

JEE Main 2021 Paper



Date: 24th February 2021 (Shift-1)

Subject: Physics

Section - A

1. Four identical particles of equal masses 1 kg made to move along the circumference of a circle of radius 1 m under the action of their own mutual gravitational attraction. The speed of each particle will be -

(1) $\frac{\sqrt{(1+2\sqrt{2})G}}{2}$

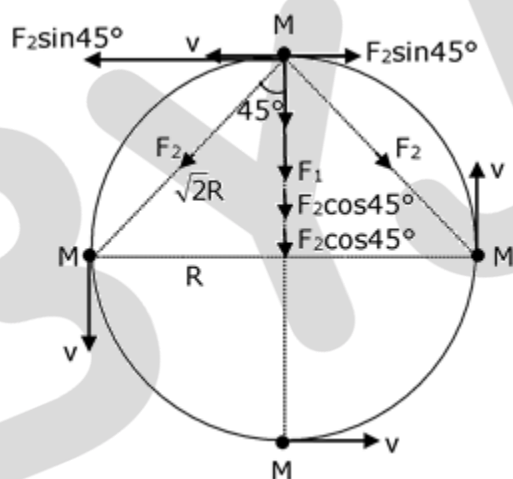
(2) $\sqrt{G(1+2\sqrt{2})}$

(3) $\sqrt{\frac{G}{2}(2\sqrt{2}-1)}$

(4) $\sqrt{\frac{G}{2}(1+2\sqrt{2})}$

Ans. (1)

Sol.



⇒ By resolving force F_2 , we get

$$\Rightarrow F_1 + F_2 \cos 45^\circ + F_2 \cos 45^\circ = F_c$$

$$\Rightarrow F_1 + 2F_2 \cos 45^\circ = F_c$$

$$F_c = \text{centripetal force} = \frac{MV^2}{R}$$

$$\Rightarrow \frac{GM^2}{(2R)^2} + \left[\frac{2GM^2}{(\sqrt{2}R)^2} \cos 45^\circ \right] = \frac{MV^2}{R}$$

$$\Rightarrow \frac{GM^2}{4R^2} + \frac{2GM^2}{2\sqrt{2}R^2} = \frac{MV^2}{R}$$

$$\Rightarrow \frac{GM}{4R} + \frac{GM}{\sqrt{2}.R} = V^2$$

$$\Rightarrow V = \sqrt{\frac{GM}{4R} + \frac{GM}{\sqrt{2}.R}}$$

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$$\Rightarrow V = \sqrt{\frac{GM}{R} \left[\frac{1+2\sqrt{2}}{4} \right]}$$

$$\Rightarrow V = \frac{1}{2} \sqrt{\frac{GM}{R} (1 + 2\sqrt{2})}$$

(Given: mass = 1 kg, radius = 1 m)

$$\Rightarrow V = \frac{1}{2} \sqrt{G(1 + 2\sqrt{2})}$$

2. Consider two satellites S1 and S2 with periods of revolution 1 hr and 8 hr respectively revolving around a planet in circular orbits. The ratio of angular velocity of satellite S1 to the angular velocity of satellite S2 is -
- (1) 8: 1 (2) 1: 8
(3) 2: 1 (4) 1: 4

Ans. (1)

Sol. We know that $\omega = \frac{2\pi}{T}$

Given: Ratio of time period

$$\frac{T_1}{T_2} = \frac{1}{8}$$

$$\Rightarrow \omega \propto \frac{1}{T}$$

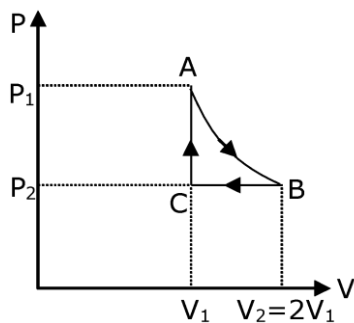
$$\Rightarrow \frac{\omega_1}{\omega_2} = \frac{T_2}{T_1}$$

$$\Rightarrow \frac{\omega_1}{\omega_2} = \frac{8}{1}$$

$$\Rightarrow \omega_1 : \omega_2 = 8 : 1$$

3. n moles of a perfect gas undergoes a cyclic process ABCA (see figure) consisting of the following processes -
- A → B: Isothermal expansion at temperature T so that the volume is doubled from V_1 to V_2 and pressure changes from P_1 to P_2 .
- B → C: Isobaric compression at pressure P_2 to initial volume V_1 .
- C → A: Isochoric change leading to change of pressure from P_2 to P_1 .
- Total work done in the complete cycle ABCA is -

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(1) 0

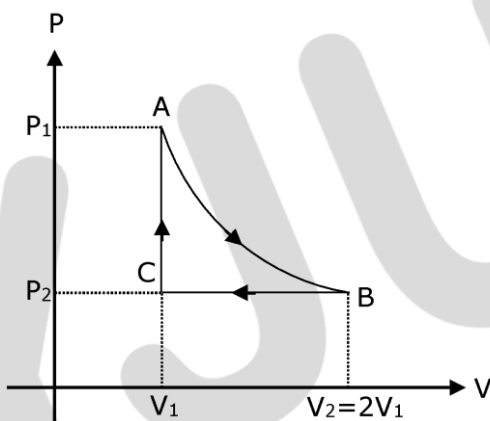
(2) $nRT \left(\ln 2 + \frac{1}{2} \right)$

(3) $nRT \ln 2$

(4) $nRT \left(\ln 2 - \frac{1}{2} \right)$

Ans. (4)

Sol.



A → B = isothermal process

B → C = isobaric process

C → A = isochoric process

Also, $V_2 = 2V_1$

Work done by gas in the complete cycle ABCA is –

$$\Rightarrow w = w_{AB} + w_{BC} + w_{CA} \quad \dots (1)$$

$$\Rightarrow w_{CA} = 0, \text{ as isochoric process}$$

$$\Rightarrow w_{AB} = P_1 V_1 \ln \left(\frac{v_2}{v_1} \right) = nRT \ln (2)$$

$$\Rightarrow w_{BC} = P_2 (V_1 - V_2) = P_2 (V_1 - 2V_1) = -P_2 V_1 = -nRT/2$$

⇒ Now putting the values of w_{AB} , w_{BC} and w_{CA} in equation, we get

$$\Rightarrow w = nRT \ln (2) - nRT/2 + 0$$

$$\Rightarrow w = nRT [\ln (2) - 1/2]$$

$$\Rightarrow w = nRT \left[\ln (2) - \frac{1}{2} \right]$$

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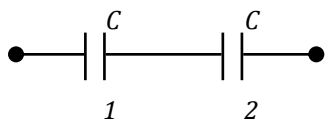
4. Two equal capacitors are first connected in series and then in parallel. The ratio of the equivalent capacities in the two cases will be -

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

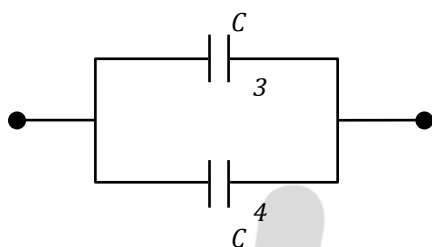
(3) 4: 1 (4) 1: 2

Ans. (2)

Sol. Given that first connection



$$\Rightarrow \frac{1}{C_{12}} = \frac{1}{C} + \frac{1}{C} \Rightarrow C_{12} = \frac{C}{2}$$



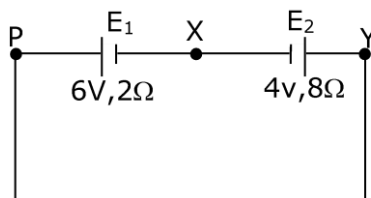
Second connection

$$C_{34} = C + C = 2C$$

Now, the ratio of equivalent capacities in the two cases will be -

$$\Rightarrow \frac{C_{12}}{C_{34}} = \frac{\frac{C}{2}}{2C} \Rightarrow \frac{C_{12}}{C_{34}} = \frac{1}{4}$$

5. A cell E_1 of emf 6V and internal resistance 2Ω is connected with another cell E_2 of emf 4V and internal resistance 8Ω (as shown in the figure). The potential difference across points X and Y is -

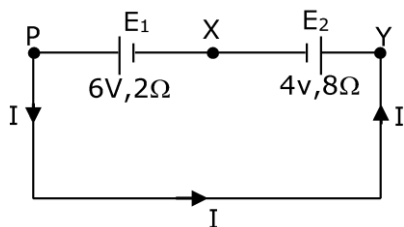


(1) 3.6V (2) 10.0V

(3) 5.6V (4) 2.0V

Ans. (3)

Sol.



emf of $E_1 = 6V$

$r_1 = 2 \Omega$

emf of $E_2 = 4V$

$r_2 = 8\Omega$

$|v_x - v_y| =$ potential difference across points X and Y

$E_{eff} = 6 - 4 = 2V$

$R_{eq} = 2 + 8 = 10 \Omega$

So, current in the circuit will be

$$\Rightarrow I = \frac{E_{eff}}{R_{eq}} \Rightarrow I = \frac{2}{10} = 0.2 \text{ A}$$

Now, potential difference across points X and Y is

$|v_x - v_y| = E + iR$

$\Rightarrow |v_x - v_y| = 4 + 0.2 \times 8 = 5.6 \text{ V}$

$\Rightarrow |v_x - v_y| = 5.6 \text{ V}$

6. If Y , K and η are the values of Young's modulus, bulk modulus and modulus of rigidity of any material respectively. Choose the correct relation for these parameters.

(1) $K = \frac{Y\eta}{9\eta - 3Y} \text{ N/m}^2$

(2) $\eta = \frac{3YK}{9K + Y} \text{ N/m}^2$

(3) $Y = \frac{9K\eta}{3K - \eta} \text{ N/m}^2$

(4) $Y = \frac{9K\eta}{2\eta + 3K} \text{ N/m}^2$

Ans. (1)

Sol. $\Rightarrow Y = 3K(1 - 2\sigma)$

$\Rightarrow \sigma = \frac{1}{2} \left(1 - \frac{Y}{3K} \right) \dots (1)$

$\Rightarrow Y = 2\eta(1 + \sigma)$

$\Rightarrow \sigma = \frac{Y}{2\eta} - 1 \dots (2)$

by comparing equation (1) and (2), we get

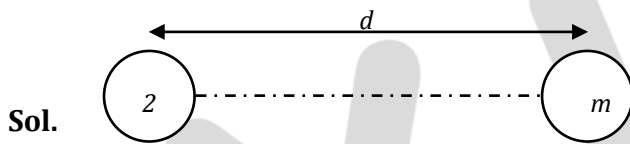
$$\Rightarrow \frac{Y}{2\eta} - 1 = \frac{1}{2} \left(1 - \frac{Y}{3K} \right)$$

$$\begin{aligned} \Rightarrow \frac{Y}{\eta} - 2 &= 1 - \frac{Y}{3K} \\ \Rightarrow \frac{Y}{\eta} &= 1 + 2 - \frac{Y}{3K} \Rightarrow \frac{Y}{\eta} = 3 - \frac{Y}{3K} \\ \Rightarrow \frac{Y}{3K} &= 3 - \frac{Y}{\eta} \Rightarrow \frac{Y}{3K} = \frac{3\eta - Y}{\eta} \\ \Rightarrow K &= \frac{\eta Y}{9\eta - 3Y} \end{aligned}$$

7. Two stars of masses m and $2m$ at a distance d rotate about their common centre of mass in free space. The period of revolution is -

- (1) $2\pi \sqrt{\frac{d^3}{3Gm}}$ (2) $\frac{1}{2\pi} \sqrt{\frac{3Gm}{d^3}}$
 (3) $\frac{1}{2\pi} \sqrt{\frac{d^3}{3Gm}}$ (4) $2\pi \sqrt{\frac{3Gm}{d^3}}$

Ans. (1)

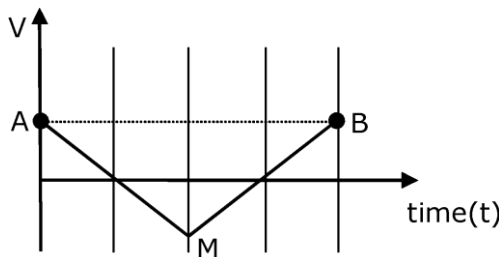


$$\begin{aligned} \Rightarrow \frac{G(m)(2m)}{d^2} &= m\omega^2 \times \frac{2d}{3} \\ \Rightarrow \frac{2Gm}{d^2} &= \omega^2 \times \frac{2d}{3} \\ \Rightarrow \omega^2 &= \frac{3Gm}{d^3} \\ \Rightarrow \omega &= \sqrt{\frac{3Gm}{d^3}} \end{aligned}$$

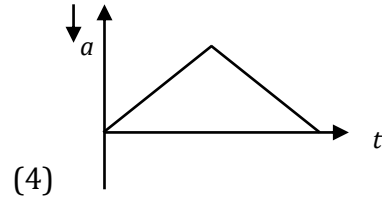
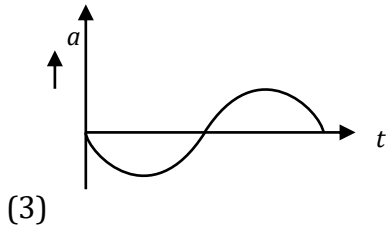
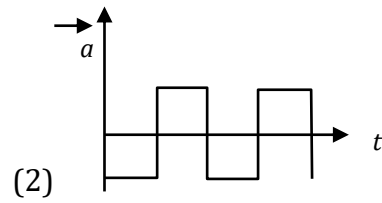
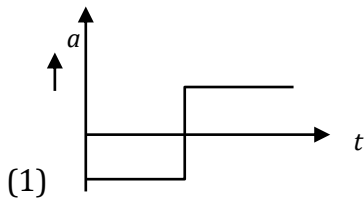
We know that, $\omega = \frac{2\pi}{T}$ so $T = \frac{2\pi}{\omega}$

$$\Rightarrow T = \frac{2\pi}{\sqrt{\frac{3Gm}{d^3}}} \Rightarrow T = 2\pi \sqrt{\frac{d^3}{3Gm}}$$

8. If the velocity-time graph has the shape AMB, what would be the shape of the corresponding acceleration-time graph?

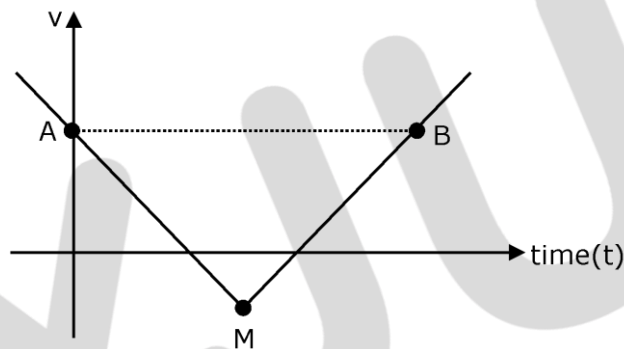


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Ans. (1)

Sol.



$$a = \frac{dv}{dt} = \text{slope of } (v - t) \text{ curve}$$

If $m = +ve$, then equation of straight line is

$$y = mx + c \Rightarrow v = mt + c \quad (\text{for MB})$$

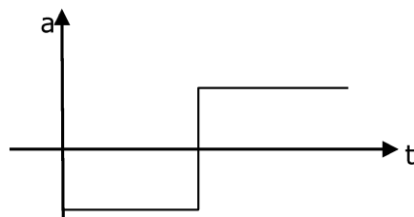
If $m = -ve$, then equation of straight line is

$$y = -mx + c \Rightarrow v = -mt + c \quad (\text{for AM})$$

If we differentiate equation (1) and (2), we get

$$a_{MB} = +ve = m \quad \text{where } m \text{ is constant.}$$

$a_{AM} = -ve = -m$, so graph of $(a-t)$ will be



9. Given below are two statements:

Statement-I: Two photons having equal linear momenta have equal wavelengths.

Statement-II: If the wavelength of photon is decreased, then the momentum and energy of a photon will also decrease.

In the light of the above statements, choose the correct answer from the options given below.

- (1) Statement-I is false but Statement-II is true
- (2) Both Statement-I and Statement-II are true
- (3) Both Statement-I and Statement-II are false
- (4) Statement-I is true but Statement-II is false

Ans. (4)

Sol. Energy of photon

$$E = hc/\lambda$$

$$= E \propto \frac{1}{\lambda}$$

Hence energy of photon increases as the wavelength of light decreases. Also, momentum of the photon $p = E/c$

$$\Rightarrow p \propto E$$

Thus, momentum of photon also increases as its wavelength decreases.

10. A current through a wire depends on time as $i = \alpha_0 t + \beta t^2$ where $\alpha_0 = 20 \text{ A/s}$ and $\beta = 8 \text{ As}^{-2}$. Find the charge crossed through a section of the wire in 15 s.

- (1) 2100 C
- (2) 260 C
- (3) 2250 C
- (4) 11250 C

Ans. (4)

Sol. Given: $i = \alpha_0 t + \beta t^2$

$$\alpha = 20 \text{ A/s and } \beta = 8 \text{ As}^{-2}$$

$$t = 15 \text{ sec}$$

$$\text{We know that, } i = \frac{dq}{dt} \Rightarrow \int_0^t i dt = \int_0^Q dq$$

$$\Rightarrow \int_0^{15} (\alpha_0 t + \beta t^2) dt = \int_0^Q dq$$

$$\Rightarrow Q = \left[\frac{\alpha_0 t^2}{2} + \frac{\beta t^3}{3} \right]_0^{15}$$

$$\Rightarrow Q = \frac{20 \times 15 \times 15}{2} + \frac{8 \times 15 \times 15 \times 15}{3} - 0$$

$$\Rightarrow Q = 11250 \text{ C}$$

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11. Match List-I with List-II

List-I	List-II
(a) Isothermal	(i) Pressure constant
(b) Isochoric	(ii) Temperature constant
(c) Adiabatic	(iii) Volume constant
(d) Isobaric	(iv) Heat content is constant

Choose the correct answer from the options given below -

- (1) (a) - (ii), (b) - (iv), (c) - (iii), (d) - (i)
- (2) (a) - (ii), (b) - (iii), (c) - (iv), (d) - (i)
- (3) (a) - (i), (b) - (iii), (c) - (ii), (d) - (iv)
- (4) (a) - (iii), (b) - (ii), (c) - (i), (d) - (iv)

Ans. (2)

Sol. (a) → (ii), (b) → (iii), (c) → (iv), (d) → (i)

By theory

In an isothermal process, temperature is constant.

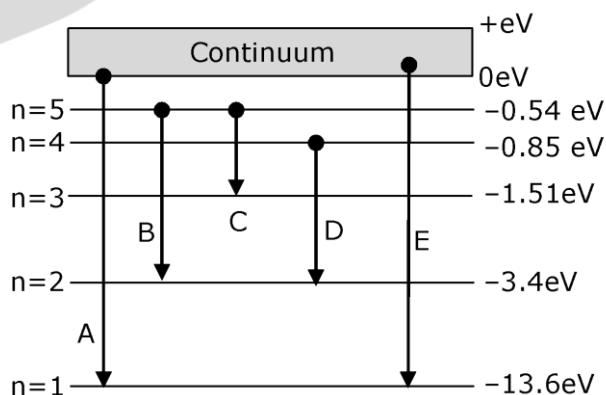
In an isochoric process, volume is constant.

In an adiabatic process, heat content is constant.

In an isobaric process, pressure is constant.

12. In the given figure, the energy levels of hydrogen atom have been shown along with some transitions marked A, B, C, D and E.

The transition A, B and C respectively represents -



(1) The series limit of Lyman series, third member of Balmer series and second member of Paschen series

(2) The first member of the Lyman series, third member of Balmer series and second member of Paschen series

(3) The ionization potential of hydrogen, second member of Balmer series and third member of Paschen series

(4) The series limit of Lyman series, second member of Balmer series and second member of Paschen series.

Ans. (1)

Sol. A → series limit of Lyman series.

B → 3rd member of Balmer series.

C → 2nd member of Paschen series.

13. The focal length f is related to the radius of curvature r of the spherical convex mirror by -

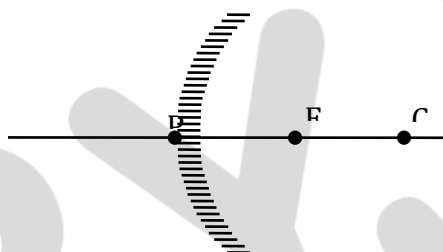
(1) $f = r$

(2) $f = -\frac{1}{2}r$

(3) $f = +\frac{1}{2}r$

(4) $f = -r$

Ans. (3)



Sol.

So, $\frac{r}{2} = f$

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

14. Moment of inertia (M.I.) of four bodies, having same mass and radius, are reported as -

I_1 = M.I. of thin circular ring about its diameter,

I_2 = M.I. of circular disc about an axis perpendicular to disc and going through the centre,

I_3 = M.I. of solid cylinder about its axis and

I_4 = M.I. of solid sphere about its diameter.

Then:

(1) $I_1 = I_2 = I_3 < I_4$

(2) $I_1 + I_2 = I_3 + \frac{5}{2} I_4$

(3) $I_1 + I_3 < I_2 + I_4$

(4) $I_1 = I_2 = I_3 > I_4$

Ans. (4)

Sol. Given ⇒ I_1 = M.I. of thin circular ring about its diameter

I_2 = M.I. circular disc about an axis perpendicular to disc and going through the centre.

I_3 = M.I. of solid cylinder about its axis

I_4 = M.I. of solid sphere about its diameter

We know that,

$$I_1 = \frac{MR^2}{2}$$

$$I_2 = \frac{MR^2}{2}$$

$$I_3 = \frac{MR^2}{2}$$

$$I_4 = \frac{2}{5} MR^2$$

So, $I_1 = I_2 = I_3 > I_4$

15. The work done by a gas molecule in an isolated system is given by, $W = \alpha\beta^2 e^{-\frac{x^2}{\alpha kT}}$, where x is the displacement, k is the Boltzmann constant and T is the temperature α and β are constants. Then the dimensions of β will be -

(1) $[M^0LT^0]$

(2) $[M^2LT^2]$

(3) $[MLT^{-2}]$

(4) $[ML^2T^{-2}]$

Ans. (3)

Sol. Given: work done = $\alpha\beta^2 e^{-\frac{x^2}{\alpha kT}}$

k = Boltzmann constant

T = temperature

x = displacement

We know that, $\frac{x^2}{\alpha kT}$ = dimensionless

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

$$[\alpha] = \left[\frac{L^2}{k.T} \right]$$

$$\Rightarrow [k] = [M^1L^2T^{-2}K^{-1}]$$

$$[T] = [K]$$

$$\Rightarrow [\alpha] = \left[\frac{L^2}{M^1L^2T^{-2}K^{-1} \times K} \right] \Rightarrow [\alpha] = [M^{-1}T^2]$$

$$\Rightarrow \omega = \alpha.\beta^2$$

$$\Rightarrow \frac{[M^1L^1T^{-2}][L^{-1}]}{[M^{-1}T^2]} = [\beta^2] = [M^2L^2T^{-4}]$$

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

16. If an emitter current is changed by 4mA , the collector current changes by 3.5mA . The value of β will be -
- (1) 7 (2) 0.875
 (3) 0.5 (4) 3.5

Ans. (1)

Sol. Given:

$$\Delta I_E = 4\text{mA}$$

$$\Delta I_C = 3.5\text{mA}$$

We know that, $\alpha = \frac{\Delta I_C}{\Delta I_E}$

$$\Rightarrow \alpha = \frac{3.5}{4} = \frac{7}{8}$$

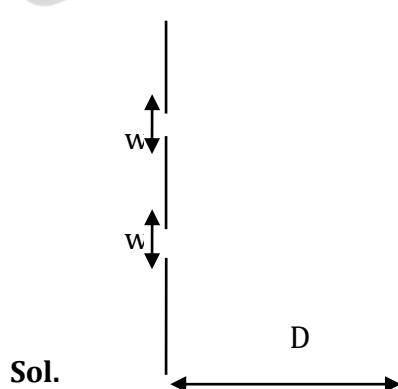
Also, $\beta = \frac{\alpha}{1-\alpha}$, so

$$\beta = \frac{\frac{7}{8}}{1-\frac{7}{8}} = \frac{7}{1}$$

$$\beta = 7$$

17. In a Young's double slit experiment, the width of the one of the slit is three times the other slit. The amplitude of the light coming from a slit is proportional to the slit-width. Find the ratio of the maximum to the minimum intensity in the interference pattern.
- (1) 4: 1 (2) 2: 1
 (3) 3: 1 (4) 1: 4

Ans. (1)



Given: $w_2 = 3w_1$

Also, $A \propto w$

$$\frac{w_1}{w_2} = \frac{1}{3} \dots (1)$$

Assume $w_1 = x, w_2 = 3x$

We know that

$$I_{\max} = (A_1 + A_2)^2, \text{ and}$$

$$I_{\min} = (A_1 - A_2)^2$$

$$\frac{A_1}{A_2} = \frac{w_1}{w_2} \dots (2)$$

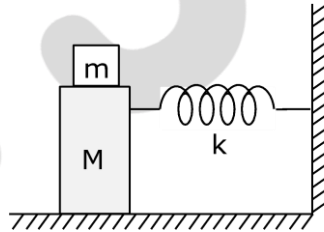
From equation (2) we can say that

$$A_1 = A \text{ and } A_2 = 3A$$

$$\text{Now, } \frac{I_{\max}}{I_{\min}} = \frac{(A+3A)^2}{(A-3A)^2} = \frac{16A^2}{4A^2} = \frac{4}{1}$$

$$\Rightarrow \frac{I_{\max}}{I_{\min}} = \frac{4}{1}$$

- 18.** In the given figure, a mass M is attached to a horizontal spring which is fixed on one side to a rigid support. The spring constant of the spring is k . The mass oscillates on a frictionless surface with time period T and amplitude A . When the mass is in equilibrium position, as shown in the figure, another mass m is gently fixed upon it. The new amplitude of oscillation will be -



(1) $A \sqrt{\frac{M}{M+m}}$

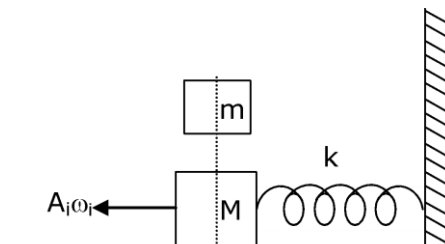
(2) $A \sqrt{\frac{M}{M-m}}$

(3) $A \sqrt{\frac{M-m}{M}}$

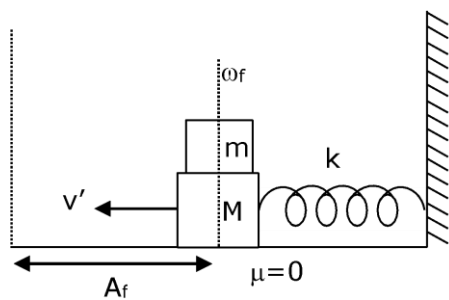
(4) $A \sqrt{\frac{M+m}{M}}$

Ans. (1)

Sol.



Before placing



After placing

We know that $\omega_f = \sqrt{\frac{k}{M+m}}$ and $\omega_i = \sqrt{\frac{k}{M}}$ $A_i = A$

Also, momentum is conserved just before and just after the block of mass (m) is placed because there is no impulsive force. So

$$MA_i\omega_i = (M + m) v'$$

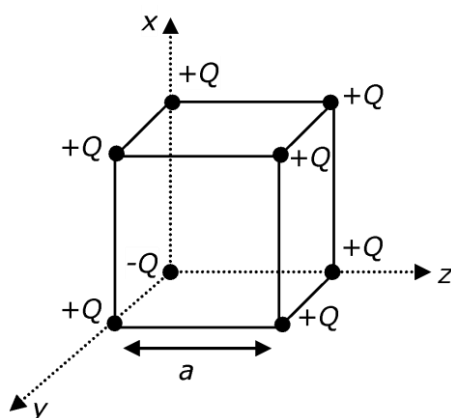
$$v' = \frac{MA_i\omega_i}{(M+m)} \Rightarrow v' = A_f\omega_f$$

$$\frac{MA\omega_i}{(M+m)} = A_f \sqrt{\frac{K}{(M+m)}}$$

$$\Rightarrow \frac{MA\sqrt{\frac{K}{M}}}{M+m} \times \sqrt{\frac{M+m}{K}} = A_f$$

$$\Rightarrow A_f = A \sqrt{\frac{M}{(M+m)}}$$

- 19.** A cube of side 'a' has point charges +Q located at each of its vertices except at the origin where the charge is -Q. The electric field at the centre of cube is:



(1) $\frac{2Q}{3\sqrt{3}\pi\epsilon_0 a^2} (\hat{x} + \hat{y} + \hat{z})$

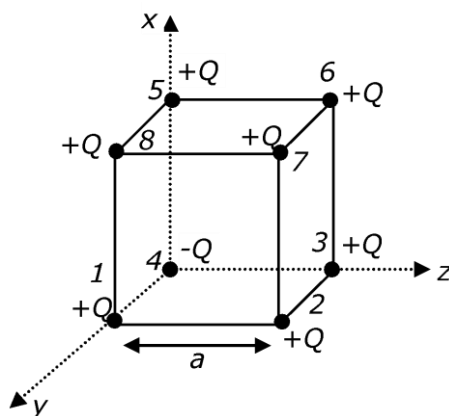
(2) $\frac{Q}{3\sqrt{3}\pi\epsilon_0 a^2} (\hat{x} + \hat{y} + \hat{z})$

(3) $\frac{-2Q}{3\sqrt{3}\pi\epsilon_0 a^2} (\hat{x} + \hat{y} + \hat{z})$

(4) $\frac{-Q}{3\sqrt{3}\pi\epsilon_0 a^2} (\hat{x} + \hat{y} + \hat{z})$

Ans. (3)

Sol.



We can replace $-Q$ charge at origin by $+Q$ and $-2Q$. Now due to $+Q$ charge at every corner of cube electric field at centre of cube is zero so now net electric field at centre is only due to $-2Q$ charge at origin.

$$\vec{E} = \frac{kq\vec{r}}{r^3} = \frac{1(-2Q)\frac{a}{2}(\hat{x}+\hat{y}+\hat{z})}{4\pi\epsilon_0\left(\frac{a}{\sqrt{2}}\right)^3}$$

$$\vec{E} = \frac{-2Q(\hat{x}+\hat{y}+\hat{z})}{3\sqrt{3}\pi a^2 \epsilon_0}$$

20. Each side of a box made of metal sheet in cubic shape is 'a' at room temperature 'T', the coefficient of linear expansion of the metal sheet is ' α '. The metal sheet is heated uniformly, by a small temperature ΔT , so that its new temperature is $T+\Delta T$. Calculate the increase in the volume of the metal box-

(1) $\frac{4}{3}\pi a^3 \alpha \Delta T$

(2) $4\pi a^3 \alpha \Delta T$

(3) $3a^3 \alpha \Delta T$

(4) $4a^3 \alpha \Delta T$

Ans. (3)

Sol. Coefficient of volumetric expansion, $\gamma = 3\alpha$

$$\frac{\Delta V}{V} = \gamma \Delta T$$

$$\Delta V = V \cdot \gamma \Delta T$$

$$\Delta V = a^3 \cdot 3\alpha \Delta T$$

SECTION-B

1. A resonance circuit having inductance and resistance 2×10^{-4} H and 6.28Ω respectively oscillates at 10 MHz frequency. The value of quality factor of this resonator is _____. [$\pi = 3.14$]

Ans. (2000)

Sol. Given: $R = 6.28 \Omega$

$$f = 10 \text{ MHz}$$

$$L = 2 \times 10^{-4} \text{ Henry}$$

we know that quality factor Q is given by

$$\Rightarrow Q = \frac{X_L}{R} = \frac{\omega L}{R}$$

also, $\omega = 2\pi f$, so

$$\Rightarrow Q = \frac{2\pi f L}{R}$$

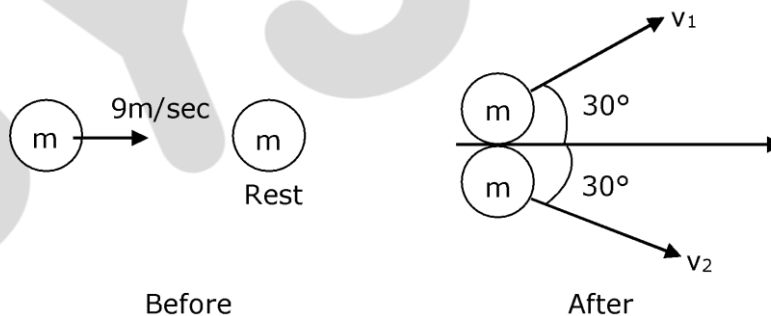
$$\Rightarrow Q = \frac{2\pi \times 10 \times 10^6 \times 2 \times 10^{-4}}{6.28} = 2000$$

$$Q = 2000$$

2. A ball with a speed of 9 m/s collides with another identical ball at rest. After the collision, the direction of each ball makes an angle of 30° with the original direction. The ratio of velocities of the balls after collision is $x : y$, where x is _____.

Ans. (1)

Sol.



Momentum is conserved just before and just after the collision in both x-y direction.

In y-direction

$$p_i = 0$$

$$p_f = mv_1 \sin 30^\circ - mv_2 \sin 30^\circ$$

$$P_f = m \times \frac{1}{2} v_1 - m \times \frac{1}{2} v_2$$

$p_i = p_f$, so

$$= \frac{mv_1}{2} - \frac{mv_2}{2} = 0$$

$$\Rightarrow \frac{mv_1}{2} = \frac{mv_2}{2} \Rightarrow v_1 = v_2$$

$$\frac{v_1}{v_2} = 1$$

3. An audio signal $v_m = 20\sin 2\pi(1500t)$ amplitude modulates a carrier $v_c = 80 \sin 2\pi(100,000t)$.

The value of percent modulation is _____.

Ans. (25)

Sol. We know that, modulation index $= \frac{A_m}{A_c}$

From given equations, $A_m = 20$ and $A_c = 80$

Percentage modulation index $= \frac{A_m}{A_c} \times 100$

$$\Rightarrow \frac{20}{80} \times 100 = 25\%$$

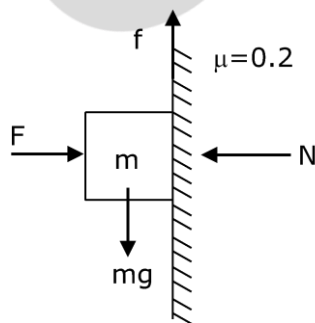
The value of percentage modulation index is
=25

4. The coefficient of static friction between a wooden block of mass 0.5 kg and a vertical rough wall is 0.2. The magnitude of horizontal force that should be applied on the block to keep it adhere to the wall will be _____ N.

[$g = 10 \text{ ms}^{-2}$]

Ans. (25)

Sol.



Given: $\mu_s = 0.2$

$m = 0.5 \text{ kg}$

$g = 10 \text{ m/s}^2$

we know that

$$f_s = \mu_s N \text{ and } \dots (1)$$

To keep the block adhere to the wall

$$\text{Here } N = F \dots (2)$$

$$f_s = mg \dots (3)$$

From equation (1), (2), and (3), we get

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$$\Rightarrow mg = \mu_s F$$

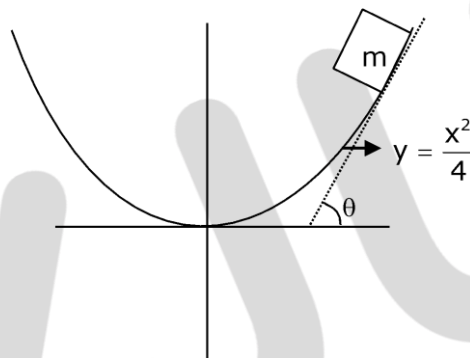
$$\Rightarrow F = \frac{mg}{\mu_s} \Rightarrow F = \frac{0.5 \times 10}{0.2}$$

$F = 25 \text{ N}$ (for all values of F greater than or equal to 25 N this case is possible)

5. An inclined plane is bent in such a way that the vertical cross-section is given by $y = \frac{x^2}{4}$ where y is in vertical and x in horizontal direction. If the upper surface of this curved plane is rough with coefficient of friction $\mu = 0.5$, the maximum height in cm at which a stationary block will not slip downward is ____ cm.

Ans. (25)

Sol.



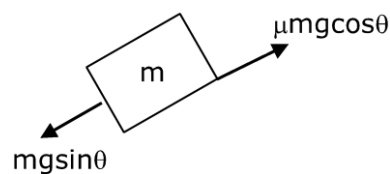
given

$$y = \frac{x^2}{4}$$

$$\mu = 0.5$$

Condition for block will not slip downward

$$mg \sin \theta = \mu mg \cos \theta$$



$$\Rightarrow \tan \theta = \mu$$

And we know that

$$\Rightarrow \tan \theta = \frac{dy}{dx}$$

$$\Rightarrow \frac{dy}{dx} = \mu \Rightarrow \frac{x}{2} = 0.5 \left[y = \frac{x^2}{4} \frac{dy}{dx} = \frac{x}{2} \right]$$

$$\Rightarrow x = 1,$$

put $x = 1$ in equation $y = x^2/4$

$$\Rightarrow y = \frac{(1)^2}{4} \Rightarrow y = \frac{1}{4} \Rightarrow y = 0.25$$

$$y = 25 \text{ cm}$$

6. An electromagnetic wave of frequency 5 GHz, is travelling in a medium whose relative electric permittivity and relative magnetic permeability both are 2. Its velocity in this medium is _____ $\times 10^7$ m/s.

Ans. (15)

Sol. Given: $f = 5 \text{ GHz}$

$$\epsilon_r = 2$$

$$\mu_r = 2$$

$$\text{Velocity of wave} \Rightarrow v = \frac{c}{n} \quad \dots(1)$$

Where, $n = \sqrt{\mu_r \epsilon_r}$ and $c = \text{speed of light} = 3 \times 10^8 \text{ m/s}$

$$n = \sqrt{2 \times 2} = 2$$

put the value of n in we get

$$\Rightarrow v = \frac{3 \times 10^8}{2} = 15 \times 10^7 \text{ m/s}$$

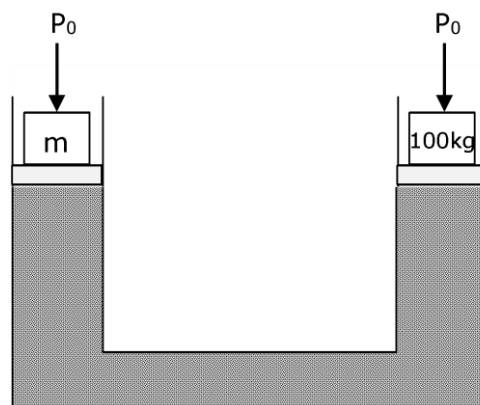
$$\Rightarrow X \times 10^7 = 15 \times 10^7$$

$$X = 15$$

7. A hydraulic press can lift 100 kg when a mass 'm' is placed on the smaller piston. It can lift _____ kg when the diameter of the larger piston is increased by 4 times and that of the smaller piston is decreased by 4 times keeping the same mass 'm' on the smaller piston.

Ans. (25600)

Sol.



Atmospheric pressure P_0 will be acting on both the limbs of hydraulic lift.

Applying pascal's law for same liquid level

$$\Rightarrow P_0 + \frac{mg}{A_1} = P_0 + \frac{(100)g}{A_2}$$

$$\Rightarrow \frac{mg}{A_1} = \frac{(100)g}{A_2} \Rightarrow \frac{m}{100} = \frac{A_1}{A_2} \quad \dots(1)$$

Diameter of piston on side of 100 kg is increased by 4 times so new area = $16A_2$

Diameter of piston on side of (m) kg is decreasing

$$A_1 = \frac{A_1}{16}$$

(In order to increasing weight lifting capacity, diameter of smaller piston must be reduced)

$$\text{Again, } \frac{mg}{\left(\frac{A_1}{16}\right)} = \frac{M'g}{16A_2} \Rightarrow \frac{256m}{M'} = \frac{A_1}{A_2}$$

$$\text{From equation (1)} = \frac{256m}{M'} = \frac{m}{100} \Rightarrow \therefore M' = 25600 \text{ kg}$$

8. A common transistor radio set requires 12 V (D.C.) for its operation. The D.C. source is constructed by using a transformer and a rectifier circuit, which are operated at 220 V (A.C.) on standard domestic A.C. supply. The number of turns of secondary coil are 24, then the number of turns of primary are _____.

Ans. (440)

Sol. Given

Primary voltage, $V_p = 220 \text{ V}$

Secondary voltage, $v_s = 12 \text{ V}$

No. of turns in secondary coil is $N_s = 24$

no. of turns in primary coil, $N_p = ?$

We know that for a transformer

$$\Rightarrow \frac{N_p}{N_s} = \frac{V_p}{V_s}$$

$$\Rightarrow N_p = \frac{V_p \times N_s}{V_s} = \frac{220 \times 24}{12}$$

$$\Rightarrow N_p = 440$$

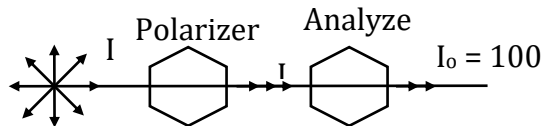
9. An unpolarized light beam is incident on the polarizer of a polarization experiment and the intensity of light beam emerging from the analyzer is measured as 100 Lumens. Now, if the analyzer is rotated around the horizontal axis (direction of light) by 30° in clockwise direction, the intensity of emerging light will be _____ Lumens.

Ans. (75)

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Sol.



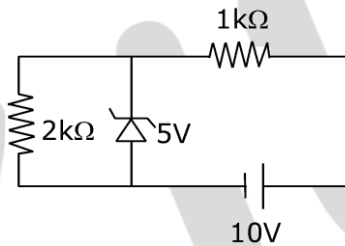
Given: $I_0 = 100$ lumens, $\theta = 30^\circ$

$$I_{\text{net}} = I_0 \cos^2\theta$$

$$I_{\text{net}} = 100 \times \left(\frac{\sqrt{3}}{2}\right)^2 = \frac{100 \times 3}{4}$$

$$I_{\text{net}} = 75 \text{ lumens}$$

10. In connection with the circuit drawn below, the value of current flowing through $2\text{k}\Omega$ resistor is _____ $\times 10^{-4}$ A.



Ans. (25)

Sol. In zener diode there will be no change in current after 5V zener diode breakdown

$$\Rightarrow i = \frac{5}{2 \times 10^3}$$

$$\Rightarrow i = 2.5 \times 10^{-3} \text{ A}$$

$$\Rightarrow i = 25 \times 10^{-4} \text{ A}$$