

AIPMT 2011 Mains — Physics Question Paper with Solutions

23 Physics questions as set in the paper · answers checked by RankUp

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1. A galvanometer of resistance G is shunted by a resistance S ohm. To keep the main current in the circuit unchanged, the resistance to be put in series with the galvanometer is

- (A) $G^2/(S + G)$
- (B) $G/(S + G)$
- (C) $S^2/(S + G)$
- (D) $SG/(S + G)$

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2. A particle covers half of its total distance with speed v_1 and the rest half distance with speed v_2 . Its average speed during the complete journey is

- (A) $v_1^2 v_2^2 / (v_1^2 + v_2^2)$
- (B) $(v_1 + v_2)/2$
- (C) $v_1 v_2 / (v_1 + v_2)$
- (D) $2v_1 v_2 / (v_1 + v_2)$

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3. A thermocouple of negligible resistance produces an e.m.f. of $40 \mu\text{V}/^\circ\text{C}$ in the linear range of temperature. A galvanometer of resistance 10 ohm whose sensitivity is $1 \mu\text{A}/\text{div}$, is employed with the thermocouple. The smallest value of temperature difference that can be detected by the system will be

- (A) 0.1°C
- (B) 0.25°C
- (C) 0.5°C
- (D) 1°C

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4. A mass m moving horizontally (along the x -axis) with velocity v collides and sticks to a mass of $3m$ moving vertically upward (along the y -axis) with velocity $2v$. The final velocity of the combination is

- (A) $(2/3)v \hat{i} + (1/3)v \hat{j}$
- (B) $(3/2)v \hat{i} + (1/4)v \hat{j}$
- (C) $(1/4)v \hat{i} + (3/2)v \hat{j}$
- (D) $(1/3)v \hat{i} + (2/3)v \hat{j}$

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5. A converging beam of rays is incident on a diverging lens. Having passed through the lens the rays intersect at a point 15 cm from the lens on the opposite side. If the lens is removed the point where the rays meet will move 5 cm closer to the lens. The focal length of the lens is

- (A) -30 cm
- (B) 5 cm
- (C) -10 cm
- (D) 20 cm

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6. The threshold frequency for a photosensitive metal is 3.3×10^{14} Hz. If light of frequency 8.2×10^{14} Hz is incident on this metal, the cut-off voltage for the photoelectric emission is nearly

- (A) 5 V
- (B) 1 V
- (C) 2 V
- (D) 3 V

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7. An electron in the hydrogen atom jumps from excited state n to the ground state. The wavelength so emitted illuminates a photosensitive material having work function 2.75 eV. If the stopping potential of the photoelectron is 10 V, then the value of n is

- (A) 5
- (B) 2
- (C) 3
- (D) 4

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8. A particle of mass M is situated at the centre of a spherical shell of same mass and radius a . The magnitude of the gravitational potential at a point situated at $a/2$ distance from the centre, will be

- (A) $4GM/a$
- (B) GM/a
- (C) $2GM/a$
- (D) $3GM/a$

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9. Two particles are oscillating along two close parallel straight lines side by side, with the same frequency and amplitudes. They pass each other, moving in opposite directions when their displacement is half of the amplitude. The mean positions of the two particles lie on a straight line perpendicular to the paths of the two particles. The phase difference is

- (A) π
- (B) $\pi/6$
- (C) 0
- (D) $2\pi/3$

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10. A conveyor belt is moving at a constant speed of 2 m/s. A box is gently dropped on it. The coefficient of friction between them is $\mu = 0.5$. The distance that the box will move relative to belt before coming to rest on it, taking $g = 10 \text{ m s}^{-2}$, is

- (A) Zero
- (B) 0.4 m
- (C) 1.2 m
- (D) 0.6 m

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11. A mass of diatomic gas ($\gamma = 1.4$) at a pressure of 2 atmospheres is compressed adiabatically so that its temperature rises from 27°C to 927°C . The pressure of the gas in the final state is

- (A) 256 atm
- (B) 8 atm
- (C) 28 atm
- (D) 68.7 atm

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12. Charge q is uniformly spread on a thin ring of radius R . The ring rotates about its axis with a uniform frequency f Hz. The magnitude of magnetic induction at the center of the ring is

- (A) $\mu_0 q / (2\pi f R)$
- (B) $\mu_0 q f / (2\pi R)$
- (C) $\mu_0 q f / (2R)$
- (D) $\mu_0 q / (2f R)$

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13. Two radioactive nuclei P and Q in a given sample decay into a stable nucleus R. At time $t = 0$, number of P species are $4N_0$ and that of Q are N_0 . Half-life of P (for conversion to R) is 1 minute whereas that of Q is 2 minutes. Initially there are no nuclei of R present in the sample. When number of nuclei of P and Q are equal, the number of nuclei of R present in the sample would be

- (A) $5N_0/2$
- (B) $2N_0$
- (C) $3N_0$
- (D) $9N_0/2$

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14. Pure Si at 500 K has equal number of electron (n_e) and hole (n_h) concentrations of $1.5 \times 10^{16} \text{ m}^{-3}$. Doping by indium increases n_h to $4.5 \times 10^{22} \text{ m}^{-3}$. The doped semiconductor is of

- (A) n-type with electron concentration $n_e = 2.5 \times 10^{23} \text{ m}^{-3}$
- (B) p-type having electron concentration $n_e = 5 \times 10^9 \text{ m}^{-3}$
- (C) n-type with electron concentration $n_e = 2.5 \times 10^{22} \text{ m}^{-3}$
- (D) p-type with electron concentration $n_e = 2.5 \times 10^{10} \text{ m}^{-3}$

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15. A thin prism of angle 15° made of glass of refractive index $\mu_1 = 1.5$ is combined with another prism of glass of refractive index $\mu_2 = 1.75$. The combination of the prisms produces dispersion without deviation. The angle of the second prism should be

- (A) 12°
- (B) 5°
- (C) 7°
- (D) 10°

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16. Two identical piano wires, kept under the same tension T , have a fundamental frequency of 600 Hz. The fractional increase in the tension of one of the wires which will lead to occurrence of 6 beats/s when both the wires oscillate together would be

- (A) 0.04
- (B) 0.01
- (C) 0.02
- (D) 0.03

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17. A small mass attached to a string rotates on a frictionless table top (the string passes through a hole at the centre of the table). If the tension in the string is increased by pulling the string causing the radius of the circular motion to decrease by a factor of 2, the kinetic energy of the mass will

- (A) Increase by a factor of 4
- (B) Decrease by a factor of 2
- (C) Remain constant
- (D) Increase by a factor of 2

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18. The electric potential V at any point (x, y, z) , in meters in space is given by $V = 4x^2$ volt. The electric field at the point $(1, 0, 2)$ in volt/meter, is

- (A) 16 along positive X-axis
- (B) 8 along negative X-axis
- (C) 8 along positive X-axis
- (D) 16 along negative X-axis

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19. A particle of mass m is thrown upwards from the surface of the earth, with a velocity u . The mass and the radius of the earth are, respectively, M and R . G is gravitational constant and g is acceleration due to gravity on the surface of the earth. The minimum value of u so that the particle does not return back to earth, is

- (A) $\sqrt{2gR^2}$
- (B) $\sqrt{2GM/R^2}$
- (C) $\sqrt{2GM/R}$
- (D) $\sqrt{2gM/R^2}$

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20. A short bar magnet of magnetic moment 0.4 J T^{-1} is placed in a uniform magnetic field of 0.16 T . The magnet is in stable equilibrium when the potential energy is

- (A) -0.082 J
- (B) 0.064 J
- (C) -0.064 J
- (D) Zero

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21. A projectile is fired at an angle of 45° with the horizontal. Elevation angle of the projectile at its highest point as seen from the point of projection is

- (A) $\tan^{-1}(\sqrt{3}/2)$
- (B) 45°
- (C) 60°
- (D) $\tan^{-1}(1/2)$

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22. A coil has resistance 30 ohm and inductive reactance 20 ohm at 50 Hz frequency. If an ac source of 200 volt , 100 Hz is connected across the coil, the current in the coil will be

- (A) $20/\sqrt{13} \text{ A}$
- (B) 2.0 A
- (C) 4.0 A
- (D) 8.0 A

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23. The density of a material in CGS system of units is 4 g/cm^3 . In a system of units in which unit of length is 10 cm and unit of mass is 100 g , the value of density of material will be

- (A) 400
- (B) 0.04
- (C) 0.4
- (D) 40

Answer key and explanations

1. Answer: (A) $G^2/(S + G)$

For the main current to stay unchanged, the shunted galvanometer plus the series resistance must still equal G . The shunted combination is $GS/(G + S)$, so $R = G - GS/(G + S) = G^2/(G + S)$. The answer $GS/(G + S)$ is only the shunted combination itself, not the extra resistance needed.

2. Answer: (D) $2v_1v_2/(v_1 + v_2)$

Each half takes d/v_1 and d/v_2 , so average speed = $2d/(d/v_1 + d/v_2) = 2v_1v_2/(v_1 + v_2)$, the harmonic mean. The arithmetic mean $(v_1 + v_2)/2$ would apply only to equal time intervals, not equal distances.

3. Answer: (B) 0.25°C

The smallest detectable current is $1\text{ }\mu\text{A}$ (one division), so the smallest detectable emf is $1\text{ }\mu\text{A} \times 10\text{ }\Omega = 10\text{ }\mu\text{V}$. With $40\text{ }\mu\text{V per }^\circ\text{C}$, $\Delta T = 10/40 = 0.25^\circ\text{C}$. Answers like 0.1°C or 0.5°C come from mixing up the ratio.

4. Answer: (C) $(1/4)v\hat{i} + (3/2)v\hat{j}$

Momentum is conserved in this perfectly inelastic collision: $m v\hat{i} + 3m(2v)\hat{j} = 4m\vec{V}$. So $\vec{V} = (v/4)\hat{i} + (6v/4)\hat{j} = (1/4)v\hat{i} + (3/2)v\hat{j}$. Swapping the components, $(3/2)v\hat{i} + (1/4)v\hat{j}$, is the common trap.

5. Answer: (A) -30 cm

Without the lens the rays meet 10 cm behind the lens position, so that point is a virtual object at $u = +10\text{ cm}$; with the lens the image is at $v = +15\text{ cm}$. $1/f = 1/v - 1/u = 1/15 - 1/10 = -1/30$, so $f = -30\text{ cm}$. The negative sign confirms a diverging lens, ruling out the positive values.

6. Answer: (C) 2 V

$eV_0 = h(\nu - \nu_0) = 6.63 \times 10^{-34} \times (8.2 - 3.3) \times 10^{14} = 3.25 \times 10^{-19}\text{ J}$, so $V_0 = 3.25 \times 10^{-19}/1.6 \times 10^{-19} \approx 2\text{ V}$. Using the incident frequency alone (ignoring the threshold) would give about 3.4 V , which is not the cut-off voltage.

7. Answer: (D) 4

Photon energy = work function + $eV_0 = 2.75 + 10 = 12.75\text{ eV}$. For hydrogen, $13.6(1 - 1/n^2) = 12.75$ gives $1/n^2 = 0.0625$, so $n = 4$. The $n = 3 \rightarrow 1$ transition gives only 12.09 eV , too little.

8. Answer: (D) $3GM/a$

Potential due to the central particle at $a/2$ is $-GM/(a/2) = -2GM/a$; inside a shell the potential is constant at $-GM/a$. Total = $-3GM/a$, magnitude $3GM/a$. Taking only the particle's contribution gives $2GM/a$, forgetting that the shell's potential inside is not zero.

9. Answer: (D) $2\pi/3$

$x = A \sin \phi = A/2$ gives $\phi = \pi/6$ for one particle and $5\pi/6$ for the other, since they move in opposite directions at that displacement. Phase difference = $5\pi/6 - \pi/6 = 2\pi/3$. Zero would mean they move together, and π would mean they cross only at the mean position.

10. Answer: (B) 0.4 m

Relative to the belt the box starts at 2 m/s and friction gives it a relative deceleration $\mu g = 5\text{ m/s}^2$. Relative distance = $u^2/2a = 4/10 = 0.4\text{ m}$. The answer zero ignores that the box slips until it reaches the belt speed.

11. Answer: (A) 256 atm

For an adiabatic process $P^{1-\gamma}T^\gamma$ is constant, so $P \propto T^{1/(\gamma-1)} = T^{3/5}$. T rises from 300 K to 1200 K , a factor of 4 , so $P_2 = 2 \times 4^{3/5} = 2 \times 128 = 256\text{ atm}$. Using Celsius temperatures or $P \propto T$ (isochoric) gives the wrong values.

12. Answer: (C) $\mu_0 qf/(2R)$

The rotating ring is equivalent to a current $I = q/T = qf$. The field at the centre of a circular loop is $\mu_0 I/(2R) = \mu_0 qf/(2R)$. The expression with $2\pi R$ in the denominator is the formula for a long straight wire, not a loop.

13. Answer: (D) $9N_0/2$

P: $4N_0(1/2)^t$ and Q: $N_0(1/2)^{(t/2)}$ with t in minutes. Setting them equal gives $2^{2-t} = 2^{-(t/2)}$, so $t = 4\text{ min}$, when $P = Q = N_0/4$. $R = 5N_0 - N_0/2 = 9N_0/2$. $5N_0/2$ would count only the decayed P nuclei incorrectly.

14. Answer: (B) p-type having electron concentration $n_e = 5 \times 10^9\text{ m}^{-3}$

Indium is trivalent, so the doped crystal is p-type. By the mass-action law $n_e = n_i^2/n_h = (1.5 \times 10^{16})^2/(4.5 \times 10^{22}) = 2.25 \times 10^{32}/4.5 \times 10^{22} = 5 \times 10^9\text{ m}^{-3}$. The n-type choices are wrong because an acceptor dopant was added.

15. Answer: (D) 10°

For no net deviation with thin prisms, $(\mu_1 - 1)A_1 = (\mu_2 - 1)A_2$, so $0.5 \times 15^\circ = 0.75 \times A_2$ and $A_2 = 10^\circ$. Using the ratio of refractive indices directly instead of $(\mu - 1)$ leads to wrong angles.

16. Answer: (C) 0.02

$f \propto \sqrt{T}$, so $\Delta f/f = \frac{1}{2} \Delta T/T$. Six beats means $\Delta f = 6\text{ Hz}$, so $6/600 = \frac{1}{2} \Delta T/T$ and $\Delta T/T = 0.02$. Forgetting the square-root dependence gives 0.01 .

17. Answer: (A) Increase by a factor of 4

The string tension acts towards the hole, so angular momentum $L = mvr$ is conserved. $KE = L^2/(2mr^2)$, so halving r makes KE four times larger. Saying it stays constant ignores the work done by the pulling force.

18. Answer: (B) 8 along negative X-axis

$E = -dV/dx = -8x$, which at $x = 1$ m is -8 V/m, i.e. 8 V/m along the negative x-axis. The value 16 V/m comes from wrong differentiation, and the positive direction ignores the minus sign in $E = -\nabla V$.

19. Answer: (C) $\sqrt{2GM/R}$

To not return, the particle must reach infinity: $\frac{1}{2}mu^2 = GMm/R$, so $u = \sqrt{2GM/R}$ ($= \sqrt{2gR}$). $\sqrt{2GM/R^2}$ and $\sqrt{2gR^2}$ are dimensionally wrong as speeds.

20. Answer: (C) - 0.064 J

$U = -MB \cos \theta$; stable equilibrium is $\theta = 0$, so $U = -MB = -0.4 \times 0.16 = -0.064$ J. $+0.064$ J is the unstable (antiparallel) equilibrium.

21. Answer: (D) $\tan^{-1}(1/2)$

At the top the projectile is at height H and horizontal distance $R/2$. $\tan \alpha = H/(R/2) = (u^2 \sin^2 \theta / 2g) / (u^2 \sin \theta \cos \theta / g) = \tan \theta / 2 = 1/2$ for $\theta = 45^\circ$. So $\alpha = \tan^{-1}(1/2)$; 45° would be the launch angle, not the elevation of the highest point.

22. Answer: (C) 4.0 A

Inductive reactance doubles with frequency: at 100 Hz $X_L = 40 \Omega$. $Z = \sqrt{30^2 + 40^2} = 50 \Omega$, so $I = 200/50 = 4$ A. Keeping $X_L = 20 \Omega$ gives $20/\sqrt{13}$ A, which is the trap.

23. Answer: (D) 40

New unit of density $= 100 \text{ g}/(10 \text{ cm})^3 = 0.1 \text{ g/cm}^3$. So $4 \text{ g/cm}^3 = 4/0.1 = 40$ new units. Dividing the wrong way gives 0.4.

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