Past-paper walk-through

Electric fields and field lines ▪ 18.1

eXercise

Questions in this set

- 9702/41 J24 Q5 ▪ 13 marks
- 9702/41 J24 Q5 ▪ 13 marks
- 9702/43 J24 Q5 ▪ 13 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 5

9702/41 J24 ▪ Q5 ▪ 13 marks

(a) Define electric field. **[2]**

(b)(i) On Fig. 5.1, draw four field lines to represent the electric field between the plates. **[2]**

(b)(ii) Determine the strength *E* of the electric field between the plates. **[2]**

(b)(iii) An electron travels at a speed of 2.6×10^{7} m s^{-1} towards the region between the plates, as shown in Fig. 5.1.

On Fig. 5.1, draw the path of the electron as it moves between and beyond the plates. **[2]**

(c)(i) Determine the direction of the uniform magnetic field. **[1]**

(c)(ii) Explain, with reference to the forces exerted by the two fields on the electron, why the path of the electron is undeviated. **[2]**

Question 5

(c)(iii) Determine the flux density B of the uniform magnetic field. Give a unit with your answer. **[2]**

Question 5

Solution 5

(a)

Mark scheme

- force per unit charge
- force on positive charge

Solution 5

(b)(i) Worked steps

Know. Between two parallel charged plates the field is **uniform**, and a field line points the way a **positive** charge would be pushed.

Draw. Four straight lines running from the **positive** plate to the **negative** one, parallel to each other and evenly spaced, each carrying an arrow. Here the upper plate is positive, so every arrow points **downwards**.

Solution 5

Check. Uniform means evenly spaced and parallel: lines that fan out or crowd together would be describing a field that changes from place to place, which is what happens only near the edges. Lines with no arrows score nothing — the direction is half the answer.

Mark scheme

- four straight vertical parallel lines, approximately evenly spaced
- arrows downwards

Solution 5

(b)(ii) Worked steps

Know. For a uniform field between parallel plates, the field strength is the potential difference divided by the separation.

Equation. $E = \dfrac{V}{d}$.

Substitute. $E = \dfrac{430}{0.067}$.

Answer. $E = 6.4 \times 10^3$ N C^{-1} (the same as V m^{-1}).

Solution 5

Check. The separation must be in **metres**. Leaving it in centimetres gives a value a hundred times too small, which is the commonest way to lose both marks here.

Mark scheme

- $E = V/d$
- $E = 430/0.067$
- $= 6.4 \times 10^3$ N C^{-1}

Solution 5

(b)(iii) Worked steps

Draw. Inside the plates the path is a **smooth curve**, and beyond them a **straight line** continuing in the direction the electron was last travelling.

Which way? The field pushes a positive charge downwards, so the force on the **electron** — negative — is **upwards**, towards the positive plate. The curve therefore bends upwards.

Solution 5

Check. This is projectile motion with the electric force in place of gravity: a constant force at right angles to a constant horizontal velocity gives a parabola while the force acts, and a straight line once it stops. Curving beyond the plates is the error to avoid; there is no field out there.

Mark scheme

- smooth curve within plates and straight lines outside plates
- direction of deflection shown as upwards

Solution 5

(c)(i) Worked steps

Know. For the path to stay straight, the magnetic force must exactly oppose the electric force. The electric force on the electron is **upwards**, so the magnetic force must be **downwards**.

Apply the rule. The electron moves to the right, and conventional current is opposite to that, so it points to the left. Using the left hand for the electron's own motion, or the right-hand rule with the conventional current, a downward force requires the field to point **into the page**.

Solution 5

Check. Reversing the field would double the deflection rather than cancel it, so a straight path is only possible one way round.

Mark scheme

- into the page

Solution 5

(c)(ii)

Mark scheme

- forces are in opposite directions
- (undeviated) when (magnitudes of) forces are equal

Solution 5

(c)(iii) Worked steps

Know. Undeviated means the two forces balance: the electric force Eq equals the magnetic force Bqv.

Equation. $Eq = Bqv$, and the charge cancels, leaving $B = \dfrac{E}{v}$.

Substitute. $B = \dfrac{6.4 \times 10^3}{2.6 \times 10^7}$.

Answer. $B = 2.5 \times 10^{-4}$ T — the unit, the tesla, is asked for.

Solution 5

Check. The charge cancelling is the point of the arrangement: **every** electron at this speed passes straight through, whatever its charge would have been. That is why the device is called a velocity selector.

Mark scheme

- $Eq = Bqv$
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Mark scheme

- into the page

Solution 5

(c)(ii)

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