JEE–MAIN EXAMINATION – JANUARY 2025

(HELD ON WEDNESDAY 29th JANUARY 2025) **TIME : 9 : 00 AM TO 12 : 00 NOON**

PHYSICS

TEST PAPER WITH SOLUTION

SECTION-A

26. Given below are two statements : one is labelled as **Assertion (A)** and the other is labelled as **Reason (R)**.

Assertion (A) : Choke coil is simply a coil having a large inductance but a small resistance. Choke coils are used with fluorescent mercury-tube fittings. If household electric power is directly connected to a mercury tube, the tube will be damaged.

Reason (R) : By using the choke coil, the voltage across the tube is reduced by a factor $\left(R/\sqrt{R^2+\omega^2L^2}\right)$, where ω is frequency of the supply across resistor R and inductor L. If the choke coil were not used, the voltage across the resistor would be the same as the applied voltage.

In the light of the above statements, choose the **most appropriate 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) Both **(A)** and **(R)** are true and **(R)** is the correct explanation of **(A)**.

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

Ans. (3)

Sol. A: Correct

B : Correct with correct explanation

27. Two projectiles are fired with same initial speed from same point on ground at angles of (45° – α) and (45° + α), respectively, with the horizontal direction. The ratio of their maximum heights attained is :

(1) $\frac{1-\tan\alpha}{1+\tan\alpha}$ (2) $\frac{1+\sin\alpha}{1-\sin\alpha}$

(3) $\frac{1-\sin2\alpha}{1+\sin2\alpha}$ (4) $\frac{1+\sin2\alpha}{1-\sin2\alpha}$

Ans. (3)

Sol. $H_{Max}=\frac{(u\sin\theta)^2}{2g}$

$$\frac{(H_{max})_1}{(H_{max})_2}=\frac{u^2\sin^2(45-\alpha)}{u^2\sin^2(45+\alpha)}$$

$$=\frac{\left(\frac{1}{\sqrt2}\cos\alpha-\frac{1}{\sqrt2}\sin\alpha\right)^2}{\left(\frac{1}{\sqrt2}\cos\alpha+\frac{1}{\sqrt2}\sin\alpha\right)^2}$$

$$=\frac{1-\sin2\alpha}{1+\sin2\alpha}$$

28. An electric dipole of mass m, charge q, and length l is placed in a uniform electric field $\vec{E}=E_0\hat{i}$. When the dipole is rotated slightly from its equilibrium position and released, the time period of its oscillations will be :

(1) $\frac{1}{2\pi}\sqrt{\frac{2ml}{qE_0}}$ (2) $2\pi\sqrt{\frac{ml}{qE_0}}$

(3) $\frac{1}{2\pi}\sqrt{\frac{ml}{2qE_0}}$ (4) $2\pi\sqrt{\frac{ml}{2qE_0}}$

Ans. (4)

Sol. $I\omega2\theta=q\ell E_0\theta$

$$2m\left(\frac{\ell}{2}\right)^2\omega^2=q\ell E_0$$

$$\omega^2=\frac{2qE_0}{m\ell}$$

$$T=2\pi\sqrt{\frac{m\ell}{2qE_0}}$$

29. The pair of physical quantities not having same dimensions is :

(1) Torque and energy

(2) Surface tension and impulse

(3) Angular momentum and Planck's constant

(4) Pressure and Young's modulus

Ans. (2)

Sol. $[\tau] = [E]$

$[\sigma] \neq [I]$

$[L] = [h]$

$[P] = [Y]$

30. Given below are two statements : one is labelled as **Assertion (A)** and the other is labelled as **Reason (R)**.

Assertion (A) : Time period of a simple pendulum is longer at the top of a mountain than that at the base of the mountain.

Reason (R) : Time period of a simple pendulum decreases with increasing value of acceleration due to gravity and vice-versa.

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

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

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

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

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

Ans. (2)

Sol. As h increases, g decreases, T increases

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

$$g = \frac{g_0R^2}{(R+h)^2}$$

31. The expression given below shows the variation of velocity (v) with time (t), $v = At^2 + \frac{Bt}{C+t}$. The dimension of ABC is :

(1) $[M^0L^2T^{-3}]$ (2) $[M^0L^1T^{-3}]$

(3) $[M^0L^1T^{-2}]$ (4) $[M^0L^2T^{-2}]$

Ans. (1)

Sol. $[LT^{-1}] = [A]\,[T^2] = \frac{[B][T]}{[C]+[T]}$

$[C] = [T]$

$[A] = [LT^{-3}]$

$[B] = [LT^{-1}]$

$[ABC] = [L^2T^{-3}]$

32. Consider I_1 and I_2 are the currents flowing simultaneously in two nearby coils 1 & 2, respectively. If L_1 = self inductance of coil 1, M_{12} = mutual inductance of coil 1 with respect to coil 2, then the value of induced emf in coil 1 will be

(1) $\varepsilon_1 = -L_1\frac{dI_1}{dt} + M_{12}\frac{dI_2}{dt}$

(2) $\varepsilon_1 = -L_1\frac{dI_1}{dt} - M_{12}\frac{dI_1}{dt}$

(3) $\varepsilon_1 = -L_1\frac{dI_1}{dt} - M_{12}\frac{dI_2}{dt}$

(4) $\varepsilon_1 = -L_1\frac{dI_2}{dt} - M_{12}\frac{dI_1}{dt}$

Ans. (3)

Sol. $\phi_1 = L_1I_1 + M_{12}I_2$

$$\varepsilon_1 = -\frac{d\phi_1}{dt} = -L_1\frac{dI_1}{dt} - M_{12}\frac{dI_2}{dt}$$

33. At the interface between two materials having refractive indices n_1 and n_2, the critical angle for reflection of an em wave is θ_{1C}. The n_2 material is replaced by another material having refractive index n_3, such that the critical angle at the interface between n_1 and n_3 materials is θ_{2C}. If $n_3 > n_2 > n_1$; $\frac{n_2}{n_3} = \frac{2}{5}$ and $\sin\theta_{2C} - \sin\theta_{1C} = \frac{1}{2}$, then θ_{1C} is

(1) $\sin^{-1}\left(\frac{1}{6n_1}\right)$ (2) $\sin^{-1}\left(\frac{2}{3n_1}\right)$

(3) $\sin^{-1}\left(\frac{5}{6n_1}\right)$ (4) $\sin^{-1}\left(\frac{1}{3n_1}\right)$

NTA Ans. (4)

Sol. $\sin\theta_{1C} = \frac{n_1}{n_2}$

$\sin\theta_{2C} = \frac{n_1}{n_3}$

$\sin\theta_{2C} - \sin\theta_{1C} = \frac{1}{2}$

$$n_1\frac{n_2}{n_3}-\frac{n_1}{n_2}=\frac{1}{2}$$

$$n_1\frac{n_2}{n_3}-n_1=\frac{n_2}{2}$$

$$n_1\left(\frac{2}{5}-1\right)=\frac{n_2}{2}$$

$$\frac{n_1}{n_2}=\frac{-5}{6}$$

$$=\sin^{-1}\left(-\frac{5}{6}\right)$$

34. Consider a long straight wire of a circular cross-section (radius a) carrying a steady current I. The current is uniformly distributed across this cross-section. The distances from the centre of the wire's cross-section at which the magnetic field [inside the wire, outside the wire] is half of the maximum possible magnetic field, any where due to the wire, will be

(1) $[a/4, 3a/2]$ (2) $[a/2, 2a]$

(3) $[a/2, 3a]$ (4) $[a/4, 2a]$

Ans. **(2)**

Sol. Maximum possible magnetic field is at the surface

$$B_{max}=\frac{\mu_0 I}{2\pi a}$$

$$\frac{B_{max}}{2}=\frac{\mu_0 I}{4\pi a}$$

It can be obtained inside as well as outside the wire

For inside,

$$\frac{\mu_0 I}{4\pi a}=\frac{\mu_0 I r}{2\pi a^2}$$

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

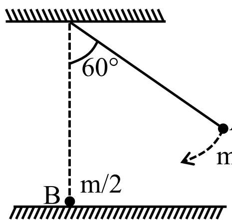
For outside

$$\frac{\mu_0 I}{4\pi a}=\frac{\mu_0 I}{2\pi r}$$

$$\Rightarrow r=2a$$

Correct answer $\left[\frac{a}{2}, 2a\right]$

35. As shown below, bob A of a pendulum having massless string of length 'R' is released from 60° to the vertical. It hits another bob B of half the mass that is at rest on a friction less table in the centre. Assuming elastic collision, the magnitude of the velocity of bob A after the collision will be (take g as acceleration due to gravity)

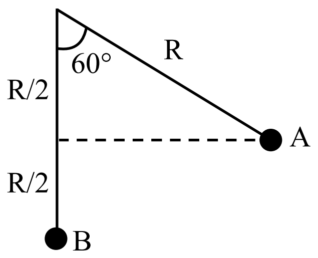


(1) $\frac{1}{3}\sqrt{Rg}$ (2) $\sqrt{Rg}$

(3) $\frac{4}{3}\sqrt{Rg}$ (4) $\frac{2}{3}\sqrt{Rg}$

Ans. **(1)**

Sol.



Velocity of a just before hitting :

$$u=\sqrt{2g\frac{R}{2}}=\sqrt{gR}$$

Just after collision, let velocity of A and B are v_1 and v_2 respectively

$\therefore$ by COM:

$$mu=mv_1+\frac{m}{2}v_2$$

$$2v_1+v_2=2u \quad \text{....(i)}$$

$$e=1=\frac{v_2-v_1}{u}$$

$$\Rightarrow v_2-v_1=u \quad \text{....(ii)}$$

From (i) –(ii)

$$\Rightarrow 3v_1=u \Rightarrow v_1=\frac{u}{3}=\frac{1}{3}\sqrt{gR}$$

36. Given below are two statements : one is labelled as **Assertion (A)** and the other is labelled as **Reason (R)**.

Assertion (A) : Emission of electrons in photoelectric effect can be suppressed by applying a sufficiently negative electron potential to the photoemissive substance.

Reason (R) : A negative electric potential, which stops the emission of electrons from the surface of a photoemissive substance, varies linearly with frequency of incident radiation.

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

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

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

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

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

Ans. **(4)**

Sol. (A) : True

(B) : True but not correct explanation

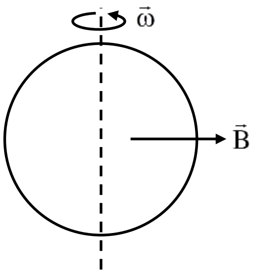
37. A coil of area A and N turns is rotating with angular velocity ω in a uniform magnetic field $\vec{B}$ about an axis perpendicular to $\vec{B}$. Magnetic flux φ and induced emf ε across it, at an instant when $\vec{B}$ is parallel to the plane of coil, are :

(1) $\varphi = AB, \varepsilon = 0$ (2) $\varphi = 0, \varepsilon = NAB\omega$

(3) $\varphi = 0, \varepsilon = 0$ (4) $\varphi = AB, \varepsilon = NAB\omega$

Ans. **(2)**

Sol.



$\phi = BAN.\cos(\omega t)$

$\varepsilon = \frac{-d\phi}{dt} = BA\omega N.\sin(\omega t)$

When B is parallel to plane, $\omega t = \frac{\pi}{2}$

$\Rightarrow \phi = 0, \varepsilon = BA\omega N$

38. The fractional compression $\left(\frac{\Delta V}{V}\right)$ of water at the depth of 2.5 km below the sea level is ________%. Given, the Bulk modulus of water = 2×10^9 Nm^{-2}, density of water = 10^3 kg m^{-3}, acceleration due to gravity = g = 10 ms^{-2}.

(1) 1.75 (2) 1.0

(3) 1.5 (4) 1.25

Ans. **(4)**

Sol. $B = \frac{\rho g h}{\left(\frac{\Delta v}{v}\right)}$

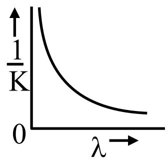
$\frac{\Delta v}{v} \times 100 = \frac{\rho g h}{B} \times 100$

$\frac{1000 \times 10 \times 2.5 \times 10^3}{2 \times 10^9} \times 100\%$

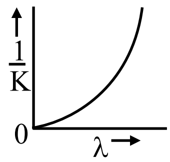
$= 1.25\ \%$

39. If λ and K are de Broglie Wavelength and kinetic energy, respectively, of a particle with constant mass. The correct graphical representation for the particle will be :-

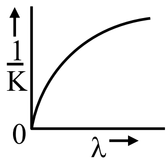
(1)



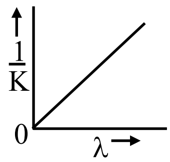
(2)



(3)



(4)



Ans. **(2)**

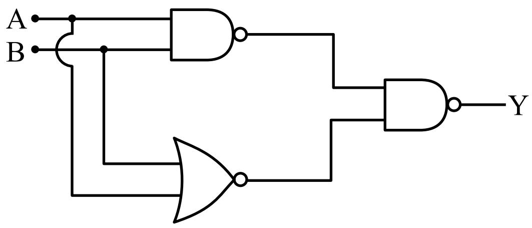
Sol. $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mK}}$

$\lambda^2 = \frac{h^2}{2m}\left(\frac{1}{k}\right)$

$Y = cx^2$

Upward facing parabola passing through origin.

40.



For the circuit shown above, equivalent GATE is :

(1) OR gate (2) NOT gate

(3) AND gate (4) NAND gate

Ans. (1)

Sol.

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

$\Rightarrow$ OR Gate

41. A body of mass 'm' connected to a massless and unstretchable string goes in verticle circle of radius 'R' under gravity g. The other end of the string is fixed at the center of circle. If velocity at top of circular path is $n\sqrt{gR}$, where, $n \geq 1$, then ratio of kinetic energy of the body at bottom to that at top of the circle is

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

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

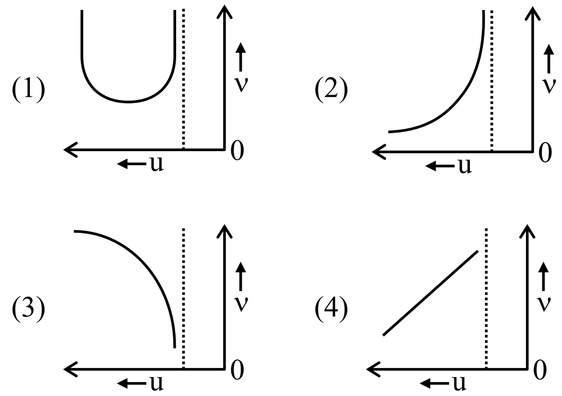
Ans. (4)

Sol. $V_{Top} = \sqrt{n^2 gR}$

$V_{Bottom} = \sqrt{n^2 gR + 4gR}$

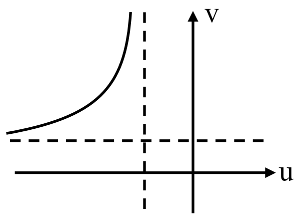
$\text{Ratio} = \frac{n^2+4}{n^2}$

42. Let u and v be the distances of the object and the image from a lens of focal length *f*. The correct graphical representation of u and v for a convex lens when $|u| > f$, is



Ans. (2)

Sol. $(u + f)(v - f) = f^2$



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

	List-I		List-II
(A)	Electric field inside (distance r > 0 from center) of a uniformly charged spherical shell with surface charge density σ, and radius R.	(I)	σ / ε_0
(B)	Electric field at distance r > 0 from a uniformly charged infinite plane sheet with surface charge density σ.	(II)	$\sigma / 2\varepsilon_0$
(C)	Electric field outside (distance r > 0 from center) of a uniformly charged spherical shell with surface charge density σ, and radius R	(III)	0
(D)	Electric field between 2 oppositely charged infinite plane parallel sheets with uniform surface charge density σ.	(IV)	$\frac{\sigma}{\varepsilon_0 r^2}$

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

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

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

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

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

Ans. **(4)**

Sol. (A) $\rightarrow$ 0 (III)

(B) $\rightarrow \frac{\sigma}{2\varepsilon_0}$ (II)

(C) $\rightarrow \frac{\sigma R^2}{\varepsilon_0 r^2}$ (No row matching)

(D) $\rightarrow \frac{\sigma}{\varepsilon_0}$ (I)

44. The workdone in an adiabatic change in an ideal gas depends upon only :

(1) change in its pressure

(2) change in its specific heat

(3) change in its volume

(4) change in its temperature

Ans. **(4)**

Sol. $\Delta W = -\Delta U = -nC_V\Delta T$

45. Given below are two statements : one is labelled as **Assertion (A)** and other is labelled as **Reason (R)**.

Assertion (A) : Electromagnetic waves carry energy but not momentum.

Reason (R) : Mass of a photon is zero.

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

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

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

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

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

Ans. **(2)**

Sol. Assertion is false because em waves have momentum.

SECTION-B

46. The coordinates of a particle with respect to origin in a given reference frame is (1, 1, 1) meters. If a force of $\vec{F} = \hat{i} - \hat{j} + \hat{k}$ acts on the particle, then the magnitude of torque (with respect to origin) in z-direction is ________.

Ans. **(2)**

Sol. $\vec{\tau} = \vec{r} \times \vec{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & 1 & 1 \\ 1 & -1 & 1 \end{vmatrix}$

$\vec{\tau} = \hat{k}(-1-1) = -2\hat{k}$

$|\vec{\tau}| = 2\text{Nm}$

47. A container of fixed volume contains a gas at 27°C. To double the pressure of the gas, the temperature of gas should be raised to _______ °C.

Ans. **(327)**

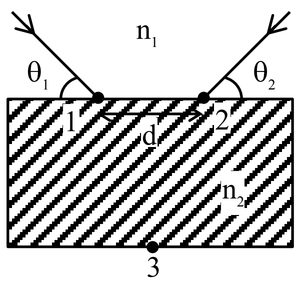
Sol. $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

$\frac{P}{300} = \frac{2P}{T_2}$

$T_2 = 600$ K

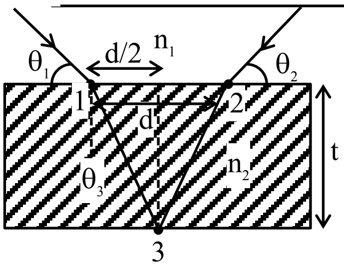
$T_2 = 327°C$

48. Two light beams fall on a transparent material block at point 1 and 2 with angle θ_1 and θ_2, respectively, as shown in figure. After refraction, the beams intersect at point 3 which is exactly on the interface at other end of the block. Given : the distance between 1 and 2, $d = 4\sqrt{3}$ cm and $\theta_1 = \theta_2 = \cos^{-1}\left(\frac{n_2}{2n_1}\right)$, where refractive index of the block n_2 > refractive index of the outside medium n_1, then the thickness of the block is ________ cm.



Ans. **(6)**

Sol.



$n_1\sin(90-\theta_1) = n_2\sin\theta_3$

$n_1\cos\theta_1 = n_2\sin\theta_3$

$n_1\dfrac{n_2}{2n_1} = n_2\sin\theta_3$

$\dfrac{1}{2} = \sin\theta_3\,,\ \theta_3 = 30$

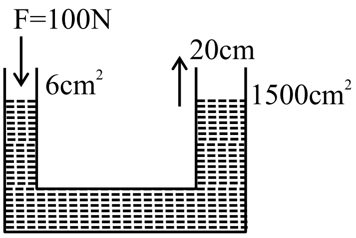
$\tan 30 = \dfrac{d}{2(t)}$

$t = \dfrac{d\sqrt{3}}{2} = \dfrac{4\sqrt{3}\times\sqrt{3}}{2}\text{cm} = 6\text{cm}$

49. In a hydraulic lift, the surface area of the input piston is 6 cm^2 and that of the output piston is 1500 cm^2. If 100 N force is applied to the input piston to raise the output piston by 20 cm, then the work done is _________ kJ.

Ans. **(5)**

Sol.



$\dfrac{F_1}{A_1} = \dfrac{F_2}{A_2}\,,\ \dfrac{100}{6} = \dfrac{F}{1500}\,,\ F = \dfrac{50}{3}\times 1500$

$F = 50 \times 500 = 25 \times 10^3$ N

$\omega = \vec{F}.\vec{S} = 25\times 10^3 \times \dfrac{20}{100}$

$= 5 \times 10^3 = 5$ kJ

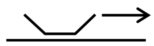
50. The maximum speed of a boat in still water is 27 km/h. Now this boat is moving downstream in a river flowing at 9 km/h. A man in the boat throws a ball vertically upwards with speed of 10 m/s. Range of the ball as observed by an observer at rest on the river bank, is _________ cm.

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

Ans. **(2000)**

Sol.

$\vec{v}_b = 9 + 27 = 36$ km/hr



$\vec{v}_b = 36\times\dfrac{1000}{36000} = 10$ m/sec

Time of flight $= \dfrac{2\times 10}{10} = 2$ sec

Range = 10 × 2 = 20m = 2000 cm