JEE MAIN-2021

PHYSICS

SECTION A

1. Sol. (4)

Work done of isothermal process,

$$W_{A\to B}=nRT\ln\left(\frac{V_2}{V_1}\right)$$
$$W_{A\to B}=nRT\ln\left(\frac{2V_1}{V_1}\right)=nRT\ln 2$$

Work done of isobaric process,

$$W_{B\to C}=P\Delta V$$
$$W_{B\to C}=nR\Delta T$$
$$W_{B\to C}=nR\left(\frac{T}{2}-T\right)=\frac{-nRT}{2}$$

Wok done for isochoric process,

$$W_{C\to A}=0 \qquad (P=0)$$

Total work done is calculated as,

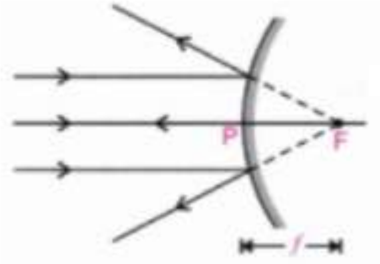
$$W_{net}=W_{A\to B}+W_{B\to C}+W_{C\to A}$$
$$W_{net}=nRT\ln 2-\frac{nRT}{2}+0$$
$$W_{net}=nRT\left(\ln 2-\frac{1}{2}\right)$$

2. Sol. (1)

The focal length of a convex mirror is positive.(as per cartesian sign conventions).

The relationship between focal length and radius of curvature is,

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



3. Sol. (3)

It is given that,

$$\frac{A_1}{A_2}=\frac{1}{3}$$

$$A_1 = x, A_2 = 3x$$

As we know that,

$$\frac{I_{\max}}{I_{\min}}=\frac{(A_1+A_2)^2}{(A_1-A_2)^2}=\frac{(4x)^2}{(2x)^2}$$

$$\frac{I_{\max}}{I_{\min}}=\frac{16}{4}$$

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

4. Sol. (2)

The $x-$ coordinate of center of mass of two stars with respect to star of mass m ,

$$x_{com}=\frac{m(0)+2m(d)}{3}=\frac{2d}{3}$$

Let the stars of mass m revolve about their centre of mass with angular velocity ω.

Then we have,

$$F_c = m\left(\frac{2d}{3}\right)\omega^2$$

$$\frac{Gm(2m)}{d^2} = m\left(\frac{2d}{3}\right)\omega^2$$

$$\frac{3Gm}{d^3} = \left(\frac{2\pi}{T}\right)^2$$

$$T^2 = (2\pi)^2\left(\frac{d^3}{3Gm}\right)$$

$$T = 2\pi\sqrt{\left(\frac{d^3}{3Gm}\right)}$$

5. Sol. (2)

As we know that, $i = \frac{dq}{dt}$

$$\int_0^Q (dq) = \int_{t=0}^{t=15} i\,dt$$

$$Q = \int_{t=0}^{t=15} \left(\alpha_0 t + \beta t^2\right)dt$$

$$Q = \int_{t=0}^{t=15} \left(20t + 8t^2\right)dt$$

$$Q = \int_{t=0}^{t=15} \left(20t + 8t^2\right)dt = \left[\left(\frac{20t^2}{2}\right) + \left(\frac{8t^3}{3}\right)\right]_{t=0}^{t=15}$$

$$Q = 10(225) + \left(8 \times \frac{225 \times 15}{3}\right)$$

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

6. Sol. (3)

$$I_1 = \frac{1}{2}MR^2$$

$$I_2 = \frac{1}{2}MR^2$$

$$I_3 = \frac{1}{2}MR^2$$

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

$$I_1 = I_2 = I_3 > I_4$$

7. Sol. (4)

The formula of energy of photon,

$$E = \frac{hc}{\lambda}$$

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

Hence, energy of photon increases as the wavelength of light decreases.

The formula of momentum is,

$$p = \frac{E}{c}$$

$$p = \frac{hc}{\lambda}$$

Thus, if Two photons having equal linear momenta should have equal wavelengths.

8. Sol. (2)

Velocity at mean position is $= A\omega$

According to law of conservation of momentum,

$$MA\sqrt{\frac{k}{M}} = (M+m)A'\sqrt{\frac{k}{M+m}}$$

$$A' = A\sqrt{\frac{M}{m+M}}$$

9. Sol. (4)

We know that,

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

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

And also,

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

$$\sigma = \frac{Y}{2\eta} - 1 \qquad (ii)$$

From above equations,

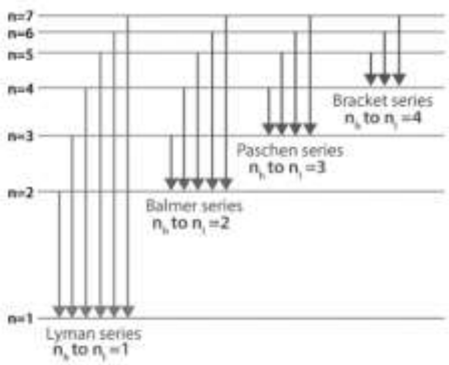
$$\frac{1}{2}\left(1-\frac{Y}{3K}\right) = \frac{Y}{2\eta} - 1$$

After solving above equation,

$$K = \frac{Y\eta}{9\eta - 3Y}\,\text{Nm}^2$$

10. Sol. (4)

The hydrogen spectrum series is shown below,



Therefore, from diagram we can conclude,

$A \rightarrow$ Series limit of laymen

$B \rightarrow 3^{rd}$ line of Balmer

$C \rightarrow 2^{rd}$ line of Paschen

11. Sol. (1)

Resolving the force F_2 along $y-$direction,

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

$$F_1 + 2F_2\cos 45^\circ = \frac{MV^2}{R}$$

$$\left(\frac{GM^2}{4R^2}\right) + \left(\frac{2GM^2}{2\sqrt{2}R^2}\right) = \frac{MV^2}{R}$$

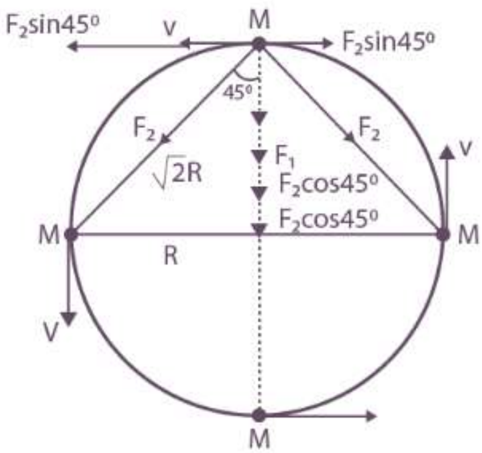
$$\frac{GM}{4R} + \frac{GM}{\sqrt{2}R} = V^2$$

On solving the above equation,

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

When $R = 1\text{ m}$ & $M = 1\text{ kg}$

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



12. Sol. (2)

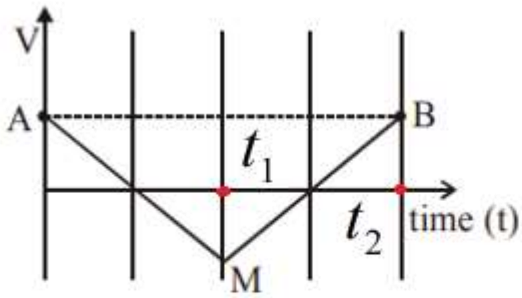
Acceleration is defined as it is the rate of change of velocity.

$$a = \frac{dv}{dt}$$

For any velocity - time graph, the slope of velocity curve at any point gives acceleration of body at that instant of time.

Now, in the given diagram, the slope of line AM is negative and constant and slope of line MB is positive and constant.

So, we can say that for interval 0 to t_1 acceleration is negative and for t_1 to t_2 acceleration is positive.



13. Sol. (3)

The formula of equivalent capacitance when C_1 and C_2 are connected in parallel is,

$$C_{net} = \frac{C_1C_2}{C_1 + C_2}$$

The formula of equivalent capacitance when C_1 and C_2 are connected in series is,

$$C_{net} = C_1 + C_2 .$$

When in series, equivalent capacitance: $C_a = \frac{C \times C}{C + C} = \frac{C}{2}$

When in parallel, equivalent capacitance: $C_b = C + C = 2C$

$$\frac{C_a}{C_b} = \frac{\frac{C}{2}}{2C} = \frac{1}{4}$$

14. Sol. (1)

$$I_C = 3.5 \text{ mA}$$
$$I_E = 4 \text{ mA}$$

The formula of current gain of transistor is,

$$\beta = \frac{I_C}{I_B} = \frac{I_C}{I_E - I_C}$$

$$\beta = \frac{35}{40-35} = \frac{35}{5} = 7$$

15. Sol. (2)

By theory,

In an isothermal process, temperature is constant.

In an isochoric process, volume is constant.

In an adiabatic process, heat content is constant.

In an isobaric process, pressure is constant.

16. Sol. (1)

As we know that,

Coefficient of volume expansion, $\gamma = 3\alpha$

$$\frac{\Delta V}{V} = \gamma \Delta T$$
$$\Delta V = V(\gamma \Delta T)$$
$$\Delta V = a^3 (3\alpha) \Delta T$$

17. Sol. (3)

The batteries are connected in opposite direction therefore the net potential is

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

Both the resistances are connected in series therefore net resistance is,

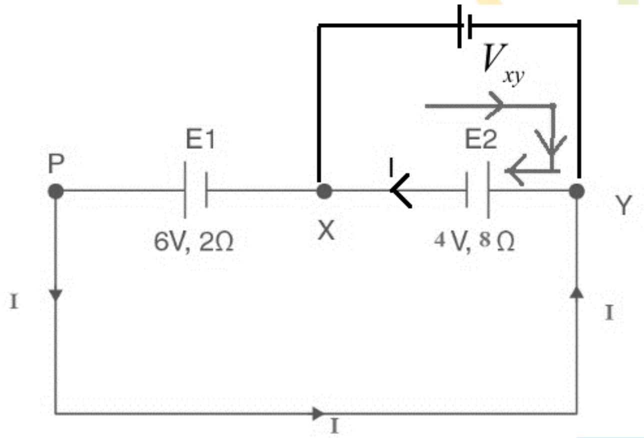
$$R_{net} = 2 + 8 = 10\Omega$$

The amount of current flowing through the circuit is,

$$I = \frac{E_{eff}}{R_{net}} = \frac{2}{10} = 0.2 \text{ V}$$

Now, applying KVL in the loop as shown below,

$$V_{xy} = -(E_2 + 4(i))$$
$$V_{xy} = -(E_2 + 8i)$$
$$V_{xy} = -\left(4 + \left(8 \times \frac{2}{10}\right)\right)$$
$$|V_{xy}| = 5.6 \text{ V}$$



18. Sol. (2)

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

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

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

19. Sol. (1)

The formula of angular speed is,

$$\omega = \frac{2\pi}{T}$$

The ratio of angular speed is,

$$\frac{\omega_1}{\omega_2} = \frac{2\pi / T_1}{2\pi / T_2} = \frac{T_2}{T_1} = \frac{8}{1}$$

20. Sol. (2)

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

$$\alpha = \frac{x^2}{kT}$$

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

$$W = \alpha \beta^2$$

$$\beta^2 = \frac{W}{\alpha}$$

$$[\beta^2] = \left[\frac{MLT^{-1}}{M^{-1}T^2}\right]$$

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

SECTION B

21. Sol. 25

The free body diagram is shown below,

In horizontal direction, the normal force is equal to applied force,

$$N = F \qquad (i)$$

The friction force is calculated as,

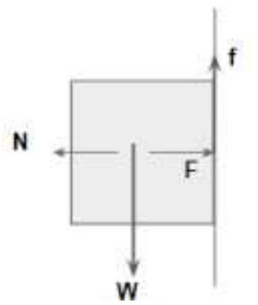
$$f = \mu N = \mu F$$

For equilibrium in vertical direction,

$$W = f = \mu F$$

$$\text{mg} = \mu F$$

$$F = \frac{\text{mg}}{\mu} = \frac{0.5 \times 10}{0.2} = 25\,\text{N}$$



22. Sol. 2000

The formula of quality factor of $LCR-$circuit is,

$$Q = \frac{x_L}{R} = \frac{\omega L}{R} = \frac{2\pi fL}{R}$$

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

$$Q = 2000$$

23. Sol. 25600

Atmospheric pressure P_0 will be acting on both the limbs of the hydraulic lift.
Applying pascal's law for the same liquid level

$$P_0 + \frac{mg}{A_1} = P_0 + \frac{100g}{A_2}$$
$$\frac{m}{100} = \frac{A_1}{A_2} \qquad (i)$$

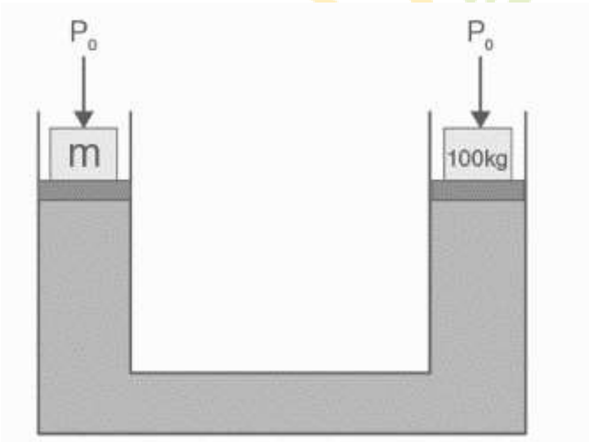
Diameter of piston on side of $100\ \text{kg}$ is increased by 4 times so new area $=16A_2$

Diameter of piston on side of ($m\ \text{kg}$) is decreasing, $A_1' = \frac{A_1}{16}$

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

From above equations,

$$M' = 25600\ \text{kg}$$



24. Sol. 25

The free body diagram is shown below,

Condition for block will not slip downward,

$$mg\sin\theta \le \mu mg\cos\theta$$
$$\tan\theta \le \mu$$

The slope of curve is,

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

$$\frac{dy}{dx}=2\left(\frac{x}{4}\right)=\frac{x}{2}$$

$$\tan\theta=\frac{x}{2}$$

From above points,

$$\tan\theta\le\mu$$

$$\frac{x}{2}\le\mu$$

$$x\le 2(0.5)=1$$

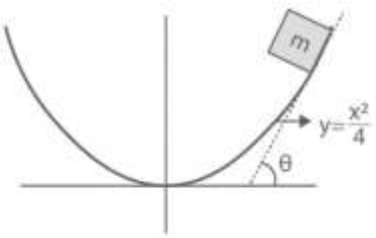
The maximum height is calculated as,

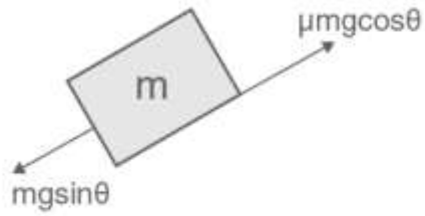
$$y=\frac{x^2}{4}$$

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

$$y=0.25\text{ m}$$

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





25. Sol. 15

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

$$v=\frac{c}{n}=\frac{3\times10^8}{2}=15\times10^7\text{ m/s}$$

26. Sol. 25

As we know that, when voltage across Zener diode is greater than its threshold voltage then it behaves as open circuit, or we call it as breakdown region.

To check, we will remove the Zener diode and check voltage across its end point,

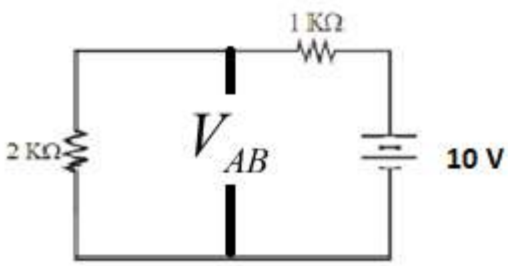
The voltage across end point is,

$$V_{AB} = \frac{2(10)}{3} = 6.66\text{ V}$$
$$V_{AB} > V_Z$$

Therefore, Zener diode is in breakdown region, and it will behave as open circuit,

The current through $2\text{ k}\Omega$ is,

$$i = \frac{5}{2\times10^3}$$
$$i = 2.5\times10^{-3}\text{ A}$$
$$i = 25\times10^{-4}\text{ A}$$



27. Sol. 25

The formula of modulation index of AM modulation is,

$$m\ \% = \frac{A_m}{A_c}\times100$$
$$m\ \% = \frac{20}{80}\times100 = 25\%$$

28. Sol. 1

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

(i)

In y-direction,

$$p_i = 0$$
$$p_f = \left(m_1v_1\sin30^\circ - m_2v_2\sin30^\circ\right)$$

According to the law of conservation of momentum,

$$p_f = p_i$$

$$p_i = 0$$

$$0 = \left(m_1 v_1 \sin 30^\circ - m_2 v_2 \sin 30^\circ\right) \qquad\qquad (m_1 = m_2)$$

$$v_1 = v_2$$

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

29. Sol. 440

For any transformer,

$$\frac{N_P}{N_S} = \frac{V_P}{V_S}$$

$$\frac{N_P}{24} = \frac{220}{12}$$

$$N_P = \frac{220(24)}{12}$$

$$N_P = 440$$

30. Sol. 75

According to Malus Law,

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

The intensity of emerging light is calculated as,

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

$$I_{net} = (100)\cos^2\left(30^\circ\right) = \frac{100(3)}{4}$$

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