

Exercise walk-through

4.3

Electric fields and potential (statements 92–99)

Pearson Edexcel · International A-Level · Physics

Scattering links observation to a model

Observation / symbol	Supported conclusion
Most pass nearly straight	Most atomic volume is empty
Rare large deflections	Tiny, dense, positive nucleus
A_ZX	Proton number Z ; nucleon number A ; neutrons $A - Z$

The quark–lepton model organises particles

Family	Constituents / example
Baryon	Three quarks; proton uud
Meson	Quark + antiquark; pion
Lepton / antilepton	Electron / positron
Photon	Electromagnetic quantum

Exercise 2.1

2.1 Parallel plates separated by 0.020 m have p.d. 600 V. Calculate field strength and force magnitude on an electron. State its force direction relative to the field. Use $e = 1.60 \times 10^{-19}$ C. [4]

○ e^-

600 V; 0.020 m

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2.1 Uniform field is p.d. per perpendicular separation.

$$E = \frac{V}{d} = \frac{600 \text{ V}}{0.020 \text{ m}} = 3.00 \times 10^4 \text{ V m}^{-1}$$

Field strength.

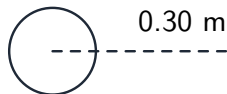
$$|F| = eE = 1.60 \times 10^{-19} \text{ C} \times 3.00 \times 10^4 \text{ N C}^{-1} = 4.80 \times 10^{-15} \text{ N}$$

Force magnitude; opposite field for the electron.

Exercise 2.2

2.2 An isolated conducting sphere has radius 0.10 m and potential +4.5 kV. Find its charge and field strength at 0.30 m from its centre. Use $k = 8.99 \times 10^9 \text{ N m}^2\text{C}^{-2}$. [4]

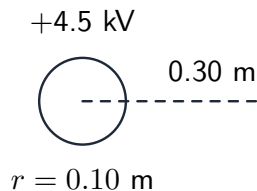
+4.5 kV



$r = 0.10 \text{ m}$

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2.2 Surface potential uses sphere radius.

$$Q = \frac{Vr}{k} = \frac{4.5 \times 10^3 \text{ V} \times 0.10 \text{ m}}{8.99 \times 10^9 \text{ N m}^2\text{C}^{-2}} = 5.01 \times 10^{-8} \text{ C}$$

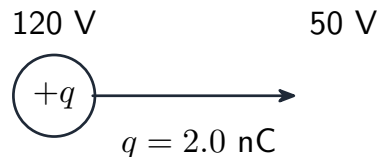
Positive charge. Use the new centre-distance in the inverse square law.

$$E = \frac{kQ}{r^2} = \frac{8.99 \times 10^9 \text{ N m}^2\text{C}^{-2} \times 5.01 \times 10^{-8} \text{ C}}{(0.30 \text{ m})^2} = 5.00 \times 10^3 \text{ N C}^{-1}$$

Field strength outward.

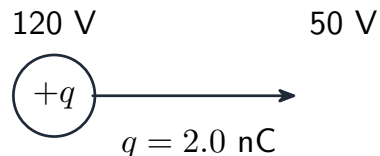
Exercise 2.3

2.3 A charge $+2.0 \text{ nC}$ moves from potential 120 V to 50 V . Find the potential-energy change and work done by the field. Explain why the sign matters. [4]



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2.3 Use final minus initial potential.

$$\Delta U = q(V_f - V_i) = 2.0 \times 10^{-9} \text{ C} \times (50 - 120) \text{ V} = -1.40 \times 10^{-7} \text{ J}$$

Energy change.

$$W_{\text{field}} = -\Delta U = -(-1.40 \times 10^{-7} \text{ J}) = +1.40 \times 10^{-7} \text{ J}$$

Work. Potential energy falls as the field does positive work; losing the sign loses that distinction.

Exercise 3.1

3.1 Explain how to obtain the potential at distance r from a positive point charge from its $E-r$ graph. Explain the relationship between field direction and equipotentials, and why zero potential at a point does not necessarily mean zero field. [4]

$E-r$

potential

equipotentials

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3.1 With zero potential at infinity, integrate the signed radial field from r to infinity; this gives potential, not the area from zero to r . Field is perpendicular to equipotentials and points towards lower potential. Potential value and potential gradient differ: opposing sources can cancel signed potentials while their fields add, or a reference can assign zero potential where the gradient is nonzero.

Exercise 3.2

3.2 A stationary oil drop of mass 6.52×10^{-15} kg lies between horizontal plates where the field points downwards with magnitude 2.00×10^5 N C⁻¹. Determine the charge, including sign, and the number of excess or missing electrons. State the force-balance assumption. [5]

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3.2 Neglect other forces and balance electrical force upwards against weight. A downwards field requires negative charge for upwards force. Use $|q|E = mg$.

$$|q| = \frac{mg}{E} = \frac{6.52 \times 10^{-15} \text{ kg} \times 9.81 \text{ m s}^{-2}}{2.00 \times 10^5 \text{ N C}^{-1}} = 3.20 \times 10^{-19} \text{ C}$$

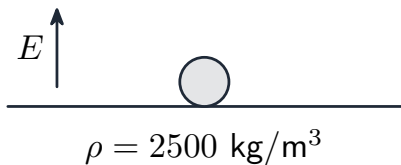
Signed charge -3.20×10^{-19} C.

$$n = \frac{|q|}{e} = \frac{3.20 \times 10^{-19} \text{ C}}{1.60 \times 10^{-19} \text{ C}} = 2.00$$

Exercise 3.3

3.3 A spherical dust grain of density 2500 kg m^{-3} carries $+8.0 \times 10^{-15} \text{ C}$. A uniform upward field of $1.0 \times 10^5 \text{ N C}^{-1}$ lifts it from a horizontal panel when electrical force exceeds weight; ignore adhesion. Derive and calculate the maximum diameter. Choose which of 30, 40, 50 μm can be lifted. Explain how the normal detachment condition changes when the panel is tilted 30° and the field remains perpendicular to it. [7]

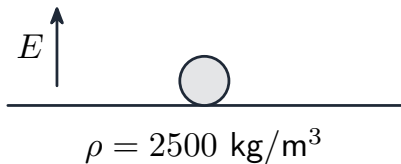
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3.3 Set threshold electrical force equal to weight using sphere volume.

$$qE = \rho \frac{4\pi r^3}{3} g \quad \Rightarrow \quad d_{\text{max}} = 2 \left(\frac{3qE}{4\pi \rho g} \right)^{1/3}$$

Full solution 3.3

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Rearrangement and diameter factor.

$$d_{\max} = 2 \left(\frac{3qE}{4\pi \rho g} \right)^{1/3} = 2 \left(\frac{3 \times 8.0 \times 10^{-15} \text{ C} \times 1.0 \times 10^5 \text{ N C}^{-1}}{4\pi \times 2500 \text{ kg m}^{-3} \times 9.81 \text{ m s}^{-2}} \right)^{1/3} = 3.96 \times 10^{-5} \text{ m}$$

Magnitude $39.6 \text{ } \mu\text{m}$. Only $30 \text{ } \mu\text{m}$ is below threshold; 40 is not justified by rounding the threshold up. On the tilt, normal detachment requires $qE > mg \cos 30^\circ$, while the weight also has a downslope component and adhesion is still excluded.