

18.1 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. Supported HL concept preparation; original classroom practice, not an official IB paper or assessed learner work.

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.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ 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.
- 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**

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: a particle has $m = 2.0 \times 10^{-27}$ kg, $v = 3.0 \times 10^6$ m/s, $|q| = 1.0 \times 10^{-19}$ C and $B = 0.20$ T. $r = mv/(|q|B) = 0.30$ m. The calculation assumes non-relativistic motion and perpendicular entry.

Example:

Use $r = mv/(|q|B)$. For $m = 2 \times 10^{-27}$ kg, $v = 2 \times 10^6$ m/s, $|q| = 1 \times 10^{-19}$ C and $B = 0.20$ T, find r . Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ **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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

A magnetic force alone continuously increases the kinetic energy of a charged particle. This claim is false: 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.

Key:

Magnetic forces: turn velocity without increasing speed: 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.

2 Practice

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

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

[1]

2.2 Use $r = mv/(|q|B)$. For $m=2\times 10^{-27}$ kg, $v=2\times 10^6$ m/s, $|q|=1\times 10^{-19}$ 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 magnetic force alone continuously increases the kinetic energy of a charged particle.

[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 A 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.

2.2 $r = mv/(|q|B) = (2 \times 10^{-27} \times 2 \times 10^6) / (1 \times 10^{-19} \times 0.20) = 0.20 \text{ m}$.

2.3 False. 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.

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.