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PHYSICS

1. A compressive force, F is applied at the two ends of a long thin steel rod. It is heated, simultaneously, such that its temeprature increass by ΔT. The net change in its length is zero. Let l be the length of the rod, A its area of cross-section, Y its Young's modulus, and α its coefficient of linear expansion. Then, F is equal to -

(1) $lA\, Y\alpha\, \Delta T$ (2) $A\, Y\alpha\, \Delta T$ (3) $\frac{AY}{\alpha \Delta T}$ (4) $l^2\, Y\alpha\, \Delta T$

Sol. **3**

Net change in length = 0

Thermal Exp. = $l \propto \Delta t$

$$y = \frac{F/A}{\Delta l / l}$$

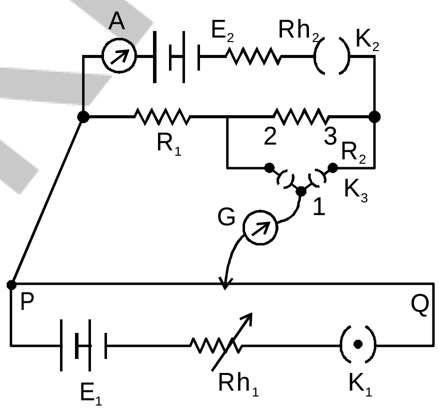
$$\frac{\Delta l}{l} = \frac{F}{Ay}$$

$$\Delta l = \frac{Fl}{Ay}$$

$$\frac{Fl}{Ay} = l \propto \Delta t$$

$$F = Ay \propto \Delta t$$

2. A potentiometer PQ is set up to comapre two resistances as shown in the figure. The ammeter A in the circuit reads 1.0 A when two way key K_3 is open. The balance point is at a length l_1 cm from P when two way key K_3 is plugged in between 2 and 1, while the balance point is at a length l_2 cm from P when key K_3 is plugged in between 3 and 1. The ratio of the two resistance $\frac{R_1}{R_2}$, is found to be -



(1) $\frac{l_1}{l_1 - l_2}$ (2) $\frac{l_2}{l_2 - l_1}$ (3) $\frac{l_1}{l_1 + l_2}$ (4) $\frac{l_1}{l_2 - l_1}$

Sol. **1**

When key is at point

$V_1 = iR_1 = xl_1$

when key is at (3)

$V_2 = i\,(R_1 + R_2) = xl_2$

$$\frac{R_1}{R_1 + R_2} = \frac{l_1}{l_2}$$

$$\frac{R_1}{R_2} = \frac{l_1}{l_2 - l_1}$$

3. A signal of frequency 20 kHz and peak voltage of 5 volt is used to modulate a carrier wave of frequency 1.2 MHz and peak voltage 25 volts. Choose the correct statement.

(1) Modulation index = 5, side frequency bands are at 1400 kHz and 1000 kHz

(2) Modulation index = 0.8, side frequency bands are at 1180 kHz and 1220 kHz

(3) Modulation index = 0.2, side frequency bands are at 1200 kHz and 1180 kHz

(4) Modulation index = 5, side frequency bands are at 21/2 kHz and 18.8 kHz

Sol. **3**

Modulation idex = m = $\frac{V_m}{V_0}$

$= \frac{1}{5} = 0.2$

Frequency = 12×10^3 kHz

F = 12.00 kHz

$F_1 = 1200 - 20 = 1180$ kHz

$F_2 = 1200 + 20 = 1220$ kHz

4. A single slit of width b is illuminated by a coherent monochromatic light of wavelength λ. If the second and fourth minima in the diffraction pattern at a distance 1 m from the slit are at 3 cm and 6 cm respectively from the central maximum, what is the width of the central maximum ? (i.e., distance between first minimum on either side of the central maximum)

(1) 4.5 cm (2) 1.5 cm (3) 6.0 cm (4) 3.0 cm

Sol. **4**

min.

$f \sin\theta = n\lambda$

$\sin\theta = \frac{n\lambda}{6}$

n = 2

$\sin\theta = \frac{2\lambda}{6} = \tan\theta_1 = \frac{x_1}{D}$

x = 4

$\sin\theta_2 = \frac{4\lambda}{6} = \frac{x_2}{D}$

$x_2 - x_1 = \frac{4\lambda}{6} - \frac{2\lambda}{6} = \frac{2\lambda}{6} = 3$ cm

width of central max = $\frac{2\lambda}{6}$ = 3 cm

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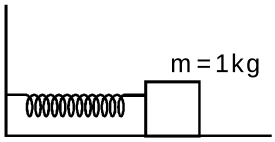
5. A 1 kg block attached to a spring vibrates with a frequency of 1 Hz on a frictionless horizontal table. Two springs identical to the original spring are attached in parallel to an 8 kg block placed on the same table. So, the frequency of vibration of the 8 kg block is -

(1) 2 Hz (2) $\frac{1}{4}$ Hz (3) $\frac{1}{2\sqrt{2}}$ Hz (4) $\frac{1}{2}$ Hz

Sol. **4**

$F = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = 1$

$4\pi^2 = \frac{k}{m}$ m = 1

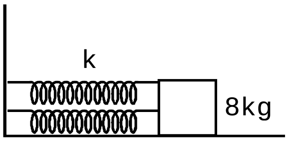


$k = 4\pi^2$

In parallel $k_{eq} = 2k$

$F = \frac{1}{2\pi}\sqrt{\frac{K\times 2}{8}}$

$= \frac{1}{2}$ Hz



6. A magentic dipole in a constant magnetic field has -

(1) maximum potential energy when the torque is maximum
(2) zero potential energy when the torque is maximum
(3) zero potential energy when the torque is minimum
(4) minimum potential energy when the torque is maximum

Sol. **2**

$PE = -PE\cos\theta$

$\tau = PE\sin\theta$

τ_{max} when $\theta = 90°$

PE = 0

7. If the earth has no rotational motion, the weight of a person on the equation is W. Detrmine the speed with which the earth would have to rotate about its axis so that the person at the equator will weight $\frac{3}{4}$ W. Radius of the earth is 6400 km and $g = 10\ m/s^2$.

(1) 0.63×10^{-3} rad/s (2) 0.28×10^{-3} rad/s
(3) 1.1×10^{-3} rad/s (4) 0.83×10^{-3} rad/s

Sol. **1**

$g' = g - \omega^2 R\cos^2\theta$

$\frac{3g}{4} = g - \omega^2 R$

$w^2 R = \frac{g}{4}$

$w = \sqrt{\frac{g}{4R}}$

$= \sqrt{\frac{10}{4\times 64\omega\times 10^3}}$

$= \frac{1}{2 \times 8 \times 100}$

$= \frac{1}{1600} = \frac{1}{16} \times 10^{-2} = 0.6 \times 10^{-3}$

8. An object is dropped from a height h from the ground. Every time it hits the ground it looses 50% of its kinetic energy. The total distance covered as $t \to \infty$ is -

(1) 2h (2) ∞ (3) $\frac{5}{3}$ h (4) $\frac{8}{3}$ h

Sol. $\frac{1}{2} mv'^2 = \frac{1}{2}\frac{1}{2} mv^2$

$v' = \frac{v}{\sqrt{2}}$

v = eu

$e = \frac{1}{\sqrt{2}}$

$H = \lambda \left(\frac{1+e^2}{1-e^2}\right)$

$= h\left(\frac{1+\frac{1}{2}}{1-\frac{1}{2}}\right) = 3h$

9. The energy stored in the electric field produced by a metal sphere is 4.5 J. If the sphere contains 4μC charge, its radius will be :

[Take : $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N – m²/C²]

(1) 32 mm (2) 16 mm (3) 28 mm (4) 20 mm

Sol. **2**

Energy of sphere = $\frac{Q^2}{2C}$

$4.5 = \frac{16 \times 10^{-12}}{2C}$

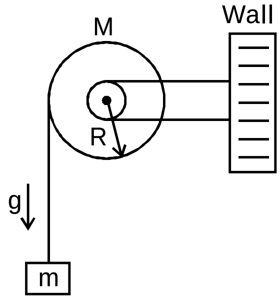
$C = \frac{16 \times 10^{-12}}{9} = 4\pi\varepsilon_0 R$

$R = \frac{16 \times 10^{-12}}{9} \times \frac{1}{4\pi\varepsilon_0}$

$= 9 \times 10^9 \times \frac{16}{9} \times 10^{-12}$

$= 16 \times 10^{-3} = 16$ mm

10. A uniform disc of radius R and mass M is free to rotate only about its axis. A string is wrapped over its rim and a body of mass m is tied to the free end of the string as shown in the figure. The body is released from rest. Then the acceleration of the body is -



(1) $\frac{2Mg}{2m+M}$ (2) $\frac{2Mg}{2M+m}$ (3) $\frac{2mg}{2M+m}$ (4) $\frac{2mg}{2m+M}$

Sol. **4**

$mg - T = ma$

$RT = I\alpha$

$RT = \frac{MR^2}{2} \cdot \frac{a}{R}$

$T = \frac{Ma}{2}$

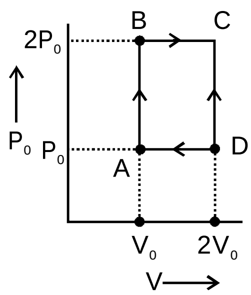
$mg - \frac{Ma}{2} = ma$

$mg = a\left(\frac{M}{2} + m\right)$

$mg = a\left(\frac{M+2m}{2}\right)$

$a = \frac{2mg}{M+2m}$

11. An engine operates by taking n moles of an ideal gas through the cycle ABCDA shown in figure. The thermal efficiency of the engine is - (Take C_V = 1.5 R, where R is gas constant)



(1) 0.24 (2) 0.15 (3) 0.32 (4) 0.08

Sol. **2**

$w = P_0V_0$

Heat given = $Q_{AB} = Q_{BC}$

$= nC_VdT_{AB} + nC_PdT_{BC}$

$= \frac{3}{2}(nRT_B - nRT_A) + \frac{5}{2}(nRT_C - nRT_B)$

$= \frac{3}{2}(2P_0V_0 - P_0V_0) + \frac{5}{2}(4P_0V_0 - 2P_0V)$

$= \frac{13}{2}P_0V_0$

$n = \frac{w}{Q\text{given}} = \frac{2}{13} = 0.15$

12. Time (T), velocity (3) and angular momentum (h) are chosen as fundamental quantities instead of mass, length and time. In terms of these, the dimensions of mass would be -

(1) $[M] = [T^{-1}C^{-2}h]$ (2) $[M] = [T\,C^{-2}h]$
(3) $[M] = [T^{-1}C^{-2}h^{-1}]$ (4) $[M] = [T^{-1}C^{2}h]$

Sol. **1**

$M \propto T^x v^y h^z$

$M' L^0T^0 = (T')^x (L^1T^{-1})^y (M^1L^2T^{-1})^z$

$M^1L^0T^0 = M^z L^{y+2z} + T^{x-y-z}$

$z = 1$

$y + 2z = 0$ $x - y - z = 0$

$y = -2$ $x + 2 - 1 = 0$

$x = -1$

$M \Rightarrow T^{-1} C^{-2} h^1$

13. In an experiment a sphere of aluminium of mass 0.20 kg is heated upto 150°C. Immediately, it is put into water of volume 150 cc at 27°C kept in a calorimeter of water equivalent to 0.025 kg. Final temperature of the system is 40°C. The specific heat of aluminium is -
(take 4.2 Joule = 1 calorie)

(1) 434J/kg-°C (2) 378J/kg-°C (3) 315J/kg-°C (4) 476J/kg-°C

Sol. **1**

Q given = Q used

$0.2 \times S \times (150 - 40) = 150 \times 1 \times (40 - 27) + 25 \times (40 - 27)$

$0.2 \times S \times 110 = 150 \times 13 + 25 \times 13$

$S = \frac{13 \times 25 \times 7}{0.2 \times 110}$

$S = 434$

14. There is a uniform electrostatic field in a region. The potential at various points on a small sphere centred at P, in the region, is found to vary between in limits 589.0V to 589.8 V. What is the potential at a point on the sphere whose radius vector makes an angle of 60° with the direction of the field ?

(1) 589.4 V (2) 589.5 V (3) 589.2 V (4) 589.6 V

Sol. **1**

$\Delta V = E.d$

$0.8 = Ed\,(\text{max})$

$\Delta V = Ed\cos\theta = 0.8 \times \cos 60$

$= 0.4$

589.4

15. Magnetic field in a plane electromagnetic wave is given by

$\vec{B} = B_0 \sin(kx + \omega t)\hat{j}T$

Expression for corresponding electric field will be

(1) $\vec{E} = -B_0 c \sin(kx + \omega t)\hat{k} V/m$

(2) $\vec{E} = B_0 c \sin(kx - \omega t)\hat{k} V/m$

(3) $\vec{E} = B_0 c \sin(kx + \omega t)\hat{k} V/m$

(4) $\vec{E} = \frac{B_0}{c} \sin(kx + \omega t)\hat{k} V/m$

Sol. **3**

$C = \frac{E_0}{B_0}$

$E = CB_0$

$= CB_0$

$= CB_0 \sin(kx + \omega t)\ \hat{i}$

16. According to Bohr's theory, the time averaged magnetic field at the centre (i.e. nucleus) of a hydrogen atom due to the motion of electrons in the n^{th} orbit is proportional to :
(n = principal quantum number)

(1) n^{-3} (2) n^{-2} (3) n^{-4} (4) n^{-5}

Sol. **2**

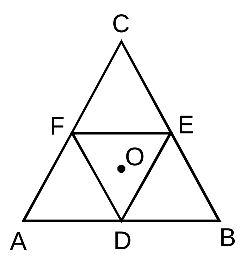
$B = \frac{\mu_0 I}{2r}$

$= \frac{\mu_0 qt}{2r}$

$r \propto n^2$

$B \propto m^{-2}$

17. Moment of inertia of an equilateral triangular lamina ABC, about the axis passing through its centre O and perpendicular to its plane is I_0 as shown in the figure. A cavithy DEF is cut out from the lamina, where D,E,F are the mid points of the sides. Moment of inertia of the remaining part of lamina about the same axis is -



(1) $\frac{15}{16}\ I_0$ (2) $\frac{3I_0}{4}$ (3) $\frac{7}{8}\ I_0$ (4) $\frac{31I_0}{32}$

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Sol. **1**

$I_0 = kml^2$ BC = l

$I_{DEF} = K\frac{m}{4}\left(\frac{l}{2}\right)^2$

$= \frac{k}{16} ml^2$

$I_{DEF} = \frac{I_0}{16}$

$I_{remain} = I_0 = \frac{I_0}{16}$

$= \frac{15I_0}{16}$

18. The maximum velocity of the photoelectrons emitted from the surface is v when light of frequency n falls on a metal surface. If the incident frequency is increased to 3n, the maximum velocity of the ejected photoelectrons will be -

(1) more than $\sqrt{3}$ v (2) equal to $\sqrt{3}$ v

(3) v (4) less than $\sqrt{3}$ v

Sol. **2**

$E_1 = hn - \phi$

$E_2 = 4hn - \phi$

$E_2 = 3(E_1 + \phi) - \phi$

$E_2 = 3E_1 + 2V$

$m_0 x \sqrt{3}\, y$

19. What is the conductivity of a semiconductor sample having electron concentration of 5×10^{18} m^{-3}, hole concentration of 5×10^{19} m^{-3}, electron mobility of 2.0 $m^2 V^{-1} s^{-1}$ and hole mobility of 0.01 $m^2 V^{-1} s^{-1}$?

(Take charge of electron as 1.6×10^{-19} C)

(1) 1.83 $(\Omega\text{-m})^{-1}$ (2) 1.68 $(\Omega\text{-m})^{-1}$

(3) 1.20 $(\Omega\text{-m})^{-1}$ (4) 0.59 $(W\text{-m})^{-1}$

Sol. **2**

$s = e(n_e\mu_e + n_n\mu_n)$

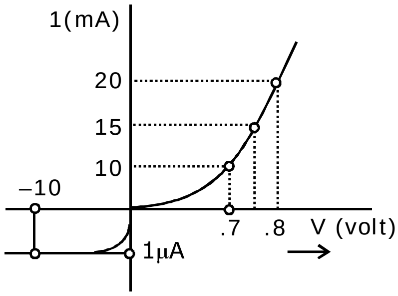
$= 1.6 \times 10^{-19}(5 \times 10^{18} \times 2 + 5 \times 10^{19} \times 0.01)$

$= 1.6 \times 10^{-19}(10^{19} + 0.05 \times 10^{19})$

$= 1.6 \times 1.05$

$= 1.68$

20. The V-I characteristic of a diode is shown in the figure. The ratio of forward to reverse bias resistance is :



(1) 100 (2) 10^6 (3) 10^{-6} (4) 10

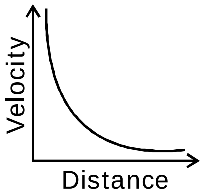
Sol. **3**

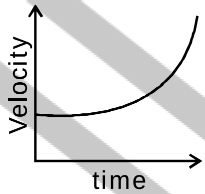
$$f.B = \frac{0.1}{10 \times 10^{-3}} I = 10$$

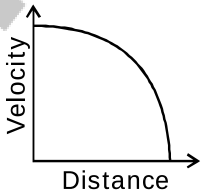
$$RB = \frac{10}{10^{-6}} = 10^7$$

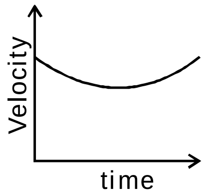
$$\frac{fB}{RB} = 10^{-6}$$

21. Which graph corresponds to an object moving with a constant negative acceleration and a positive velocity ?

(1) 

(2) 

(3) 

(4) 

Sol. **3**

$a = -C$

$$\frac{VdV}{dx} = -C$$

$VdV = -CdX$

$$\frac{V^2}{2} = -Cx + k$$

$$x = -\frac{V^2}{2C} + \frac{K}{C}$$

22. A small circular loop of wire of radius a is located at the centre of a much larger circular wire loop of radius b. The two loops are in the same plane. The outer loop of radius b carries an alternating current $I = I_0 \cos(\omega t)$. The emf induced in the smaller inner loop is nearly ?

(1) $\pi\mu_0 I_0 \frac{a^2}{b}\omega \sin(\omega t)$ (2) $\frac{\pi\mu_0 I_0}{2}.\frac{a^2}{b}\omega \cos(\omega t)$

(3) $\frac{\pi\mu_0 I_0 b^2}{a}\omega \cos(\omega t)$ (4) $\frac{\pi\mu_0 I_0}{2}.\frac{a^2}{b}\omega \sin(\omega t)$

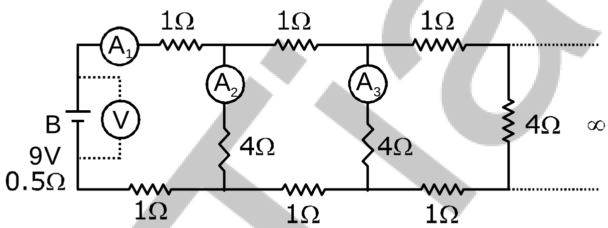
Sol. **4**

$e = MdI$

$dT \quad M = \frac{\mu_0 \pi a^2}{2b}$

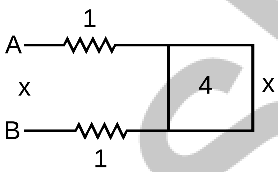
$= \frac{\mu_0 \pi a^2}{2b} = \omega I_0 I\omega t$

23.



A 9 V battery with internal resistance of 0.5 Ω is connected across an infinite network as shown in the figure. All ammeters A_1, A_2, A_3 and voltmeter V are ideal.
Choose correct statement.
(1) Reading of A_1 is 18 A
(2) Reading of V is 9 V
(3) Reading of V is 7 V
(4) Reading of A_1 is 2 A

Sol. **4**



$$x = \frac{4x}{4+x} + 2$$

$$x = \frac{8+6x}{4+x}$$

$4x + x^2 = 8 + 6x$
$x^2 - 2x - 8 = 0$

$$x = \frac{2 \pm \sqrt{4 - 4(1)(-8)}}{2} = \frac{2 \pm \sqrt{36}}{2}$$

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$= \frac{2 \pm 6}{2} = 4$

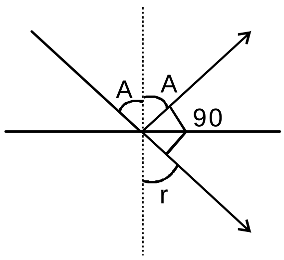
$A' = \frac{9}{4 + 0.5} = 2$

$A' = 9$

24. Let the refractive index of a denser medium with respect to a rarer medium be n_{12} and its critical angle be θ_C. At an angle of incidence A when light is travelling from denser medium to rarer medium, a part of the light is reflected and the rest is refracted and the angle between reflected and refracted rays is 90°. Angle A given by -

(1) $\tan^{-1}(\sin\theta_C)$ (2) $\frac{1}{\tan^{-1}(\sin\theta_C)}$ (3) $\cos^{-1}(\sin\theta_C)$ (4) $\frac{1}{\cos^{-1}(\sin\theta_C)}$

Sol. **1**



$\mu = \frac{\mu_R}{\mu_D} = \frac{\sin i_c}{\sin 90°}$

$\frac{\mu_R}{\mu_D} = \sin i_i$

$\mu = \frac{\mu_R}{\mu_D} = \frac{\sin A}{\sin r}$

$= \frac{\sin A}{\sin(90 - A)} = \frac{\sin A}{\cos A}$

$\frac{\mu_R}{\mu_D} = \tan A$

$\tan A = \sin\theta_C$

$A = \tan^{-1}(\sin\theta_C)$

25. The ratio of maximum acceleration to maximum velocity in a simple harmonic motion is 10 s^{-1}.

At, t = 0 the displacement is 5 m. What is the maximum acceleration ? The initial phase is $\frac{\pi}{4}$.

(1) 500 m/s^2 (2) 750 $\sqrt{2}$ m/s^2 (3) 750 m/s^2 (4) 500 $\sqrt{2}$ m/s^2

Sol. **4**

$f_{max} = \omega a$

$v_{min} = a\omega$

$\frac{\omega a}{a\omega} = 10$

w = 10

x = a sin ($\omega + \pi/4$)

at f = 0

5 = a sin ($\pi/4$)

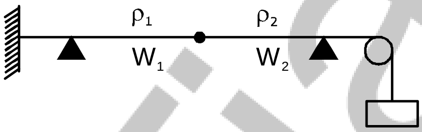
a = $5\sqrt{2}$

max acc. = w2a

= 100 × $5\sqrt{2}$

= 500 $\sqrt{2}$

26. Two wires W_1 and W_2 have the same radius r and respective densities ρ_1 and ρ_2 such that $\rho_2 = 4\rho_1$. They are joined together at the point O, as shown in the figure. The combination is used as a sonometer wire and kept udner tension T. The point O is midway between the two bridges. When a stationary waves is set up in the composite wire, the joint is found to be a node. The ratio of the number of antinodes formed in W_1 to W_2 is -



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

Sol. **2**

$n_1 = n_2$

T → same

r → same

l → same

$n = \frac{p}{2l}\sqrt{\frac{T}{\pi r^2 d}}$

$n_1 = n_2$

$\frac{p_1}{\sqrt{d_1}} = \frac{p_2}{\sqrt{d_2}}$

$\frac{p_1}{p_2} = \frac{1}{2}$

27. An ideal gas has molecules with 5 degrees of freedom. The ratio of specific heats at constant pressure (C_P) and at constant volume (C_V) is

(1) $\frac{7}{5}$ (2) 6 (3) $\frac{7}{2}$ (4) $\frac{5}{2}$

Sol. **1**

$f = \frac{C_p}{C_a} = 1 + \frac{2}{1}$

= 7/5

28. Two deuterons udnergo nuclear fusion to form a Helium nucleus. Energy released in this process is : (given binding energy per nucleon for deuteron = 1.1 MeV and for helium = 7.0 MeV)

(1) 23.6 MeV (2) 25.8 MeV (3) 30.2 MeV (4) 32.4 MeV

Sol. **1**

${}_1H^2 + {}_1H^1 \rightarrow 2H_c{}^4$

initiate $\Rightarrow$ 1.1 × 4 = 4.4

final $\Rightarrow$ 4 × 7 = 28

release $\Rightarrow$ 28 – 4.4 = 23.6

29. In a certain region static electric and magentic fields exist. The magnetic field is given by $\vec{B} = B_0(\hat{i} + 2\hat{j} - 4\hat{k})$. If a test charge moving with a velocity $\vec{\upsilon} = \upsilon_0(3\hat{i} - \hat{j} + 2\hat{k})$ experience no force in that region, then the electric field in the region, in SI units, is -

(1) $\vec{E} = -\upsilon_0 B_0(\hat{i} + \hat{j} + 7\hat{k})$ (2) $\vec{E} = -\upsilon_0 B_0(3\hat{i} - 2\hat{j} - 4\hat{k})$

(3) $\vec{E} = \upsilon_0 B_0(14\hat{j} + 7\hat{k})$ (4) $\vec{E} = -\upsilon_0 B_0(14\hat{j} + 7\hat{k})$

Sol. **4**

$F_e = F_n = 0$

$F_e = -F_m$

$= -q\ (\vec{v} \times \vec{B})$

$= -\upsilon_0 v_0\ [(3\hat{i} - \hat{j} + 2\hat{k}) \times (\hat{i} + 2\hat{j} - 4\hat{k})]$

$= -\upsilon_0 v_0\ (14\hat{i} + 7\hat{k})$

30. In a physical balance working on the principle of moments, when 5 mg weight is placed on the left pan, the beam becomes horizontal. Both the empty pans of the balance are of equal mass. Which of the following statements is correct ?

(1) Every object that is weighted using this balance appears lighter than its actual weight
(2) Left arm is shorter than the right arm
(3) Both the arms are of same length
(4) Left arm is longer than the right arm

Sol. **2**