

Exercise walk-through

18.2

Motion in electromagnetic fields (full D.3)

International Baccalaureate · IB Diploma · Physics · HL

Charged Motion · 2.1

Reasoning

The magnetic force magnitude is $F = |q|vB \sin\theta$. It is perpendicular to velocity and magnetic field, with direction determined by charge sign. For perpendicular entry into a uniform field, it can provide the centripetal force for circular motion. magnetic force: Force due to a magnetic field on a moving charge or current; momentum : Mass multiplied by velocity in the classical model.

Charged Motion · 3.1

Reasoning

Equate magnetic force with mv^2/r to obtain $r = mv/(|q|B)$ for perpendicular motion. A stronger field makes a smaller radius at fixed momentum. Parallel entry gives zero magnetic force in this model. Draw velocity, field and force as separate arrows using stated into/out-of-page conventions. Use supplied beam data or a simulation. Do not treat a current-carrying wire direction as identical to electron-motion direction.

Crossed fields select speed

- 1 Set the model** Electric and magnetic forces oppose one another with $E = 1.5 \times 10^4 \text{ V/m}$ and $B = 0.050 \text{ T}$.
- 2 Calculate** For a straight path $|q|E = |q|vB$, so $v = E/B = 3.0 \times 10^5 \text{ m/s}$.

Decision

A magnetic field alone changes velocity direction without doing work. A circular path requires entry perpendicular to the magnetic field.

Exercises 2.1·2.3

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]

Exercises 2.1-2.3

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

2.1 The magnetic force always acts perpendicular to the velocity; a perpendicular force does no work, so the speed and hence kinetic energy stay constant.

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]

2.2 $r = m_e v / qB = (9.1 \times 10^{-31} \times 1.0 \times 10^6) / (1.6 \times 10^{-19} \times 0.20) = 9.1 \times 10^{-25} / 3.2 \times 10^{-20} = 2.8 \times 10^{-5}$ m.

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

2.3 The electric and magnetic forces must balance: $qE = qvB$, so only $v = E/B$ passes undeflected.

Exercises 2.4·3.2

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

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]

Exercises 2.4·3.2

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2.4 Attraction.

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3.1 $F = BIL \sin \theta = 0.20 \times 5.0 \times 0.30 \times 1 = 0.30 \text{ N}$; parallel to the field, $\theta = 0$ so $\sin \theta = 0$ – the force falls to zero.

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

3.2 $v = E/B = 1.5 \times 10^4 / 0.050 = 3.0 \times 10^5 \text{ m/s}$; for a faster particle the magnetic force qvB exceeds the electric force qE , so it deflects along the magnetic-force direction (the same side regardless of sign, since both forces flip with charge).

Exercises 3.3-3.4

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]

Exercises 3.3-3.4

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3.3 $r = mv/qB = (6.6 \times 10^{-27} \times 1.0 \times 10^6)/(3.2 \times 10^{-19} \times 0.40) = 6.6 \times 10^{-21}/1.28 \times 10^{-19} = 5.2 \times 10^{-2}$ m; $q/m = v/(rB) = 1.0 \times 10^6/(5.2 \times 10^{-2} \times 0.40) = 4.8 \times 10^7$ C/kg; a proton's charge-to-mass ratio (9.6×10^7 C/kg) is twice the alpha's, so its radius is half: $r_p \approx 2.6 \times 10^{-2}$ m.

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]

3.4 $F/L = \mu_0 I_1 I_2 / 2\pi r = (4\pi \times 10^{-7} \times 10 \times 10)/(2\pi \times 0.050) = 4.0 \times 10^{-4}$ N/m; same-direction currents attract, so reversing one current turns it into repulsion.