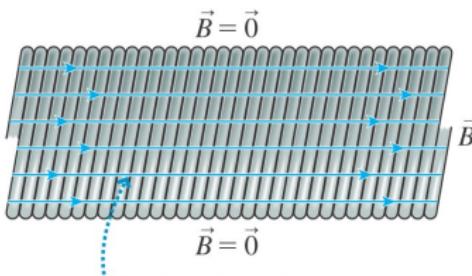


Ampere's Law and a Solenoid

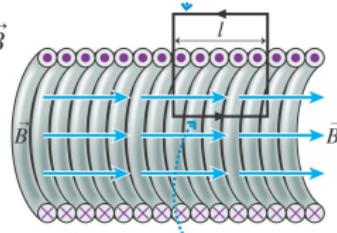
(b)



The magnetic field is uniform inside this section of an ideal, infinitely long solenoid. The magnetic field outside the solenoid is zero.

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This is the integration path for Ampère's law. There are N turns inside.



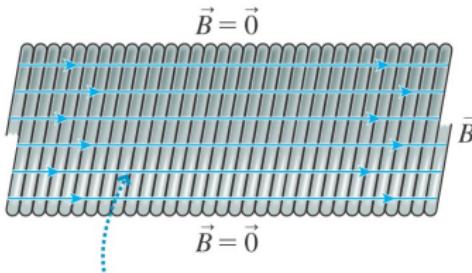
\vec{B} is tangent to the integration path along the bottom edge.

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- We can use Ampere's Law to calculate the magnetic field inside a solenoid.

Ampere's Law and a Solenoid

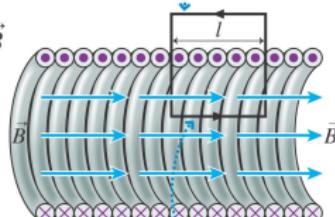
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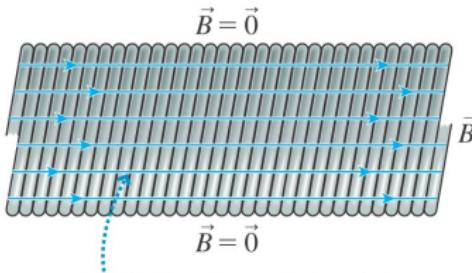


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- We can use Ampere's Law to calculate the magnetic field inside a solenoid.
- Draw a rectangular loop through which some (N) of the current-carrying coils pass.

Ampere's Law and a Solenoid

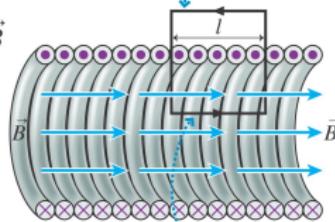
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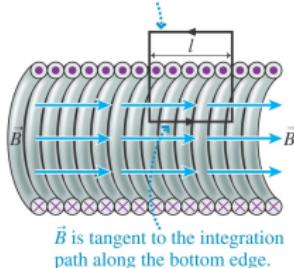
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- We can use Ampere's Law to calculate the magnetic field inside a solenoid.
- Draw a rectangular loop through which some (N) of the current-carrying coils pass.
- Each of the wires carries the same current I , so the total current through the loop is NI and:

$$\oint \vec{B} \cdot d\vec{s} = \mu I_{\text{through}} = \mu_0 NI$$

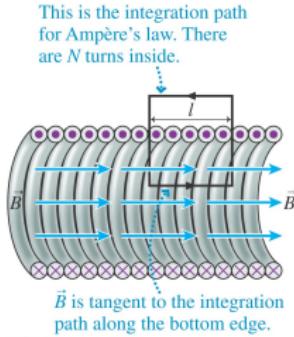
Ampère's Law and a Solenoid

This is the integration path for Ampère's law. There are N turns inside.



- The line integral is the sum of integrals around 4 sides of the rectangle. The top is outside, so the integral is zero, the sides are perpendicular to the field so the integrals are zero.

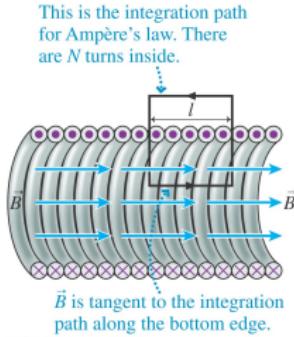
Ampere's Law and a Solenoid



- The line integral is the sum of integrals around 4 sides of the rectangle. The top is outside, so the integral is zero, the sides are perpendicular to the field so the integrals are zero.
- Only the bottom matters...and that is parallel to the field so

$$\oint \vec{B} \cdot d\vec{s} = BL = \mu_0 NI$$

Ampere's Law and a Solenoid

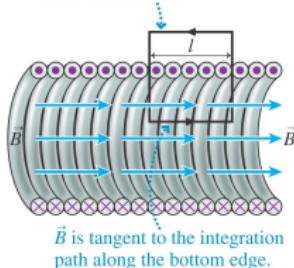


- The line integral is the sum of integrals around 4 sides of the rectangle. The top is outside, so the integral is zero, the sides are perpendicular to the field so the integrals are zero.
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Ampere's Law and a Solenoid

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- Only the bottom matters...and that is parallel to the field so

$$\oint \vec{B} \cdot d\vec{s} = BL = \mu_0 NI$$

$$B_{\text{solenoid}} = \frac{\mu_0 NI}{L} = \mu_0 nI$$

(where n is turns per unit length)

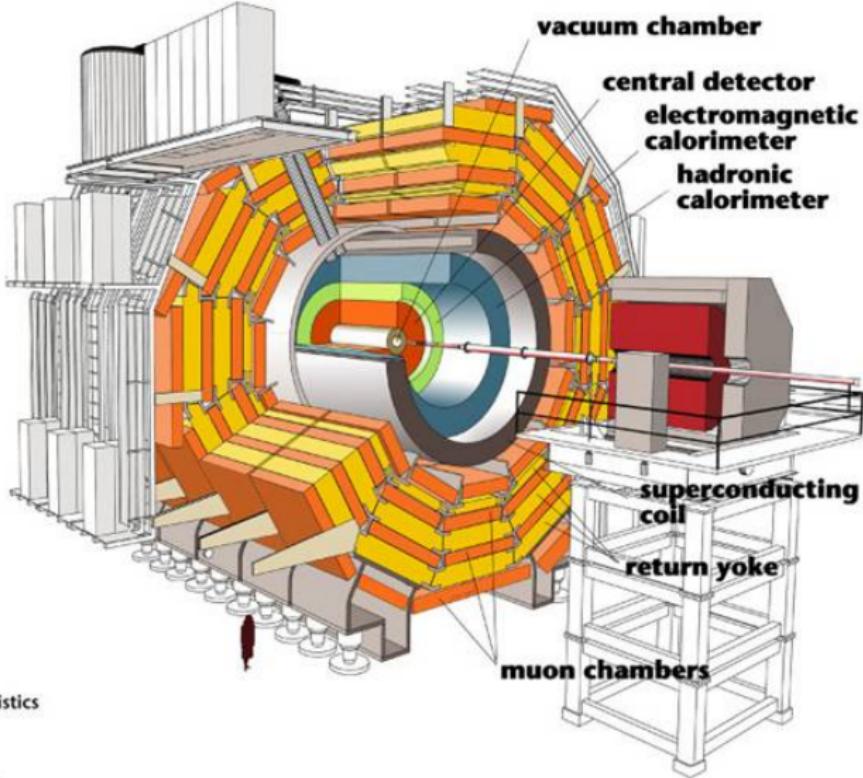
Large Solenoids



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0.5-3T magnet with a bore big enough for a human

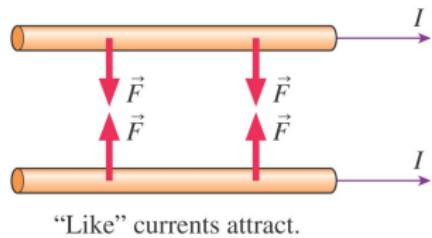
Large Solenoids



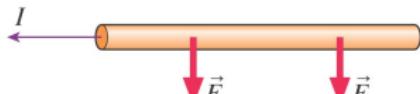
Detector characteristics

Width: 22m
Diameter: 15m
Weight: 14'500t

The Magnetic Force on a Moving Charge (33.7)

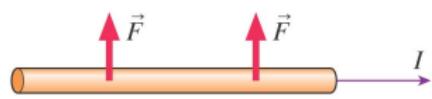
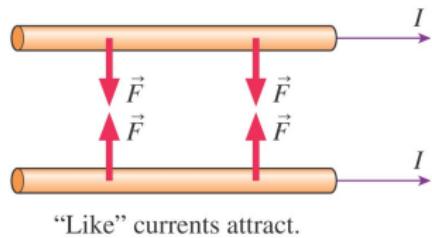


- Since we know that current in a wire causes a magnetic field, two wires should act like two magnets...they should attract or repel.

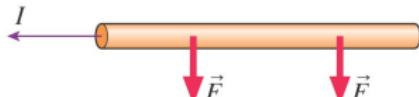


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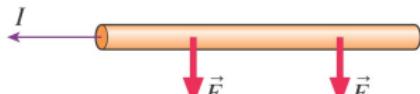
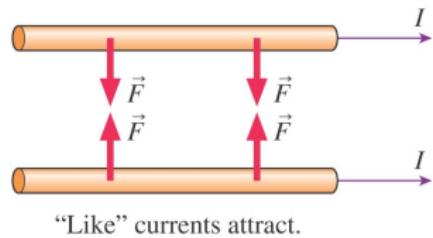
- Since we know that current in a wire causes a magnetic field, two wires should act like two magnets...they should attract or repel.
- Ampere did the experiment and voila!



"Opposite" currents repel.

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The Magnetic Force on a Moving Charge (33.7)

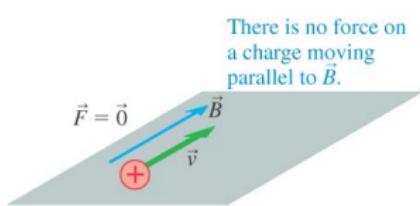


"Opposite" currents repel.

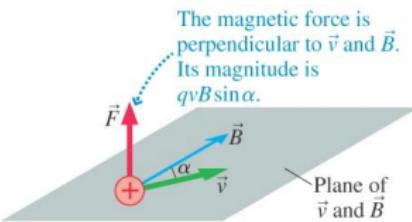
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- Since we know that current in a wire causes a magnetic field, two wires should act like two magnets...they should attract or repel.
- Ampere did the experiment and voila!
- Current flowing in the same direction will attract, opposite directions will repel.

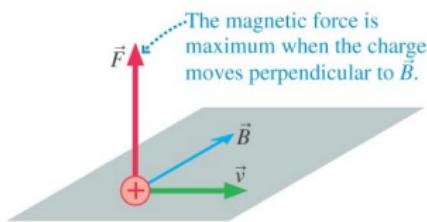
The Relationship between \vec{v} , \vec{B} and \vec{F}



There is no force on a charge moving parallel to \vec{B} .



The magnetic force is perpendicular to \vec{v} and \vec{B} . Its magnitude is $qvB \sin \alpha$.



The magnetic force is maximum when the charge moves perpendicular to \vec{B} .

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$$\vec{F}_{\text{on } q} = q\vec{v} \times \vec{B}$$

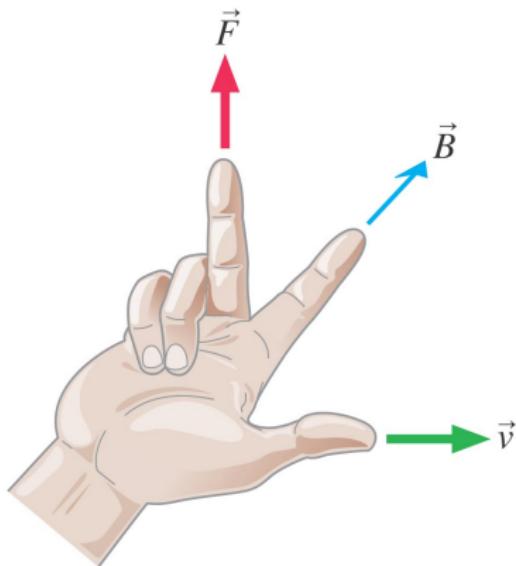
Magnitude:

$$F_{\text{on } q} = qvB \sin \alpha$$

The Relationship between \vec{v} , \vec{B} and \vec{F}

Properties of the magnetic force:

- 1 Only a moving charge feels a magnetic force



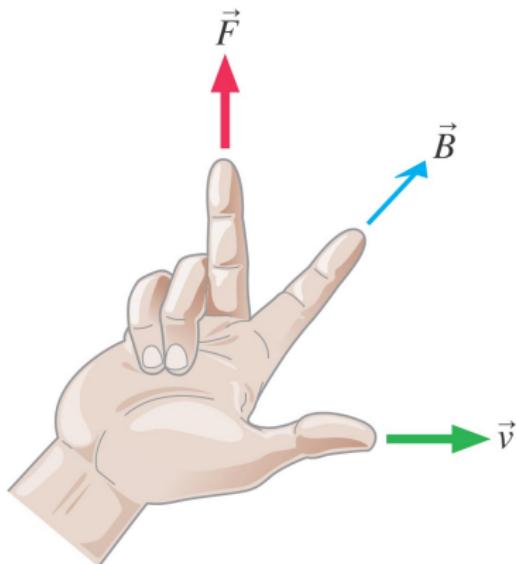
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Magnetism is some sort of interaction between moving charges.

The Relationship between \vec{v} , \vec{B} and \vec{F}

Properties of the magnetic force:

- ① Only a moving charge feels a magnetic force
- ② There is no force on a charge moving parallel (or anti-parallel) to a magnetic field.

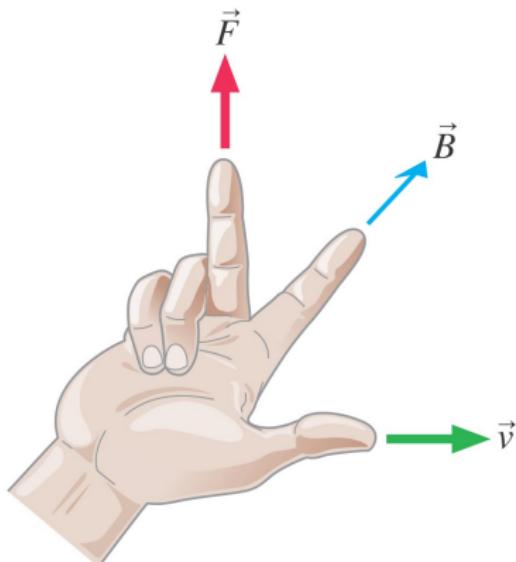


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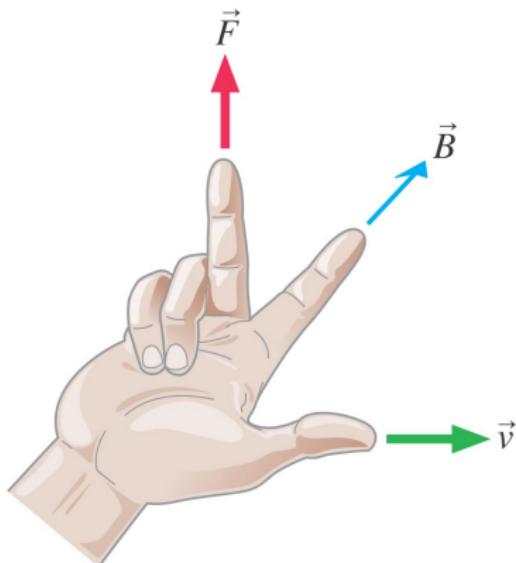
- 1 Only a moving charge feels a magnetic force
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- 3 When there is a force, it is perpendicular to both \vec{v} and \vec{B}

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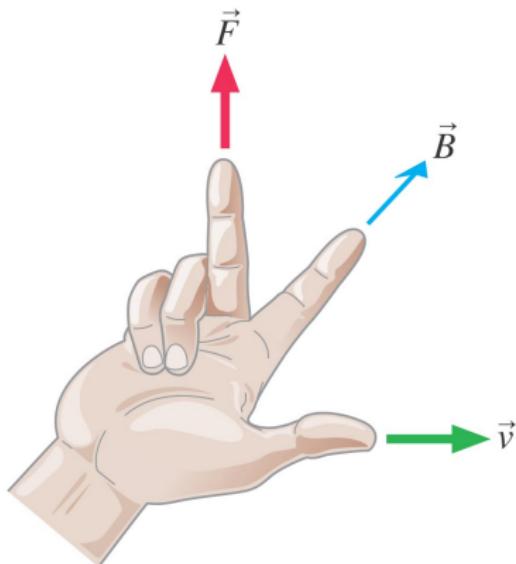
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- 4 The force on a negative charge is opposite to $\vec{v} \times \vec{B}$

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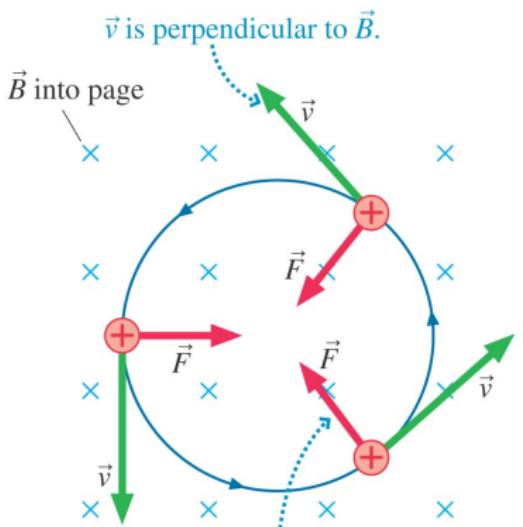


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- ④ The force on a negative charge is opposite to $\vec{v} \times \vec{B}$
- ⑤ For a charge moving perpendicular to \vec{B} , the magnitude of the force is $F = |q|vB$.

Magnetism is some sort of interaction between moving charges.

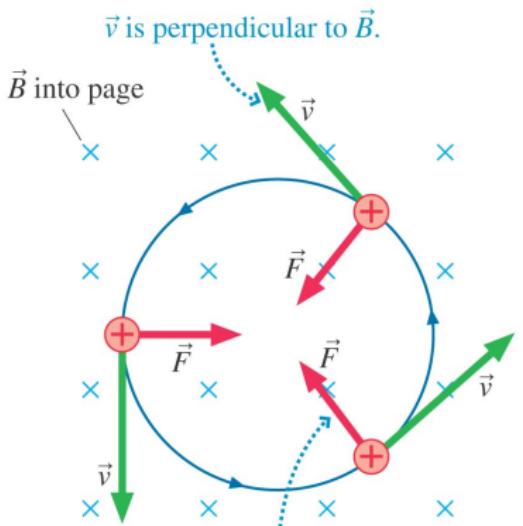
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Cyclotron Motion



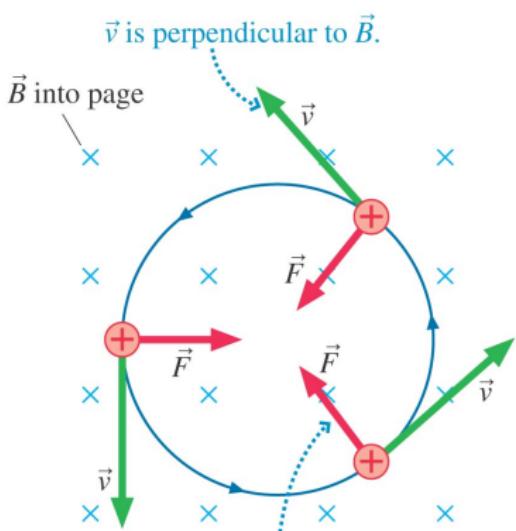
- If you put a moving charged particle in a uniform magnetic field you get the picture at the left.

Cyclotron Motion



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- **cyclotron motion** should remind you a lot of planetary motion...or a ball on a string...

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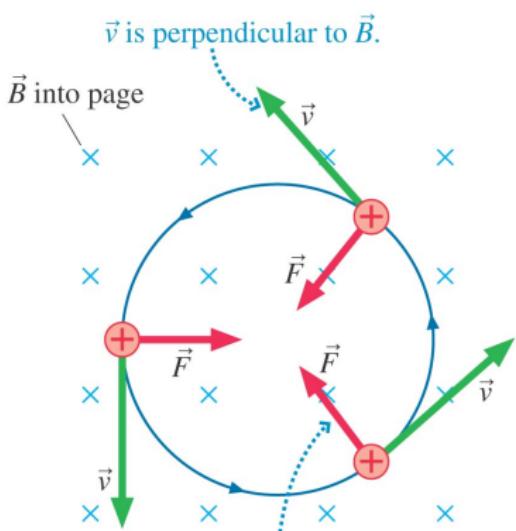


The magnetic force is always perpendicular to \vec{v} , causing the particle to move in a circle.

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- Using Newton's Law we get

$$F = qvB = ma_r = \frac{mv^2}{r}$$

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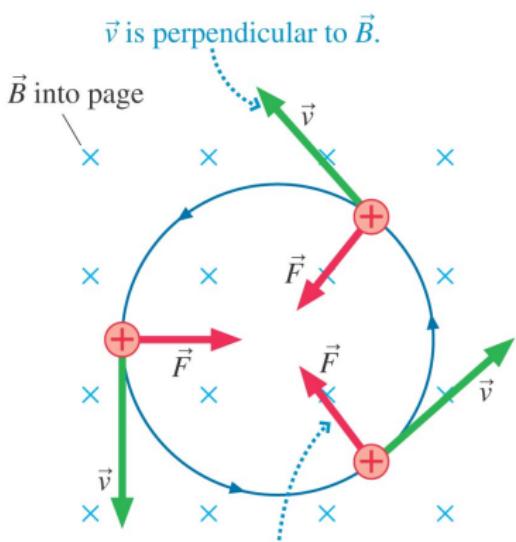


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$$F = qvB = ma_r = \frac{mv^2}{r}$$
$$r_{cyc} = \frac{mv}{qB}$$

Notice that the size of the orbit can shrink if you increase the magnetic field.