Exercise walk-through

Electric Charge and Electric Force ▪ 8.1

eXercise

You must be able to

- describe **electric charge 电荷** as **quantized** in multiples of e and **conserved 守恒**
- apply **Coulomb's law 库仑定律** $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$
- use the **superposition principle 叠加原理** to find the net force from several charges
- compare the electrostatic force with the **gravitational force 引力**

Method — Coulomb's law

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} = k\frac{q_1 q_2}{r^2}, \text{ with } k = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9 \text{ N m}^2\,\text{C}^{-2}.$$

Method — Superposition

The net force on a charge is the **vector sum** of the Coulomb forces from every other charge.

Method — Charge is quantized and conserved

Any charge is a whole multiple of $e = 1.6 \times 10^{-19}$ C, and total charge is conserved. The electric force vastly exceeds gravity between two charged particles.

Practice 2.1 ▪ 2 marks

Two $+2.0\ \mu$C charges are 0.30 m apart. Find the force between them.

Solution 2.1

Method: Charge is quantized and conserved

Worked steps

$$F = k\frac{q_1 q_2}{r^2} = 8.99 \times 10^9 \times \frac{(2.0 \times 10^{-6})^2}{(0.30)^2} = 0.40 \text{ N}$$ M1 A1.

Practice 2.2 ▪ 1 mark

State which is stronger for two charged particles: the electrostatic force or the gravitational force.

Solution 2.2

Method: Charge is quantized and conserved

Worked steps

the electrostatic force (by far) B1.

Practice 2.3 ▪ 2 marks

An object carries a charge of 8.0×10^{-19} C. Find the number of elementary charges.

Solution 2.3

Method: Charge is quantized and conserved

Worked steps

$$N = \frac{8.0 \times 10^{-19}}{1.6 \times 10^{-19}} = 5 \quad \text{M1 A1}.$$

Exam-style 3.1 ▪ 1 mark

The Coulomb force between two point charges is proportional to

A r

B $1/r$

C $1/r^2$

D r^2

Solution 3.1

A r

B $1/r$

C $1/r^2$ ✓

D r^2

Worked steps

C.

Exam-style 3.2 ▪ 1 mark

To find the net force on a charge from several others, you use

A only the nearest charge

B vector superposition of all the forces

C the average of the forces

D the largest force only

Solution 3.2

A only the nearest charge

B vector superposition of all the forces ✓

C the average of the forces

D the largest force only

Worked steps

B.

Exam-style 3.3 ▪ 2 marks

Charges of $+3.0\ \mu$C sit at $x = 0$ and $x = 0.20$ m. A $+1.0\ \mu$C charge is placed at the midpoint $x = 0.10$ m.

(a) Find the force on the middle charge from **one** of the outer charges.

(b) State the net force on the middle charge, and explain why.

Solution 3.3

Method: Charge is quantized and conserved

Worked steps

(a) $F = 8.99 \times 10^9 \times \dfrac{(3.0 \times 10^{-6})(1.0 \times 10^{-6})}{(0.10)^2} = 2.7$ N M1 A1. (b) zero B1 — the two outer charges push the middle charge with equal forces in opposite directions, which cancel B1.