

SOLUTIONS TO CONCEPTS

CHAPTER – 4

1. $m = 1 \text{ gm} = 1/1000 \text{ kg}$

$$F = 6.67 \times 10^{-17} \text{ N} \Rightarrow F = \frac{Gm_1m_2}{r^2}$$

$$\therefore 6.67 \times 10^{-17} = \frac{6.67 \times 10^{-11} \times (1/1000) \times (1/1000)}{r^2}$$

$$\Rightarrow r^2 = \frac{6.67 \times 10^{-11} \times 10^{-6}}{6.67 \times 10^{-17}} = \frac{10^{-17}}{10^{-17}} = 1$$

$$\Rightarrow r = \sqrt{1} = 1 \text{ metre.}$$

So, the separation between the particles is 1 m.

2. A man is standing on the surface of earth

The force acting on the man = mg (i)

Assuming that, m = mass of the man = 50 kg

And g = acceleration due to gravity on the surface of earth = 10 m/s^2

$W = mg = 50 \times 10 = 500 \text{ N}$ = force acting on the man

So, the man is also attracting the earth with a force of 500 N

3. The force of attraction between the two charges

$$= \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} = 9 \times 10^9 \frac{1}{r^2}$$

The force of attraction is equal to the weight

$$Mg = \frac{9 \times 10^9}{r^2}$$

$$\Rightarrow r^2 = \frac{9 \times 10^9}{m \times 10} = \frac{9 \times 10^8}{m} \quad [\text{Taking } g=10 \text{ m/s}^2]$$

$$\Rightarrow r = \sqrt{\frac{9 \times 10^8}{m}} = \frac{3 \times 10^4}{\sqrt{m}} \text{ mt}$$

For example, Assuming $m = 64 \text{ kg}$,

$$r = \frac{3 \times 10^4}{\sqrt{64}} = \frac{3}{8} 10^4 = 3750 \text{ m}$$

4. mass = 50 kg

$$r = 20 \text{ cm} = 0.2 \text{ m}$$

$$F_G = G \frac{m_1 m_2}{r^2} = \frac{6.67 \times 10^{-11} \times 2500}{0.04}$$

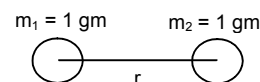
$$\text{Coulomb's force } F_C = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} = 9 \times 10^9 \frac{q^2}{0.04}$$

$$\text{Since, } F_G = F_C = \frac{6.7 \times 10^{-11} \times 2500}{0.04} = \frac{9 \times 10^9 \times q^2}{0.04}$$

$$\Rightarrow q^2 = \frac{6.7 \times 10^{-11} \times 2500}{0.04} = \frac{6.7 \times 10^{-9}}{9 \times 10^9} \times 25$$

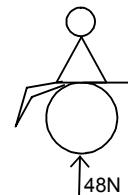
$$= 18.07 \times 10^{-18}$$

$$q = \sqrt{18.07 \times 10^{-18}} = 4.3 \times 10^{-9} \text{ C.}$$



5. The limb exerts a normal force 48 N and frictional force of 20 N. Resultant magnitude of the force,

$$\begin{aligned} R &= \sqrt{(48)^2 + (20)^2} \\ &= \sqrt{2304 + 400} \\ &= \sqrt{2704} \\ &= 52 \text{ N} \end{aligned}$$



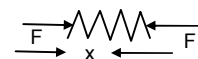
6. The body builder exerts a force = 150 N.

Compression $x = 20 \text{ cm} = 0.2 \text{ m}$

\therefore Total force exerted by the man = $f = kx$

$$\Rightarrow kx = 150$$

$$\Rightarrow k = \frac{150}{0.2} = \frac{1500}{2} = 750 \text{ N/m}$$



7. Suppose the height is h .

At earth station $F = GMm/R^2$

M = mass of earth

m = mass of satellite

R = Radius of earth

$$F = \frac{GMm}{(R+h)^2} = \frac{GMm}{2R^2}$$

$$\Rightarrow 2R^2 = (R+h)^2 \Rightarrow R^2 - h^2 - 2Rh = 0$$

$$\Rightarrow h^2 + 2Rh - R^2 = 0$$

$$H = \frac{(-2R \pm \sqrt{4R^2 + 4R^2})}{2} = \frac{-2R \pm 2\sqrt{2}R}{2}$$

$$= -R \pm \sqrt{2}R = R(\sqrt{2} - 1)$$

$$= 6400 \times (0.414)$$

$$= 2649.6 = 2650 \text{ km}$$

8. Two charged particle placed at a sehortion 2m. exert a force of 20m.

$$F_1 = 20 \text{ N.} \quad r_1 = 20 \text{ cm}$$

$$F_2 = ? \quad r_2 = 25 \text{ cm}$$

$$\text{Since, } F = \frac{1}{4\pi\epsilon_0} \frac{q_1q_2}{r^2}, \quad F \propto \frac{1}{r^2}$$

$$\frac{F_1}{F_2} = \frac{r_2^2}{r_1^2} \Rightarrow F_2 = F_1 \times \left(\frac{r_1}{r_2}\right)^2 = 20 \times \left(\frac{20}{25}\right)^2 = 20 \times \frac{16}{25} = \frac{64}{5} = 12.8 \text{ N} = 13 \text{ N.}$$

9. The force between the earth and the moon, $F = G \frac{m_m m_c}{r^2}$

$$F = \frac{6.67 \times 10^{-11} \times 7.36 \times 10^{22} \times 6 \times 10^{24}}{(3.8 \times 10^8)^2} = \frac{6.67 \times 7.36 \times 10^{35}}{(3.8)^2 \times 10^{16}}$$

$$= 20.3 \times 10^{19} = 2.03 \times 10^{20} \text{ N} = 2 \times 10^{20} \text{ N}$$

10. Charge on proton = 1.6×10^{-19}

$$\therefore F_{\text{electrical}} = \frac{1}{4\pi\epsilon_0} \times \frac{q_1q_2}{r^2} = \frac{9 \times 10^9 \times (1.6)^2 \times 10^{-38}}{r^2}$$

$$\text{mass of proton} = 1.732 \times 10^{-27} \text{ kg}$$

$$F_{\text{gravity}} = G \frac{m_1 m_2}{r^2} = \frac{6.67 \times 10^{-11} \times (1.732) \times 10^{-54}}{r^2}$$

$$\frac{F_e}{F_g} = \frac{\frac{9 \times 10^9 \times (1.6)^2 \times 10^{-38}}{r^2}}{\frac{6.67 \times 10^{-11} \times (1.732) \times 10^{-54}}{r^2}} = \frac{9 \times (1.6)^2 \times 10^{-29}}{6.67 (1.732)^2 \times 10^{-65}} = 1.24 \times 10^{36}$$

11. The average separation between proton and electron of Hydrogen atom is $r = 5.3 \times 10^{-11} \text{ m}$.

a) Coulomb's force $= F = 9 \times 10^9 \times \frac{q_1 q_2}{r^2} = \frac{9 \times 10^9 \times (1.0 \times 10^{-19})^2}{(5.3 \times 10^{-11})^2} = 8.2 \times 10^{-8} \text{ N}$.

- b) When the average distance between proton and electron becomes 4 times that of its ground state

$$\text{Coulomb's force } F = \frac{1}{4\pi\epsilon_0} \times \frac{q_1 q_2}{(4r)^2} = \frac{9 \times 10^9 \times (1.6 \times 10^{-19})^2}{16 \times (5.3)^2 \times 10^{-22}} = \frac{9 \times (1.6)^2}{16 \times (5.3)^2} \times 10^{-7}$$

$$= 0.0512 \times 10^{-7} = 5.1 \times 10^{-9} \text{ N}.$$

12. The geostationary orbit of earth is at a distance of about 36000 km.

We know that, $g' = GM / (R+h)^2$

At $h = 36000 \text{ km}$. $g' = GM / (36000+6400)^2$

$$\therefore \frac{g'}{g} = \frac{6400 \times 6400}{42400 \times 42400} = \frac{256}{106 \times 106} = 0.0227$$

$$\Rightarrow g' = 0.0227 \times 9.8 = 0.223$$

[taking $g = 9.8 \text{ m/s}^2$ at the surface of the earth]

A 120 kg equipment placed in a geostationary satellite will have weight

$$Mg' = 0.233 \times 120 = 26.79 = 27 \text{ N}$$

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