

PQ2 Coulomb's Law

Questions & Answers

Q1

What is the force of repulsion between two electrons held one metre apart in a vacuum? What is the gravitational force of attraction between them? By what factor is the electric repulsion greater than the gravitational attraction?

$$\text{mass of an electron} = 9.11 \times 10^{-31} \text{ kg}$$

$$\text{mass of a proton} = 1.67 \times 10^{-27} \text{ kg}$$

$$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$$

$$F = kQ_1Q_2/r^2 = (9.0 \times 10^9 \times 1.6 \times 10^{-19} \times 1.6 \times 10^{-19})/ 1^2 = 2.3 \times 10^{-28} \text{ N}$$

$$F = Gm_1m_2/r^2 = (6.67 \times 10^{-11} \times 9.11 \times 10^{-31} \times 9.11 \times 10^{-31})/ 1^2 = 5.5 \times 10^{-71} \text{ N}$$

$$\text{Electrical force/gravitational force} = 2.3 \times 10^{-28} / 5.5 \times 10^{-71} = 4 \times 10^{42} \quad \text{!!!!}$$

Q2

By what factor is the electric force between two protons greater than the gravitational force between them?

$$\text{mass of an electron} = 9.11 \times 10^{-31} \text{ kg}$$

$$\text{mass of a proton} = 1.67 \times 10^{-27} \text{ kg}$$

$$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$$

Electrical force is same as with 2 electrons (they have the same magnitude of charge).

$$\text{Gravitational force} = (6.67 \times 10^{-11} \times 1.67 \times 10^{-27} \times 1.67 \times 10^{-27}) / 1^2 = 1.9 \times 10^{-64} \text{ N}$$

$$\text{Electrical force/gravitational force} = 1.2 \times 10^{36}$$

Q3

Given the difference in magnitudes of gravitational and electrical forces you've just discovered, why do you feel gravitational attraction from the earth, but no electrical forces?

Because even though the Earth has a very large mass, providing a strong gravitational field, both it and you are electrically neutral overall.

Q4

- An object has a total electrical charge of +1.2 mC.
- Does the object have excess electrons, or a shortage of electrons?
- How many electrons?

$$\begin{aligned}\text{Number of electrons} &= \frac{\text{total charge}}{\text{charge per electron}} \\ &= \frac{1.2 \times 10^{-6}}{1.60 \times 10^{-19}} \\ &= 7.5 \times 10^{12}\end{aligned}$$

Q5

- Two latex balloons are rubbed against hair and charged to **-2.0 μC** . The balloons are held a distance of **0.70 m** apart.
- a) What is the **FORCE** on each of the balloons?
- b) Is the force **ATTRACTIVE** or **REPULSIVE**?

$$F = k \frac{q_1 q_2}{r^2}$$

$$F = 9.0 * 10^9 \text{ Nm}^2 / \text{C}^2 \frac{(-2.0 * 10^{-6} \text{ C})(-2.0 * 10^{-6} \text{ C})}{0.70 \text{ m}^2}$$

$$F = \frac{36 * 10^{-3} \text{ N}}{.49} = 73.5 * 10^{-3}$$

$$F = 7.35 * 10^{-2} \text{ N}$$

Both have a negative charge, so they will repel

A positive sign for force means repel
A negative would mean attract

Q6

Electrons and protons have equal but opposite charges.
The magnitude of this charge is known as the:

$$\text{Elementary Charge} = 1.60 \times 10^{-19} \text{ C}$$

A hydrogen atom contains one proton and one electron. If the electrostatic force of attraction is $8.2 \times 10^{-8} \text{ N}$, how far apart are they?

$$q_{p^+} = q_{e^-} = 1.60 \times 10^{-19} \text{ C}$$

$$F_E = \frac{k q_1 q_2}{r^2}$$

$$r = \sqrt{\frac{k q_1 q_2}{F_E}}$$

$$r = \sqrt{\frac{(9 \times 10^9)(1.6 \times 10^{-19})(1.6 \times 10^{-19})}{8.2 \times 10^{-8}}}$$

$$= \underline{\underline{5.3 \times 10^{-11} \text{ m}}}$$

Q7

- Two charges feel a repulsive force of 96 (N). What is the force if the separation, r , is quadrupled.

Since Coulomb's law scales as r^{-2} , and r becomes larger by a factor of 4, the new force should be (1/4) squared, or one sixteenth of the old force.

$$F = 96/16 \text{ (N)}$$

$$F = 6.0 \text{ (N)}$$

Q8

- Calculate the electrostatic force between two electrons placed 1.5 nm apart.

$$F = 9 \times 10^9 \times \frac{1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{(1.5 \times 10^{-9})^2}$$

Q9

- The electrostatic repulsive force between two protons in a nucleus is 14 N.
- Find the separation between the protons.

$$14 = 9 \times 10^9 \times \frac{1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{r^2} \quad \text{giving} \quad r = 4.1 \times 10^{-15} \text{ m}$$

Q10

A point charge of $+3.00 \times 10^{-6} \text{ C}$ is 12.0 cm distant from a second point charge of $-1.50 \times 10^{-6} \text{ C}$. Calculate the magnitude of the force on each charge.

Being of opposite signs, the two charges *attract* one another, and the magnitude of this force is given by Coulomb's law :

$$\begin{aligned} F &= k \frac{|q_1 q_2|}{r^2} \\ &= (8.99 \times 10^9 \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}) \frac{(3.00 \times 10^{-6} \text{ C})(1.50 \times 10^{-6} \text{ C})}{(12.0 \times 10^{-2} \text{ m})^2} = 2.81 \text{ N} \end{aligned}$$

Each charge experiences a force of attraction of magnitude 2.81 N.