

**PAPER-1(B.E./B. TECH.)**

# **JEE (Main) 2021**

**Questions & Solutions**

**Date : 26 February, 2021 (SHIFT-1) Time ; (9.00 am to 12.00 pm)**

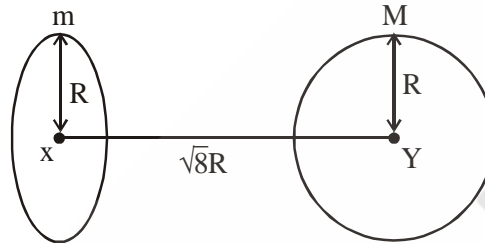
**Duration : 3 Hours | Max. Marks : 300**

**SUBJECT : PHYSICS**

**JEE-MAIN 2021 (26 FEBRUARY ATTEMPT) SHIFT-1**

**PHYSICS**

1. Find the gravitational force of attraction between the ring and sphere as shown in the diagram, where the plane of the ring is perpendicular to the line joining the centres. If  $\sqrt{8}R$  is the distance between the centres of a ring (of mass 'm') and a sphere (mass 'M') where both have equal radius 'R'.



- (1)  $\frac{\sqrt{8}}{9} \cdot \frac{GmM}{R}$       (2)  $\frac{2\sqrt{2}}{3} \cdot \frac{GMm}{R^2}$       (3)  $\frac{1}{3\sqrt{8}} \cdot \frac{GMm}{R^2}$       (4)  $\frac{\sqrt{8}}{27} \cdot \frac{GmM}{R^2}$

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

Sol.  $F = \frac{GMm\sqrt{8}R}{(R^2 + 8R^2)^{3/2}} = \frac{GMm}{R^2} \times \frac{\sqrt{8}}{27}$

2. Consider the combination of 2 capacitors  $C_1$  and  $C_2$ , with  $C_2 > C_1$ , when connected in parallel, the equivalent capacitance is  $\frac{15}{4}$  time the equivalent capacitance of the same connected in series.

Calculate the ratio of capacitors,  $\frac{C_2}{C_1}$ .

- (1)  $\frac{15}{11}$       (2)  $\frac{111}{80}$       (3)  $\frac{29}{15}$       (4)  $\frac{15}{4}$

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

**Reliable Ans. Bonus**

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

$$4(C_1 + C_2)^2 = 15C_1 C_2$$

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

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

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

$\frac{C_2}{C_1}$  has not real value.

$\frac{C_2}{C_1} = \text{Imaginary.}$

3. In a typical combustion engine the work done by a gas molecule is given  $W = \alpha^2 \beta e^{-\frac{\beta x^2}{kT}}$ , where x is the displacement, k is the Boltzmann constant and T is the temperature. If  $\alpha$  and  $\beta$  are constants, dimensions of  $\alpha$  will be :

- (1)  $[MLT^{-2}]$                       (2)  $[M^0LT^0]$                       (3)  $[M^2LT^{-2}]$                       (4)  $[MLT^{-1}]$

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

Sol.  $\frac{\beta x^2}{kT}$  is dimension less so  $kT = \beta x^2 \Rightarrow M^1 L^2 T^{-2} = \beta L^2$

$$\beta = M^1 T^{-2}$$

$$w = \alpha^2 \times \beta$$

$$M^1 L^2 T^{-2} = \alpha^2 \times M^1 T^{-2}$$

$$\alpha = L$$

4. If  $\lambda_1$  and  $\lambda_2$  are the wavelengths of the third member of Lyman and first member of the Paschen series respectively, then the value of  $\lambda_1 : \lambda_2$  is :

- (1) 1 : 9                                      (2) 7 : 108                                      (3) 7 : 135                                      (4) 1 : 3

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

**Sol.**  $\frac{1}{\lambda_1} = R \left[ 1 - \frac{1}{(4)^2} \right]$ , Lyman,

$$\frac{1}{\lambda_2} = R \left[ \frac{1}{9} - \frac{1}{(4)^2} \right], \text{Parchen}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{\left( \frac{1}{9} - \frac{1}{16} \right)}{\left( 1 - \frac{1}{16} \right)} = \frac{7}{15}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{7}{9 \times 15} = \frac{7}{135}$$

5. A short straight object of height 100 cm lies before the central axis of a spherical mirror whose focal length has absolute value  $|f| = 40\text{cm}$ . The image of object produced by the mirror is of height 25 cm and has the same orientation of the object. One may conclude from the information:
- (1) Image is real, same side of concave mirror.
  - (2) Image is virtual, opposite side of concave mirror.
  - (3) Image is real, same side of convex mirror.
  - (4) Image is virtual, opposite side of convex mirror.

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

**Sol.** Same orientation so image is virtual. It is combination of real object and virtual image using height it is possible only from convex mirror.

6. Assume that a tunnel is dug along a chord of the earth, at a perpendicular distance  $(R/2)$  from the earth's centre, where 'R' is the radius of the Earth. The wall of the tunnel is frictionless. If a particle is released in this tunnel, it will execute a simple harmonic motion with a time period :

(1)  $\frac{2\pi R}{g}$                       (2)  $\frac{g}{2\pi R}$                       (3)  $\frac{1}{2\pi} \sqrt{\frac{g}{R}}$                       (4)  $2\pi \sqrt{\frac{R}{g}}$

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

**Sol.** If displaced from equilibrium position,

$$F_{\text{res towards equilibrium}} = \left( \frac{GMm r}{R^3} \right) \cos \theta$$

$$= \frac{GMm r}{R^3} \cdot \frac{x}{r}$$

$$= \left( \frac{GMm}{R^3} \right) x$$

$$= \left( \frac{gm}{R} \right) x$$

$$\therefore T = 2\pi \sqrt{\frac{m}{\frac{mg}{R}}} = 2\pi \sqrt{\frac{R}{g}}$$

7. An alternating current is given by the equation  $i = i_1 \sin \omega t + i_2 \cos \omega t$ . The rms current will be

(1)  $\frac{1}{\sqrt{2}}(i_1^2 + i_2^2)^{\frac{1}{2}}$       (2)  $\frac{1}{\sqrt{2}}(i_1 + i_2)^2$       (3)  $\frac{1}{2}(i_1^2 + i_2^2)^{\frac{1}{2}}$       (4)  $\frac{1}{\sqrt{2}}(i_1 + i_2)$

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

**Sol.**  $I = \sqrt{I_1^2 + I_2^2 + 2I_1I_2 \cos 90^\circ}$

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

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

8. The normal density of a material is  $\rho$  and its bulk modulus of elasticity is  $K$ . The magnitude of increase in density of material, when a pressure  $P$  is applied uniformly on all sides, will be :

(1)  $\frac{\rho K}{P}$       (2)  $\frac{\rho P}{K}$       (3)  $\frac{K}{\rho P}$       (4)  $\frac{PK}{\rho}$

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

**Sol.**  $K = -\frac{P}{\frac{dv}{v}}$

$$\rho \propto \frac{1}{v}$$

$$\frac{d\rho}{\rho} = -\frac{dv}{v}$$

$$\frac{d\rho}{\rho} = \frac{P}{K}$$

$$d\rho = \frac{P\rho}{K}$$

9. A particle is moving with uniform speed along the circumference of a circle of radius  $R$  under the action of a central fictitious force  $F$  which is inversely proportional to  $R^3$ . Its time period of revolution will be given by :

(1)  $T \propto R^2$                       (2)  $T \propto R^{\frac{3}{2}}$                       (3)  $T \propto R^{\frac{5}{2}}$                       (4)  $T \propto R^{\frac{4}{3}}$

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

**Sol.**  $F = \frac{C}{R^3} = m\omega^2 R$

$\therefore \omega^2 \propto \frac{1}{R^4}$

$\therefore \omega \propto \frac{1}{R^2}$

$\therefore T \propto R^2$

10. A planet revolving in elliptical orbit has :

- (A) a constant velocity of revolution.  
 (B) has the least velocity when it is nearest to the sun.  
 (C) its areal velocity is directly proportional to its velocity.  
 (D) areal velocity is inversely proportional to its velocity.  
 (E) to follow a trajectory such that the areal velocity is constant.

Choose the correct answer from the options given below :

- (1) A only                      (2) D only                      (3) C only                      (4) E only

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

11. Given below are two statements: One is labelled as Assertion A and the other is labelled as Reason R.

**Assertion A :** Body 'P' having mass  $M$  moving with speed 'u' has head-on collision elastically with another body 'Q' having mass 'm' initially at rest. If  $m \ll M$ , body 'Q' will have a maximum speed equal to '2u' after collision.

**Reason R :** During elastic collision, the momentum and kinetic energy are both conserved.

In the light of the above statements, choose the most appropriate answer from the options given below :

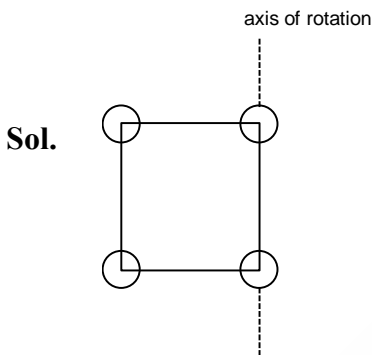
- (1) A is not correct but R is correct.  
 (2) Both A and R are correct but R is NOT the correct explanation of A.  
 (3) Both A and R are correct and R is the correct explanation of A.  
 (4) A is correct but R is not correct.

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

12. Four identical solid spheres each of mass 'm' and radius 'a' are placed with their centres on the four corners of a square of side 'b'. The moment of inertia of the system about one side of square where the axis of rotation is parallel to the plane of the square is :

(1)  $\frac{4}{5}ma^2 + 2mb^2$       (2)  $\frac{8}{5}ma^2 + mb^2$       (3)  $\frac{8}{5}ma^2 + 2mb^2$       (4)  $\frac{4}{5}ma^2$

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



$$I = 2 \times \frac{2}{5} ma^2 + 2 \left[ \frac{2}{5} ma^2 + mb^2 \right]$$

$$I = \frac{4}{5} ma^2 + \frac{4}{5} ma^2 + 2mb^2$$

$$= \frac{8}{5} ma^2 + 2mb^2$$

13. In a Young's double slit experiment two slits are separated by 2 mm and the screen is placed one meter away. When a light of wavelength 500 nm is used, the fringe separation will be:
- (1) 0.25 mm      (2) 0.50 mm      (3) 0.75 mm      (4) 1 mm

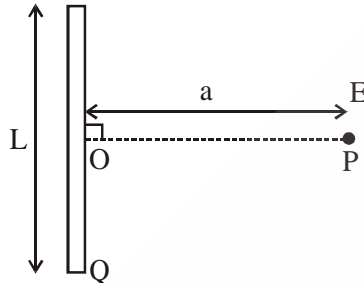
**Official Ans. by NTA (1)**

Sol.  $\beta = \frac{\lambda D}{d} = \frac{500 \times 10^{-9} \times 1}{2 \times 10^{-3}}$

$$= 2.5 \times 10^{-4}$$

$$= 0.25 \text{ mm}$$

- 14.** Find the electric field at point P (as shown in figure) on the perpendicular bisector of a uniformly charged thin wire of length L carrying a charge Q. The distance of the point P from the centre of the rod is  $a = \frac{\sqrt{3}}{2}L$ .



- (1)  $\frac{\sqrt{3}Q}{4\pi\epsilon_0 L^2}$                       (2)  $\frac{Q}{3\pi\epsilon_0 L^2}$   
 (3)  $\frac{Q}{2\sqrt{3}\pi\epsilon_0 L^2}$                       (4)  $\frac{Q}{4\pi\epsilon_0 L^2}$

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

**Sol.**  $E = \frac{K\lambda}{r} (\sin \theta_1 + \sin \theta_2)$

$$\theta_1 = \theta_2 = 30^\circ, \quad r = \frac{\sqrt{3} \ell}{2}, \quad \lambda = \frac{Q}{\ell}$$

$$E = \frac{1}{4\pi\epsilon_0} \frac{\frac{Q}{\ell} \left( \frac{1}{2} + \frac{1}{2} \right)}{\frac{\sqrt{3} \ell}{2}} = \frac{Q}{2\sqrt{3} \pi \epsilon_0 \ell^2}$$

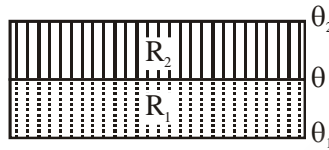
- 15.** If two similar springs each of spring constant  $K_1$  are joined in series, the new spring constant and time period would be changed by a factor:

- (1)  $\frac{1}{2}, \sqrt{2}$                       (2)  $\frac{1}{4}, \sqrt{2}$   
 (3)  $\frac{1}{4}, 2\sqrt{2}$                       (4)  $\frac{1}{2}, 2\sqrt{2}$

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



16. The temperature  $\theta$  at the junction of two insulating sheets, having thermal resistances  $R_1$  and  $R_2$  as well as top and bottom temperatures  $\theta_1$  and  $\theta_2$  (as shown in figure) is given by :



- (1)  $\frac{\theta_2 R_2 - \theta_1 R_1}{R_2 - R_1}$       (2)  $\frac{\theta_1 R_2 - \theta_2 R_1}{R_2 - R_1}$       (3)  $\frac{\theta_1 R_2 + \theta_2 R_1}{R_1 + R_2}$       (4)  $\frac{\theta_1 R_1 + \theta_2 R_2}{R_1 + R_2}$

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

**Sol.**  $\frac{\theta_2 - \theta}{R_2} = \frac{\theta - \theta_1}{R_1}$

$$\theta_2 R_1 - \theta R_1 = \theta R_2 - \theta_1 R_2$$

$$\theta [R_1 + R_2] = \theta_1 R_2 + \theta_2 R_1$$

$$\theta = \frac{\theta_1 R_2 + \theta_2 R_1}{R_1 + R_2}$$

17. Given below are two statements: One is labelled as Assertion A and the other is labelled as Reason R.

**Assertion A:** An electron microscope can achieve better resolving power than an optical microscope.

**Reason R:** The de Broglie's wavelength of the electrons emitted from an electron gun is much less than wavelength of visible light.

In the light of the above statements, choose the correct answer from the options given below:

- (1) A is true but R is false.  
 (2) Both A and R are true and R is the correct explanation of A.  
 (3) Both A and R are true but R is NOT the correct explanation of A.  
 (4) A is false but R is true.

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

- Sol.** The wave length of wave associated with  $e^{-1}$  is less than that of visible light. Therefore the resolving power of an electron microscope is higher than that of an optical microscope.

18. LED is constructed from Ga-As-P semiconducting material. The energy gap of this LED is 1.9 eV. Calculate the wavelength of light emitted and its colour.

$$[h = 6.63 \times 10^{-34} \text{ Js and } c = 3 \times 10^8 \text{ ms}^{-1}]$$

- (1) 1046 nm and red colour  
(2) 654 nm and orange colour  
(3) 1046 nm and blue colour  
(4) 654 nm and red colour

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

**Sol.**  $\lambda = \frac{1242}{1.9} \text{ nm} = 654 \text{ nm, Red..}$

19. A large number of water drops, each of radius  $r$ , combine to have a drop of radius  $R$ . If the surface tension is  $T$  and mechanical equivalent of heat is  $J$ , the rise in heat energy per unit volume will be:

- (1)  $\frac{2T}{J} \left( \frac{1}{r} - \frac{1}{R} \right)$                       (2)  $\frac{2T}{rJ}$   
(3)  $\frac{3T}{rJ}$     (4)  $\frac{3T}{J} \left( \frac{1}{r} - \frac{1}{R} \right)$

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

**Sol.**  $n \frac{4}{3} \pi r^3 = \frac{4}{3} \pi R^3$

$$(n^{1/3})r = R$$

$\Delta u$  loss

$$= T (\text{change in surface area})$$

$$= T(n4\pi r^2 - 4\pi R^2)$$

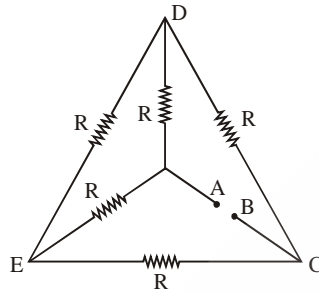
$$= T4\pi (nr^2 - R^2).$$

$$\Delta U = 4\pi T \left[ \left( \frac{R}{r} \right)^3 r^2 - R^2 \right]$$

$$\Delta U = 4\pi T \frac{\left[ \frac{R^3}{r} - R^2 \right]}{J}$$

$$\frac{\Delta U}{V} = \frac{4\pi T \left[ \frac{R^3}{r} - R^2 \right]}{J \times \frac{4}{3} \pi R^3} = \frac{3T}{J} \left[ \frac{1}{r} - \frac{1}{R} \right]$$

20. Five equal resistances are connected in a network as shown in figure. The net resistance between the points A and B is :



- (1)  $2R$                       (2)  $\frac{R}{2}$                       (3)  $\frac{3R}{2}$                       (4)  $R$

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

**Sol.** It is balanced wheat stone bridge so  
 $R_{AB} = R$

21. A person standing on a spring balance inside a stationary lift measures 60 kg. The weight of that person if the lift descends with uniform downward acceleration of  $1.8 \text{ m/s}^2$  will be \_\_\_\_\_ N.  
[ $g = 10 \text{ m/s}^2$ ]

**Official Ans. by NTA 492**

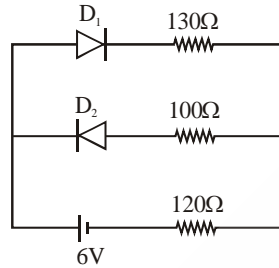
**Sol.**  $mg - T = ma$   
 $T = m(g-a)$   
 $= 60 [10 - 1.8]$   
 $= 60 \times 8.2$   
 $= 492 \text{ N}$

22. In an electrical circuit, a battery is connected to pass 20 C of charge through it in a certain given time. The potential difference between two plates of the battery is maintained at 15 V. The work done by the battery is \_\_\_\_\_ J.

**Official Ans. by NTA 300**

**Sol.**  $\omega = QV$   
 $= 15 \times 20 = 300 \text{ Joules}$

23. The circuit contains two diodes each with a forward resistance of  $50\ \Omega$  and with infinite reverse resistance. If the battery voltage is  $6\text{V}$ , the current through the  $120\ \Omega$  resistance is  $\_\text{mA}$ .



**Official Ans. by NTA 20**

Sol.  $i = \frac{6}{300} = \frac{1}{50}\text{A}$   
 $= \frac{1000}{50}\text{mA}$   
 $= 20\text{mA}$

24. A radiation is emitted by  $1000\text{W}$  bulb and it generates an electric field and magnetic field at  $P$ , placed at a distance of  $2\text{m}$ . The efficiency of the bulb is  $1.25\%$ . The value of peak electric field at  $P$  is  $x \times 10^{-1}\text{V/m}$ . Value of  $x$  is  $\_\_$ . (Rounded-off to the nearest integer)  
 [Take  $\epsilon_0 = 8.85 \times 10^{-12}\text{C}^2\text{N}^{-1}\text{m}^{-2}$ ,  $c = 3 \times 10^8\text{ms}^{-1}$ ]

**Official Ans. by NTA 137**

**Reliable Ans. 13**

Sol.  $I = \frac{1}{2}(\epsilon_0 c)E_0^2 = \frac{\text{Power}}{4\pi(2)^2}$   
 $\therefore \frac{1}{2} \times (4\pi\epsilon_0)(c)E_0^2 = \frac{1000 \times 1.2}{4} \times \frac{1}{100}$   
 $\therefore \frac{1}{2} \times \frac{3 \times 10^8}{9 \times 10^9} \times E_0^2 = 3$   
 $\therefore E_0^2 = 180$   
 $\therefore E_0 = 13.41\text{V/m}$   
 $\approx 13\text{V/m}$

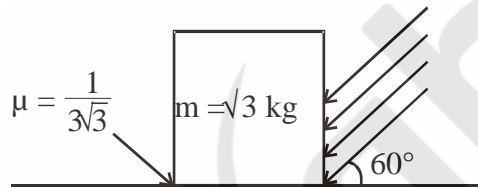
25. A boy pushes a box of mass 2 kg with a force  $\vec{F} = (20\hat{i} + 10\hat{j})\text{N}$  on a frictionless surface. If the box was initially at rest, then \_\_\_\_\_ m is displacement along the x-axis after 10 s.

**Official Ans. by NTA 500**

**Sol.**  $a_x = \frac{20}{2} = 10 \text{ m/s}^2$

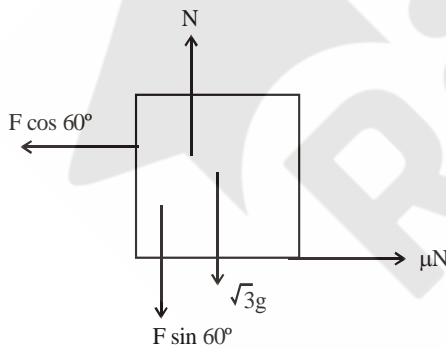
$$x = 0 + \frac{1}{2} \times 10 \times 10^2 = 500 \text{ m.}$$

26. As shown in the figure, a block of mass  $\sqrt{3}$  kg is kept on a horizontal rough surface of coefficient of friction  $\frac{1}{3\sqrt{3}}$ . The critical force to be applied on the vertical surface as shown at an angle  $60^\circ$  with horizontal such that it does not move, will be  $3x$ . The value of  $x$  will be  
[ $g = 10 \text{ m/s}^2$ ;  $\sin 60^\circ = \frac{\sqrt{3}}{2}$ ;  $\cos 60^\circ = \frac{1}{2}$ ]



**Official Ans. by NTA 10**  
**Reliable Ans. 3**

**Sol.**



$$F \cos 60^\circ = \mu(\sqrt{3}g + F \sin 60^\circ)$$

$$\therefore \frac{F}{2} = \mu \left( \sqrt{3}g + \frac{\sqrt{3}F}{2} \right)$$

$$\therefore \frac{F}{2} = \frac{\sqrt{3}g}{3\sqrt{3}} + \frac{F}{6}$$

$$\therefore \frac{F}{3} = \frac{\sqrt{3}g}{3\sqrt{3}}$$

$$\therefore F = g = 10$$

$$3x = 10$$

$$x = \frac{10}{3} = 3.33$$

27. A container is divided into two chambers by a partition. The volume of first chamber is 4.5 litre and second chamber is 5.5 litre. The first chamber contain 3.0 moles of gas at pressure 2.0 atm and second chamber contain 4.0 moles of gas at pressure 3.0 atm. After the partition is removed and the mixture attains equilibrium, then the common equilibrium pressure existing in the mixture is  $x \times 10^{-1}$  atm. Value of x is\_.

**Official Ans. by NTA 25**

**Reliable Ans. 25.5**

**Sol.** using energy conservation

$$\frac{f}{2} \times 2 \times 4.5 + \frac{f}{2} \times 3 \times 5.5 = \frac{f}{2} \times P \times 10$$

$$2 \times \frac{9}{2} + 3 \times \frac{11}{2} = P \times 10$$

$$\frac{18}{2} + \frac{33}{2} = P \times 10$$

$$P = \frac{51}{20}$$

$$P = 2.55 \text{ atmosphere} = x \times 10^{-1} \text{ atm}$$

$$x = 25.5$$

28. The mass per unit length of a uniform wire is 0.135 g/cm. A transverse wave of the form  $y = -0.21 \sin(x + 30t)$  is produced in it, where x is in meter and t is in second. Then, the expected value of tension in the wire is  $x \times 10^{-2}$  N. Value of x is . (Round-off to the nearest integer)

**Official Ans. by NTA (12)**

**Sol.**  $v = \frac{\omega}{K} = 30 \text{ m/s}$

$$v = \sqrt{\frac{T}{\mu}}$$

$$T = v^2 \times \mu = \frac{(30)^2 \times (0.135) \times 10^{-3}}{10^{-2}}$$

$$= 900 \times 0.135 \times 10^{-1}$$

$$T = 12.15 \text{ N} = 12 \text{ N}$$

29. In a series LCR resonant circuit, the quality factor is measured as 100. If the inductance is increased by two fold and resistance is decreased by two fold, then the quality factor after this change will be \_\_\_\_\_.

**Official Ans. by NTA (400)**

**Reliable Ans. 283**

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

$$Q^1 = \frac{\sqrt{2L} \cdot 2}{\sqrt{C} R} = 2\sqrt{2}Q$$

$$Q^1 = 2\sqrt{2}(100) = 288 = 283$$

30. The maximum and minimum amplitude of an amplitude modulated wave is 16V and 8V respectively. The modulation index for this amplitude modulated wave is  $x \times 10^{-2}$ . The value of x is \_\_\_\_\_.

**Official Ans. by NTA (33)**

Sol.  $u = \frac{A_{\max} - A_{\min}}{A_{\max} + A_{\min}}$

$$= \frac{16-8}{16+8} = \frac{8}{24} = \frac{1}{3}$$

$$= 0.33 = 33 \times 10^{-2}$$

$x = 33$