286.

Problem 27.33 (RHK)

(a) *We have to find the equal amount of positive charge that would have to be placed on the Earth and on the Moon to neutralise their gravitational attraction. Do we have to know the Moon's distance from the Earth for answering this problem?* (b) *We have to calculate in metric tons the amount of hydrogen that would be needed to provide charge equal to that calculated in the part* (a) *of the problem. We may use that the molar mass of hydrogen is* 1.008 g mol^{-1}.

Solution:

We use the following data:

Mass of the Earth, $M_{earth} = 5.98 \times 10^{24}\ \text{kg}$,

mass of the Moon, $m_{moon} = 7.36 \times 10^{22}\ \text{kg}$.

The magnitude of the force of attraction between the Earth and the Moon will be

$$F_g = \frac{GM_{earth}m_{moon}}{R^2} = \frac{6.67\times10^{-11}\times5.98\times10^{24}\times7.36\times10^{22}}{R^2}\ \text{N}$$

$$= \frac{2.94\times10^{37}}{R^2}\ \text{N},$$

where R is the distance of the Moon from the Earth. Let Q C be the amount of positive charge which when placed on both the Earth and the Moon would balance their gravitational attraction. By Coulomb's law the magnitude of the force of electrostatic repulsion will be

$$F_c = \frac{Q^2}{4\pi\varepsilon_0 R^2}.$$

Therefore, if $F_c = F_g$, we have

$$\frac{Q^2}{4\pi\varepsilon_0} = 2.94\times10^{37},$$

or

$$Q^2 = \frac{2.94\times10^{37}}{8.99\times10^9}\ \text{C}^2 = 0.327\times10^{28}\ \text{C}^2.$$

Therefore,

$$Q = 5.71\times10^{13}\ \text{C} = 57.1\ \text{TC}.$$

It would have been noticed that as both the gravitational force and the Coulomb force are inverse square forces, we did not need to know the distance between the Earth and the Moon for answering the part (a) of the problem.

(b)

We will next use the data that the mass of 6.02×10^{23} protons (proton is a nucleus of hydrogen atom) is 1.008 g. The total number of protons that will have charge of 5.71×10^{13} C will be

$$N=\frac{5.71\times10^{13}}{1.6\times10^{-19}}=3.568\times10^{32}.$$

As the molar mass of hydrogen is 1.008 g, the mass of 3.568×10^{32} hydrogen atoms will be

$$m=\frac{1.008\times3.568\times10^{32}}{6.02\times10^{23}}\ \text{g}=5.98\times10^{8}\ \text{g}=598\ \text{metric tons.}$$