JEE–MAIN EXAMINATION – JANUARY 2025

(HELD ON TUESDAY 28th JANUARY 2025) **TIME : 3 : 00 PM TO 6 : 00 PM**

PHYSICS — TEST PAPER WITH SOLUTION

SECTION-A

26. A uniform magnetic field of 0.4 T acts perpendicular to a circular copper disc 20 cm in radius. The disc is having a uniform angular velocity of 10 π rad s^{-1} about an axis through its centre and perpendicular to the disc. What is the potential difference developed between the axis of the disc and the rim ? (π = 3.14)

(1) 0.0628 V (2) 0.5024 V

(3) 0.2512 V (4) 0.1256 V

Ans. (3)

Sol. B = 0.4 T

r = 20 cm

ω = 10π rad/s

$$E = \frac{1}{2}B\omega R^2$$

= 0.2512 V

27. A parallel plate capacitor of capacitance 1 μF is charged to a potential difference of 20 V. The distance between plates is 1 μm. The energy density between plates of capacitor is :

(1) 1.8×10^3 J/m^3 (2) 2×10^{-4} J/m^3

(3) 2×10^2 J/m^3 (4) 1.8×10^5 J/m^3

Ans. (1)

Sol. C = 1 μF

V = 20 V

d = 1 μm

Energy density = $= \frac{1}{2}\epsilon_0 E^2$

$$E = \frac{V}{d} = 20\times10^6 \text{ v/m}$$

U = 1.77×10^3 J/m^3

28. Match **List-I** with **List-II**

	List-I		List-II
(A)	Angular Impulse	(I)	$[M^0 L^2 T^{-2}]$
(B)	Latent Heat	(II)	$[M L^2 T^{-3} A^{-1}]$
(C)	Electrical resistivity	(III)	$[M L^2 T^{-1}]$
(D)	Electromotive force	(IV)	$[M L^3 T^{-3} A^{-2}]$

Choose the **correct** answer from the options given below :

(1) (A)-(III), (B)-(I), (C)-(IV), (D)-(II)

(2) (A)-(I), (B)-(III), (C)-(IV), (D)-(II)

(3) (A)-(III), (B)-(I), (C)-(II), (D)-(IV)

(4) (A)-(II), (B)-(I), (C)-(IV), (D)-(III)

Ans. (1)

Sol. Angular impulse = $[M L^2 T^{-1}]$

Latent Heat = $[M^0 L^2 T^{-2}]$

Electrical resistivity = $[M L^3 T^{-3} A^{-2}]$

Electromotive force = $[M L^2 T^{-3} A^{-1}]$

29. The ratio of vapour densities of two gases at the same temperature is $\frac{4}{25}$, then the ratio of r.m.s. velocities will be :

(1) $\frac{25}{4}$ (2) $\frac{2}{5}$

(3) $\frac{5}{2}$ (4) $\frac{4}{25}$

Ans. (3)

Sol. $\frac{\rho_1}{\rho_2} = \frac{4}{25}$

Ratio of rms velocities = $\sqrt{\frac{\rho_2}{\rho_1}} = \frac{5}{2}$

30. The kinetic energy of translation of the molecules in 50g of CO_2 gas at 17°C is :

(1) 3986.3 J (2) 4102.8 J

(3) 4205.5 J (4) 3582.7 J

Ans. (2)

Sol. $(KE)_{Translational} = \left[\frac{3}{2}KT\right] \times$ no. of molecule

No. of molecule $= \left[\frac{50}{44}\times 6.023\times 10^{23}\right]$

$(KE)_{Translational} = 4108.644$ J

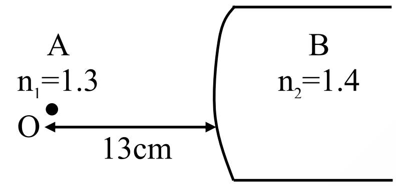
31. In a long glass tube, mixture of two liquids A and B with refractive indices 1.3 and 1.4 respectively, forms a convex refractive meniscus towards A. If an object placed at 13 cm from the vertex of the meniscus in A forms an image with a magnification of '–2' then the radius of curvature of meniscus is :

(1) 1 cm (2) $\frac{1}{3}$cm

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

Ans. (3)

Sol.



$$\frac{n_2}{v}-\frac{n_1}{u}\frac{n_2-n_1}{R}$$

$$\frac{1.4}{v}-\frac{1.3}{-13}=\frac{0.1}{R}$$

$$\frac{1.4}{v}=\frac{1-R}{10R}$$

$$\frac{1.4}{v}=\frac{1-R}{10R}$$

$$m=\frac{v/n_2}{u/n_1}$$

$$-2\times\frac{(-13)}{1.3}=\frac{10R}{1-R}$$

$$R=\frac{2}{3}\text{cm}$$

32. The frequency of revolution of the electron in Bohr's orbit varies with n, the principal quantum number as

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

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

Ans. (2)

Sol. Frequency of revolution $\propto \frac{1}{n^3}$

33. Which of the following phenomena can not be explained by wave theory of light ?

(1) Reflection of light

(2) Diffraction of light

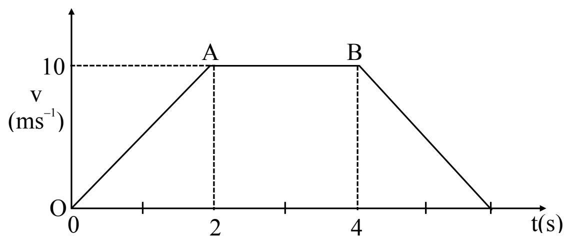
(3) Refraction of light

(4) Compton effect

Ans. (4)

Sol. Comptan effect is based on particle nature of light.

34. The velocity-time graph of an object moving along a straight line is shown in figure. What is the distance covered by the object between t = 0 to t = 4s ?



(1) 30 m (2) 10 m

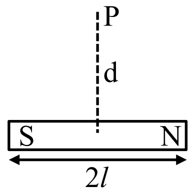
(3) 13 m (4) 11 m

Ans. (1)

Sol. Distance = Area under v v/s t graph

Distance $= \frac{1}{2}\times 2\times 10+2\times 10=30$m

35.



A bar magnet has total length $2l = 20$ units and the field point P is at a distance d = 10 units from the centre of the magnet. If the relative uncertainty of length measurement is 1%, then uncertainty of the magnetic field at point P is :

(1) 10% (2) 4%

(3) 3% (4) 5%

Ans. (2,3)

Sol. Method-1 :

Without considering uncentainity in ℓ.

$$B = \frac{\mu_0}{4\pi}\frac{m}{r^3}$$

$$B \propto \frac{1}{r^3}$$

$$\frac{\Delta B}{B} = 3 \times \left(\frac{\Delta r}{r}\right)$$

% uncertainity in B = 3%

Method-2 :

With considering uncentainity in ℓ.

$$B \propto \frac{1}{r^3}$$

$$\frac{\Delta B}{B} = \frac{\Delta \ell}{\ell} + 3 \times \left(\frac{\Delta r}{r}\right) = 1 + 3 \times 1 = 4\%$$

% uncertainity in B = 4%

36. Earth has mass 8 times and radius 2 times that of a planet. If the escape velocity from the earth is 11.2 km/s, the escape velocity in km/s from the planet will be :

(1) 11.2 (2) 5.6

(3) 2.8 (4) 8.4

Ans. (2)

Sol. $V_{escape} = \sqrt{\frac{2GM}{R}}$

$$\frac{(V_{escape})_{Planet}}{(V_{escape})_{Earth}} = \sqrt{\left(\frac{M_P}{M_E}\right) \times \left(\frac{R_E}{R_P}\right)} = \frac{1}{2}$$

$$(V_{escape})_{Planet} = \frac{1}{2}(V_{escape})_{Earth} = 5.6 \text{km/s}$$

37. Given below are two statements. One is labelled as **Assertion (A)** and the other is labelled as **Reason (R)**.

Assertion (A) : Knowing initial position x_0 and initial momentum p_0 is enough to determine the position and momentum at any time t for a simple harmonic motion with a given angular frequency ω.

Reason (R) : The amplitude and phase can be expressed in terms of x_0 an p_0.

In the light of the above statements, choose the **correct** answer from the options given below :

(1) Both **(A)** and **(R)** are true but **(R)** is **NOT** the correct explanation of **(A)**.

(2) **(A)** is false but **(R)** is true.

(3) **(A)** is true but **(R)** is false.

(4) Both **(A)** and **(R)** are true and **(R)** is the correct explanation of **(A)**.

Ans. (4)

Sol. $x = A \sin(\omega t + \phi)$

$x_0 = A \sin\phi$ …(1)

$p = mA\omega \cos(\omega t + \phi)$

$p_0 = mA\omega \cos\phi$ ….(2)

$$(2)/(1) \Rightarrow \tan\phi = \left(\frac{x_0}{p_0}\right) m\omega$$

$$\sin\phi = \frac{x_0 m\omega}{\sqrt{(m\omega x_0)^2 + p_0^2}}$$

$$\text{From (1), } A = \frac{x_0}{\sin\phi} = \frac{\sqrt{(m\omega x_0)^2 + p_0^2}}{m\omega}$$

This means we can explain assertion with the given reason.

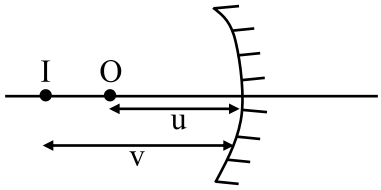
38. A concave mirror produces an image of an object such that the distance between the object and image is 20 cm. If the magnification of the image is '–3', then the magnitude of the radius of curvature of the mirror is :

(1) 3.75 cm (2) 30 cm

(3) 7.5 cm (4) 15 cm

Ans. (4)

Sol.



$m = -3 = -\frac{v}{u}$ and $v - u = 20$ cm

$f = \frac{vu}{v+u} = \frac{(-30)(-10)}{-30-10}$

$\therefore R = +15$

39. A body of mass 4 kg is placed on a plane at a point P having coordinate (3, 4) m. Under the action of force $\vec{F} = \left(2\hat{i} + 3\hat{j}\right)N$, it moves to a new point Q having coordinates (6, 10)m in 4 sec. The average power and instantaneous power at the end of 4 sec are in the ratio of :

(1) 13 : 6 (2) 6 : 13

(3) 1 : 2 (4) 4 : 3

Ans. **(2)**

Sol. $<p> = \frac{(2\hat{i}+3\hat{j}).(3\hat{i}+6\hat{j})}{4} = 6$

$\vec{a} = \left(\frac{\vec{F}}{m} = \frac{1}{2}\hat{i} + \frac{3}{4}\hat{j}\right)$

$\vec{v}$ at $t = 4$ sec $= \left(\frac{1}{2}\hat{i} + \frac{3}{4}\hat{j}\right) \times 4 = (2\hat{i} + 3\hat{j})$

$P_{ins} = (2\hat{i} + 3)(2\hat{i} + 3\hat{j}) = 13$

$\frac{<P>}{P_{ins}} = \frac{6}{13}$

Note : Given data is not matching.

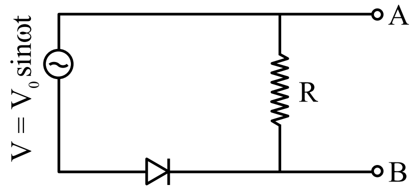
$S = ut + \frac{1}{2}at^2$

$S = 0 + \frac{1}{2}\frac{(2\hat{i}+3\hat{j})}{4}(4)^2 = 4\hat{i} + 6\hat{j}$

If $\vec{r}_i = 3\hat{i} + 4\hat{j}$ then $\vec{r}_f = 7\hat{i} + 10\hat{j}$

But Final position given in the question is (6, 10).

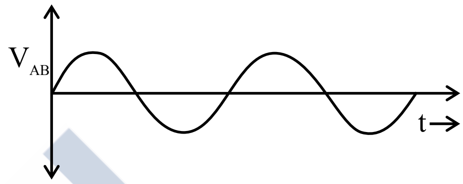
40.



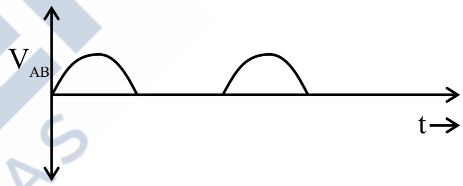
In the circuit shown here, assuming threshold voltage of diode is negligibly small, then voltage V_{AB} is correctly represented by :

(1) V_{AB} would be zero at all times

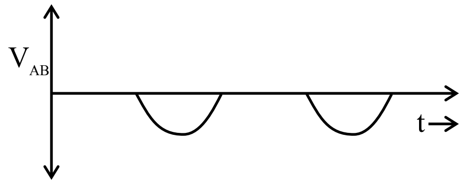
(2)



(3)



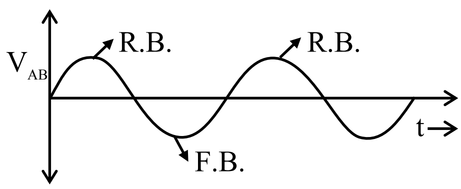
(4)



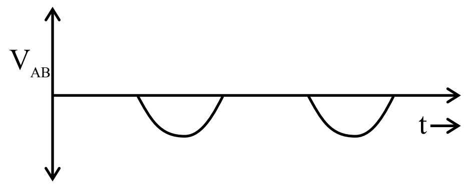
Ans. **(4)**

Sol. $V = V_0 \sin\omega t$

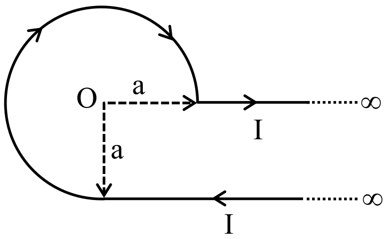
Input



Output



41.



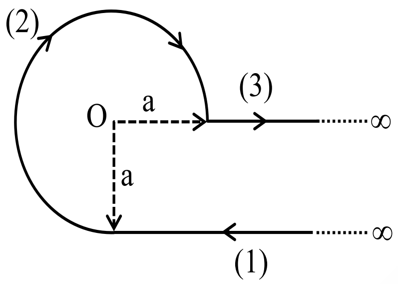
An infinite wire has a circular bend of radius a, and carrying a current I as shown in figure. The magnitude of magnetic field at the origin O of the arc is given by :

(1) $\frac{\mu_0}{4\pi}\frac{I}{a}\left[\frac{\pi}{2}+1\right]$ (2) $\frac{\mu_0}{4\pi}\frac{I}{a}\left[\frac{3\pi}{2}+1\right]$

(3) $\frac{\mu_0}{2\pi}\frac{I}{a}\left[\frac{\pi}{2}+2\right]$ (4) $\frac{\mu_0}{4\pi}\frac{I}{a}\left[\frac{3\pi}{2}+2\right]$

Ans. (2)

Sol.



$B_1 = \frac{\mu_0 i}{4\pi a} \otimes$

$B_2 = \frac{\mu_0}{4\pi}\frac{i}{a}\left(\frac{3\pi}{2}\right) \otimes$

$B_3 = 0$

$B = \frac{\mu_0}{4\pi}\frac{i}{a}\left(1 \frac{3\pi}{2}\right) \otimes$

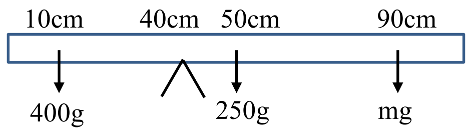
42. A uniform rod of mass 250 g having length 100 cm is balanced on a sharp edge at 40 cm mark. A mass of 400 g is suspended at 10 cm mark. To maintain the balance of the rod, the mass to be suspended at 90 cm mark, is

(1) 300 g (2) 190 g

(3) 200 g (4) 290 g

Ans. (2)

Sol.



$\tau_{Net} = 0 \Rightarrow (400g \times 30) = (250g \times 10)\ (mg \times 50)$

$m = \frac{12000 - 2500}{50} = \frac{9500}{50}$

M = 190 g

43. a 400 g solid cube having an edge of length 10 cm floats in water. How much volume of the cube is outside the water ?

(Given : density of water = 1000 kg m^{-3})

(1) 1400 cm^3 (2) 4000 cm^3

(3) 400 cm^3 (4) 600 cm^3

Ans. (4)

Sol. $Mg = F_B \Rightarrow (400 \times 10^{-3}) = 10^3 \times V_d$

$V_d = 400 \times 10^{-6}\ m^3$

$(\text{Vol.})_{outside} = (10 \times 10^{-2})^3 - 400 \times 10^{-6}$

$= 600 \times 10^{-6}\ m^2 = 600\ cm^3$

44. The magnetic field of an E.M. wave is given by

$\vec{B} = \left(\frac{\sqrt{3}}{2}\hat{i} + \frac{1}{2}\hat{j}\right)30\sin\left[\omega\left(t - \frac{z}{c}\right)\right]$ (S.I. Units)

The corresponding electric field in S.I. units is :

(1) $\vec{E} = \left(\frac{1}{2}\hat{i} - \frac{\sqrt{3}}{2}\hat{j}\right)30c\sin\left[\omega\left(t - \frac{z}{c}\right)\right]$

(2) $\vec{E} = \left(\frac{3}{4}\hat{i} + \frac{1}{4}\hat{j}\right)30c\cos\left[\omega\left(t - \frac{z}{c}\right)\right]$

(3) $\vec{E} = \left(\frac{1}{2}\hat{i} + \frac{\sqrt{3}}{2}\hat{j}\right)30c\sin\left[\omega\left(t + \frac{z}{c}\right)\right]$

(4) $\vec{E} = \left(\frac{\sqrt{3}}{2}\hat{i} - \frac{1}{2}\hat{j}\right)30c\sin\left[\omega\left(t + \frac{z}{c}\right)\right]$

Ans. (1)

Sol. $\vec{B} = \left(\frac{\sqrt{3}}{2}\hat{i} + \frac{1}{2}\hat{j}\right)30\sin\left[\omega\left(t - \frac{z}{c}\right)\right]$

$\vec{E} = \vec{B} \times \vec{c}$ and $E = B_0 c$

Here $\vec{E}\left(\frac{\sqrt{3}}{2}(-\hat{j}) + \frac{1}{2}\hat{i}\right)$

$E_0 = 30c$

$\vec{E} = \left(\frac{1}{2}\hat{i} - \frac{\sqrt{3}}{2}\hat{j}\right)30c\sin\left[\omega\left(t - \frac{z}{c}\right)\right]$

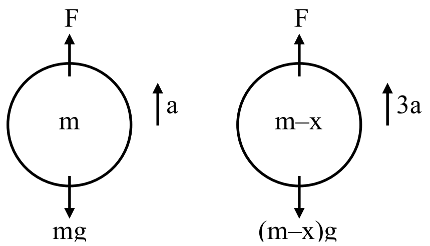
45. A balloon and its content having mass M is moving up with an acceleration 'a'. The mass that must be released from the content so that the balloon starts moving up with an acceleration '3a' will be : (Take 'g' as acceleration due to gravity)

(1) $\frac{3Ma}{2a-g}$ (2) $\frac{3Ma}{2a+g}$

(3) $\frac{2Ma}{3a+g}$ (4) $\frac{2Ma}{3a-g}$

Ans. (3)

Sol.



$F - mg = ma$

$F = ma + mg$

$F - (m - x)g = (m - x)\, 3a$

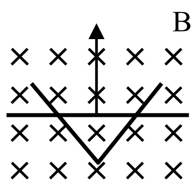
Put F

$Ma + mg - mg + xg = 3ma - 3xa$

$x = \frac{2ma}{g+3a}$

SECTION-B

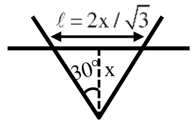
46.



A conducting bar moves on two conducting rails as shown in the figure. A constant magnetic field B exists into the page. The bar starts to move from the vertex at time t = 0 with a constant velocity. If the induced EMF is $E \propto t^n$, then value of n is ___ .

Ans. (1)

Sol.



$E = \ell v B$

$E = \frac{2x}{\sqrt{3}} \times vB$ and $x = vt$

$E = \frac{2}{\sqrt{3}} v^2 B t$ $E \propto t^1$

47. An electric dipole of dipole moment 6×10^{-6} Cm is placed in uniform electric field of magnitude 10^6 V/m. Initially, the dipole moment is parallel to electric field. The work that needs to be done on the dipole to make its dipole moment opposite to the field, will be _____ J.

Ans. (12)

Sol. $p = 6 \times 10^{-6}$ Cm

$E = 10^6$ v/m

$W = \Delta U = -pE(\cos\theta_f - \cos\theta_i)$

$W = 2pE = 12$ J

48. The volume contraction of a solid copper cube of edge length 10 cm, when subjected to a hydraulic pressure of 7×10^6 Pa, would be _____ mm^3.

(Given bulk modulus of copper = 1.4×10^{11} Nm^{-2})

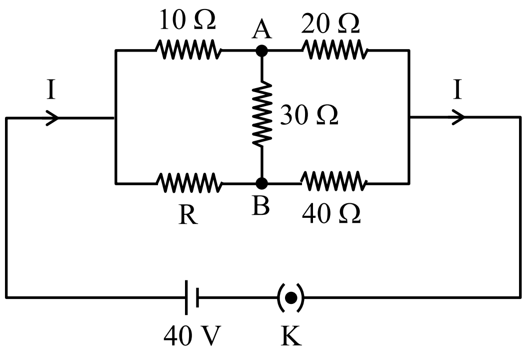
Ans. (50)

Sol. $B = \frac{\Delta P}{\frac{\Delta V}{V}}$

$\Delta V = \frac{7 \times 10^6}{1.4 \times 10^{11}} \times (10 \times 10^{-2})^3$

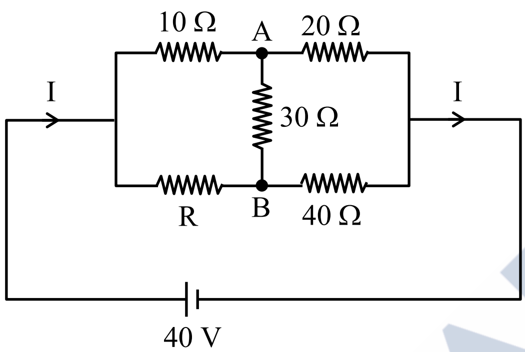
$\Delta V = 50\ mm^3$

49. The value of current I in the electrical circuit as given below, when potential at A is equal to the potential at B, will be __________ A.



Ans. (2)

Sol.



$V_A = V_B \Rightarrow$ the bridge is balanced

$\Rightarrow \frac{10}{R} = \frac{20}{40}$

$R = 20\Omega$

$I = \frac{40}{20} = 2A$

50. A thin transparent film with refractive index 1.4, is held on circular ring of radius 1.8 cm. The fluid in the film evaporates such that transmission through the film at wavelength 560 nm goes to a minimum every 12 seconds. Assuming that the film is flat on its two sides, the rate of evaporation is _______ $\pi \times 10^{-13}$ m^3/s.

Ans. (54)

Sol. Maxima condition

$$2\mu t = n\lambda \Rightarrow \mathbf{t = \frac{n\lambda}{2\mu}} \Rightarrow t = \frac{\lambda}{2\mu}, \frac{2\lambda}{2\mu}, ...$$

Minima condition $2\mu t = (2n - 1)\lambda/2$

$$\Rightarrow \mathbf{t = \frac{(2n-1)\lambda}{4\mu}} \Rightarrow t = \frac{\lambda}{4\mu}, \frac{3\lambda}{4\mu}, ...$$

$$\mathbf{\Delta t = \frac{2\lambda}{4\mu}}$$

$$\text{Rate of evaporation} = \frac{A(\Delta t)}{\text{time}} = 54 \times 10^{-13}\ m^3/s$$