

Exercise walk-through

18.1

Magnetic forces: turn velocity without increasing speed

International Baccalaureate · IB Diploma · Physics · HL

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. Original classroom practice for IB HL; not an official IB paper.

1 Key knowledge and worked examples

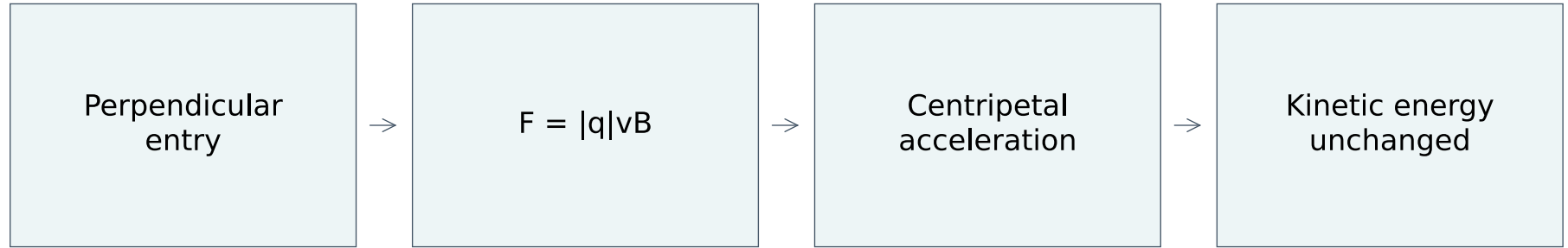
■ What would explain this observation?

- 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 $m = 2.0 \times 10^{-27}$ 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.

Your turn: 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 .

■ 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 0.40 m

- Use $r = mv$ divided by the product of charge magnitude and magnetic field.
- Take $m = 2 \text{ times } 10 \text{ to the minus } 27 \text{ kg}$, $v = 2 \text{ times } 10 \text{ to the } 6 \text{ metres per second}$,

charge magnitude 1 times 10 to the minus 19 coulomb and $B = 0.10$ T. A magnetic force perpendicular to the velocity does no work.

Exercises 2.1·2.2

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 $m=2\times 10^{-27}$ 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]

Exercises 2.1·2.2

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]

2.1 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 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]

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

Exercises 2.3-3.1

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]

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

Exercises 2.3-3.1

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]

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

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

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]

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.