FINAL JEE–MAIN EXAMINATION – MARCH, 2021

(Held On Thursday 18th March, 2021) TIME : 9 : 00 AM to 12 : 00 NOON

PHYSICS

TEST PAPER WITH ANSWER & SOLUTION

SECTION-A

1. An oil drop of radius 2 mm with a density 3g cm^{-3} is held stationary under a constant electric field 3.55×10^5 V m^{-1} in the Millikan's oil drop experiment. What is the number of excess electrons that the oil drop will possess ? (consider g = 9.81 m/s^2)

(1) 48.8×10^{11}

(2) 1.73×10^{10}

(3) 17.3×10^{10}

(4) 1.73×10^{12}

Official Ans. by NTA (2)

Sol. $qE = Mg$

$$neE = \rho\left(\frac{4}{3}\pi r^3\right) \times g$$

$$n \times 1.6 \times 10^{-19} \times 3.55 \times 10^5$$

$$= 3 \times 10^3 \times \frac{4}{3} \times \pi \times (2 \times 10^{-3})^3 \times 9.81$$

$$n = 173 \times 10^{(3-9-5+19)}$$

$$n = 1.73 \times 10^{10}$$

2. Match List–I with List–II.

List–I

(a) 10 km height over earth's surface

(b) 70 km height over earth's surface

(c) 180 km height over earth's surface

(d) 270 km height over earth's surface

List–II

(i) Thermosphere

(ii) Mesosphere

(iii) Stratosphere

(iv) Troposphere

(1) (a)–(iv), (b)–(iii), (c)–(ii), (d)–(i)

(2) (a)–(i), (b)–(iv), (c)–(iii), (d)–(ii)

(3) (a)–(iii), (b)–(ii), (c)–(i), (d)–(iv)

(4) (a)–(ii), (b)–(i), (c)–(iv), (d)–(iii)

Official Ans. by NTA (1)

Sol. Order of atmosphere stratification from bottom Troposphere, stralospherre, Mesosphre, Thermosphere

(a) → (iv)

(b) → (iii)

(c) → (ii)

(d) → (i)

3. Imagine that the electron in a hydrogen atom is replaced by a muon (μ). The mass of muon particle is 207 times that of an electron and charge is equal to the charge of an electron. The ionization potential of this hydrogen atom will be :-

(1) 13.6 eV (2) 2815.2 eV

(3) 331.2 eV (4) 27.2 eV

Official Ans. by NTA (2)

Sol. $E \propto \frac{1}{r}$ $r \propto \frac{1}{m}$

$E \propto m$

$$\text{Ionization potential} = 13.6 \times \frac{(\text{Mass}_\mu)\text{eV}}{(\text{Mass}_e)}$$

$= 13.6 \times 207$ eV $= 2815.2$ eV

4. A plane electromagnetic wave of frequency 100 MHz is travelling in vacuum along the x-direction. At a particular point in space and time, $\vec{B} = 2.0 \times 10^{-8}\hat{k}T$. (where, $\hat{k}$ is unit vector along z-direction) What is $\vec{E}$ at this point ?

(1) $0.6\hat{j}$ V/m (2) $6.0\hat{k}$ V/m

(3) $6.0\hat{j}$ V/m (4) $0.6\hat{k}$ V/m

Official Ans. by NTA (3)

Sol. E = BC = 6

(Dir. of wave) $\parallel (\vec{E}\times\vec{B})$

$\hat{i}=\hat{j}\times\hat{k}$

$\vec{E}=6\hat{j}\ V/m$

5. A thin circular ring of mass M and radius r is rotating about its axis with an angular speed ω. Two particles having mass m each are now attached at diametrically opposite points. The angular speed of the ring will become :

(1) $\omega\frac{M}{M+m}$ (2) $\omega\frac{M+2m}{M}$

(3) $\omega\frac{M}{M+2m}$ (4) $\omega\frac{M-2m}{M+2m}$

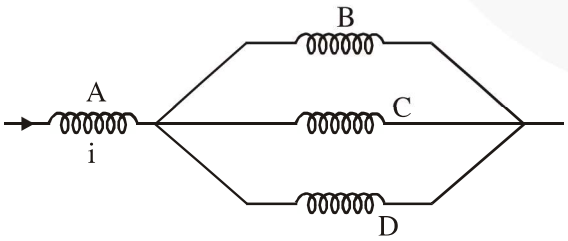
Official Ans. by NTA (3)

Sol. Using conservation of angular momentum

$(Mr^2)\omega = (Mr^2 + 2mr^2)\omega'$

$\omega'=\frac{M\omega}{M+2m}$

6. Four identical long solenoids A, B, C and D are connected to each other as shown in the figure. If the magnetic field at the center of A is 3T, the field at the center of C would be : (Assume that the magnetic field is confined with in the volume of respective solenoid).

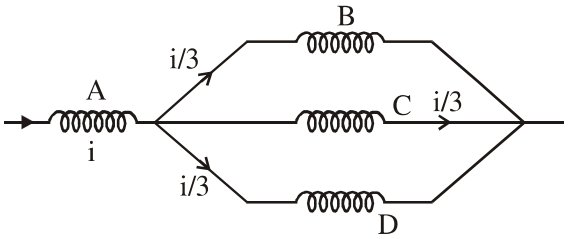


(1) 12T (2) 6T

(3) 9T (4) 1T

Official Ans. by NTA (4)

Sol.



$\phi \propto i$

$\Rightarrow B \propto i$

so, field at centre of C = $\frac{3}{3}=1T$

7. The time period of a simple pendulum is given by $T=2\pi\sqrt{\frac{\ell}{g}}$. The measured value of the length of pendulum is 10 cm known to a 1mm accuracy. The time for 200 oscillations of the pendulum is found to be 100 second using a clock of 1s resolution. The percentage accuracy in the determination of 'g' using this pendulum is 'x'. The value of 'x' to the nearest integer is:-

(1) 2% (2) 3%

(3) 5% (4) 4%

Official Ans. by NTA (2)

Sol. $g=\frac{4\pi^2\ell}{T^2}$

$$\frac{\Delta g}{g}=\frac{\Delta\ell}{\ell}+2\frac{\Delta T}{T}=\frac{0.1}{10}+2\left(\frac{\frac{1}{200}}{0.5}\right)$$

$$\frac{\Delta g}{g}=\frac{1}{100}+\frac{1}{50}$$

$$\frac{\Delta g}{g}\times 100=3\%$$

8. A constant power delivering machine has towed a box, which was initially at rest, along a horizontal straight line. The distance moved by the box in time 't' is proportional to :-

(1) $t^{2/3}$ (2) $t^{3/2}$

(3) t (4) $t^{1/2}$

Official Ans. by NTA (2)

Sol. $P = C$

$FV = C$

$$M\frac{dV}{dt}V = C$$

$$\frac{V^2}{2} \propto t$$

$$V \propto t^{1/2}$$

$$\frac{dx}{dt} \propto t^{1/2}$$

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

9. What will be the average value of energy along one degree of freedom for an ideal gas in thermal equilibrium at a temperature T ? (k_B is Boltzmann constant)

(1) $\frac{1}{2}k_BT$ (2) $\frac{2}{3}k_BT$

(3) $\frac{3}{2}k_BT$ (4) k_BT

Official Ans. by NTA (1)

Sol. Energy associated with each degree of freedom per molecule = $\frac{1}{2}k_BT$.

10. A radioactive sample disintegrates via two independent decay processes having half lives $T_{1/2}^{(1)}$ and $T_{1/2}^{(2)}$ respectively. The effective half-life $T_{1/2}$ of the nuclei is :

(1) None of the above (2) $T_{1/2} = T_{1/2}^{(1)} + T_{1/2}^{(2)}$

(3) $T_{1/2} = \frac{T_{1/2}^{(1)}T_{1/2}^{(2)}}{T_{1/2}^{(1)} + T_{1/2}^{(2)}}$ (4) $T_{1/2} = \frac{T_{1/2}^{(1)} + T_{1/2}^{(2)}}{T_{1/2}^{(1)} - T_{1/2}^{(2)}}$

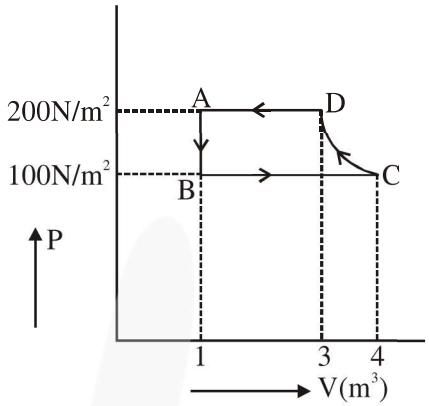
Official Ans. by NTA (3)

Sol. $\lambda_{eq} = \lambda_1 + \lambda_2$

$$\frac{1}{T_{1/2}} = \frac{1}{T_{1/2}^{(1)}} + \frac{1}{T_{1/2}^{(2)}}$$

$$T_{1/2} = \frac{T_{1/2}^{(1)}T_{1/2}^{(2)}}{T_{1/2}^{(1)} + T_{1/2}^{(2)}}$$

11. The P-V diagram of a diatomic ideal gas system going under cyclic process as shown in figure. The work done during an adiabatic process CD is (use $\gamma = 1.4$) :



(1) –500 J (2) –400 J

(3) 400 J (4) 200 J

Official Ans. by NTA (1)

Sol. Adiabatic process is from C to D

$$WD = \frac{P_2V_2 - P_1V_1}{1-\gamma}$$

$$= \frac{P_DV_D - P_CV_C}{1-\gamma}$$

$$= \frac{200(3) - (100)(4)}{1-1.4}$$

= –500 J Ans. (1)

12. In Young's double slit arrangement, slits are separated by a gap of 0.5 mm, and the screen is placed at a distance of 0.5 m from them. The distance between the first and the third bright fringe formed when the slits are illuminated by a monochromatic light of 5890 Å is :-

(1) 1178×10^{-9} m (2) 1178×10^{-6} m

(3) 1178×10^{-12} m (4) 5890×10^{-7} m

Official Ans. by NTA (2)

Sol. $\beta = \frac{\lambda D}{d} = \frac{5890 \times 10^{-10} \times 0.5}{0.5 \times 10^{-3}}$

$= 589 \times 10^{-6}$ m

Distance between first and third bright fringe is $2\beta = 2 \times 589 \times 10^{-6}$ m

$= 1178 \times 10^{-6}$ m Ans. (2)

13. A particle is travelling 4 times as fast as an electron. Assuming the ratio of de-Broglie wavelength of a particle to that of electron is 2 : 1, the mass of the particle is :-

(1) $\frac{1}{16}$ times the mass of e^-

(2) 8 times the mass of e^-

(3) 16 times the mass of e^-

(4) $\frac{1}{8}$ times the mass of e^-

Official Ans. by NTA (4)

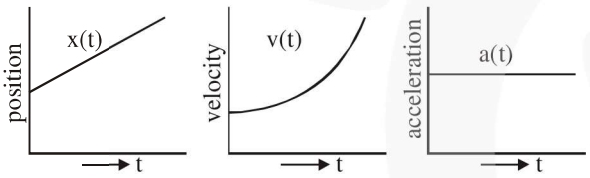
Sol. $\lambda = \frac{h}{p}$

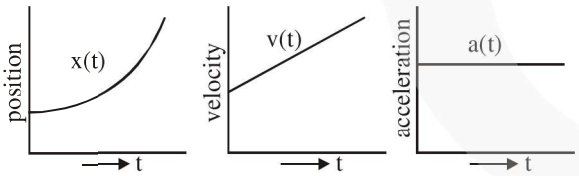
$$\frac{\lambda_p}{\lambda_e} = \frac{p_e}{p_p} = \frac{m_e v_e}{m_p v_p}$$

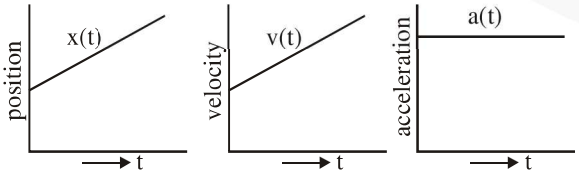
$$2 = \frac{m_e}{m_p}\left(\frac{v_e}{4v_e}\right)$$

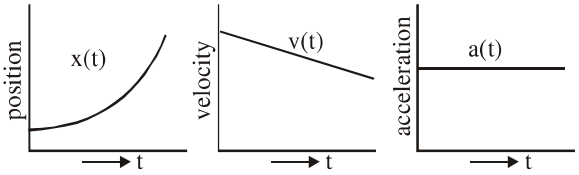
$$\therefore \quad m_p = \frac{m_e}{8} \qquad \text{Ans. (4)}$$

14. The position, velocity and acceleration of a particle moving with a constant acceleration can be represented by :

(1) 

(2) 

(3) 

(4) 

Official Ans. by NTA (2)

Sol. Option (2) represent correct graph for particle moving with constant acceleration, as for constant acceleration velocity time graph is straight line with positive slope and x-t graph should be an opening upward parabola.

15. In the experiment of Ohm's law, a potential difference of 5.0 V is applied across the end of a conductor of length 10.0 cm and diameter of 5.00 mm. The measured current in the conductor is 2.00 A. The maximum permissible percentage error in the resistivity of the conductor is :-

(1) 3.9 (2) 8.4

(3) 7.5 (4) 3.0

Official Ans. by NTA (1)

Sol. $R = \frac{\rho \ell}{A} = \frac{V}{I}$

$$\rho = \frac{AV}{I\ell} = \frac{\pi d^2 V}{4I\ell} \qquad \left(A = \frac{\pi d^2}{4}\right)$$

$$\therefore \quad \frac{\Delta\rho}{\rho} = \frac{2\Delta d}{d} + \frac{\Delta V}{V} + \frac{\Delta I}{I} + \frac{\Delta \ell}{\ell}$$

$$\frac{\Delta\rho}{\rho} = 2\left(\frac{0.01}{5.00}\right) + \frac{0.1}{5.0} + \frac{0.01}{2.00} + \frac{0.1}{10.0}$$

$$\frac{\Delta\rho}{\rho} = 0.004 + 0.02 + 0.005 + 0.01$$

$$\frac{\Delta\rho}{\rho} = 0.039$$

$$\% \text{ error} = \frac{\Delta\rho}{\rho} \times 100 = 0.039 \times 100 = 3.90\%$$

Ans. (1)

16. In a series LCR resonance circuit, if we change the resistance only, from a lower to higher value :

(1) The bandwidth of resonance circuit will increase.

(2) The resonance frequency will increase.

(3) The quality factor will increase.

(4) The quality factor and the resonance frequency will remain constant.

Official Ans. by NTA (1)

Sol. Bandwidth = R/L

Bandwidth $\propto$ R

So bandwidth will increase

17. An AC source rated 220 V, 50 Hz is connected to a resistor. The time taken by the current to change from its maximum to the rms value is :

(1) 2.5 ms (2) 25 ms

(3) 2.5 s (4) 0.25 ms

Official Ans. by NTA (1)

Sol. $i = i_0 \cos(\omega t)$

$i = i_0$ at $t = 0$

$$i = \frac{i_0}{\sqrt{2}} \text{ at } \omega t = \frac{\pi}{4}$$

$$t = \frac{\pi}{4\omega} = \frac{\pi}{4(2\pi f)} = \frac{1}{8f}$$

$$t = \frac{1}{400} = 2.5 \text{ ms}$$

18. Your friend is having eye sight problem. She is not able lo see clearly a distant uniform window mesh and it appears to her as non-uniform and distorted. The doctor diagnosed the problem as :

(1) Astigmatism

(2) Myopia with Astigmatism

(3) Presbyopia with Astigmatism

(4) Myopia and hypermetropia

Official Ans. by NTA (2)

Sol. If distant objects are blurry then problem is Myopia.

If objects are distorted then problem is Astigmatism

19. A loop of flexible wire of irregular shape carrying current is placed in an external magnetic field. Identify the effect of the field on the wire.

(1) Loop assumes circular shape with its plane normal to the field.

(2) Loop assumes circular shape with its plane parallel to the field.

(3) Wire gets stretched to become straight.

(4) Shape of the loop remains unchanged.

Official Ans. by NTA (1)

Sol. Every part ($d\ell$) of the wire is pulled by force $i(d\ell)B$ acting perpendicular to current & magnetic field giving it a shape of circle.

20. The time period of a satellite in a circular orbit of radius R is T. The period of another satellite in a circular orbit of radius 9R is :

(1) 9 T (2) 27 T

(3) 12 T (4) 3 T

Official Ans. by NTA (2)

Sol. $T^2 \propto R^3$

$$\left(\frac{T'}{T}\right)^2 = \left(\frac{9R}{R}\right)^3$$

$T'^2 = T^2 \times 9^3$

$T' = T \times 3^3$

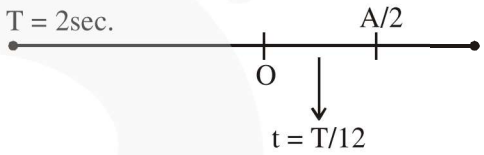
$T' = 27\ T$

SECTION-B

1. A particle performs simple harmonic motion with a period of 2 second. The time taken by the particle to cover a displacement equal to half of its amplitude from the mean position is $\frac{1}{a}$s. The value of 'a' to the nearest integer is _____ .

Official Ans. by NTA (6)

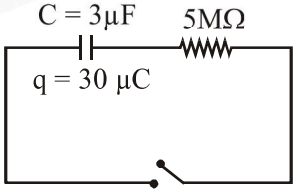
Sol.



$$t = \frac{2}{12} = \frac{1}{6}$$

$\therefore$ Correct answer = 6.00

2. The circuit shown in the figure consists of a charged capacitor of capacity 3 μF and a charge of 30 μC. At time t = 0, when the key is closed, the value of current flowing through the 5 MΩ resistor is 'x' μ-A. The value of 'x to the nearest integer is _____.

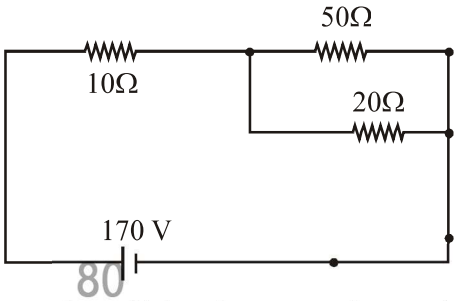


Official Ans. by NTA (2)

Sol. $i_0 = \frac{V}{R} = \frac{30/3}{5 \times 10^6} = 2 \times 10^{-6}$

$\therefore$ Ans. = 2.00

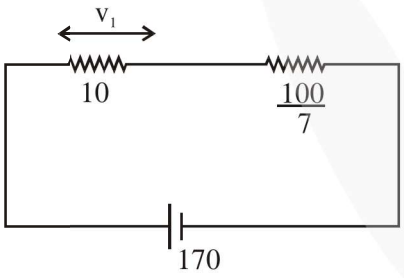
3. The voltage across the 10Ω resistor in the given circuit is x volt.



The value of 'x' to the nearest integer is _____.

Official Ans. by NTA (70)

Sol. $R_{eq_1} = \frac{50 \times 20}{70} = \frac{100}{7}$



$R_{eq} = \frac{170}{7}$

$v_1 = \left[\frac{\frac{170}{7}}{\frac{170}{7}}\right] \times 10 = 70v$

Ans. = 70.00

4. Two separate wires A and B are stretched by 2 mm and 4 mm respectively, when they are subjected to a force of 2 N. Assume that both the wires are made up of same material and the radius of wire B is 4 times that of the radius of wire A. The length of the wires A and B are in the ratio of a : b. Then a/b can be expressed as 1/x where x is _____ .

Official Ans. by NTA (32)

Sol. For A $\frac{E}{\pi r^2} = y\frac{2mm}{a}$ ....(1)

For B $\frac{E}{\pi.16r^2} = y\frac{4mm}{b}$ ....(2)

$\therefore$ (1)/(2)

$16 = \frac{2b}{4a}$

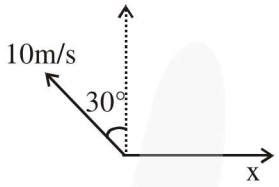
$\frac{a}{b} = \frac{1}{32}$

$\therefore$ Answer = 32

5. A person is swimming with a speed of 10 m/s at an angle of 120° with the flow and reaches to a point directly opposite on the other side of the river. The speed of the flow is 'x' m/s. The value of 'x' to the nearest integer is _____.

Official Ans. by NTA (5)

Sol.



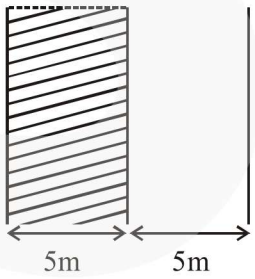
10 sin 30° = x

x = 5 m/s

6. A parallel plate capacitor has plate area 100 m^2 and plate separation of 10 m. The space between the plates is filled up to a thickness 5 m with a material of dielectric constant of 10. The resultant capacitance of the system is 'x' pF. The value of $\varepsilon_0 = 8.85 \times 10^{-12}$ $F.m^{-1}$. The value of 'x' to the nearest integer is_____.

Official Ans. by NTA (161)

Sol.



$A = 100\ m^2$

Using $C = \frac{k \in_0 A}{d}$

$C_1 = \frac{10 \in_0 (100)}{5}$

$= 200\ \in_0$

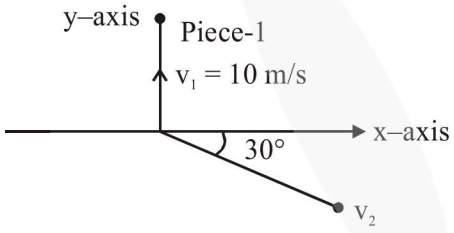
$C_2 = \frac{\in_0 (100)}{5} = 20 \in_0$

C_1 & C_2 are in series so $C_{eqv.} = \frac{C_1 C_2}{C_1 + C_2}$

$= \frac{4000 \in_0}{220}$

$= 160.9 \times 10^{-12} \simeq 161$ pF

7. A ball of mass 10 kg moving with a velocity $10\sqrt{3}$ m/s along the x-axis, hits another ball of mass 20 kg which is at rest. After the collision, first ball comes to rest while the second ball disintegrates into two equal pieces. One piece starts moving along y-axis with a speed of 10 m/s. The second piece starts moving at an angle of 30° with respect to the x-axis. The velocity of the ball moving at 30° with x-axis is x m/s. The configuration of pieces after collision is shown in the figure below. The value of x to the nearest integer is _____ .



Official Ans. by NTA (20)

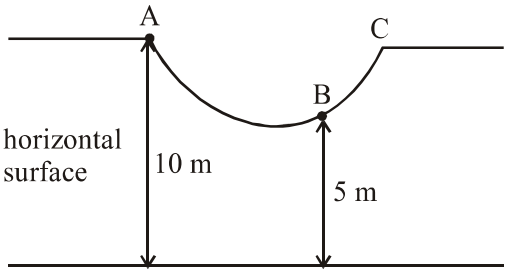
Sol. Let velocity of 2nd fragment is $\vec{v}$ then by conservation of linear momentum

$$10\left(10\sqrt{3}\right)\hat{i} = (10)\left(10\hat{j}\right) + 10\vec{v}$$

$$\Rightarrow \vec{v} = 10\sqrt{3}\hat{i} - 10\hat{j}$$

$$|\vec{v}| = \sqrt{300+100} = \sqrt{400} = 20\,m/s$$

8. As shown in the figure, a particle of mass 10 kg is placed at a point A. When the particle is slightly displaced to its right, it starts moving and reaches the point B. The speed of the particle at B is x m/s. (Take g = 10 m/s^2)
The value of 'x' to the nearest integer is_____.



Official Ans. by NTA (10)

Sol. Using work energy theorem,
$W_g = \Delta K.E.$

$$(10)\,(g)\,(5) = \frac{1}{2}(10)v^2 - 0$$

$$v = 10 \text{ m/s}$$

9. An npn transistor operates as a common emitter amplifier with a power gain of 10^6. The input circuit resistance is 100Ω and the output load resistance is 10 KΩ. The common emitter current gain 'β' will be _____. (Round off to the Nearest Integer)

Official Ans. by NTA (100)

Sol. $$10^6 = \beta^2 \times \frac{R_0}{R_i}$$

$$10^6 = \beta^2 \times \frac{10^4}{10^2}$$

$$\beta^2 = 10^4 \Rightarrow \beta = 100$$

10. A bullet of mass 0.1 kg is fired on a wooden block to pierce through it, but it stops after moving a distance of 50 cm into it. If the velocity of bullet before hitting the wood is 10 m/s and it slows down with uniform deceleration, then the magnitude of effective retarding force on the bullet is 'x' N. The value of 'x' to the nearest integer is _____ .

Official Ans. by NTA (10)

Sol. $v^2 = u^2 + 2as$

$$0 = (10)^2 + 2\,(-a)\left(\frac{1}{2}\right)$$

$$a = 100 \text{ m/s}^2$$

$$F = ma = (0.1)\,(100) = 10 \text{ N}$$