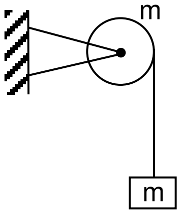
PART : PHYSICS

1. A block of mass m is suspended from a pulley in form of a circular disc of mass m & radius R. The system is released from rest, find the angular velocity of disc when block has dropped by height h. (there is no slipping between string & pulley)



(1) $\frac{1}{R}\sqrt{\frac{4gh}{3}}$ (2) $\frac{1}{R}\sqrt{\frac{2gh}{3}}$ (3) $R\sqrt{\frac{2gh}{3}}$ (4) $R\sqrt{\frac{4gh}{3}}$

Ans. **(1)**

Sol. $mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

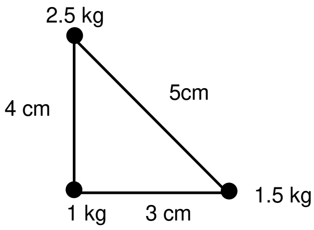
$v = \omega R$ (no slipping)

$mgh = \frac{1}{2}m\omega^2R^2 + \frac{1}{2}\frac{mR^2}{2}\omega^2$

$mgh = \frac{3}{4}m\omega^2R^2$

$\omega = \sqrt{\frac{4gh}{3R^2}} = \frac{1}{R}\sqrt{\frac{4gh}{3}}$

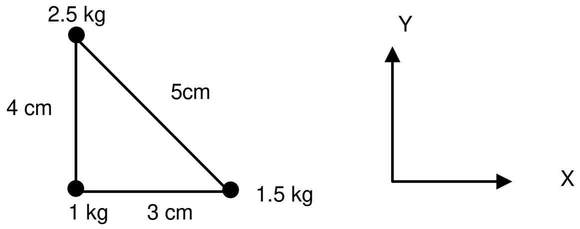
2. Three point masses 1kg, 1.5 kg, 2.5 kg are placed at the vertices of a triangle with sides 3cm,4cm and 5cm as shown in the figure. The location of centre of mass with respect to 1kg mass is :



(1) 0.6 cm to the right of 1 kg and 2 cm above 1 kg mass
(2) 0.9 cm to the right of 1kg and 2 cm above 1 kg mass
(3) 0.9 cm to the left of 1kg and 2 cm above 1kg mass
(4) 0.9 cm to the right of 1 kg and 1.5 cm above 1kg mass

Ans. **(2)**

Sol. Take 1kg mass at origin



$$X_{cm} = \frac{1\times 0 + 1.5\times 3 + 2.5\times 0}{5} = 0.9\text{cm}$$

$$Y_{cm} = \frac{1\times 0 + 1.5\times 0 + 2.5\times 4}{5} = 2\text{cm}$$

3. In a single slit diffraction set up, second minima is observed at an angle of 60°. The expected position of first minima is

(1) 25° (2) 20° (3) 30° (4) 45°

Ans. **(1)**

Sol. For 2nd minima

$d \sin\theta = 2\lambda$

$\sin\theta = \frac{\sqrt{3}}{2}$ (given)

$\Rightarrow \quad \frac{\lambda}{d} = \frac{\sqrt{3}}{4} \quad \ldots$ (i)

So for 1st minima is

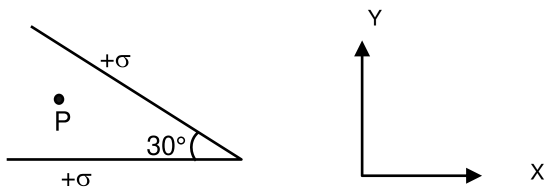
$d \sin\theta = \lambda$

$\sin\theta = \frac{\lambda}{d} = \frac{\sqrt{3}}{4}$ (from equation (i))

$\theta = 25.65°$ (from sin table)

$\theta \approx 25°$

4. There are two infinite plane sheets each having uniform surface charge density $+\sigma$ C/m^2. They are inclined to each other at an angle 30° as shown in the figure. Electric field at any arbitrary point P is:

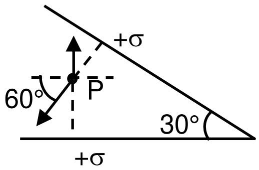


(1) $\frac{\sigma}{2\varepsilon_0}\left[\left(1-\frac{\sqrt{3}}{2}\right)\hat{y}-\frac{1}{2}\hat{x}\right]$ (2) $\frac{\sigma}{2\varepsilon_0}\left[\left(1+\frac{\sqrt{3}}{2}\right)\hat{y}-\frac{1}{2}\hat{x}\right]$

(3) $\frac{\sigma}{2\varepsilon_0}\left[\left(1-\frac{\sqrt{3}}{2}\right)\hat{y}+\frac{1}{2}\hat{x}\right]$ (4) $\frac{\sigma}{2\varepsilon_0}\left[\left(1+\frac{\sqrt{3}}{2}\right)\hat{y}+\frac{1}{2}\hat{x}\right]$

Ans. **(1)**

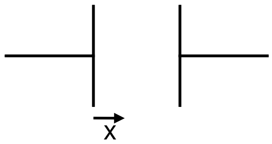
Sol.



$$\vec{E} = \frac{\sigma}{2\varepsilon_0}\cos 60°(-\hat{x}) + \left[\frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0}\sin 60°\right](\hat{y})$$

$$\vec{E} = \frac{\sigma}{2\varepsilon_0}\left[\left(1 - \frac{\sqrt{3}}{2}\right)\hat{y} - \frac{1}{2}\hat{x}\right]$$

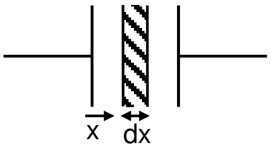
5. A parallel plate capacitor with plate area A & plate separation d is filled with a dielectric material of dielectric constant given by $k = k_0(1 + \alpha x)$. Calculate capacitance of system: (given $\alpha d << 1$).



(1) $\frac{k_0\varepsilon_0 A}{d}(1 + \alpha^2 d^2)$ (2) $\frac{k_0\varepsilon_0 A}{d}\left(1 + \frac{\alpha d}{2}\right)$ (3) $\frac{k_0\varepsilon_0 A}{2d}(1 + \alpha d)$ (4) $\frac{k_0\varepsilon_0 A}{2d}\left(1 + \frac{\alpha d}{2}\right)$

Ans. **(2)**

Sol. Capacitance of element = $\frac{k\varepsilon_0 A}{dx}$



Capacitance of element, C' = $\frac{k_0(1+\alpha x)\varepsilon_0 A}{dx}$

$$\sum \frac{1}{C'} = \int_0^d \frac{dx}{k_0\varepsilon_0 A(1+\alpha x)}$$

$$\frac{1}{C} = \frac{1}{k_0\varepsilon_0 A\alpha}\ell n(1+\alpha d)$$

Given $\alpha d << 1$

$$\frac{1}{C} = \frac{1}{k_0\varepsilon_0 A\alpha}\left(\alpha d - \frac{\alpha^2 d^2}{2}\right)$$

$$\frac{1}{C} = \frac{d}{k_0\varepsilon_0 A}\left(1 - \frac{\alpha d}{2}\right)$$

$$C = \frac{k_0\varepsilon_0 A}{d}\left(1 + \frac{\alpha d}{2}\right)$$

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

(1) current will change its direction and its emf will be zero at t = 0.25sec.
(2) current will not change its direction & emf will be maximum at t = 0.5sec
(3) current will not change direction and emf will be zero at 0.25sec.
(4) current will change its direction and its emf will be zero at t = 0.5sec.

Ans. **(4)**

Sol. $I = I_0 t - I_0 t^2$

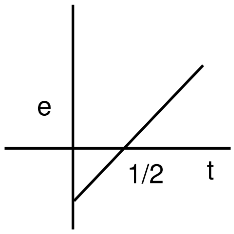
$\phi = BA$

$\phi = \mu_0 n I A$

$V_R = -\frac{d\phi}{dt} = -\mu_0 n A I_0 (1 - 2t)$

$V_R = 0$ at $t = \frac{1}{2}$

and $I_R = \frac{V_R}{\text{Resistance of loop}}$



7. If 10% of intensity is passed from analyser, then, the angle by which analyser should be rotated such that transmitted intensity becomes zero. (Assume no absorption by analyser and polarizer).

(1) 60° (2) 18.4° (3) 45° (4) 71.6°

Ans. (B)

Sol. $I = I_0 \cos^2\theta$

$\frac{I_0}{10} = I_0 \cos^2\theta$

$\cos\theta = \frac{1}{\sqrt{10}} = 0.31$

$\theta = 71.6°$

angle rotated should be = 90° – 71.6° = 18.4°

8. Three moles of ideal gas A with $\frac{c_P}{c_V} = \frac{4}{3}$ is mixed with two moles of another ideal gas B with $\frac{c_P}{c_V} = \frac{5}{3}$.

The $\frac{c_P}{c_v}$ of mixture is (Assuming temperature is constant)

(1) 1.5 (2) 1.42 (3) 1.7 (4) 1.3

Ans. **(2)**

Sol. $\gamma_{mixture} = \frac{n_1 c_{P_1} + n_2 c_{P_2}}{n_1 c_{V_1} + n_2 c_{V_2}} = \frac{n_1 \frac{\gamma_1 R}{\gamma_1 - 1} + n_2 \frac{\gamma_2 R}{\gamma_2 - 1}}{\frac{n_1 R}{\gamma_1 - 1} + \frac{n_2 R}{\gamma_2 - 1}}$

on rearranging we get,

$\frac{n_1 + n_2}{\gamma_{mix} - 1} = \frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1}$

$\frac{5}{\gamma_{mix} - 1} = \frac{3}{1/3} + \frac{2}{2/3}$

$\frac{5}{\gamma_{mix} - 1} = 9 + 3 = 12$

$\Rightarrow \gamma_{mixure} = \frac{17}{12} = 1 + \frac{5}{12}$

$\gamma_{mix} = 1.42$

9. Given magnetic field equation is $B = 3 \times 10^{-8} \sin(\omega t + kx + \phi)\ \hat{j}$

then appropriate equation for electric field (E) will be :

(1) $20 \times 10^{-9} \sin(\omega t + kx + \phi)\ \hat{k}$
(2) $9 \sin(\omega t + kx + \phi)\ \hat{k}$
(3) $16 \times 10^{-9} \sin(\omega t + kx + \phi)\ \hat{k}$
(4) $3 \times 10^{-9} \sin(\omega t + kx + \phi)\ \hat{k}$

Ans. **(2)**

Sol. $\frac{E_0}{B_0} = C$ (speed of light in vacuum)

$E_0 = B_0 C = 3 \times 10^{-8} \times 3 \times 10^{8}$

$= 9$ N/C

So $E = 9 \sin(\omega t + kx + \phi)$

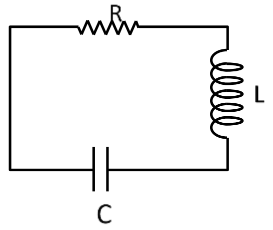
10. There is a LCR circuit , If it is compared with a damped oscillation of mass m oscillating with force constant k and damping coefficient 'b'. Compare the terms of damped oscillation with the devices in LCR circuit.

(1) $L \to m$, $C \to \frac{1}{k}$, $R \to b$
(2) $L \to m$, $C \to k$, $R \to b$
(3) $L \to k$, $C \to b$, $R \to m$
(4) $L \to \frac{1}{m}$, $C \to \frac{1}{k}$, $R \to \frac{1}{b}$

Ans. **(1)**

Sol. In damped oscillation

ma + bv + kx = 0



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

In the circuit

$$-iR - L\frac{di}{dt} - \frac{q}{c} = 0$$

$$L\frac{d^2q}{dt^2} + R\frac{dq}{dt} + \frac{1}{c}.q = 0 \quad \ldots(ii)$$

Comparing equation (i) and (ii)

$$m = L,\ b = R,\ k = \frac{1}{c}$$

11. A lift can hold 2000kg, friction is 4000N and power provided is 60HP. (1 HP = 746W) Find the maximum speed with which lift can move up.

(1) 1.9 m/s (2) 1.7 m/s (3) 2 m/s (4) 1.5 m/s

Ans. **(1)**

Sol. $4000 \times V + mg \times V = P$

$$\frac{60 \times 746}{4000 + 20000} = V$$

$V = 1.86$ m/s. ≈ 1.9 m/s.

12. A H–atom in ground state has time period $T = 1.6 \times 10^{-16}$ sec. find the frequency of electron in first excited state

(1) 7.8×10^{14} (2) 7.8×10^{16} (3) 3.7×10^{14} (4) 3.7×10^{16}

Ans. **(1)**

Sol. $T \propto \frac{r}{v} \propto \frac{n^2}{z} \times \frac{n}{z} \propto \frac{n^3}{z^2}$

$$\frac{T_1}{T_2} = \frac{n_1^3}{n_2^3} = \frac{1}{8}$$

$T_2 = 8T_1$

$= 8 \times 1.6 \times 10^{-16} = 12.8 \times 10^{-16}$

$$f_2 = \frac{1}{12.8 \times 10^{-16}} \approx 7.8 \times 10^{14}$$

13. Magnification of compound microscope is 375. Length of tube is 150mm. Given that focal length of objective lens is 5mm, then value of focal length of eyepiece is:

(1) 2mm (2) 22mm (3) 12mm (4) 33mm

Ans. **(2)**

Sol. **Case-I**

If final image is at least distance of clear vision

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

$$375 = \frac{150}{5}\left[1 + \frac{25}{f_e}\right]$$

$$\frac{375}{30} = 1 + \frac{25}{f_e}$$

$$\frac{345}{30} = \frac{25}{f_e}$$

$f_e = \frac{750}{345} = 2.17$ cm

$f_e \approx 22$ mm

Case-II

If final image is at infinity

M.P. = $\frac{L}{f_0}\left(\frac{D}{f_e}\right) = 375$

$f_e = 20$ mm

14. 1 litre of a gas at STP is expanded adiabatically to 3 litre. Find work done by the gas. Given $\gamma = 1.40$ and $3^{1.4} = 4.65$

(1) 100.8J (2) 90.5J (3) 45J (4) 18J

Ans. **(2)**

Sol. $P_1 = 1$atm, $T_1 = 273$K

$P_1V_1^{\gamma} = P_2V_2^{\gamma}$

$P_2 = P_1\left[\frac{V_1}{V_2}\right]^{\gamma}$

$= 1\text{atm}\left(\frac{1}{3}\right)^{1.4}$

now work done = $\frac{P_1V_1 - P_2V_2}{\gamma - 1} = 88.7$ J

Most appropriate ans is 90.5 J

15. A string of length 60 cm, mass 6gm and area of cross section 1mm^2 and velocity of wave 90m/s. Given young's modulus is $Y = 1.6 \times 10^{11}$ N/m^2. Find extension in string

(1) 0.3 mm (2) 0.2 mm (3) 0.1 mm (4) 0.4 mm

Ans. **(1)**

Sol. $v = \sqrt{\frac{T}{\mu}}$

$T = \mu v^2$

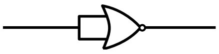
$\frac{\mu v^2}{A} = Y\frac{\Delta\ell}{\ell}$

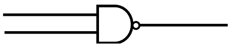
$\Delta\ell = \frac{\mu v^2 \ell}{AY}$

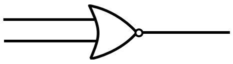
after substituting valu of μ,v,ℓ,A and Y we get

$\Delta\ell = 0.3$ mm

16. Which of the following gate is reversible

(1) 

(2) 

(3) 

(4) 

Ans. (1)

Sol. A logic gate is reversible if we can recover input data from the output

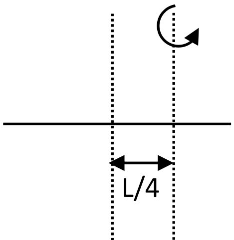
eg. NOT gate

17. A thin uniform rod of mass M and length L. Find the radius of gyration for rotation about an axis passing through a point at a distance of $\frac{L}{4}$ from centre and perpendicular to rod.

(1) $\sqrt{\frac{7}{48}}L$ (2) $\sqrt{\frac{5}{48}}L$ (3) $\sqrt{\frac{7}{24}}L$ (4) $\sqrt{\frac{19}{24}}L$

Ans. **(1)**

Sol.



$$\frac{ML^2}{12} + M\left(\frac{L}{4}\right)^2 = MK^2$$

$$\frac{L^2}{12} + \frac{L^2}{16} = K^2$$

$$K = \sqrt{\frac{7}{48}}L$$

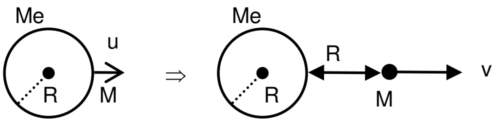
18. A satellite of mass 'M' is projected radially from surface of earth with speed 'u'. When is reaches a height equal to radius of earth, it ejects a rocket of mass $\frac{M}{10}$ and it itself starts orbiting the earth in circular path of radius 2R, find the kinetic energy of rocket.

(1) $5M\left(u^2 - \frac{119GM_e}{200R}\right)$ (2) $5M\left(u^2 - \frac{113GM_e}{200R}\right)$

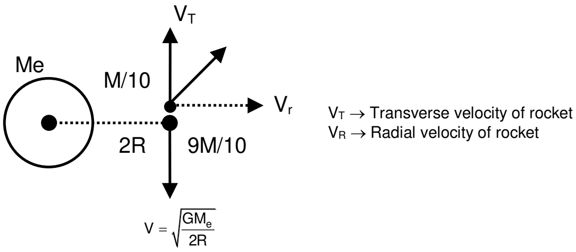
(3) $\frac{M}{20}\left(u^2 - \frac{119GM_e}{100R}\right)$ (4) $\frac{M}{20}\left(u^2 - \frac{113GM_e}{200R}\right)$

Ans. **(1)**

Sol. $\frac{-GM_eM}{R} + \frac{1}{2}Mu^2 = \frac{-GM_eM}{2R} + \frac{1}{2}Mv^2$



$$v = \sqrt{u^2 - \frac{GM_e}{R}}$$



$$\frac{M}{10}V_T = \frac{9M}{10}\sqrt{\frac{GM_e}{2R}}$$

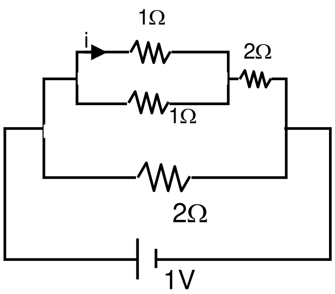
$$\frac{M}{10}V_r = M\sqrt{u^2 - \frac{GM_e}{R}}$$

Kinetic energy = $\frac{1}{2}\frac{M}{10}\left(V_T^2 + V_r^2\right) = \frac{M}{20}\left(81\frac{GM_e}{2R} + 100u^2 - 100\frac{GM_e}{R}\right)$

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

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

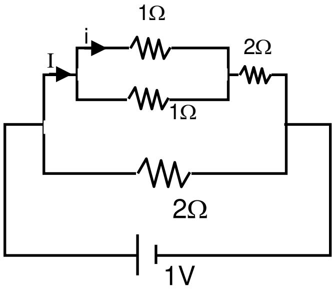
19. The current 'i' in the given circuit is



(1) 0.2A (2) 0.3A (3) 0.5A (4) 0.25A

Ans. **(1)**

Sol.



$I = \frac{1}{2.5} = 0.4A$

$i = \frac{I}{2} = 0.2A$

20. A current carrying circular loop is placed in an infinite plane if ϕ_i is the magnetic flux through the inner region and ϕ_o is magnitude of magnetic flux through the outer region, then

(1) $\phi_i > \phi_o$ (2) $\phi_i < \phi_o$

(3) $\phi_i = -\phi_o$ (4) $\phi_i = \phi_o$

Ans. **(3)**

Sol. As magnetic field lines always form a closed loop, hence every magnetic field line creating magnetic flux in the inner region must be passing through the outer region. Since flux in two regions are in opposite direction,

$\therefore \quad \phi_i = -\phi_0$

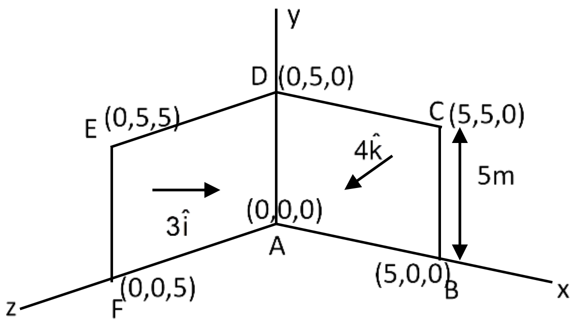
Numerical Value Type ( )

This section contains **5 Numerical value type questions.**

21. Consider a loop ABCDEFA. With coordinates A (0, 0, 0), B(5, 0, 0), C(5, 5, 0), D(0, 5, 0) E(0, 5, 5) and F(0, 0, 5). Find magnetic flux through loop due to magnetic field $\vec{B} = 3\hat{i} + 4\hat{k}$

Ans. 175

Sol. $\phi = \vec{B}.\vec{A} = (3\hat{i} + 4\hat{k}).(25\hat{i} + 25\hat{k})$



$\phi = (3 \times 25) + (4 \times 25) = 175$ weber

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

Ans. 600

Sol. $\eta = \frac{W}{Q_h} = 1 - \frac{300}{900} = \frac{2}{3}$

$Q_h = \frac{3}{2} W = 1800 \text{ J}$

$Q_L = Q_h - W = 600 \text{ J}$

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

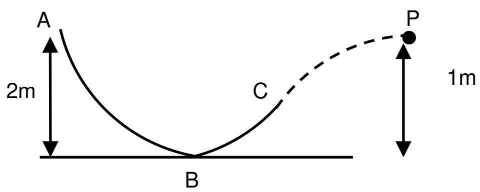
Ans. **60**

Sol. $V = 2\alpha_2 + \alpha_1$

$= 10 \times 10^{-6} + 5 \times 10^{-5}$

$= 60 \times 10^{-6}$ /°C

24. A particle is released at point A. Find Kinetic energy at point P Given m = 1 kg and all surfaces are frictionless



Ans. **10**

Sol. $KE = PE_1 - PE_2 = mgh_1 - mgh_2$

$= 1 \times 10 \times 2 - 1 \times 10 \times 1 = 10\text{J}$

25. On a photosensitive metal of area 1 cm^2 and work function 2eV, light of intensity 6.4×10^{-5} W/cm^2 in wavelength 310 nm fall normally. If 1 out of every 10^3 photons are successful, then number of photoelectrons emitted in one second is 10^x. Find x

Ans. **11**

Sol. Energy of photon. $E = \frac{1240}{310} = 4\text{eV} > 2\text{eV}$ (so photoelectric effect will take place)

$= 4 \times 1.6 \times 10^{-19} = 6.4 \times 10^{-19}$ Joule

No. of photons falling per second

$= \frac{6.4 \times 10^{-5} \times 1}{6.4 \times 10^{-19}} = 10^{14}$

No. of photoelectron per second

$= \frac{10^{14}}{10^3} = 10^{11}$