

3. In an adiabatic process, the volume is doubled. Find the ratio of final average relaxation time and initial relaxation time. Given $\frac{C_p}{C_v} = \gamma$

- a. $\frac{1}{2}$ b. $(2)^{\frac{1+\gamma}{2}}$
 c. $(\frac{1}{2})^\gamma$ d. $(\frac{1}{2})^{\frac{\gamma}{2}+1}$

Solution:(b)

Relaxation time (τ) dependence on volume and temperature can be given by $(\tau) \propto \frac{V}{\sqrt{T}}$

Also, for an adiabatic process,

$$T \propto \frac{1}{V^{\gamma-1}}$$

$$\Rightarrow \tau \propto V^{\frac{1+\gamma}{2}}$$

Thus,

$$\frac{\tau_f}{\tau_i} = \left(\frac{2V}{V}\right)^{\frac{1+\gamma}{2}}$$

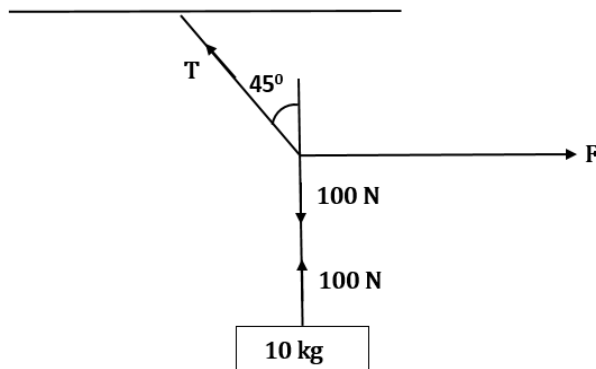
$$\frac{\tau_f}{\tau_i} = (2)^{\frac{1+\gamma}{2}}$$

4. A block of mass 10 kg is suspended from a string of length 4 m. When pulled by a force F along horizontal from the midpoint. The upper half of the string makes 45° with the vertical, value of F is

- a. 100 N b. 90 N
 c. 75 N d. 70 N

Solution: (a)

Equating the vertical and horizontal components of the forces acting at point



$$\frac{T}{\sqrt{2}} = 100$$

$$\frac{T}{\sqrt{2}} = F$$

$$F = 100 \text{ N}$$

5. The surface mass density of a disc varies with radial distance as $\sigma = A + Br$, where A and B are positive constants. The moment of inertia of the disc about an axis passing through its centre and perpendicular to the plane is

- a. $2\pi a^4 \left(\frac{A}{4} + \frac{Ba}{5}\right)$ b. $2\pi a^4 \left(\frac{4A}{4} + \frac{B}{5}\right)$
 c. $\pi a^4 \left(\frac{A}{4} + \frac{Ba}{5}\right)$ d. $2\pi a^4 \left(\frac{A}{5} + \frac{Ba}{4}\right)$

Solution: (a)

$$\sigma = A + Br$$

$$\int dm = \int (A + Br)2\pi r dr$$

$$I = \int dm r^2$$

$$= \int_0^a (A + Br)2\pi r^3 dr$$

$$= 2\pi \left(A \frac{a^4}{4} + B \frac{a^5}{5} \right)$$

$$= 2\pi a^4 \left(\frac{A}{4} + \frac{Ba}{5} \right)$$

6. Cascaded Carnot engine is an arrangement in which heat sink of one engine is source for other. If high temperature for one engine is T_1 , low temperature for other engine is T_2 (Assume work done by both engines is same). Calculate lower temperature of first engine.

- a. $\frac{2T_1T_2}{T_1+T_2}$ b. $\frac{T_1+T_2}{2}$
 c. 0 d. $\sqrt{T_1T_2}$

Solution:

(b)

Heat input to 1st engine = Q_H

Heat rejected from 1st engine = Q_L

Heat rejected from 2nd engine = Q_L

Work done by 1st engine = Work done by 2nd engine

$$Q_H - Q_L = Q_L - Q_L$$

$$2 Q_L = Q_H + Q_L$$

$$\beta = \lambda \frac{D}{d} = \frac{589 \times 10^{-9} \times 1.5}{0.5 \times 10^{-3}}$$

$$= 5.9 \text{ mm}$$

9. An ideal fluid is flowing in a pipe in streamline flow. Pipe has maximum and minimum diameter of 6.4 cm and 4.8 cm respectively. Find out the ratio of minimum to maximum velocity.

a. $\frac{81}{256}$
c. $\frac{3}{4}$

b. $\frac{9}{16}$
d. $\frac{3}{16}$

Solution:

(b)

Using equation of continuity

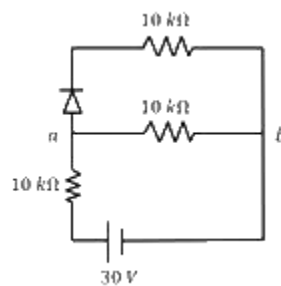
$$A_1 V_1 = A_2 V_2$$

$$\frac{V_1}{V_2} = \frac{A_2}{A_1} = \left(\frac{4.8}{6.4}\right)^2 = \frac{9}{16}$$

10. There is an electric circuit as shown in the figure. Find potential difference between points *a* and *b*

a. 0 V
c. 10 V

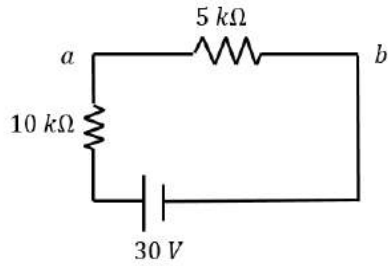
b. 15 V
d. 5 V



Solution:

(c)

Diode is in forward bias, so it will behave as simple wire. So, the circuit effectively becomes



$$V_{ab} = \frac{30}{5+10} \times 5 = 10 \text{ V}$$

11. A particle of mass m and positive charge q is projected with a speed of V_0 in y -direction in the presence of electric and magnetic field and both of them are in x -direction. Find the instant of time at which the speed of particle becomes double the initial speed.

a. $t = \frac{mV_0\sqrt{3}}{qE}$

b. $t = \frac{mV_0\sqrt{2}}{qE}$

c. $t = \frac{mV_0}{qE}$

d. $t = \frac{mV_0}{2qE}$

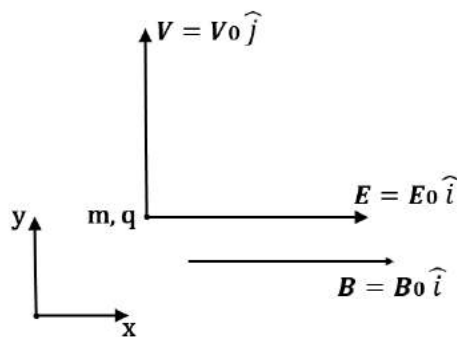
Solution:

(a)

As $\vec{V} = V_0\hat{j}$ (magnitude of velocity does not change in y - z plane)

$$(2V_0)^2 = V_0^2 + V_x^2$$

$$V_x = \sqrt{3}V_0$$



$$\therefore \sqrt{3}V_x = 0 + \frac{qE}{m}t \Rightarrow t = \frac{mV_0\sqrt{3}}{qE}$$

12. Two sources of sound moving with the same speed V and emitting frequencies of 1400 Hz are moving such that one source s_1 is moving towards the observer and s_2 is moving away from the observer. If observer hears a beat frequency of 2 Hz , then find the speed of the source (Given $V_{\text{sound}} \gg V_{\text{source}}$ and $V_{\text{sound}} = 350 \text{ m/s}$.)

- a. $\frac{1}{4}$
c. 2

- b. 4
d. $\frac{1}{2}$

Solution:

(a)

$$f_0 \left(\frac{C}{C - V} \right) - f_0 \left(\frac{C}{C + V} \right) = 2$$

$$V = \frac{1}{4} m/s$$

13. An electron and a photon have same energy E . Find the de Broglie wavelength of electron to wavelength of photon. (Given mass of electron is m and speed of light is c)

- a. $\frac{2}{c} \left(\frac{E}{2m} \right)^{\frac{1}{2}}$
c. $\frac{1}{c} \left(\frac{E}{m} \right)^{\frac{1}{2}}$

- b. $\frac{1}{c} \left(\frac{E}{2m} \right)^{\frac{1}{3}}$
d. $\frac{1}{c} \left(\frac{E}{2m} \right)^{\frac{1}{2}}$

Solution:

(d)

$$\lambda_d \text{ for electron} = \frac{h}{\sqrt{2mE}}$$

$$\lambda \text{ for photon} = \frac{hc}{E}$$

$$\text{Ratio} = \frac{h}{\sqrt{2mE}} \frac{E}{hc} = \frac{1}{c} \sqrt{\frac{E}{2m}}$$

14. A ring is rotated about diametric axis in a uniform magnetic field perpendicular to the plane of the ring. If initially the plane of the ring is perpendicular to the magnetic field. Find the instant of time at which EMF will be maximum and minimum respectively.

- a. 2.5 sec, 5 sec
c. 2.5 sec, 7.5 sec

- b. 5 sec, 7.5 sec
d. 10 sec, 5 sec

Solution:

(a)

$$\omega = \frac{2\pi}{T} = \frac{\pi}{5}$$

$$\text{When } \omega t = \frac{\pi}{2}$$

Then ϕ_{flux} will be minimum

$\therefore e$ will be maximum

$$t = \frac{\frac{\pi}{2}}{\frac{\pi}{5}} = 2.5 \text{ sec}$$

When $\omega t = \pi$

Then ϕ_{flux} will be maximum

$\therefore e$ will be minimum

$$t = \frac{\pi}{\frac{\pi}{5}} = 5 \text{ sec}$$

15. Electric field in space is given by $\vec{E}(t) = \frac{E_0(\hat{i}+\hat{j})}{\sqrt{2}} \cos(\omega t + kz)$. A positively charged particle at $(0, 0, \pi/k)$ is given velocity $v_0\hat{k}$ at $t = 0$. Direction of force acting on particle is

a. $f = 0$

b. Antiparallel to $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

c. Parallel to $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

d. \hat{k}

Solution:

(b)

Force due to electric field is in direction $-\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

Because at $t = 0, E = -\frac{(\hat{i}+\hat{j})}{\sqrt{2}} E_0$

Force due to magnetic field is in direction $q(\vec{v} \times \vec{B})$ and $\vec{v} \parallel \hat{k}$

\therefore It is parallel to \vec{E}

\therefore Net force is antiparallel to $\frac{(\hat{i}+\hat{j})}{\sqrt{2}}$.

16. Focal length of convex lens in air is 16 cm ($\mu_{glass} = 1.5$). Now the lens is submerged in liquid of refractive index 1.42. Find the ratio of focal length in medium to focal length in air.

a. 9

b. 17

c. 1

d. 5

Solution:

(a)

$$\frac{1}{f_a} = \left(\frac{\mu_g}{\mu_l} - 1 \right) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m} - 1\right) \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{f_a}{f_m} = \frac{\left(\frac{\mu_g}{\mu_m} - 1\right)}{\left(\frac{\mu_g}{\mu_a} - 1\right)} = \frac{\left(\frac{1.50}{1.42} - 1\right)}{\left(\frac{1.50}{1} - 1\right)} = \frac{0.08}{(1.92)(0.5)}$$

$$\frac{f_m}{f_a} = \frac{(1.42)(0.5)}{0.08} = 8.875 = 9$$

17. A lift of mass 920 kg has a capacity of 10 persons. If average mass of person is 68 kg. Friction force, between lift and lift shaft is 6000 N. The minimum power of motor required to move the lift upward with constant velocity 3 m/s is [$g = 10 \text{ m/s}^2$]
- a. 66000 W b. 63248 W
c. 48000 W d. 56320 W

Solution:

(a)

Net force on motor will be

$$F_m = [920 + 68(10)]g + 6000$$

$$F_m = 22000 \text{ N}$$

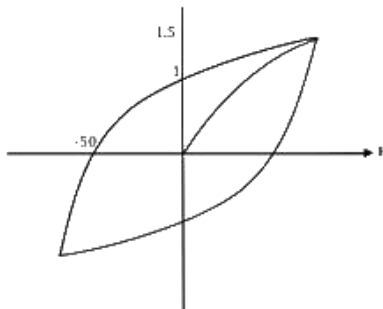
So, required power for motor

$$P_m = \vec{F}_m \cdot \vec{v}$$

$$= 22000 \times 3$$

$$= 66000 \text{ W}$$

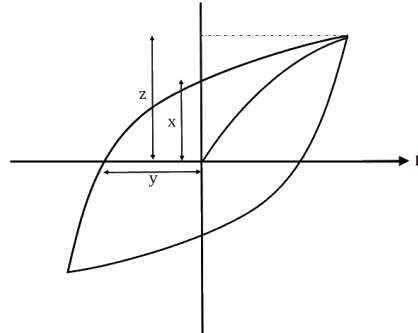
18. The hysteresis curve for a material is shown in the figure. Then for the material retentivity, coercivity and saturation magnetization respectively will be



- a. 50 A/m, 1 T, 1.5 T b. 1.5 T, 50 A/m, 1 T
c. 1 T, 50 A/m, 1.5 T d. 50 A/m, 1.5 T, 1 T

Solution:

(c)



x = retentivity

y = coercivity

z = saturation magnetization

19. An inductor of inductance 10 mH and a resistance of 5Ω is connected to a battery of 20 V at $t = 0$. Find the ratio of current in the circuit at $t = \infty$ to current at $t = 40\text{ sec}$.

a. 1.06

b. 1.48

c. 1.15

d. 0.84

Solution:

(a)

$$\begin{aligned} i &= i_0 \left(1 - e^{-\frac{t}{L/R}}\right) \\ &= \frac{20}{5} \left(1 - e^{-\frac{t}{0.01/5}}\right) \\ &= 4(1 - e^{-500t}) \\ i_\infty &= 4 \end{aligned}$$

$$i_{40} = 4(1 - e^{-500 \times 40}) = 4 \left(1 - \frac{1}{(e^2)^{10000}}\right) = 4 \left(1 - \frac{1}{7.29^{10000}}\right)$$

$$\frac{i_\infty}{i_{40}} \approx 1 \text{ (Slightly greater than one)}$$

20. Find the dimensions of $\frac{B^2}{2\mu_0}$

a. $ML^{-1}T^{-2}$

b. ML^2T^{-2}

c. $ML^{-1}T^2$

d. $ML^{-2}T^{-1}$

Solution:

(a)

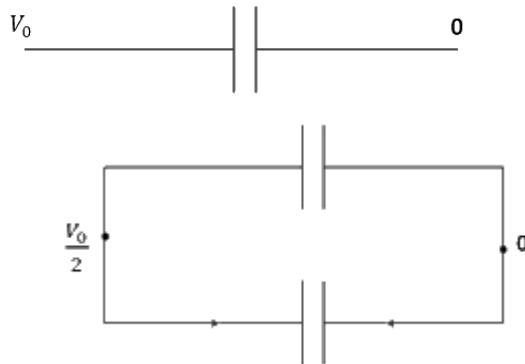
Energy density in magnetic field = $\frac{B^2}{2\mu_0}$

$$= \frac{\text{Force} \times \text{displacement}}{(\text{displacement})^3} = \frac{MLT^{-2} \cdot L}{(L)^3} = ML^{-1}T^{-2}$$

21. A capacitor of 60 pF charged to 20 V . Now, the battery is removed, and this capacitor is connected to another identical uncharged capacitor. Find heat loss in nJ.

Solution:

(6)



$$V_0 = 20 \text{ V}$$

$$\text{Initial potential energy } U_i = \frac{1}{2} CV_0^2$$

After connecting identical capacitor in parallel, voltage across each capacitor will be

$$\frac{V_0}{2}. \text{ Then, final potential energy } U_f = 2 \left[\frac{1}{2} C \left(\frac{V_0}{2} \right)^2 \right]$$

$$\text{Heat loss} = U_i - U_f$$

$$= \frac{CV_0^2}{2} - \frac{CV_0^2}{4} = \frac{CV_0^2}{4} = \frac{60 \times 10^{-12} \times 20^2}{4} = 6 \times 10^{-9} = 6 \text{ nJ}$$

22. When m grams of steam at 100°C is mixed with 200 grams of ice at 0°C , it results in water at 40°C . Find the value of m in grams

(Given, Latent heat of fusion (L_f) = 80 cal/g , Latent heat of vaporization (L_v) = 540 cal/g , specific heat of water (C_w) = $1 \text{ cal/g}^\circ \text{C}$)

Solution:

(40)

Here, heat absorbed by ice = $m_{ice} L_f + m_{ice} C_w(40 - 0)$

Heat released by steam = $m_{steam} L_v + m_{steam} C_w(100 - 40)$

Heat absorbed = heat released

$$m_{ice} L_f + m_{ice} C_w(40 - 0) = m_{steam} L_v + m_{steam} C_w(100 - 40)$$

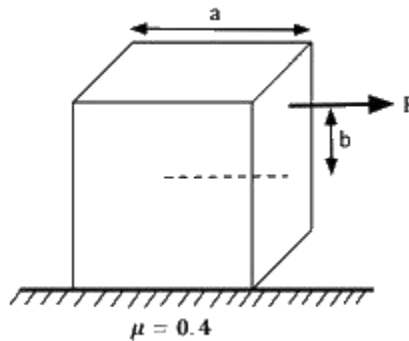
$$\Rightarrow 200 \times 80 \text{ cal/g} + 200 \times 1 \text{ cal/g/}^\circ\text{C} \times (40 - 0)$$

$$= m \times 540 \text{ cal/g} + 540 \times 1 \text{ cal/g/}^\circ\text{C} \times (100 - 40)$$

$$\Rightarrow 200 [80 + (40)1] = m[540 + (60)1]$$

$$m = 40 \text{ g}$$

23. A solid cube of side 'a' is shown in the figure. Find the maximum value of $c \frac{100b}{a}$ for which the block does not topple before sliding.



Solution:

(50)

F balances kinetic friction so that the block can move

$$\text{So, } F = \mu mg$$

For no toppling, the net torque about bottom right edge should be zero

$$\text{i.e. } F \left(\frac{a}{2} + b \right) \leq mg \frac{a}{2}$$

$$\mu mg \left(\frac{a}{2} + b \right) \leq mg \frac{a}{2}$$

$$F \mu \frac{a}{2} + \mu b \leq \frac{a}{2}$$

$$0.2a + 0.4b \leq 0.5a$$

$$0.4b \leq 0.3a$$

$$b \leq \frac{3}{4} a$$

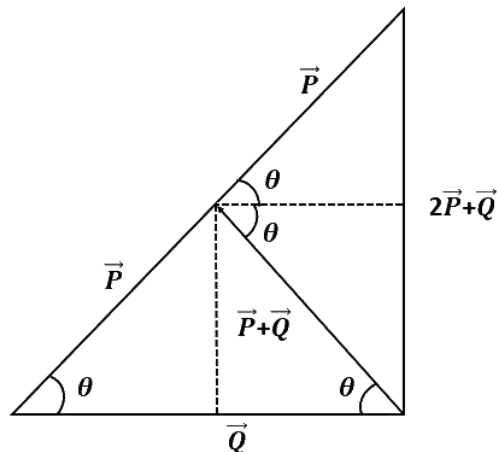
But, maximum value of b can only be $0.5a$

\therefore Maximum value of $100 \frac{b}{a}$ is 50.

24. Magnitude of resultant of two vectors \vec{P} and \vec{Q} is equal to magnitude of \vec{P} . Find the angle between \vec{Q} and resultant of $2\vec{P}$ and \vec{Q} .

Solution:

(90°)



25. A battery of unknown emf connected to a potentiometer has balancing length 560 cm. If a resistor of resistance 10Ω is connected in parallel with the cell the balancing length change by 60 cm. If the internal resistance of the cell is $\frac{n}{10} \Omega$, the value of 'n' is

Solution:

(12)

Let the emf of cell is ϵ internal resistance is ' r ' and potential gradient is x .

$$\epsilon = 560 x \quad (1)$$

After connecting the resistor

$$\frac{\epsilon \times 10}{10 + r} = 500x \quad (2)$$

From (1) and (2)

$$\frac{560 \times 10}{10 + r} = 500x$$

$$56 = 540 + 5r$$

$$r = \frac{6}{5} = 1.2 \Omega$$

$$n = 12$$

