

Exercise walk-through

17.2

Electric and magnetic fields (full D.2, HL)

International Baccalaureate · IB Diploma · Physics · HL

Electric Fields · 2.1

Reasoning

Electric field strength is force per unit positive test charge. Like charges repel and unlike charges attract. Field lines point away from positive charges and toward negative charges. Closely spaced lines represent a stronger field within a consistently drawn diagram. electric field strength: Electric force per unit positive test charge; test charge: A small charge used to probe an electric field.

Electric Fields · 3.1

Reasoning

In a uniform field between ideal parallel plates, $E = V/d$ away from edge effects. The force is $F = qE$, so its direction reverses for a negative charge. Coulomb force between ideal point charges decreases with separation squared. Sketch labelled plate polarities, field arrows and the charge before calculating. Convert separation to metres. In school, use simulations or approved low-voltage electrostatic models rather than exposed high-voltage equipment.

A conducting sphere is equipotential

- 1 Set the model** A conducting sphere of radius 0.10 m carries $+1.0\text{ }\mu\text{C}$. Set potential zero at infinity.
- 2 Calculate** At its surface $V = kQ/R = 9.0 \times 10^4\text{ V}$. Inside the conductor $E = 0$ and V remains this constant value.

Decision

Zero field does not imply zero potential. Work by an external agent in a slow move is $q\Delta V$; work by the electric field has the opposite sign.

Exercises 2.1·2.3

2.1 State Coulomb's law and the direction of the force between two negative charges. [2]

2.2 Two charges of $+2.0 \mu\text{C}$ and $-3.0 \mu\text{C}$ sit 0.060 m apart. Calculate the magnitude of the force between them. [3]

2.3 State what Millikan's oil-drop experiment showed about electric charge. [2]

Exercises 2.1·2.3

2.1 State Coulomb's law and the direction of the force between two negative charges. [2]

2.1 $F = kq_1q_2/r^2$, proportional to the product of the charges and the inverse square of their separation; two negative charges repel – forces point away from each other along the joining line.

2.2 Two charges of $+2.0 \mu\text{C}$ and $-3.0 \mu\text{C}$ sit 0.060 m apart. Calculate the magnitude of the force between them. [3]

2.2 $F = (9.0 \times 10^9 \times 2.0 \times 10^{-6} \times 3.0 \times 10^{-6}) / (0.060)^2 = (5.4 \times 10^{-2}) / (3.6 \times 10^{-3}) = 15 \text{ N}$, attractive since the signs are opposite.

2.3 State what Millikan's oil-drop experiment showed about electric charge. [2]

2.3 Charge is quantized: every drop carried a whole-number multiple of the electron charge $e = 1.6 \times 10^{-19} \text{ C}$, never a fraction of it.

Exercises 2.4·3.1

2.4 A charged rod is brought near (not touching) an isolated conducting sphere, which is then grounded briefly. Describe the sphere's net charge after the ground is removed and the rod taken away. [3]

2.5 Calculate the electric potential at 0.30 m from a point charge of $+2.0 \mu\text{C}$. [2]

3.1 Two parallel plates 5.0 mm apart hold 250 V across them. Calculate the field strength between them and the force on an electron placed there, and state one assumption about the field. [4]

Exercises 2.4·3.1

2.4 A charged rod is brought near (not touching) an isolated conducting sphere, which is then grounded briefly. Describe the sphere's net charge after the ground is removed and the rod taken away. [3]

2.4 The rod's field separates the sphere's charges – near side opposite, far side like the rod; grounding drains the like charge away to Earth; after the ground is removed first and the rod leaves, the sphere keeps a net charge opposite to the rod – charging by induction.

2.5 Calculate the electric potential at 0.30 m from a point charge of $+2.0 \mu\text{C}$. [2]

2.5 $V_e = kQ/r = (9.0 \times 10^9 \times 2.0 \times 10^{-6})/0.30 = 6.0 \times 10^4 \text{ V}$.

3.1 Two parallel plates 5.0 mm apart hold 250 V across them. Calculate the field strength between them and the force on an electron placed there, and state one assumption about the field. [4]

3.1 $E = V/d = 250/5.0 \times 10^{-3} = 5.0 \times 10^4 \text{ V/m}$; $F = eE = 1.6 \times 10^{-19} \times 5.0 \times 10^4 = 8.0 \times 10^{-15} \text{ N}$; assumes a uniform field – ignoring edge effects.

Exercises 3.2-3.3

3.2 Describe the magnetic field-line pattern around a long straight current-carrying wire, and state how the pattern changes if the current direction reverses. [3]

3.3 Sketch in words: the electric field-line pattern for two equal opposite point charges, giving two rules the pattern obeys. [4]

Exercises 3.2-3.3

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3.2 Concentric circles centred on the wire, lying in the plane perpendicular to it; direction given by the right-hand grip rule with the thumb along the current; reversing the current reverses the sense of every circle.

3.3 Sketch in words: the electric field-line pattern for two equal opposite point charges, giving two rules the pattern obeys. [4]

3.3 Lines run from the positive charge to the negative, curving so pairs meet the charges symmetrically; the straight line joins the two charges through the middle; rules: lines start on positive and end on negative charge, never cross, and their local density represents the field strength – dense near each charge, weakest in the far field.

Exercises 3.4-3.5

3.4 Explain how a balloon rubbed on hair can attract small neutral pieces of paper, naming the process that acts on the paper. [3]

3.5 An electron is accelerated from rest through a potential difference of 500 V. Calculate the work done on it in electronvolts and in joules, and the speed it reaches ($m_e = 9.1 \times 10^{-31}$ kg). [4]

Exercises 3.4·3.5

3.4 Explain how a balloon rubbed on hair can attract small neutral pieces of paper, naming the process that acts on the paper. [3]

3.4 Rubbing transfers electrons, leaving the balloon charged; the charged balloon polarizes the neutral paper – induction separates its charges, opposite sign nearer the balloon; the nearer opposite charge feels the stronger attraction (inverse-square), so the paper is pulled to the balloon.

3.5 An electron is accelerated from rest through a potential difference of 500 V. Calculate the work done on it in electronvolts and in joules, and the speed it reaches ($m_e = 9.1 \times 10^{-31}$ kg). [4]

3.5 $W = q\Delta V_e = 500 \text{ eV} = 500 \times 1.6 \times 10^{-19} = 8.0 \times 10^{-17} \text{ J}$; $\frac{1}{2}mv^2 = W$ so $v = \sqrt{2W/m_e} = \sqrt{(1.6 \times 10^{-16})/(9.1 \times 10^{-31})} = 1.3 \times 10^7 \text{ m/s}$.