JEE Main July 2021

Question Paper With Text Solution

20 July. | Shift-2

PHYSICS

MATRIX

JEE Main & Advanced | XI-XII Foundation| VI-X Pre-Foundation

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JEE MAIN JULY 2021 | 20TH JULY SHIFT-2

SECTION – A

1. With what speed should a galaxy move outward with respect to earth so that the sodium-D line at wavelength 5890Å is observed at 5896Å ?

(1) 296 km/sec

(2) 336km/sec

(3) 306 km/sec

(4) 322 km/sec

Ans. Official Answer NTA (3)

Sol. $\frac{\lambda_r}{\lambda_s} = \sqrt{\frac{1+\beta}{1-\beta}}$ $\quad\left\{\beta = \frac{v}{c}\right\}$

$\frac{\lambda_r}{\lambda_s} = (1+\beta)^{\frac{1}{2}}(1-\beta)^{-\frac{1}{2}}$

If β<<1

$\frac{\lambda_r - \lambda_s}{\lambda_s} = (1+\beta)^1 - 1$

$\frac{6}{5890} = \frac{v}{c}$

$v \approx 306\ \text{km/s}$

2. A body rolls down an inclined plane without slipping. The kinetic energy of rotation is 50% of its translational kinetic energy. The body is :

(1) Solid cylinder

(2) Hollow cylinder

(3) Ring

(4) Solid sphere

Ans. Official Answer NTA (1)

Sol. $\text{R.K.E} = \frac{1}{2}\ \text{T.K.E}$

$\frac{1}{2}I\omega^2 = \frac{1}{2} \times \left(\frac{1}{2}mv^2\right)$

For rolling without slipping $\omega = \frac{v}{r}$

$$\frac{1}{2} I \frac{v^2}{R^2} = \frac{1}{4} mv^2$$

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

Body is a uniform disc or a uniform solid cylinder.

3. If the Kinetic energy of a moving body becomes four times its initial kinetic energy, then the percentage change in its momentum will be :

(1) 400%

(2) 300%

(3) 100%

(4) 200%

Ans. Official Answer NTA (3)

Sol. $p = \sqrt{2mk}$

$p' = \sqrt{2m(4k)} = 2p$

Percentage change = $\frac{2p - p}{p} \times 100 = 100\%$

4. The magnetic susceptibility of a material of a rod is 499. Permeability in vacuum is $4\pi \times 10^{-7}\,H/m$. Absolute permeability of the material of the rod is :

(1) $\pi \times 10^{-4}\,H/m$

(2) $4\pi \times 10^{-4}\,H/m$

(3) $2\pi \times 10^{-4}\,H/m$

(4) $3\pi \times 10^{-4}\,H/m$

Ans. Official Answer NTA (3)

Sol. $\mu_r = 1 + x$ {x = magnetic susceptibility}

$= 500$

$\mu = \mu_0 \mu_r = 4\pi \times 10^{-7} \times 500$

$= 2\pi \times 10^{-4}\,H/m$

5. For a series LCR circuit with $R = 100\,\Omega$, $L = 0.5$ mH and $C = 0.1$ pF connected across 220 V–50 Hz AC supply, the phase angle between current and supplied voltage and the nature of the circuit is :

(1) $\approx 90°$, predominantly capacitive circuit

(2) 0°, resistive circuit

(3) 0°, resonance circuit

(4) $\approx 90°$, predominantly inductive circuit

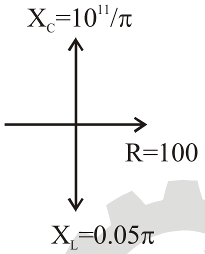
Ans. Official Answer NTA (1)

Sol. $X_C = \frac{1}{\omega C} = \frac{1}{(100\pi)\times 0.1\times 10^{-12}}$

$X_C = \frac{10^{11}}{\pi}$

$X_L = \omega L = (100\pi)\times 0.5\times 10^{-3}$

$= 0.05\,\pi$



$X_C >> R$ and X_L

So Z will almost be aligned with X_C

$\theta \approx 90°$, it will be predominantly capacitive circuit

6. A particle is making simple harmonic motion along the X-axis. If at a distances x_1 and x_2 from the mean position the velocities of the particle are v_1 and v_2 respectively. The time period of its oscillation is given as :

(1) $T = 2\pi\sqrt{\frac{x_2^2 + x_1^2}{\upsilon_1^2 + \upsilon_2^2}}$

(2) $T = 2\pi\sqrt{\frac{x_2^2 - x_1^2}{\upsilon_1^2 - \upsilon_2^2}}$

(3) $T = 2\pi\sqrt{\frac{x_2^2 - x_1^2}{\upsilon_1^2 + \upsilon_2^2}}$

(4) $T = 2\pi\sqrt{\frac{x_2^2 + x_1^2}{\upsilon_1^2 - \upsilon_2^2}}$

Ans. Official Answer NTA (2)

Sol. $v_1^2 = \omega^2\left(A^2 - x_1^2\right)$ ....(1)

$v_2^2 = \omega^2\left(A^2 - x_2^2\right)$ ....(2)

From (1) and (2)

$$\frac{v_1^2 + \omega^2 x_1^2}{v_2^2 + \omega^2 x_2^2} = 1$$

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

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

7. A body at rest is moved along a horizontal straight line by a machine delivering a constant power. The distance moved by the body in time 't' is proportional to :

(1) $t^{\frac{1}{2}}$

(2) $t^{\frac{1}{4}}$

(3) $t^{\frac{3}{4}}$

(4) $t^{\frac{3}{2}}$

Ans. Official Answer NTA (4)

Sol. power $p = \frac{dk}{dt} = \text{const}$

$$\frac{d}{dt}\left(\frac{1}{2}mv^2\right) = p$$

$$\frac{1}{2}m \times 2v\frac{dv}{dt} = p$$

$$\int_0^v v\,dv = \frac{p}{m}\int_0^t dt$$

$$\frac{v^2}{2} = \frac{pt}{m}$$

$$v = \sqrt{\frac{2p}{m}}\ t^{\frac{1}{2}}$$

$$\int_0^x dx = \sqrt{\frac{2p}{m}}\int_0^t t^{\frac{1}{2}}\ dt$$

$$x = \sqrt{\frac{2p}{m}}\ \frac{t^{3/2}}{3/2}$$

$x \propto t^{3/2}$

8. A boy reaches the airport and finds that the escalator is not working. He walks up the stationary escalator in time t_1. If he remains stationary on a moving escalator then the escalator takes him up in the time t_2. The time taken by him to walk up on the moving escalator will be :

(1) $\frac{t_1 t_2}{t_2 + t_1}$

(2) $\frac{t_1 t_2}{t_2 - t_1}$

(3) $t_2 - t_1$

(4) $\frac{t_1 + t_2}{2}$

Ans. Official Answer NTA (1)

Sol. Suppose length of escalator $= L$

$v_{boy/esc} \frac{L}{t_1} =$ velocity of boy on stationary escalator

$$v_{esc} = \frac{L}{t_2}$$

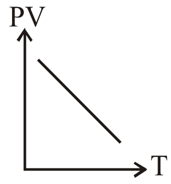
velocity of boy on moving escalator $= v_{boy}$

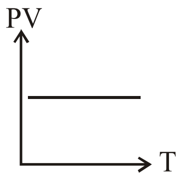
$$v_{boy} = v_{boy/esc} + v_{esc} = L\left(\frac{1}{t_1} + \frac{1}{t_2}\right)$$

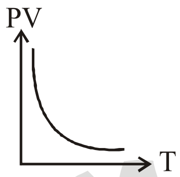
$$t = \frac{L}{v_{boy}} = \frac{L}{L\left(\frac{1}{t_1} + \frac{1}{t_2}\right)}$$

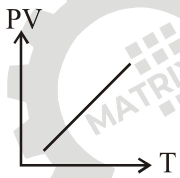
$$t = \frac{t_1 t_2}{t_2 + t_1}$$

9. Which of the following graphs represent the behavior of an ideal gas ? Symbols have their usual meaning.

(1) 

(2) 

(3) 

(4) 

Ans. Official Answer NTA (4)

Sol. pv = (nR)T

nR = const. for a closed system

pv = y and T = x

y = mx $\Rightarrow$ Straight line with positive slope

10. The length of a metal viree is l_1, when the tension in it is T_1 and is l_2 when the tension is T_2. The natural length of the wire is :

(1) $\frac{l_1 T_2 - l_2 T_1}{T_2 - T_1}$

(2) $\sqrt{l_1 l_2}$

(3) $\frac{l_1 T_2 + l_2 T_1}{T_2 + T_1}$

(4) $\frac{l_1 + l_2}{2}$

Ans. Official Answer NTA (1)

Sol. $\frac{T_1}{A} = \frac{y(l_1 - L)}{L}$ ....(1)

$\frac{T_2}{A} = \frac{y(l_2 - L)}{L}$ ....(2)

(1) ÷ (2)

$\frac{T_1}{T_2} = \frac{l_1 - L}{l_2 - L}$

$L = \frac{l_1 T_2 - l_2 T_1}{T_2 - T_1}$

11. If time(t), velocity(v), and angular momentum(l) are taken as the fundamental units. Then the dimension of mass (m) in terms of t, v, and l is :

(1) $[t^1 v^2 l^{-1}]$

(2) $[t^{-1} v^1 l^{-2}]$

(3) $[t^{-1} v^{-2} l^1]$

(4) $[t^{-2} v^{-1} l^1]$

Ans. Official Answer NTA (3)

Sol. $m = t^a v^b l^c$

$M = T^a (LT^{-1})^b (ML^2T^{-1})^c$

$M = M^c L^{b+2c} T^{a-b-c}$

$c = 1$

$b + 2c = 0 \Rightarrow b = -2$

$a - b - c = 0 \Rightarrow a = -1$

$m = t^{-1} v^{-2} l^1$

12. Two small drops of mercury each of radius R coalesce to from a single large drop. The ratio of total surface energy before and after the change is :

(1) 1 : 2

(2) $2^{\frac{1}{3}}:1$

(3) 2 : 1

(4) $1:2^{\frac{1}{3}}$

Ans. Official Answer NTA (2)

Sol. Initial surface energy = $T \times 4\pi R^2 \times 2$ {T = surface tension}

Final surface energy = $T \times 4\pi (R')^2$ $\{\frac{4}{3}\pi(R')^3 = 2\times\frac{4}{3}\pi R^3, \quad R' = 2^{\frac{1}{3}}R\}$

$= T\times 4\pi\times R^2\times 2^{2/3}$

$\frac{U_i}{U_f} = \frac{2^{\frac{1}{3}}}{1}$

13. An electron having de-Broglie wavelength λ is incident on a target in a X-ray tube. Cut-off wavelength of emitted X-ray is :

(1) $\frac{2mc\lambda^2}{h}$

(2) $\frac{hc}{mc}$

(3) $\frac{2m^2c^2\lambda^2}{h^2}$

(4) 0

Ans. Official Answer NTA (1)

Sol. K.E of electron $=\frac{(h/\lambda)^2}{2m} = \frac{hc}{\lambda_c}$ $\{\lambda_c$ = cut off wavelength of x-ray$\}$

$\lambda_c = \frac{2mc\lambda^2}{h}$

14. A satellite is launched into a circular orbit of radius R around earth, while a second satellite is launched into a circular orbit of radius 1.02R. The percentage difference in the time periods of the two satellites is :

(1) 2.0

(2) 0.7

(3) 3.0

(4) 1.5

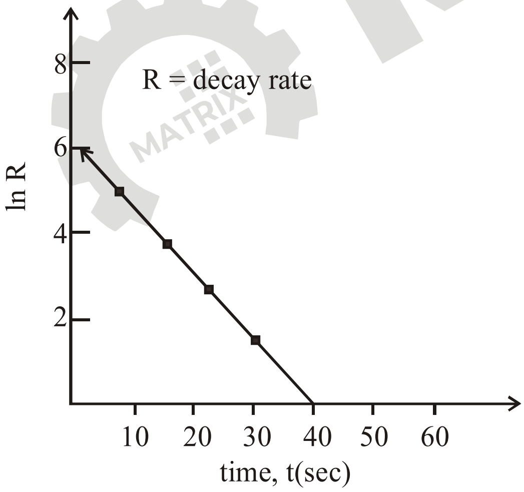
Ans. Official Answer NTA (2)

Sol. $T = \frac{2\pi R^{3/2}}{\sqrt{GM}}$

$\frac{dT}{T} = \frac{3}{2}\frac{dR}{R}$

$\frac{dT}{T} \times 100 = \frac{3}{2} \times \frac{0.02R}{R} \times 100 = 3\%$

15. For a certain radioactive process the graph between ln R and t(sec) is obtained as shown in the figure. Then the value of half life for the unknown radioactive material is approximately:



(1) 6.93 sec

(2) 2.62 sec

(3) 9.15 sec

(4) 4.62 sec

Ans. Official Answer NTA (4)

Sol. $R = R_0 e^{-\lambda t}$

$\ln R = \ln R_0 - \lambda t$ $\{y = c - mx\}$

Slope of line $= \dfrac{-6}{40} = -\lambda$

$T_{1/2} = \dfrac{\ln 2}{\lambda} = \dfrac{0.693}{6} \times 40 = 4.62$ sec

16. Two vectors $\vec{P}$ and $\vec{Q}$ have equal magnitudes. If the magnitude of $\vec{P}+\vec{Q}$ is n times the magnitude of $\vec{P}-\vec{Q}$, then angle between $\vec{P}$ and $\vec{Q}$ is :

(1) $\sin^{-1}\left(\dfrac{n^2-1}{n^2+1}\right)$

(2) $\sin^{-1}\left(\dfrac{n-1}{n+1}\right)$

(3) $\cos^{-1}\left(\dfrac{n-1}{n+1}\right)$

(4) $\cos^{-1}\left(\dfrac{n^2-1}{n^2+1}\right)$

Ans. Official Answer NTA (4)

Sol. $|\vec{P}+\vec{Q}| = n|\vec{P}-\vec{Q}|$

Suppose angle between $\vec{P}$ and $\vec{Q}$ $= \theta$

$P^2 + Q^2 + 2PQ\cos\theta = n^2\left(P^2 + Q^2 - 2PQ\cos\theta\right)$

Since, P = Q

$\cos\theta = \dfrac{n^2-1}{n^2+1}$

$\theta = \cos^{-1}\left(\dfrac{n^2-1}{n^2+1}\right)$

17. In an electromagnetic wave the electric field vector and magnetic field vector are given as $\vec{E} = E_0\hat{i}$ and $\vec{B} = B_0\hat{k}$ respectively. The direction of propagation of electromagnetic wave is along :

(1) $\hat{j}$

(2) $(\hat{k})$

(3) $(-\hat{k})$

(4) $(-\hat{j})$

Ans. Official Answer NTA (4)

Sol. Direction of propagation of electromagnetic wave is in the direction of vector $\vec{E}\times\vec{B}$ i.e. $(-\hat{j})$ in the given question.

18. The correct relation between the degrees of freedom f and the ratio of specific heat γ is ;

(1) $f = \frac{\gamma+1}{2}$

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

(3) $f = \frac{1}{\gamma+1}$

(4) $f = \frac{2}{\gamma+1}$

Ans. Official Answer NTA (2)

Sol. $\gamma = \frac{f+2}{f}$ or $f = \frac{2}{\gamma-1}$

19. At an angle of 30° to the magnetic meridian, the apparent dip is 45°. Find the true dip :

(1) $\tan^{-1}\frac{2}{\sqrt{3}}$

(2) $\tan^{-1}\sqrt{3}$

(3) $\tan^{-1}\frac{\sqrt{3}}{2}$

(4) $\tan^{-1}\frac{1}{\sqrt{3}}$

Ans. Official Answer NTA (3)

Sol. $\tan\theta' = \dfrac{\tan\theta}{\cos\alpha}$

Where θ' = apparent dip
θ = true dip
α = angle with magnetic meridian in horizontal plane

$\tan 45^\circ = \dfrac{\tan\theta}{\cos(30^\circ)}$

$\theta = \tan^{-1}\dfrac{\sqrt{3}}{2}$

20. Consider a binary star system of star A and star B with masses m_A and m_B revolving in a circular orbit of radii r_A and r_B, respectively. If T_A and T_B are the time period of star A and star B, respectively, then :

(1) $\dfrac{T_A}{T_B} = \left(\dfrac{r_A}{r_B}\right)^{\frac{3}{2}}$

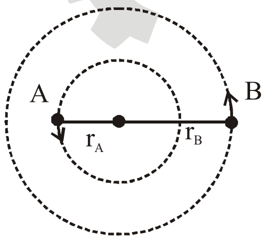
(2) $T_A > T_B \left(\text{if } r_A > r_B\right)$

(3) $T_A = T_B$

(4) $T_A > T_B \left(\text{if } m_A > m_B\right)$

Ans. Official Answer NTA (3)

Sol. If a binary star system is revolving in a circular orbit about their COM under mutual gravitational attraction, then their time periods are exactly equal.



$$\frac{Gm_A m_B}{(r_A + r_B)^2} = \frac{m_A v_A^2}{r_A}$$

$$v_A = \sqrt{\frac{G m_B r_A}{(r_A + r_B)^2}}$$

$$v_B = \sqrt{\frac{G m_A r_B}{(r_A + r_B)^2}}$$

$r_A = \dfrac{(r_A + r_B)m_B}{m_A + m_B}$

$r_B = \dfrac{(r_A + r_B)m_A}{m_A + m_B}$

$T_A = \dfrac{2\pi r_A}{v_A}$

$T_B = \dfrac{2\pi r_B}{v_B}$

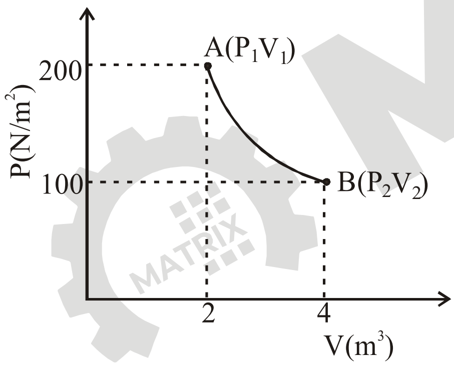
On putting the values of r_A, r_B, v_A & v_B

$T_A = T_B$

SECTION - B

1. One mole of an ideal gas at 27° C is taken from A to B as shown in the given PV indicator diagram. The work done by the system will be _______ $\times 10^{-1}$ J. [Given : R = 8.3 J/mole K, *l*n2 = 0.6931]

(Round off to the nearest integer)



Ans. Official Answer NTA (17258)

Sol. $P_1V_1 = P_2V_2 \Rightarrow$ Isothermal process

$W = nRT\, ln \dfrac{v_2}{v_1}$

$= 1 \times 8.3 \times 300 \times ln\, 2$

$= 1725.82 = 17258.2 \times 10^{-1}$ J

Nearest integer = 17258

2. Two bodies, a ring and a solid cylinder of same material are rolling down without slipping an inclined plane. The radii of the bodies are same. The ratio of velocity o the centre of mass at the bottom of the inclined plane of the ring to that of the cylinder is $\frac{\sqrt{x}}{2}$. Then, the value of x is ______.

Ans. Official Answer NTA (3)

Sol. Conservation of energy

For Ring : $mgH = \frac{1}{2}mv_1^2 + \frac{1}{2}\left(mR^2\right)\left(\frac{v_1^2}{R^2}\right)$

$v_1 = \sqrt{gH}$

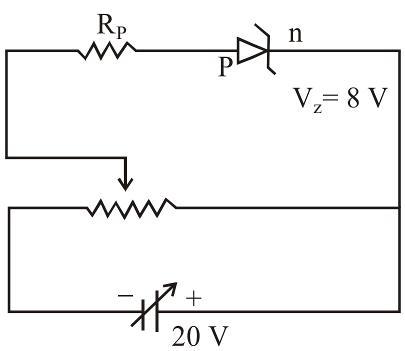
For solid cylinder : $MgH = \frac{1}{2}Mv_2^2 + \frac{1}{2}\left(\frac{MR^2}{2}\right)\left(\frac{v_2^2}{R^2}\right)$

$v_2 = \sqrt{\frac{4}{3}gH}$

$\frac{v_1}{v_2} = \frac{\sqrt{3}}{2}$

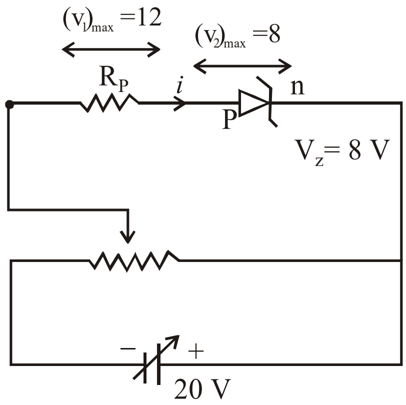
$x = 3$

3. A zener diode having zener voltage 8V and power dissipation rating of 0.5 W is connected across a potential divider arranged with maximum potential drop across zener diode is as shown in the diagram. The value of protective resistance R_p is _______Ω.



Ans. Official Answer NTA (192)

Sol.



$8 \times i = 0.5$
$i = 0.0625$ A
For $R_P \Rightarrow V = iR_P$
$12 = 0.0625 \times R_P$

$R_P = 192$

4. A body of mass 'm' is launched up on a rough inclined plane making an angle of 30° with the horizontal. The coefficient of friction between the body and plane is $\frac{\sqrt{x}}{5}$ if the time of ascent is half of the time o descent. The value of x is ______.

Ans. Official Answer NTA (3)

Sol. For ascent :

$a = g(\sin\theta + \mu\cos\theta)$

$s = vt - \frac{1}{2}at^2$

$s = 0 - \frac{1}{2}\left(-g(\sin\theta + \mu\cos\theta)\right)t_1^2$

$t_1^2 = \frac{2s}{g(\sin\theta + \mu\cos\theta)}$

For Descent : $a = g(\sin\theta - \mu\cos\theta)$

$t_2^2 = \frac{2s}{g\left(\sin\theta - \mu\cos\theta\right)}$

$2t_1 = t_2$ (according to question)

$4t_1^2 = t_2^2$

$$\frac{4}{g(\sin\theta+\mu\cos\theta)}=\frac{1}{g(\sin\theta-\mu\cos\theta)}$$

Putting $\theta = 30^\circ$

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

x = 3

5. A body rotating with an angular speed of 600 rpm is uniformly accelerated to 1800 rpm in 10 sec. The number of rotations made in the process is _____.

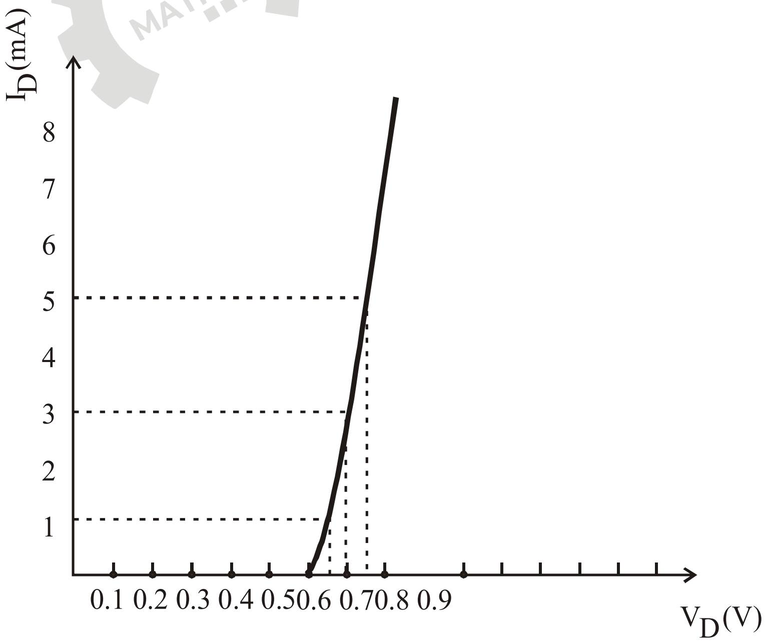
Ans. Official Answer NTA (200)

Sol. For uniform angular acceleration :

$$\theta=\left(\frac{\omega_i+\omega_f}{2}\right)t$$

$$=\left(\frac{600+1800}{2}\right)\times\left(\frac{10}{60}\text{min}\right)=200 \text{ rotations}$$

6. For the forward biased diode characteristics shown in the figure, the dynamic resistance at I_D = 3 mA will be ______ Ω.



Ans. Official Answer NTA (25)

Sol. $R_D = \frac{\Delta V}{\Delta I} = \frac{0.75 - 0.7}{(5-3)\times 10^{-3}}$

$= 0.025 \times 10^3$

$= 25\ \Omega$

7. A series LCR circuit of R = 5 Ω, L = 20 mH and C = 0.5 μF is connected across an AC supply of 250 V, having variable frequency. The power dissipated at resonance condition is _______$\times 10^2$W.

Ans. Official Answer NTA (125)

Sol. At resonance $z = R = 5\ \Omega$

$i_{RMS} = \frac{v_{RMS}}{z} = \frac{250}{5} = 50A$

$p = i_{RMS}^2 R = 50^2 \times 5 = 12500 = 125 \times 10^2\ W$

8. A radioactive substance decays to $\left(\frac{1}{16}\right)^{th}$ of its initial activity in 80 days. The half life of the radioactive substance expressed in days is _______.

Ans. Official Answer NTA (20)

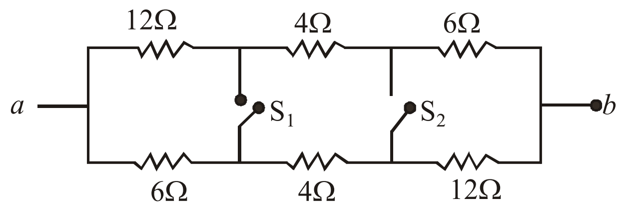
Sol. $R = \frac{R_0}{2^n} = \frac{R_0}{16}$

n = 4 half-lives

t = 80 days = $4T_{1/2}$

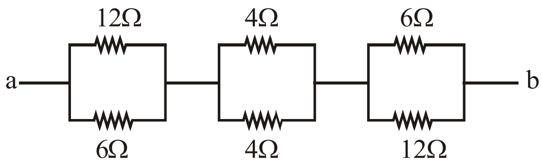
$T_{1/2}$ = 20 days

9. In the given figure switches S_1 and S_2 are in open condition. The resistance across ab when the switches S_1 and S_2 are closed is_______Ω.



Ans. Official Answer NTA (10)

sol. Equivalent circuit :



$$R_{eq} = \frac{12\times 6}{12+6} + \frac{4\times 4}{4+4} + \frac{12\times 6}{12+6} = 10\Omega$$

10. A certain metallic surface is illuminated by monochromatic radiation of wavelength λ. The stopping potential for photoelectric current for this radiation is $3V_0$. If the same surface is illuminated with a radiation of wavelength 2λ, the stopping potential is V_0. The threshold wavelength of this surface for photoelectric effect is ______λ.

Ans. Official Answer NTA (4)

Sol. $\frac{hc}{\lambda} - \phi = e(3V_0)$ ....(1)

$\frac{hc}{2\lambda} - \phi = eV_0$ ....(2)

(1) ÷ (2)

$$\frac{hc}{2\lambda} - \phi = 3\left(\frac{hc}{2\lambda} - \phi\right)$$

$\phi = \frac{hc}{4\lambda} = \frac{hc}{\lambda_t}$ {λ_t = threshold wavelength}

$\lambda_t = 4\lambda$