15.1 Magnetic forces: turn velocity without increasing speed

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

KEY WORDS magnetic force • momentum

Objective

Magnetic forces: turn velocity without increasing speed. Original classroom practice for IB SL; not an official IB paper.

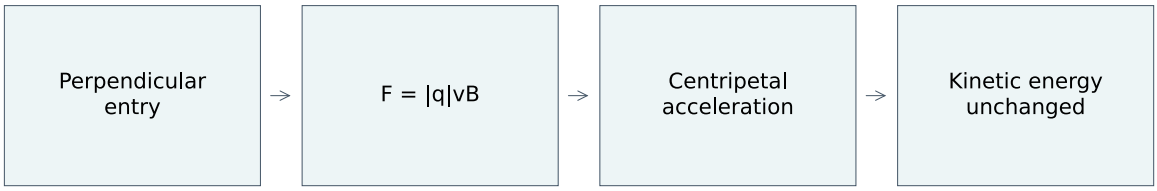
1 Key knowledge and worked examples

What would explain this observation?

- A charged particle curves in a uniform magnetic field. Its direction changes although the **magnetic force** alone does not increase its kinetic energy.

Build the model

- 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.



Choose evidence that can test it

- 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.

In the lab: 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.

Work from known quantities

- Known: a particle has $m = 2.0\times10^{-27}$ kg, $v = 3.0\times10^{6}$ m/s, $|q| = 1.0\times10^{-19}$ C and $B = 0.20$ T. $r = mv/(|q|B) = 0.30$ m.
- The calculation assumes non-relativistic motion and perpendicular entry.

Your turn: Use $r = mv/(|q|B)$. For $m=2\times10^{-27}$ kg, $v=2\times10^{6}$ m/s, $|q|=1\times10^{-19}$ C and $B=0.20$ T, find r.

Check the conclusion and its limits

- A magnetic force can change momentum direction without doing work.
- Adding an electric field can change the energy, so conclusions about a magnetic field alone do not cover every combined-field apparatus.

Not true: A magnetic force alone continuously increases the kinetic energy of a charged particle. A force perpendicular to the velocity does no work (work = force x distance ALONG the force), so a magnetic field alone cannot change a particle's kinetic energy - only its direction. Speeding up needs a field component along the motion, which only an electric field provides.

Key:

- The magnetic force magnitude is $F = |q|vB \sin\theta$.
- Equate magnetic force with mv^2/r to obtain $r = mv/(|q|B)$ for perpendicular motion.
- Watch for: A magnetic force can change momentum direction without doing work.

Write from an orbital radius of 0.50 m

- Use r = mv divided by the product of charge magnitude and magnetic field.
- Take m = 2 times 10 to the minus 27 kg, v = 2 times 10 to the 6 metres per second, charge magnitude 1 times 10 to the minus 19 coulomb and B = 0.08 T. A magnetic force perpendicular to the velocity does no work.

2 Practice

2.1 What changes under a magnetic force alone in perpendicular circular motion? Choose one answer.

- **A** Kinetic energy continuously increases
- **B** Velocity direction
- **C** Charge magnitude [1]

2.2 Use r = mv/(|q|B). For m=2×10^{-27} kg, v=2×10^{6} m/s, |q|=1×10^{-19} C and B=0.20 T, find r. Show the relation, substitution and units. [2]

2.3 Decide whether this claim is true and justify: A force perpendicular to the velocity does no work (work = force x distance ALONG the force), so a magnetic field alone cannot change a particle's kinetic energy - only its direction. [2]

2.4 Force due to a magnetic field on a moving charge or current: write the technical term. [1]

3 Exam-style questions

3.1 At fixed perpendicular speed and field, reverse charge sign with mass and charge magnitude fixed. Compare radius, curvature direction and magnetic work. [4]

Solutions

2.1 B A magnetic force acts perpendicular to the velocity, so it changes the velocity's DIRECTION only, producing circular motion. A perpendicular force does no work, so kinetic energy cannot increase, and the charge magnitude is intrinsic.

2.2 r=mv/(|q|B)=$(2\times10^{-27}\times2\times10^{6})/(1\times10^{-19}\times0.20)$=0.20 m.

2.3 True. True. A force perpendicular to the velocity does no work (work = force x distance ALONG the force), so a magnetic field alone cannot change a particle's kinetic energy - only its direction. Speeding up needs a field component along the motion, which only an electric field provides.

2.4 magnetic force. magnetic force means Force due to a magnetic field on a moving charge or current.

3.1 Radius is unchanged; curvature reverses because q changes sign. Magnetic force is perpendicular to velocity and does no work. Oblique entry requires the perpendicular velocity component.