

## 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. Supported SL 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 → model → relation → substitution → 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

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**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

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**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

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**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.