JEE Main February 2021

Question Paper With Text Solution

26 Feb.| Shift-1

PHYSICS

MATRIX

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

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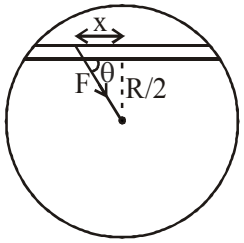
JEE MAIN FEB 2021 | 26TH FEB SHIFT-1

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

Ans. Official Answer for NTA (1)

Sol.



Restoring force = $F\cos\theta$

$$ma = \frac{GM\sqrt{\frac{R^2}{4}+x^2}}{R^3}\times m\times\frac{x}{\sqrt{\frac{R^2}{4}+x^2}}$$

$$a = \frac{GM}{R^3}x$$

$$\omega = \sqrt{\frac{GM}{R^3}} = \sqrt{\frac{g}{R}}$$

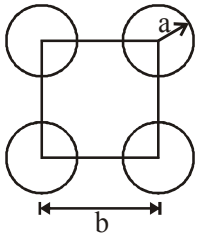
$$T = 2\pi\sqrt{\frac{R}{g}}$$

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

Ans. Official Answer for NTA (3)

Sol.



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

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

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

Ans. Official Answer for NTA (3)

Sol. $i = i_1 \sin(\omega t) + i_2 \cos(\omega t)$

$$i_{RMS}^2 = \frac{\int_0^{\frac{2\pi}{\omega}} (i_1 \sin(\omega t) + i_2 \cos(\omega t))^2 dt}{\frac{2\pi}{\omega}}$$

$$= \frac{i_1^2 \int_0^{\frac{2\pi}{\omega}} \sin^2(\omega t)\, dt}{\frac{2\pi}{\omega}} + \frac{i_2^2 \int_0^{\frac{2\pi}{\omega}} \cos^2(\omega t)\, dt}{\frac{2\pi}{\omega}} + \frac{i_1 i_2 \int_0^{\frac{2\pi}{\omega}} \sin(2\omega t)\, dt}{\frac{2\pi}{\omega}}$$

$$i_{RMS}^2 = \frac{i_1^2}{2} + \frac{i_2^2}{2} + 0$$

$$i_{RMS} = \frac{1}{\sqrt{2}}\sqrt{i_1^2 + i_2^2}$$

4. Given below are two statements : one is labelled as Assertion A and the othere is labbelled 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 but R is NOT the correct explanation of A.

(3) A is false but R is true.

(4) Both A and R are true and R is the correct explanation of A.

Ans. Official Answer for NTA (4)

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

5. 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) $\frac{PK}{\rho}$

Ans. Official Answer for NTA (2)

Sol. $P = -\beta \frac{\Delta V}{V}$

$P = \beta \frac{\Delta \rho}{\rho}$

$\Delta \rho = \frac{P\rho}{\beta} = \frac{P\rho}{K}$

6. Consider the combination of 2 capacitors C_1 and C_2,with $C_2 > C_1$, when connected in parallel, the equivlent capaciance is $\frac{15}{4}$ times 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) $\frac{15}{4}$ (4) $\frac{29}{15}$

Ans. Official Answer for NTA (2)

Ans. (Bonus)

Sol. $C_1 + C_2 = \frac{15}{4}\left(\frac{C_1C_2}{C_1 + C_2}\right)$

$\left(C_1^2 + C_2^2 + 2C_1C_2\right) = \frac{15}{4}C_1C_2$

$\frac{C_1}{C_2} + \frac{C_2}{C_1} + 2 = \frac{15}{4}$

assume $= \frac{C_1}{C_2} = x$

So, $x + \frac{1}{x} = \frac{7}{4}$

above quardatic equation doesn't have real roots.

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

Ans. Official Answer for NTA (1)

Sol. $\frac{1}{Keq} = \frac{1}{K_1} + \frac{1}{K_1}$

$Req = \frac{K_1}{2}$

$T = 2\pi\sqrt{\frac{m}{Keq}} = 2\pi\sqrt{\frac{m}{K_1}} \times \sqrt{2}$

8. A short straight object of height 100 cm lies before the central axis of a spherical mirror whose focal length has absolute value $|f| = 40\,cm$. 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 convex mirror.

(2) Image is virtual, opposite side of concave mirror.

(3) Image is virtual, opposite side of convex mirror.

(4) Image is real, same side of concave mirror.

Ans. Official Answer for NTA (3)

Sol. $m = \frac{-v}{u} = \frac{h_I}{h_0} = \frac{25}{100}$

$v = \frac{-u}{4}$

u & v will have opposte signs this means, if object is real, then image will be virtual.

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

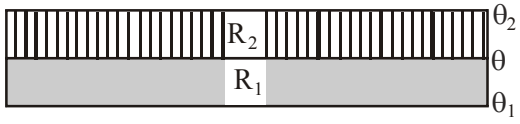
$\frac{4}{-u} + \frac{1}{4} = \frac{1}{f}$

$f = \frac{-u}{3}$

for real object, u = –ve. This means f = +ve

= convex mirror

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

Ans. Official Answer for NTA (2)

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

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

10. In a typical combustion engine the workdone by a gas molecule is given by $W = \alpha^2 \beta e^{\frac{-\beta x^2}{kT}}$, 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) [M L T^{-2}] (2) [M L T^{-1}] (3) [M^2 L T^{-2}] (4) [M^0 L T^0]

Ans. Official Answer for NTA (4)

Sol. $[w] = [\alpha^2 \beta]$

$[\alpha^2 \beta] = ML^2T^{-2}$ ....(i)

$$\left[\frac{\beta x^2}{KT}\right] = 1$$

$$\frac{[\beta] \times L^2}{ML^2T^{-2}K^{-1}K} = 1$$

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

Using equation (1): $[\alpha]^2 \times MT^{-2} = ML^2T^{-2}$

$[\alpha] = L$

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 << 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 appropeiate anser from the options given below :

(1) A is not correct but R is correct.

(2) A is correct but R is not correct.

(3) Both A and R are correct and R is the correct explanation of A.

(4) Both A and R are correct but R is NOT the correct explanation of A.

Ans. Official Answer for NTA (3)

Ans. (3)

Sol.

Since, m << M

Change in velocity of 'M' will be negligible

$$e = 1 = \frac{v - u}{u}$$

$$v = 2u$$

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

Ans. Official Answer for NTA (4)

Sol. $F = \frac{k}{R^3}$ (k = constant)

$$\frac{k}{R^3} = \frac{mv^2}{R}$$

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

$$T = \frac{2\pi R}{v}$$

$$T \propto R^2$$

13. 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) E only (2) C only (3) D only (4) A only

Ans. Official Answer for NTA (1)

Sol. For a planet revolving in elliptical orbit:

For (A) velocty is not constant

For (B) has maximum velocity when it is nearest to the sun

For (C, D, E) has constant areal velocity

14. In a Young's double slit experiment two slits are separated by 2mm and the screen is placed one meter away. When a light of wavelength 500 nm is used, the fringe separation will be :

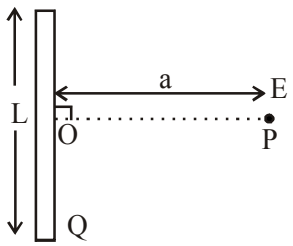
(1) 1mm (2) 0.75 mm (3) 0.25 mm (4) 0.50 mm

Ans. Official Answer for NTA (3)

Sol. Fringe width = $\frac{\lambda D}{d} = \frac{500\times10^{-9}\times1}{2\times10^{-3}}$

$= 250\times10^{-6} = 0.25\,\text{mm}$

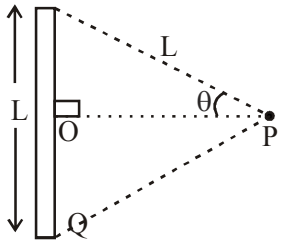
15. Find the electric field at point P (as shown in figure) on the perpendicular bisector of a uniformly charged thin wire of length L carrying a charge Q. The distance of the point P from the centre of the rod is a = $\frac{\sqrt{3}}{2}$L.



(1) $\frac{Q}{3\pi\varepsilon_0 L^2}$ (2) $\frac{Q}{2\sqrt{3}\pi\varepsilon_0 L^2}$ (3) $\frac{Q}{4\pi\varepsilon_0 L^2}$ (4) $\frac{\sqrt{3}Q}{4\pi\varepsilon_0 L^2}$ 0

Ans. Official Answer for NTA (2)

Sol.



$$E = \frac{k\lambda}{a}(2\sin\theta)$$

$$= \frac{kQ}{L\times\frac{\sqrt{3}L}{2}}\times 2\times\frac{L/2}{L}$$

$$= \frac{Q}{2\sqrt{3}\pi\varepsilon_0 L^2}$$

16. 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 = 6.63×10^{-34} Js and c = 3×10^{8} ms^{-1}]

(1) 1046 nm and red colour (2) 654 nm and red colour

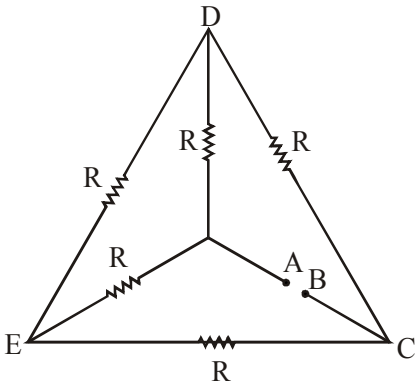
(3) 654 nm and orange colour (4) 1046 nm blue colour

Ans. Official Answer for NTA (2)

Sol. $\frac{hc}{\lambda} = 1.9ev$

$\lambda = 654$ nm and red colour

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

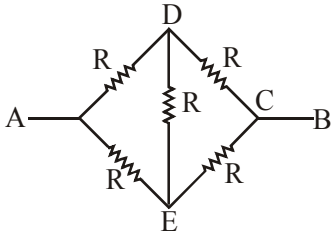


(1) $\frac{R}{2}$ (2) R (3) 2R (4) $\frac{3R}{2}$

Ans. Official Answer for NTA (2)

Sol.

Equivalent circuit



This is a balanced wheatslone bridge

Req = R

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

Ans. Official Answer for NTA (3)

Ans. (4)

Sol. Rise in heat = Loss of surface energy

$Q = T[4\pi r^2 \times n - 4\pi R^2]$

$\left(\frac{4}{3}\pi r^3 \times n = \frac{4}{3}\pi R^3\right)$

$\frac{Q}{v} = \frac{T \times 4\pi r^2}{n \times \frac{4}{3}\pi r^3}\left[n - n^{2/3}\right]$

$\frac{Q}{v}(\text{in calories}) = \frac{3T}{rJ}\left[1 - \frac{1}{n^{1/3}}\right] = \frac{3T}{J}\left[\frac{1}{r} - \frac{1}{R}\right]$

19. 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) 7 : 135 (2) 1 : 3 (3) 7 : 108 (4) 1 : 9

Ans. Official Answer for NTA (1)

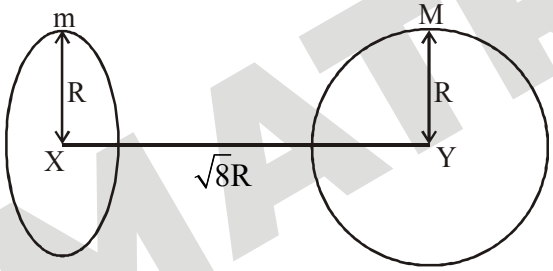
Sol. $\frac{1}{\lambda_1} RZ^2\left[\frac{1}{1^2}-\frac{1}{4^2}\right]$

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

$\frac{\lambda_1}{\lambda_2}=\frac{7\times16}{144\times15}$

$=\frac{7}{135}$

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

Ans. Official Answer for NTA (3)

Sol. F = gravitational field due to ring at the centre of sphere × Mass of sphere

$F=\frac{Gm\sqrt{8}R}{27R^3}\times M$

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

Section-B

1. 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)

Ans. Official Answer for NTA (12)

Ans. (1215)

Sol. $\mu = 0.135$ g/cm

$\mu = 135 \times 10^{-4}$ kg/m

$$v = \frac{\omega}{k} = 30$$

$$v = \sqrt{\frac{T}{\mu}} \Rightarrow T = \mu v^2$$

$T = 135 \times 10^{-4} \times 900$

$T = 1215 \times 10^{-2}$ N

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

Ans. Official Answer for NTA (33)

Sol. $$A_m = \frac{A_{max} - A_{min}}{2}$$

$$A_c = \frac{A_{max} + A_{min}}{2}$$

$$m_i = \frac{A_m}{A_c} = \frac{16-8}{16+8} = \frac{8}{24} = \frac{1}{3} = 33 \times 10^{-2}$$

3. A radiation is emitted by 1000 W bulb and it generates an electric field and magnetic field at P, placed at a distance of 2m. The efficiency of the bulb is 1.25%. The value of peak electric field at P is $x \times 10^{-1}$ V/m. Value of x is ..... . (Rounded-off to the nearest integer)

[Take $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2 N^{-1} m^{-2}$, $c = 3 \times 10^8$ ms^{-1}]

Ans. Official Answer for NTA (137)

Sol. $i = \frac{1}{2}(\varepsilon_0 c) E_0^2 = \frac{\text{Power}}{4\pi(r)^2} \times \text{Efficiency}$

$= \frac{1}{2} \times (4\pi\varepsilon_0)(c) E_0^2 = \frac{1000 \times 1.25}{2^2} \times \frac{1}{100}$

$= \frac{1}{2} \times \frac{3 \times 10^8}{9 \times 10^9} \times E_0^2 = \frac{125}{40}$

$E_0 = 136.9 \times 10^{-1} V/m$

$= 137 \times 10^{-1} V/m$

4. 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 workdone by the battery is .... J.

Ans. Offcial Answer for NTA (300)

Sol. w = qv

= 15 × 20 = 300 Joule

5. 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 perssure 3.0 atm. After the partition is removed and the mixture attains equilibrium, then, the common equlibrium pressure existing in the mixture is $x \times 10^{-1}$ atm. Value of x is ..... .

Ans. Official Answer for NTA (25)

Sol. By energy conservation

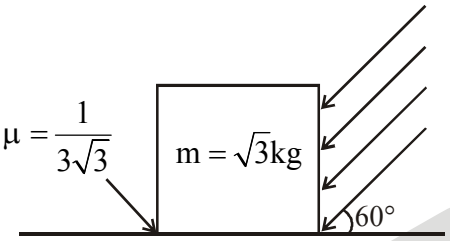
$\frac{f}{2} n_1 RT_1 + \frac{f}{2} n_2 RT_2 = \frac{f}{2} (n_1 + n_2) RT$

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

$P = \frac{P_1 V_1 + P_2 V_2}{V_1 + V_2} = \frac{2 \times 4.5 + 3 \times 5.5}{10} = 25.5 \times 10^{-1} \text{atm}$

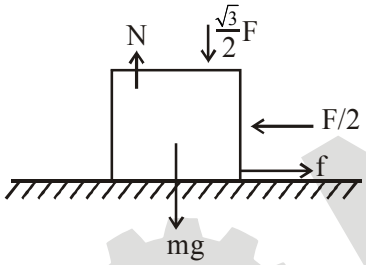
6. As shown in the figure, a block of mass $\sqrt{3}$ kg is kept on a horizontal rough surface of coefficient of friction $\frac{1}{3\sqrt{3}}$. The critical force to be applied on the vertical surface as shown at an angle 60° with horizontal such that it does not move, will be 3x. The value of x will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

[g = 10 m/s^2; sin 60° = $\frac{\sqrt{3}}{2}$; cos60° = $\frac{1}{2}$]



Ans. Official Answer for NTA (10)

Sol.



$N = \frac{\sqrt{3}F}{2} + mg$

for no slipping

$\frac{F}{2} \le f_{max}$

$\frac{F}{2} \le \mu\left(\frac{\sqrt{3}}{2}F + mg\right)$

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

$F \le 10$

so, $x = \frac{10}{3}$

7. 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 ..... .

Ans. Official Answer for NTA (400)

Sol. $Q = \frac{\omega L}{R}$

$\frac{Q'}{Q} = \frac{L'}{L} \times \frac{R}{R'}$

$Q' = 4Q = 400$

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

Ans. Official Answer for NTA (500)

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

$a = 10\hat{i} + 5\hat{j}$

$x = \frac{1}{2} a_x t^2$

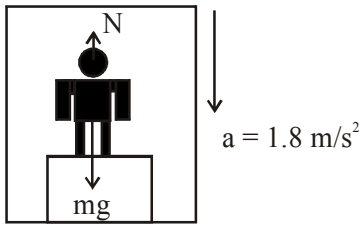
$= \frac{1}{2} \times (10) \times (10)^2$

x = 500 m

9. 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 m/s^2 will be ..... N. [g = 10m/s^2]

Ans. Official Answer for NTA (492)

Sol.

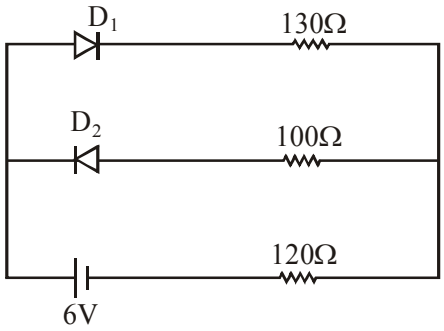


FBD of man

mg – N = m(1.8)

N = 492 N

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



Ans. Official Answer for NTA (20)

Sol. $i = \frac{V}{R_{eq}}$

D_2 in reverse bias so $R_{eq} = 130 + 50 + 120 = 300\Omega$

$i = \frac{6}{300} A = 20 \times 10^{-3} A$

$i = 20$ mA