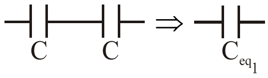
PHYSICS

CAPACITOR

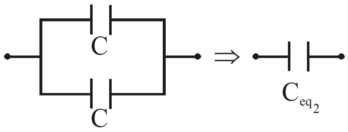
1. Official Ans. by NTA (3)

Sol. For series combination



$$\frac{1}{C_{eq_1}} = \frac{1}{C} + \frac{1}{C} \Rightarrow \boxed{C_{eq_1} = \frac{C}{2}}$$

For parallel combination

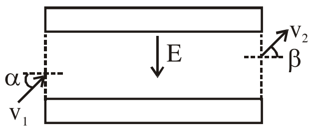


$$C_{eq_2} = C + C \Rightarrow C_{eq_2} = 2C$$

$$\Rightarrow \frac{C_{eq_1}}{C_{eq_2}} = \frac{(C/2)}{2C} = \frac{1}{4} = 1:4$$

2. Official Ans. by NTA (2)

Sol.



velocity along the plate will not change.

$\therefore v_1 \cos\alpha = v_2 \cos\beta$

$$\frac{K_1}{K_2} \Rightarrow \frac{v_1^2}{v_2^2} = \frac{\cos^2\beta}{\cos^2\alpha}$$

3. Official Ans. by NTA (BONUS)

Sol. When connected in parallel

$C_{eq} = C_1 + C_2$

When in series

$$C'_{eq} = \frac{C_1C_2}{C_1 + C_2}$$

$$C_1 + C_2 = \frac{15}{4}\left(\frac{C_1C_2}{C_1 + C_2}\right)$$

$4(C_1 + C_2)^2 = 15\, C_1C_2$

$4C_1^2 + 4C_2^2 - 7C_1C_2 = 0$

dividing by C_1^2

$$4\left(\frac{C_2}{C_1}\right)^2 - \frac{7C_2}{C_1} + 4 = 0$$

Let $\frac{C_2}{C_1} = x$

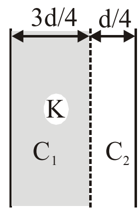
$4x^2 - 7x + 4 = 0$

$b^2 - 4ac = 49 - 64 < 0$

No solution exits

4. Official Ans. by NTA (3)

Sol.



$$C_0 = \frac{\epsilon_0 A}{d}$$

$C' = C_1$ and C_2 in series.

i.e. $\frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2}$ $\quad \frac{1}{C'} = \frac{(3d/4)}{\epsilon_0 KA} + \frac{d/4}{\epsilon_0 A}$

$$\frac{1}{C'} = \frac{d}{4\epsilon_0 A}\left(\frac{3+K}{K}\right)$$

$$C' = \frac{4KC_0}{(3+K)}$$

5. Official Ans. by NTA (3)

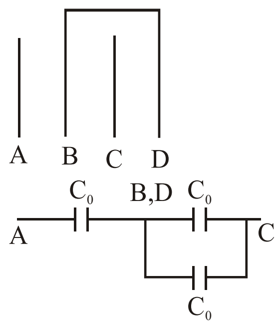
Sol. Ans. (3)

$$C = \frac{\varepsilon_0 A}{\frac{d}{2K} + \frac{d}{2}} = \frac{2\varepsilon_0 A}{\frac{d}{K} + d}$$

$$= \frac{2 \times 2\varepsilon_0}{\frac{1}{3.2} + 1} = \frac{4 \times 3.2}{4.2}\varepsilon_0 = 3.04\,\varepsilon_0$$

6. Official Ans. by NTA (2)

Sol.



$$C_{eq} = \frac{2C_0}{3} = \frac{2}{3}\frac{\epsilon_0 A}{d}$$

$$C_{eq} = \frac{2\epsilon_0}{3d} \times \left(2 \times \frac{3}{2}\right) = 2 \quad (\because A = lb = 2 \times \frac{3}{2})$$

7. Official Ans. by NTA (864)

Sol. $U_i = \frac{1}{2} \times 14 \times 12 \times 12$ pJ $\quad (\because U = \frac{1}{2}CV^2)$

$= 1008$ pJ

$U_f = \frac{1008}{7}$ pJ $= 144$ pJ $\qquad (\because C_m = kC_0)$

Mechanical energy $= \Delta U$

$= 1008 - 144 = 864$ pJ

8. Official Ans. by NTA (16)

Sol. $20 = (C_1 + C_2)V \Rightarrow V = 2$ volt.

$Q_2 = C_2V = 16\mu C = 16$

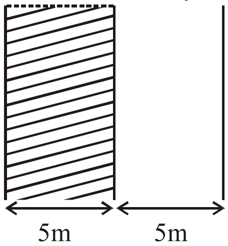
9. Official Ans. by NTA (2)

Sol. $i_0 = \frac{V}{R} = \frac{30/3}{5\times10^6} = 2\times10^{-6}$

$\therefore$ Ans. = 2.00

10. Official Ans. by NTA (161)

Sol.



A = 100 m²

Using $C = \frac{k\in_0 A}{d}$

$C_1 = \frac{10\in_0(100)}{5} = 200\in_0$

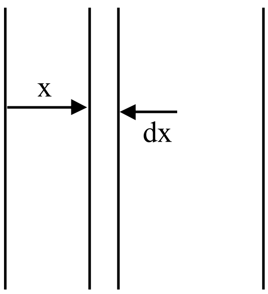
$C_2 = \frac{\in_0(100)}{5} = 20\in_0$

C_1 & C_2 are in series so $C_{eqv.} = \frac{C_1C_2}{C_1+C_2}$

$= \frac{4000\in_0}{220} = 160.9\times10^{-12} \simeq 161$ pF

11. Official Ans. by NTA (2)

Sol.



Taking an element of width dx at a distance x (x < d/2) from left plate

$dc = \frac{(\varepsilon_0 + kx)A}{dx}$

Capacitance of half of the capacitor

$\frac{1}{C} = \int_0^{d/2}\frac{1}{dc} = \frac{1}{A}\int_0^{d/2}\frac{dx}{\varepsilon_0 + kx}$

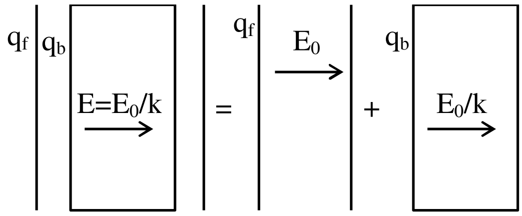
$\frac{1}{C} = \frac{1}{kA}\ln\left(\frac{\varepsilon_0 + kd/2}{\varepsilon_0}\right)$

Capacitance of second half will be same

$C_{eq} = \frac{C}{2} = \frac{kA}{2\ln\left(\frac{2\varepsilon_0 + kd}{2\varepsilon_0}\right)}$

12. Official Ans. by NTA (2)

Sol.



When a dielectric is inserted in a capacitor

Due to free charge $\vec{E} = \vec{E}_0$ only

After dielectric $E' = \frac{E_0}{k}$

$q_B = q_f\left(1 - \frac{1}{k}\right)$

13. Official Ans. by NTA (3)

Sol. $V = V_0\left(1 - e^{-\frac{t}{RC}}\right)$

$50 = 100\left(1 - e^{-\frac{t}{RC}}\right)$

$t = 0.69\times10^{-4}$ sec.

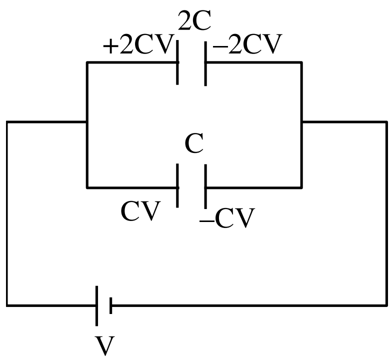
14. Official Ans. by NTA (1)

Sol. $\frac{1}{C_{eff}} = \frac{d}{K\in_0 A} + \frac{2d}{3K\in_0 A} + \frac{3d}{5K\in_0 A}$

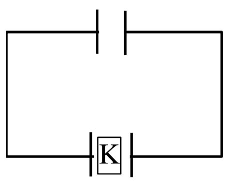
$C_{eff} = \frac{15K\in_0 A}{34d}$

15. Official Ans. by NTA (3)

Sol.



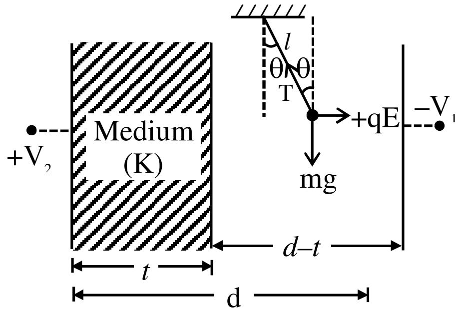
Now,



$V_C = \frac{2CV + CV}{KC + 2C} = \frac{3V}{K+2}$

16. Official Ans. by NTA (3)

Sol.

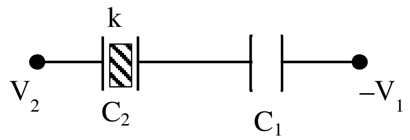


Let E be electric field in air

T sinθ = qE

T cosθ = mg

$\tan\theta = \dfrac{qE}{mg}$



$$Q = \left[\frac{C_1C_2}{C_1+C_2}\right][V_1 + V_2]$$

$$E = \frac{Q}{A\in_o} = \left[\frac{C_1C_2}{C_1+C_2}\right]\frac{[V_1+V_2]}{A\in_o}$$

$$C_1 = \frac{\in_o A}{d-t} \quad \Rightarrow E = \frac{C_2[V_1+V_2]}{(C_1+C_2)(d-t)}$$

$$\text{Now } \theta = \tan^{-1}\left[\frac{q.E}{mg}\right]$$

$$\theta = \tan^{-1}\left[\frac{q}{mg}\times\frac{C_2(V_1+V_2)}{(C_1+C_2)(d-t)}\right]$$

17. Official Ans. by NTA (3)

Sol. $\rho = 200\ \Omega m$

$C = 2\times10^{-12}F$

$V = 40\ V$

$K = 56$

$$i = \frac{q}{\rho k\varepsilon_0} = \frac{q_0}{\rho k\varepsilon_0}e^{-\frac{t}{\rho k\varepsilon_0}}$$

$$i_{max} = \frac{2\times10^{-12}\times40}{200\times50\times8.85\times10^{-12}}$$

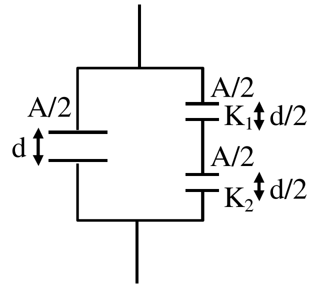
$$= \frac{80}{10^4\times8.85} = 903\mu A = 0.9 mA$$

Option (3)

18. Official Ans. by NTA (1)

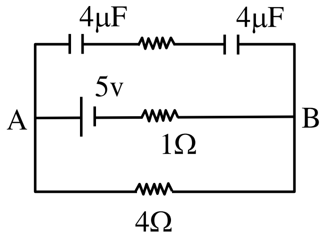
Sol. $$C_{eq} = \frac{\frac{A}{2}\varepsilon_0}{d} + \frac{A\varepsilon_0}{d}\frac{K_1K_2}{K_1+K_2}$$

$$= \frac{A\varepsilon_0}{d}\left(\frac{1}{2}+\frac{K_1K_2}{K_1+K_2}\right)$$



19. Official Ans. by NTA (1)

Sol. On simplifying circuit we get



No current in upper wire.

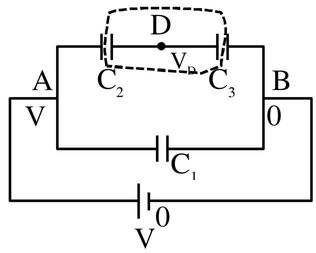
$\therefore\ V_{AB} = \dfrac{5}{4+1}\times4 = 4$ v.

$\therefore\ \theta = (C_{eq})v$

$\Rightarrow 2\times4 = 8\mu C$

20. Official Ans. by NTA (3)

Sol.



$(V_D - V)\ C_2 + (V_D - 0)\ C_3 = 0$

$(V_D - V)\ 6 + (V_D - 0)\ 12 = 0$

$V_D - V + 2V_D = 0$

$V_D = \dfrac{V}{3}$

$q_2 = (V - V_D)\ C_2 = \left(V-\dfrac{V}{3}\right)(6\ \mu F)$

$q_2 = (4V)\ \mu F$

$q_3 = (V_D - 0)\ C_3 = \dfrac{V}{3}\times12\mu F = 4V\mu F$

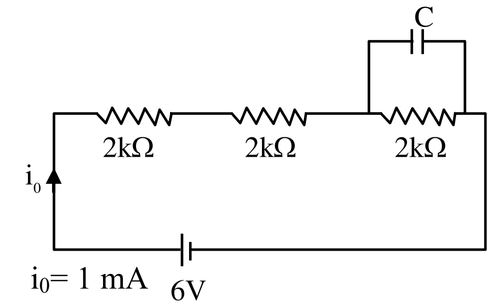
$q_1 = (V - 0)\ C_1 = V(2\mu F)$

$q_1 : q_2 : q_3 = 2 : 4 : 4$

$q_1 : q_2 : q_3 = 1 : 2 : 2$

21. Official Ans. by NTA (100)

Sol.



Pot. Diff. across each resistor = 2V

q = CV

$= 50 \times 10^{-6} \times 2 = 100 \times 10^{-6} = 100\ \mu C$

22. Official Ans. by NTA (4)

Sol. $\Delta U = \frac{1}{2}(\Delta C)V^2$

$\Delta U = \frac{1}{2}(KC - C)V^2$

$\Delta U = \frac{1}{2}(2-1)CV^2$

$\Delta U = \frac{1}{2} \times 200 \times 10^{-6} \times 200 \times 200$

$\Delta U = 4$ J

23. Official Ans. by NTA (2)

Sol. $V = V_0\left(1 - e^{-t/RC}\right)$

$2 = 20\left(1 - e^{-t/RC}\right)$

$\frac{1}{10} = 1 - e^{-t/RC}$

$e^{-t/RC} = \frac{9}{10}$

$e^{t/RC} = \frac{10}{9}$

$\frac{t}{RC} = \ell n\left(\frac{10}{9}\right) \Rightarrow C = \frac{t}{R\ell n\left(\frac{10}{9}\right)}$

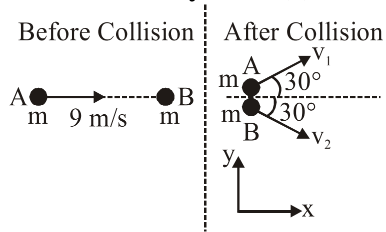
$C = \frac{10^{-6}}{10 \times .105} = .95\mu F$

Option (2)

COM & COLLISION

1. Official Ans. by NTA (1)

Sol.



From conservation of momentum along y-axis.

$\vec{P}_{iy} = \vec{P}_{fy}$

$0 + 0 = mv_1 \sin 30°\, \hat{j} + mv_2 \sin 30°(-\hat{j})$

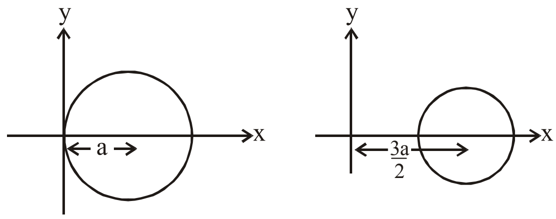
$mv_2 \sin 30° = mv_1 \sin 30°$

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

Ans. 1

2. Official Ans. by NTA (3)

Sol.



Let σ be the uniform mass density of disc then

$$x_{COM} = \frac{(\sigma\pi a^2)a - \sigma\pi\left(\frac{a^2}{4}\right) \times \frac{3a}{2}}{\sigma\pi a^2 - \frac{\sigma\pi a^2}{4}}$$

$$= \frac{a - \frac{3a}{8}}{1 - \frac{1}{4}} = \frac{5a}{6}$$

Option (2) is correct.

3. Official Ans. by NTA (2)

Sol. Kinetic energy $K = \frac{P^2}{2m}$, $(P_A = P_B)$

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

$\frac{K_A}{K_B} = \frac{m_B}{m_A} = \frac{2}{1}$

Ans. (2)

4. Official Ans. by NTA (1)

Sol. $\frac{p_1^2}{2 \times 4} = \frac{p_2^2}{2 \times 16}$

$\frac{p_1}{p_2} = \frac{1}{2}$

5. Official Ans. by NTA (3)

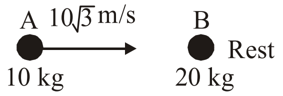
Sol. For e = 1 & second body at rest

$$V_2 = \frac{2m_1u_1}{m_1+m_2} = \frac{2u(M)}{M+m} \simeq 2u$$

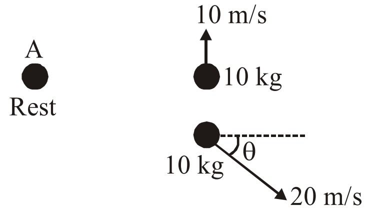
Since M >> m

6. Official Ans. by NTA (30)

Sol. Before Collision



After Collision



From conservation of momentum along x axis;

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

$10 \times 10\sqrt{3} = 200 \cos\theta$

$\cos\theta = \dfrac{\sqrt{3}}{2}$, $\theta = 30°$

7. Official Ans. by NTA (3)

Sol. From energy conservation,

$\left[\begin{array}{l}\text{after bullet gets embedded till the}\\ \text{system comes momentarily at rest}\end{array}\right]$

$(M + m)g\,h = \dfrac{1}{2}(M+m)v_1^2$

[v_1 is velocity after collision]

$\therefore\ v_1 = \sqrt{2gh}$

Applying momentum conservation, (just before and just after collision)

$mv = (M + m)v_1$

$$v = \left(\frac{M+m}{m}\right)v_1 = \frac{6}{10\times10^{-3}}\times\sqrt{2\times9.8\times9.8\times10^{-2}}$$

≈ 831.55 m / s

8. Official Ans. by NTA (4)

Sol. (4) $v_0 = \sqrt{2gh}$

$v = e\sqrt{2gh} = \sqrt{2gh} \Rightarrow e = 0.9$

$S = h + 2e^2h + 2e^4h + \ldots\ldots\ldots$

$$t = \sqrt{\frac{2h}{g}} + 2e\sqrt{\frac{2h}{g}} + 2e^2\sqrt{\frac{2h}{g}} + \ldots\ldots\ldots$$

$v_{av} = \dfrac{s}{t} = 2.5$ m/s

9. Official Ans. by NTA (1)

Sol. (1) C comes to rest

V_{cm} of A & B = $\dfrac{v}{2}$

$\Rightarrow \dfrac{1}{2}$ is $v_{ret}^2 = \dfrac{1}{2}kx^2$

$$x = \sqrt{\frac{\mu\times v^2}{k}} = \sqrt{\frac{m}{2k}}v$$

10. Official Ans. by NTA (4)

Sol. C.O.M of quarter disc is at $\dfrac{4a}{3\pi}, \dfrac{4a}{3\pi}$ = 4

11. Official Ans. by NTA (20)

Sol. Let velocity of 2nd fragment is $\vec{v}$ then by conservation of linear momentum

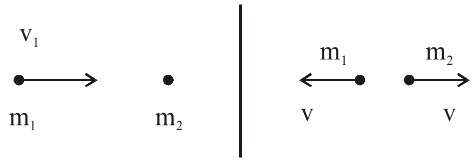
$10\left(10\sqrt{3}\right)\hat{i} = (10)\left(10\hat{j}\right) + 10\vec{v}$

$\Rightarrow \vec{v} = 10\sqrt{3}\hat{i} - 10\hat{j}$

$|\vec{v}| = \sqrt{300+100} = \sqrt{400} = 20\text{m / s}$

12. Official Ans. by NTA (1)

Sol.



$m_1v_1 = -m_1v + m_2v$

$v_1 = -v + \dfrac{m_2}{m_1}v$

$\dfrac{(v_1+v)}{v} = \dfrac{m_2}{m_1}$

$e = \dfrac{2v}{v_1} = 1$

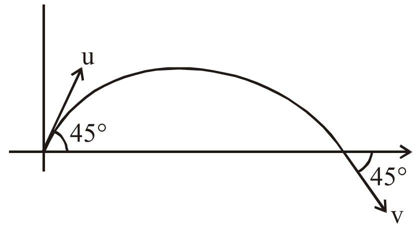
$v = \dfrac{v_1}{2}$

$\dfrac{v_1 + v_1/2}{v_1/2} = \dfrac{m_2}{m_1}$

$3 = \dfrac{m_2}{m_1}$

13. Official Ans. by NTA (5)

Sol.



$|\vec{u}| = |\vec{v}|$ ... (1)

$\vec{u} = u\cos45\hat{i} + u\sin45\hat{j}$ ... (2)

$\vec{v} = v\cos45\hat{i} - v\sin45\hat{j}$ ... (3)

$\left|\overrightarrow{\Delta P}\right| = \left|m\left(\vec{v}-\vec{u}\right)\right|$ ... (4)

$\Delta P = 2mu\sin45°$

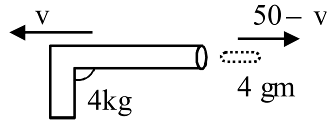
$= 2\times5\times10^{-3}\times5\sqrt{2}\times\dfrac{1}{\sqrt{2}}$

$= 50 \times 10^{-3}$

$= 5 \times 10^{-2}$

14. Official Ans. by NTA (2)

Sol.



By momentum conservation

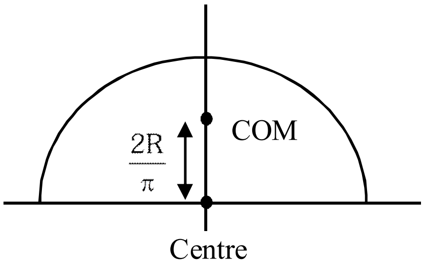
$4 \times 10^{-3}(50 - v) - 4v = 0$

$v = \dfrac{4 \times 10^{-3} \times 50}{4 + 4 \times 10^{-3}} \approx 0.05 ms^{-1}$

Impulse $J = mv = 4 \times .05 = 0.2\ kgms^{-1}$

15. Official Ans. by NTA (2)

Sol. COM of semi-circular ring is at $\dfrac{2R}{\pi}$



Distance from centre $\Rightarrow x = 2$

16. Official Ans. by NTA (2)

Sol. Impulse = change in momentum

Ball (a) $|\overrightarrow{\Delta p}| = 2mu = J_1$

Ball (b) $|\overrightarrow{\Delta p}| = 2mu \cos 45° = J_2$

$\dfrac{J_1}{J_2} = \dfrac{1}{\cos 45°} = \sqrt{2}$

17. Official Ans. by NTA (25)

Sol. $p_i = p_f$

$2 \times 4 = 2 \times 1 + m_2 \times v_2$

$m_2 v_2 = 6$ ....(i)

by coefficient of restitution

$1 = \dfrac{v_2 - 1}{4} \Rightarrow v_2 = 5\ m/s$

by (i)

$m_2 \times 5 = 6$

$m_2 = 1.2$ kg

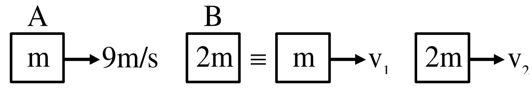
$v_{cm} = \dfrac{m_1 v_1 + m_2 v_2}{m_1 + m_2}$

$v_{cm} = \dfrac{2 \times 1 + 1.2 \times 5}{2 + 1.2} = \dfrac{8}{3.2} = \dfrac{25}{10}$

$\boxed{x = 25}$

18. Official Ans. by NTA (4)

Sol. Collision between A and B

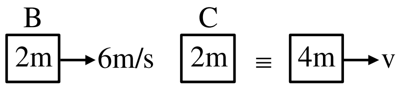


$m \times 9 = mv_1 + 2m\, v_2$ (from momentum conservation)

$e = 1 = \dfrac{v_2 - v_1}{9}$

$\Rightarrow v_2 = 6$ m/sec. , $v_1 = -3$ m/sec.

collision between B and C

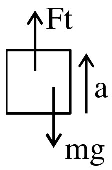


$2m \times 6 = 4mv$ (from momentum conservation)

$v = 3$ m/s

19. Official Ans. by NTA (4)

Sol.



$F_{thrust} = \left(\dfrac{dm}{dt} \cdot V_{rel}\right)$

$\left(\dfrac{dm}{dt} V_{rel} - mg\right) = ma$

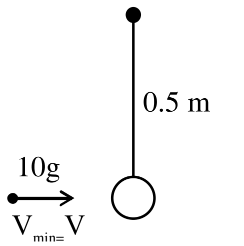
$\Rightarrow \left(\dfrac{dm}{dt}\right) \times 500 - 10^3 \times 10 = 10^3 \times 20$

$\dfrac{dm}{dt} = (60 kg/s)$

Option (4)

20. Official Ans. by NTA (400)

Sol.



$V' = \sqrt{5gR} = \sqrt{5 \times 10 \times 0.5}$

$V' = 5$ m/s

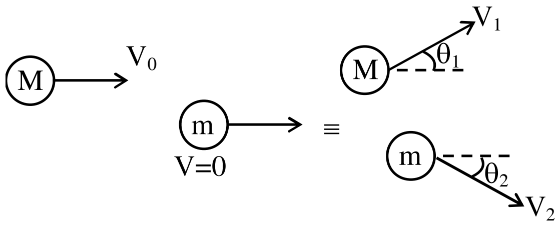
$m_1 V = m_2 \times 5 - m_1 \times 100$

$\dfrac{10}{1000} \times V = 5 - \dfrac{10}{1000} \times 100$

$V = 400$ m/s

21. Official Ans. by NTA (3)

Sol.



given $\theta_1 = \theta_2 = \theta$

from momentum conservation

in x-direction $MV_0 = MV_1 \cos\theta + mV_2 \cos\theta$

in y-direction $0 = MV_1 \sin\theta - mV_2 \sin\theta$

Solving above equations

$$V_2 = \frac{MV_1}{m}, V_0 = 2V_1 \cos\theta$$

From energy conservation

$$\frac{1}{2}MV_0^2 = \frac{1}{2}MV_1^2 + \frac{1}{2}MV_2^2$$

Substituting value of V_2 & V_0, we will get

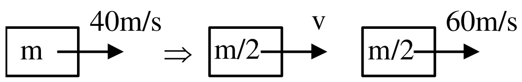
$$\frac{M}{m} + 1 = 4\cos^2\theta \le 4$$

$$\frac{M}{m} \le 3$$

Option (3)

22. Official Ans. by NTA (1)

Sol.



$P_i = P_f$

$$m \times 40 = \frac{m}{2} \times v + \frac{m}{2} \times 60$$

$$40 = \frac{v}{2} + 30 \Rightarrow v = 20$$

$$(K.E.)_I = \frac{1}{2} m \times (40)^2 = 800m$$

$$(K.E.)_f = \frac{1}{2}\frac{m}{2}.(20)^2 + \frac{1}{2}.\frac{m}{2}(60)^2 = 1000\ m$$

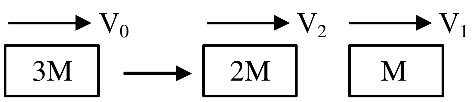
$$|\Delta K.E.| = |1000m - 800m| = 200m$$

$$\frac{\Delta K.E}{(K.E.)_i} = \frac{200m}{800m} = \frac{1}{4} = \frac{x}{4}$$

x = 1

23. Official Ans. by NTA (3)

Sol.



$3MV_0 = 2MV_2 + MV_1$

$3V_0 = 2V_2 + V_1$

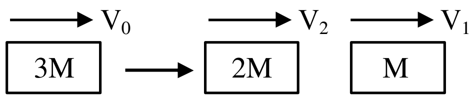
$120 = 2V_2 + 60 \Rightarrow V_2 = 30$ m/s

$$\frac{\Delta K.E.}{K.E.} = \frac{\frac{1}{2}MV_1^2 + \frac{1}{2}2MV_2^2 - \frac{1}{2}3MV_0^2}{\frac{1}{2}3MV_0^2}$$

$$= \frac{V_1^2 + 2V_2^2 - 3V_0^2}{3V_0^2} = \frac{3600 + 1800 - 4800}{4800} = \frac{1}{8}$$

24. Official Ans. by NTA (3)

Sol.



$3MV_0 = 2MV_2 + MV_1$

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$$= \frac{V_1^2 + 2V_2^2 - 3V_0^2}{3V_0^2}$$

$$= \frac{3600 + 1800 - 4800}{4800} = \frac{1}{8}$$

CIRCULAR MOTION

1. Official Ans. by NTA (180)

Sol. $-PQ \sin\theta$

$= PQ \sin\theta$

$\Rightarrow \theta = 180°$

2. Official Ans. by NTA (1)

Sol. $F \propto \frac{1}{R^3}$

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

$$\omega^2 = \frac{K}{m} \times \frac{1}{R^4}$$

$$\left(\frac{2\pi}{T}\right)^2 = \frac{K}{m} \times \frac{1}{R^4}$$

$T^2 \propto R^4$

$T \propto R^2$

3. Official Ans. by NTA (4)

Sol. $N = m\omega^2 R$

$$N = m\left[\frac{4\pi^2}{T^2}\right]R \quad .....(1)$$

Given m = 0.2 kg, T = 40 S, R = 0.2 m

Put values in equation (1)

$N = 9.859 \times 10^{-4}$ N

4. Official Ans. by NTA (4)

Sol. Statement I :

$v_{max} = \sqrt{\mu Rg} = \sqrt{(0.2)\times 2\times 9.8}$

$v_{max} = 1.97$ m/s

7 km/h = 1.944 m/s

Speed is lower than v_{max}, hence it can take safe turn.

Statement II

$$v_{max} = \sqrt{Rg\left[\frac{\tan\theta+\mu}{1-\mu\tan\theta}\right]}$$

$$= \sqrt{2\times 9.8\left[\frac{1+0.2}{1-0.2}\right]} = 5.42 \text{ m/s}$$

18.5 km/h = 5.14 m/s

Speed is lower than v_{max}, hence it can take safe turn.

5. Official Ans. by NTA (728)

Sol. We know, $\theta = \left(\frac{\omega_1+\omega_2}{2}\right)t$

Let number of revolutions be N

$\therefore\ 2\pi N = 2\pi\left(\frac{900+2460}{60\times 2}\right)\times 26$

N = 728

6. Official Ans. by NTA (2)

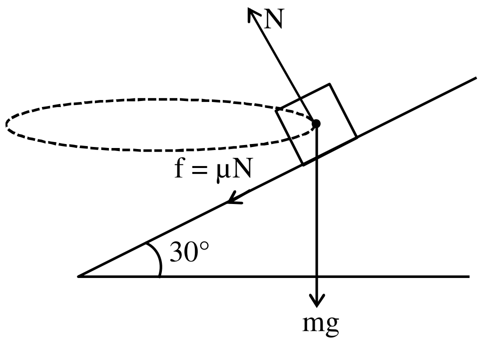
Sol. $\mu_s N = \frac{mv^2}{R}$

$N = \frac{mv^2}{\mu_s R} = mg + F_L$

$F_L = \frac{mv^2}{\mu_s R} - mg$

7. Official Ans. by NTA (1)

Sol.



At v_{max}, f will be limiting in nature.

$\therefore$ Balancing force in vertical direction,

$N\cos30° - mg - \mu N\cos60° = 0$

$\Rightarrow N[\cos30° - \mu\cos60°] = mg$

$\therefore N = \frac{800\times 10}{(0.87-0.1)} \approx 10.2\times 10^3 \text{ kg m/s}^2$

Hence option 1.

8. Official Ans. by NTA (200)

Sol. $\omega_f = \omega_0 + \alpha t$

$\alpha = 1200\times 6$

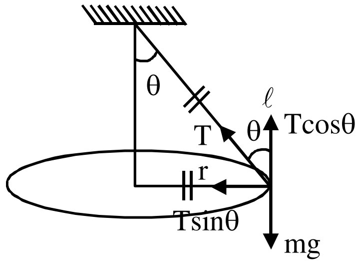
$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$

$= 600\times\frac{10}{60}+\frac{1}{2}\times 1200\times 6\times\frac{1}{36}$

$\theta = 200$

9. Official Ans. by NTA (1)

Sol. Conical pendulum



$r = \frac{\ell}{\sqrt{2}}$

$\sin\theta = \frac{r}{\ell} = \frac{1}{\sqrt{2}}$

$\theta = 45°$

$T\sin\theta = \frac{mv^2}{r}$

$T\cos\theta = mg$

$\tan\theta = \frac{v^2}{rg} \Rightarrow v = \sqrt{rg}$

Ans. 1

10. Official Ans. by NTA (2)

Sol. $R = \frac{\ell}{\theta}$

$\text{Time} = \frac{4\times 2\pi R}{v} = \frac{4\times 2\pi}{v}\left(\frac{\ell}{\theta}\right)$

put $\ell = 4.4\times 9.46\times 10^{15}$

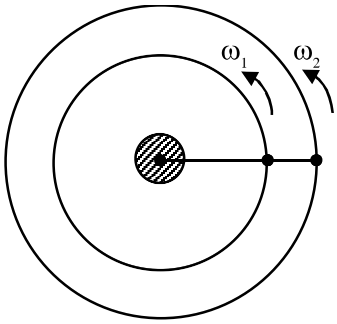
$v = 8\times 1.5\times 10^{11}$

$\theta = \frac{4}{3600}\times\frac{\pi}{180}$ rad.

we get time $= 4.5\times 10^{10}$ sec

11. Official Ans. by NTA (3)

Sol.



$T_1 = 1$ hour

$\Rightarrow \omega_1 = 2\pi$ rad/hour

$T_2 = 8$ hours

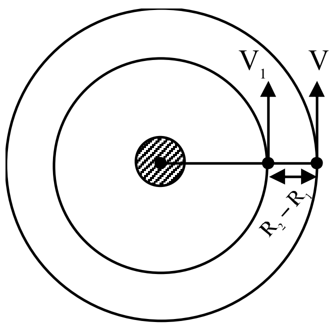
$\Rightarrow \omega_2 = \frac{\pi}{4}$ rad / hour

$R_1 = 2 \times 10^3$ km

As $T^2 \propto R^3$

$$\Rightarrow \left(\frac{R_2}{R_1}\right)^3 = \left(\frac{T_2}{T_1}\right)^2$$

$$\Rightarrow \frac{R_2}{R_1} = \left(\frac{8}{1}\right)^{2/3} = 4 \Rightarrow R_2 = 8 \times 10^3 \text{ km}$$



$V_1 = \omega_1 R_1 = 4\pi \times 10^3$ km / h

$V_2 = \omega_2 R_2 = 2\pi \times 10^3$ km / h

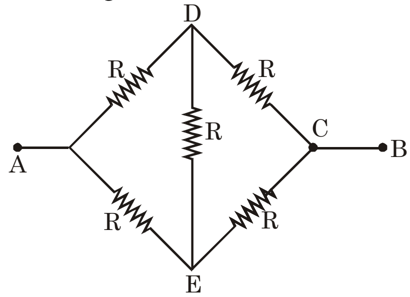
Relative $\omega = \frac{V_1 - V_2}{R_2 - R_1} = \frac{2\pi \times 10^3}{6 \times 10^3}$

$= \frac{\pi}{3}$ rad / hour x = 3

CURRENT ELECTRICITY

1. Official Ans. by NTA (4)

Sol. This diagram can be drawn like



It is a wheat stone bridge

$\therefore R_{eq} = \frac{2R \times 2R}{2R + 2R} \Rightarrow R$

2. Official Ans. by NTA (300)

Sol. Work done by battery = Q (ΔV)

$\Rightarrow 20 \times 15 = 300$ J

$\therefore$ Ans. 300

3. Official Ans. by NTA (3)

Sol. $I = \frac{6-4}{10} = \frac{1}{5}$ A

$V_x + 4 + 8 \times \frac{1}{5} - V_y = 0$

$V_x - V_y = -5.6 \Rightarrow |Vx - Vy| = 5.6$ V

4. Official Ans. by NTA (5)

Sol. Conductivity $\sigma = 5 \times 10^7$ S/m

Radius r = 0.5 mm = 5×10^{-4} m

$E = 10 \times 10^{-3} \frac{V}{m}$

$J = \sigma E = 10 \times 10^{-3} \times 5 \times 10^7$

$J = 5 \times 10^5$

$\frac{i}{A} = 5 \times 10^5$

$i = 5 \times 10^5 \times \pi r^2$

$= 5 \times 10^5 \times \pi \times (5 \times 10^{-4})^2$

$= 125\pi \times 10^{-3}$ Amp

$i = 125\ \pi$ mA

$\boxed{x = 5}$ $\boxed{\text{Ans. } 5}$

5. Official Ans. by NTA (1)

Sol. Length of AB = 10 m

For battery E_1, balancing length is l_1

$l_1 = 380$ cm [from end A]

For battery E_2, balancing length is l_2

$l_2 = 760$ cm [from end A]

Now, we know that $\frac{E_1}{E_2} = \frac{l_1}{l_2}$

$\Rightarrow \frac{E_1}{E_2} = \frac{380}{760} = \frac{1}{2} = \frac{a}{b}$

$\therefore$ a = 1 & b = 2 a = 1

6. Official Ans. by NTA (2)

Sol. For parallel combination current devides in the inverse ratio of resistance.

$i_{PQ} = \frac{2}{6} \times 6$ A

7. Official Ans. by NTA (1)

Sol. $R_0 = 1\Omega$ $\quad R_1 = ?$

$\ell_0 = 1m$ $\quad \ell_1 = 1.25m$

$A_0 = A$

As volume of wire remains constant so

$A_0\ell_0 = A_1\ell_1 \Rightarrow A_1 = \frac{\ell_0 A_0}{\ell_1}$

Now

Resistance (R) = $\frac{\rho\ell}{A}$

$\frac{R_0}{R_1} = \frac{\ell_0 / A_0}{\rho\ell_1 / A_1}$

$\frac{1}{R_1} = \frac{\ell_0}{A_0}\left(\frac{\ell_0 A_0}{\ell_1 \times \ell_1}\right)$ $\quad R_1 = \frac{\ell_1^2}{\ell_0^2} = 1.5625\Omega$

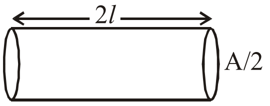
So % change in resistance

$= \frac{R_1 - R_0}{R_0} \times 100\% = \frac{1.5625 - 1}{1} \times 100\%$

$= 56.25\%$

8. Official Ans. by NTA (1)

Sol. As per the question

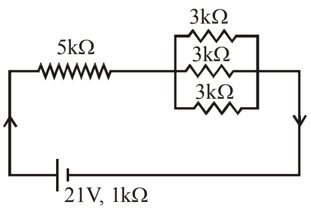


Resistance = $\frac{\rho(2l)}{(A/2)} = \frac{4\rho l}{A}$

$\Rightarrow$ Current = $\frac{V}{R} = \frac{VA}{4\rho l}$

9. Official Ans. by NTA (3)

Sol.



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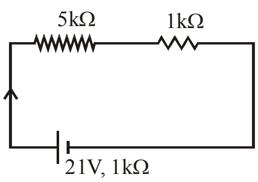


$I = \frac{21}{5+1+1} = 3$ mA

10. Official Ans. by NTA (4)

Sol. $500 = (1.5)^2 \times R \times 20$

$E = (3)^2 \times R \times 20$

$E = 2000$ J

11. Official Ans. by NTA (2500)

Sol. Ans. (2500)

$Q = i^2 RT$

$R = \frac{Q}{i^2 t} = \frac{10 \times 10^{-3}}{4 \times 10^{-6} \times 1} = 2500\ \Omega$

12. Official Ans. by NTA (2)

Sol. $i = 10A$, $A = 5\ mm^2 = 5 \times 10^{-6}\ m^2$

and $v_d = 2 \times 10^{-3}$ m/s

We know, $i = neAvd$

$\therefore\ 10 = n \times 1.6 \times 10^{-19} \times 5 \times 10^{-6} \times 2 \times 10^{-3}$

$\Rightarrow n = 0.625 \times 10^{28} = 625 \times 10^{25}$

13. Official Ans. by NTA (4)

Sol. $R_1 + R_2 = s$ ... (1)

$\frac{R_1 R_2}{R_1 + R_2} = p$ ... (2)

$R_1R_2 = sp$

$R_1R_2 = np^2$

$R_1 + R_2 = \frac{nR_1R_2}{(R_1 + R_2)}$

$\frac{(R_1 + R_2)^2}{R_1R_2} = n$

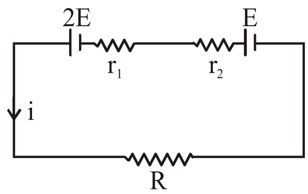
for minimum value of n

$R_1 = R_2 = R$

$\therefore\ n = \frac{(2R)^2}{R^2} = 4$

14. Official Ans. by NTA (2)

Sol. (2)



$i = \frac{3E}{R + r_1 + r_2}$

$TPD = 2E - ir_1 = 0$

$2E = ir_1$

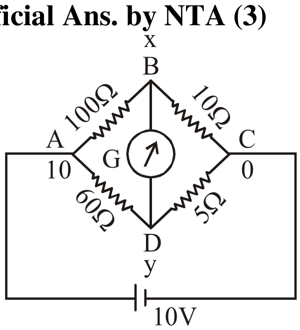
$2E = \frac{3E \times r_1}{R + r_1 + r_2}$

$2R + 2r_1 + 2r_2 = 3r_1$

$R = \frac{r_1}{2} - r_2$

15. Official Ans. by NTA (3)

Sol. (3)



$$\frac{x-10}{100}+\frac{x-y}{15}+\frac{x-0}{10}=0$$

$53x - 20y = 30$ .....(1)

$$\frac{y-10}{60}+\frac{y-x}{15}+\frac{y-0}{5}=0$$

$17y - 4x = 10$ ......(2)

on solving (1) & (2)

$x = 0.865$

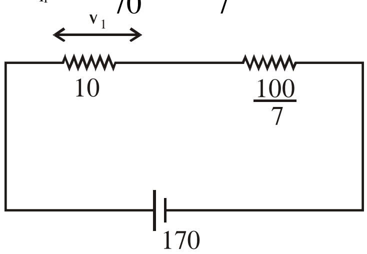
$y = 0.792$

$\Delta V = 0.073$ $R = 15\Omega$

$i = 4.87$ mA

16. Official Ans. by NTA (70)

Sol. $R_{eq_1} = \frac{50\times 20}{70} = \frac{100}{7}$



$$R_{eq} = \frac{170}{7}$$

$$v_1 = \left[\frac{170}{\frac{170}{7}}\right]\times 10 = 70v$$

Ans. = 70.00

17. Official Ans. by NTA (48)

Sol. In Balanced conditions

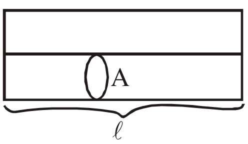
$$\frac{12}{6}=\frac{x}{72-x}$$

$x = 48$ cm

18. Official Ans. by NTA (4)

Sol. $\because$ in parallel

$$R_{net} = \frac{R_1R_2}{R_1+R_2}$$



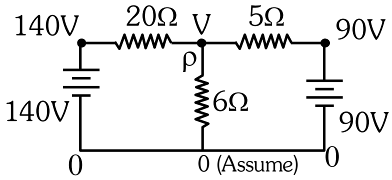
$$\frac{\rho\ell}{2A} = \frac{\rho_1\frac{\ell}{A}\times\rho_2\frac{\ell}{A}}{\rho_1\frac{\ell}{A}+\rho_2\frac{\ell}{A}}$$

$$\frac{\rho}{2}=\frac{6\times 3}{6+3}=2$$

$\rho = 4$

19. Official Ans. by NTA (3)

Sol.



Applying KCL at point P,

$$\frac{V-0}{6}+\frac{V-90}{5}+\frac{V-140}{20}=0$$

$\Rightarrow 10V + 12V - 1080 + 3V - 420 = 0$

$\Rightarrow V = 60$

$\therefore$ current in $6\Omega = \frac{V-0}{6} = 10A$

Hence option 3.

20. Official Ans. by NTA (3)

Sol. $I = \vec{J}\cdot\vec{A} = JA\cos(\theta)$

$$5 = J\left(\frac{4}{100}\right)\times\cos(60)$$

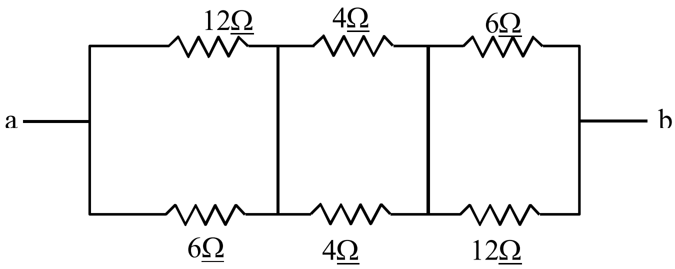
$J = 5 \times 50 = 250$ A/m^2

Now, $\vec{E} = \rho\cdot\vec{J}$

$= 44 \times 10^{-8} \times 250 = 11 \times 10^{-5}$ V/m

21. Official Ans. by NTA (10)

Sol. when switch S_1 and S_2 are closed



$$\frac{12\times 6}{12+6}+2+\frac{6\times 12}{6+12}$$

$$\frac{72}{18}+2+\frac{72}{18} = 4+2+4 = 10\Omega$$

22. Official Ans. by NTA (4)

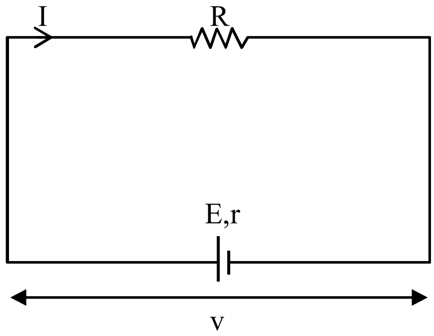
Sol. $R = \frac{R_1R_2}{R_1+R_2} = \frac{\ell}{A}\cdot\frac{\rho_1\rho_2}{\rho_1+\rho_2}$

$$R = \frac{25\times 10^{-2}}{3\times 10^{-6}}\times\frac{1.7\times 2.6\times 10^{-16}}{4.3\times 10^{-8}}$$

$R = 0.858$ mΩ

23. Official Ans. by NTA (15)

Sol.



Terminal voltage $v = iR = \dfrac{ER}{R+r}$

$1^{st} \rightarrow 1.25 = \dfrac{E(5)}{5+r}$ ..(i)

$2^{nd} \rightarrow 1 = \dfrac{E(2)}{2+r}$ ...(ii)

By (i) and (ii)

$r = 1\Omega, E = \dfrac{3}{2}V = \dfrac{15}{10}\text{volt} \Rightarrow x = 15$

24. Official Ans. by NTA (1)

Sol. Max. voltage that can be measured by this potentiometer will be equal to potential drop across AB

$R_{AB} = 10 \times 0.1 \times 100 = 100$ ohm.

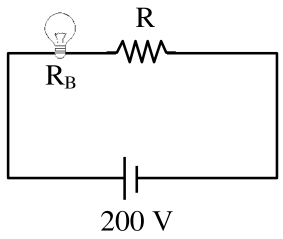
$\therefore\ V_{AB} = \dfrac{6}{20+100} \times 100 = 6 \times \dfrac{100}{120} = 5V$

25. Official Ans. by NTA (50)

Sol. Power, $P = \dfrac{V^2}{R_B}$

$R_B = \dfrac{V^2}{P} = \dfrac{100 \times 100}{200}$

$R_B = 50\Omega$



To produce same power, same voltage (i.e. 100 V) should be across the bulb

Hence, $R = R_B$

$R = 50\ \Omega$

26. Official Ans. by NTA (1)

Sol. $E_1 = k\ell_1$ ... (i)

$E_1 + E_2 = k\ell_2$ ... (ii)

$\dfrac{E_1}{E_1+E_2} = \dfrac{\ell_1}{\ell_2} = \dfrac{250}{400} = \dfrac{5}{8}$

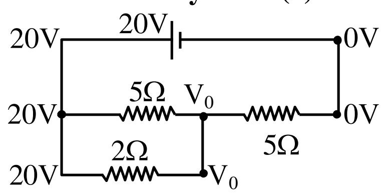
$8E_1 = 5E_1 + 5E_2$

$3E_1 = 5E_2$

$\dfrac{E_1}{E_2} = \dfrac{5}{3}$

27. Official Ans. by NTA (3)

Sol.



$\dfrac{20-V_0}{5} + \dfrac{0-V_0}{5} + \dfrac{20-V_0}{2} = 0$

$4 + 10 = \dfrac{2V_0}{5} + \dfrac{V_0}{2}$

$14 = \dfrac{4V_0 + 5V_0}{10}$

$V_0 = \dfrac{140}{9}\text{Volt}$

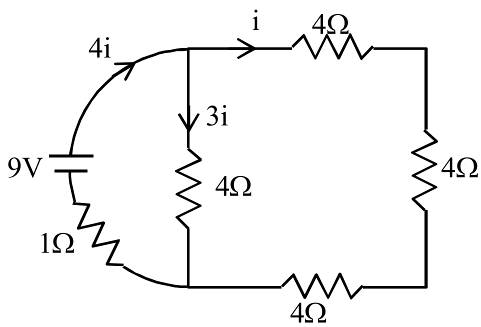
Potential difference across 2Ω resistor is $20 - V_0$

That is $\left(20 - \dfrac{140}{9}\right)\text{Volt}$

Hence answer is $\left(\dfrac{40}{9}\right)\text{Volt}$

28. Official Ans. by NTA (45)

Sol. here assume current as



By KVL in outer loop

$9 - 12i - 4\,i = 0$

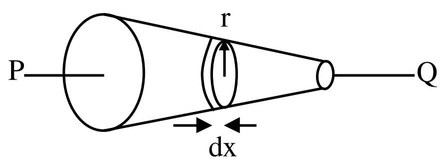
$16i = 9$

$8i = \dfrac{9}{2} = 4.5$

$= 45 \times 10^{-1}$

29. Official Ans. by NTA (1)

Sol.



Current is constant in conductor

i = constant

Resistance of element $dR = \frac{\rho dx}{\pi r^2}$

$dV = idR = \frac{i\rho dx}{\pi r^2}$

$E = \frac{dV}{dx} = \frac{i\rho}{\pi r^2}$ & $V_d = \frac{eE\tau}{m}$

$\therefore V_d \propto E \to E \propto \frac{1}{r^2}$

if r decreases , E will increase $\therefore$ V_d will increase

30. Official Ans. by NTA (3)

Sol. $16 = R_o\,[1 + \alpha\,(15 - T_o)\,]$

$20 = R_o\,[1 + \alpha\,(100 - T_o)\,]$

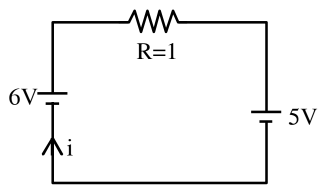
Assuming $T_o = 0°C$, as a general convention.

$\Rightarrow \frac{16}{20} = \frac{1 + \alpha \times 15}{1 + \alpha \times 100}$

$\Rightarrow \alpha = 0.003\ °C^{-1}$

31. Official Ans. by NTA (1)

Sol. From graph voltage at t = 3.2 sec is 6 volt.

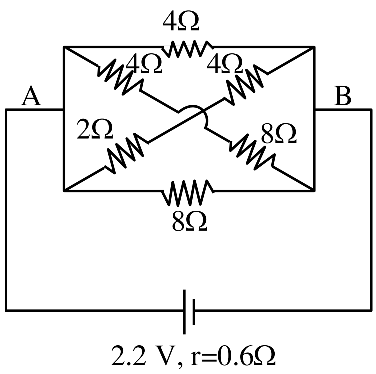


$i = \frac{6-5}{1}$

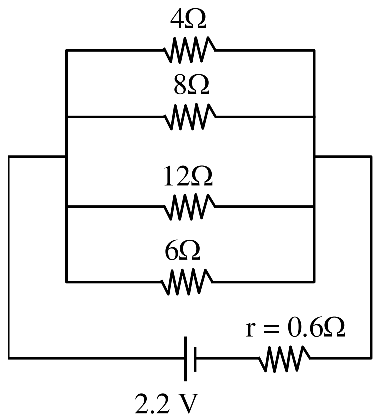
i = 1 A

32. Official Ans. by NTA (3)

Sol.



$\Rightarrow$



$$\frac{1}{R_{eq}} = \frac{1}{4} + \frac{1}{8} + \frac{1}{12} + \frac{1}{6} = \frac{6+3+2+4}{24} = \frac{15}{24}$$

$$R_{eq} = \frac{24}{15} = 1.6 \Rightarrow R_T = 1.6 + 0.6 = 2.2\Omega$$

$$P = \frac{V^2}{R_T} = \frac{(2.2)^2}{2.2} = 2.2W$$

Option (3)

33. Official Ans. by NTA (2)

Sol. $\frac{R_1R_2}{R_1+R_2} = 3$

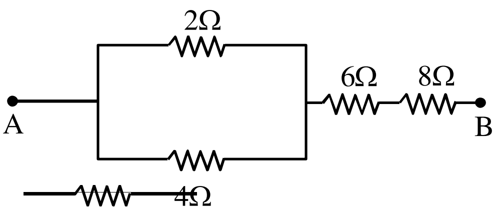
$$\frac{\frac{(12\times10^{-6}\times10^{-2})\ell\times4}{\pi(2)^2\times10^{-6}} \times \frac{(51\times10^{-6}\times10^{-2})\ell\times4}{\pi(2)^2\times10^{-6}}}{\frac{63\times10^{-6}\times10^{-2}\times\ell\times4}{\pi(2)^2\times10^{-6}}}$$

$\Rightarrow \ell = 97m$

Option (2)

34. Official Ans. by NTA (4)

Sol.

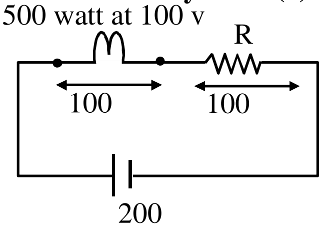


$\frac{46}{3}\Omega$

Ans 4

35. Official Ans. by NTA (1)

500 watt at 100 v



Sol.

P = Vi

500 = Vi

i = 5 Amp

V = i × R

R = 20 Ans. 1

36. Official Ans. by NTA (1)

Sol. $i_1 = \dfrac{25}{5+R}$

$i_2 = \dfrac{5}{R+\dfrac{1}{5}}$

$i_1 = i_2 \Rightarrow 5\left(R+\dfrac{1}{5}\right) = 5+R$

$4R = 4$ $\qquad R = 1\Omega$

37. Official Ans. by NTA (20)

Sol. In series

$R_{eq} = nR = 10\,n$

$i_s = \dfrac{20}{10+10n} = \dfrac{2}{1+n}$

in parallel

$R_{eq} = \dfrac{10}{n}$

$i_p = \dfrac{20}{\dfrac{10}{n}+10} = \dfrac{2n}{1+n}$

$\dfrac{i_p}{i_s} = 20\,;\ \dfrac{\left(\dfrac{2n}{1+n}\right)}{\left(\dfrac{2}{1+n}\right)} = 20$

$n = 20$

38. Official Ans. by NTA (4)

Sol. $R = 75 \times 10^2 \pm 5\%$ of 7500

$R = (7500 \pm 375)\Omega$

39. Official Ans. by NTA (4)

Sol. $I_{max} = \dfrac{50}{2} = 25mA$

R = $\dfrac{V}{I} = \dfrac{50mV}{25mA} = 2\Omega$

40. Official Ans. by NTA (9)

Sol. $R_{eq\ open} = \dfrac{3R}{2}$

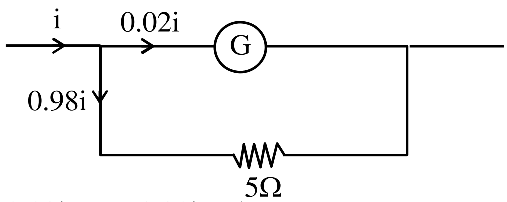
$R_{eq\ closed} = 2 \times \dfrac{R \times 2R}{3R} = \dfrac{4R}{3}$

$\dfrac{R_{eq\ open}}{R_{eq\ closed}} = \dfrac{3R}{2} \times \dfrac{3}{4R} = \dfrac{9}{8}$

$\therefore\ x = 9$

41. Official Ans. by NTA (3)

Sol.



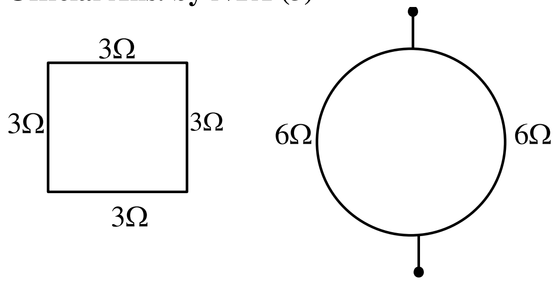
$0.02i\,Rg = 0.98i \times 5$

$Rg = 245\ \Omega$

Option (3)

42. Official Ans. by NTA (3)

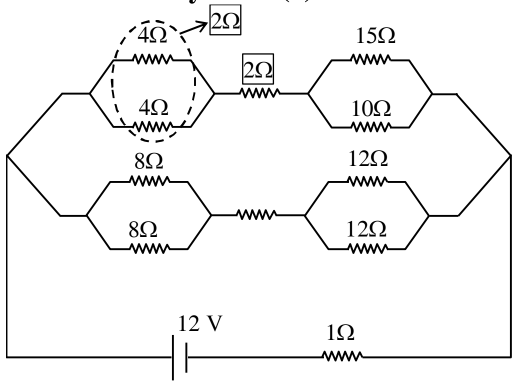
Sol.



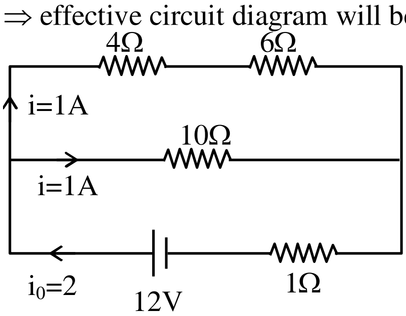
$R_{eq} = 3\Omega$

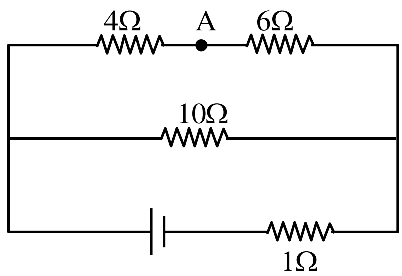
43. Official Ans. by NTA (6)

Sol.

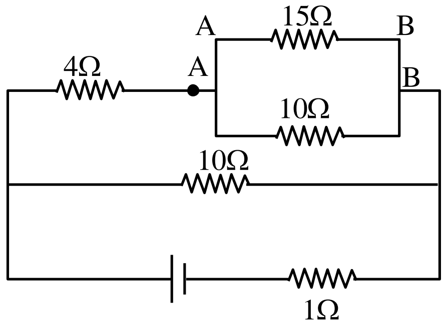


$\Rightarrow$ effective circuit diagram will be





$\Rightarrow$

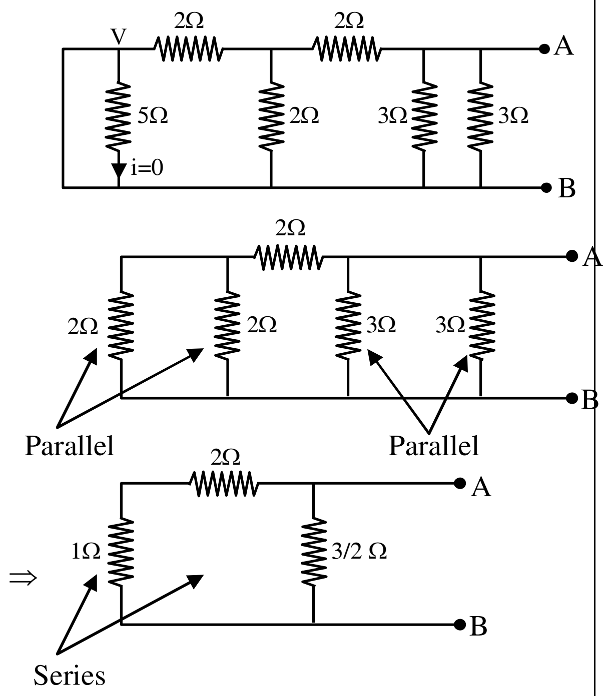


Point drop across $6\Omega = 1 \times 6 = 6 = V_{AB}$

$\Rightarrow$ Hence point drop across $15\Omega = 6$ volt $= V_{AB}$

44. Official Ans. by NTA (4)

Sol.



$$R_{eq} = \frac{3 \times 3/2}{3 + 3/2} = \frac{9/2}{9/2} = 1\Omega$$

45. Official Ans. by NTA (3840)

Sol. $E = i^2Rt$

$192 = 16 (R) (1)$

$R = 12\ \Omega$

$E^1 = (8)^2 (12) (5) = 3840$ J

46. Official Ans. by NTA (4)

Sol. First case $P_1 = \frac{V^2}{R} = \frac{(240)^2}{36}$

Second case Resistance of each half = 18 Ω

$$P_2 = \frac{(240)^2}{18} + \frac{(240)^2}{18} = \frac{(240)^2}{9}$$

$$\frac{P_1}{P_2} = \frac{1}{4}$$

x = 4.00

ELASTICITY

1. Official Ans. by NTA (4)

Sol. Y- Younge modulus, K- Bulk modulus,

η- modulus of rigidity

We know that

$y = 3k (1 - 2\sigma)$

$$\sigma = \frac{1}{2}\left(1 - \frac{y}{3k}\right) \quad \text{....(i)}$$

$y = 2\eta (1 + \sigma)$

$$\sigma = \frac{y}{2\eta} - 1 \quad \text{....(ii)}$$

From Eq.(i) and Eq. (ii)

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

$$1 - \frac{y}{3k} = \frac{y}{\eta} - 2$$

$$\frac{y}{3k} = 3 - \frac{y}{\eta}$$

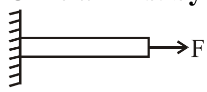
$$\frac{y}{3k} = \frac{3\eta - y}{\eta}$$

$$\frac{\eta y}{3k} = 3\eta - y$$

$$k = \frac{\eta y}{9\eta - 3y}$$

2. Official Ans. by NTA (2)

Sol.



$$F = Y.A.\frac{\Delta\ell}{\ell}$$

$$\Delta\ell = \frac{F}{Y.A.}.\ell$$

$$\Delta\ell = \frac{F.\ell}{Y.\pi r^2}$$

$$\Delta\ell \propto \frac{\ell}{r^2}$$

$$\frac{\Delta\ell_2}{\Delta\ell_1} = \left(\frac{\ell_2}{\ell_1}\right)\left(\frac{r_1}{r_2}\right)^2 = (2)\left(\frac{1}{2}\right)^2$$

$$\frac{\Delta\ell_2}{\Delta\ell_1} = \frac{1}{2}$$

$$\Delta\ell_2 = \frac{\Delta\ell_1}{2}$$

$$= \frac{0.04}{2} = 0.02 \text{ m}$$

$\boxed{\Delta\ell_2 = 2\text{cm}}$ $\boxed{\text{Ans.} = 2}$

3. Official Ans. by NTA (2)

Sol. $\rho = \frac{M}{V}$

$$\frac{d\rho}{\rho} = -\frac{dV}{V}$$

$$k = -\frac{P}{\frac{dV}{V}}$$

$$-\frac{dV}{V} = \frac{P}{k}$$

$$\frac{d\rho}{\rho} = \frac{P}{k} \Rightarrow d\rho = \frac{\rho P}{k}$$

4. Official Ans. by NTA (3)

Sol. Assuming Hooke's law to be valid.

$T \propto (\Delta\ell)$

$T = k(\Delta\ell)$

Let, ℓ_0 = natural length (original length)

$\Rightarrow T = k(\ell - \ell_0)$

so, $T_1 = k(\ell_1 - \ell_0)$ & $T_2 = k(\ell_2 - \ell_0)$

$$\Rightarrow \frac{T_1}{T_2} = \frac{\ell_1 - \ell_0}{\ell_2 - \ell_0} \Rightarrow \ell_0 = \frac{T_2\ell_1 - T_1\ell_2}{T_2 - T_1}$$

5. Official Ans. by NTA (4)

Sol. (4) $P = h\rho g$

$$\beta = \frac{p}{\frac{\Delta V}{V}} = \frac{2\times10^3\times10^3\times9.8}{1.36\times10^{-2}}$$

$= 1.44 \times 10^9$ N/m^2

6. Official Ans. by NTA (32)

Sol. For A $\dfrac{E}{\pi r^2} = y\dfrac{2mm}{a}$ ....(1)

For B $\dfrac{E}{\pi.16r^2} = y\dfrac{4mm}{b}$ ....(2)

$\therefore$ (1)/(2)

$$16 = \frac{2b}{4a}$$

$\dfrac{a}{b} = \dfrac{1}{32}$ $\therefore$ Answer = 32

7. Official Ans. by NTA (1)

Sol. $Y = \dfrac{FL}{A\Delta L}$

$$\Rightarrow Y = \frac{T_1\ell_0}{A(\ell_1 - \ell_0)} = \frac{T_2\ell_0}{A(\ell_2 - \ell_0)}$$

$$1 = \frac{T_1(\ell_2 - \ell_0)}{T_2(\ell_1 - \ell_0)}$$

$T_2\ell_1 - T_2\ell_0 = T_1\ell_2 - T_1\ell_0$

$(T_1 - T_2)\ell_0 = T_1\ell_2 - T_2\ell_1$

$$\ell_0 = \left(\frac{T_1\ell_2 - T_2\ell_1}{T_1 - T_2}\right)$$

8. Official Ans. by NTA (2)

Sol. $T_1 = k(\ell_1 - \ell_0)$

$T_2 = k(\ell_2 - \ell_0)$

$$\frac{T_1}{T_2} = \frac{\ell_1 - \ell_0}{\ell_2 - \ell_0}$$

$$\frac{T_1\ell_2 - T_2\ell_1}{T_1 - T_2} = \ell_0$$

9. Official Ans. by NTA (5)

Sol. Elastic energy $= \dfrac{Y}{2}(\text{strain})^2 \times \text{Area} \times \text{length}$

$\Rightarrow$ Elastic energy per unit length

$= \dfrac{Y}{2}(\text{strain})^2 \times \text{Area}$

$$\left(\text{strain} = \frac{\Delta\ell}{\ell} = \alpha\Delta T = 10^{-5}\times10 = 10^{-4}\right)$$

$$= \frac{10^{11}}{2}\times(10^{-4})^2\times10^{-2} = 5\,J/m$$

10. Official Ans. by NTA (2)

Sol. In series combination $\Delta l = \ell_1 + \ell_2$

$$Y = \frac{F/A}{\Delta\ell/\ell} \Rightarrow \Delta\ell = \frac{F\ell}{AY}$$

$$\Rightarrow \Delta\ell \propto \frac{\ell}{Y}$$

Equivalent length of rod after joing is $= 2\ell$

As, lengths are same and force is also same in series

$\Delta\ell = \Delta\ell_1 + \Delta\ell_2$

$$\frac{\ell_{eq}}{Y_{eq}} = \frac{\ell}{Y_1} + \frac{\ell}{Y_2} \Rightarrow \frac{2\ell}{Y} = \frac{\ell}{Y_1} + \frac{\ell}{Y_2}$$

$$\therefore\ Y = \frac{2Y_1Y_2}{Y_1 + Y_2}$$

11. Official Ans. by NTA (20)

Sol. By energy conservation

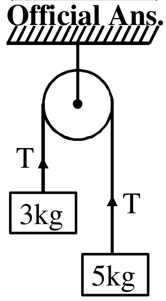
$$\frac{1}{2}.\frac{YA}{L}.x^2 = \frac{1}{2}mv^2$$

$$\frac{0.5\times10^9\times10^{-6}\times(0.04)^2}{0.1} = \frac{20}{1000}v^2$$

$\therefore\ v^2 = 400$

$\boxed{v = 20\ m/s}$

12. Official Ans. by NTA (3)



Sol.

$$T = \frac{2m_1m_2g}{m_1 + m_2} = \frac{2\times3\times5\times10}{8}$$

$$= \frac{75}{2}$$

Stress $= \dfrac{T}{A}$

$$\frac{24}{\pi}\times10^2 = \frac{75}{2\times\pi R^2}$$

$$R^2 = \frac{75}{2\times24\times100} = \frac{3}{8\times24}$$

$\Rightarrow R = 0.125$ m

R = 12.5 cm

13. Official Ans. by NTA (40)

Sol. B.S$_1$ = $\frac{T_{1max}}{8\times10^{-7}} \Rightarrow T_{1\,max} = 8 \times 1.25 \times 100$

= 1000 N

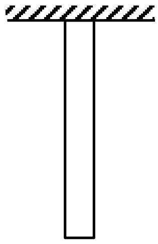
B.S$_2$ = $\frac{T_{2max}}{4\times10^{-7}} \Rightarrow T_{2max} = 4\times1.25\times100$

= 500 N

$m = \frac{500-100}{10} = 40\ \text{kg}$

14. Official Ans. by NTA (4)

Sol.



We know,

$$\Delta\ell = \frac{WL}{2AY}$$

$$\Delta\ell = \frac{10\times1}{2\times5}\times100\times10^{-4}\times2\times10^{11}$$

$$\Delta\ell = \frac{1}{2}\times10^{-9} = 5\times10^{-10}\,\text{m}$$

Option (4)

15. Official Ans. by NTA (500)

Sol. $B = -\frac{\Delta P}{\left(\frac{\Delta V}{V}\right)} = -\frac{\rho gh}{\left(\frac{\Delta V}{V}\right)}$

$$-\frac{B\frac{\Delta V}{V}}{\rho g} = h$$

$$\frac{9.8\times10^8\times0.5}{100\times10^3\times9.8} = h$$

h = 500

16. Official Ans. by NTA (2)

Sol. Force on each column = $\frac{mg}{4}$

Strain = $\frac{mg}{4AY}$

$$= \frac{50\times10^3\times9.8}{4\times\pi(1-0.25)\times2\times10^{11}}$$

$= 2.6 \times 10^{-7}$

ELECTROSTATICS

1. Official Ans. by NTA (2)

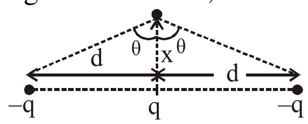
Sol. We can replace –Q charge at origin by +Q and –2Q. Now due to +Q charge at every corner of cube. Electric field at center of cube is zero so now net electric field at center is only due to –2Q charge at origin.

$$\vec{E} = \frac{kq\vec{r}}{r^3} = \frac{1(-2Q)\frac{a}{2}(\hat{x}+\hat{y}+\hat{z})}{4\pi\varepsilon_0\left(\frac{a}{2}\sqrt{3}\right)^3}$$

$$\vec{E} = \frac{-2Q(\hat{x}+\hat{y}+\hat{z})}{3\sqrt{3}\pi a^2\varepsilon_0}$$

2. Official Ans. by NTA (3)

Sol. From the given condition, we have



$$F_{netq} = -\left[2F_{q/q}\cos\theta\right]$$

$$F_{netq} = -2.\frac{1}{4\pi\varepsilon_0}.\frac{q^2}{\left(\sqrt{d^2+x^2}\right)^2}.\frac{x}{\sqrt{d^2+x^2}}$$

$$= -\frac{q^2}{2\pi\varepsilon_0}\frac{x}{(d^2+x^2)^{3/2}}$$

For x << d,

$$F_{net\,q} = -\frac{q^2}{2\pi\varepsilon_0 d^3}x$$

$$\therefore\ a = -\frac{q^2}{2\pi\varepsilon_0.md^3}x$$

Comparing with equation of SHM ($a = -\omega^2 x$)

$$\therefore\ \omega = \sqrt{\frac{q^2}{2\pi\varepsilon_0 md^3}}$$

Hence option (3) is correct

3. Official Ans. by NTA (226)

Sol. From symmetry $\phi = \frac{1}{6}\left(\frac{q}{\varepsilon_0}\right)$

$$= \frac{12\times10^{-6}}{6\times8.85\times10^{-12}} = 225.98\times10^3\ \frac{Nm^2}{s}$$

$$\simeq 226\times10^3\ \frac{Nm^2}{C}$$

4. Official Ans. by NTA (1)

Sol. $\vec{E} = \left(\frac{3E_0}{5}\hat{i} + \frac{4E_0}{5}\hat{j}\right)\frac{N}{C}$

$A_1 = 0.2\ m^2$ [parallel to y – z plane]

$= \vec{A}_1 = 0.2\ m^2\,\hat{i}$

$A_2 = 0.3\ m^2$ [parallel to x – z plane]

$\vec{A}_2 = 0.3\,m^2\,\hat{j}$

Now $\phi_a = \left[\frac{3E_0}{5}\hat{i} + \frac{4E_0}{5}\hat{j}\right] \cdot \left[0.2\hat{i}\right] = \frac{3\times0.2}{5}E_0$

& $\phi_b = \left[\frac{3E_0}{5}\hat{i} + \frac{4E_0}{5}\hat{j}\right] \cdot \left[0.3\hat{j}\right] = \frac{4\times0.3}{5}E_0$

Now $\frac{\phi_a}{\phi_b} = \frac{0.6}{1.2} = \frac{1}{2} = \frac{a}{b}$

$\Rightarrow a : b = 1 : 2 \Rightarrow a = 1$

5. Official Ans. by NTA (128)

Sol. $Q = 512q$

$\text{Volume}_i = \text{Volume}_f$

$512 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

$2^9 r^3 = R^3$

$R = 8r$

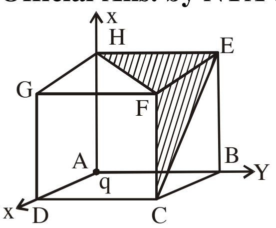
$2 = \frac{kq}{r}$

$V = \frac{kQ}{R} = \frac{k\,512\,q}{8r}$

$V = 128.$

6. Official Ans. by NTA (2)

Sol.



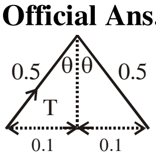
flux through cube $= \frac{q}{8\epsilon_0}$

flux through surfaces ABEH, ADGH, ABCD will be zero

ϕ (EFGH) = ϕ (DCFG) = ϕ (EBCF) = $\frac{1}{3}\left(\frac{q}{8\epsilon_0}\right) = \frac{q}{24\epsilon_0}$

7. Official Ans. by NTA (20)

Sol.



$T\cos\theta = mg = 10 \times 10^{-6} \times 10 = 10^{-4}$

$T\sin\theta = \frac{9\times10^9\times q^2}{0.04} = F$

$\tan\theta = \frac{0.1}{\sqrt{0.24}} = \frac{F}{mg}$

$q = \frac{2\sqrt{10}}{3\sqrt{\sqrt{24}}}\times10^{-8}$

$0.95 \times 10^{-8} = \frac{a}{21}\times10^{-8}$; $a = 20$

8. Official Ans. by NTA (36)

Sol. $q = \frac{(2.1-0.1)}{2}\,nC = 1nC$

$f = \frac{9\times10^9\times10^{-18}}{(0.5)^2} = 36 \times 10^{-9}$

9. Official Ans. by NTA (3)

Sol. $E = \frac{k\lambda}{a}(\sin\theta_1 + \sin\theta_2)$

$E = \frac{1}{4\pi\varepsilon_0}\times\frac{Q}{L}\times\frac{1}{\left(\frac{\sqrt{3}L}{2}\right)}\times(2\sin\theta)$

$\tan\theta = \frac{L/2}{\frac{\sqrt{3}L}{2}} = \frac{1}{\sqrt{3}}$

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

$E = \frac{1}{4\pi\varepsilon_0}\times\frac{2Q}{\sqrt{3}L^2}\times\left(2\times\frac{1}{2}\right)$

$E = \frac{Q}{2\sqrt{3}\pi\varepsilon_0 L^2}$

10. Official Ans. by NTA (243)

Sol. $(27)\left(\frac{4}{3}\pi r^3\right) = \frac{4}{3}\pi R^3$

$R = 3r$

Potential energy of smaller drop :

$U_1 = \frac{3}{5}\frac{kq^2}{r}$

Potential energy of bigger drop :

$U = \frac{3}{5}\frac{kQ^2}{R}$

$U = \frac{3}{5}\frac{k(27q)^2}{R}$

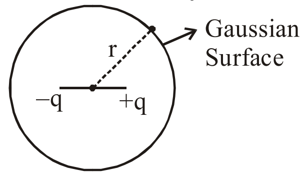
$U = \frac{3}{5}k\frac{(27)(27)q^2}{3r}$

$U = \frac{(27)(27)}{3}\left(\frac{3}{5}\frac{kq^2}{r}\right)$

$U = 243\,U_1$

11. Official Ans. by NTA (2)

Sol.

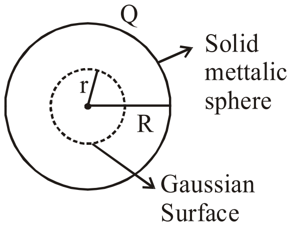


$\oint \vec{E}.\vec{ds} = \frac{q_{in}}{\varepsilon_0} = 0 = \phi$

Flux of $\vec{E}$ through sphere is zero.

But $\oint \vec{E}.\vec{ds} = 0 \Rightarrow \{\vec{E}.\vec{ds} \neq 0\}$ for small section ds only

Statement-2



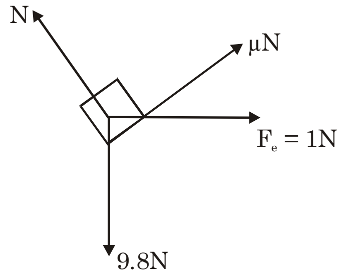
As change encloses within gaussian surface is equal to zero.

$\phi = \oint \vec{E}.\vec{ds} = 0$

Option(2) statement-1 correct statement-2 false.

12. Official Ans. by NTA (4)

Sol. FBD



here N = 9.8 cos 30 + 1 sin 30

≈ 9N

so $a = \dfrac{9.8\sin 30 - 1\cos 30 - \mu N}{1}$

a = 2.233 m/s^2

By $S = ut + \dfrac{1}{2}at^2$

$= \dfrac{1}{2}(2.233)t^2$

sin30°   t ≈ 1.3 sec

13. Official Ans. by NTA (1)

Sol. $\dfrac{2K\lambda}{r} = \dfrac{\sigma}{\varepsilon_0}$ (x = 3m)

$\sigma = 0.424 \times 10^{-9} \dfrac{C}{m^2}$

14. Official Ans. by NTA (640)

Sol. $\phi = E_x A \Rightarrow \dfrac{2}{5} \times 4 \times 10^3 \times 0.4 = 640$

15. Official Ans. by NTA (2)

Sol. qE = Mg

$neE = \rho\left(\dfrac{4}{3}\pi r^3\right) \times g$

$n \times 1.6 \times 10^{-19} \times 3.55 \times 10^5$

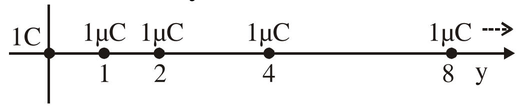
$= 3 \times 10^3 \times \dfrac{4}{3} \times \pi \times (2 \times 10^{-3})^3 \times 9.81$

$n = 173 \times 10^{(3-9-5+19)}$

$n = 1.73 \times 10^{10}$

16. Official Ans. by NTA (12)

Sol.

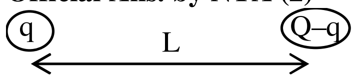


$F = k(1C)(1\mu C)\left[1 + \dfrac{1}{2^2} + \dfrac{1}{4^2} + \dfrac{1}{8^2} + ...\right]$

$= 9 \times 10^3 \left[\dfrac{1}{1 - \dfrac{1}{4}}\right] = 12 \times 10^3 N$

17. Official Ans. by NTA (2)

Sol.



$F_q = \dfrac{kq(Q-q)}{L^2} = \dfrac{k}{L^2}(qQ - q^2)$

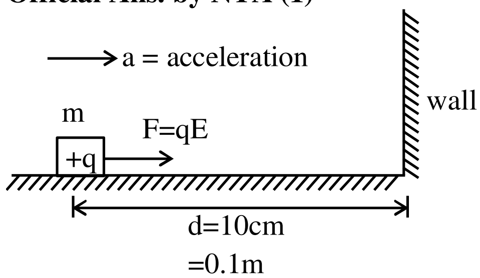
$\dfrac{dF}{dq} = 0$ when force is maximum

$\dfrac{dF}{dq} = \dfrac{k}{L^2}[Q - 2q] = 0$

$\Rightarrow Q - 2q = 0 \Rightarrow Q = 2q$

18. Official Ans. by NTA (1)

Sol.



F = ma

qE = ma

$a = \dfrac{qE}{m}$

Now $d = \dfrac{1}{2}at^2$

$t = \sqrt{\dfrac{2d}{a}}$

$t = \sqrt{\dfrac{2d}{\left(\dfrac{qE}{m}\right)}}$

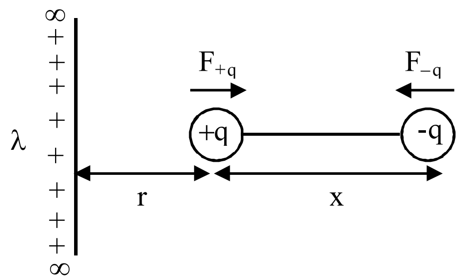
$t = \sqrt{\dfrac{2 \times 0.1}{\left(\dfrac{8 \times 10^{-6}}{10^{-3}}\right) \times 100}} = \dfrac{1}{2}$

∴ Time period = 2t = 1 sec

Ans. = 1.00

19. Official Ans. by NTA (4)

Sol.



r = 10 mm, x = 2,,

$$\left|\vec{F}_q\right| = \frac{2k\lambda}{r}.q$$

$$\left|\vec{F}_{-q}\right| = \frac{2k\lambda}{r+x}.q$$

$$\Rightarrow \quad \left|\vec{F}_{net}\right| = \frac{2k\lambda q}{r} - \frac{2k\lambda q}{r+x}$$

$$\left|\vec{F}_{net}\right| = \frac{2k\lambda q.x}{r(r+x)}$$

$$4 = \frac{2\times 9\times 10^9 \times 3\times 10^{-6}\times q\times 2\text{mm}}{10\text{mm}.12\text{mm}}$$

$\Rightarrow$ q = 4.44 μC

20. Official Ans. by NTA (4)

Sol. Electric flux density

$$\left(\vec{D}\right) = \frac{\text{charge}}{\text{Area}}\times\hat{r} = \frac{Q}{4\pi r^2}\hat{r} = \epsilon_0\left(\frac{Q}{4\pi\epsilon_0 r^2}\hat{r}\right)$$

$$\Rightarrow \vec{E} = \frac{\vec{D}}{\epsilon_0} = \frac{e^{-x}\sin y\hat{i} - e^{-x}\cos y\hat{j} + 2z\hat{k}}{\epsilon_0}$$

Also by Gauss's law

$$\frac{\rho}{\epsilon_0} = \left(\frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}\right).\vec{E}$$

$$= \left(\frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}\right).\frac{\vec{D}}{\epsilon_0}$$

$$\Rightarrow \rho = \frac{\partial}{\partial x}\left(e^{-x}\sin y\right) + \frac{\partial}{\partial y}\left(-e^{-x}\cos y\right) + \frac{\partial}{\partial z}(2z)$$

$$\rho = -e^{-x}\sin y + e^{-x}\sin y + 2$$

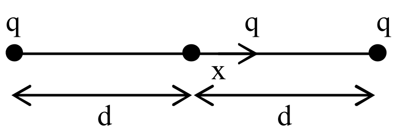
At origin $\rho = -e^{-0}\sin 0 + e^{-0}\sin 0 + 2$

$$\rho = 2C/m^3$$

Charge = ρ × volume = 2 × 2 × 10^{-9} = 4 × 10^{-9} = 4nC

21. Official Ans. by NTA (6000)

Sol.



Net force on free charged particle

$$F = \frac{kq^2}{(d+x)^2} - \frac{kq^2}{(d-x)^2}$$

$$F = -kq^2\left[\frac{4dx}{(d^2-x^2)^2}\right]$$

$$a = -\frac{4kq^2d}{m}\left(\frac{x}{d^4}\right)$$

$$a = -\left(\frac{4kq^2}{md^3}\right)x$$

So, angular frequency

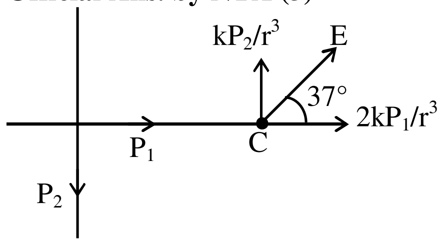
$$\omega = \sqrt{\frac{4kq^2}{md^3}}$$

$$\omega = \sqrt{\frac{4\times 9\times 10^9\times 10}{1\times 10^{-6}\times 1^3}}$$

ω = 6 × 10^8 rad/sec

22. Official Ans. by NTA (3)

Sol.

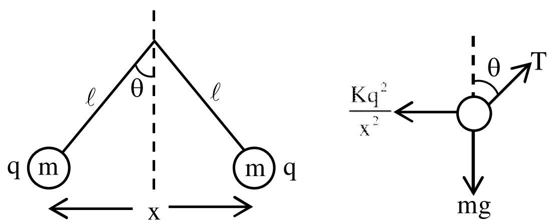


$$\tan 37° = \frac{3}{4} = \frac{\frac{kP_2}{r^3}}{\frac{2kP_1}{r^3}} = \frac{P_2}{2P_1} = \frac{3}{4}$$

$$\frac{P_2}{P_1} = \frac{3}{2}; \quad \frac{P_1}{P_2} = \frac{2}{3}$$

23. Official Ans. by NTA (2)

Sol.



Tcosθ = mg

$$T\sin\theta = \frac{kq^2}{x^2}$$

$$\tan\theta = \frac{kq^2}{x^2mg}$$

as $\tan\theta \approx \sin\theta \approx \frac{x}{2L}$

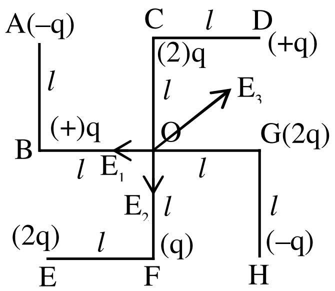
$$\frac{x}{2L} = \frac{Kq^2}{x^2mg}$$

$$x = \left(\frac{q^2L}{2\pi\varepsilon_0 mg}\right)^{1/3}$$

24. Official Ans. by NTA (2)

Sol. $E_1 = \dfrac{kq}{\ell^2} = E_2$; $\quad E_3 = \dfrac{kq}{(\sqrt{2}\ell)^2} = \dfrac{kq}{2\ell^2}$

$$E = \frac{\sqrt{2}kq}{\ell^2} - \frac{kq}{2\ell^2} = \frac{kq}{2\ell^2}\left(2\sqrt{2}-1\right)$$

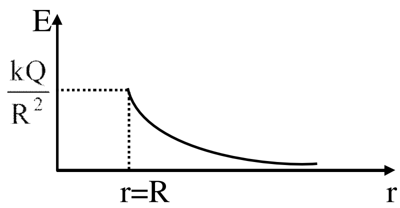


25. Official Ans. by NTA (1)

Sol. Considering outer spherical shell is non-conducting

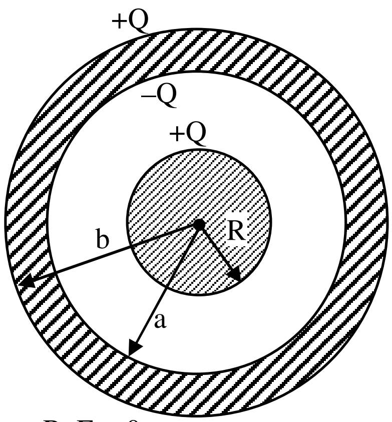
Electric field inside a metal sphere is zero.

$r < R \Rightarrow E = 0$; $\ r > R \Rightarrow E = \dfrac{kQ}{r^2}$



Option (2)

Considering outer spherical shell is conducting

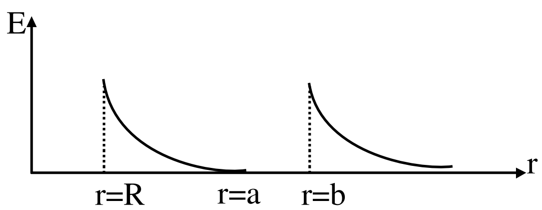


$r < R, E = 0$

$R \le r < a \qquad E = \dfrac{kQ}{r^2}$

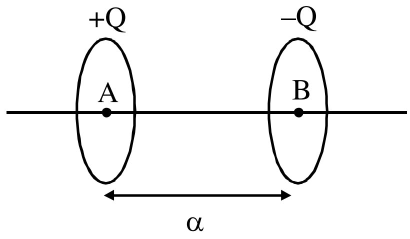
$a \le r < b, \qquad E = 0$

$r \ge b \qquad E = \dfrac{kQ}{r^2}$



26. Official Ans. by NTA (4)

Sol.



$$V_A = \frac{KQ}{a} - \frac{KQ}{\sqrt{a^2+s^2}}$$

$$V_B = \frac{-KQ}{a} + \frac{KQ}{\sqrt{a^2+s^2}}$$

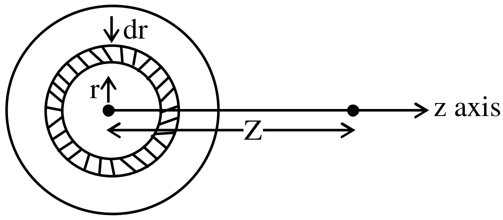
$$V_A - V_B = \frac{2KQ}{a} - \frac{2KQ}{\sqrt{a^2+s^2}}$$

$$= \frac{Q}{2\pi\varepsilon_0}\left(\frac{1}{a} - \frac{1}{\sqrt{s^2+a^2}}\right)$$

Ans 4

27. Official Ans. by NTA (1)

Sol. Consider a small ring of radius r and thickness dr on disc.



area of elemental ring on disc

$dA = 2\pi r dr$

charge on this ring $dq = \sigma dA$

$$dE_z = \frac{kdqz}{\left(z^2+r^2\right)^{3/2}}$$

$$E = \int_0^R dE_z = \frac{\sigma}{2\epsilon_0}\left[1 - \frac{z}{\sqrt{R^2+z^2}}\right]$$

28. Official Ans. by NTA (2)

Sol. $\varepsilon = \dfrac{2k\lambda}{R}\sin\left(\dfrac{\theta}{2}\right)(-\hat{i})$

$$\lambda = \left(\frac{-Q}{R\theta}\right) = \left(\frac{-Q}{R.\frac{2\pi}{3}}\right)$$

$$\lambda = \frac{-3Q}{2\pi R}$$

$$\varepsilon = \frac{2k}{R}.\frac{-3Q}{2\pi R}.\sin(60°)(-\hat{i})$$

$$\varepsilon = \frac{3\sqrt{3}Q}{8\pi^2\epsilon_o R^2}(+\hat{i})$$

29. Official Ans. by NTA (2)

Sol. 20μC –5μC

Null point is possible only right side of –5μC

20μC –5μC N

x

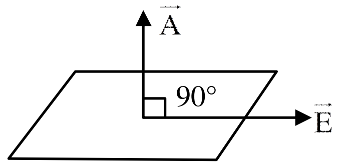
$$E_N = +\frac{k(-5\mu C)}{x^2} + \frac{k(20\mu C)}{(5+x)^2} = 0$$

x = 5 cm

∴ option (2) is correct

30. Official Ans. by NTA (3)

Sol. Since $\phi = \vec{E}.\vec{A} = EA\cos\theta$



θ = 90° ∴ ϕ = 0

31. Official Ans. by NTA (2)

Sol. As electric field is in y-direction so electric flux is only due to top and bottom surface

Bottom surface y = 0

⇒ E = 0 ⇒ ϕ = 0

Top surface y = 0.5 m

$\Rightarrow E = 150\,(.5)^2 = \frac{150}{4}$

Now flux $\phi = EA = \frac{150}{4}(.5)^2 = \frac{150}{16}$

By Gauss's law $\phi = \frac{Q_{in}}{\epsilon_0}$

$\frac{150}{16} = \frac{Q_{in}}{\epsilon_0}$

$Q_{in} = \frac{150}{16} \times 8.85 \times 10^{-12} = 8.3 \times 10^{-11}$ C

Option (2)

EM WAVES

1. Official Ans. by NTA (15)

Sol. Given : Frequency of wave f = 5 GHz

$= 5 \times 10^9$ Hz

Relative permittivity, $\epsilon_r = 2$

and Relative permeability, $\mu_r = 2$

Since speed of light in a medium is given by,

$v = \frac{1}{\sqrt{\mu \in}} = \frac{1}{\sqrt{\mu_r \mu_0 \cdot \in_r \in_0}}$

$v = \frac{1}{\sqrt{\mu_r \in_r}} \frac{1}{\sqrt{\mu_0 \in_0}} = \frac{C}{\sqrt{\mu_r \in_r}}$

Where C is speed of light is vaccum.

$\therefore\ v = \frac{3\times 10^8}{\sqrt{4}} = \frac{30\times 10^7}{2}$ m/s

$= 15 \times 10^7$ m/s ∴ Ans. is 15

2. Official Ans. by NTA (4)

Sol. (a) Source of microwave frequency is magnetron.

(b) Source of infrared frequency is vibration of atoms and molecules.

(c) Source of Gamma rays is radioactive decay of nucleus

(d) Source of X-rays inner shell electron transition.

Option (4) is correct.

3. Official Ans. by NTA (667)

Sol. λ in vacuum = $\frac{c}{f} = \frac{3\times 10^8}{3\times 10^9} = 0.1\text{m}$

∴ λ in medium = $\frac{0.1}{\mu}$

Where refractive index

$\mu = \sqrt{\mu_r \varepsilon_r}$

Assuming non-magnetic material $\mu_r = 1$

$\therefore\ \mu = \sqrt{2.25} = 1.5$

$\lambda_m = \frac{0.1}{1.5} = \frac{1}{15}\text{m} = 6.67\,\text{cm}$

$= 667 \times 10^{-2}$ cm $\boxed{\text{Ans. } 667}$

4. Official Ans. by NTA (2)

Sol. $I = \frac{1}{2} c \in_0 E_0^2$

$\frac{8}{4\pi \times 10^2} \times \frac{1}{2} = \frac{1}{4} \times c \times \frac{1}{\mu_0 c^2} \times E_0^2$

$E_0 = \frac{2}{10} \times \sqrt{\frac{\mu_0 c}{\pi}} \Rightarrow x = 2$

5. Official Ans. by NTA (137)

Sol. $I_{avg} = \frac{1}{2}\varepsilon_0 E_0^2 C$

$\frac{1.25}{100} \times \frac{1000}{4\pi(2)^2} = \frac{1}{2} \times 8.85 \times 10^{-12} \times 3 \times 10^8 \times$

E_0^2 $E_0^2 = 187.4$

∴ $E_0 = 13.689$ V/m

$= 136.89 \times 10^{-1}$ V/m

∴ x = 136.89

Rounding off to nearest integer

x = 137

6. Official Ans. by NTA (1)

Sol. $f = 5 \times 10^8$ Hz

EM wave is travelling towards $+\hat{j}$

$\vec{B} = 8.0 \times 10^{-8}\hat{z}\text{T}$

$\vec{E} = \vec{B} \times \vec{C} = (8 \times 10^{-8}\hat{z}) \times (3 \times 10^8\ \hat{y})$

$= -24\,\hat{x}$ V / m

7. Official Ans. by NTA (1)

Sol. In EMW, Average energy density due to electric (U_e) and magnetic (U_m) fields is same.

8. Official Ans. by NTA (3)

Sol. $c \in_0 E^2 = \frac{100}{4\pi \times 3^2}$

$c \in_0 \left(\sqrt{\frac{x}{5}}E\right)^2 = \frac{60}{4\pi \times 3^2}$

$\Rightarrow \frac{x}{5} = \frac{3}{5} \Rightarrow x = 3$

9. Official Ans. by NTA (3)

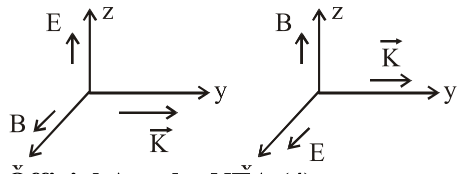
Sol. $E = BC = 6$

(Dir. of wave) $\parallel \left(\vec{E} \times \vec{B}\right)$

$\hat{i} = \hat{j} \times \hat{k} \qquad \vec{E} = 6\hat{j}\ V/m$

10. Official Ans. by NTA (3)

Sol.



11. Official Ans. by NTA (4)

Sol. Direction of propagation = $\vec{E} \times \vec{B} = \hat{i} \times \hat{k} = -\hat{j}$

12. Official Ans. by NTA (1)

Sol. $I_{avg} = \frac{B_0^2 C}{2\mu_0}$ & $\frac{1}{\mu_0} = \in_0 C^2$

$I = \frac{B_0^2}{2} \in_0 C^3$

$B_0 = \sqrt{\frac{2I}{\in_0 C^3}}$

$B_0 = 2.77 \times 10^{-8}$ T

13. Official Ans. by NTA (4)

Sol. Reflected wave will have direction opposite to incident wave.

14. Official Ans. by NTA (4)

Sol. $\frac{E_0}{C} = B_0$

$F_{max} = eB_0 V$

$= 1.6 \times 10^{-19} \times \frac{800}{3 \times 10^8} \times 3 \times 10^7$

$= 12.8 \times 10^{-18}$ N

Ans. 4

15. Official Ans. by NTA (3)

Sol. $\vec{F} = q\left(\vec{V} \times \vec{B}\right)$

$\vec{F}_1 = 4\pi\left[0.5c\hat{i} \times B_0\left(\frac{\hat{i}+\hat{j}}{2}\right)\cos\left(K.\frac{\pi}{K} - 0\right)\right]$

$\vec{F}_2 = 2\pi\left[0.5c\hat{i} \times B_0\left(\frac{\hat{i}+\hat{j}}{2}\right)\cos\left(K.\frac{3\pi}{K} - 0\right)\right]$

$\cos\pi = -1, \quad \cos 3\pi = -1$

$\therefore \frac{F_1}{F_2} = 2$

16. Official Ans. by NTA (3)

Sol. $V = \frac{\omega}{K} = \frac{10 \times 10^{10}}{500} = 2 \times 10^8$

V = $\frac{2C}{3}$.

17. Official Ans. by NTA (2)

Sol. $|B| = \frac{|E|}{C} = \frac{6}{3 \times 10^8}$

$= 2 \times 10^{-8}$ T

$\therefore x = 2$

18. Official Ans. by NTA (500)

Sol. $E = 50\sin\left(\omega t - \frac{\omega}{c}.x\right)$

Energy density = $\frac{1}{2} \in_0 E_0^2$

Energy for volume V = $\frac{1}{2} \in_0 E_0^2.V = 5.5 \times 10^{-12}$

$\frac{1}{2} 8.8 \times 10^{-12} \times 2500V = 5.5 \times 10^{-12}$

$V = \frac{5.5 \times 2}{2500 \times 8.8} = .0005 m^3$

$= .0005 \times 10^6 (c.m)^3$

$= 500 (c.m)^3$

19. Official Ans. by NTA (1)

Sol. Speed of wave = $\frac{2 \times 10^{10}}{200} = 10^8 m/s$

Refractive index **=** $\frac{3 \times 10^8}{10^8} = 3$

Now refractive index = $\sqrt{\varepsilon_r \mu_r}$

$3 = \sqrt{\varepsilon_r (1)} \Rightarrow \varepsilon_r = 9$

Option (1)

20. Official Ans. by NTA (354)

Sol. $E_0 = 200$

$I = \frac{1}{2}\varepsilon_0 E_0^2 \cdot C$

Radiation pressure

$P = \frac{2I}{C}$

$= \left(\frac{2}{C}\right)\left(\frac{1}{2}\varepsilon_0 E_0^2 C\right) = \varepsilon_0 E_0^2$

$= 8.85 \times 10^{-12} \times 200^2$

$= 8.85 \times 10^{-8} \times 4 = \frac{354}{10^9}$

Ans. 354.0

EMI & AC

1 Official Ans. by NTA (2000)

Sol. Given : $L = 2 \times 10^{-4}$ H
$R = 6.28\ \Omega$
$f = 10$ MHz $= 10^7$ Hz

Since quality factor,

$$Q = \omega_0 \frac{L}{R} = 2\pi f \frac{L}{R}$$

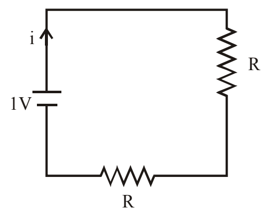
$$\therefore Q = 2\pi \times 10^7 \times \frac{2\times10^{-4}}{6.28}$$

$Q = 2 \times 10^3 = 2000$

$\therefore$ Ans. is 2000

2. Official Ans. by NTA (1)

Sol. Just after the switch is closed, inductor will behave like infinite resistance (open circuit) so the circuit will look like



$$i = \frac{9}{R+R} = \frac{9}{4} = 2.25$$

Option (1) is correct.

3. Official Ans. by NTA (900)

Sol. At resonance

$$P = \frac{V^2}{R}$$

$$R = \frac{V^2}{P} = \frac{(120)^2}{16} = 900\Omega$$

4. Official Ans. by NTA (2)

Sol. Current through 60Ω resistance $= \frac{15}{60} = \frac{1}{4}$ A

thus capacitor current $= \frac{1}{4}$ A

$\because\ V_C = I X_C$

$$10 = \frac{1}{4} \times \frac{1}{\omega C}$$

$$\therefore C = \frac{1}{40\omega} = \frac{1}{4000} = 250\ \mu F$$

Now,

current through 40Ω resistance $= \frac{20}{40} = \frac{1}{2}$ A

thus current through inductor $= \frac{1}{2} - \frac{1}{4} = \frac{1}{4}$ A

$$V_L = IX_L = \frac{1}{4} \times \omega L$$

$$20 = \frac{1}{4} \times 100 \times L$$

$\Rightarrow L = 0.8$ H

5. Official Ans. by NTA (4)

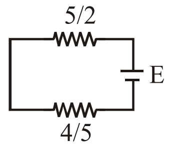
Sol. At t = 0, current through inductor is zero,

hence $R_{eq} = (5+1) \parallel (5+4) = \frac{18}{5}$

$$i_1 = \frac{E}{18/5} = \frac{5E}{18}$$

At t = ∞, inductor becomes a simple wire and now the circuit will be as shown in figure

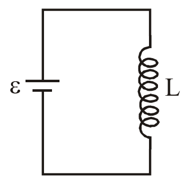
hence $R_{eq} = (5\|5) + (4\|1) = \frac{33}{10}$; ($\|$ ⇒ parallel)



$$i_2 = \frac{E}{33/10} = \frac{10E}{33}$$

6. Official Ans. by NTA (144)

Sol. $\varepsilon = \frac{L\,dI}{dt}$



$$3\int_0^4 t\,dt = 2\int_0^I dI$$

$$\frac{3}{2} \times 16 = 2I$$

$I = 12$

$$V = \frac{1}{2}LI^2 = \frac{1}{2} \times 2(12)^2 = 144\ J$$

7. Official Ans. by NTA (4)

Sol. $\tan 45° = \frac{1}{\omega CR} = \frac{\omega L}{R} \Rightarrow X_L = X_C$

⇒ resonance

$$i = \frac{V}{R} = \frac{220}{110} = 2A$$

8. Official Ans. by NTA (1)

Sol. $i = i_1 \sin\omega t + i_2 \sin(\omega t + 90)$

$$i = \sqrt{i_1^2 + i_2^2}\,\sin(\omega t + \phi)$$

$$i_{rms} = \frac{i_0}{\sqrt{2}} = \frac{\sqrt{i_1^2 + i_2^2}}{\sqrt{2}}$$

9. Official Ans. by NTA (283)

Sol. $Q = \frac{X_L}{R} = \frac{\omega L}{R} = \frac{1}{\sqrt{LC}}\frac{L}{R} = \frac{\sqrt{L}}{R\sqrt{C}}$

$$Q' = \frac{\sqrt{2L}}{\left(\frac{R}{2}\right)\sqrt{C}} = 2\sqrt{2}Q = 2\sqrt{2}(100)$$

$= 282.84$

10. Official Ans. by NTA (1)

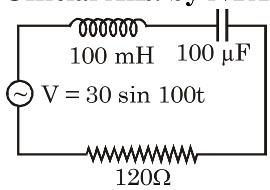
Sol. $\in = [\vec{B}\vec{V}\vec{L}] = BVL\sin\theta$

$$= (2.5 \times 10^{-4} T)\left(180 \times \frac{5}{18} m/s\right)(10m)\sin 60°$$

$= 108.25 \times 10^{-3}$V

11. Official Ans. by NTA (1)

Sol.



as given $z = \sqrt{(x_L - x_C)^2 + R^2}$

$x_L = \omega_L = 100 \times 100 \times 10^{-3} = 10\Omega$

$x_C = \frac{1}{\omega_C} = \frac{1}{100 \times 100 \times 10^{-6}} = 10\Omega$

$z = \sqrt{(10-100)^2 + R^2} = \sqrt{90^2 + 120^2}$

$= 30 \times 5 = 150\Omega$

$i_{peak} = \frac{\Delta v}{z} = \frac{30}{150} = \frac{1}{5} amp = 0.2 amp$

& For resonant frequency

$\Rightarrow \omega L = \frac{1}{\omega C} \Rightarrow \omega^2 = \frac{1}{LC} \Rightarrow \omega = \frac{1}{\sqrt{LC}}$

& $f = \frac{1}{2\pi\sqrt{LC}} \Rightarrow \frac{1}{2\pi\sqrt{100 \times 10^{-3} \times 100 \times 10^{-6}}}$

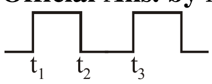
$= \frac{100\sqrt{10}}{2\pi} = \frac{100\pi}{2\pi} = 50 Hz$

as $\sqrt{10} \approx \pi$

Answer (1)

12. Official Ans. by NTA (3)

Sol.

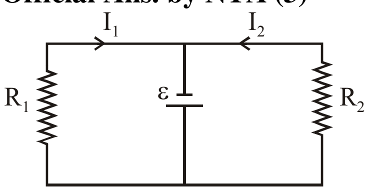


For $t_1 - t_2$ Charging graph

$t_2 - t_3$ Discharging graph

13. Official Ans. by NTA (3)

Sol.



14. Official Ans. by NTA (4)

Sol. At resonance power (P)

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

$P = \frac{(250/\sqrt{2})^2}{8} = 3906.25$ W

≈ 4 kW

15. Official Ans. by NTA (3)

Sol. $V_S = \frac{P}{i} = \frac{60}{0.11} = 545.45$

$V_P = 220$

$V_S > V_P$

$\Rightarrow$ Step up transformer

16. Official Ans. by NTA (1)

Sol. $A = A_0 e^{-\gamma t} = A_0 e^{-\frac{bt}{2m}}$

$\frac{A_0}{2} = A_0 e^{-\frac{bt}{2m}}$

$\frac{bt}{2m} = \ln 2$

$t = \frac{2m}{b}\ln 2 = \frac{2 \times 500 \times 0.693}{20}$

t = 34.65 second.

17. Official Ans. by NTA (2)

Sol. $I = I_1 \sin \omega t + I_2 \cos \omega t$

$\therefore I_0 = \sqrt{I_1^2 + I_2^2}$

$\therefore I_{rms} = \frac{I_0}{\sqrt{2}} = \sqrt{\frac{I_1^2 + I_2^2}{2}}$

18. Official Ans. by NTA (1)

Sol. $B = \mu nI = \mu_0 \mu_r nI$

$B = 4\pi \times 10^{-7} \times 500 \times 1000 \times 5$

$B = \pi$ Tesla

19. Official Ans. by NTA (Bonus)

Sol. $A = A_0 e^{-\gamma t}$

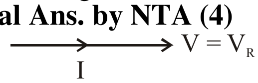
$\ln 2 = \frac{b}{2m} \times 120$

$\frac{0.693 \times 2 \times 1}{120} = b$

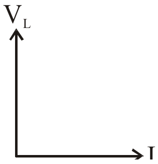
1.16×10^{-2} kg/sec.

20. Official Ans. by NTA (4)

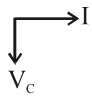
Sol. (4) (a)



(b)



(c)



(d) $\tan \phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$

21. Official Ans. by NTA (2)

Sol. (2) $X_L = \omega L$

$i = \frac{V_0}{\omega L}$

22. Official Ans. by NTA (6)

Sol. $J_c = \frac{E}{\rho} = \frac{V}{\rho d}$

$J_d = \frac{1}{A}\frac{dq}{dt}$

$= \frac{C}{A}\frac{dV_c}{dt} = \frac{\in}{d}\frac{dV_c}{dt}$

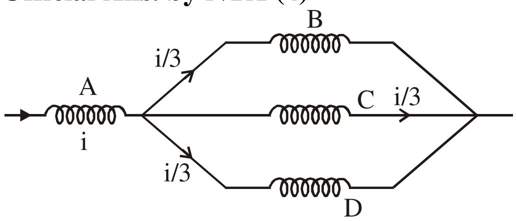
$\Rightarrow \frac{V_0 \sin 2\pi ft}{\rho d} = 10^x \times \frac{80\varepsilon_0}{d} V_0 (2\pi f) \cos 2\pi ft$

$\tan\left(2\pi \times \frac{900}{800}\right) = 10^x \times \frac{40}{9 \times 10^9} \times 900$

$= x = 6$

23. Official Ans. by NTA (4)

Sol.



$\phi \propto i$

$\Rightarrow B \propto i$

so, field at centre of C = $\frac{3}{3} = 1T$

24. Official Ans. by NTA (1)

Sol. Bandwidth = R/L

Bandwidth $\propto$ R

So bandwidth will increase

25. Official Ans. by NTA (1)

Sol. $i = i_0 \cos(\omega t)$

$i = i_0$ at $t = 0$

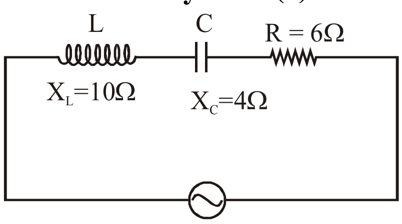
$i = \frac{i_0}{\sqrt{2}}$ at $\omega t = \frac{\pi}{4}$

$t = \frac{\pi}{4\omega} = \frac{\pi}{4(2\pi f)} = \frac{1}{8f}$

$t = \frac{1}{400} = 2.5\text{ ms}$

26. Official Ans. by NTA (3)

Sol.

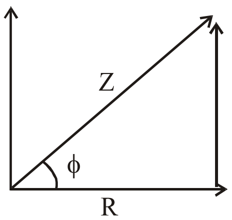


We know that power factor is $\cos\phi$,

$\cos\phi = \frac{R}{Z}$ ... (1)

$Z = \sqrt{R^2 + (X_L - X_C)^2}$ ... (2)

$(\omega L - 1/\omega C)$



$\Rightarrow Z = \sqrt{6^2 + (10-4)^2}$

$\Rightarrow Z = 6\sqrt{2}$ | $\cos\phi = \frac{6}{6\sqrt{2}}$

$\cos\phi = \frac{1}{\sqrt{2}}$

27. Official Ans. by NTA (3)

Sol. Magnetic energy = $\frac{1}{2}Li^2 = 25\%$

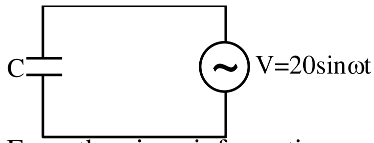
$ME \Rightarrow 25\% \Rightarrow i = \frac{i_0}{2}$

$i = i_0(1 - R^{-Rt/L})$ for charging

$t = \frac{L}{R}\ell n2$

28. Official Ans. by NTA (3)

Sol.



From the given information,

$C = \frac{\in_0 A}{d} = \frac{\in_0 \times 1}{2\times 10^{-3}} F$

$\therefore X_C = \frac{1}{\omega C} = \frac{2\times 10^{-3}}{2\times 50\pi \times \in_0} = \frac{2\times 10^{-3}}{25\times 4\pi \in_0}\Omega$

$\therefore X_C = \frac{2\times 10^{-3}}{25} \times 9\times 10^9 = \frac{18}{25}\times 10^6 \Omega$

$\therefore i_0 = \frac{V_0}{X_C} = \frac{20\times 25}{18}\times 10^{-6} A = 27.47\ \mu A.$

The value of amplitude of displacement current will be same as value of amplitude of conventional current.

Hence option 3.

29. Official Ans. by NTA (3)

Sol. As rod moves in field area increases upto x = b then field is absent and again flux is generated on return journey from x = b to x = 0. Thus plot A for flux.

$\Rightarrow e = -\frac{d\phi}{dt} \Rightarrow$ curve B for emf

$\Rightarrow$ Power dissipated = vi $\Rightarrow$ curve C for power dissipated

30. Official Ans. by NTA (3)

Sol. $\tan\phi = \frac{x_C - x_L}{R}$

$\tan 45 = \frac{x_C - x_L}{R}$

$x_C - x_L = R$

$\frac{1}{\omega C} - \omega L = R$

$\frac{1}{\omega C} - 300\times 0.03 = 1$

$\frac{1}{\omega C} = 10$

$C = \frac{1}{10\omega} = \frac{1}{10\times 300}$; $C = \frac{1}{3}\times 10^{-3}$

X = 3

31. Official Ans. by NTA (4)

Sol. $R = 100\Omega$

$X_L = \omega L = 50\pi \times 10^{-3}$

$X_C = \frac{1}{\omega C} = \frac{10^{11}}{100\pi}$

$X_C >> X_L \ \& \ |X_C - X_L| >> R$

32. Official Ans. by NTA (125)

Sol. $X_L = X_C$ (due to resonance)

$Z = R$ so $i_{rms} = \frac{V}{Z} = \frac{V}{R}$

$\frac{V^2}{R} = \frac{250 \times 250}{5} = 125 \times 10^2$ W

33. Official Ans. by NTA (3)

Sol. In capacitor, current lead voltage by $\frac{\pi}{2}$

34. Official Ans. by NTA (1)

Sol. (a) For $x_L > x_C$, voltage leads the current
(ii)
(b) For $x_L = x_C$, voltage & current are in same phase
(i)
(c) For $x_L < x_C$, current leads the voltage
(iv)
(d) For resonant frequency $x_L = x_C$, current is maximum
(iii)

35. Official Ans. by NTA (74)

Sol. $I_{max} = \frac{V}{R} = \frac{20V}{10K\Omega} = 2mA$

For LR – decay circuit

$I = I_{max}\, e^{-Rt/L}$

$I = 2mA\, e^{\frac{-10\times10^3\times1\times10^{-6}}{10\times10^{-3}}}$

$I = 2mA\ e^{-1}$

$I = 2 \times 0.37$ mA

$I = \frac{74}{100}$ mA

$\boxed{x = 74}$

36. Official Ans. by NTA (80)

Sol. $\phi = \vec{B}.\vec{S}$

$\phi = \frac{4}{\pi} \times 10^{-3}\left(1 - \frac{t}{100}\right).\pi R^2$

$\phi = 4 \times 10^{-3} \times (1)^2\left(1 - \frac{t}{100}\right)$

$\varepsilon = \frac{-d\phi}{dt}$

$\varepsilon = \frac{-d}{dt}\left(4 \times 10^{-3}\left(1 - \frac{t}{100}\right)\right)$

$\varepsilon = 4 \times 10^{-3}\left(\frac{1}{100}\right) = 4 \times 10^{-5}$ **V**

When B = 0

$1 - \frac{t}{100} = 0$

t = 100 sec

Heat $= \frac{\varepsilon^2}{R} t$

Heat $= \frac{(4 \times 10^{-5})^2}{2 \times 10^{-6}} \times 100$ J

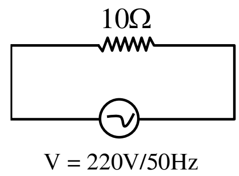
Heat $= \frac{16 \times 10^{-10} \times 100}{2 \times 10^{-6}}$ J

Heat = 0.08 J

Heat = 80 mJ

37. Official Ans. by NTA (1)

Sol.



$\Rightarrow i = i_0 \sin\omega t$

When $i = i_0$

$i_0 = i_0 \sin\omega t_1 \Rightarrow \omega t_1 = \frac{\pi}{2}$ ... (i)

When $i = \frac{i_0}{\sqrt{2}}$

$\frac{i_0}{\sqrt{2}} = i_0 \sin\omega t_2 \Rightarrow \omega t_2 = \frac{\pi}{4}$ ... (ii)

Time taken by current from maximum value to rms value

$\Rightarrow (t_1 - t_2) = \frac{\pi}{2\omega} - \frac{\pi}{4\omega} = \frac{\pi}{4\omega} = \frac{\pi}{4 \times 2\pi f}$

$= \frac{1}{8 \times 50} = \frac{1}{400}$ sec $= 2.5$ ms

38. Official Ans. by NTA (500)

Sol. For figure (a)

$P_{avg} = \frac{v_{rms}^2}{R}$

$\frac{v_{rms}^2}{Z^2} \times R = \frac{v_{rms}^2}{R} \times 1$

$R^2 = Z^2$

$25 = \left(\sqrt{(x_C - x_L)^2 + 5^2}\right)^2$

$25 = (x_c - x_L)^2 + 25$

$x_c = x_L \Rightarrow \frac{1}{\omega C} = \omega L$

$\omega^2 = \frac{1}{LC} = \frac{10^6}{0.1 \times 40}$

$\omega = 500$

39. Official Ans. by NTA (1)

Sol. $\phi = \tan^{-1}\left(\frac{X_L}{R}\right)$

$X_L = \omega L$

$X_L = 2 \times \frac{22}{7} \times 50 \times 0.07 = 22\,\Omega$

$\phi = \tan^{-1}\left(\frac{22}{12}\right)$ R = 12 Ω

$\phi = \tan^{-1}\left(\frac{11}{6}\right)$

$Z = \sqrt{X_L^2 + R^2} = 25.059$

$I = \frac{V}{Z} = \frac{220}{25.059} = 8.77\,A$

40. Official Ans. by NTA (3)

Sol. When T_1 and T_2 are connected, then the steady state current in the inductor $I = \frac{6}{6} = 1A$

When T_1 and T_3 are connected then current through inductor remains same. So potential difference across 3Ω

V = Ir = 1 × 3 = 3 volt

41. Official Ans. by NTA (4)

Sol. C = 0.1 μF = 10^{-7} F

Resonant frequency = 60 Hz

$\omega_o = \frac{1}{\sqrt{LC}}$

$2\pi f_o = \frac{1}{\sqrt{LC}} \Rightarrow L = \frac{1}{4\pi^2 f_o^2 C}$

by putting values $L \simeq 70.3$ Hz.

42. Official Ans. by NTA (60)

Sol. $|\epsilon| = \frac{d\phi}{dt} = 20t + 20$ mV

$|i| = \frac{|\epsilon|}{R} = 10t + 10$ mA

at t = 5

|i| = 60 mA

43. Official Ans. by NTA (4)

Sol. $U = \frac{1}{2}Li^2 = 64 \Rightarrow L = 2$

$i^2R = 640$

$R = \frac{640}{(8)^2} = 10$

$\tau = \frac{L}{R} = \frac{1}{5} = 0.2$

Option (4)

44. Official Ans. by NTA (1)

Sol. For maximum average power

$X_L = X_C$

$250\pi = \frac{1}{2\pi(50)C}$

$C = 4 \times 10^{-6}$

Option (1)

45. Official Ans. by NTA (DROP)

Sol. $Z_C = \sqrt{\left(\frac{1}{\omega C}\right)^2 + R^2}$

$= \sqrt{\left(\frac{1}{100 \times 100 \times 10^{-6}}\right)^2 + 100^2}$

$Z_C = \sqrt{(100)^2 + (100)^2} = 100\sqrt{2}$

$Z_L = \sqrt{(\omega L)^2 + R^2}$

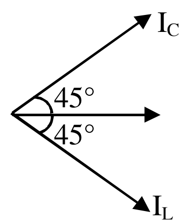
$\sqrt{(100 \times 0.5)^2 + 50^2} = 50\sqrt{2}$

$i_C = \frac{200}{z_C} = \frac{200}{100\sqrt{2}} = \sqrt{2}$

$i_L = \frac{200}{z_L} = \frac{200}{50\sqrt{2}} = 2\sqrt{2}$

$\cos\phi_1 = \frac{100}{10\sqrt{2}} = \frac{1}{\sqrt{2}} \Rightarrow \phi_1 = 45°$

$\cos\phi_2 = \frac{50}{50\sqrt{2}} = \frac{1}{\sqrt{2}} \Rightarrow \phi_2 = 45°$



$I = \sqrt{I_C^2 + I_L^2} = \sqrt{2+8} = \sqrt{10}$

I = 3.16 A

Ans. 3.16

46. Official Ans. by NTA (60)

Sol. Maximum emf ε = N ωAB

N = 20, ω = 50, B = 3 ×10^{-2}T

ε = 20 × 50 × π × $(0.08)^2$ × 3 × 10^{-2}

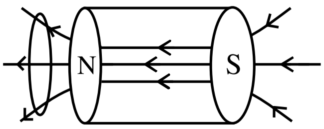
= 60.28 × 10^{-2}

Rounded off to nearest integer = 60

Ans.60

47. Official Ans. by NTA (3)

Sol.



→ When magnet passes through centre region of solenoid , no current / Emf is induced in loop.

→ While entering flux increases so negative induced emf

48. Official Ans. by NTA (11)

Sol. $f_{rms}^2 = f_{1rms}^2 + f_{2rms}^2$

$= \left(\frac{\sqrt{42}}{\sqrt{2}}\right)^2 + 10^2$

$= 121 \Rightarrow f_{rms} = 11$ A

49. Official Ans. by NTA (3)

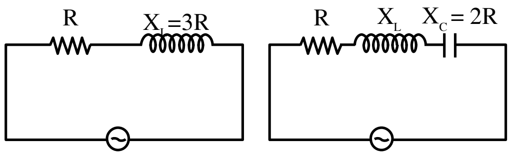
Sol. emf = BLV

= 1.(2R) .1

= 2 V

50. Official Ans. by NTA (1)

Sol.

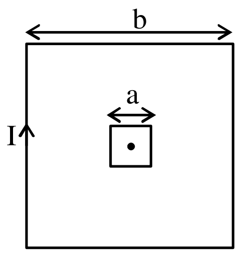


$\cos\phi = \frac{R}{\sqrt{R^2 + 3R^2}} = \frac{1}{\sqrt{10}}$ $\cos\phi' = \frac{R}{\sqrt{R^2 + R^2}} = \frac{1}{\sqrt{2}}$

$\frac{\cos\phi'}{\cos\phi} = \frac{\sqrt{10}}{\sqrt{2}} = \frac{\sqrt{5}}{1}$ $\therefore x = 1$

51. Official Ans. by NTA (1)

Sol.



$$B = \left[\frac{\mu_0}{4\pi}\frac{I}{b/2} \times 2\sin 45\right] \times 4$$

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

$$\therefore M = \frac{\phi}{I} = \frac{2\sqrt{2}\mu_0 a^2}{\pi b} = \frac{\mu_0}{4\pi}8\sqrt{2}\frac{a^2}{b}$$

Option (1)

52. Official Ans. by NTA (3)

Sol. $Z = \sqrt{(X_L - X_C)^2 + R^2} = R \because X_L = X_C$

Option (3)

53. Official Ans. by NTA (1)

Sol. $\vec{B}$ must not be parallel to the plane of coil for non zero flux and according to lenz law if B is outward it should be decreasing for anticlockwise induced current.

54. Official Ans. by NTA (2)

Sol. $X_L = 2\pi fL$

f is very large

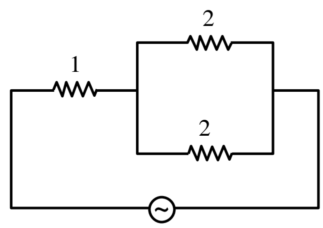
$\therefore X_L$ is very large hence open circuit.

$X_C = \frac{1}{2\pi fC}$

f is very large.

$\therefore X_C$ is very small, hence short circuit.

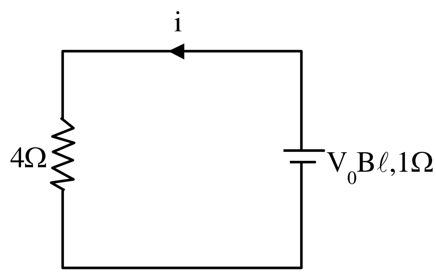
Final circuit



$Z_{eq} = 1 + \frac{2 \times 2}{2 + 2} = 2$

55. Official Ans. by NTA (2)

Sol. Equivalent circuit

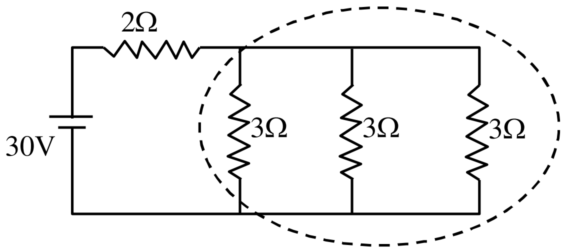


$i = \frac{V_0 B\ell}{4+1} \Rightarrow V_0 = \frac{5(2mA)}{5 \times .2} = 10^{-2}$ m/s = 1 cm/s

Option (2)

56. Official Ans. by NTA (3)

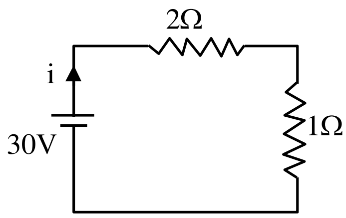
Sol. In steady state, inductor behaves as a conducting wire.
So, equivalent circuit becomes



Parallel (R_{eq})

$$\frac{1}{R_{eq}} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = 1 \Rightarrow R_{eq} = 1\Omega$$

$\Rightarrow$ Circuit becomes



$$\Rightarrow\ i = \frac{30}{3} = 10A$$

ERROR & PRACTICAL PHYSICS

1. Official Ans. by NTA (1)

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

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

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

$$\frac{\Delta g}{g} = \frac{1\times10^{-3}}{1} + 2\times\frac{0.01}{1.95}$$

$$\frac{\Delta g}{g} = 0.0113 \quad \text{or} \quad 1.13\%$$

option (1) is correct

2. Official Ans. by NTA (2)

Sol. Least count = $\frac{1\text{mm}}{100}$ = 0.01mm
zero error = + 8 × LC = + 0.08 mm
True reading (Diameter)
= (1 mm + 72 × LC) – (Zero error)
= (1 mm + 72 × 0.01 mm) – 0.08 mm
= 1.72 mm – 0.08 mm
= 1.64 mm
therefore, radius = $\frac{1.64}{2}$ = 0.82 mm.

3. Official Ans. by NTA (4)

Sol. (n – 1)a = n(a')

$$a' = \frac{(n-1)a}{n}$$

$\therefore$ L.C. = 1 MSD – 1 VSD

= (a – a')cm

$$= a - \frac{(n-1)a}{n} = \frac{na - na + a}{n}$$

$$= \frac{a}{n}\text{cm} = \left(\frac{10a}{n}\right)\text{mm}$$

4. Official Ans. by NTA (5)

Sol. $\frac{\Delta R}{R} \times 100 = \frac{\Delta V}{V} \times 100 + \frac{\Delta I}{I} \times 100$

% error in R = $\frac{2}{50} \times 100 + \frac{0.2}{20} \times 100$

% error in R = 4 + 1

% error in R = 5%

5. Official Ans. by NTA (4)

Sol. $Y = \frac{\text{Stress}}{\text{Strain}} = \frac{FL}{Al} = \frac{mg.L}{\pi R^2.\ell}$

$$\frac{\Delta Y}{Y} = \frac{\Delta m}{m} + \frac{\Delta L}{L} + 2.\frac{\Delta R}{R} + \frac{\Delta\ell}{\ell}$$

$$\frac{\Delta Y}{Y} \times 100 = 100\left[\frac{1}{1000} + \frac{1}{1000} + 2\left(\frac{0.001}{0.2}\right) + \frac{0.001}{0.5}\right]$$

$$= \frac{1}{10} + \frac{1}{10} + 1 + \frac{1}{5} = \frac{14}{10} = 1.4\%$$

6. Official Ans. by NTA (2)

Sol. Positive zero error = 0.2 mm
Main scale reading = 8.5 cm
Vernier scale reading = 6 × 0.01 = 0.06 cm
Final reading = 8.5 + 0.06 – 0.02 = 8.54 cm

7. Official Ans. by NTA (2)

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

$$\frac{\Delta g}{g} = \frac{\Delta\ell}{\ell} + 2\frac{\Delta T}{T} = \frac{0.1}{10} + 2\left(\frac{\frac{1}{200}}{0.5}\right)$$

$$\frac{\Delta g}{g} = \frac{1}{100} + \frac{1}{50}$$

$$\frac{\Delta g}{g} \times 100 = 3\%$$

8. Official Ans. by NTA (1)

Sol. $R=\frac{\rho\ell}{A}=\frac{V}{I}$

$\rho=\frac{AV}{I\ell}=\frac{\pi d^2V}{4I\ell}$ $\quad\left(A=\frac{\pi d^2}{4}\right)$

$\therefore\ \frac{\Delta\rho}{\rho}=\frac{2\Delta d}{d}+\frac{\Delta V}{V}+\frac{\Delta I}{I}+\frac{\Delta\ell}{\ell}$

$\frac{\Delta\rho}{\rho}=2\left(\frac{0.01}{5.00}\right)+\frac{0.1}{5.0}+\frac{0.01}{2.00}+\frac{0.1}{10.0}$

$\frac{\Delta\rho}{\rho}=0.004+0.02+0.005+0.01$

$\frac{\Delta\rho}{\rho}=0.039$

% error $=\frac{\Delta\rho}{\rho}\times100=0.039\times100=3.90\%$

Ans. (1)

9. Official Ans. by NTA (34)

Sol. $\because\ v=\frac{4}{3}\pi r^3$

taking log & then differentiate

$\frac{dV}{V}=3\frac{dr}{r}$

$=\frac{3\times0.85}{7.5}\times100\%=34\ \%$

10. Official Ans. by NTA (13)

Sol. For (A)

Reading = MSR + CSR + Error

0.322 = 0.300 + CSR + 5 × LC

0.322 = 0.300 + CSR + 0.005

CSR = 0.017

For B

Reading = MSR + CSR + Error

0.322 = 0.200 + CSR + 0.092

CSR = 0.030

Difference = 0.030 – 0.017 = 0.013 cm

Division on circular scale $=\frac{0.013}{0.001}=13$

11. Official Ans. by NTA (1)

Sol. Least count $=\frac{\text{Pitch}}{\text{total division on circular scale}}$

In 5 revolution, distance travel, 5 mm

In 1 revolution, it will travel 1 mm.

So least count $=\frac{1}{50}=0.02$

12. Official Ans. by NTA (3)

Sol. $\frac{\Delta y}{y}=\frac{2\Delta m}{m}+\frac{4\Delta r}{r}+\frac{x\Delta g}{g}+\frac{3}{2}\frac{\Delta\ell}{\ell}$

$18=2(1)+4(0.5)+xp+\frac{3}{2}(4)$

$8=xp$

By checking from options.

$x=\frac{16}{3},\ p=\pm\frac{3}{2}$

13. Official Ans. by NTA (1)

Sol. $T=2\pi\sqrt{\frac{\ell}{g}}\Rightarrow g=\frac{4\pi^2\ell}{T^2}$

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

$\Delta T=\frac{\text{least count of time }(\Delta T_0)}{\text{number of oscillations(n)}}$

$\frac{\Delta g}{g}=\frac{\Delta\ell}{\ell}+\frac{2\Delta T_0}{nT}$

As $\Delta\ell$ and ΔT_0 are same for all observations so

$\frac{\Delta g}{g}$ is minimum for highest value of ℓ, n and T

$\Rightarrow$ Minimum percentage error in g is for student number-1

14. Official Ans. by NTA (3)

Sol. Least count (L.C) $=\frac{0.5}{50}$

True reading $=5+\frac{0.5}{50}\times20-\frac{0.5}{50}\times5$

$=5+\frac{0.5}{50}(15)=5.15\text{mm}$

Option (3)

15. Official Ans. by NTA (3)

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

$\frac{\Delta T}{T}=\frac{1}{2}\frac{\Delta\ell}{\ell}$

$\Delta T=\frac{1}{2}\times\frac{0.1}{100}\times24\times3600$

$\Delta T=43.2$

Ans. 3

16. Official Ans. by NTA (14)

Sol. $T=2\pi\sqrt{\frac{\ell}{g}}\Rightarrow\ell=\frac{T^2g}{4\pi^2}$

$E=mg\ell\frac{\theta^2}{2}=mg^2\frac{T^2\theta^2}{8\pi^2}$

$\frac{dE}{E}=2\left(\frac{dg}{g}+\frac{dT}{T}\right)=(4+3)=14\%$

17. Official Ans. by NTA (52)

Sol. 9 MSD = 10 VSD

9×1 mm = 10 VSD

$\therefore$ 1 VSD = 0.9 mm

LC = 1 MSD – 1 VSD = 0.1 mm

Reading = MSR + VSR × LC

$10 + 8 \times 0.1 = 10.8$ mm

Actual reading = 10.8 – 0.4 = 10.4 mm

radius $= \frac{d}{2} = \frac{10.4}{2} = 5.2$ mm $= 52 \times 10^{-2}$ cm

18. Official Ans. by NTA (2)

Sol. $y = \frac{MgL^3}{4bd^3\delta}$

$$\frac{\Delta y}{y} = \frac{\Delta M}{M} + \frac{3\Delta L}{L} + \frac{\Delta b}{b} + \frac{3\Delta d}{d} + \frac{\Delta\delta}{\delta}$$

$$\frac{\Delta y}{y} = \frac{10^{-3}}{2} + \frac{3\times10^{-3}}{1} + \frac{10^{-2}}{4} + \frac{3\times10^{-2}}{4} + \frac{10^{-2}}{5}$$

$$= 10^{-3}\left[0.5 + 3 + 2.5 + 7.5 + 2\right] = 0.0155$$

Option (2)

19. Official Ans. by NTA (3)

Sol. $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{R_{eq}} = \frac{1}{4} + \frac{1}{4} \Rightarrow R_{eq} = 2\Omega$

Also $\frac{\Delta R_{eq}}{R_{eq}^2} = \frac{\Delta R_1}{R_1^2} + \frac{\Delta R_2}{R_2^2}$

$\frac{\Delta R_{eq}}{4} = \frac{.8}{16} + \frac{.4}{16} = \frac{1.2}{16}$

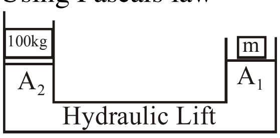
$\Delta R_{eq} = 0.3\Omega$

$R_{eq} = (2 \pm 0.3)\Omega$ Option (3)

FLUID

1. Official Ans. by NTA (25600)

Sol. Using Pascals law



$\frac{100\times g}{A_2} = \frac{mg}{A_1}$ ....(1)

Let m mass can lift M_0 in second case then

$\frac{M_0 g}{16A_2} = \frac{mg}{A_1/16}$ ....(2)

{Since $A = \frac{\pi d^2}{4}$ }

From equation (1) and (2) we get

$\frac{M_0}{16.100} = 16$

$\Rightarrow M_0 = 25600$ kg

2. Official Ans. by NTA (4)

Sol. $n \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

$\therefore n^{1/3} r = R$

$\therefore$ Total change in surface energy

$= (n(4\pi r^2) - 4\pi R^2)T$

$\Rightarrow 4\pi T\,(nr^2 - R^2)$

$\therefore$ Heat energy

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

Put $nr^3 = R^3$

$\therefore \frac{3T}{J}\left(\frac{1}{r} - \frac{1}{R}\right)$

3. Official Ans. by NTA (1)

Sol. $P_1 = \rho g d + P_0 = 3 \times 10^5$ Pa

$\therefore \rho g d = 2 \times 10^5$ Pa

$P_2 = 2\rho g d + P_0$

$= 4 \times 10^5 + 10^5 = 5 \times 10^5$ Pa

%increase $= \frac{P_2 - P_1}{P_1} \times 100$

$= \frac{5\times10^5 - 3\times10^5}{3\times10^5} \times 100 = \frac{200}{3}\%$

4. Official Ans. by NTA (4)

Sol. The nature of flow is determined by Reynolds Number.

$R_e = \frac{\rho v D}{\eta}$

[$\rho \rightarrow$ density of fluid ; $\eta \rightarrow$ coefficient of viscosity
$v \rightarrow$ velocity of flow
$D \rightarrow$ Diameter of pipe]

From NCERT

If $R_e < 1000$ $\rightarrow$ flow is steady

$1000 < R_e < 2000 \rightarrow$ flow becomes unsteady

$R_e > 2000 \rightarrow$ flow is turbulent

$$R_{e\,initial} = 10^3 \times \frac{0.18\times10^{-3}}{\pi\times(0.5\times10^{-2})^2\times60} \times \frac{1\times10^{-2}}{10^{-3}}$$

= 382.16

$$R_{e\,final} = 10^3 \times \frac{0.48\times10^{-3}}{\pi\times(0.5\times10^{-2})^2\times60} \times \frac{1\times10^{-2}}{10^{-3}}$$

= 1019.09

5. Official Ans. by NTA (1)

Sol. Excess pressure at common surface is given by

$P_{ex} = 4T\left(\frac{1}{a} - \frac{1}{b}\right) = \frac{4T}{r}$

$\therefore \frac{1}{r} = \frac{1}{a} - \frac{1}{b}$; $r = \frac{ab}{b-a}$

6. Official Ans. by NTA (25)

Sol. $4t_T = 100 \times \frac{4}{3}\pi r^3$

$= 100 \times \frac{4\pi}{3} \times \frac{3}{40\pi} \times 10^{-9} = 10^{-8}\ cm^3$

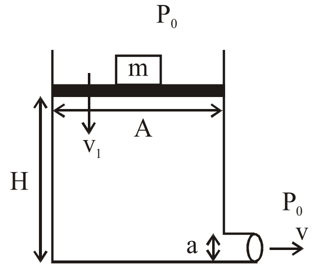
$t_T = 25 \times 10^{-10}$ cm

$= 25 \times 10^{-12}$ m

$t_0 = 0.01\ t_T = 25 \times 10^{-14}$ m = 25

7. Official Ans. by NTA (3)

Sol.



m = 24 kg

A = 0.4 m²

a = 1 cm²

H = 40cm

Using Bernoulli's equation

$$\Rightarrow \left(P_0 + \frac{mg}{A}\right) + \rho gH + \cancelto{0}{\frac{1}{2}\rho v_1^2}$$

$$= P_0 + 0 + \frac{1}{2}\rho v^2 \qquad \text{... (1)}$$

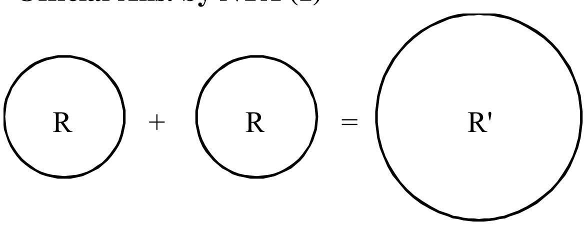
$\Rightarrow$ Neglecting v_1

$\Rightarrow v = \sqrt{2gH + \frac{2mg}{A\rho}} \qquad \Rightarrow v = \sqrt{8 + 1.2}$

$\Rightarrow v = 3.033$ m/s $\qquad \Rightarrow v \simeq 3\,m/s$

8. Official Ans. by NTA (1)

Sol.



$$\frac{4}{3}\pi R^3 + \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R'^3$$

$$R' = 2^{\frac{1}{3}}R \qquad \text{….(i)}$$

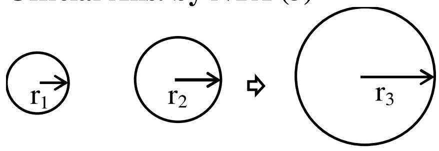
$$A_i = 2[4\pi R^2]$$

$$A_f = 4\pi R'^2$$

$$\frac{U_i}{U_f} = \frac{A_i}{A_f} = \frac{2R^2}{2^{2/3}R^2} = 2^{1/3}$$

9. Official Ans. by NTA (3)

Sol.



no. of moles is conserved

$n_1 + n_2 = n_3$

$P_1V_1 + P_2V_2 = P_3V$

$$\frac{4S}{r_1}\left(\frac{4}{3}\pi r_1^3\right) + \frac{4S}{r_2}\left(\frac{4}{3}\pi r_2^3\right) = \frac{4S}{r_3}\left(\frac{4}{3}\pi r_3^3\right)$$

$$r_1^2 + r_2^2 = r_3^2$$

$$r_3 = \sqrt{r_1^2 + r_2^2}$$

10. Official Ans. by NTA (3)

Sol. For no sliding

$f \geq \rho a v^2$

$\mu mg \geq \rho a v^2$

$\mu \rho Ahg \geq \rho a 2gh$

$$\boxed{\mu \geq \frac{2a}{A}}$$

Option (3)

11. Official Ans. by NTA (3)

Sol. At terminal speed

$a = 0$

$F_{net} = 0$

$mg = F_v = 6\pi\eta Rv$

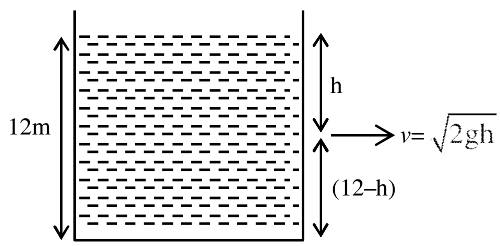
$$v = \frac{mg}{6\pi\eta Rv}$$

$$v = \frac{\rho_w \frac{4\pi}{3}R^3 g}{6\pi\eta R} = \frac{2\rho_w R^2 g}{9\eta}$$

$$= \frac{400}{81}\ \text{m/s} = 4.94\ \text{m/s}$$

12. Official Ans. by NTA (6)

Sol.



$$R = \sqrt{2gh} \times \sqrt{\frac{(12-h)\times 2}{g}}$$

$$\sqrt{4h(12-h)} = R$$

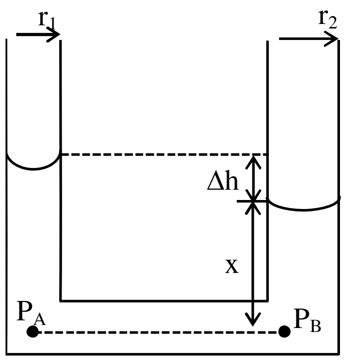
For maximum R

$$\frac{dR}{dh} = 0$$

$\Rightarrow h = 6m$

13. Official Ans. by NTA (2)

Sol.



We have $P_A = P_B$. [Points A & B at same horizontal level]

$$\therefore P_{atm} - \frac{2T}{r_1} + \rho g(x + \Delta h) = P_{atm} - \frac{2T}{r_2} + \rho g x$$

$$\therefore \rho g \Delta h = 2T\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

$$= 2 \times 7.3 \times 10^{-2}\left[\frac{1}{2.5 \times 10^{-3}} - \frac{1}{4 \times 10^{-3}}\right]$$

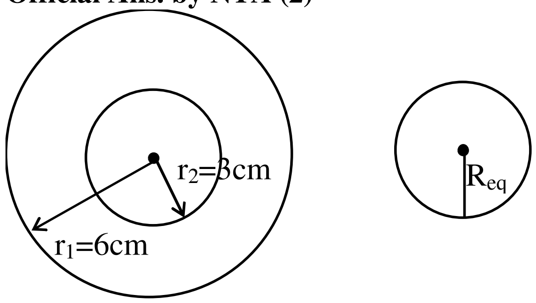
$$\therefore \Delta h = \frac{2 \times 7.3 \times 10^{-2} \times 10^{3}}{10^{3} \times 10}\left[\frac{1}{2.5} - \frac{1}{4}\right]$$

$= 2.19 \times 10^{-3}$m = 2.19 mm

Hence option (2)

14. Official Ans. by NTA (2)

Sol.



Excess pressure inside the smaller soap bubble

$$\Delta P = \frac{4S}{r_1} + \frac{4S}{r_2} \quad \text{…. (i)}$$

The excess pressure inside the equivalent soap bubble

$$\Delta P = \frac{4S}{R_{eq}} \quad \text{… (ii)}$$

From (i) & (ii)

$$\frac{4S}{R_{eq}} = \frac{4S}{r_1} + \frac{4S}{r_2}$$

$$\frac{1}{R_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} = \frac{1}{6} + \frac{1}{3}$$

$R_{eq} = 2$ cm

Ans. 2.00

15. Official Ans. by NTA (2)

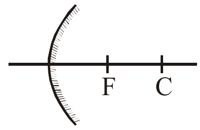
Sol. Viscous force = Weight

$$= \rho \times \left(\frac{4}{3}\pi r^3\right) g = 3.9 \times 10^{-10}$$

GEOMETRICAL OPTICS

1. Official Ans. by NTA (1)

Sol. For convex mirror, focus is behind the mirror.



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

2. Official Ans. by NTA (15)

Sol. $m = \frac{f}{u + f}$

$$+m = \frac{f}{-10 + f} \quad \text{... (1)}$$

$$-m = \frac{f}{-20 + f} \quad \text{... (2)}$$

(1) / (2)

$$-1 = \frac{f - 20}{f - 10}$$

$10 - f = f - 20$

$30 = 2f$

$f = 15$ cm

3. Official Ans. by NTA (4)

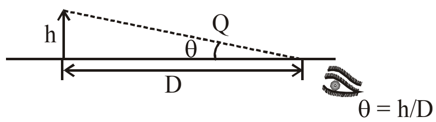
Sol. Since orientation is same image is virtual. Since image is smaller the mirror has to be convex

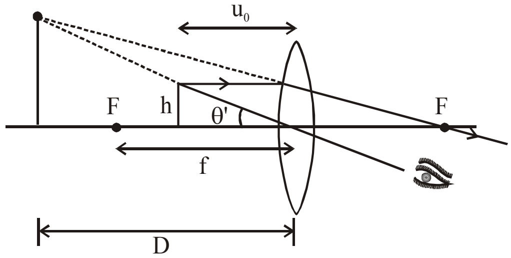
Ans. (4)

4. Official Ans. by NTA (3)

Allen Ans. (2)

Sol.





$\theta' = \frac{h}{u_0}$; θ' is same for both object and image

$$m = \frac{\theta'}{\theta} = \frac{D}{\mu_0}$$

$u_0 < D$

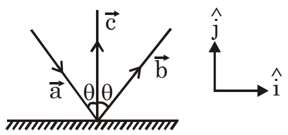
Hence m > 1

5. Official Ans. by NTA (3)

Sol. $\vec{a} = \sin\theta\hat{i} - \cos\theta\hat{j}$

$\vec{b} = \sin\theta\hat{i} + \cos\theta\hat{j}$

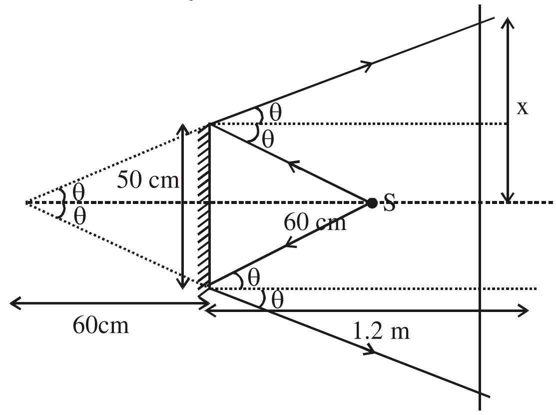
$\vec{c} = \hat{j}$



$\vec{a} - 2(\vec{a}.\vec{c})\vec{c} = \sin\theta\hat{i} + \cos\theta\hat{j}$

6. Official Ans. by NTA (150)

Sol.



$\tan\theta = \frac{25}{60} = \frac{x}{180}$

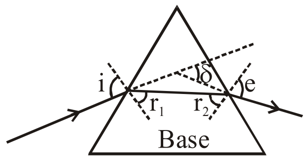
x = 75 cm

so distance between extreme point = 2x = 2 × 75 = 150 cm

7. Official Ans. by NTA (1)

Sol. Deviation is minimum in a prism when :

$i = e$, $r_1 = r_2$ and ray (2) is parallel to base of prism.



8. Official Ans. by NTA (2)

Sol. $\frac{1}{F} = \left[\frac{\mu_L}{\mu_S} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

If $\mu_L = \mu_S \Rightarrow \frac{1}{F} = 0 \Rightarrow F = \infty$

9. Official Ans. by NTA (1)

Sol. Red light and blue light have different wavelength and different frequency.

10. Official Ans. by NTA (12)

Sol. **Ans. (12)**

$\omega_1 = 0.02$; $\mu_1 = 1.5$; $\omega_2 = 0.03$; $\mu_2 = 1.6$

Achromatic combination

$\therefore \theta_{net} = 0$

$\theta_1 - \theta_2 = 0$

$\theta_1 = \theta_2$

$\omega_1\delta_1 = \omega_2\delta_2$

& $\delta_{net} = \delta_1 - \delta_2 = 2°$

$\delta_1 - \frac{\omega_1\delta_1}{\omega_2} = 2°$

$\delta_1\left(1 - \frac{\omega_1}{\omega_2}\right) = 2°$

$\delta_1\left(1 - \frac{2}{3}\right) = 2°$

$\delta_1 = 6°$

$\delta_1 = (\mu_1 - 1)\,A_1$

$6° = (1.5 - 1)\,A_1$

$A_1 = 12°$

11. Official Ans. by NTA (4)

Sol. $R^2 = r^2 + (R - t)^2$

$R^2 = r^2 + R^2 + t^2 - 2Rt$

Neglecting t^2, we get

$R = \frac{r^2}{2t}$

$\therefore \frac{1}{f} = (\mu - 1)\left(\frac{1}{R} - \frac{1}{\infty}\right) = \frac{\mu - 1}{R}$

$f = \frac{R}{\mu - 1} = \frac{r^2}{2t(\mu - 1)} = \frac{(3\times10^{-2})^2}{2\times3\times10^{-3}\times\left(\frac{3}{2} - 1\right)}$

$= \frac{9\times10^{-4}}{6\times10^{-3}\times1} \times 2$

f = 0.3 m = 30 cm

12. Official Ans. by NTA (64)

Sol. $V_e = \sqrt{\frac{2Gm}{R}}$ .... (1)

$10V_e = \sqrt{\frac{2Gm}{R'}}$ ... (2)

$\therefore 10 = \sqrt{\frac{R}{R'}}$

$\Rightarrow R' = \frac{R}{100} = \frac{6400}{100} = 64$ km

13. Official Ans. by NTA (30)

Sol. $\lambda_m = \frac{\lambda_a}{\mu} \Rightarrow \mu = \frac{3}{2}$

$\frac{\mu}{v} - \frac{1}{u} = \frac{\mu - 1}{R}$

$\frac{3}{2\times10} + \frac{1}{15} = \frac{\frac{3}{2} - 1}{R}$

$R = \frac{30}{13} = 30$

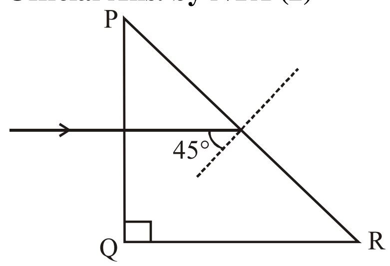
14. Official Ans. by NTA (2)

Sol. If distant objects are blurry then problem is Myopia.

If objects are distorted then problem is Astigmatism

15. Official Ans. by NTA (2)

Sol.



Assuming that the right angled prism is an isoceles prism, so the other angles will be 45° each.

⇒ Each incident ray will make an angle of 45° with the normal at face PR.

⇒ The wavelength corresponding to which the incidence angle is less than the critical angle, will pass through PR.

⇒ θ_C = critical angle

$$\Rightarrow \theta_C = \sin^{-1}\left(\frac{1}{\mu}\right)$$

⇒ If $\theta_C \geq 45°$

the light ray will pass

$$\Rightarrow (\theta_C)_{Red} = \sin^{-1}\left(\frac{1}{1.27}\right) = 51.94°$$

Red will pass.

$$\Rightarrow (\theta_C)_{Green} = \sin^{-1}\left(\frac{1}{1.42}\right) = 44.76°$$

Green will not pass

$$\Rightarrow (\theta_C)_{Blue} = \sin^{-1}\left(\frac{1}{1.49}\right) = 42.15°$$

Blue will not pass

⇒ So only red will pass through PR.

16. Official Ans. by NTA (4)

Sol. $$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{1.4}{v} - \frac{1.25}{-40} = \frac{1.4 - 1.25}{-25}$$

$$\frac{1.4}{v} = -\frac{0.15}{25} - \frac{1.25}{40}$$

$v = -37.58$ cm

Hence option (4)

17. Official Ans. by NTA (25)

Sol. For simple microscope,

$$m = 1 + \frac{D}{f_0}$$

$$6 = 1 + \frac{D}{f_0}$$

$$5 = \frac{25}{f_0}$$

$f_0 = 5$ cm

For compound microscope,

$$m = \frac{\ell \cdot D}{f_0 \cdot f_e}$$

$$12 = \frac{60 \times 25}{5 \cdot f_e}$$

$f_e = 25$ cm

18. Official Ans. by NTA (4)

Sol. $r + r' + 90° = 180° \Rightarrow r' = 90 - r = 90 - i$

$n_1 \sin i = n_2 \sin r' = n_2 \sin (90 - i)$

$n_1 \sin i = n_2 \cos i \Rightarrow \tan i = \dfrac{n_2}{n_1}$

Now $\sin C = \dfrac{n_2}{n_1} = \tan i$

$\Rightarrow C = \sin^{-1}(\tan i) = \sin^{-1}(\tan r)$

19. Official Ans. by NTA (60)

Sol. At minimum deviation $r_1 = r_2 = \dfrac{A}{2}$

Also given $i = 2r_1 = A$

Now $1.\sin i = \sqrt{3} \sin r_1$

$$1 \sin A = \sqrt{3} \sin \frac{A}{2}$$

$$\Rightarrow \quad 2\sin\frac{A}{2}\cos\frac{A}{2} = \sqrt{3}\sin\frac{A}{2}$$

$$\Rightarrow \quad \cos\frac{A}{2} = \frac{\sqrt{3}}{2} \Rightarrow \frac{A}{2} = 30°$$

$\Rightarrow \quad A = 60°$

20. Official Ans. by NTA (3)

Sol. $$\sin\theta_C = \frac{1}{\mu} = \frac{1}{2\mu_2} < \sin\theta_C$$

$\sin\theta > \sin\theta_C$

$\theta > \theta_C$

Total internal reflection will happen

21. Official Ans. by NTA (1)

Sol. $$\mu = \frac{\sin\left(\frac{A + \delta_{min}}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

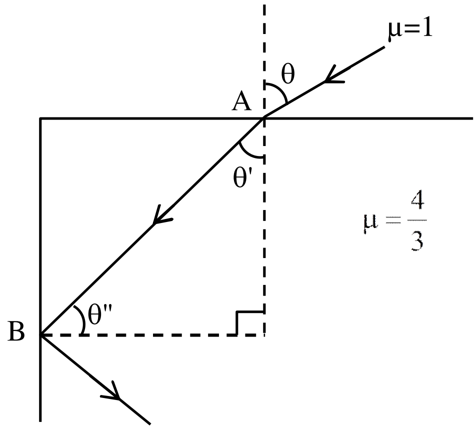
$$\mu = \frac{\sin\left(\frac{A + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$\mu = \frac{\sin A}{\sin\frac{A}{2}} = 2\cos\frac{A}{2}$$

$$A = 2\cos^{-1}\left(\frac{\mu}{2}\right)$$

22. Official Ans. by NTA (1)

Sol.



At maximum angle θ ray at point B goes in gazing emergence, at all less values of θ, TIR occurs.

At point B

$$\frac{4}{3}\times\sin\theta''=1\times\sin 90^\circ$$

$$\theta''=\sin^{-1}\left(\frac{3}{4}\right)$$

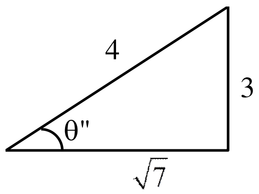
$$\theta'=\left(\frac{\pi}{2}-\theta''\right)$$

At point A

$$1\times\sin\theta=\frac{4}{3}\times\sin\theta'$$

$$\sin\theta=\frac{4}{3}\times\sin\left(\frac{\pi}{2}-\theta''\right)$$

$$\sin\theta=\frac{4}{3}\cos\left[\cos^{-1}\frac{\sqrt{7}}{4}\right]$$



$$\sin\theta=\frac{4}{3}\times\frac{\sqrt{7}}{4}$$

$$\theta=\sin^{-1}\left(\frac{\sqrt{7}}{3}\right)$$

23. Official Ans. by NTA (600)

Sol. For no bending, $n_1 = n_2$

$$1.2+\frac{10.8\times10^{-14}}{\lambda^2}=1.45+\frac{1.8\times10^{-4}}{\lambda^2}$$

On solving,

$9\times10^{-14}=25\,\lambda^2$

$\lambda = 6\times10^{-7}$

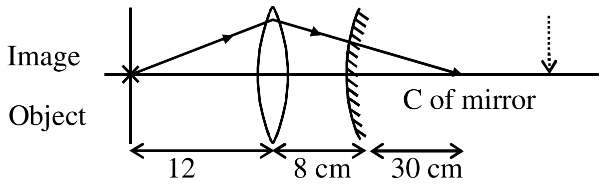
λ = 600 nm

24. Official Ans. by NTA (2)

Sol. Standard graph between angle of deviation and incident angle.

25. Official Ans. by NTA (50)

Sol.



For the object to coincide with image, the light must fall perpendicularly to mirror. Which means that the light will have to converge at C of mirror.

Without the mirror also, the light would coverage at C.

So the distance is : 12 + 8 + 30 = 50 cm

26. Official Ans. by NTA (1)

Sol. Using Newton"s formula

$(f+d_1)(f-d_2)=f^2$

$f^2 + fd_1 - fd_2 - d_1d_2 = f^2$

$f=\frac{d_1d_2}{d_1-d_2}\quad\therefore\ R=\frac{2d_1d_2}{d_1-d_2}$

27. Official Ans. by NTA (1)

Sol. $\frac{1}{V_1}+\frac{1}{30}=\frac{1}{10}$

$\frac{1}{V_1}=\frac{2}{30}\Rightarrow V_1 = 15$ cm

$\frac{1}{V_2}-\frac{1}{10}=-\frac{1}{10}$

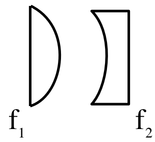
$\frac{1}{V_2}=0\ V_2=\infty$

V_3 = 30 cm

OV_3 = 75 cm

28. Official Ans. by NTA (2)

Sol.



$$\frac{1}{f_1}=(\mu_1-1)\left(\frac{1}{R}\right)$$

$$\frac{1}{f_2}=(\mu_2-1)\left(-\frac{1}{R}\right)$$

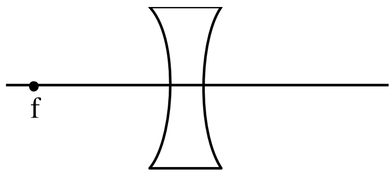
$$\frac{1}{f_1}+\frac{1}{f_2}=\frac{1}{f_{eq}}=\frac{(\mu_1-1)-(\mu_2-1)}{R}$$

$$\frac{1}{f_{eq}}=\frac{(\mu_1-\mu_2)}{R}$$

$$\frac{R}{f_{eq}}=(\mu_1-\mu_2)$$

29. Official Ans. by NTA (3)

Sol.



$U = -f$

$\frac{1}{V} - \frac{1}{U} = \frac{1}{-f} \Rightarrow \frac{1}{V} = -\frac{2}{f}$

$V = \frac{-f}{2}$

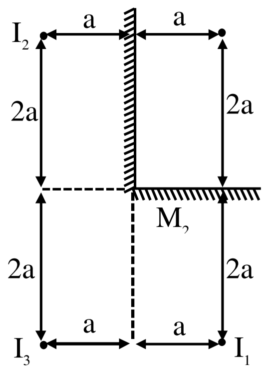
$m = \frac{V}{U} = \frac{1}{2}$

distance $= \frac{f}{2}$

Option (3)

30. Official Ans. by NTA (2)

Sol.



Shortest distance is 2a between I_1 & I_3

But answer given is for I_1 & I_2

$\sqrt{(4a)^2 + (2a)^2}$

$a\sqrt{20} \simeq 4.47$ a

Option (2)

31. Official Ans. by NTA (5)

Sol. $i = A = 60°$

$\delta_{min} = 2i - A$

$= 2 \times 60° - 60° = 60°$

$$\mu = \frac{\sin^{-1}\left(\frac{\delta_{min} + A}{2}\right)}{\sin^{-1}\left(\frac{A}{2}\right)} = \sqrt{3}$$

$V_{prism} = \frac{3 \times 10^8}{\sqrt{3}}$

$AP = 10 \times 10^{-2} \times \frac{\sqrt{3}}{2}$

$\text{time} = \frac{5 \times 10^{-2}}{3 \times 10^8} \times \sqrt{3} \times \sqrt{3}$

$= 5 \times 10^{-10}$ sec Ans = 5

32. Official Ans. by NTA (4)

Sol.

Mirror used is convex mirror (rear-view mirror)

$\therefore V_{I/m} = -m^2 V_{O/m}$

Given,

$V_{O/m} = 40 m/s$

$m = \frac{f}{f-u} = \frac{10}{10+190} = \frac{10}{200}$

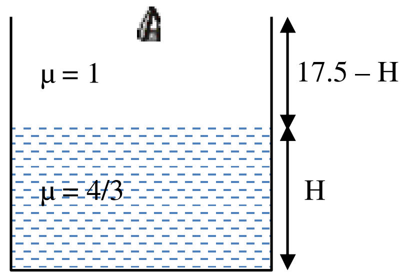
$\therefore V_{I/m} = -\frac{1}{400} \times 40 = -0.1 m/s$

$\therefore$ Car will appear to move with speed 0.1 m/s.

Hence option (4)

33. Official Ans. by NTA (2)

Sol.



Height of water observed by observer

$= \frac{H}{\mu_w} = \frac{H}{(4/3)} = \frac{3H}{4}$

Height of air observed by observer = 17.5 – H

According to question, both height observed by observer is same.

$\frac{3H}{4} = 17.5 - H$

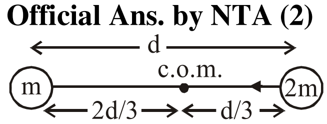
$\Rightarrow$ H = 10 cm

Option (2)

GRAVITATION

1. Official Ans. by NTA (2)

Sol.



$F = \frac{G(2m)m}{d^2} = (2m)\omega^2 (d/3)$

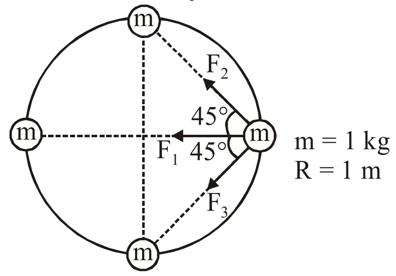
$\frac{Gm}{d^2} = \omega^2 \frac{d}{3}$

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

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

2. Official Ans. by NTA (4)

Sol.



$$F_1 = \frac{Gmm}{(2R)^2} = \frac{Gm^2}{4R^2}$$

$$F_2 = \frac{Gmm}{(\sqrt{2}R)^2} = \frac{Gm^2}{2R^2}$$

$$F_3 = \frac{Gmm}{(\sqrt{2}R)^2} = \frac{Gm^2}{2R^2}$$

$$\Rightarrow F_{net} = F_1 + F_2\cos 45° + F_3 \cos 45°$$

$$= \frac{Gm^2}{4R^2} + \frac{Gm^2}{2R^2}\frac{1}{\sqrt{2}} + \frac{Gm^2}{2R^2}\frac{1}{\sqrt{2}}$$

$$= \frac{Gm^2}{R^2}\left(\frac{1}{4} + \frac{1}{2\sqrt{2}} + \frac{1}{2\sqrt{2}}\right)$$

$$= \frac{Gm^2}{R^2}\left(\frac{1}{4} + \frac{1}{\sqrt{2}}\right) = \frac{Gm^2}{4R^2}\left(1+2\sqrt{2}\right)$$

$$F_{net} = \frac{Gm^2}{4R^2}\left(1+2\sqrt{2}\right) = \frac{mv^2}{R}$$

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

3. Official Ans. by NTA (1)

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

$$\frac{2\pi/\omega_1}{2\pi/\omega_2} = \frac{1}{8}$$

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

4. Official Ans. by NTA (2)

Sol. Weight of pole = mg = 49 N

At equator due to rotation = $g_e = g - R\omega^2$

so $W = mg_e = m(g - R\omega^2)$

$\therefore W_P > W_e$ $\qquad W_P = 49$ N

So, $W_e = 48.83$ N. $\qquad W_e < 49$ N

Option (2) is correct.

5. Official Ans. by NTA (1)

Sol. $T = 2\pi\sqrt{\frac{r^3}{GM}}$

$$T_A = 2\pi\sqrt{\frac{(6400+600)\times 10^3}{GM}}$$

$$T_A = 2\pi \times 10^9\sqrt{\frac{7^3}{GM}}$$

$$T_B = 2\pi \times 10^9\sqrt{\frac{8^3}{GM}}$$

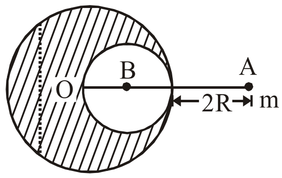
$$T_B - T_A = \frac{2\pi 10^9}{\sqrt{GM}}\left[8\sqrt{8} - 7\sqrt{7}\right]$$

$= 314 \times 4.107 = 1289.64 = 1.289 \times 10^3$ s

6. Official Ans. by NTA (3)

Sol. Let initial mass of sphere is m'. Hence mass of removed portion will be m'/8

$$F_1 = m.E. = \frac{m.Gm'}{9R^2}$$



$$F_2 = m\left[\frac{G.m'}{(3R)^2} - \frac{G.m'/8}{(5R/2)^2}\right]$$

$$= \frac{Gm'}{9R^2} - \frac{Gm'\times 4}{8\times 25} = \left(\frac{1}{9} - \frac{1}{50}\right)\frac{Gm'}{R^2}$$

$$F_2 = \frac{41}{50\times 9}.\frac{Gm'}{R^2}$$

$$\frac{F_1}{F_2} = \frac{1}{9}\times\frac{50\times 9}{41} = \frac{50}{41}$$

7. Official Ans. by NTA (2)

Sol. $V_e = \sqrt{\frac{2GM}{R}}$

$$\frac{M_1}{R_1} = \frac{M_2}{R_2}$$

$M_1R_2 = M_2R_1$

Hence reason R is not correct.

8. Official Ans. by NTA (10)

Sol. $\frac{-GMm}{11R} = \frac{-GMm}{R} + \frac{1}{2}mv^2$

$$v = \sqrt{\frac{20GM}{11R}}$$

9. Official Ans. by NTA (4)

Sol. Gravitational field of ring

$$= -\frac{Gmx}{\left(R^2 + x^2\right)^{3/2}}$$

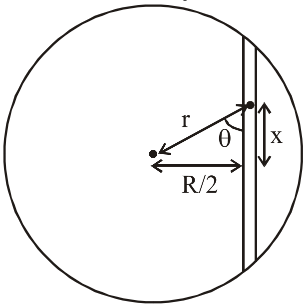
Force between sphere & ring

$$= \frac{GmM\left(\sqrt{8}R\right)}{\left(R^2 + 8R^2\right)^{3/2}} = \frac{GmM}{R^2}\times\frac{\sqrt{8}}{27}$$

Ans. (4)

10. Official Ans. by NTA (4)

Sol.



Force along the tunnel

$$F = -\left(\frac{GMmr}{R^3}\right)\cos\theta$$

$$F = -\frac{gm}{R}x \quad \left(\frac{GM}{R^2} = g, r\cos\theta = x\right)$$

$$a = -\frac{g}{R}x$$

$$\omega^2 = \frac{g}{R} \qquad T = 2\pi\sqrt{\frac{R}{g}}$$

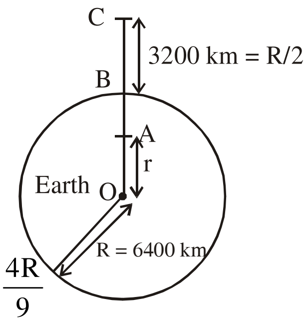
Ans. (4)

11. Official Ans. by NTA (4)

Sol. As per Keppler's 2nd law, Areal velocity is constant.

12. Official Ans. by NTA (4)

Sol.



$$g_A = \frac{GM(r)}{R^3}$$

$$g_C = \frac{GM}{\left(R + \frac{R}{2}\right)^2}$$

$g_A = g_C$

$$\frac{r}{R^3} = \frac{1}{\frac{9}{4}R^2} \Rightarrow r = \frac{4R}{9}$$

so $OA = \frac{4R}{9}$; $AB = R - r = \frac{5R}{9}$

OA : AB = 4 : 5

13. Official Ans. by NTA (3)

Sol. By angular momentum conservation :

$mv_1r_1 = mv_2r_2$

$$v_1 = \frac{48 \times 10^{14}}{1.6 \times 10^{12}} = 3000 \text{ m/sec}$$

$= 3 \times 10^3$ m/sec.

14. Official Ans. by NTA (3)

Sol. Ans. (3)

Energy given $= U_f - U_i$

$$= 0 - \left(-\frac{3}{5}\frac{GM^2}{R}\right)$$

$$= \frac{3}{5}\frac{GM^2}{R} \qquad x = 3$$

15. Official Ans. by NTA (3)

Sol. (3) $T \propto R^{3/2}$

$$\frac{24}{T} = \left(\frac{12R}{3R}\right)^{3/2} \Rightarrow T = 3\text{hr}$$

16. Official Ans. by NTA (2)

Sol. $T^2 \propto R^3$

$$\left(\frac{T'}{T}\right)^2 = \left(\frac{9R}{R}\right)^3$$

$T'^2 = T^2 \times 9^3$

$T' = T \times 3^3$

$T' = 27\,T$

17. Official Ans. by NTA (4)

Sol. For objects to float

$mg = m\omega^2R$

ω = angular velocity of earth.

R = Radius of earth

$$\omega = \sqrt{\frac{g}{R}} \qquad \text{... (1)}$$

Duration of day = T

$$T = \frac{2\pi}{\omega} \qquad \text{... (2)}$$

$$\Rightarrow T = 2\pi\sqrt{\frac{R}{g}}$$

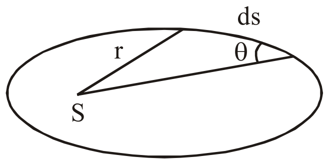
$$= 2\pi\sqrt{\frac{6400 \times 10^3}{10}}$$

$$\Rightarrow \frac{T}{60} = 83.775 \text{ minutes}$$

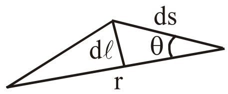
$\simeq$ 84 minutes

18. Official Ans. by NTA (4)

Sol.



For small displacement ds of the planet its area can be written as



$$dA = \frac{1}{2}r\,d\ell$$

$$= \frac{1}{2}r\,ds\sin\theta$$

$$A.vel = \frac{dA}{dt} = \frac{1}{2}r\sin\theta\frac{ds}{dt} = \frac{Vr\sin\theta}{2}$$

$$\frac{dA}{dt} = \frac{1}{2}\frac{mVr\sin\theta}{m} = \frac{L}{2m}$$

19. Official Ans. by NTA (1)

Sol. $U = -\frac{C}{r}$

$F = -\frac{dU}{dr} = -\frac{C}{r^2}$

$|F| = \frac{mv^2}{r}$

$\frac{C}{r^2} = \frac{mv^2}{r}$

$v^2 \propto \frac{1}{r}$

20. Official Ans. by NTA (1)

Sol. At neutral point g = 0 so graph (C) is correct Hence option (1).

21. Official Ans. by NTA (4)

Sol. $T^2 \propto R^3$

$T = kR^{3/2}$

$\frac{dT}{T} = \frac{3}{2}\frac{dR}{R} = \frac{3}{2} \times 0.02 = 0.03$

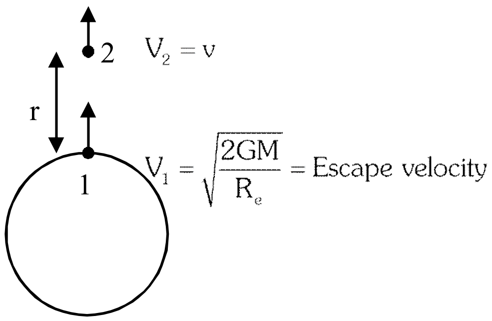
% Change = 3%

22. Official Ans. by NTA (2)

Sol. $T_A = T_B$ (since $\omega_A = \omega_B$)

23. Official Ans. by NTA (4)

Sol.



Applying energy conservation from (1) to (2)

$\frac{1}{2}m.\left(\frac{2GM}{R_e}\right) - \frac{GMm}{R_e} = \frac{1}{2}mv^2 - \frac{GMm}{R+r}$

$\Rightarrow \quad \frac{1}{2}mv^2 = \frac{GMm}{R+r}$

$\Rightarrow \quad v = \sqrt{\frac{2GM}{R+r}} = \frac{dr}{dt}$

$\Rightarrow \quad \sqrt{2GM}\int_0^t dt = \int_{R_e}^{R_e+h}\left(\sqrt{R+r}\right)dr$

$\sqrt{2GM}.\ t = \frac{2}{3}\left[(R+r)^{3/2}\right]_{R_e}^{R_e+h}$

$t = \frac{2}{3}\sqrt{\frac{R_e^3}{2GM}}\left[\left(1+\frac{h}{R_e}\right)^{3/2} - 1\right]$

$\frac{GM}{R_e^2} = g$

$t = \frac{1}{3}\sqrt{\frac{2R_e}{g}}\left[\left(1+\frac{h}{R_e}\right)^{3/2} - 1\right]$

24. Official Ans. by NTA (4)

Sol. Angular momentum conservation equation

$v_0x_2 = v_1x_1$

$v_1 = \frac{v_0x_2}{x_1}$

25. Official Ans. by NTA (3)

Sol. Density is same

$M = \frac{4}{3}\pi R^3\rho,\ 2m = \frac{4}{3}\pi R'^3\rho$

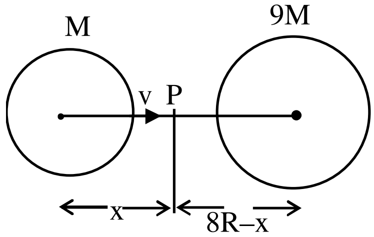
$R' = 2^{1/3}R$

$\omega = \frac{GMm}{R^2}$; $\omega_2 = \frac{G2Mm}{R'^2}$

$\omega_2 = 2^{1/3}\omega$

26. Official Ans. by NTA (4)

Sol.



Acceleration due to gravity will be zero at P therefore,

$\frac{GM}{x^2} = \frac{G9M}{(8R-x)^2}$

8R – x = 3x

x = 2R

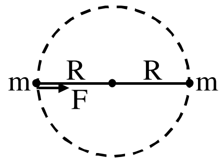
Apply conservation of energy and consider velocity at P is zero.

$\frac{1}{2}mv^2 - \frac{GMm}{R} - \frac{G9Mm}{7R} = 0 - \frac{GMm}{2R} - \frac{G9Mm}{6R}$

$\therefore\ V = \sqrt{\frac{4}{7}\frac{GM}{R}}$

27. Official Ans. by NTA (2)

Sol.



$F = \frac{Gm^2}{(2R)^2} = mR\omega^2$

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

28. Official Ans. by NTA (4)

Sol. Option D is correct

$$T^2 = \frac{4\pi^2}{GM} \cdot r^3$$

$$M = \frac{4\pi^2}{G} \cdot \frac{r^3}{T^2}$$

by putting values

$M = 6 \times 10^{23}$

29. Official Ans. by NTA (1)

Sol. Inside a spherical shell, gravitational field is zero and hence potential remains same everywhere

Hence option (1)

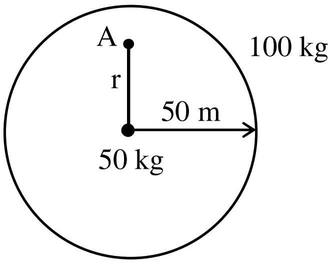
30. Official Ans. by NTA (2)

Sol. Energy is maximum when mass is split equally

so $\frac{M}{m} = 2$

31. Official Ans. by NTA (4)

Sol.



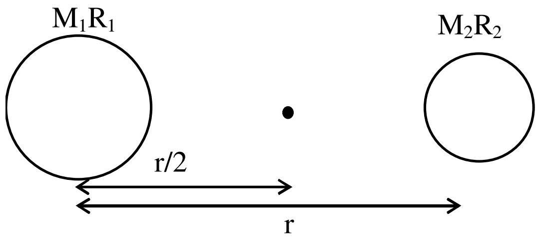
$$V_A = \left[-\frac{GM_1}{r} - \frac{GM_2}{R}\right]$$

$$= \left[-\frac{50}{25}G - \frac{100}{50}G\right]$$

$= -4G$

32. Official Ans. by NTA (2)

Sol.



$$\frac{1}{2}mV^2 - \frac{GM_1m}{r/2} - \frac{GM_2m}{r/2} = 0$$

$$\frac{1}{2}mV^2 = \frac{2Gm}{r}(M_1 + M_2)$$

$$V = \sqrt{\frac{4G(M_1 + M_2)}{r}}$$

Option (2)

33. Official Ans. by NTA (4)

Sol. $g_{up} = \frac{g}{\left(1 + \frac{r}{R}\right)^2}$

$$g_{down} = g\left(1 - \frac{r}{R}\right)$$

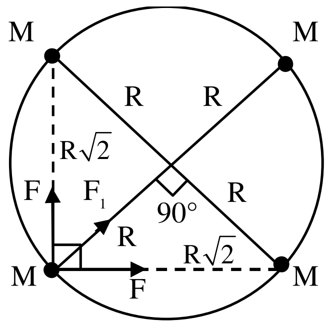
$$\frac{g_{down}}{g_{up}} = \left(1 - \frac{r}{R}\right)\left(1 + \frac{r}{R}\right)^2$$

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

$$= 1 + \frac{r}{R} - \frac{r^2}{R^2} - \frac{r^3}{R^3}$$

34. Official Ans. by NTA (2)

Sol.



$$F_{net} = \frac{MV^2}{R}$$

$$\sqrt{2}F + F_1 = \frac{MV^2}{R}$$

$$\sqrt{2}\frac{GMM}{(\sqrt{2}R)^2} + \frac{GMM}{(2R)^2} = \frac{MV^2}{R}$$

$$\frac{GM}{R}\left(\frac{1}{\sqrt{2}} + \frac{1}{4}\right) = V^2$$

$$\frac{GM}{R}\left(\frac{4 + \sqrt{2}}{4\sqrt{2}}\right) = V^2$$

$$V = \sqrt{\frac{GM(4 + \sqrt{2})}{R4\sqrt{2}}}$$

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

Option (2)

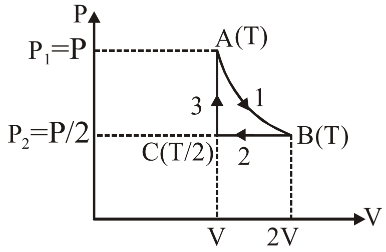
HEAT & THERMODYNAMICS

1. Official Ans. by NTA (4)

Sol. $W_{Isothermal} = nRT\ln\left(\frac{v_2}{v_1}\right)$

$W_{Isobaric} = P\Delta V = nR\Delta T$

$W_{Isochoric} = 0$



$W_1 = nRT\ln\left(\frac{2V}{V}\right) = nRT\ln 2$

$W_2 = nR\left(\frac{T}{2} - T\right) = -nR\frac{T}{2}$

$W_3 = 0 \Rightarrow W_{net} = W_1 + W_2 + W_3$

$W_{net} = nRT\left(\ln 2 - \frac{1}{2}\right)$

2. Official Ans. by NTA (2)

Sol. (a) Isothermal $\Rightarrow$ Temperature constant

(a) $\rightarrow$ (ii)

(b) Isochoric $\Rightarrow$ Volume constant

(a) $\rightarrow$ (iii)

(c) Adiabatic $\Rightarrow \Delta Q = 0$

$\Rightarrow$ Heat content is constant

(c) $\rightarrow$ (iv)

(d) Isobaric $\Rightarrow$ Pressure constant

(d) $\rightarrow$ (i)

3. Official Ans. by NTA (1)

Sol. $\Delta V = V\gamma\Delta T$

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

4. Official Ans. by NTA (4)

Sol. From the assumption of KTG, the molecules of gas collide with the walls and suffers momentum change which results in force on the wall and hence pressure.

Hence option (4) is correct

5. Official Ans. by NTA (1)

Sol. A – B = isothermal process

$W_{AB} = P_1V_1\ \ln\left[\frac{2V_1}{V_1}\right] = P_1V_1\ln(2)$

B – C $\rightarrow$ Isochoric process

$W_{BC} = 0$

C – A $\rightarrow$ Adiabatic process

$W_{CA} = \dfrac{P_1V_1 - \frac{P_1}{4}\times 2V_1}{1-\gamma} = \dfrac{P_1V_1\left[1-\frac{1}{2}\right]}{1-\gamma} = \dfrac{P_1V_1}{2(1-\gamma)}$

$W_{net} = W_{AB} + W_{BC} + W_{CA} \qquad \{P_1V_1 = RT\}$

$= P_1V_1\ln(2) + 0 + \dfrac{P_1V_1}{2(1-\gamma)}$

$W_{net} = RT\left[\ln(2) - \dfrac{1}{2(\gamma-1)}\right]$

Option (1) is correct.

6. Official Ans. by NTA (400)

Sol. $v_{rms} = \sqrt{\dfrac{3RT}{M}}$

$v_{rms} \propto \sqrt{T}$

$\dfrac{(v_{rms})_2}{(v_{rms})_1} = \sqrt{\dfrac{T_2}{T_1}}$

$= \sqrt{\dfrac{400}{300}} = \dfrac{2}{\sqrt{3}}$

$(v_{rms})_2 = \dfrac{2}{\sqrt{3}}(v_{rms})_1$

$= \dfrac{2}{\sqrt{3}}\times 200$

$(v_{rms})_2 = \dfrac{400}{\sqrt{3}}\ m/s$

$\boxed{\text{Ans. 400}}$

7. Official Ans. by NTA (1)

Sol. A and R are true but R is not the correct explanation of A.

8. Official Ans. by NTA (2)

Sol. $dU = nC_vdT$

$dQ = nC_pdT$

$dW = PdV = nRdT$ (isobaric process)

$dU : dQ : dW\ :\ C_v : C_p : R$

$= \dfrac{5R}{2} : \dfrac{7R}{2} : R = 5 : 7 : 2$

9. Official Ans. by NTA (50)

Sol. $P = kV^3$

$T_i = 100°C$ & $T_f = 300°C$

$\Delta T = 300 - 100$

$\Delta T = 200°C$

$P = kV^3$

now $PV = nRT$

$\therefore kV^4 = nRT$

now $4kV^3\ dV = nRdT$

$\therefore PdV = nRdT/4$

$\therefore$ Work $= \int PdV = \int\dfrac{nRdT}{4} = \dfrac{nR}{4}\Delta T$

$= \dfrac{200}{4}\times nR = 50nR$

10. Official Ans. by NTA (3600)

Sol. Given that mass of gas is 4u hence its molar mass M is 4g/mol

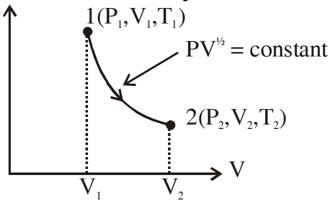
$\therefore \frac{1}{2}mv^2 = nC_v\Delta T$

$\frac{1}{2}m\times(30)^2 = \frac{m}{M}\times\frac{3R}{2}\times\Delta T$

$\therefore \Delta T = \frac{3600}{3R}$

11. Official Ans. by NTA (3)

Sol.



$PV^{½} = c$

$\frac{nRT}{V}V^{½} = c$

$T = c^1 V^{½}$

$\frac{T_2}{T_1} = \left(\frac{V_2}{V_1}\right)^{1/2} = \left(\frac{2V_1}{V_1}\right)^{1/2}$

$\frac{T_2}{T_1} = \sqrt{2}$

12. Official Ans. by NTA (4)

Sol. (4) Translational degree of freedom = 3
Rotational degree of freedom = 2

13. Official Ans. by NTA (208)

Sol. $\eta = \frac{1}{4} = 1 - \frac{T_2}{T_1}$

$\frac{T_2}{T_1} = \frac{3}{4}$; $\frac{T_2 - 52}{T_1} = \frac{1}{2}$

14. Official Ans. by NTA (26)

Sol. Let common equilibrium pressure of mixture is P atmp. then

$U_1 + U_2 = U_{mixutre}$

$\frac{f}{2}P_1V_1 + \frac{f}{2}P_2V_2 = \frac{f}{2}P(V_1 + V_2)$

$\frac{f}{2}(2)(4.5) + \frac{f}{2}(3)(5.5) = \frac{f}{2}P(4.5 + 5.5)$

$\Rightarrow P = 2.55 \;\; = x \times 10^{-1}$ atmp

So x = 25.5 ≈ 26 (Nearest integer)

15. Official Ans. by NTA (2)

Sol. $U = 3PV + 4$

$\frac{nf}{2}RT = 3PV + 4$

$\frac{f}{2}PV = 3PV + 4$

$f = 6 + \frac{8}{PV}$

Since degree of freedom is more than 6 therefore gas is polyatomic

16. Official Ans. by NTA (60)

Sol. We know that work done is

$W = \int PdV$ ... (1)

$\Rightarrow P = \frac{nRT}{V}$ ... (2)

$\Rightarrow W = \int \frac{nRT}{V}dv$ ... (3)

and $V = KT^{2/3}$ ... (4)

$\Rightarrow W = \int \frac{nRT}{KT^{2/3}}\cdot dv$ ... (5)

$\Rightarrow$ from (4) : $dv = \frac{2}{3}KT^{-1/3}dT$

$\Rightarrow W = \int_{T_1}^{T_2} \frac{nRT}{KT^{2/3}}\frac{2}{3}K\frac{1}{T^{1/3}}dT$

$\Rightarrow W = \frac{2}{3}nR\times(T_2 - T_1)$ ... (6)

$\Rightarrow T_2 - T_1 = 90$ K ... (7)

$\Rightarrow W = \frac{2}{3}nR\times 90 \Rightarrow W = 60\,nR$

Assuming 1 mole of gas

n = 1

So W = 60R

17. Official Ans. by NTA (25)

Sol. $Q = \Delta U + W$

$Q = \Delta U + \frac{Q}{5}$

$\Delta U = \frac{4Q}{5}$

$nC_v\Delta T = \frac{4}{5}nC\Delta T$

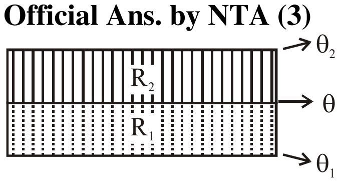
$\frac{5}{4}C_V = C$

$C = \frac{5}{4}\left(\frac{f}{2}\right)R = \frac{5}{4}\left(\frac{5}{2}\right)R$

$C = \frac{25}{8}R \quad x = 25$

18. Official Ans. by NTA (3)

Sol.



Heat flow rate will be same through both

$\therefore \frac{\theta_1 - \theta}{R_1} = \frac{\theta - \theta_2}{R_2}$

$R_2\theta_1 - R_2\theta = R_1\theta - R_1\theta_2$

$\theta = \frac{R_2\theta_1 + R_1\theta_2}{R_1 + R_2}$

Ans. (3)

19. Official Ans. by NTA (3)

Sol. $PV = (n_1 + n_2 + n_3)RT$

$$P \times V = \left[\frac{16}{32}+\frac{28}{28}+\frac{44}{44}\right]RT$$

$$PV = \left[\frac{1}{2}+1+1\right]RT$$

$$P = \frac{5}{2}\frac{RT}{V}$$

20. Official Ans. by NTA (1)

Sol. Heat and work are treated as path functions in thermodynamics.

$\Delta Q = \Delta U + \Delta W$

Since work done by gas depends on type of process i.e. path and ΔU depends just on initial and final states, so ΔQ i.e. heat, also has to depend on process is path.

21. Official Ans. by NTA (4)

Sol. $$\lambda = \frac{RT}{\sqrt{2}\pi d^2 N_A P}$$

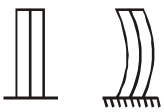
λ =102 nm

22. Official Ans. by NTA (4)

Sol. $\alpha_A > \alpha_B$

Length of both strips will decrease

$\Delta L_A > \Delta L_B$



23. Official Ans. by NTA (113)

Official Ans. by ALLEN (–113)

Sol. Ans. (–113)

$$n = 0.60 = 1 = \frac{T_L}{T_H}$$

$$\frac{T_L}{T_H} = 0.4 \Rightarrow T_L = 0.4 \times 400$$

$= 160\text{ K} = -113°C$

24. Official Ans. by NTA (1)

Sol. Since each vibrational mode has 2 degrees of freedom hence total vibrational degrees of freedom = 48

$f = 3 + 3 + 48 = 54$

$$\gamma = 1 + \frac{2}{f} = \frac{28}{27} = 1.03$$

25. Official Ans. by NTA (4)

Sol. $$\eta = \frac{T_2}{T_1} = \frac{Q_2}{Q_1} = \frac{Q_1 - W}{Q_1} \qquad (\because W = Q_1 - Q_2)$$

$$\frac{400}{800} = 1 - \frac{W}{Q_1}$$

$$\frac{W}{Q_1} = 1 - \frac{1}{2} = \frac{1}{2} \qquad Q_1 = 2W = 2400\text{ J}$$

26. Official Ans. by NTA (2)

Sol. Let the final temperature of the mixture be T. Since, there is no loss in energy.

$\Delta U = 0$

$$\Rightarrow \frac{F_1}{2} n_1R\,\Delta T + \frac{F_2}{2} n_2R\Delta T = 0$$

$$\Rightarrow \frac{F_1}{2} n_1R\,(T_1 - T) + \frac{F_2}{2} n_2R\,(T_2 - T) = 0$$

$$\Rightarrow T = \frac{F_1n_1RT_1 + F_2n_2RT_2}{F_1n_1R + F_2n_2R} \Rightarrow \frac{F_1n_1T_1 + F_2n_2T_2}{F_1n_1 + F_2n_2}$$

27. Official Ans. by NTA (2)

Sol. (2) $f = 4 + 3 + 3 = 10$

assuming non linear

$$\beta = \frac{C_p}{C_v} = 1 + \frac{2}{f} = \frac{12}{10} = 1.2$$

28. Official Ans. by NTA (2)

Sol. (2) Option (a) is wrong ; since in adiabatic process $V \neq$ constant.

Option (b) is wrong, since in isothermal process T = constant

Option (c) & (d) matches isothermes & adiabatic formula :

$$TV^{\gamma-1} = \text{constant} \;\&\; \frac{T^\gamma}{P^{\gamma-1}} = \text{constant}$$

29. Official Ans. by NTA (1)

Sol. Energy associated with each degree of freedom per molecule = $\frac{1}{2}k_BT$.

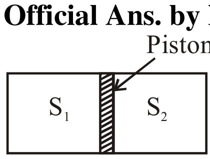
30. Official Ans. by NTA (1)

Sol. Adiabatic process is from C to D

$$WD = \frac{P_2V_2 - P_1V_1}{1-\gamma} = \frac{P_DV_D - P_CV_C}{1-\gamma}$$

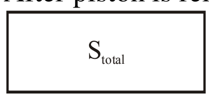
$$= \frac{200(3) - (100)(4)}{1 - 1.4} = -500\text{ J} \quad \text{Ans. (1)}$$

31. Official Ans. by NTA (4)

Sol. 

; $S_1 > S_2$

After piston is removed



; $S_{total} = S_1 + S_2$

32. Official Ans. by NTA (3)

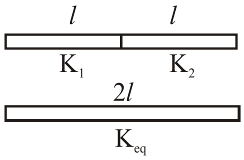
Sol. $$v_{rms} = \sqrt{\frac{3RT}{M}}$$

$$v_{avg} = \sqrt{\frac{8}{\pi}\frac{RT}{M}}$$

$$\frac{v_{rms}}{v_{avg}} = \sqrt{\frac{3\pi}{8}}$$

33. Official Ans. by NTA (1)

Sol.



$$R_{eff} = \frac{l}{K_1A} + \frac{l}{K_2A} = \frac{2l}{K_{eq}A}$$

$$K_{eq} = \frac{2K_1K_2}{K_1 + K_2}$$

34. Official Ans. by NTA (1)

Sol. PV^{γ} = constant

Differentiating

$$\frac{dP}{dV} = -\frac{\gamma P}{V};\ \frac{dP}{P} = -\frac{\gamma dV}{V}$$

35. Official Ans. by NTA (4)

Sol. $\Delta Q = \Delta U + \Delta W$

Here $\Delta W = 0$

$\Delta Q = \Delta U = nC_V\Delta T$

$$\Delta Q = 4 \times \frac{5R}{2}(50) = 500R$$

Hence option (4).

36. Official Ans. by NTA (4)

Sol. $V_{RMS} = \sqrt{\frac{3RT}{M}}$

$m_A < m_B < m_C$

$\Rightarrow V_A > V_B > V_C$

$$\Rightarrow \frac{1}{V_A} < \frac{1}{V_B} < \frac{1}{V_C}$$

37. Official Ans. by NTA (4)

Sol. $S = \alpha^2\beta\,\ell n\left(\frac{\mu KR}{J\beta^2} + 3\right)$

$$S = \frac{Q}{T} = \text{joulek / k}$$

$[\alpha^2\ \beta]$ = Joule/k

PV = nRT $\qquad \left[\frac{\mu KR}{J\beta^2}\right] = 1$

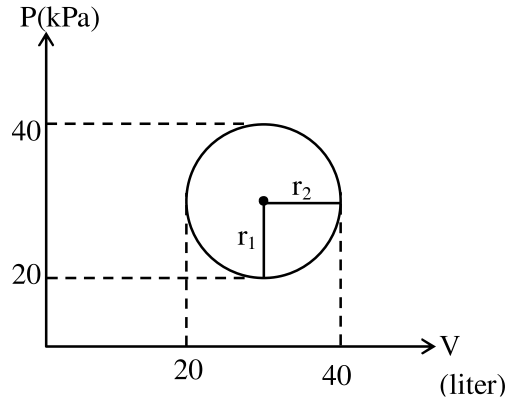
$$R = \frac{\text{Joule}}{K}$$

$$\Rightarrow R = \frac{\text{Joule}}{K}, K = \frac{\text{Joule}}{R} \quad \Rightarrow \beta = \left(\frac{\text{Joule}}{K}\right)$$

$$\alpha^2\beta = \left(\frac{\text{Joule}}{K}\right) \qquad \Rightarrow \alpha = \text{dimensionless}$$

38. Official Ans. by NTA (100)

Sol.



For complete cyclic process

$\Delta U = 0$

$\therefore$ from $\Delta Q = \Delta U + W$

$= 0 + W$

$\Delta Q = W$

= Area

$= \pi r_1 \cdot r_2$

$= \pi \times (10 \times 10^3) \times (10 \times 10^{-3})$

$\Delta Q = 100\ \pi$

$\therefore$ Ans. = 100

39. Official Ans. by NTA (3)

Sol. PV = nRT

$PV \propto T$

Straight line with positive slope (nR)

40. Official Ans. by NTA (1)

Sol. $\gamma = 1 + \frac{2}{f}$

$$f = \frac{2}{\gamma - 1}$$

41. Official Ans. by NTA (17258)

Sol. Process of isothermal

$$W = nRT\ell n\left(\frac{V_2}{V_1}\right)$$

$= 1 \times 8.3 \times 300 \times \ln 2$

$= 17258 \times 10^{-1}$ J

42. Official Ans. by NTA (3)

Sol. As per Equi-partition law :

Each degree of freedom contributes

$\frac{1}{2}k_BT$ Average Energy

In monoatomic gas D.O.F. = 3

$\Rightarrow$ Average energy = $3 \times \frac{1}{2}k_BT = \frac{3}{2}k_BT$

43. Official Ans. by NTA (57)

Sol. By newton's law of cooling (with approximation)

$$\frac{\Delta T}{\Delta t} = -C\left(T_{avg} - T_s\right)$$

$$1^{st}\ \frac{-10°C}{5\,min} = -C(70°C - 25°C)$$

$$\Rightarrow\quad C = \frac{2}{45}\,min^{-1}$$

$$2^{nd}\ \frac{T-65}{5\,min} = -C\left(\frac{T+65}{2} - 25\right) = -\left(\frac{2}{45}\right)\left(\frac{T+15}{2}\right)$$

$\Rightarrow$ 9 (T – 65) = – (T + 15)

$\Rightarrow$ 10T = 570

$\Rightarrow$ T = 57°C

Alternate Solution :

Newton's law of cooling (without approximation)

$$T_P - T_S = \left(T_i - T_S\right)e^{-Ct}$$

1^{st} $65 - 25 = (75 - 25)e^{-5C} \Rightarrow e^{-5C} = \frac{4}{5}$

2^{nd} $T - 25 = (65 - 25)e^{-5C} = 40 \times \frac{4}{5} = 32$

T = 57°C

44. Official Ans. by NTA (4)

Sol. $C_P - C_V = R$ for ideal gas and gas behaves as ideal gas at high temperature

so $T_P > T_Q$

45. Official Ans. by NTA (2)

Sol. PV^r = const.

TV^{r-1} = const.

$$T(\ell)^{\frac{5}{3}-1} = \text{const.}$$

$$\frac{T_1}{T_2} = \left(\frac{\ell_2}{\ell_1}\right)^{2/3}$$

46. Official Ans. by NTA (2)

Sol.
$$\left(\frac{\Delta Q}{\Delta t}\right)_A = \left(\frac{\Delta Q}{\Delta t}\right)_B$$

$$mS_A\left(\frac{\Delta T}{\Delta t}\right)_A = mS_B\left(\frac{\Delta T}{\Delta t}\right)_B$$

$$\frac{S_A}{S_B} = \frac{\left(\frac{\Delta T}{\Delta t}\right)_A}{\left(\frac{\Delta T}{\Delta t}\right)_B} = \frac{90/6}{120/3} = \frac{15}{40} = \frac{3}{8}$$

47. Official Ans. by NTA (4)

Sol.
$$\eta = 1 - \frac{T_L}{T_H} \ldots \text{(i)}$$

$$2\eta = 1 - \frac{\left(T_L - 62\right)}{T_H} = 1 - \frac{T_L}{T_H} + \frac{62}{T_H}$$

$$\Rightarrow \eta = \frac{62}{T_H} \Rightarrow \frac{1}{6} = \frac{62}{T_H} \Rightarrow T_H = 6 \times 62 = 372K$$

In °C $\Rightarrow$ 372 – 273 = 99°C

48. Official Ans. by NTA (25)

Sol. $\because$ mean free path

$$\lambda = \frac{1}{\sqrt{2}\pi d^2 n}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{d_2^2 n_2}{d_1^2 n_1}$$

$$= \left(\frac{5}{10}\right)^2 = 0.25 = 25 \times 10^{-2}$$

49 Official Ans. by NTA (3)

Sol. $KE = \frac{3}{2}kT$

$$PV = \frac{N}{N_A}RT$$

$$N = \frac{PV}{kT}$$

$= N = 1.5 \times 10^{11}$

50. Official Ans. by NTA (2)

Sol. Work done in adiabatic process = $\frac{-nR}{\gamma - 1}\left(T_f - T_i\right)$

$$\therefore\ W_{AD} = \frac{-nR}{\gamma - 1}\left(T_2 - T_1\right)$$

and $W_{BC} = \frac{-nR}{\gamma - 1}\left(T_2 - T_1\right)$

$\therefore\ W_{AD} = W_{BC}$

51. Official Ans. by NTA (4)

Sol. $\frac{\Delta T}{\Delta t} = K(T_t - T_S)$ $\quad T_t$ = average temp.

T_S = surrounding temp.

$$\frac{61-59}{4} = K\left(\frac{61+59}{2} - 30\right) \quad \text{....(1)}$$

$$\frac{51-49}{t} = K\left(\frac{51+49}{2} - 30\right) \quad \text{....(2)}$$

Divide (1) & (2)

$$\frac{t}{4} = \frac{60-30}{50-30} = \frac{30}{20}$$

so, t = 6 minutes

52. Official Ans. by NTA (2)

Sol. Since, each vibrational mode, corresponds to two degrees of freedom, hence, f = 3 (trans.) + 3(rot.) + 8 (vib.) = 14

& $\gamma = 1 + \frac{2}{f}$

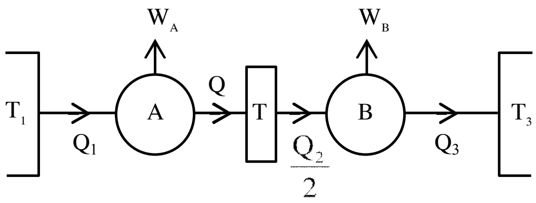
$$\gamma = 1 + \frac{2}{14} = \frac{8}{7}$$

$$W = \frac{nR\Delta T}{\gamma - 1} = -582$$

As W < 0. work is done on the gas.

53. Official Ans. by NTA (4)

Sol.



$W_A = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T}{T_1} \Rightarrow \frac{Q_2}{Q_1} = \frac{T}{T_1}$

$W_B = 1 - \frac{Q_3}{(Q_2/2)} = 1 - \frac{T_3}{T} \Rightarrow \frac{2Q_3}{Q_2} = \frac{T_3}{T}$

Now, $W_A = W_B$

$Q_1 - Q_2 = \frac{Q_2}{2} - Q_3$

$\Rightarrow \frac{2Q_1}{Q_2} + \frac{2Q_3}{Q_2} = 3$

$\Rightarrow \frac{2T_1}{T} + \frac{T_3}{T} = 3$

$\frac{2T_1}{3} + \frac{T_3}{3} = T$

54. Official Ans. by NTA (1)

Sol. $\Delta Q = \Delta U + \Delta W$

$\frac{\Delta Q}{\Delta t} = \frac{\Delta U}{\Delta t} + \frac{\Delta W}{\Delta t}$

$\frac{6000}{60}\frac{J}{sec} = \frac{2.5\times10^3}{\Delta t} + 90$

$\Delta t = 250$ sec

Option (1)

55. Official Ans. by NTA (1)

Sol. $V_{RMS} = \sqrt{\frac{3RT}{M_W}}$

At the same temperature $V_{RMS} \propto \frac{1}{\sqrt{M_w}}$

$\Rightarrow V_H > V_O > V_C$

Option (1)

56. Official Ans. by NTA (3)

Sol.

X	Y	Z
$m_1 = m$	$m_2 = m$	$m_3 = m$
$T_1 = 10°C$	$T_2 = 20°C$	$T_3 = 30°C$
s_1	s_2	s_3

when x & y are mixed, $T_{f_1} = 16°C$

$m_1s_1T + m_2s_2T_2 = (m_1s_1 + m_2s_2)Tf_1$

$s_1 \times 10 + s_2 \times 20 = (s_1 + s_2) \times 16$

$s_1 = \frac{2}{3}s_2$ ….(i)

when y & z are mixex, $T_{f_2} = 26°C$

$m_2s_2T + m_3s_3T_3 = (m_3s_3 + m_3s_3)Tf_2$

$s_2 \times 20 + s_3 \times 30 = (s_2 + s_3) \times 26$

$s_3 = \frac{3}{2}s_2$ .....(ii)

when x & z are mixex

$m_1s_1T_1 + m_3s_3T_3 = (m_1s_1 + m_3s_3)Tf$

$\frac{2}{3}s_2 \times 10 + \frac{2}{3}s_2 \times 20 = \left(\frac{2}{3}s_2 + \frac{3}{2}s_2\right)T_f$

$T_f = 23.84°C$

Ans (3)

57. Official Ans. by NTA (3)

Sol. $V = 4 \times 10^{-3}\ m^3$

n = 3 moles

T = 400K

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

$P = \frac{3\times8.3\times400}{4\times10^{-3}} = 24.9 \times 10^5$ Pa

Ans 3

58. Official Ans. by NTA (1)

Sol. $\frac{T_L}{T_H - T_L} = \text{C.O.P.} = \frac{\frac{dH}{dt}}{\frac{dW}{dt}}$

$\frac{263}{35} \times 35 = \frac{dH}{dt}$

$\frac{dH}{dt} = 263$ watts

Ans.1

59. Official Ans. by NTA (4)

Sol. $P_m = \rho RT$

$\therefore \frac{P_1}{P_2} = \frac{\rho_1 T_1}{\rho_2 T_2}$

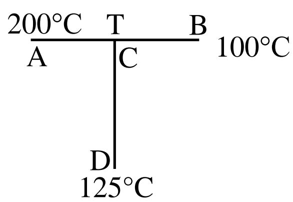
$\frac{\rho_1}{\rho_2} \Rightarrow \frac{P_1T_2}{P_2T_1} = \left(\frac{76}{45}\right)\times\frac{266}{300}$

$\frac{\rho_1}{\rho_2} \Rightarrow \frac{M_1}{M_2} = \frac{76\times266}{45\times300}$

$\therefore M_2 \Rightarrow \frac{45\times300\times185}{76\times266} = 123.54$ kg

60. Official Ans. by NTA (2)

Sol.



Rods are identical so

$R_{AB} = R_{CD} = 10\ Kw^{-1}$

C is mid-point of AB, so

$R_{AC} = R_{CB} = 5\ Kw^{-1}$
at point C

$$\frac{200-T}{5} = \frac{T-125}{10} + \frac{T-100}{5}$$

$2(200 - T) = T - 125 + 2(T - 100)$
$400 - 2T = T - 125 + 2T - 200$

$$T = \frac{725}{5} = 145°C$$

$$I_h = \frac{145-125}{10}w = \frac{20}{10}w$$

$$\boxed{I_h = 2w}$$

61. Official Ans. by NTA (1)

Sol. $V_{rms} = \sqrt{\frac{3KT}{M}}$

$$\frac{(V_{rms})_{O_2}}{(V_{rms})_{H_2}} = \sqrt{\frac{M_{H_2}}{M_{O_2}}} = \sqrt{\frac{2}{32}}$$

$$(V_{rms})_{H_2} = 4 \times (V_{rms})_{O_2}$$

$= 4 \times 160 = 640$ m/s

62. Official Ans. by NTA (1)

Sol. Change in P.E. = Heat energy
$mgh = mS\Delta T$

$$\Delta T = \frac{gh}{S}$$

$$= \frac{10 \times 63}{4200 J/kgC} = 0.147°C$$

63. Official Ans. by NTA (500)

Sol. $Q_{in} = 300$ J ; $Q_{out} = 240$ J
Work done $= Q_{in} - Q_{out} = 300 - 240 = 60$ J

Efficiency $= \frac{W}{Q_{in}} = \frac{60}{300} = \frac{1}{5}$

efficiency $= 1 - \frac{T_2}{T_1}$

$$\frac{1}{5} = 1 - \frac{400}{T_1} \Rightarrow \frac{400}{T_1} = \frac{4}{5}$$

$T_1 = 500$ k

64. Official Ans. by NTA (1)

Sol. T_2 = sink temperature

$$\eta = 1 - \frac{T_2}{T_1}$$

$$\frac{1}{4} = 1 - \frac{T_2}{T_1}$$

$$\frac{T_2}{T_1} = \frac{3}{4} \quad \ldots (i)$$

$$\frac{1}{2} = 1 - \frac{T_2 - 58}{T_1}$$

$$\frac{T_2}{T_1} - \frac{58}{T_1} = \frac{1}{2}$$

$$\frac{3}{4} = \frac{58}{T_1} + \frac{1}{2}$$

$$\frac{1}{4} = \frac{58}{T_1} \Rightarrow T_1 = 232$$

$$T_2 = \frac{3}{4} \times 232$$

$T_2 = 174$ K

65. Official Ans. by NTA (1)

Sol. $\int_{p_0}^{p} \frac{dp}{P} = -a\int_{0}^{v} dv$

$$\ell n\left(\frac{p}{p_0}\right) = -av$$

$$p = p_0 e^{-av}$$

For temperature maximum p-v product should be maximum

$$T = \frac{pv}{nR} = \frac{p_0 v e^{-av}}{R}$$

$$\frac{dT}{dv} = 0 \Rightarrow \frac{p_0}{R}\left\{e^{-av} + ve^{-av}(-a)\right\}$$

$$\frac{p_0 e^{-av}}{R}\{1 - av\} = 0$$

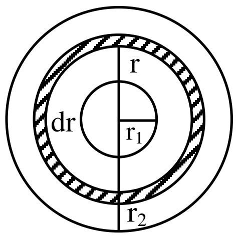
$$v = \frac{1}{a}, \infty$$

$$T = \frac{p_0 1}{Rae} = \frac{p_0}{Rae}$$

at $v = \infty$
$T = 0$
Option (1)

66. Official Ans. by NTA (1)

Sol.



Thermal resistance of spherical sheet of thickness dr and radius r is

$$dR = \frac{dr}{K(4\pi r^2)}$$

$$R = \int_{r_1}^{r_2} \frac{dr}{K(4\pi r^2)}$$

$R = \frac{1}{4\pi K}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = \frac{1}{4\pi K}\left(\frac{r_2 - r_1}{r_1 r_2}\right)$

Thermal current (i) = $\frac{\theta_2 - \theta_1}{R}$

$i = \frac{4\pi K r_1 r_2}{r_2 - r_1}(\theta_2 - \theta_1)$

67. Official Ans. by NTA (3)

Sol. PV = nRT

$400 \times 10^3 \times 500 \times 10^{-6} = n\left(\frac{25}{3}\right)(300)$

$n = \frac{2}{25}$

$n = n_1 + n_2$

$\frac{2}{25} = \frac{M_1}{2} + \frac{M_2}{32}$

Also $M_1 + M_2 = 0.76$ gm

$\frac{M_2}{M_1} = \frac{16}{3}$

68. Official Ans. by NTA (480)

Sol. $\nu = 1.5$

$p_1 v_1^{\nu} = p_2 v_2^{\nu}$

$(200)(1200)^{1.5} = P^2 (300)^{1.5}$

$P_2 = 200\,[4]^{3/2} = 1600$ kPa

$|W.D.| = \frac{p_2 v_2 - p_1 v_1}{\nu - 1} = \left(\frac{480 - 240}{0.5}\right) = 480$ J

69. Official Ans. by NTA (2)

Sol. mass of ice $m = \rho A \ell = 10^3 \times 10^{-4} \times 1 = 10^{-1}$ kg

Energy required to melt the ice

$Q = ms\Delta T + mL$

$= 10^{-1}(2 \times 10^3 \times 10 + 3.33 \times 10^5) = 3.53 \times 10^4$ J

$Q = i^2RT \Rightarrow 3.53 \times 10^4 = \left(\frac{1}{2}\right)^2 (4 \times 10^3)(t)$

Time = 35.3 sec

Option (2)

70. Official Ans. by NTA (3)

Sol. PT^3 = constant

$\left(\frac{nRT}{v}\right)T^3$ = constant

$T^4 V^{-1}$ = constant

$T^4 = kV$

$\Rightarrow 4\frac{\Delta T}{T} = \frac{\Delta V}{V}$ ....(1)

$\Delta V = V\gamma\Delta T$.............(2)

comparing (1) and (2)

we get

$\gamma = \frac{4}{T}$

71. Official Ans. by NTA (25)

Sol. Pressure is not changing $\Rightarrow$ isobaric process

$\Rightarrow \Delta U = nC_v\Delta T = \frac{5nR\Delta T}{2}$

and $W = nR\Delta T$

$\frac{\Delta U}{W} = \frac{5}{2} = \frac{x}{10} \Rightarrow x = 25.00$

72. Official Ans. by NTA (500)

Sol. Given

Translation K.E. of N_2 = K.E. of electron

$\frac{3}{2}kT = eV$

$\frac{3}{2} \times 1.38 \times 10^{-23}\,T = 1.6 \times 10^{-19} \times 0.1$

$\Rightarrow T = 773k$

$T = 773 - 273 = 500°C$

73. Official Ans. by NTA (8)

Sol. Thermal force $F = Ay\alpha\Delta T$

$F = (10 \times 10^{-4})(2 \times 10^{11})(10^{-5})(400)$

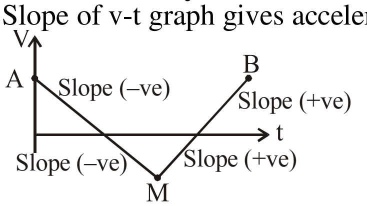
$F = 8 \times 10^5$ N

$\Rightarrow x = 8$

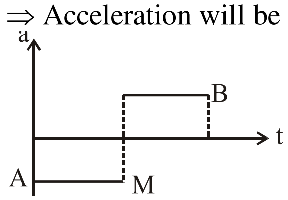
KINEMATICS

1. Official Ans. by NTA (2)

Sol. Slope of v-t graph gives acceleration



$\Rightarrow$ Acceleration will be



2. Official Ans. by NTA (4)

Sol. $F = -\alpha x^2$

$ma = -\alpha x^2$

$a = \frac{-\alpha x^2}{m}$

$\frac{vdv}{dx} = -\frac{\alpha}{m}x^2$

$\int_{v_0}^{0} v\,dv = \int_0^x -\frac{\alpha}{m}x^2 dx$

$\left(\frac{v^2}{2}\right)_{v_0}^{0} = -\frac{\alpha}{m}\left(\frac{x^3}{3}\right)_0^x$

$\frac{-v_0^2}{2} = -\frac{\alpha}{m}\frac{x^3}{3}$

$\boxed{x = \left(\frac{3mv_0^2}{2\alpha}\right)^{\frac{1}{3}}}$

Option(4) is most suitable option as (m) is not given in any option

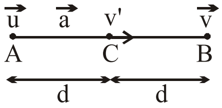
3. Official Ans. by NTA (1)

Sol. $(v')^2 = u^2 + 2ad$

$v^2 = (v')^2 + 2ad$

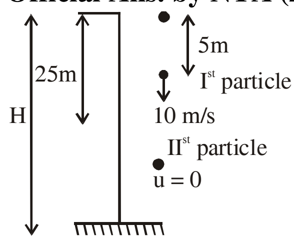
solving, we get

$v' = \sqrt{\frac{v^2 + u^2}{2}}$



4. Official Ans. by NTA (2)

Sol.



Time for particle to meet = $t' = \frac{S_{rel}}{S_{rel}} = \frac{20}{10} = 2$sec

Time taken by I[st] particle to reach ground = 3sec

$H = \frac{1}{2} g (3)^2 = 45$ m

5. Official Ans. by NTA (1)

Sol. $y = \alpha x - \beta x^2$

comparing with trajectory equation

$y = x \tan\theta - \frac{1}{2}\frac{gx^2}{u^2\cos^2\theta}$

$\tan\theta = \alpha \Rightarrow \theta = \tan^{-1}\alpha$

$\beta = \frac{1}{2}\frac{g}{u^2\cos^2\theta}$

$u^2 = \frac{g}{2\beta\cos^2\theta}$

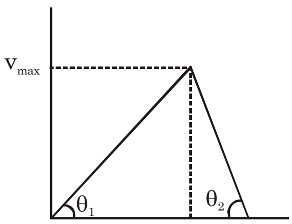
Maximum height : H

$H = \frac{u^2\sin^2\theta}{2g} = \frac{g}{2\beta\cos^2\theta}\frac{\sin^2\theta}{2g}$

$H = \frac{\tan^2\theta}{4\beta} = \frac{\alpha^2}{4\beta}$

6. Official Ans. by NTA (2)

Sol. Draw vt curve



$\tan\theta_1 = a_1 = \frac{v_{max}}{t_1}$

& $\tan\theta_2 = a_2 = \frac{v_{max}}{t_2}$

÷ above

$\frac{t_1}{t_2} = \frac{a_2}{a_1}$

7. Official Ans. by NTA (1)

Sol. For $0 \le x \le 200$

$v = mx + C$

$v = \frac{1}{5}x + 10$

$a = \frac{vdv}{dx} = \left(\frac{x}{5} + 10\right)\left(\frac{1}{5}\right)$

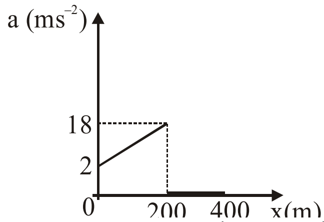
$a = \frac{x}{25} + 2 \Rightarrow$ Straight line till x = 200

for x > 200

v = constant

$\Rightarrow a = 0$

$\Rightarrow$



Hence most approriate option will be (1), otherwise it would be BONUS.

8. Official Ans. by NTA (2)

Official Ans. by ALLEN (Bonus)

Sol. Given :

$\vec{v} = 0.5t^2\hat{i} + 3t\hat{j} + 9\hat{k}$

$\vec{v}_{at\ t=2} = 2\hat{i} + 6\hat{j} + 9\hat{k}$

$\therefore$ Angle made by direction of motion of mosquito will be,

$\cos^{-1}\frac{2}{11}$ (from x-axis) $= \tan^{-1}\frac{\sqrt{117}}{2}$

$\cos^{-1}\frac{6}{11}$ (from y-axis) $= \tan^{-1}\frac{\sqrt{85}}{6}$

$\cos^{-1}\frac{9}{11}$ (from z-axis) $= \tan^{-1}\frac{\sqrt{40}}{9}$

None of the option is matching.

Hence this question should be bonus.

9. Official Ans. by NTA (120)

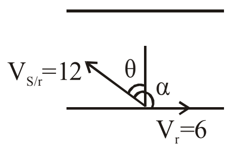
Sol. Ans. (12)

$12\sin\theta = v_r$

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

$\theta = 30°$

$\therefore\ \alpha = 120°$



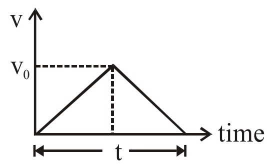
10. Official Ans. by NTA (3)

Sol. $v_0 = \alpha t_1$ and $0 = v_0 - \beta t_2 \Rightarrow v_0 = \beta t_2$

$t_1 + t_2 = t$

$v_0\left(\frac{1}{\alpha} + \frac{1}{\beta}\right) = t$

$\Rightarrow v_0 = \frac{\alpha\beta t}{\alpha + \beta}$



Distance = area of v-t graph

$= \frac{1}{2} \times t \times v_0 = \frac{1}{2} \times t \times \frac{\alpha\beta t}{\alpha + \beta} = \frac{\alpha\beta t^2}{2(\alpha + \beta)}$

11. Official Ans. by NTA (2)

Sol. (2) $v = v_0 + gt + Ft^2$

$$\frac{ds}{dt} = v_0 + gt + Ft^2$$

$$\int ds = \int_0^1 (v_0 + gt + Ft^2)dt$$

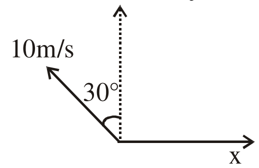
$$s = \left[v_0 t + \frac{gt^2}{2} + \frac{Ft^3}{3}\right]_0^1 ; \quad s = v_0 + \frac{g}{2} + \frac{F}{3}$$

12. Official Ans. by NTA (2)

Sol. Option (2) represent correct graph for particle moving with constant acceleration, as for constant acceleration velocity time graph is straight line with positive slope and x-t graph should be an opening upward parabola.

13. Official Ans. by NTA (5)

Sol.



$10 \sin 30° = x$

$x = 5$ m/s

14. Official Ans. by NTA (3)

Sol. $v = -\left(\frac{v_0}{x_0}\right)x + v_0$

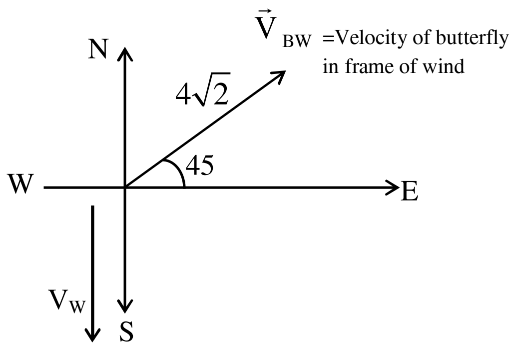
$$a = \frac{vdv}{dx}$$

$$a = \left[-\left(\frac{v_0}{x_0}\right)x + v_0\right]\left[-\frac{v_0}{x_0}\right]$$

$$a = \left(\frac{v_0}{x_0}\right)^2 x - \frac{v_0^2}{x_0}$$

15. Official Ans. by NTA (4)

Sol.



$$\vec{V}_{BW} = 4\sqrt{2}\cos 45\hat{i} + 4\sqrt{2}\sin 45\hat{j}$$

$$= 4\hat{i} + 4\hat{j}$$

$$\vec{V}_W = -\hat{j}$$

$$\vec{V}_B = \vec{V}_{BW} + \vec{V}_W = 4\hat{i} + 3\hat{j}$$

$$\vec{S}_B = \vec{V}_B \times t = \left(4\hat{i} + 3\hat{j}\right)\times 3 = 12\hat{i} + 9\hat{j}$$

$$\left|\vec{S}_B\right| = \sqrt{(12)^2 + (9)^2} = 15\text{m}$$

16. Official Ans. by NTA (3)

Sol. L = Length of escalator

$$V_{b/esc} = \frac{L}{t_1}$$

When only escalator is moving.

$$V_{esc} = \frac{L}{t_2}$$

when both are moving

$$V_{b/g} = V_{b/esc} + V_{esc}$$

$$V_{b/g} = \frac{L}{t_1} + \frac{L}{t_2} \Rightarrow \left[t = \frac{L}{V_{b/g}} = \frac{t_1 t_2}{t_1 + t_2}\right]$$

17. Official Ans. by NTA (3)

Sol. In 4 sec. 1st drop will travel

$$\Rightarrow \frac{1}{2}\times(9.8)\times(4)^2 = 78.4 \text{ m}$$

$\therefore$ 2nd drop would have travelled

$\Rightarrow 78.4 - 34.3 = 44.1$ m.

Time for 2nd drop

$$\frac{1}{2}(9.8)t^2 = 44.1$$

$$\boxed{t = 3\text{sec}}$$

$\therefore$ each drop have time gap of 1 sec

$\therefore$ 1 drop per sec

18. Official Ans. by NTA (1)

Sol. $t = mx^2 + nx$

$$\frac{1}{v} = \frac{dt}{dx} = 2mx + n ; \quad v = \frac{1}{2mx + n}$$

$$\frac{dv}{dt} = -\frac{2m}{(2mx+n)^2}\left(\frac{dx}{dt}\right)$$

$$a = -(2m)v^3$$

19. Official Ans. by NTA (3)

Sol. $\frac{d\vec{v}}{dt} = \vec{a} = \frac{\vec{F}}{m} = \left(8\hat{i} + 2\hat{j}\right)\text{m/s}^2$

$$\frac{d\vec{r}}{dt} = \vec{v} = \left(8t\,\hat{i} + 2t\,\hat{j}\right)\text{m/s}$$

$$\vec{r} = \left(8\hat{i} + 2\hat{j}\right)\frac{t^2}{2}\text{m}$$

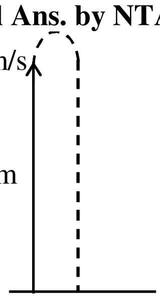
At t = 10 sec

$$\vec{r} = \left[\left(8\hat{i} + 2\hat{j}\right)50\right]\text{m}$$

$$\Rightarrow \vec{r} = \left(400\hat{i} + 100\hat{j}\right)\text{m}$$

20. Official Ans. by NTA (3)

Sol.



Object is projected as shown so as per motion under gravity

$$S = ut + \frac{1}{2}at^2$$

$$-75 = +10t + \frac{1}{2}(-10)t^2 \Rightarrow t = 5 \text{ sec}$$

Object takes t = 5 s to fall on ground
Height of balloon from ground
H = 75 + ut
= 75 + 10 × 5 = 125 m

21. Official Ans. by NTA (2)

Sol. $V = \alpha t + \beta t^2$

$$\frac{ds}{dt} = \alpha t + \beta t^2$$

$$\int_{S_1}^{S_2} ds = \int_1^2 (\alpha t + \beta t^2) dt$$

$$S_2 - S_1 = \left[\frac{\alpha t^2}{2} + \frac{\beta t^3}{3}\right]_1^2$$

As particle is not changing direction
So distance = displacement.

$$\text{Distance} = \left[\frac{\alpha[4-1]}{2} + \frac{\beta[8-1]}{3}\right]$$

$$= \frac{3\alpha}{2} + \frac{7\beta}{3}$$

22. Official Ans. by NTA (3)

Sol. $u = \sqrt{2gh}$

Now,

$$S = \frac{h}{3} \qquad a = -g$$

$$S = ut + \frac{1}{2}at^2$$

$$\frac{h}{3} = \sqrt{2gh}\,t + \frac{1}{2}(-g)t^2$$

$$t^2\left(\frac{g}{2}\right) - \sqrt{2gh}\;t + \frac{h}{3} = 0$$

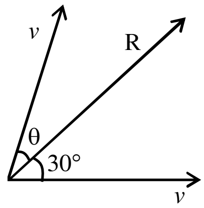
From quadratic equation

$$t_1, t_2 = \frac{\sqrt{2gh} \pm \sqrt{2gh - \frac{4g}{2}\frac{h}{3}}}{g}$$

$$\frac{t_1}{t_2} = \frac{\sqrt{2gh} - \sqrt{\frac{4gh}{3}}}{\sqrt{2gh} + \sqrt{\frac{4gh}{3}}} = \frac{\sqrt{3}-\sqrt{2}}{\sqrt{3}+\sqrt{2}}$$

23. Official Ans. by NTA (30)

Sol.

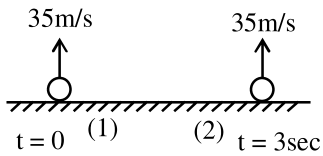


Both velocity vectors are of same magnitude therefore resultant would pass exactly midway through them

θ = 30°

24. Official Ans. by NTA (50)

Sol.



When both balls will collied

$y_1 = y_2$

$$35t - \frac{1}{2}\times 10\times t^2 = 35(t-3) - \frac{1}{2}\times 10\times (t-3)^2$$

$$35t - \frac{1}{2}\times 10\times t^2 = 35t - 105 - \frac{1}{2}\times 10\times t^2$$

$$-\frac{1}{2}\times 10\times 3^2 + \frac{1}{2}\times 10\times 6t$$

0 = 150 – 30 t
t = 5 sec
∴ Height at which both balls will collied

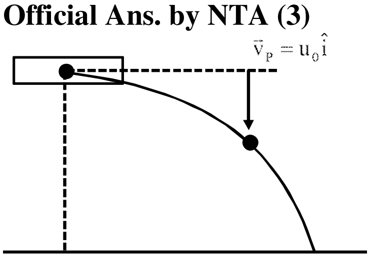
$$h = 35t - \frac{1}{2}\times 10\times t^2$$

$$= 35\times 5 - \frac{1}{2}\times 10\times 5^2$$

h = 50 m
Ans. 50.00

25. Official Ans. by NTA (3)

Sol.



$v_B = u_0\hat{i} - gt\hat{j}$

$\vec{v}_{B/P} = \vec{v}_B - \vec{v}_P$

$\vec{v}_{B/P} = -8t\hat{j}$

straight line vertically down
Ans.3

26. Official Ans. by NTA (12)

Sol. $V = \sqrt{5000 + 24x}$

$$\frac{dV}{dx} = \frac{1}{2\sqrt{5000+24x}} \times 24 = \frac{12}{\sqrt{5000+24x}}$$

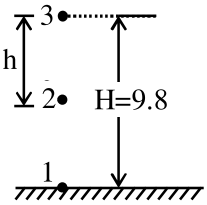
now $a = V\frac{dV}{dx}$

$$= \sqrt{5000+24x} \times \frac{12}{\sqrt{5000+24x}}$$

$\boxed{a = 12 m/s^2}$

27. Official Ans. by NTA (4)

Sol.



$$H = \frac{1}{2}gt^2$$

$$\frac{9.8 \times 2}{9.8} = t^2$$

$t = \sqrt{2}$ sec

Δt: time interval between drops

$$h = \frac{1}{2}g(\sqrt{2} - \Delta t)^2$$

$$0 = \frac{1}{2}g(\sqrt{2} - 2\Delta t)^2$$

$$\Delta t = \frac{1}{\sqrt{2}}$$

$$h = \frac{1}{2}g\left(\sqrt{2} - \frac{1}{\sqrt{2}}\right)^2 = \frac{1}{2} \times 9.8 \times \frac{1}{2} = \frac{9.8}{4} = 2.45m$$

$H - h = 9.8 - 2.45$

$= 7.35$ m

28. Official Ans. by NTA (3)

Sol. $H = \frac{U^2 \sin^2\theta}{2g}$

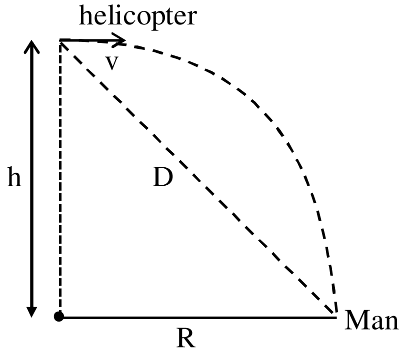
$$= \frac{(25)^2.(\sin 45)^2}{2 \times 10} = 15.625 \text{ m}$$

$$T = \frac{U\sin\theta}{g} = \frac{25 \times \sin 45°}{10}$$

$= 2.5 \times 0.7 \quad = 1.77$ s

29. Official Ans. by NTA (3)

Sol.



$$R = \sqrt{\frac{2h}{g}} \cdot v$$

$$D = \sqrt{R^2 + h^2}$$

$$= \sqrt{\left(\sqrt{\frac{2h}{g}} \cdot v\right)^2 + h^2}$$

$$D = \sqrt{\frac{2hv^2}{g} + h^2}$$

Option (3) is correct

30. Official Ans. by NTA (1)

Sol. $y = mx + C$

$$v^2 = \frac{20}{10}x + 20$$

$v^2 = 2x + 20$

$$2v\frac{dv}{dx} = 2$$

$$\therefore\ a = v\frac{dv}{dx} = 1$$

31. Official Ans. by NTA (2)

Sol. Range $R = \frac{u^2 \sin 2\theta}{g}$ and same for θ and $90 - \theta$

So same for 42° and 48°

Maximum height $H = \frac{u^2 \sin^2\theta}{2g}$

H is high for higher θ

So H for 48° is higher than H for 42°

Option (2)

MAGNETISM

1. Official Ans. by NTA (4)

Sol. Soft ferromagnetic materials are materials which can be easily magnetised and demagnetised by external magnetic field. When external field is applied, the domains experiences a net torque hence change its orientation.

Hence option (4) is correct

2. Official Ans. by NTA (2)

Sol. $F = q(\vec{v}\times\vec{B}) = \frac{q}{m}(\vec{P}\times\vec{B}) \Rightarrow F \propto \frac{q}{m}$

thus $F_1 : F_2 : F_3 = \frac{q_1}{m_1} : \frac{q_2}{m_2} : \frac{q_3}{m_3}$

$= \frac{e}{m_p} : \frac{e}{2m_p} : \frac{2e}{4m_p}$

$= \frac{1}{1} : \frac{1}{2} : \frac{2}{4} = 2 : 1 : 1$

Now for speed calculation

$P = \text{constant} \Rightarrow v \propto \frac{1}{m}$

thus $v_1 : v_2 : v_3 = \frac{1}{m_p} : \frac{1}{2m_p} : \frac{1}{4m_p}$

$= \frac{1}{1} : \frac{1}{2} : \frac{1}{4} = 4 : 2 : 1$

3. Official Ans. by NTA (2)

Sol. We know, the magnetic field on the axis of a current carrying circular ring is given by

$B = \frac{\mu_0}{4\pi}\frac{2NIA}{(R^2+x^2)^{3/2}}$

$\therefore \frac{B_1}{B_2} = \frac{8}{1} = \left[\frac{R^2+(0.2)^2}{R^2+(0.05)^2}\right]^{3/2}$

$4[R^2 + (0.05)^2] = [R^2 + (0.2)^2]$

$4R^2 - R^2 = (0.2)^2 - 4 \times (0.05)^2$

$4R^2 - R^2 = (0.2)^2 - (0.1)^2$

$3R^2 = 0.3 \times 0.1$

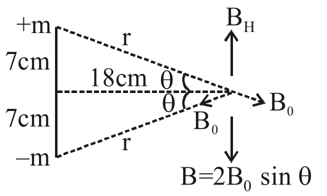
$R^2 = (0.1)^2 \Rightarrow R = 0.1$

4. Official Ans. by NTA (4)

Sol. (4) conceptual

5. Official Ans. by NTA (3)

Sol.



i.e. $\frac{2\mu_0}{4\pi}\frac{m}{r^2}\times\frac{7}{r} = 0.4 \times 10^{-4}$

$\Rightarrow 2 \times 10^{-7} \times \frac{m\times 7}{(7^2+18^2)^{3/2}} \times 10^4 = 0.4 \times 10^{-4}$

$m = \frac{4\times10^{-2}\times(373)^{3/2}}{14}$

$M = m \times 14\text{ cm} = m \times \frac{14}{100}$

$= \frac{0.04\times(373)^{3/2}}{14} \times \frac{14}{100}$

$= 4 \times 10^{-4} \times 7203.82 = 2.88$ J/T

6. Official Ans. by NTA (3)

Sol. Since force on a point charge by magnetic field is always perpendicular to $\vec{v}\left[\vec{F} = q\vec{V}\times\vec{B}\right]$

$\therefore$ Work by magnetic force on the point charge is zero.

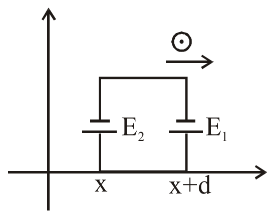
7. Official Ans. by NTA (3)

Sol. $E_1 = \frac{B_0(x+d)}{a}v_0 d$

$E_2 = \frac{B_0(x)}{a}v_0 d$

$E_{net} = E_1 - E_2$

$E_{net} = \frac{B_0 v_0 d^2}{a}$



8. Official Ans. by NTA (2)

Sol. (2) $B = 2 \times B_{st.wire} + B_{loop}$

$B = 2 \times \frac{\mu_0 i}{4\pi r} + \frac{\mu_0 i}{2r}\left(\frac{\pi}{2\pi}\right)$

$B = \frac{\mu_0 i}{4\pi r}(2+\pi)$

9. Official Ans. by NTA (1)

Sol. Every part ($d\ell$) of the wire is pulled by force $i(d\ell)B$ acting perpendicular to current & magnetic field giving it a shape of circle.

10. Official Ans. by NTA (1)

Sol. Statement (C) is correct because, the magnetic field outside the toroid is zero and they form closed loops inside the toroid itself.

Statement (E) is correct because we know that super conductors are materials inside which the net magnetic field is always zero and they are perfect diamagnetic.

$\mu_r = 1 + \chi$

$\chi = -1$

$\mu_r = 0$

For superconductors.

11. Official Ans. by NTA (2)

Sol. $r = \frac{mv}{qB} = \frac{\sqrt{2mk}}{qB}$

$\frac{r_d}{r_\alpha} = \sqrt{\frac{m_d}{m_\alpha}\frac{q_\alpha}{q_d}} = \sqrt{\frac{2}{4}\left(\frac{2}{1}\right)} = \sqrt{2}$

Hence option (2).

12. Official Ans. by NTA (4)

Sol. $A \tan\delta = \tan\delta' \cos\theta$

$= \tan 45° \cos 30°$

$\tan\delta = 1 \times \frac{\sqrt{3}}{2}$

$\delta = \tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$

13. Official Ans. by NTA (2)

Sol. $\mu = \mu_0(1 + x_m)$

$= 4\pi \times 10^{-7} \times 500$

$= 2\pi \times 10^{-4}$ H/m

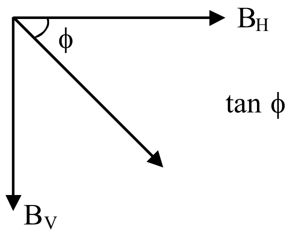
14. Official Ans. by NTA (1)

Sol. As temperature increases, domains disintegrate so ferromagnetism decreases and above curie temperature it become paramagnet.

15. Official Ans. by NTA (2)

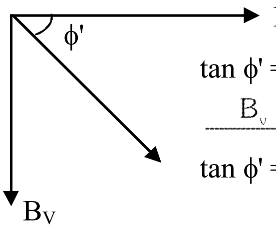
Sol. If apparent dip circle is at an angle α with true dip circle then

True dip circle



$\tan\phi = \frac{B_v}{B_H}$

Apparent dip circle



$\tan\phi' = \frac{B_v}{\text{-----}}$

$\tan\phi' = \frac{\tan\phi}{\cos\alpha}$

As $\cos\alpha < 1$

Hence true dip (ϕ) is less than apparent dip (ϕ')

16. Official Ans. by NTA (22)

Sol. $B = \mu.(H+I)$

$B = \mu.H\left(1+\frac{I}{H}\right)$

$B = B_0(1+x)$

$B - B_0 = B_0x$

$\frac{B-B_0}{B_0} = x$

$\frac{B-B_0}{B_0} \times 100 = 100x = 2.2 \times 10^{-3} = \frac{22}{10^4}$

17. Official Ans. by NTA (2)

Sol. $R = \frac{mv}{qB} \Rightarrow \frac{R_1}{R_2} = \frac{\frac{mv_1}{q_1B}}{\frac{mv_2}{q_2B}}$

$= \frac{v_1}{q_1} \times \frac{q_2}{v_2} = \frac{q_2}{q_1} \times \frac{v_1}{v_2} = \frac{2}{1} \times \left(\frac{2}{3}\right) = \frac{4}{3}$

18. Official Ans. by NTA (3)

Sol. $V = \frac{c}{\sqrt{\mu_r \varepsilon_r}}$

$= 3.33 \times 10^7$ m/sec

19. Official Ans. by NTA (8)

Sol. $T = 2\pi\sqrt{\frac{I}{MB}}$

$B = 80 \times 10^{-4} = 8$mT

20. Official Ans. by NTA (1)

Sol. $q = CV$

$[C] = \left[\frac{q}{V}\right] = \frac{(A \times T)^2}{ML^2T^{-2}}$

$= M^{-1}L^{-2}T^4A^2$

$[E] = \left[\frac{F}{q}\right] = \frac{MLT^{-2}}{AT}$

$= MLT^{-3}A^{-1}$

$F = \frac{q_1q_2}{4\pi \in_o r^2}$

$[\in_o] = M^{-1}L^{-3}T^4A^2$

Speed of light $c = \frac{1}{\sqrt{\mu_o \in_o}}$

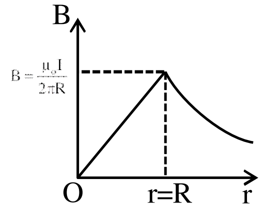
$\mu_o = \frac{1}{\in_o c^2}$

$[\mu_o] = \frac{1}{[M^{-1}L^{-3}T^4A^2][LT^{-1}]^2}$

$= [M^1L^1T^{-2}A^{-2}]$

21. Official Ans. by NTA (3)

Sol. Graph for wire of radius R :



As $b > a$

$B_a > B_b$

$B_a = \frac{\mu_0 i}{2\pi a}$; $B_b = \frac{\mu_0 i}{2\pi b}$

22. Official Ans. by NTA (4)

Sol. $B_{axis} = \frac{\mu_0 iR^2}{2\left(R^2+x^2\right)^{3/2}}$; $B_{centre} = \frac{\mu_0 i}{2R}$

$\therefore B_{centre} = \frac{\mu_0 i}{2a}$ $\therefore B_{axis} = \frac{\mu_0 ia^2}{2\left(a^2+r^2\right)^{3/2}}$

$\therefore$ fractional change in magnetic field

$$=\frac{\frac{\mu_0 i}{2a}-\frac{\mu_0 i a^2}{2\left(a^2+r^2\right)^{3/2}}}{\frac{\mu_0 i}{2a}}=1-\frac{1}{\left[1+\left(\frac{r^2}{a^2}\right)\right]^{3/2}}$$

$$\approx 1-\left[1-\frac{3}{2}\frac{r^2}{a^2}\right]=\frac{3}{2}\frac{r^2}{a^2}$$

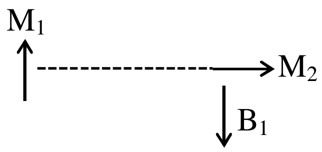
Note : $\left(1+\frac{r^2}{a^2}\right)^{-3/2}\approx\left(1-\frac{3}{2}\frac{r^2}{a^2}\right)$

[True only if $r << a$]

Hence option (4) is the most suitable option

23. Official Ans. by NTA (1)

Sol.



$\vec{\tau}=\vec{M}_2\times\vec{B}_1$

$\tau=M_2B_1\sin 90°$

$=1\times\frac{\mu_0}{4\pi}\frac{M_1}{(1)^3}1$ = 10^{-7} N.m

Ans. 1.00

24. Official Ans. by NTA (543)

Sol. V = 12 kV

Number of revolution = n

$n\left[2\times q_P\times V\right]=\frac{1}{2}m_P\times v_P^2$

$n[2\times 1.6\times 10^{-19}\times 12\times 10^3$

$=\frac{1}{2}\times 1.67\times 10^{-27}\times\left[\frac{3\times 10^8}{6}\right]^2$

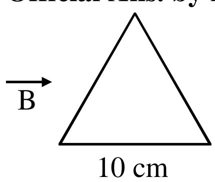
$n(38.4\times 10^{-16}) = 0.2087\times 10^{-11}$

n = 543.4

Ans. 543

25. Official Ans. by NTA (3)

Sol.



$\vec{\tau}=\vec{M}\times\vec{B}$ = MBsin90°

$=MB=\frac{i\sqrt{3}\ell^2}{4}B$

$=\sqrt{3}\times 10^{-5}\,N-m$

Ans. 3

26. Official Ans. by NTA (2)

Sol. $r=\frac{P}{qB}=\frac{\sqrt{2mk}}{qB}$

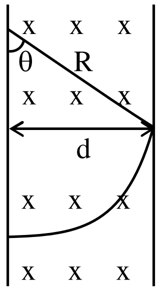
Given they have same kinetic energy

$r\propto\frac{\sqrt{m}}{q}$

$\frac{r_1}{r_2}=\frac{\sqrt{4}}{2}\times\frac{3}{\sqrt{16}}=\frac{3}{4}$

$\boxed{r_2=\frac{4r_1}{3}}$

(r_2 is for hearier ion and r_1 is for lighter ion)



$\sin\theta=\frac{d}{R}$

$\theta\rightarrow$ Deflection

$\theta\propto\frac{1}{R}$

($R\rightarrow$ Radius of path)

$\because R_2 > R_1 \Rightarrow \theta_2 < \theta_1$

27. Official Ans. by NTA (3)

Sol. In triangle shape $N_t=\frac{24a}{3a}=8$

In square $N_s=\frac{24a}{4a}=6$

$\frac{M_t}{M_3}=\frac{N_tIA_t}{N_sIA_s}$ [I will be same in both]

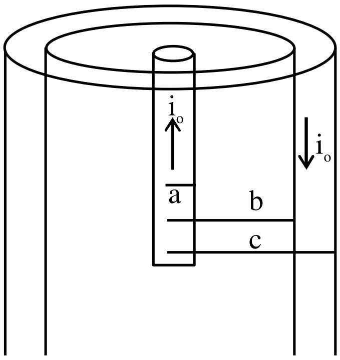
$=\frac{8\times\frac{\sqrt{3}}{4}\times a^2}{6\times a^2}$

$\frac{M_t}{M_s}=\frac{1}{\sqrt{3}}$

$\boxed{y=3}$

28. Official Ans. by NTA (1)

Sol.



when x < a

$$B_1\,(2\pi x) = \mu_o\left(\frac{i_o}{\pi a^2}\right)\pi x^2$$

$$B(2\pi x) = \frac{\mu_o i_o x^2}{a^2}$$

$$B_1 = \frac{\mu_o i_o x}{2\pi a^2} \qquad ...(1)$$

when a < x < b

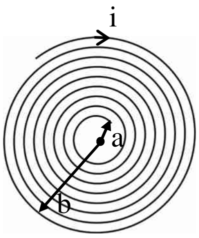
$$B_2(2\pi x) = \mu_o i_o$$

$$B_2 = \frac{\mu_o i_o}{2\pi x} \qquad ...(2)$$

$$\frac{B_1}{B_2} = \frac{\mu_o i_o \dfrac{x}{2\pi a^2}}{\dfrac{\mu_o i_o}{2\pi x}} = \frac{x^2}{a^2}$$

29. Official Ans. by NTA (1)

Sol.



No. of turns in dx width = $\frac{N}{b-a}dx$

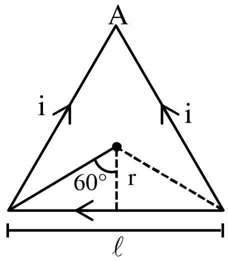
$$\int dB = \int_a^b \left(\frac{N}{b-a}\right)dx\,\frac{\mu_0 i}{2x}$$

$$B = \frac{N\mu_0 i}{2(b-a)}\ell n\left(\frac{b}{a}\right)$$

Option (1)

30. Official Ans. by NTA (4)

Sol.



$$B = 3\left[\frac{\mu_0 i}{4\pi r}(\sin 60° + \sin 60°)\right]$$

$$\tan 60° = \frac{\ell/2}{r}$$

Where r = $\frac{9\times10^{-2}}{2\sqrt{3}}$M

$\therefore$ B = 3×10^{-5} T

Current is flowing in clockwise direction so, $\vec{B}$ is inside plane of triangle by right hand rule.

31. Official Ans. by NTA (250)

Sol. $\frac{\Delta M}{M} = \frac{\Delta\mu}{\mu} = \frac{250}{500} = \frac{1}{2}$

$$\frac{1}{2} = \frac{x}{499} \Rightarrow x \simeq 250$$

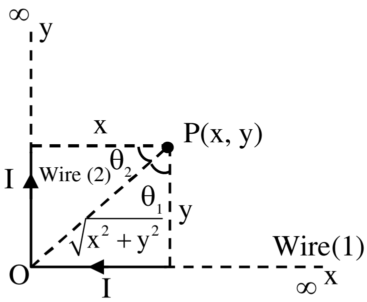
32. Official Ans. by NTA (1)

Sol. Conceptual question

Option (1)

33. Official Ans. by NTA (1)

Sol.



$$B_{\text{due to wire (1)}} = \frac{\mu_o I}{4\pi y}\left[\sin 90 + \sin\theta_1\right]$$

$$= \frac{\mu_0}{4\pi}\frac{I}{y}\left(1+\frac{x}{\sqrt{x^2+y^2}}\right) \quad ......(1)$$

$$B_{\text{due to wire (2)}} = \frac{\mu_0}{4\pi}\frac{I}{x}\left(\sin 90° + \sin\theta_2\right)$$

$$= \frac{\mu_0}{4\pi}\frac{I}{x}\left(1+\frac{y}{\sqrt{x^2+y^2}}\right) \quad .....(2)$$

Total magnetic field

$B = B_1 + B_2$

$$B=\frac{\mu_0 I}{4\pi}\left[\frac{1}{y}+\frac{x}{y\sqrt{x^2+y^2}}+\frac{1}{x}+\frac{y}{x\sqrt{x^2+y^2}}\right]$$

$$B=\frac{\mu_0 I}{4\pi}\left[\frac{x+y}{xy}+\frac{x^2+y^2}{xy\sqrt{x^2+y^2}}\right]$$

$$B=\frac{\mu_0 I}{4\pi}\left[\frac{x+y}{xy}+\frac{\sqrt{x^2+y^2}}{xy}\right]$$

$$B=\frac{\mu_0 I}{4\pi xy}\left[\sqrt{x^2+y^2}+(x+y)\right]$$

Option (1)

MODERN PHYSICS

1. Official Ans. by NTA (4)

Sol. If linear momentum are equal then wavelength also equal

$$p=\frac{h}{\lambda},\ E=\frac{hc}{\lambda}$$

On decreasing wavelength, momentum and energy of photon increases.

2. Official Ans. by NTA (3)

Sol. A $\rightarrow$ Series limit of Lymen series.

B $\rightarrow$ Third member of Balmer series.

C $\rightarrow$ Second member of Paschen series.

3. Official Ans. by NTA (2)

Sol. $\lambda=\dfrac{h}{mv}$

$\lambda_P = \lambda_\alpha$

$m_P v_P = m_\alpha v_\alpha$

$m_P v_P = 4m_p v_\alpha$ $\quad(m_\alpha = 4m_P)$

$\dfrac{v_P}{v_\alpha}=4$ $\quad$ (Option 2) is correct

4. Official Ans. by NTA (1)

Sol. $\lambda_{min}=\dfrac{1240}{\Delta V}(\text{nm})$

$$=\frac{1240}{1.24\times10^6}=10^{-3}\text{nm}$$

Option (1) is correct.

5. Official Ans. by NTA (2)

Sol. $\Delta E = 13.6\left[\dfrac{1}{n_1^2}-\dfrac{1}{n_2^2}\right]=h\nu$

It is maximum if $n_1 = 1$ and $n_2 = 2$

n = 5 .... –0.544 eV

n = 4 .... –0.850 eV

n = 3 .... –1.511 eV

n = 2 .... –3.4 eV

n = 1 .... –13.6 eV

Option (2) is correct.

6. Official Ans. by NTA (4)

Sol. $\lambda=\dfrac{h}{p}=\dfrac{h}{\sqrt{2mqV}}$

$$\frac{\lambda_p}{\lambda_\alpha}=\sqrt{\frac{m_\alpha q_\alpha}{m_p q_p}}=\sqrt{\frac{4m_p\times2e}{m_p\times e}}=\sqrt{8}=2\sqrt{2}$$

$= 2\sqrt{2}$

$\dfrac{\lambda_p}{\lambda_\alpha}=2\times1.4=2.8$

7. Official Ans. by NTA (3)

Sol. $T_x = t$; $T_y = 2t$

$3T_y = 6t,$

$N_1' = N_2'$

$N_1e^{-\lambda_1 6t}=N_2e^{-\lambda_2 6t}$

$$\frac{N_1}{N_2}=e^{(\lambda_1-\lambda_2)6t}=e^{\ln 2\left(\frac{1}{t}-\frac{1}{2t}\right)\times6t}=e^{(\ln 2)\times3}=e^{\ln 8}=8$$

$\dfrac{N_1}{N_2}=\dfrac{8}{1}$

8. Official Ans. by NTA (4)

Sol. $\dfrac{1}{\lambda}=R\left(\dfrac{1}{1^2}-\dfrac{1}{2^2}\right)$

$\lambda = 121.8$ nm.

9. Official Ans. by NTA (1)

Sol. $$\frac{\lambda_e}{\lambda_p}=\frac{\frac{h}{m_e v}}{\frac{h}{m_p v}}=1836$$

10. Official Ans. by NTA (3)

Sol. $\dfrac{hc}{\lambda}=\phi+eV_s$

$\dfrac{1240}{491}=\phi+0.71.$ $\quad$ ...(1)

$\dfrac{1240}{\lambda}=\phi+1.43$ $\quad$ ...(2)

$\therefore\ \lambda = 382$ nm Ans.

11. Official Ans. by NTA (10)

Sol. $\dfrac{hc}{\lambda}=mc^2$

$m=\dfrac{h}{c\lambda}$

12. Official Ans. by NTA (3)

Sol. $\frac{1}{\lambda_1}=R\left[\frac{1}{1^2}-\frac{1}{4^2}\right]$

$\frac{1}{\lambda_2}=R\left[\frac{1}{3^2}-\frac{1}{4^2}\right]$

$\frac{\lambda_1}{\lambda_2}=\frac{\left[\frac{1}{9}-\frac{1}{16}\right]}{\left[1-\frac{1}{16}\right]}=\frac{7}{9\times15}$

$\frac{\lambda_1}{\lambda_2}=\frac{7}{135}$

Ans. (3)

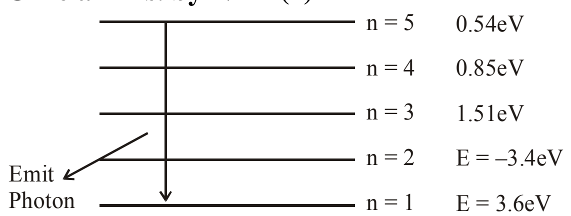
13. Official Ans. by NTA (2)

Sol. Resolving power $\propto \frac{1}{\lambda}$

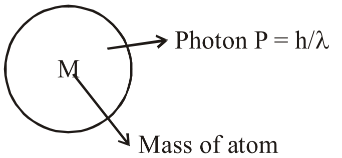
Since wavelength of electron is much less than visible light, its resolving power will be much more.

14. Official Ans. by NTA (1)

Sol.



(ΔE) Releases when photon going from n = 5 to n = ΔE = (13.6 – 0.54) eV = 13.06 eV.



$P_i = P_f$ (By linear momentum conservation)

$0=\frac{h}{\lambda}-Mv=V_{Recoil}=\frac{h}{\lambda M}$ …(i)

& $\Delta E=\frac{hc}{\lambda}=\frac{hc}{\lambda M}\times M \Rightarrow McV_{Recoil}$

$V_{Recoil}=\frac{\Delta E}{Mc}=\frac{13.06\times1.6\times10^{-19}}{1.67\times10^{-27}\times3\times10^{8}}=4.17\text{ m / sec}$

15. Official Ans. by NTA (3)

Sol. Let initial activity be A_0

$A = A_0 e^{-\lambda t_1}$ …(i)

$\frac{A}{5}=A_0e^{-\lambda t_2}$ …(ii)

(i) ÷ (ii)

$5 = e^{\lambda(t_2-t_1)}$

$\lambda=\frac{\ell n5}{t_2-t_1}=\frac{1}{\tau}$; $\tau=\frac{t_2-t_1}{\ell n5}$

16. Official Ans. by NTA (1)

Sol. $KE_{max} = h\nu - \phi$

$\frac{1}{2}mv^2 = h\nu-\phi$

$v=\sqrt{\frac{2(h\nu-\phi)}{m}}$

Given $h\nu_1 = 2\phi$

$h\nu_2 = 10\phi$

$\therefore \frac{v_1}{v_2}=\sqrt{\frac{h\nu_1-\phi}{h\nu_2-\phi}}$

$\frac{v_1}{v_2}=\sqrt{\frac{2\phi-\phi}{10\phi-\phi}}=\frac{1}{3}$

17. Official Ans. by NTA (4)

Sol. Stopping potential changes linearly with frequency of incident radiation.

18. Official Ans. by NTA (15)

Sol. For 1st line

$\frac{1}{\lambda_1}=Rz^2\left(\frac{1}{2^2}-\frac{1}{3^2}\right)$

$\frac{1}{\lambda_1}=Rz^2\frac{5}{36}$ .....(i)

For 3rd line

$\frac{1}{\lambda_3}=Rz^2\left(\frac{1}{2^2}-\frac{1}{5^2}\right)$

$\frac{1}{\lambda_3}=Rz^2\frac{21}{100}$ .....(ii)

(ii) + (i)

$\frac{\lambda_1}{\lambda_3}=\frac{21}{100}\times\frac{36}{5}=1.512=15.12\times10^{-1}$

$x \approx 15$

19. Official Ans. by NTA (4)

Sol. $\lambda=\frac{h}{mv}=\frac{h}{\sqrt{2mK}}=\frac{h}{\sqrt{2mqV}}$

$\frac{\lambda_1}{\lambda_2}=\sqrt{\frac{m_2}{m_1}}$

$\frac{\lambda_e}{\lambda_P}=\sqrt{\frac{m_P}{m_e}}=\sqrt{1831.4}=42.79$

20. Official Ans. by NTA (2)

Sol. $A = \lambda N$

$N = nN_A$ $\left(t_{1/2}=\frac{\ln 2}{\lambda}\right)$

$N=\left(\frac{1.5\times10^{-3}}{198}\right)N_A$

$A=\left(\frac{\ln 2}{t_{1/2}}\right)N$

1 Curie = 3.7×10^{10} Bq

A = 365 Bq

21. Official Ans. by NTA (2)

Sol. $N_1 = N_0 e^{-\lambda t_1}$

$\frac{N_1}{N_0} = e^{-\lambda t_1}$

$0.67 = e^{-\lambda t_1}$

$\ln(0.67) = -\lambda t_1$

$N_2 = N_0 e^{-\lambda t_2}$

$\frac{N_2}{N_0} = e^{-\lambda t_2}$

$0.33 = e^{-\lambda t_2}$

$\ln(0.33) = -\lambda t_2$

$\ln(0.67) - \ln(0.33) = \lambda t_1 - \lambda t_2$

$\lambda(t_1 - t_2) = \ln\left(\frac{0.67}{0.33}\right)$

$\lambda(t_1 - t_2) \cong \ln 2$

$t_1 - t_2 \simeq \frac{\ln 2}{\lambda} = t_{1/2}$

Half life = $t_{1/2}$ = 20 minutes.

22. Official Ans. by NTA (2)

Sol. We know velocity of electron in n^{th} shell of hydrogen atom is given by

$v = \frac{2\pi kZe^2}{nh} \therefore v \propto \frac{1}{n}$

23. Official Ans. by NTA (2)

Sol. $\lambda_1 = \frac{h}{\sqrt{2mE}}$; $\lambda_2 = \frac{hc}{E}$; $\frac{\lambda_1}{\lambda_2} = \frac{1}{c}\left(\frac{E}{2m}\right)^{1/2}$

24. Official Ans. by NTA (2)

Sol. Energy of H-atom is $E = -13.6\ Z^2/n^2$

for H-atom Z = 1 & for ground state, n = 1

$\Rightarrow E = -13.6 \times \frac{1^2}{1^2} = -13.6$ eV

Now for carbon atom (single ionised), Z = 6

$E = -13.6\ \frac{Z^2}{n^2} = -13.6$ (given)

$\Rightarrow n^2 = 6^2 \Rightarrow n = 6$

25. Official Ans. by NTA (25)

Sol. $F = \frac{IA}{C}$

$I = \frac{FC}{A} = \frac{2.5\times10^{-6}\times3\times10^{8}}{30} = 25\ \text{W/cm}^2$

26. Official Ans. by NTA (4)

Sol. (4) Conceptual

27. Official Ans. by NTA (1)

Sol. (1) $\frac{1}{2}mv_1^2 = hf_1 - \phi$

$\frac{1}{2}mv_2^2 = hf_2 - \phi$

$v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$

28. Official Ans. by NTA (3)

Sol. $F = \frac{-dU}{dr} = -4U_0 r^3 = \frac{mv^2}{r}$

$mv^2 = 4U_0 r^4$

$v \propto r^2$

$mvr = \frac{nh}{2\pi}$

$r^3 \propto n$

$r \propto n1/3 = 3$

29. Official Ans. by NTA (2)

Sol. $E \propto \frac{1}{r}$ $\qquad r \propto \frac{1}{m}$

$E \propto m$

Ionization potential = $13.6 \times \frac{(\text{Mass}_\mu)\text{eV}}{(\text{Mass}_e)}$

$= 13.6 \times 207$ eV = 2815.2 eV

30. Official Ans. by NTA (4)

Sol. $\lambda = \frac{h}{p}$

$\frac{\lambda_p}{\lambda_e} = \frac{p_e}{p_p} = \frac{m_e v_e}{m_p v_p}$

$2 = \frac{m_e}{m_p}\left(\frac{v_e}{4v_e}\right)$

$\therefore m_p = \frac{m_e}{8}$ Ans. (4)

31. Official Ans. by NTA (4)

Sol. $r = \frac{mv}{qB} = \frac{p}{qB}$ $\qquad \frac{m_\alpha}{m_p} = 4$

$\frac{r_p}{r_\alpha} = \frac{p_p}{q_p}\frac{q_\alpha}{p_\alpha} = \frac{2}{1}$

$\frac{p_p}{p_\alpha} = \frac{2q_p}{q_\alpha} = 2\left(\frac{1}{2}\right)$

$\frac{p_p}{p_\alpha} = 1$

$\frac{K_p}{K_\alpha} = \frac{p_p^2}{p_\alpha^p}\frac{m_\alpha}{m_p} = (1)(4)$

32. Official Ans. by NTA (2)

Sol. It is possible only inside the nucleus and not otherwise.

33. Official Ans. by NTA (1)

Sol. Resolving power (RP) $\propto \frac{1}{\lambda}$

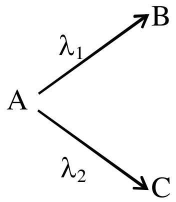
$\lambda = \frac{h}{P} = \frac{h}{mv}$

So (RP) $\propto \frac{mv}{h}$

RP $\propto$ P
RP $\propto$ mv
RP $\propto$ m

34. Official Ans. by NTA (4)

Sol.



Given $\lambda_1 = \frac{\ell n2}{700}$ / year , $\lambda_2 = \frac{\ell n2}{1400}$ / year

$\therefore \lambda_{net} = \lambda_1 + \lambda_2 = \ell n2\left[\frac{1}{700} + \frac{1}{1400}\right]$

$= \frac{3\ell n2}{1400}$ / year

Now, Let initial no. of radioactive nuclei be No.

$\therefore \frac{N_0}{3} = N_0 e^{-\lambda_{net} t}$

$\Rightarrow \ell n\frac{1}{3} = -\lambda_{net} t$

$\Rightarrow 1.1 = \frac{3 \times 0.693}{1400} t \Rightarrow t \approx 740$ years

Hence option 4.

35. Official Ans. by NTA (4)

Sol. Energy of γ ray [E_γ] = hν

Momentum of γ ray $\left[P_\gamma\right] = \frac{h}{\lambda} = \frac{h\nu}{C}$

Total momentum is conserved.

$\vec{P}_\gamma + \vec{P}_{Nu} = 0$

Where $\vec{P}_{Nu}$ = Momentum of decayed nuclei

$\Rightarrow P_\gamma = P_{Nu}$

$\Rightarrow \frac{h\nu}{C} = P_{Nu}$

$\Rightarrow$ K.E. of nuclei

$= \frac{1}{2}Mv^2 = \frac{(P_{Nu})^2}{2M} = \frac{1}{2M}\left[\frac{h\nu}{C}\right]^2$

Loss in internal energy = E_γ + K.E_{Nu}

$= h\nu + \frac{1}{2M}\left[\frac{h\nu}{C}\right]^2$

$= h\nu\left[1 + \frac{h\nu}{2MC^2}\right]$

36. Official Ans. by NTA (4)

Sol.

1.51 ———— n = 3

3.4 ———— n =

13.6 ———— n = 1

$3 \rightarrow 2 \Rightarrow 1.89$ eV

5×10^{-4} T r = 7mm

$r = \frac{mv}{qB} \Rightarrow mv = qrB \Rightarrow E = \frac{P^2}{2m} = \frac{(qRB)^2}{2m}$

$= \frac{(1.6 \times 10^{-19} \times 7 \times 10^{-3} \times 5 \times 10^{-4})^2}{2 \times 9.1 \times 10^{-31}\text{Joule}}$

$= \frac{3136 \times 10^{-52}}{18.2 \times 10^{-31} \times 1.6 \times 10^{-19}}$ eV

= 1.077 eV

We know work function = energy incident – $(KE)_{electron}$

$\phi = 1.89 - 1.077 = 0.813$ eV

37. Official Ans. by NTA (3)

Sol. $\lambda = \frac{h}{mv}$

kinetic energy, $\frac{P^2}{2m} = \frac{h^2}{2m\lambda^2} = \frac{hc}{\lambda_c}$

$\lambda_C = \frac{2m\lambda^2 c}{h}$

38. Official Ans. by NTA (4)

Sol. $R = R_0 e^{-\lambda t}$

$\ell nR = \ell nR_0 - \lambda t$

$-\lambda$ is slope of straight line

$\lambda = \frac{3}{20}$

$t_{1/2} = \frac{\ell n2}{\lambda} = 4.62$

39. Official Ans. by NTA (4)

Sol. KE = $\frac{hc}{\lambda} - \phi$ hc

$e(3V_0) = \frac{hc}{\lambda_0} - \phi$ …(i)

$eV_0 = \frac{hc}{2\lambda_0} - \phi$ …(ii)

Using (i) & (ii)

$\phi = \frac{hc}{4\lambda_0} = \frac{hc}{\lambda_t}$ $\lambda_t = 4\lambda_0$

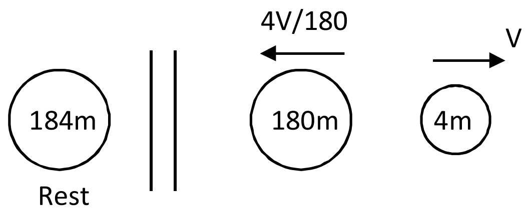
40. Official Ans. by NTA (20)

Sol. $N_0 \xrightarrow{t_{\frac{1}{2}}} \frac{N_0}{2} \xrightarrow{t_{\frac{1}{2}}} \frac{N_0}{4} \xrightarrow{t_{\frac{1}{2}}} \frac{N_0}{8} \xrightarrow{t_{\frac{1}{2}}} \frac{N_0}{16}$

$4 \times t_{1/2} = 80$

$t_{1/2} = 20$ days

41. Official Ans. by NTA (4)



Sol.

$$\frac{1}{2}(4m)v^2 + \frac{1}{2}(180m)\left(\frac{4v}{180}\right)^2 = 5.5\text{MeV}$$

$$\Rightarrow \frac{1}{2}4mv^2\left[1+45\left(\frac{4}{180}\right)^2\right] = 5.5\text{MeV}$$

$$\Rightarrow K.E_\alpha = \frac{5.5}{1+45.\left(\frac{4}{180}\right)^2}\text{MeV}$$

$K.E_\alpha = 5.38\text{MeV}$

42. Official Ans. by NTA (3)

Sol. $KE = e\Delta V$

$$\lambda_e = \frac{h}{\sqrt{2m_e(e\Delta V)}}$$

$$\lambda_P = \frac{h}{\sqrt{2m_p(e\Delta V)}} \Rightarrow \frac{\lambda_e}{\lambda_P} = \sqrt{\frac{m_P}{m_e}}$$

43. Official Ans. by NTA (3)

Sol. $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} \propto \frac{1}{\sqrt{m}}$

$m_\alpha > m_p > m_e$

so $\lambda_e > \lambda_p > \lambda_\alpha$

44. Official Ans. by NTA (4)

Sol. $\lambda = \frac{h}{p}$

both the particles will move with momentum same in magnitude & opposite in direction.

So De-Broglie wavelength of both will be same i.e. ratio 1 : 1

45. Official Ans. by NTA (4)

Sol. $\frac{3N_0}{4} = N_0e^{-\lambda t_1}$

$\frac{N_0}{2} = N_0e^{-\lambda t_2}$

$\ln(3/4) = -\lambda t_1$ .....(i)

$\ln(1/2) = -\lambda t_2$ .....(i)

$\ln(3/4) - \ln(1/2) = \lambda(t_2 - t_1)$ .....(i)

$\Delta t = \frac{\ln(3/2)}{\lambda}$

46. Official Ans. by NTA (4)

Sol. $A = \lambda N$

$$\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{3\times24\times60\times60}\sec^{-1} = 2.67\times10^{-6}\sec^{-1}$$

N = Number of atoms in 2 mg Au

$$= \frac{2\times10^{-3}}{198}\times6\times10^{23} = 6.06\times10^{15}$$

$A = \lambda N = 1.618 \times 10^{13} = 16.18 \times 10^{12}$ dps

47. Official Ans. by NTA (2)

Sol. $V_S = h\nu - \phi$

$4.8 = \frac{hc}{\lambda} - \phi$ ... (i)

$1.6 = \frac{hc}{2\lambda} - \phi$ ... (ii)

Using above equation (i) – (ii)

$3.2 = \frac{hc}{\lambda} - \frac{hc}{2\lambda}$

$3.2 = \frac{hc}{2\lambda}$ ... (iii)

$\left[\lambda = \frac{hc}{6.4}\right]$

Put in equation (ii)

$\phi = 1.6$

$\frac{hc}{\lambda_{th}} = 1.6$

$\lambda_{th} = \frac{hc}{1.6} = \left(\frac{hc}{6.4}\right)\times4 = 4\lambda$

48. Official Ans. by NTA (125)

Sol. By photoelectric equation

$\frac{hc}{\lambda} - \phi = k_{max}$

$k_{max} = \frac{1240}{500} - 1.25 \approx 1.25$

$r = \frac{\sqrt{2mk}}{eB}$

$B = \frac{\sqrt{2mk}}{er} = 125 \times 10^{-7}T$

49. Official Ans. by NTA (27)

Sol. $\Delta m = (Zm_P + (A-Z)m_n) - M_{A\ell}$

$= (13 \times 1.00726 + 14 \times 1.00866) - 27.18846$

$= 27.21562 - 27.18846$

$= 0.02716$ u

$E = 27.16 \text{ x} \times 10^{-3}$ J

50. Official Ans. by NTA (10)

Sol. $A = A_0e^{-\lambda t}$

$\frac{A_0}{8} = A_0e^{-\lambda t} \Rightarrow \lambda t = \ln 8$

$\lambda t = 3\ln 2$

$\frac{\ln 2}{\lambda} = \frac{t}{3} = \frac{30}{3} = 10$ years

51. Official Ans. by NTA (3)

Sol. $N = N_0e^{-\lambda t}$

$N_d = N_0 - N$

$N_d = N_0(1 - e^{-\lambda t})$

$\frac{N_d}{N_0} = f = 1 - e^{-\lambda t}$

$\frac{df}{dt} = \lambda e^{-\lambda t}$

52. Official Ans. by NTA (112)

Sol. $I = \frac{e}{T} = \frac{e\omega}{2\pi} = \frac{eV}{2\pi r}$

$I = \frac{1.6\times10^{-19}\times2.2\times10^{6}\times7}{2\times22\times0.5\times10^{-10}}$

$= 1.12$ mA

112×10^{-2} mA

53. Official Ans. by NTA (150)

Sol. $T_m = 30$ ms

$C = 200\ \mu F$

$\frac{q}{N} = \frac{Q_0e^{-t/RC}}{N_0e^{-\lambda t}} = \frac{Q_0}{N_0}e^{t\left(\lambda - \frac{1}{RC}\right)}$

Since q/N is constant hence

$\lambda = \frac{1}{RC}$

$R = \frac{1}{\lambda C} = \frac{T_m}{C} = \frac{30\times10^{-3}}{200\times10^{-6}} = 150\ \Omega$

54. Official Ans. by NTA (910)

Sol. For photon $\lambda_1 = \frac{h}{P} = \frac{6.6\times10^{-34}}{10^{-27}}$

For particle $\lambda_2 = \frac{h}{mv} = \frac{6.6\times10^{-34}}{9.1\times10^{-31}\times10^{6}}$

$\therefore \frac{\lambda_1}{\lambda_2} = 910$

55. Official Ans. by NTA (2)

Sol. Initially, energy of electron = +3eV

finally, in 2nd excited state,

energy of electron $= -\frac{(13.6\text{eV})}{3^2}$

$= -1.51\text{eV}$

Loss in energy is emitted as photon,

So, photon energy $\frac{hc}{\lambda} = 4.51$ eV

Now, photoelectric effect equation

$KE_{max} = \frac{hc}{\lambda} - \phi = 4.51 - \left(\frac{hc}{\lambda_{th}}\right)$

$= 4.51\text{ eV} - \frac{12400\text{ eV}\text{Å}}{4000\text{ Å}}$

56. Official Ans. by NTA (2)

Sol. (A) True, atom of each element emits characteristic spectrum.

(B) True, according to Bohr's postulates

$mvr = \frac{nh}{2\pi}$ and hence electron resides into orbits of specific radius called stationary orbits.

(C) False, density of nucleus is constant

(D) False, A free neutron is unstable decays into proton and electron and antineutrino.

(E) True unstable nucleus show radioactivity.

57. Official Ans. by NTA (10)

Sol. $E_{k_\alpha} = E_k - E_L$

$\frac{hc}{\lambda_{k_\alpha}} = E_k - E_L$

$E_L = E_k - \frac{hc}{\lambda_{k_\alpha}}$

$= 27.5\text{ KeV} - \frac{12.42\times10^{-7}\text{ eVm}}{0.071\times10^{-9}\text{m}}$

$E_L = (27.5 - 17.5)$ keV = 10 keV = 1.41 eV

58. Official Ans. by NTA (4)

Sol. $nf_1 = k\left(\frac{1}{1} - \frac{1}{3^2}\right)$

$nf_2 = k\left(1 - \frac{1}{2^2}\right)$

$\frac{f_1}{f_2} = \frac{8/9}{3/4} \Rightarrow f_2 = 2.46\times10^{15}$

Option (4)

59. Official Ans. by NTA (1)

Sol. $KE_{max} = eV_S = \frac{hc}{\lambda} - \phi$

$\Rightarrow eV_S = \frac{1240}{280} - 2.5 = 1.93\text{eV}$

$\to V_{S_1} = 1.93\text{V}$ ... (i)

$\to eV_{S_2} = \frac{1240}{400} - 2.5 = 0.6\text{eV}$

$\Rightarrow V_{S_2} = 0.6\text{V}$ ... (ii)

$\Delta V = V_{S_1} - V_{S_2} = 1.93 - 0.6 = 1.33\text{V}$

Option (1)

60. Official Ans. by NTA (2)

Sol. $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$, $mv = \sqrt{2mE}$

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

$\frac{\lambda_2}{\lambda_1} = \sqrt{\frac{E_1}{E_2}} = \frac{3}{4}$, $\lambda_2 = 0.75\ \lambda_1$

$\frac{E_1}{E_2} = \left(\frac{3}{4}\right)^2$

$E_2 = \frac{16}{9}E_1 = \frac{16}{9}E \qquad (E_1 = E)$

Extra energy given $= \frac{16}{9}E - E = \frac{7}{9}E$

Ans. 2

61. Official Ans. by NTA (3)

Sol. $A \to B,\ B \to C$

$\frac{dN_B}{dt} = \lambda N_A - \lambda N_B$

$\frac{dN_B}{dt} = 2\lambda N_{B_0} e^{-\lambda t} - \lambda N_B$

$e^{-\lambda t}\left(\frac{dN_B}{dt} + \lambda N_B\right) = 2\lambda N_{B_0} e^{-\lambda t} \times e^{\lambda t}$

$\frac{d}{dt}\left(N_B e^{\lambda t}\right) = 2\lambda N_{B_0}$, on integrating

$N_B e^{\lambda t} = 2\lambda t N_{B_0} + N_{B_0}$

$N_B = N_{B_0}[1 + 2\lambda t]e^{-\lambda t}$

$\frac{dN_B}{dt} = 0$ at $-\lambda[1+2\lambda t)e^{-\lambda t} + 2\lambda e^{-\lambda t} = 0$

$N_{B_{max}}$ at $t = \frac{1}{2\lambda}$

62. Official Ans. by NTA (2)

Sol. $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}}$

$\frac{N}{10^{10}} = \left(\frac{1}{2}\right)^{\frac{30}{60}}$

$\Rightarrow N = 10^{10} \times \left(\frac{1}{2}\right)^{\frac{1}{2}} = \frac{10^{10}}{\sqrt{2}} \approx 7 \times 10^9$

63. Official Ans. by NTA (4)

Sol. $\rightarrow$ Increasing intensity means number of incident photons are increased.

$\rightarrow$Kinetic energy of ejected electrons depend on the frequency of incident photons, not the intensity.

64. Official Ans. by NTA (2)

Sol. $kE_{max} = \frac{hc}{\lambda_i} + \phi$

or $\quad eV_o = \frac{hc}{\lambda_i} + \phi$

when $\lambda_i = 670.5$ nm ; $V_o = 0.48$

when $\lambda_i = 474.6$ nm ; $V_o = ?$

So, $\quad e(0.48) = \frac{1240}{670.5} + \phi \qquad ...(1)$

$e(V_o) = \frac{1240}{474.6} + \phi \qquad ...(2)$

(2) – (1)

$e(V_o - 0.48) = 1240\left(\frac{1}{474.6} - \frac{1}{670.5}\right)eV$

$V_o = 0.48 + 1240\left(\frac{670.5 - 474.6}{474.6 \times 670.5}\right)$ Volts

$V_o = 0.48 + 0.76$

$V_o = 1.24\ V \simeq 1.25\ V$

65. Official Ans. by NTA (15)

Sol. No. of different wavelengths $= \frac{n(n-1)}{2}$

$= \frac{6\times(6-1)}{2} = \frac{6\times5}{2} = 15$

66. Official Ans. by NTA (2)

Sol. $A \longrightarrow B \longrightarrow C$ (stable)

Initially no. of atoms of B = 0 after t = 0, no. of atoms of B will starts increasing & reaches maximum value when rate of decay of B = rate of formation of B.

After that maximum value, no. of atoms will starts decreasing as growth & decay both are exponential functions, so best possible graph is (2)

Option (2)

67. Official Ans. by NTA (1)

Sol. $\lambda_P = \frac{h}{P_P} \qquad \lambda_e = \frac{h}{P_e}$

$\because \lambda_P = \lambda_e$

$\Rightarrow P_P = P_e$

$(K)_P = \frac{P_P^2}{2m_P}$

$(K)_e = \frac{P_e^2}{2m_e}$

$K_P < K_e$ as $m_P > m_e \qquad$ Option (1)

68. Official Ans. by NTA (3)

Sol. For every large distance P.E. = 0

& total energy = 2.6 + 0 = 2.6 eV

Finally in first excited state of H atom total energy = –3.4 eV

Loss in total energy = 2.6 – (–3.4)

= 6eV

It is emitted as photon

$$\lambda = \frac{1240}{6} = 206 \text{ nm}$$

$$f = \frac{3\times10^8}{206\times10^{-9}} = 1.45 \times 10^{15} \text{ Hz}$$

$= 1.45 \times 10^9$ Hz

69. Official Ans. by NTA (3)

Sol. $\Delta x.\Delta p \geq \frac{h}{4\pi}$

$$\Delta x = \frac{h}{4\pi m\Delta v} \qquad v = \sqrt{\frac{3KT}{m}}$$

$$\frac{\Delta x_e}{\Delta x_p} = \sqrt{\frac{m_p}{m_e}}$$

70. Official Ans. by NTA (1)

Sol. De-Broglie wavelength

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$$

Where E is kinetic energy

$$E = \frac{3kT}{2} \text{ for gas}$$

$$\lambda = \frac{h}{\sqrt{3mkT}} = \frac{6.6\times10^{-34}}{\sqrt{3\times9\times10^{-31}\times1.38\times10^{-23}\times300}}$$

$\lambda = 6.26 \times 10^{-9}$ m = 6.26 nm

Option (1)

71. Official Ans. by NTA (2)

Sol. $(t_{1/2})_x = (\tau)_y$

$$\Rightarrow \frac{\ell n 2}{\lambda_x} = \frac{1}{\lambda_y} \Rightarrow \lambda_x = 0.693\ \lambda_y$$

Also initially $N_x = N_y = N_0$

Activity $A = \lambda N$

As $\lambda_x < \lambda_y \Rightarrow A_x < A_y$

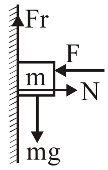
$\Rightarrow$ y will decay faster than x

Option (2)

NLM & FRICTION

1. Official Ans. by NTA (25)

Sol. F.B.D. of the block is shown in the diagram



Since block is at rest therefore

$fr - mg = 0$ ...(1)

$F - N = 0$ ...(2)

$fr \leq \mu N$

In limiting case

$fr = \mu N = \mu F$ ...(3)

Using eq. (1) and (3)

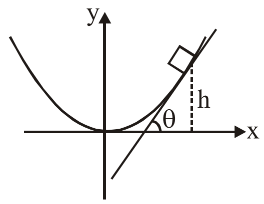
$\therefore \mu F = mg$

$$\Rightarrow F = \frac{0.5\times10}{0.2} = 25 \text{ N}$$

Ans. 25.00

2. Official Ans. by NTA (25)

Sol.



At maximum ht. block will experience maximum friction force. Therefore if at this height slope of the tangent is tan θ, then θ = Angle of repose.

$$\therefore \tan\theta = \frac{dy}{dx} = \frac{2x}{4} = \frac{x}{2} = 0.5$$

$$\Rightarrow x = 1 \text{ and therefore } y = \frac{x^2}{4} = 0.25 \text{ m}$$

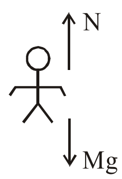
= 25 cm

$\therefore$ Answer is 25 cm

(Assuming that x & y in the equation are given in meter)

3. Official Ans. by NTA (492)

Sol.



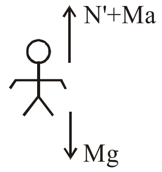
When lift is at rest

N = mg

$\Rightarrow 60 \times 10 = 600$ N

When lift moves with downward acceleration.

In frame of lift pseudo force will be in upward direction.



N' = M (g – a)

$\Rightarrow$ 60 (10 – 1.8)

N' $\Rightarrow$ 492 N

4. Official Ans. by NTA (500)

Sol. $\vec{F} = 20\hat{i} + 10\hat{j}$

$\vec{a} = \frac{\vec{F}}{m} = \frac{20\hat{i} + 10\hat{j}}{2} \Rightarrow 10\hat{i} + 5\hat{j}$

$\therefore \vec{s} = \frac{1}{2}\vec{a}t^2 = \frac{1}{2}\left(10\hat{i} + 5\hat{j}\right) \times (10)^2$

$\Rightarrow 50\left(10\hat{i} + 5\hat{j}\right)m$

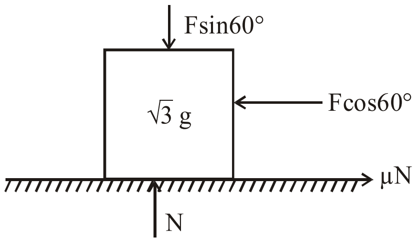
$\therefore$ Displacement along x-axis

$\Rightarrow$ 50 × 10 $\Rightarrow$ 500 m

$\therefore$ Ans. 500

5. Official Ans. by NTA (3)

Sol.



F cos 60° = μN or $\frac{F}{2} = \frac{1}{3\sqrt{3}}N$ ... (1)

& $N = \sin 60° + \sqrt{3}g$ ... (2)

From equation (1) & (2)

$$\frac{F}{2} = \frac{1}{3\sqrt{3}}\left(\frac{F\sqrt{3}}{2} + \sqrt{3}g\right)$$

$\Rightarrow$ F = g = 10 Newton = 3x

So $x = \frac{10}{3}$ = 3.33

6. Official Ans. by NTA (4)

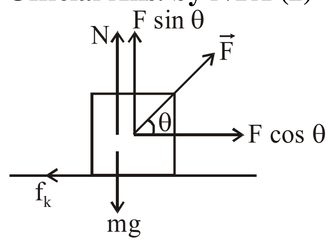
Sol. $a_{cm} = \frac{m_1a_1 + m_2a_2}{m_1 + m_2}$

$\frac{F}{2M} = \frac{Ma + Ma_B}{2M}$

$a_B = \frac{F - Ma}{M}$

7. Official Ans. by NTA (2)

Sol.



N = mg – f sin θ

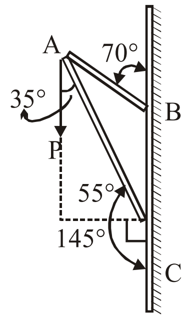
F cos θ – μ_kN = ma

F cos θ – μ_k (mg – F sin θ) = ma

$a = \frac{F}{m}\cos\theta - \mu_K\left(g - \frac{F}{m}\sin\theta\right)$

8. Official Ans. by NTA (82)

Sol.



Component along AC

= 100 cos 35°N

= 100 × 0.819 N

= 81.9 N

≈ 82 N

9. Official Ans. by NTA (12)

Sol. Ans. (12)

$\vec{a} = \frac{\vec{F}}{m} = \frac{2\hat{i} + 3\hat{j} + 5\hat{k}}{2}$

$= \hat{i} + 1.5\hat{j} + 2.5\hat{k}$

$\vec{\tau} = \vec{u}t + \frac{1}{2}\vec{a}t^2$

$= 0 + \frac{1}{2}(\hat{i} + 1.5\hat{j} + 2.5\hat{k})$ (16)

$= 8\hat{i} + 12\hat{j} + 20\hat{k}$

b = 12

10. Official Ans. by NTA (21)

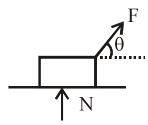
Sol. $a_{max} = \mu g = \frac{3}{7} \times 9.8$

F = (M + m) a_{max} = 5 a_{max}

= 21 Newton

11. Official Ans. by NTA (5)

Sol.



F cos θ = μN

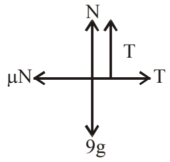
F sin θ + N = mg

$$\Rightarrow F = \frac{\mu mg}{\cos\theta + \mu\sin\theta}$$

$$F_{min} = \frac{\mu mg}{\sqrt{1+\mu^2}} = \frac{\frac{1}{\sqrt{3}}\times 10}{\frac{2}{\sqrt{3}}} = 5$$

12. Official Ans. by NTA (30)

Sol.



N + T = 90

T = μ N = 0.5 (90–T)

1.5 T = 45

T = 30

13. Official Ans. by NTA (10)

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

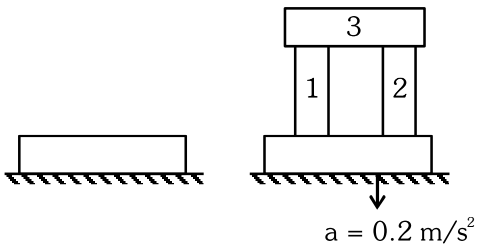
$$0 = (10)^2 + 2(-a)\left(\frac{1}{2}\right)$$

$a = 100\ m/s^2$

F = ma = (0.1) (100) = 10 N

14. Official Ans. by NTA (2)

Sol.



Writing force equation in vertical direction

Mg – N = Ma

$\Rightarrow 70g - N = 70 \times 0.2$

$\Rightarrow N = 70\,[g - 0.2] = 70 \times 9.8$

$\therefore$ N = 686 Newton

Note : Since there is no compressive normal from the sides, hence friction will not act.

Hence option 2.

15. Official Ans. by NTA (3)

Sol. t = 0, u = 0

$$a = \frac{F_o}{M} - \frac{F_o}{MT^2}(t-T)^2 = \frac{dv}{dt}$$

$$\int_0^v dv = \int_{t=0}^{2T}\left(\frac{F_o}{M} - \frac{F_o}{MT^2}(t-T)^2\right)dt$$

$$V = \left[\frac{F_o}{M}t\right]_o^{2T} - \frac{F_o}{MT^2}\left[\frac{t^3}{3} - t^2T + T^2t\right]_0^{2T}$$

$$V = \frac{4F_oT}{3M}$$

16. Official Ans. by NTA (3)

Sol. $t_a = \frac{1}{2}t_d$

$$\sqrt{\frac{2s}{a_a}} = \frac{1}{2}\sqrt{\frac{2s}{a_d}} \qquad \text{....(i)}$$

$a_a = g\sin\theta + \mu g\cos\theta$

$= \frac{g}{2} + \frac{\sqrt{3}}{2}\mu g$

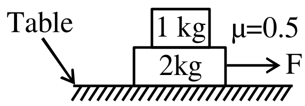
$a_d = g\sin\theta - \mu g\cos\theta$

$= \frac{g}{2} - \frac{\sqrt{3}}{2}\mu g$

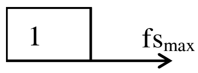
using the above values of a_a and a_d and putting in eqution (i) we will gate $\mu = \frac{\sqrt{3}}{5}$

17. Official Ans. by NTA (15)

Sol.



F = 3a (For system) ....(i)

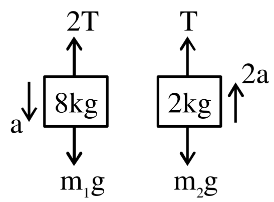


$fs_{max} = 1a$ (for 1kg block) ....(ii)

$\mu \times 1 \times g = a \Rightarrow 5 = a$ F = 15N

18. Official Ans. by NTA (4)

Sol.



$(m_1g - 2T) = m_1a$ – (1)

$T - m_2g = m_2(2a)$

$2T - 2m_2g = 4m_2\,a$ – (2)

$m_1g - 2m_2g = (m_1 + 4m_2)\,a$

$$a = \frac{(8-4)g}{(8+8)} = \frac{4}{16}g = \frac{g}{4}$$

$$a = \frac{10}{4}\ m/s^2$$

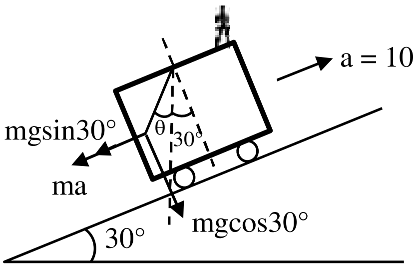
$$S = \frac{1}{2}at^2$$

$$\frac{0.2\times2\times4}{10} = t^2$$

t = 0.4 sec

19. Official Ans. by NTA (30)

Sol.



$$\tan(30+\theta)=\frac{mg\sin 30°+ma}{mg\cos 30°}$$

$$\tan(30+\theta)=\frac{5+10}{5\sqrt{3}}=\frac{1+2}{\sqrt{3}}$$

$$\frac{\tan\theta+\frac{1}{\sqrt{3}}}{1-\frac{1}{\sqrt{3}}\tan\theta}=\sqrt{3}$$

$$\sqrt{3}\tan\theta+1=3-\sqrt{3}\tan\theta$$

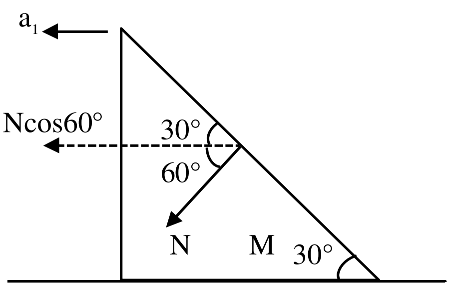
$$2\sqrt{3}\tan\theta=2$$

$$\tan\theta=\frac{1}{\sqrt{3}}$$

$\theta = 30°$

20. Official Ans. by NTA (4)

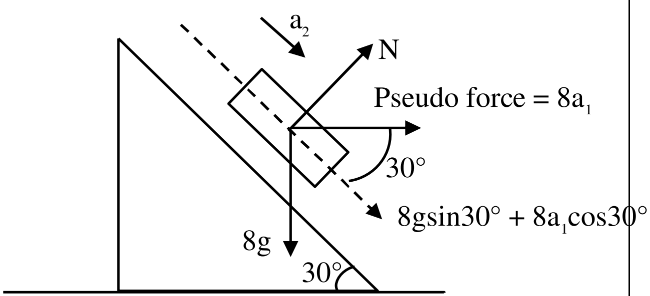
Sol. Let acceleration of wedge is a_1 and acceleration of block w.r.t. wedge is a_2



$$N\cos 60° = Ma_1 = 16a_1$$

$\Rightarrow N = 32a_1$

F.B.D. of block w.r.t wedge



$\perp$ to incline

$N = 8g\cos 30° - 8a_1\sin 30° \Rightarrow 32a_1 = 4\sqrt{3}g-4a_1$

$$\Rightarrow a_1=\frac{\sqrt{3}}{9}g$$

Along incline

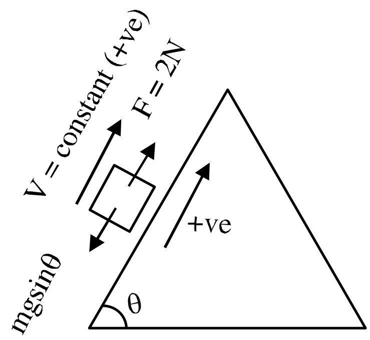
$8g\sin30° + 8a_1\cos30° = ma_2 = 8a_2$

$$a_2=g\times\frac{1}{2}+\frac{\sqrt{3}}{9}g.\frac{\sqrt{3}}{2}=\frac{2g}{3}$$

Option (4)

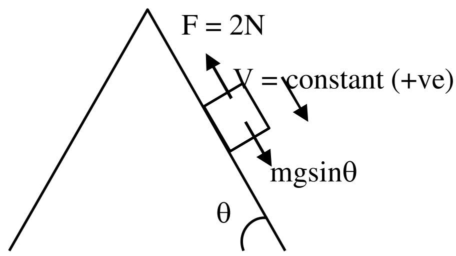
21. Official Ans. by NTA (2)

Sol. During upward motion



F = 2N = (+ve) constant

During downward motion

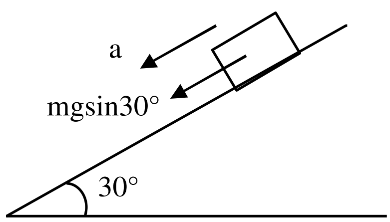


$\Rightarrow$ F = 2N = (–ve) constant

$\Rightarrow$ Best possible answer is option (2)

22. Official Ans. by NTA (3)

Sol.

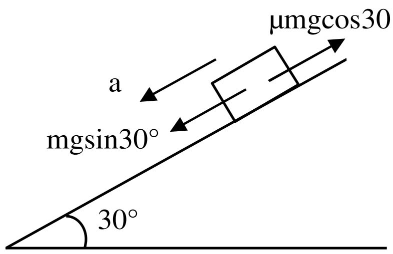


On smooth incline

$a = g\sin30°$

by $S = ut + \frac{1}{2}at^2$

$$S=\frac{1}{2}\frac{g}{2}T^2=\frac{g}{4}T^2 \;.......(i)$$



On rough incline

$a = g \sin 30° - \mu g \cos 30°$

by $S = ut + \frac{1}{2}at^2$

$S = \frac{1}{4}g\left(1-\sqrt{3}\mu\right)\left(\alpha T\right)^2$ ...(ii)

By (i) and (ii)

$\frac{1}{4}gT^2 = \frac{1}{4}g\left(1-\sqrt{3}\mu\right)\alpha^2 T^2$

$\Rightarrow 1-\sqrt{3}g = \frac{1}{\alpha^2} \Rightarrow g = \left(\frac{\alpha^2-1}{\alpha^2}\right).\frac{1}{\sqrt{3}}$

$\Rightarrow x = 3.00$

POC

1. Official Ans. by NTA (25)

Sol. % modulation = $\frac{Am}{Ac} \times 100$

% modulation = $\frac{20}{80} \times 100$

% modulation = 25%

Ans 25

2. Official Ans. by NTA (8)

Sol. Sound level decreases by 5dB every km so sound level decreased in 20 km = 100 dB

$\beta_2 - \beta_1 = 10\log_{10}\frac{I_2}{I_1}$

$-100 = 10\log_{10}\frac{I_2}{I_1} \Rightarrow \frac{I_1}{I_2} = 10^{10}$

$I_2 = 10^{-10} I_1 \Rightarrow P_2 = 10^{-10} P_1 = 10^{-8}$ W

x = 8 $\boxed{\text{Ans. 8}}$

3. Official Ans. by NTA (3)

Sol. $f_m = 2$kHz

$f_c = 1$MHz = 1000 kHz

Band width = $2f_m$ = 4kHz

∴ Side frequencies will be

$= f_c \pm f_m$

= (1000 ± 2) kHz

= 998 kHz & 1002 kHz

So statement-I & statement-II both are correct.

4. Official Ans. by NTA (10)

Sol. $\lambda = 960$ m

$C = 2.56\ \mu F = 2.56 \times 10^{-6}$ F

$c = 3 \times 10^8$ m/s

L = ?

Now at resonance, $\omega_0 = \frac{1}{\sqrt{LC}}$

[Resoant frequency]

$2\pi f_0 = \frac{1}{\sqrt{LC}}$

On substituting $f_0 = \frac{c}{\lambda}$, we have $2\pi\frac{c}{\lambda} = \frac{1}{\sqrt{LC}}$

Squaring both sides : $4\pi^2\frac{c^2}{\lambda^2} = \frac{1}{LC}$

$= \frac{4\times10\times(3\times10^8)^2}{(960)^2} = \frac{1}{L\times2.56\times10^{-6}}$

$\Rightarrow \frac{1}{L} = \frac{4\times10\times9\times10^{16}\times2.56\times10^{-6}}{960\times960}$

$\Rightarrow L = 10 \times 10^{-8}$ H

5. Official Ans. by NTA (4)

Sol. (4) $\lambda = \frac{v}{f} = \frac{c}{f_c}$

6. Official Ans. by NTA (33)

Sol. Modulation index = $\frac{A_{max} - A_{min}}{A_{max} + A_{min}}$

$= \frac{16-8}{16+8} = \frac{8}{24} = \frac{1}{3} = 0.33$

$x \times 10^{-2} = 0.33$

x = 33

7. Official Ans. by NTA (9)

Sol. B. W. (Bandwidth) = 2 × maximum frequency at modulating signal

= 2 × 5kHz = 10 kHz

∴ No of stations accommodate

$= \frac{90}{10} = 9$

8. Official Ans. by NTA (4)

Sol. Length of Antena = 25m = $\frac{\lambda}{4}$

$\Rightarrow \boxed{\lambda = 100\,\text{m}}$

9. Official Ans. by NTA (2)

Sol. $D = 2\sqrt{2Rh}$

$h = \frac{D^2}{8R} = \frac{45^2}{8\times6400}\text{km} \cong 39.55\,\text{m}$

10. Official Ans. by NTA (1206)

Sol. $d = \sqrt{2Rh}$

$A = \pi d^2$

$A = \pi 2Rh$

$= 3.14 \times 2 \times 6400 \times \dfrac{30}{1000}$

$A = 1205.76\ km^2$

$A \simeq 1206\ km^2$

11. Official Ans. by NTA (4)

Sol. (4) Band width = $2\ f_m$

$\omega_m = 1.57 \times 10^8 = 2\pi f_m$

$BW = 2f_m = \dfrac{10^8}{2} Hz = 50\ MHz$

12. Official Ans. by NTA (1)

Sol. Order of atmosphere stratification from bottom Troposphere, stratosphere, Mesosphere, Thermosphere

(a) $\rightarrow$ (iv)

(b) $\rightarrow$ (iii)

(c) $\rightarrow$ (ii)

(d) $\rightarrow$ (i)

13. Official Ans. by NTA (50)

Sol. Range = $\sqrt{2Rh}$

Range (i) = $\sqrt{2Rh}$

Range (ii) = $\sqrt{2Rh} + \sqrt{2Rh'}$

where h = 20 m & h' = 5m

Ans $= \dfrac{\sqrt{2Rh'}}{\sqrt{2Rh}} \times 100\% = \dfrac{\sqrt{5}}{\sqrt{20}} \times 100\% = 50\%$

14. Official Ans. by NTA (40)

Sol. Maximum amplitude

$A_{max} = A_m + A_C$

$\Rightarrow V_{max} = V_m + V_C$

$200 = V_m + 160$

$V_m = 40$

$\therefore$ Peak voltage $A_m = 40$

Ans. 40

15. Official Ans. by NTA (1)

Sol. Radius covered $r = \sqrt{2RH_T}$

$150\ km = \sqrt{2 \times (6.5 \times 10^6 m) H_T}$

$(150\ km \times 10^3)^2 = 2 \times 6.5 \times 10^6\ H_T$

$H_T = 1731m$

Population covered = $(\pi r^2)(2000/km^2)$

$= 3.14 \times (150)^2 \times 2000 = 1413 \times 10^5$

16. Official Ans. by NTA (1)

Sol. Bandwidth = $2 \times f_m$

$= 2 \times 10^5$ HZ = 200 KHZ

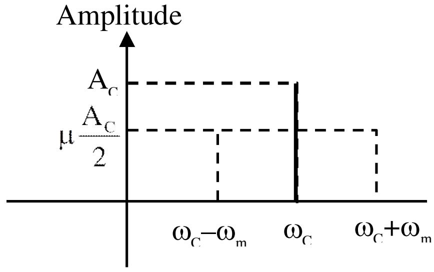
17. Official Ans. by NTA (1)

Sol. Modulation index

$\mu = \dfrac{A_m}{A_c} = \dfrac{20}{20} = 1$

18. Official Ans. by NTA (1)

Sol.



$\dfrac{a}{10} = \dfrac{b}{10} = \dfrac{\mu A_C}{2}$

$\Rightarrow \dfrac{a}{b} = 1$

19. Official Ans. by NTA (1)

Sol. $A_{max} = A_c + A_m = 12$

$A_{min} = A_c - A_m = 3$

$\Rightarrow A_c = \dfrac{15}{2}$ & $A_m = \dfrac{9}{2}$

modulation index $= \dfrac{A_m}{A_c} = \dfrac{9/2}{15/2} = 0.6$

$\Rightarrow x = 1$

20. Official Ans. by NTA (2)

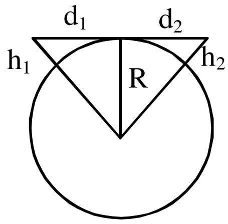
Sol. $W_m = 12560 = 2\pi f_m$

$f_m = \dfrac{12560}{2\pi} = 2000$ Hz

Ans. 2.00

21. Official Ans. by NTA (4)

Sol.



$d_t = \sqrt{2Rh_1} + \sqrt{2Rh_2}$

$= \sqrt{2R}\left(\sqrt{h_1} + \sqrt{h_2}\right)$

$= (2 \times 6400 \times 10^3)^{1/2}\left(\sqrt{50} + \sqrt{80}\right)$

= 3578 (7.07 + 8.94) = 57.28 Km

22. Official Ans. by NTA (224)

Sol. $d_m = \sqrt{2Rh_T} + \sqrt{2Rh_R}$

$d_m = \left(\sqrt{2 \times 6400 \times 10^3 \times 320} + \sqrt{2 \times 6400 \times 10^3 \times 2000}\right) m$

$\boxed{d_m = 224 km}$

23. Official Ans. by NTA (2)

Sol. h : height of antenna

λ : wavelength of signal

$h < \lambda$

$\lambda > h$

$\lambda > 400$ m

24. Official Ans. by NTA (64)

Sol. $h_T = h_R = 160$ … (i)

$$d = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$

$$d = \sqrt{2R}\left[\sqrt{h_T} + \sqrt{h_R}\right]$$

$$d = \sqrt{2R}\left[\sqrt{x} + \sqrt{160 - x}\right]$$

$$\frac{d(d)}{dx} = 0$$

$$\frac{1}{2\sqrt{x}} + \frac{1(-1)}{2\sqrt{160 - x}} = 0$$

$$\frac{1}{\sqrt{x}} = \frac{1}{\sqrt{160 - x}}$$

$x = 80$ m

$$d_{max} = \sqrt{2 \times 6400}\left[\sqrt{\frac{80}{1000}} + \sqrt{\frac{20}{1000}}\right]$$

$$= \frac{80\sqrt{2} \times 2\sqrt{80}}{10\sqrt{10}}$$

$$= 8 \times 2 \times \sqrt{2} \times 2\sqrt{2} = 64 \text{ km}$$

25. Official Ans. by NTA (500)

Sol. Signal bandwidth = 2 fm

= 12 kHz

$$\therefore\ N = \frac{6MHZ}{12kHZ} = \frac{6 \times 10^6}{12 \times 10^3} = 500$$

26. Official Ans. by NTA (200)

Sol. $A_{max} = A_C + A_m = 250 + 150 = 400$

$A_{min} = A_C - A_m = 250 - 150 = 100$

$$\frac{A_{min}}{A_{max}} = \frac{100}{400} = \frac{1}{4} = \frac{50}{200}$$

$x = 200$

ROTATIONAL MOTION

1. Official Ans. by NTA (3)

Sol. Ring $I_1 = \frac{MR^2}{2}$ about diameter

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

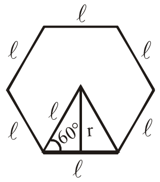
Solid cylinder $I_3 = \frac{MR^2}{2}$

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

$I_1 = I_2 = I_3 > I_4$

2. Official Ans. by NTA (8)

Sol.



m = mass of one side of hexagon = 1 kg

$6\ell = 2.4$ $\boxed{\ell = 0.4\,m}$

$$\sin 60° = \frac{r}{\ell}$$

$$r = \ell \sin 60° = \frac{\ell\sqrt{3}}{2}$$

MOI, $I = \left[\frac{m\ell^2}{12} + mr^2\right]6$

$$= \left[\frac{m\ell^2}{12} + m\left(\frac{\ell\sqrt{3}}{2}\right)^2\right]6$$

$= 5\, m\ell^2$

$= 5 \times 1 \times 0.16$

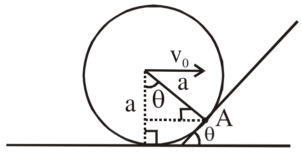
$= 0.8$

$I = 8 \times 10^{-1}$ kg m^2

$\boxed{\text{Ans. } 8}$

3. Official Ans. by NTA (BONUS)

Sol.



Angular momentum conservation about A

$$mv_0\, a \cos\theta + \frac{2}{5} ma^2\omega$$

$$= mva + \frac{2}{5} ma^2\omega^1$$

$$mv_0 a\left[\frac{2}{5} + \cos\theta\right] = \frac{7}{5} mva$$

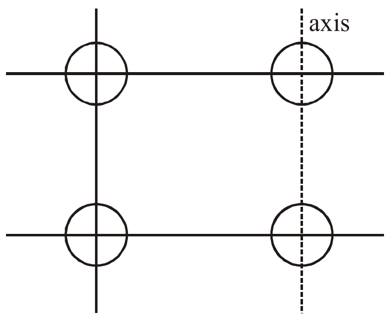
$$v = \frac{5}{7} = v_0\left[\frac{2}{5} + \cos\theta\right]$$

$$\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{7}{10}mv^2 = mgh$$

No option Maching

4. Official Ans. by NTA (3)

Sol.

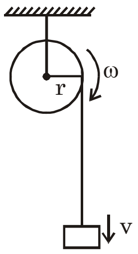


$$I = 2 \times \left(\frac{2}{5}ma^2\right) + 2 \times \left(\frac{2}{5}ma^2 + mb^2\right)$$

$$I = \frac{8}{5}ma^2 + 2mb^2$$

5. Official Ans. by NTA (2)

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



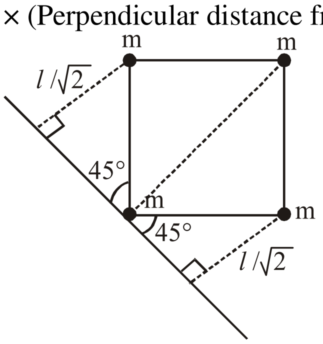
$v = \omega r$

$mgh = \frac{1}{2}I\omega^2 + \frac{1}{2}m\omega^2 r^2$

$\frac{2mgh}{\left(I + mr^2\right)} = \omega^2$

6. Official Ans. by NTA (3)

Sol. Moment of inertia of point mass
= mass × (Perpendicular distance from axis)^2



Moment of Inertia

$= m(0)^2 + m\,(l\sqrt{2})^2 + m\left(\frac{l}{\sqrt{2}}\right)^2 + m\left(\frac{l}{\sqrt{2}}\right)^2$

$= 3\,ml^2$

7. Official Ans. by NTA (20)

Sol. $\alpha = \frac{\tau}{I} = \frac{F.R.}{mR^2/2} = \frac{2F}{mR}$

$\alpha = \frac{2 \times 200}{20 \times (0.2)} = 10$ rad/s^2

$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

$(50)^2 = 0^2 + 2(10)\,\Delta\theta \Rightarrow \Delta\theta = \frac{2500}{20}$

$\Delta\theta = 125$ rad

No. of revolution $= \frac{125}{2\pi} \approx 20$ revolution

8. Official Ans. by NTA (20)

Sol. **Ans. (20)**

$\vec{\tau} = \vec{r} \times \vec{F}$

$\vec{r} = (2\hat{i}) - (2\hat{i} + 3\hat{j} + 4\hat{k}) = -3\hat{j} - 4\hat{k}$

& $\vec{F} = 4\hat{i} + 3\hat{j} + 4\hat{k}$

$$\vec{\tau} = \vec{r} \times \vec{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & -3 & -4 \\ 4 & 3 & 4 \end{vmatrix}$$

$= \hat{i}(-12 + 12) - \hat{j}(0 + 16) + \hat{k}(0 + 12)$

$= -16\hat{i} + 12\hat{k}$

$\therefore |\vec{\tau}| = \sqrt{16^2 + 12^2} = 20$

9. Official Ans. by NTA (3)

Sol. **Ans. (3)**

$a = \frac{g\sin\theta}{1 + \frac{I}{mR^2}} = \frac{g\sin\theta}{1 + \frac{1}{2}} = \frac{2}{3}g\sin\theta$

$b = 3$

10. Official Ans. by NTA (1)

Sol. $\vec{F} = 4\hat{i} - 3\hat{j}$

$\vec{r}_1 = 5\hat{i} + 5\sqrt{3}\hat{j}$ & $\vec{r}_2 = -5\hat{i} + 5\sqrt{3}\hat{j}$

Torque about 'O'

$\vec{\tau}_O = \vec{r}_1 \times \vec{F} = \left(-15 - 20\sqrt{3}\right)\hat{k} = \left(15 + 20\sqrt{3}\right)\left(-\hat{k}\right)$

Torque about 'Q'

$\vec{\tau}_Q = \vec{r}_2 \times \vec{F} = \left(-15 + 20\sqrt{3}\right)\hat{k} = \left(15 - 20\sqrt{3}\right)\left(-\hat{k}\right)$

11. Official Ans. by NTA (4)

Sol. We know, $\vec{L} = m(\vec{r} \times \vec{v})$

Now with respect to A, we always get direction of $\vec{L}$ along +ve z-axis and also constant magnitude as mvr. But with respect to B, we get constant magnitude but continuously changing direction.

12. Official Ans. by NTA (4)

Sol. $Mg\sin\theta\, R = (mk^2 + mR^2)\,\alpha$

$\alpha = \frac{Rg\sin\theta}{k^2 + R^2} \Rightarrow a = \frac{g\sin\theta}{1 + \frac{k^2}{R^2}}$

$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2s}{g\sin\theta}\left(1 + \frac{k^2}{R^2}\right)}$

for least time, k should be least & we know k is least for solid sphere.

13. Official Ans. by NTA (3)

Sol. (3) $a = \frac{g\sin\theta}{1 + \frac{I}{mR^2}} = \frac{5}{7} \times \frac{10}{2} = \frac{25}{7}$

$t = \frac{2v_0}{a} = \frac{2 \times 1 \times 7}{25} = 0.56$

14. Official Ans. by NTA (3)

Sol. Using conservation of angular momentum

$(Mr^2)\omega = (Mr^2 + 2mr^2)\omega'$

$\omega' = \frac{M\omega}{M + 2m}$

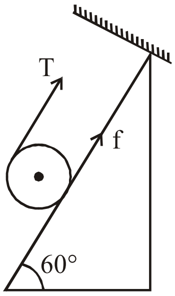
15. Official Ans. by NTA (3)

Sol. $\pi r = L \Rightarrow r = \frac{L}{\pi}$

$I = Mr^2 = \frac{ML^2}{\pi^2}$

16. Official Ans. by NTA (3)

Sol.



Let's take solid cylinder is in equilibrium

$T + f = mg\ \sin60$ ....(i)

$TR - fR = 0$ ....(ii)

Solving we get

$$T = f_{req} = \frac{mg\sin\theta}{2}$$

But limiting friction < required friction

$$\mu mg\cos60° < \frac{mg\sin60°}{2}$$

$\therefore$ Hence cylinder will not remain in equilibrium

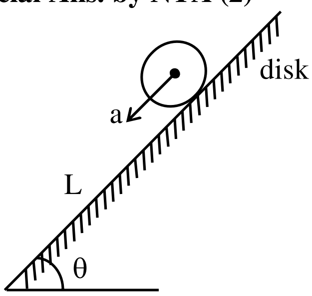
Hence f = kinetic

$= \mu_k N$

$$= \mu_k mg\cos 60° = \frac{mg}{5}$$

17. Official Ans. by NTA (2)

Sol.



If disk slips on inclined plane, then it's acceleration

$a_1 = g\sin\theta$

$$L = \frac{1}{2}a_1 t_1^2$$

$$\Rightarrow t_1 = \sqrt{\frac{2L}{a_1}} \quad \text{.... (i)}$$

If disk rolls on inclined plane, its acceleration,

$$a_2 = \frac{g\sin\theta}{1+\frac{I}{mR^2}}$$

$$a_2 = \frac{g\sin\theta}{1+\frac{mR^2}{2mR^2}}$$

$$a_2 = \frac{2}{3}g\sin\theta$$

$$\text{Now } L = \frac{1}{2}a_2 \cdot t_2^2$$

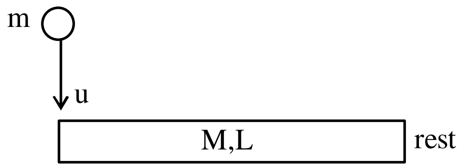
$$\Rightarrow t_2 = \sqrt{\frac{2L}{a_2}} \quad \text{... (ii)}$$

$$\text{Now } \frac{t_2}{t_1} = \sqrt{\frac{a_1}{a_2}} = \sqrt{\frac{3}{2}}$$

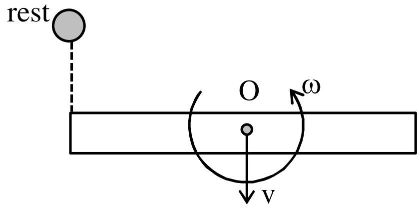
$\Rightarrow x = 2$

18. Official Ans. by NTA (4)

Sol.



Just before collision



Just after collision

From momentum conservation, $P_i^0 = P_f$

$mu = Mv$ .... (i)

From angular momentum conservation about O,

$$mu \cdot \frac{L}{2} = \frac{ML^2}{12}\omega$$

$$\Rightarrow \omega = \frac{6mu}{ML} \quad \text{... (ii)}$$

$$\text{From } e = \frac{R.V.S}{R.V.A}$$

$$1 = \frac{V + \frac{\omega L}{2}}{u}$$

$$v + \frac{\omega L}{2} = u$$

$$v + \frac{3mu}{M} = u$$

$$\frac{mu}{M} + \frac{3mu}{M} = u$$

$$\frac{4mu}{M} = u \;;\quad \frac{m}{M} = \frac{1}{4}$$

$X = 4$

19. Official Ans. by NTA (2)

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

$I = \frac{1}{2}mR^2$

Body is solid cylinder

20. Official Ans. by NTA (3)

Sol. I in both cases is about point of contact

Ring

$mgh = \frac{1}{2}I\omega^2$

$mgh = \frac{1}{2}(2mR^2)\frac{v_R^2}{R^2}$

$v_R = \sqrt{gh}$

Solid cylinder

$mgh = \frac{1}{2}I\omega^2$

$mgh = \frac{1}{2}\left(\frac{3}{2}mR^2\right)\frac{v_C^2}{R^2}$

$v_C = \sqrt{\frac{4gh}{3}}$; $\frac{v_R}{v_C} = \frac{\sqrt{3}}{2}$

21. Official Ans. by NTA (1)

Sol. $a = \frac{g\sin\theta}{1+\frac{I}{mR^2}}$

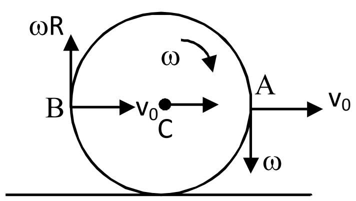
$I_{ring} > I_{solid\ cylinder} > I_{solid\ sphere}$

$\Rightarrow a_{ring} < a_{solid\ cylinder} < a_{solid\ sphere}$

$\Rightarrow v_{ring} < v_{solid\ cylinder} < v_{solid\ sphere}$

22. Official Ans. by NTA (2)

Sol.



For no slipping $v_0 = \omega R$

Now $v_A = v_B = \sqrt{v_0^2 + (\omega R)^2}$

$= \sqrt{2}v_0 \Rightarrow x = 2$

23. Official Ans. by NTA (2)

Sol. $I_z = I_x + I_y$ (using perpendicular axis theorem)

& $I = mk^2$ (K : radius of gyration)

so $mK_z^2 = mK_x^2 + mK_y^2$

$K_z^2 = K_x^2 + K_y^2$

so radius of gyration about axes x, y & z won't be same hense asseration A is not correct reason R is correct statement (property of a rigid body)

24. Official Ans. by NTA (10)

Sol. $\vec{r} = 10\alpha t^2\hat{i} + 5\beta(t-5)\hat{j}$

$\vec{v} = 20\alpha t\hat{i} + 5\beta\hat{j}$

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

$= m[10\alpha t^2\hat{i} + 5\beta(t-5)\hat{j}]\times[20\alpha t\hat{i} + 5\beta\hat{j}]$

$\vec{L} = m[50\alpha\beta t^2\hat{k} - 100\alpha\beta(t^2-5t)\hat{k}]$

At t = 0, $\vec{L} = \vec{0}$

$50\alpha\beta t^2 - 100\alpha\beta(t^2-5t) = 0$

t – 2 (t–5) = 0

t = 10 sec

25. Official Ans. by NTA (4)

Sol. $\tau = \frac{\Delta L}{\Delta t} = \frac{I(\omega_f - \omega_i)}{\Delta t}$

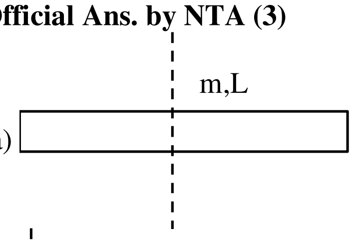
$\tau = \frac{\frac{mR^2}{2}\times[0-\omega]}{\Delta t}$

$= \frac{10\times(20\times10^{-2})^2}{2}\times\frac{600\times\pi}{30\times10}$

$= 0.4\pi = 4\pi\times10^{-2}$

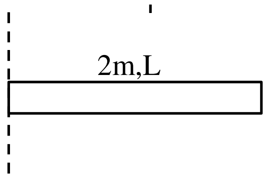
26. Official Ans. by NTA (3)

Sol. (a)



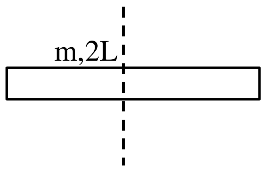
$I = \frac{mL^2}{12}$

(b)



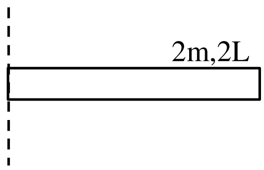
$I = \frac{(2m)(L^2)}{3}$

(c)



$I = \frac{m(2L)^2}{12} = \frac{mL^2}{3}$

(d)



$I = \frac{2m(2L)^2}{3} = \frac{8}{3}mL^2$

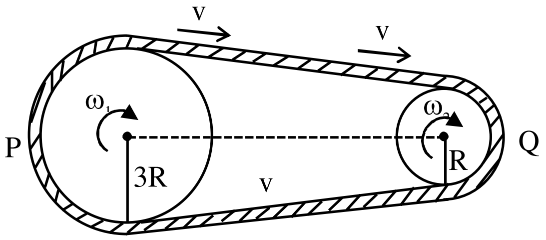
27. Official Ans. by NTA (4)

Sol. Ratio of moment of inertia $= \frac{\frac{1}{2}MR^2}{\frac{1}{4}mr^2}$

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

28. **Official Ans. by NTA (9)**

Sol.



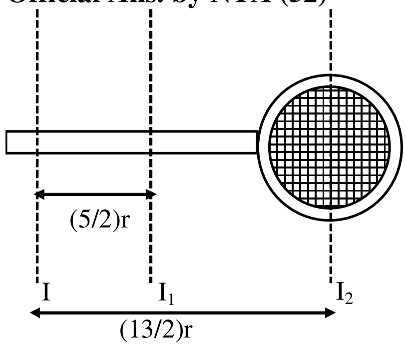
$$\frac{1}{2}I_1(\omega_1)^2 = \frac{1}{2}I_2(\omega_2)^2$$

$$I_1\left(\frac{v}{3R}\right)^2 = I_2\left(\frac{v}{R}\right)^2$$

$$\frac{I_1}{I_2} = \frac{9}{1}$$

29. **Official Ans. by NTA (52)**

Sol.



$$I = \left[I_1 + M\left(\frac{5}{2}r\right)^2\right] + \left[I_2 + M\left(\frac{13r}{2}\right)^2\right]$$

$$= \left[\frac{M(36r^2)}{12} + \frac{M(25r^2)}{4}\right] + \left[\frac{Mr^2}{2} + \frac{169Mr^2}{4}\right]$$

$= 52\ Mr^2$

Ans. 52.00

30. **Official Ans. by NTA (4)**

Sol. Parallel axis theorem

$I = I_{CM} + Md^2$

$$I = \frac{Mr^2}{2} + M\left(\frac{L}{2}\right)^2$$

$$2.7 = M\frac{(0.2)^2}{2} + M\left(\frac{0.8}{2}\right)^2$$

$$2.7 = M\left[\frac{2}{100} + \frac{16}{100}\right]$$

$M = 15kg$

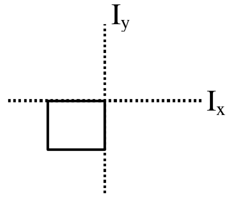
$$\Rightarrow \rho = \frac{M}{\pi r^2 L} = \frac{15}{\pi(0.2)^2 \times 0.8}$$

$= 0.1492 \times 10^3$

Ans. 4

31. **Official Ans. by NTA (4)**

Sol. According to perpendicular Axis theorem.



$I_x + I_y = I_z$

$$I_z \Rightarrow \frac{m\ell^2}{3} + \frac{m\ell^2}{3} = \frac{2m\ell^2}{3}$$

32. **Official Ans. by NTA (3)**

Sol. From conservation of angular momentum we get

$I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\omega$

$$\omega = \frac{I_1\omega_1 + I_2\omega_2}{I_1 + I_2}$$

$$k_i = \frac{1}{2}I_1\omega_1^2 + \frac{1}{2}I_2\omega_2^2$$

$$k_f = \frac{1}{2}(I_1 + I_2)\omega^2$$

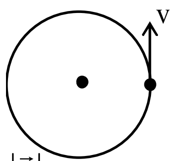
$$k_i - k_f = \frac{1}{2}\left[I_1\omega_1^2 + I_2\omega_2^2 - \frac{(I_1\omega_1 + I_2\omega_2)^2}{I_1 + I_2}\right]$$

Solving above we get

$$k_i - k_f = \frac{1}{2}\left(\frac{I_1 I_2}{I_1 + I_2}\right)(\omega_1 - \omega_2)^2$$

33. **Official Ans. by NTA (2)**

Sol.



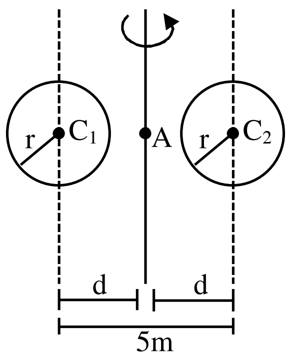
$|\vec{L}| = mvr$

And direction will be upward & remain constant

Option (2)

34. **Official Ans. by NTA (3)**

Sol.

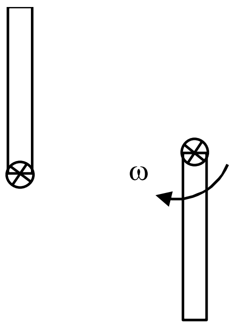


$M = 1.5$ kg, $r = 0.5$ m, $d = \frac{5}{2}$ m

$$I = 2\left(\frac{2}{5}Mr^2 + Md^2\right) = 19.05\ kgm^2$$

35. Official Ans. by NTA (6)

Sol.



by energy conservation

$$mg\ell = \frac{1}{2}I\omega^2 = \frac{1}{2}\frac{m\ell^2\omega^2}{3}$$

$$\Rightarrow \omega = \sqrt{\frac{6g}{\ell}}$$

Speed $v = \omega r = \omega\ell = \sqrt{6g\ell}$

$$v = \sqrt{6\times10\times.6} = 6m/s$$

SEMICONDUCTORS

1. Official Ans. by NTA (1)

Sol. $I_\varepsilon = I_C + I_B$

$\Rightarrow \Delta I_\varepsilon = \Delta I_C + \Delta I_B$

$4mA = 3.5\ mA + \Delta I_B$

$\Rightarrow \Delta I_B = 0.5\ mA$

$$\Rightarrow \beta = \frac{\Delta I_C}{\Delta I_B}$$

$$\beta = \frac{3.5}{0.5}$$

$\Rightarrow \beta = 7$

2. Official Ans. by NTA (25)

Sol. Current through 2kΩ resistance

$$I = \frac{5}{2\times10^3} = 2.5\times10^{-3}\ A$$

$I = 25\times10^{-4}\ A$

Ans. 25

3. Official Ans. by NTA (440)

Sol. $\frac{N_P}{N_S} = \frac{V_P}{V_S}$

$$\frac{N_P}{24} = \frac{220}{12}$$

$$N_P = \frac{220\times24}{12}$$

$N_P = 440$

Ans. 440 turns

4. Official Ans. by NTA (4)

Sol. Truth table of the given gate :

A	B	C
0	0	0
0	1	1
1	0	0
1	1	0

Truth table of option (1)

A	B	C
0	0	1
0	1	1
1	0	0
1	1	1

Truth table of option (2)

A	B	C
0	0	1
0	1	0
1	0	1
1	1	1

Truth table of option (3)

A	B	C
0	0	1
0	1	0
1	0	0
1	1	0

Truth table of option (4)

A	B	C
0	0	0
0	1	1
1	0	0
1	1	0

Since option (1) has same truth table, hence answer is option (4) is correct.

Alternative solution :

Given Boolean expression can be written as

$$\overline{A+\overline{B}} = C$$

$$\therefore\ C = \overline{A}\cdot\overline{\overline{B}} = \overline{A}\cdot B$$

Hence option (4) is correct

5. Official Ans. by NTA (1)

Sol. Back to back diode will not the make a transistor

$$\beta = \frac{i_c}{i_b}$$

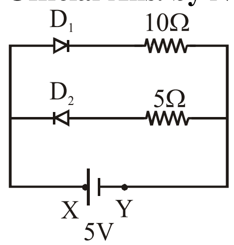
6. Official Ans. by NTA (2)

Sol. Zener diode is heavily doped and have narrow depletion layer.

Option (2) is correct.

7. Official Ans. by NTA (4)

Sol.



Here only D_1 will work and we know for silicon diode, potential drop on D_1 will be 0.7V

$$I = \frac{5-0.7}{10} = 0.43 \text{ A}$$

8. Official Ans. by NTA (2)

Sol. (2) conceptual

9. Official Ans. by NTA (2)

Sol. $y = \overline{\left(A\bar{B} + \bar{A}B\right)}$

$y = \overline{A\bar{B}}\,.\,\overline{\bar{A}B}$

$y = \left(\bar{A} + B\right).\left(A + \bar{B}\right)$

$y = \bar{A}\,.\,A + \bar{A}\bar{B} + A.B + B\bar{B}$

$y = AB + \bar{A}\bar{B}$

A	B	$Y = AB + \bar{A}\bar{B}$
0	0	1
0	1	0
1	0	0
1	1	1

10. Official Ans. by NTA (1)

Sol. (a) Rectifier $\rightarrow$ AC to DC

(b) Stabilizer $\rightarrow$ used for constant output voltage even when input voltage or current change.

(c) Transformer $\rightarrow$ Step - up or step - down ac voltage.

(d) Filter $\rightarrow$ used to remove any ripple in the rectified output voltage.

11. Official Ans. by NTA (4)

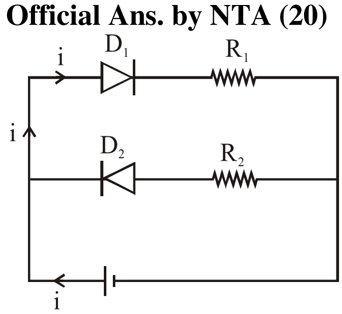
Sol. $\lambda = \frac{hc}{E} = \frac{6.6\times10^{-34}\times3\times10^{8}}{1.9\times1.6\times10^{-19}} = 6.54\times10^{-7}$

= 654 nm

Red color

12. Official Ans. by NTA (20)

Sol.



In this circuit D_1 will be forward bias and D_2 will be revers bias.

$\therefore$ There will be no current through D_2 and R_2

Apply KVL in circuit we get

$+ 6 - 50i - 130i - 120i = 0$

$$i = \frac{6}{300}\text{A} = \frac{6}{300}\times1000\text{mA}$$

$\Rightarrow$ 20 mA

13. Official Ans. by NTA (4)

Sol. According to gates

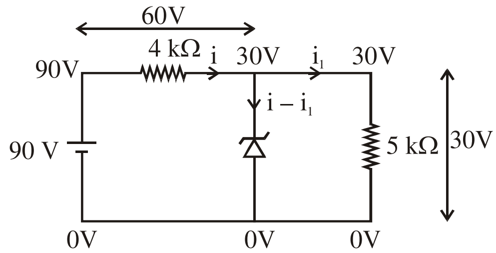
by Demorgan's law

$\overline{\bar{A} + B} = A\,.\,\bar{B}$

By observation.

14. Official Ans. by NTA (9)

Sol.



$$i = \frac{60}{4000}\text{A}$$

$$i_1 = \frac{30}{5000}\text{A}$$

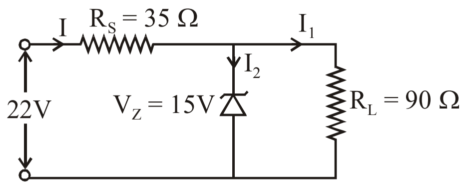
$$i - i_1 = \frac{60}{4000} - \frac{30}{5000} = \frac{9}{1000}\text{A}$$

current from zener diode

$i_Z = i - i_1 = 9\text{mA}$

15. Official Ans. by NTA (5)

Sol.



Voltage across $R_S = 22 - 15 = 7V$

Current through $R_S = I = \frac{7}{35} = \frac{1}{5}$ A

Current through $90\Omega = I_2 = \frac{15}{90} = \frac{1}{6}$ A

Current through zener $= \frac{1}{5} - \frac{1}{6} = \frac{1}{30}$ A

Power through zener diode

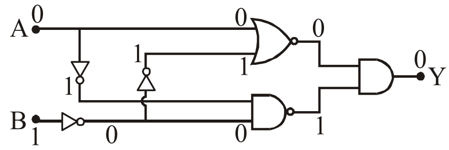
P = VI

$P = 15 \times \frac{1}{30} = 0.5$ watt

$P = 5 \times 10^{-1}$ watt

16. Official Ans. by NTA (0)

Sol.



17. Official Ans. by NTA (1)

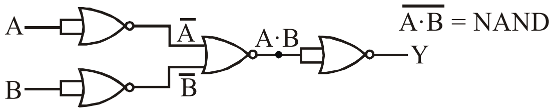
Sol. Truth table for the given logic gate :

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

The truth table is similar to that of a NOR gate.

18. Official Ans. by NTA (2)

Sol. By De Morgan's theorem, we have



19. Official Ans. by NTA (4)

Sol. (4) Conceptual

20. Official Ans. by NTA (100)

Sol. $10^6 = \beta^2 \times \dfrac{R_0}{R_i}$

$10^6 = \beta^2 \times \dfrac{10^4}{10^2}$

$\beta^2 = 10^4 \Rightarrow \beta = 100$

21. Official Ans. by NTA (4)

Sol. $\alpha = \dfrac{I_C}{I_E}, \beta = \dfrac{I_C}{I_B}$

$I_E = I_B + I_C$

$\alpha = \dfrac{I_C}{I_B + I_C} = \dfrac{1}{\dfrac{I_B}{I_C} + 1}$

$\alpha = \dfrac{1}{\dfrac{1}{\beta} + 1}$; $\alpha = \dfrac{\beta}{1+\beta}$

22. Official Ans. by NTA (200)

Sol. $\beta = \dfrac{\Delta I_C}{\Delta I_B} = \dfrac{2\times10^{-3}}{10\times10^{-6}}$

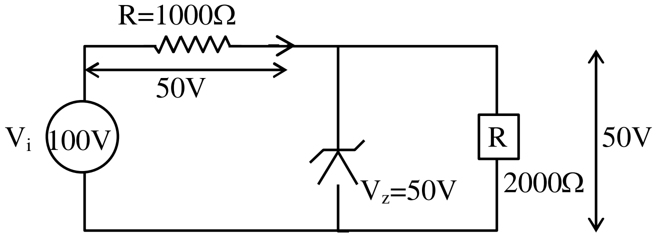
$\beta = \dfrac{1}{5}\times10^3$

$\beta = 2 \times 10^2$

$\beta = 200$

23. Official Ans. by NTA (1)

Sol. $I = \dfrac{50}{1000} = 50\text{mA}$



$I = \dfrac{50}{2000} = 25\text{mA}$

$I_Z = I_{1000} - I_{2000} = 50 - 25 = 25$ mA

24. Official Ans. by NTA (192)

Sol. P = Vi

$0.5 = 8i;\ \ i = \dfrac{1}{16}A$

$E = 20 = 8 + i R_P$

$R_P = 12 \times 16 = 192\Omega$

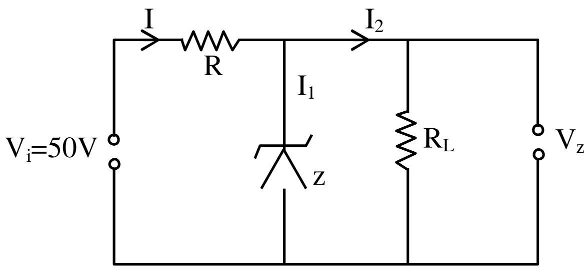
25. Official Ans. by NTA (25)

Sol. $R_d = \dfrac{dV}{di} = \dfrac{1}{\dfrac{di}{dv}} = \dfrac{1}{\dfrac{5-1\times10^{-3}}{0.75-0.65}}$

$\dfrac{100}{4} = 25\Omega$

26. Official Ans. by NTA (500)

Sol.



Voltage across R_L = 5V

$\Rightarrow i_2 = \dfrac{5}{R_L}$

Also voltage across R = 50 – 5 = 45 volt

By v = iR $\Rightarrow R = \dfrac{v}{i} = \dfrac{45}{i_i + i_2}$

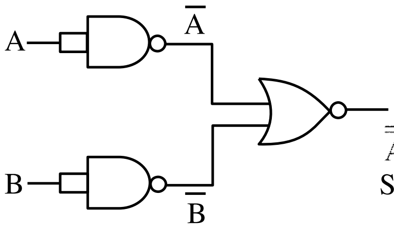
$R = \dfrac{45}{90\text{mA} + \dfrac{5}{R_L}}$

Current in zener diode is maximum when $R_L \to \infty$ ($i_2 \to 0$ and $i_i = i$)

So $R = \dfrac{45}{90\text{mA}} = 500\Omega$

27. Official Ans. by NTA (2)

Sol.



$\overline{\overline{A}+\overline{B}} = A.B$

So AND gate

28. Official Ans. by NTA (5)

Sol. $n_e n_h = n_i^2$

$$n_e = \frac{n_i^2}{n_h} = \frac{(1.5\times10^{16})^2}{4.5\times10^{22}} = \frac{1.5\times1.5\times10^{32}}{4.5\times10^{22}}$$

$5\times10^9\ /m^3$

29. Official Ans. by NTA (25)

Sol. $\beta = \frac{I_C}{I_B} = 24$; $R_C = 1000$

$\Delta V = 0.6$

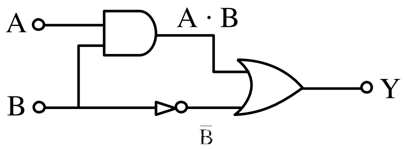
$$I_C = \frac{0.6}{1000}$$

$I_C = 6\times10^{-4}$

$$I_B = \frac{I_C}{\beta} = \frac{6\times10^{-4}}{24} = 25\,\mu A$$

30. Official Ans. by NTA (2)

Sol.



$Y = A\cdot B + \overline{B}$

A	B	Y
0	0	1
0	1	0
1	0	1
1	1	1

31. Official Ans. by NTA (1)

Sol. Band gap = $\frac{hc}{\lambda_0}$

λ_0 ; threshold wavelength

Band gap = $\frac{1242\ ev-nm}{621nm} = 2eV$

32. Official Ans. by NTA (3)

Sol.

A	B	X	Y	Z
1	1	0	0	0
1	0	0	1	0
0	1	1	0	0
0	0	1	1	1

Option (3)

33. Official Ans. by NTA (1)

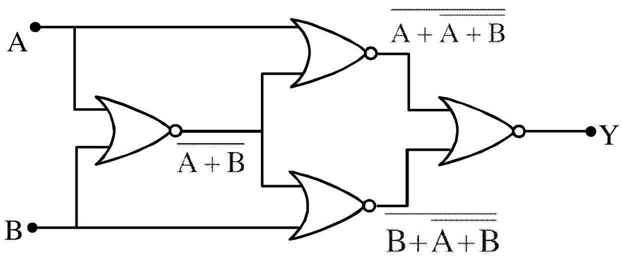
Sol. Pentavalent activities have excess free e^-

So e^- density increases but overall semiconductor is neutral.

Option (1)

34. Official Ans. by NTA (4)

Sol.



$$y = \overline{\overline{(A+\overline{A+B})}+\overline{(B+\overline{A+B})}}$$

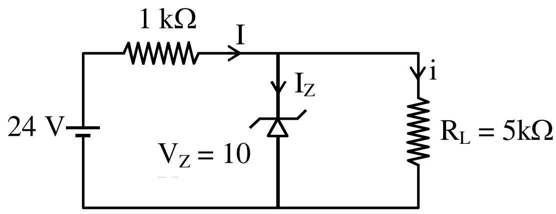
$$y = (A+\overline{A+B}).(B+\overline{A+B})$$

A	B	y
0	0	1
0	1	0
1	0	0
1	1	1

Ans.4

35. Official Ans. by NTA (120)

Sol.



$i = \frac{10V}{5k\Omega} = 2mA$ $\qquad$ $I = \frac{14V}{1k\Omega} = 14mA$

$\therefore I_z = 12mA$

$\therefore P = I_z V_z = 120\ mW$

Ans. 120

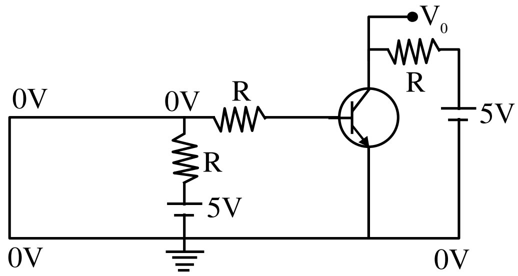
36. Official Ans. by NTA (4)

Sol. Active region of the CE transistor is linear region and is best suited for its use as an amplifier

37. Official Ans. by NTA (5)

Sol. As diodes D_1 and D_2 are in forward bias, so they acted as neligible resistances

$\Rightarrow$ Input voltage become zero



$\Rightarrow$ Input current is zero

$\Rightarrow$ Output current is zero

$\Rightarrow V_0 = 5$ volt

38. Official Ans. by NTA (2)

Sol. $\alpha = \frac{I_C}{I_E}$, $\beta = \frac{I_C}{I_B}$; $I_E = I_C + I_B$

$$\alpha = \frac{I_C}{I_C + I_B} = \frac{I_C / I_B}{\frac{I_C}{I_B} + 1} = \frac{\beta}{\beta + 1} +$$

$$1 + \frac{1}{\beta} = \frac{1}{\alpha} ; \frac{1}{\beta} = \frac{1-\alpha}{\alpha} ; \beta = \frac{\alpha}{1-\alpha}$$

39. Official Ans. by NTA (20)

Sol. When unregulated voltage is 14 V voltage across zener diode must be 10 V So potential difference across resistor $\Delta V_{Rs} = 4V$

and $P_{zener} = 2W$

$VI = 2$

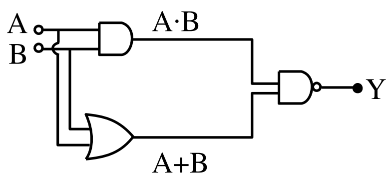
$I = \frac{2}{10} = 0.2$ A

$\Delta V_{Rs} = I R_s$

$4 \times 0.2 R_s \Rightarrow R_s = \frac{40}{2} = 20\Omega$

40. Official Ans. by NTA (3)

Sol.



$$Y = \overline{(A \cdot B) \cdot (A + B)}$$

$Y)_{(0,0)} = 1$

$Y)_{(0,1)} = 1$

$Y)_{(1,0)} = 1$

$Y)_{(1,1)} = 0$ Option (3) is correct

41. Official Ans. by NTA (3)

Official Ans. by ALLEN (1)

Sol. When $V_i > 3$ volt, $V_R > 0$

Because diode will be in forward biased state

When $V_i \le 3$volt ; $V_R = 0$

Because diode will be in reverse biased state.

42. Official Ans. by NTA (2)

Sol. $V_A = 5V \Rightarrow A = 1$

$V_A = 0\ V \Rightarrow A = 0$

$V_B = 5\ V \Rightarrow B = 1$

$V_B = 0\ V \Rightarrow B = 0$

If A = B = 0, there is no potential anywhere here

$V_0 = 0$

If A = 1, B = 0, Diode D_1 is forward biased, here $V_0 = 5V$

If A = 0, B = 1, Diode D_2 is forward biased hence $V_0 = 5V$

If A = 1, B = 1, Both diodes are forward biased hence $V_0 = 5V$

Truth table for Ist

A	B	Output
0	0	0
0	1	1
1	0	1
1	1	1

$\therefore$ Given circuit is OR gate

For IInd circuit

$V_B = 5V$, A = 1

$V_B = 0V$, A = 0

When A = 0, E–B junction is unbiased there is no current through it

$\therefore V_0 = 1$

When A = 1, E–B junction is forward biased

$V_0 = 0$

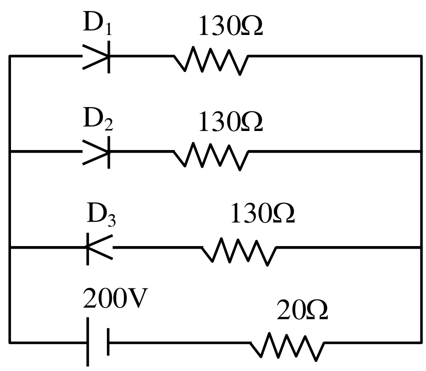
$\therefore$ Hence this circuit is not gate.

43. Official Ans. by NTA (4)

Sol. To convert pulsating dc into steady dc both of mentioned method are correct.

44. Official Ans. by NTA (3)

Sol.

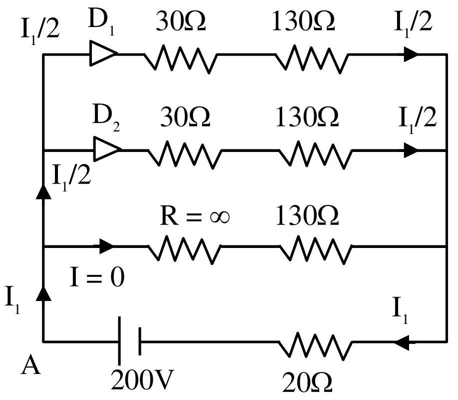


As per diagram,

Diode D_1 & D_2 are in forward bias i.e. R = 30Ω whereas diode D_3 is in reverse bias i.e. R = infinite

⇒ Equivalent circuit will be

Applying KVL starting from point A



$$-\left(\frac{I_1}{2}\right)\times 30-\left(\frac{I_1}{2}\right)\times 130-I_1\times 20+200=0$$

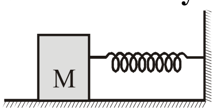
⇒ $-100\,I_1 + 200 = 0$

$I_1 = 2$ Option (3)

SIMPLE HARMONIC MOTION

1. Official Ans. by NTA (2)

Sol.



Momentum of system remains conserved.

$p_i = p_f$

$MA\omega = (m + M)\,A'\omega'$

$$MA\sqrt{\frac{k}{M}} = (m+M)\,A'\sqrt{\frac{k}{m+M}}$$

$$A' = A\sqrt{\frac{M}{M+m}}$$

2. Official Ans. by NTA (2)

Sol. For a particle executing SHM,

$x = A\sin(\omega t+\phi)$

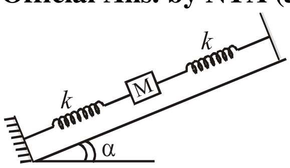
$v = \omega A\cos(\omega t+\phi)$

$\Rightarrow \frac{v^2}{\omega^2A^2}+\frac{x^2}{A^2}=1$ ⇒ equation of ellipse between v and x

Hence option (2)

3. Official Ans. by NTA (3)

Sol.



$K_{eq} = K_1 + K_2 = K + K = 2K$

$$T = 2\pi\sqrt{\frac{m}{K_{eq}}} = 2\pi\sqrt{\frac{m}{2K}}$$

$$f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{2K}{m}}$$ (Option 3) is correct

4. Official Ans. by NTA (3)

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

$2 = 2\pi\sqrt{\frac{2}{g}} \Rightarrow g = 2\pi^2$

5. Official Ans. by NTA (4)

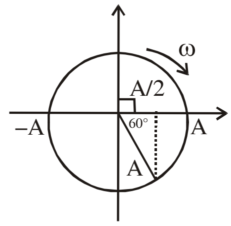
Sol. (4) For parallel combination $k_{eq} = k_1 + k_2$

$k_{eq} = 4k$

$T = 2\pi\sqrt{\frac{m}{k_{eq}}}$

6. Official Ans. by NTA (3)

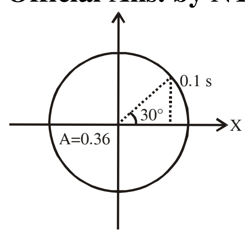
Sol.



initial phase $\frac{\pi}{2}+\frac{\pi}{3}=\frac{5\pi}{6}$

7. Official Ans. by NTA (4)

Sol.



$30° \rightarrow 0.1$ s

$360° \rightarrow 1.2$ s = T

$\omega = \frac{2\pi}{T} = \frac{5\pi}{3}$

At M, $F = m\omega^2A \Rightarrow \frac{F}{m} = \omega^2 A$

8. Official Ans. by NTA (1)

Sol. $\frac{1}{k_{eq}} = \frac{1}{k_1}+\frac{1}{k_2}$

$\frac{1}{k_{eq}} = \frac{1}{k}+\frac{1}{k} \Rightarrow k_{eq} = \frac{k}{2}$

$k' = \frac{k}{2}$

$T = 2\pi\sqrt{\frac{M}{k}}$; $T' = 2\pi\sqrt{\frac{M}{k'}}$

$\Rightarrow T' = 2\pi\sqrt{\frac{M}{k}}\times\sqrt{2}$ $T' = \sqrt{2}T$

9. Official Ans. by NTA (3)

Sol. $v^2 = \omega^2(A^2 - x^2)$

$$\frac{v^2}{\omega^2} + x^2 = A^2$$

$$\frac{v^2}{(\omega A)^2} + \frac{x^2}{A^2} = 1$$

This is an equation of an ellipse.

10. Official Ans. by NTA (2)

Sol. Second pendulum has a time period of 2 sec so statement 1 is false but from one extreme to other it takes only half the time period so statement 2 is true.

11. Official Ans. by NTA (3)

Sol. $V = \omega\sqrt{A^2 - x^2}$ $\qquad V_{max} = A\omega$

$$\frac{A\omega}{2} = \omega\sqrt{A^2 - x^2}$$

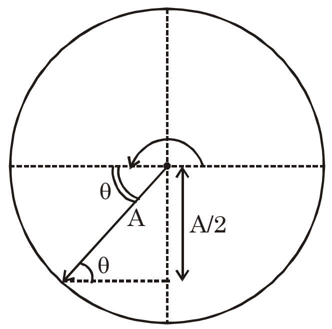
$$\frac{A^2}{4} = A^2 - x^2$$

$$x^2 = \frac{3A^2}{4}$$

$$x = \frac{\sqrt{3}}{2}A$$

12. Official Ans. by NTA (7)

Sol. $\frac{5}{8}$th of oscillation = $\left(\frac{1}{2} + \frac{1}{8}\right)^{th}$ of oscillation



$\pi + \theta = \omega t$

$$\pi + \frac{\pi}{6} = \left(\frac{2\pi}{T}\right)t$$

$$\frac{7\pi}{6} = \left(\frac{2\pi}{T}\right)t \; ; \quad t = \frac{7T}{12}$$

13. Official Ans. by NTA (4)

Sol. When lift is stationary

$$T = 2\pi\sqrt{\frac{L}{g}}$$

When lift is moving upwards

$\Rightarrow$ Pseudo force acts downwards

$\Rightarrow g_{eff} = g + \frac{g}{2} = \frac{3g}{2}$

$\Rightarrow$ New time period

$$T' = 2\pi\sqrt{\frac{L}{g_{eff}}} = 2\pi\sqrt{\frac{2L}{3g}}$$

$$\boxed{T' = \sqrt{\frac{2}{3}}\,T}$$

14. Official Ans. by NTA (3)

Sol. KE = PE

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

$A^2 - x^2 = x^2$

$2x^2 = A^2$

$$x = \pm\frac{A}{\sqrt{2}}$$

15. Official Ans. by NTA (2)

Sol. $T_a = 2\pi\sqrt{\frac{M}{K}}$

$$T_b = 2\pi\sqrt{\frac{M}{K/2}}$$

$$\frac{T_b}{T_a} = \sqrt{2} = \sqrt{x}$$

$\Rightarrow x = 2$

16. Official Ans. by NTA (4)

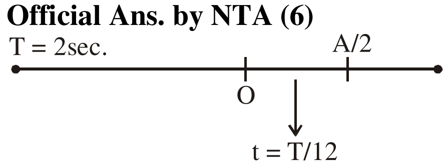
Sol. (4) $A_1\omega_1 = A_2\omega_2$

$$A_1\sqrt{\frac{k_1}{m}} = A_2\sqrt{\frac{k_2}{m}}$$

$$\frac{A_1}{A_2} = \sqrt{\frac{k_2}{k_1}}$$

17. Official Ans. by NTA (6)

Sol.



$$t = \frac{2}{12} = \frac{1}{6}$$

$\therefore$ Correct answer = 6.00

18. Official Ans. by NTA (4)

Sol. Time period $T = \frac{2\pi}{\omega'}$

$$\frac{\pi}{\omega} = \frac{2\pi}{\omega'}$$

$\omega' = 2\omega \rightarrow$ Angular frequency of SHM

Option (3)

$$\sin^2\omega t = \frac{1}{2}(2\sin^2\omega t) = \frac{1}{2}(1 - \cos 2\omega t)$$

Angular frequency of $\left(\frac{1}{2} - \frac{1}{2}\cos 2\omega t\right)$ is 2ω

Option (4)

Angular frequency of SHM

$3\cos\left(\frac{\pi}{4}-2\omega t\right)$ is 2ω.

So option (3) & (4) both have angular frequency 2ω but option (4) is direct answer.

19. Official Ans. by NTA (4)

Sol. $v^2=\omega^2(A^2-x^2)$

$$A^2=x_1^2+\frac{v_1^2}{\omega^2}=x_2^2+\frac{v_2^2}{\omega^2}$$

$$\omega^2=\frac{v_2^2-v_1^2}{x_1^2-x_2^2}$$

$$T=2\pi\sqrt{\frac{x_1^2-x_2^2}{v_2^2-v_1^2}}$$

20. Official Ans. by NTA (4)

Sol. $T_0=2\pi\sqrt{\frac{\ell}{g}}$

New time period T = $=2\pi\sqrt{\frac{\ell/16}{g}}=\frac{2\pi}{4}\sqrt{\frac{\ell}{g}}$

$T=\frac{T_0}{4}$

21. Official Ans. by NTA (4)

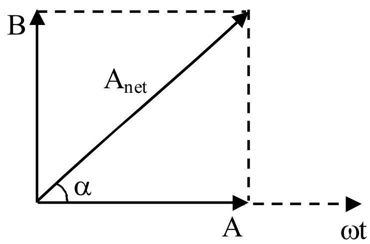
Sol. $x = A\sin\omega t + B\cos\omega t$

$v=\frac{dx}{dt}=A\omega\cos\omega t - B\omega\sin\omega t$

At $t = 0$, $x(0) = B$

$v(0) = A\omega$

$x = A\sin\omega t + B\sin(\omega t + 90°)$



$A_{net}=\sqrt{A^2+B^2}$

$\tan\alpha=\frac{B}{A}\Rightarrow\cot\alpha=\frac{A}{B}$

$\Rightarrow x=\sqrt{A^2+B^2}\sin(\omega t+\alpha)$

$\Rightarrow x=\sqrt{A^2+B^2}\cos(\omega t-(90-\alpha))$

$x = C\cos(\omega t-\phi)$

$\Rightarrow C=\sqrt{A^2+B^2}$

$$C=\sqrt{\frac{[v(0)]^2}{\omega^2}+[x(0)]^2}$$

$\phi=90-\alpha$

$\tan\alpha=\cos\alpha=\frac{A}{B}$

$\Rightarrow \tan\phi=\frac{v(0)}{x(0).\omega}$

$\phi=\tan^{-1}\left(\frac{v(0)}{x(0)\omega}\right)$

22. Official Ans. by NTA (10)

Sol. $\omega=\sqrt{\frac{k_{eq}}{\mu}}$

μ = reduced mass

springs are in series connection

$k_{eq}=\frac{k_1k_2}{k_1+k_2}$

$k_{eq}=\frac{k\times4k}{5k}=\frac{4k}{5}$

$k_{eq}=\frac{4\times20}{5}N/m=16\ N/m$

$\mu=\frac{m_1m_2}{m_1+m_2}=\frac{0.2\times0.8}{0.2+0.8}=0.16\ kg$

$\omega=\sqrt{\frac{16}{0.16}}=\sqrt{100}=10$

23. Official Ans. by NTA (2)

Sol. $K=\frac{1}{2}m\omega^2\left(A^2-x^2\right)$

$=\frac{1}{2}m\omega^2\left(A^2-\frac{A^2}{4}\right)=\frac{1}{2}m\omega^2\left(\frac{3A^2}{4}\right)$

$K=\frac{3}{4}\left(\frac{1}{2}m\omega^2A^2\right)$

24. Official Ans. by NTA (4)

Sol. $E=\frac{1}{2}Ka^2$

$\frac{3E}{4}=\frac{1}{2}K(a^2-y^2)$

$\frac{3}{4}\times\frac{1}{2}Ka^2=\frac{1}{2}K(a^2-y^2)$

$y^2=a^2-\frac{3a^2}{4}$; $y=\frac{a}{2}$

25. Official Ans. by NTA (1)

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

$0.2=2\pi\sqrt{\frac{0.5}{k}}$

$k=50\pi^2\approx500$

$x = A\sin(\omega t+\phi)$

$= 5 \text{ cm} \sin\left(\frac{\omega T}{4}+0\right)$

$= 5 \text{ cm} \sin\left(\frac{\pi}{2}\right) = 5 \text{ cm}$

$PE = \frac{1}{2}kx^2$

$= \frac{1}{2}(500)\left(\frac{5}{100}\right)^2 = 0.6255$

26. Official Ans. by NTA (2)

Sol. $x(t) = A \sin(\omega t + \phi)$

$v(t) = A\omega \cos(\omega t + \phi)$

$2 \quad = A \sin \phi \qquad$ ......(1)

$2\omega \quad = A\omega \cos \phi \qquad$ ......(2)

From (1) and (2)

$\tan \phi = 1$

$\phi = 45°$

Putting value of ϕ in equation (1)

$2 = A\left\{\frac{1}{\sqrt{2}}\right\}$

$A = 2\sqrt{2}$

$x = 2$

27. Official Ans. by NTA (2)

Sol. $x_2 = 5\sqrt{2}\left(\frac{1}{\sqrt{2}}\sin 2\pi t + \frac{1}{\sqrt{2}}\cos 2\pi t\right)\sqrt{2}$

$= 10\sin\left(2\pi t + \frac{\pi}{4}\right)$

$\therefore \frac{A_2}{A_1} = \frac{10}{5} = 2$

Ans. 2

28. Official Ans. by NTA (4)

Sol. Potential energy is maximum at maximum distance from mean.

29. Official Ans. by NTA (1)

Sol. $y_1 = 10 \sin\left(3\pi t + \frac{\pi}{3}\right) \Rightarrow$ Amplitude= 10

$y_2 = 5 (\sin 3\pi t + \sqrt{3} \cos 3\pi t)$

$y_2 = 10\left(\frac{1}{2}\sin 3\pi t + \frac{\sqrt{3}}{2}\cos 3\pi t\right)$

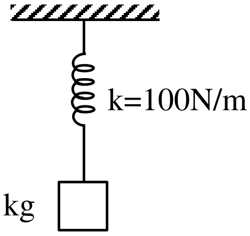
$y_2 = 10\left(\cos\frac{\pi}{3}\sin 3\pi t + \sin\frac{\pi}{3}\cos 3\pi t\right)$

$y_2 = 10 \sin\left(3\pi t + \frac{\pi}{3}\right) \Rightarrow$ Amplitude = 10

So ratio of amplitudes = $\frac{10}{10} = 1$

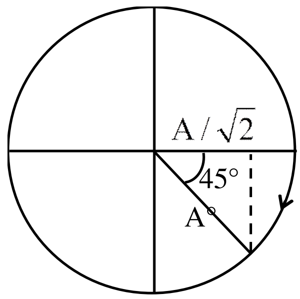
30. Official Ans. by NTA (8)

Sol.



KE = PE

$y = \frac{A}{\sqrt{2}} = A \sin \omega t$



$t = \frac{T}{8} = \frac{T}{x}$

$x = 8$

31. Official Ans. by NTA (4)

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

When bob is immersed in liquid

$mg_{eff} = mg$ – Buoyant force

$mg_{eff} = mg - v\sigma g \qquad (\sigma = \text{density of liquid})$

$= mg - v\frac{\rho}{4}g$

$= mg - \frac{mg}{4} = \frac{3mg}{4}$

$\therefore g_{eff} = \frac{3g}{4}$

$T_1 = 2\pi\sqrt{\frac{\ell_1}{g_{eff}}}$; $\ell_1 = \ell + \frac{\ell}{3} = \frac{4\ell}{3}$, $\ell_{eff} = \frac{3g}{4}$

By solving

$T_1 = \frac{4}{3}2\pi\sqrt{\ell / g}$

$T_1 = \frac{4T}{3}$

32. Official Ans. by NTA (1)

Sol. In S.H.M. total mechanical energy remains constant and also <K.E.> = <P.E> = $\frac{1}{4}KA^2$

(for 1 time period)

33. Official Ans. by NTA (3)

Sol. From potential energy curve

$U_{max} = \frac{1}{2}kA^2 \Rightarrow 10 = \frac{1}{2}k(2)^2$

$\Rightarrow k = 5$

Now $T_{spring} = T_{pendulum}$

$2\pi\sqrt{\frac{5}{5}} = 2\pi\sqrt{\frac{4}{g}}$

$\Rightarrow 1 = \sqrt{\frac{4}{g}} \Rightarrow g = 4$ on planet

Option (3)

UNIT & DIMENSION

1. Official Ans. by NTA (2)

Sol. $\frac{x^2}{\alpha kT} \to$ dimensionless

$\Rightarrow [\alpha] = \frac{[x^2]}{[kT]} = \frac{L^2}{ML^2T^{-2}} = M^{-1}T^2$

Now $[W] = [\alpha][\beta]^2$

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

2. Official Ans. by NTA (2)

Sol. By dimensional analysis.

3. Official Ans. by NTA (1)

Sol. $F = \frac{1}{4\pi\in_0}\frac{e^2}{r^2}$; $E = \frac{hc}{\lambda}$

$\left[\frac{e^2}{4\pi\varepsilon_0}\times\frac{1}{hc}\right] = \frac{Fr^2}{E\lambda} = (M^0L^0T^0)$

4. Official Ans. by NTA (2)

Sol. kT has dimension of energy

$\frac{\beta x^2}{kT}$ is dimensionless

$[\beta][L^2] = [ML^2T^{-2}]$

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

$\alpha^2\beta$ has dimensions of work

$[\alpha^2][MT^{-2}] = [ML^2T^{-2}]$

$[\alpha] = [M^0LT^0]$

Ans. 2

5. Official Ans. by NTA (4)

Sol. $\lambda = \frac{C}{V} = \frac{Q/V}{V} = \frac{Q}{V^2}$

$V = \frac{\text{work}}{Q}$

$\lambda = \frac{Q^3}{(\text{work})^2} = \frac{(It)^3}{(F.s)^2}$

$= \frac{[I^3T^3]}{[ML^2T^{-2}]^2} = [M^{-2}L^{-4}I^3T^7]$

6. Official Ans. by NTA (4)

Sol. $m \propto t^a v^b \ell^c$

$m \propto [T]^a[LT^{-1}]^b[ML^2T^{-1}]^c$

$M^1L^0T^0 = M^cL^{b+2c}T^{a-b-c}$

comparing powers

c = 1, b = –2, a = –1

$m \propto t^{-1}v^{-2}\ell^1$

7. Official Ans. by NTA (2)

Sol. $[A] = [MLT^{-2}]$

$[B] = [L^{-1}]$

$[D] = [T^{-1}]$

$\left[\frac{AD}{B}\right] = \frac{[MLT^{-2}][T^{-1}]}{[L^{-1}]}$

$\left[\frac{AD}{B}\right] = [ML^2T^{-3}]$

8. Official Ans. by NTA (4)

Sol. $E = ML^2T^{-2}$

$L = ML^2T^{-1}$

$m = M$

$G = M^{-1}L^{+3}T^{-2}$

$P = \frac{EL^2}{M^5G^2}$

$[P] = \frac{(ML^2T^{-2})(M^2L^4T^{-2})}{M^5(M^{-2}L^6T^{-4})} = M^0L^0T^0$

Option (4)

9. Official Ans. by NTA (4)

Sol. (a) Magnetic Induction = $MT^{-2}A^{-1}$

(b) Magnetic Flux = $ML^2T^{-2}A^{-1}$

(c) Magnetic Permeability = $MLT^{-2}A^{-2}$

(d) Magnetization = $M^0L^{-1}A$

Ans. 4

10. Official Ans. by NTA (3)

Sol. $[\mu_r] = 1$ as $\mu_r = \frac{\mu}{\mu_m}$

[power factor $(\cos\phi)$] = 1

$\mu_0 = \frac{B_0}{H}$ (unit = NA^{-2}) : Not dimensionless

$[\mu_0] = [MLT^{-2}A^{-2}]$

quality factor (Q) = $\frac{\text{Energy stored}}{\text{Energy dissipated per cycle}}$

So Q is unitless & dimensionless.

11. Official Ans. by NTA (1)

Sol. Unit of $\frac{E}{H}$ is $\frac{\text{volt / metre}}{\text{Ampere / metre}}$

$= \frac{\text{volt}}{\text{Ampere}}$ = ohm

12. Official Ans. by NTA (2)

Sol. SI unit of Rydberg const. = m^{-1}

SI unit of Plank's const. = $kg\ m^2s^{-1}$

SI unit of Magnetic field energy density= $kg\ m^{-1}s^{-2}$

SI unit of coeff. of viscosity = $kg\ m^{-1}s^{-1}$

13. Official Ans. by NTA (1)

Sol. Density = $[F^aL^bT^c]$

$[ML^{-3}] = [M^aL^aT^{-2a}L^bT^c]$

$[M^1L^{-3}] = [M^aL^{a+b}T^{-2a+c}]$

$a = 1;\ a + b = -3;\ -2a + c = 0$

$1 + b = -3 \quad c = 2a$

$b = -4 \quad c = 2$

So, density = $[F^1L^{-4}T^2]$

14. Official Ans. by NTA (1)

Sol. torque $\tau \rightarrow ML^2T^{-2}$ (III)

Impulse $I \Rightarrow MLT^{-1}$ (I)

Tension force $\Rightarrow MLT^{-2}$ (IV)

Surface tension $\Rightarrow MT^{-2}$ (II)

Option (1)

15. Official Ans. by NTA (1)

Sol. (i) $\frac{\pi pa^4}{8\eta L} = \frac{dv}{dt}$ = Volumetric flow rate (poiseuille's law)

(ii) $h\rho g = \frac{2s}{r}\cos\theta$

(iii) RHS $\Rightarrow \varepsilon \times \frac{1}{4\pi\varepsilon_0}\frac{a}{r^2}\times\frac{1}{\varepsilon} = \frac{q}{t}\times\frac{1}{r^2}$

$= \frac{I}{L^2} = IL^{-2}$

LHS

$T = \frac{I}{A} = IL^{-2}$

(iv) $W = \tau\theta$

Option (1)

16. Official Ans. by NTA (2)

Sol. $[M] = K[F]^a\ [T]^b\ [V]^c$

$[M^1] = [M^1L^1T^{-2}]^a\ [T^1]^b\ [L^1T^{-1}]^c$

$a = 1, b = 1, c = -1$

$\therefore [M] = [FTV^{-1}]$

VECTORS, BASIC MATHS & CALCULUS

1. Official Ans. by NTA (2)

Sol. $i = 20t + 8t^2$

$i = \frac{dq}{dt} \Rightarrow \int dq = \int idt$

$\Rightarrow q = \int_0^{15}(20t + 8t^2)dt$

$q = \left(\frac{20t^2}{2} + \frac{8t^3}{3}\right)_0^{15}$

$q = 10 \times (15)^2 + \frac{8(15)^3}{3}$

$q = 2250 + 9000$

$q = 11250$ C

2. Official Ans. by NTA (2)

Sol. We know,

$\because \overrightarrow{OA} + \overrightarrow{OB} + \overrightarrow{OC} + \overrightarrow{OD} + \overrightarrow{OE} + \overrightarrow{OF} + \overrightarrow{OG} + \overrightarrow{OH} = \vec{0}$

By triangle law of vector addition, we can write

$\overrightarrow{AB} = \overrightarrow{AO} + \overrightarrow{OB}\ ;\ \overrightarrow{AC} = \overrightarrow{AO} + \overrightarrow{OC}$

$\overrightarrow{AD} = \overrightarrow{AO} + \overrightarrow{OD}\ ;\ \overrightarrow{AE} = \overrightarrow{AO} + \overrightarrow{OE}$

$\overrightarrow{AF} = \overrightarrow{AO} + \overrightarrow{OF}\ ;\ \overrightarrow{AG} = \overrightarrow{AO} + \overrightarrow{OG}$

$\overrightarrow{AH} = \overrightarrow{AO} + \overrightarrow{OH}$

Now

$\overrightarrow{AB} + \overrightarrow{AC} + \overrightarrow{AD} + \overrightarrow{AE} + \overrightarrow{AF} + \overrightarrow{AG} + \overrightarrow{AH}$

$= (7\ \overrightarrow{AO}) + \overrightarrow{OB} + \overrightarrow{OC} + \overrightarrow{OD} + \overrightarrow{OE} + \overrightarrow{OF} + \overrightarrow{OG} + \overrightarrow{OH}$

$= (7\ \overrightarrow{AO}) + \vec{0} - \overrightarrow{OA}$

$= (7\ \overrightarrow{AO}) + \overrightarrow{AO}$

$= 8\overrightarrow{AO} = 8(2\hat{i} + 3\hat{j} - 4\hat{k})$

$= 16\hat{i} + 24\hat{j} - 32\hat{k}$

3. Official Ans. by NTA (4)

Sol. $\vec{A}\cdot\vec{B} = |\vec{A}\times\vec{B}|$

$AB\cos\theta = AB\sin\theta \Rightarrow \theta = 45°$

$|\vec{A} - \vec{B}| = \sqrt{A^2 + B^2 - 2AB\cos 45°}$

$= \sqrt{A^2 + B^2 - \sqrt{2}AB}$

Hence option (4).

4. Official Ans. by NTA (4)

Sol. $|\vec{P}| = |\vec{Q}| = x$ …(i)

$|\vec{P} + \vec{Q}| = n|\vec{P} - \vec{Q}|$

$\mathbf{P^2 + Q^2 + 2PQ\cos\theta = n^2(P^2 + Q^2 - 2PQ\cos\theta)}$

Using (i) in above equation

$\cos\theta = \frac{n^2 - 1}{1 + n^2}$

$\theta = \cos^{-1}\left(\frac{n^2 - 1}{n^2 + 1}\right)$

5. Official Ans. by NTA (4)

Sol. $(A\cos\theta)\hat{B} = A\left(\frac{\vec{A}.\vec{B}}{AB}\right)\hat{B} = \frac{\vec{A}.\vec{B}}{B}\hat{B}$

$= \frac{2}{\sqrt{2}}\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right) = \hat{i}+\hat{j}$

6. Official Ans. by NTA (3)

Sol. Direction of P $\hat{v}_1 = \pm\frac{\vec{A}\times\vec{B}}{|\vec{A}\times\vec{B}|} = \pm\frac{\hat{i}-\hat{j}+\hat{k}}{\sqrt{3}}$

Direction of Q $\hat{v}_2 = \pm\frac{\vec{A}\times\vec{C}}{|\vec{A}\times\vec{C}|} = \pm\frac{2\hat{k}}{2} = \pm\hat{k}$

Angle between $\hat{v}_1$ and $\hat{v}_2$

$\frac{\hat{v}_1.\hat{v}_2}{|\hat{v}_1||\hat{v}_2|} = \frac{\pm 1/\sqrt{3}}{(1)(1)} = \pm\frac{1}{\sqrt{3}}$

$\Rightarrow x = 3$

7. Official Ans. by NTA (2)

Sol. (a) $\vec{C} = \vec{A}+\vec{B}$

Option (iv)

(b) $\vec{A} = \vec{B}+\vec{C} = \vec{C}+\vec{B}$

Option (iii)

(c) $\vec{B} = \vec{A}+\vec{C}$

Option (i)

(d) $\vec{A}+\vec{B}+\vec{C} = 0$

Option (ii)

8. Official Ans. by NTA (2)

Sol. Given X = Y

$\sqrt{X^2+Y^2-2\times Y\cos\theta}$

$= n\sqrt{X^2+Y^2+2\times Y\cos\theta}$

Square both sides

$2X^2(1-\cos\theta) = n^2.2X^2(1+\cos\theta)$

$1 - \cos\theta = n^2 + n^2\cos\theta$

$\cos\theta = \frac{1-n^2}{1+n^2}$

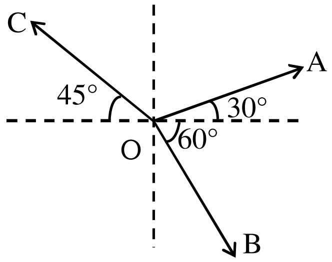
$\theta = \cos^{-1}\left[\frac{n^2-1}{-n^2-1}\right]$

9. Official Ans. by NTA (4)

Sol. Polygon law is applicable in both but the equation given in the reason is not useful in explaining the assertion.

10. Official Ans. by NTA (1)

Sol.



Let magnitude be equal to λ.

$\overline{OA} = \lambda\left[\cos 30°\hat{i}+\sin 30\hat{j}\right] = \lambda\left[\frac{\sqrt{3}}{2}\hat{i}+\frac{1}{2}\hat{j}\right]$

$\overline{OB} = \lambda\left[\cos 60°\hat{i}-\sin 60\hat{j}\right] = \lambda\left[\frac{1}{2}\hat{i}-\frac{\sqrt{3}}{2}\hat{j}\right]$

$\overline{OC} = \lambda\left[\cos 45°\left(-\hat{i}\right)+\sin 45\hat{j}\right] = \lambda\left[-\frac{1}{\sqrt{2}}\hat{i}+\frac{1}{\sqrt{2}}\hat{j}\right]$

$\therefore \overline{OA}+\overline{OB}-\overline{OC}$

$= \lambda\left[\left(\frac{\sqrt{3}+1}{2}+\frac{1}{\sqrt{2}}\right)\hat{i}+\left(\frac{1}{2}-\frac{\sqrt{3}}{2}-\frac{1}{\sqrt{2}}\right)\hat{j}\right]$

$\therefore$ Angle with x-axis

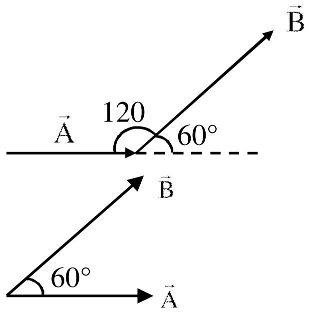
$\tan^{-1}\left[\frac{\frac{1}{2}-\frac{\sqrt{3}}{2}-\frac{1}{\sqrt{2}}}{\frac{\sqrt{3}}{2}+\frac{1}{2}+\frac{1}{\sqrt{2}}}\right] = \tan^{-1}\left[\frac{\sqrt{2}-\sqrt{6}-2}{\sqrt{6}+\sqrt{2}+2}\right]$

$= \tan^{-1}\left[\frac{1-\sqrt{3}-\sqrt{2}}{\sqrt{3}+1+\sqrt{2}}\right]$

Hence option (1)

11. Official Ans. by NTA (3)

Sol.



Angle between $\vec{A}$ and $\vec{B}$, $\theta = 60°$

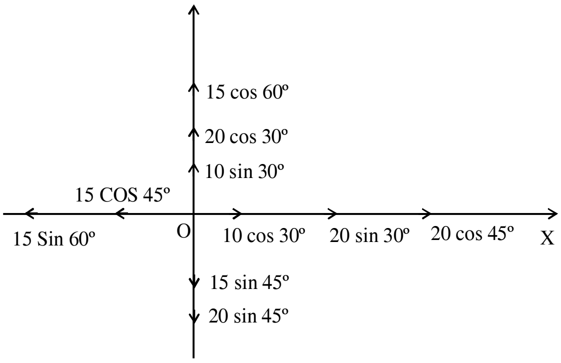
Angle betwenn $\vec{A}$ and $\vec{A}-\vec{B}$

$\tan\alpha = \frac{B\sin\theta}{A-B\cos\theta} = \frac{B\sqrt{\frac{3}{2}}}{A-B\times\frac{1}{2}2}$

$\tan\alpha = \frac{\sqrt{3}B}{2A-B}$ Ans 3

12. Official Ans. by NTA (1)

Sol.



$$\vec{F}_x = \left(10\times\frac{\sqrt{3}}{2}+20\left(\frac{1}{2}\right)+20\left(\frac{1}{\sqrt{2}}\right)-15\left(\frac{1}{\sqrt{2}}\right)-15\left(\frac{\sqrt{3}}{2}\right)\right)\hat{i}$$

$= 9.25\ \hat{i}$

$$\vec{F}_y = \left(15\left(\frac{1}{2}\right)+20\left(\frac{\sqrt{3}}{2}\right)+10\left(\frac{1}{2}\right)-15\left(\frac{1}{\sqrt{2}}\right)-20\left(\frac{1}{\sqrt{2}}\right)\right)\hat{j}$$

$= 5\,\hat{j}$

13. Official Ans. by NTA (2)

Sol. $\vec{A} = \vec{P}+\vec{Q}$

$\vec{B} = \vec{P}-\vec{Q}$ $\qquad\qquad \vec{P}\perp\vec{Q}$

$|\vec{A}| = |\vec{B}| = \sqrt{P^2+Q^2}$

$|\vec{A}+\vec{B}| = \sqrt{2(P^2+Q^2)(1+\cos\theta)}$

For $|\vec{A}+\vec{B}| = \sqrt{3(P^2+Q^2)}$

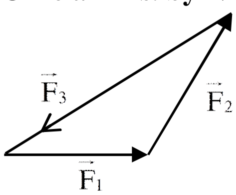
$\theta_1 = 60°$

For $|\vec{A}+\vec{B}| = \sqrt{2(P^2+Q^2)}$

$\theta_2 = 90°$

14. Official Ans. by NTA (4)

Sol.



Here $\vec{F}_1+\vec{F}_2+\vec{F}_3 = 0$

$\vec{F}_1+\vec{F}_2 = -\vec{F}_3$

Since $\vec{F}_{net} = 0$ (equilibrium)

Both statements correct

WORK POWER ENERGY

1. Official Ans. by NTA (5)

Sol. Let the speed of bob at lowest position be v_1 and at the highest position be v_2.

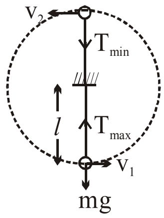
Maximum tension is at lowest position and minimum tension is at the highest position.

Now, using, conservation of mechanical energy,

$$\frac{1}{2}mv_1^2 = \frac{1}{2}mv_2^2 + mg\,2l$$

$\Rightarrow v_1^2 = v_2^2 + 4gl$ ... (1)

Now $T_{max} - mg = \frac{mv_1^2}{l}$



$\Rightarrow T_{max} = mg + \frac{mv_1^2}{l}$

& $T_{min} + mg = \frac{mv_2^2}{l}$

$\Rightarrow T_{min} = \frac{mv_2^2}{l} - mg$

$\frac{T_{max}}{T_{min}} = \frac{5}{1}$

$$\Rightarrow \frac{mg+\frac{mv_1^2}{l}}{\frac{mv_2^2}{l}-mg} = \frac{5}{1}$$

$$\Rightarrow mg+\frac{mv_1^2}{l} = \left[\frac{mv_2^2}{l}-mg\right]5$$

$$\Rightarrow mg+\frac{m}{l}\left[v_2^2+4gl\right] = \frac{5mv_2^2}{l}-5mg$$

$$\Rightarrow mg+\frac{mv_2^2}{l}+4mg = \frac{5mv_2^2}{l}-5mg$$

$$\Rightarrow 10mg = \frac{4mv_2^2}{l}$$

$$v_2^2 = \frac{10\times10\times1}{4}$$

$\Rightarrow v_2^2 = 25 \Rightarrow v_2 = 5$ m/s

Thus, velocity of bob at highest position is 5 m/s.

2. Official Ans. by NTA (1)

Sol. For equilibrium

$\frac{dU}{dr} = 0$

$\frac{-10\alpha}{r^{11}} + \frac{5\beta}{r^6} = 0$

$\frac{5\beta}{r^6} = \frac{10\alpha}{r^{11}}$

$r^5 = \frac{2\alpha}{\beta}$; $r = \left(\frac{2\alpha}{\beta}\right)^{\frac{1}{5}}$

a = 1

3. Official Ans. by NTA (2)

Sol. P = C

FV = C

$M\frac{dV}{dt}V = C$

$\frac{V^2}{2} \propto t$

$V \propto t^{1/2}$

$\frac{dx}{dt} \propto t^{1/2}$ $\qquad x \propto t^{3/2}$

4. Official Ans. by NTA (10)

Sol. Using work energy theorem,

$W_g = \Delta K.E.$

$(10)\,(g)\,(5) = \frac{1}{2}(10)v^2 - 0$

$v = 10$ m/s

5. Official Ans. by NTA (6)

Sol. Let's say the compression in the spring by : y.

So, by work energy theorem we have

$\Rightarrow \frac{1}{2}mv^2 = \frac{1}{2}ky^2$

$\Rightarrow y = \sqrt{\frac{m}{k}} \cdot v$

$\Rightarrow y = \sqrt{\frac{4}{100}} \times 10$

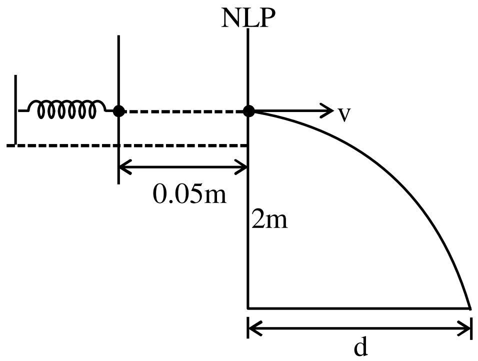
$\Rightarrow y = 2m$

$\Rightarrow$ final length of spring

$= 8 - 2 = 6m$

6. Official Ans. by NTA (1)

Sol.



$\frac{1}{2}kx^2 = \frac{1}{2}mv^2$

$Kx^2 = mv^2$

$v = x\sqrt{\frac{k}{m}} = 0.05\sqrt{\frac{100}{0.1}} = 0.05 \times 10\sqrt{10}$

$v = 0.5\sqrt{10}$

From $h = \frac{1}{2}gt^2$

$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 2}{10}} = \frac{2}{\sqrt{10}}$

$\therefore d = vt = 0.5\sqrt{10} \times \frac{2}{\sqrt{10}} = 1m$

7. Official Ans. by NTA (1)

Sol. $K_2 = 4K_1$

$\frac{1}{2}mv_2^2 = 4\frac{1}{2}mv_1^2$

$v_2 = 2v_1$

$P = mv$

$P_2 = mv_2 = 2mv_1$

$P_1 = mv_1$

% change

$= \frac{\Delta P}{P_1} \times 100 = \frac{2mv_1 - mv_1}{mv_1} \times 100 = 100\%$

8. Official Ans. by NTA (1)

Sol. P = constant

$\frac{1}{2}mv^2 = Pt$

$\Rightarrow v \propto \sqrt{t}$

$\frac{dx}{dt} = C\sqrt{t}$ C = constant

by integration.

$x = C\frac{t^{\frac{1}{2}+1}}{\frac{1}{2}+1}$

$x \propto t^{3/2}$

9. Official Ans. by NTA (2)

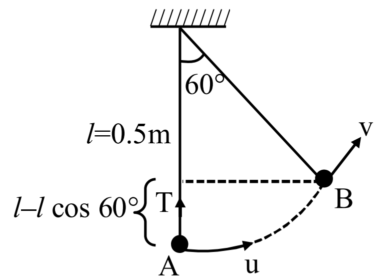
Sol. $W_{Porter} + W_{mg} = \Delta K.E. = 0$

$W_{Porter} = -W_{mg} = -mgh$

$= -80 \times 9.8 \times .8 = -627.2$ J

10. Official Ans. by NTA (2)

Sol.



Applying work energy theorem :

$w_g + w_T = \Delta K$

$-mgl(1-\cos 60^\circ) = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$v^2 = u^2 - 2gl(1-\cos 60^\circ)$

$v^2 = 9 - 2 \times 10 \times 0.5\left(\frac{1}{2}\right)$

$v^2 = 4$

$v = 2$ m/s

11. Official Ans. by NTA (450)

Sol. $F = (5y + 20)\hat{j}$

$\omega = \int F dy = \int_0^{10}(5y + 20)dy$

$= \left(\frac{5y^2}{2} + 20y\right)_0^{10}$

$= \frac{5}{2} \times 100 + 20 \times 10$

$= 250 + 200 = 450$ J

12. Official Ans. by NTA (2)

Sol. $E_{mech.} = 8J$

(A) at $x > x_4$, U = constant = 6J

$K = E_{mech.} - U = 2J$ = constant

(B) at $x < x_1$, U = constant = 8J

$K = E_{mech.} - U = 8 - 8 = 0$ J

Particle is at rest.

(C) At $x = x_2$, $U = 0 \Rightarrow E_{mech.} = K = 8$ J

KE is greatest, and particle is moving at fastest speed.

(D) At $x = x_3$, $U = 4$ J

$U + K = 8$ J

$K = 4$ J

13. Official Ans. by NTA (4)

Sol. P = const.

$$P = Fv = \frac{mv^2 dv}{dx}$$

$$\int_0^x \frac{P}{m}dx = \int_0^v v^2 dv \; ; \; \frac{Px}{m} = \frac{v^3}{3}$$

$$\left(\frac{3Px}{m}\right)^{1/3} = v = \frac{dx}{dt}$$

$$\left(\frac{3P}{m}\right)^{1/3} \int_0^t dt = \int_0^x x^{-1/3}dx \Rightarrow x = \left(\frac{8P}{9m}\right)^{1/2} t^{3/2}$$

14. Official Ans. by NTA (2)

Sol. Given, m = 0.5 kg and u = 20 m/s

Initial kinetic energy (k_i) = $\frac{1}{2}mu^2$

$= \frac{1}{2} \times 0.5 \times 20 \times 20 = 100$ J

After deflection it moves with 5% of k_i

$\therefore k_f = \frac{5}{100} \times k_i \Rightarrow \frac{5}{100} \times 100 \Rightarrow k_f = 5$ J

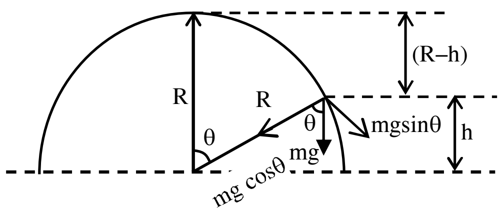
Now, let the final speed be 'v' m/s, then :

$k_f = 5 = \frac{1}{2}mv^2$

$\Rightarrow v^2 = 20 \Rightarrow v = \sqrt{20} = 4.47$ m/s

15. Official Ans. by NTA (2)

Sol.



$$mg\cos\theta = \frac{mv^2}{R} \quad ....(1)$$

$$\cos\theta = \frac{h}{R}$$

Energy conservation

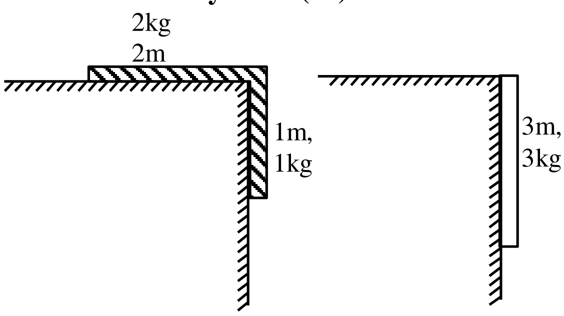
$$mg\{R - h\} = \frac{1}{2}mv^2 \quad ....(2)$$

from (1) & (2) $\Rightarrow mg\left\{\frac{h}{R}\right\} = \frac{2mg\{R-h\}}{R}$

$$h = \frac{2R}{3} = 2m$$

16. Official Ans. by NTA (40)

Sol.



From energy conservation

$K_i + U_i = k_f + U_f$

$$0 + \left(-1 \times 10 \times \frac{1}{2}\right) = k_f + \left(-3 \times 10 \times \frac{3}{2}\right)$$

$-5 = k_f - 45$; $k_f = 40$ J

Ans. 40.00

17. Official Ans. by NTA (2)

Sol. Given $W_A = W_B$

$F_A d\cos 45° = F_B d\cos 60°$

$$F_A \times \frac{1}{\sqrt{2}} = F_B \times \frac{1}{2}$$

$$\frac{F_A}{F_B} = \frac{\sqrt{2}}{2} = \frac{1}{\sqrt{2}}$$

$\boxed{x = 2}$

18. Official Ans. by NTA (1)

Sol. Work done = Change in kinetic energy

$$W_{mg} + W_{air\text{-}friction} = \frac{1}{2}m\left(.8\sqrt{gh}\right)^2 - \frac{1}{2}m(0)^2$$

$$W_{air-friction} = \frac{.64}{2}mgh - mgh = -0.68mgh$$

Option (1)

19. Official Ans. by NTA (16)

Sol. Work = ΔK.E.

$$W_{friction} + W_{spring} = 0 - \frac{1}{2}mv^2$$

$$-\frac{90}{100}\left(\frac{1}{2}mv^2\right) + W_{Spring} = -\frac{1}{2}mv^2$$

$$W_{spring} = -\frac{10}{100} \times \frac{1}{2}mv^2 \; ; \; -\frac{1}{2}kx^2 = -\frac{1}{20}mv^2$$

$$\Rightarrow k = \frac{40000 \times (20)^2}{10 \times (1)^2} = 16 \times 10^5$$

WAVE MOTION

1. Official Ans. by NTA (1)

Sol. $y = F(x, t)$

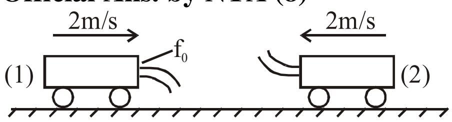
For travelling wave y should be linear function of x and t and they must exist as $(x \pm vt)$

$y = A\sin(15x - 2t) \rightarrow$ linear function in x and t

Option (1) is correct.

2. Official Ans. by NTA (8)

Sol.



Frequency of sound heard by car-1, which comes by reflection from car-2

$$f_1 = f_0\left(\frac{340+2}{340-2}\right)\left(\frac{340+2}{340-2}\right) = f_0\left(\frac{342}{338}\right)^2$$

Frequency of sound coming directly from car-2

$$f_2 = f_0\left(\frac{340+2}{340-2}\right)$$

$$\therefore\ f_1 - f_2 = f_0\left(\frac{342}{338}\right)\left(\frac{342}{338} - 1\right) = 8.09 \simeq 8$$

3. Official Ans. by NTA (4)

Sol. d = 6cm, f = 504, v = 336 m/s

e = 0.3d

$l + e = \frac{\lambda}{4} = \frac{V}{4f}$

$l = 16.66 - 0.3 \times 6$

$l = 14.866$ cm

$l = 14.8$ cm

4. Official Ans. by NTA (2)

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

$\frac{\Delta V}{V} = \frac{1}{2}\frac{\Delta T}{T}$

5. Official Ans. by NTA (1215)

Sol. $\mu = 0.135$ gm/cm $= 0.0135$ kg/m

$y = -0.21 \sin(x + 30t)$

(x in meter & t in sec)

$v = \frac{\omega}{k} = \frac{30}{1} = 30\text{m/s}$

$v = \sqrt{\frac{T}{\mu}} \Rightarrow T = v^2\mu = (30)^2\,(0.0135)$

$= 12.15$

$= x \times 10^{-2}$ N $\Rightarrow x = 1215$

6. Official Ans. by NTA (3)

Sol. Initially beat frequency = 5 Hz

so, $\rho_A = 340 \pm 5 = 345$ Hz, or 335 Hz

after filing frequency increases slightly

so, new value of frequency of A $> \rho_A$

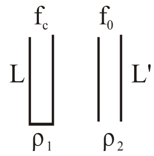
Now, beat frequency = 2Hz

$\Rightarrow$ new $\rho_A = 340 \pm 2 = 342$ Hz, or 338 Hz

hence, original frequency of A is $\rho_A = 335$ Hz

7. Official Ans. by NTA (4)

Sol. **Ans. (4)**



$f_c = f_0$

$\frac{3V_C}{4L} = \frac{2V_0}{2L'}$

$\frac{3V_C}{4L} = \frac{V_0}{L'}$

$L' = \frac{4L}{3}\frac{V_0}{V_C} = \frac{4L}{3}\sqrt{\frac{B.\rho_1}{\rho_2.B}}$ (B is bulk modulus)

$= \frac{4L}{3}\sqrt{\frac{\rho_1}{\rho_2}}$ x = 4

8. Official Ans. by NTA (4)

Sol. (4) $\omega = 2\pi f$

$= 1.5 \times 10^3$

$A = \frac{6}{2} = 3$ cm $= 0.03$ m

9. Official Ans. by NTA (2)

Sol. At t = 0, $y = \frac{1}{1+x^2}$

At time t = t, $y = \frac{1}{1+(x-vt)^2}$

At t = 1, $y = \frac{1}{1+(x-v)^2}$ … (i)

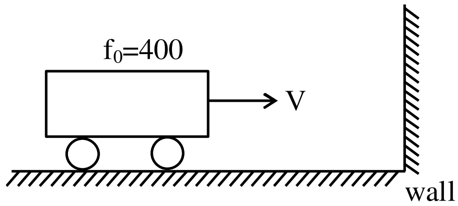
At t = 1, $y = \frac{1}{1+(x-2)^2}$ … (ii)

Comparing (i) & (ii)

v = 2m/s

10. Official Ans. by NTA (132)

Sol.



Wall as an observer

Frequency received by wall

$$f_1 = f_0\left(\frac{C}{C-V}\right)$$

Again wall as a source

Frequency received by observer on car

$$f_2 = f_1\left(\frac{C+V}{C}\right)$$

$$f_2 = f_0\left(\frac{C+V}{C-V}\right);\quad 500 = 400\left(\frac{C+V}{C-V}\right)$$

$$\frac{5}{4}=\frac{C+V}{C-V}$$

$C = 9V$

$$V=\frac{C}{9}=\frac{330}{9}\,m/s$$

$$V=\frac{330}{9}\times\frac{18}{5}=132 km/hr$$

11. Official Ans. by NTA (1)

Sol. $f=f_0\sqrt{\frac{1+\beta}{1-\beta}}$; $\beta=\frac{v}{c}$

$$\frac{f}{f_0}\sqrt{\frac{1+\beta}{1-\beta}}$$

$$\left(1+\frac{\Delta f}{f_0}\right)^2=(1+\beta)(1-\beta)^{-1}$$

β is small compared to 1

$$\left(1+\frac{2\Delta f}{f_0}\right)=(1+2\beta)$$

$$\beta=\frac{\Delta f}{f_0}=\frac{v}{c}$$

$$v=6\times\frac{c}{5890}=305.6\text{ km/s}$$

12. Official Ans. by NTA (2025)

Sol.

$$f'=f\left(\frac{C-V_0}{C+V_s}\right)$$

$$1800=f\left(\frac{340-20}{340+20}\right)$$

f = 2025 Hz

Ans. 2025

13. Official Ans. by NTA (1)

Sol. For node

$$\cos\left(1.57cm^{-1}\right)x=0$$

$$\left(1.57cm^{-1}\right)x=\frac{\pi}{2}$$

$$x=\frac{\pi}{2(1.57)}cm=1cm$$

Ans. 1.00

14. Official Ans. by NTA (7)

Sol. $y_1 = A_1\sin k(x - vt)$

$y_1 = 12 \sin 6.28 (x - vt)$

$y_2 = 5 \sin 6.28 (x - vt + 3.5)$

$$\Delta\phi=\frac{2\pi}{\lambda}(\Delta x)$$

$= K(\Delta x)$

$$= 6.28\times 3.5=\frac{7}{2}\times 2\pi=7\pi$$

$$A_{net}=\sqrt{A_1^2+A_2^2+2A_1A_2\cos\phi}$$

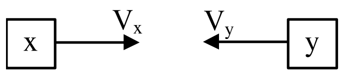
$$A_{net}=\sqrt{(12)^2+(5)^2+2(12)(5)\cos(7\pi)}$$

$$=\sqrt{144+25-120}$$

Ans. 7

15. Official Ans. by NTA (1210)

Sol.



V_x = 36 km/hr = 10 m/s

V_y = 72 km/hr = 20 m/s

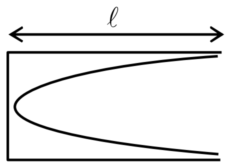
by doppler's effect

$$F'=F_0\left(\frac{V\pm V_0}{V\pm V_s}\right)$$

$$1320=F_0\left(\frac{340+20}{340-10}\right)\Rightarrow F_0 = 1210\text{ Hz}$$

16. Official Ans. by NTA (34)

Sol.



$$\frac{\lambda}{4}=\ell\Rightarrow\lambda=4\ell$$

$$f=\frac{V}{\lambda}=\frac{V}{4\ell}$$

$$\Rightarrow 250=\frac{340}{4\ell}$$

$$\Rightarrow\ \ell=\frac{34}{4\times 25}=0.34m$$

$\ell = 34cm$

17. Official Ans. by NTA (10)

Sol. $\mu=9.0\times10^{-4}\frac{kg}{m}$

T = 900 N

$$V=\sqrt{\frac{T}{\mu}}=\sqrt{\frac{900}{9\times10^{-4}}}=1000m/s$$

f_1 = 500 Hz

f = 550

$$\frac{nV}{2\ell} = 500 \quad \ldots\ (i)$$

$$\frac{(n+1)V}{2\ell} = 500 \quad \ldots\ (ii)$$

(ii) (i) $\frac{V}{2\ell} = 50$

$$\ell = \frac{1000}{2\times 50} = 10$$

WAVE OPTICS

1. Official Ans. by NTA (3)

Sol. Amplitude $\propto$ Width of slit

$\Rightarrow A_2 = 3A_1$

$$\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{I_1}+\sqrt{I_2}}{|\sqrt{I_1}-\sqrt{I_2}|}\right)^2$$

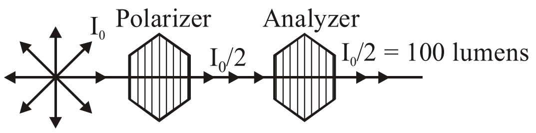
$\because$ Intensity $I \propto A^2$

$$\Rightarrow \frac{I_{max}}{I_{min}} = \left(\frac{A_1+A_2}{|A_1-A_2|}\right)^2$$

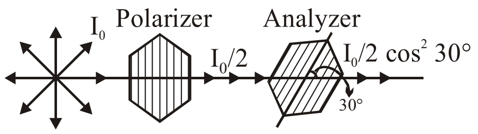
$$= \left(\frac{A_1+3A_1}{|A_1-3A_1|}\right)^2$$

$$= \left(\frac{4A_1}{2A_1}\right)^2 = 4:1$$

2. Official Ans. by NTA (75)

Sol. 

Assuming initially axis of Polarizer and Analyzer are parallel



Now emerging intensity = $\frac{I_0}{2}\cos^2 30°$

$$= 100\left(\frac{\sqrt{3}}{2}\right)^2 = 100\times\frac{3}{4} = 75$$

Ans. 75

3. Official Ans. by NTA (1)

Sol. $\beta = \frac{\lambda.D}{d}$

$\lambda_R > \lambda_V$

$\beta_R = \frac{\lambda_R D}{d}$ and $\beta_V = \frac{\lambda_V D}{d}$

$\beta_R > \beta_V$

Fringe pattern will shrink.

Option (1) is correct.

4. Official Ans. by NTA (4)

Sol. Given that, $\frac{I_1}{I_2} = 2x$

We know,

$I_{max} = \left(\sqrt{I_1}+\sqrt{I_2}\right)^2$ & $I_{min} = \left(\sqrt{I_1}-\sqrt{I_2}\right)^2$

$$\therefore \frac{I_{max}-I_{min}}{I_{max}+I_{min}} = \frac{2\sqrt{I_1 I_2}}{I_1+I_2} = \frac{2\sqrt{I_1/I_2}}{\frac{I_1}{I_2}+1} = \frac{2\sqrt{2x}}{2x+1}$$

5. Official Ans. by NTA (4)

Sol. $\sin\theta = \frac{m\lambda}{a}$

when a increases, θ decreases,

width decreases

width decreases so intensity will increases

6. Official Ans. by NTA (1)

Sol. $\beta = \frac{\lambda D}{d} = \frac{500\times10^{-9}\times1}{2\times10^{-3}}$

$\beta = \frac{5}{2}\times10^{-4}\,m = 2.5\times10^{-1}\,mm$

b = 0.25 mm

7. Official Ans. by NTA (2)

Sol. $\beta = \frac{\lambda D}{d} = \frac{5890\times10^{-10}\times0.5}{0.5\times10^{-3}}$

$= 589\times10^{-6}$ m

Distance between first and third bright fringe is

$2\beta = 2\times589\times10^{-6}$ m

$= 1178\times10^{-6}$ m Ans. (2)

8. Official Ans. by NTA (6)

Sol. $\frac{\Delta\lambda}{\lambda}c = v$

$$\Delta\lambda = \frac{v}{c}\times\lambda = \frac{286}{3\times10^5}\times630\times10^{-9}$$

$= 6\times10^{-10}$

9. Official Ans. by NTA (2)

Sol. Fringe Width, $\beta = \frac{\lambda D}{d}$

$\beta_{max} \Rightarrow d_{min}$ and $\beta_{min} \Rightarrow d_{max}$

$d = d_0 + a_0 \sin\omega t$

$d_{max} = d_0 + a_0$ and $d_{min} = d_0 - a_0$

$\therefore\ \beta_{min} = \frac{\lambda D}{d_0 + a_0}$ and $\therefore\ \beta_{max} = \frac{\lambda D}{d_0 - a_0}$

$$\beta_{max} - \beta_{min} = \frac{\lambda D}{d_0 - a_0} - \frac{\lambda D}{d_0 + a_0} = \frac{2\lambda D a_0}{d_0^2 - a_0^2}$$

10. Official Ans. by NTA (2)

Sol. Fringe width = $\lambda D/d$

as λ decreases , fringe width also decreases

11. Official Ans. by NTA (2)

Sol. Thickness $t = n\lambda$

So, $n\,\lambda_{vac} = (n+1)\,\lambda_{air}$

$n\,\lambda = (n+1)\,\frac{\lambda}{\mu_{air}}$

$n = \frac{1}{\mu_{air} - 1} = \frac{10^4}{3}$

$t = n\lambda$

$= \frac{10^4}{3} \times 6000\text{Å} = 2\text{ mm}$

12. Official Ans. by NTA (300)

Sol. Position of bright fringe $y = n\frac{D\lambda}{d}$

y_1 of red $= \frac{D\lambda_r}{d} = 3.5\text{mm}$

$\lambda_r = 3.5 \times 10^{-3}\,\frac{d}{D}$

Similarly $\lambda_v = 2 \times 10^{-3}\,\frac{d}{D}$

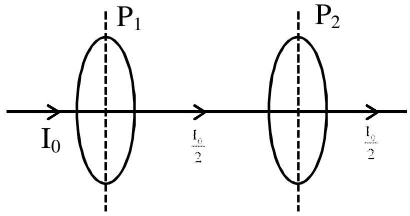
$$\lambda_r - \lambda_v = \left(1.5 \times 10^{-3}\right)\left(\frac{0.3 \times 10^{-3}}{1.5}\right)$$

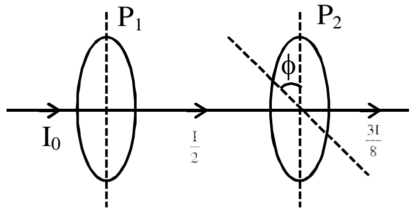
$= 3 \times 10^{-7} = 300$ nm

Ans. 300.0

13. Official Ans. by NTA (30)

Sol. $I = \frac{I_0}{2}\cos^2\phi$





$\frac{I}{2}\cos^2\phi = \frac{3I}{8}$

$\cos^2\phi = \frac{3}{4}$

$\cos^2\phi = \frac{\sqrt{3}}{2} \Rightarrow \phi = 30$

Ans. 30

14. Official Ans. by NTA (4)

Sol. $I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2 = 4I_o$

15. Official Ans. by NTA (600)

Sol. $\beta = \frac{\lambda D}{d}$; $\lambda = \frac{\beta d}{D}$

$\lambda = \frac{6 \times 10^{-3} \times 10^{-3}}{10}$

$\lambda = 6 \times 10^{-7}$ m $= 600 \times 10^{-9}$ m

$\lambda = 600$ nm

16. Official Ans. by NTA (5)

Sol. $8\beta = 2.4$ cm; $\frac{8\lambda\Delta}{d} = 2.4$ cm

$\frac{8 \times 1.5 \times c}{0.3 \times 10^{-3} \times f} = 2.4 \times 10^{-2}$

$f = 5 \times 10^{14}$ Hz

17. Official Ans. by NTA (1)

Sol. Given amplitude $\propto$ slit width

Also intensity $\propto$ (Amplitude)^2 $\propto$ (Slit width)^2

$\frac{I_1}{I_2} = \left(\frac{3}{1}\right)^2 = 9 \Rightarrow I_1 = 9I_2$

$$\frac{I_{min}}{I_{max}} = \left(\frac{\sqrt{I_1} - \sqrt{I_2}}{\sqrt{I_1} + \sqrt{I_2}}\right)^2 = \left(\frac{3-1}{3+1}\right)^2 = \frac{1}{4} = \frac{x}{4}$$

$\Rightarrow x = 1.00$