

## Chapter 21: Electrostatics

### In-Class Exercises

21.1.a + 21.2.a + 21.3.a + 21.4.a + 21.5.a + 21.6.b + 21.7.a + 21.8.a + 21.9.a + 21.10.a

### Multiple Choice

21.1.b + 21.2.b + 21.3.b + 21.4.a + 21.5.b + 21.6.b + 21.7.a + 21.8.a + 21.9.a + 21.10.b

### Questions

**21.11.** The given quantities are the charge of the two particles,  $Q_1 = Q$  and  $Q_2 = Q$ . They are separated by a distance  $d$ . The Coulomb force between the charged particles is  $F = k \frac{Q_1 Q_2}{d^2} = k \frac{Q^2}{d^2}$ . If the charge on each particle is doubled so that  $Q'_1 = 2Q$  and  $Q'_2 = 2Q$  and the separation distance is  $d' = 2d$  then the Coulomb force is given by:  $F' = k \frac{Q'^2}{d'^2} = k \frac{Q^2}{d^2}$  so the force is the same as it was in the initial situation.

**21.12.** The gravitational force between the Sun and the Earth is  $F_g = G \frac{M_s M_e}{r^2}$ , where  $G$  is the gravitational constant and is equal to  $6.67 \cdot 10^{-11} \text{ N m}^2 / \text{kg}^2$ .  $M_s$  is the mass of the Sun ( $1.989 \cdot 10^{30} \text{ kg}$ ) and  $M_e$  is the mass of the Earth ( $5.974 \cdot 10^{24} \text{ kg}$ ). The Coulomb force is given by the equation  $F_c = k \frac{Q_1 Q_2}{r^2}$ , where  $k$  is Coulomb's constant ( $k = 8.99 \cdot 10^9 \text{ N m}^2 / \text{C}^2$ ). In this question  $Q_1 = Q_2 = Q$  and is the charge given to the Earth and Sun to cancel out the gravitational force.

$$F_c = F_g \Rightarrow \frac{kQ^2}{r^2} = \frac{GM_s M_e}{r^2} \Rightarrow Q = \sqrt{\frac{G}{k}} M_s M_e$$

Therefore,

$$Q = \sqrt{\frac{(6.67 \cdot 10^{-11} \text{ N m}^2 / \text{kg}^2)(1.989 \cdot 10^{30} \text{ kg})(5.974 \cdot 10^{24} \text{ kg})}{8.99 \cdot 10^9 \text{ N m}^2 / \text{C}^2}} = 2.97 \cdot 10^7 \text{ C}.$$

I can get the number of elementary charges,  $n$ , by dividing  $Q$  by  $1.602 \cdot 10^{-19} \text{ C}$  (the charge of one electron):

$$n = \frac{2.97 \cdot 10^7 \text{ C}}{1.602 \cdot 10^{-19} \text{ C}} = 1.85 \cdot 10^{26}.$$

To estimate the number of elementary charge of either sign for the Earth I can assume the mass of the Earth is due to the mass of the protons, neutrons and electrons of which it is primarily composed. If I assume that the Earth's mass is due to the proton and neutron masses primarily (because an electron's mass is much smaller than a proton's) and I assume that there are an equal number of protons and neutrons then I can get the number of protons by dividing the Earth's mass by two times the mass of a proton. The mass of a proton is  $m_p = 1.6726 \cdot 10^{-27} \text{ kg}$ , so you can estimate

the number of elementary charges on the Earth,  $n_e$ , by  $n_e = \frac{m_E}{m_p} = \frac{5.97 \cdot 10^{24} \text{ kg}}{1.67 \cdot 10^{-27} \text{ kg}} = 3.57 \cdot 10^{49}$ . So the

percentage of the Earth's charges that would be required to cancel out the gravitational force is  $(n/n_e) \cdot 100\% = 5.18 \cdot 10^{-23}\%$ , a very small percentage.

**21.13.** One reason that it took such a long time to understand the electrostatic force may have been because it was not observed as frequently as the gravitational force. All massive objects are acted on

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**C Cleary**



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