

FINAL JEE-MAIN EXAMINATION – JANUARY, 2024

 (Held On Saturday 27th January, 2024)

TIME : 3 : 00 PM to 6 : 00 PM

PHYSICS
SECTION-A

31. The equation of state of a real gas is given by $\left(P + \frac{a}{V^2}\right)(V - b) = RT$, where P, V and T are

pressure, volume and temperature respectively and R is the universal gas constant. The dimensions of

$\frac{a}{b^2}$ is similar to that of :

- (1) PV
- (2) P
- (3) RT
- (4) R

Ans. (2)

Sol. $[P] = \left[\frac{a}{V^2}\right] \Rightarrow [a] = [PV^2]$

And $[V] = [b]$

$$\frac{[a]}{[b^2]} = \frac{[PV^2]}{[V^2]} = [P]$$

32. Wheatstone bridge principle is used to measure the specific resistance (S_1) of given wire, having length L, radius r. If X is the resistance of wire,

then specific resistance is : $S_1 = X \left(\frac{\pi r^2}{L} \right)$. If the

length of the wire gets doubled then the value of specific resistance will be :

- (1) $\frac{S_1}{4}$
- (2) $2S_1$
- (3) $\frac{S_1}{2}$
- (4) S_1

Ans. (4)

Sol. As specific resistance does not depend on dimension of wire so, it will not change.

TEST PAPER WITH SOLUTION

33. Given below are two statements : one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : The angular speed of the moon in its orbit about the earth is more than the angular speed of the earth in its orbit about the sun.

Reason (R) : The moon takes less time to move around the earth than the time taken by the earth to move around the sun.

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

- (1) (A) is correct but (R) is not correct
- (2) Both (A) and (R) are correct and (R) is the correct explanation of (A)
- (3) Both (A) and (R) are correct but (R) is not the correct explanation of (A)
- (4) (A) is not correct but (R) is correct

Ans. (2)

Sol. $\omega = \frac{2\pi}{T} \Rightarrow \omega \propto \frac{1}{T}$

$T_{\text{moon}} = 27 \text{ days}$

$T_{\text{earth}} = 365 \text{ days } 4 \text{ hour}$

$\Rightarrow \omega_{\text{moon}} > \omega_{\text{earth}}$

34. Given below are two statements :

Statement (I) : The limiting force of static friction depends on the area of contact and independent of materials.

Statement (II) : The limiting force of kinetic friction is independent of the area of contact and depends on materials.

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

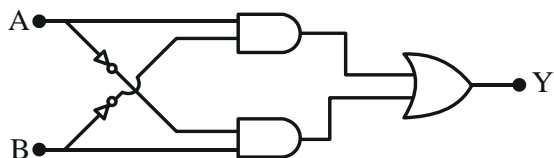
- (1) Statement I is correct but Statement II is incorrect
- (2) Statement I is incorrect but Statement II is correct
- (3) Both Statement I and Statement II are incorrect
- (4) Both Statement I and Statement II are correct

Ans. (2)

Sol. Co-efficient of friction depends on surface in contact So, depends on material of object.



35. The truth table of the given circuit diagram is :



A	B	Y
0	0	1
(1) 0	1	0
1	0	0
1	1	1

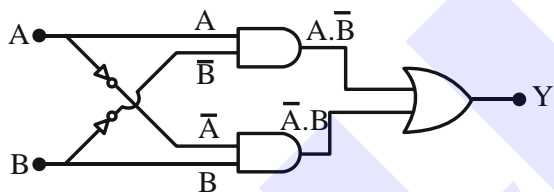
A	B	Y
0	0	0
(2) 0	1	1
1	0	1
1	1	0

A	B	Y
0	0	0
(3) 0	1	0
1	0	0
1	1	1

A	B	Y
0	0	1
(4) 0	1	1
1	0	1
1	1	0

Ans. (2)

Sol.



$$Y = A \cdot \bar{B} + \bar{A} \cdot B$$

This is XOR GATE

36. A current of $200 \mu\text{A}$ deflects the coil of a moving coil galvanometer through 60° . The current to cause deflection through $\frac{\pi}{10}$ radian is :

- (1) $30 \mu\text{A}$ (2) $120 \mu\text{A}$
(3) $60 \mu\text{A}$ (4) $180 \mu\text{A}$

Ans. (3)

Sol. $i \propto \theta$ (angle of deflection)

$$\therefore \frac{i_2}{i_1} = \frac{\theta_2}{\theta_1} \Rightarrow \frac{i_2}{200 \mu\text{A}} = \frac{\pi/10}{\pi/3} = \frac{3}{10}$$

$$\Rightarrow i_2 = 60 \mu\text{A}$$

37. The atomic mass of ${}_6\text{C}^{12}$ is 12.000000 u and that of ${}_6\text{C}^{13}$ is 13.003354 u . The required energy to remove a neutron from ${}_6\text{C}^{13}$, if mass of neutron is 1.008665 u , will be :

- (1) 62.5 MeV (2) 6.25 MeV
(3) 4.95 MeV (4) 49.5 MeV

Ans. (3)

$$\text{Sol. } {}_6\text{C}^{13} + \text{Energy} \rightarrow {}_6\text{C}^{12} + {}_0\text{n}^1$$

$$\Delta m = (12.000000 + 1.008665) - 13.003354$$

$$= -0.00531 \text{ u}$$

$$\therefore \text{Energy required} = 0.00531 \times 931.5 \text{ MeV}$$

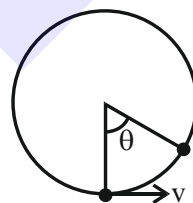
$$= 4.95 \text{ MeV}$$

38. A ball suspended by a thread swings in a vertical plane so that its magnitude of acceleration in the extreme position and lowest position are equal. The angle (θ) of thread deflection in the extreme position will be :

- (1) $\tan^{-1}(\sqrt{2})$ (2) $2\tan^{-1}\left(\frac{1}{2}\right)$
(3) $\tan^{-1}\left(\frac{1}{2}\right)$ (4) $2\tan^{-1}\left(\frac{1}{\sqrt{5}}\right)$

Ans. (2)

Sol.



Loss in kinetic energy = Gain in potential energy

$$\Rightarrow \frac{1}{2}mv^2 = mg\ell(1 - \cos\theta)$$

$$\Rightarrow \frac{v^2}{\ell} = 2g(1 - \cos\theta)$$

$$\text{Acceleration at lowest point} = \frac{v^2}{\ell}$$

$$\text{Acceleration at extreme point} = g\sin\theta$$

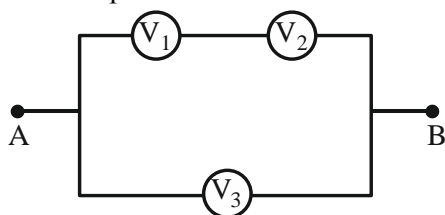
$$\text{Hence, } \frac{v^2}{\ell} = g\sin\theta$$

$$\therefore \sin\theta = 2(1 - \cos\theta)$$

$$\Rightarrow \tan\frac{\theta}{2} = \frac{1}{2} \Rightarrow \theta = 2\tan^{-1}\left(\frac{1}{2}\right)$$



39. Three voltmeters, all having different internal resistances are joined as shown in figure. When some potential difference is applied across A and B, their readings are V_1 , V_2 and V_3 . Choose the correct option.



- (1) $V_1 = V_2$ (2) $V_1 \neq V_3 - V_2$
(3) $V_1 + V_2 > V_3$ (4) $V_1 + V_2 = V_3$

Ans. (4)

Sol. From KVL,

$$V_1 + V_2 - V_3 = 0 \Rightarrow V_1 + V_2 = V_3$$

40. The total kinetic energy of 1 mole of oxygen at 27°C is :

[Use universal gas constant (R) = 8.31 J/mole K]

- (1) 6845.5 J (2) 5942.0 J
(3) 6232.5 J (4) 5670.5 J

Ans. (3)

Sol. Kinetic energy = $\frac{f}{2} nRT$

$$= \frac{5}{2} \times 1 \times 8.31 \times 300 \text{ J}$$

$$= 6232.5 \text{ J}$$

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

Assertion (A) : In Vernier calliper if positive zero error exists, then while taking measurements, the reading taken will be more than the actual reading.

Reason (R) : The zero error in Vernier Calliper might have happened due to manufacturing defect or due to rough handling.

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

- (1) Both (A) and (R) are correct and (R) is the correct explanation of (A)
(2) Both (A) and (R) are correct but (R) is not the correct explanation of (A)
(3) (A) is true but (R) is false
(4) (A) is false but (R) is true

Ans. (2)

Sol. Assertion & Reason both are correct Theory

42. Primary side of a transformer is connected to 230 V, 50 Hz supply. Turns ratio of primary to secondary winding is 10 : 1. Load resistance connected to secondary side is 46Ω . The power consumed in it is :

- (1) 12.5 W (2) 10.0 W
(3) 11.5 W (4) 12.0 W

Ans. (3)

Sol. $\frac{V_1}{V_2} = \frac{N_1}{N_2}$

$$\frac{230}{V_2} = \frac{10}{1}$$

$$V_2 = 23 \text{ V}$$

$$\text{Power consumed} = \frac{V_2^2}{R}$$

$$= \frac{23 \times 23}{46} = 11.5 \text{ W}$$

43. During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its absolute temperature. The ratio of $\frac{C_p}{C_v}$ for the gas is :

- (1) $\frac{5}{3}$ (2) $\frac{3}{2}$
(3) $\frac{7}{5}$ (4) $\frac{9}{7}$

Ans. (2)

Sol. $P \propto T^3 \Rightarrow PT^{-3} = \text{const}$

$$PV^\gamma = \text{const}$$

$$P \left(\frac{nRT}{P} \right)^\gamma = \text{const}$$

$$P^{1-\gamma} T^\gamma = \text{const}$$

$$PT^{\frac{\gamma}{1-\gamma}} = \text{const}$$

$$\frac{\gamma}{1-\gamma} = -3$$

$$\gamma = -3 + 3\gamma$$

$$3 = 2\gamma$$

$$\gamma = \frac{3}{2}$$



44. The threshold frequency of a metal with work function 6.63 eV is :

- (1) 16×10^{15} Hz
- (2) 16×10^{12} Hz
- (3) 1.6×10^{12} Hz
- (4) 1.6×10^{15} Hz

Ans. (4)

Sol. $\phi_0 = h\nu_0$

$$6.63 \times 1.6 \times 10^{-19} = 6.63 \times 10^{-34} \nu_0$$

$$\nu_0 = \frac{1.6 \times 10^{-19}}{10^{-34}}$$

$$\nu_0 = 1.6 \times 10^{15} \text{ Hz}$$

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

Assertion (A) : The property of body, by virtue of which it tends to regain its original shape when the external force is removed, is Elasticity.

Reason (R) : The restoring force depends upon the bonded inter atomic and inter molecular force of solid.

In the light of the above statements, choose the correct 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 (A)
- (4) Both (A) and (R) are true but (R) is not the correct explanation of (A)

Ans. (3 or 4)

Sol. Theory

46. When a polaroid sheet is rotated between two crossed polaroids then the transmitted light intensity will be maximum for a rotation of :

- (1) 60°
- (2) 30°
- (3) 90°
- (4) 45°

Ans. (4)

Sol. Let I_0 be intensity of unpolarised light incident on first polaroid.

$$I_1 = \text{Intensity of light transmitted from 1}^{\text{st}} \text{ polaroid} = \frac{I_0}{2}$$

θ be the angle between 1st and 2nd polaroid

ϕ be the angle between 2nd and 3rd polaroid

$\theta + \phi = 90^\circ$ (as 1st and 3rd polaroid are crossed)

$$\phi = 90^\circ - \theta$$

I_2 = Intensity from 2nd polaroid

$$I_2 = I_1 \cos^2 \theta = \frac{I_0}{2} \cos^2 \theta$$

I_3 = Intensity from 3rd polaroid

$$I_3 = I_2 \cos^2 \phi$$

$$I_3 = I_1 \cos^2 \theta \cos^2 \phi$$

$$I_3 = \frac{I_0}{2} \cos^2 \theta \cos^2 \phi$$

$$\phi = 90^\circ - \theta$$

$$I_3 = \frac{I_0}{2} \cos^2 \theta \sin^2 \theta$$

$$I_3 = \frac{I_0}{2} \left[\frac{2 \sin \theta \cos \theta}{2} \right]^2$$

$$I_3 = \frac{I_0}{8} \sin^2 2\theta$$

I_3 will be maximum when $\sin 2\theta = 1$

$$2\theta = 90^\circ$$

$$\theta = 45^\circ$$

47. An object is placed in a medium of refractive index 3. An electromagnetic wave of intensity $6 \times 10^8 \text{ W/m}^2$ falls normally on the object and it is absorbed completely. The radiation pressure on the object would be (speed of light in free space $= 3 \times 10^8 \text{ m/s}$) :

- (1) 36 Nm^{-2}
- (2) 18 Nm^{-2}
- (3) 6 Nm^{-2}
- (4) 2 Nm^{-2}

Ans. (3)

Sol. Radiation pressure $= \frac{I}{v}$

$$= \frac{I \cdot \mu}{c}$$

$$= \frac{6 \times 10^8 \times 3}{3 \times 10^8}$$

$$= 6 \text{ N/m}^2$$



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

Assertion (A) : Work done by electric field on moving a positive charge on an equipotential surface is always zero.

Reason (R) : Electric lines of forces are always perpendicular to equipotential surfaces.

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

- (1) Both (A) and (R) are correct but (R) is not the correct explanation of (A)
(2) ((A) is correct but (R) is not correct
(3) (A) is not correct but (R) is correct
(4) Both (A) and (R) are correct and (R) is the correct explanation of (A)

Ans. (4)

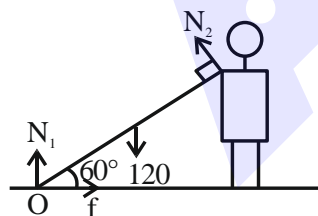
Sol. Electric line of force are always perpendicular to equipotential surface so angle between force and displacement will always be 90° . So work done equal to 0.

49. A heavy iron bar of weight 12 kg is having its one end on the ground and the other on the shoulder of a man. The rod makes an angle 60° with the horizontal, the weight experienced by the man is :

- (1) 6 kg
(2) 12 kg
(3) 3 kg
(4) $6\sqrt{3}$ kg

Ans. (3)

Sol.



Torque about O = 0

$$120 \left(\frac{L}{2} \cos 60^\circ \right) - N_2 L = 0$$

$$N_2 = 30 \text{ N}$$

50. A bullet is fired into a fixed target loses one third of its velocity after travelling 4 cm. It penetrates further $D \times 10^{-3}$ m before coming to rest. The value of D is :

- (1) 2
(2) 5
(3) 3
(4) 4

Ans. (Bonus)

Sol. $v^2 - u^2 = 2aS$

$$\left(\frac{2u}{3} \right)^2 = u^2 + 2(-a)(4 \times 10^{-2})$$

$$\frac{4u^2}{9} = u^2 - 2a(4 \times 10^{-2})$$

$$-\frac{5u^2}{9} = -2a(4 \times 10^{-2}) \dots (1)$$

$$0 = \left(\frac{2u}{3} \right)^2 + 2(-a)(x)$$

$$-\frac{4u^2}{9} = -2ax \dots (2)$$

$$(1) / (2)$$

$$\frac{5}{4} = \frac{4 \times 10^{-2}}{x}$$

$$x = \frac{16}{5} \times 10^{-2}$$

$$x = 3.2 \times 10^{-2} \text{ m}$$

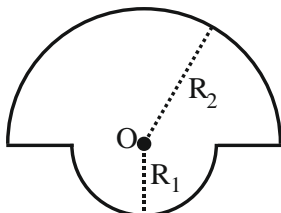
$$x = 32 \times 10^{-3} \text{ m}$$

Note : Since no option is matching, Question should be bonus.



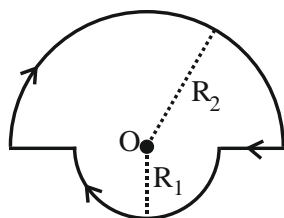
SECTION-B

51. The magnetic field at the centre of a wire loop formed by two semicircular wires of radii $R_1 = 2\pi$ m and $R_2 = 4\pi$ m carrying current $I = 4$ A as per figure given below is $\alpha \times 10^{-7}$ T. The value of α is _____. (Centre O is common for all segments)



Ans. (3.00)

Sol.



$$\frac{\mu_0 I}{2R_2} \left(\frac{\pi}{2\pi} \right) \otimes + \frac{\mu_0 I}{2R_1} \left(\frac{\pi}{2\pi} \right) \otimes$$

$$\left(\frac{\mu_0 I}{4R_2} + \frac{\mu_0 I}{4R_1} \right) \otimes$$

$$\frac{4\pi \times 10^{-7} \times 4}{4 \times 4\pi} + \frac{4\pi \times 10^{-7} \times 4}{4 \times 2\pi}$$

$$= 3 \times 10^{-7} = \alpha \times 10^{-7}$$

$$\alpha = 3$$

52. Two charges of $-4 \mu\text{C}$ and $+4 \mu\text{C}$ are placed at the points A(1, 0, 4)m and B(2, -1, 5) m located in an electric field $\vec{E} = 0.20 \hat{i}$ V/cm. The magnitude of the torque acting on the dipole is $8\sqrt{\alpha} \times 10^{-5}$ Nm, Where $\alpha =$ _____.

Ans. (2.00)

Sol.

$$\begin{array}{cc} (1, 0, 4) & (2, -1, 5) \\ \bullet & \bullet \\ A & B \\ -4\mu\text{C} & 4\mu\text{C} \end{array}$$

$$\vec{\tau} = \vec{p} \times \vec{E}$$

$$\vec{p} = q\vec{\ell}$$

$$\vec{E} = 0.2 \frac{\text{V}}{\text{cm}} = 20 \frac{\text{V}}{\text{m}}$$

$$\vec{p} = 4 \times (\hat{i} - \hat{j} + \hat{k})$$

$$= (4\hat{i} - 4\hat{j} + 4\hat{k}) \mu\text{C} - \text{m}$$

$$\vec{\tau} = (4\hat{i} - 4\hat{j} + 4\hat{k}) \times (20\hat{i}) \times 10^{-6} \text{ Nm}$$

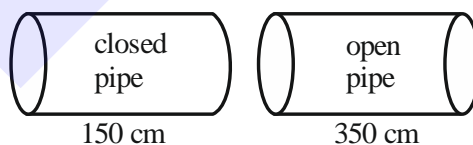
$$= (8\hat{k} + 8\hat{j}) \times 10^{-5} = 8\sqrt{2} \times 10^{-5}$$

$$\alpha = 2$$

53. A closed organ pipe 150 cm long gives 7 beats per second with an open organ pipe of length 350 cm, both vibrating in fundamental mode. The velocity of sound is _____ m/s.

Ans. (294.00)

Sol.



$$f_c = \frac{v}{4\ell_1} \quad f_o = \frac{v}{2\ell_2}$$

$$|f_c - f_o| = 7$$

$$\frac{v}{4 \times 150} - \frac{v}{2 \times 350} = 7$$

$$\frac{v}{600 \text{ cm}} - \frac{v}{700 \text{ cm}} = 7$$

$$\frac{v}{6\text{m}} - \frac{v}{7\text{m}} = 7$$

$$v \left(\frac{1}{42} \right) = 7$$

$$v = 42 \times 7$$

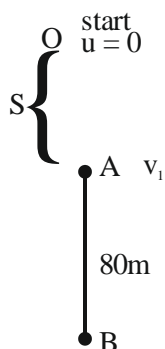
$$= 294 \text{ m/s}$$



54. A body falling under gravity covers two points A and B separated by 80 m in 2s. The distance of upper point A from the starting point is _____ m (use $g = 10 \text{ ms}^{-2}$)

Ans. (45.00)

Sol.



From A \rightarrow B

$$-80 = -v_1 t - \frac{1}{2} \times 10 t^2$$

$$-80 = -2v_1 - \frac{1}{2} \times 10 \times 2^2$$

$$-80 = -2v_1 - 20$$

$$-60 = -2v_1$$

$$v_1 = 30 \text{ m/s}$$

From O to A

$$v^2 = u^2 + 2gS$$

$$30^2 = 0 + 2 \times (-10)(-S)$$

$$900 = 20 S$$

$$S = 45 \text{ m}$$

55. The reading of pressure metre attached with a closed pipe is $4.5 \times 10^4 \text{ N/m}^2$. On opening the valve, water starts flowing and the reading of pressure metre falls to $2.0 \times 10^4 \text{ N/m}^2$. The velocity of water is found to be $\sqrt{V} \text{ m/s}$. The value of V is _____

Ans. (50)

Sol. Change in pressure $= \frac{1}{2} \rho v^2$

$$4.5 \times 10^4 - 2.0 \times 10^4 = \frac{1}{2} \times 10^3 \times v^2$$

$$2.5 \times 10^4 = \frac{1}{2} \times 10^3 \times v^2$$

$$v^2 = 50$$

$$v = \sqrt{50}$$

$$\text{Velocity of water} = \sqrt{V} = \sqrt{50}$$

$$= V = 50$$

56. A ring and a solid sphere roll down the same inclined plane without slipping. They start from rest. The radii of both bodies are identical and the ratio of their kinetic energies is $\frac{7}{x}$ where x is _____.

Ans. (7.00)

Sol. In pure rolling work done by friction is zero. Hence potential energy is converted into kinetic energy. Since initially the ring and the sphere have same potential energy, finally they will have same kinetic energy too.

$$\therefore \text{Ratio of kinetic energies} = 1$$

$$\Rightarrow \frac{7}{x} = 1 \Rightarrow x = 7$$

57. A parallel beam of monochromatic light of wavelength 5000 \AA is incident normally on a single narrow slit of width 0.001 mm . The light is focused by convex lens on screen, placed on its focal plane. The first minima will be formed for the angle of diffraction of _____ (degree).

Ans. (30.00)

Sol. For first minima

$$a \sin \theta = \lambda$$

$$\Rightarrow \sin \theta = \frac{\lambda}{a} = \frac{5000 \times 10^{-10}}{1 \times 10^{-6}} = \frac{1}{2}$$

$$\Rightarrow \theta = 30^\circ$$



58. The electric potential at the surface of an atomic nucleus ($z = 50$) of radius 9×10^{-13} cm is $\times 10^6$ V.

Ans. (8.00)

Sol. Potential $= \frac{kQ}{R} = \frac{kZe}{R}$

$$= \frac{9 \times 10^9 \times 50 \times 1.6 \times 10^{-19}}{9 \times 10^{-13} \times 10^{-2}}$$

$$= 8 \times 10^6 \text{ V}$$

59. If Rydberg's constant is R , the longest wavelength of radiation in Paschen series will be $\frac{\alpha}{7R}$, where

$\alpha =$ _____.

Ans. (144.00)

Sol. Longest wavelength corresponds to transition between $n = 3$ and $n = 4$

$$\frac{1}{\lambda} = RZ^2 \left(\frac{1}{3^2} - \frac{1}{4^2} \right) = RZ^2 \left(\frac{1}{9} - \frac{1}{16} \right)$$

$$= \frac{7RZ^2}{9 \times 16}$$

$$\Rightarrow \lambda = \frac{144}{7R} \text{ for } Z = 1 \quad \therefore \alpha = 144$$

60. A series LCR circuit with $L = \frac{100}{\pi}$ mH, $C = \frac{10^{-3}}{\pi}$ F and $R = 10 \Omega$, is connected across an ac source of 220 V, 50 Hz supply. The power factor of the circuit would be _____.

Ans. (1.00)

Sol. $X_C = \frac{1}{\omega C} = \frac{\pi}{2\pi \times 50 \times 10^{-3}} = 10\Omega$

$$X_L = \omega L = 2\pi \times 50 \times \frac{100}{\pi} \times 10^{-3}$$

$$= 10\Omega$$

$\therefore X_C = X_L$, Hence, circuit is in resonance

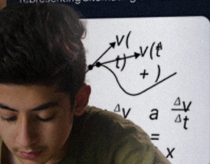
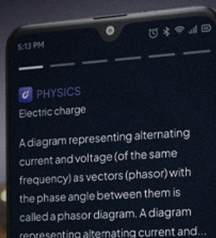
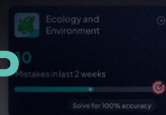
$$\therefore \text{power factor} = \frac{R}{Z} = \frac{R}{R} = 1$$

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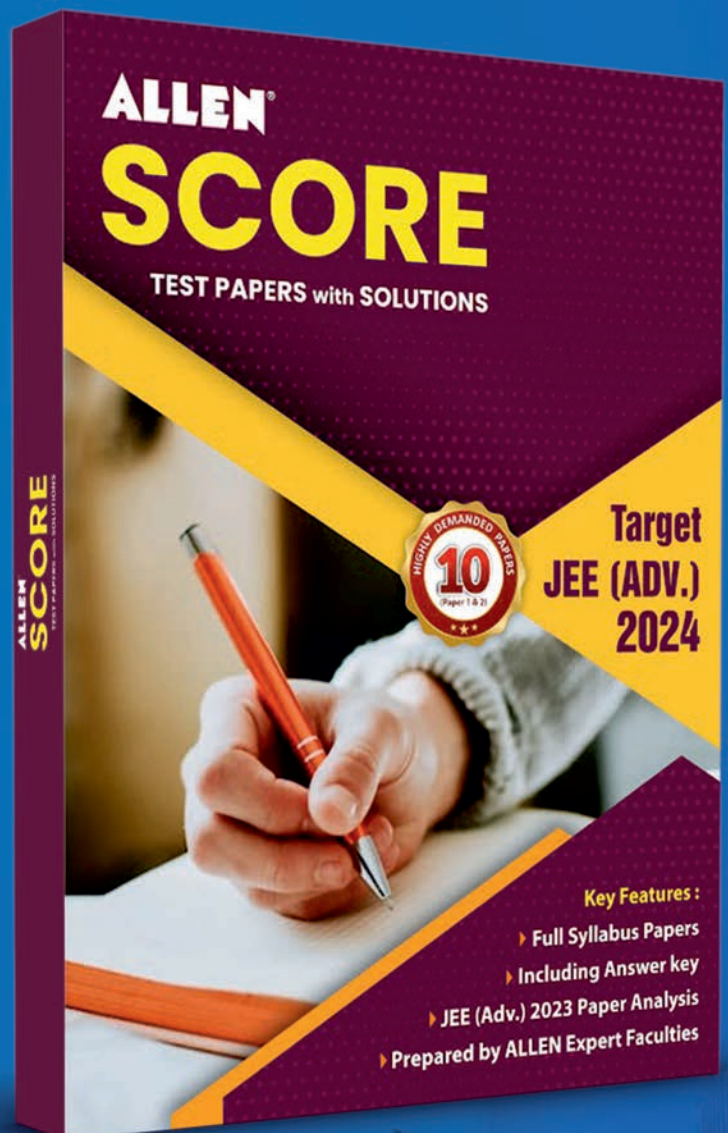
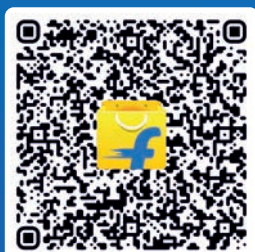


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