ALLEN CAREER INSTITUTE KOTA (RAJASTHAN)

path to success

Chapter Contents 01

JEE (MAIN)
TOPICWISE SOLUTION OF TEST PAPERS JANUARY & SEPTEMBER 2020

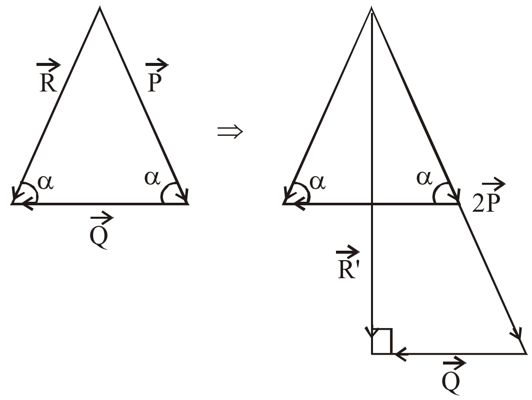
PHYSICS

JANUARY & SEPTEMBER 2020 ATTEMPT (PHYSICS)

BASIC MATHS & VECTOR

1. NTA Ans. (90)

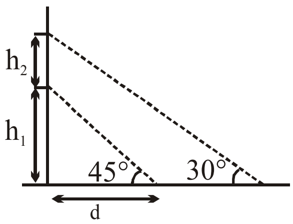
Sol.



Hence angle 90°

2. Official Ans. by NTA (1)

Sol.



$$\frac{h_1}{d} = \tan 45° \Rightarrow h_1 = d \;\ldots (1)$$

$$\frac{h_1 + h_2}{d + 2.464\,d} = \tan 30°$$

$$\Rightarrow (h_1 + h_2) \times \sqrt{3} = 3.46\ d$$

$$(h_1 + h_2) = \frac{3.46\,d}{\sqrt{3}}$$

$$\Rightarrow d + h_2 = \frac{3.46\,d}{\sqrt{3}}$$

$h_2 = d$

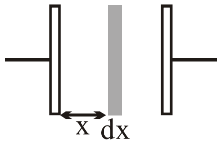
CAPACITOR

1. NTA Ans. (1)

Sol. As K is variable we take a plate element of Area A and thickness dx at distance x

Capacitance of element

$$dC = \frac{(A)K(1+\alpha x)\varepsilon_0}{dx}$$



Now all such elements are is series so equivalent capacitance

$$\frac{1}{C} = \int \frac{1}{dC} = \int_0^d \frac{dx}{AK\varepsilon_0(1+\alpha x)}$$

$$\frac{1}{C} = \frac{1}{\alpha AK\varepsilon_0} \ln\left(\frac{1+\alpha d}{1}\right)$$

$$= \frac{1}{C} = \frac{1}{\alpha AK\varepsilon_0}\left(\alpha d - \frac{(\alpha d)^2}{2} + \frac{(\alpha d)^3}{3} + \ldots\right)$$

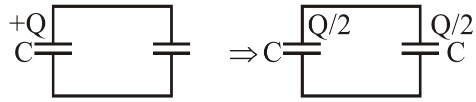
$$\Rightarrow \frac{1}{C} = \frac{\alpha d}{\alpha AK\varepsilon_0}\left(1 - \frac{\alpha d}{2} + \frac{(\alpha d)^2}{3} + \ldots\right)$$

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

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

2. NTA Ans. (6)

Sol.



$Q = CV$

$$\Delta Q_L = \frac{Q^2}{2C} - \left[\frac{(Q/2)^2}{2C} \times 2\right] = \frac{Q^2}{4C}$$

$$= \frac{1}{4} CV^2$$

$$= \frac{1}{4} \times 60 \times 10^{-12} \times 4 \times 10^2$$

$= 6nJ$

3. NTA Ans. (3)

Sol. $C_1 + C_2 = 10$ ....(i)

$$\frac{1}{2} C_2 V^2 = 4 \times \frac{1}{2} C_1 V^2$$

$\therefore\ C_2 = 4C_1$ ....(ii)

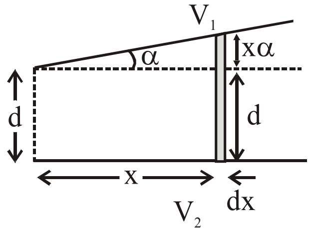
$\therefore\ C_1 = 2\ \&\ C_2 = 8$

For series combination

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = 1.6$$

4. NTA Ans. (4)

Sol. Assume small element dx at a distance x from left end



Capacitance for small element dx is

$$dC = \frac{\varepsilon_0 a\, dx}{d + x\alpha}$$

$$C = \int_0^a \frac{\varepsilon_0 a\, dx}{d + x\alpha}$$

$$= \frac{\varepsilon_0 a}{\alpha} \ln\left(\frac{1+\alpha a}{d}\right)\Bigg|_0^a \qquad \left(\ln(1+x) \approx x - \frac{x^2}{2}\right)$$

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

5. Official Ans. by NTA (36)
Official Ans. by ALLEN (4 Actual 4.033)

Sol. $u_i = \frac{1}{2} \times 5 \times 10^{-6} (220)^2$

Final common potential

$$v = \frac{220 \times 5 + 0 \times 2.5}{5 + 2.5} = 220 \times \frac{2}{3}$$

$$u_f = \frac{1}{2}(5 + 2.5) \times 10^{-6}\left(220 \times \frac{2}{3}\right)^2$$

$\Delta u = u_f - u_i$

$\Delta u = -403.33 \times 10^{-4}$

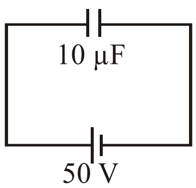
$\Rightarrow -403.33 \times 10^{-4} = \frac{X}{100}$

X = –4.03

or magnitude or value of X is approximate 4

6. Official Ans. by NTA (2)

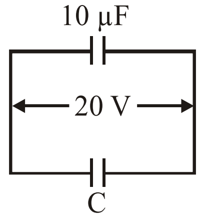
Sol. Initially



- Charge on capacitor 10 μF

Q = CV = (10 μF) (50V)

Q = 500 μC



- Final Charge on 10 μF capacitor

Q = CV = (10 μF) (20V)

Q = 200 μC

- From charge conservation,

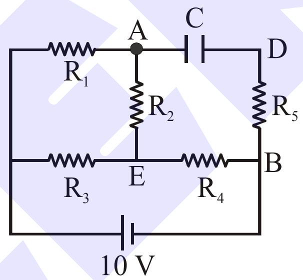
Charge on unknown capacitor

C = 500 μC – 200 μC = 300 μC

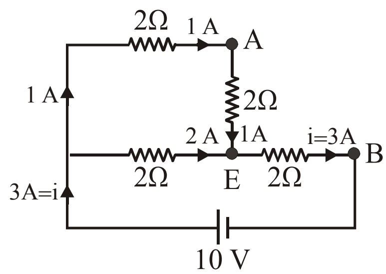
$$\Rightarrow \text{Capacitance (C)} = \frac{Q}{V} = \frac{300\ \mu C}{20\ V} = 15\ \mu F$$

7. Official Ans. by NTA (8.00)

Sol.



- R_1 to R_5 → each 2Ω
- Cap. is fully charged
- So no current is there in branch ADB
- Effective circuit of current flow :



$$R_{eq} = \left(\frac{4 \times 2}{4 + 2}\right) + 2$$

$$R_{eq} = \frac{4}{3} + 2 = \frac{10}{3}\Omega$$

$$i = \frac{10}{10/3} = 3A$$

So potential different across AEB

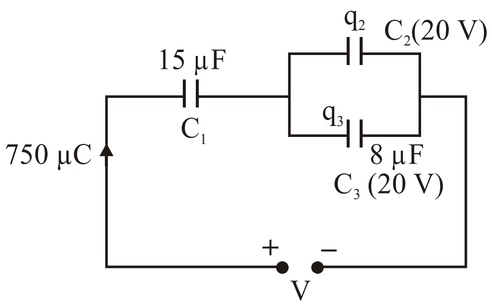
⇒ 2 × 1 + 2 × 3 = 8V

Hence potential difference across

Capacitor = ΔV = V_{AEB} = 8V

8. Official Ans. by NTA (1)

Sol.



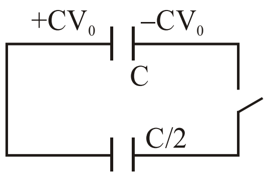
$q_3 = 20 \times 8 = 160\ \mu C$

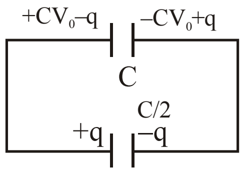
$\therefore\ q_2 = 750 - 160 = 590\ \mu C$

9. Official Ans. by NTA (4)

Official Ans. by ALLEN (1)

Sol.





$$\frac{CV_0 - q}{C} = \frac{q}{C/2} = \frac{2q}{C}$$

$$V_0 = \frac{3q}{C} \quad \Rightarrow q = \frac{CV_0}{3}$$

$$U_i = \frac{1}{2}CV_0^2$$

$$U_f = \frac{\left(\frac{2CV_0}{3}\right)^2}{2C} + \frac{\left(\frac{CV_0}{3}\right)^2}{2\left(\frac{C}{2}\right)}$$

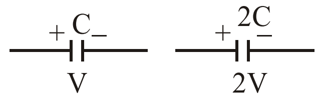
$$= \frac{1}{2}CV_0^2\left[\frac{4}{9}+\frac{2}{9}\right] = \frac{1}{2}CV_0^2\left(\frac{2}{3}\right)$$

$$\text{Heat loss} = \frac{1}{2}CV_0^2 - \left(\frac{2}{3}\right)\left(\frac{1}{2}CV_0^2\right)$$

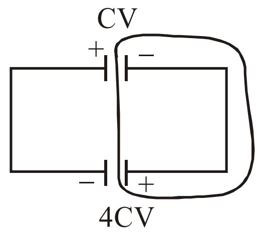
$$= \frac{1}{6}CV_0^2$$

10. Official Ans. by NTA (4)

Sol.



$Q_1 = CV \qquad Q_2 = 2C \times 2V = 4CV$



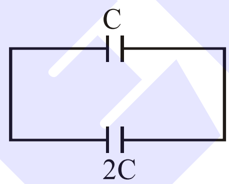
$\Rightarrow$ By conservation of charge

$q_i = q_f$

$Q_1 + Q_2 = q_1 + q_2$

$4CV - CV = (C + 2C)\ V_C$

$$V_C = \frac{3CV}{3C} \Rightarrow V$$

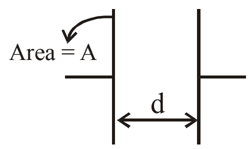


$$\Rightarrow \frac{1}{2}\times(3C)\times V_C^2$$

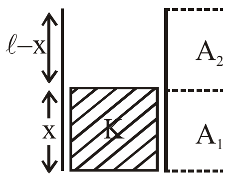
$$= \frac{1}{2} \times 3C \times V^2 = \frac{3}{2}CV^2$$

11. Official Ans. by NTA (3)

Sol.



Before inserting slab



After inserting dielectric slab

$$C_i = \frac{\varepsilon_0 A}{d} \qquad C_f = C_1 + C_2$$

$$C_i = \frac{\varepsilon_0 \ell w}{d} \qquad C_f = \frac{K\varepsilon_0 A_1}{d} + \frac{\varepsilon_0 A_2}{d}$$

$$C_f = \frac{K\varepsilon_0 wx}{d} + \frac{\varepsilon_0 w(\ell - x)}{d}$$

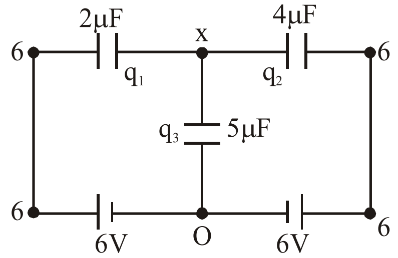
$$C_f = 2C_i \Rightarrow \frac{K\varepsilon_0 wx}{x} + \frac{\varepsilon_0 w(\ell - x)}{d} = \frac{2\varepsilon_0 \ell w}{d}$$

$$4x + \ell - x = 2\ell$$

$$\boxed{x = \frac{\ell}{3}}$$

12. Official Ans. by NTA (2)

Sol.



Let potential of point O $v_0 = 0$

Now, using junction analysis

We can say, $q_1 + q_2 + q_3 = 0$

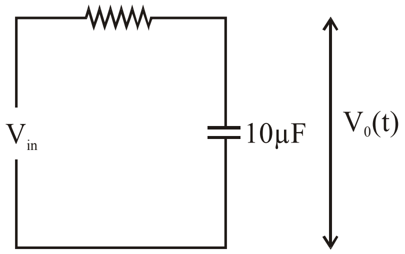
$2(x - 6) + 4(x - 6) + 5(x) = 0$

$x = \frac{36}{11}$ $\quad q_3 = \frac{36(5)}{11} = \frac{180}{11}$

$q_3 = 16.36\ \mu C$

13. Official Ans. by NTA (1)

Sol.



$$V_0(t) = V_{in}\left(1 - e^{-\frac{t}{RC}}\right)$$

at t = 5μs

$$V_0(t) = 5\left(1 - e^{-\frac{5\times10^{-6}}{10^3\times10\times10^{-9}}}\right)$$

$= 5\ (1 - e^{-0.5}) = 2V$

Now $V_{in} = 0$ means discharging

$$V_0(t) = 2e^{-\frac{t}{RC}} = 2e^{-0.5}$$

= 1.21 V

Now for next 5 μs

$$V_0(t) = 5 - 3.79e^{-\frac{t}{RC}}$$

after 5 μs again

$V_0(t) = 2.79$ Volt ≈ 3V

Most appropeiate Ans. (1)

$$U\left(r = \left(\frac{2B}{A}\right)^{1/6}\right) = -\frac{A}{2B/A} + \frac{B}{4B^2/A^2}$$

$$= \frac{-A^2}{2B} + \frac{A^2}{4B} = \frac{-A^2}{4B}$$

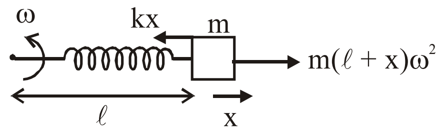
CIRCULAR MOTION

1. NTA Ans. (4)

Sol. $W = 196 - m\omega^2 R$

2. NTA Ans. (2)

Sol.

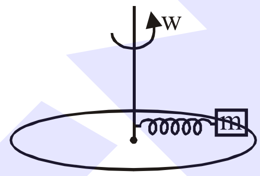


$kx = m\ell\omega^2 + mx\omega^2$

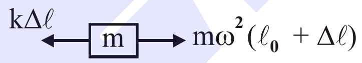
$$x = \frac{m\ell\omega^2}{k - m\omega^2}$$

3. NTA Ans. (4)

Sol.



FBD of m in frame of disc/-



$k\Delta\ell = m\omega^2(\ell_0 + \Delta\ell)$

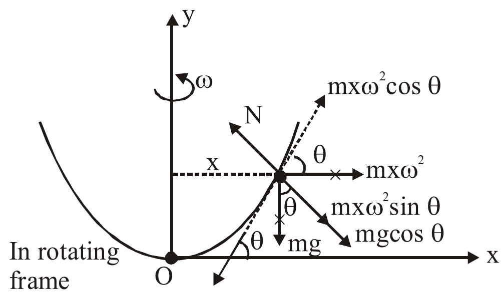
$$\Delta\ell = \frac{m\omega^2\ell_0}{k - m\omega^2} \approx \frac{m\omega\ell_0}{k}$$

$$\frac{\Delta\ell}{\ell_0} = \text{Relative change} = \frac{m\omega^2}{k}$$

∴ Correct answer (4)

4. Official Ans. by NTA (2)

Sol.



$mx\omega^2\cos\theta = mg\sin\theta$

$x\omega^2 = g\tan\theta$

$$x\omega^2 = g.\frac{dy}{dx}$$

$x\omega^2 = g.(8cx)$

$\omega^2 = 8gc$

$$\omega = 2\sqrt{2gc}$$

5. Official Ans. by NTA (1)

Sol. $R = 0.1$ m

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{60} = 0.105 \text{ rad/sec}$$

$a = \omega^2 R$

$= (0.105)^2\ (0.1)$

$= 0.0011$

$= 1.1 \times 10^{-3}$

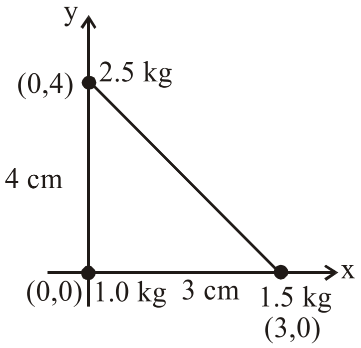
Average acceleration is of the order of 10^{-3}

$\therefore$ correct option is (1)

CENTRE OF MASS & COLLISION

1. NTA Ans. (2)

Sol.



Let 1 kg as origin and x-y axis as shown

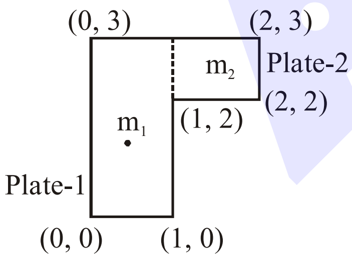
$$x_{cm} = \frac{1(0)+1.5(3)+2.5(0)}{5} = 0.9 \text{ cm}$$

$$y_{cm} = \frac{1(0)+1.5(0)+2.5(4)}{5} = 2 \text{ cm}$$

2. NTA Ans. (4)

Sol. $m_1 = 3$kg

$m_2 = 1$kg



Mass of plate-1 is assumed to be concentrated at (0.5, 1.5)

Mass of plate-2 is assumed to be concentrated at (1.5, 2.5).

$$x_{cm} = \frac{m_1x_1 + m_2x_2}{m_1+m_2} = \frac{3\times0.5+1\times1.5}{4} = 0.75$$

$$y_{cm} = \frac{m_1y_1 + m_2y_2}{m_1+m_2} = \frac{3\times1.5+1\times2.5}{4} = 1.75$$

3. NTA Ans. (1.00)

Sol. By conservation of linear momentum :

$$(0.1)(3\hat{i}) + (0.1)(5\hat{j}) = (0.1)(4)(\hat{i}+\hat{j}) + (0.1)\vec{v}$$

$\Rightarrow \vec{v} = -\hat{i} + \hat{j}$

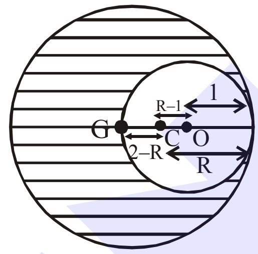
$\therefore$ Speed of B after collision $|\vec{v}| = \sqrt{2}$

Now, kinetic energy $= \frac{1}{2}mV^2 = \frac{1}{2}(0.1)(2) = \frac{1}{10}$

$\therefore x = 1$

4. NTA Ans. (3)

Sol.



By concept of COM

$m_1R_1 = m_2R_2$

Remaining mass × (2–R) = cavity mass × (R–1)

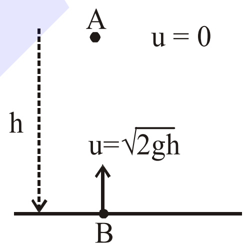
$$\left(\frac{4}{3}\pi R^3\rho - \frac{4}{3}\pi 1^3\rho\right)(2-R) = \frac{4}{3}\pi 1^3 \rho \times (R-1)$$

$(R^3 - 1)(2 - R) = R - 1$

$(R^2 + R + 1)(2 - R) = 1$

5. NTA Ans. (4)

Sol.

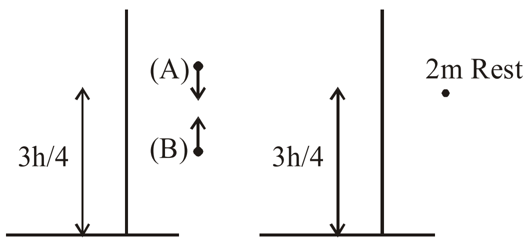


Particles will collide after time $t_0 = \frac{h}{\sqrt{2gh}}$

at collision, $v_A = gt_0$ $\quad v_B = u_B - gt_0$

$\Rightarrow v_A = -v_B$

Before collision $\qquad$ After collision



Time taken by combined mass to reach the ground

$$\text{time} = \sqrt{\frac{2\times3h/4}{g}} = \sqrt{\frac{3h}{2g}}$$

6. NTA Ans. (2)

Sol. From momentum conservation

$$mu\hat{i} + mu\left(\frac{\hat{i}+\hat{j}}{2}\right) = (m + m)\,\overline{v}$$

$$\Rightarrow \quad \overline{v} = \frac{3}{4}u\hat{i} + \frac{u}{4}\hat{j}$$

$$\Rightarrow \quad |v| = \frac{u}{4}\sqrt{10}$$

Final kinetic energy $= \frac{1}{2}2m\left(\frac{u}{4}\sqrt{10}\right)^2 = \frac{5}{8}mu^2$

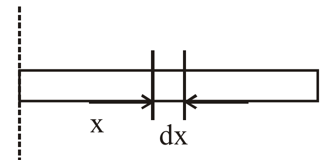
Initial kinetic energy

$$= \frac{1}{2}mu^2 + \frac{1}{2}m\left(\frac{u}{\sqrt{2}}\right)^2 = \frac{6}{8}mu^2$$

Loss in K.E. $= k_i - k_f = \frac{1}{8}mu^2$

7. NTA Ans. (4)

Sol.



x = 0 dm = λdx

$$x_{cm} = \frac{\int x\,dm}{\int dm} = \frac{\int(\lambda dx)x}{\int dm}$$

$$= \frac{\int_0^L\left(a + \frac{bx^2}{L^2}\right)x\,dx}{\int_0^L\left(a + \frac{bx^2}{L^2}\right)dx}$$

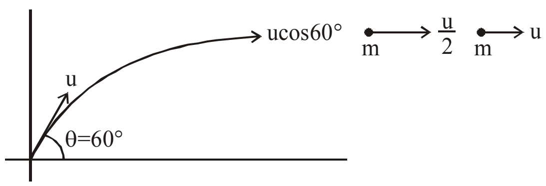
$$= \frac{\frac{aL^2}{2} + \frac{b}{L^2}\cdot\frac{L^4}{4}}{aL + \frac{b}{L^2}\cdot\frac{L^3}{3}}$$

$$= \frac{\left(\frac{4a+2b}{8}\right)L}{\frac{(3a+b)}{3}} = \frac{3}{4}\frac{(2a+b)L}{(3a+b)}$$

$\therefore$ correct answer 4

8. NTA Ans. (3)

Sol.



By momentum conservation,

$$\frac{mu}{2} + mu = 2mv'$$

$$v' = \frac{3v}{4}$$

Range after collision $= \frac{3v}{4}\sqrt{\frac{2H}{g}}$

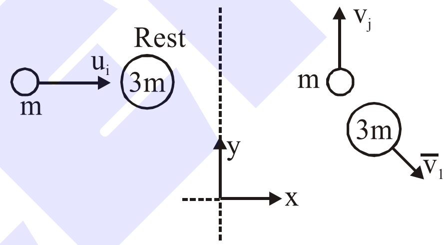
$$= \frac{3v}{4}\sqrt{\frac{2\cdot u^2\sin^2 60°}{g\,2g}}$$

$$= \frac{3}{4}\frac{\sqrt{3}}{2}\cdot\frac{u^2}{g} = \frac{3\sqrt{3}u^2}{8g}$$

$\therefore$ Correct answer (3)

9. Official Ans. by NTA (4)

Sol.



From momentum conservation

$$\vec{P}_i = \vec{P}_f$$

$$m(ui) + 3m(0) = mvj + 3m\,\overline{v}_1$$

$$mui - mvj = 3m\,\overline{v}_1$$

$$\overline{v}_1 = \frac{ui - vj}{3}$$

$$\text{or } |v_1| = \frac{\sqrt{u^2+v^2}}{3}$$

$$\text{or } v_1^2 = \frac{u^2+v^2}{9} \quad ....(1)$$

As collision is perfectly elastic hence

$k_i = k_j$

$$\frac{1}{2}mu^2 + \frac{1}{2}3m0^2 = \frac{1}{2}mv^2 + \frac{1}{2}3mv_1^2$$

$\Rightarrow u^2 = v^2 + 3{v_1}^2$

$$u^2 = v^2 + 3\frac{(u^2+v^2)}{9}$$

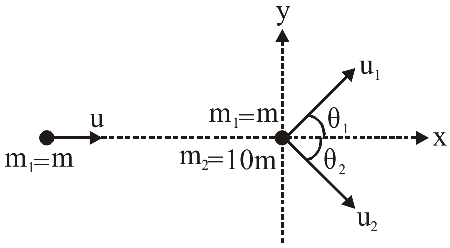
$\Rightarrow 3u^2 = 3v^2 + u^2 + v^2$

$\Rightarrow 2u^2 = 4v^2$

$$v = \frac{u}{\sqrt{2}}$$

10. Official Ans. by NTA (10.00)

Sol.



By momentum conservation along y :

$m_1u_1\sin\theta_1 = m_2u_2\sin\theta_2$

i.e. $mu_1\sin\theta_1 = 10mu_2\sin\theta_2$

$$\Rightarrow \boxed{u_1\sin\theta_1 = 10u_2\sin\theta_2} \quad .....(i)$$

$$kf_{m_1} = \frac{1}{2}ki_{m_1} \quad \text{i.e. } \frac{1}{2}mu_1^2 = \frac{1}{2}\times\frac{1}{2}mu^2$$

$$\text{i.e. } \boxed{u_1 = \frac{u}{\sqrt{2}}} \quad .....(ii)$$

Also collision is elastic : $k_i = k_f$

$$\frac{1}{2}mu^2 = \frac{1}{2}mu_1^2 + \frac{1}{2}.10m.u_2^2$$

$$\frac{1}{2}mu^2 = \frac{1}{2}\times\frac{1}{2}mu^2 + \frac{1}{2}\times10m.u_2^2$$

$$\frac{1}{4}mu^2 = \frac{1}{2}\times10\times mu_2^2$$

$$\boxed{u_2 = \frac{u}{\sqrt{20}}} \quad ....(iii)$$

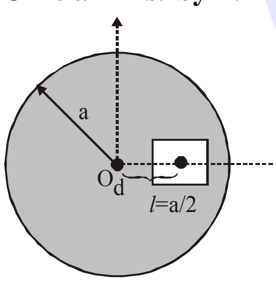
Putting (ii) & (iii) in (i)

$$\frac{u}{\sqrt{2}}\sin\theta_1 = 10.\frac{u}{\sqrt{20}}\sin\theta_2$$

$$\boxed{\sin\theta_1 = \sqrt{10}\sin\theta_2} \rightarrow \text{Hence } n = 10$$

11. Official Ans. by NTA (23.00)

Sol.



$$X_{com} = \frac{m_1x_1 - m_2x_2}{m_1 - m_2}$$

where :

- m_1 = mass of complete disc
- m_2 = removed mass
- Let σ = surface mass density of disc material

$$\text{wrt 'O' : } X_{com} = \frac{\sigma\pi a^2(O) - \sigma.\frac{a^2}{4}.d}{\sigma\pi a^2 - \sigma\frac{a^2}{4}} = \frac{-\frac{a^2}{4}d}{\pi a^2 - \frac{a^2}{4}}$$

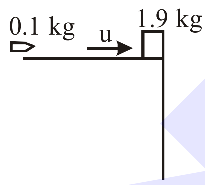
$$= \frac{-d}{4\pi - 1} = -\frac{a}{2(4\pi - 1)}$$

So, X = 2(4π–1) = (8π–2) = 23.12

So, nearest integer value of X = 23

12. Official Ans. by NTA (1)

Sol.



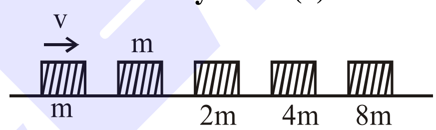
$p_i = p_f \Rightarrow 0.1 \times 20 = 2v$

$\therefore$ v = 1 m/s

$$KE_f = mgh + \frac{1}{2}mv^2 = 213$$

13. Official Ans. by NTA (4)

Sol.



All collisions are perfectly inelastic, so after the final collision, all blocks are moving together. So let the final velocity be v', so on applying momentum conservation:

mv = 16m v' ⇒ v' = v/16

$$\text{Now initial energy } E_i = \frac{1}{2}mv^2$$

$$\text{Final energy : } E_f = \frac{1}{2}\times16m\times\left(\frac{v}{16}\right)^2$$

$$\Rightarrow E_f = \frac{1}{2}m\frac{v^2}{16}$$

$$\text{Energy loss : } E_i - E_f \quad \Rightarrow \frac{1}{2}mv^2 - \frac{1}{2}m\frac{v^2}{16}$$

$$\Rightarrow \frac{1}{2}mv^2\left[1 - \frac{1}{16}\right] \Rightarrow \frac{1}{2}mv^2\left[\frac{15}{16}\right]$$

$$\%p = \frac{\text{Energy loss}}{\text{Original energy}}\times100$$

$$= \frac{\frac{1}{2}mv^2\left[\frac{15}{16}\right]}{\frac{1}{2}mv^2}\times100 = 93.75\%$$

⇒ Value of P is close to 94.

14. Official Ans. by NTA (4)

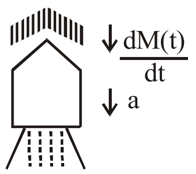
Sol. $\frac{dm(t)}{dt} = bv^2$

$F_{thast} = v\frac{dm}{dt}$

Force on statellile = $-\vec{v}\frac{dm(t)}{dt}$

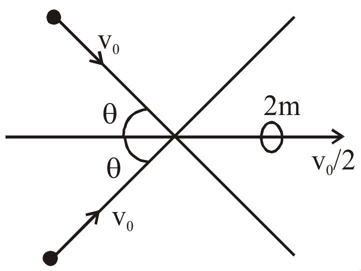
M(t) a = – v (bv^2)

$$\boxed{a = a\frac{bv^3}{M(t)}}$$



15. Official Ans. by NTA (120.00)

Sol.



Momentum conservation along x

$2mv_0\cos\theta = 2m\frac{v_0}{2}$

$\cos\theta = \frac{1}{2}$

θ = 60

Angle is 2θ = 120

Ans. 120.00

16. Official Ans. by NTA (4)

Sol. $\vec{v}_{01} = (\sqrt{3}\hat{i} + \hat{j})\ m/s$

$\vec{v}_{02} = \vec{0}$

$m_1 = 2m_2$

After collision, $\vec{v}_1 = (\hat{i} + \sqrt{3}\hat{j})\ m/s$

$\vec{v}_2 = ?$

Applying conservation of linear momentum,

$m_1\vec{v}_{01} + m_2\vec{v}_{02} = m_1\vec{v}_1 + m_2\vec{v}_2$

$2m_2(\sqrt{3}\hat{i} + \hat{j}) + 0 = 2m_2(\hat{i} + \sqrt{3}\hat{j}) + m_2\vec{v}_2$

$\vec{v}_2 = 2(\sqrt{3}\hat{i} + \hat{j}) - 2(\hat{i} + \sqrt{3}\hat{j})$

$= 2(\sqrt{3}\hat{i} - \hat{j}) + 2(\hat{i} - \sqrt{3}\hat{j})$

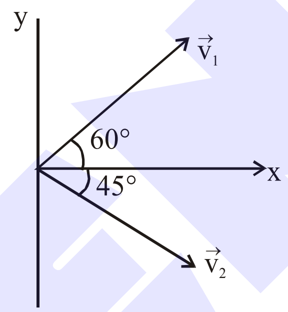
$\vec{v}_2 = 2(\sqrt{3} - 1)(\hat{i} - \hat{j})$

for angle between $\vec{v}_1$ & $\vec{v}_2$,

$\cos\theta = \frac{\vec{v}_1 . \vec{v}_2}{v_1 v_2} = \frac{2(\sqrt{3}-1)(1-\sqrt{3})}{2\times 2\sqrt{2}(\sqrt{3}-1)}$

$\cos\theta = \frac{1-\sqrt{3}}{2\sqrt{2}} \Rightarrow \theta = 105°$

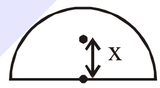
or



17. Official Ans. by NTA (3.00)

Sol. $x = \frac{3R}{8} = 3cm$

x = 3

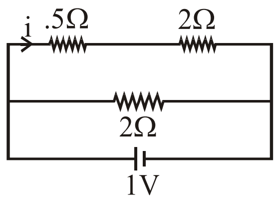


CURRENT ELECTRICITY

1. NTA Ans. (2)

Sol. Equivalent resistance of upper branch of circuit

R = 2.5 Ω



Voltage across upper branch = 1 V

$\Rightarrow\ i = \frac{1}{2.5} = .4\ A$

$\Rightarrow I_1 = 0.2\ A$

2. NTA Ans. (4)

Sol. $220\,I = P = 15\times 45 + 15\times 100 + 15\times 10 + 2\times 10^3$

$I = \frac{4325}{220} = 19.66$

I ≃ 20 A

3. NTA Ans. (12)

Sol. $r = R\left(\dfrac{x - x'}{x'}\right)$

$= 10 \times \dfrac{60}{500} = 12$

4. NTA Ans. (4)

Sol. $5 = \lambda\ell$

where λ is potential gradient & L is total length of wire.

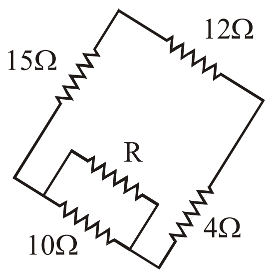
$5 = \dfrac{\Delta V}{L}\ell$

$\Delta V = \dfrac{5 \times L}{\ell} = 5 \times \dfrac{12}{10} = 6V = 60 \text{ mA} \times R$

$R = 100\Omega$

5. NTA Ans. (10.00)

Sol.



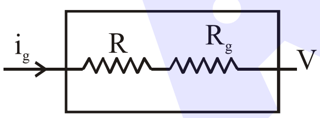
Let the resistance to be connected is R.
For balanced wheatstone bridge,

$15 \times 4 = 12 \times \dfrac{10R}{10 + R}$

$\Rightarrow R = 10\Omega$

6. NTA Ans. (1)

Sol. $i_g = 1$ mA , $R_g = 100\ \Omega$



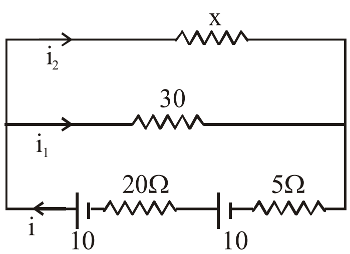
$V = i_g(R + R_g)$

$10 = 1 \times 10^{-3}\ (R + 100)$

$R = 9.9\ k\Omega$

7. NTA Ans. (30)

Sol.



$E_1 = E - ir$
$= 10 - i20 = 0$

$E_2 = E - ir$
$= 10 - 0.5 \times 5$

$i = 0.5$ A
$= 7.5$ V

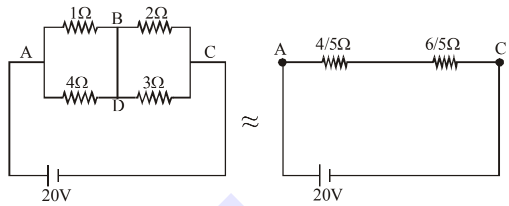
$E_{net} = E_1 + E_2 = 7.5V$

$i = i_1 + i_2$

$0.5 = \dfrac{7.5}{x} + \dfrac{7.5}{30}$ $x = 30\ \Omega$

8. NTA Ans. (2)

Sol.



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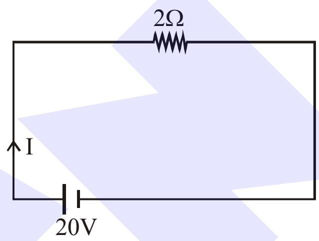
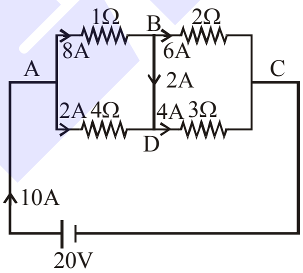


$\Rightarrow I = \dfrac{20}{2} = 10A$

Now,



9. NTA Ans. (40.00)

Sol. In balancing

$\dfrac{R}{S} = \dfrac{25}{75}$

New resistance $R' = \dfrac{\rho\ell}{A}$

$= \dfrac{\rho \times \dfrac{\ell}{2}}{\dfrac{A}{4}} = \dfrac{\rho\ell}{2} \times 4A$

$R' = 2R$

$\dfrac{2R}{S} = \dfrac{\ell'}{100 - \ell'}$

$2 \times \dfrac{1}{3} = \dfrac{\ell'}{100 - \ell'} = 3\ell' = 200 - 2\ell'$

$5\ell' = 200$

$\ell' = 40$

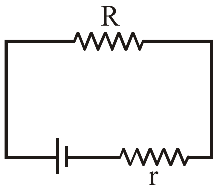
$\therefore$ Correct answer 40

10. Official Ans. by NTA (4)

Sol. $\rho_M > \rho_A > \rho_C$

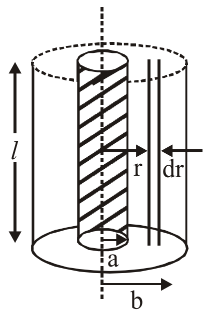
11. Official Ans. by NTA (4)

Sol. Maximum power in external resistance is generated when it is equal to internal resistance of battery.



$$P_R = \left(\frac{\in}{r+R}\right)^2 R$$

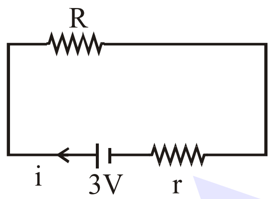
P_R is max. when r = R



$$\int dr = \int_a^b \frac{\rho dr}{2\pi r l} \Rightarrow r = \frac{\rho}{2\pi l} ln \frac{b}{a}$$

12. Official Ans. by NTA (4)

Sol.



$P_R = 0.5W$

$\Rightarrow i^2R = 0.5W$

Also, V = E – ir

2.5 = 3 – ir

$\Rightarrow$ ir = 0.5

Power dissipated across 'r' : $P_r = i^2r$

Now iR = 2.5

ir = 0.5

On dividing : $\frac{R}{r} = 5$

Now $\frac{P_R}{P_r} = \frac{i^2R}{i^2r} \Rightarrow \frac{P_R}{P_r} = \frac{R}{r} \Rightarrow \frac{P_R}{P_r} = 5$

$\Rightarrow P_r = \frac{P_R}{5}$

$\Rightarrow P_r = \frac{0.50}{5} \Rightarrow P_r = 0.10$ W

option (4) is correct.

13. Official Ans. by NTA (4)

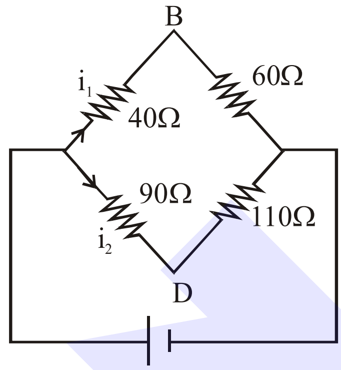
Sol. Voltage across AC = 8V

$R_{AC} = 4 + 4 = 8\Omega$

$$i_1 = \frac{V}{R_{AC}} = \frac{8}{8} = 1 \text{ A}$$

14. Official Ans. by NTA (2)

Sol.



$$i_1 = \frac{40}{40+60} = 0.4$$

$$i_2 = \frac{40}{90+110} = \frac{1}{5}$$

$v_B + i_1 (40) - i_2 (90) = v_D$

$$v_B - v_D = \frac{1}{5}(90) - \frac{4}{10} \times 40$$

$v_B - v_D = 18 - 16 = 2$

15. Official Ans. by NTA (2)

Sol. vi = 10^3

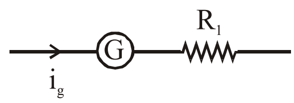
$$i = \frac{1000}{220}$$

$$\text{loss} = i^2R = \left(\frac{50}{11}\right)^2 \times 2$$

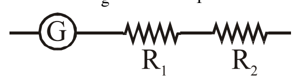
$$\text{efficiency} = \frac{1000}{1000 + i^2R} \times 100 = 96\%$$

16. Official Ans. by NTA (2)

Sol.



$\Rightarrow 1 = i_g(G + R_1)$ ... (1)



$\Rightarrow 2 = i_g(R_1 + R_2 + G)$ ...(2)

(1) % (2)

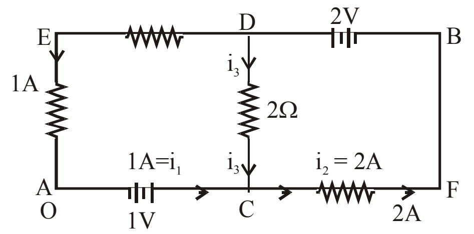
$$\Rightarrow \frac{1}{2} = \frac{G + R_1}{G + R_1 + R_2}$$

$G + R_1 + R_2 = 2G + 2h_1$

$(R_2 = G + R_1)$

17. Official Ans. by NTA (1)

Sol.



Let us asssume the potential at A = V_A = 0

Now at junction C, According to KCL

$i_1 + i_3 = i_2$

$1A + i_3 = 2A$

$i_3 = 2A$

Now Analyse potential along ACDB

$v_A + 1 + i_3(2) - 2 = v_B$

$0 + 1 + 2(1) - 2 = v_B$

$v_B = 3 - 2$

$v_B = 1$ Amp

18. Official Ans. by NTA (1)

Sol. Figure of Merit = C = $\frac{i}{\theta}$

$= C = \frac{6\times10^{-3}}{2} = 3\times10^{-3}\,Am^2$

19. Official Ans. by NTA (1)

Sol. Conceptual

Option (1) is correct

Ammeter :- In series connection, the same current flows through all the components. It aims at measuring the curent flowing through the circuit and hence, it is connected in series.

Voltmeter :- A voltmeter measures voltage change between two points in a circuit, So we have to place the voltmeter in parallal with the circuit component.

20. Official Ans. by NTA (3)

Sol. $E_{eq} = \frac{20\times10}{17} = \frac{200}{17}$

and $R_{eq} = \frac{7\times10}{17} = \frac{70}{17}$

21. Official Ans. by NTA (1)

Sol. Balancing length is measured from P.

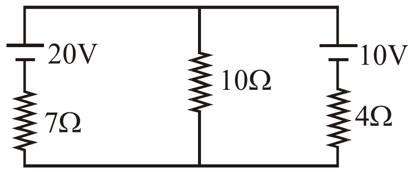
So 100 – 49 = 51 cm

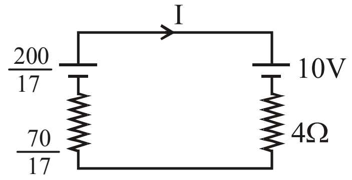
$E_2 = \phi \times 51$

Where ϕ = Potential gradient

$1.02 = \phi \times 51$

$\phi = 0.02$ V/cm





$\therefore \quad I = \frac{\frac{20}{17} - 10}{4 + \frac{70}{17}} = 0.21$ A

from +ve to –ve terminal

ELASTICITY

1. NTA Ans. (4.00)

Sol. $T = m\omega^2\ell$

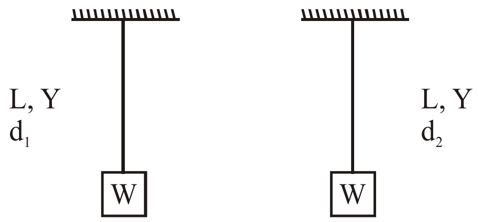
Breaking stress = $\frac{T}{A} = \frac{m\omega^2\ell}{A}$

$\Rightarrow \omega^2 = \frac{4.8\times10^7\times(10^{-2}\times10^{-4})}{10\times0.3} = 16$

$\Rightarrow \omega = 4$

2. NTA Ans. (4)

Sol.



$\frac{\text{Energy stored}}{\text{Volume}} = \frac{1}{2}\frac{(\text{Stress})^2}{Y}$

$\frac{u_1}{u_2} = \frac{1}{4} \Rightarrow 4u_1 = u_2$

$4\frac{1}{2Y}\left[\frac{W\cdot4}{\pi d_1^2}\right]^2 = \frac{1}{2Y}\left[\frac{W\cdot4}{\pi d_2^2}\right]^2$

$4 = \left(\frac{d_1}{d_2}\right)^4$

$\Rightarrow \frac{d_1}{d_2} = \sqrt{2}:1$

$\therefore$ Correct answer (4)

3. NTA Ans. (750.00)

Sol. The length of the screen used portion for 15 fringes, and also for ten fringes

$$15\times 500\times \frac{D}{\lambda}=10\times \frac{\lambda D}{\lambda}$$

$15 \times 50 = \lambda$

$\lambda = 750$ nm

$\therefore$ Correct answer 750

4. Official Ans. by NTA (2)

Sol. $B = \dfrac{-\Delta P}{\dfrac{\Delta V}{V}}$

$$\left|\frac{\Delta V}{V}\right|=\frac{\Delta P}{B}$$

$$=\frac{4\times 10^9}{8\times 10^{10}}=\frac{1}{20}$$

$$\frac{\Delta \ell}{\ell}=\frac{1}{3}\times \frac{\Delta V}{V}=\frac{1}{60}$$

Percentage change $= \dfrac{\Delta \ell}{\ell}\times 100\%$

$$=\frac{100}{60}\%=1.67\%$$

5. Official Ans. by NTA (1)

Sol. An elastic wire can be treated as a spring with

$$k=\frac{YA}{\ell}$$

$$T=2\pi\sqrt{\frac{m}{k}}$$

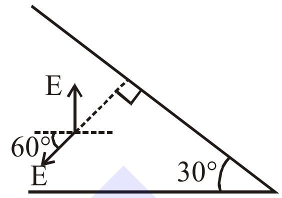
$$f=\frac{1}{2\pi}\sqrt{\frac{k}{m}}=\frac{1}{2\pi}\sqrt{\frac{YA}{m\ell}}$$

Ans. (1)

ELECTROSTATICS

1. NTA Ans. (2)

Sol. Electric field due to each sheet is uniform and equal to $E=\dfrac{\sigma}{2\varepsilon_0}$



Now net electric field between plates

$$\vec{E}_{net}=E\cos 60°(-\hat{x})+(E-E\sin 60°)(\hat{y})$$

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

2. NTA Ans. (4)

Sol. $|\vec{E}|$ should be constant on the surface and the surface should be equipotential.

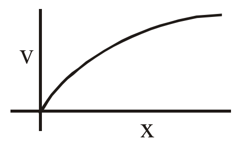
3. NTA Ans. (4)

Sol. $E_x=\dfrac{K(4q)}{R^2}\cos 30°+\dfrac{K(2q)}{R^2}\cos 30°+\dfrac{K(2q)}{R^2}\cos 30°$

4. NTA Ans. (3)

Sol. $v^2 = u^2 + 2as$

$v^2 = 0 + 2\left(\dfrac{qE}{m}\right)x$



$v^2 = \dfrac{2qE}{m}x$

5. NTA Ans. (4)

Sol. $E_1 = \dfrac{KQ_1}{R_1^2}$ $\qquad E_2 = \dfrac{KQ_2}{R_2^2}$

Given,

$$\frac{E_1}{E_2}=\frac{R_1}{R_2}$$

$$\frac{\dfrac{KQ_1}{R_1^2}}{\dfrac{KQ_2}{R_2^2}}=\frac{R_1}{R_2}\quad\Rightarrow\quad \boxed{\frac{Q_1}{Q_2}=\frac{R_1^3}{R_2^3}}$$

$$\frac{V_1}{V_2}=\frac{KQ_1/R_1}{KQ_2/R_2}=\frac{R_1^2}{R_2^2}$$

6. NTA Ans. (4)

Sol. Fill the empty space with $+\rho$ and $-\rho$ charge density.

$$|E_A| = 0 + \frac{k\rho.\frac{4}{3}\pi\left(\frac{R}{2}\right)^3}{\left(\frac{R}{2}\right)^2} = k\rho\frac{4}{3}\pi\left(\frac{R}{2}\right)$$

$$|E_B| = \frac{k\rho.\frac{4}{3}\pi R^3}{R^2} - \frac{k\rho.\frac{4}{3}\pi\left(\frac{R}{2}\right)^3}{\left(\frac{3R}{2}\right)^2}$$

$$= k\rho\frac{4}{3}\pi R - k\rho\frac{4}{3}\pi\frac{R}{18} = k\rho.\frac{4}{3}\pi\left(\frac{17R}{18}\right)$$

$$\frac{E_A}{E_B} = \frac{9}{17} = \frac{18}{34}$$

7. NTA Ans. (3)

Sol. Since $\vec{r}$ and $\vec{p}$ are perpendicular to each other therefore point lies on the equitorial plane. Therefore electric field at the point will be antiparallel to the dipole moment.

i.e. $\vec{E} \parallel -\vec{p}$

$$\vec{E} \parallel (\hat{i} + 3\hat{j} - 2\hat{k})$$

8. NTA Ans. (-48.00)

Sol. The flux passes through ABCD $(x - y)$ plane is zero, because electric field parallel to surface.

Flux of the electric field through surface BCGF (y - z)

At BCGF (electric field) $\Rightarrow \vec{E} = 12\hat{i} - \left(y^2 + 1\right)\hat{j}$

$(x = 3m)$

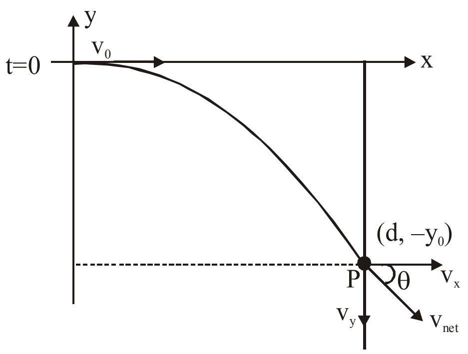
Flux $\phi_{II} = 12 \times 4 = 48\ Nm^2/C$

So $\phi_I - \phi_{II} = 0 - 48 = -48\ Nm^2/C$

$\therefore$ Correct answer –48

9. Official Ans. by NTA (1)

Sol.



Let particle have charge q and mass 'm'

Solve for (q,m) mathematically

$F_x = 0$, $a_x = 0$, $(v)_x$ = constant

time taken to reach at 'P' $= \frac{d}{v_0} = t_0$ (let) ...(1)

(Along –y), $y_0 = 0 + \frac{1}{2}.\frac{qE}{m}.t_0^2$ ....(2)

$v_x = v_0$

$v = u + at$ (along -ve 'y')

speed $v_{y0} = \frac{qE}{m}.t_0$

$$\tan\theta = \frac{v_y}{v_x} = \frac{qEt_0}{m.v_0}, (t_0 = \frac{d}{v_0})$$

$$\tan\theta = \frac{qEd}{m.v_0^2}$$

$$\boxed{\text{slope} = \frac{-qEd}{mv_0^2}}$$

Now we have to find eq^n of straight line whose slope is $\frac{-qEd}{mv_0^2}$ and it pass through point $\rightarrow (d, -y_0)$

Because after $x > d$

No electric field $\Rightarrow F_{net} = 0$, $\vec{v}$ = const.

$$y = mx + c \ , \left\{ \begin{matrix} m = \frac{qEd}{mv_0^2} \\ (d, -y_0) \end{matrix} \right\}$$

$$-y_0 = \frac{-qEd}{mv_0^2}.d + c \Rightarrow c = -y_0 + \frac{qEd^2}{mv_0^2}$$

Put the value

$$y = \frac{-qEd}{mv_0^2}x - y_0 + \frac{qEd^2}{mv_0^2}$$

$$y_0 = \frac{1}{2}.\frac{qE}{m}\left(\frac{d}{v_0}\right)^2 = \frac{1}{2}\frac{qEd^2}{mv_0^2}$$

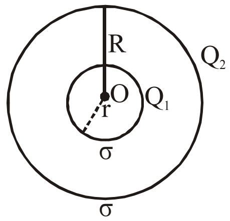
$$y = \frac{-qEdx}{mv_0^2} - \frac{1}{2}\frac{qEd^2}{mv_0^2} + \frac{qEd^2}{mv_0^2}$$

$$y = \frac{-qEd}{mv_0^2}x + \frac{1}{2}\frac{qEd^2}{mv_0^2}$$

$$\boxed{y = \frac{qEd}{mv_0^2}\left(\frac{d}{2} - x\right)}$$

10. Official Ans. by NTA (3)

Sol. Let the charges on inner and outer spheres are Q_1 and Q_2.



Since charge density 'σ' is same for both spheres, so

$$\sigma = \frac{Q_1}{4\pi r^2} = \frac{Q_2}{4\pi R^2} \Rightarrow \frac{Q_1}{Q_2} = \frac{r^2}{R^2}$$

$$Q_1 + Q_2 = Q \Rightarrow \frac{Q_2 r^2}{R^2} + Q_2 = Q$$

$$\Rightarrow Q_2 = \frac{QR^2}{(r^2+R^2)}$$

$$Q_1 = \frac{r^2}{R^2}\cdot\frac{QR^2}{(R^2+r^2)} = \frac{Qr^2}{(R^2+r^2)}$$

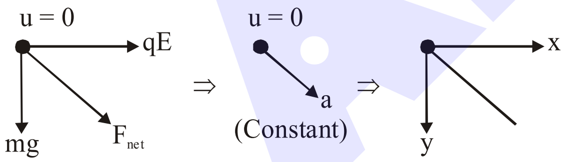
Potential at centre 'O' $= \dfrac{kQ_1}{r} + \dfrac{kQ_2}{R}$

$$= k\left[\frac{Qr^2}{r(R^2+r^2)} + \frac{QR^2}{R(R^2+r^2)}\right]$$

$$= \frac{kQ(r+R)}{(R^2+r^2)} = \frac{1}{4\pi\epsilon_0}\frac{(R+r)}{(R^2+r^2)}Q$$

11. Official Ans. by NTA (4)

Sol.



Since initial velocity is zero and acceleration of particle will be constant, so particle will travel on a straight line path.

12. Official Ans. by NTA (1)

Sol. Now

$Q_1 + Q_2 = Q'_1 + Q'_2 = 12\ \mu C - 3\ \mu C = 9\ \mu C$

& $V_1 = V_2 \Rightarrow \dfrac{KQ'_1}{\frac{2R}{3}} = \dfrac{KQ'_2}{\frac{R}{3}}$

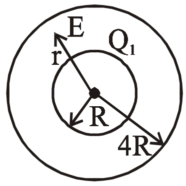
$Q'_1 = 2Q'_2 \Rightarrow 2Q'_2 + Q'_2 = 9\mu C$

$\Rightarrow Q'_2 = 3\ \mu C$

& $Q'_1 = 6\ \mu C$

13. Official Ans. by NTA (1)

Sol.



$$E = \frac{KQ_1}{r^2}$$

$$\Delta V = \int_R^{4R} E\,dr = \frac{3KQ_1}{4R}$$

14. Official Ans. by NTA (1)

Sol. (1) Multimeter shows deflection when it connects with capacitor

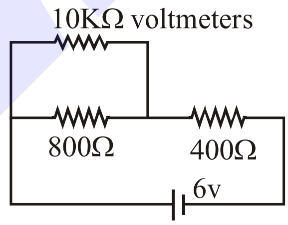
(2) If we assume that LED has negligiable resistance then multimeter shows no deflection for the forward blas but when it connects in reverse direction, it break down occurs so splash of light out.

(3) The resistance of metal wire may be taken zero, so no deflection in multimeter

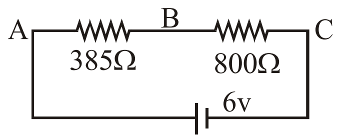
(4) No matter, how we connect the resistance across multimeter It shows same deflection.

15. Official Ans. by NTA (2)

Sol.



⇒



So the potential difference in voltmeter across the points A and B is $\dfrac{6}{1185}\times 385 = 1.949\ V$

16. Official Ans. by NTA (3)

Sol. Potential of –q is same as initial and final point of the path therefore potential due to 4q will only change and as potential is decreasing the energy will decrease

Decrease in potential energy = q ($V_i - V_f$)

Decrease in potential energy

$$= q\left[\frac{k4q}{d/2} - \frac{k4q}{3d/2}\right] = \frac{4q^2}{3\pi\varepsilon_0 d}$$

Therefore correct answer is 3.

17. Official Ans. by NTA (1)

Sol. Thin infinite uniformly charged planes produces uniform electric field therefore option 2 and option 3 are obviously wrong.

And as positive charge density is bigger in magnitude so its field along Y direction will be bigger than field of negative charge in X direction and this is evident in option 1 so it is correct.

18. Official Ans. by NTA (4)

Sol. $E = E_0 (1 - ax^2)$

$$W = \int qE\, dx = qE_0 \int_0^{x_0} (1 - ax^2)\, dx$$

$$= qE_0 \left[x_0 - \frac{ax_0^3}{3} \right]$$

For $\Delta KE = 0$, $W = 0$

Hence $x_0 = \sqrt{\frac{3}{a}}$

19. Official Ans. by NTA (1)

Sol. $\frac{kQq}{R} + mgy$

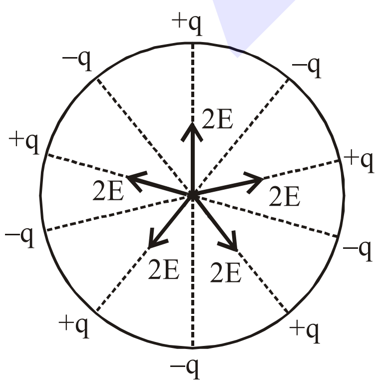
$$= \frac{kQq}{R+y} + \frac{1}{2}mv^2$$

$$v^2 = 2gy + \frac{2kQqy}{mR(R+y)}$$

20. Official Ans. by NTA (3)

Sol. Potential of centre = V = $\Sigma\left(\frac{kq}{R}\right)$

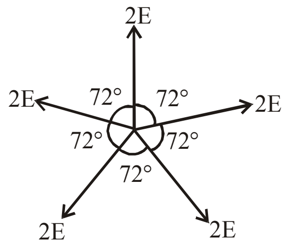
$$V_C = \frac{K(\Sigma q)}{R}$$



$$V_C = \frac{K(0)}{R} = 0$$

Electric field at centre $\vec{E}_B = \Sigma \vec{E}$

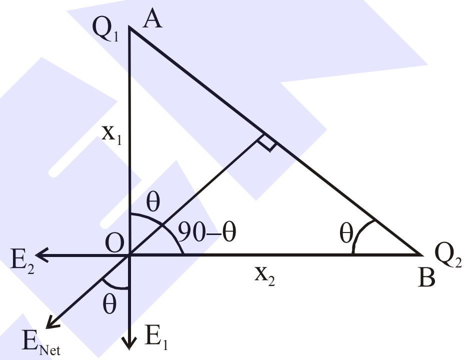
Let E be electric field produced by each charge at the centre, then resultant electric field will be



$E_C = 0$, Since equal electric field vectors are acting at equal angle so their resultant is equal to zero.

21. Official Ans. by NTA (3)

Sol.



E_2 = electric field due to Q_2

$$= \frac{kQ_2}{x_2^2}$$

$$E_1 = \frac{kQ_1}{x_1^2}$$

From diagram

$$\tan\theta = \frac{E_2}{E_1} = \frac{x_1}{x_2}$$

$$\frac{kQ_2}{x_2^2 \times \frac{kQ_1}{x_1^2}} = \frac{x_1}{x_2}$$

$$\frac{Q_2 x_1^2}{Q_1 x_2^2} = \frac{x_1}{x_2}$$

$$\frac{Q_2}{Q_1} = \frac{x_2}{x_1}$$

$$\frac{Q_1}{Q_2} = \frac{x_1}{x_2}$$

Ans. (3)

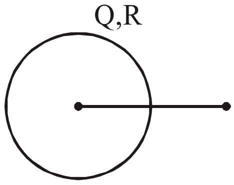
22. Official Ans. by NTA (1)

Sol. Inside the shell

E = 0

hence F = 0

Oustside the sheell



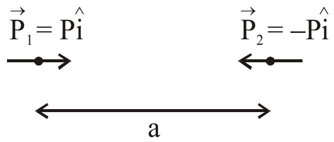
$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

hence $F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$ for r > R

23. Official Ans. by NTA (3)

Sol. Using energy conservation:

$KE_i + PE_i = KE_f + PE_f$



$$O + \frac{2KP}{a^3} \times P = \frac{1}{2}mv^2 \times 2 + 0$$

$$V = \sqrt{\frac{2P^2}{4\pi\varepsilon_0 a^3 m}} = \frac{P}{a}\sqrt{\frac{1}{2\pi\varepsilon_0 am}}$$

EM WAVE

1. NTA Ans. (1)

Sol. $\vec{E} \times \vec{B} = \vec{C} = -\hat{i}$

where $\vec{B}$ is along $\hat{j}$

$$\frac{E}{B} = C$$

E = 3 × 10^{-8} × 3 × 10^8 = 9 V/m.

2. NTA Ans. (3)

Sol. $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$

$$\vec{E} = E_0\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)\cos\pi$$

$$= -E_0\frac{\hat{i}+\hat{j}}{\sqrt{2}}$$

as $\vec{E} \times \vec{B} = \vec{c}$

$$+E_0\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right) \times \vec{B} = c\hat{k}$$

$$\Rightarrow \vec{B} = -\left(\frac{\hat{i}-\hat{j}}{\sqrt{2}}\right)\frac{E_0}{c}$$

$$\vec{F} = q\left(-E_0\frac{(\hat{i}+\hat{j})}{\sqrt{2}} - \frac{v_0\hat{k}}{c} \times (\hat{i}-\hat{j})E_0\right)$$

since $\frac{v_0}{c} << 1$

$\Rightarrow$ F is antiparallel to $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

3. NTA Ans. (2)

Sol. E = $\vec{B} \times \vec{V}$

$= (5 \times 10^{-8}\hat{j}) \times (3 \times 10^8\hat{k})$

$= 15\,\hat{i}$ V / m

4. NTA Ans. (3)

Sol. $\vec{E}_1 = E_0\hat{j}\cos(\omega t - kx)$

Its corresponding magnetic field will be

$$\vec{B}_1 = \frac{E_0}{c}\hat{k}\cos(\omega t - kx)$$

$$\vec{E}_2 = E_0\hat{k}\cos(\omega t - ky)$$

$$\vec{B}_2 = \frac{E_0}{c}\hat{i}\cos(\omega t - ky)$$

Net force on charge particle

$$= q\vec{E}_1 + q\vec{E}_2 + q\vec{v} \times B_1 + q\vec{v} \times \vec{B}_2$$

$$= qE_0\hat{j} + qE_0\hat{k} + q(0.8c\hat{j}) \times \left(\frac{E_0}{c}\hat{k}\right) + q(0.8c\hat{j}) \times \left(\frac{E_0}{c}\hat{i}\right)$$

$$= qE_0\hat{j} + qE_0\hat{k} + 0.8qE_0\hat{i} - 0.8qE_0\hat{k}$$

$$\vec{F} = qE_0[0.8\hat{i} + 1\hat{j} + 0.2\hat{k}]$$

5. Official Ans. by NTA (2)

Sol. Energy density $\frac{dU}{dV} = \frac{B_0^2}{2\mu_0}$

$$1.02 \times 10^{-8} = \frac{B_0^2}{2 \times 4\pi \times 10^{-7}}$$

$$B_0^2 = (1.02 \times 10^{-8}) \times (8\pi \times 10^{-7})$$

B_0 = 16 × 10^{-8} T = 160 nT

6. Official Ans. by NTA (1)

Sol. $\hat{E} = \hat{k}$

$$\vec{B} = 2\hat{i} - 2\hat{j} \Rightarrow \hat{B} = \frac{\vec{B}}{|B|} = \frac{2\hat{i}-2\hat{j}}{2\sqrt{2}}$$

$$\Rightarrow \hat{B} = \frac{1}{\sqrt{2}}(\hat{i}-\hat{j})$$

Direction of wave propagation $= \hat{C} = \hat{E} \times \hat{B}$

$$\hat{C} = \hat{k} \times \left[\frac{1}{\sqrt{2}}(\hat{i}-\hat{j})\right]$$

$$\hat{C} = \frac{1}{\sqrt{2}}(\hat{k}\times\hat{i} - \hat{k}\times\hat{j})$$

$$\hat{C} = \frac{1}{\sqrt{2}}(\hat{i}+\hat{j})$$

7. Official Ans. by NTA (2)

Sol. $\vec{B} = 3\times10^{-8}\sin[200\pi(y+ct)]\hat{i}$ T

$E_0 = CB_0 \Rightarrow E_0 = 3\times10^{8}\times3\times10^{-8}$

$= 9$ V/m

and direction of wave propagation is given as

$(\vec{E}\times\vec{B}) \| \vec{C}$

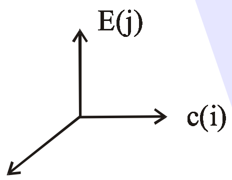
$\hat{B} = \hat{i}$ & $\hat{C} = -\hat{j}$

so $\hat{E} = -\hat{k}$

$\therefore \vec{E} = E_0 \sin[200\pi(y+ct)](-\hat{k})$ V / m

8. Official Ans. by NTA (3)

Sol.



$\therefore \vec{B}(\hat{k})$

$\Rightarrow \vec{B} = B_0\cos(wt-kx)\hat{k}$

Now put t = 0.

9. Official Ans. by NTA (3)

Sol. Information based

$\lambda_{radiowaves} > \lambda_{microwaves} > \lambda_{visible} > \lambda_{x\text{-}rays}$

10. Official Ans. by NTA (2)

Sol. $\vec{E} = E_0(\hat{x}+\hat{y})\sin(kz-\omega t)$

direction of propagation $= +\hat{k}$

$$\hat{E} = \frac{\hat{i}+\hat{j}}{\sqrt{2}}$$

$$\hat{k} = \hat{E}\times\hat{B}$$

$$\hat{k} = \left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)\times\hat{B} \qquad \Rightarrow \hat{B} = \frac{-\hat{i}+\hat{j}}{\sqrt{2}}$$

$$\therefore \vec{B} = \frac{E_0}{C}(-\hat{x}+\hat{y})\sin(kz-\omega t)$$

11. Official Ans. by NTA (2)

Sol. $\Rightarrow$E= $\vec{E} = 30\hat{j}\sin(1.5\times10^{7}t - 5\times10^{-2}x)$V / m

$\Rightarrow B \Rightarrow E/V \Rightarrow \dfrac{30}{1.5\times10^{7}}\times5\times10^{-2}$

$\Rightarrow 10^{-7}$ Tesla

$\Rightarrow F_{mag} = q(\vec{V}\times\vec{B}) = |qVB|$

$= 1.6\times10^{-19}\times0.1\times 3\times10^{8}\times10^{-7}$

$= 4.8\times10^{-19}$ N

12. Official Ans. by NTA (4)

Sol. Energes of given Radiation can have The following relation

$E_{\gamma\text{-Rays}} > E_{X\text{-Rays}} > E_{microwave} > E_{AM\ Radiowaves}$

$\therefore \lambda_{\gamma\text{-Rays}} < \lambda_{X\text{-Rays}} < \lambda_{microwave} < \lambda_{AM\ Radiowaves}$

According To tres.

(a) Microwave $\to 10^{-3}$m (iv)

(b) Gamma Rays $\to 10^{-15}$m (ii)

(c) AM Radio wave $\to$ 100 m (i)

(d) X-Rays $\to 10^{-10}$m (iii)

13. Official Ans. by NTA (275.00)

Allen Ans. (194.00)

Sol. $I = \epsilon_0 E_{rms}^2 C$

$$E_{rms}^2 = \frac{I}{\epsilon_0 C}$$

$$= \frac{315}{\pi\epsilon_0}\times\frac{1}{C}$$

$$= \frac{4\times315}{4\pi\epsilon_0}\times\frac{1}{3\times10^{8}}$$

$$= \frac{4\times315\times9\times10^{9}}{3\times10^{8}}$$

$E_{rms}^2 = 4\times315\times30$

$E_{rms} = 2\sqrt{315\times30}$

$= 194.42$

Ans. 194.00

14. Official Ans. by NTA (2)

Sol. $\vec{E}$ and $\vec{B}$ are perpendicular for EM wave

$E_0 = CB_0$

$= 3 \times 10^8 \times 1.2 \times 10^{-7}$

$= 36$

Having same phase

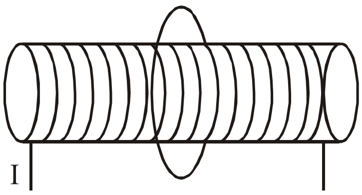
Propagation is along –x-axis, $\vec{B}$ is along z-axis hence $\vec{E}$ must be along y-axis.

So, option (2) is correct

EMI & AC

1. NTA Ans. (1)

Sol.



Magnetic flux (ϕ) through ring is $\phi = \pi(R)^2.B$

$\phi = (\pi R^2)(\mu_0 nI) = (\pi R^2\mu_0 nI_0)(t - t^2)$

Induced e.m.f. of $V_R = \frac{-d\phi}{dt}$

$= (\pi R^2\mu_0 nI_0)(2t - 1)$

and induced current $I_R = \frac{\pi R^2\mu_0 nI_0(2t-1)}{R_R}$

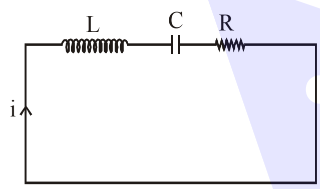
($R_R \to$ Resistance of Ring)

Clearly V_R and I_R are zero at $t = \frac{1}{2} = 0.5$ sec.

and their sign also changes at t = 0.5 sec.

2. NTA Ans. (1)

Sol.



By kVL

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

$$L\frac{d^2q}{dt^2} + \frac{1}{C}q + R\frac{dq}{dt} = 0$$

for damped oscillator

net force = –kx – bv = ma

$$\frac{md^2x}{dt^2} + kx + \frac{bdx}{dt} = 0$$

by comparing ; Equivalence is

$$L \to m\ ;\ C \to \frac{1}{K}\ ;\ R \to b.$$

3. NTA Ans. (1)

ALLEN Ans. (2)

Sol. $i = i_0(1 - e^{-Rt/L})$

$$\frac{i_0}{i} = \frac{1}{1 - e^{-2\times10^4}}$$

$$\frac{i_0}{i} \simeq 1$$

4. NTA Ans. (4)

Sol. Flux $\phi = \vec{B}\cdot\vec{A} = BA\cos\theta = BA\cos\omega t$

$|\text{Induced emf}| = |e| = \left|\frac{d\phi}{dt}\right| = |BA\omega\sin\omega t|$

$|e|$ will be maximum at $\omega t = \frac{\pi}{2}$

$$\left(\frac{2\pi}{T}\right)t = \frac{\pi}{2}$$

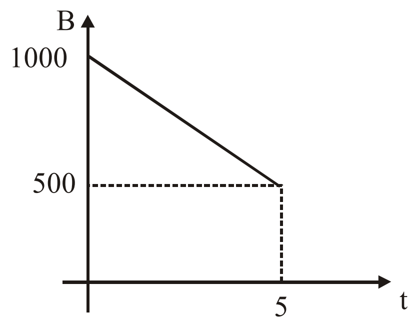
$$\left(\frac{2\pi}{10}\right)t = \frac{\pi}{2} \Rightarrow t = 2.5 \text{ sec}$$

$|e|$ will be minimum at $\omega t = \pi$

$$\left(\frac{2\pi}{10}\right)t = \pi \Rightarrow t = 5 \text{ sec}$$

5. NTA Ans. (3)

Sol.



$$\frac{dB}{dt} = 100$$

A = 16 ×4 – 4 × 2 = 56 cm²

$$\varepsilon = \frac{dB}{dt}A = 100\times10^{-4}\times56\times10^{-4}$$

6. NTA Ans. (4)

Sol. $i = i_0(1 - e^{-Rt/L}) = i_0(1 - e^{-t/T_C})$

$q = \int_0^{T_C} i\,dt \quad \Rightarrow = \int_0^{T_C} \frac{\varepsilon}{R}(1 - e^{-t/T_C})$

$= \frac{\varepsilon}{R}\left(t - \frac{e^{-t/T_C}}{-1/T_C}\right)\Bigg|_0^{T_C}$

$= \frac{e}{R}(T_C - T_C e^{-1}) - \frac{e}{R}(0 + T_C) \Rightarrow q = \frac{e}{R} \times T_C \; e^{-1}$

$= \frac{\varepsilon}{R} \times \frac{L}{R}\,\frac{1}{e} \quad \Rightarrow = \frac{\varepsilon L}{eR^2}$

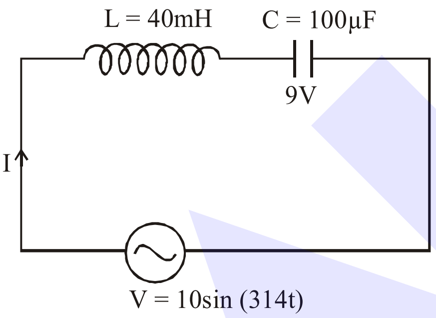
7. NTA Ans. (10.00)

Sol. $V = \left|L\frac{di}{dt}\right|$

$\Rightarrow L = \frac{V}{\left|\frac{di}{dt}\right|} = \frac{100}{\frac{0.25}{0.025 \times 10^{-3}}} = 10\text{mH}$

8. NTA Ans. (1)

Sol.

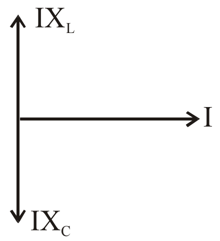


$X_L = \omega L = 314 \times 40 \times 10^{-3} = 12.56\Omega$

$X_C = \frac{1}{\omega C} = \frac{1}{314 \times 100 \times 10^{-6}}$

$= \frac{10^4}{314} = 31.84\Omega$

Phasor



$V_m = I_m(X_C - X_L)$

$10 = I_m(31.84 - 12.56)$

$I_m = \frac{10}{19.28} = 0.52\text{A}$

$I = 0.52 \sin\left(314t + \frac{\pi}{2}\right)$

∴ Correct answer (1)

9. Official Ans. by NTA (15)

Sol. $r = 0.1$ m $\quad \frac{T}{2} = 0.2$ sec

$B = 3 \times 10^{-5}$ m $\qquad T = 0.4$ sec

At any time

flux $\phi = BA \cos \omega t$

$|\text{emf}| = \left|\frac{d\phi}{dt}\right| = |BA\omega \sin \omega t|$

$(\text{emf})_{max} = BA\omega = BA\frac{2\pi}{T}$

$= \frac{3 \times 10^{-5} \times \pi \times (0.1)^2 \times 2\pi}{0.4}$

$= \frac{6\pi^2}{4} \times 10^{-6} \qquad \begin{pmatrix}\pi^2 \simeq 10 \\ \text{take}\end{pmatrix}$

$= 15 \times 10^{-6}$

$= 15\ \mu V$

10. Official Ans. by NTA (1)

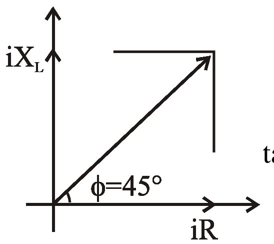
Sol.

- Reactance of inductance coil

$= \sqrt{R^2 + x_L^2} = 100 \qquad .....(i)$

- f = 1000 Hz of applied AC signal
- Voltage leads current by 45°

ie



$\tan 45° = \frac{iX_L}{iR} = \frac{\omega L}{R}$

ie $R = X_L = \omega L$

Putting in eqn (i) : $\sqrt{X_L^2 + X_L^2} = 100$

$\sqrt{2}X_L = 100 \Rightarrow X_L = 50\sqrt{2}$

ie $\omega L = 50\sqrt{2}$

$L = \frac{50\sqrt{2}}{\omega} = \frac{50\sqrt{2}}{2\pi f} = \frac{25\sqrt{2}}{\pi \times 1000}$ H

$= 1.125 \times 10^{-2}$ H

11. Official Ans. by NTA (3)

Sol. f = 750 Hz, V_{rms} = 20V,

R = 100 Ω, L = 0.1803 H,

C = 10 μF, S = 2 J/°C

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + (\omega L - 1/\omega C)^2}$$

$$= \sqrt{R^2 + \left(2\pi f L - \frac{1}{2\pi f C}\right)^2}$$

Putting values

|Z| = 834Ω

In AC power P = $V_{rms}\, i_{rms} \cos\phi$

$$\text{Cos}\phi = \frac{R}{|Z|} \qquad i_{rms} = \frac{V_{rms}}{|Z|}$$

$$= \frac{V_{rms}^2 R}{(|Z|)^2}$$

$$= \left(\frac{20}{834}\right)^2 \times 100 = 0.0575 \text{ J/s}$$

H = Pt = SΔθ

$$t = \frac{2(10)}{0.0575} = 348 \text{ sec}$$

12. Official Ans. by NTA (1)

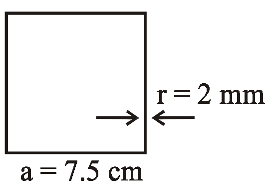
Sol. $\in = NAB\omega\cos\omega t$ $\boxed{N = 1}$

$$P_{avg} = <\frac{\in^2}{R}> = <\frac{(AB\omega\cos\omega t)^2}{R}>$$

$$= \frac{A^2B^2\omega^2}{R}\frac{1}{2} = \frac{\pi^2 a^2 b^2 B^2 \omega^2}{2R}$$

13. Official Ans. by NTA (1)

Sol.



$$q_i = \frac{d(Ba^2)}{dt} = a^2\frac{dB}{dt}$$

$$i = \frac{q}{R} = \frac{a^2 dB/dt}{\frac{\rho(40)}{\pi r^2}}$$

14. Official Ans. by NTA (3)

Sol. When bar magnet is entering with constant speed, flux will change and an e.m.f. is induced, so galvanometer will deflect in positive direction.

When magnet is completely inside, flux will not change, so reading of galvanometer will be zero.

When bar magnet is making on exit, again flux will change and on e.m.f. is induced in opposite direction to not of (a), so galvanometer will deflect in negative direction.

Looking at options, option (3) is correct.

15. Official Ans. by NTA (3)

Sol. $U_{max} = \frac{1}{2}LI_{max}^2$

$$i = I_{max}\left(1 - e^{-Rt/L}\right)$$

For U to be $\frac{U_{max}}{n}$; i has to be $\frac{I_{max}}{\sqrt{n}}$

$$\frac{I_{max}}{\sqrt{n}} = I_{max}(1 - e^{-Rt/L})$$

$$e^{-Rt/L} = 1 - \frac{1}{\sqrt{n}} = \frac{\sqrt{n} - 1}{\sqrt{n}}$$

$$-\frac{Rt}{L} = \ln\left(\frac{\sqrt{n} - 1}{\sqrt{n}}\right)$$

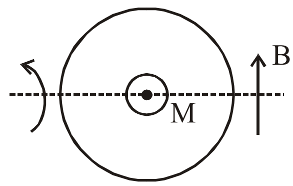
$$t = \frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n} - 1}\right)$$

16. Official Ans. by NTA (1)

Official Ans. by ALLEN (BONUS)

Sol. I_{dia} = 0.8 kg/m²

M = 20 Am²



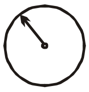
$U_i + K_i = U_f + K_f$

$$0 + 0 = -MB\cos 30° + \frac{1}{2}I\omega^2$$

$$20 \times 4 \times \frac{\sqrt{3}}{2} = \frac{1}{2}(0.8)\,\omega^2$$

$$\omega = \sqrt{100\sqrt{3}} = 10(3)^{1/4}$$

17. Official Ans. by NTA (5.00)

Sol. 

$$B=\frac{\mu_0 NI}{2R}$$

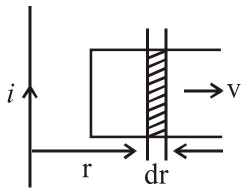
$$\phi=\frac{\mu_0 NN'I}{2R}\pi r^2$$

$$\varepsilon=\frac{d\phi}{dt}=\frac{2\pi\times10^{-7}\times10^{5}\times\pi\times10^{-4}}{0.2}$$

$= 8 \times 10^{-4} = 0.8$ mV

18. Official Ans. by NTA (2)

Sol. $B=\frac{\mu_0 i}{2\pi r}$



$$\phi=\frac{\mu_0 i}{2\pi r}\ell dr$$

$$\Rightarrow \frac{d\phi}{dt}=\frac{\mu_0 i\ell}{2\pi r}\cdot\frac{dr}{dt}$$

$$\Rightarrow e=\frac{\mu_0}{2\pi}\cdot\frac{iv\ell}{r}$$

$$i=\frac{e}{R}=\frac{\mu_0}{2\pi}\cdot\frac{iv\ell}{Rr}$$

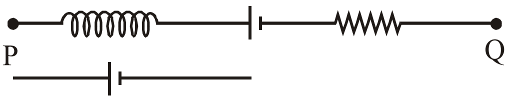
19. Official Ans. by NTA (2)

Sol. $Q=\frac{1}{R}\sqrt{\frac{L}{C}}=\frac{1}{100}\sqrt{\frac{80\times10^{-3}}{2\times10^{-6}}}$

$$=\frac{1}{100}\sqrt{40\times10^{3}}$$

$$=\frac{200}{100}=2$$

20. Official Ans. by NTA (33.00)

Sol. 

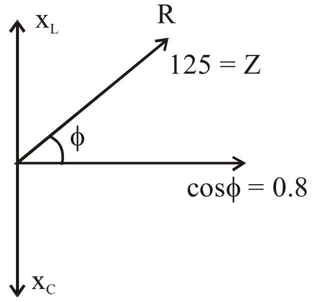
$$\frac{Ldi}{dt}=5$$

$V_P - 5 - 30 + 2 \times 1 = VQ$

$V_P - V_Q = 33$ volt

Ans. 33.00

21. Official Ans. by NTA (400.00)

Sol. 

$$P=\frac{E_{rms}^2}{Z}\cos\phi$$

$$400=\frac{(250)^2\times0.8}{Z}$$

$Z = 25 \times 5 = 125$

$X_L = 125 \sin\phi = 125 \times 0.6 = 75$

ERROR & MEASURMENT

1. NTA Ans. (3)

Sol. $T=2\pi\sqrt{\frac{\ell}{g}}$

$$g=\frac{4\pi^2\ell}{T^2}$$

$$\frac{\Delta g}{g}=\frac{\Delta\ell}{\ell}+\frac{2\Delta T}{T}$$

$$=\frac{0.1}{25}+\frac{2\times1}{50}$$

$$\frac{\Delta g}{g}=4.4\%$$

2. NTA Ans. (2)

Sol. Given on six rotation, reading of main scale changes by 3mm.

$\therefore$ 1 rotation corresponds to $\frac{1}{2}$mm

Also no. of division on circular scale = 50.

$\therefore$ Least count of the screw gauge will be

$\frac{0.5}{50}$mm = 0.001 cm.

3. NTA Ans. (BONUS)

Sol. $A_1 + B_1 + C_1 = 24.36 + 0.0724 + 256.2$
= 280.6324
= 280.6 (After rounding off)
$A_2 + B_2 + C_2 = 24.44 + 16.082 + 240.2$
= 280.722
= 280.7 (After rounding off)
$A_3 + B_3 + C_3 = 25.2 + 19.2812 + 236.183$
= 280.6642
= 280.7 (After rounding off)
$A_4 + B_4 + C_4 = 25 + 236.191 + 19.5$
= 280.691
= 281 (After rounding off)
$A_4 + B_4 + C_4 > A_3 + B_3 + C_3 = A_2 + B_2 + C_2 > A_1 + B_1 + C_1$

No option is matching Question should be (BONUS)

Best possible option is (2)

∴ Correct answer (2)

4. Official Ans. by NTA (4)

Sol. Least count = 1 mm or 0.01 cm
Zero error = 0 + 0.01 × 7 = 0.07 cm
Reading = 3.1 + (0.01 × 4) – 0.07
= 3.1 + 0.04 – 0.07
= 3.1 – 0.03
= 3.07 cm

5. Official Ans. by NTA (4)

Sol. $$LC = \frac{\text{pitch}}{\text{CSD}} = \frac{0.1\text{ cm}}{50} = 0.002\text{ cm}$$

So any measurement will be integral Multiple of LC.
So ans. will be 2.124 cm

6. Official Ans. by NTA (2)

Sol. $$\frac{\Delta Z}{Z} = \frac{2\Delta a}{a} + \frac{2}{3}\frac{\Delta b}{b} + \frac{1}{2}\frac{\Delta c}{c} + \frac{3\Delta d}{d} = 14.5\%$$

7. Official Ans. by NTA (2)

Sol. Least count of screw gauge

$$= \frac{\text{Pitch}}{\text{no. of division on circular scale}}$$

$$= \frac{0.5}{50}\text{mm} = 1 \times 10^{-5}\text{ m}$$

= 10 μm
Zero error in positive
Ans. (2)

8. Official Ans. by NTA (1050.00)

Sol. $$\rho = \frac{M}{V} = \frac{M}{\frac{4}{3}\pi\left(\frac{D}{2}\right)^3}$$

$$\rho = \frac{6}{\pi} M\ D^{-3}$$

taking log

$$\ell n\rho = \ell n\left(\frac{6}{\pi}\right) + \ell nM - 3\ell mD$$

Differentiates

$$\frac{d\rho}{\rho} = 0 + \frac{dM}{M} - 3\frac{d(D)}{D}$$

for maximum error

$$100 \times \frac{d\rho}{\rho} = \frac{dM}{M} \times 100 + \frac{3dD}{D} \times 100$$

= 6 + 3 × 1.5
= 10.5 %

$= \frac{1050}{100}\%$ so x = 1050.00

9. Official Ans. by NTA (3)

Sol. Use significant figures. Answer must be upto three significant figures.
Ans. (3)

FLUIDS

1. NTA Ans. (4)

Sol. $A_1v_1 = A_2v_2$

$$\frac{v_{min}}{v_{max}} = \frac{A_{min}}{A_{max}} \Rightarrow \frac{v_{min}}{v_{max}} = \left(\frac{4.8}{6.4}\right)^2$$

$$\frac{v_{min}}{v_{max}} = \frac{9}{16}$$

2. NTA Ans. (4)

Sol. In case of minimum density of liqued, sphere will be floating while completely submerged
So mg = B

$$m = \int_0^R \rho(4\pi r^2 dr) = B$$

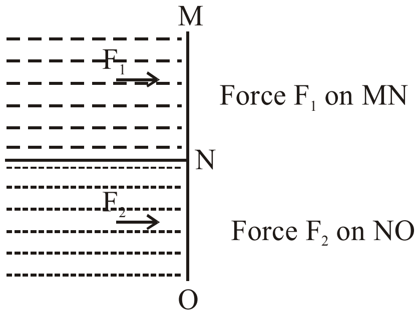
$$= \rho_0 \int_0^R \left(1 - \frac{r^2}{R^2}\right) 4\pi r^2 dr = \frac{4}{3}\pi R^3 \rho_\ell g$$

On Solving

$$\rho_\ell = \frac{2\rho_0}{5}$$

3. NTA Ans. (1)

Sol.



$$F_1 = \frac{\rho g h}{2} \times A$$

$$F_2 = \left(\rho g h + \frac{2\rho g h}{2}\right)A$$

$$\frac{F_1}{F_2} = \frac{1}{4}$$

4. NTA Ans. (3)

Sol. Rate of flow of water = $A_A V_A = A_B V_B$

$(40)V_A = (20)V_B$

$V_B = 2V_A$ .... (1)

Using Bernoulli's theorem

$$P_A + \frac{1}{2}\rho V_A^2 = P_B + \frac{1}{2}\rho V_B^2$$

$$P_A - P_B = \frac{1}{2}\rho(V_B^2 - V_A^2)$$

$$700 = \frac{1}{2} \times 1000(4V_A^2 - V_A^2)$$

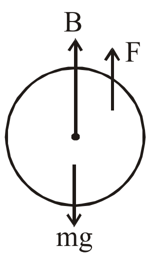
V_A = 0.68 m/s = 68 cm/s

Rate of flow = $A_A V_A$

= (40) (68) = 2720 cm^3/s

5. NTA Ans. (2)

Sol. FBD of droplet



B + F = mg

$$B = \left(\frac{2}{3}\pi R^3\right)\rho g$$

F = T(2πR)

$$m = d\left(\frac{4}{3}\pi R^3\right)$$

$$\left(\frac{2}{3}\pi R^3\right)\rho g + T(2\pi R) = d\left(\frac{4}{3}\pi R^3\right)g$$

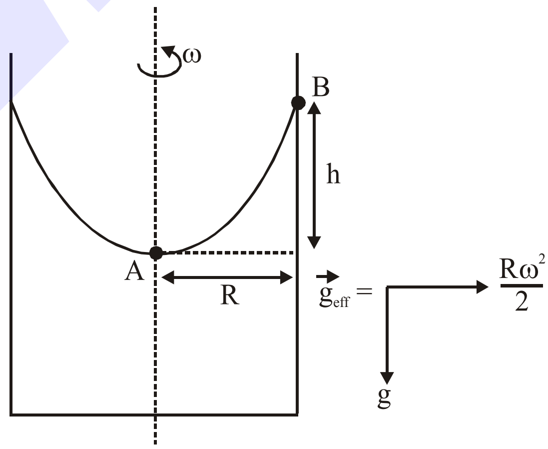
$$T(2\pi R) = \left(\frac{2}{3}\pi R^3\right)g[2d - \rho]$$

$$R = \sqrt{\frac{3T}{(2d-\rho)g}}$$

∴ Correct answer (2)

6. Official Ans. by NTA (1)

Sol.



Applying pressure equation from A to B

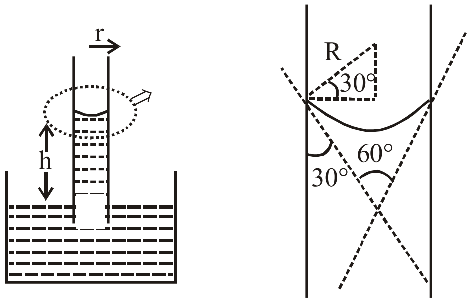
$$P_0 + \rho.\frac{R\omega^2}{2}.R - \rho g h = P_0$$

$$\frac{\rho R^2 \omega^2}{2} = \rho g h$$

$$h = \frac{R^2\omega^2}{2g} = (5)^2\frac{\omega^2}{2g} = \frac{25}{2}\frac{\omega^2}{g}$$

7. Official Ans. by NTA (3)

Sol.



r → radius of capillary
R → Radius of meniscus.

From figure, $\frac{r}{R} = \cos 30°$

$$R = \frac{2r}{\sqrt{3}} = \frac{2 \times 0.15 \times 10^{-3}}{\sqrt{3}}$$

$$= \frac{0.3}{\sqrt{3}} \times 10^{-3} \text{m}$$

Height of capillary

$$h = \frac{2T}{\rho g R} = 2\sqrt{3}\ T$$

$$h = \frac{2 \times 0.05}{667 \times 10 \times \left(\frac{0.3 \times 10^{-3}}{\sqrt{3}}\right)}$$

h = 0.087 m

8. Official Ans. by NTA (1)

Sol. $\Delta P_1 = 0.01 = 4T/R_1$ .....(1)

$\Delta P_2 = 0.02 = 4T/R_2$ .....(2)

Equation (1) ÷ (2)

$$\frac{1}{2} = \frac{R_2}{R_1}$$

$R_1 = 2R_2$

$$\frac{V_1}{V_2} = \frac{R_1^3}{R_2^3} = \frac{8R_2^3}{R_2^3} = 8$$

9. Official Ans. by NTA (101)

Sol. Capillary rise

$$h = \frac{2S\cos\theta}{\rho g r} \quad \Rightarrow S = \frac{\rho g r h}{2\cos\theta}$$

$$= \frac{(900)(10)(15 \times 10^{-5})(15 \times 10^{-2})}{2}$$

$S = 1012.5 \times 10^{-4}$

$S = 101.25 \times 10^{-3} = 101.25$ mN/m

In question closest integer is asked so closest integer = 101.00 Ans.

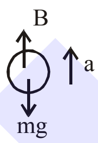
10. Official Ans. by NTA (3)

Sol. Volume $V = \frac{4\pi}{3} r^3 = \frac{4\pi}{3} \times (1)^3 = 4.19 \text{cm}^3$

$a = 9.8 \text{ cm/s}^2$

B – mg = ma

$$m = \frac{B}{g + a}$$

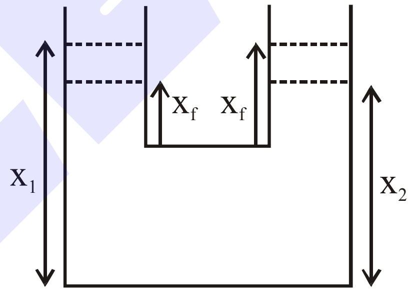


$$\Rightarrow m = \frac{(V\rho_\omega g)}{g + a} = \frac{V\rho_\omega}{1 + \frac{a}{g}}$$

$$= \frac{(4.19) \times 1}{1 + \frac{9.8}{980}} = \frac{4.19}{1.01} = 4.15 \text{gm}$$

11. Official Ans. by NTA (3)

Sol.



$$U_i = (\rho S x_1) g \cdot \frac{x_1}{2} + (\rho S x_2) g \cdot \frac{x_2}{2}$$

$$U_f = (\rho S x_f) g \cdot \frac{x_f}{2} \times 2$$

By volume conservation

$Sx_1 + Sx_2 = S(2x_f)$

$$x_f = \frac{x_1 + x_2}{2}$$

$$\Delta U = \rho S g \left[\left(\frac{x_1^2}{2} + \frac{x_2^2}{2}\right) - x_f^2\right]$$

$$= \rho S g \left[\frac{x_1^2}{2} + \frac{x_2^2}{2} - \left(\frac{x_1 + x_2}{2}\right)^2\right]$$

$$= \frac{\rho S g}{2}\left[\frac{x_1^2}{2} + \frac{x_2^2}{2} - x_1 x_2\right]$$

$$= \frac{\rho S g}{4}(x_1 - x_2)^2$$

12. Official Ans. by NTA (2)

Sol. $\frac{4}{3}\pi\left(R^3 - r^3\right)\rho_m g = \frac{4}{3}\pi R^3 \rho_w g$

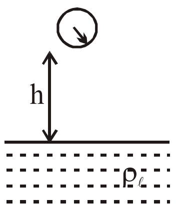
$$1 - \left(\frac{r}{R}\right)^3 = \frac{8}{27}$$

$$\Rightarrow \frac{r}{R} = \left(\frac{19}{27}\right)^{1/3} = \frac{19^{1/3}}{3}$$

$$= 0.88 \simeq \frac{8}{9}$$

13. Official Ans. by NTA (2)

Sol.



After falling through h, the velocity be equal to terminal velocity

$$\sqrt{2gh} = \frac{2}{9}\frac{r^2 g}{\eta}(\rho_\ell - \rho)$$

$$\Rightarrow h = \frac{2}{81}\frac{r^4 g\,(\rho_\ell - \rho)^2}{\eta^2}$$

$\Rightarrow h \propto r^4$

14. Official Ans. by NTA (2)

Sol. Applying Bernoulli's Equation

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

$$P + \frac{1}{2}\rho v^2 = \frac{P}{2} + \frac{1}{2}\rho V^2$$

$$\frac{2P}{2\rho} + \frac{1}{2}\frac{\rho v^2}{\rho} \times 2 = V^2$$

$$\sqrt{\frac{P}{\rho} + v^2} = V$$

Ans. (2)

GEOMETRICAL OPTICS

1. NTA Ans. (1)

Sol. $m = \frac{LD}{f_e \times f_0} = \frac{150 \times 250}{f_e \times 25} = 375$

$f_e = 20$ mm.

2. NTA Ans. (3)

Sol. Using $\frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$$\frac{1}{f} = \left(\frac{1.5}{1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{....(1)}$$

and $\frac{1}{f_1} = \left(\frac{1.5}{1.42} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ ....(2)

equation (1)/(2),

we get $\frac{f_1}{f} = \frac{0.5}{0.056}$

$= 8.93 \approx 9$

3. NTA Ans. (4)

Sol. $L = f_0 + f_e = 60$ cm

$M = \frac{f_0}{f_e} = 5$

$\Rightarrow f_0 = 5f_e$

$\therefore$ $6f_e = 60$ cm

$f_e = 10$ cm

4. NTA Ans. (4)

Sol. $\sin\theta_C = \frac{1}{\mu} = \frac{1}{\sqrt{3 \times 4/3}}$

$\theta_C = 30°$

5. NTA Ans. (60.00)

Sol. Using Lens-Maker's formula :

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{1}{f} = (1.5 - 1)\left(\frac{1}{30} - 0\right)$$

f = 60 cm

6. NTA Ans. (2)

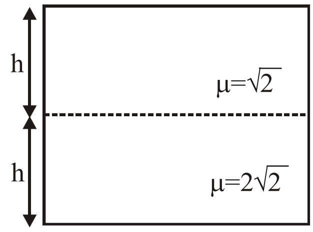
Sol. $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

At focus $m = \infty$　　$x = f$

At centre $m = -1$　　$x = 2f$

7. NTA Ans. (2)

Sol.



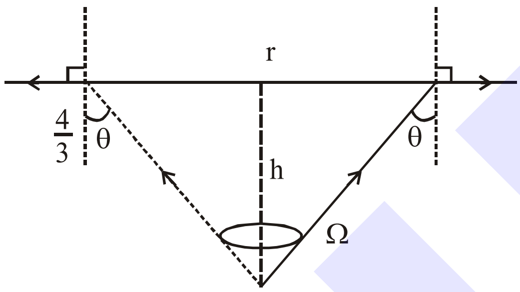
For near normal incidence,

$$h_{app} = \frac{h_{actual}}{\left(\frac{\mu_{in}}{\mu_{ref.}}\right)}$$

$$\therefore \quad h_{apparent} = \frac{\frac{h}{\left(\frac{2\sqrt{2}}{\sqrt{2}}\right)} + h}{\frac{\sqrt{2}}{1}} = \frac{3h}{2\sqrt{2}} = \frac{3}{4}h\sqrt{2}$$

8. NTA Ans. (1)

Sol.



$$\frac{4}{3}\sin\theta = 1\sin 90°$$

$$\sin\theta = \frac{3}{4}$$

Area of sphere in which light spread = $4\pi R^2$

$\Omega = 2\pi\,(1 - \cos\,\theta)$

$$\Omega = 2\pi\left(1 - \frac{\sqrt{7}}{4}\right)$$

$P \rightarrow 4\pi$ steradians

$$P' \rightarrow \frac{P}{4\pi}(1-\cos\theta)$$

$$\text{Ratio} = \frac{P'}{P} = \frac{2\pi(1-\cos\theta)}{4\pi} = \frac{(1-\cos\theta)}{2} = \frac{1-\frac{\sqrt{7}}{4}}{2}$$

$$= \frac{0.33}{2} = 0.17$$

$\therefore$ Correct answer (1)

9. Official Ans. by NTA (1)
Official Ans. by ALLEN (4)

Sol. $f = \frac{-8}{2} = -4\text{cm}$

u = –10 cm

v = ?

as $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$$\frac{1}{v} + \left(\frac{1}{-10}\right) = \frac{1}{-4}$$

$$\frac{1}{v} = \frac{1}{10} - \frac{1}{4}$$

$$\frac{1}{v} = \frac{4-10}{40}$$

$$v = \frac{40}{-6}$$

$$v = \frac{-20}{3}$$

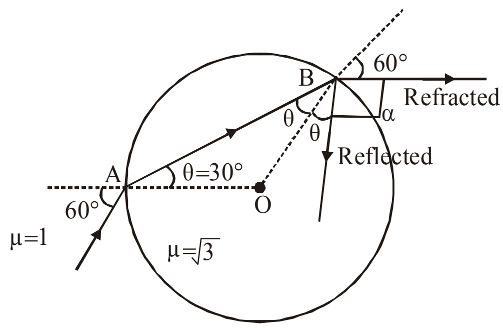
$$m = \frac{-v}{u}$$

$$m = \frac{-\left(-\frac{20}{3}\right)}{-10} \Rightarrow m = \frac{-2}{3}$$

or image will be real, inverted and unmagnified.

10. Official Ans. by NTA (90.00)

Sol.



By Snell's law at A :

$1 \times \sin 60° = \sqrt{3} \times \sin\theta$

$$\frac{\sqrt{3}}{2} = \sqrt{3}\sin\theta$$

$$\sin\theta = \frac{1}{2} \Rightarrow \theta = 30°$$

So at B :

$\theta + 60° + \alpha = 180°$

$30° + 60° + \alpha = 180°$

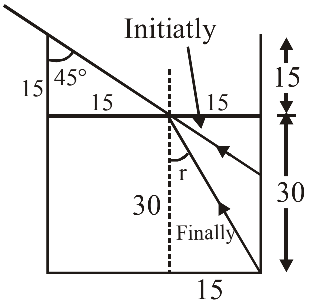
$\alpha = 90°$

11. Official Ans. by NTA (158)

Sol. $\tan r = \frac{15}{30} = \frac{1}{2}$

$\sin r = \frac{1}{\sqrt{5}}$

$1\sin 45° = \mu \sin r$



$\frac{1}{\sqrt{2}} = \mu\left(\frac{1}{\sqrt{5}}\right)$

$\boxed{\mu = \sqrt{\frac{5}{2}} = 1.581}$

$\frac{N}{100} = \mu$

$N = 100\ \mu$

$N = 158.11$

So integer value of N = 15800

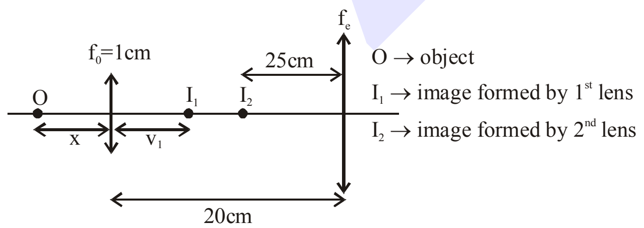
12. Official Ans. by NTA (1)

Sol. $\left|\left(\frac{dv}{dt}\right)\right| = \left|\frac{v^2}{4^2}\right|\left|\frac{du}{dt}\right|$

$= \left(\frac{10}{30}\right)2 \times 9 = 1 m/s$

13. Official Ans. by NTA (5)
Official Ans. by ALLEN (4.48)

Sol.



for first lens = $\frac{1}{v_1} - \frac{1}{-x} = \frac{1}{1} \Rightarrow v_1 = \frac{x}{x-1}$

also magnification $|m_1|$ = $\left|\frac{v_1}{u_1}\right| = \frac{1}{x-1}$

for 2nd lens this is acting as object

so $u_2 = -(20 - v_1) = -\left(20 - \frac{x}{x-1}\right)$

and $v_2 = -25$cm

angular magnification $|m_A| = \left|\frac{D}{u_2}\right| = \frac{25}{|u_2|}$

Total magnification $m = m_1 m_A = 100$

$$\left(\frac{1}{x-1}\right)\left(\frac{25}{20 - \frac{x}{x-1}}\right) = 100$$

$$\frac{25}{20(x-1)-x} = 100 \Rightarrow 1 = 80(x-1) - 4x$$

$\Rightarrow 76x = 81 \Rightarrow x = \frac{81}{76}$

$\Rightarrow u_2 = -\left(20 - \frac{81/76}{81/76 - 1}\right) = \frac{-19}{5}$

now by lens formula

$$\frac{1}{-25} - \frac{1}{-19/5} = \frac{1}{f_e} \Rightarrow f_e = \frac{25 \times 19}{106} \approx 4.48\text{cm}$$

14. Official Ans. by NTA (5)
Official Ans. by ALLEN (476)

Sol. Using displacement method

$f = \frac{D^2 - d^2}{4D}$

Here, D = 100 cm
d = 40 cm

$f = \frac{100^2 - 40^2}{4(100)} = 21$ cm

$P = \frac{1}{f} = \frac{100}{21}$ D $\qquad \frac{N}{100} = \frac{100}{21} \qquad N = 47$

15. Official Ans. by NTA (4)

Sol. $v = \frac{uf}{u+f}$

Case-I

If $v = u$

$\Rightarrow f + u = f$

$\Rightarrow u = 0$

Case-II

If $u = \infty$

then $v = f$

Only option (4) satisfies this condition.

16. Official Ans. by NTA (50.00)

Sol. Final image at ∞

⇒ obj. for eye piece at 5cm

⇒ image for objective at 5 cm

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \qquad \Rightarrow \frac{1}{5}+\frac{1}{x}=1$$

$$\frac{1}{x}=1-\frac{1}{5}=\frac{4}{5} \Rightarrow x=\frac{5}{4}$$

17. Official Ans. by NTA (5.00)

Sol. $\delta_{min} = (\mu - 1)\ A$

$= (1.5 - 1)1$

$= 0.5$

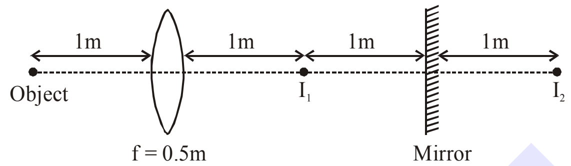
$$\delta_{min} = \frac{5}{10}$$

N = 5

18. Official Ans. by NTA (1,4)

Official Ans. by ALLEN (3)

Sol.



Object is at 2f. So image will also be at '2f'. (I_1).

Image of I_1 will be 1m behind mirror.

i.e. ⇒ I_2

Now I_2 will be object for lens.

∴ u ⇒ – 3m

f ⇒ +0.5 m

$$\frac{1}{v} \Rightarrow \frac{1}{f}+\frac{1}{u} \qquad \Rightarrow \frac{1}{+0.5}+\frac{1}{-3}$$

$$v \Rightarrow \frac{3}{5} \Rightarrow 0.6\text{m}$$

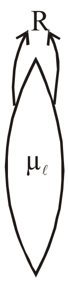
So total distance from mirror ⇒ 2 + 0.6

⇒ 2.6 m and real image

Ans. (3)

19. Official Ans. by NTA (4)

Sol.



$R_1 = R_2 = R$

Power (P)

Refractive index is assume (μ_ℓ)

$$P=\frac{1}{f}=(\mu_\ell-1)\left(\frac{2}{R}\right) \qquad ....(i)$$

$$P'=\frac{1}{f'}=(\mu_\ell-1)\left(\frac{1}{R'}\right) \qquad ....(ii)$$

$$P'=\frac{3}{2}P$$

$$(\mu_\ell-1)\left(\frac{1}{R'}\right)=\mu\frac{3}{2}(\mu_\ell-1)\left(\frac{2}{R}\right)$$

$$\therefore \quad R'=\frac{R}{3}$$

GRAVITATION

1. NTA Ans. (2)

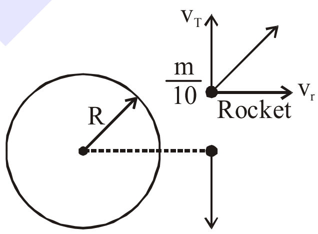
Sol. Applying energy conservation

$$K_i + U_i = K_f + U_f$$

$$\frac{1}{2}mu^2+\left(-\frac{GMm}{R}\right)=\frac{1}{2}mv^2-\frac{GMm}{2R}$$

$$v=\sqrt{u^2-\frac{GM}{R}} \qquad ....(i)$$

By momentum conservation, we have



$$\frac{m}{10}v_T=\frac{9m}{10}\sqrt{\frac{GM}{2R}} \qquad ....(ii)$$

$$\& \quad \frac{m}{10}v_r = mv$$

$$\Rightarrow \frac{m}{10}v_r = m\sqrt{u^2-\frac{GM}{R}} \qquad ....(iii)$$

Kinetic energy of rocket

$$=\frac{1}{2}m\left(v_T^2+v_r^2\right)$$

$$=\frac{m}{20}\left(81\frac{GM}{2R}+100u^2-100\frac{GM}{R}\right)$$

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

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

2. NTA Ans. (4)

Sol. Gravitational field on the surface of a solid sphere $I_g = \frac{GM}{R^2}$

By the graph

$$\frac{GM_1}{(1)^2} = 2 \quad \text{and} \quad \frac{GM_2}{(2)^2} = 3$$

On solving

$$\frac{M_1}{M_2} = \frac{1}{6}$$

3. NTA Ans. (16)

Sol. $U_1 + K_1 = U_2 + K_2$

$$-\frac{GM_e m}{10R} + \frac{1}{2}mv_0^2 = -\frac{GM_e m}{R} + \frac{1}{2}mv^2$$

$$+\frac{9}{10} \times \frac{GM_e m}{R} + \frac{1}{2}mv_0^2 = \frac{1}{2}mv^2$$

$$\frac{9}{10} \times \frac{1}{2}M \times v_e^2 + \frac{1}{2}mv_0^2 = \frac{1}{2}mv^2$$

$$v^2 = \frac{9}{10}v_e^2 + v_0^2 \qquad \Rightarrow = \frac{9}{10} \times (11.2)^2 + (12)^2$$

$v^2 = 112.896 + 144$

$v = 16.027$

$v = 16$ km/s

4. NTA Ans. (1)

Sol. Initially, the body of mass m is moving in a circular orbit of radius R. So it must be moving with orbital speed.

$$v_0 = \sqrt{\frac{GM}{R}}$$

After collision, let the combined mass moves with speed v_1

$$mv_0 + \frac{m}{2}\frac{v_0}{2} = \left(\frac{3m}{2}\right)v_1 \qquad \Rightarrow v_1 = \frac{5v_0}{6}$$

Since after collision, the speed is not equal to orbital speed at that point. So motion cannot be circular. Since velocity will remain tangential, so it cannot fall vertically towards the planet.

Their speed after collision is less than escape speed $\sqrt{2}v_0$, so they cannot escape gravitational field.

So their motion will be elliptical around the planet.

5. NTA Ans. (1)

Sol. $V_e = \sqrt{\frac{2GM}{R}}$ (Escape velocity)

$$V_A = \sqrt{\frac{2GM}{R}}$$

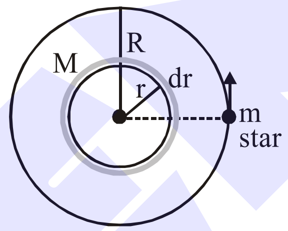
$$V_B = \sqrt{\frac{2G[M/2]}{R/2}} = \sqrt{\frac{2GM}{R}}$$

$$\frac{V_A}{V_B} = 1 = \frac{n}{4} \Rightarrow n = 4$$

$\therefore$ Correct answer (1)

6. Official Ans. by NTA (3)

Sol.



$dm = \rho dv$

$$dm = \left(\frac{k}{r}\right)(4\pi r^2 dr)$$

$dm = 4\pi k r dr$

$$M = \int_0^R dm = \int_0^R 4\pi k r dr$$

$$M = 4\pi k \left.\frac{r^2}{2}\right|_0^R$$

$M = 2\pi k(R^2 - 0)$

$M = 2\pi k R^2$

for circular motion gravitational force will provide required centripital force or

$$\frac{GMm}{R^2} = \frac{mv^2}{R}$$

$$\frac{G(2\pi k R^2)m}{R^2} = \frac{mv^2}{R} \Rightarrow v = \sqrt{2\pi G k R}$$

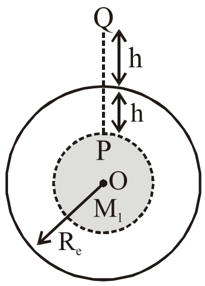
Time period $T = \frac{2\pi R}{v}$

$$T = \frac{2\pi R}{\sqrt{2\pi G k R}} \propto \sqrt{R}$$

or $T^2 \propto R$

7. Official Ans. by NTA (1)

Sol.



- M = mass of earth

M_1 = mass of shaded portion

R = Radius of earth

- $M_1 = \dfrac{M}{\frac{4}{3}\pi R^3}\cdot\dfrac{4}{3}\pi(R-h)^3$

$= \dfrac{M(R-h)^3}{R}$

- Weight of body is same at P and Q

i.e. $mg_P = mg_Q$

$g_P = g_Q$

$\dfrac{GM_1}{(R-h)^2} = \dfrac{GM}{(R+h)^2}$

$\dfrac{GM(R-h)^3}{(R-h)^2 R^3} = \dfrac{GM}{(R+h)^2}$

$(R-h)(R+h)^2 = R^3$

$R^3 - hR^2 - h^2R - h^3 + 2R^2 h - 2Rh^2 = R^3$

$R^2 - Rh^2 - h^3 = 0$

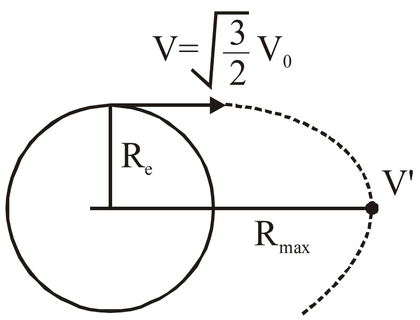
$R^2 - Rh - h^2 = 0$

$h^2 + Rh - R^2 = 0 \Rightarrow h = \dfrac{-R \pm \sqrt{R^2+4R^2}}{2}$

ie $h = \dfrac{-R+\sqrt{5}R}{2} = \left(\dfrac{\sqrt{5}-1}{2}\right)R$

8. Official Ans. by NTA (2)

Sol.



$V_0 = \sqrt{\dfrac{GM}{R_e}}$

$\dfrac{-GMm}{R_e} + \dfrac{1}{2}mv^2 = \dfrac{-GMm}{R_{max}} + \dfrac{1}{2}mv'^2$ ....(i)

$VR_e = V'R_{max}$ ....(ii)

Solving (i) & (ii)

$\boxed{R_{max} = 3R_e}$

9. Official Ans. by NTA (2)

Sol. $E\,4\pi r^2 = \int \rho_0 4\pi r^2 dr$

$\Rightarrow Er^2 = 4\pi G\int_0^r \rho_0\left(1-\dfrac{r^2}{R^2}\right)r^2 dr$

$\Rightarrow E = 4\pi G\rho_0\left(\dfrac{r^3}{3} - \dfrac{r^5}{5R^2}\right)$

$\dfrac{dE}{dr} = 0 \;\therefore\; r = \sqrt{\dfrac{5}{9}}R$

10. Official Ans. by NTA (1)

Sol. Given $E_G = \dfrac{Ax}{(x^2+a^2)^{3/2}}$, $V_\infty = 0$

$\int_{V_\infty}^{V_x} dV = -\int_\infty^x \vec{E}_G\cdot\vec{d}_x$

$V_x - V_\infty = -\int_\infty^x \dfrac{Ax}{(x^2+a^2)^{3/2}}dx$

put $x^2 + a^2 = z$

$2x\,dx = dz$

$V_x - 0 = -\int_\infty^x \dfrac{A\,dz}{2(z)^{3/2}} = \left[\dfrac{A}{z^{1/2}}\right]_\infty^x = \left[\dfrac{A}{(x^2+a^2)^{1/2}}\right]_\infty^x$

$V_x = \dfrac{A}{(x^2+a^2)^{1/2}} - 0 = \dfrac{A}{(x^2+a^2)^{1/2}}$

11. Official Ans. by NTA (3)

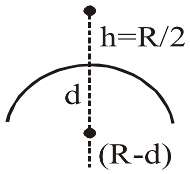
Sol. $V_{orbit} = \sqrt{\dfrac{GM}{R}}$

$V_{escape} = \sqrt{\dfrac{2GM}{R}}$

$\dfrac{V_{orbit}}{V_{escape}} = \dfrac{1}{\sqrt{2}}$

12. Official Ans. by NTA (4)

Sol.



$$g_1 = \frac{GM}{\left(R+\frac{R}{2}\right)^2} \quad \text{... (1)}$$

$$g_2 = \frac{GM(R-d)}{R^3} \quad \text{... (2)}$$

$$g_1 = g_2$$

$$\frac{GM}{\left(\frac{3R}{2}\right)^2} = \frac{GM(R-d)}{R^3}$$

$$\Rightarrow \frac{4}{9} = \frac{(R-d)}{R}$$

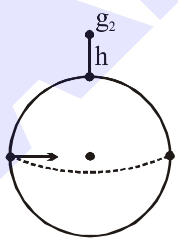
$$4R = 9R - 9d$$

$$5R = 9d \Rightarrow \frac{d}{R} = \frac{5}{9}$$

13. Official Ans. by NTA (4)

Sol. $g_e = g - R\omega^2$

$$g_2 = g\left(1-\frac{2h}{R}\right) \qquad g_1 = ge$$



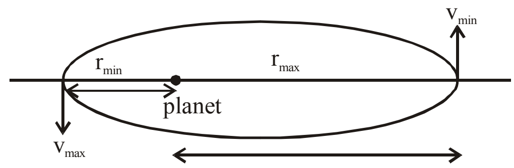
$$g_2 = g - \frac{2gh}{R}$$

Now $R\omega^2 = \frac{2gh}{R}$

$$h = \frac{R^2\omega^2}{2g}$$

14. Official Ans. by NTA (1)

Sol.



By angular momentum conservation

$r_{min}v_{max} = r_{max}v_{min}$ ... (i)

Given $v_{min} = \frac{v_{max}}{6}$

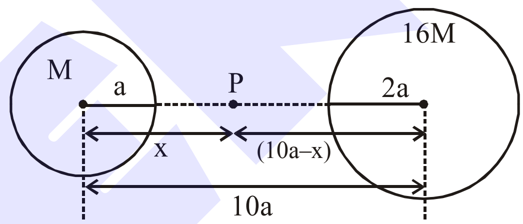
from equation (i)

$$\frac{r_{min}}{r_{max}} = \frac{v_{min}}{v_{max}} = \frac{1}{6}$$

Ans. (1)

15. Official Ans. by NTA (2)

Sol.



$$\frac{GM}{x^2} = \frac{G(16M)}{(10a-x)^2}$$

$$\frac{1}{x} = \frac{4}{(10a-x)} \qquad \Rightarrow 4x = 10a - x$$

$x = 2a$ ....(i)

COME

$$-\frac{GMm}{8a} - \frac{G(16M)m}{2a} + KE$$

$$= -\frac{GMm}{2a} - \frac{G(16M)m}{8a}$$

$$KE = GMm\left[\frac{1}{8a}+\frac{16}{2a}-\frac{1}{2a}-\frac{16}{8a}\right]$$

$$KE = GMm\left[\frac{1+64-4-16}{8a}\right]$$

$$\frac{1}{2}mv^2 = GMm\left[\frac{45}{8a}\right]$$

$$V = \sqrt{\frac{90GM}{8a}}$$

$$V = \frac{3}{2}\sqrt{\frac{5GM}{a}}$$

HEAT & THERMODYNAMICS

1. NTA Ans. (1)

Sol. $w = \dfrac{nR(T_1 - T_2)}{\gamma - 1} = \dfrac{P_1V_1 - P_2V_2}{0.4}$

$= \dfrac{100 - \dfrac{100}{4.6555} \times 3}{0.4} = 88.90 \cdot$

2. NTA Ans. (2)

Sol. $C_{Peq} = \dfrac{n_1C_{P_1} + n_2C_{P_2}}{n_1 + n_2}$

$C_{Veq} = \dfrac{n_1C_{V_1} + n_2C_{V_2}}{n_1 + n_2}$

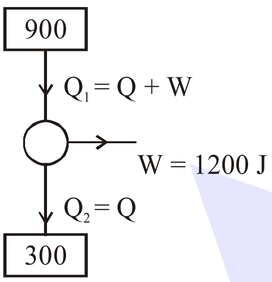
$\gamma_{eq} = \dfrac{C_{P_{eq}}}{C_{V_{eq}}} = \dfrac{2 \times \dfrac{5R}{2} + 3 \times \dfrac{8R}{2}}{2 \times \dfrac{3R}{2} + 3 \times \dfrac{6R}{2}}$

$= \dfrac{5+12}{3+9} = \dfrac{17}{12} \simeq 1.42$

Correct Answer : 2

3. NTA Ans. (600)

Sol.



for carnot engine

$\dfrac{Q_1}{Q_2} = \dfrac{T_1}{T_2}$

$\dfrac{Q + 1200}{Q} = \dfrac{900}{300}$

Q + 1200 = 3Q

Q = 600 J.

4. NTA Ans. (60)

Sol. $\gamma = \alpha_x + \alpha_y + \alpha_z$

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

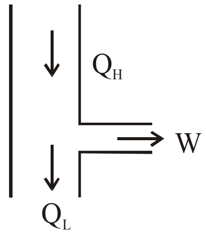
$= (50 + 5 + 5) \times 10^{-6}$

$\gamma = 60 \times 10^{-6}$

C = 60.

5. NTA Ans. (3)

Sol.



$\dfrac{Q_H}{Q_L} = \dfrac{T_1}{T}$ and $W = Q_H - Q_L$ ....(1)

$\dfrac{Q_L}{Q'_L} = \dfrac{T}{T_2}$ and $W = Q_L - Q'_L$ ....(2)

6. NTA Ans. (1)

Sol. $t \propto \dfrac{V}{\sqrt{T}}$ ....(1)

$TV^{\gamma-1}$ = constant ....(2)

$\therefore t \propto V^{\frac{\gamma+1}{2}}$

7. NTA Ans. (40)

Sol. $M \times 540 + M + 60 = 200 \times 80 + 200 \times 1 \times (40 - 0)$

$\Rightarrow M = 40$

8. NTA Ans. (4)

Sol. Mean free time = $\dfrac{\text{Mean free path}}{\text{Average speed}}$

$= \dfrac{\dfrac{1}{\sqrt{2}\pi D^2 n}}{\sqrt{\dfrac{8RT}{\pi M_w}}}$

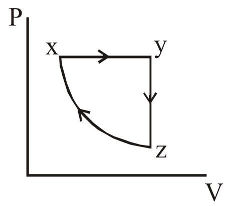
$t \propto \dfrac{1}{\sqrt{T}}$

9. NTA Ans. (4)

Sol. $x \to y \Rightarrow$ Isobaric

$y \to z \Rightarrow$ Isochoric

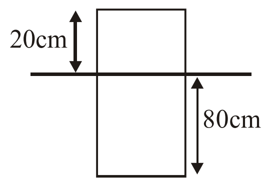
$z \to x \Rightarrow$ Isothermal



10. NTA Ans. (1)

Sol. $m = \rho_0 A\ (80)$ ....(i)

$m = \rho A\ (79)$ ....(ii)



11. NTA Ans. (3)

Sol. Refrigerator cycle is :

$$\eta = \frac{W}{Q_+} = \frac{W}{W+Q_-}$$

$$\frac{1}{10} = \frac{10}{10+Q_-}$$

$Q_- = 90$ J

Heat absorbed from the reservoir at lower temperature is 90 J

12. NTA Ans. (2)

Sol. $$\frac{C_P}{C_V}\text{mix} = \frac{n_1C_{P_1}+n_2C_{P_2}}{n_1C_{V_1}+n_2C_{V_2}}$$

$$\frac{C_P}{C_V}\text{mix} = \frac{n\times\left(\frac{5R}{2}\right)+2n\left(\frac{7R}{2}\right)}{n\times\frac{3R}{2}+2n\left(\frac{5R}{2}\right)}$$

$$\frac{C_P}{C_V} = \frac{19}{13}$$

13. NTA Ans. (50)

Sol. According to table and applying law of calorimetry

$1T_1 + 2T_2 = (1+2)60°$ ....(1)

$= 180$

$1T_2 + 2T_3 = (1+2)30°$ ....(2)

$= 90$

$2T_1 + 1T_3 = (1+2)60$

$= 180$ ....(3)

Adding (1) + (2) + (3)

$3(T_1 + T_2 + T_3) = 450$

$T_1 + T_2 + T_3 = 150°$

Hence,

$T_1 + T_2 + T_3 = (1+1+1)\theta$

$150 = 3\theta$

$\theta = 50°C$

14. NTA Ans. (2)

Sol. Degree of freedom of a diatomic molecule if vibration is absent = 5

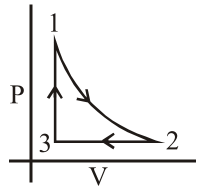
Degree of freedom of a diatomic molecule if vibration is present = 7

$$\therefore\ C_v^A = \frac{f_A}{2}R = \frac{5}{2}R \ \& \ C_v^B = \frac{f_B}{2}R = \frac{7}{2}R$$

$$\therefore\ \frac{C_v^A}{C_v^B} = \frac{5}{7}$$

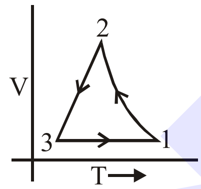
15. NTA Ans. (4)

Sol.



In process 2 to 3 pressure is constant & in process 3 to 1 volume is constant which is correct only in option 4.

Correct graph is



16. NTA Ans. (1)
ALLEN Ans. (3)

Sol. $$\lambda = \frac{1}{\sqrt{2}\pi n_v d^2}$$

$$\tau = \frac{\lambda}{v} = \frac{1}{\sqrt{2}\pi n_v d^2 v} = \frac{1}{\sqrt{2}\pi n_v d^2}\sqrt{\frac{M}{3RT}}$$

$$\frac{\tau_1}{\tau_2} = \sqrt{\frac{M_1}{M_2}}\frac{d_2^2}{d_1^2}$$

$$= \sqrt{\frac{40}{140}}\frac{(0.1)^2}{(0.07)^2}$$

$= 1.09$

$\therefore$ Nearest possible answer (3)

17. NTA Ans. (1816.00 to 1820)

Sol. PV^γ = constant

$TV^{\gamma-1} = C$

$$300\times V^{\frac{7}{5}-1} = T_2\left(\frac{V}{16}\right)^{\frac{7}{5}-1}$$

$$300\times 2^{4\times\frac{2}{5}} = T_2$$

Isobaric process

$$V = \frac{nRT}{P}$$

$V_2 = kT_2$ ... (1)

$2V_2 = KT_f$ ... (2)

$$\frac{1}{2} = \frac{T_2}{T_f} \Rightarrow T_f = 2T_2$$

$$T_f = 2\times300\times2^{\frac{8}{5}} = 1818.85$$

$\therefore$ Correct answer 1819

18. Official Ans. by NTA (2)

Sol. $u=\frac{f_1n_1RT}{2}+\frac{f_2n_2RT}{2}$

$u=\frac{5}{2}\times 3RT+\frac{3\times 5RT}{2}=15RT$

19. Official Ans. by NTA (46)
Official Ans. by ALLEN (46 Actual 45.78)

Sol. Diatomic :
f = 5
$\gamma = 7/5$
$T_i = T = 273 + 20 = 293$ K
$V_i = V$
$V_f = V/10$
Adiabatic $TV^{\gamma-1}$ = constant

$T_1V_1^{\gamma-1}=T_2V_2^{\gamma-1}$

$T.V^{7/5-1}=T_2\left(\frac{V}{10}\right)^{7/5-1}$

$\Rightarrow T_2 = T.\ 10^{2/5}$

$\Delta U=\frac{nfR(T_2-T_1)}{2}=\frac{5\times 5\times \frac{25}{3}\times (T.10^{2/5}-T)}{2}$

$=\frac{25\times 25\times}{6}T\,(10^{2/5}-1)$

$=\frac{625\times 293\times (10^{2/5}-1)}{6}$

$=4.033\times 10^3\approx 4kJ$

20. Official Ans. by NTA (3)

Sol. $\eta=\frac{\text{Work done}}{\text{Heat supplied}}$

$\frac{1}{2}=\eta=\frac{1915-40+125-Q}{1915+125}$

$\frac{1}{2}=\frac{2000-Q}{2040}$ $\Rightarrow 2040 = 4000 - 2Q$

2Q = 1960
Q = 980 J

21. Official Ans. by NTA (4)

Sol. The mean free path of molecules of an ideal gas is given as:

$\lambda=\frac{V}{\sqrt{2}\pi d^2N}$

where : V = Volume of container
N = No of molecules

Hence with increasing temp since volume of container does not change (closed container), so mean free path is unchanged.

Average collision time

$=\frac{\text{mean free path}}{V_{av}}=\frac{\lambda}{(\text{avg speed of molecules})}$

$\because$ avg speed $\alpha\sqrt{T}$

$\therefore$ Avg coll. time $\alpha\frac{1}{\sqrt{T}}$

Hence with increase in temperature the average collision time decreases.

22. Official Ans. by NTA (2)

Sol. Given $\frac{\Delta L}{L}=0.02\%$

$\therefore \Delta L=L\alpha\Delta T\Rightarrow\frac{\Delta L}{L}=\alpha\Delta T=0.02\%$

$\therefore\ \beta = 2\alpha$ (Areal coefficient of expansion)
$\Rightarrow \beta\Delta T = 2\alpha\Delta T = 0.04\%$
Volume = Area × Length

$\text{Density}(\rho)=\frac{\text{Mass}}{\text{Volume}}=\frac{\text{Mass}}{\text{Area}\times\text{Length}}=\frac{M}{AL}$

$\Rightarrow\frac{\Delta\rho}{\rho}=\cancelto{0}{\frac{\Delta M}{M}}-\frac{\Delta A}{A}-\frac{\Delta L}{L}$ (Mass remains constant)

$\Rightarrow\left(\frac{\Delta\rho}{\rho}\right)=\frac{\Delta A}{A}+\frac{\Delta L}{L}=\beta\Delta T+\alpha\Delta T$

= 0.04% + 0.02%
= 0.06%

23. Official Ans. by NTA (2)

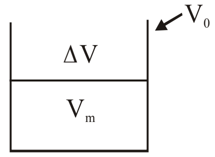
Sol. Bursting of helium balloon is irreversible & adiabatic.

24. Official Ans. by NTA (4)

Sol. DOF = 3 + 3 = 6

$U=\frac{f}{2}nRT=3RT$

25. Official Ans. by NTA (20)

Sol.


$\Rightarrow \boxed{\Delta V=(V_0-V_m)}$

After increasing temperature
$\Delta V' = (V'_0 - V'_m)$
$\Delta V' = \Delta V$
$V_0 - V_m = V_0(1+\gamma_b\Delta T) - V_m(1+\gamma_M\Delta T)$
$V_0\gamma_b = V_m\gamma_m$

$V_m=\frac{V_0\gamma_b}{\gamma_m}=\frac{(500)(6\times 10^{-6})}{(1.5\times 10^{-4})}$
= 20 CC

26. Official Ans. by NTA (3)

Sol. $nC_p(50) = 160$

$nC_v\ (100) = 240$

$$\Rightarrow \frac{C_p}{2C_v} = \frac{160}{240} = \frac{\gamma}{2}$$

$$\therefore\ \gamma = \frac{4}{3} \text{ and } f = \frac{2}{\gamma - 1} = 6$$

27. Official Ans. by NTA (1)

Sol. $$\frac{50-40}{300} = \beta\left(\frac{50+40}{2} - 20\right)$$

$$\frac{40-T}{300} = \beta\left(\frac{40+T}{2} - 20\right)$$

$$\therefore\ T = \frac{100}{3}$$

28. Official Ans. by NTA (2)

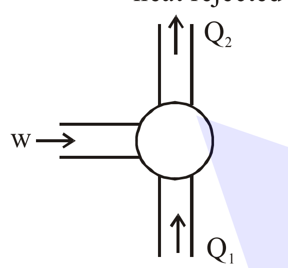
Sol.

Cal	H_2O	Sterm
20gm	180gm	m
25^oC	25^oC	100^oC

$200 \times 1 \times (31 - 25)$
$= m \times 540 + m \times 1 \times (100 - 31)$

29. Official Ans. by NTA (8791)

Sol.



$w + Q_1 = Q_2$
$w = Q_2 - Q_1$

$$\text{C.O.P.} = \frac{Q_1}{w} = \frac{Q_1}{Q_2 - Q_1} = \frac{273}{300-273} = \frac{Q_1}{W}$$

$$w = \frac{27}{273} \times 80 \times 100 \times 4.2$$

$Q_2 = w + \theta_1$

$$Q_2 = \frac{27}{273} \times 80 \times 100 \times 4.2 + 80 \times 100 \times 4.2$$

$$Q_2 = \frac{300}{273} \times 80 \times 100 = 8791.2 \text{ cal}$$

30. Official Ans. by NTA (1)

Sol. $$\gamma = \frac{C_p}{C_v} = 1 + \frac{2}{f}$$

where 'f' is degree of freedom

(A) Monoatomic f = 3, $\gamma = 1 + \frac{2}{3} = \frac{5}{3}$

(B) Diatomic rigid molecules,

f = 5, $\gamma = 1 + \frac{2}{3} = \frac{7}{5}$

(C) Diatomic non-rigid molecules

f = 7, $\gamma = 1 + \frac{2}{7} = \frac{9}{7}$

(D) Triatomic rigid molecules

f = 6, $\gamma = 1 + \frac{2}{6} = \frac{4}{3}$

31. Official Ans. by NTA (4)

Sol. $$\because\ \frac{d\theta}{dt} = kA\frac{dT}{dx}$$

$$k = \frac{\left(\frac{d\theta}{dt}\right)}{A\left(\frac{dT}{dx}\right)}$$

$$[k] = \frac{[ML^2T^{-3}]}{[L^2][KL^{-1}]} = [MLT^{-3}K^{-1}]$$

32. Official Ans. by NTA (1)

Sol. Here the water will provide heat for ice to melt therefore

$m_w\ s_w\ \Delta\theta = m_{ice}\ L_{ice}$

$$m_{ice} = \frac{0.2 \times 4200 \times 25}{3.4 \times 10^5}$$

= 0.0617 kg
= 61.7 gm

Remaining ice will remain un-melted
so correct answer is 1

33. Official Ans. by NTA (266)
Official Ans. by ALLEN (266.67)

Sol. As work done on gas and heat supplied to the gas are zero,
total internal energy of gases remain same

$u_1 + u_2 = u_1' + u_2'$

$(0.1)\ C_v\ (200) + (0.05)\ C_v\ (400) = (0.15)C_v\ T$

$$T = \frac{800}{3} k = 266.67 k$$

34. Official Ans. by NTA (1)

Sol. (I) Adiabatic process $\Rightarrow \Delta Q = 0$

No exchange of heat takes place with surroundings

(II) Isothermal proess $\Rightarrow$ Temperature remains constant ($\Delta T = 0$)

$$\Delta u = \frac{F}{2} nR\Delta T \Rightarrow \Delta u = 0$$

No change in internal energy [$\Delta u = 0$]

(III) Isochoric process Volume remains constant $\Delta V = 0$

$$W = \int P.dV = 0$$

Hence work done is zero.

(IV) Isobaric process $\Rightarrow$ Pressure remains constant

$$W = P.\ \Delta V \neq 0$$

$$\Delta u = \frac{F}{2} nR\Delta T = \frac{F}{2}[P\Delta V] \neq 0$$

$$\Delta Q = nC_P\Delta T \neq 0$$

35. Official Ans. by NTA (150)

Sol. $PV = nRT$

$P\Delta V + V\Delta P = 0$ (for constant temp.)

$P\Delta V = nR\Delta T$ (for constant pressure)

$$\Delta T = \frac{P\Delta V}{nR}$$

$$\Delta P = -\frac{P\Delta V}{V} \quad (\Delta V \text{ is same in both cases})$$

$$\frac{\Delta T}{\Delta P} = \frac{P\Delta V}{nR} \frac{V}{-P\Delta V} = \frac{-V}{nR} = -\frac{T}{P}$$

($PV = nRT$)

$$\left(\frac{V}{nR} = \frac{T}{P}\right) \qquad \left|\frac{\Delta T}{\Delta P}\right| = \left|\frac{-300}{2}\right| = 150$$

36. Official Ans. by NTA (1)

Sol. $\Delta U = nC_v\ \Delta T$ = same

AB $\rightarrow$ volume is increasing $\Rightarrow W > 0$

AD $\rightarrow$ volume is decreasing $\Rightarrow W < 0$

AC $\rightarrow$ volume is constant $\Rightarrow W = 0$

37. Official Ans. by NTA (2)

Sol. $$\frac{1}{2}mv^2 \times \frac{1}{2} = ms\Delta T$$

$$\Delta T = \frac{v^2}{4\times 5} = \frac{210^2}{4\times 30\times 4.200}$$

$= 87.5°C$

38. Official Ans. by NTA (3)

Sol. $$n = \frac{PV}{RT}, \frac{3}{2}kT = 4\times 10^{-14}$$

$$N = \frac{PV}{RT}\times Na$$

$$= \frac{2\times 13.6\times 980\times 4}{\frac{8}{3}\times 10^{-14}} = 3.99 \times 10^{18}$$

39. Official Ans. by NTA (4)

Sol. In adiabatic process

PV^{γ} = constant

$$P\left(\frac{m}{\rho}\right)^{\gamma} = \text{constant}$$

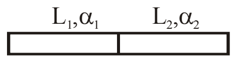
as mass is constant

$P \propto \rho^{\gamma}$

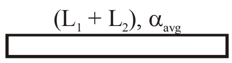
$$\frac{P_f}{P_i} = \left(\frac{\rho_f}{\rho_i}\right)^{\gamma} = (32)^{7/5} = 2^7 = 128$$

40. Official Ans. by NTA (4)

Sol. At T°C $\quad L = L_1 + L_2$



At $T + \Delta T$ $\quad L_{eq}' = L_1' + L_2'$



where $L_1' = L_1(1+\alpha_1\Delta T)$

$$L_2' = L_2(1+\alpha_2\Delta T)$$

$$L_{eq}' = (L_1 + L_2)\ (1+\alpha_{avg}\Delta T)$$

$$\Rightarrow (L_1 + L_2)(1+\alpha_{avg}\Delta T) = L_1 + L_2 + L_1\alpha_1\Delta T + L_2\alpha_2\Delta T$$

$$\Rightarrow (L_1 + L_2)\ \alpha_{avg} = L_1\alpha_1 + L_2\alpha_2$$

$$\Rightarrow \alpha_{avg} = \frac{L_1\alpha_1 + L_2\alpha_2}{L_1 + L_2}$$

41. Official Ans. by NTA (41.00)

Official Ans. by ALLEN (40.93)

Sol. $$V_{rms} = \sqrt{\frac{3RT}{M}}$$

$$V_{N_2} = V_{H_2}$$

$$\sqrt{\frac{3RT_{N_2}}{M_{N_2}}} = \sqrt{\frac{3RT_{H_2}}{M_{H_2}}}$$

$$\frac{573}{28} = \frac{T_{H_2}}{2} \Rightarrow T_{H_2} = 40.928$$

42. Official Ans. by NTA (4)

Sol. Total degree of freedom = 3 + 2 = 5

$$U = \frac{nfRT}{2} \Rightarrow \frac{5RT}{2}$$

$$\gamma \Rightarrow \frac{C_P}{C_V} \Rightarrow 1 + \frac{2}{f} \Rightarrow 1 + \frac{2}{5} \Rightarrow \frac{7}{5}$$

Ans. (4)

43. Official Ans. by NTA (5.00)

Sol. PV = nRT

P_1V_1 = nR 250

$$P_2(2V_1) = \frac{5n}{4}R \times 2000$$

Divide

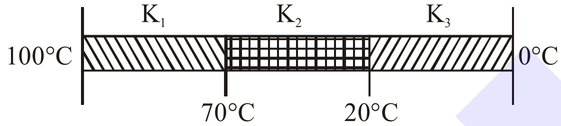
$$\frac{P_1}{2P_2} = \frac{4 \times 250}{5 \times 2000}$$

$$\frac{P_1}{P_2} = \frac{1}{5} \qquad \Rightarrow \frac{P_2}{P_1} = 5$$

Ans. 5.00

44. Official Ans. by NTA (1)

Sol.



Rods are identical have same length (ℓ) and area of cross-section (A)

Combination are in series, so heat current is same for all Rods

$$\left(\frac{\Delta Q}{\Delta t}\right)_{AB} = \left(\frac{\Delta Q}{\Delta t}\right)_{BC} = \left(\frac{\Delta Q}{\Delta t}\right)_{CD} = \text{Heat current}$$

$$\frac{(100-70)K_1A}{\ell} = \frac{(70-20)K_2A}{\ell} = \frac{(20-0)K_3A}{\ell}$$

$30K_1 = 50K_2 = 20K_3$

$3K_1 = 2K_3$

$$\frac{K_1}{K_3} = \frac{2}{3} = 2:3$$

$5K_2 = 2K_3$

$$\frac{K_2}{K_3} = \frac{2}{5} = 2:5$$

45. Official Ans. by NTA (3)

Sol. $v_{avg} \propto \sqrt{T}$

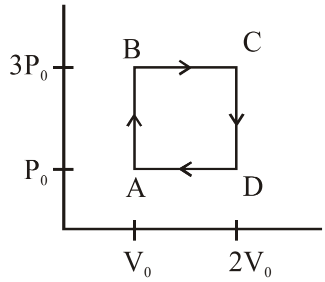
t_0 : mean time

λ : mean free path

$$t_0 = \frac{\lambda}{v_{avg}} \propto \frac{1}{\sqrt{T}}$$

46. Official Ans. by NTA (19.00)

Sol.



$W_{ABCDA} = 2P_0V_0$

$Q_{in} = Q_{AB} + Q_{BC}$

$Q_{AB} = nC(T_B - T_A)$

$$= \frac{n3R}{2}(T_B - T_A)$$

$$= \frac{3}{2}(P_BV_B - P_AV_A)$$

$$= \frac{3}{2}(3P_BV_0 = P_0V_0) = 3P_0V_0$$

$Q_{BC} = nC_P(T_C - T_B)$

$$= \frac{n5R}{2}(T_C - T_B)$$

$$= \frac{5}{2}(P_CV_C - P_BV_B)$$

$$= \frac{5}{2}(6P_0V_0 - 3P_0V_0) = \frac{15}{2}P_0V_0$$

$$\eta = \frac{W}{Q_{in}} \times 100 = \frac{2P_0V_0}{3P_0V_0 + \frac{15}{2}P_0V_0} \times 100$$

$$\eta = \frac{400}{21} = 19.04 \approx 19$$

$\eta = 19$

KINEMATICS

1. NTA Ans. (580.00)

Sol. $x = 10 + 8t - 3t^2$

$v_x = 8 - 6t$

$(v_x)_{t=1} = 2\hat{i}$

$y = 5 - 8t^3$

$v_y = -24t^2$

$(v_y)_{t=1} = -24\hat{j}$

Now

$$\sqrt{v} = \sqrt{(24)^2 + (2)^2} = \sqrt{580}$$

$\therefore$ v = 580 m^2/s^2

2. NTA Ans. (1)

Sol. $\vec{r}(t) = \cos\omega t\,\hat{i} + \sin\omega t\,\hat{j}$

On diff. we get

$$\vec{v} = -\omega\sin\omega t\ \hat{i} + \omega\cos\omega t\ \hat{j}$$

$$\vec{a} = -\omega^2\vec{r}$$

$$\vec{v}\cdot\vec{r} = 0$$

3. NTA Ans. (8 or 2888)

Sol. Time to travel 81 m is t sec.

Time to travel 100 m is $t + \frac{1}{2}$ sec.

$$81 = \frac{1}{2}\times a\times t^2 \qquad \Rightarrow t = 9\sqrt{\frac{2}{a}}$$

$$100 = \frac{1}{2}\times a\times\left(t+\frac{1}{2}\right)^2 \qquad \Rightarrow t+\frac{1}{2} = 10\sqrt{\frac{2}{a}}$$

$$9\sqrt{\frac{2}{a}}+\frac{1}{2} = 10\sqrt{\frac{2}{a}}$$

$$\frac{1}{2} = \sqrt{\frac{2}{a}}$$

$$\boxed{a = 8\ m/s^2}$$

4. NTA Ans. (3.00)

Sol. $x = \sqrt{at^2+2bt+c}$

Differentiating w.r.t. time

$$\frac{dx}{dt} = v = \frac{1}{2\sqrt{at^2+2bt+c}}\times(2at+2b)$$

$$\Rightarrow v = \frac{at+b}{x}$$

$\Rightarrow vx = at + b$

Differentiating w.r.t. x

$$\Rightarrow \frac{dv}{dx}\times x + v = a\times\frac{dt}{dx}$$

Multiply both side by v

$$\Rightarrow \left(v\frac{dv}{dx}\right)x + v^2 = a$$

$\Rightarrow a'x = a - v^2$ [Here a' is acceleration]

$$\Rightarrow a'x = a - \left(\frac{at+b}{x}\right)^2$$

$$\Rightarrow a'x = \frac{ax^2-(at+b)^2}{x^2}$$

$$\Rightarrow a'x = \frac{a(at^2+2bt+c)-(at+b)^2}{x^2}$$

$$\Rightarrow a'x = \frac{ac-b^2}{x^2}$$

$$\Rightarrow a' = \frac{ac-b^2}{x^3}$$

$$\therefore a' \propto \frac{1}{x^3} \qquad \therefore n = 3$$

5. NTA Ans. (3)

Sol. $x = u_x t + \frac{1}{2}a_x t^2$

$y = u_y t + \frac{1}{2}a_y t^2$

$32 = 0\times t + \frac{1}{2}(4)(t)^2$

$t^2 = 16$

$t = 4$ sec

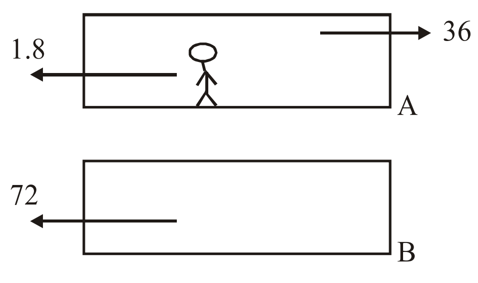
$x = 3\times 4 + \frac{1}{2}\times 6\times 4^2$

$= 12 + 48 = 60$ m

$\therefore$ Correct answer (3)

6. Official Ans. by NTA (2)

Sol.



Velocity of man with respect to ground

$\vec{V}_{m/g} = \vec{V}_{m/A} + \vec{V}_A = -1.8 + 36$

Velocity of man w.r.t. B

$\vec{V}_{m/B} = \vec{V}_m - \vec{V}_B$

$= -1.8 + 36 - (-72)$

$= 106.2$ km/hr

$= 29.5$ m/s

7. Official Ans. by NTA (3)

Sol. Given $\vec{u} = 5\hat{j}\,m/s,\ \vec{a} = 10\hat{i} + 4\hat{j}$, final coordinate (20, y_0) in time t

$S_x = 4_x t + \frac{1}{2} a_x t^2$

$20 - 0 = 0 + \frac{1}{2} \times 10 \times t^2$

t = 2sec

$S_y = u_y \times t + \frac{1}{2} a_y t^2$

$y_0 = 5 \times 2 + \frac{1}{2} 4 \times 2^2 = 18m$

2 sec and 18 m

8. Official Ans. by NTA (3)

Sol. Velocity at ground (means zero height) is non-zero therefore one is incorrect and velocity versus height is non-linear therefore two is also incorrect.

$v^2 = 2gh$

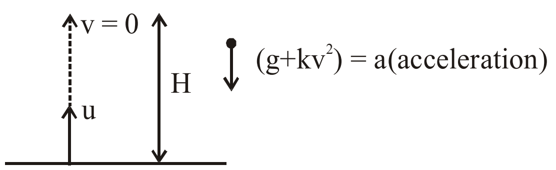
$v\frac{dv}{dh} = 2g = \text{const.}$

$\frac{dv}{dh} = \frac{\text{constant}}{v}$

Here we can see slope is very high when velocity is low therefore at Maximum height the slope should be very large which is in option 3 and as velocity increases slope must decrease there for option 3 is correct.

9. Official Ans. by NTA (2)

Sol.



$\vec{F} = mkv^2 - mg$

$\vec{a} = \frac{\vec{F}}{m} = -\left[kv^2 + g\right]$

$\Rightarrow v.\frac{dv}{dh} = -[kv^2 + g]$

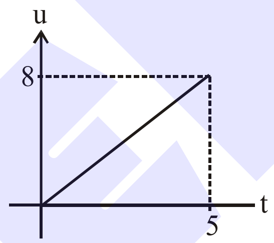
$\Rightarrow \int_u^0 \frac{v.dv}{kv^2 + g} = -\int_0^H dh$

$\frac{1}{2K} \ln\left[kv^2 + g\right]_u^0 = -H$

$\Rightarrow \frac{1}{2K} \ln\left[\frac{ku^2 + g}{g}\right] = H$

10. Official Ans. by NTA (20)

Sol.

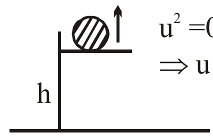


Distance = $\int v\,dt$

Area under graph = $\frac{1}{2} \times 5 \times 8$ = 20

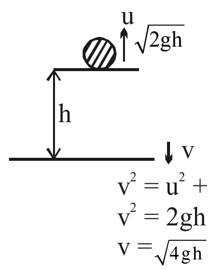
11. Official Ans. by NTA (3)

Sol.



$u^2 = 0 + 2gh$

$\Rightarrow u = \sqrt{2gh}$



$v^2 = u^2 + 2as$

$v^2 = 2gh + 2gh$

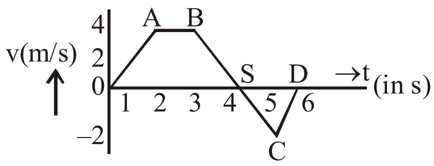
$v = \sqrt{4gh}$

$\Rightarrow \sqrt{4gh} = \sqrt{2gh} + gt$

$\Rightarrow t = \sqrt{\frac{4h}{g}} - \sqrt{\frac{2h}{g}} \Rightarrow 3.4\sqrt{\frac{h}{g}}$

12. Official Ans. by NTA (4)

Sol.



$OS = 4+\frac{1}{3}=\frac{13}{3}$

$SD = 2-\frac{1}{3}=\frac{5}{3}$

Area of OABS is A_1

Area of SCD is A_2

Distance = $|A_1| + |A_2|$

$A_1 = \frac{1}{2}\left[\frac{13}{3}+1\right]4=\frac{32}{3}$

$A_2 = \frac{1}{2}\times\frac{5}{3}\times 2=\frac{5}{3}$

Distance = $|A_1| + |A_2|$

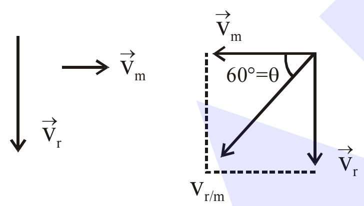
$= \frac{32}{3}+\frac{5}{3}$

$= \frac{37}{3}$

13. Official Ans. by NTA (4)

Sol. Rain is falling vertically downwards.

$\vec{v}_{r/m} = \vec{v}_r - \vec{v}_m$

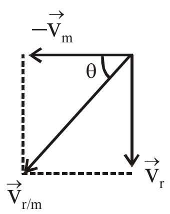


$\tan 60° = \frac{v_r}{v_m} = \sqrt{3}$

$v_r = v_m\sqrt{3} = v\sqrt{3}$

Now, $v_m = (1 + B)v$

and $\theta = 45°$



$\tan 45 = \frac{v_r}{v_m} = 1$

$v_r = v_m$

$v\sqrt{3} = (1+\beta)v$

$\sqrt{3} = 1+\beta$

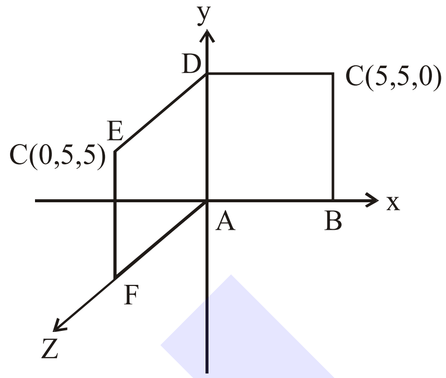
$\Rightarrow \beta = \sqrt{3}-1 = 0.73$

MAGNETISM

1. NTA Ans. (1)

2. NTA Ans. (175)

Sol.



$\vec{A}_{ABCD} = 25\hat{k}$

$\vec{A}_{ADEF} = 25\hat{i}$

$\vec{A}_{net} = 25\hat{i}+25\hat{k}$

$\vec{B} = 3\hat{i}+4\hat{k}$

$\phi = \vec{B}.\vec{A}$

$= 25 \times 3 + 25 \times 4$

ϕ = 175 $W_{b.}$

3. NTA Ans. (3)

Sol. $(2V_0)^2 = v_0^2+\upsilon_x^2$

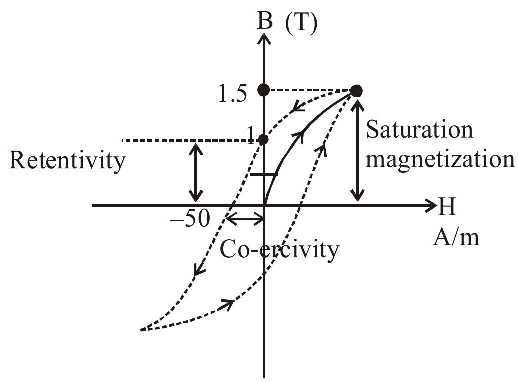
$v_x = \sqrt{3}\, v_0$

$\sqrt{3}\, v_0 = 0 + \frac{qE_0}{m}t$

$t = \frac{\sqrt{3}v_0 m}{qE_0}$

4. NTA Ans. (2)

Sol.



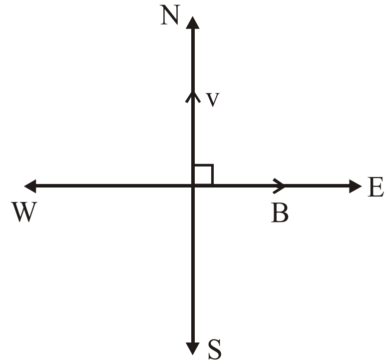
Retentivity = 1.0 T

Co-ercivity = 50 A/m

Saturation = 1.5 T

5. NTA Ans. (4)

Sol. $a = \dfrac{qvB}{m}$



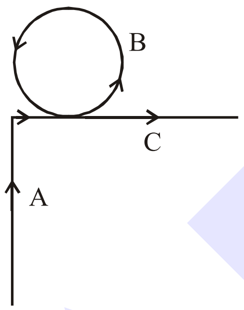
$$B = \frac{ma}{qv} = \frac{ma\sqrt{m}}{\sqrt{2k}}$$

$$= \frac{m^{3/2}a}{e\sqrt{2k}} = \frac{(1.6\times10^{-27})^{3/2}\times10^{12}}{1.6\times10^{-19}\sqrt{2\times1\times10^{6}\times1.6\times10^{-19}}}$$

= 0.71 mT

6. NTA Ans. (3)

Sol. We say we have 3 parts (A, B, C)



$B = B_A + B_B + B_C$

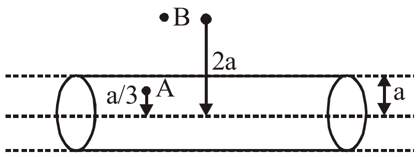
$$= \frac{\mu_0 I}{4\pi R}(\sin 90^\circ - \sin 45^\circ)\otimes + \frac{\mu_0 I}{2R}\odot + \frac{\mu_0 I}{4\pi R}(\sin 45^\circ + \sin 90^\circ)\odot$$

$$= \frac{\mu_0 I}{2\pi R}(\sin 45^\circ + \pi)$$

$$= \frac{\mu_0 I}{2\pi R}\left(\pi + \frac{1}{\sqrt{2}}\right)$$

7. NTA Ans. (1)

Sol.



Let current density be J.

∴ Applying Ampere's law.

$$\oint \vec{B}.d\vec{\ell} = \mu_0 i \Rightarrow B_A 2\pi\frac{a}{3} = \mu_0 J\pi\left(\frac{a}{3}\right)^2$$

$$\therefore\ B_A = \frac{\mu_0 Ja}{6}$$

Similarly, $B_B = \dfrac{\mu_0 Ja}{4}$

$$\therefore\ \frac{B_A}{B_B} = \frac{\mu_0 Ja\times4}{\mu_0 J6a} = \frac{2}{3}$$

8. NTA Ans. (2)

Sol. Option (A)

$W = k_f - k_i$

$$qE(2a-0) = \frac{1}{2}m(2V)^2 - \frac{1}{2}mV^2$$

$$qE2a = \frac{3}{2}mV^2 \qquad \Rightarrow E = \frac{3}{4}\frac{mv^2}{qa}$$

Option (B)

Rate of work done $P = \vec{F}.\vec{V} = FV\cos\theta = FV$

Power = qEV

$$\text{Power} = q\left(\frac{3}{4}\frac{mV^2}{qa}\right)V$$

$$\text{Power} = q\frac{3}{4}\frac{mV^3}{qa}$$

$$\text{Power} = \frac{3}{4}\frac{mV^3}{a}$$

Option (C)

Angle between electric force and velocity is 90º, hence rate of work done will be zero at Q.

Option (D)

Initial angular momentum L_i = mVa

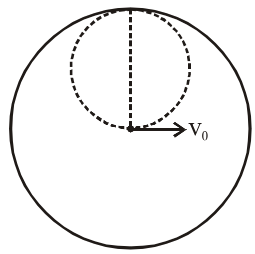
Final angular momentum L_f = m(2V) (2a)

Change in angular momentum $L_f - L_i$ = 3mVa

(Note : angular momentum is calculated about O)

9. NTA Ans. (2)

Sol. Top view of solenoid



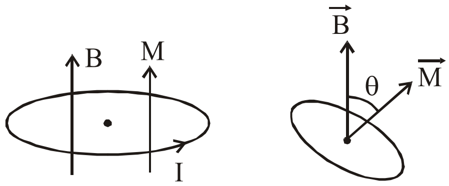
Maximum possible radius of electron = $\dfrac{R}{2}$

$$\therefore \frac{R}{2} = \frac{mv}{qB} = \frac{mv_{max}}{e(\mu_0 ni)} \qquad \Rightarrow v_{max} = \frac{R}{2}\frac{e\mu_0 ni}{m}$$

∴ Correct answer = 2

10. NTA Ans. (2)

Sol.



$\vec{T} = \vec{M} \times \vec{B} = -MB\sin\theta$

$I\alpha = -MB\ \sin\theta$

for small θ,

$$\alpha = -\frac{MB}{I}\theta$$

$$\omega = \sqrt{\frac{MB}{I}} = \sqrt{\frac{(i)(\pi R^2)B}{\left(\frac{mR^2}{2}\right)}}$$

$$\omega = \sqrt{\frac{2i\pi B}{m}}$$

$$\therefore = T = \frac{2\pi}{\omega} = \sqrt{\frac{2\pi m}{iB}}$$

∴ Correct answer (2)

11. Official Ans. by NTA (2)

Sol. $\text{Pitch} = \frac{2\pi m}{qB} v\cos\theta$

$$\text{Pitch} = \frac{2(3.14)(1.67\times10^{-27})\times4\times10^5\times\cos 60}{(1.69\times10^{-19})(0.3)}$$

Pitch = 0.04m = 4 cm

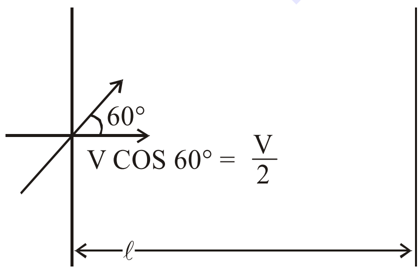
12. Official Ans. by NTA (4)

Sol. As for permanent magnet large retentivity and large coercivity required

13. Official Ans. by NTA (3)

Sol. $T = \frac{2\pi m}{qB}$

total time t = 10 T



Kinematics

$$\ell = \frac{V}{2}t \qquad \Rightarrow \ell = \frac{V}{2}10\times\frac{2\pi m}{qB}$$

$$= 4\times10^5\times10\times\frac{3.14\times1.67\times10^{-27}}{1.6\times10^{-19}\times0.3}$$

= 0.439

14. Official Ans. by NTA (1)

Sol. M = NIA

N = 1

For ABCD

$$\vec{M}_1 = abI\ \hat{K}.$$

For DEFA

$$\vec{M}_2 = abI\ \hat{j}$$

$$\vec{M} = \vec{M}_1 + \vec{M}_2$$

$$= ab\ I\ (\hat{k} + \hat{j}) \qquad \Rightarrow = ab\ I\ \sqrt{2}\ \left(\frac{\hat{j}}{\sqrt{2}} + \frac{\hat{k}}{\sqrt{2}}\right)$$

15. Official Ans. by NTA (3)

Sol. $\vec{F} = 9(\vec{V}\times\vec{B})$ (Force on charge particle moving in magnetic field)

$$\vec{V}\times\vec{B} = (2\hat{i} + 3\hat{j} + 4\hat{k})\times(5\hat{i} + 3\hat{j} - 6\hat{k})\times10^{-3}$$

$$= \begin{pmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & 3 & 4 \\ 5 & 3 & -6 \end{pmatrix} \times 10^{-3}$$

$$= \left[\hat{i}[-18-12] - \hat{j}[-12-20] + \hat{k}[6-15]\right]\times10^{-3}$$

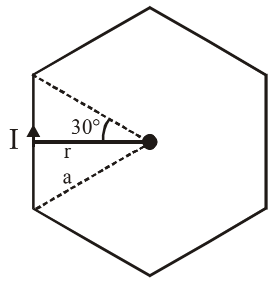
$$= \left[\hat{i}[-30] + \hat{j}[32] + \hat{k}[-9]\right]\times10^{-3}$$

$$\text{Force} = 10^{-6}[-30\hat{i} + 32\hat{j} - 9\hat{k}]\times10^{-3}$$

$$= 10^{-9}[-30\hat{i} + 32\hat{j} - 9\hat{k}]$$

16. Official Ans. by NTA (3)

Sol.



r = acos30°

$$B = \frac{6\mu_0 I}{4\pi a\cos30^\circ}\times2\sin30^\circ\times50$$

$$= \frac{\mu_0 I}{\pi}\frac{150}{\sqrt{3}a} = \frac{50\sqrt{3}}{0.1}\frac{\mu_0 I}{\pi}$$

$$= 500\sqrt{3}\frac{\mu_0 I}{\pi}$$

17. Official Ans. by NTA (1)

Sol. A perfect diamagnetic substance will completely expel the magnetic field. Therefore, there will be no magnetic field inside the cavity of sphere. Hence the paramagnetic substance kept inside the cavity will experience no force.

18. Official Ans. by NTA (20)

Sol. $\vec{\tau} = \vec{m} \times \vec{B}$

$\tau = NI \times A \times B$

$105 = 500 \times 3\times10^{-4} \times \frac{1}{2} \times B$

$B = 20$

19. Official Ans. by NTA (3)

Sol. Given $i_A = 2$, $r_A = 2$ cm, $\theta_A = 2\pi - \frac{\pi}{2} = \frac{3\pi}{2}$

$i_B = 3$, $r_B = 4$ cm, $\theta_B = 2\pi - \frac{\pi}{3} = \frac{5\pi}{3}$

$B = \frac{\mu_0 I\theta}{4\pi R} \quad \Rightarrow \frac{B_A}{B_B} = \frac{I_A}{I_B} \times \frac{\theta_A R_B}{\theta_B R_A} = \frac{6}{5}$

20. Official Ans. by NTA (4)

Sol. Torque on a bar magnet : $I = MB \sin\theta$

Here, $\theta = 30°$, $I = 0.018$ N-m, $B = 0.06$ T

$\Rightarrow 0.018 = M \times 0.06 \times \sin 30°$

$\Rightarrow 0.018 = M \times 0.06 \times \frac{1}{2}$

$\Rightarrow M = 0.6$ A-m^2

Now $v = -MB\cos\theta$

Position of stable equilibrium ($\theta = 0°$) : $u_i = -MB$

Position of unstable equilibrium ($\theta = 180°$) : $u_f = MB$

$\Rightarrow$ work done : ΔU

$\Rightarrow W = 2MB$

$\Rightarrow W = 2 \times 0.6 \times 0.06$

$\Rightarrow W = 7.2 \times 10^{-2}$ J

option (4) is correct

21. Official Ans. by NTA (2)

Sol. For paramagnetic material

According to curies law

$\chi \propto \frac{1}{T}$

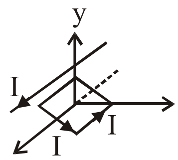
$\chi \propto \frac{1}{T} \quad \Rightarrow \quad \chi_1 T_1 = \chi_2 T_2$

$\Rightarrow \frac{6}{0.4} \times 4 = \frac{I}{0.3} \times 24$

$I = \frac{0.3}{0.4} = 0.75$ A / m

22. Official Ans. by NTA (1)

Sol.



$\vec{\tau} = \vec{M} \times \vec{B}$

$= 4a^2 I \times \frac{\mu_0 I}{2\pi b}$

23. Official Ans. by NTA (4)

Sol. $M = \mu_r NiA$

Here

μ_r = Relative permeability

N = No. of turns

i = Current

A = Aea of cross section

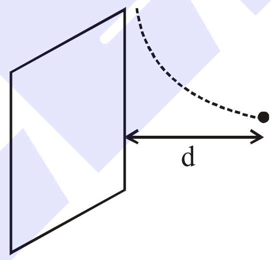
$M = \mu_r NiA = \mu_r n\ell iA$

$M = \mu_r niV = 1000(1000)\ 0.5\ (10^{-3})$

$= 500 = 5 \times 10^2$ Am^2

24. Official Ans. by NTA (2)

Sol.



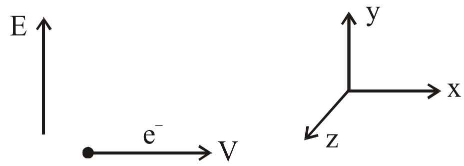
In uniform magnetic field particle moves in a circular path, if the radius of the circular path is 'd', particle will not hit the screen.

$d = \frac{mv}{qB_0} \qquad \Rightarrow v = \frac{qB_0 d}{m}$

$\therefore$ correct option is (2)

25. Official Ans. by NTA (1)

Sol.



$\vec{B}$ must be in +z axis.

$\vec{V} = 6 \times 10^6 \hat{i}$

$\vec{E} = 300\hat{j}$ V/cm = 3×10^4 V/m

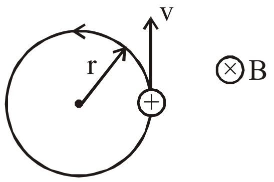
$q\vec{E} + q\vec{V} \times \vec{B} = 0$

$E = VB$

$B = \frac{E}{V} = \frac{3\times10^4}{6\times10^6} = 5\times10^{-3}$T

26. Official Ans. by NTA (4)

Sol.



Magnetic moment
M = iA

$$M = \left(\frac{q}{T}\right) \times \pi r^2 = \frac{q\pi r^2}{\left(\frac{2\pi r}{v}\right)} = \frac{qvr}{2}$$

$$M = \frac{qv}{2} \times \frac{vm}{qB}$$

$$M = \frac{mv^2}{2B}$$

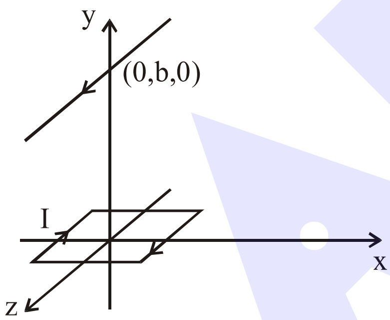
As we can see from the figure, direction of magnetic moment (M) is opposite to magnetic field.

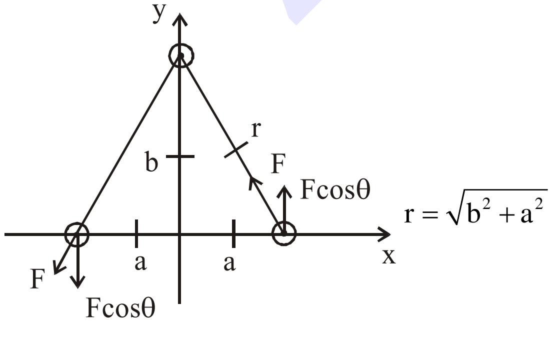
$$\vec{M} = -\frac{mv^2}{2B}\hat{B}$$

$$= -\frac{mv^2}{2B^2}\vec{B}$$

27. Official Ans. by NTA (1)

Sol.





$$F = BI2a = \frac{\mu_0 I}{2\pi r} I \times 2a$$

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

$$\tau = F\cos\theta \times 2a$$

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

$$\tau = \frac{2\mu_0 I^2 a^2 b}{\pi(a^2 + b^2)}$$

If b >> a then $\tau = \frac{2\mu_0 I^2 a^2}{\pi b}$

But among the given options (1) is most appropriate

MODERN PHYSICS

1. NTA Ans. (3)

Sol. Time period of revolution of electron in n^{th} orbit

$$T = \frac{2\pi r}{V} = \frac{2\pi a_0\left(\frac{n^2}{Z}\right)}{V_0\left(\frac{Z}{n}\right)}$$

$$\Rightarrow T \propto \frac{n^3}{Z^2}$$

$$\frac{T_2}{T_1} = \frac{(2)^3}{(1)^3} = 8 \Rightarrow T_2 = 8 \times 1.6 \times 10^{-16}$$

Now frequency $f_2 = \frac{1}{T_2} = \frac{10^{16}}{8 \times 1.6} \approx 7.8 \times 10^{14}$ Hz.

2. NTA Ans. (11)

Sol. Power incident P = I × A

n = no. of photons incident/second

$nE_{ph} = IA$

$$n = \frac{IA}{E_{ph}}$$

$$n = \frac{IA}{\left(\frac{hc}{\lambda}\right)} = \frac{6.4 \times 10^{-5} \times 1}{\frac{1240}{310} \times 1.6 \times 10^{-19}}$$

n = 10^{+14} per second

Since efficiency = 10^{-3}

no. of electrons emitted = 10^{+11} per second.

x = 11.

3. NTA Ans. (4)

Sol. $A = A_0 \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$

$500 = 700 \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$

$0.7 \approx \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$

$\left(\frac{1}{2}\right)^{1/2} \approx \frac{t}{T_{1/2}}$

$\frac{30}{T_{1/2}} \approx \frac{1}{2} \Rightarrow T_{1/2} = 60$

4. NTA Ans. (2)

Sol. $\frac{\lambda_{electron}}{\lambda_{photon}} = ?$

$E = \frac{hc}{\lambda_{photon}}$ ....(1)

$\lambda_{electron} = \frac{h}{\sqrt{2mE}}$ ....(2)

from (1) and (2)

$\frac{\lambda_{electron}}{\lambda_{photon}} = \frac{1}{c}\left(\frac{E}{2m}\right)^{1/2}$

5. NTA Ans. (3)

Sol. $\lambda_B = 2\lambda_A$

$\Rightarrow \frac{h}{\sqrt{2T_B m}} = \frac{2h}{\sqrt{2T_A m}}$

$T_A = 4T_B$ ....(i)

and $T_B = (T_A - 1.5)$ eV ....(ii)

from (i) and (ii)

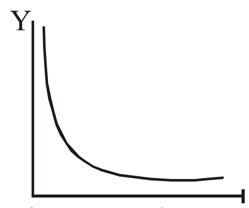
$3T_B$ 1.5 eV $\Rightarrow T_B = 0.5$ eV

$T_B = 0.5$ eV $= 4.5$ eV $-\phi_B$

$\phi = 4$eV

6. NTA Ans. (3)

Sol.



$Y \propto \frac{1}{\left(\sin\frac{\theta}{2}\right)^4}$

7. NTA Ans. (3)

Sol. By de-Broglie hypothesis

$\lambda = \frac{h}{mv}$

$\lambda_0 = \frac{h}{m\sqrt{2}v_0}$ ....(1)

$\lambda' = \frac{h}{\sqrt{v_0^2 + v_0^2 + \left(\frac{eE_0 t}{m}\right)^2}}$

$= \frac{h}{m\sqrt{2v_0^2 + \frac{e^2E_0^2t^2}{m^2}}}$ ....(2)

By (1) and (2)

$\lambda' = \frac{\lambda_0}{\sqrt{1 + \frac{e^2E_0^2t^2}{2m^2v_0^2}}}$

8. NTA Ans. (486)

Sol. For Balmer series,

$\frac{1}{\lambda} = R_H\left(\frac{1}{2^2} - \frac{1}{n_2^2}\right)$

$\frac{\lambda_2}{\lambda_1} = \frac{\left(\frac{1}{2^2} - \frac{1}{3^2}\right)}{\left(\frac{1}{2^2} - \frac{1}{4^2}\right)}$

$\frac{\lambda_2}{6561} = \frac{5/36}{3/16}$

$\lambda_2 = \frac{20}{27} \times 6561$

$\lambda_2 = 4860$ Å $= 486$ nm

9. NTA Ans. (3)

Sol. Given, de-Broglie wavelength = $\frac{h}{\sqrt{2mE}} = \lambda$

Also, $\frac{h}{\sqrt{2m(E+\Delta E)}} = \frac{\lambda}{2}$

$\therefore \frac{E+\Delta E}{E} = 4 \Rightarrow \Delta E = 3E.$

10. NTA Ans. (2)

Sol. Let the work function be ϕ.

$\therefore \ KE_{max} = \frac{hc}{\lambda} - \phi$

Again, $R_{max} = \frac{\sqrt{2mKE_{max}}}{qB} = \frac{\sqrt{2m\left(\frac{hc}{\lambda} - \phi\right)}}{qB}$

$\therefore \frac{R_{max}^2 q^2 B^2}{2m} = \frac{hc}{\lambda} - \phi$

$\therefore \ \phi = \frac{hc}{\lambda} - \frac{R_{max}^2 q^2 B^2}{2m}$ = 1.0899 eV ≈ 1.1eV

11. NTA Ans. (4)

Sol. 1 Rydberg energy = 13.6 eV

So, ionisation energy = ($13.6\ Z^2$)eV

= 9 × 13.6eV

Z = 3

$\frac{1}{\lambda} = RZ^2\left(\frac{1}{1^2} - \frac{1}{3^2}\right) = 1.09 \times 10^7 \times 9 \times \frac{8}{9}$

λ = 11.4 nm

12. NTA Ans. (1)

Sol. $a = \frac{eE}{m}$

$v = u + at = \left(\frac{eE}{m}\right)t$

$\lambda = \frac{h}{mv}$

$\frac{d\lambda}{dt} = \frac{-(hm)\cdot\frac{dv}{dt}}{(mv)^2} = -\frac{ah}{mv^2} = -\frac{h}{|e|Et^2}$

$\therefore$ Correct answer (1)

13. Official Ans. by NTA (2)

Sol. Number of uranium atoms in 2kg

$= \frac{2 \times 6.023 \times 10^{26}}{235}$

energy from one atom is 200 × 10^6 e.v. hence total energy from 2 kg uranium

$= \frac{2 \times 6.023 \times 10^{26}}{235} \times 200 \times 10^6 \times 1.6 \times 10^{-19}\,J$

2 kg uranium is used in 30 days hence this energy is recieved in 30 days hence energy recived per second or power is

$\text{Power} = \frac{2 \times 6.023 \times 10^{26} \times 200 \times 10^6 \times 1.6 \times 10^{-19}}{235 \times 30 \times 24 \times 3600}$

Power = 63.2 × 10^6 watt or 63.2 Mega Watt

14. Official Ans. by NTA (9)

Sol. $\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + eV$ .....(i)

$\frac{hc}{3\lambda} = \frac{hc}{\lambda_0} + \frac{e \cdot V}{4}$ .....(ii)

(multiply by 4)

$\frac{4hc}{3\lambda} = \frac{4hc}{\lambda_0} + eV$ ....(iii)

From (i) & (iii)

$\frac{hc}{\lambda} - \frac{hc}{\lambda_0} = \frac{4hc}{3\lambda} - \frac{4hc}{\lambda_0}$

$-\frac{hc}{3\lambda} = -\frac{3hc}{\lambda_0}$

$\boxed{9\lambda = \lambda_0}$

n = 9

15. Official Ans. by NTA (2)

Sol. In hydrogen atom,

$E_n = \frac{-E_0}{n^2}$

Where E_0 is Ionisation Energy of H.

→ For transition from (n + 1) to n, the energy of emitted radiation is equal to the difference in energies of levels.

$\Delta E = E_{n+1} - E_n$

$\Delta E = E_0\left(\frac{1}{n^2} - \frac{1}{(n+1)^2}\right)$

$\Delta E = h\nu = E_0\left(\frac{(n+1)^2 - n^2}{n^2(n+1)^2}\right)$

$h\nu = E_0\left[\frac{2n+1}{n^4\left(1+\frac{1}{n}\right)^2}\right]$

$h\nu = E_0\left[\frac{n\left(2+\frac{1}{n}\right)}{n^4\left(1+\frac{1}{n}\right)^2}\right]$

Since n >>> 1

Hence, $\frac{1}{n} \simeq 0$

$h\nu = E_0\left[\frac{2}{n^3}\right]$

$\nu \, \alpha \, \frac{1}{n^3}$

16. Official Ans. by NTA (4)

Sol. Let mass of particle = m

Let speed of e^- = V

⇒ speed of particle = 5V

Debroglie wavelength $\lambda_d = \frac{h}{P} = \frac{h}{mv}$

$\Rightarrow (\lambda_d)_P = \frac{h}{m(5V)}$ .....(1)

$\Rightarrow (\lambda_d)_e = \frac{h}{m_e.V}$ .....(2)

According to question

$\frac{(1)}{(2)} = \frac{m_e}{5m} = 1.878 \times 10^{-4}$

$\Rightarrow m = \frac{m_e}{5 \times 1.878 \times 10^{-4}}$

$\Rightarrow m = \frac{9.1 \times 10^{-31}}{5 \times 1.878 \times 10^{-4}}$

$\Rightarrow m = 9.7 \times 10^{-28}$ kg

17. Official Ans. by NTA (1)

Sol. $\frac{3}{1} = \frac{\frac{hc}{200\text{ nm}} - \phi}{\frac{hc}{500\text{ nm}} - \phi}$, hc = 1240 eV-nm

On solving ϕ = 0.61 eV

18. Official Ans. by NTA (1)

Sol. First order decay

$N(t) = N_0 e^{-\lambda t}$

Given $N(t) / N_0 = 9/16 = e^{-\lambda t}$

Now, $N(t/2) = N_0\, e^{-\lambda t/2}$

$\frac{N(t/2)}{N_0} = \sqrt{e^{-\lambda t}} = \sqrt{9/16}$

$N(t/2) = 3/4\ N_0$

19. Official Ans. by NTA (3)

Sol.

$\rho_{\text{nucleus}} = \frac{\text{mass}}{\text{volume}} = \frac{A}{(4/3)\pi r_0^3 A} = \frac{3}{4\pi r_0^3} = 2.3 \times 10^{17}\text{ kg/m}^3$

20. Official Ans. by NTA (4)

Sol. $q\Delta V = \frac{1}{2}mV^2 \Rightarrow v = \sqrt{\frac{2q\Delta V}{m}}$

$\therefore \frac{V_1}{V_2} = \sqrt{\frac{e}{m}\frac{4m}{e}} = 2$

21. Official Ans. by NTA (1)

Sol. $P = \frac{nhc}{\lambda t}$

$\therefore \frac{n_1}{n_2} = \frac{\lambda_1}{\lambda_2} = \frac{1}{5}$

22. Official Ans. by NTA (1)

Sol. Graph of V_s and f given (B 5.5, 0)

$h\nu = \phi + eV_s$

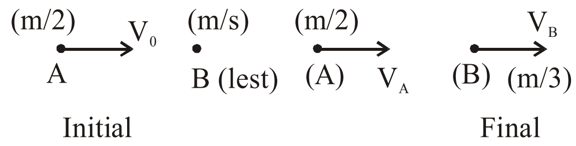
at B $V_s = 0$, $\nu = 5.5$

⇒ $h \times 5.5 \times 10^{14} = \phi$

$\phi = \frac{6.62 \times 10^{-34} \times 5.5 \times 10^{14}}{1.6 \times 10^{-19}} eV = 2.27 eV$

23. Official Ans. by NTA (1)

Sol.



Applying momentum conservation

$$\frac{m}{2}\times V_0+\frac{m}{3}\times(0)=\frac{m}{2}V_A+\frac{m}{3}V_B$$

$$=\frac{V_0}{2}=\frac{V_A}{2}+\frac{V_B}{3} \quad .... (1)$$

Since, collision is elastic (e = 1)

$$e = 1 = \frac{V_B-V_A}{V_0} \Rightarrow V_0 = V_B - V_A \quad ... (2)$$

On solving (1) & (2) : $V_A=\frac{V_0}{5}$

Now, De-Broglie wavelength of A before collision :

$$\lambda_0=\frac{h}{m_A V_0}=\frac{h}{\left(\frac{m}{2}\right)V_0}$$

$$\Rightarrow \lambda_0=\frac{2h}{mV_0}$$

Final De-Broglie wavelength :

$$\lambda_f=\frac{h}{m_A V_0}=\frac{h}{\frac{m}{2}\times\frac{V_0}{5}} \Rightarrow \lambda_f=\frac{10h}{mV_0}$$

Now $\Delta\lambda = \lambda_f - \lambda_0$

$$\Delta\lambda=\frac{10h}{mV_0}-\frac{2h}{mV_0}$$

$$\Rightarrow \Delta\lambda=\frac{8h}{mv_0} \quad \Rightarrow \Delta\lambda = 4\times\frac{2h}{mv_0}$$

$$\Rightarrow \Delta\lambda = 4\lambda_0$$

option (1) is correct.

24. Official Ans. by NTA (10553)
Official Ans. by ALLEN (10553.14)

Sol. $\lambda=\dfrac{c}{\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)}$

for lyman series

$$\lambda_1=\frac{c}{\frac{1}{1^2}-\frac{1}{\infty^2}}=c \ (n=\infty \text{ to } n=1)$$

$$\lambda_2=\frac{c}{\frac{1}{1^2}-\frac{1}{2^2}}=\frac{4c}{3} \ (n=2 \text{ to } n=1)$$

$$\Delta\lambda=\lambda_2-\lambda_1=\frac{c}{3}=304\text{Å}\Rightarrow c=912\text{Å}$$

for paschen series

$$\lambda_1=\frac{c}{\frac{1}{3^2}-\frac{1}{\infty^2}}=9c \ (n=\infty \text{ to } n=3)$$

$$\lambda_2=\frac{c}{\frac{1}{3^2}-\frac{1}{4^2}}=\frac{144c}{7} \ (n=4 \text{ to } n=3)$$

$$\Delta\lambda=\lambda_2-\lambda_1=\frac{144c}{7}-9c=\frac{81c}{7}=\frac{81\times912}{7}$$

$= 10553.14$ Å

25. Official Ans. by NTA (3)

Sol. $eV=\dfrac{hc}{\lambda}-\phi$

$$V=\left(\frac{hc}{e}\right)\left(\frac{1}{\lambda}\right)-\phi$$

Slope of the line in above equation and all other terms are independent of intensity.
The graph does not change.

26. Official Ans. by NTA (3)

Sol. $R = R_0 e^{-\lambda t}$

$\ln R = \ln R_0 - \lambda t$

$$\lambda_A=\frac{6}{10} \Rightarrow T_A=\frac{10}{6}\ln 2$$

$$\lambda_B=\frac{6}{5} \Rightarrow T_B=\frac{5\ln 2}{6}$$

$$\lambda_C=\frac{2}{5} \Rightarrow T_C=\frac{5\ln 2}{2}$$

$$\frac{10}{6}:\frac{5}{6}:\frac{15}{6} :: 2:1:3$$

27. Official Ans. by NTA (51.00)

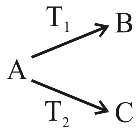
Sol. $mV_0 = MV = p$

$$10.2 = \frac{p^2}{2m} - \frac{p^2}{2M} = \frac{p^2}{2m}\left(1-\frac{m}{M}\right)$$

$$= \frac{p^2}{2m}(1-0.2)$$

$$\Rightarrow \frac{p^2}{2m} = K = \frac{10.2}{0.8}$$

28. Official Ans. by NTA (1)

Sol. 

$$\frac{1}{T_{eff}} = \frac{1}{T_1} + \frac{1}{T_2}$$

$$T_{eff} = \frac{T_1T_2}{T_1+T_2} = \frac{1000}{110} = \frac{100}{11} = 9.09$$

$$T_{eff} \cong 9$$

29. Official Ans. by NTA (2.00)

Sol. $E_1 = \phi + K_1$ ...(1)

$E_2 = \phi + K_2$ ...(2)

$E_1 - E_2 = K_1 - K_2$

Now $\frac{V_1}{V_2} = 2 \quad \Rightarrow \frac{K_1}{K_2} = 4$

$K_1 = 4K_2$

Now from equation (2)

$\Rightarrow 4–2.5 = 4K_2 - K_2$

$1.5 = 3K_2$

$K_2 = 0.5eV$

Now putting This

Value in equation (2)

$2.5 = \phi + 0.5eV$

$\boxed{\phi = 2ev}$

30. Official Ans. by NTA (4)

Sol. $\lambda = \frac{h}{P} = \frac{h}{\sqrt{2m(KE)}}$

$$\lambda \propto \frac{1}{\sqrt{m}} \Rightarrow \lambda = \frac{C}{\sqrt{m}}$$

$m_{He^{++}} > m_P > m_e$

$\therefore \lambda_{He^{++}} < \lambda_P < \lambda_e$

$\therefore$ correct option is (4)

31. Official Ans. by NTA (2)

Sol. ${}^7_3Li + {}^1_1H \rightarrow 2\left({}^4_2He\right)$

$\Delta m \Rightarrow [m_{Li} + m_H] - 2[M_{He}]$

Energy released in 1 reaction $\Rightarrow \Delta mc^2$.

In use of 7.016 u Li energy is Δmc^2

In use of 1gm Li energy is $\frac{\Delta mc^2}{m_{Li}}$

In use of 20 gm energy is $\Rightarrow \frac{\Delta mc^2}{m_{Li}} \times 20gm$

$$\Rightarrow \frac{[(7.016+1.0079)-2\times 4.0026]u\times c^2}{7.016\times 1.6\times 10^{-24}gm} \times 20gm$$

$$\Rightarrow \left(\frac{0.0187\times 1.6\times 10^{-19}\times 10^9}{7.016\times 1.6\times 10^{-24}gm}\times 20gm\right) \text{ Joule}$$

$\Rightarrow 0.05 \times 10^{+14}$ J

$\Rightarrow 1.4 \times 10^{+6}$ kwh

$[1 \text{ J} \Rightarrow 2.778 \times 10^{-7}$ kwh]

32. Official Ans. by NTA (1)

Sol. Only in case-I, $M_{LHS} > M_{RHS}$ i.e. total mass on reactant side is greater then that on the product side. Hence it will only be allowed.

33. Official Ans. by NTA (2)

Sol. $v_{rms} = \sqrt{\frac{3KT}{m}}$

$m \rightarrow$ mass of one molecule (in kg) $= \frac{\text{molar mass}}{NA}$

de-Broglie wavelenth,

$$\lambda = \frac{h}{mv}$$

given, $v = v_{rms}$

$$\lambda = \frac{h}{m\sqrt{\frac{3KT}{m}}} \quad \Rightarrow \lambda = \frac{h}{\sqrt{3KTm}}$$

$$= \frac{6.63\times 10^{-34}}{\sqrt{3\times 1.38\times 10^{-23}\times 400\times\left(\frac{28\times 10^{-3}}{6.023\times 10^{-23}}\right)}}$$

$$\lambda = \frac{6.63\times 10^{-11}}{2.77} = 2.39\times 10^{-11} m$$

$\lambda = 0.24$ Å

34. Official Ans. by NTA (1)

Sol. B.E. = $[\Delta m].c^2$

$M_{expected} = ZM_p + (A - Z)M_n$
$= 50\ [1.00783] + 70\ [1.00867]$

$M_{actual} = 119.902199$

$$B.E. = \left[50[1.00783] + 70[1.00867] - 119.902199\right] \times 931$$

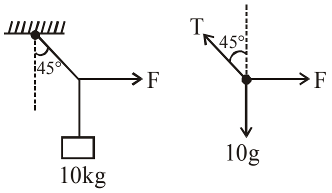
$= 1020.56$

$$\frac{BE}{nucleon} = \frac{1020.56}{120} = 8.5\ MeV$$

NLM & FRICTION

1. NTA Ans. (1)

Sol.



For equilibrium,

T sin 45° = F ....(1)

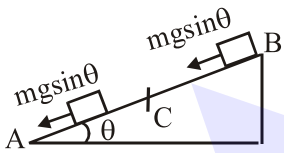
and T cos 45° = 10g ....(2)

equation (1)/(2)

we get F = 10g = 100 N

2. Official Ans. by NTA (3)

Sol.



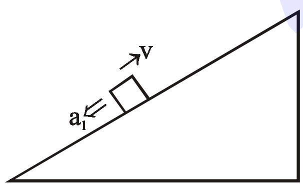
Apply work energy theorem

mgsinθ (AC + 2AC) – μmg cosθAC = 0

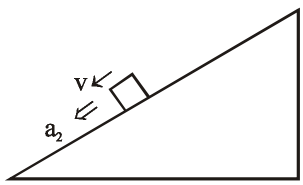
μ = 3tanθ

3. Official Ans. by NTA (346)

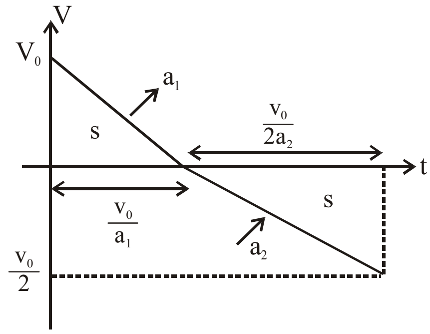
Sol.



$a_1 = g(\sin\theta + \mu \cos\theta)$



$a_2 = g(\sin\theta + \mu \cos\theta)$



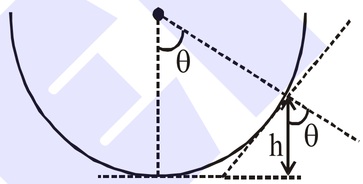
$$\therefore \frac{1}{2}v_0\frac{v_0}{a_1} = \frac{1}{2}\left(\frac{v_0}{2}\right)\left(\frac{v_0}{2a_1}\right)$$

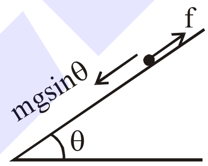
$\Rightarrow 3 \sin\theta = 5 \mu \cos\theta$

$\therefore \mu = \sqrt{3}/5$

4. Official Ans. by NTA (4)

Sol.



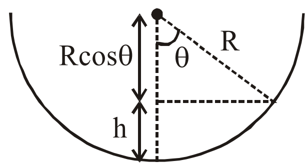


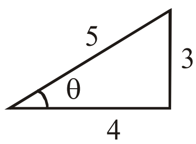
For balancing mgsinθ = f

mgsinθ = μmgcosθ

tanθ = μ

$$\tan\theta = \frac{3}{4}$$





h = R – R cosθ

$$= R - R\left(\frac{4}{5}\right) = \frac{R}{5}$$

$$h = \frac{R}{5} = 0.2m$$

$\therefore$ correct option is (4)

PRINCIPAL OF COMUNICATION

1. **Official Ans. by NTA (3)**

Official Ans. by ALLEN

(Close Option is 3 Amax. = 8, Amin. = 2)

Sol. $V_m = 5(1+0.6\cos 6280t)\sin(2\pi \times 10^4 t)$

$V_m = [5+3\cos 6820t]\sin(2\pi \times 10^4 t)$

$V_{max.} = 5 + 3 = 8$

$V_{min.} = 5 - 3 = 2$

ROTATIONAL MECHANICS

1. **NTA Ans. (3)**

Sol. $mgh = \frac{1}{2}mv^2 + \frac{1}{2}\times\frac{1}{2}mr^2 \times \frac{v^2}{r^2} = \frac{3}{4}mv^2$

$u = \sqrt{\frac{4}{3}gh}$

$\omega = \frac{v}{r}$

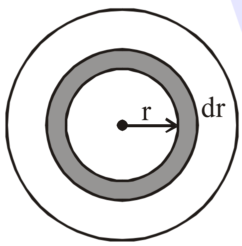
2. **NTA Ans. (2)**

Sol. $m\frac{l^2}{12} + m\frac{l^2}{16} = mk^2$

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

3. **NTA Ans. (1)**

Sol.



$dI = dmr^2$

$dI = \sigma 2\pi r\, dr\, r^2$

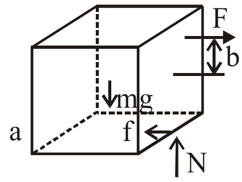
$dI = 2\pi(A + Br)\, r^3\, dr$

$\int dI = 2\pi\int_0^a (Ar^3 + Br^4)dr$

$I = 2\pi a^4 \left(\frac{A}{4} + \frac{B9}{5}\right)$

4. **NTA Ans. (75)**

Sol.



$F = \mu mg$ ...(1)

$F\left(b + \frac{a}{2}\right) = mg\ \frac{a}{2}$ ...(2)

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

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

$0.4 = \mu = \frac{a}{2b+a}$

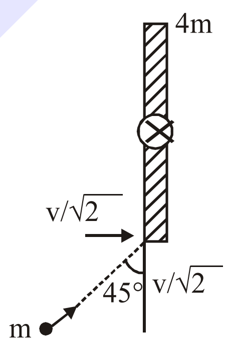
$0.8b + 0.4a = a$

$0.8\ b = 0.6\ a$

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

5. **NTA Ans. (2)**

Sol.



Let angular velocity of the system after collision be ω.

By conservation of angular momentum about the hinge :

$m\left(\frac{v}{\sqrt{2}}\right)\left(\frac{\ell}{2}\right) = \left[\frac{4m\ell^2}{12} + \frac{m\ell^2}{4}\right]\omega$

On solving

$\omega = \frac{3\sqrt{2}}{7}\left(\frac{v}{\ell}\right)$

6. NTA Ans. (1)

Sol. m = 0.5 kg, v = 5 cm/s

KE in rolling = $\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

$= \frac{1}{2}mv^2\left(1+\frac{K^2}{R^2}\right)$

$= 8.75 \times 10^{-4}$ J

7. NTA Ans. (1)

Sol. From parallel axis theorem

$$I_0 = 3\times\left[\frac{2}{5}M\left(\frac{d}{2}\right)^2 + M\left(\frac{d}{\sqrt{3}}\right)^2\right] = \frac{13}{10}Md^2$$

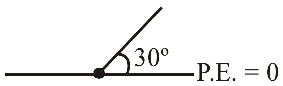
$$I_A = I_0 + 3M\left(\frac{d}{\sqrt{3}}\right)^2$$

$$= \frac{13}{10}Md^2 + Md^2$$

$$= \frac{23}{10}Md^2 \qquad \Rightarrow \frac{I_0}{I_A} = \frac{13}{23}$$

8. NTA Ans. (15.00)

Sol.



From mechanical energy conservation,

$U_i + K_i = U_f + K_f$

$$\Rightarrow mg\frac{\ell}{2}\sin 30° + 0 = 0 + \frac{1}{2}I\omega^2$$

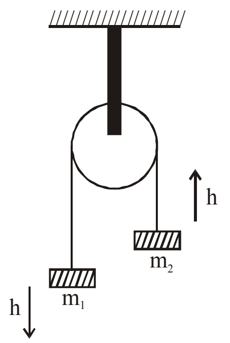
$$\Rightarrow mg \times \frac{1}{2} \times \frac{1}{2} + 0 = 0 + \frac{1}{2} \times \frac{m(1)^2}{3}\omega^2$$

$$\Rightarrow \omega^2 = \frac{3g}{2} \Rightarrow \omega = \sqrt{15}$$

$\therefore$ n = 15

9. NTA Ans. (2)

Sol.



by using work energy theorem

$W_g = \Delta KE$

$$(m_1 - m_2)gh = \frac{1}{2}(m_1+m_2)V^2 + \frac{1}{2}I\omega^2$$

$$(m_1 - m_2)gh = \frac{1}{2}(m_1+m_2)(\omega R)^2 + \frac{1}{2}I\omega^2$$

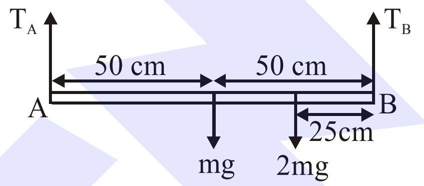
$$(m_1 - m_2)gh = \frac{\omega^2}{2}\left[(m_1+m_2)R^2 + I\right]$$

$$\omega = \sqrt{\frac{2(m_1-m_2)gh}{(m_1+m_2)R^2+I}}$$

$\therefore$ Correct answer (2)

10. Official Ans. by NTA (4)

Sol.



$\tau_B = 0$ (torque about point B is zero)

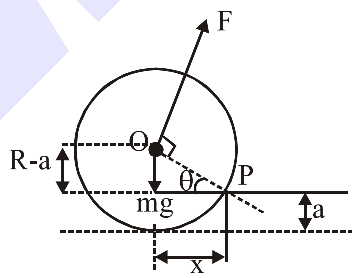
$(T_A) \times 100 - (mg) \times 50 - (2mg) \times 25 = 0$

$100\ T_A = 100$ mg

$T_A = 1$ mg

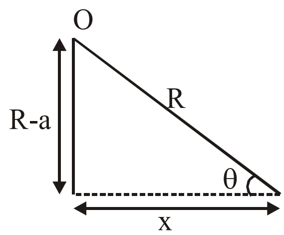
11. Official Ans. by NTA (4)

Sol.



$(\tau)_P = 0$

F.R. – mgx = 0



$$x = \sqrt{R^2 - (R-a)^2}$$

$$F = mg\frac{x}{R}$$

$$F = mg\sqrt{1-\left(\frac{R-a}{R}\right)^2}$$

= minimum value of force to pull

12. Official Ans. by NTA (4)

Sol. • Both discs are rotating in same sense

• Angular momentum conserved for the system

i.e. $L_1 + L_2 = L_{final}$

$I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\omega_f$

$0.1 \times 10 + 0.2 \times 5 = (0.1+0.2) \times \omega_f$

$$\omega_f = \frac{20}{3}$$

• Kinetic energy of combined disc system

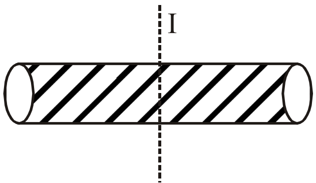
$$\Rightarrow \frac{1}{2}(I_1 + I_2)\omega_f^2$$

$$= \frac{1}{2}(0.1+0.2).\left(\frac{20}{3}\right)^2$$

$$= \frac{0.3}{2} \times \frac{400}{9} = \frac{120}{18} = \frac{20}{3}\text{J}$$

13. Official Ans. by NTA (3)

Sol.



$$I = M\left(\frac{R^2}{4} + \frac{L^2}{12}\right) \quad .....(1)$$

as mass is constant $\Rightarrow m = \rho V$ = constant

V = constant

$\pi^2 R l$ = constant $\Rightarrow R^2L$ = constant

$$2RL + R^2\frac{dL}{dR} = 0 \quad .....(2)$$

From equation (1)

$$\frac{dI}{dR} = M\left(\frac{2R}{4} + \frac{2L}{12} \times \frac{dL}{dr}\right) = 0$$

$$\frac{R}{2} + \frac{L}{6}\frac{dL}{dR} = 0$$

Substituting value of $\frac{dL}{dR}$ from eqution (2)

$$\frac{R}{2} + \frac{L}{6}\left(\frac{-2L}{R}\right) = 0$$

$$\frac{R}{2} = \frac{L^2}{3R} \Rightarrow \frac{L}{R} = \sqrt{\frac{3}{2}}$$

14. Official Ans. by NTA (2)

Sol. Angular momentum conservation

$$mvl = \frac{Ml^2}{3}\omega + ml^2\omega$$

$$\Rightarrow \omega = \frac{1\times 6 \times 1}{\frac{2}{3}+1} = \frac{18}{5}$$

Now using energy consevation

$$\frac{1}{2}\left(M\frac{l^2}{3}\right)\omega^2 + \frac{1}{2}(ml^2)\omega^2$$

$$= (m+M)r_{cm}(1-\cos\theta)$$

$$= (m+M)\left(\frac{ml + \frac{Ml}{2}}{m+M}\right)g(1-\cos\theta)$$

$$\frac{5}{6}\times\left(\frac{18}{5}\right)^2 = 20(1-\cos\theta)$$

$$\Rightarrow 1-\cos\theta = \frac{18}{5}\times\frac{3}{20}$$

$$\cos\theta = 1 - \frac{27}{50}$$

$$\cos\theta = \frac{23}{50} \Rightarrow \theta \simeq 63°$$

15. Official Ans. by NTA (9)

Sol. $L_i = L_f$

$$\left(80R^2 + \frac{200R^2}{2}\right)\omega = \left(0 + \frac{200R^2}{2}\right)\omega_1$$

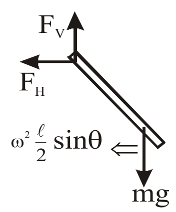
$180\omega_0 = 100\omega_1$

$\omega_1 = 1.8\omega_0 = 1.8 \times 5$

$= 9$ rpm

16. Official Ans. by NTA (2)

Sol.



$F_V = mg$

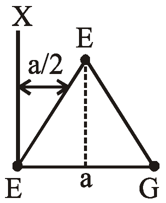
$$F_H = m\omega^2\frac{\ell}{2}\sin\theta$$

$$mg\frac{\ell}{2}\sin\theta - m\omega^2\frac{\ell}{2}\sin\theta\frac{\ell}{2}\cos\theta = \frac{m\ell^2}{12}\omega^2\sin\theta\cos\theta$$

$$\cos\theta = \frac{3}{2}\frac{g}{\omega^2\ell} \quad .....(ii)$$

17. Official Ans. by NTA (25)

Sol.

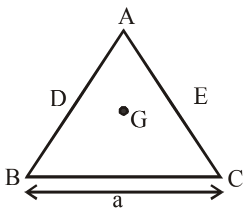


$$I = 0 + m\left(\frac{a}{2}\right)^2 + ma^2$$

$$= \frac{5}{4}ma^2$$

18. Official Ans. by NTA (11)

Sol. Let side of triangle is a and mass is m



MOI of plate ABC about centroid

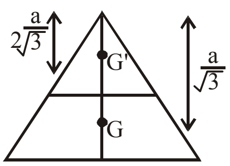
$$I_0 = \frac{m}{3}\left(\left(\frac{a}{2\sqrt{3}}\right)^2 \times 3\right) = \frac{ma^2}{12}$$

triangle ADE is also an equilateral triangle of side a/2.

Let moment of inertia of triangular plate ADE about it's centroid (G') is I_1 and mass is m_1

$$m_1 = \frac{m}{\frac{\sqrt{3}a^2}{4}} \times \frac{\sqrt{3}}{4}\left(\frac{a}{2}\right)^2 = \frac{m}{4}$$

$$I_1 = \frac{m_1}{12}\left(\frac{a}{2}\right)^2 = \frac{m}{4 \times 12}\frac{a^2}{4} = \frac{ma^2}{192}$$



distance GG' $= \frac{a}{\sqrt{3}} - \frac{a}{2\sqrt{3}} = \frac{a}{2\sqrt{3}}$

so MOI of part ADE about centroid G is

$$I_2 = I_1 + m_1\left(\frac{a}{2\sqrt{3}}\right)^2 = \frac{ma^2}{192} + \frac{m}{4}.\frac{a^2}{12}$$

$$= \frac{5ma^2}{192}$$

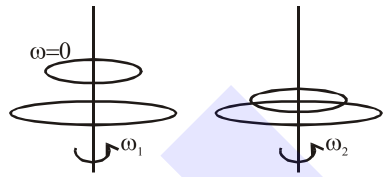
now MOI of remaining part

$$= \frac{ma^2}{12} - \frac{5ma^2}{192} = \frac{11ma^2}{12 \times 16} = \frac{11I_0}{16}$$

$\Rightarrow$ N = 11

19. Official Ans. by NTA (20)

Sol.



Let moment of inertia of bigger disc is $I = \frac{MR^2}{2}$

$\Rightarrow$ MOI of small disc $I_2 = \frac{M\left(\frac{R}{2}\right)^2}{2} = \frac{I}{4}$

by angular momentum conservation

$$I\omega_1 + \frac{I}{4}(0) = I\omega_2 + \frac{I}{4}\omega_2 \Rightarrow \omega_2 = \frac{4\omega_1}{5}$$

initial kinetic energy $K_1 = \frac{1}{2}I\omega_1^2$

final kinetic energy K_2

$$= \frac{1}{2}\left(I + \frac{I}{4}\right)\left(\frac{4\omega_1}{5}\right)^2 = \frac{1}{2}I\omega_1^2\left(\frac{4}{5}\right)$$

$$P\% = \frac{K_1 - K_2}{K_1} \times 100\% = \frac{1 - 4/5}{1} \times 100 = 20\%$$

20. Official Ans. by NTA (2)

Sol. $I_1 = \frac{MR^2}{2} = \frac{\rho(\pi R^2)t.R^2}{2}$

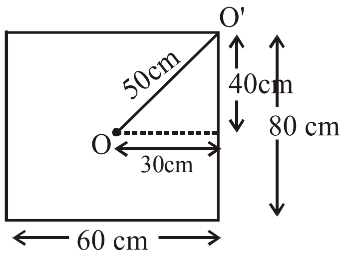
$I \propto R^4$

$$\frac{I_1}{I_2} = \frac{R_1^4}{R_2^4} = \frac{1}{16}$$

$$\therefore \frac{R_1}{R_2} = \frac{1}{2}$$

21. Official Ans. by NTA (4)

Sol.



Rectangular sheet

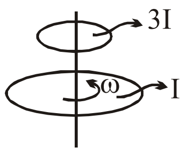
$$I_O = \frac{M}{12}[L^2 + B^2] = \frac{M}{12}[80^2 + 60^2]$$

$$I_{O'} = I_0 + Md^2 \{\text{parallel axis theorem}\}$$
$$= \frac{M}{12}\left[80^2 + 60^2\right] + M\,[50]^2$$

$$\frac{I_O}{I_{O'}} = \frac{M/12[80^2 + 60^2]}{\frac{M}{12}[80^2 + 60^2] + M[50]^2} = \frac{1}{4}$$

22. Official Ans. by NTA (3)

Sol.



By anglar momentum conservation

$$\omega I + 3I \times 0 = 4I\omega' \Rightarrow \omega' = \frac{\omega}{4}$$

$$(KE)_i = \frac{1}{2} I\omega^2$$

$$(KE)_f = \frac{1}{2} \times (4I) \times \left(\frac{\omega}{4}\right)^2 = \frac{I\omega^2}{8}$$

$$\Delta KE = \frac{3}{8} I\omega^2$$

$$\text{fractional loss} = \frac{\Delta KE}{KE_1} = \frac{\frac{3}{8}I\omega^2}{\frac{1}{2}I\omega^2} = \frac{3}{4}$$

23. Official Ans. by NTA (195)

Sol. $\vec{\tau} = \left(\vec{r}_2 - \vec{r}_1\right) \times \vec{F}$

$$= [(4\hat{i} + 3\hat{j} - \hat{k}) - (\hat{i} + 2\hat{j} + \hat{k})] \times \vec{F}$$

$$= \left(3\hat{i} + \hat{j} - 2\hat{k}\right) \times \left(\hat{i} + 2\hat{j} + 3\hat{k}\right)$$

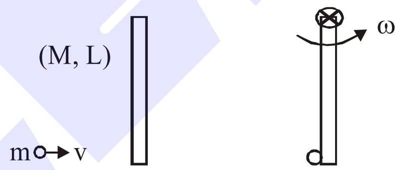
$$\tau = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & 1 & -2 \\ 1 & 2 & 3 \end{vmatrix}$$

$$= 7\hat{i} - 11\hat{j} + 5\hat{k}$$

$$|\vec{\tau}| = \sqrt{195}$$

24. Official Ans. by NTA (20.00)

Sol.



Before collision After collision

$$\vec{L}_i = \vec{L}_f$$

$$mvL = I\omega$$

$$mvL = \left(\frac{ML^2}{3} + mL^2\right)\omega$$

$$0.1 \times 80 \times 1 = \left(\frac{0.9 \times 1^2}{3} + 0.1 \times 1^2\right)\omega$$

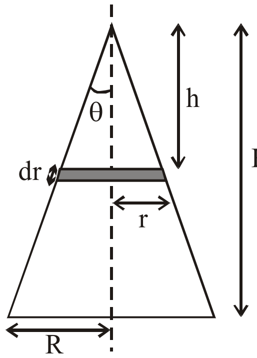
$$8 = \left(\frac{3}{10} + \frac{1}{10}\right)\omega$$

$$8 = \frac{4}{10}\omega$$

$$\omega = 20 \text{ rad}\frac{\text{rad}}{\text{sec}}$$

25. Official Ans. by NTA (1)

Sol.



Area = $\pi R\ell = \pi R\left(\sqrt{H^2+R^2}\right)$

Area of element dA = $2\pi r d\ell = = 2\pi r\dfrac{dh}{\cos\theta}$

mass of element $dm = \dfrac{M}{\pi R\sqrt{H^2+R^2}}\times\dfrac{2\pi r dh}{\cos\theta}$

$dm = \dfrac{2Mh\tan\theta dh}{R\sqrt{H^2+R^2}\cos\theta}$ (here r = h tanθ)

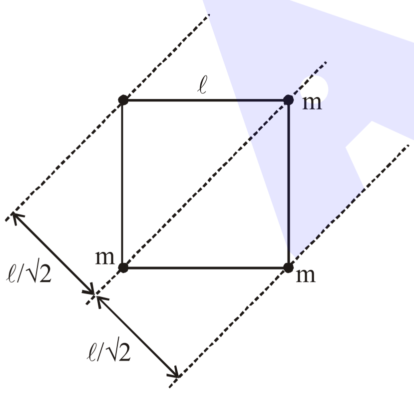
$I = \int(dm)r^2 = \int\dfrac{h^2\tan^2\theta}{\cos\theta}\left(\dfrac{2m}{R}\dfrac{h\tan\theta}{\sqrt{R^2+H^2}}\right)dh$

$= \dfrac{2M}{\cos\theta R}\dfrac{\tan^3\theta}{\sqrt{R^2+H^2}}\int_0^H h^3 dh = \dfrac{MR^2H^4}{2RH^3\sqrt{R^2+H^2}\cos\theta}$

$= \dfrac{MR^2H\sqrt{R^2+H^2}}{2\sqrt{R^2+H^2}\times H} \Rightarrow = \dfrac{MR^2}{2}$

26. Official Ans. by NTA (2)

Sol.



$I = m(0)^2 + m\left(\dfrac{\ell}{\sqrt{2}}\right)^2\times 2 + m\left(\sqrt{2}\ell\right)^2$

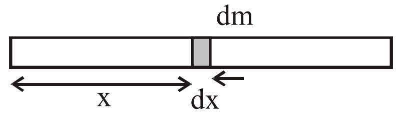
$= \dfrac{2m\ell^2}{2} + 2m\ell^2 = 3m\ell^2$

Angular momentum L = Iω

= $3m\ell^2\omega$

27. Official Ans. by NTA (4)

Sol.



$I = \int r^2 dm = \int x^2\lambda dx \Rightarrow I = \int_0^L x^2\lambda_0\left(1+\dfrac{x}{L}\right)dx$

$I = \lambda_0\int_0^L\left(x^2+\dfrac{x^3}{L}\right)dx$

$I = \lambda\left[\dfrac{L^3}{3}+\dfrac{L^3}{4}\right]$

$I = \dfrac{7L^3\lambda_0}{12}$ ....(i)

$M = \int_0^L\lambda dx = \int_0^L\lambda_0\left(1+\dfrac{x}{L}\right)dx$

$M = \lambda_0\left(L+\dfrac{L}{2}\right) = \lambda_0\dfrac{3L}{2}$

$\dfrac{2}{3}M = (\lambda_0 L)$ ....(ii)

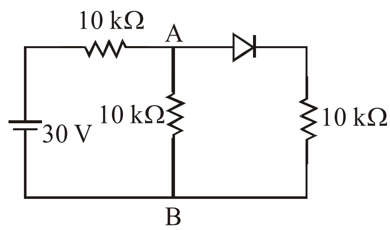
From (i) & (ii) $I = \dfrac{7}{12}\left(\dfrac{2}{3}M\right)L^2 = \dfrac{7ML^2}{18}$

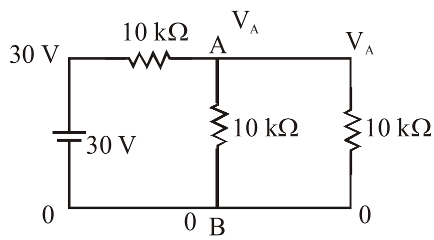
Ans. (4)

SEMICONDUCTOR

1. **Official Ans. by NTA (2)**
2. **Official Ans. by NTA (2)**

Sol.





$\dfrac{30-V_A}{10}+\dfrac{0-V_A}{10}+\dfrac{0-V_A}{10}=0$

$3 = \dfrac{3V_A}{10}$

V_A = 10 V

3. Official Ans. by NTA (3)

Sol.

A	B	Y
0	0	1
1	0	0
0	1	0
1	1	0

4. Official Ans. by NTA (2)

Sol. $Y = \overline{\overline{AB}.A}$

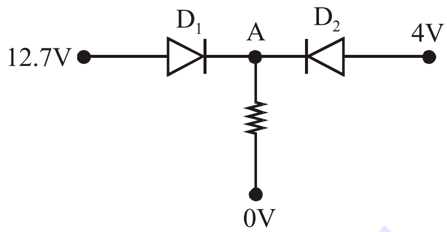
$= \overline{\overline{AB}} + \overline{A}$

$= 0 + 0$

$= 0$

5. Official Ans. by NTA (12.00)

Sol.

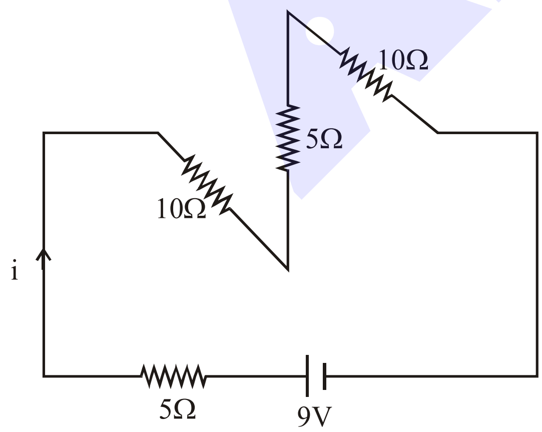


Diode D_1 is forward biased and D_2 is reverse biased.

$\therefore$ $V_A = 12.7 - 0.7 = 12V.$

6. Official Ans. by NTA (3)

Sol.

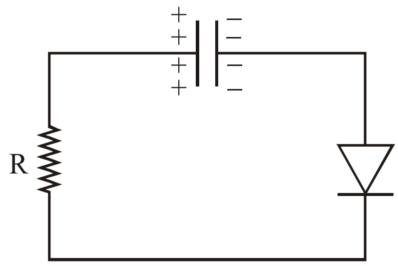


$i = \frac{9}{(5+10+5+10)} = \frac{9}{30} A$

$\therefore$ Correct answer (3)

7. Official Ans. by NTA (1)

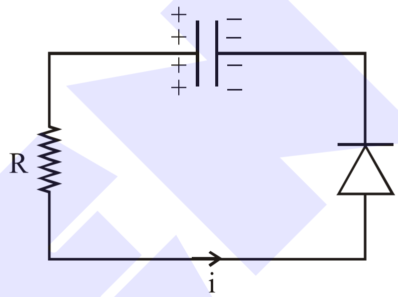
Sol. For (A)



No current flows

Hence $Q_A = CV$

For (B)



$i = \frac{V}{R} e^{-\frac{t}{RC}}$

$q = CVe^{-\frac{t}{RC}}$

at $t = CR$

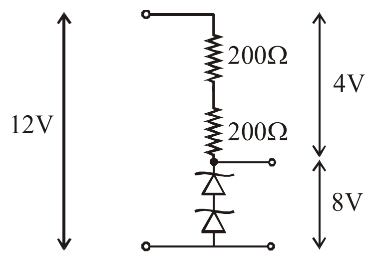
$Q_B = CVe^{-1} = \frac{CV}{e}$

$\therefore$ Correct answer (1)

8. Official Ans. by NTA (12.00)

ALLEN Ans. (40.00)

Sol.



Current in circuit $= \frac{4}{400} = \frac{1}{100} A$

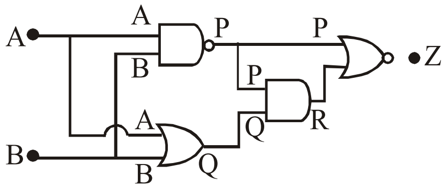
So power dissipated in each diode = VI

$= 4 \times \frac{1}{100} W = 40 \times 10^{-3}$ mW

$\therefore$ Correct answer 40

9. Official Ans. by NTA (3)

Sol.



$Z = \overline{(P+R)}$

$Z = \overline{(P+PQ)}$

$Z = \overline{(P(1+Q))}$

$Z = \overline{(P)}$ [Using Identity $(1+A)=1$]

$Z = \overline{(\overline{AB})}$

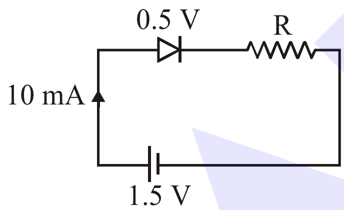
Z = AB

Truth table for Z = AB

A	B	Z
1	0	0
0	0	0
1	1	1

10. Official Ans. by NTA (1)

Sol.



$1.5 - 0.5 - R \times 10 \times 10^{-3} = 0$

$\therefore$ R = 100 Ω

11. Official Ans. by NTA (3)

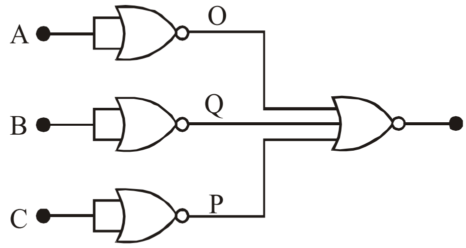
Sol. $\Delta E = \frac{\lambda c}{\lambda e} = 3.1 eV$

12. Official Ans. by NTA (2)

Sol. As there are two zener diodes in reverse polarity so if one is in forward bias the other will be in reverse bias and above 6V the reverse bias will too be in conduction mode. Therefore when voltage is more than 6V the output will be constant. And when it is less than 6V it will follow the input voltage so correct answer is two.

13. Official Ans. by NTA (1)

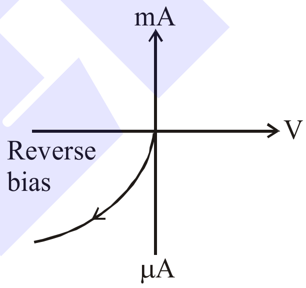
Sol.



A	B	C	
0	0	0	0
1	0	0	0
0	1	0	0
0	0	1	0
1	1	0	0
1	0	1	0
0	1	1	0
1	1	1	1

14. Official Ans. by NTA (1)

Sol. I-V characteristic of a photodiode is as follows:



On increasing the potential difference the current first increases and then attains a saturation.

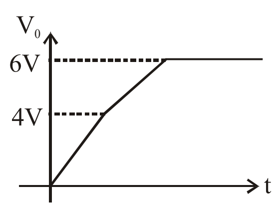
15. Official Ans. by NTA (4)

Official Ans. by ALLEN (2)

Sol. Till input voltage Reaches 4V No zener is in Breakdown Region So $V_0 = V_i$ Then Now when V_i changes between 4V to 6V One Zener with 4V will Breakdown are P.D. across This zener will become constant and Remaining Potential will drop. acro

Resistance in series with 4V Zener.

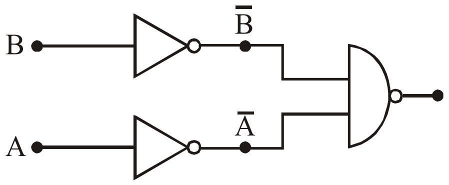
Now current in circuit increases Abruptly and source must have an internal resistance due to which. Some potential will get drop across the source also so correct graph between V_0 and t. will be



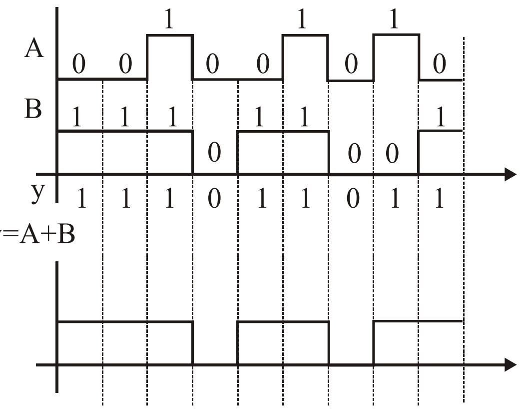
We have to Assume some resistance in series with source.

16. Official Ans. by NTA (3)
Official Ans. by ALLEN None (Approx Ans can be 2)

Sol.



$y = \overline{\bar{A}.\bar{B}} = \bar{\bar{A}} + \bar{\bar{B}} = A + B$



17. Official Ans. by NTA (150.00)

Sol. $\Delta I_B = (30 - 20) = 10\mu A$

$\Delta I_C = (4.5 - 3)\ mA = 1.5mA$

$$\beta_{ac} = \frac{\Delta I_C}{\Delta I_B} = \frac{1.5mA}{10\mu A} = 150$$

$\beta_{ac} = 150$

SIMPLE HARMONIC MOTION

1. Official Ans. by NTA (4)

Sol. (A) $F = ma$ $\quad a = -\omega^2 x$

at $\frac{3T}{4}$ displacement zero ($x = 0$), so $a = 0$

$F = 0$

(B) at $t = T$ displacement (x) = A

x maximum, So acceleration is maximum.

(C) $V = \omega\sqrt{A^2 - x^2}$

V_{max} at $x = 0$

$V_{max} = A\omega$

at $t = \frac{T}{4}$, $x = 0$, So $V_{max.}$

(D) KE = PE

$\therefore$ at $x = \frac{A}{\sqrt{2}}$.

at $t = \frac{T}{2}$ $x = -A$ (So not possible)

2. Official Ans. by NTA (4)

Sol. At equilibrium position

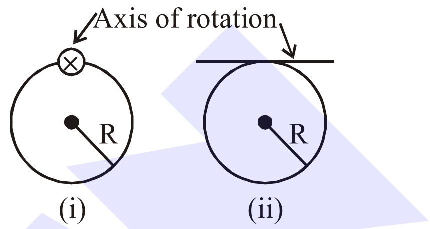
$$V_0 = \omega_0 A = \sqrt{\frac{K}{m}}A \quad .....(i)$$

$$V = \omega A^1 = \sqrt{\frac{K}{\frac{m}{2}}}A^1 \quad .....(ii)$$

$$\therefore \ A^1 = \frac{A}{\sqrt{2}}$$

3. Official Ans. by NTA (1)

Sol.



Moment of inertia in case (i) is I_1

Moment of inertia in case (ii) is I_2

$I_1 = 2MR^2$

$I_2 = \frac{3}{2}MR^2$

$$T_1 = 2\pi\sqrt{\frac{I_1}{Mgd}} \ ; \ T_2 = 2\pi\sqrt{\frac{I_2}{Mgd}}$$

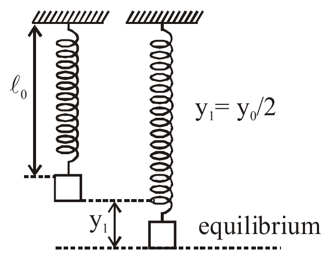
$$\frac{T_1}{T_2} = \sqrt{\frac{I_1}{I_2}} = \sqrt{\frac{2MR^2}{\frac{3}{2}MR^2}} = \frac{2}{\sqrt{3}}$$

4. Official Ans. by NTA (2)

Sol. $y = y_0 \sin^2\omega t$

$$y = \frac{y_0}{2}(1 - \cos 2\omega t) \Rightarrow y - \frac{y_0}{2} = -\frac{y_0}{2}\cos 2\omega t$$

Amplitude : $\frac{y_0}{2}$



$$\frac{y_0}{2} = \frac{mg}{K} \Rightarrow 2\omega = \sqrt{\frac{K}{m}} = \sqrt{\frac{2g}{y_0}}$$

$$\omega = \sqrt{\frac{g}{2y_0}}$$

Ans. (2)

UNIT & DIMENSION

1. NTA Ans. (1)

Sol. Magnetic energy stored per unit volume is

$\frac{B^2}{2\mu_0}$ $\Rightarrow$ Dimension is $ML^{-1}T^{-2}$

2. NTA Ans. (BONUS)

Sol. $v_0 = h^x c^y G^z A^w$

$\frac{ML^2T^{-2}}{AT} = (ML^2T^{-1})^x(LT^{-1})^y(M^{-1}L^3T^{-2})^z A^w$

$\Rightarrow w = -1$

$(x - z = 1)$

$2x + y + 3x = 2$

$- x - y - 2z = -3$

$2x = 0$

$x = 0$

$z = -1$

$2 \times 0 + y + 3x - 1 = 2$

$y = 5 \quad \Rightarrow v_0 = h^0c^5G^{-1}A^{-1}$

So Bonus

3. NTA Ans. (3)

Sol. $[h] = M^1L^2T^{-1}$

$[C] = L^1T^{-1}$

$[G] = M^{-1}L^3T^{-2}$

$[f] = \sqrt{\frac{M^1L^2T^{-1} \times L^5T^{-5}}{M^{-1}L^3T^{-2}}} = M^1L^2T^{-2}$

4. Official Ans. by NTA (1)

Sol. $Y = F^xA^yV^z$

$M^1L^{-1}T^{-2} = [MLT^{-2}]^x[L^2]^y[LT^{-1}]^z$

$M^1L^1T^{-2} = [M]^x[L]^{x+2y+z}[T]^{-2x-z}$

comparing power of ML and T

$x = 1$...(1)

$x + 2y + z = -1$ ....(2)

$-2x - z = -2$ ...(3)

after solving

$x = 1$

$y = -1$

$z = 0$

$Y = FA^{-1}V^0$

5. Official Ans. by NTA (2)

Sol. Let $[E] = [P]^x [A]^y [T]^z$

$ML^2T^{-2} = [MLT^{-1}]^x [L^2]^y [T]^z$

$ML^2T^{-2} = M^x L^{x+2y} T^{-x+z}$

$\rightarrow x = 1$

$\rightarrow x + 2y = 2$

$1 + 2y = 2$

$y = \frac{1}{2}$

$\rightarrow -x + z = -2$

$-1 + z = -2$

$z = -1$

$[E] = [PA^{1/2} T^{-1}]$

6. Official Ans. by NTA (4)

Sol. $S = \frac{P}{A} = \frac{ML^2T^{-3}}{L^2} = MT^{-3}$

7. Official Ans. by NTA (3)

Sol. $x = \frac{IFV^2}{WL^4}$

$[x] = \frac{[ML^2][MLT^{-2}][LT^{-1}]^2}{[ML^2T^{-2}][L]^4}$

$[x] = [ML^{-1}T^{-2}]$

$[\text{Energy density}] = \left[\frac{E}{V}\right]$

$= \left[\frac{ML^2T^{-2}}{L^3}\right]$

$= [ML^{-1}T^{-2}]$

Same as x

8. Official Ans. by NTA (2)

Sol. $x = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = \text{speed} \Rightarrow [x] = [L^1T^{-1}]$

$y = \frac{E}{B} = \text{speed} \Rightarrow [y] = [L^1T^{-1}]$

$z = \frac{\ell}{RC} = \frac{\ell}{\tau} \Rightarrow [z] = [L^1T^{-1}]$

So, x, y, z all have the same dimensions.

WAVE MOTION

1. NTA Ans. (3)

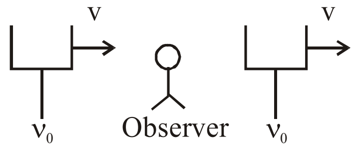
Sol. $v = \sqrt{\frac{T}{\mu}}$

$$90 = \sqrt{\frac{\frac{YA}{l}\Delta l}{\frac{m}{l}}} = \sqrt{\frac{16\times10^{11}\times10^{-6}\times\Delta l}{6\times10^{-3}}}$$

$$= \frac{8100\times3}{8}\times10^{-8} = \Delta l$$

2. NTA Ans. (4)

Sol.



$\nu_1 = \left(\frac{c}{c-v}\right)\nu_0$

$\nu_2 = \left(\frac{c}{c+v}\right)\nu_0$

beat frequency $= \nu_1 - \nu_2$

$= c\nu_0\left(\frac{1}{c-v} - \frac{1}{c+v}\right)$

$= c\nu_0\left(\frac{c+v-c+v}{c^2-v^2}\right) = \frac{2c\nu_0^2 v}{c^2-v^2}$

$\approx \frac{2c\nu_0 v}{c^2} = \frac{2\nu_0 v}{c} = 2$

$\Rightarrow \frac{2\times1400\times v}{350} = 2$

$\Rightarrow v = \frac{1}{4}$ m/s

3. NTA Ans. (106.00 to 107.20)

Sol. $v_s = \sqrt{\frac{\gamma P}{\rho}}$

$\frac{v_{gas}}{v_{air}} = \sqrt{\frac{\rho_{air}}{\rho_{gas}}}$ $\Rightarrow \frac{v_{gas}}{300} = \frac{1}{\sqrt{2}}$

$\Rightarrow v_{gas} = \frac{300}{\sqrt{2}}$ $\Rightarrow \therefore\ v_{gas} = 150\sqrt{2}$

Now $n_2 - n_1 = \frac{v_{gas}}{2\ell} = \frac{150\sqrt{2}}{2(1)} = 75\sqrt{2}$

$\Rightarrow \Delta n = 106.06$ Hz

4. NTA Ans. (2)

Sol. Velocity of transverse wave $V \propto \sqrt{T}$

$V \to \frac{V}{2} \Rightarrow T \to T' = \frac{T}{4}$

$T' = \frac{2.06\times10^4}{4} = 5.15\times10^3 N$

5. NTA Ans. (1)

Sol. Let amplitude of each wave is A.

Resultant wave equation

$= A \sin \omega t + A \sin\left(\omega t - \frac{\pi}{4}\right) + A \sin\left(\omega t + \frac{\pi}{4}\right)$

$= A \sin \omega t + \sqrt{2} A \sin \omega t$

$= \left(\sqrt{2}+1\right) A \sin \omega t$

Resultant wave amplitude $= \left(\sqrt{2}+1\right)A$

as $I \propto A^2$

so $\frac{I}{I_0} = \left(\sqrt{2}+1\right)^2$

$I = 5.8\ I_0$

6. NTA Ans. (4)

Sol. $\frac{nv}{2\ell} = 420$

$\frac{(n+1)v}{2\ell} = 490$

$\frac{v}{2\ell} = 70$

$\ell = \frac{v}{140} = \frac{1}{140}\sqrt{\frac{540}{6\times10^{-3}}} = \frac{1}{140}\sqrt{90\times10^3}$

$\ell = \frac{300}{140} = 2.142$

$\therefore$ Correct answer (4)

7. Official Ans. by NTA (3)

Sol. $f = \frac{1}{2\ell}\sqrt{\frac{T}{\mu}}$

For identical string l and μ will be same

$f \propto \sqrt{T}$

$\frac{450}{300} = \sqrt{\frac{T_x}{T_y}}$

$\frac{T_x}{T_y} = \frac{9}{4} = 2.25$

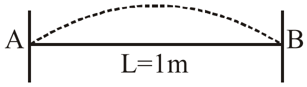
8. Official Ans. by NTA (35.00)

Sol. $\rho_{wire} = 9\times10^{-3}\dfrac{kg}{cm^3} = \dfrac{9\times10^{-3}}{10^{-6}} kg/m^3$

$= 9000\ kg/m^2$

(A = CSA of wire)

($Y = 9\times10^{10}\ Nm^2$)



(Strain = 4.9×10^{-4})

$\Rightarrow L = 1m = \dfrac{\lambda}{2} \Rightarrow \lambda = 2m$

$\Rightarrow v = f\lambda \Rightarrow \sqrt{\dfrac{T}{\mu}} = f\,\lambda$

Where $Y = \dfrac{T/A}{strain} \Rightarrow T = Y.A.strain$

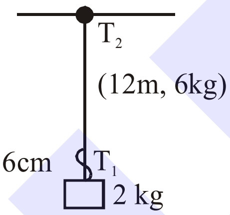
9. Official Ans. by NTA (2)

Sol. $V \propto \lambda$ $T_2 = 8g$

$T_1 = 2g$

$\dfrac{V_1}{V_2} = \dfrac{\lambda_1}{\lambda_2}$

$\lambda = 6cm$



$\lambda_2 = \dfrac{V_2}{V_1}\lambda_1 = \sqrt{\dfrac{T_2}{T_1}}\times\lambda_1$

$= \sqrt{\dfrac{8g}{2g}}\lambda_1 = 2\times6 = 12\ cm$

10. Official Ans. by NTA (4)

Sol. Given T to C 1.5 m

C to C 5m

T to C = $(2n_1 + 1)\dfrac{\lambda}{2}$

C to C = $n_2\lambda$

$\dfrac{1.5}{5} = \dfrac{(2n_1+1)}{2n_2} \Rightarrow 3n_2 = 10n_1 + 5$

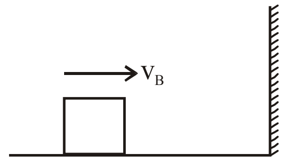
$n_1 = 1, n_2 = 5 \rightarrow \lambda = 1$

$n_1 = 4, n_2 = 15 \rightarrow \lambda = 1/3$

$n_1 = 7, n_2 = 25 \rightarrow \lambda = 1/5$

11. Official Ans. by NTA (1)

Sol.



$f_1 = \left(\dfrac{330}{330 - v_B}\right)420$

$f_2 = \left(\dfrac{330+v_0}{330}\right)\left(\dfrac{330}{330-v_B}\right)420$

$490 = \left(\dfrac{330+v_B}{330-v_B}\right)420$

$\dfrac{7}{6} = \dfrac{330+v_B}{330-v_B}$

$v_B = \dfrac{330}{13}\ m/s$

$= \dfrac{330}{13}\times\dfrac{18}{5} \approx 91\ km/hr$

12. Official Ans. by NTA (3)

Sol. $\Rightarrow \lambda = 2\,(l_2 - l_1) \Rightarrow 2\times(24.5 - 17)$

$\Rightarrow 2\times7.5 = 15\ cm$

& $v = f\lambda \Rightarrow 330 = \lambda\times15\times10^{-2}$

$\lambda = \dfrac{330}{15}\times100 \Rightarrow \dfrac{1100\times100}{5}$

$\Rightarrow 2200\ Hz$

13. Official Ans. by NTA (2)

Sol. $\Delta p = BkS_0$

$= \rho v^2 \times \dfrac{\omega}{v}\times S_0$

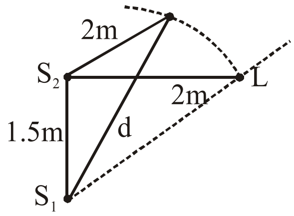
$\Rightarrow S_0 = \dfrac{\Delta p}{\rho v\omega}$

$\approx \dfrac{10}{1\times300\times1000} m$

$= \dfrac{1}{30} mm \approx \dfrac{3}{100} mm$

14. Official Ans. by NTA (2)

Sol.



Initially $S_2L = 2m$

$$S_1L = \sqrt{2^2 + (3/2)^2}$$

$$S_1L = \frac{5}{2} = 2.5 \text{ m}$$

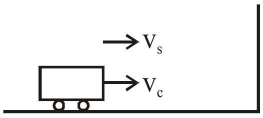
$\Delta x = S_1L - S_2L = 0.5$ m

So since $\lambda = 1m \quad \therefore \Delta x = \frac{\lambda}{2}$

So while listener moves away from S_1
Then, Δx (= $S_1L - S_2L$) increases
and hence, at $\Delta x = \lambda$ first maxima will appear.
$\Delta x = \lambda = S_1L - S_2L$
$1 = d - 2 \Rightarrow d = 3m$

15. Official Ans. by NTA (4)

Sol.



f_1 = frequency heard by wall = $f_s = \left(\frac{v_s}{v_s - v_c}\right)$

f_2 = frequency heard by driver after reflection from wall

$$f_2 = \left(\frac{v_s + v_c}{v_s}\right) f_1 = \left(\frac{v_s + v_c}{v_s - v_c}\right) f_0$$

$$\frac{f_2}{f_0} = \frac{v_s - v_c}{v_s + v_c}$$

$$\frac{48}{44} = \frac{v_s - v_c}{v_s + v_c}$$

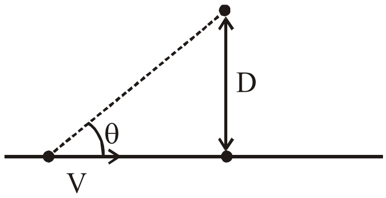
$12(v_s + v_c) = 11(v_s - v_c)$
$23v_c = v_s$

$$v_c = \frac{v_s}{23} = \frac{345}{23} = 15 m/s$$

$$= \frac{15 \times 18}{5} = 54 \text{ km/hr}$$

16. Official Ans. by NTA (4)

Sol.



$$f_{observed} \Rightarrow \left(\frac{v_{sound}}{v_{sound} - v\cos\theta}\right) f_0$$

initially θ will be less $\Rightarrow \cos\theta$ more
$\therefore$ $f_{observed}$ more, then it will decrease.
$\therefore$ Ans. (4)

WAVE OPTICS

1. NTA Ans. (4)

Sol. $\sin\theta = \frac{2\lambda}{\omega}$

$$\sin 60° = \frac{2\lambda}{\omega}$$

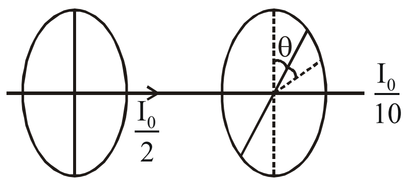
$$\sin\theta_1 = \frac{\lambda}{\omega} = \frac{\sqrt{3}}{4}$$

$\theta_1 = 25°$

2. NTA Ans. (1)

Sol. $\frac{I_0}{10} = I = \frac{I_0}{2} \times \cos^2\theta$

$$\cos\theta = \frac{1}{\sqrt{5}}$$



$\theta = 63.44°$

angle rotated = 90 – 63.44° = 26.56°

Closest is 1.

3. NTA Ans. (2)

Sol. Finge width, $\beta = \frac{D\lambda}{d} = \frac{1.5 \times 589 \times 10^{-9}}{0.15 \times 10^{-3}}$

$= 5.9 \times 10^{-3}$ m

= 5.9 mm

4. NTA Ans. (4)

Sol. $I = I_0 \cos^2\left(\frac{\Delta\phi}{2}\right)$

$$\frac{I}{I_0} = \cos^2\left(\frac{\Delta\phi}{2}\right)$$

$$\frac{I}{I_0} = \cos^2\left(\frac{\frac{2\pi}{\lambda}\times\frac{\lambda}{8}}{2}\right)$$

$$\frac{I}{I_0} = \cos^2\left(\frac{\pi}{8}\right) \qquad \Rightarrow \frac{I}{I_0} = 0.853$$

5. NTA Ans. (3)

Sol. Let distance is x then

$$d\theta = \frac{1.22\lambda}{D} \quad \text{(D = diameter)}$$

$$\frac{x}{d} = \frac{1.22\lambda}{D} \text{ (d = distance between earth \& moon)}$$

$$x = \frac{1.22\times(5500\times10^{-10})\times(4\times10^{8})}{5} = 53.68\,\text{m}$$

most appropriate is 60m.

6. NTA Ans. (1)

Sol. Direction of polarisation $= \hat{E} = \hat{k}$

Direction of propagation $= \hat{E}\times\hat{B} = \frac{\hat{i}+\hat{j}}{\sqrt{2}}$

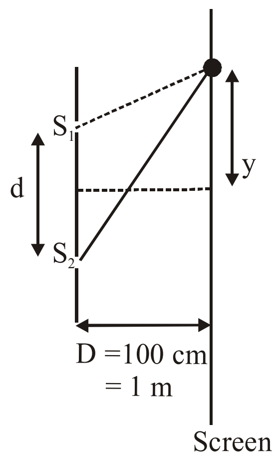
$$\therefore \hat{E}\times\hat{B} = \frac{\hat{i}+\hat{j}}{\sqrt{2}}$$

$$\hat{B} = \frac{\hat{i}-\hat{j}}{\sqrt{2}}$$

Correct answer (1)

7. Official Ans. by NTA (1)

Sol.



$$y = \frac{nD\lambda}{d}$$

$$n = \frac{yd}{D\lambda} = \frac{1.27\times10^{-3}\times10^{-3}}{1\times632.8\times10^{-9}} = 2$$

Path difference $\Delta x = n\lambda$

$= 2 \times 632.8$ nm

$= 1265.6$ nm

$= 1.27$ μm

8. Official Ans. by NTA (1)

Sol. Let the length of segment is "ℓ"

Let N is the no. of fringes in "ℓ"

and w is fringe width.

→ We can write

$N w = \ell$

$$N\left(\frac{\lambda D}{d}\right) = \ell$$

$$\frac{N_1\lambda_1 D}{d} = \ell$$

$$\frac{N_2\lambda_2 D}{d} = \ell$$

$N_1\lambda_1 = N_2\lambda_2$

$16 \times 700 = N_2 \times 400$

$N_2 = 28$

9. Official Ans. by NTA (4)

Sol. $\Delta\theta_0 = \left(\frac{\lambda}{d}\times\frac{180}{\pi}\right)^0$

$= 0.57°$

10. Official Ans. by NTA (1)

Sol. $\Delta p = n_1 L_1 - n_2 L_2$

$$\Delta\phi = \frac{2\pi}{\lambda}\Delta p$$

11. Official Ans. by NTA (3)

Sol. Intensity, $I = 3.3\ Wm^{-2}$

Area, $A = 3 \times 10–4\ m^2$

Angular speed, $\omega = 31.4$ rad/s

$\because \langle\cos^2\theta\rangle = \frac{1}{2}$, in one time period

$\therefore$ Average energy $= I_0A \times \frac{1}{2}$

$$= \frac{(3.3)(3\times10^{-4})}{2}$$

$$\simeq 5\times10^{-4}\,\text{J}$$

12. Official Ans. by NTA (200)

Official Ans. by ALLEN (198)

Sol. Condition for minimum,

$d\sin\theta = n\lambda$

$\therefore \ \sin\theta = \dfrac{n\lambda}{d} < 1$

$n < \dfrac{d}{\lambda} = \dfrac{6\times10^{-5}}{6\times10^{-7}} = 100$

$\therefore$ Total number of minima on one side

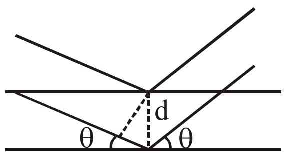
= 99

Total number of minima = 198

Correct Answer is 198

13. Official Ans. by NTA (50.00)

Sol.



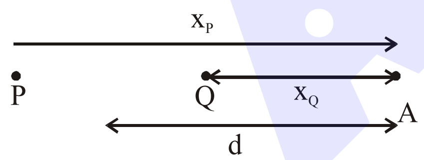
$2d\sin\theta = \lambda = \dfrac{h}{\sqrt{2mE}}$

$2\times10^{-10}\times\dfrac{\sqrt{3}}{2} = \dfrac{6.6\times10^{-34}}{\sqrt{2mE}}$

$E = \dfrac{1}{2}\times\dfrac{6.64^2\times10^{-48}}{9.1\times10^{-31}\times3\times1.6\times10^{-19}} = 50.47$

14. Official Ans. by NTA (4)

Sol. For (A)



$x_P - x_Q = (d + 2.5) - (d - 2.5)$

= 5m

$\Delta\phi$ due to path difference = $\dfrac{2\pi}{\lambda}(\Delta x) = \dfrac{2\pi}{20}(5)$

$= \dfrac{\pi}{2}$

At A, Q is ahead of P by path, as wave emitted by Q reaches before wave emitted by P.

Total phase difference at A

$= \dfrac{\pi}{2} - \dfrac{\pi}{2}$ (due to P being ahead of Q by 90°)

= 0

$I_A = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\Delta\phi$

$= I + I + 2\sqrt{I}\sqrt{I}\cos(0)$

= 4I

For C

$x_Q - x_P = 5$ m

$\Delta\phi$ due to path difference $= \dfrac{2\pi}{\lambda}(\Delta x)$

$= \dfrac{2\pi}{20}(5) = \dfrac{\pi}{2}$

Total phase difference at C = $\dfrac{\pi}{2} + \dfrac{\pi}{2} = \pi$

$I_{net} = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos(\Delta\phi)$

$= I + I + 2\sqrt{I}\sqrt{I}\cos(\pi) = 0$

For B

$x_P - x_Q = 0$,

$\Delta\phi = \dfrac{\pi}{2}$ (Due to P being ahead of Q by 90°)

$I_B = I + I + 2\sqrt{I}\sqrt{I}\cos\dfrac{\pi}{2} = 2I$

$I_A : I_B : I_C = 4I : 2I : 0$

= 2 : 1 : 0

$\therefore$ correct option is (4)

15. Official Ans. by NTA (9.00)

Sol. $I_{max} = k$

$I_1 = I_2 = K/4$

$\Delta x = \lambda/6 \quad \Rightarrow \Delta\phi = \pi/3$

$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

$I = \dfrac{K}{4} + \dfrac{K}{4} + 2\times\dfrac{K}{4}\dfrac{1}{2}$

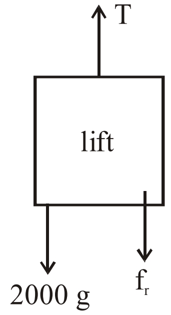
$= \dfrac{K}{2} + \dfrac{K}{4} = \dfrac{3K}{4} = \dfrac{9K}{12}$

n = 9

WORK POWER ENERGY

1. NTA Ans. (3)

Sol.



Let elevator is moving upward with constant speed V.

Tension in cable

T = 2000 g + f_r = 2000 + 4000

T = 24000 N

Power P = TV

$\Rightarrow$ 60 × 746 = (24000) V

$V = \frac{60 \times 746}{24000} = 1.865 \approx 1.9$ m/s.

2. NTA Ans. (10)

Sol. Mechanical energy conservation between A & P

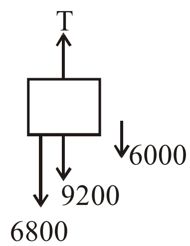
$U_1 + \cancel{K_1} = K_2 + U_2$

mg × 2 = mg × 1 + K_2

K_2 = mg × 1 = 10 J.

3. NTA Ans. (3)

Sol.



elevater moving with constant speed hence

T = 6800 + 9200 + 6000

T = 22000 N

power = T·v = 22000 × 3

= 66000 W

4. NTA Ans. (2)

Sol. $W = \int_{\vec{r}_i}^{\vec{r}_g} \vec{F}.d\vec{r}$

$W = \int_1^0 -x\,dx + \int_0^1 y\,dy$

$W = \left.\frac{-x^2}{2}\right|_1^0 + \left.\frac{y^2}{2}\right|_0^1$

$= -\left(\frac{0^2}{2} - \frac{1^2}{2}\right) + \left(\frac{1^2}{2} - \frac{0^2}{2}\right)$

W = 1J

5. Official Ans. by NTA (150)

Sol. $W_F = \frac{1}{2}mv^2 = mgh$

F(S) = mgh

F(0.2) = (0.15) (10) (20)

$\boxed{F = 150N}$

6. Official Ans. by NTA (3)

Sol. $\frac{dK}{dE} = P = \text{cost} \Rightarrow K = Pt = \frac{1}{2}mV^2$

$\therefore\ V = \sqrt{\frac{2Pt}{m}} = \frac{ds}{dt} \therefore S = \sqrt{\frac{2P}{m}}\frac{2}{3}t^{\frac{3}{2}}$

7. Official Ans. by NTA (2)

Sol. F = 200 N for $0 \le x \le 15$

$= 200 - \frac{100}{15}(x-15)$ for $15 \le x < 30$

$W = \int F\,dx$

$= \int_0^{15} 200\,dx + \int_{15}^{30}\left(300 - \frac{100}{15}x\right)dx$

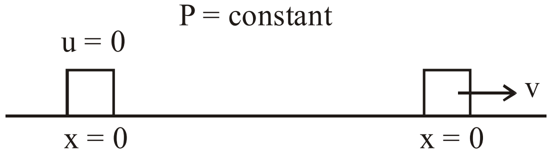
$= 200 \times 15 + 300 \times 15 - \frac{100}{15} \times \frac{(30^2 - 15^2)}{2}$

= 3000 + 4500 – 2250

= 5250 J

8. Official Ans. by NTA (18.00)

Sol.



$P = mav$

$$m\frac{dv}{dt}v = P$$

$$\int_0^v v\,dv = \frac{P}{m}\int_0^t dt$$

$$\frac{v^2}{2} = \frac{Pt}{m} \Rightarrow v = \left(\frac{2Pt}{m}\right)^{1/2}$$

$$\frac{dx}{dt} = \sqrt{\frac{2P}{m}}\,t^{1/2}$$

$$\int_0^x dx = \sqrt{\frac{2P}{m}}\int_0^t t^{1/2}\,dt$$

$$x = \sqrt{\frac{2P}{m}}\frac{t^{3/2}}{3/2} = \sqrt{\frac{2P}{m}} \times \frac{2}{3}t^{3/2}$$

$$= \sqrt{\frac{2\times 1}{2}} \times \frac{2}{3} \times 9^{3/2}$$

$$= \frac{2}{3} \times 27 = 18$$

9. Official Ans. by NTA (3)

Sol. $U = \frac{-A}{r^6} + \frac{B}{r^{12}}$

$$F = -\frac{dU}{dr} = -\left(A\left(-6r^{-7}\right)\right) + B\left(-12r^{-13}\right)$$

$$0 = \frac{6A}{r^7} - \frac{12B}{r^{13}}$$

$$\frac{6A}{12B} = \frac{1}{r^6} \Rightarrow r = \left(\frac{2B}{A}\right)^{1/6}$$

$$U\left(r = \left(\frac{2B}{A}\right)^{1/6}\right) = -\frac{A}{2B/A} + \frac{B}{4B^2/A^2}$$

$$= \frac{-A^2}{2B} + \frac{A^2}{4B} = \frac{-A^2}{4B}$$

10. Official Ans. by NTA (3)

Sol. $\frac{dv_x}{dt} = \frac{k}{m}v_y$

$$\frac{dv_y}{dt} = \frac{k}{m}v_x$$

$$\frac{dv_y}{dv_x} = \frac{v_x}{v_y} \Rightarrow \int v_y dv_y = \int v_x dv_x$$

$$v_y^2 = v_x^2 + C$$

$$v_y^2 - v_x^2 = \text{constant}$$

Option (3)

$$\vec{v} \times \vec{a} = (v_x\hat{i} + v_y\hat{j}) \times \frac{k}{m}(v_y\hat{i} + v_x\hat{j})$$

$$= (v_x^2\hat{k} - v_y^2\hat{k})\frac{k}{m}$$

$$= (v_x^2 - v_y^2)\frac{k}{m}\hat{k}$$

= Constant

IMPORTANT NOTES