JEE Main 2021(July) Paper

(Memory Based)

Date of Exam: 20^{th} July 2021
Time: 3:00 p.m.-6:00 p.m.
Subject: Physics

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1. If kinetic energy of particle becomes four times, then % change in momentum will be:
   a. 200
   b. 100
   c. 150
   d. 50

   Solution: (b)

$$\text{K.E.} \Rightarrow \text{K} = \frac{P^2}{2m}$$
$$P \propto \sqrt{K}$$
$$\frac{P_2}{P_1} = \sqrt{\frac{K_2}{K_1}} \Rightarrow \frac{P_2}{P_1} = \sqrt{\frac{4K}{K}}$$
$$\Rightarrow \frac{P_2}{P_1} = 2$$
$$\Rightarrow \frac{P_2 - P_1}{P_1}\% = \left(\frac{P_2}{P_1} - 1\right) \times 100 = (2-1) \times 100 = 100$$
$$\Rightarrow \frac{\Delta P}{P_1}\% = 100\%$$

2. A RLC circuit is in its resonance condition. Its circuit components have value
$$R = 5\Omega,\ \ L = 2\text{H},\ \ C = 0.5\text{mF},\ \ V = 250\text{V}$$
   Then find the power in circuit.
   a. 6 kW
   b. 10 kW
   c. 12 kW
   d. 12.5 kW

   Solution: (d)

   As circuit is in resonance. Thus
$$X_L = X_C$$
$$\therefore\ \ Z = R\ \text{ so, }\ i_{rms} = \frac{V}{Z} = \frac{V}{R}$$
$$P = i_{rms}^2 R$$
$$P = \frac{V^2}{R} = \frac{250 \times 250}{5} = 12500\ \frac{\text{J}}{\text{s}} = 12.5\ \text{kW}$$

3. A satellite is revolving around a planet in an orbit of radius R. Suddenly radius of orbit becomes 1.02 R, then what will be percentage change in its time period of revolution?

   a. 2% b. 3%
   c. 5% d. 7%

Solution: (b)

$$T \propto R^{\frac{3}{2}}$$
$$T = kR^{3/2}$$
$$\frac{\Delta T}{T} = \frac{3}{2}\frac{\Delta R}{R} = 3\%$$

4. A person walks up a stationary escalator in the time t_1. If he remains stationary on the escalator, then it can take him up in time t_2. Determine the time it would take to walk up on the moving escalator?

   a. $\frac{t_1 t_2}{t_1+t_2}$ b. $\frac{t_1 t_2}{t_1-t_2}$
   c. $\frac{2t_1 t_2}{t_1+t_2}$ d. $\frac{2t_1 t_2}{t_1-t_2}$

Solution: (a)

Suppose length of escalator $= L$

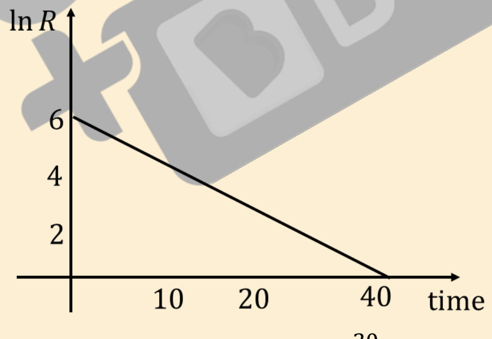
Speed of man w.r.t escalator $\frac{L}{t_1}$

Speed of escalator $= \frac{L}{t_2}$

Speed of man w.r.t ground when escalator is moving $= \frac{L}{t_1} + \frac{L}{t_2}$

Time taken by the man to walk on the moving escalator $= \frac{L}{\frac{L}{t_1}+\frac{L}{t_2}} = \frac{t_1 t_2}{t_1+t_2}$

5. For given graph between decay rate & time. Find half-life (where $R =$ decay rate)



   a. $\frac{10}{3}\ln 2$ b. $\frac{20}{3}\ln 2$
   c. $\frac{3}{20}\ln 2$ d. $\frac{3}{10}\ln 2$

Solution: (a)

$$R = R_o e^{-\lambda t}$$
$$\ln R = \ln R_o - \lambda t$$
$$\text{slope} = -\lambda = -\frac{6}{40}$$
$$\lambda = \frac{3}{20}$$
$$t_{1/2} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{3} \times 20 = \frac{20}{3} \ln 2$$

6. A wheel rotating with an angular speed of $600\, rpm$ is given constant acceleration of $1800\, rpm^2$ for $10\, sec$. Number of revolutions revolved by the wheel is
   a. 125
   b. 100
   c. 75
   d. 50

Solution: (a)

$$\omega_o = 600\, rpm$$
$$\alpha = 1800\, rpm^2$$
$$t = 10\, sec = \frac{1}{6}\, min$$
$$\theta = \omega_o t + \frac{1}{2} \alpha t^2$$
$$\theta = 600 \times \frac{10}{60} + \frac{1}{2} \times 1800 \times \frac{1}{36}$$
$$\theta = 100 + 25 = 125 \text{ revolutions}$$

7. $|\vec{P}| = |\vec{Q}|, |\vec{P} + \vec{Q}| = |\vec{P} - \vec{Q}|$. Find the angle between $\vec{P}$ and $\vec{Q}$.
   a. $45°$
   b. $90°$
   c. $135°$
   d. $150°$

Solution: (b)

$$|\vec{P} + \vec{Q}| = |\vec{P} - \vec{Q}|$$
$$|\vec{P}|^2 + |\vec{Q}|^2 + 2|\vec{P}||\vec{Q}|\cos\theta = |\vec{P}|^2 + |\vec{Q}|^2 - 2|\vec{P}||\vec{Q}|\cos\theta$$
$$|\vec{P}||\vec{Q}|\cos\theta = 0$$
$$\theta = 90°$$

8. Time (T) ,Velocity (C) and angular momentum (h) are chosen as fundamental quantities instead of mass, length and time. In terms of these, dimension of mass would be
   a. $[M] = [T^{-1}C^{-2}h]$
   b. $[M] = [T^{-1}C^{2}h]$
   c. $[M] = [T^{-1}C^{-2}h^{-1}]$
   d. $[M] = [TC^{-2}h]$

Solution: (a)

$M \propto T^x c^y h^z$

$[M^1 L^0 T^0] = [T^x] [LT^{-1}]^y [ML^2T^{-1}]^z$

On comparing the powers, we get:

Z = 1 ………… (1)

X – y + z = 0. ……….(2)

Y +2z = 0 ………… (3)

So, y = -2

X = -1

$[M] = [T^{-1}C^{-2}h]$

9. Find relation between γ (adiabatic constant) and degree of freedom (f) .

a. $f = \frac{2}{\gamma-1}$

b. $f = \frac{\gamma}{\gamma-1}$

c. $f = \frac{\gamma-1}{2}$

d. $f = \frac{\gamma-1}{\gamma}$

Solution: (a)

We know that,

$$C_v = \frac{f\,R}{2}$$

$$C_p = (\frac{f}{2} + 1)R \text{ R}$$

$$\gamma = \frac{C_P}{C_V} = 1 + \frac{2}{f}$$

$$f = \frac{2}{\gamma - 1}$$

10. Two identical drops of Hg coalesce to form a bigger drop. Find the ratio of surface energy of bigger drop to smaller drop.

a. $2^{3/2}$

b. $3^{2/5}$

c. $2^{2/3}$

d. $5^{2/3}$

Solution: (c)

$$2 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

$$\frac{R}{r} = 2^{1/3}$$

$$\frac{U_{bigger}}{U_{smaller}} = \frac{S \times 4\pi R^2}{S \times 4\pi r^2} = \left(\frac{R}{r}\right)^2 = 2^{2/3}$$

11. The velocities of particle performing SHM at a distance of x_1 and x_2 from mean position are v_1 and v_2 find the time period of oscillation?

a. $2\pi\sqrt{\frac{x_2^2+x_1^2}{v_1^2-v_2^2}}$

b. $2\pi\sqrt{\frac{x_2^2-x_1^2}{v_1^2+v_2^2}}$

c. $2\pi\sqrt{\frac{x_2^2-x_1^2}{v_1^2-v_2^2}}$

d. $2\pi\sqrt{\frac{x_2^2+x_1^2}{v_1^2+v_2^2}}$

Solution: (c)

$$v = \omega\sqrt{A^2 - x^2}$$

$$v_1 = \omega\sqrt{A^2 - x_1^2}$$

$$v_2 = \omega\sqrt{A^2 - x_2^2}$$

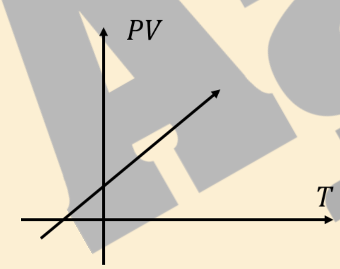
$$\left(\frac{v_1}{\omega}\right)^2 - \left(\frac{v_2}{\omega}\right)^2 = x_2^2 - x_1^2$$

$$\omega^2 = \frac{v_1^2 - v_2^2}{x_2^2 - x_1^2}$$

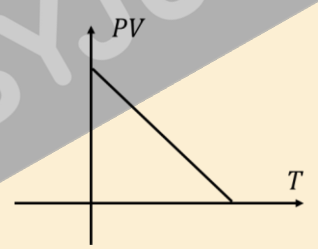
$$\omega = \sqrt{\frac{v_1^2 - v_2^2}{x_2^2 - x_1^2}}$$

$$T = 2\pi\sqrt{\frac{x_2^2 - x_1^2}{v_1^2 - v_2^2}}$$

12. Identify correct graph between PV and T for an ideal gas.



a.



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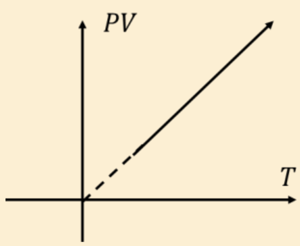
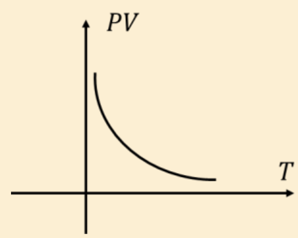


c.



d.

Solution: (c)

$PV = nRT \Rightarrow PV = CT$
Therefore, PV v/s T graph is straight line.

13. In photoelectric effect stopping potential is $3V_o$ for incident wavelength λ_o and stopping potential V_o for incident wavelength $2\lambda_o$. Find threshold wavelength.

a. $3\lambda_o$
b. $2\lambda_o$
c. $4\lambda_o$
d. $8\lambda_o$

Solution: (c)

$KE = hv - W$

$eV = \frac{hc}{\lambda} - W$

For first case

$e(3V_o) = \frac{hc}{\lambda_o} - W$ ……..(i)

For second case:

$e(V_o) = \frac{hc}{2\lambda_o} - W$ ……(ii)

From equation (i) and (ii), we get,

$W = \frac{hc}{4\lambda_o}$

For λ_{th}

$w = \frac{hc}{\lambda_{th}}$

$\Rightarrow \frac{hc}{4\lambda_o} = \frac{hc}{\lambda_{\ th}}$

$\Rightarrow \lambda_{th} = 4\lambda_o$

14. A plane electromagnetic wave travels in free space. Electric field is $\vec{E} = E_0\hat{\imath}$ and magnetic field is represented by $\vec{B} = B_0\hat{k}$. What is the unit vector along the direction of propagation of electromagnetic wave?

a. $\hat{\jmath}$
b. $-\hat{k}$
c. $-\hat{\jmath}$
d. $\hat{k}$

Solution: (c)

Direction of EM wave is given by direction of $\vec{E} \times \vec{B}$.

Unit vector in direction $\vec{E} \times \vec{B}$ is, $= \frac{\vec{E}\times\vec{B}}{|\vec{E}\times\vec{B}|}$

$$= \frac{E_0\hat{i} \times B_0\hat{k}}{E_0B_0 Sin\ 90^0}$$
$$= \hat{i} \times \hat{k}$$
$$= -\hat{j}$$

15. Two satellites of mass M_A and M_B are revolving around a planet of mass M in radius R_A and $R_B$respectively. Then

a. $T_A > T_B$ if $R_A > R_B$
b. $T_A > T_B$ if $M_A > M_B$
c. $T_A = T_B$ if $M_A > M_B$
d. $T_A > T_B$ if $R_A < R_B$

Solution: (a)

According to Keplers law of planetary motion,

$$T \propto R^{3/2}$$

$$\frac{T_A}{T_B} = \left(\frac{R_A}{R_B}\right)^{3/2}$$

So, if $R_A > R_B$ then $T_A > T_B$.
Hence, option (a) is correct answer.

16. At 45° of magnetic meridian angle of dip is 30° then find the angle of dip in vertical plane at 45° ?

a. $\tan^{-1}\left(\frac{1}{\sqrt{6}}\right)$
b. $\tan^{-1}\left(\frac{1}{\sqrt{2}}\right)$
c. $\tan^{-1}\left(\frac{1}{\sqrt{4}}\right)$
d. $\tan^{-1}\left(\frac{1}{\sqrt{3}}\right)$

Solution: (a)

let horizontal and vertical component of earth's magnetic field at meridian will be V and H.
Angle of dip, $\tan\theta = \frac{V}{H}$ ......(i)
At angle of 45° from magnetic meridian, angle of dip = 30°

$$\tan 30° = \frac{V}{H\cos 45°}$$

$$\Rightarrow \frac{1}{\sqrt{3}} = \frac{V}{H\cos 45°}$$

$$\frac{V}{H} = \frac{1}{\sqrt{6}}$$

$$\tan\theta = \frac{V}{H} = \frac{1}{\sqrt{6}}$$

$$\Rightarrow \theta = \tan^{-1}\left(\frac{1}{\sqrt{6}}\right)$$

17. A sodium lamp in space was emitting waves of wavelength 2880 Å. When observed from a planet, its wavelength was recorded 2886 Å. Find the speed of planet ?

a. $4.25 \times 10^5\ m/s$
b. $6.25 \times 10^5\ m/s$
c. $2.75 \times 10^5\ m/s$
d. $3.75 \times 10^5\ m/s$

Solution: (b)

$$\frac{V_{rel}}{C} = \frac{\Delta\lambda}{\lambda}$$
$$V_{rel} = \frac{6}{2880} \times 3 \times 10^8$$
$$V_{rel} = 6.25 \times 10^5\ m/s$$

18. For a body in pure rolling, its rotational kinetic energy is $\frac{1}{2}$ times of its translational kinetic energy. The body should be?

a. Solid cylinder
b. Ring
c. Solid sphere
d. Hollow sphere

Solution: (a)

Given,

Rotational K.E = $\frac{1}{2}$ Translational K.E

$\frac{1}{2}\ \mathrm{I}\omega^2 = \frac{1}{2} \times \frac{1}{2}\ mv^2$

In pure rolling, v = Rω

$\frac{1}{2}\ \mathrm{I}\omega^2 = \frac{1}{4}\ mR^2\omega^2$

$\mathrm{I} = \frac{1}{2}\ mR^2$

Hence, it is a solid cylinder.

19. Magnetic susceptibility of a material is 499 & $\mu_0 = 4\pi \times 10^{-7}\ SI\ unit$. Then find μ_r

a. 500
b. 400
c. 300
d. 200

Solution: (a)

Given, $\chi = 499$

The relative permeability, $\mu_r = 1 + \chi = 500$

20. An electron having the debroglie wavelength λ falls on a X-ray tube. The cut-off wavelength of emitted X-ray is

a. $\frac{2mc\lambda^2}{h}$

b. $\frac{2h}{mc}$

c. $\frac{h}{mc}$

d. $\frac{2mc\lambda^2}{3h}$

Solution: (a)

De-broglie wavelength, $\lambda_B = \frac{h}{P}$

$P = \frac{h}{\lambda_B}$

Kinetic energy of electron, $E = \frac{P^2}{2m_e} = \frac{h^2}{2m_e \lambda_B{}^2}$

For cutoff wavelength of emitted X-ray: $E = \frac{hc}{\lambda}$

$\frac{h^2}{2m_e \lambda_B{}^2} = \frac{hc}{\lambda}$

$\lambda = \frac{2m_e c \lambda_B{}^2}{h} = \frac{2mc\lambda^2}{h}$ where $\lambda_B = \lambda$ and $m_e = m$

21. A body is moved from rest along a straight line by a machine delivering a constant power. Time taken by the body to travel a distance S is proportional to :

a. $S^{\frac{1}{3}}$

b. $S^{\frac{2}{3}}$

c. $S^{\frac{1}{2}}$

d. $S^{\frac{1}{4}}$

Solution: (b)

Energy supplied in time t sec is,

$E = P \times t$

Here P represents the power delivered by machine.

$\Rightarrow Pt = \frac{1}{2}mv^2$

$v \propto \sqrt{t}$

Writing the velocity in terms of the displacement of the body,

$\Rightarrow \frac{dS}{dt} = C\sqrt{t}$

Here C is a constant.

$\Rightarrow \int_0^S dS = C\int_0^t t^{\frac{1}{2}}\,dt$

$S = \frac{2Ct^{\frac{3}{2}}}{3}$

$t^{\frac{3}{2}} = \frac{3S}{2C} \quad \Rightarrow t = S^{\frac{2}{3}}\left(\frac{3}{2C}\right) \quad \Rightarrow t \propto S^{\frac{2}{3}}$

22. A uniform rod of young's modulus Y is stretched by two tension forces T_1 and T_2 such that the rods get expanded to length L_1 and L_2 respectively. Find the initial length of the rod ?

a. $\frac{L_1 T_1 - L_2 T_2}{T_1 - T_2}$

b. $\frac{L_2 T_1 - L_1 T_2}{T_2 - T_1}$

c. $\frac{L_1 T_2 - L_2 T_1}{T_2 - T_1}$

d. $\frac{L_1}{T_1} \times \frac{T_2}{L_2}$

Solution: (c)

Let the initial length of the rod to be L_0 and area A

In this case the external force on the rod is tension hence from hook's law,

$$\frac{F}{A} = Y\frac{\Delta l}{l}$$

$$\Rightarrow \frac{T}{A} = Y\frac{\Delta l}{l}$$

For both the cases we can relate the tension and elongation produced in rod as,

$$\frac{T_1}{A} = \frac{Y(L_1 - L_0)}{L_0} \dots\dots (i)$$

Here $(L_1 - L_0)$ is the elongation in rod when T_1 is applied.

Similarly,

$$\frac{T_2}{A} = \frac{Y(L_2 - L_0)}{L_0} \dots\dots (ii)$$

Here $(L_2 - L_0)$ is the elongation in rod when T_2 is applied.

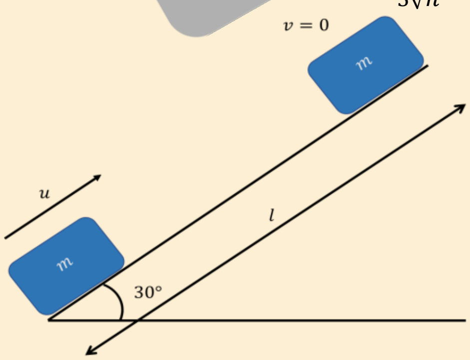
On dividing Eq.(i) and (ii) we get,

$$\frac{T_1}{T_2} = \frac{L_1 - L_0}{L_2 - L_0}$$

$$\Rightarrow T_1 L_2 - T_1 L_0 = T_2 L_1 - T_2 L_0$$

$$\text{Or, } L_0 = \frac{L_1 T_2 - L_2 T_1}{T_2 - T_1}$$

23. A block is projected up to a rough plane of inclination 30°. If time of ascending is half the time for descending and the coefficient of friction is $\mu = \frac{3}{5\sqrt{n}}$. Then $n =$



Solution: (n=3)

$S = \frac{1}{2}a_A t_A^2$ ..... (1)

$S = \frac{1}{2}a_D t_D^2$ ..... (2)

From equation (1) and (2)

$$\frac{t_A^2}{t_D^2} = \frac{a_D}{a_A}$$

$$\Rightarrow \frac{t_A^2}{t_D^2} = \frac{g\ \sin\theta - \mu g\cos\theta}{g\ \sin\theta + \mu g\cos\theta}$$

$$\Rightarrow \frac{t_A}{t_D} = \sqrt{\frac{g\ \sin\theta - \mu g\cos\theta}{g\ \sin\theta + \mu g\cos\theta}}$$

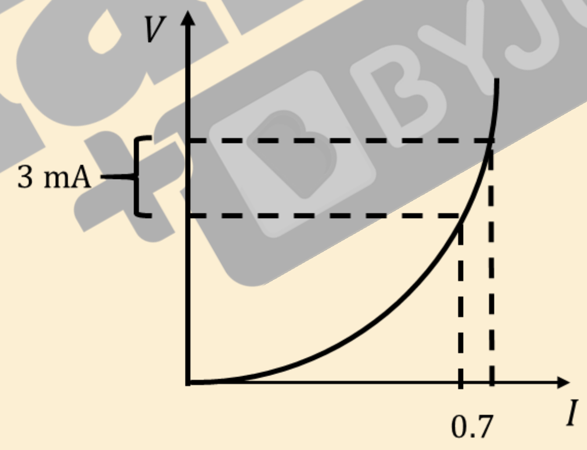
$$\Rightarrow \frac{1}{2} = \sqrt{\frac{1-\sqrt{3}\mu}{1+\sqrt{3}\mu}}$$

$$\Rightarrow 1+\sqrt{3}\mu = 4-4\sqrt{3}\mu$$

$$\Rightarrow 5\sqrt{3}\mu = 3$$

$$\Rightarrow \mu = \frac{3}{5\sqrt{3}}$$

24. I-V characteristic curve of a diode in forward bias is given in fig. Find out dynamic resistance.



a. 212.3 Ω
b. 205.3 Ω
c. 245.3 Ω
d. 233.3 Ω

Solution: (d)

$$\text{Dynamic resistance} = \frac{\Delta V}{\Delta I}$$

$$= \frac{0.7\ \text{V}}{3\ \text{mA}} = 233.3\ \Omega$$

25. A electron is accelerated through a voltage of 40 kV. What will be its wavelength?
 a. 0.061 Å
 b. 0.011 Å
 c. 0.021 Å
 d. 0.161 Å

Solution: (a).

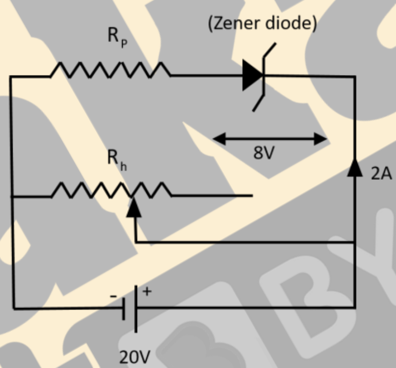
$$\lambda_B = \frac{h}{P}$$

$$= \frac{h}{\sqrt{2meV}}$$

$$= \frac{12.27}{\sqrt{V}}\ \text{Å}$$

$$= \frac{12.27}{\sqrt{40 \times 10^3}} = 0.061\ \text{Å}$$

26. Find the value of R_P in the given circuit ? ($V_Z = 8V$)



 a. 4Ω
 b. 6Ω
 c. 3Ω
 d. 5Ω

Solution: (b)

Applying KVL

$20 - 8 - 2R_P = 0$

$R_P = 6\Omega$

27. Two stars of masses m_1 and m_2 are in mutual interaction and revolving in orbits of radii r_1 and r_2 respectively. Time period of revolution for this system will be ?

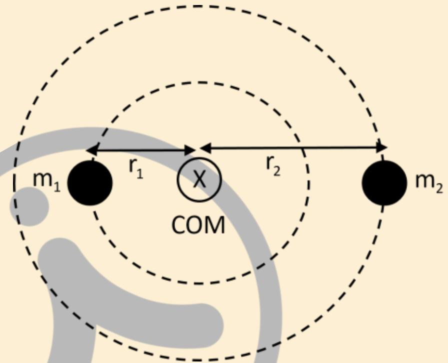
a. $2\pi\sqrt{\frac{(r_1-r_2)^3}{G(m_1+m_2)}}$

b. $2\pi\sqrt{\frac{(r_1+r_2)^3}{G(m_1+m_2)}}$

c. $2\pi\sqrt{\frac{(r_1-r_2)^3}{G(m_1-m_2)}}$

d. $2\pi\sqrt{\frac{(r_1+r_2)^3}{G(m_1-m_2)}}$

Solution: (b)



Let angular velocity will be ω

For mass m_1,

$$\frac{Gm_1m_2}{(r_1+r_2)^2} = m_1 r_1\omega^2 = m_1 \times \frac{m_2(r_1+r_2)}{m_1+m_2}\omega^2$$

$$\omega = \frac{\sqrt{G(m_1+m_2)}}{(r_1+r_2)^{\frac{3}{2}}}$$

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

$$T = 2\pi\sqrt{\frac{(r_1+r_2)^3}{G(m_1+m_2)}}$$

28. If N_0 active nuclei become $N_0/16$ in 80 days. Find half-life of nuclei?

a. 40 days

b. 20 days

c. 60 days

d. 30 days

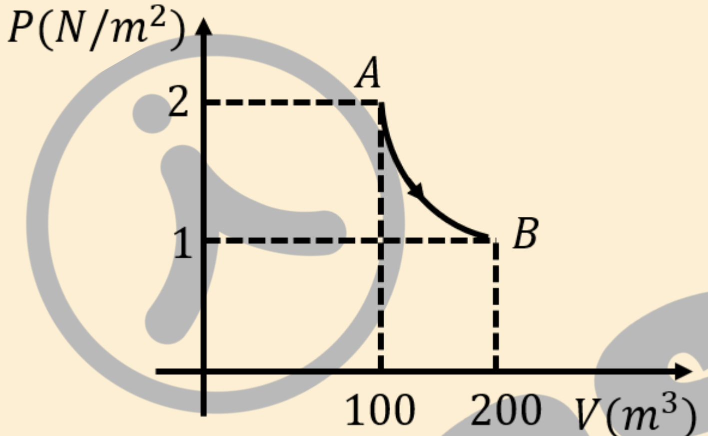
Solution: (b)

$$N_0 \xrightarrow{t_{1/2}} \frac{N_0}{2} \xrightarrow{t_{1/2}} \frac{N_0}{4} \xrightarrow{t_{1/2}} \frac{N_0}{8} \xrightarrow{t_{1/2}} \frac{N_0}{16}$$

$4 \times t_{1/2} = 80\ days$

$\Rightarrow t_{1/2} = 20\ days$

29. A gas is undergoing change in state by an isothermal process AB as follow. Work done by gas in process AB is



a. $100\ ln2\ Joule$
b. $-100\ ln2\ Joule$
c. $200\ ln2\ Joule$
d. $-200\ ln2\ Joule$

Solution: (c)

$W_{isothermal} = P_1V_1 \ln\frac{V_2}{V_1}$

$V_1 = 100\ m^3$

$V_2 = 200\ m^3$

$P_1 = 2\ N/m^2$

$W_{isothermal} = 2 \times 100 \ln\frac{200}{100}$

$W = 200\ ln2\ Joule$