A-LEVEL PHYSICS • EXERCISE SHEET

18.3 Electric force between point charges

Name: _____ Class: _____ Date: _____ **Total: 23 marks**

KEY WORDS point charge 点电荷 • coulomb's law 库仑定律 • force 力

Objective

Build the skills to answer exam questions on **Coulomb's law** — the force between two point charges.

You must be able to:

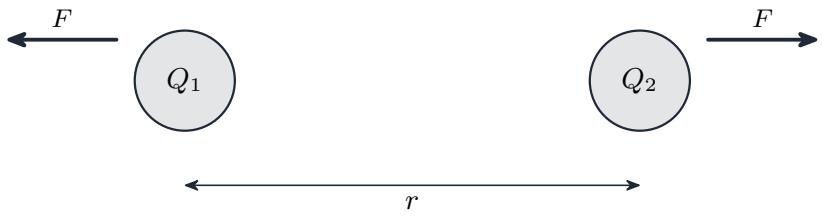
- use Coulomb's law $F = \dfrac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$
- treat a charged sphere as a **point charge** at its centre

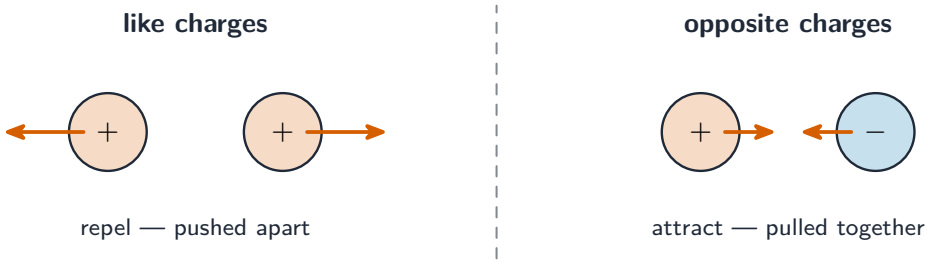
1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Coulomb's law

Two point charges a distance r apart exert **equal, opposite** forces along the line joining them:





Coulomb force between point charges

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}, \qquad \frac{1}{4\pi\varepsilon_0} = 9.0 \times 10^9 \text{ N m}^2 \text{ C}^{-2}.$$

Like charges repel; **opposite** charges attract. A charged sphere acts as a **point charge at its centre**.

Worked example. +2.0 nC and +3.0 nC, 4.0 cm apart:

$$F = \frac{(9.0 \times 10^9)(2.0 \times 10^{-9})(3.0 \times 10^{-9})}{(0.040)^2} = 3.4 \times 10^{-5} \text{ N (repulsive)}.$$

2 Practice

Now apply the methods above.

2.1 State **Coulomb's law**. [2]

2.2 State the value of $\dfrac{1}{4\pi\varepsilon_0}$. [1]

2.3 State whether **like** charges attract or repel. [1]

3 Exam-style questions

3.1 If the distance between two charges is **doubled**, the Coulomb force becomes: [1]

A	B
C	D

A twice as large
B half as large
C one quarter as large
D four times as large

3.2 Calculate the force between point charges of +2.0 nC and +3.0 nC placed 4.0 cm apart. [3]

3.3 Two charges of +5.0 nC are 2.0 cm apart. Calculate the force between them, and state whether it is attractive or repulsive. [3]

3.4 A simplified model of a helium atom has a nucleus of charge $+2e$ with two electrons in a circular orbit of radius 2.6×10^{-11} m around it. Take $e = 1.60 \times 10^{-19}$ C, $\dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}$ m F^{-1} and the electron mass as 9.11×10^{-31} kg. Ignore the force between the two electrons.

(a) **State** Coulomb's law. [2]

(b) **Show that** the electric force between the nucleus and one electron is about 1.4×10^{-7} N. [2]

(c) This force provides the centripetal force on the electron. **Calculate** the speed of the orbiting electron. [3]

(d) **Determine** the period of the orbit. [2]

(e) **Determine** the ratio $\frac{\text{electric force on the electron}}{\text{gravitational force on the electron}}$, given that the nucleus has mass 6.6×10^{-27} kg and $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}, and **suggest** what your answer means for a model of the atom. [3]