

**FINAL JEE-MAIN EXAMINATION – JULY, 2021**
**(Held On Tuesday 20<sup>th</sup> July, 2021)**
**TIME : 3 : 00 PM to 6 : 00 PM**
**PHYSICS**
**TEST PAPER WITH SOLUTION**
**SECTION-A**

1. 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) 100% (2) 200%  
 (3) 300% (4) 400%

**Official Ans. by NTA (1)**
**Sol.**  $K_2 = 4K_1$ 

$$\frac{1}{2}mv_2^2 = 4 \frac{1}{2}mv_1^2$$

$$v_2 = 2v_1$$

$$P = mv$$

$$P_2 = mv_2 = 2mv_1$$

$$P_1 = mv_1$$

$$\% \text{ change} = \frac{\Delta P}{P_1} \times 100 = \frac{2mv_1 - mv_1}{mv_1} \times 100 = 100\%$$

2. 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 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)  $\frac{t_1 + t_2}{2}$  (3)  $\frac{t_1 t_2}{t_2 + t_1}$  (4)  $t_2 - t_1$

**Official Ans. by NTA (3)**
**Sol.**  $L = \text{Length of escalator}$ 

$$V_{b/esc} = \frac{L}{t_1}$$

When only escalator is moving.

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

when both are moving

$$V_{b/g} = V_{b/esc} + V_{esc}$$

$$V_{b/g} = \frac{L}{t_1} + \frac{L}{t_2} \Rightarrow t = \frac{L}{V_{b/g}} = \frac{t_1 t_2}{t_1 + t_2}$$

3. 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  $1.02 R$ . The percentage difference in the time periods of the two satellites is :

- (1) 1.5 (2) 2.0  
 (3) 0.7 (4) 3.0

**Official Ans. by NTA (4)**
**Sol.**  $T^2 \propto R^3$ 

$$T = kR^{3/2}$$

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

$$= \frac{3}{2} \times 0.02 = 0.03$$

$$\% \text{ Change} = 3\%$$

4. With what speed should a galaxy move outward with respect to earth so that the sodium-D line at wavelength  $5890 \text{ \AA}$  is observed at  $5896 \text{ \AA}$  ?

- (1) 306 km/sec (2) 322 km/sec  
 (3) 296 km/sec (4) 336 km/sec

**Official Ans. by NTA (1)**
**Sol.**  $f = f_0 \sqrt{\frac{1+\beta}{1-\beta}}$   $\beta = \frac{v}{c}$ 

$$\frac{f}{f_0} = \sqrt{\frac{1+\beta}{1-\beta}}$$

$$\left(1 + \frac{\Delta f}{f_0}\right)^2 = (1+\beta)(1-\beta)^{-1}$$

 $\beta$  is small compared to 1

$$\left(1 + \frac{2\Delta f}{f_0}\right) = (1+2\beta)$$

$$\beta = \frac{\Delta f}{f_0} = \frac{v}{c}$$

$$v = 6 \times \frac{c}{5890} = 305.6 \text{ km/s}$$

5. The length of a metal wire is  $\ell_1$ , when the tension in it is  $T_1$  and is  $\ell_2$  when the tension is  $T_2$ . The natural length of the wire is :

(1)  $\sqrt{\ell_1 \ell_2}$                       (2)  $\frac{\ell_1 T_2 - \ell_2 T_1}{T_2 - T_1}$   
 (3)  $\frac{\ell_1 T_2 + \ell_2 T_1}{T_2 + T_1}$                       (4)  $\frac{\ell_1 + \ell_2}{2}$

**Official Ans. by NTA (2)**

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

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

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

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

6. 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)  $(\hat{k})$   
 (2)  $\hat{j}$   
 (3)  $(-\hat{k})$   
 (4)  $(-\hat{j})$

**Official Ans. by NTA (4)**

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

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

- (1)  $0^\circ$ , resistive circuit  
 (2)  $\approx 90^\circ$ , predominantly inductive circuit  
 (3)  $0^\circ$ , resonance circuit  
 (4)  $\approx 90^\circ$ , predominantly capacitive circuit

**Official Ans. by NTA (4)**

**Sol.**  $R = 100 \Omega$

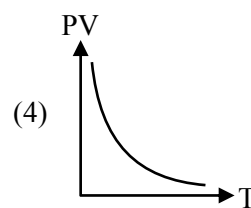
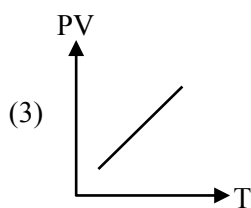
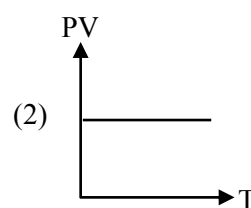
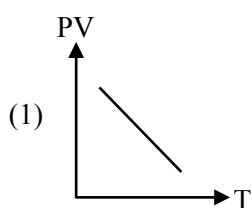
$X_L = \omega L = 50\pi \times 10^{-3}$

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

$X_C \gg X_L$

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

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



**Official Ans. by NTA (3)**

**Sol.**  $PV = nRT$

$PV \propto T$

Straight line with positive slope ( $nR$ )

9. 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)  $T = 2\pi \sqrt{\frac{x_2^2 + x_1^2}{v_1^2 - v_2^2}}$                       (2)  $T = 2\pi \sqrt{\frac{x_2^2 + x_1^2}{v_1^2 + v_2^2}}$

(3)  $T = 2\pi \sqrt{\frac{x_2^2 - x_1^2}{v_1^2 + v_2^2}}$                       (4)  $T = 2\pi \sqrt{\frac{x_2^2 - x_1^2}{v_1^2 - v_2^2}}$

**Official Ans. by NTA (4)**

**Sol.**  $v^2 = \omega^2 (A^2 - x^2)$

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

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

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

10. An electron having de-Broglie wavelength  $\lambda$  is incident on a target in a X-ray tube. Cut-off wavelength of emitted X-ray is :

(1) 0 (2)  $\frac{2m^2c^2\lambda^2}{h^2}$   
(3)  $\frac{2mc\lambda^2}{h}$  (4)  $\frac{hc}{mc}$

Official Ans. by NTA (3)

Sol.  $\lambda = \frac{h}{mv}$

kinetic energy,  $\frac{p^2}{2m} = \frac{h^2}{2m\lambda^2} = \frac{hc}{\lambda_c}$

$\lambda_c = \frac{2m\lambda^2c}{h}$

11. 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 sphere  
(2) Solid cylinder  
(3) Hollow cylinder  
(4) Ring

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

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

Official Ans. by NTA (4)

Sol.  $m \propto t^a v^b l^c$

$m \propto [T]^a [LT^{-1}]^b [ML^2T^{-1}]^c$

$M^1L^0T^0 = M^cL^{b+2c}T^{a-b-c}$

comparing powers

$c = 1, b = -2, a = -1$

$m \propto t^{-1}v^{-2}l^1$

13. The correct relation between the degrees of freedom  $f$  and the ratio of specific heat  $\gamma$  is :

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

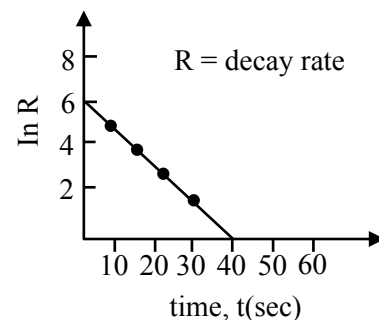
(3)  $f = \frac{\gamma+1}{2}$  (4)  $f = \frac{1}{\gamma+1}$

Official Ans. by NTA (1)

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

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

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



- (1) 9.15 sec (2) 6.93 sec  
(3) 2.62 sec (4) 4.62 sec

Official Ans. by NTA (4)

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

$\ln R = \ln R_0 - \lambda t$

$-\lambda$  is slope of straight line

$\lambda = \frac{3}{20}$

$t_{1/2} = \frac{\ln 2}{\lambda} = 4.62$

15. 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 :

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

$$(2) T_A = T_B$$

$$(3) T_A > T_B \text{ (if } m_A > m_B \text{)}$$

$$(4) T_A > T_B \text{ (if } r_A > r_B \text{)}$$

**Official Ans. by NTA (2)**

**Sol.**  $T_A = T_B$  (since  $\omega_A = \omega_B$ )

16. At an angle of  $30^\circ$  to the magnetic meridian, the apparent dip is  $45^\circ$ . Find the true dip :

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

$$(3) \tan^{-1} \frac{2}{\sqrt{3}} \quad (4) \tan^{-1} \frac{\sqrt{3}}{2}$$

**Official Ans. by NTA (4)**

**Sol.**  $A \tan \delta = \tan \delta' \cos \theta$

$$= \tan 45^\circ \cos 30^\circ$$

$$\tan \delta = 1 \times \frac{\sqrt{3}}{2}$$

$$\delta = \tan^{-1} \left( \frac{\sqrt{3}}{2} \right)$$

17. 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 :

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

**Official Ans. by NTA (1)**

**Sol.**  $P = \text{constant}$

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

$$\Rightarrow v \propto \sqrt{t}$$

$$\frac{dx}{dt} = C\sqrt{t} \quad C = \text{constant}$$

by integration.

$$x = C \frac{t^{\frac{1}{2}+1}}{\frac{1}{2}+1}$$

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

18. 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 :

$$(1) \sin^{-1} \left( \frac{n-1}{n+1} \right) \quad (2) \cos^{-1} \left( \frac{n-1}{n+1} \right)$$

$$(3) \sin^{-1} \left( \frac{n^2-1}{n^2+1} \right) \quad (4) \cos^{-1} \left( \frac{n^2-1}{n^2+1} \right)$$

**Official Ans. by NTA (4)**

**Sol.**  $|\vec{P}| = |\vec{Q}| = x \quad \dots(i)$

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

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

Using (i) in above equation

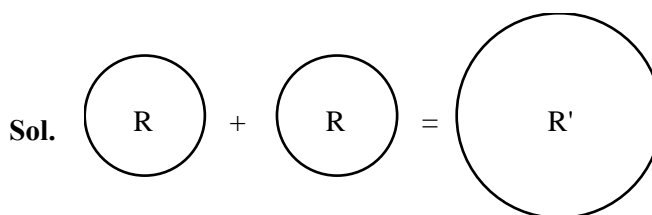
$$\cos\theta = \frac{n^2-1}{1+n^2}$$

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

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

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

**Official Ans. by NTA (1)**



$$\frac{4}{3}\pi R^3 + \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R'^3$$

$$R' = 2^{\frac{1}{3}} R \quad \dots(i)$$

$$A_i = 2[4\pi R^2]$$

$$A_f = 4\pi R'^2$$

$$\frac{U_i}{U_f} = \frac{A_i}{A_f} = \frac{2R^2}{2^{\frac{2}{3}}R^2} = 2^{1/3}$$

20. 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 :

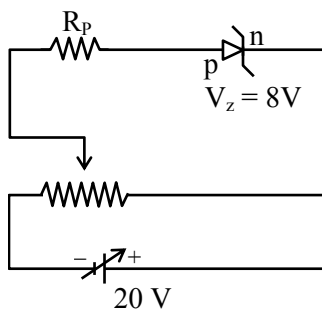
- (1)  $4\pi \times 10^{-4}$  H/m
- (2)  $2\pi \times 10^{-4}$  H/m
- (3)  $3\pi \times 10^{-4}$  H/m
- (4)  $\pi \times 10^{-4}$  H/m

**Official Ans. by NTA (2)**

**Sol.**  $\mu = \mu_0 (1 + \chi_m)$   
 $= 4\pi \times 10^{-7} \times 500$   
 $= 2\pi \times 10^{-4}$  H/m

### SECTION-B

1. A zener diode having zener voltage 8 V 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 ..... $\Omega$ .



**Official Ans. by NTA (192)**

**Sol.**  $P = Vi$   
 $0.5 = 8i$   
 $i = \frac{1}{16}$  A  
 $E = 20 = 8 + i R_p$   
 $R_p = 12 \times 16 = 192\Omega$

2. A body of mass 'm' is launched up on a rough inclined plane making an angle of  $30^\circ$  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 of descent. The value of x is \_\_\_\_\_.

**Official Ans. by NTA (3)**

**Sol.**  $t_a = \frac{1}{2} t_d$

$$\sqrt{\frac{2s}{a_a}} = \frac{1}{2} \sqrt{\frac{2s}{a_d}} \quad \dots(i)$$

$$a_a = g \sin \theta + \mu g \cos \theta$$

$$= \frac{g}{2} + \frac{\sqrt{3}}{2} \mu g$$

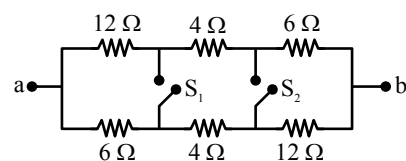
$$a_d = g \sin \theta - \mu g \cos \theta$$

$$= \frac{g}{2} - \frac{\sqrt{3}}{2} \mu g$$

using the above values of  $a_a$  and  $a_d$  and putting in

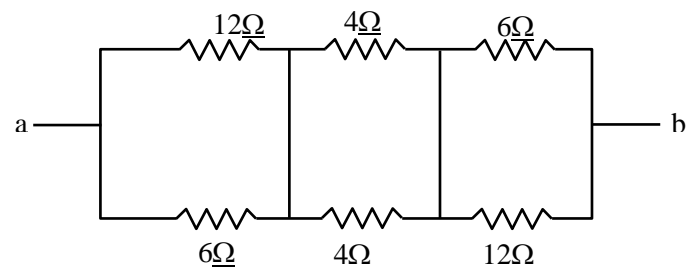
equation (i) we will get  $\mu = \frac{\sqrt{3}}{5}$

3. 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 \_\_\_\_\_ $\Omega$ .



**Official Ans. by NTA (10)**

**Sol.** when switch  $S_1$  and  $S_2$  are closed



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

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

4. 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 of 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 \_\_\_\_\_.

**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

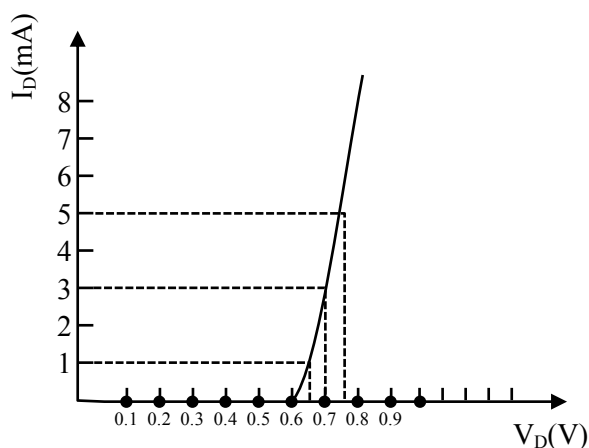
$$mgh = \frac{1}{2} I \omega^2$$

$$mgh = \frac{1}{2} \left( \frac{3}{2} mR^2 \right) \frac{v_C^2}{R^2}$$

$$v_C = \sqrt{\frac{4gh}{3}}$$

$$\frac{v_R}{v_C} = \frac{\sqrt{3}}{2}$$

5. For the forward biased diode characteristics shown in the figure, the dynamic resistance at  $I_D = 3$  mA will be \_\_\_\_\_  $\Omega$ .



**Official Ans. by NTA (25)**

**Sol.**  $R_d = \frac{dV}{di} = \frac{1}{\frac{di}{dv}} = \frac{1}{\frac{5 - 1 \times 10^{-3}}{0.75 - 0.65}}$

$$\frac{100}{4} = 25 \Omega$$

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

**Official Ans. by NTA (125)**

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

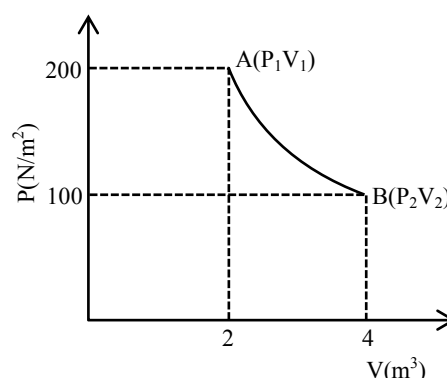
$$Z = R \text{ so } i_{rms} = \frac{V}{Z} = \frac{V}{R}$$

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

7. One mole of an ideal gas at  $27^\circ \text{C}$  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,  $\ln 2 = 0.6931$ ]

(Round off to the nearest integer)



**Official Ans. by NTA (17258)**

**Sol.** Process of isothermal

$$W = nRT \ln \left( \frac{V_2}{V_1} \right)$$

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

$$= 17258 \times 10^{-1} \text{ J}$$

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

**Official Ans. by NTA (4)**

**Sol.**  $KE = \frac{hc}{\lambda} - \phi$

$$e(3V_0) = \frac{hc}{\lambda_0} - \phi \quad \dots(i)$$

$$eV_0 = \frac{hc}{2\lambda_0} - \phi \quad \dots(ii)$$

Using (i) & (ii)

$$\phi = \frac{hc}{4\lambda_0} = \frac{hc}{\lambda_t}$$

$$\lambda_t = 4\lambda_0$$

9. 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 \_\_\_\_.

**Official Ans. by NTA (200)**

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

$$\alpha = 1200 \times 6$$

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

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

$$\theta = 200$$

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

**Official Ans. by NTA (20)**

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

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

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