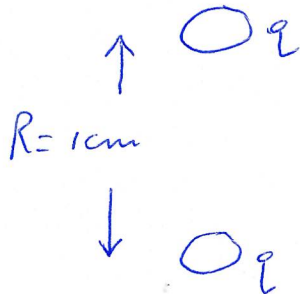


Assignment 9 Electrostatics

1. Two equally charged 1 gram masses separated by a distance of 1 cm repel each other. The lower mass is held fixed.
 - a) What is the charge on each mass for the Coulomb force to balance the gravitational force on the upper mass?



Coulomb Force = Grav. Force

$$\frac{kq^2}{R^2} = mg$$

$$q = \sqrt{\frac{mg}{k}} R$$

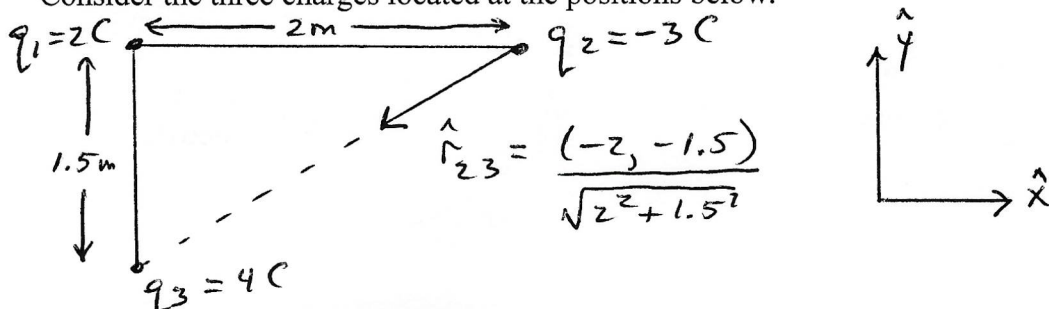
$$= \sqrt{\frac{10^{-3} \text{ kg} \times 9.8 \text{ m/s}^2}{9 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{Coul}^2}}} \cdot 10^{-2} \text{ m}$$

$$= 1.04 \times 10^{-8} \text{ Coul}$$

- b) How many electrons does this charge represent?

$$\begin{aligned}
 1.04 \times 10^{-8} \text{ C} &= \frac{1.04 \times 10^{-8} \text{ Coul}}{1.6 \times 10^{-19} \text{ Coul/elect.}} \\
 &= 6.5 \times 10^{10} \text{ electrons}
 \end{aligned}$$

2. Consider the three charges located at the positions below.



- a) Find the electric field on charge q_3 .

$$\begin{aligned}\vec{E}_{\text{on } q_3} &= \frac{kq_1}{r_{13}^2} \hat{r}_{13} + \frac{kq_2}{r_{23}^2} \hat{r}_{23} \\ &= 9 \times 10^9 \left\{ \frac{2}{1.5^2} (-\hat{y}) + \frac{(-3)}{2^2 + 1.5^2} \cdot \frac{(-2, -1.5)}{\sqrt{2^2 + 1.5^2}} \right\} \\ &= (3.46, -5.40) \times 10^9 \text{ Nt/Coul.}\end{aligned}$$

- b) Find the force on q_3 .

$$\begin{aligned}\vec{F}_{\text{on } q_3} &= q_3 \vec{E}_{\text{on } q_3} \\ &= 4\text{C} \times (3.46, -5.40) \times 10^9 \text{ Nt/Coul} \\ &= (1.38, -2.16) \times 10^{10} \text{ Nt.}\end{aligned}$$

- c) What happens if the charges are free to move?

Charges fly apart because forces are nonzero.

3. Two metal plates have a uniform charge density of 10 Coulombs/meter². The plates have dimensions of 0.6 x 0.6 meter² and are separated by 2 mm.
- a) Ignoring edge effects, the electric field (volts/meter) between the two plates is given by $E = 1.13 \times 10^{11} \text{ Q / A}$ where Q is the charge in Coulombs on one plate and A is the area in meters². Evaluate the field.

$$E = 1.13 \times 10^{11} \times 10 \text{ Coul/m}^2$$
$$= 1.13 \times 10^{12} \frac{\text{Coul}}{\text{m}^2}$$

- b) What is the voltage between the two plates?

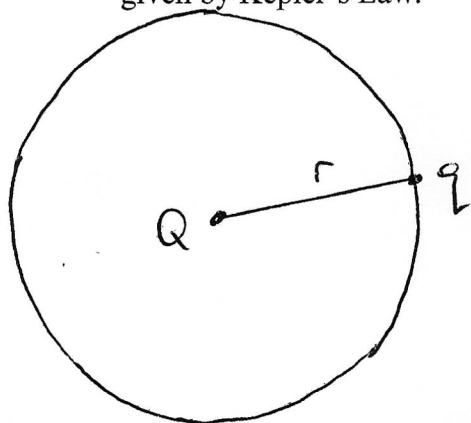
$$\text{Voltage} = E \times \text{plate separation}$$
$$= 1.13 \times 10^{12} \times .002$$
$$= 2.26 \times 10^9 \text{ volts}$$

- c) What is the charge stored on one plate?

$$Q = 10 \frac{\text{Coul}}{\text{m}^2} \times (0.6 \text{ m})^2$$
$$= 3.6 \text{ Coul.}$$

4. Consider two opposite charges. One is very heavy and may be assumed to be fixed while the other one has a mass m and orbits the second at a radius r and velocity v .

a) Show that the relation between the orbital radius and the orbital period is given by Kepler's Law.



Centripetal = Coulomb
Force Force

$$\frac{mv^2}{r} = \frac{kqQ}{r^2}$$

$$rv^2 = \frac{kqQ}{m}$$

$$r \left(\frac{2\pi r}{T} \right)^2 = \frac{kqQ}{m}$$

$\therefore$ Kepler's Law:

$$\boxed{\frac{r^3}{T^2} = \text{constant}}$$

b) If the radius is doubled what happens to the period?

$$T^2 \propto r^3$$

$$\text{or } T \propto r^{+3/2}$$

$$\text{If } r \rightarrow 2r \text{ then } T \rightarrow 2^{3/2} T = 2.83 T$$