JEE MAINS_8-APRIL-2017
PHYSICS

1. Time (T), velocity (C) 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) $[M] = [T^{-1}C^{-2}h]$

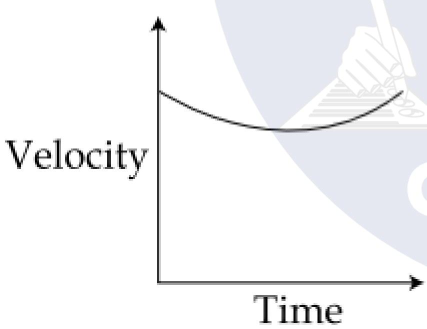
(2) $[M] = [T^{-1}C^{2}h]$

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

(4) $[M] = [TC^{-2}h]$

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

(1)



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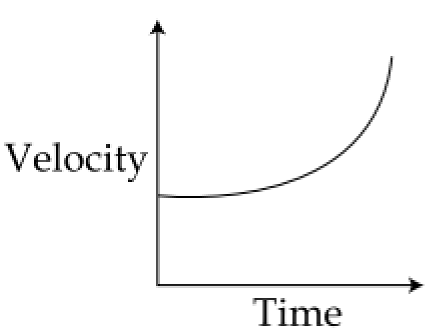

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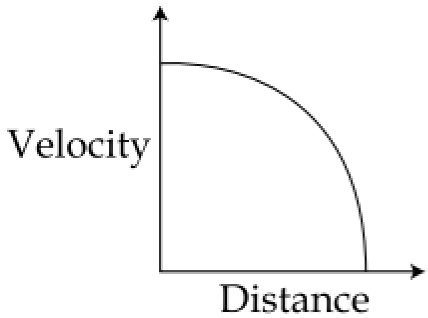

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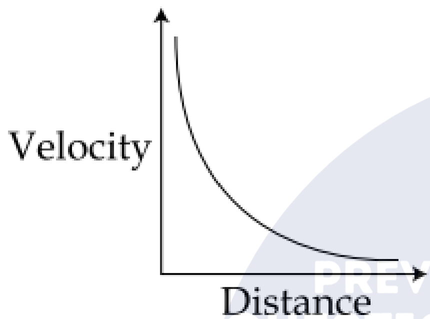


3. A 1 kg block attached to a spring vibrates with a frequency of 1 Hz on a frictionless horizontal table. Two springs identical to the original spring are attached in parallel to an 8 kg block placed on the same table. So, the frequency of vibration of the 8 kg block is:

(1) $\frac{1}{4}$HZ

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

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

(4) 2 Hz

4. 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:

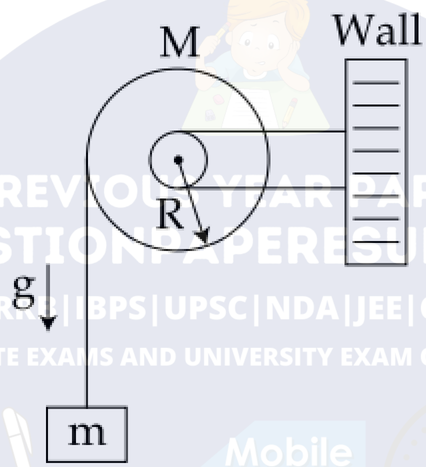
(1) 2h

(2) ∞

(3) $\frac{5}{3}h$

(4) $\frac{8}{3}h$

5. 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) $\frac{2\,mg}{2m+M}$

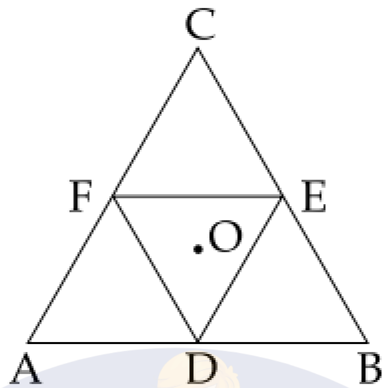
(2) $\frac{2\,Mg}{2\,m+M}$

(3) $\frac{2\,mg}{2\,M+m}$

(4) $\frac{2\,Mg}{2M+m}$

6. Moment of inertia of an equilateral triangular lamina ABC, about the axis passing through its centre O and perpendicular to its plane is Io as shown in the figure. A cavity 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) $\frac{7}{8}I_0$

(2) $\frac{15}{16}I_0$

(3) $\frac{3\,I_0}{4}$

(4) $\frac{31\,I_0}{32}$

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

(1) 1.1×10^{-3} rad/s

(2) 0.83×10^{-3} rad/s

(3) 0.63×10^{-3} rad/s

(4) 0.28×10^{-3} rad/s

8. In an experiment a sphere of aluminium of mass 0.20 kg is heated upto 1508C. Immediately, it is put into water of volume
150 cc at 278C kept in a calorimeter of water equivalent to 0.025 kg. Final temperature of the system is 408C. The specific heat of aluminium is: (take 4.2 Joule=1 calorie)

(1) $378\ \text{J/kg-°C}$

(2) $315\ \text{J/kg-°C}$

(3) $476\ \text{J/kg-°C}$

(4) $434\ \text{J/kg-°C}$

(9) A compressive force, F is applied at the two ends of a long thin steel rod. It is heated, simultaneously, such that its temperature increases 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:

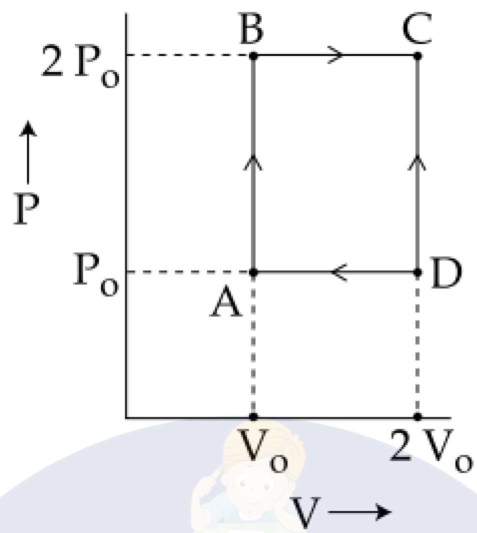
(1) $l^2 Y\alpha\,\Delta T$

(2) $lAY\alpha\,\Delta T$

(3) $AY\alpha\,\Delta T$

(4) $\dfrac{AY}{\alpha\,\Delta T}$

10. 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

11. 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) 6

(2) $\frac{7}{2}$

(3) $\frac{5}{2}$

(4) $\frac{7}{5}$

12. 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) $500\sqrt{2}\ m/s^2$

(3) $750\ m/s^2$

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

13. 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 under tension T. The point O is midway between the two bridges. When a stationary wave 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) $1:1$

(2) $1:2$

(3) $1:3$

(4) $4:1$

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 the limits 589.0 V 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) 589.5 V

(2) 589.2 V

(3) 589.4 V

(4) 589.6 V

15. The energy stored in the electric field produced by a metal sphere is 4.5 J. If the sphere contains 4 μC charge, its radius will be: $\left[\text{Take: } \frac{1}{4\pi\varepsilon_0} = 9\times10^9 \text{ N-m}^2/\text{C}^2\right]$

(1) 20 mm

(2) 32 mm

(3) 28 mm

(4) 16 mm

16. What is the conductivity of a semiconductor sample having electron concentration of $5\times10^{18}\ \text{m}^{-3}$, hole concentration of $5\times10^{19}\ \text{m}^{-3}$, electron mobility of $2.0\ \text{m}^2\text{V}^{-1}\text{s}^{-1}$ and hole mobility of $0.01\ \text{m}^2\text{V}^{-1}\text{s}^{-1}$?

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

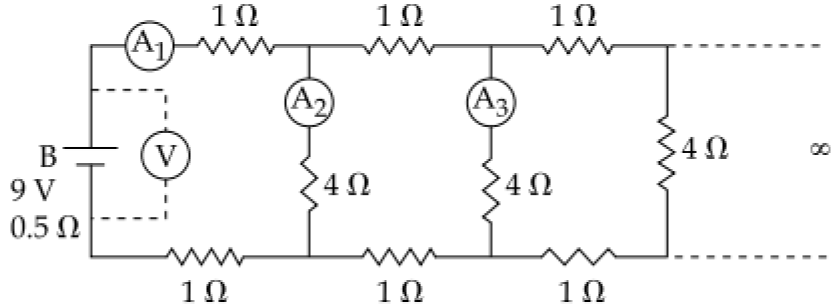
(1) $1.68\ (\Omega\text{-m})^{-1}$

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

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

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

17.



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 $2\ A$

(2) Reading of A_1 is $18\ A$

(3) Reading of V is $9\ V$

(4) Reading of V is $7\ V$

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

(1) $\vec{E} = -v_0 B_0\left(3\hat{i} - 2\hat{j} - 4\hat{k}\right)$

(2) $\vec{E} = -v_0 B_0\left(\hat{i} + \hat{j} + 7\hat{k}\right)$

(3) $\vec{E} = v_0 B_0\left(14\hat{j} + 7\hat{k}\right)$

(4) $\vec{E} = -v_0 B_0\left(14\hat{j} + 7\hat{k}\right)$

19. A magnetic dipole in a constant magnetic field has:

(1) maximum potential energy when the torque is maximum.

(2) zero potential energy when the torque is minimum.

(3) zero potential energy when the torque is maximum.

(4) minimum potential energy when the torque is maximum.

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

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

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

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

21. 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 will be:

Where c is speed of light.

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

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

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

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

22. 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 is given by:

(1) $\frac{1}{\cos^{-1}(\sin\theta_C)}$

(2) $\dfrac{1}{\tan^{-1}(\sin\theta_C)}$

(3) $\cos^{-1}(\sin\theta_C)$

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

23. 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) 1.5 cm

(2) 3.0 cm

(3) 4.5 cm

(4) 6.0 cm

24. 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) less than $\sqrt{3}v$

(2) v

(3) more than $\sqrt{3}v$

(4) equal to $\sqrt{3}v$

25. 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 nth orbit is proportional to: (n=principal quantum number)

(1) n^{-4}

(2) n^{-5}

(3) n^{-3}

(4) n^{-2}

26. Two deuterons undergo 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)

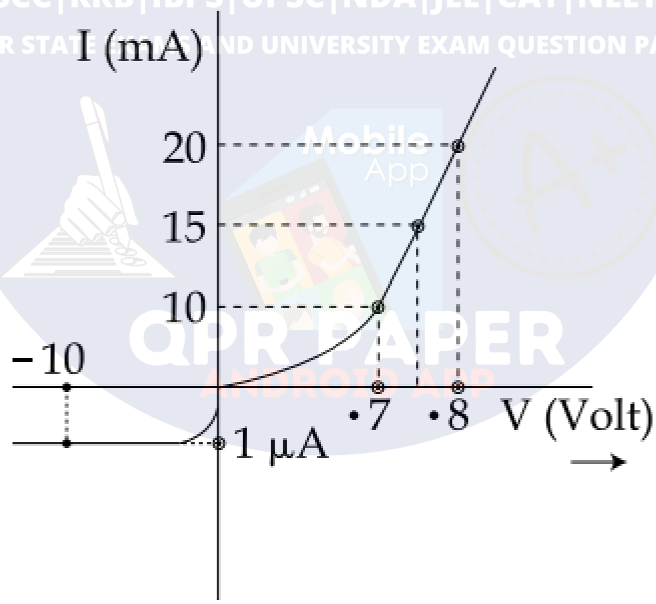
(1) 30.2 MeV

(2) 32.4 MeV

(3) 23.6 MeV

(4) 25.8 MeV

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



(1) 10

(2) 10^{-6}

(3) 10^{6}

(4) 100

28. 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 = 5, side frequency bands are at 21.2 kHz and 18.8 kHz

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

(4) Modulation index = 0.2, side frequency bands are at 1220 kHz and 1180 kHz

29. 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?

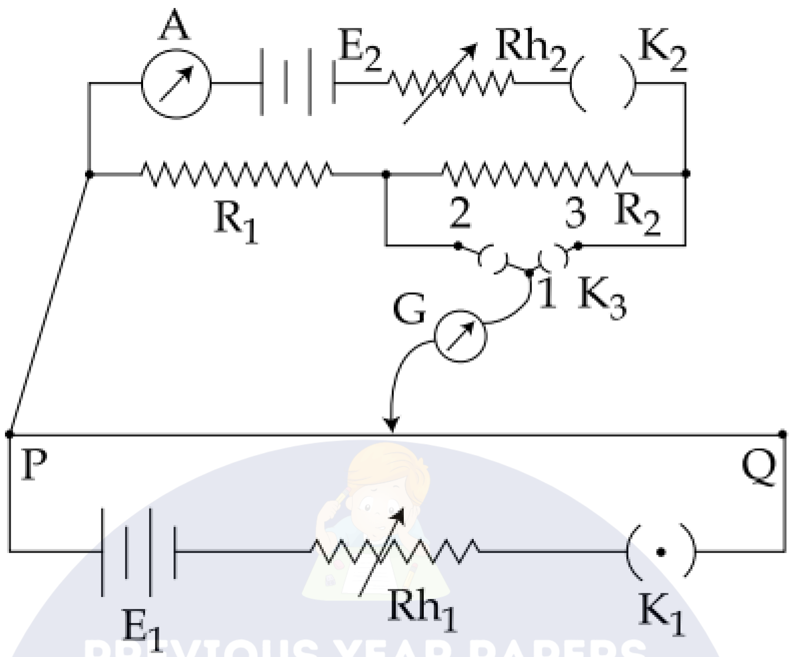
(1) Left arm is longer than the right arm

(2) Both the arms are of same length

(3) Left arm is shorter than the right arm

(4) Every object that is weighed using this balance appears lighter than its actual weight.

30. A potentiometer PQ is set up to compare 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 l1 cm from P when two way key K_3 is plugged in between 2 and 1, while the balance point is at a length l2 cm from P when key K_3 is plugged in between 3 and 1. The ratio of two resistances $\frac{R_1}{R_2}$, is found to be:



(1) $\dfrac{l_1}{l_1 + l_2}$

(2) $\dfrac{l_2}{l_2 - l_1}$

(3) $\dfrac{l_1}{l_1 - l_2}$

(4) $\dfrac{l_1}{l_2 - l_1}$

Part-2

The dimension of length is given as,

$$[L]=[CT]$$

The dimension of the mass can be given as,

$$[M]=\frac{[\text{Angular momentum}]}{[\text{Velocity}][\text{Length}]}$$

Therefore,

$$[M]=\frac{[h]}{[C][CT]}$$
$$=\left[C^{-2}T^{-1}h\right]$$

2. The expression to calculate the acceleration of moving object is given by,

$$a=\frac{vdv}{dx}$$

The negative acceleration for a moving object is constant.

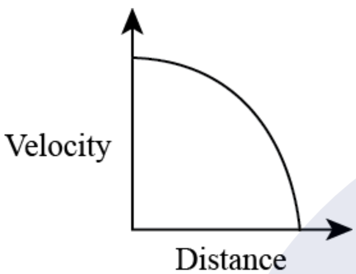
$$\frac{vdv}{dx}=-C$$
$$vdv=-Cdx$$

Integrate both sides of the above equation.

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

$$x = -\frac{v^2}{2C} + \frac{k}{C}$$

From, the above equation, the correct graph is,



3. The formula to calculate the frequency of spring is given as,

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

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

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

$$k = 4\pi^2$$

When the springs are attached in parallel the equivalent spring constant is,

$$k_{eq} = 2k$$

Frequency of vibration of 8kg block is,

$$f = \frac{1}{2\pi}\sqrt{\frac{2 \times k}{8}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{2 \times 4\pi^2}{8}}$$

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

4. The Velocity of the object when it falls through a height h is given by,

$$v = \sqrt{2gh}$$

The Kinetic energy of the block is calculated as,

$$K.E. = \frac{1}{2}mv^2$$

$$= \frac{1}{2}m \times 2gh$$

$$= mgh$$

Loss in K.E can be calculated as,

$$\Delta KE = \frac{1}{2}\text{mgh}$$

The Velocity of the ball is given as,

$$v = eu$$

And,

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

Total distance covered by ball is,

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

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

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

$$= 3h$$

5. Tension in the rope is calculated as,

$$T = mg - ma$$

Work done by the disc is calculated as,

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

$$T = \frac{MR^2 a}{2R^2}$$

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

Solve the above equation for acceleration,

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

$$\frac{Ma}{2} + ma = ma$$

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

6. Moment of inertia of lamina ABC is given by,

$$\mathrm{I}_0 = \mathrm{kml}^2$$

Moment of inertia of lamina DEF is given by,

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

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

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

The Remaining moment of inertia can be calculated as,

$$I_{REM} = I_0 - I_{DEF}$$

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

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

7. The equation for the Rotation of earth is given by,

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

The equation when Person is at equator is given by,

$$g' = \frac{3g}{4}$$

Substitute the value of g'.

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

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

$$= \sqrt{\frac{10}{4 \times 6400}}$$

$$= 0.6 \times 10^{-3} \text{ rad/s}$$

8. The expression the calculate the value of heat is given by,

$$Q = mCdt$$

Heat rejection by aluminum is equal to the heat gained by water.

$$Q_{al} = Q_w$$

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

$$22C = 2275$$

$$C = 434 \text{ J/kg°C}$$

9. Net change in length = 0

Thermal expansion = $l \propto \Delta t$

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

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

$$\frac{F}{AY} = I \propto \Delta t$$

$$F = AY \propto \Delta t$$

10. Work done by the engine is calculated as,

$$w = P_0V_0$$

The heat added during constant volume process is given as,

$$Q_1 = nC_v dT$$
$$= 1.5\left(nRT_B - nRT_A\right)$$
$$= 1.5\left(2P_0V_0 - P_0V_0\right)$$
$$= 1.5P_0V_0$$

The heat added during constant pressure process is given by,

$$Q_2 = nC_v dT$$
$$= 2.5\left(nRT_c - nRT_b\right)$$
$$= 2.5\left(4P_0V_0 - 5P_0V_0\right)$$
$$= 5P_0V_0$$

Thus, total heat added to the system is ,

$$Q = Q_1 + Q_2$$
$$= 6.5P_0V_0$$

Thermal efficiency of the engine is,

$$\eta = \frac{W}{Q}$$

$$= \frac{P_0V_0}{6.5P_0V_0}$$

$$= 0.15$$

11. Atomicity of the gas is given by,

$$\gamma = \frac{C_p}{C_v}$$

And,

$$\gamma = 1 + \frac{2}{f}$$

Thus,

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

$$= 1 + \frac{2}{5}$$

$$= \frac{7}{5}$$

12. The maximum velocity in a simple harmonic motion is given by,

$$v_{\max} = A\omega$$

Maximum acceleration in a simple harmonic motion is calculated as,

$$a_{\max} = A\omega^2$$

Ratio of maximum acceleration to maximum velocity is,

$$\frac{A\omega^2}{A\omega} = 10$$

$$\omega = 10\ \text{s}^{-1}$$

Displacement in simple harmonic motion is,

$$x = A\sin\left(\omega + \frac{\pi}{4}\right)$$

At t = 0,

$$5 = A\sin\left(\frac{\pi}{4}\right)$$

$$A = 5\sqrt{2}$$

Substitute the value of A.

$$a = 10 \times 10 \times 5\sqrt{2}$$

$$= 500\sqrt{2}\ \text{m/s}^2$$

13. The expression for number of nodes is given by,

$$\text{n} = \frac{\rho}{2\text{l}}\sqrt{\frac{\text{T}}{\pi \text{rd}}}$$

Here,

$$n_1 = n_2$$

$$\frac{\rho_1}{\sqrt{d_1}} = \frac{4\rho_1}{\sqrt{d_2}}$$

$$\frac{\sqrt{d_1}}{\sqrt{d_2}} = \frac{1}{4}$$

$$\frac{d_1}{d_2} = \frac{1}{2}$$

14. Change in electric field is given by,

$$\begin{aligned} E &= 589.0\ V - 589.8\ V \\ &= 0.8\ V \end{aligned}$$

The expression for electric potential on the sphere is given as,

$$\begin{aligned} \Delta V &= E d\cos\theta \\ &= 0.8 \times 1 \times \cos 60^\circ \\ &= 0.4 \end{aligned}$$

Potential at a point on the sphere is calculated as,

$$\begin{aligned} V &= 589.0\ V + 0.4\ V \\ &= 589.4\ V \end{aligned}$$

15. The expression to calculate the capacitance of sphere is given by,

$$C = 4\pi\varepsilon_0 R$$

The energy of sphere is calculated as,

$$E = \frac{Q^2}{2C}$$

$$4.5 = \frac{\left(4\times10^{-6}\right)^2}{2C}$$

$$C = \frac{\left(4\times10^{-6}\right)^2}{2\times4.5}$$

$$C = 1.77\times10^{-12}$$

Substitute the value of C to find the Radius of the sphere.

$$1.77\times10^{-12} = 4\pi\varepsilon_0 R$$

$$R = \frac{1.77\times10^{-12}}{4\pi\varepsilon_0}$$

$$= \frac{1.77\times10^{-12}}{9\times10^{9}}$$

$$= 16 \text{ mm}$$

16. The conductivity of electron concentration of semiconductor is given by,

$$\sigma_e = qn\mu_e$$

$$= 1.6\times10^{-19}\ \text{C}\left(5\times10^{18}\ \text{m}^{-3}\times2\ \text{m}^2\text{V}^{-1}\text{s}^{-1}\right)$$

$$= 1.6\ (\Omega\text{m})^{-1}$$

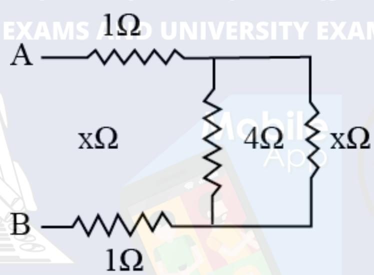
The conductivity of hole concentration of semiconductor is,

$$\sigma_h = qn\mu_h$$
$$= 1.6\times10^{-19}\ \text{C}\left(5\times10^{19}\ \text{m}^{-3}\times0.01\,\text{m}^2\text{V}^{-1}\text{s}^{-1}\right)$$
$$= 0.08\left(\Omega\text{m}\right)^{-1}$$

The expression for conductivity of semiconductor is given as,

$$\sigma = q\left(n\mu_n + p\mu_p\right)$$
$$= \sigma_h + \sigma_e$$
$$= 1.6\left(\Omega\text{m}\right)^{-1} + 0.08\left(\Omega\text{m}\right)^{-1}$$
$$= 1.68\left(\Omega\text{m}\right)^{-1}$$

17. The given circuit can be redrawn as,



The expression to calculate the equivalent resistance when they are connected in parallel is,

$$\frac{1}{\text{R}} = \frac{1}{\text{R}_1} + \frac{1}{\text{R}_2}$$

As 4Ω and $x\Omega$ are connected in parallel,

$$\frac{1}{R'} = \frac{1}{4} + \frac{1}{x}$$

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

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

And 1Ω and 1Ω are also parallel then,

$$R'' = 1 + 1$$

$$= 2\Omega$$

The equivalent resistance of the circuit is calculated as,

$$R = R' + R''$$

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

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

$$x^2 - 2x - 8 = 0$$

Solve the equation for x

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

$$= \frac{2 \pm \sqrt{36}}{2}$$

$$= 4$$

Reading of ammeter is,

$$A_1 = \frac{V}{(R + r)}$$

$$= \frac{9}{4 + 0.5}$$

$$= 2\ A$$

18. The electric force of a moving charge is calculated as,

$$F_e = q\left(\vec{v} \times \vec{B}\right)$$

At equilibrium,

$$F_e = -F_m$$

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

$$= -q\left(v_0\left(3\hat{i} - \hat{j} + 2\hat{k}\right) \times B_0\left(\hat{i} + 2\hat{j} - 4\hat{k}\right)\right)$$

$$= -qv_0B_0\left(14\hat{j} + 7\hat{k}\right)$$

Thus, the electric field produced by the charge is,

$$\vec{E} = \frac{\vec{F}_e}{q}$$

$$= -\frac{qv_0B_0\left(14\hat{j} + 7\hat{k}\right)}{q}$$

$$= -v_0B_0\left(14\hat{j} + 7\hat{k}\right)$$

19. The expression of torque in a magnetic field is given by,

$$\tau = PE\sin\theta$$

For maximum value of τ, $\theta = 90°$.

The expression for potential energy is given as,

$$\begin{aligned} PE &= -PE\cos\theta \\ &= PE(\cos 90°) \\ &= 0 \end{aligned}$$

20. The Magnetic field of circular loop is given by,

$$\begin{aligned} M &= \frac{\mu_0 I}{2R} \\ &= \frac{\mu_0 I_0 \cos\omega t}{2R} \end{aligned}$$

Here, $R = b$

The magnetic flux in the loop is calculated as,

$$\begin{aligned} \phi &= M \cdot A \\ &= \frac{\mu_0 I_0 \cos\omega t}{2b} \cdot (\pi a^2) \end{aligned}$$

Thus, the emf induced in the smaller inner loop is given by,

$$\begin{aligned} e &= \left| \frac{-d\phi}{dt} \right| \\ &= \left| -\frac{\mu_0 I_0 \cos\omega t}{2b} \cdot (\pi a^2) \right| \\ &= \frac{\mu_0 I_0 \pi}{2b} \cdot a^2 \cdot \omega \sin\omega t \end{aligned}$$

21. The relation between electric field and magnetic field is,

$$E = cB$$

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

The direction of propagation of wave is along x axis and the direction of magnetic field is along y axis, thus the direction of electric field should be perpendicular to both x and y axis. Therefore, the direction of electric field is along z direction.

22. The refractive index of the medium is calculated as,

$$n_{12} = \frac{n_1}{n_2}$$

$$= \frac{\sin i_c}{\sin 90^\circ}$$

The refractive index after the reflection is calculated as,

$$n = \frac{\sin A}{\sin r}$$

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

$$= \frac{\sin A}{\cos A}$$

$$= \tan A$$

The critical angle of reflected ray is calculated as,

$$\theta_c = \sin^{-1}\left(\frac{n_1}{n_2}\right)$$

$$\sin\theta_c = \tan A$$

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

23. From Young's slit experiment,

$$d\sin\theta = n\lambda$$

For second minima,

$$6\sin\theta = n\lambda$$

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

For $n = 2$

$$\sin\theta_1 = \frac{2\lambda}{6}$$

For $n = 4$,

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

The width of the central maximum is calculated as,

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

$$= \frac{2\lambda}{6}$$

$$= 3\text{ cm}$$

24. The expression for photoelectric equation is given by,

$$\text{h}\nu = \varphi + \frac{1}{2}\text{mv}^2$$

If $\nu = 3\nu$, then,

$$h3\nu = \varphi + \frac{1}{2}m\left(\sqrt{3}v\right)^2$$

From above equation, it can be concluded that if frequency is changed to three times its original value the maximum velocity of the electron becomes $\sqrt{3}$ times of its original value.

25. According to Bohr's theory,

$$r \propto n^2$$
$$I \propto n^{-3}$$

Magnetic field at the centre of nucleus is,

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

Where,

$$B \propto \frac{I}{r}$$
$$B \propto \frac{n^{-3}}{n^2}$$
$$B \propto n^{-5}$$

26. The chemical reaction for Nuclear fission of two deuterons is given by,

$${}_1^2D + {}_1^2D \rightarrow {}_2^4He$$

The energy produced during fission of deuterons is calculated as,

$$E = -2m\left({}_1^2D\right) + m\left({}_2^4He\right)$$
$$= -4 \times 1.1 + 4 \times 7$$
$$= -4.4 + 28 \text{ MeV}$$
$$= 23.6 \text{ MeV}$$

27. The expression for forward bias is given by,

$$R_{F.B} = \frac{\Delta V}{\Delta I}$$
$$= \frac{V_2 - V_1}{I_2 - I_1}$$
$$= \frac{0.1}{10 \times 10^{-3}} \Omega$$
$$= 10\ \Omega$$

The expression for reverse bias is given by,

$$R_{R.B} = \frac{V_2 - V_1}{I_2 - I_1}$$
$$= \frac{10}{10^{-6}} \Omega$$
$$= 10^7\ \Omega$$

The ratio of forward and reverse bias is calculated as,

$$\frac{R_{F.B}}{R_{R.B}} = \frac{10}{10^7}$$
$$= 10^{-6}$$

28. The value of modulation index is calculated as,

$$m = \frac{V_m}{V_0}$$
$$= \frac{5}{25}$$
$$= \frac{1}{2}$$
$$= 0.2$$

The expression for Side frequency bands is given by,

$$f = f_c \pm f_0$$

Thus,

$$f_1 = 1200 - 20$$
$$= 1180 \text{ kHz}$$
$$f_2 = 1200 + 20$$
$$= 1220 \text{ kHz}$$

29. At equilibrium,

Anti-clockwise moment = clockwise moment

$$F_1 d_1 = F_2 d_2$$
$$(5mg + mg) d_1 = mgd_2$$
$$6mgd_1 = mgd_2$$
$$6d_1 = d_2$$

From above equation, it can be concluded that the left arm is shorter than the right arm.

30. The expression for voltage when the key is at point 1 is given by,

$$V_1 = iR_1$$
$$= xl_1 \qquad (1)$$

The expression for voltage when the key is at point 3 is given by,

$$V_2 = i\left(R_1 + R_2\right)$$
$$= xl_2 \qquad (2)$$

Divide equation (1) by (2).

$$\frac{iR_1}{i\left(R_1 + R_2\right)} = \frac{xl_1}{xl_2}$$

$$\frac{R_1}{\left(R_1 + R_2\right)} = \frac{l_1}{l_2}$$

$$1 + \frac{R_1}{R_2} = \frac{l_1}{l_2}$$

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