_2}{P_1}\times\frac{V_2}{V_1} = (100)^2\times 2\times\frac{2}{3}$

$v_{rms_2} = \frac{200}{\sqrt{3}}\text{ m s}^{-1}$

9. (c): Given : $v_1 = 1.5\text{ m min}^{-1} = \frac{1.5}{60}\text{ ms}^{-1}$

$A_1 = 8\text{ cm}^2 = 8\times 10^{-4}\text{ m}^2$

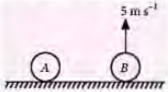
$A_2 = \frac{\pi d_2^2}{4} = \frac{\pi}{4}(10^{-3})^2\text{ m}^2$

$n = 40;\ A_1v_1 = n(A_2v_2)$

$v_2 = \frac{A_1v_1}{nA_2} = \frac{(8\times10^{-4}\text{ m}^2)\times\left(\frac{1.5}{60}\right)\text{ ms}^{-1}}{40\times\frac{\pi}{4}\times10^{-6}\text{ m}^2} = 0.64\text{ ms}^{-1}$.

10. (d): Acceleration of B w.r.t. A

$\vec{a}_{BA} = \vec{a}_B - \vec{a}_A = (-10) - (-10) = 0$



Initial relative velocity

$\vec{v}_{BA} = \vec{v}_B - \vec{v}_A = 10 - 5 = 5\text{ ms}^{-1}$

Hence, separation between A and B after 1 s, $S_B - S_A$ = 5 m

11. (b): Mean free path $\lambda = \frac{1}{\sqrt{2}\pi d^2 n}$

$\lambda = \frac{k_BT}{\sqrt{2}\pi d^2 p}(\because p = nk_BT)$

or $\lambda = \frac{(1.38\times10^{-23})(290)}{(1.414)(3.14)(2\times10^{-10})^2(2.026\times10^5)}$

$= 1.1\times10^{-7}\text{ m}$

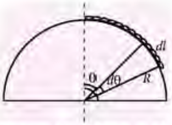
Now, $v_{rms} = \sqrt{\frac{3k_BT}{m}} = \sqrt{\frac{3\times1.38\times10^{-23}\times290}{28\times1.66\times10^{-27}}}$

$= 5.1\times10^2\text{ m s}^{-1}$

$\therefore$ collision frequency

$\upsilon = \frac{v_{rms}}{\lambda} = \frac{5.1\times10^2}{1.1\times10^{-7}} = 4.6\times10^9\text{ s}^{-1}$

12. (d) : Let m be the mass of the chain of length l. Consider an element of length dl of the chain at an angle θ with vertical, From figure, $dl = Rd\theta$;



Force responsible for acceleration, $dF = (dm)g\sin\theta$;
Mass of the element,

$$dm = \frac{m}{l}dl; \text{ or } dm = \frac{m}{l}.R\,d\theta$$

$$\therefore\ dF = \left(\frac{m}{l}R\,d\theta\right)(g\sin\theta) = \frac{mgR}{l}\sin\theta\,d\theta$$

Net force on the chain can be obtained by integrating the above relation between 0 to α, we have

$$F = \int_0^{\alpha}\frac{mg\,R}{l}\sin\theta\,d\theta = \frac{mg\,R}{l}\left[-\cos\theta\right]_0^{\alpha} = \frac{mg\,R}{l}[1-\cos\alpha]$$

$$= \frac{mg\,R}{l}\left[1-\cos\frac{l}{R}\right]$$

$$\therefore\ \text{Accelaration, } a = \frac{F}{m} = \frac{gR}{l}\left(1-\cos\frac{l}{R}\right).$$

13. (b) : When the source moves towards the north, the observer in the north will observe higher frequency *i.e.* lower wavelength.

$$\lambda' = \lambda\frac{(v_{\text{sound}} - v_{\text{source}})}{v_{\text{sound}}}$$

$$\Rightarrow\ \lambda' = \frac{60\times\frac{4}{5}v_{\text{sound}}}{v_{\text{sound}}}\ \left(\text{Given}: v_{\text{source}} = \frac{1}{5}v_{\text{sound}}\right)$$

$$\Rightarrow\ \lambda' = 48\text{ cm}$$

The observer situated in the south will observe

$$\lambda_{\text{south}} = \lambda\frac{(v_{\text{sound}} + v_{\text{source}})}{v_{\text{sound}}} = \lambda\frac{\frac{6}{5}v_{\text{sound}}}{v_{\text{sound}}} = \frac{60\times 6}{5}$$

$$\Rightarrow\ \lambda_{\text{south}} = 72\text{ cm}$$

The wavelengths observed in the north and south are 48 cm and 72 cm respectively.

14. (c) : The sound wave bifurcates at the junction of the straight and the rectangular parts. The wave through the straight part travels a distance $d_1 = 10$ cm and the wave through the rectangular part travels a distance $d_2 = 3 \times 10$ cm $= 30$ cm before they meet again and travel to the receiver. The path difference between the two waves received is, therefore

$\Delta d = d_2 - d_1 = 30\text{ cm} - 10\text{ cm} = 20\text{ cm}$

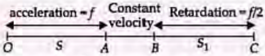
The wavelength of either wave is $\lambda = \dfrac{v}{\upsilon} = \dfrac{400\text{ m s}^{-1}}{\upsilon}$.

For constructive interference, $\Delta d = n\lambda$, where n is an integer.

$$\text{or, } \Delta d = n\frac{v}{\upsilon} \Rightarrow \upsilon = \frac{nv}{\Delta d} = \frac{400}{0.2}n = 2000\,n$$

Thus, the frequencies within the specified range which cause maximum of intensity are 2000×1 Hz and 2000×2 Hz.

15. (b) :



Taking motion of car from O to A,

$u = 0, a = f, s = S, v = ?$

As $v^2 = u^2 + 2as$;

So $v^2 = 0 + 2\times f\times S$ or $v = \sqrt{2fS}$

The velocity of car at A = velocity of car at $B = (2fS)^{1/2}$

As magnitude of retardation of the car from B to C is half of that of acceleration from O to A when velocity changes by v, so distance $BC = S_1 = 2S$

Distance $AB = 15S - (S + 2S) = 12S$

As distance AB is covered with constant velocity in time t

So, $12S = vt = (2fS)^{1/2}\times t$

or $144S^2 = 2fSt^2$ or $S = \dfrac{1}{72}ft^2$

◆◆

GET SET GO *for* NEET

with exclusive and brain storming MCQs

Practicing these MCQs help to strengthen your concepts and give you extra edge in your NEET preparation

1. A sphere of radius R carries charge such that its volume charge density is proportional to the square of the distance from the center. What is the ratio of the magnitude of the electric field at a distance $2R$ from the center to the magnitude of the electric field at a distance of $R/2$ from the center?
   (a) 1 (b) 2 (c) 4 (d) 8

2. The potential difference between A and B is

   (a) 13.2 V (b) –13.2 V
   (c) –6 V (d) 6 V

3. Two cities are 150 km apart. Electric power is sent from one city to another city through copper wires. The fall of potential per km is 8 volt and the average resistance per km is 0.5 Ω. The power loss in the wire is
   (a) 19.2 W (b) 19.2 kW
   (c) 19.2 J (d) 12.2 kW

4. The maximum intensity in Young's double slit experiment is I_0. Distance between the slits is $d = 5\lambda$, where λ is the wavelength of monochromatic light used in the experiment. What will be the intensity of light in front of one of the slits on a screen at a distance $D = 10d$?
   (a) I_0 (b) $2I_0$ (c) $I_0/4$ (d) $I_0/2$

5. In a black body radiation at certain temperature T_1, the wavelength having maximum intensity of radiation equals 9000 Å. When the temperature is increased from T_1 to T_2, the total radiation increases 16 times. The peak radiation at T_2 is found to be capable of ejecting photoelectrons. The maximum kinetic energy of the photoelectrons is the same as the energy of photon that one gets when one of electrons in the M-shell of hydrogen atom jumps to L-shell. The work function of the metal is
   (a) 1.45 eV (b) 0.45 eV
   (c) 0.88 eV (d) 7.23 eV

6. The displacement current flows in the dielectric of a capacitor when the potential difference across its plate
   (a) is increasing with time
   (b) is decreasing with time
   (c) has assumed a constant value
   (d) both (a) and (b).

7. The graph of log (R/R_0) versus log A [where A is mass number of the nucleus and R is its radius] is
   (a) a circle (b) a parabola
   (c) a straight line (d) a hyperbola.

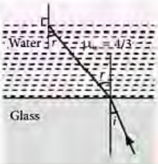
8. The combination of two bar magnets makes 10 oscillations per second in an oscillation magnetometer when like poles are tied together and 2 oscillations per second when unlike poles are tied together. Find the ratio of the magnetic moments of the magnets.

(a) $\frac{11}{10}$ (b) $\frac{13}{12}$ (c) $\frac{19}{11}$ (d) $\frac{13}{10}$

9. An AC source of angular frequency ω is fed across a resistor R and a capacitor C in series. The current registered is I. If now the frequency of source is changed to $\omega/3$ (but maintaining the same voltage), the current in the circuit is found to be halved. The ratio of reactance to resistance at the original frequency ω is

(a) $\sqrt{\frac{3}{5}}$ (b) $\sqrt{\frac{2}{5}}$ (c) $\sqrt{\frac{1}{5}}$ (d) $\sqrt{\frac{4}{5}}$

10. A ray of light is incident on the glass-water interface at an angle i, it emerges finally parallel to the surface of water, the value of μ_g would be

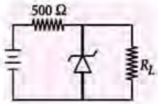


(a) $(4/3) \sin i$
(b) $1/\sin i$
(c) $4/3$
(d) 1

11. Two point charges $+8q$ and $-2q$ are located at $x = 0$ and $x = L$ respectively. The location of a point on the x-axis at which the net electric field due to these two point charges is zero, is

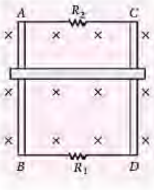
(a) $8L$ (b) $4L$ (c) $2L$ (d) $\frac{L}{4}$

12. In the circuit shown, if the current through the 500 Ω resistor is 25 mA and that through the load R_L is 5 mA, then the maximum current through the Zener diode is



(a) 5 mA (b) 20 mA
(c) 30 mA (d) 125 mA

13. Two parallel vertical metallic rails AB and CD are separated by 1 m. They are connected at the two ends by resistances R_1 and R_2 as shown in figure. A horizontal metallic bar of mass 0.2 kg slides without friction vertically down the rails under the action of gravity. There is a uniform horizontal magnetic field of 0.6 T perpendicular to the plane of the rails. It is observed that when the terminal velocity is attained, the power dissipated in R_1 and R_2 are 0.76 W and 1.2 W respectively. The terminal velocity of the bar is



(a) 1 m s^{-1} (b) 2 m s^{-1}
(c) 0.5 m s^{-1} (d) 5 m s^{-1}

14. A hydrogen like atom of atomic number Z is in an excited state of quantum number $2n$. It can emit a maximum energy photon of 204 eV. If it makes a transition to quantum state n, a photon of energy 40.8 eV is emitted. The value of n will be

(a) 1 (b) 2 (c) 3 (d) 4

15. A common emitter amplifier has a voltage gain of 50 and current gain is 25. The power gain of the amplifier is

(a) 500 (b) 1000 (c) 1250 (d) 100

SOLUTIONS

1. (b) : Volume charge density, $\rho = Cr^2$

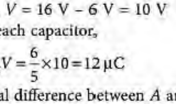
As, $q = \int_0^r 4\pi r^2 dr\rho = \int_0^r 4\pi C r^4 dr = \frac{4}{5}\pi C r^5$

$$E_{r=2R} = \frac{kq_{(r=R)}}{(2R)^2} = \frac{k(4/5)\pi CR^5}{4R^2} \quad ...(i)$$

$$E_{r=R/2} = \frac{kq_{(r=R/2)}}{(R/2)^2} = \frac{k(4/5)\pi C(R/2)^5}{(R/2)^2} \quad ...(ii)$$

Solving eqn. (i) and (ii), we get $\frac{E_{r=2R}}{E_{r=R/2}} = 2$

2. (c) : Here, 2 μF and 3 μF capacitors are connected in series.



Their equivalent capacitance is

$$\frac{1}{C_S} = \frac{1}{2} + \frac{1}{3} \text{ or } C_S = \frac{6}{5}\mu F$$

Net voltage, $V = 16\text{ V} - 6\text{ V} = 10\text{ V}$

Charge on each capacitor,

$$q = C_S V = \frac{6}{5} \times 10 = 12\,\mu C$$

The potential difference between A and B is

$$= -\frac{12\,\mu C}{2\,\mu F} = -6\text{ V}$$

3. (b): Here,
Distance between two cities = 150 km
Resistance of the wire, $R = (0.5\ \Omega\ \text{km}^{-1})(150\ \text{km})$ $= 75\ \Omega$
Voltage drop across the wire,
$V = (8\ \text{V km}^{-1})(150\ \text{km}) = 1200\ \text{V}$
Power loss in the wire is

$$P = \frac{V^2}{R} = \frac{(1200\ \text{V})^2}{75\ \Omega} = 19200\ \text{W} = 19.2\ \text{kW}$$

4. (d): Path difference, $\Delta x = \frac{yd}{D}$
Here, $y = \frac{d}{2} = \frac{5\lambda}{2}$ and $D = 10d = 50\lambda$

$$\therefore \Delta x = \left(\frac{5\lambda}{2}\right)\left(\frac{5\lambda}{50\lambda}\right) = \frac{\lambda}{4}$$

Corresponding phase difference, $\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{4} = \frac{\pi}{2}$

$$I = I_0 \cos^2\frac{\phi}{2} = I_0 \cos^2\left(\frac{\pi}{4}\right) = \frac{I_0}{2}$$

5. (c): Given, $\frac{T_2^4}{T_1^4} = 16 \Rightarrow T_2 = 2T_1$
As, $\lambda_2 T_2 = \lambda_1 T_1 \Rightarrow \lambda_2 = \frac{\lambda_1 T_1}{T_2} = 4500\ \text{Å}$

$$\therefore \frac{hc}{\lambda_2} = \frac{12400}{4500} = \frac{124}{45}\ \text{eV}$$

Now according to question, maximum kinetic energy of electron,

$$K_{max} = 13.6\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 1.9\ \text{eV}$$

Also, $\phi = \frac{hc}{\lambda_2} - K_{max} = \frac{124}{45} - 1.9 = 0.88\ \text{eV}$

6. (d): As, $I_D = \varepsilon_0 \frac{d\phi}{dt} = \varepsilon_0 \frac{AdE}{dt}$; $I_D \neq 0$ whenever $\frac{dE}{dt} \neq 0$
This will possible when potential difference across a capacitor varies.

7. (c): The radius of the nucleus is given by the approximate relation $R = R_0 A^{1/3}$

$$\log R = \log R_0 + \frac{1}{3}\log A \Rightarrow \log R - \log R_0 = \frac{1}{3}\log A$$

or $\log\left(\frac{R}{R_0}\right) = \frac{1}{3}\log A \Rightarrow \log\left(\frac{R}{R_0}\right) \propto \log A$

Therefore, the graph of $\log\left(\frac{R}{R_0}\right)$ versus $\log A$ is a straight line.

8. (b): As, $\upsilon = \frac{1}{2\pi}\sqrt{\frac{MB_H}{I}}$

$$\Rightarrow \upsilon_1 = \frac{1}{2\pi}\sqrt{\frac{(M_1 + M_2)B_H}{I_1 + I_2}}$$

and $\upsilon_2 = \frac{1}{2\pi}\sqrt{\frac{(M_1 - M_2)B_H}{I_1 + I_2}}$, where $M_1 > M_2$

$$\therefore \frac{\upsilon_1^2}{\upsilon_2^2} = \frac{M_1 + M_2}{M_1 - M_2}$$

or, $\frac{\upsilon_1^2 + \upsilon_2^2}{\upsilon_1^2 - \upsilon_2^2} = \frac{(M_1 + M_2) + (M_1 - M_2)}{(M_1 + M_2) - (M_1 - M_2)} = \frac{M_1}{M_2}$

or, $\frac{M_1}{M_2} = \frac{100 + 4}{100 - 4} = \frac{13}{12}$

9. (a): At angular frequency ω, the current in RC circuit is given by

$$i_{rms} = \frac{V_{rms}}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}} \quad \text{....(i)}$$

Also $\frac{i_{rms}}{2} = \frac{V_{rms}}{\sqrt{R^2 + \left(\frac{1}{\frac{\omega}{3}C}\right)^2}} = \frac{V_{rms}}{\sqrt{R^2 + \frac{9}{\omega^2 C^2}}}$ ....(ii)

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

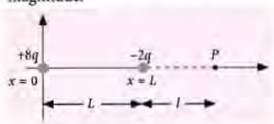
$$3R^2 = \frac{5}{\omega^2 C^2} \Rightarrow \frac{\frac{1}{\omega C}}{R} = \sqrt{\frac{3}{5}} \Rightarrow \frac{X_C}{R} = \sqrt{\frac{3}{5}}$$

10. (b): For glass-water interface, ${}_g\mu_w = \frac{\sin i}{\sin r}$ ...(i)
For water-air interface, ${}_w\mu_a = \frac{\sin r}{\sin 90^\circ}$ ...(ii)

$$\Rightarrow {}_g\mu_w \times {}_w\mu_a = \frac{\sin i}{\sin r} \times \frac{\sin r}{\sin 90^\circ} = \sin i$$

$$\Rightarrow \frac{\mu_w}{\mu_g} \times \frac{\mu_a}{\mu_w} = \sin i \Rightarrow \mu_g = \frac{1}{\sin i}$$

11. (c): The net field will be zero at a point outside the charges and near the charge which is smaller in magnitude.

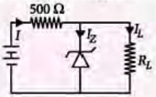


Suppose electric field is zero at P as shown.

Hence at P, $k \cdot \frac{8q}{(L+l)^2} = \frac{k \cdot (2q)}{l^2} \Rightarrow l = L$

So distance of P from origin is $L + L = 2\,L$.

12. (b) : The current distribution is shown in figure.



As $I = I_Z + I_L$

$\therefore \quad I_Z = I - I_L$
$= 25\text{ mA} - 5\text{ mA}$
$= 20\text{ mA}$

13. (a) : The rod will acquire terminal velocity only when magnetic force $F_M = BIl$ due to electromagnetic induction balances its weight, *i.e.*, $BIl = mg$, *i.e.*,

$$I = \frac{0.2 \times 9.8}{0.6 \times 1} = \frac{9.8}{3}\text{ A}$$

Now if ε is the *emf* induced in the rod,

$$\varepsilon \times I = P = P_1 + P_2 \quad \text{so, } \varepsilon = \frac{(0.76 + 1.20)}{(9.8/3)} = 0.6\text{ V}$$

Now as this ε is generated due to motion of rod with terminal velocity in the magnetic field, *i.e.*,

$$\varepsilon = Bv_T l \quad \text{so } v_T = \frac{\varepsilon}{Bl} = \frac{0.6}{0.6 \times 1} = 1\text{ m s}^{-1}$$

14. (b) : Let ground state energy (in eV) be E_1

Then from the given condition

$$E_{2n} - E_1 = 204\text{ eV or } \frac{E_1}{4n^2} - E_1 = 204\text{ eV}$$

$$\Rightarrow \quad E_1\left(\frac{1}{4n^2} - 1\right) = 204\text{ eV} \qquad \text{....(i)}$$

and $E_{2n} - E_n = 40.8$ eV

$$\Rightarrow \quad \frac{E_1}{4n^2} - \frac{E_1}{n^2} = E_1\left(-\frac{3}{4n^2}\right) = 40.8\text{ eV} \qquad \text{....(ii)}$$

From equation (i) and (ii),

$$\frac{1 - \frac{1}{4n^2}}{\frac{3}{4n^2}} = 5 \Rightarrow n = 2$$

15. (c) : AC power gain $= \frac{\text{Change in output power}}{\text{Change in input power}}$

$$= \frac{\Delta V_c \times \Delta i_c}{\Delta V_i \times \Delta i_b} = \left(\frac{\Delta V_c}{\Delta V_i}\right) \times \left(\frac{\Delta i_c}{\Delta i_b}\right) = A_v \times \beta_{ac}$$

$\therefore \quad \beta_{ac} = 25 \quad A_V = 50$

Now, AC power gain $= A_V \times \beta_{ac}$
$= 50 \times 25 = 1250$

CBSE warm-up! CLASS-XII

Practice questions for CBSE Exams as per the reduced syllabus, latest pattern and marking scheme issued by CBSE for the academic session 2020-21.

Practice Paper 2021

Time Allowed : 3 hours
Maximum Marks : 70

GENERAL INSTRUCTIONS

(1) All questions are compulsory. There are 33 questions in all.
(2) This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
(3) Section A contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each, Section B has two case based questions of 4 marks each, Section C contains nine short answer questions of 2 marks each, Section D contains five short answer questions of 3 marks each and Section E contains three long answer questions of 5 marks each.
(4) There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.

Section - A

1. State Lenz's law.

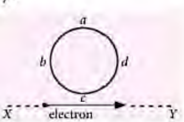
OR

The peak value of emf in ac is E_0. Write its (i) rms (ii) average value over a complete cycle.

2. Do electromagnetic waves carry energy and momentum?

3. An electron having mass m and kinetic energy E enter in uniform magnetic field B perpendicularly, then what is its frequency?

4. An electron moves on a straight line path XY as shown. The $abcd$ is a coil adjacent to the path of electron. What will be the direction of current, if any, induced in the coil?



OR

Give one example of use of eddy currents.

5. When is H_α line of the Balmer series in the emission spectrum of hydrogen atom obtained?

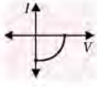
6. The photoelectric work function for a metal surface is 4.125 eV. What is the cut-off wavelength for this surface?

7. How is the radius of a nucleus related to its mass number A?

OR

Write any two characteristic properties of nuclear force.

8. Name the junction diode whose I-V characteristics are drawn below :



OR

Due to which the depletion region in forward biasing of the p-n junction becomes this?

9. What happens to the width of depletion layer of a p-n junction when it is (i) forward biased, (ii) reverse biased ?

10. A p-n photodiode is fabricated from a semiconductor with a band gap of 2.5 eV. Find the wavelength of signal which it can detect?

For question numbers 11, 12, 13 and 14, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of A

(b) Both A and R are true but R is NOT the correct explanation of A

(c) A is true but R is false

(d) A is false and R is also false

11. **Assertion (A) :** Young's double slit experiment can be performed using a source of white light.
 Reason (R) : The wavelength of red light is less than the wavelength of other colours in white light.

12. **Assertion (A) :** A point charge is brought in an electric field. The field at a nearby point is increase, whatever be the nature of the charge.
 Reason (R) : The electric field is independent of the nature of charge.

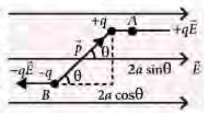
13. **Assertion (A) :** Sharper is the curvature of spot on a charged body lesser will be the surface charge density at that point
 Reason (R) : Electric field is non-zero inside a charged conductor.

14. **Assertion (A) :** The focal length of an equiconvex lens placed in air is equal to radius of curvature of either face. Lens is made up of material of refractive index of 1.5.
 Reason (R) : For an equiconvex lens radius of curvature of both the faces is same.

Section - B

Questions 15 and 16 are case study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

15. When electric dipole is placed in uniform electric field, its two charges experience equal and opposite forces, which cancel each other and hence net force on electric dipole in uniform electric field is zero. However these forces are not collinear, so they give rise to some torque on the dipole. Since net force on electric dipole in uniform electric field is zero, so no work is done in moving the electric dipole in uniform electric field. However some work is done in rotating the dipole against the torque acting on it.



(i) The dipole moment of a dipole in a uniform external field $\vec{E}$ is $\vec{P}$. Then the torque $\vec{\tau}$ acting on the dipole is

(a) $\vec{\tau} = \vec{P} \times \vec{E}$ (b) $\vec{\tau} = \vec{P} \cdot \vec{E}$

(c) $\vec{\tau} = 2(\vec{P} + \vec{E})$ (d) $\vec{\tau} = (\vec{P} + \vec{E})$

(ii) An electric dipole consists of two opposite charges, each of magnitude 1.0 μC separated by a distance of 2.0 cm. The dipole is placed in an external field of 10^5 N C^{-1}. The maximum torque on the dipole is

(a) 0.2×10^{-3} Nm (b) 1×10^{-3} Nm

(c) 2×10^{-3} Nm (d) 4×10^{-3} Nm

(iii) Torque on a dipole in uniform electric field is minimum when θ is equal to

(a) 0° (b) 90°

(c) 180° (d) Both (a) and (c)

(iv) When an electric dipole is held at an angle in a uniform electric field, the net force F and torque τ on the dipole are

(a) $F = 0, \tau = 0$ (b) $F \neq 0, \tau \neq 0$

(c) $F = 0, \tau \neq 0$ (d) $F \neq 0, \tau = 0$

(v) An electric dipole of moment p is placed in an electric field of intensity E. The dipole acquires a position such that the axis of the dipole makes an angle θ with the direction of the field. Assuming that the potential energy of the dipole to be zero when θ = 90°, the torque and the potential energy of the dipole will respectively be

(a) $pE\sin\theta, -pE\cos\theta$ (b) $pE\sin\theta, -2pE\cos\theta$

(c) $pE\sin\theta, 2pE\cos\theta$ (d) $pE\cos\theta, -pE\sin\theta$

16. Refraction of light is the change in the path of light as it passes obliquely from one transparent medium to another medium. According to law of refraction $\frac{\sin i}{\sin r} = {}^1\mu_2$, where ${}^1\mu_2$ is called refractive index of second medium with respect to first medium.

From refraction at a convex spherical surface, we have $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$. Similarly from refraction at a concave spherical surface when object lies in the rarer medium, we have $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$ and when object lies in the denser medium, we have $\frac{\mu_1}{v} - \frac{\mu_2}{u} = \frac{\mu_1 - \mu_2}{R}$.

(i) Refractive index of a medium depends upon

(a) nature of the medium

(b) wavelength of the light used

(c) temperature

(d) all of these

(ii) A ray of light of frequency 5×10^{14} Hz is passed through a liquid. The wavelength of light measured inside the liquid is found to be 450×10^{-9} m. The refractive index of the liquid is

(a) 1.33 (b) 2.52 (c) 2.22 (d) 0.75

(iii) A ray of light is incident at an angle of 60° on one face of a rectangular glass slab of refractive index 1.5. The angle of refraction is

(a) $\sin^{-1}(0.95)$ (b) $\sin^{-1}(0.58)$
(c) $\sin^{-1}(0.79)$ (d) $\sin^{-1}(0.86)$

(iv) A point object is placed at the centre of a glass sphere of radius 6 cm and refractive index 1.5. The distance of the virtual image from the surface of sphere is

(a) 2 cm (b) 4 cm (c) 6 cm (d) 12 cm

(v) In refraction, light waves are bent on passing from one medium to the second medium because in the second medium

(a) the frequency is different
(b) the co-efficient of elasticity is different
(c) the speed is different
(d) the amplitude is smaller.

Section - C

17. Consider a solid sphere of radius r and mass m which has a charge q distributed uniformly over its volume. The sphere is rotated about a diameter with an angular speed ω. Find magnetic moment of the sphere.

18. A parallel beam of light of 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 minimum is at a distance of 2.5 mm from the centre of the screen. Calculate the width of the slit.

OR

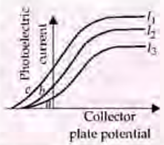
Two slits are made one millimetre apart and the screen is placed one metre away. What is the fringe separation when blue-green light of wavelength 500 nm is used?

19. Two point charges q and $-2q$ are kept 'd' distance apart. Find the location of point relative to charge 'q' at which potential due to this system of charges is zero.

OR

(a) Draw equipotential surfaces due to point $Q > 0$.
(b) Are these surfaces equidistant from each other? If no, explain why?

20. The figure shows a plot of three curves a, b, c showing the variation of photocurrent versus collector plate potential for three different intensities I_1, I_2 and I_3 having frequencies υ_1, υ_2 and υ_3 respectively, incident on a photosensitive surface. Point out the two curves for which the incident radiations have same frequency but different intensities.

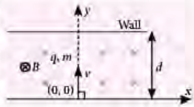


21. Two identical loops, one of copper and the other of aluminium, are rotated with the same angular speed in the same magnetic field. Compare (i) the induced emf and (ii) the current produced in the two coils. Justify your answer.

22. In Young's double slit experiment, the two slits 0.15 mm apart are illuminated by monochromatic light of wavelength 450 nm. The screen is 1.0 m away from the slits.

(a) Find the distance of the second (i) bright fringe, (ii) dark fringe from the central maximum.
(b) How will the fringe pattern change if the screen is moved away from the slits?

23. What should be the speed of charged particle so that it can't collide with the upper wall? Also find the coordinate of the point where the particle strikes the lower plate in the limiting case of velocity.



OR

A particle of charge q and mass m enters a magnetic field B of width d. Find the deviation of the particle and time spent inside the field. The particle enters the field with speed v at right angled to the field, if $d = \frac{mv}{2qB}$.

24. (i) Draw energy band diagrams of n-type and p-type semiconductors.
(ii) Compare their conductivities at absolute zero temperature and at room temperature.

25. A diverging lens of focal length 20 cm is placed coaxially 5 cm towards left of a converging mirror of focal length 10 cm. Where should an object be placed towards left of the lens so that a real image is formed at the object itself?

Section - D

26. Define the term 'mutual inductance' between the two coils. Obtain the expression for mutual inductance of a pair of long coaxial solenoids each of length l and radii r_1 and r_2 ($r_2 >> r_1$). Total number of turns in the two solenoids are N_1 and N_2 respectively.

27. A cell of emf 'E' and internal resistance 'r' is connected across a variable load resistor R. Draw the plots of the terminal voltage V versus (i) R and (ii) the current I.

It is found that when $R = 4\ \Omega$, the current is 1 A and when R is increased to 9 Ω, the current reduces to 0.5 A. Find the values of the emf E and internal resistance r.

OR

Two cells of emfs E_1 and E_2 and internal resistance r_1 and r_2 are connected in parallel. Obtain the expression for the emf and internal resistance of a single equivalent cell that can replace this combination ?

28. Ultraviolet light of wavelength 2271 Å from a 100 W mercury source is incident on a photocell made of molybdenum metal. If the stopping potential is 1.3 V, estimate the work function of the metal.

OR

When a light of wavelength 400 nm falls on a metal of work function 2.5 eV, what will be the maximum magnitude of linear momentum of emitted photoelectron?

29. The value of ground state energy of hydrogen atom is −13.6 eV.

(i) What does the negative sign signify?

(ii) How much energy is required to take an electron in this atom from the ground state to the first excited state?

30. Group the following six nuclides into three pairs of (i) isotones (ii) isotopes (iii) isobars :

How does the size of nucleus depend on its mass number? Hence explain why the density of nuclear matter should be independent of the size of the nucleus.

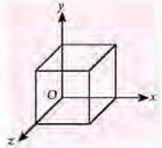
Section - E

31. An electric dipole of dipole moment $\vec{p}$ consists of point charges $+q$ and $-q$ separated by a distance $2a$ apart. Deduce the expression for the electric field $\vec{E}$ due to the dipole at a distance x from the centre of the dipole on its axial line in terms of the dipole moment $\vec{p}$. Hence show that in the limit $x >> a$, $\vec{E} \longrightarrow 2\vec{p}/(4\pi\varepsilon_0 x^3)$.

OR

(a) Draw the equipotential surfaces due to an electric dipole. Locate the points where the potential due to the dipole is zero.

(b) A cube of side 20 cm is kept in a region as shown in the figure. An electric field $\vec{E}$ exists in the region such that the potential at a point is given by $V = 10x + 5$, where V is in volt and x is in m.



Find the

(i) electric field $\vec{E}$, and

(ii) total electric flux through the cube.

32. (a) In a series LCR circuit connected across an ac source of variable frequency, obtain the expression for its impedance and draw a plot showing its variation with frequency of the ac source.

(b) What is the phase difference between the voltages across inductor and the capacitor at resonance in the LCR circuit ?

(c) When an inductor is connected to a 200 V dc voltage, a current of 1 A flows through it. When the same inductor is connected to a 200 V, 50 Hz ac source, only 0.5 A current flows. Explain, why ? Also, calculate the self inductance of the inductor.

OR

(a) State the principle of a step-up transformer. Explain, with the help of a labelled diagram, its working.

(b) Describe briefly any two energy losses, giving the reasons for their occurrence in actual transformers.

33. (a) State the importance of coherent sources in the phenomenon of interference.

(b) In Young's double slit experiment to produce interference pattern, obtain the conditions for constructive and destructive interference. Hence deduce the expression for the fringe width.

(c) How does the fringe width get affected, if the entire experimental apparatus of Young's is immersed in water?

OR

(a) Draw a labelled ray diagram of an astronomical telescope to show the image formation of a distant object. Write the main considerations required in selecting the objective and eyepiece lenses in order to have large magnifying power and high resolution of the telescope.

(b) A compound microscope has an objective of focal length 1.25 cm and eyepiece of focal length 5 cm. A small object is kept at 2.5 cm from the objective. If the final image formed is at infinity, find the distance between the objective and the eyepiece.

SOLUTIONS

1. Lenz's law states that the direction of the induced emf and the direction of induced current are such that they oppose the cause which produces them.

OR

E_0 = peak value of emf

(i) rms value $[E_{rms}] = \frac{E_0}{\sqrt{2}}$

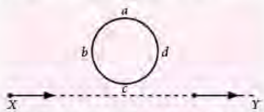
(ii) average value $[E_{av}]$ = zero

2. Yes, electromagnetic waves carry energy and momentum.

3. The frequency of revolution of charged particle in a perpendicular magnetic field is

$$\upsilon = \frac{1}{T} = \frac{1}{2\pi r / v} = \frac{v}{2\pi r} = \frac{v}{2\pi} \times \frac{eB}{mv} = \frac{eB}{2\pi m}.$$

4.



When the electron moves from X to Y, the flux linked with the coil *abcd* (which is into the page) will first increase and then decrease as the electron passes by. So the induced current in the coil will be first anticlockwise and will reverse its direction (*i.e.* will become clockwise) as the electron goes past the coil.

OR

Eddy current is used for magnetic breaking in trains. Strong electromagnets are situated in the train, just above the rails. When the electromagnets are activated, the eddy currents induced in the rails opposes the motion of the train.

5. H_α line of the Balmer series in the emission spectrum of hydrogen atoms obtained when the transition occurs from $n = 3$ to $n = 2$ state.

6. $\phi = h\upsilon = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{\phi} = \frac{1242 \text{ eV. nm}}{4.125} = 3000 \text{ Å}$

7. The volume of the nucleus is directly proportional to the number of nucleons (mass number) constituting the nucleus.

$\frac{4}{3}\pi R^3 \propto A$ Where $R \rightarrow$ radius

$R \propto A^{1/3}$ $A \rightarrow$ Mass number

$R = R_0 A^{1/3}$

OR

Nuclear forces are strongest forces in nature: Magnitude of nuclear forces is 100 times that of electrostatic force and 10^{38} times the gravitational forces.

Nuclear forces are charge independent: Nuclear forces between a pair of protons, a pair of neutrons or a pair of neutron and proton act with same strength.

8. The junction diode is solar cell.

OR

In forward biasing, the positive terminal of the battery is connected to p-side and the negative terminal to n-side of p-n junction. The forward bias voltage opposes the potential barrier. Due to it, the depletion region becomes thin.

9. (i) Forward biased : As forward voltage opposes the potential barrier and effective barrier potential decreases. It makes the width of the depletion layer smaller.

(ii) Reverse biased : As reverse voltage supports the potential barrier and effective barrier potential increases. It makes the width of the depletion layer larger.

10. (c) : Band gap = 2.5 eV

The wavelength corresponding to 2.5 eV

$= \frac{12400 \text{ eV Å}}{2.5 \text{ eV}} = 4960 \text{ Å}.$

4000 Å can excite this.

11. (c) : When source in Young's double slit experiment is of white light, the central fringe is white as all colours meet there in phase.

12. (d): Electric field at the nearby point will be resultant of existing field and field due to the charge brought. It may increase or decrease if the charge is positive or negative depending on the position of the point with respect to the charge brought.

13. (d): Surface of a charged conductor is always an equipotential surface, whatever may be its shape. Hence σR = constant, at every point on the surface of charged conductor *i.e.*, at the sharpest point ($R \to 0$) of the surface, charge density will be maximum. A uniformly charged conductor exerts no electrostatic force on a point field is zero.

14. (b): For an equiconvex lens, $R_1 = R_2 = R$

From $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

[using lens maker's formula]

For glass, $\mu = 1.5$ placed in air.

Therefore, $\frac{1}{f} = (1.5-1)\frac{2}{R} \Rightarrow f = R.$

15. (i) (a): As τ = either force × perpendicular distance between the two forces

$= qaE\sin\theta$ or $\tau = PE\sin\theta$ or $\tau = \vec{P}\times\vec{E}$ ($\because qa = P$)

(ii) (c): The maximum torque on the dipole in an external electric field is given by

$\tau = pE = q(2a)\times E$

Here, $q = 1\ \mu C = 10^{-6}$ C, $2a = 2$ cm $= 2\times10^{-2}$ m,

$E = 10^5$ N C^{-1}, τ =?

$\therefore\ \tau = 10^{-6}\times2\times10^{-2}\times10^5 = 2\times10^{-3}$ N m

(iii)(d): When θ is 0 or 180°, the τ is minimum, which means the dipole moment should be parallel to the direction of the uniform electric field.

(iv) (c): Net force is zero and torque acts on the dipole, trying to align p with E.

(v) (a): Torque, $\tau = pE\sin\theta$ and potential energy, $U = -pE\cos\theta$

16. (i) (d): Refractive index of a medium depends upon nature and temperature of the medium, wavelength of light.

(ii) (a): Here $\nu = 5\times10^{14}$ Hz; $\lambda = 450\times10^{-9}$m

$c = 3\times10^8$ m s^{-1}

Refractive index of the liquid,

$$\mu = \frac{c}{v} = \frac{c}{\nu\lambda} = \frac{3\times10^8}{5\times10^{14}\times450\times10^{-9}}$$

$\mu = 1.33$

(iii)(b): Here $i = 60°$; $\mu = 1.5$

By snell's law, $\mu = \frac{\sin i}{\sin r}$

$$\sin r = \frac{\sin i}{\mu} = \frac{\sin 60°}{1.5} = \frac{0.866}{1.5}$$

$\sin r = 0.5773$ or $r = \sin^{-1}(0.58)$

(iv) (c): As object is at the centre of the sphere, the image must be at the centre only.

$\therefore$ Distance of virtual image from centre of sphere = 6 cm.

(v) (c): Speed of light in second medium is different than that in first medium.

17. Ratio of magnetic moment and angular momentum is given by $\frac{M}{L} = \frac{q}{2m}$

$$\therefore\ \frac{M}{\frac{2}{5}mr^2\omega} = \frac{q}{2m} \text{ or } M = \frac{1}{5}q\omega r^2$$

18. Position of first minimum in diffraction pattern

$y = \frac{D\lambda}{a}$

So, slit width $a = \frac{D\lambda}{y} = \frac{1\times500\times10^{-9}}{2.5\times10^{-3}} = 2\times10^{-4}$m

OR

Here, $d = 1$ mm $= 1\times10^{-3}$ m

$D = 1$ m, $\lambda = 500$ nm $= 5\times10^{-7}$ m

Fringe spacing,

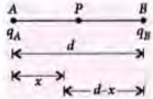
$$\beta = \frac{\lambda D}{d} = \frac{5\times10^{-7}\times1}{1\times10^{-3}} = 5\times10^{-4} \text{ m} = 0.5 \text{ mm}$$

19. $q_A = q$ and $q_B = -2q$

$V_{PA} = \frac{kq_A}{x}$; $V_{PB} = \frac{kq_B}{(d-x)}$

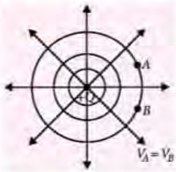
$V_{PA} + V_{PB} = 0$

$\frac{kq}{x} = \frac{2kq}{(d-x)}$; $d - x = 2x$; $3x = d$; $x = \frac{d}{3}$



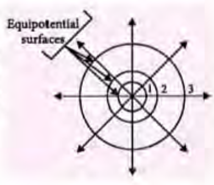
OR

(a)



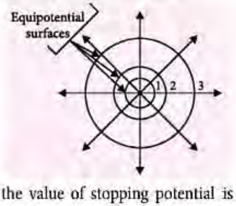
(b) These surfaces are not equidistant from each other because electric field at a point, distance r from point charge, is given by

$$E = +\frac{Q}{4\pi\varepsilon_0 r^2}$$



As electric field $E \propto \frac{1}{r^2}$, the field is non uniform.

So, distance between adjacent equipotential surfaces goes on increasing as shown in figure.



20. Since the value of stopping potential is same for curves a and b, hence frequency υ_1 and υ_2 are the same but their intensities are different.

21. (i) Induced emf in a coil is $\varepsilon = NBA\omega\sin\omega t$

As the angular speed is same, induced emf will also be same in both the loops.

(ii) Current induced in a loop is $I = \frac{\varepsilon}{R} = \frac{\varepsilon A}{\rho l}$

As the resistivity of copper is lesser, more amount of current is induced in it.

22. Here $d = 0.15$ mm $= 0.15 \times 10^{-3}$ m $= 15 \times 10^{-5}$ m

$\lambda = 450$ nm $= 450 \times 10^{-9}$ m $= 4.5 \times 10^{-7}$ m, $D = 1.0$ m

(a) (i) Distance of the second bright fringe

$$x_2 = \frac{2\lambda D}{d} \qquad \left[\because\ x_n = \frac{n\lambda D}{d}\right]$$

$$= \frac{2\times 4.5\times 10^{-7}\times 1.0}{15\times 10^{-5}} = \frac{2\times 4.5}{15}\times 10^{-2}$$

$= 0.6 \times 10^{-2}$ m $= 6$ mm

(ii) Distance of the second dark fringe

$$x_2 = \frac{3\lambda D}{2d} \qquad \left(\because\ x_n = (2n-1)\frac{\lambda}{2}\frac{D}{d}\right)$$

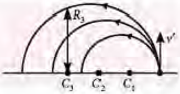
$$= \frac{3\times 4.5\times 10^{-7}\times 1.0}{2\times 15\times 10^{-5}} = \frac{3\times 4.5}{30}\times 10^{-2}$$

$= 0.45 \times 10^{-2}$ m $= 4.5$ mm

(b) Fringe width $\beta = \frac{\lambda D}{d}$

When screen is moved away, D increases, therefore width of the fringes increases but the angular separation (λ/d) remains the same.

23. The path of the particle will be circular .Larger the velocity, larger will be the radius.



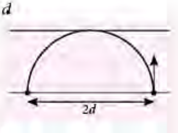
For particle not to strike $R < d$

$$\therefore\ \frac{mv}{qB} < d \Rightarrow v < \frac{qBd}{m}.$$

For limiting case $v = \frac{qBd}{m}$

$R = d$

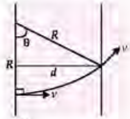
$\therefore$ Coordinate $= (-2d, 0, 0)$



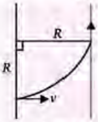
OR

(i) $\sin\theta = \frac{d}{R}$, where $R = \frac{mv}{qB}$

$$\sin\theta = \frac{\frac{mv}{2qB}}{\frac{mv}{qB}} = \frac{1}{2} \quad \text{or} \quad \theta = \frac{\pi}{6}$$



Time spent inside the field, $t = \frac{R\theta}{v} = \frac{\pi R}{6v}$

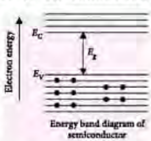


24. (i) The required energy band diagrams are given here :

(a) Energy band diagram of n-type semiconductor at $T > 0$ K

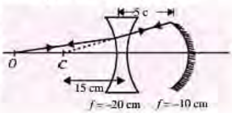
(b) Energy band diagram of p-type semiconductor at $T > 0$ K

(ii) At absolute zero temperature (0 K) conduction band of semiconductor is completely empty, *i.e.*, $\sigma = 0$. Hence the semiconductor behaves as an insulator. At room temperature, some valence electrons acquire enough thermal energy and jump to the conduction band where they are free to conduct electricity. Thus the semiconductor acquires a small conductivity at room temperature.



Energy band diagram of semiconductor at $T = 0$ K

25. Image is formed at the object itself if the image formed due to lens is at centre of curvature of the mirror.

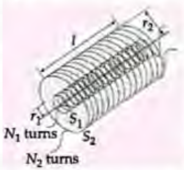


For refraction by lens,

$$\frac{1}{-20}=\frac{1}{-15}-\frac{1}{u} \Rightarrow u=-60\text{ cm}$$

26. (i) The phenomena of inducing current in a circuit by changing the current or flux in a neighbouring circuit is called mutual induction. S.I. unit of mutual inductance is henry denoted by H.

(ii) Consider two long coaxial solenoids each of length l. Let n_1 be the number of turns per unit length of inner solenoid S_1 of radius r_1, n_2 be the number of turns per unit length of outer solenoid S_2 of radius r_2. Let N_1 and N_2 be the total number of turns of solenoids S_1 and S_2 respectively.



When a current I_2 is passed through S_2, the magnetic flux linked with solenoid S_1 is

$N_1\phi_1 = M_{12}I_2$ ...(i)

where M_{12} is called the mutual inductance of solenoid S_1 with respect to solenoid S_2.

It is also referred as the coefficient of mutual induction.

The magnetic field due to current I_2 in S_2 is

$B_2 = \mu_0 n_2 I_2$ ...(ii)

$\therefore$ The magnetic flux linked with S_1 is

$N_1\phi_1 = B_2(\pi r_1^2)n_1 l = \mu_0 n_1 n_2 \pi r_1^2 l I_2$ ...(iii)

where $n_1 l$ is the total number of turns in solenoid S_1.

From (i) and (iii), we get

$M_{12} = \mu_0 n_1 n_2 \pi r_1^2 l$ ...(iv)

which is required expression.

Similarly, $M_{21} = \mu_0 n_1 n_2 \pi r_1^2 l$ ...(v)

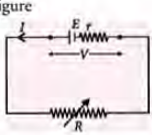
From (iv) and (v), we get

$M_{12} = M_{21} = M$

Hence, coefficient of mutual induction between two coaxial solenoids is

$$M = \mu_0 n_1 n_2 \pi r_1^2 l \text{ or, } M = \frac{\mu_0 N_1 N_2 \pi r_1^2}{l}$$

27. Given situation is shown in figure



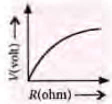
$$I = \frac{E}{r+R}$$

(i) V versus R,

Terminal voltage,

$V = E - Ir$

$$V = E - Ir = E - \frac{E}{r+R}r = \frac{ER}{r+R}$$



(ii) V versus I,

$V = E - Ir$

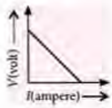
When $R = 4\ \Omega$,

then $I_1 = 1$ A

$$\therefore\ 1 = \frac{E}{r+4};\ r+4 = E \qquad ...(i)$$

When $R = 9\ \Omega$, then $I = 0.5\text{ A} = \frac{1}{2}$ A

$$\therefore\ \frac{1}{2} = \frac{E}{r+9} = \frac{r+4}{r+9} \quad \text{[Using eqn. (i)]}$$



$r + 9 = 2r + 8,\ r = 1\ \Omega$

From eqn. (i)

emf, $E = 1 + 4 = 5$ V

OR

Here, $I = I_1 + I_2$ ...(i)

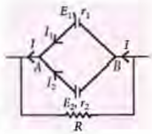
Let V = Potential difference between A and B

For cell E_1,

$$V = E_1 - I_1 r_1 \Rightarrow I_1 = \frac{E_1 - V}{r_1}$$

Similarly, for cell E_2, $I_2 = \frac{E_2 - V}{r_2}$

Putting these values in equation (i)



$$I = \frac{E_1 - V}{r_1} + \frac{E_2 - V}{r_2}$$

$$\text{or } I = \left(\frac{E_1}{r_1} + \frac{E_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

$$\text{or } V = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right) - I\left(\frac{r_1 r_2}{r_1 + r_2}\right) \qquad ...(ii)$$

Comparing the above equation with the equivalent circuit of emf 'E_{eq}' and internal resistance 'r_{eq}' then,

$V = E_{eq} - I r_{eq}$ ...(iii)

Then

$$E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} \text{ and } r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

28. From Einstein's equation

$$h\upsilon = \phi_0 + K = \phi_0 + eV_s \text{ or } \phi_0 = h\upsilon - eV_s = \frac{hc}{\lambda} - eV_s$$

(Equation is independent of the power of the source)

$$\phi_0 = \frac{6.6\times10^{-34}\times3\times10^{8}}{2271\times10^{-10}} - 1.3 \text{ eV}$$

$$= \left(\frac{6.6\times10^{-34}\times3\times10^{8}}{2271\times10^{-10}\times1.6\times10^{-19}} - 1.3\right)\text{eV}$$

$= 5.5$ eV $- 1.3$ eV $= 4.2$ eV

OR

$$K_{max} = \frac{hc}{\lambda} - \phi$$

$$\frac{p^2}{2m} = \left(\frac{1.24\times10^{4}}{4000} - 2.5\right)\text{eV} = 0.6 \text{ eV}$$

$$p = \sqrt{2\times9.1\times10^{-31}\times0.6\times1.6\times10^{-19}}$$

$= 4.2 \times 10^{-25}$ kg m s^{-1}

29. (i) The negative sign signifies that the electron is bound to the nucleus and the force is attractive. So, energy has to be supplied to remove the electron from the nucleus.

(ii) Energy of hydrogen atom in n^{th} state is

$$E_n = -\frac{13.6}{n^2} \text{ where, } n = 1, 2, 3, ...$$

In the ground state, $n = 1$

$$E_1 = -\frac{13.6}{1^2} = -13.6 \text{ eV}$$

In the first excited state, $n = 2$,

$$E_2 = -\frac{13.6}{2^2} = -3.4 \text{ eV}$$

$\therefore$ Required energy $= E_2 - E_1$

$= (-3.4) - (-13.6) = 10.2$ eV

30. (i) Isotones : $_{80}Hg^{198}$, $_{79}Au^{197}$

(ii) Isotopes : $_6C^{12}$ $_6C^{14}$

(iii) Isobars : $_2He^3$, $_1H^3$

Volume of the nucleus $\propto$ mass number

$$\frac{4}{3}\pi R^3 \propto A$$

Where R is the radius of the nucleus.

or $R \propto A^{1/3}$ *i.e.*, $R = R_0 A^{1/3}$

Where R_0 is a constant. Its value is 1.1×10^{-15} m.

$$\text{Nuclear density, } \rho = \frac{\text{Mass of nucleus}}{\text{Volume of nucleus}}$$

$$\rho = \frac{mA}{\frac{4}{3}\pi R_0^3 A}; \rho = \frac{3m}{4\pi R_0^3}$$

Thus, density of nuclear matter is independent of the size of the nucleus.

31. *Refer to answer 22(a), page no. 13 (MTG CBSE Champion Physics Class 12).*

OR

(a) *Refer to answer 29, page no. 34 (MTG CBSE Champion Physics Class 12).*

(b) *Refer to answer 24, page no. 34 (MTG CBSE Champion Physics Class 12).*

32. *Refer to answer 37, page no. 162-163 (MTG CBSE Champion Physics Class 12).*

OR

Refer to answer 74, page no. 170 (MTG CBSE Champion Physics Class 12).

33. *Refer to answer 49, page no. 248-249 (MTG CBSE Champion Physics Class 12).*

OR

Refer to answer 122, page no. 224 (MTG CBSE Champion Physics Class 12).

❖❖