

FINAL JEE-MAIN EXAMINATION – FEBRUARY, 2021

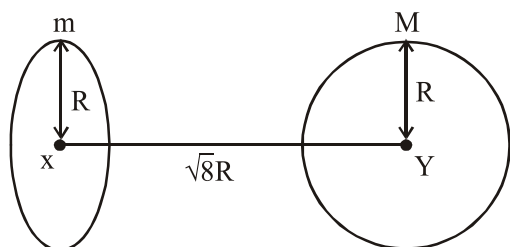
(Held On Friday 26th February, 2021) TIME : 9 : 00 AM to 12 : 00 NOON

PHYSICS

TEST PAPER WITH ANSWER & SOLUTIONS

SECTION-A

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. Gravitational field of ring

$$= -\frac{Gmx}{(R^2 + x^2)^{3/2}}$$

Force between sphere & ring

$$= \frac{GmM(\sqrt{8}R)}{(R^2 + 8R^2)^{3/2}}$$

$$= \frac{GmM}{R^2} \times \frac{\sqrt{8}}{27}$$

Ans. (4)

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)

Allen Ans. (Bonus)

Sol. When connected in parallel

$$C_{eq} = C_1 + C_2$$

When in series

$$C'_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

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

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

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

dividing by C_1^2

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

$$\text{Let } \frac{C_2}{C_1} = x$$

$$4x^2 - 7x + 4 = 0$$

$$b^2 - 4ac = 49 - 64 < 0$$

No solution exists

Ans. (Bonus)

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 α and β are constants, dimensions of α will be :

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

Official Ans. by NTA (2)

Sol. kT has dimension of energy

$\frac{\beta x^2}{kT}$ is dimensionless

$$[\beta] [L^2] = [ML^2T^{-2}]$$

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

$\alpha^2\beta$ has dimensions of work

$$[\alpha^2] [MT^{-2}] = [ML^2 T^{-2}]$$

$$[\alpha] = [M^0LT^0]$$

Ans. 2

4. If λ_1 and λ_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. $\frac{1}{\lambda_1} = R \left[\frac{1}{1^2} - \frac{1}{4^2} \right]$

$$\frac{1}{\lambda_2} = R \left[\frac{1}{3^2} - \frac{1}{4^2} \right]$$

$$\frac{\lambda_1}{\lambda_2} = \frac{\left[\frac{1}{9} - \frac{1}{16} \right]}{\left[1 - \frac{1}{16} \right]} = \frac{7}{9 \times 15}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{7}{135}$$

Ans. (3)

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)

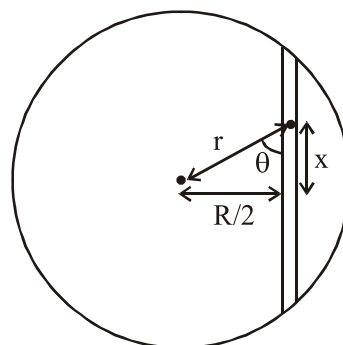
Sol. Since orientation is same image is virtual. Since image is smaller the mirror has to be convex
Ans. (4)

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.



Force along the tunnel

$$F = -\left(\frac{GMmr}{R^3}\right)\cos\theta$$

$$F = -\frac{gm}{R}x \left(\frac{GM}{R^2} = g, r\cos\theta = x\right)$$

$$a = -\frac{g}{R}x$$

$$\omega^2 = \frac{g}{R} \quad T = 2\pi\sqrt{\frac{R}{g}}$$

Ans. (4)

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.** $i = i_1 \sin\omega t + i_2 \sin(\omega t + 90)$

$$i = \sqrt{i_1^2 + i_2^2} \sin(\omega t + \phi)$$

$$i_{\text{rms}} = \frac{i_0}{\sqrt{2}} = \frac{\sqrt{i_1^2 + i_2^2}}{\sqrt{2}}$$

8. The normal density of a material is ρ 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.** $\rho = \frac{M}{V}$

$$\frac{d\rho}{\rho} = -\frac{dV}{V}$$

$$k = -\frac{P}{\frac{dV}{V}}$$

$$-\frac{dV}{V} = \frac{P}{k}$$

$$\frac{d\rho}{\rho} = \frac{P}{k} \Rightarrow d\rho = \frac{\rho P}{k}$$

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.** $F \propto \frac{1}{R^3}$

$$\frac{K}{R^3} = m\omega^2 R$$

$$\omega^2 = \frac{K}{m} \times \frac{1}{R^4}$$

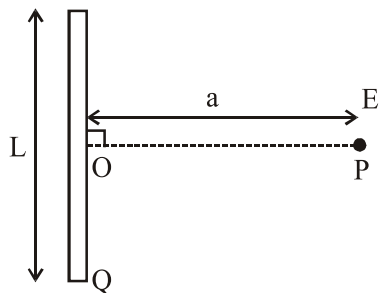
$$\left(\frac{2\pi}{T}\right)^2 = \frac{K}{m} \times \frac{1}{R^4}$$

$$T^2 \propto R^4$$

$$T \propto R^2$$

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. $E = \frac{k\lambda}{a}(\sin\theta_1 + \sin\theta_2)$

$$E = \frac{1}{4\pi\epsilon_0} \times \frac{Q}{L} \times \frac{1}{\left(\frac{\sqrt{3}L}{2}\right)} \times (2\sin\theta)$$

$$\tan\theta = \frac{L/2}{\frac{\sqrt{3}L}{2}} = \frac{1}{\sqrt{3}}$$

$$\sin\theta = \frac{1}{2}$$

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

$$E = \frac{Q}{2\sqrt{3}\pi\epsilon_0 L^2}$$

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)

Sol. $\frac{1}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2}$

$$\frac{1}{k_{eq}} = \frac{1}{k} + \frac{1}{k} \Rightarrow k_{eq} = \frac{k}{2}$$

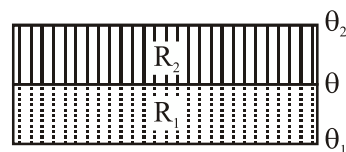
$$k' = \frac{k}{2}$$

$$T = 2\pi\sqrt{\frac{M}{k}} \qquad T' = 2\pi\sqrt{\frac{M}{k'}}$$

$$\Rightarrow T' = 2\pi\sqrt{\frac{M}{k}} \times \sqrt{2}$$

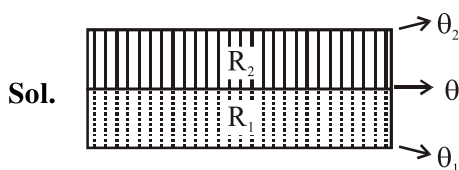
$$T' = \sqrt{2}T$$

16. The temperature θ at the junction of two insulating sheets, having thermal resistances R_1 and R_2 as well as top and bottom temperatures θ_1 and θ_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)



Heat flow rate will be same through both

$$\therefore \frac{\theta_1 - \theta}{R_1} = \frac{\theta - \theta_2}{R_2}$$

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

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

Ans. (3)

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. Resolving power $\propto \frac{1}{\lambda}$

Since wavelength of electron is much less than visible light, its resolving power will be much more.

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. $\lambda = \frac{hc}{E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.9 \times 1.6 \times 10^{-19}} = 6.54 \times 10^{-7}$

$$= 654 \text{ nm}$$

Red color

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:

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

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

Official Ans. by NTA (4)

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

$$\therefore n^{1/3} r = R$$

$$\therefore \text{Total change in surface energy}$$

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

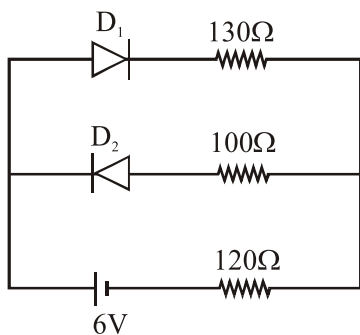
$$\Rightarrow 4\pi T (nr^2 - R^2)$$

$$\therefore \text{Heat energy}$$

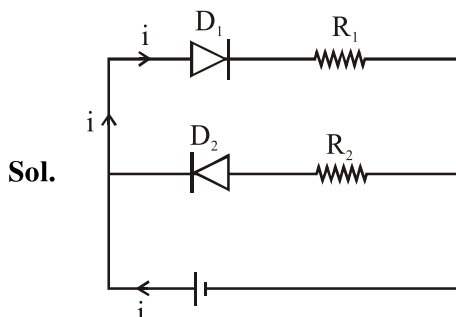
$$= \frac{4\pi T (nr^2 - R^2)}{J \times \frac{4}{3} \pi R^3} = \frac{3T}{J} \left(\frac{nr^2}{R^3} - \frac{1}{R} \right)$$

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



Official Ans. by NTA (20)



In this circuit D_1 will be forward bias and D_2 will be reverse bias.

\therefore There will be no current through D_2 and R_2

Apply KVL in circuit we get

$$+ 6 - 50i - 130i - 120i = 0$$

$$i = \frac{6}{300}\text{ A} = \frac{6}{300} \times 1000\text{ mA}$$

$$\Rightarrow 20\text{ mA}$$

4. A radiation is emitted by 1000 W bulb and it generates an electric field and magnetic field at P, placed at a distance of 2 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)

Sol. $I_{\text{avg}} = \frac{1}{2} \epsilon_0 E_0^2 C$

$$\frac{1.25}{100} \times \frac{1000}{4\pi(2)^2} = \frac{1}{2} \times 8.85 \times 10^{-12} \times 3$$

$$\times 10^8 \times E_0^2$$

$$E_0^2 = 187.4$$

$$\therefore E_0 = 13.689\text{ V/m}$$

$$= 136.89 \times 10^{-1}\text{ V/m}$$

$$\therefore x = 136.89$$

Rounding off to nearest integer

$$x = 137$$

5. 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. $\vec{F} = 20\hat{i} + 10\hat{j}$

$$\vec{a} = \frac{\vec{F}}{m} = \frac{20\hat{i} + 10\hat{j}}{2} \Rightarrow 10\hat{i} + 5\hat{j}$$

$$\therefore \vec{s} = \frac{1}{2} \vec{a} t^2 = \frac{1}{2} (10\hat{i} + 5\hat{j}) \times (10)^2$$

$$\Rightarrow 50(10\hat{i} + 5\hat{j})\text{ m}$$

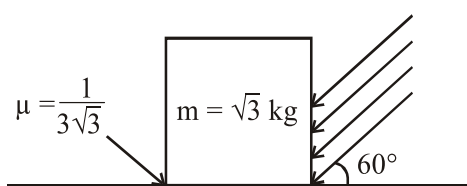
\therefore Displacement along x-axis

$$\Rightarrow 50 \times 10 \Rightarrow 500\text{ m}$$

$$\therefore \text{Ans. } 500$$

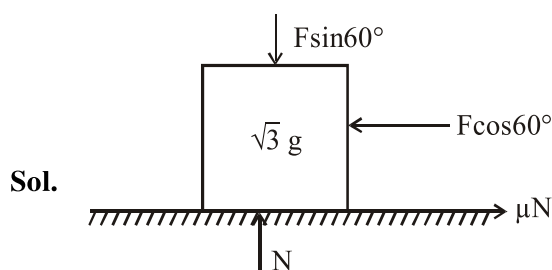
6. As shown in the figure, a block of mass $\sqrt{3}$ kg is kept on a horizontal rough surface of coefficient of friction $\frac{1}{3\sqrt{3}}$. The critical force to be applied on the vertical surface as shown at an angle 60° with horizontal such that it does not move, will be $3x$. The value of x will 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)

Allen Ans. (3.33)



$$F \cos 60^\circ = \mu N \text{ or } \frac{F}{2} = \frac{1}{3\sqrt{3}} N \dots (1)$$

$$\& N = \sin 60^\circ + \sqrt{3}g \dots (2)$$

From equation (1) & (2)

$$\frac{F}{2} = \frac{1}{3\sqrt{3}} \left(\frac{F\sqrt{3}}{2} + \sqrt{3}g \right)$$

$$\Rightarrow F = g = 10 \text{ Newton} = 3x$$

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

7. 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)

Allen Ans. (25.50)

- Sol.** Let common equilibrium pressure of mixture is P atmp. then

$$U_1 + U_2 = U_{\text{mixture}}$$

$$\frac{f}{2} P_1 V_1 + \frac{f}{2} P_2 V_2 = \frac{f}{2} P (V_1 + V_2)$$

$$\frac{f}{2} (2)(4.5) + \frac{f}{2} (3)(5.5) = \frac{f}{2} P (4.5 + 5.5)$$

$$\Rightarrow P = 2.55 = x \times 10^{-1} \text{ atmp}$$

$$\text{So } x = 25.5 \approx 26 \text{ (Nearest integer)}$$

8. 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)

Allen Ans. (1215)

- Sol.** $\mu = 0.135 \text{ gm/cm} = 0.0135 \text{ kg/m}$

$$y = -0.21 \sin(x + 30t)$$

(x in meter & t in sec)

$$v = \frac{\omega}{k} = \frac{30}{1} = 30 \text{ m/s}$$

$$v = \sqrt{\frac{T}{\mu}} \Rightarrow T = v^2 \mu = (30)^2 (0.0135)$$

$$= 12.15$$

$$= x \times 10^{-2} \text{ N}$$

$$\Rightarrow x = 1215$$

9. 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)

Allen Ans. (282.84)

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

$$Q' = \frac{\sqrt{2L}}{\left(\frac{R}{2}\right)\sqrt{C}} = 2\sqrt{2}Q = 2\sqrt{2}(100)$$

$$= 282.84$$

10. 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. Modulation index = $\frac{A_{\max} - A_{\min}}{A_{\max} + A_{\min}}$

$$= \frac{16-8}{16+8} = \frac{8}{24} = \frac{1}{3} = 0.33$$

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

$$x = 33$$