

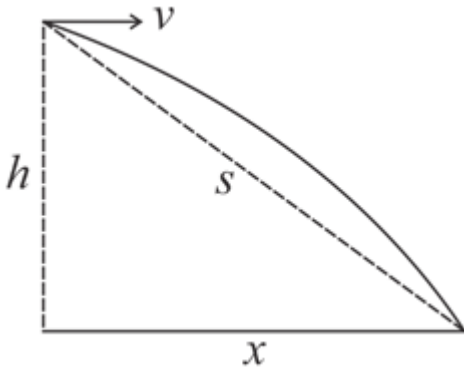
JEE Main 2021 August 31, Shift 1 (Physics)

1. An aero plane flying horizontally with velocity v at some height h . A ball is dropped from the plane such that it reaches a person standing on ground. At what distance from the plane the person should stand so that he catches the ball.

- (a) $h\sqrt{1 + \frac{v^2}{gh}}$
(b) $h\sqrt{1 + \frac{v^2}{2gh}}$
(c) $\sqrt{h}\sqrt{1 + \frac{2v^2}{gh}}$
(d) $h\sqrt{1 + \frac{2v^2}{gh}}$

Correct option: (d)

Solution:



From equation of motion in vertical direction, $s = ut + \frac{1}{2}at^2$

$$\Rightarrow h = \frac{1}{2}gT^2 \Rightarrow T = \sqrt{\frac{2h}{g}}$$

Velocity in horizontal direction will be constant. So, $x = vT = v\sqrt{\frac{2h}{g}}$

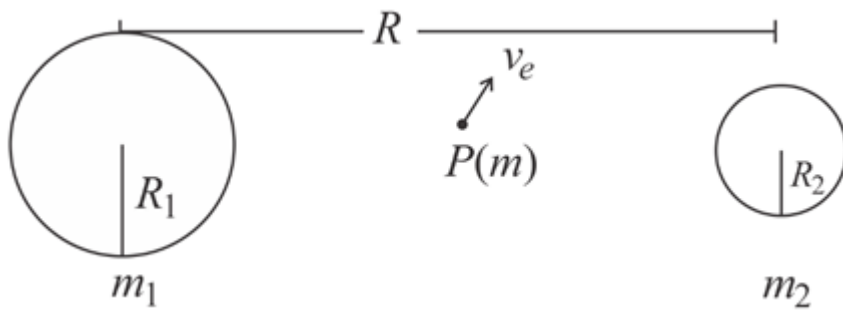
From Pythagoras theorem, $s = \sqrt{h^2 + x^2} = \sqrt{h^2 + v^2\left(\frac{2h}{g}\right)} = h\sqrt{1 + \frac{2v^2}{gh}}$

2. Two stars have masses m_1 and m_2 and radii R_1 and R_2 respectively. Their centers are separated R distance apart. Find the escape velocity of a particle placed at the midpoint of their centers.

- (a) $\sqrt{\frac{G(m_1+m_2)}{R}}$
(b) $\sqrt{\frac{2G(m_1+m_2)}{R}}$
(c) $\sqrt{\frac{4G(m_1+m_2)}{R}}$
(d) $\sqrt{\frac{3G(m_1+m_2)}{R}}$

Correct option: (c)

Solution:



To escape from the field of stars, the total energy of the particle should be non-negative.

$$\text{Initial energy} = \frac{1}{2}mv_e^2 - \frac{Gm_1m}{\frac{R}{2}} - \frac{Gm_2m}{\frac{R}{2}}$$

For escaping, initial energy ≥ 0

$$\Rightarrow v_e^2 \geq \frac{4G}{R}(m_1 + m_2)$$

$$\Rightarrow v_e \geq 2\sqrt{\frac{G(m_1+m_2)}{R}}$$

3. A ball contracts by 0.5%, when it is taken to bottom of sea of depth d . The bulk modulus of elasticity of the material of ball is $9.8 \times 10^8 \frac{N}{m^2}$, Find the depth d .

Ans. 500 m

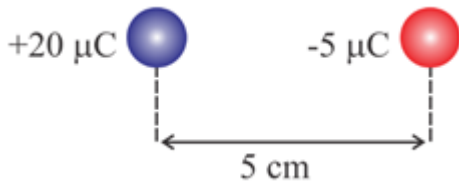
Solution:

$$\text{Change in pressure, } \Delta P = \rho g(\Delta h) = 1000 \times 9.8 \times d$$

$$\text{Fractional change in volume, } \frac{\Delta V}{V} = -\frac{0.5}{100}$$

$$\text{Bulk modulus, } B = \frac{-\Delta P}{\Delta V/V} \Rightarrow 9.8 \times 10^8 = \frac{1000 \times 9.8 \times d}{0.005} \Rightarrow d = 500 \text{ m}$$

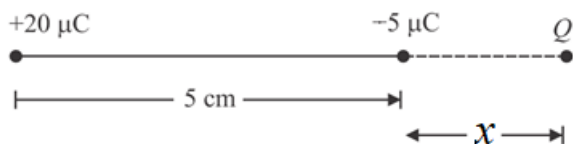
4. Two fixed charges are placed as shown in figure. Where should the third charge be placed so that it is in equilibrium?



- (a) 10 cm to left of $-5\mu C$
- (b) 10 cm to left of $+20\mu C$
- (c) 5 cm to right of $-5\mu C$
- (d) 2.5 cm to left of $-5\mu C$

Correct option: (c)

Solution:



$F_1 \rightarrow$ force on Q due to $-5\mu C$

$F_2 \rightarrow$ force on Q due to $+20\mu C$

$Q \rightarrow +ve$ (Assume all charges are point charges)

$$k \cdot \frac{20\mu C \times Q}{\left(\frac{5}{100} + x\right)^2} = k \cdot \frac{(5\mu C)Q}{x^2}$$

$$\Rightarrow x^2 \times \frac{20}{5} = \left(\frac{5}{100} + x\right)^2$$

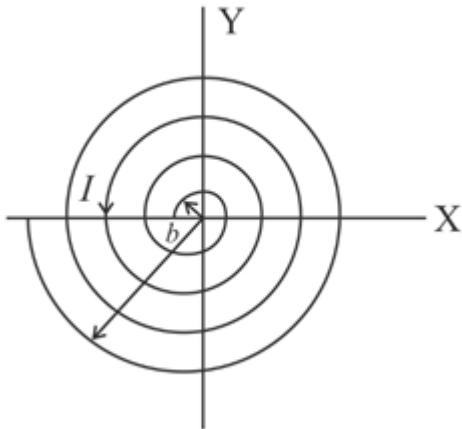
$$\Rightarrow 4x^2 = \left(\frac{5}{100} + x\right)^2$$

$$\Rightarrow 2x = \frac{5}{100} + x$$

$$\Rightarrow x = \frac{5}{100} m$$

$$\Rightarrow x = 5 \text{ cm right of } -5\mu C$$

5. A long insulated copper wire is closely wound as a spiral of N turns. The spiral has inner radius a and outer radius b . The spiral lies in the XY plane and a steady current I flows through the wire. The Z -component of the magnetic field at the centre of the spiral is:



- (a) $\frac{\mu_0 NI}{2(b-a)} \ln\left(\frac{b}{a}\right)$
- (b) $\frac{\mu_0 NI}{2(b-a)} \ln\left(\frac{b+a}{b-a}\right)$
- (c) $\frac{\mu_0 NI}{2b} \ln\left(\frac{b}{a}\right)$
- (d) $\frac{\mu_0 NI}{2b} \ln\left(\frac{b+a}{b-a}\right)$

Correct option: (a)

Solution:

Let us consider an elementary ring of radius r and thickness dr in which current I is flowing. Number of turns in this elementary ring $dN = \frac{N}{b-a} dr$

Thus, magnetic field at the center O due to this ring $dB = \frac{\mu_0 I dN}{2r}$

We get, $dB = \frac{\mu_0 I N dr}{2(b-a)r}$

Net magnetic field at center of spiral $B = \int_a^b \frac{\mu_0 I N}{2(b-a)} \frac{dr}{r}$

$$\therefore B = \frac{\mu_0 I N}{2(b-a)} \int_a^b \frac{dr}{r}$$

$$\text{Or } B = \frac{\mu_0 I N}{2(b-a)} \times \ln r \Big|_a^b$$

$$\text{Or } B = \frac{\mu_0 I N}{2(b-a)} \times \ln\left(\frac{b}{a}\right)$$

6. A real object is placed at focus of concave lens. Focal length of concave lens is f . Find magnification and location of image.

- (a) $m = +\frac{1}{2}$, Image is at $\frac{f}{2}$ from optical center and at same side as of object
- (b) $m = -\frac{1}{2}$, Image is at $\frac{f}{2}$ from optical center and at same side as of object
- (c) $m = +\frac{1}{2}$, Image is at $\frac{f}{2}$ from optical center and at other side as of object
- (d) $m = -\frac{1}{2}$, Image is $\frac{f}{2}$ from optical center and at other side as of object

Correct option: (a)

Solution:

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

Focal length of concave lens is negative, by convention $u = -f$ and $f = -f$,

$$-\frac{1}{f} = \frac{1}{v} - \frac{1}{-f}$$

$$\Rightarrow -\frac{2}{f} = \frac{1}{v}$$

$$\Rightarrow v = -\frac{f}{2}$$

Negative indicate image formed at same side where object is placed,

$$-\frac{1}{f} = \frac{1}{v} - \frac{1}{-f}$$

$$\Rightarrow -\frac{2}{f} = \frac{1}{v}$$

$$\text{Magnification, } m = \frac{v}{u} = \frac{-\frac{f}{2}}{-f} = \frac{1}{2}$$

7. Choose the incorrect formula from the following:

(a) $h = \frac{2Scos\theta}{r\rho g}$

(b) work = $\tau\theta$

(c) $\frac{\Delta V}{\Delta t} = \frac{\pi R^4(P_1 - P_2)}{8L}$

(d) $\left(P + \frac{an^2}{v^2}\right)(V - nb) = nRT$

Correct option: (c)

Solution:

Correct relation of Poiseuille formula is

$$\frac{\Delta V}{\Delta t} = \frac{\pi R^4(P_1 - P_2)}{8\eta L}$$

Hence, option c is the correct answer.

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8. A square loop has $3\ \Omega$ resistor on each side. This square loop is now bent in a circular loop, find the equivalent resistance across diametrically opposite ends

(a) $5\ \Omega$

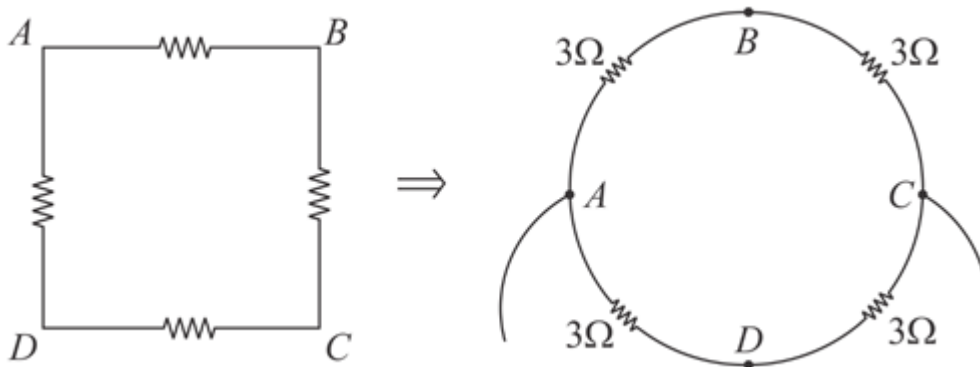
(b) $1.5\ \Omega$

(c) $3\ \Omega$

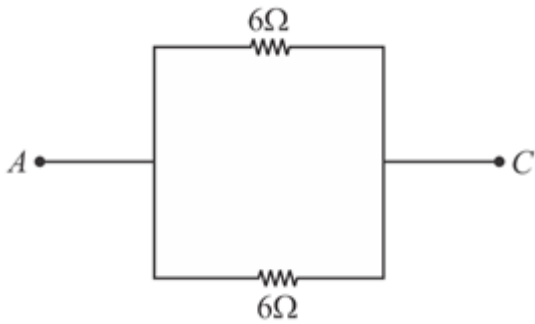
(d) $2\ \Omega$

Correct option: (c)

Solution:



Resistor between AB and BC are in series and AD and CD are also in series,



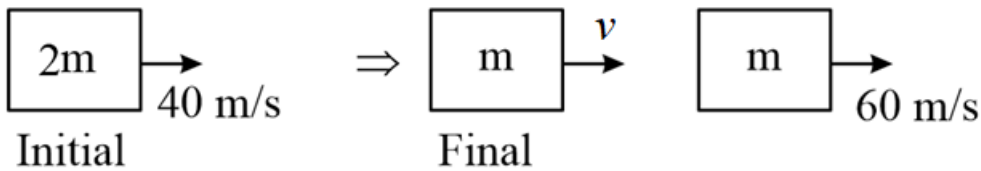
Both 6Ω resistors are in parallel. The equivalent resistance is 3Ω .

9. A block was moving in a horizontal plane with velocity 40 m/s . The block splits in two blocks of equal mass and one is moving with velocity 60 m/s . Calculate the ratio of initial and final kinetic energy of system.

- (a) 1 : 2
- (b) 3 : 2
- (c) 3 : 5
- (d) 4 : 5

Correct option: (d)

Solution:



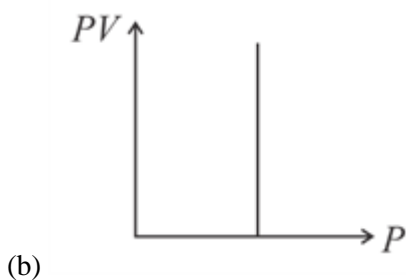
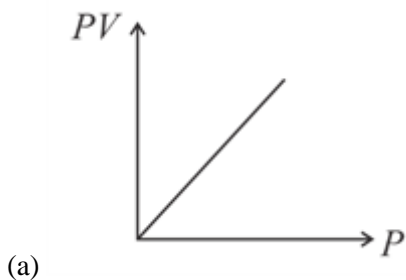
$$2m \times 40 = 60 \times m + mv$$

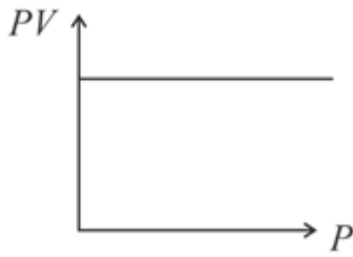
$$v = 20\text{ m s}^{-1}$$

Now,

$$\frac{KE_i}{KE_f} = \frac{\frac{1}{2} \times 2mu^2}{\frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2} = \frac{2 \times (40)^2}{(60)^2 + (20)^2} = \frac{4}{5}$$

10. If we compressed a gas isothermally, select the correct option: -





(c)

(d) None of these

Correct option: (c)

Solution:

As we know,

For Isothermal process,

$$\Delta T = 0, T = \text{constant}$$

From ideal gas equation, $PV = nRT$

$$PV = \text{constant}$$

11. A particle of mass M is moving with a speed of u . It collides with another particle of mass m which was at rest. After collision they are going at an angle of θ_1 and θ_2 respectively. For what value of $\frac{M}{m}$, θ_1 and θ_2 will be equal.

(Assume elastic collision)

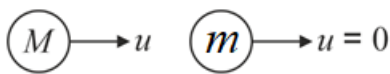
(a) $4\sin^2\theta - 1$

(b) $4\cos^2\theta - 1$

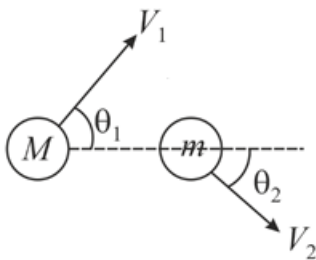
(c) $4\operatorname{cosec}^2\theta - 1$

(d) $4\sec^2\theta - 1$

Correct option is (b)



Before Collision



After Collision

Applying conservation of momentum in x-direction.

$$Mu = MV_1\cos\theta_1 + mV_2\cos\theta_2$$

From question, $\theta_1 = \theta_2 = \theta$

$$Mu = MV_1\cos\theta + mV_2\cos\theta$$

$$Mu = (MV_1 + mV_2)\cos\theta \dots (i)$$

Applying conservation of momentum in y-direction

$$M \times 0 + m \times 0 = MV_1\sin\theta - mV_2\sin\theta$$

$$V_2 = \frac{M}{m}V_1 \dots (ii)$$

Applying conservation of energy.

$$\frac{1}{2}Mu^2 = \frac{1}{2}MV_1^2 + \frac{1}{2}mV_2^2$$

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$$\frac{1}{2}Mu^2 = \frac{1}{2}MV_1^2 + \frac{1}{2}m\frac{M^2V_1^2}{m^2}$$

$$\frac{1}{2}Mu^2 = \frac{1}{2}MV_1^2 \left(1 + \frac{M}{m}\right)$$

$$u^2 = V_1^2 \left(1 + \frac{M}{m}\right)$$

$$\text{From (i), } V_1 = \frac{Mu}{(M+m)\cos\theta}$$

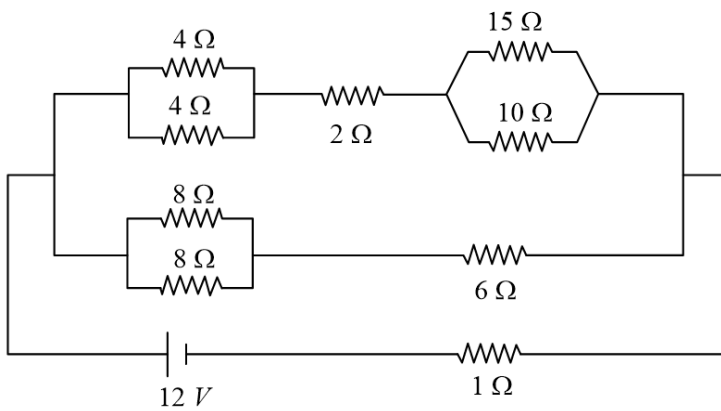
On solving,

$$u^2 = \frac{u^2}{4\cos^2\theta} \left(1 + \frac{M}{m}\right)$$

$$\frac{M}{m} = 4\cos^2\theta - 1$$

$$\frac{M}{m} = 4\cos^2\theta - 1$$

12. Find potential difference across $15\ \Omega$ resistor:



BIBE

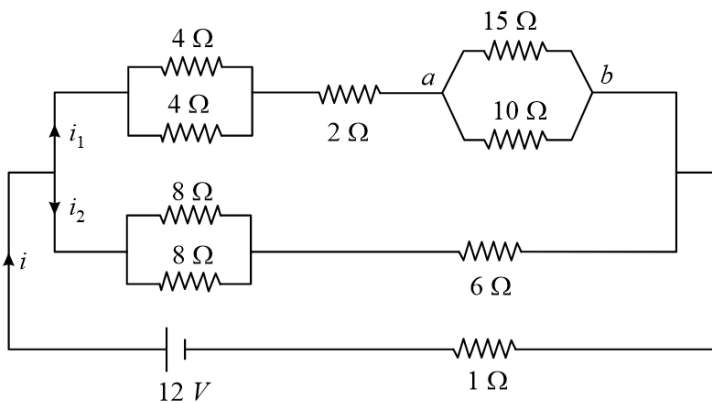
(A) 2 V

(B) 6 V

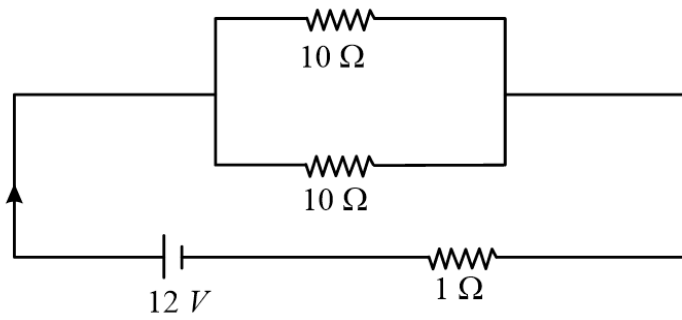
(C) 8 V

(D) 4 V

Ans. (B)



equivalent circuit

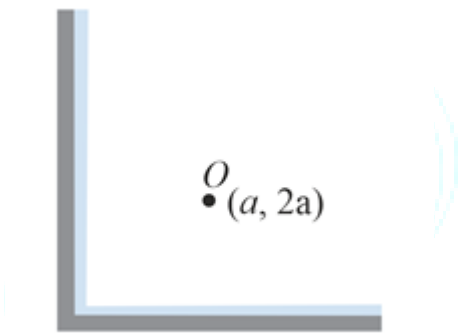


$$i = \frac{12}{6} = 2 \text{ A}$$

$$i_1 = i_2 = i/2 = 1 \text{ A}$$

$$V_{15\Omega} = i_1 \times R_{ab} = 1 \times 6 = 6 \text{ V}$$

13. Find the shortest distance between the image? ($\sqrt{5} \approx 2.3$)

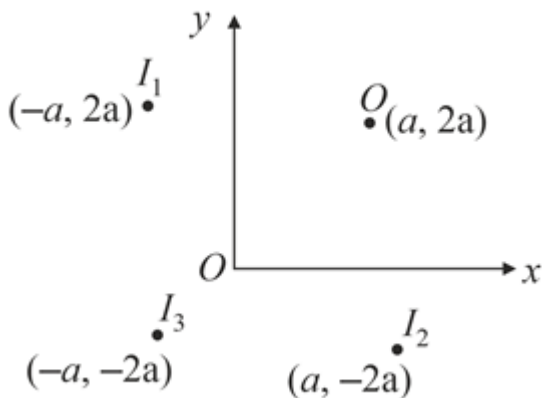


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- (a) $4.6a$
- (b) $2.3a$
- (c) $2\sqrt{10}a$
- (d) $2a$

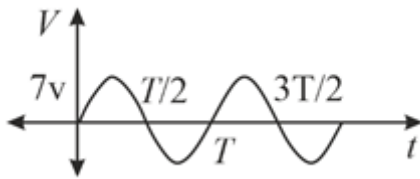
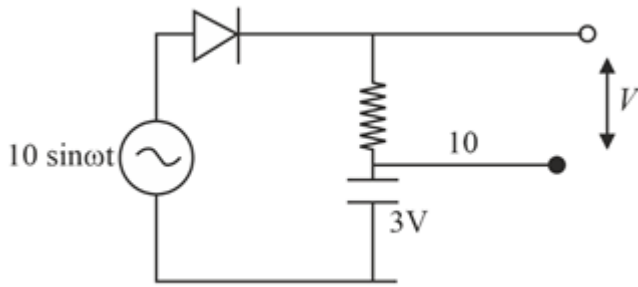
Correct option: (d)

Solution:

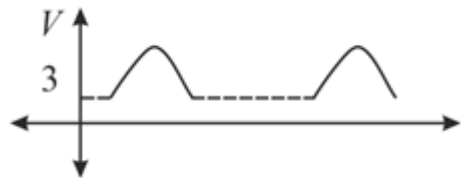


$$\begin{aligned} \text{Shortest distance between the images} &= \sqrt{(2a - (-2a))^2 + (a - a)^2} \\ &= \sqrt{(4a)^2 + 0^2} \\ &= 4a \end{aligned}$$

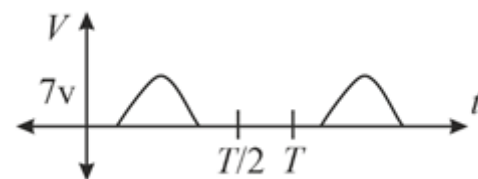
14. Which of the following graph is a correct $V - t$ graph for given electronics circuit? Use $(T = \frac{2\pi}{\omega})$ Assume diode to be ideal.



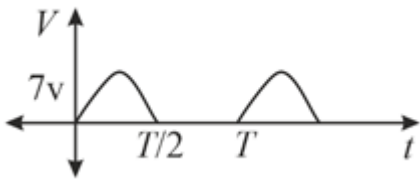
(a)



(b)



(c)



(d)

Correct option: (b)

Solution:

Since for

$t = 0$ to $T/2$ diode is in forward bias

$$0 < t < \frac{\sin^{-1}(0.3)}{\omega}, V_{out} = 0$$

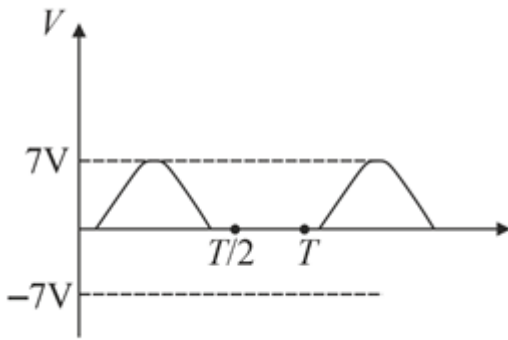
$$\frac{\sin^{-1}(0.3)}{\omega} < t < \frac{T}{2} - \frac{\sin^{-1}(0.3)}{\omega}, V = 10\sin\omega t - 3$$

$$V_{max} = 7V$$

For $t = \frac{T}{2}$ to T , Diode is reverse bias.

$$V_{out} = 0$$

EMBIBE



15. mass per unit length of a wire is $(9 \times 10^{-4} \text{ kg m}^{-1})$ having tension 900 N is fixed at both ends. if one of the resonating frequency is 500 Hz and the next is 550 Hz then What is the length of the wire?

- (a) 30 m
- (b) 40 m
- (c) 10 m
- (d) 50 m

Correct option: (c)

Solution:

$$L = \frac{1}{50 \times 2} \times 1000 = 10 \text{ m}$$

$$f_n = 500 \text{ Hz}$$

$$f_{n+1} = 550 \text{ Hz}$$

$$T = 900 \text{ N}$$

$$f_n = \frac{n}{2L} \sqrt{\frac{T}{\mu}} \dots (i)$$

$$f_{n+1} = \frac{n+1}{2L} \sqrt{\frac{T}{\mu}} = \frac{n}{2L} \sqrt{\frac{T}{\mu}} + \frac{1}{2L} \sqrt{\frac{T}{\mu}} \dots (ii)$$

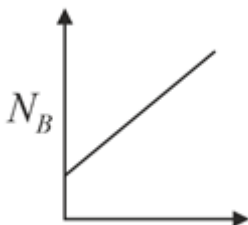
From equation (i) and (ii)

$$f_{n+1} = f_n + \frac{1}{2L} \sqrt{\frac{T}{\mu}}$$

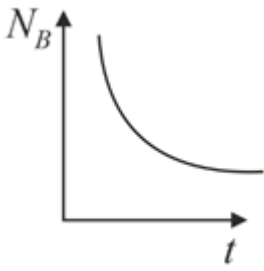
$$550 = 500 + \frac{1}{2L} \sqrt{\frac{900}{9 \times 10^{-4}}}$$

$$L = \frac{1}{50 \times 2} \times 1000 = 10 \text{ m}$$

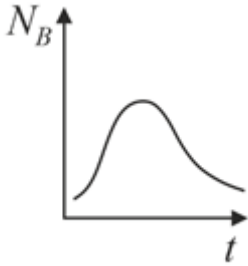
16. A radioactive sample "A" decays to "B" and finally decays to "C". Plot the graph between no. of molecule left of B with respect to time.



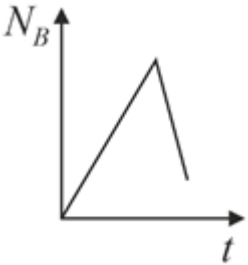
(a)



(b)

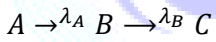


(c)



(d)

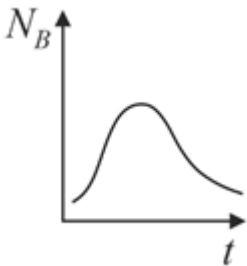
Ans. (c)



$$N_B = \frac{\lambda_A}{\lambda_B - \lambda_A} N_{A_0} (e^{-\lambda_A t} - e^{-\lambda_B t})$$

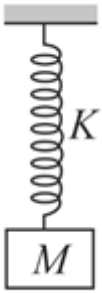
$$N_B = K(e^{-\lambda_A t} - e^{-\lambda_B t})$$

$$K = \frac{\lambda_A}{\lambda_B - \lambda_A} N_{A_0}$$



EMBIBE

17. A spring block system is shown below. At $t=0$ if mass M is stretched to x distance below equilibrium point and is released from here then Find the time instant when kinetic energy and potential energy is same.



(a) $\frac{\pi}{4} \sqrt{\frac{m}{k}}$

(b) $\pi \sqrt{\frac{m}{k}}$

(c) $\frac{\pi}{2} \sqrt{\frac{m}{k}}$

(d) $\frac{\pi}{8} \sqrt{\frac{m}{k}}$

Correct option is (a)

As we know the equation of SHM is

$$x = a \sin \omega t$$

K.E = P.E

$$\frac{1}{2} m u^2 = \frac{1}{2} k x^2$$

$$\frac{1}{2} m \omega^2 (a^2 - x^2) = \frac{1}{2} m \omega^2 x^2$$

$$a^2 - x^2 = x^2$$

$$x = \frac{a}{\sqrt{2}}$$

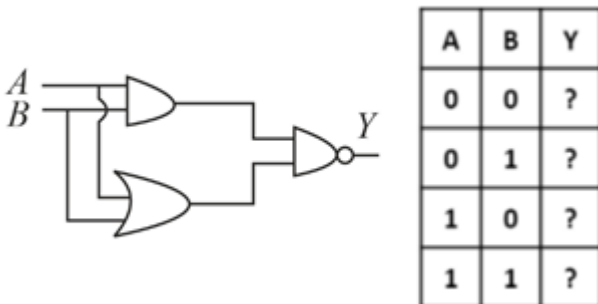
$$\frac{a}{\sqrt{2}} = a \sin \omega t$$

$$\omega t = \frac{\pi}{4}$$

$$t = \frac{\pi}{4} \sqrt{\frac{m}{k}}$$

EMBIBE

18. A and B are the inputs then what should be the truth table of the logic gates shown below ?



Y
1
1
1
0

(a)

Y
0
0
0
1

(b)

Y
0
1
1
1

(c)

Y
1
1
1
1

(d)

Correct option is (a)

19. The temperature of the sink of a Carnot cycle is T and its efficiency is 0.25. Now, the temperature of sink is reduced to 58°C such that efficiency is doubled. Find T .

- (a) 313°C
- (b) 223.5°C
- (c) 423.5°C
- (d) 367 K

Correct option: (c)

Solution:

Efficiency of the Carnot cycle is $\eta = 1 - \frac{T_{\text{sink}}}{T_{\text{source}}}$

In second case, $\frac{1}{2} = 1 - \frac{331}{T_{\text{source}}} \Rightarrow T_{\text{source}} = 662\text{ K}$

Initially, $\frac{1}{4} = 1 - \frac{T_{\text{sink}}}{662} \Rightarrow T_{\text{sink}} = 662 \times \frac{3}{4} = 496.5\text{ K} = 223.5^\circ\text{C}$

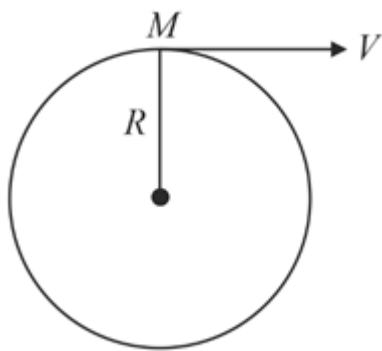
EMBIBE

20. Find the angular momentum of particle about the axis passing through centre. If a particle is moving in a horizontal circular motion of radius R with constant speed V .

- (a) Magnitude is varying
- (b) Constant
- (c) Direction is varying
- (d) Both magnitude and direction are varying

Correct option is (b)

Solution:



As we know,

$$\vec{L} = m(\vec{r} \times \vec{v})$$

⇒ Here direction of angular momentum is perpendicular to the plane of r and v .

So it will remain constant

⇒ Since magnitude of velocity is not changing so magnitude of angular momentum will also remain constant.

21. For space wave communication system sum of height of antenna and receiver is 160 cm . Find maximum line of sight

Ans. 64

$$h_r + h_t = 160 \text{ (Given)}$$

$$\text{LOS} = \sqrt{2R}(\sqrt{h_r} + \sqrt{h_t})$$

$$\text{LOS} = \sqrt{2R}(\sqrt{h_r} + \sqrt{160 - h_r})$$

$$\frac{d\text{LOS}}{dh_r} = 0 = \sqrt{2R} \left(\frac{1}{2\sqrt{h_r}} - \frac{1}{2\sqrt{160-h_r}} \right) = 0$$

$$h_r = h_t = 80 \text{ cm}$$

$$\text{LOS} = \sqrt{2R}(\sqrt{0.80} + \sqrt{0.80}) = 2\sqrt{2 \times 6400 \times 10^3 \times 0.80} = 64 \text{ km}$$

22. Match the following columns and select the correct option.

Column I	Column II
(a) Torque	(P) $M^1L^2T^0$
(b) Tension	(Q) $M^1L^0T^{-2}$
(c) Moment of inertia	(R) $M^1L^1T^{-2}$
(d) Surface tension	(S) $M^1L^2T^{-2}$

(a) a-S, b-P, c-R, d-Q

(b) a-S, b-R, c-P, d-Q

(c) a-R, b-Q, c-S, d-P

(d) a-Q, b-P, c-R, d-S

Correct option: (b)

Solution:

$$\text{Torque: } [\tau] = [F][r] = MLT^{-2}L = M'L^2T^{-2}$$

$$\text{Tension force: } [F] = M^1L^1T^{-2}$$

$$\text{Moment of Inertia: } [I] = [M][r^2] = M'L^2T^0$$

$$\text{Surface Tension: } [T] = \frac{[F]}{[l]} = \frac{MLT^{-2}}{L} = M^1L^0T^{-2}$$

a-S, b-R, c-P, d-Q

23. If the de broglie wavelength of a proton and an electron is same and kinetic energy of proton is k_p and of electron is k_e . Also momentum of proton is p_p and of electron is p_e . Which of the following options is correct?

(a) $p_p = p_e, k_p > k_e$

(b) $p_p = p_e, k_p = k_e$

(c) $p_p = p_e, k_p < k_e$

(d) $p_p < p_e, k_p = k_e$

Correct option is (c)

Solution:

Kinetic energy of particle of mass m having momentum p is,

$$K \cdot E = \frac{1}{2} \frac{p^2}{m}$$

$$\Rightarrow p = \sqrt{2mK}$$

De-Broglie wavelength,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$$

$$p = \frac{h}{\lambda} \dots (1)$$

and,

$$K = \frac{h^2}{2m\lambda^2} \dots (2)$$

If λ is constant, then from equation (1)

$$p = \text{constant.}$$

Also we can write

$$m_p v_p = m_e v_e$$

$$\frac{v_p}{v_e} = \frac{m_e}{m_p} < 1 \text{ or}$$

$$v_p < v_e$$

If λ is constant, then from (ii)

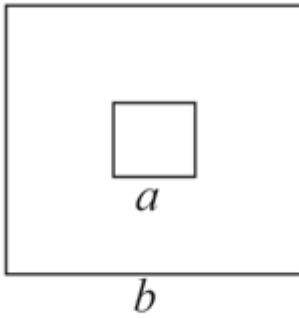
$$K \propto \frac{1}{m}$$

Now we can write

$$\frac{K_p}{K_e} = \frac{m_e}{m_p} < 1$$

$$K_p < K_e$$

24. If both given loops are in the same plane, find the mutual induction between them. Consider $b \gg a$.



- (a) $\frac{2\sqrt{2}\mu_0 a^2}{b}$
- (b) $\frac{2\sqrt{2}\mu_0 a^2}{\pi b}$
- (c) $\frac{\sqrt{2}\mu_0 a^2}{\pi b}$
- (d) $\frac{2\mu_0 a^2}{\pi b}$

Correct option is (b)

Solution:

$$M = \frac{\phi}{i} = \frac{\frac{4\mu_0 i}{4\pi(\frac{b}{2})} \cdot (\frac{2}{\sqrt{2}})a^2}{i}$$

$$= \frac{2\sqrt{2}\mu_0 a^2}{\pi b}$$

25. If $\frac{dP}{dV} = -aP$ at $P = P_0, V = 0$. Then what will be the maximum temperature of the body.

- (a) 0
- (b) $\frac{P_0 a}{nR}$
- (c) $\frac{P_0}{naRe}$
- (d) 1

Correct option is (C)

Solution:

$$\frac{dP}{dV} = -aP$$

$$\frac{dP}{P} = -a dV$$

After integration,

$$\ln\left(\frac{P}{P_0}\right) = -aV$$

$$P = P_0 e^{-aV}$$

Now according to ideal gas equation,

$$PV = nRT$$

Put the value of P

$$P_0 V e^{-aV} = nRT$$

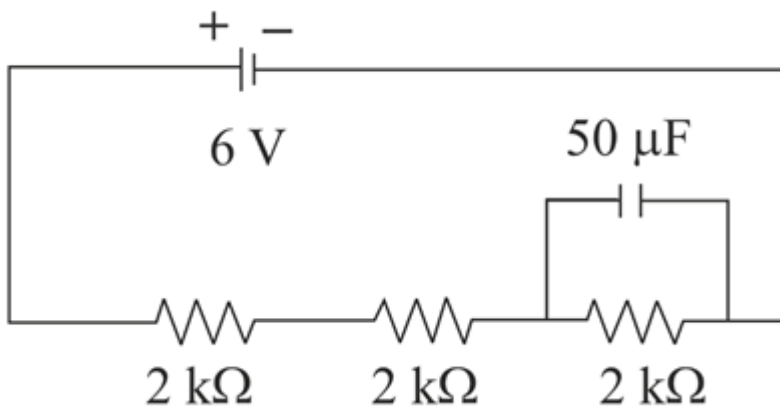
Now as we know for maxima of temperature

$$\frac{dT}{dV} = 0$$

By solving we get

$$T = \frac{P_0}{naRe}$$

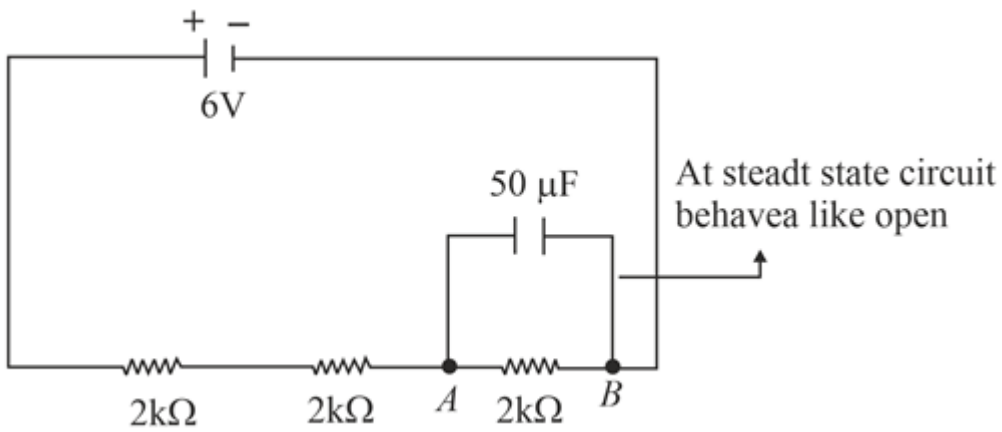
26. In the given circuit , what will be the charge on the left plate of the capacitor in steady state



- (a) 0.1 mC
- (b) 1 mC
- (c) 5 mC
- (d) 6 mC

Correct option is (a)

Solution:



IB E

$$R_{eq} = R_1 + R_2 + R_3$$

$$R_{eq} = 6$$

Now,

$$V = iR$$

$$6 = (i)(R) \Rightarrow 6 = (i)(6 \times 10^3) \Rightarrow i = 10^{-3} \text{ A}$$

$$V_{AB} = 10^{-3} \times 2 \times 10^3 = 2 \text{ V}$$

$$\Rightarrow Q = (C)(V)$$

$$Q = 50 \times 10^{-6} \times 2 = 100 \times 10^{-6} \Rightarrow 10^{-4} 10^{-1} \times 10^{-3}$$

$$Q = 0.1 \text{ mC}$$