JEE Main 2020 Paper

Date of Exam: **7^{th} January 2020 (Shift 1)**
Time: **9:30 am- 12:30 pm**
Subject: **Physics**

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1. A polarizer-analyzer set is adjusted such that the intensity of light coming out of the analyzer is just 10 % of the original intensity. Assuming that the polarizer-analyzer set does not absorb any light, the angle by which the analyser need to be rotated further to reduce the output intensity to be zero is

   a. 45^o b. 71.6^o

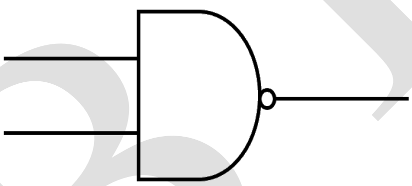
   c. 90^o d. 18.4^0

   Solution:(d)

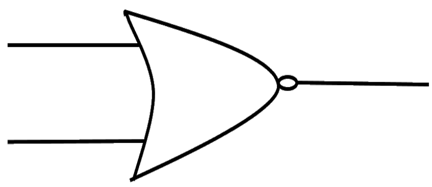
$$\text{Intensity after polarisation through polaroid} = I_o cos^2\phi$$
$$\text{So, } 0.1I_o = I_o cos^2\phi$$
$$\Rightarrow cos\phi = \sqrt{0.1}$$
$$\Rightarrow cos\phi = 0.316$$

Since, $\cos\phi < \cos 45^o$ therefore, $\phi > 45^o$ If the light is passing at 90^o from the plane of polaroid, than its intensity will be zero.
Then, $\theta = 90^o - \phi$ therefore, θ will be less than 45^o. So, the only option matching is option d which is 18.4^o

2. Which of the following gives reversible operation?



a.



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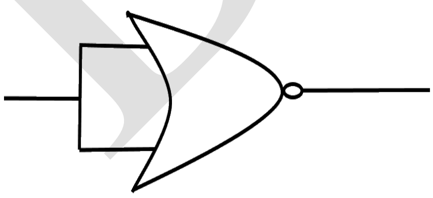
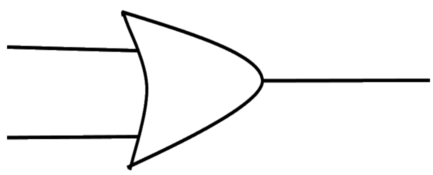
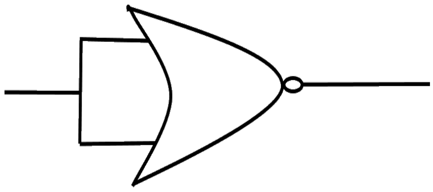


c.



d.

Solution: (c)



Since, there is only one input hence the operation is reversible.

3. A 60 HP electric motor lifts an elevator with a maximum total load capacity of 2000 kg. If the frictional force on the elevator is 4000 N, the speed of the elevator at full load is close to (Given 1 HP = 746 W, $g = 10\ m/s^2$)

a. $1.5\ m/s$ b. $2.0\ m/s$

c. $1.7\ m/s$ d. $1.9\ m/s$

Solution:(d)
Friction will oppose the motion

$$\text{Net force} = 2000\text{ kg} + 4000 = 24000$$
$$N\,\text{Power of lift} = 60\text{ HP}$$
$$\text{Power} = \text{Force} \times \text{Velocity}$$
$$v = \frac{P}{} = \frac{60 \times 746}{F24000}$$
$$v = 1.86\ m/s$$
= 1.9 m/s

4. A long solenoid of radius R carries a time (t) dependent current $I(t) = I_0 t(1-t)$. A ring of radius $2R$ is placed coaxially near its middle. During the time instant $0 \le t \le 1$, the induced current (I_R) and the induced EMF (V_R) in the ring changes as:

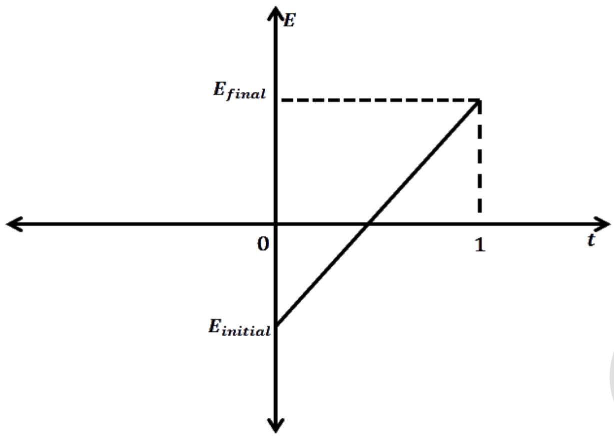
a. Direction of I_R remains unchanged and V_R is maximum at $t = 0.5$

b. Direction of I_R remains unchanged and V_R is zero at $t = 0.25$

c. At $t = 0.5$ direction of I_R reverses and V_R is zero

d. At $t = 0.25$ direction of I_R reverses and V_R is maximum

Solution:(c)



Field due to solenoid near the middle $= \mu_o NI$

$$\text{Flux,} \quad \phi = BA \qquad \text{where}(A = \pi(R)^2)$$
$$= \mu_o N I_o t(1-t)\pi R^2$$
$$E = -\frac{d\phi}{dt} \qquad \text{[By Lenz's law]}$$
$$E = -\frac{d}{dt}(\mu_o N I_o t(1-t)\pi R^2)$$
$$E = -\mu_o N I_o \pi R^2 \frac{d}{dt}[t(1-t)]$$
$$E = -\pi \mu_o I_o N R^2 (1-2t)$$

Current will change its direction when EMF will be zero

$$\implies (1-2t) = 0$$
$$So, \qquad t = 0.5\ sec$$

5. Two moles of an ideal gas with $\frac{C_p}{C_v} = 5/3$ are mixed with 3 moles of another ideal gas with $\frac{C_p}{C_v} = 4/3$. The value of $\frac{C_p}{C_v}$ for the mixture is

a. 1.47 b. 1.42

c. 1.45 d. 1.50

Solution:(b)

$$\text{For first gas having } \gamma = \frac{C_p}{C_v} = \frac{5}{3}$$
$$\text{Using formula } C_p = \frac{R\gamma}{\gamma - 1}$$
$$C_v = \frac{R}{\gamma - 1}$$

$$C_p = \frac{5R}{2} \quad C_v = \frac{3R}{2}$$

Similarly for 2^{nd} gas having $\gamma = \frac{C_p}{C_v} = \frac{4}{3}$

$$C_p = 4R \quad C_v = 3R$$

Now γ of mixture $= \frac{n_1 C_{p_1} + n_2 C_{p_2}}{n_1 C_{v_1} + n_2 C_{v_2}}$

Given that $n_1 = 2$ and $n_2 = 3$

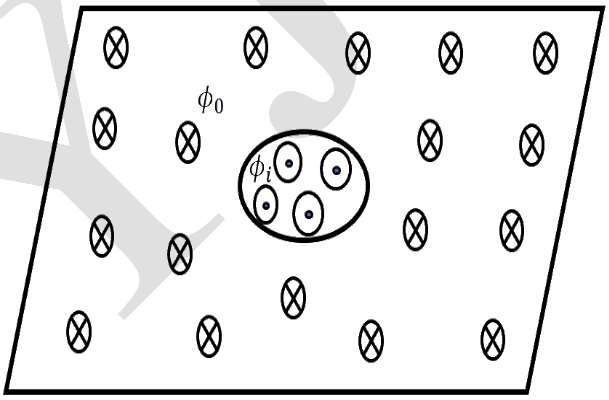
$$\gamma = \frac{2 \times \frac{5R}{2} + 3 \times 4R}{2 \times \frac{3R}{2} + 3 \times 3R} = \frac{17}{12} = 1.42$$

6. Consider a circular coil of wire carrying current I, forming a magnetic dipole. The magnetic flux through an infinite plane that contains the circular coil and excluding the circular coil area is given by ϕ_i. The magnetic flux through the area of the circular coil area is given by ϕ_0. Which of the following option is correct?

a. $\phi_i = -\phi_o$ b. $\phi_i > \phi_o$

c. $\phi_i < \phi_o$ d. $\phi_i = \phi_o$

Solution:(a)



As magnetic field line of ring will form close loop therefore all outgoing from circular hole passing through the infinite plate.

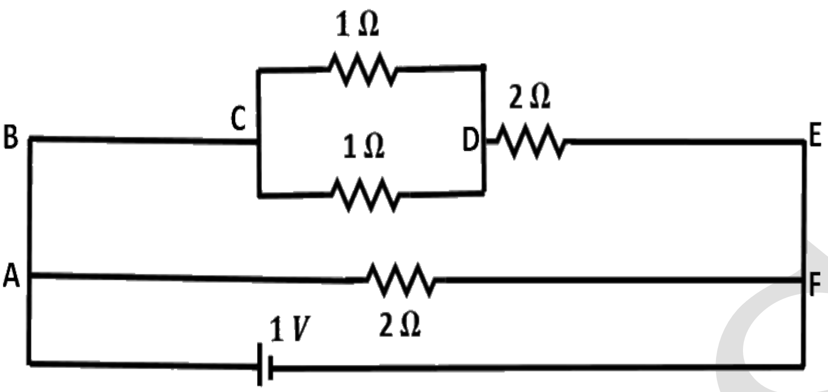
$\therefore \phi_1 = -\phi_0$ (because the magnetic field lines going inside is equal to the magnetic field lines coming out.)

7. The current (i_1) (in A) flowing through $1\ \Omega$ resistor in the following circuit is

a. $0.40\ A$ b. $0.20\ A$

c. $0.25\ A$ d. $0.5\ A$

Solution:(b)



Net resistance across CD $= \frac{1}{2}\,\Omega$

Net resistance across BE $= 2 + \frac{1}{2} = \frac{5}{2}\,\Omega$

Net resistance across BE $= \frac{\frac{5}{2}\times 2}{\frac{5}{2}+2} = \frac{10}{9}\,\Omega.$

Total current in circuit $= \frac{V}{R} = \frac{9}{10}\,A$

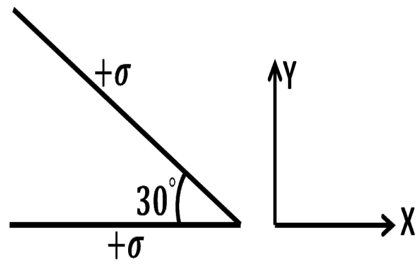
In the given circuit,voltage across BE = voltage across BF $= 1\,V$

Current across BE $= \frac{V_{BE}}{R} = \frac{2}{5}\,A$

Current across CD and DE will be same which is $\frac{2}{5}\,A.$

Now, current across any $1\,\Omega$ resistor will be same and given by $= I = \frac{1}{2}\times\frac{2}{5} = \frac{1}{5} = 0.20\,A$

8. Two infinite planes each with uniform surface charge density $+\sigma\ C/m^2$ are kept in such a way that the angle between them is 30^o. The electric field in the region shown between them is given by:



a. $\frac{\sigma}{2\epsilon_0}\left[(1-\frac{\sqrt{3}}{2})\hat{y} - \frac{1}{2}\hat{x}\right]$

b. $\frac{\sigma}{2\epsilon_0}\left[(1+\frac{\sqrt{3}}{2})\hat{y} - \frac{1}{2}\hat{x}\right]$

c. $\frac{\sigma}{2\epsilon_0}\left[(1-\frac{\sqrt{3}}{2})\hat{y} + \frac{1}{2}\hat{x}\right]$

d. $\frac{\sigma}{2\epsilon_0}\left[(1+\frac{\sqrt{3}}{2})\hat{y}+\frac{1}{2}\hat{x}\right]$

Solution:(a)

$$\text{Field due to single plate} = \frac{\sigma}{2\epsilon_o} = \left[\vec{E_1}\right] = \left[\vec{E_2}\right]$$
$$\text{Net electric field } \vec{E} = \vec{E_1} + \vec{E_2}$$
$$= \frac{\sigma}{2\epsilon_0}\cos 30^0(-\hat{j}) + \frac{\sigma}{2\epsilon_0}\sin 30^0(-\hat{i}) + \frac{\sigma}{2\epsilon_0}(\hat{j})$$
$$= \frac{\sigma}{2\epsilon_0}\left(1-\frac{\sqrt{3}}{2}\right)(\hat{j}) - \frac{\sigma}{4\epsilon_0}(\hat{i})$$
$$= \frac{\sigma}{2\epsilon_0}\left[\left(1-\frac{\sqrt{3}}{2}\right)\hat{y} - \frac{1}{2}\hat{x}\right]$$

9. If the magnetic field in a plane electromagnetic wave is given by $\vec{B} = 3\times10^{-8}\sin(1.6\times10^3x+48\times10^{10}t)\hat{j}\ T$ then what will be expression for electric field?

a. $\vec{E} = 3\times10^{-8}\sin(1.6\times10^3x+48\times10^{10}t)\hat{i}\ V/m$

b. $\vec{E} = 3\times10^{-8}\sin(1.6\times10^3x+48\times10^{10}t)\hat{j}\ V/m$

c. $\vec{E} = 60\sin(1.6\times10^3x+48\times10^{10}t)\hat{k}\ V/m$

d. $\vec{E} = 9\sin(1.6\times10^3x+48\times10^{10}t)\hat{k}\ V/m$

Solution:(d)
We know that,

$$\left|\frac{E_0}{B_0}\right| = c$$
$$B_0 = 3\times10^{-8}$$
$$\implies E_0 = B_0\times c = 3\times10^{-8}\times3\times10^8$$
$$= 9\ N/C$$
$$\therefore E = E_o\sin(\omega t - kx+\phi)\hat{k} = 9\sin(\omega t-kx+\phi)\hat{k}$$
$$\vec{E} = 9\sin(1.6\times10^3x+48\times10^{10}t)\hat{k}\ V/m$$

10. The time period of revolution of electron in its ground state orbit in a hydrogen atom is $1.6\times10^{-16}s$. The frequency of revolution of the electron in its first excited state (in s^{-1}) is :

a. 6.2×10^{15}

b. 1.6×10^{14}

c. 7.8×10^{14}

d. 5.6×10^{12}

Solution:(c)
Time period is proportional to $\frac{n^3}{Z^2}$.

Let T_1 be the time period in ground state and T_2 be the time period in it's first excited state.

$$T_1 = \frac{n^3}{2^2}$$

(Where, n = excitation level and 2 is atomic no.)

$$\frac{T_1}{T_2} = \left(\frac{n_1}{n_2}\right)^3$$

Given,

$$T_1 = 1.6 \times 10^{-16} s$$

So,

$$\frac{1.6 \times 10^{-16}}{T2} = \left(\frac{1}{2}\right)^3$$

$$T_2 = 12.8 \times 10^{-16}\ s$$

Frequency is given by $f = \frac{1}{T}$

$$f = \frac{1}{12.8} \times 10^{16}\ Hz$$

$$f = 7.8128 \times 10^{14}\ Hz$$

11. A LCR circuit behaves like a damped harmonic oscillator. Comparing it with a physical spring-mass damped oscillator having damping constant 'b', the correct equivalence will be

a. $L \leftrightarrow \frac{1}{b}, C \leftrightarrow \frac{1}{m}, R \leftrightarrow \frac{1}{k}$

b. $L \leftrightarrow k, C \leftrightarrow b, R \leftrightarrow m$

c. $L \leftrightarrow m, C \leftrightarrow k, R \leftrightarrow b$

d. $L \leftrightarrow m, C \leftrightarrow \frac{1}{k}, R \leftrightarrow b$

Solution:(d)

For damped oscillator by Newton's second law

$$-kx - bv = ma$$

$$kx + bv + ma = 0$$

$$kx + b\frac{dx}{dt} + m\frac{d^2x}{dt^2} = 0$$

For LCR circuit by KVL

$$-IR - L\frac{dI}{dt} - \frac{q}{c} = 0$$

$$\implies IR + L\frac{dI}{dt} + \frac{q}{c} = 0$$

$$\implies \frac{q}{c} + R\frac{dq}{dt} + L\frac{d^2q}{dt^2} = 0$$

By comparing

$R \implies b$

$$c \implies \frac{1}{k}$$
$$m \implies L$$

12. Visible light of wavelength $6000 \times 10^{-8} cm$ falls normally on a single slit and produces a diffraction pattern. It is found that the second diffraction minima is at 60^o from the central maxima. If the first minimum is produced at θ_1, then θ_1 is close to

a. 20^o
b. 30^o
c. 45^o
d. 25^o

Solution:(d)
For single slit diffraction experiment:
Angle of minima are given by

$$\sin\theta_n = \frac{n\lambda}{d} \quad (\sin\theta_n \neq \theta_n \text{ as } \theta \text{ is large })$$
$$\sin\theta_2 = \sin 60^\circ = \frac{\sqrt{3}}{2} = \frac{2\lambda}{d} = \frac{2\times 6000\times 10^{-10}}{d} \qquad (1)$$
$$\sin\theta_1 = \frac{\lambda}{d} = \frac{6000\times 10^{-10}}{d} \qquad (2)$$

Dividing (1) and (2)

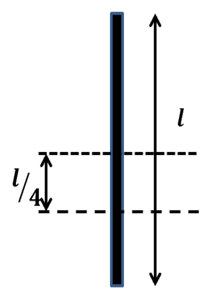
$$\implies \frac{\sqrt{3}}{2sin\theta_1} = 2 \implies sin\theta_1 = \frac{\sqrt{3}}{4} = 0.43$$

As, the value is coming less than 30^o the only available option are 20^o and 25^o but by using approximation we get $\theta_1 = 25^\circ$

13. The radius of gyration of a uniform rod of length l about an axis passing through a point $l/4$ away from the center of the rod, and perpendicular to it, is

a. $\sqrt{\frac{7}{48}}l$
b. $\sqrt{\frac{3}{8}}l$
c. $\frac{1}{4}l$
d. $\frac{1}{8}l$

Solution:(a)



Moment of inertia of rod about axis perpendicular to it passing through its centre is given by

$$I = \frac{Ml^2}{12} + M\left(\frac{l}{4}\right)^2$$
$$= \frac{3Ml^2 + 4Ml^2}{48}$$
$$= \frac{7Ml^2}{48}$$

Now, comparing with $I = Mk^2$ where k is the radius of gyration

$$k = \sqrt{\frac{7l^2}{48}}$$
$$k = l\sqrt{\frac{7}{48}}$$

14. A satellite of mass m is launched vertically upward with an initial speed u from the surface of the earth. After it reaches height R(R = radius of earth), it ejects a rocket of mass $m/10$ so that subsequently the satellite moves in a circular orbit. The kinetic energy of the rocket is (G = gravitational constant; M is the mass of earth)

a. $5m\left[u^2 - \frac{119}{200}\frac{GM}{R}\right]$

b. $\frac{m}{20}\left[u - \sqrt{\frac{2GM}{3R}}\right]^2$

c. $\frac{3m}{8}\left[u + \sqrt{\frac{5GM}{6R}}\right]^2$

d. $\frac{m}{20}\left[u^2 + \frac{113}{200}\frac{GM}{R}\right]$

Solution:(a)
As we know,

$$T.E_{ground} = T.E_R$$
$$\frac{1}{2}mu^2 + \left(\frac{-GMm}{R}\right) = \frac{1}{2}mv^2 + \left(\frac{-GMm}{2R}\right)$$
$$\frac{1}{2}mv^2 = \frac{1}{2}mu^2 + \left(\frac{-GMm}{2R}\right)$$
$$v^2 = u^2 + \left(\frac{-GM}{R}\right) \tag{1}$$
$$\implies v = \sqrt{u^2 + \left(\frac{-GM}{R}\right)}$$

The rocket splits at height R. Since, sepration of rocket is impulsive therefore conservation of momentum in both radial and tangential direction can be applied.

$$\frac{m}{10}V_T = \frac{9m}{10}\sqrt{\frac{GM}{2R}}$$
$$\frac{m}{10}V_r = m\sqrt{u^2 - \frac{GM}{R}}$$

Kinetic energy of rocket $= \frac{1}{2} \times \frac{m}{10}(V_T^2 + V_R^2) = \frac{m}{20}\left(81\frac{GM}{2R} + 100u^2 - 100\frac{GM}{R}\right)$

$$= \frac{m}{20}\left(100u^2 - \frac{119GM}{2R}\right)$$

$$= 5m\left(u^2 - \frac{119GM}{200R}\right)$$

15. Three point particles of mass 1 kg, 1.5 kg and 2.5 kg are placed at three corners of a right triangle of sides 4.0 cm, 3.0 cm and 5.0 cm as shown in the figure. The centre of mass of the system is at the point:

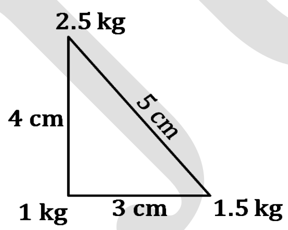
a. 0.9 cm right and 2.0 cm above 1 kg mass

b. 2.0 cm right and 0.9 cm above 1 kg mass

c. 1.5 cm right and 1.2 cm above 1 kg mass

d. 0.6 cm right and 2.0 cm above 1 kg mass

Solution: (a)



Taking 1 kg as the origin

$$x_{com} = \frac{m_1x_1 + m_2x_2 + m_3x_3}{m_1 + m_2 + m_3}$$
$$x_{com} = \frac{1 \times 0 + 1.5 \times 3 + 2.5 \times 0}{5}$$
$$x_{com} = 0.9$$
$$y_{com} = \frac{m_1y_1 + m_2y_2 + m_3y_3}{m_1 + m_2 + m_3}$$
$$y_{com} = \frac{1 \times 0 + 1.5 \times 0 + 2.5 \times 4}{5}$$
$$y_{com} = 2$$

Centre of mass is at $(0.9, 2)$

16. If we need a magnification of 375 from a compound microscope of tube length 150 mm and an objective of focal length 5 mm, the focal length of the eye-piece should be close to:

a. 22 mm

b. 2 mm

c. 12 mm

d. 33 mm

Solution:(a)

Magnification of compound microscope for least distance of distinct vision setting(strained eye)

$$M = \frac{L}{f_0}\left(1 + \frac{D}{f_e}\right)$$

where L is the tube length

f_0 is the focal length of objective

D is the least distance of distinct vision $= 25$ cm

$$\text{i.e.} \qquad 375 = \frac{150 \times 10^{-3}}{5 \times 10^{-3}}\left(1 + \frac{25 \times 10^{-2}}{f_e}\right)$$

$$\text{i.e.} \qquad 12.5 = 1 + \frac{25 \times 10^{-2}}{f_e}$$

$$\text{i.e.} \qquad \frac{25 \times 10^{-2}}{f_e} = 11.5$$

$$\therefore \quad f_e \approx 21.7 \times 10^{-3}\text{m} = 22 \text{ mm}$$

17. Speed of transverse wave on a straight wire (mass $6.0\ g$, length $60\ cm$ and area of cross-section $1.0\ mm^2$) is 90 m/s. If the Young's modulus of wire is $16 \times 10^{11} Nm^{-2}$, the extension of wire over its natural length is

a. $0.03\ mm$

b. $0.02\ mm$

c. $0.04\ mm$

d. $0.01\ mm$

Solution:(a)

Given, $M = 6\ grams = 6 \times 10^{-3}\ kg$

$$L = 60\ cm = 0.6\ m$$

$$A = 1\ mm^2 = 1 \times 10^{-6}\ m^2$$

Using the relation, $v^2 = \frac{T}{\mu}$

$$\Rightarrow T = \mu v^2 = V^2 \times \frac{M}{L}$$

As Young's modulus, $Y = \frac{stress}{strain}$

$$strain = \frac{stress}{Y} = \frac{T}{AY}$$

$$strain = \frac{\Delta L}{L} = \frac{V^2 \frac{M}{L}}{AY} = V^2 \frac{M}{AYL}$$

$$\Rightarrow \Delta L = \frac{V^2 M}{AY}$$

$$\Delta L = \frac{8100 \times 6 \times 10^{-3}}{1 \times 10^{-6} \times 16 \times 10^{11}}$$

$$\Delta L = 0.03\ mm$$

18. 1 liter of dry air at STP expands adiabatically to a volume of 3 litres. If $\gamma = 1.4$, the work done by air is ($3^{1.4} = 4.655$) (take air to be an ideal gas)

a. $48\ J$

b. $90.5\ J$

c. $100.8\ J$

d. $60.7\ J$

Solution:(b)
Given, $P_1 = 1\ atm, T_1 = 273\ K$ (At STP)
In adiabatic process,

$$P_1V_1^\gamma = P_2V_2^\gamma$$
$$P_2 = P_1\left[\frac{V_1}{V_2}\right]^\gamma$$
$$P_2 = 1 \times \left[\frac{1}{3}\right]^{1.4}$$
$$P_2 = 0.2164\ atm$$

Work done in adiabatic process is given by

$$W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$
$$W = \frac{1 \times 1 - 3 \times .2164}{0.4} \times 101.325$$

Since, $1\ atm = 101.325\ kPa$ and $1\ Liter = 10^{-3}\ m^3$

$$W = 89.87\ J$$

19. A bob of mass m is tied by a massless string whose other end portion is wound on a fly wheel (disc) of radius r and mass m. When released from the rest, the bob starts falling vertically. When it has covered a distance h, the angular speed of the wheel will be:

a. $r\sqrt{\frac{3}{4gh}}$

b. $\frac{1}{r}\sqrt{\frac{4gh}{3}}$

c. $r\sqrt{\frac{3}{2gh}}$

d. $\frac{1}{r}\sqrt{\frac{2gh}{3}}$

Solution:(b)
By energy conservation,

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$
$$\Rightarrow gh = \frac{v^2}{2} + \frac{\omega^2r^2}{4} \qquad (1)$$

Since the rope is inextensible and also it is not slipping,

$$\therefore v = r\omega \tag{2}$$

from eq. (1) and (2)

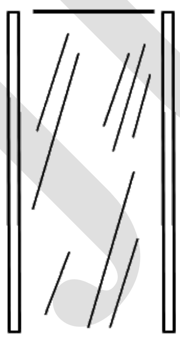
$$gh = \frac{\omega^2 r^2}{2} + \frac{\omega^2 r^2}{4}$$

$$\Rightarrow gh = \frac{3}{4} r^2 \omega^2$$

$$\Rightarrow \omega^2 = \frac{4gh}{3r^2}$$

$$\Rightarrow \omega = \frac{1}{r}\sqrt{\frac{4gh}{3}}$$

20. A parallel plate capacitor has plates of area A separated by distance 'd' between them. It is filled with a dielectric which has a dielectric constant varies as $k\ (x) = k(1 + \alpha x)$, where 'x' is the distance measured from one of the plates. If $(\alpha d \ll 1)$, the total capacitance of the system is best given by the expression:



a. $\frac{A\varepsilon_0 k}{d}\left[1 + \left(\frac{\alpha d}{2}\right)^2\right]$

b. $\frac{Ak\varepsilon_0}{d}\left[1 + \left(\frac{\alpha d}{2}\right)\right]$

c. $\frac{A\varepsilon_0 k}{d}\left[1 + \left(\frac{\alpha^2 d}{2}\right)\right]$

d. $\frac{Ak\varepsilon_0}{d}\left[1 + \alpha d\right]$

Solution:(b)

Given, $k(x) = k\,(1 + \alpha x)$

dC = $\frac{A\varepsilon_0 k}{dx}$

Since all capacitance are in series, we can apply

$$\frac{1}{Ceq} = \int \frac{1}{dC} = \int_0^d \frac{dx}{k\,(1 + \alpha x)\,\epsilon_0 A}$$

$$\frac{1}{Ceq} = \left[\frac{\ln\,(1 + \alpha x)}{k\epsilon_0 A\alpha}\right]_0^d$$

On putting the limits from 0 to d

$$= \frac{\ln(1+\alpha d)}{k\epsilon_0 A\alpha}$$

Using expression $\ln(1+x) = x - \frac{x^2}{2} + ...$
And putting $x = \alpha d$ where, x approaches to 0.

$$\frac{1}{C} = \frac{d}{k\epsilon_0 A d\alpha}\left[\alpha d - \frac{(\alpha d)^2}{2}\right]$$

$$\frac{1}{C} = \frac{d}{k\epsilon_0 A}\left[1 - \frac{\alpha d}{2}\right]$$

$$C = \frac{k\epsilon_0 A}{d}\left[1 + \frac{\alpha d}{2}\right]$$

21. A non- isotropic solid metal cube has coefficient of linear expansion as $5 \times 10^{-5}/^\circ C$ along the x-axis and $5 \times 10^{-6}/^\circ C$ along y-axis and z-axis. If the coefficient of volumetric expansion of the solid is $C \times 10^{-6}/^\circ C$ then the value of C is _______

Solution:(60)
We know that, $V = xyz$

$$\frac{\Delta v}{v} = \frac{\Delta x}{x} + \frac{\Delta y}{y} + \frac{\Delta z}{z}$$

$$\frac{1}{T}\frac{\Delta v}{v} = \frac{1}{T}\frac{\Delta x}{x} + \frac{1}{T}\frac{\Delta y}{y} + \frac{1}{T}\frac{\Delta z}{z}$$

$$y = \alpha_n + \alpha_y + \alpha_z$$

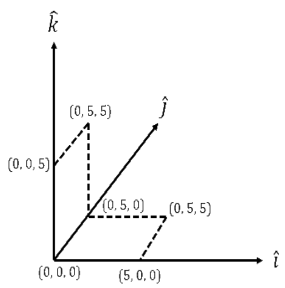
$$y = 50 \times 10^{-6}/^\circ C + 5 \times 10^{-6}/^\circ C + 5 \times 10^{-6}/^\circ C$$

$$y = 60 \times 10^{-6}/^\circ C$$

$$\therefore C = 60$$

22. A loop $ABCDEFA$ of straight edges has six corner points A(0,0,0), B(5,0,0), C(5,5,0), D(0,5,0), E(0,5,5), F(0,0,5). The magnetic field in this region is $\vec{B} = (3\hat{i} + 4\hat{k})\,T$. The quantity of flux through the loop $ABCDEFA$ (in Wb) is _______

Solution:(175)



As we know, magnetic flux $= \vec{B} \cdot \vec{A}$

$$\implies (B_x + B_z) \cdot (A_x + A_z)$$
$$\implies (3\hat{i} + 4\hat{k}) \cdot (25\hat{i} + 25\hat{k})$$
$$\implies (75 + 100)\, Wb$$
$$\implies 175\, Wb$$

23. A carnot engine operates between two reservoirs of temperature 900 K and 300 K. The engine performs 1200 J of work per cycle. The heat energy in(J) delivered by the engine to the low temperature reservoir, in a cycle, is _______

Solution:(600 J)

$$\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{300}{900} = \frac{2}{3}$$

Given, $W = 1200\ J$

From conservation of energy

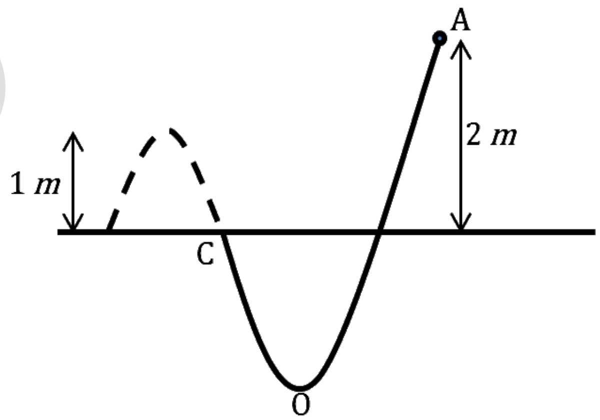
$$Q_1 - Q_2 = W$$

$$\eta = \frac{Q_1 - Q_2}{Q_1} = \frac{W}{Q_1} \implies Q_1 = 1800 \text{ J}$$

$$\Rightarrow Q_2 = Q_1 - W = 600 \text{ J}$$

24. A particle of mass 1 kg slides down a frictionless track (AOC) starting from rest at a point A(height 2 m). After reaching C, the particle continues to move freely in air as a projectile. When it reaches its highest point P(height 1 m) the kinetic energy of the particle (in J) is:(Figure drawn is schematic and not to scale; take $g = 10\ m/s^2$)_______

Solution:(10)



As the particle starts from rest the total energy at point $A = mgh = T.E_A$(where $h = 2\ m$)

After reaching point P

$$T.E_c = K.E. + mgh$$

By conservation of energy

$$T.E_A = T.E_p$$

$$\implies K.E. = mgh = 10\ J$$

25. A beam of electromagnetic radiation of intensity 6.4$\times$ $10^{-5}\ W/cm^2$ is comprised of wavelength, $\lambda = 310\ nm$. It falls normally on a metal (work function $\phi = 2\ eV$) of surface area $1\ cm^2$. If one in 10^3 photons ejects an electron, total number of electrons ejected in $1s$ is 10^x ($hc = 1240\ eV - nm, 1\ eV = 1.6 \times 10^{-19}\ J$), then x is -------

Solution:(11)

$$P = \text{Intensity} \times \text{Area}$$
$$= 6.4 \times 10^{-5}\text{W} - \text{cm}^{-2} \times 1\ \text{cm}^2$$
$$= 6.4 \times 10^{-5}\ \text{W}$$

For photoelectric effect to take place, energy should be greater than work function

Now,

$$E = \frac{1240}{310} = 4\ eV > 2\ eV$$

Therefore, photoelectric effect takes place

Here n is the number of photons emitted.

$$n \times E = I \times A$$
$$\implies n = \frac{IA}{E} = \frac{6.4 \times 10^{-5}}{6.4 \times 10^{-19}} = 10^{14}$$

Where, n is number of incident photon

Since, 1 out of every 1000 photons are sucessfull in ejecting 1 photoelectron

Therefore, the number of photoelectrons emitted is

$$= \frac{10^{14}}{10^3}$$

$$\therefore x = 11$$