

20.3 Force on a moving charge

Name: _____ Class: _____ Date: _____

Total: 26 marks

KEY WORDS velocity 速度 • velocity selector 速度选择器 • uniform field 匀强场
• hall voltage 霍尔电压 • magnetic field 磁场

Objective

Build the skills to answer exam questions on the **force on a moving charge** in a magnetic field.

You must be able to:

- use $F = BQv \sin \theta$ and find the force direction
- describe the **circular motion** of a charge in a uniform field
- explain the **Hall voltage** and **velocity selection**

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

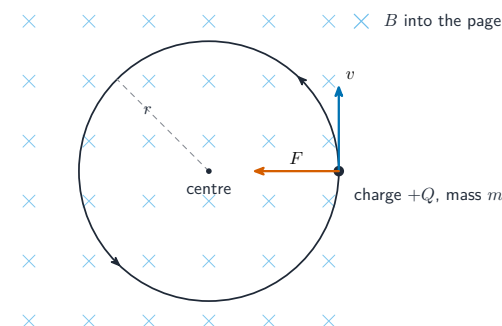
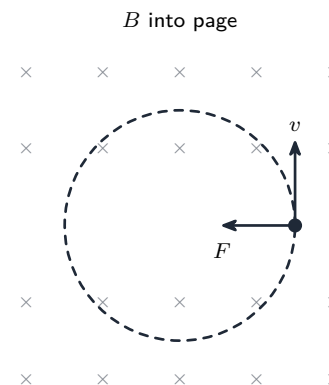
■ Force on a moving charge

$$F = BQv \sin \theta.$$

Maximum when v is at right angles to B ; zero when v is along B .

■ Circular motion

A charge moving **perpendicular** to a uniform field feels a force at right angles to v — so it moves in a **circle** at constant speed (the force does **no work**):



$$BQv = \frac{mv^2}{r} \Rightarrow r = \frac{mv}{BQ}$$

A moving charge curves in a magnetic field

Set magnetic force = centripetal force: $BQv = \frac{mv^2}{r}$, so $r = \frac{mv}{BQ}$.

A **velocity selector** uses crossed electric and magnetic fields: only charges with $v = E/B$ (where the forces balance) pass straight through.

2 Practice

Now apply the methods above.

2.1 Write the equation for the force on a moving charge. [1]

2.2 A charge of 1.6×10^{-19} C moves at 2.0×10^6 m s⁻¹ at right angles to a 0.50 T field. Find the force. [2]

2.3 State the **path** of a charge moving perpendicular to a uniform magnetic field. [1]

2.4 State **why** the magnetic force does **no work** on the moving charge. [1]

3 Exam-style questions

3.1 A charged particle moving **perpendicular** to a uniform field follows: [1]

- | | |
|---|---|
| A | B |
| C | D |
- A a straight line
B a parabola
C a circle
D a spreading spiral

3.2 An electron ($m = 9.1 \times 10^{-31}$ kg, $q = 1.6 \times 10^{-19}$ C) moves at 3.0×10^6 m s⁻¹ at right angles to a 0.020 T field. Calculate the **radius** of its circular path. [3]

3.3 Explain why the **speed** of the particle stays constant. [2]

3.4 Describe how a **velocity selector** selects charges of one particular speed. [2]

3.5 A narrow beam of electrons, each of charge -1.60×10^{-19} C and mass 9.11×10^{-31} kg, enters a region of uniform magnetic field of flux density 3.5 mT. The electrons travel at 2.4×10^7 m s⁻¹ **perpendicular** to the field, and follow a circular path.

(a) **Explain** why the magnetic force makes the electrons move in a **circle** rather than speeding them up. [2]

(b) **Determine** the magnitude of the force on one electron. [2]

(c) **Determine** the radius of the circular path. [3]

(d) **Determine** the time for one complete circle, and **state** what happens to that time if the electrons are made to enter at twice the speed. [3]

(e) An electric field is now applied in the same region so that the electrons pass through **undeflected**. **Determine** the magnitude of the electric field strength required, and **state** its direction relative to the magnetic force. [3]