

Magnetic Fields & Electromagnetism

AP Physics C: E&M • Unit 12

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Magnetic Fields & Electromagnetism

What we will cover

- 1 Magnetic fields
- 2 Force on a moving charge
- 3 Fields of current-carrying wires
- 4 Ampère's law



1 Magnetic fields

Magnetic Fields & Electromagnetism

↳ Magnetic fields

Magnetic fields

A **magnetic field** 磁场 $\vec{B}$ has field lines in **closed loops** – there are **no monopoles** 磁单极子. Materials differ by how their **atomic dipoles** 原子磁偶极子 align:

- **ferromagnetic** 铁磁性 – align strongly, stay (iron)
- **paramagnetic** 顺磁性 – align weakly
- **diamagnetic** 抗磁性 – weakly oppose



Aurora magnetism

2 Moving charges

Magnetic Fields & Electromagnetism

↳ Moving charges

Force on a moving charge

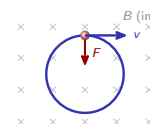
A cross product

$$\vec{F} = q \vec{v} \times \vec{B}$$

Size $qvB \sin \theta$; $\perp$ to $\vec{v}$, so it does **no work**. A wire feels $\vec{F} = I \vec{L} \times \vec{B}$.

Perpendicular entry $\Rightarrow$ a circle:

$$qvB = \frac{mv^2}{r}, \text{ so } r = \frac{mv}{qB}$$



3 Wire fields

Fields of current-carrying wires

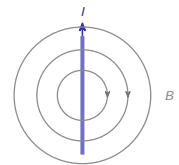
Moving charge **makes** magnetic field:

Biot-Savart law

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I d\vec{l} \times \hat{r}}{r^2}$$

Integrate for standard results:

- long straight wire: $B = \frac{\mu_0 I}{2\pi r}$
- loop centre: $B = \frac{\mu_0 I}{2R}$



4 Ampere

Ampère's law

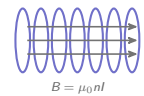
For enough symmetry, Ampère's law beats integrating Biot-Savart:

The loop integral

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enc}$$

Choose an **Amperian loop** 安培环路 where B is constant and parallel, so the integral becomes $B \times \text{length}$.

Inside a **solenoid** 螺线管: $B = \mu_0 nI$, uniform.



5 Recap

Unit 12 – key takeaways

1 Fields

lines in closed loops; no magnetic monopoles

2 Force

$\vec{F} = q\vec{v} \times \vec{B}$, does no work; circle
 $r = mv/qB$

3 Wire fields

Biot-Savart; long wire $\mu_0 I/2\pi r$

4 Ampère

$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enc}$; solenoid $\mu_0 nI$

Check yourself

- 1 Why does the magnetic force on a moving charge do no work?
- 2 Which law gives the field of a symmetric current quickly?
- 3 Double the distance from a straight wire – what happens to B ?
- 4 Is the field inside an ideal solenoid uniform?



Answers 1. it is perpendicular to $\vec{v}$ 2. Ampère's law 3. it halves 4. yes