PQ 1 Coulomb’s Law

Questions and Answers

Q1

- What is the total charge of 75.0 kg of electrons?

The mass of *one* electron is 9.11×10^{-31} kg

$$= \frac{(75.0\,\text{kg})}{(9.11 \times 10^{-31}\,\text{kg})} = 8.23 \times 10^{31} \quad \text{electrons}$$

The charge of *one* electron is $-e = -1.60 \times 10^{-19}\,\text{C}$, so that the total charge

$$= (8.23 \times 10^{31})(-1.60 \times 10^{-19}\,\text{C}) = -1.32 \times 10^{13}\,\text{C}$$

Q2

A point charge of $+3.00 \times 10^{-6}$ C is 12.0 cm distant from a second point charge of -1.50×10^{-6} 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

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

$$= (8.99 \times 10^9 \, \tfrac{\mathrm{N \cdot m^2}}{\mathrm{C^2}})\frac{(3.00 \times 10^{-6}\,\mathrm{C})(1.50 \times 10^{-6}\,\mathrm{C})}{(12.0 \times 10^{-2}\,\mathrm{m})^2} = 2.81\,\mathrm{N}$$

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

Q3

What must be the distance between point charge $q_1 = 26.0\,\mu\text{C}$ and point charge $q_2 = -47.0\,\mu\text{C}$ for the electrostatic force between them to have a magnitude of $5.70\,\text{N}$?

We are given the charges and the magnitude of the (attractive) force between them. We can use Coulomb's law to solve for r, the distance between the charges:

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

Plug in the given values:

$$r^2 = \left(8.99 \times 10^9\,\tfrac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\frac{(26.0 \times 10^{-6}\,\text{C})(47.0 \times 10^{-6}\,\text{C})}{(5.70\,\text{N})} = 1.93\,\text{m}^2$$

This gives:

$$r = \sqrt{1.93\,\text{m}^2} = 1.39\,\text{m}$$

Q4

The most common isotope of hydrogen contains a proton and an electron separated by about 5.0×10^{-11} m. The mass of a proton is approximately 1.7×10^{-27} kg. The mass of the electron is approximately 9.0×10^{-31} kg.

a) Use Newton's law of universal gravitation to calculate the gravitational force between the electron and proton in the hydrogen atom.

$$F_g = \frac{G m_1 m_2}{r^2} = \frac{(6.67\times10^{-11}\,Nm^2/kg^2)(1.7\times10^{-27}\,kg)(9\times10^{-31}\,kg)}{(5\times10^{-11}\,m)^2} = 4.1\times10^{-47}\,N$$

b) Use 1.6×10^{-19} C as the elementary unit of charge to determine the force of attraction between the two particles.

$$F_e = \frac{k q_1 q_2}{r^2} = \frac{(9\times10^{9}\,Nm^2/C^2)(+1.6\times10^{-19}\,C)(-1.6\times10^{-19}\,C)}{(5\times10^{-11}\,m)^2} = -9.2\times10^{-8}\,N$$

Q5

Two positive charges of 6.0 x 10^{-6} C are separated by 0.50 m. Draw a force diagram for each of the charges, considering only electrostatic forces. What is the magnitude of the force between the charges? Is this force repulsive or attractive?

$$F = \frac{k q_1 q_2}{r^2} = \frac{\left(9\times10^{9}\,\frac{Nm^2}{C^2}\right)\left(6.0\times10^{-6}\,C\right)^2}{(0.5\,m)^2} = +1.3\ N$$

repulsive

Q6

A negative charge of 2.0 x 10^{-4} C and a positive charge of 8.0 x 10^{-4} C are separated by 0.30 m. What is the magnitude of the force between the charges? Is this force repulsive or attractive?

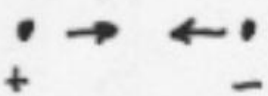
$$F = \frac{k q_1 q_2}{r^2} = \frac{(9 \times 10^9 \, Nm^2/C^2)(-2.0 \times 10^{-4} C)(+8.0 \times 10^{-4} C)}{(0.3m)^2} = -1.6 \times 10^4 N$$

attractive

Q7

A young man accumulates a charge q_1 of $+2.0 \times 10^{-5}$ C while sliding out of the front seat of a car. His girlfriend, who had been waiting in the wind, has picked up some extra electrons and now has a charge q_2 of -8.0×10^{-5} C.

Draw a sketch of the situation. Estimate the magnitude of the electrical force that each person exerts on the other when separated by a distance of 6.0 m. Is the force attractive or repulsive?



$$F = \frac{k q_1 q_2}{r^2} = \frac{(9\times10^{9}\,\mathrm{N\,m^2/C^2})(+2.0\times10^{-5}\,\mathrm{C})(-8.0\times10^{-5}\,\mathrm{C})}{(6.0\,\mathrm{m})^2}$$

$$= -4\times10^{-1}\,\mathrm{N} \approx 0.4\,\mathrm{N} \quad \text{(attractive)}$$

Q8

A charge of 5.67×10^{-18} C is placed 3.5×10^{-6} m away from another charge of -3.79×10^{-19} C. What is the force of attraction between them?

electrical proportionality constant = 9.0×10^{9} Nm^2/C
charge of a proton = +1 = 1.6×10^{-19} C
charge of an electron = -1 = -1.6×10^{-19} C

$q_1 = 5.67 \times 10^{-18}$ C
$q_2 = -3.79 \times 10^{-19}$ C
$d = 3.5 \times 10^{-6}$ m

$$F_e = k\frac{q_1 q_2}{d^2}$$

5.67×10^{-18} C x -3.79×10^{-19}=2.15×10^{-36}

$(3.5 \times 10^{-6})^2 = 1.22 \times 10^{-11}$

$2.15 \times 10^{-36} \div 1.22 \times 10^{-11} = 1.76 \times 10^{-25}$

$1.76 \times 10^{-25} \times 9 \times 10^{9} =$ 1.58×10^{-15} N

Q9

What is the magnitude of electrical force of attraction between an iron nucleus (26 protons) and its innermost electron if the distance between them is 1.0×10^{-12} m?

$q_1 = 26+$
$q_2 = 1-$
$d = 1.0 \times 10^{-12}$ m

$$F_e = k\frac{q_1 q_2}{d^2}$$

electrical proportionality constant = 9.0×10^{9} Nm^2/C
charge of a proton = +1 = 1.6×10^{-19} C
charge of an electron = -1 = -1.6×10^{-19} C

$q_1 = 26(1.6 \times 10^{-19}) = 4.16 \times 10^{-18}$
$q_2 = 1(-1.6 \times 10^{-19}) = -1.6 \times 10^{-19}$
$4.16 \times 10^{-18} \times -1.6 \times 10^{-19} = -6.66 \times 10^{-37}$
$(1.0 \times 10^{-12})^2 = 1.0 \times 10^{-24}$
$-6.66 \times 10^{-3} \div 1.0 \times 10^{-24} = -6.66 \times 10^{-13}$
$-6.66 \times 10^{-13} (9 \times 10^{9})$

-5.99×10^{-3} N

Q10

How far apart must two electrons be if the force between them is 1.0×10^{-12} N?

$q_1 = 1-$
$q_2 = 1-$
$F_e = 1.0 \times 10^{-12}$ N
$k = 9 \times 10^9$

electrical proportionality constant = 9.0×10^9 Nm^2/C
charge of a proton = +1 = 1.6×10^{-19} C
charge of an electron = -1 = -1.6×10^{-19} C

$q_1 = q_2 = -1.6 \times 10^{-19}$

$9 \times 10^9 \times -1.6 \times 10^{-19} \times -1.6 \times 10^{-19} =$
2.3×10^{-28}

$2.3 \times 10^{-28} \div 1.0 \times 10^{-12} = 2.3 \times 10^{-16}$

$$\sqrt{2.3x10^{-16}}$$

1.52×10^{-8} m