

JEE Main 2019 Physics Paper With Solutions
January 11 Shift 1

1. The force of interaction between two atoms is given by $F = \alpha\beta \exp\left[\frac{-x^2}{\alpha kt}\right]$; where x is the distance, k is the Boltzmann constant and T is temperature α and β are two constants. The dimension of β is:

- a. $M^2L^2T^{-2}$
- b. M^2LT^{-4}
- c. $M^0L^2T^{-4}$
- d. MLT^{-2}

Answer: (b)

Solution

$$F = \alpha\beta e^{\frac{-x^2}{\alpha KT}}$$

$$\left[\frac{x^2}{\alpha KT}\right] = M^0L^0T^0$$

$$\left[\frac{L^2}{\alpha ML^2T^{-2}}\right] = M^0L^0T^0$$

$$[\alpha] = M^{-1}T^2$$

$$[F] = [\alpha][\beta]$$

$$[MLT^{-2}] = M^{-1}T^2[\beta]$$

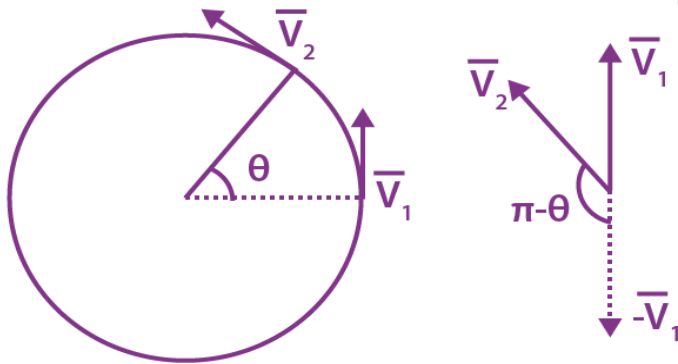
$$[\beta] = M^2LT^{-4}$$

2. A particle is moving along a circular path with a constant speed of 10 ms^{-1} . What is the magnitude of the change in velocity of the particle, when it moves through an angle of 60° around the centre of the circle?

- a. zero
- b. 10 m/s
- c. $10\sqrt{3} \text{ m/s}$
- d. $10\sqrt{2} \text{ m/s}$

Answer: (b)

Solution



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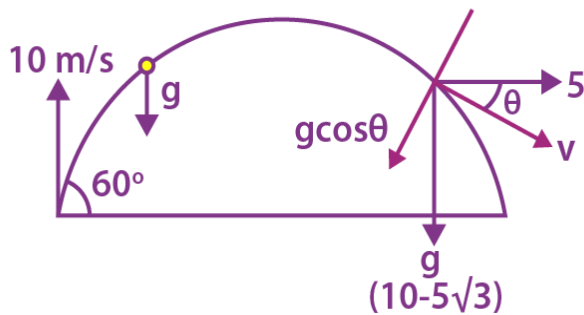
$$\begin{aligned}
 |\Delta \vec{v}| &= \sqrt{v_1^2 + v_2^2 + 2v_1v_2 \cos(\pi - \theta)} \\
 &= 2v \sin \frac{\theta}{2} \text{ (since } |\vec{v}_1| = |\vec{v}_2| \text{)} \\
 &= (2 \times 10) \times \sin(30^\circ) \\
 &= 10 \text{ m/s}
 \end{aligned}$$

3. A body is projected at $t = 0$ with a velocity 10 ms^{-1} at an angle of 60° with the horizontal. The radius of curvature of its trajectory at $t = 1 \text{ s}$ is R . Neglecting air resistance and taking acceleration due to gravity $g = 10 \text{ ms}^{-2}$, the value of R is:

- a. 2.5 m
- b. 10.3 m
- c. 2.8 m
- d. 5.1 m

Answer: (c)

Solution:



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$$v_x = 10\cos60^\circ = 5 \text{ m/s}$$

$$v_y = 10\cos30^\circ = 5\sqrt{3} \text{ m/s}$$

velocity after $t = 1$ sec.

$$v_y = |(5\sqrt{3} - 10)| = 10 - 5\sqrt{3} \quad a_n = \frac{v^2}{R} = \frac{v_x^2 + v_y^2}{a_n}$$

$$a_n = \frac{25 + 100 + 75 - 100\sqrt{3}}{10\cos\theta} \quad \tan\theta = \frac{10 - 5\sqrt{3}}{5} = 2 - \sqrt{3} \Rightarrow \theta = 15^\circ$$

$$R = \frac{100(2 - \sqrt{3})}{10\cos15} = 2.8m$$

4. A liquid of density ρ is coming out of a hose pipe of radius a with horizontal speed v and hits a mesh. 50% of the liquid passes through the mesh unaffected. 25% loses all of its momentum and 25% comes back with the same speed. The resultant pressure on the mesh will be:

- a. ρv^2
- b. $\frac{3}{4} \rho v^2$
- c. $\frac{1}{2} \rho v^2$
- d. $\frac{1}{4} \rho v^2$

Answer: (b)

Solution

Momentum per second carried by liquid per

second is ρv^2

$$\text{net force due to reflected liquid} = 2 \times \left[\frac{1}{4} \rho v^2 \right]$$

$$\text{net force due to stopped liquid} = \left[\frac{1}{4} \rho v^2 \right]$$

$$\text{Total force} = \left[\frac{3}{4} \rho v^2 \right]$$

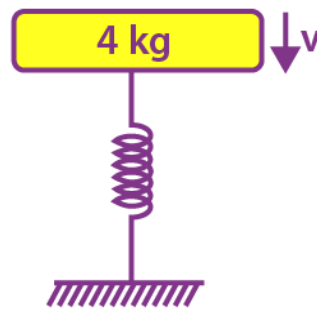
$$\text{net pressure} = \left[\frac{3}{4} \rho v^2 \right]$$

5. A body of mass 1 kg falls freely from a height of 100 m on a platform of mass 3 kg which is mounted on a spring having spring constant $k = 1.25 \times 10^6$ N/m. The body sticks to the platform and the spring's maximum compression is found to be x . Given that $g = 10 \text{ ms}^{-2}$, the value of x will be close to:

- a. 4 cm
- b. 8 cm
- c. 80 cm
- d. 40 cm

Answer: (a)

Solution



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Velocity of 1 kg block just before it collides

$$\sqrt{2gh} = \sqrt{2000} \text{ m/s}$$

with 3kg block =

Applying momentum conservation just before and just after collision.

$$1x\sqrt{2000} = 4v \Rightarrow \sqrt{2000}/4 \text{ m/s}$$

initial compression of spring

$$1.25 \times 10^6 X_0 = 30$$

Therefore, $X_0 = 0$ (approx)

applying work energy theorem,

$$W_g + W_{sp} = \Delta KE$$

$$\Rightarrow 40 \times x + \frac{1}{2} \times 1.25 \times 10^6 (0^2 - x^2)$$

$$= 0 - (1/2) \times 4 \times v^2$$

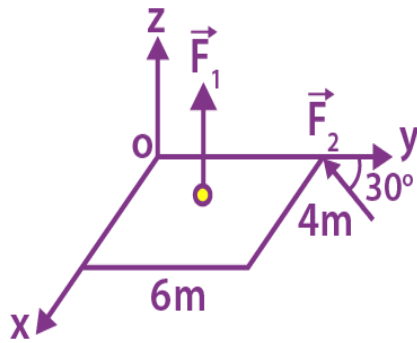
solving $x = 4$ cm (approx)

6. A slab is subjected to two forces \vec{F}_1 and \vec{F}_2 of same magnitude F as shown in the

figure. Force \vec{F}_2 is in XY-plane while force \vec{F}_1 acts along z-axis at the point

$$(2\vec{i} + 3\vec{j})$$

.The moment of these forces about point O will be:



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- a. $(3\hat{i} - 2\hat{j} - 3\hat{k})F$
- b. $(3\hat{i} + 2\hat{j} + 3\hat{k})F$
- c. $(3\hat{i} + 2\hat{j} - 3\hat{k})F$
- d. $(3\hat{i} - 2\hat{j} + 3\hat{k})F$

Answer: (d)

Solution

Torque for F_1 force

$$\vec{F}_1 = \frac{F}{2}(-\hat{i}) + \frac{F\sqrt{3}}{2}(-\hat{j})$$

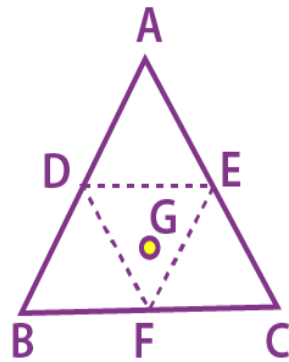
$$\vec{r}_1 = 0\hat{i} + 6\hat{j}$$

$$\vec{\tau}_{F_1} = \vec{r}_1 \times \vec{F}_1 = 3F\hat{k}$$

$$\vec{\tau}_{F_2} = \vec{r}_2 \times \vec{F}_2 = 3F\hat{i} + 2F(-\hat{j})$$

$$\begin{aligned} \vec{\tau}_{F_{net}} &= \vec{\tau}_{F_1} + \vec{\tau}_{F_2} \\ &= 3F\hat{k} + 3F\hat{i} + 2F(-\hat{j}) \end{aligned}$$

7. An equilateral triangle ABC is cut from a thin solid sheet of wood. (see figure) D, E and F are the mid-points of its sides as shown and G is the centre of the triangle. The moment of inertia of the triangle about an axis passing through G and perpendicular to the plane of the triangle is I_0 . If the smaller triangle DEF is removed from ABC, the moment of inertia of the remaining figure about the same axis is I. Then:



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- a. $I = \frac{9}{16} I_0$
- b. $I = \frac{3}{4} I_0$
- c. $I = \frac{1}{4} I_0$
- d. $I = \frac{15}{4} I_0$

Answer: (d)

Solution

Suppose M is mass and a is side of large triangle, then M/4 and a/2 will be mass and side length of smaller triangle.

$$\frac{I_{removed}}{I_{original}} = \frac{\frac{M}{4} \left(\frac{a}{2}\right)^2}{M(a)^2}$$

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

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

8. A satellite is revolving in a circular orbit at a height h from the earth surface, such that $h \ll R$ where R is the radius of the earth. Assuming that the effect of earth's atmosphere can be neglected the minimum increase in the speed required so that the satellite could escape from the gravitational field of earth is :

a. \sqrt{gR}

b. $\sqrt{2gR}$

c. $\sqrt{gR}(\sqrt{2} - 1)$

d. $\sqrt{\frac{gR}{2}}$

Answer: (c)

Solution

$$v_0 = \sqrt{g(R+h)} \approx \sqrt{gR} \quad v_e = \sqrt{2g(R+h)} \approx \sqrt{2gR}$$

$$\Delta v = v_e - v_0 = (\sqrt{2} - 1)\sqrt{gR}$$

9. Ice at -20°C is added to 50 g of water at 40°C . When the temperature of the mixture reaches 0°C , it is found that 20 g of ice is still not melted. The amount of ice added to the water was close to

(Specific heat of water = $4.2\text{ J/g}^\circ\text{C}$)

Specific heat of Ice = $2.1\text{ J/g}^\circ\text{C}$

Heat of fusion of water at 0°C = 334 J/g

a. 50 g

b. 40 g

c. 60 g

d. 100 g

Answer (b)

Solution

Let amount of ice is m gm.

According to principal of calorimeter

Heat taken by ice = Heat given by water

Therefore, $20 \times 2.1 \times m + (m - 20) \times 334$

$= 50 \times 4.2 \times 40$

$376 m = 8400 + 6680$

$m = 40.1\text{ g}$

10. A rigid diatomic ideal gas undergoes an adiabatic process at room temperature. The relation between temperature and volume of this process is $TV^x = \text{constant}$, then x is:

a. $(5/3)$

b. $(2/5)$

c. $(2/3)$

d. $(3/5)$

Answer: (b)

Solution:

Diatomic gas

$$r = 1 + (2/5) = 7/5$$

$$PV^r = \text{constant}$$

$$\left(\frac{nRT}{V}\right)V^r = C$$

$$TV^{r-1} = \text{constant}$$

$$TV^{r-1} = TV^x$$

$$x = r - 1 = (7/5) - 1 = 2/5$$

11. A gas mixture consists of 3 moles of oxygen and 5 moles of argon at temperature T. Considering only translational and rotational modes, the total internal energy of the system is

- a. 4RT
- b. 12 RT
- c. 15 RT
- d. 20 RT

Answer: (c)

Solution:

$$f_{min} = \frac{n_1 f_1 + n_2 f_2}{n_1 + n_2} = \frac{(3 \times 5) + (5 \times 3)}{8} = \frac{15}{4}$$

$$U = \frac{f}{2} nRT = \frac{15}{8} \times 8 \times RT = 15RT$$

12. A particle undergoing simple harmonic motion has time dependent displacement given

by $x(t) = A \sin \frac{\pi t}{90}$. The ratio of kinetic to potential energy of this particle at $t = 210$ s will be

- a. 1
- b. 3
- c. 1/9
- d. 2

Answer: (b)

Solution:

$$k = \frac{1}{2} m \omega^2 A^2 \cos^2 \omega t \quad U = \frac{1}{2} m \omega^2 A^2 \sin^2 \omega t$$

$$\frac{k}{U} = \cot^2 \omega t = \cot^2 \frac{\pi}{90} (210) = 1/3$$

Hence ratio is 3

13. Equation of travelling wave on a stretched string of linear density 5 g/m is $y = 0.03 \sin(450t - 9x)$ where distance and time are measured in SI units. The tension in the string is:

- a. 12.5 N
- b. 7.5 N
- c. 10 N
- d. 5 N

Answer: (a)

Solution

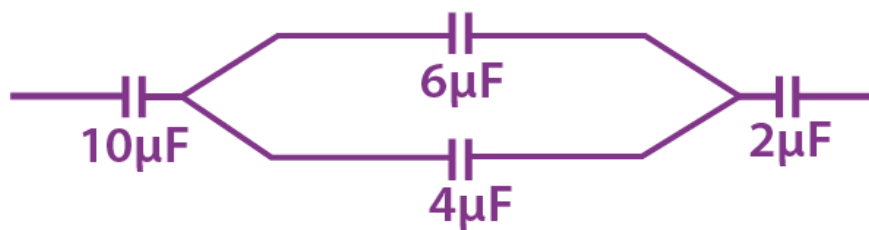
$$y = 0.03 \sin(450t - 9x)$$

$$v = \frac{\omega}{k} = \frac{450}{9} = 50 \text{ m/s}$$

$$v = \sqrt{\frac{T}{\mu}} \Rightarrow \frac{T}{\mu} = 2500 \text{ T} = 2500 \times 5 \times 10^{-3}$$

$$T = 12.5 \text{ N}$$

14. In the figure shown below, the charge on the left plate of the $10\mu\text{F}$ capacitor is $-30\mu\text{C}$. The charge on the right plate of the $6\mu\text{F}$ capacitor is :



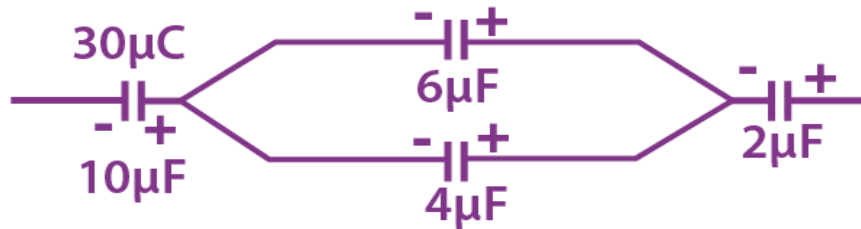
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- a. $-18\mu\text{C}$
- b. $-12\mu\text{C}$
- c. $+12\mu\text{C}$
- d. $+18\mu\text{C}$

Answer: (d)

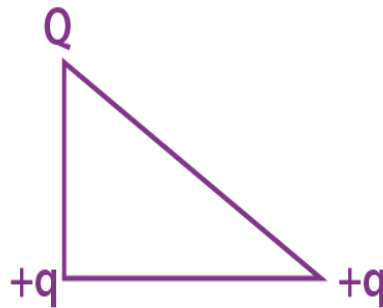
Solution



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$6\mu\text{F}$ & $4\mu\text{F}$ are in parallel & total charge on this combination is $30\mu\text{C}$
 Charge on $6\mu\text{F}$ capacitor = $[\frac{6}{6+4}] \times 30 = 18\mu\text{C}$
 Since charge is asked on right plate therefore is $+18\mu\text{C}$

15. Three charges Q $+q$ and $+q$ are placed at the vertices of a right-angle isosceles triangle as shown below. The net electrostatic energy of the configuration is zero, if the value of Q is



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- a. $-q/(1 + \sqrt{2})$
- b. $-2q/(2 + \sqrt{2})$
- c. $-2q$
- d. $+q$

Answer: (b)

Solution

Net electrostatic energy of the configuration will be

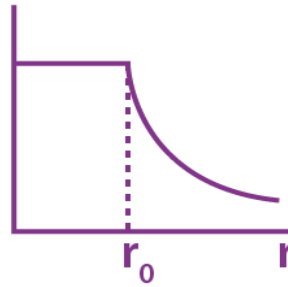
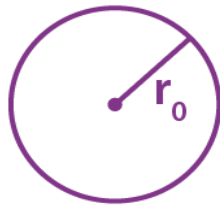
$$U = K \left[\frac{q \cdot q}{a} + \frac{Q \cdot q}{\sqrt{2}a} + \frac{Q \cdot q}{a} \right]$$

$$\text{Here, } K = \frac{1}{4\pi\epsilon_0}$$

Putting $U = 0$ we get,

$$Q = \frac{-2q}{2 + \sqrt{2}}$$

16: The given graph shows variation (with distance r from centre) of:



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- a. Potential of a uniformly charged sphere
- b. Potential of a uniformly charged spherical shell
- c. Electric field of uniformly charged spherical shell
- d. Electric field of uniformly charged sphere

Answer: (b)

Solution

Theory

$$V = \frac{KQ}{R}; r < R$$

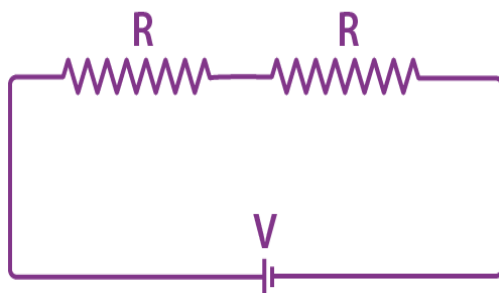
$$V = \frac{KQ}{r}; r > R$$

17. Two equal resistance when connected in series to a battery, consumes electric power of 60 W. If these resistances are now connected in parallel combination to the same battery, the electric power consumed will be:

- a. 60 W
- b. 240 W
- c. 30 W
- d. 120 W

Answer: (b)

Solution



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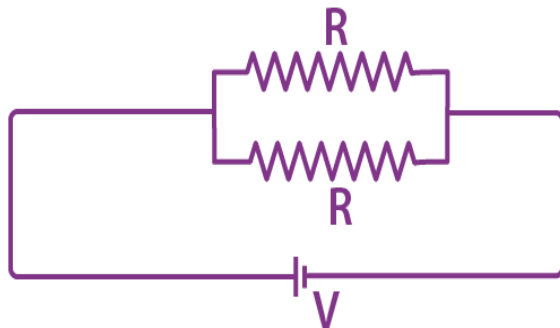
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In series condition, equivalent resistance is $2R$
thus power consumed is 60W

$$P = 60 = \frac{V^2}{2R}$$

$$\frac{V^2}{R} = 120 \text{ Watt}$$

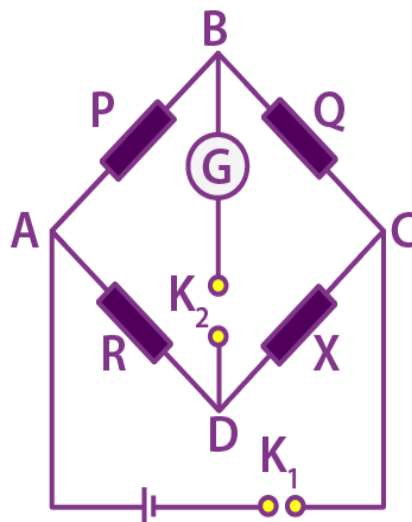
In parallel condition, equivalent resistance is $R/2$ thus new power is



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$$P = \frac{V^2}{(R/2)} = 2(120) = 240\text{W}$$

18. In a Wheatstone bridge (see fig.), Resistances P and Q are approximately equal. When $R = 400 \Omega$, the bridge is equal. When $R = 400 \Omega$, the bridge is balanced. On inter-changing P and Q, the value of R, for balance, is 405Ω . The value of X is close to



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- a. 403.5 ohm
- b. 404.5 ohm
- c. 401.5 ohm
- d. 402.5 ohm

Answer: (d)

Solution

Initially

$$\frac{P}{Q} = \frac{R_1}{X} \text{-----(1)}$$

After interchanging P and Q

$$\frac{Q}{P} = \frac{R_2}{X} \text{-----(2)}$$

From (i) and (ii) we have

$$1 = \frac{R_1 R_2}{X^2}$$
$$X = \sqrt{R_1 R_2} = \sqrt{400 \times 405} = 402.5 \Omega$$

19. In an experiment, electrons are accelerated, from rest, by applying a voltage of 500 V. Calculate the radius of the path if a magnetic field 100 mT is then applied.

[Charge of the electron = 1.6×10^{-19} C

Mass of the electron = 9.1×10^{-31} kg]

- a. 7.5×10^{-4} m
- b. 7.5×10^{-3} m
- c. 7.5 m
- d. 7.5×10^{-2} m

Answer: (a)

Solution

$$r = \frac{\sqrt{2mk}}{eB} = \frac{\sqrt{2me\Delta v}}{eB}$$

$$r = \frac{\sqrt{\frac{2m}{e} \Delta v}}{B}$$

$$r = \frac{\sqrt{\frac{2 \times 9.1 \times 10^{-31}}{1.6 \times 10^{-19}} 500}}{100 \times 10^{-3}}$$

$$r = 7.5 \times 10^{-4} \text{ m}$$

20. There are two long co-axial solenoids of same length l . the inner and outer coils have radii r_1 and r_2 and number of turns per unit length n_1 and n_2 respectively. The ratio of mutual inductance to the self-inductance of the inner-coil is:

a. $\frac{n_2}{n_1} \frac{r_2^2}{r_1^2}$

b. $\frac{n_2}{n_1} \frac{r_1}{r_2}$

c. $\frac{n_1}{n_2}$

d. $\frac{n_2}{n_1}$

Answer: (d)

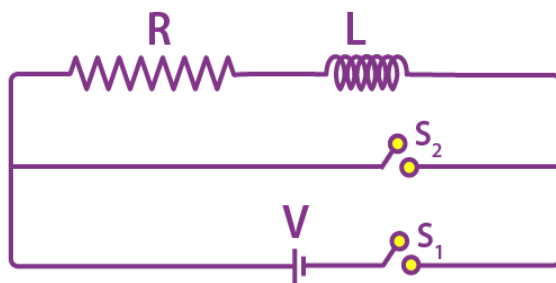
Solution

Mutual Inductance = $\mu_0 n_1 n_2 R_2^2 l$

Self Inductance = $\mu_0 n_1^2 R_2^2 l$

Ratio = n_2/n_1

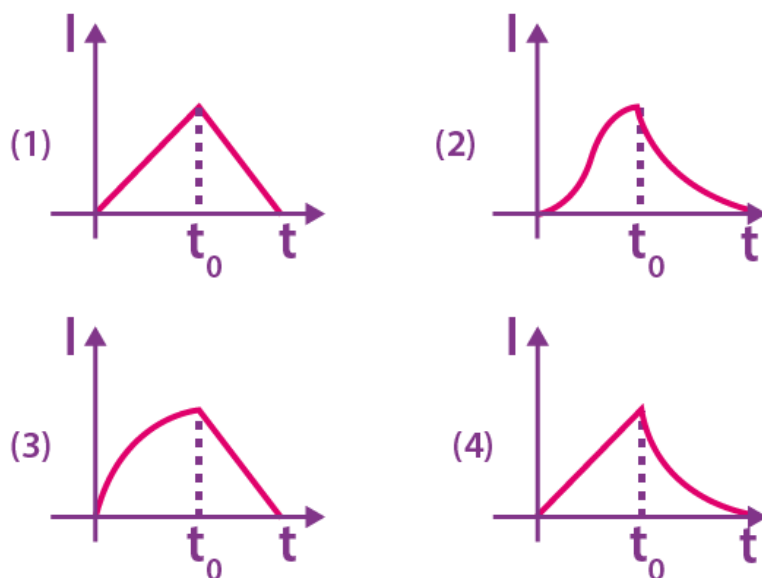
21. In the circuit shown,



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the switch S_1 is closed at time $t = 0$ and the switch S_2 is kept open. At some later time (t_0), the switch S_1 is opened and S_2 is closed. The behaviour of the current I as a function of time ' t ' is given by:

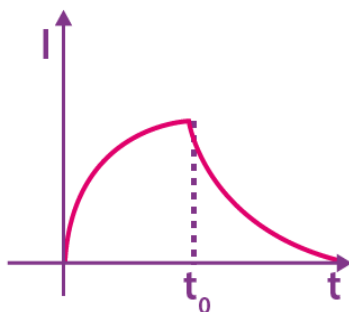


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Answer: (b)

Solution:

From time $t = 0$ to $t = t_0$, growth of current takes place and after that decay of current takes place.



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22. An electromagnetic wave of intensity 50 Wm^{-2} enters in a medium of refractive index 'n' without any loss. The ratio of the magnitudes of electric fields, and the ratio of the magnitudes of magnetic fields of the wave before and after entering into the medium are respectively, given by:

a. $\left[\frac{1}{\sqrt{n}}, \frac{1}{\sqrt{n}} \right]$

b. $\left[\sqrt{n}, \frac{1}{\sqrt{n}} \right]$

c. $[\sqrt{n}, \sqrt{n}]$

d. $\left[\frac{1}{\sqrt{n}}, \sqrt{n} \right]$

Answer: (b)

Solution

$$C = \frac{1}{\sqrt{\mu_0 \epsilon_0}} \quad V = \frac{1}{\sqrt{k \mu_0 \epsilon_0}}$$

(For transparent medium $\mu_r \approx \mu_0$)

Therefore, $\frac{C}{V} = \sqrt{k} = n$

$$\frac{1}{2} \epsilon_0 E_0^2 C = \text{intensity} = \frac{1}{2} \epsilon_0 k E^2 v \quad E_0^2 C = k E^2 v$$

$$\Rightarrow \frac{E_0^2}{E^2} = \frac{kV}{C} = \frac{n^2}{n} \Rightarrow \frac{E_0}{E} = \sqrt{n}$$

Similarly,

$$\frac{B_0^2 C}{2\mu_0} = \frac{B^2 C}{2\mu_0} \Rightarrow \frac{B_0}{B} = \frac{1}{\sqrt{n}}$$

23. An object at a distance of 20m from a convex lens of focal length 0.3m. The lens forms an image of the object. If the object moves away from the lens at a speed of 5m/s, the speed and direction of the image will be

- a. 3.22×10^{-3} m/s towards the lens
- b. 2.26×10^{-3} m/s away from the lens
- c. 1.16×10^{-3} m/s towards the lens
- d. 0.92×10^{-3} m/s away from the lens

Answer: (c)

Solution:

$$\begin{aligned} \frac{dV}{dt} &= \left(\frac{f}{f+u} \right)^2 \frac{du}{dt} \\ &= \frac{dV}{dt} = \left(\frac{0.3}{0.3-20} \right)^2 \times 5 \end{aligned}$$

$$= 1.16 \times 10^{-3} \text{ m/s towards lens}$$

24. In a Young's double slit experiment, the path difference, at a certain point on the screen between two interfering waves is $(1/8)^{\text{th}}$ of wavelength. The ratio of the intensity at this point to that at the centre of a bright fringe is close to

- a. 0.74
- b. 0.80
- c. 0.85
- d. 0.94

Answer: (c)

Solution

$$I = I_0 \cos^2(\phi/2) = I_0 \cos^2\left(\frac{\pi}{8}\right) = I_0 \left(\frac{1 + \cos(\frac{\pi}{4})}{2}\right)$$

$$= I_0 \left(\frac{1 + (\frac{1}{\sqrt{2}})}{2}\right) = (0.85)I_0$$

25. If the deBroglie wavelength of an electron is equal to 10^3 times the wavelength of a photon of frequency 6×10^{14} Hz, then the speed of electron is equal to : (Speed of light = 3×10^8 m/s, Planck's constant = 6.63×10^{-34} J . Mass of electron = 9.11×10^{-31} kg)

- a. 1.8×10^6 m/s
- b. 1.45×10^6 m/s
- c. 1.1×10^6 m/s
- d. 1.7×10^6 m/s

Answer: (b)

Solutions

$$\frac{h}{mV} = 10^{-3} \left(\frac{3 \times 10^8}{6 \times 10^{14}}\right) V = \frac{6.63 \times 10^{-34} \times 6 \times 10^{14}}{9.1 \times 10^{-31} \times 3 \times 10^5}$$

$$V = 1.45 \times 10^6 \text{ m/s}$$

26. A hydrogen atom, initially in the ground state is excited by absorbing a photon of wavelength 980 \AA . The radius of the atom in the excited state, in terms of Bohr radius a_0 , will be:

$$(hc = 12500 \text{ eV} - \text{\AA})$$

- a. $9a_0$
- b. $25a_0$
- c. $4a_0$
- d. $16a_0$

Answer: (d)

Solution

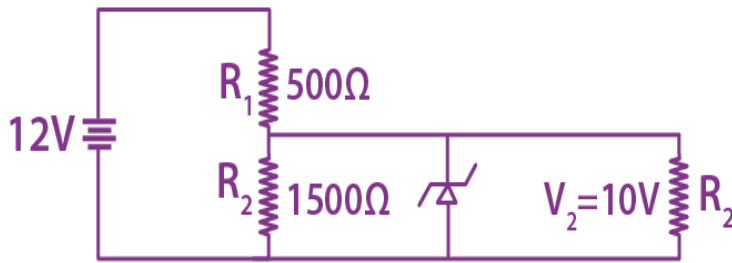
Energy of photon = $12500/980 = 12.75 \text{ eV}$

Electron will excite to $n = 4$

Since, $R \propto n^2$

Radius of atom will be $16a_0$

27. In the given circuit the current through Zener Diode is close to:



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- a. 6.7 mA
- b. 4.0 mA
- c. 0.0 mA
- d. 6.0 mA

Answer: (c)

Solution

Since voltage across zener diode must be less than 10V therefore it will not work in breakdown region, & its resistance will be infinite & current through it = 0

28. An amplitude modulated signal is given by $V(t) = 10[1 + 0.3\cos(2.2 \times 10^4)]\sin(5.5 \times 10^5t)$. Here t is in seconds. The sideband frequencies (in kHz) are, [Given $\pi = 22/7$]

- a. 1785 and 1715
- b. 892.5 and 857.5
- c. 89.25 and 85.75
- d. 178.5 and 171.5

Answer: (c)

Solution

$$V(t) = 10 + \frac{3}{2} [2\cos A \sin B]$$

$$V(t) = 10 + \frac{3}{2} [\sin(A + B) - \sin(A - B)]$$

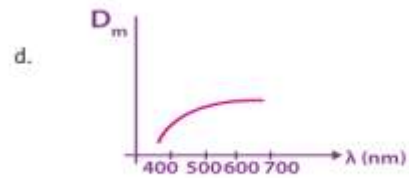
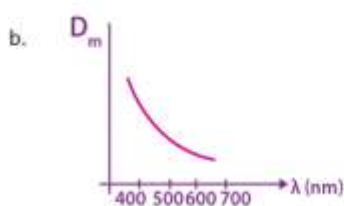
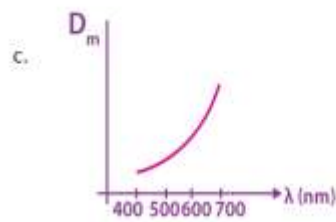
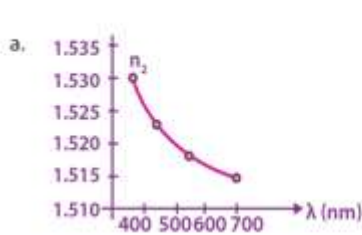
$$V(t) = 10 + \frac{3}{2} [\sin(57.2 \times 10^4 t) - \sin(52.8 \times 10^4 t)]$$

$$\omega_1 = 57.2 \times 10^4 = 2\pi f_1 \quad f_1 = \frac{57.2 \times 10^4}{2 \times (\frac{22}{7})} = 91 \text{ KHz}$$

$$f_2 = \frac{52.8 \times 10^4}{2 \times (\frac{22}{7})} = 84 \text{ KHz}$$

Closest answer is (c)

29. The variation of refractive index of a crown glass thin prism with wavelength of the incident light is shown. Which of the following graphs is the correct one, if D_m is the angle of minimum deviation?

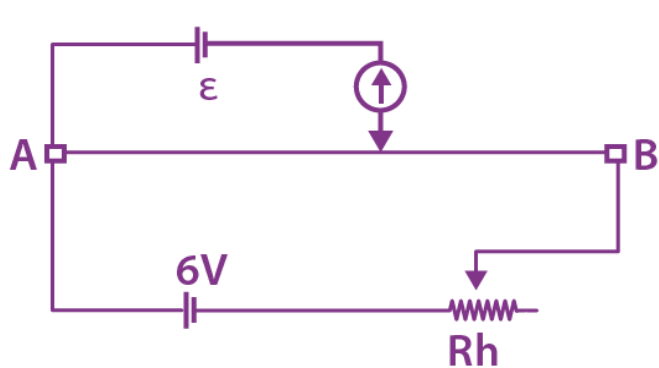


Answer: (a)

Solution

Since $D_m = (\mu - 1)A$ and on increasing the wavelength, μ decreases and hence D_m decreases. Therefore, correct answer is (a)

30. The resistance of the meter bridge AB in the given figure is 4Ω . With a cell of emf = 0.5 V and rheostat resistance $R_h = 2\Omega$ the null point is obtained at some point J. When the cell is replaced by another one of emf $\epsilon = \epsilon_2$ the same null point J is found for $R_h = 6\Omega$. The emf ϵ_2 is;



- a. 0.3 V
- b. 0.5 V
- c. 0.4 V
- d. 0.6 V

Answer: (a)

Solution

$$R_h = 2\Omega i_1 = \frac{6}{4+2} = 1A \quad \varepsilon = \frac{1 \times 4}{AB} \times AJ$$

$$AJ = \frac{AB}{4} \times \varepsilon \quad \text{---(1)}$$

$$\text{When } R_h = 6\Omega \quad i_1 = \frac{6}{4+6} = 0.6A \quad \varepsilon_2 = \frac{0.6 \times 4}{AB} \times AJ$$

$$AJ = \frac{AB \times \varepsilon_2}{0.6 \times 4} \quad \text{---(2)}$$

From (1) and (2)

$$\frac{\varepsilon_2 \times AB}{0.6 \times 4} = \frac{\varepsilon \times AB}{4} \quad \varepsilon_2 = 0.6 \times \varepsilon = 0.6 \times 0.5 = 0.3V$$

