15.2 Motion in electromagnetic fields (full D.3)

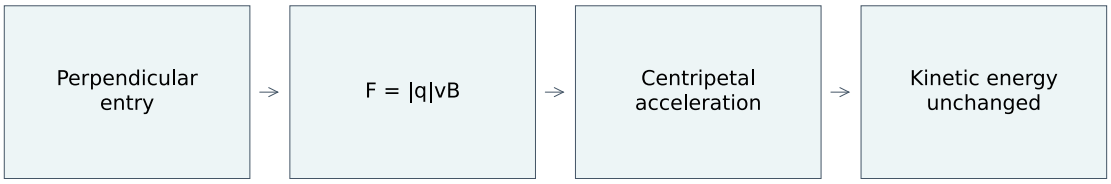
Name: _____ Class: _____ Date: _____ **Total: 23 marks**

KEY WORDS magnetic force • charge-to-mass ratio • velocity selector

Objective

Practise the full guide D.3 toolkit: motion of a charged particle in a uniform electric field (parabolic path), in a uniform magnetic field ($F = qvB\sin\theta$, circular path at constant kinetic energy, $r = mv/qB$ and the charge-to-mass ratio), crossed perpendicular fields as a velocity selector $v = E/B$, the wire force $F = BIL\sin\theta$, and the force per unit length between parallel wires. Original practice; not an official IB paper.

1 Key knowledge and worked examples



■ **The D.3 rule set**

$$F = qvB\sin\theta \qquad r = \frac{mv}{qB} \qquad v = \frac{E}{B} \qquad F = BIL\sin\theta \qquad \frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi r}$$

Electric field: constant force, parabolic path. Magnetic field: force perpendicular to velocity, circular path, speed unchanged. Crossed fields: balance selects one speed.

■ **Worked example: reading a proton's track**

A proton moves at 2.0×10^6 m/s perpendicular to a 0.50 T field. $r = mv/qB = (1.67 \times 10^{-27} \times 2.0 \times 10^6)/(1.6 \times 10^{-19} \times 0.50) = 4.2 \times 10^{-2}$ m, and inverting gives $q/m = v/(rB) = 9.5 \times 10^7$ C/kg. Two habits: check the angle – $\sin\theta$ is 1 only when velocity is perpendicular to the field – and remember the magnetic force never changes a particle's speed, only its direction.

2 Practice

2.1 Explain why a magnetic field cannot change a charged particle's kinetic energy. [2]

2.2 An electron moves at 1.0×10^6 m/s perpendicular to a 0.20 T field. Calculate the radius of its circular path ($m_e = 9.1 \times 10^{-31}$ kg). [3]

2.3 State the condition for a charged particle to pass undeflected through perpendicular electric and magnetic fields. [2]

2.4 Two long parallel wires carry currents in the same direction. State the direction of the force between them. [1]

3 Exam-style questions

3.1 A 0.30 m wire carries 5.0 A at right angles to a 0.20 T field. Calculate the force on it, and state what happens to the force when the wire runs parallel to the field. [3]

3.2 In a velocity selector, $E = 1.5 \times 10^4$ V/m and $B = 0.050$ T. Calculate the speed that passes straight through, and describe the deflection of a faster particle. [4]

3.3 An alpha particle ($q = 3.2 \times 10^{-19}$ C, $m = 6.6 \times 10^{-27}$ kg) moves at 1.0×10^6 m/s perpendicular to a 0.40 T field. Calculate the radius of its path and its charge-to-mass ratio from that radius, and compare the radius with a proton at the same speed in the same field. [5]

3.4 Two long parallel wires 0.050 m apart each carry 10 A. Calculate the force per unit length between them, and state whether it is attraction or repulsion when one current is reversed. [3]