Past-paper walk-through

Force on a moving charge ▪ 20.3

eXercise

Questions in this set

- 9702/43 J25 Q7 ▪ 10 marks
- 9702/42 M25 Q6 ▪ 11 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.

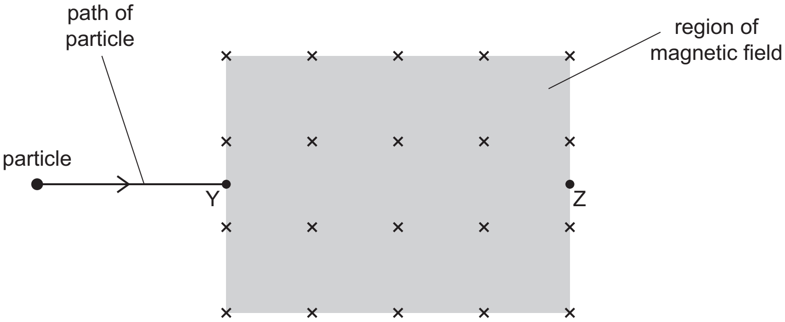
Question 7

9702/43 J25 ▪ Q7 ▪ 10 marks

7 **(a)** Define magnetic flux density.

Question 7

(b) A particle of mass *m* and charge +*Q* moves at speed *v* into a region where there is a uniform magnetic field, as shown in Fig. 7.1.



Question 7

Question 7

Fig. 7.1

The uniform magnetic field is into the page and has flux density B. The particle enters the region of the field at point Y.

(i) State an expression, in terms of some or all of m, Q, B and v, for the magnetic force F that acts on the particle when it is at point Y.

Question 7

(ii) On Fig. 7.1, draw an arrow at point Y to indicate the direction of the force in **(b)(i)**. [1]

(iii) On Fig. 7.1, draw a line to show a possible path for the particle through the region of the magnetic field. [1]

(c) **(i)** Explain how an electric field can be used with the magnetic field to ensure that the particle in **(b)** now passes through point Z.

Question 7

(ii) Derive an expression for v in terms of B and the electric field strength E.

Question 7

[Total: 10]

Solution 7

(a) Worked steps

Magnetic flux density is **defined by the force it exerts**, so the definition has to say force per unit of *what*, and under what condition. Build it from $F = BIL$ rearranged as $B = \dfrac{F}{IL}$ — every term in that fraction becomes a phrase.

Three separate points are credited, and two of them earn the marks:

- force **per unit length** (of the conductor) — the L in the denominator;
- force **per unit current** — the I;
- with the **current perpendicular to the field** — the condition under which $F = BIL$ holds at all.

Solution 7

So: *the force per unit length per unit current on a straight conductor placed at right angles to the field.*

The condition is what makes it a definition rather than a rough description. At any other angle the force is $BIL\sin\theta$, so the quotient $\frac{F}{IL}$ would not give B, and "perpendicular" is the word that fixes it. **Mark scheme**

- ▪
- force per unit length
- ▪
- force per unit current

Solution 7

- ▪
- length / current perpendicular to field
- 1 mark for any two points, 2 marks for all three points.

Solution 7

(b)(i)

Mark scheme

- $F = BQv$

(b)(ii)

Mark scheme

- arrow at Y pointing vertically upwards

Solution 7

(b)(iii)

Mark scheme

- upwards deflection showing circular path

Solution 7

(c)(i)

Mark scheme

- electric field applied vertically downwards (may be shown on a labelled diagram)
- electric force on particle in opposite direction to magnetic force (may be shown on a labelled diagram)
- particle undeflected when magnitudes of electric and magnetic forces are equal

Solution 7

(c)(ii) Worked steps

A charged particle passes through a velocity selector undeflected when the electric and magnetic forces on it are equal and opposite.

- Electric force: $F_E = EQ$
- Magnetic force on a charge moving perpendicular to the field: $F_B = BQv$
- Undeflected means $F_E = F_B$, so $EQ = BQv$.
- The charge Q cancels: $v = \dfrac{E}{B}$

Solution 7

Two things this result tells you, and both are worth writing down. The selected speed does **not** depend on the charge or the mass — every particle at that speed passes, whatever it is made of. And the two forces must be **antiparallel**, not merely equal in size, which is why the field directions in the diagram are arranged the way they are.

Solution 7

Substitute with E in $\mathrm{V\,m^{-1}}$ and B in tesla, and the speed comes out in $\mathrm{m\,s^{-1}}$ with no conversion.

Mark scheme

- EQ = BQv
- v = E / B
- 9702/43
- May/June 2025

Question 6

9702/42 M25 ▪ Q6 ▪ 11 marks

6 An electric field and a magnetic field are used to form a velocity selector. Charged particles, called ions, pass into a region of uniform electric and magnetic fields that is between parallel plates, as shown in Fig. 6.1.

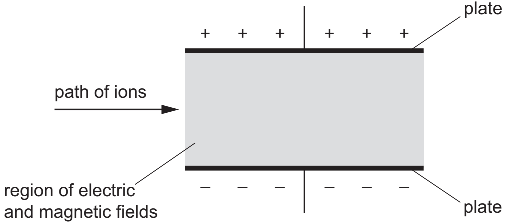


Fig. 6.1

Question 6

(a) The potential difference (p.d.) between the plates of the velocity selector is V. The separation of the plates is d and the magnetic flux density is B.

Show that the speed u of ions that pass undeviated through the velocity selector is given by

$$u = \frac{V}{Bd}.$$

Question 6

[2]

(b) Positive ions with kinetic energy 4.1×10^{-17} J and mass 3.2×10^{-27} kg pass undeviated through the velocity selector when V is equal to 980 V and d is equal to 3.6×10^{-2} m.

Determine B.

Question 6

(c) A proton passes undeviated through the velocity selector.

An alpha particle enters the velocity selector at the same speed as the proton.

State how the expression in **(a)** predicts that the alpha particle also passes undeviated through the velocity selector.

Question 6

(d) By reference to Fig. 6.1 and to the forces acting on a positive ion, determine the direction of the magnetic field. Explain your reasoning.

(e) The positive ions in **(b)** enter the velocity selector with greater kinetic energy.

On Fig. 6.1, sketch the path of these ions. [2]

[Total: 11]

Solution 6

(a) Worked steps

A velocity selector works because the two forces on a moving charge point in opposite directions, and only one of them depends on the speed.

- The **magnetic** force on a charge moving perpendicular to the field is $F_B = Bqu$ — it grows with the speed.
- The **electric** force between the plates is $F_E = qE$, and with a p.d. V across a separation d, $E = \frac{V}{d}$, so $F_E = \frac{qV}{d}$ — it does not depend on the speed at all.

Solution 6

A particle passes straight through only when the two balance:

- $Bqu = \dfrac{qV}{d}$
- The charge q cancels, leaving $u = \dfrac{V}{Bd}$.

Solution 6

Two things worth saying out loud in the answer, because they are what the marks are for: the forces must be **equal and opposite**, and q cancelling is why the selector picks a speed regardless of the charge or the mass of the particle. That is the whole point of the device.

Mark scheme

- FB = FE
- either: Bqu = qE and E = V / d leading to u = V / Bd
- or:
- Bqu = qV / d leading to u = V / Bd
- 9702/42
- February/March 2025

Solution 6

(b) **Worked steps**

Substitute into the expression just derived, with every quantity in SI units.

- $u = \dfrac{V}{Bd}$, so put the p.d. in volts, the flux density in tesla and the plate separation in **metres**.

Solution 6

The separation is the quantity most often left in millimetres; doing so makes the selected speed a thousand times too small. Check the answer against light: a velocity selector for charged particles gives something well below 3×10^8 m s^{-1}, so a result above that means a unit was missed.

Mark scheme

- EK = ½mu2
- u = √[(2 × 4.1 × 10–17) / (3.2 × 10–27)]
- = 1.6 × 105 m s–1
- B = 980 / (3.6 × 10–2 × 1.6 × 105)
- = 0.17 T

Solution 6

(c)

Mark scheme

- expression is independent of mass and charge

Solution 6

(d)

Mark scheme

- either: electric force is downwards so magnetic force is upwards
- or:
- no resultant force so magnetic force is upwards
- (positive ions so) current is from left to right
- from (Fleming's) left-hand rule, magnetic field is into the page

Solution 6

(e)

Mark scheme

- curved path inside plates with consistent direction of curvature and with no discontinuity at entry or in curvature
- direction of deflection is upwards