A stone attracts small iron nails;
what force does the stone exert on the nails?

1. None of the force below
2. Force of gravity
3. Elastic force
4. Frictional force
5. Normal force
6. Electric force

Magnetic field

A stone attracts small iron nails;
what force does the stone exert on the nails?

It is NOT force:

of Gravity (wrong direction);

Elastic (no strings or springs attached);

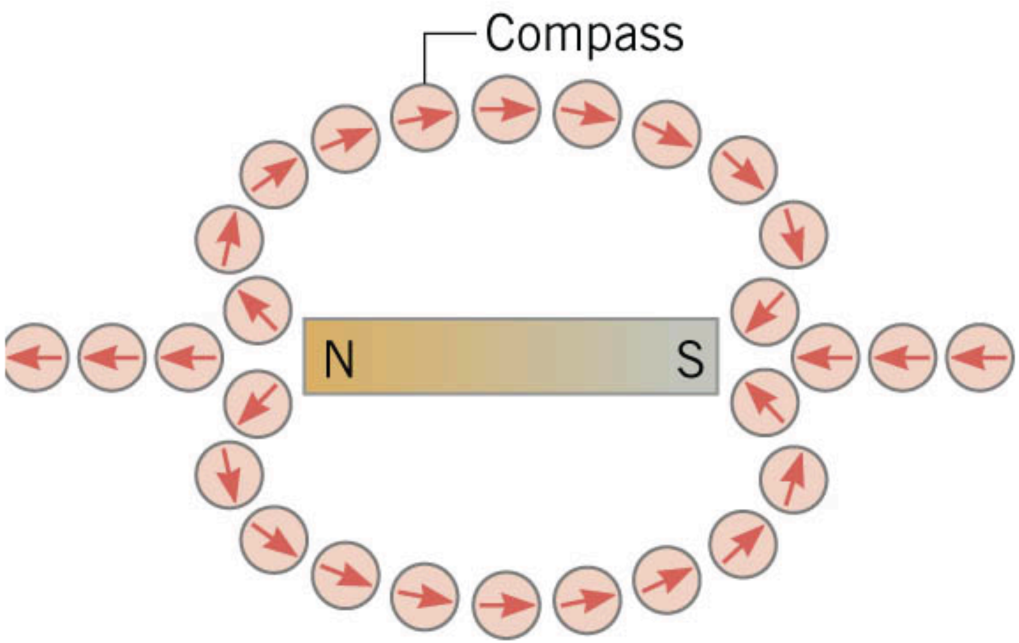
Frictional (not moving along a surface);

Normal (no support from any object);

Electric (no source of electric field; no charges around).

It is a new - MAGNETIC - force!

Surrounding a magnet there is a ***magnetic field***. The direction of the magnetic field at any point in space is the direction indicated by the north pole of a small compass needle placed at that point.



Basic Properties of Magnetic field

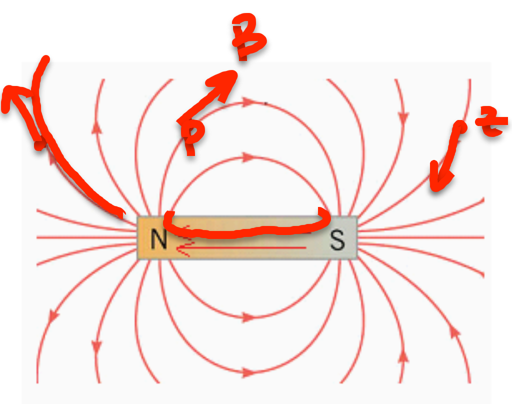
The usual notation is $\vec{B}$

It is a vector (an arrow; has a magnitude and a direction)  $\vec{B}$

The SI unit is tesla (T) (The Earth's magnetic field is about 5×10^{-5} T)

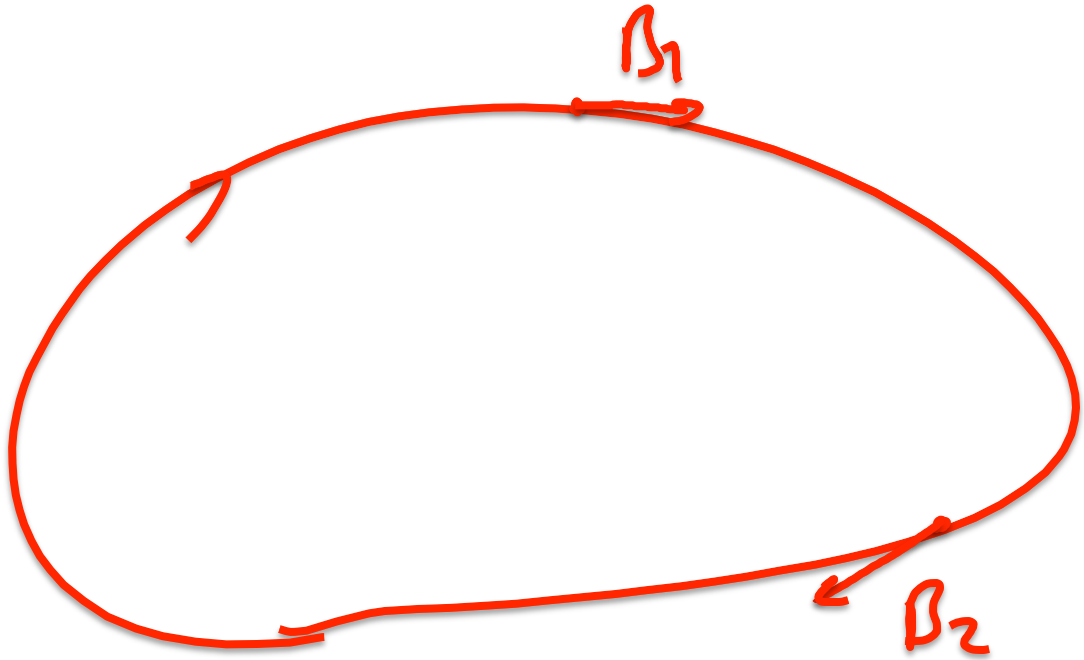
The usual source is a magnet (but there are others).

Every (EVERY!) magnet has TWO magnetic poles: north and south.

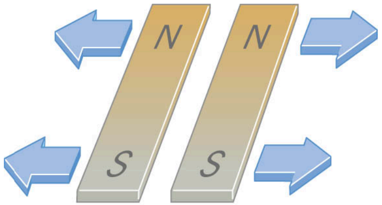


Outside a magnet the field is directed from the north pole to the south pole.

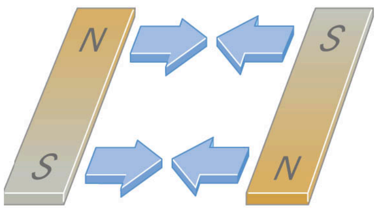
Inside a magnet the field runs from south to north.


β1
β2

Basic Properties of Magnetic field



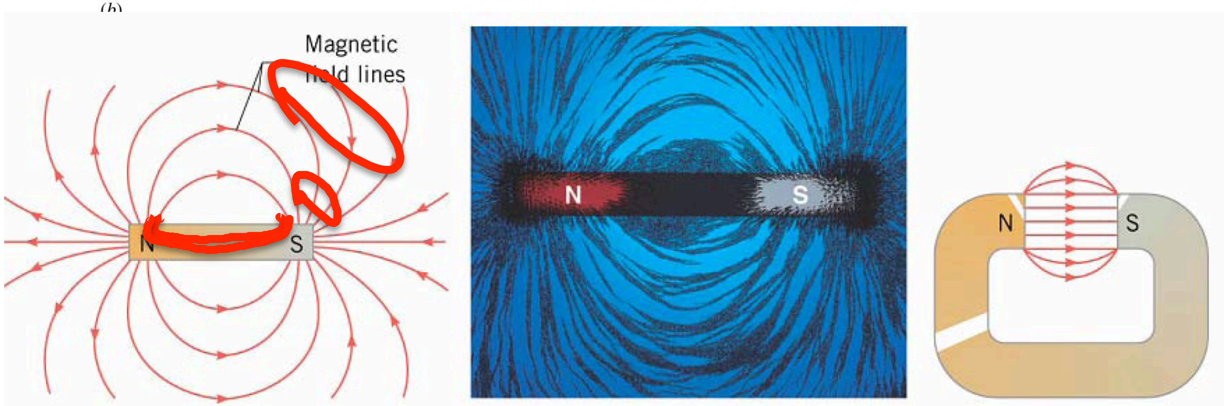
Like poles repel
(a)



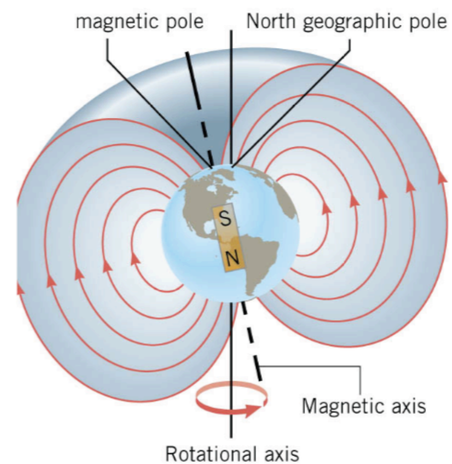
Unlike poles attract
(b)

Like poles repel; unlike poles attract.

Magnetic field can be visualized with the use of magnetic field lines.

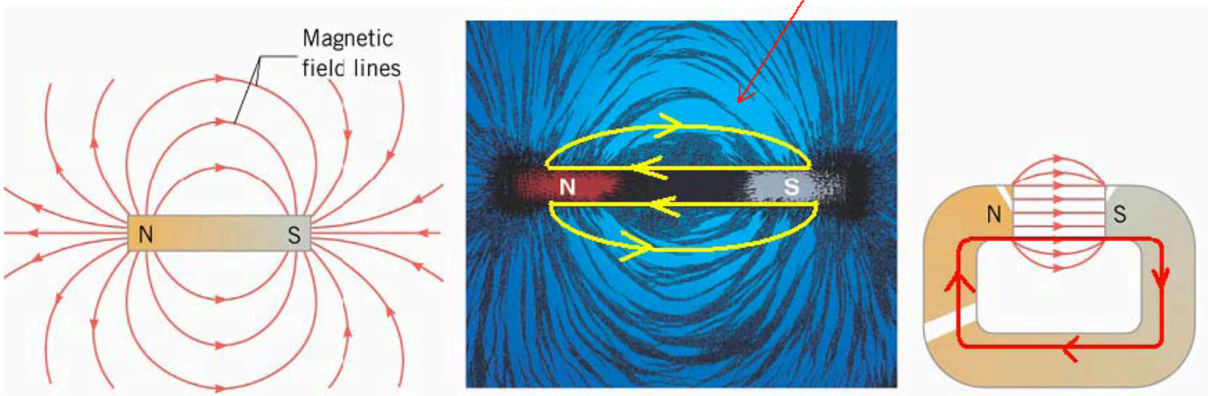


(a) (b) (c)

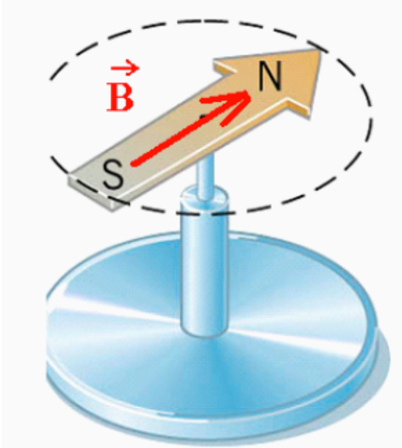


Magnetic field lines are continuous loops.

Magnetic field line NEVER can go away to infinity,
they can only make loops!



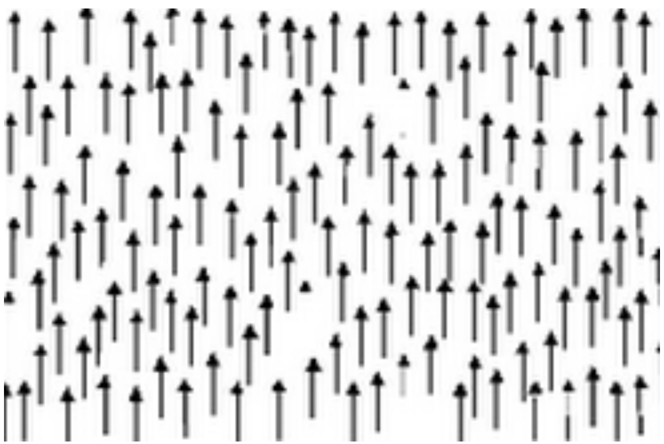
(b) (c)



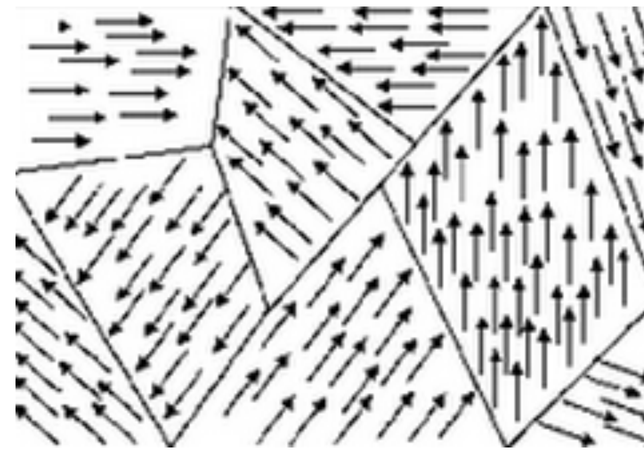
The direction of the magnetic field can be measured (found) by the compass a (small magnetic needle on a pivot).

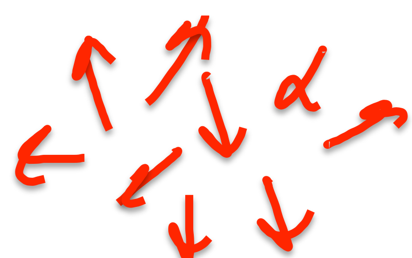
Magnetic field points in the direction of the force experienced by a north pole (it points from S to N *inside* the magnet!).

An (ideal) magnet



A ferromagnetic





When a magnet is getting closer to an electron beam, the beam is getting deflected because of the force acting from a magnet on moving electrons.

That force is ...

1. **None of the force below**

2. **Force of gravity**

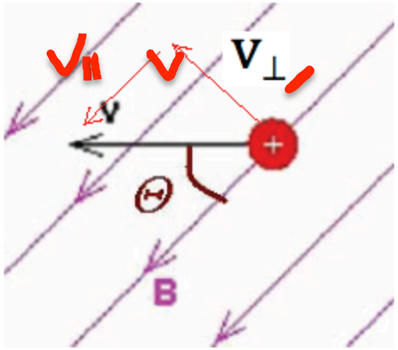
3. **Elastic force**

4. **Frictional force**

5. **Normal force**

6. **Electric force**

A moving charge in a uniform magnetic field



A charge q is moving at the velocity **v** in the magnetic field **B**

⇩

The charge experiences a force **F** acting on it.

The force has its magnitude and direction, which have to be found *independently* from each other!

The magnitude of the force:

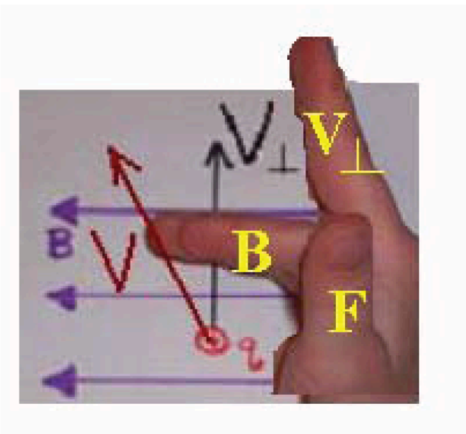
$$F = |\vec{F}| = |q \cdot v \cdot B \cdot \sin(\theta)| = |q| \cdot |v| \cdot |B| \cdot |\sin(\theta)|$$

The magnitude of the force is *the same* for positive and negative charges!

$$|F| = |q| B v_{\perp}$$

Our RHR

Make three of your fingers of your right hand being *perpendicular* to each other.



Make the oriented in a such a manner that:

A) the index (point) finger is parallel to the $V_\perp$;

B) the middle finger (or/and the ring finger and the little finger) is parallel to the magnetic field.

C) The thumb (stick it out, make it perpendicular to the index and the middle fingers) shows the direction of the force acting on a *positive* charge!

The magnetic force always remains perpendicular to the velocity and is directed toward the center of the circular path.

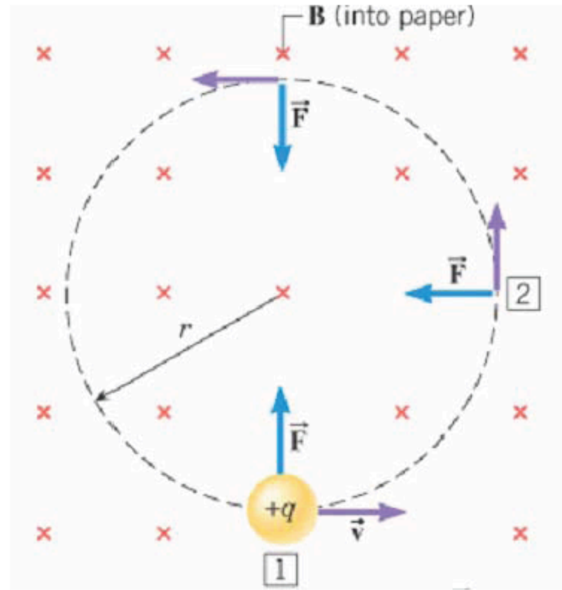
$$F = ma \qquad a = a_c = \frac{v^2}{r}$$

$$F = m\frac{v^2}{r}$$

$$F = |qvB\sin(90^0)| = |q|vB$$

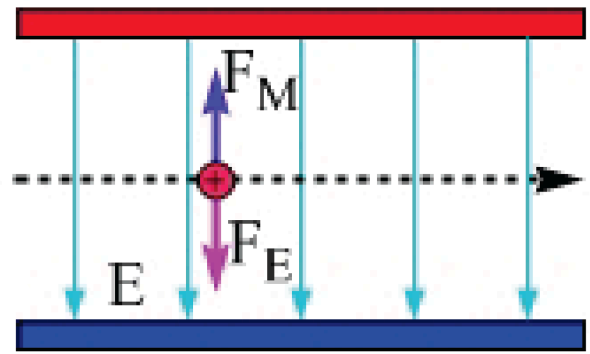
$$|q|vB = m\frac{v^2}{r}$$

$$r = \frac{mv}{|q|B}$$

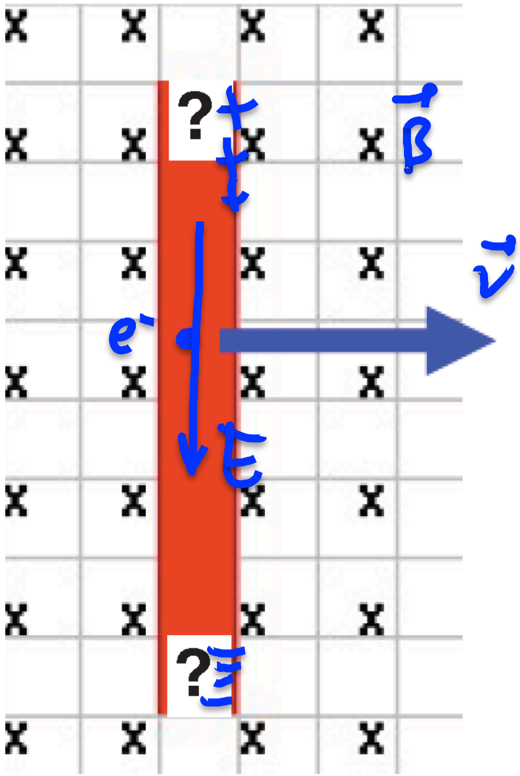


Magnetic field in the velocity selector

The right-hand rule tells us that the magnetic field is directed into the screen



There is a uniform magnetic field, directed perpendicular to the page, between the plates.



An aluminum rod is moving through a magnetic field as shown.

Which end is positively charged?

1. top

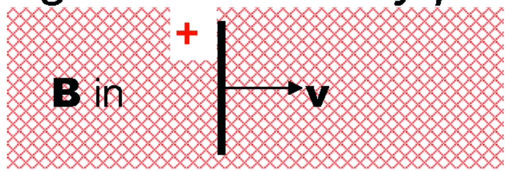
2. bottom

3. both

4. neither

"Motional emf"

Motional emf is the voltage induced across a conductor moving "across" a magnetic field. "across" means that *the velocity, field, and length are mutually perpendicular.*



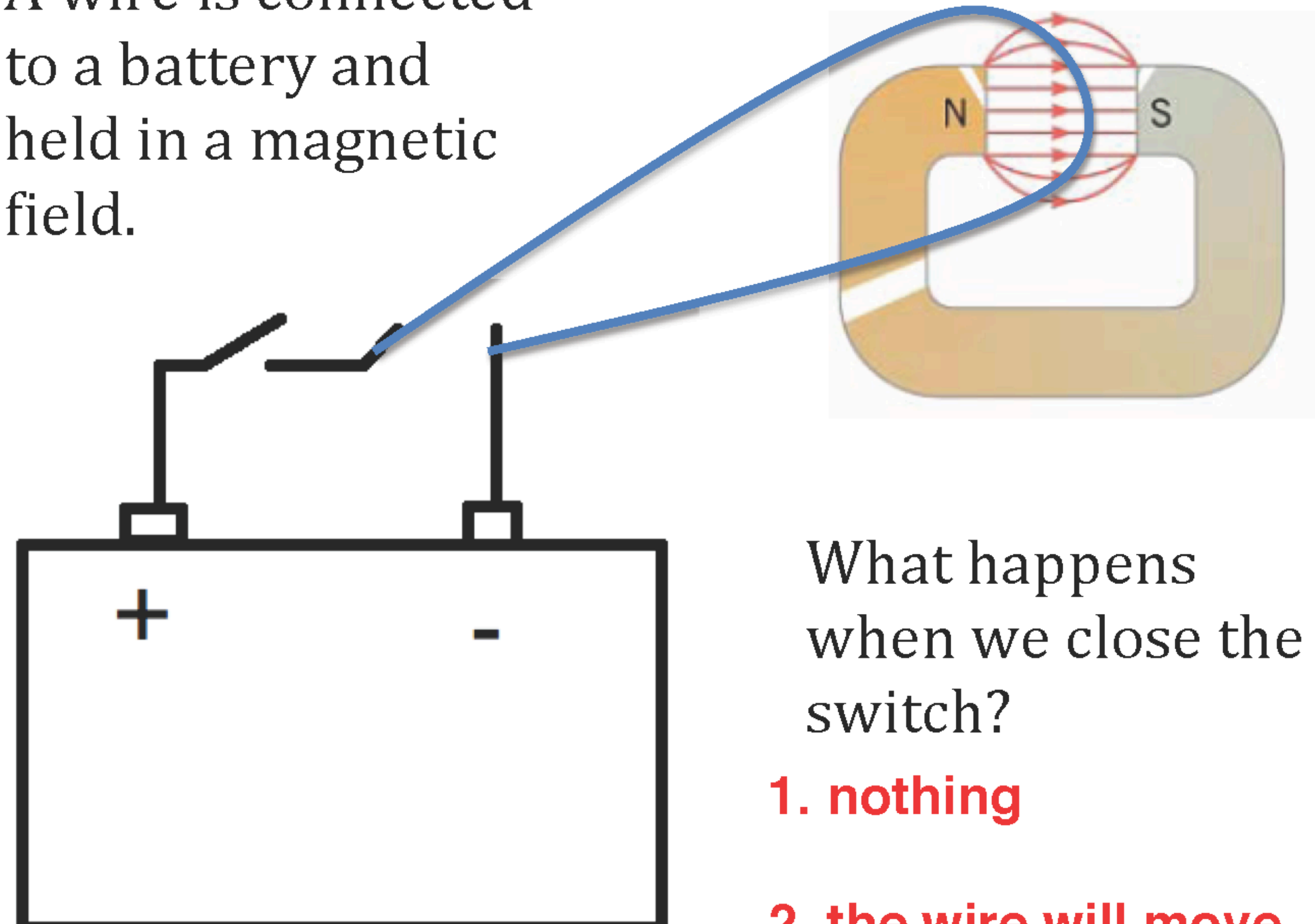
If a metal rod of length *L* moves at velocity ***v*** through a magnetic field ***B***, the motional emf is:

$$|\varepsilon| = |vLB|$$

In which direction do the protons in the rod move?

1. up **2. down** **3. I have a differentanswer**

A wire is connected to a battery and held in a magnetic field.

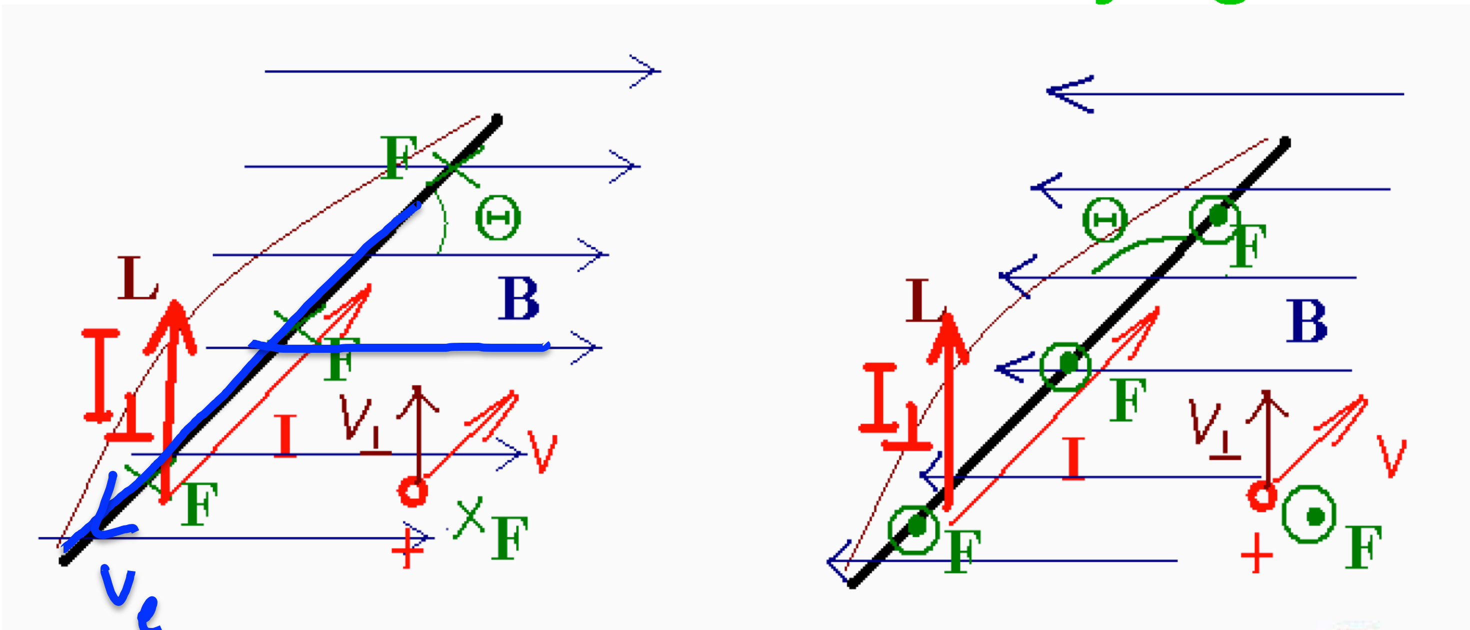


What happens when we close the switch?

1. nothing

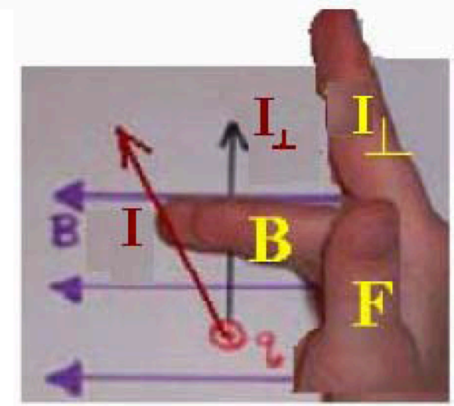
2. the wire will move

The force on a current-carrying wire

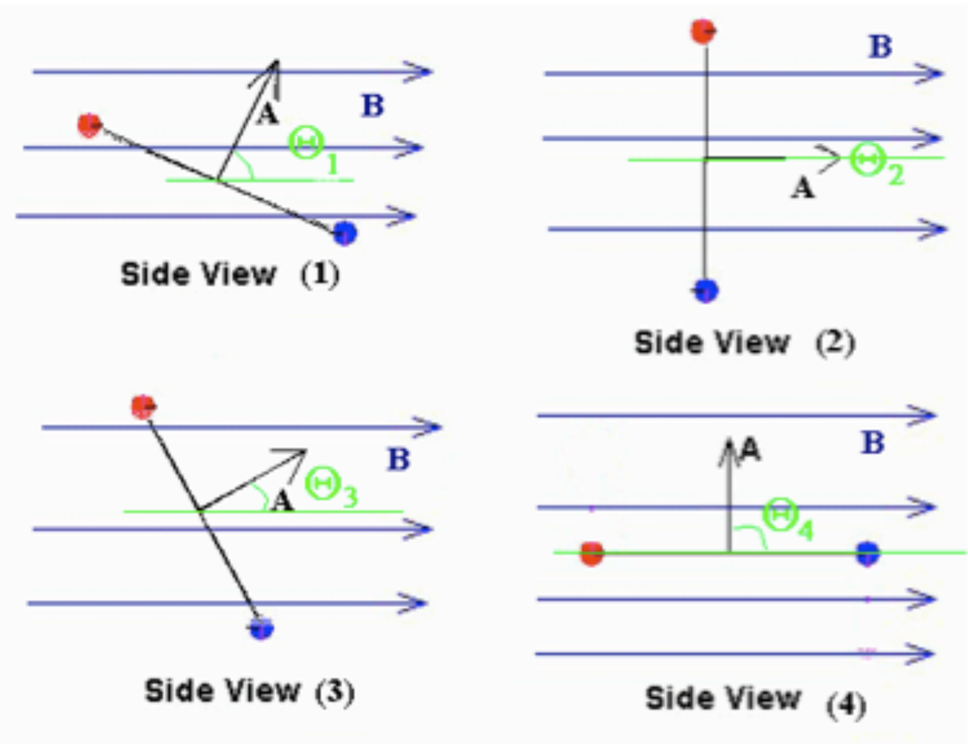


$$|F| = ILB\,|\sin\theta|$$

The right-hand rule!



A loop in a magnetic field

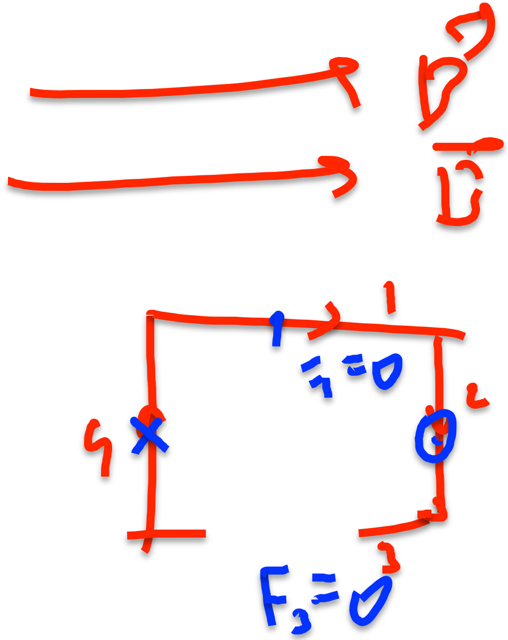


Four pictures show the instantaneous position of a square loop in a DC motor.

Rank the picture by the magnitude of the torque from the field on the loop from the greatest to the smallest.

The magnitude of the torque is:

$$\tau = | IAB \sin\theta |$$



180

0

↑

$$F_{1,2,3,4} = I\,l\,B \sin\theta$$

Net Force acting on loop

1. → 3. ← 5. ⊙ 7. 0

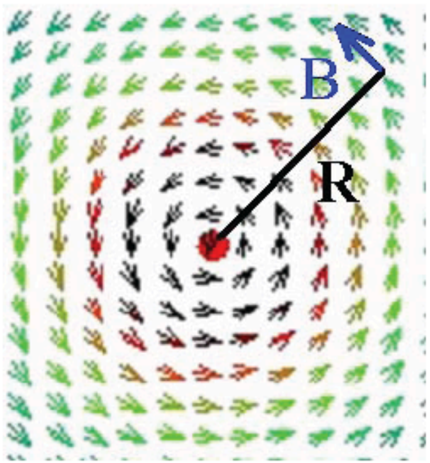
2. ↑ 4. ↓ 6. ⊗ 8. None

The magnetic field from a long straight wire

The long straight current-carrying wire, for magnetism, is analogous to the point charge for electric fields.

The magnetic field a distance *r* from a wire with current I is:

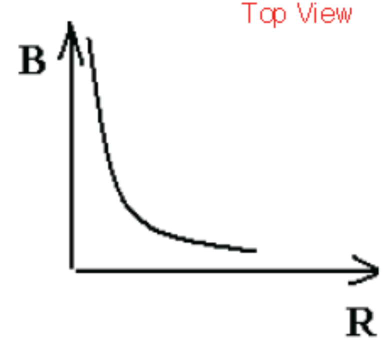
$$B = \frac{\mu_0 I}{2\pi r}$$

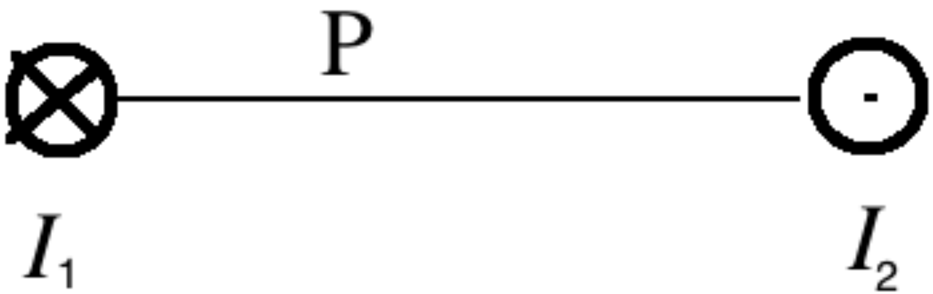


Top View

μ_0 , the permeability of free space, is:

$$\mu_0 = 4\pi \times 10^{-7} \text{ Tm/A}$$





Current I_1 is into the screen;

Current I_2 is out of the screen;

Can net magnetic field at point P be 0?

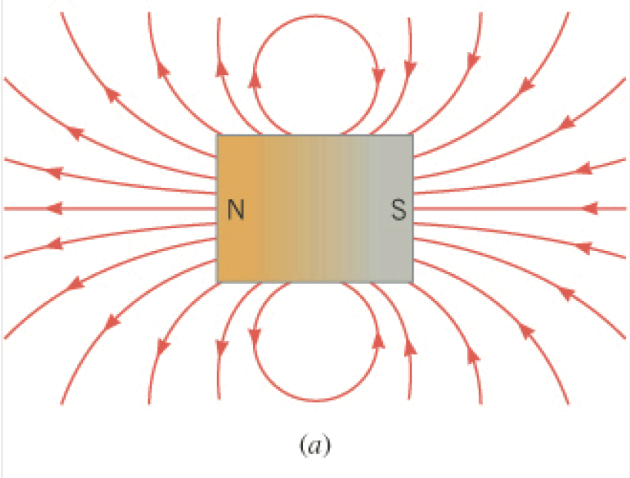
1. Yes **2. No**

3. Maybe if currents have correct values.

Magnetic fields

Magnetic fields can be generated by materials with atoms that have nonzero spin- or orbital- angular momentum. (These elementary dipoles align with their neighbors.)

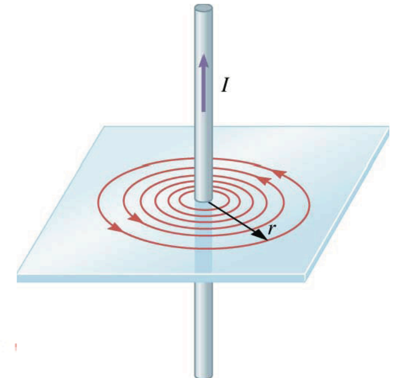
"Permanent magnets"

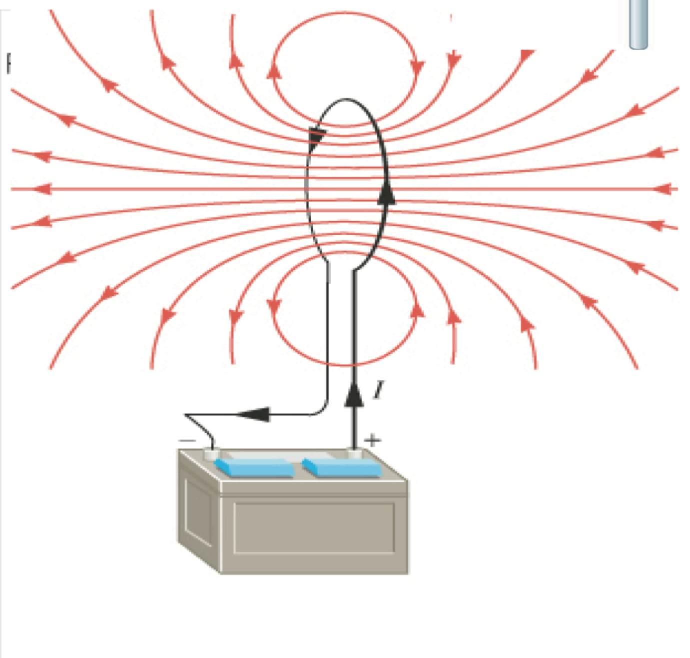


(a)

They also can be generated by electric currents in wires.

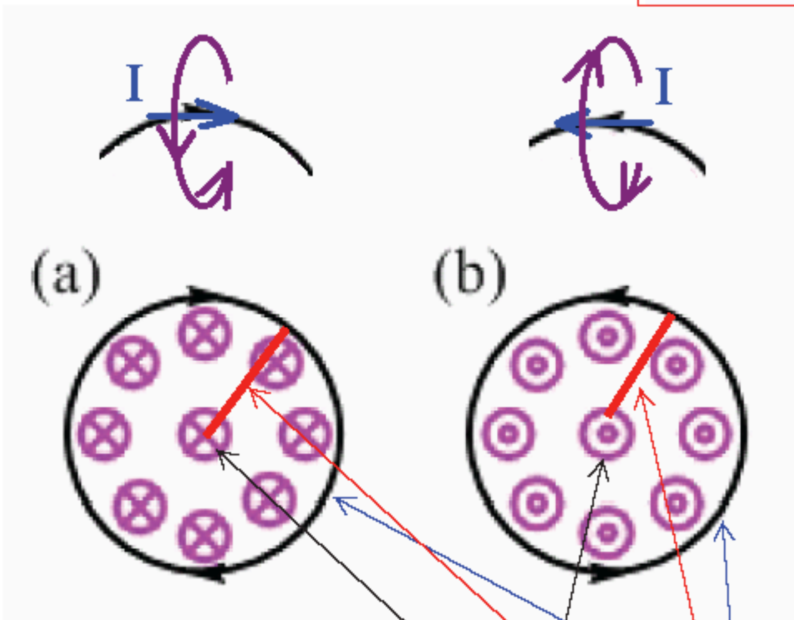
"Electromagnets"

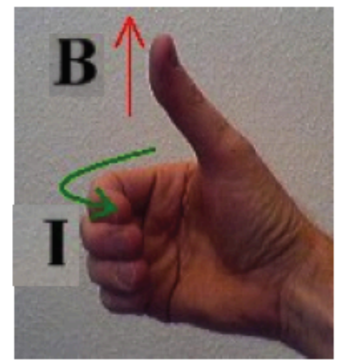




A field in the loop

At the center of the loop $|B| = \frac{\mu_0 I}{2R}$





At the center of the loop $|B| = \frac{\mu_0 I}{2R}$

(xN for a *flat* loop with N turns)