

AIPMT 2009 Prelims — Physics Question Paper with Solutions

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

AIPMT 2009 Prelims · Q1

1. In the nuclear decay given below:



the particles emitted in the sequence are: [notation: (mass number, atomic number)]

- (A) γ , β , α
- (B) β , γ , α
- (C) α , β , γ
- (D) β , α , γ

AIPMT 2009 Prelims · Q2

2. A thin circular ring of mass M and radius R is rotating in a horizontal plane about an axis vertical to its plane with a constant angular velocity ω . If two objects each of mass m be attached gently to the opposite ends of a diameter of the ring, the ring will then rotate with an angular velocity:

- (A) $\omega M/(M + 2m)$
- (B) $\omega(M + 2m)/M$
- (C) $\omega M/(M + m)$
- (D) $\omega(M - 2m)/(M + 2m)$

AIPMT 2009 Prelims · Q3

3. In thermodynamic processes which of the following statements is not true?

- (A) In an isochoric process pressure remains constant
- (B) In an isothermal process the temperature remains constant
- (C) In an adiabatic process $PV^\gamma = \text{constant}$
- (D) In an adiabatic process the system is insulated from the surroundings

AIPMT 2009 Prelims · Q4

4. The number of photo electrons emitted for light of a frequency ν (higher than the threshold frequency ν_0) is proportional to:

- (A) Threshold frequency (ν_0)
- (B) Intensity of light
- (C) Frequency of light (ν)
- (D) $\nu - \nu_0$

AIPMT 2009 Prelims · Q5

5. A simple pendulum performs simple harmonic motion about $x = 0$ with an amplitude a and time period T . The speed of the pendulum at $x = a/2$ will be:

- (A) $\pi a/T$
- (B) $3\pi^2 a/T$
- (C) $\pi a\sqrt{3}/T$
- (D) $\pi a\sqrt{3}/(2T)$

AIPMT 2009 Prelims · Q7

6. A body, under the action of a force $F = 6\hat{i} - 8\hat{j} + 10\hat{k}$, acquires an acceleration of 1 m/s^2 . The mass of this body must be:

- (A) 10 kg
- (B) 20 kg
- (C) $10\sqrt{2}$ kg
- (D) $2\sqrt{10}$ kg

7. If $\vec{F}$ is the force acting on a particle having position vector $\vec{r}$ and $\vec{\tau}$ be the torque of this force about the origin, then:

- (A) $\vec{r} \cdot \vec{\tau} > 0$ and $\vec{F} \cdot \vec{\tau} < 0$
- (B) $\vec{r} \cdot \vec{\tau} = 0$ and $\vec{F} \cdot \vec{\tau} = 0$
- (C) $\vec{r} \cdot \vec{\tau} = 0$ and $\vec{F} \cdot \vec{\tau} \neq 0$
- (D) $\vec{r} \cdot \vec{\tau} \neq 0$ and $\vec{F} \cdot \vec{\tau} = 0$

8. The two ends of a rod of length L and a uniform cross-sectional area A are kept at two temperatures T_1 and T_2 ($T_1 > T_2$). The rate of heat transfer, dQ/dt , through the rod in a steady state is given by:

- (A) $dQ/dt = k(T_1 - T_2)/(LA)$
- (B) $dQ/dt = kLA(T_1 - T_2)$
- (C) $dQ/dt = kA(T_1 - T_2)/L$
- (D) $dQ/dt = kL(T_1 - T_2)/A$

9. A p-n photodiode is fabricated from a semiconductor with a band gap of 2.5 eV. It can detect a signal of wavelength:

- (A) 4000 nm
- (B) 6000 nm
- (C) 4000 Å
- (D) 6000 Å

10. If the dimensions of a physical quantity are given by $M^a L^b T^c$, then the physical quantity will be:

- (A) Velocity if $a = 1, b = 0, c = -1$
- (B) Acceleration if $a = 1, b = 1, c = -2$
- (C) Force if $a = 0, b = -1, c = -2$
- (D) Pressure if $a = 1, b = -1, c = -2$

11. A transistor is operated in common-emitter configuration at $V_c = 2$ V such that a change in the base current from 100 μA to 200 μA produces a change in the collector current from 5 mA to 10 mA. The current gain is:

- (A) 100
- (B) 150
- (C) 50
- (D) 75

12. The mass of a lift is 2000 kg. When the tension in the supporting cable is 28000 N, then its acceleration is:

- (A) 4 m s⁻² upwards
- (B) 4 m s⁻² downwards
- (C) 14 m s⁻² upwards
- (D) 30 m s⁻² downwards

13. Four identical thin rods each of mass M and length l , form a square frame. Moment of inertia of this frame about an axis through the centre of the square and perpendicular to its plane is :

- (A) $(2/3) Ml^2$
- (B) $(13/3) Ml^2$
- (C) $(1/3) Ml^2$
- (D) $(4/3) Ml^2$

AIPMT 2009 Prelims · Q16

14. Each of the two strings of length 51.6 cm and 49.1 cm are tensioned separately by 20 N force. Mass per unit length of both the strings is same and equal to 1 g/m. When both the strings vibrate simultaneously the number of beats is:

- (A) 7
- (B) 8
- (C) 3
- (D) 5

AIPMT 2009 Prelims · Q17

15. The number of beta particles emitted by a radioactive substance is twice the number of alpha particles emitted by it. The resulting daughter is an:

- (A) isomer of parent
- (B) isotone of parent
- (C) isotope of parent
- (D) isobar of parent

AIPMT 2009 Prelims · Q19

16. The Figure shows elliptical orbit of a planet m about the sun S . The shaded area SCD is twice the shaded area SAB . If t_1 is the time for the planet to move from C to D and t_2 is the time to move from A to B then:

- (A) $t_1 = 4t_2$
- (B) $t_1 = 2t_2$
- (C) $t_1 = t_2$
- (D) $t_1 > t_2$

AIPMT 2009 Prelims · Q20

17. A black body at 227°C radiates heat at the rate of $7 \text{ cal/cm}^2 \text{ s}$. At a temperature of 727°C , the rate of heat radiated in the same units will be:

- (A) 50
- (B) 112
- (C) 80
- (D) 60

AIPMT 2009 Prelims · Q21

18. The driver of a car travelling with speed 30 m/sec towards a hill sounds a horn of frequency 600 Hz. If the velocity of sound in air is 330 m/s, the frequency of reflected sound as heard by driver is:

- (A) 555.5 Hz
- (B) 720 Hz
- (C) 500 Hz
- (D) 550 Hz

AIPMT 2009 Prelims · Q23

19. A rectangular, a square, a circular and an elliptical loop, all in the $(x-y)$ plane, are moving out of a uniform magnetic field with a constant velocity, $\vec{v} = v \hat{i}$. The magnetic field is directed along the negative z axis direction. The induced emf, during the passage of these loops, out of the field region, will not remain constant for:

- (A) the circular and the elliptical loops
- (B) only the elliptical loop
- (C) any of the four loops
- (D) the rectangular, circular and elliptical loops

20. A galvanometer having a coil resistance of $60\ \Omega$ shows full scale deflection when a current of 1.0 amp passes through it. It can be converted into an ammeter to read currents upto 5.0 amp by:

- (A) putting in series a resistance of $15\ \Omega$
- (B) putting in series a resistance of $240\ \Omega$
- (C) putting in parallel a resistance of $15\ \Omega$
- (D) putting in parallel a resistance of $240\ \Omega$

21. Power dissipated in an LCR series circuit connected to an a.c. source of emf ε is:

- (A) $\varepsilon^2 \sqrt{[R^2 + (L\omega - 1/C\omega)^2]}/R$
- (B) $\varepsilon^2 [R^2 + (L\omega - 1/C\omega)^2]/R$
- (C) $\varepsilon^2 R / \sqrt{[R^2 + (L\omega - 1/C\omega)^2]}$
- (D) $\varepsilon^2 R / [R^2 + (L\omega - 1/C\omega)^2]$

22. Three concentric spherical shells have radii a , b and c ($a < b < c$) and have surface charge densities σ , $-\sigma$ and σ respectively. If V_A , V_B and V_C denote the potentials of the three shells, then for $c = a + b$, we have:

- (A) $V_C = V_B \neq V_A$
- (B) $V_C \neq V_B \neq V_A$
- (C) $V_C = V_B = V_A$
- (D) $V_C = V_A \neq V_B$

23. An engine pumps water continuously through a hose. Water leaves the hose with a velocity v and m is the mass per unit length of the water jet. What is the rate at which kinetic energy is imparted to water?

- (A) mv^2
- (B) $(1/2)mv^2$
- (C) $(1/2)m^2v^2$
- (D) $(1/2)mv^3$

24. A bar magnet having a magnetic moment of $2 \times 10^4\text{ J T}^{-1}$ is free to rotate in a horizontal plane. A horizontal magnetic field $B = 6 \times 10^{-4}\text{ T}$ exists in the space. The work done in taking the magnet slowly from a direction parallel to the field to a direction 60° from the field is:

- (A) 12 J
- (B) 6 J
- (C) 2 J
- (D) 0.6 J

25. In a Rutherford scattering experiment when a projectile of charge z_1 and mass M_1 approaches a target nucleus of charge z_2 and mass M_2 , the distance of closest approach is r_0 . The energy of the projectile is:

- (A) directly proportional to $z_1 z_2$
- (B) inversely proportional to z_1
- (C) directly proportional to mass M_1
- (D) directly proportional to $M_1 \times M_2$

26. Monochromatic light of wavelength 667 nm is produced by a helium neon laser. The power emitted is 9 mW. The number of photons arriving per sec on the average at a target irradiated by this beam is:

- (A) 3×10^{16}
- (B) 9×10^{15}
- (C) 3×10^{19}
- (D) 9×10^{17}

27. A wave in a string has an amplitude of 2 cm. The wave travels in the + ve direction of x axis with a speed of 128 m/sec. and it is noted that 5 complete waves fit in 4 m length of the string. The equation describing the wave is:

- (A) $y = (0.02) \text{ m} \sin (15.7x - 2010t)$
- (B) $y = (0.02) \text{ m} \sin (15.7x + 2010t)$
- (C) $y = (0.02) \text{ m} \sin (7.85x - 1005t)$
- (D) $y = (0.02) \text{ m} \sin (7.85x + 1005t)$

28. Which one of the following equations of motion represents simple harmonic motion? Where k , k_0 , k_1 and a are all positive.

- (A) acceleration = $-k(x + a)$
- (B) acceleration = $k(x + a)$
- (C) acceleration = kx
- (D) acceleration = $-k_0x + k_1x^2$

29. A student measures the terminal potential difference (V) of a cell (of emf ε and internal resistance r) as a function of the current (I) flowing through it. The slope, and intercept, of the graph between V and I , then, respectively, equal:

- (A) $-r$ and ε
- (B) r and $-\varepsilon$
- (C) $-\varepsilon$ and r
- (D) ε and $-r$

30. If a diamagnetic substance is brought near the north or the south pole of a bar magnet, it is:

- (A) repelled by the north pole and attracted by the south pole
- (B) attracted by the north pole and repelled by the south pole
- (C) attracted by both the poles
- (D) repelled by both the poles

31. A bus is moving with a speed of 10 m s^{-1} on a straight road. A scooterist wishes to overtake the bus in 100 s. If the bus is at a distance of 1 km from the scooterist, with what speed should the scooterist chase the bus?

- (A) 40 m s^{-1}
- (B) 25 m s^{-1}
- (C) 10 m s^{-1}
- (D) 20 m s^{-1}

32. The internal energy change in a system that has absorbed 2 kcal of heat and done 500 J of work is:

- (A) 6400 J
- (B) 5400 J
- (C) 7900 J
- (D) 8900 J

33. Three capacitors each of capacitance C and of breakdown voltage V are joined in series. The capacitance and breakdown voltage of the combination will be:

- (A) $3C$, $V/3$
- (B) $C/3$, $3V$
- (C) $3C$, $3V$
- (D) $C/3$, $V/3$

34. An explosion blows a rock into three parts. Two parts go off at right angles to each other. These two are, 1 kg first part moving with a velocity of 12 m s^{-1} and 2 kg second part moving with a velocity of 8 m s^{-1} . If the third part flies off with a velocity of 4 m s^{-1} , its mass would be:

- (A) 7 kg
- (B) 17 kg
- (C) 3 kg
- (D) 5 kg

35. A particle starts its motion from rest under the action of a constant force. If the distance covered in first 10 seconds is S_1 and that covered in the first 20 seconds is S_2 , then:

- (A) $S_2 = 3S_1$
- (B) $S_2 = 4S_1$
- (C) $S_2 = S_1$
- (D) $S_2 = 2S_1$

36. A body of mass 1 kg is thrown upwards with a velocity 20 m/s. It momentarily comes to rest after attaining a height of 18 m. How much energy is lost due to air friction? ($g = 10 \text{ m/s}^2$)

- (A) 30 J
- (B) 40 J
- (C) 10 J
- (D) 20 J

37. A conducting circular loop is placed in a uniform magnetic field 0.04 T with its plane perpendicular to the magnetic field. The radius of the loop starts shrinking at 2 mm/s. The induced emf in the loop when the radius is 2 cm is:

- (A) $4.8\pi \mu\text{V}$
- (B) $0.8\pi \mu\text{V}$
- (C) $1.6\pi \mu\text{V}$
- (D) $3.2\pi \mu\text{V}$

38. The magnetic force acting on a charged particle of charge $-2 \mu\text{C}$ in a magnetic field of 2 T acting in y direction, when the particle velocity is $(2\hat{i} + 3\hat{j}) \times 10^6 \text{ m s}^{-1}$, is:

- (A) 4 N in z direction
- (B) 8 N in y direction
- (C) 8 N in z direction
- (D) 8 N in $-z$ direction

39. Two bodies of mass 1 kg and 3 kg have position vectors $\hat{i} + 2\hat{j} + \hat{k}$ and $-3\hat{i} - 2\hat{j} + \hat{k}$, respectively. The centre of mass of this system has a position vector:

- (A) $-2\hat{i} - \hat{j} + \hat{k}$
- (B) $2\hat{i} - \hat{j} - 2\hat{k}$
- (C) $-\hat{i} + \hat{j} + \hat{k}$
- (D) $-2\hat{i} + 2\hat{k}$

40. The electric potential at a point (x, y, z) is given by $V = -x^2y - xz^3 + 4$. The electric field $\vec{E}$ at that point is:

- (A) $\vec{E} = \hat{i} 2xy + \hat{j}(x^2 + y^2) + \hat{k}(3xz - y^2)$
- (B) $\vec{E} = \hat{i} z^3 + \hat{j} xyz + \hat{k} z^2$
- (C) $\vec{E} = \hat{i}(2xy - z^3) + \hat{j} xy^2 + \hat{k} 3z^2x$
- (D) $\vec{E} = \hat{i}(2xy + z^3) + \hat{j} x^2 + \hat{k} 3xz^2$

41. The mean free path of electrons in a metal is $4 \times 10^{-8} \text{ m}$. The electric field which can give on an average 2 eV energy to an electron in the metal will be in units of V/m :

- (A) 5×10^{-11}
- (B) 8×10^{-11}
- (C) 5×10^7
- (D) 8×10^7

42. The ionization energy of the electron in the hydrogen atom in its ground state is 13.6 eV . The atoms are excited to higher energy levels to emit radiations of 6 wavelengths. Maximum wavelength of emitted radiation corresponds to the transition between:

- (A) $n = 3$ to $n = 1$ states
- (B) $n = 2$ to $n = 1$ states
- (C) $n = 4$ to $n = 3$ states
- (D) $n = 3$ to $n = 2$ states

43. Under the influence of a uniform magnetic field, a charged particle moves with constant speed V in a circle of radius R . The time period of rotation of the particle:

- (A) depends on R and not on V
- (B) is independent of both V and R
- (C) depends on both V and R
- (D) depends on V and not on R

44. The electric field part of an electromagnetic wave in a medium is represented by

$E_x = 0$;

$E_y = 2.5 \text{ (N/C)} \cos[(2\pi \times 10^6 \text{ rad/s}) t - (\pi \times 10^{-2} \text{ rad/m}) x]$;

$E_z = 0$. The wave is:

- (A) moving along x direction with frequency 10^6 Hz and wave length 100 m
- (B) moving along x direction with frequency 10^6 Hz and wave length 200 m
- (C) moving along $-x$ direction with frequency 10^6 Hz and wave length 200 m
- (D) moving along y direction with frequency $2\pi \times 10^6 \text{ Hz}$ and wave length 200 m

45. A block of mass M is attached to the lower end of a vertical spring. The spring is hung from a ceiling and has force constant value k . The mass is released from rest with the spring initially unstretched. The maximum extension produced in the length of the spring will be:

- (A) $2Mg/k$
- (B) $4Mg/k$
- (C) $Mg/2k$
- (D) Mg/k

Answer key and explanations

1. Answer: (D) β , α , γ

X to Y keeps the mass number and raises the atomic number by 1, which is β^- emission. Y to B^* lowers A by 4 and Z by 2, which is α emission. B^* to B changes neither A nor Z, so the excited nucleus de-excites by γ emission, giving the order β , α , γ .

2. Answer: (A) $\omega M/(M + 2m)$

No external torque acts, so angular momentum is conserved: $MR^2\omega = (MR^2 + 2mR^2)\omega'$. Hence $\omega' = \omega M/(M + 2m)$. The added masses increase the moment of inertia, so the angular velocity must fall, which rules out the expression larger than ω .

3. Answer: (A) In an isochoric process pressure remains constant

In an isochoric process the volume is held constant; constant pressure describes an isobaric process. The other statements (constant temperature in isothermal, $PV^\gamma = \text{constant}$ and thermal insulation in adiabatic) are all correct.

4. Answer: (B) Intensity of light

Above threshold, each photon ejects at most one electron, so the number of photoelectrons depends on the number of photons arriving per second, i.e. the intensity. The frequency (and $v - v_0$) decides the kinetic energy of the electrons, not their number.

5. Answer: (C) $\pi a\sqrt{3}/T$

$v = \omega\sqrt{a^2 - x^2}$ with $\omega = 2\pi/T$. At $x = a/2$, $v = (2\pi/T)\sqrt{(3a^2/4)} = (2\pi/T)(\sqrt{3}a/2) = \pi a\sqrt{3}/T$. The value with $2T$ in the denominator forgets that ω already carries the factor 2π .

6. Answer: (C) $10\sqrt{2} \text{ kg}$

$|F| = \sqrt{6^2 + 8^2 + 10^2} = \sqrt{200} = 10\sqrt{2} \text{ N}$. With $a = 1 \text{ m/s}^2$, $m = F/a = 10\sqrt{2} \text{ kg}$. Simply adding the components or taking $2\sqrt{10}$ is a mistake in the magnitude.

7. Answer: (B) $\vec{r} \cdot \vec{\tau} = 0$ and $\vec{F} \cdot \vec{\tau} = 0$

$\vec{\tau} = \vec{r} \times \vec{F}$ is perpendicular to the plane containing $\vec{r}$ and $\vec{F}$. A vector perpendicular to both has zero dot product with each, so $\vec{r} \cdot \vec{\tau} = 0$ and $\vec{F} \cdot \vec{\tau} = 0$.

8. Answer: (C) $dQ/dt = kA(T_1 - T_2)/L$

Fourier's law for steady conduction gives $dQ/dt = kA(T_1 - T_2)/L$: the heat current grows with area and temperature difference and falls with length. Forms with L in the numerator or A in the denominator have the wrong dependence.

9. Answer: (C) $4000 \text{ \AA}$

The longest detectable wavelength is $\lambda = hc/E_g = 1240 \text{ eV nm}/2.5 \text{ eV} \approx 496 \text{ nm} \approx 5000 \text{ \AA}$. Only photons of shorter wavelength have enough energy, so $4000 \text{ \AA}$ (400 nm) is detected. $6000 \text{ \AA}$ and the nm values of 4000 and 6000 are all longer than the cut-off.

10. Answer: (D) Pressure if $a = 1$, $b = -1$, $c = -2$

Pressure = force/area = $MLT^{-2}/L^2 = ML^{-1}T^{-2}$, so $a = 1$, $b = -1$, $c = -2$. Velocity has no mass dimension ($a = 0$), acceleration has no mass dimension, and force is MLT^{-2} , so the other pairings are wrong.

11. Answer: (C) 50

Current gain $\beta = \Delta I_c / \Delta I_b = (10 - 5) \text{ mA} / (200 - 100) \mu\text{A} = 5 \times 10^{-3} \text{ A} / 10^{-4} \text{ A} = 50$. A value of 100 or more comes from mishandling the milli and micro prefixes.

12. Answer: (A) 4 m s^{-2} upwards

$T - mg = ma$ gives $28000 - 2000 \times 10 = 2000a$, so $a = 4 \text{ m s}^{-2}$ upwards. The tension exceeds the weight, so the acceleration must be upward; 14 m s^{-2} ignores gravity.

13. Answer: (D) $(4/3) \text{ MI}^2$

Each rod's centre is $l/2$ from the axis: $I = MI^2/12 + M(l/2)^2 = MI^2/3$ (parallel-axis theorem). Four rods give $4MI^2/3$. Forgetting the parallel-axis term would give only $MI^2/3$ for the frame.

14. Answer: (A) 7

Wave speed $v = \sqrt{T/\mu} = \sqrt{20/10^{-3}} \approx 141.4 \text{ m/s}$. Fundamentals: $f = v/2l$ gives $141.4/1.032 \approx 137.0 \text{ Hz}$ and $141.4/0.982 \approx 144.0 \text{ Hz}$. Beat frequency = $144 - 137 = 7$ per second.

15. Answer: (C) isotope of parent

One α emission lowers Z by 2 and A by 4; two β^- emissions raise Z by 2 and leave A unchanged. Net: same Z , A reduced by 4, so the daughter is an isotope of the parent, not an isobar (same mass number).

16. Answer: (B) $t_1 = 2t_2$

Kepler's second law: the radius vector sweeps equal areas in equal times, so time is proportional to area swept. Area $SCD = 2 \times$ area SAB gives $t_1 = 2t_2$. The fact that the planet moves faster near the sun is already accounted for by the equal-area law.

17. Answer: (B) 112

Stefan's law: $E \propto T^4$ with absolute temperatures. $227^\circ\text{C} = 500 \text{ K}$ and $727^\circ\text{C} = 1000 \text{ K}$, so E rises by $(1000/500)^4 = 16$: $7 \times 16 = 112 \text{ cal/cm}^2 \text{ s}$. Using Celsius temperatures directly gives wrong ratios.

18. Answer: (B) 720 Hz

The hill receives $f_1 = 600 \times 330/(330 - 30)$ from the approaching car and reflects it; the driver, moving towards the hill, hears $f = f_1 \times (330 + 30)/330 = 600 \times 360/300 = 720 \text{ Hz}$. The reflected sound is heard at a higher, not lower, frequency.

19. Answer: (A) the circular and the elliptical loops

Induced emf = Bvl , where l is the length of the loop lying on the field boundary as it leaves. For a rectangle or square moving perpendicular to a side, l is a constant side length, so the emf is constant; for a circle or ellipse the chord at the boundary changes continuously, so the emf changes. A shrinking flux alone does not make the emf vary; it is the rate of change of flux that matters.

20. Answer: (C) putting in parallel a resistance of 15Ω

Shunt $S = IgG/(I - Ig) = (1 \times 60)/(5 - 1) = 15 \Omega$ connected in parallel, so the extra 4 A bypasses the coil. A series resistance would make a voltmeter, not an ammeter.

21. Answer: (D) $\epsilon^2 R / [R^2 + (L\omega - 1/C\omega)^2]$

Average power $P = \epsilon_{\text{rms}} I_{\text{rms}} \cos \phi$ with $I = \epsilon/Z$ and $\cos \phi = R/Z$, so $P = \epsilon^2 R / Z^2 = \epsilon^2 R / [R^2 + (L\omega - 1/C\omega)^2]$. Using only one factor of Z (the square-root form) gives the wrong power.

22. Answer: (D) $VC = VA \neq VB$

$VA = (\sigma/\epsilon_0)(a - b + c) = 2a\sigma/\epsilon_0$ for $c = a + b$. $VC = (\sigma/\epsilon_0)(a^2 - b^2 + c^2)/c = (\sigma/\epsilon_0)(2a^2 + 2ab)/(a + b) = 2a\sigma/\epsilon_0$. $VB = (\sigma/\epsilon_0)(a^2/b - b + c) = (\sigma/\epsilon_0)(a^2/b + a)$, which differs from $2a\sigma/\epsilon_0$ unless $a = b$, so $VC = VA \neq VB$.

23. Answer: (D) $(1/2)mv^3$

Mass leaving per second = (mass per length) $\times$ speed = mv . KE delivered per second = $\frac{1}{2}(mv)v^2 = \frac{1}{2}mv^3$. Taking $\frac{1}{2}mv^2$ treats m as the mass per second instead of per unit length.

24. Answer: (B) 6 J

Work = $MB(\cos 0^\circ - \cos 60^\circ) = 2 \times 10^4 \times 6 \times 10^{-4} \times \frac{1}{2} = 6 \text{ J}$. The value 12 J is MB itself, which would be the work only for a 90° turn.

25. Answer: (A) directly proportional to $z_1 z_2$

At the distance of closest approach all kinetic energy becomes electrostatic potential energy: $E = k z_1 z_2 e^2 / r_0$. So, for a given r_0 , the energy is directly proportional to $z_1 z_2$ and does not depend on the masses.

26. Answer: (A) 3×10^{16}

Energy per photon = $hc/\lambda = (6.63 \times 10^{-34} \times 3 \times 10^8)/(667 \times 10^{-9}) \approx 2.98 \times 10^{-19}$ J. Photons per second = $9 \times 10^{-3}/2.98 \times 10^{-19} \approx 3 \times 10^{16}$. Forgetting the milli prefix gives 3×10^{19} .

27. Answer: (C) $y = (0.02) \sin(7.85x - 1005t)$

$\lambda = 4/5 = 0.8$ m, so $k = 2\pi/0.8 \approx 7.85 \text{ m}^{-1}$ and $\omega = kv = 7.85 \times 128 \approx 1005 \text{ s}^{-1}$. A wave moving towards +x has the form $\sin(kx - \omega t)$, so $y = 0.02 \sin(7.85x - 1005t)$; the '+' form travels towards -x and 15.7 uses $\lambda = 0.4$ m.

28. Answer: (A) acceleration = $-k(x + a)$

Put $X = x + a$; then acceleration = $-kX$, which is SHM about $x = -a$ with $\omega^2 = k$. Acceleration = $+kx$ or $k(x + a)$ points away from equilibrium, and the x^2 term makes the motion non-linear.

29. Answer: (A) $-r$ and ϵ

Terminal voltage $V = \epsilon - Ir$, a straight line in I . Its slope is $-r$ and its intercept on the V axis ($I = 0$) is ϵ . A positive slope r would mean the voltage rises as more current is drawn.

30. Answer: (D) repelled by both the poles

Diamagnetic materials get a weak induced moment opposite to the applied field, so they are pushed towards weaker field regions. This happens regardless of which pole is used, so they are repelled by both poles.

31. Answer: (D) 20 m s^{-1}

The scooter must close 1000 m in 100 s, so its speed relative to the bus is 10 m s^{-1} . Its ground speed = $10 + 10 = 20 \text{ m s}^{-1}$. Answering 10 m s^{-1} gives only the relative speed.

32. Answer: (C) 7900 J

First law: $\Delta U = Q - W = 2 \times 4200 - 500 = 7900 \text{ J}$ ($1 \text{ cal} = 4.2 \text{ J}$). Adding the work instead of subtracting gives 8900 J.

33. Answer: (B) $C/3$, 3V

Capacitors in series: $1/C_{\text{eq}} = 3/C$, so $C_{\text{eq}} = C/3$. The same charge sits on each, so the applied voltage divides equally and each can take V before breakdown: total 3V.

34. Answer: (D) 5 kg

Momenta of the two pieces are $1 \times 12 = 12$ and $2 \times 8 = 16 \text{ kg m s}^{-1}$ at right angles, with resultant $\sqrt{(12^2 + 16^2)} = 20 \text{ kg m s}^{-1}$. The third piece must carry an equal and opposite 20 kg m s^{-1} , so $m = 20/4 = 5 \text{ kg}$.

35. Answer: (B) $S_2 = 4S_1$

From rest under constant force, $S = \frac{1}{2}at^2$, so $S \propto t^2$. Doubling the time from 10 s to 20 s makes $S_2 = 4S_1$. $S_2 = 3S_1$ is the distance in the second 10 s, not the total.

36. Answer: (D) 20 J

Initial KE = $\frac{1}{2} \times 1 \times 20^2 = 200 \text{ J}$. PE at 18 m = $1 \times 10 \times 18 = 180 \text{ J}$. Energy lost to air friction = $200 - 180 = 20 \text{ J}$.

37. Answer: (D) $3.2\pi \mu\text{V}$

Emf = $B dA/dt = B \times 2\pi r \times dr/dt = 0.04 \times 2\pi \times 0.02 \times 2 \times 10^{-3} = 3.2\pi \times 10^{-6} \text{ V} = 3.2\pi \mu\text{V}$. Missing the factor 2 from $d(\pi r^2)/dt$ gives $1.6\pi \mu\text{V}$.

38. Answer: (D) 8 N in $-z$ direction

$\mathbf{F} = q(\mathbf{\bar{v}} \times \mathbf{B})$. Only the x component of velocity matters: $(2 \times 10^6 \hat{i}) \times (2\hat{j}) = 4 \times 10^6 \hat{k}$. Multiplying by $q = -2 \times 10^{-6} \text{ C}$ gives $-8\hat{k} \text{ N}$, i.e. 8 N in $-z$ direction. Ignoring the negative charge gives $+z$.

39. Answer: (A) $-2\hat{i} - \hat{j} + \hat{k}$

$\mathbf{r}_{\text{cm}} = (m_1\mathbf{r}_1 + m_2\mathbf{r}_2)/(m_1 + m_2) = [(\hat{i} + 2\hat{j} + \hat{k}) + 3(-3\hat{i} - 2\hat{j} + \hat{k})]/4 = (-8\hat{i} - 4\hat{j} + 4\hat{k})/4 = -2\hat{i} - \hat{j} + \hat{k}$.

40. Answer: (D) $\mathbf{E} = \hat{i}(2xy + z^3) + \hat{j}x^2 + \hat{k}3xz^2$

$\mathbf{E} = -\nabla V$. $-\partial V/\partial x = 2xy + z^3$, $-\partial V/\partial y = x^2$, $-\partial V/\partial z = 3xz^2$. So $\mathbf{E} = \hat{i}(2xy + z^3) + \hat{j}x^2 + \hat{k}3xz^2$. A sign slip on the z^3 term gives the $(2xy - z^3)$ form.

41. Answer: (C) 5×10^7

An electron gains energy $eE\lambda$ while travelling one mean free path. Setting $eE\lambda = 2 \text{ eV}$ gives $E = 2 \text{ V}/(4 \times 10^{-8} \text{ m}) = 5 \times 10^7 \text{ V/m}$. The very small values (10^{-11}) would come from multiplying by λ instead of dividing.

42. Answer: (C) $n = 4$ to $n = 3$ states

Number of lines from level $n = n(n - 1)/2 = 6$, so $n = 4$. The longest wavelength needs the smallest energy gap, which is between $n = 4$ and $n = 3$. The $3 \rightarrow 1$ or $2 \rightarrow 1$ lines have larger gaps and shorter wavelengths.

43. Answer: (B) is independent of both V and R

$qVB = mV^2/R$ gives $R = mV/qB$, and $T = 2\pi R/V = 2\pi m/qB$. Since R grows in proportion to V, T depends on neither speed nor radius.

44. Answer: (B) moving along x direction with frequency 10^6 Hz and wave length 200 m

Comparing with $E_0 \cos(\omega t - kx)$: $\omega = 2\pi \times 10^6$ rad/s gives $f = 10^6$ Hz, and $k = \pi \times 10^{-2}$ rad/m gives $\lambda = 2\pi/k = 200$ m. The $(\omega t - kx)$ form means propagation along +x. Taking $f = 2\pi \times 10^6$ Hz confuses ω with f.

45. Answer: (A) 2 Mg/k

Released from rest with the spring unstretched, the block moves until it is momentarily at rest again.

Energy conservation: $Mgx = \frac{1}{2}kx^2$, so the maximum extension is $x = 2Mg/k$. Mg/k is only the equilibrium extension (where the block moves fastest), not the maximum.

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