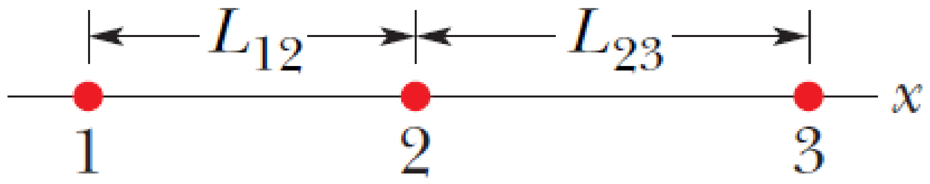
Recitation 6

•4 In the return stroke of a typical lightning bolt, a current of 2.5×10^4 A exists for 20 μs. How much charge is transferred in this event?

$$Q = i\Delta t = (2.5 \times 10^4 \text{ A})(20 \times 10^{-6} \text{ s}) = 0.50 \text{ C}.$$

••7 In Fig. 21-22, three charged particles lie on an x axis. Particles 1 and 2 are fixed in place. Particle 3 is free to move, but the net electrostatic force on it from Particles 1 and 2 happens to be zero. If $L_{23} = L_{12}$, what is the ratio q_1/q_2?



$$F_{31} = F_{32}$$

$$k\frac{|q_1||q_3|}{(2r)^2} = k\frac{|q_2||q_3|}{r^2}$$

Thus,

$$\frac{|q_1|}{|q_2|} = 4.$$

However, q_1 and q_2 must have opposite signs to have zero net force on Particle 3. Thus,

$$\frac{q_1}{q_2} = -4.$$

$R_E = 6.37 \times 10^6$ m

••31 ILW Earth's atmosphere is constantly bombarded by *cosmic ray protons* that originate somewhere in space. If the protons all passed through the atmosphere, each square meter of Earth's surface would intercept protons at the average rate of 1500 protons per second. What would be the electric current intercepted by the total surface area of the planet?

$$A_E = 4\pi R_E^2 = 4\pi(6.37 \times 10^6 \text{ m})^2 = 5.10 \times 10^{14} \text{ m}^2.$$

$$i = \left(1500 \frac{\text{proton}}{\text{s} \cdot \text{m}^2}\right)\left(1.60 \times 10^{-19} \frac{\text{C}}{\text{proton}}\right)(5.10 \times 10^{14} \text{ m}^2)$$

$$= 0.122 \frac{\text{C}}{\text{s}} = 0.122 \text{ A} = 122 \text{ mA}.$$

$M_M = 7.35 \times 10^{22}$ kg $\qquad M_E = 5.97 \times 10^{24}$ kg

41 (a) What equal positive charges would have to be placed on Earth and on the Moon to neutralize their gravitational attraction? (b) Why don't you need to know the lunar distance to solve this problem? (c) How many kilograms of hydrogen ions (that is, protons) would be needed to provide the positive charge calculated in (a)?

a)

$$F_g = F_C$$

$$\frac{GM_EM_M}{r^2} = \frac{kQ^2}{r^2}$$

$$Q = \sqrt{\frac{GM_EM_M}{k}} = \sqrt{\frac{\left(6.67 \times 10^{-11}\,\frac{\mathrm{N \cdot m^2}}{\mathrm{kg^2}}\right)(5.97 \times 10^{24}\ \mathrm{kg})(7.35 \times 10^{22}\ \mathrm{kg})}{8.99 \times 10^{9}\,\frac{\mathrm{N \cdot m^2}}{\mathrm{c^2}}}}$$

$$= 5.71 \times 10^{13}\ \mathrm{C}.$$

b) Both F_g and F_C are proportional to r^2.

c)

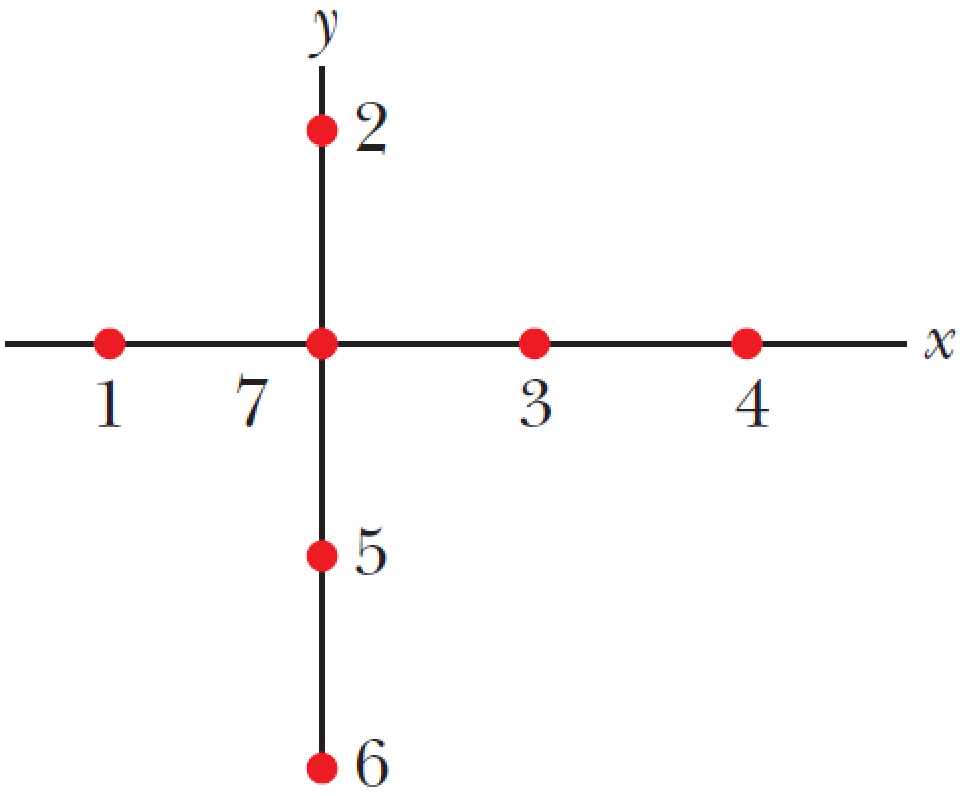
$$N = \frac{Q}{e} = \frac{5.71 \times 10^{13}\ \mathrm{C}}{1.60 \times 10^{-19}\ \mathrm{C/proton}}$$

$$= 3.57 \times 10^{32}\ \text{protons (hydrogen ions)}$$

$$m = Nm_p = \left(1.67 \times 10^{-27}\ \frac{\mathrm{kg}}{\mathrm{proton}}\right)(3.57 \times 10^{32}\ \text{protons})$$

$$= 5.96 \times 10^{5}\ \mathrm{kg.} = 596\ \text{ton.}$$

60 GO In Fig. 21-43, six charged particles surround particle 7 at radial distances of either $d = 1.0$ cm or $2d$, as drawn. The charges are $q_1 = +2e, q_2 = +4e, q_3 = +e, q_4 = +4e, q_5 = +2e, q_6 = +8e, q_7 = +6e$, with $e = 1.60 \times 10^{-19}$ C. What is the magnitude of the net electrostatic force on particle 7?



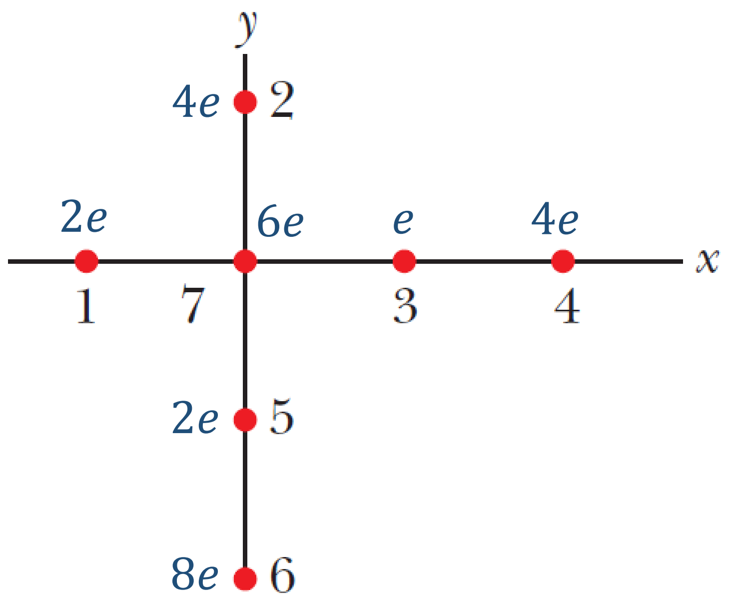
Along the y-axis:

$$\vec{F}_{72} = k\frac{(6e)(4e)}{d^2}(-\hat{\jmath}) = k\frac{24e^2}{d^2}(-\hat{\jmath})$$

$$\vec{F}_{75} = k\frac{(6e)(2e)}{d^2}\,\hat{\jmath} = k\frac{12e^2}{d^2}\,\hat{\jmath}$$

$$\vec{F}_{76} = k\frac{(6e)(8e)}{(2d)^2}\,\hat{\jmath} = k\frac{12e^2}{d^2}\,\hat{\jmath}$$

$$\vec{F}_{net,y} = 0$$



Along the x-axis:

$$\vec{F}_{71} = k\frac{(6e)(2e)}{d^2}\hat{\imath} = k\frac{12e^2}{d^2}\hat{\imath}$$

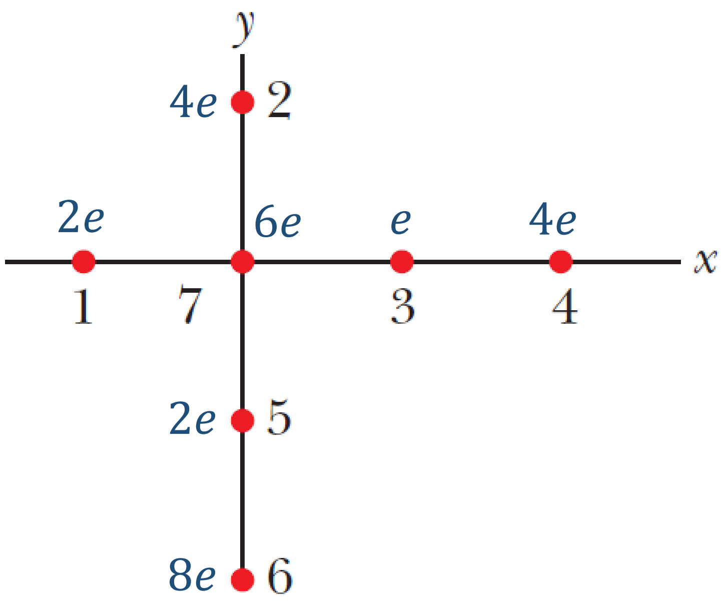
$$\vec{F}_{73} = k\frac{(6e)(e)}{d^2}(-\hat{\imath}) = k\frac{6e^2}{d^2}(-\hat{\imath})$$

$$\vec{F}_{74} = k\frac{(6e)(4e)}{(2d)^2}(-\hat{\imath}) = k\frac{6e^2}{d^2}(-\hat{\imath})$$

$$\vec{F}_{net,x} = 0$$

Thus,

$$\vec{F}_{net} = 0$$



71 In a spherical metal shell of radius R, an electron is shot from the center directly toward a tiny hole in the shell, through which it escapes. The shell is negatively charged with a *surface charge density* (charge per unit area) of 6.90×10^{-13} C/m^2. What is the magnitude of the electron's acceleration when it reaches radial distances (a) $r = 0.500R$ and (b) $2.00R$?

a) By the shell theorem, $a = 0$.

b) By the shell theorem

$$F = k\frac{|Qq_e|}{r^2} = k\frac{A\sigma e}{r^2} = k\frac{4\pi R^2\sigma e}{(2.00\,R)^2} = k\pi\sigma e$$

$$a = \frac{F}{m_e} = k\frac{\pi\sigma e}{m_e}$$

$$= \left(8.99\times10^9\,\frac{\mathrm{N\cdot m^2}}{\mathrm{c^2}}\right)\frac{\pi(6.90\times10^{-13}\mathrm{C/m^2})(1.60\times10^{-19}\mathrm{C})}{(9.11\times10^{-31}\,\mathrm{kg})}$$

$$= 3.42\times10^9\,\mathrm{m/s^2}.$$