

Year 11 Physics Term 3 Week 5

Coulomb's Law

Introduction

- The interaction between charged objects is a non-contact force that acts over some distance of separation.
- Charge, charge and distance.
- The electrical force expressed using the unit Newton.
- Has magnitude and direction
- The direction of the electrical force is dependent upon the charged objects and upon their spatial orientation.

Determining the Direction of the Electrical Force Vector



Factors that influence the Magnitude of the Electrical Force

- The quantity of charge on A
- The quantity of charge on B
- The distance
- The magnitude of the force and the distance between the objects is *inversely related*.

Coulomb's Law Equation

- ...the electrical force between two charged objects is directly proportional to the product of the quantity of charge on the objects and inversely proportional to the square of the separation distance between the two objects!

$$F = \frac{k Q_1 Q_2}{r^2}$$

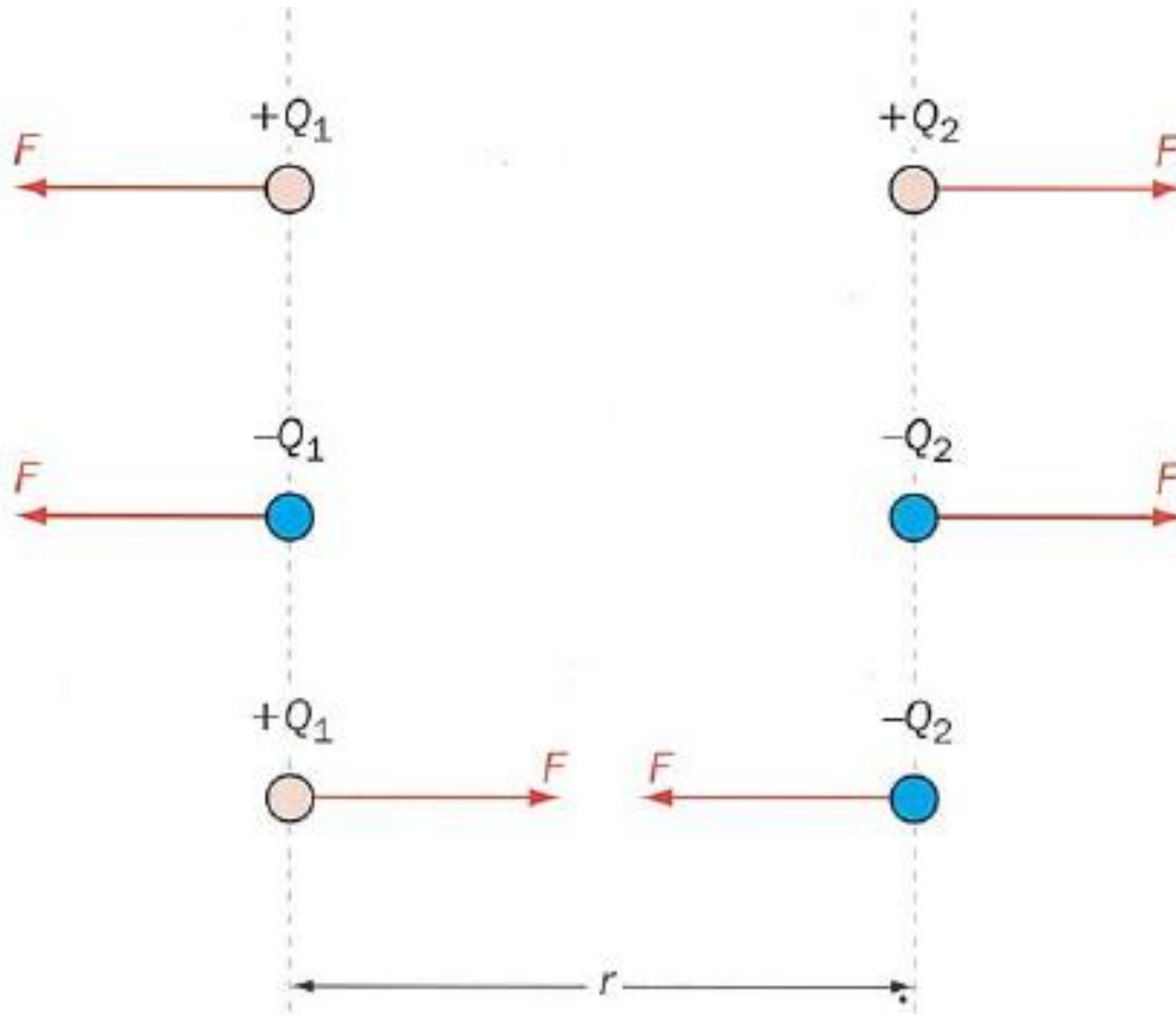
F is the force, in newtons

Q_1 and Q_2 are the charges, in coulombs

r is the distance apart, in metres

k is the constant of proportionality

Graphically



The value of the constant k

k is $9.0 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$.

Another inverse square law

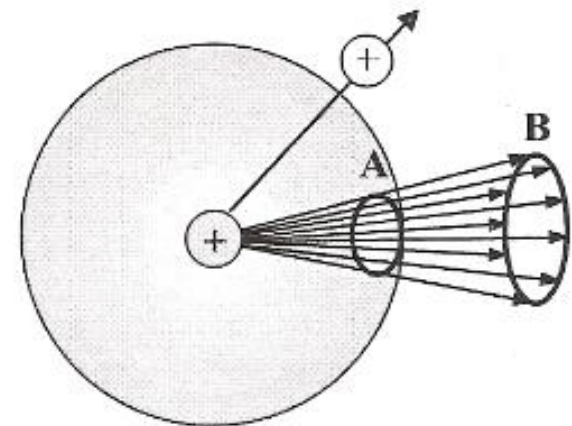
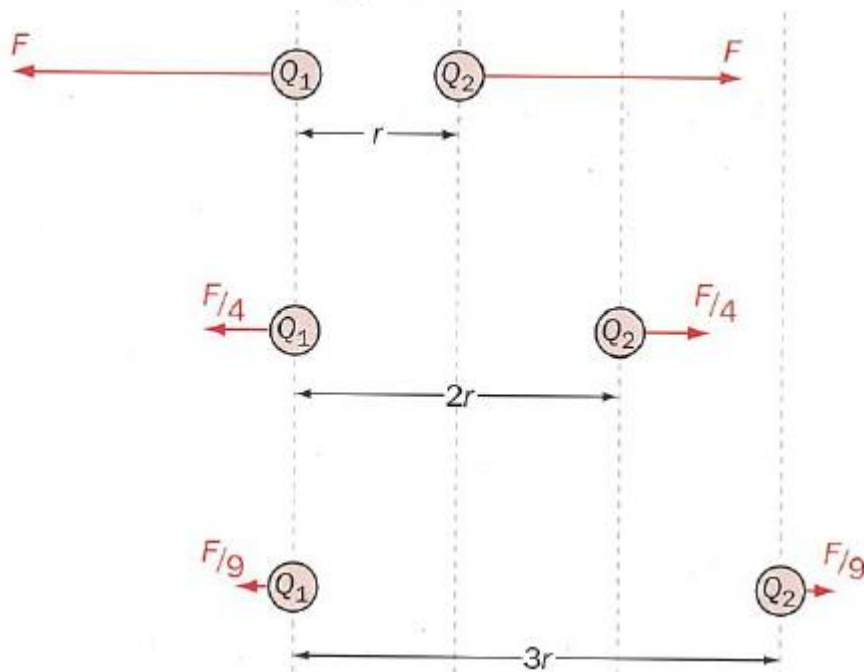
This means that if we double the distance between the charges, the force decreases to $(\frac{1}{2})^2$ or $\frac{1}{4}$ of its previous value.

Coulomb's law:

$$F = \frac{k Q_1 Q_2}{r^2}$$

Newton's law of gravitation

$$F = \frac{G m_1 m_2}{r^2}$$



Coulomb's law of charge

The force is 'felt' by objects with charge.

The force is proportional to the size of the charges.

The force is inversely proportional to the square of the separation of the charges.

There is an electric field round a charge

There are two types of charge – positive and negative.

The constant is k , and its value depends on the material. In air $k = 1/4\pi\epsilon_0 = 9.0 \times 10^9 \text{ N m}^{-2} \text{ C}^{-2}$

The electric force is very strong, but not normally noticed as the charges cancel out.

Example 1

Two charges are separated by a distance of 3 cm. Charge one is $3.0 \times 10^{-9} \text{ C}$ whilst charge two is $-12 \times 10^{-9} \text{ C}$. What is the force between the two charges and is it attractive or repulsive?

$$q_1 = 3.0 \times 10^{-9} \text{ C}$$

$$q_2 = -12 \times 10^{-9} \text{ C}$$

$$r = 3 \times 10^{-2} \text{ m}$$

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

$$= 9.00 \times 10^9 \frac{3.0 \times 10^{-9} \times 12 \times 10^{-9}}{(3 \times 10^{-2})^2}$$

$$= 3.6 \times 10^{-4} \text{ N} \quad \text{Attractive}$$

Example 2

Suppose that two point charges, each with a charge of +1.00 Coulomb are separated by a distance of 1.00 metres. Determine the magnitude of the electrical force of repulsion between them.

$$F = \frac{k Q_1 Q_2}{r^2}$$

$$Q_1 = 1.00 \text{ C}$$

$$Q_2 = 1.00 \text{ C}$$

$$d = 1.00 \text{ m}$$

$$F_{\text{elect}} = (9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2) \cdot (1.00 \text{ C}) \cdot (1.00 \text{ C}) / (1.00 \text{ m})^2$$

$$F_{\text{elect}} = 9.0 \times 10^9 \text{ N}$$

Charge is often expressed in units of microCoulomb (μC) and nanoCoulomb (nC).

$$1 \text{ Coulomb} = 10^6 \text{ microCoulomb}$$

$$1 \text{ Coulomb} = 10^9 \text{ nanoCoulomb}$$

Example 3

Two balloons are charged with an identical quantity and type of charge: -6.25 nC. They are held apart at a separation distance of 61.7 cm. Determine the magnitude of the electrical force of repulsion between them.

$$Q_1 = -6.25 \text{ nC} = -6.25 \times 10^{-9} \text{ C}$$

$$Q_2 = -6.25 \text{ nC} = -6.25 \times 10^{-9} \text{ C}$$

$$d = 61.7 \text{ cm} = 0.617 \text{ m}$$

$$F_{\text{elect}} = (9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2) \cdot (6.25 \times 10^{-9} \text{ C}) \cdot (6.25 \times 10^{-9} \text{ C}) / (0.617 \text{ m})^2$$

$$F_{\text{elect}} = 9.23 \times 10^{-7} \text{ N}$$

The resulting "+" and "-" signs on F signifies whether the force is attractive (a "-" F value) or repulsive (a "+" F value).