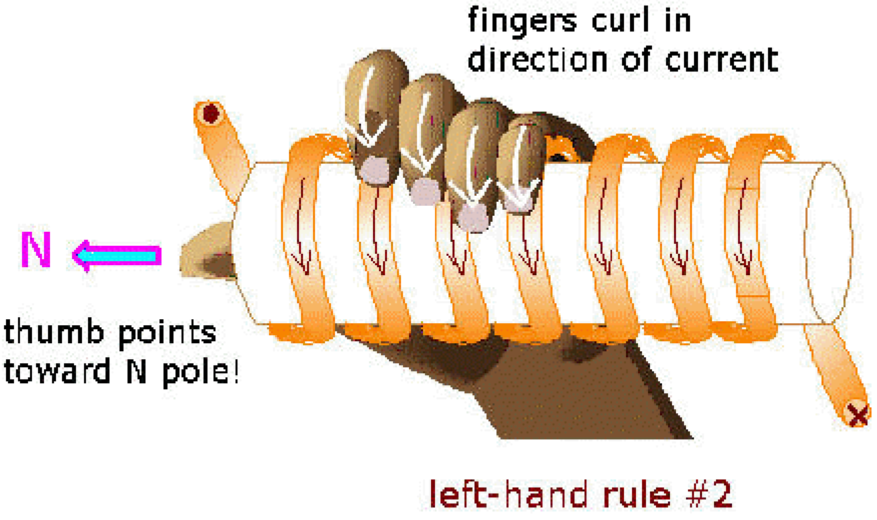
Electromagnetic Induction

Unit 2: Section 3



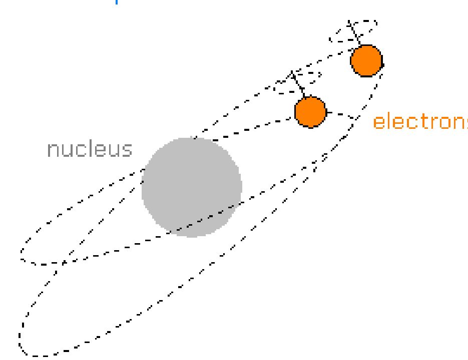
Physics 3204

Unit 3: Section 3 Electromagnetism

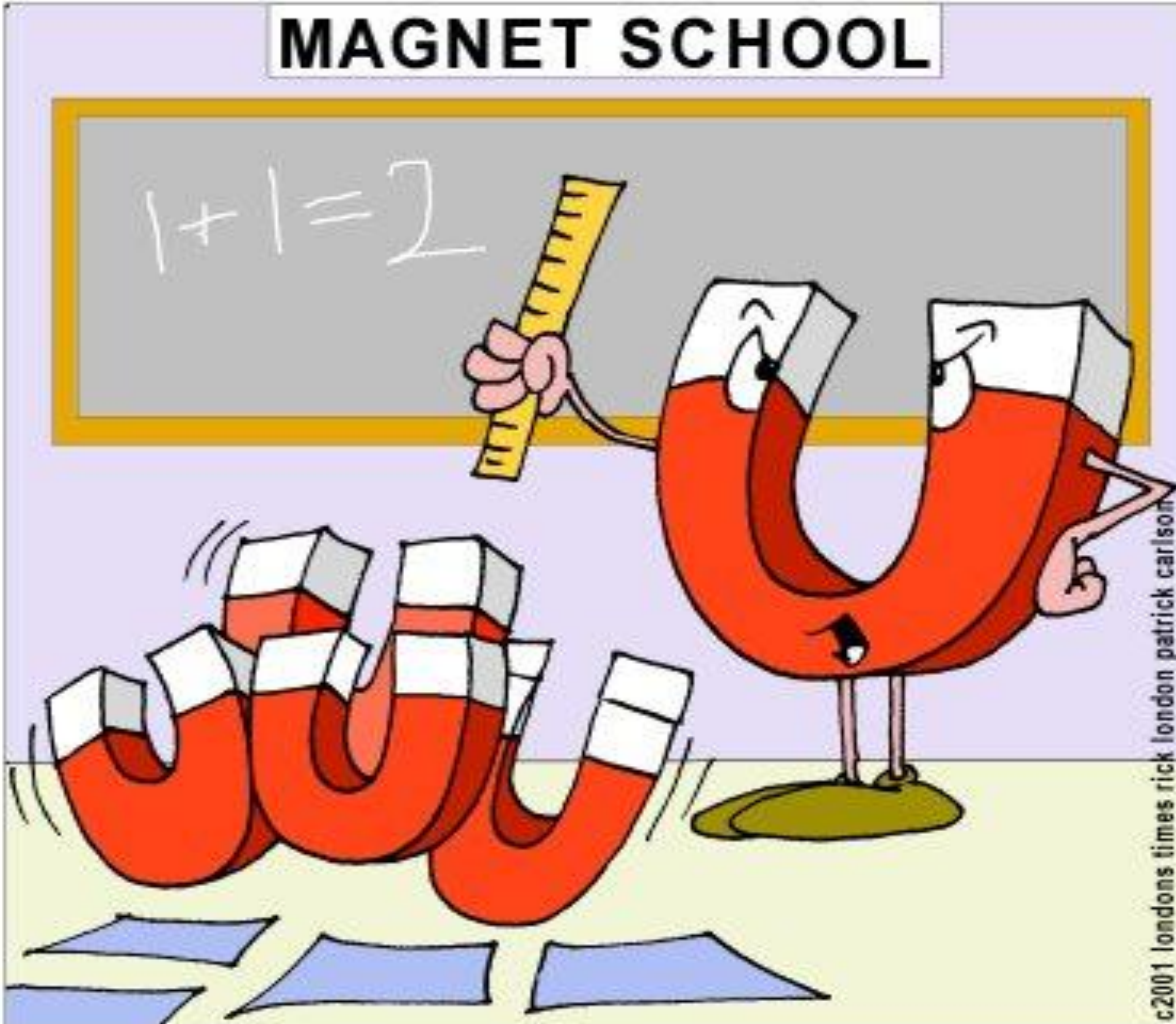
Topic 1: What is a magnet?

TEXT REFERENCE

A simple atomic model

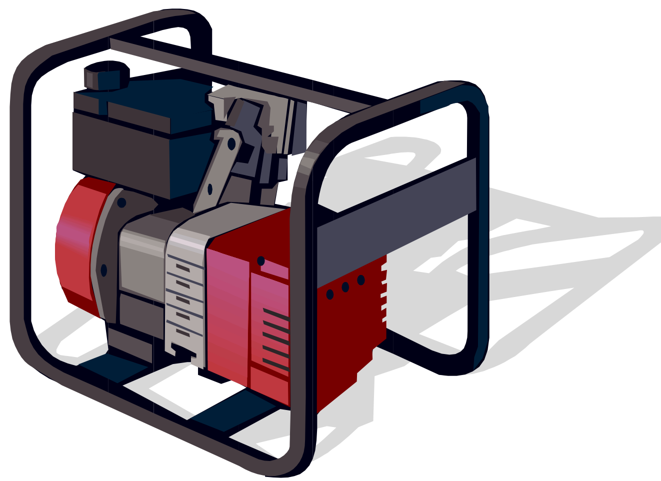


electrons revolve and spin


MAGNET SCHOOL
1+1=2
c2001 londons times rick london patrick carlson

Where Magnets are Used

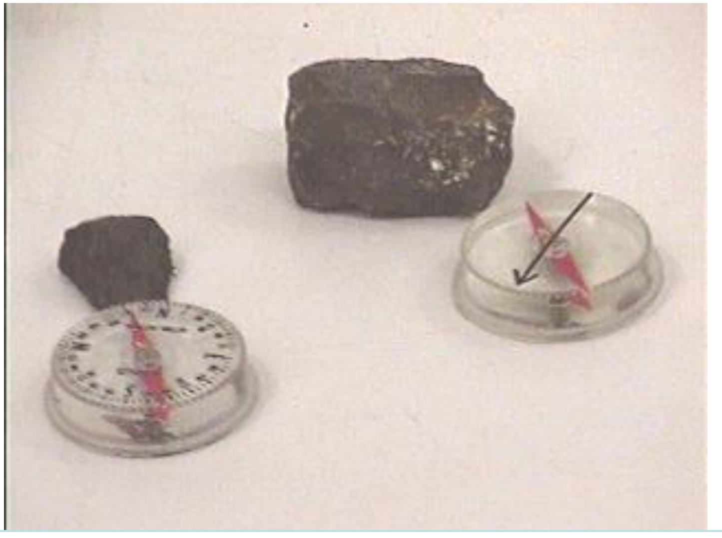
Generators



Electric guitars

Metal detectors

Lodestone



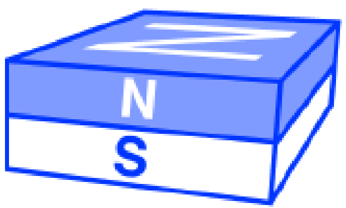
The first known magnets were naturally occurring lodestones, a type of iron ore called magnetite (Fe_3O_4). People of ancient Greece.

China discovered that a lodestone would always align itself in a longitudinal direction if it was allowed to rotate freely. This property of lodestones allowed for the creation of compasses two thousand years ago, which was the first known use of the magnet.

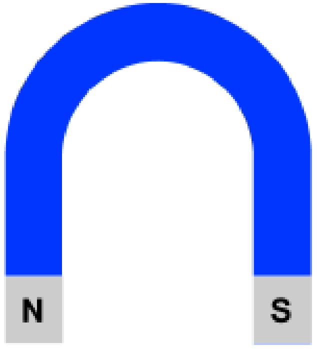
What is a magnet?

If a material is **magnetic**, it has the ability to exert forces on magnets or other magnetic materials.

1) Permanent magnet is a material that keeps its magnetic properties even when it is NOT close to other magnets.



Bar magnet



Horseshoe magnet

2) Induced Magnet:

Temporary Magnet: are those which act like a permanent magnet when they are within a strong magnetic field, but lose their magnetism when the magnetic field disappears. Examples would be paperclips and nails and other soft iron items.

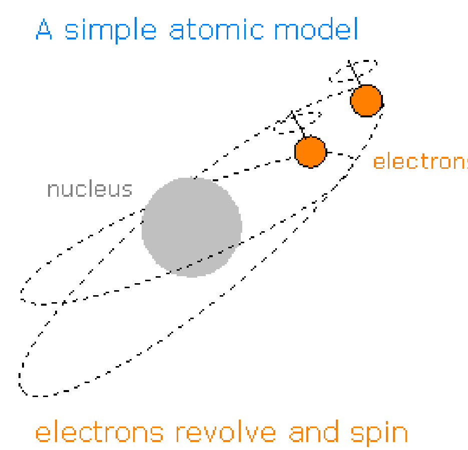
Electromagnet is a tightly wound coil of wire, usually with an iron core, which acts like a permanent magnet when current is flowing in the wire.

Physics 3204

Unit 3: Section 3 Electromagnetism

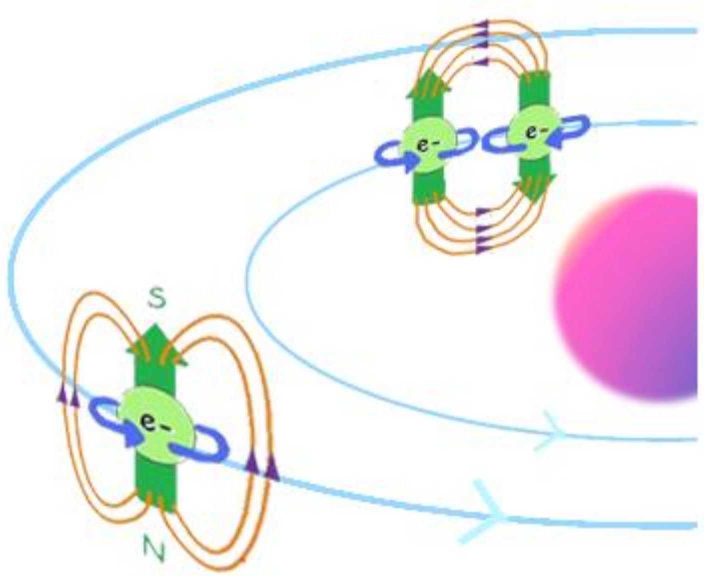
Topic 2: Atomic Magnetism

TEXT REFERENCE



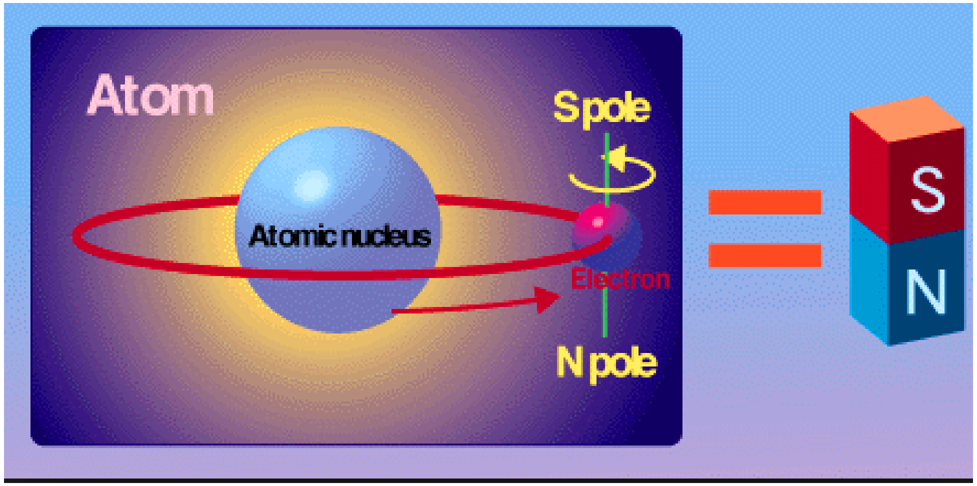
Electrons and Magnetism

When electrons are still they have an **electric field** around them (last section on electrostatics), but when electrons are moving they have an additional field called a **magnetic field**.



All magnetism is due to the motion of electrons.

The electrons undergo two types of motion: spinning and revolving.

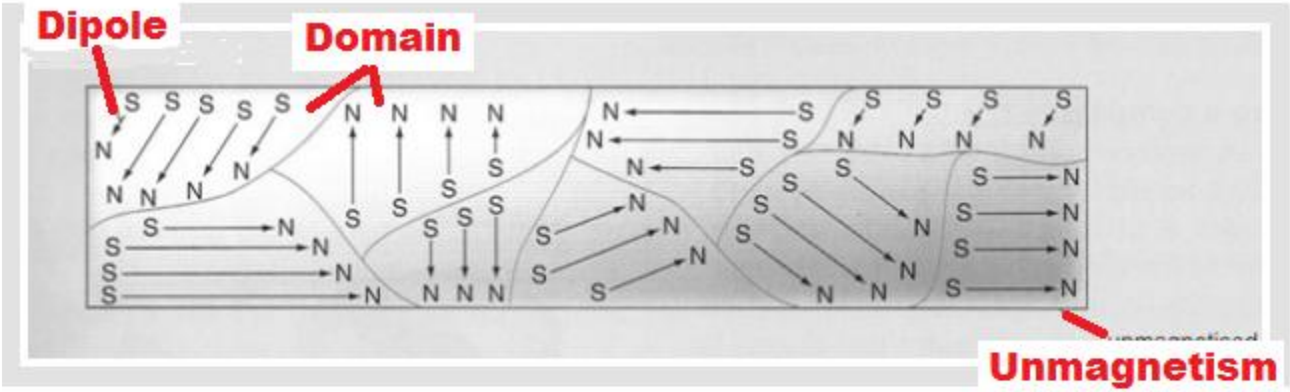


This causes the atom to have a magnetic field around it. That is.. It's like a tiny, tiny magnet.

The word for such a tiny magnet is **dipole**, where di-pole means two poles, a north pole a south pole.

Explaining Magnetism

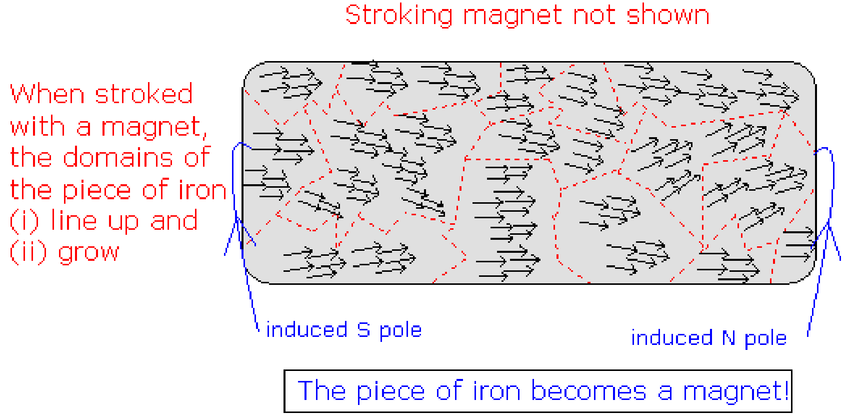
Domain Theory is used to explain how a piece of material (ie. Like iron) can become a magnet.



The arrows represent the direction of the magnetic fields of individual dipoles due to the spinning electrons.

Domain refers to cells or neighborhoods in which the dipoles have the same orientation. Therefore, each domain has a north and south pole.

This piece of iron is unmagnetized because the magnetic fields of different domains are in random.



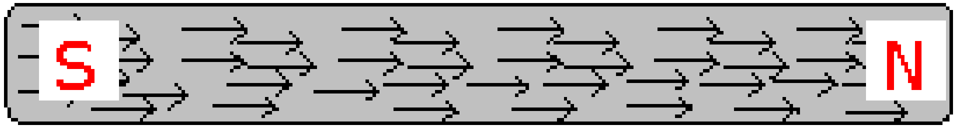
The picture below shows what happens to the domains of the piece of iron if it is stroked many times with a magnet.

The magnetic field of the magnet causes the domains of iron to line up. Not only do the domains line up, but some domains become larger.

The piece of iron has become a magnet. **(Induced Magnet)**

Any magnet, whether factory made or home made, can have only a certain strength. Once all the domains are lined up or nearly lined up, that's it! It can't become any stronger.

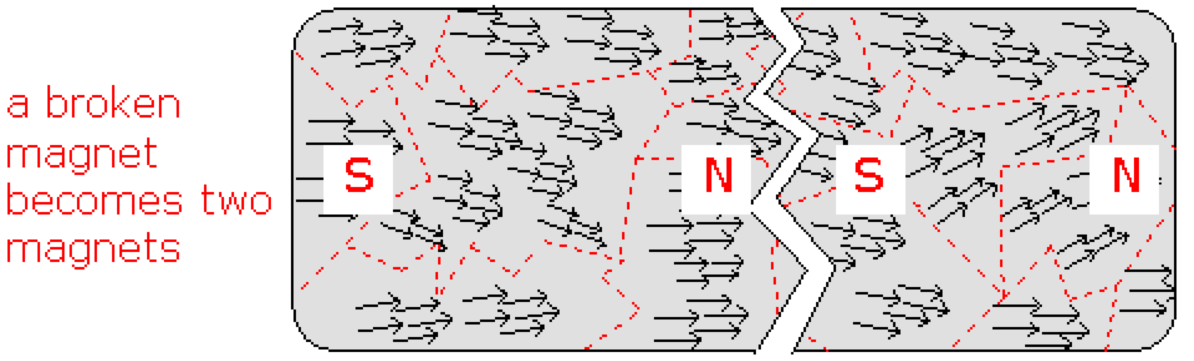
in a magnet the domains are lined up



The magnetic fields of the domains of a magnet will be almost perfectly lined up as shown.

The picture also shows that a magnet is a very large dipole.

If the piece of iron is snapped in two, you will have two magnets! Each of the two pieces will have N and S poles.



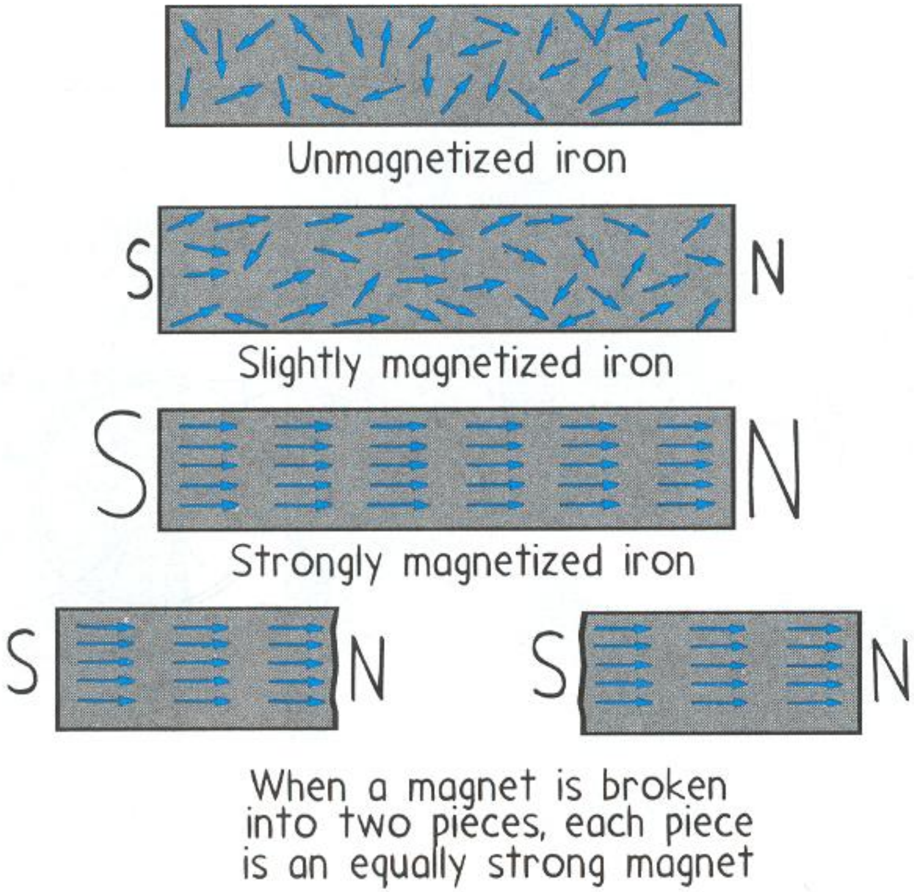
Since the magnet was created by causing the domains to line up, the piece of iron can be demagnetized by making sure that the domains take up random directions once again.

Two ways to do this are:

1. By heating the iron

2. By submitting it to some other kind of shock which will cause molecular disturbance.

SUMMARY



Unmagnetized iron
S
N
Slightly magnetized iron
S
N
Strongly magnetized iron
S
N
S
N
When a magnet is broken
into two pieces, each piece
is an equally strong magnet

Physics 3204

Unit 3: Section 3 Electromagnetism

Magnetic Properties of Materials

Topic 3: Magnetic Properties of Materials

TEXT REFERENCE

Fred brings home one too many cute refrigerator magnets.

How do magnets interact with different materials?

1) Substances that are attracted

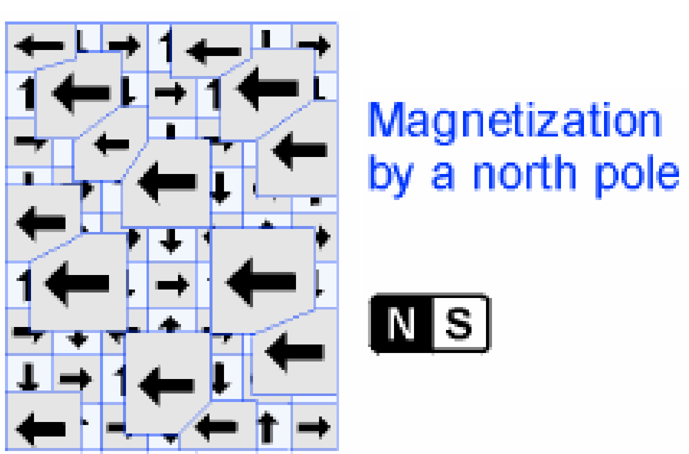
Ferromagnetic refers to substances that are strongly attracted to magnets. This would include elements like iron, nickel, and cobalt.

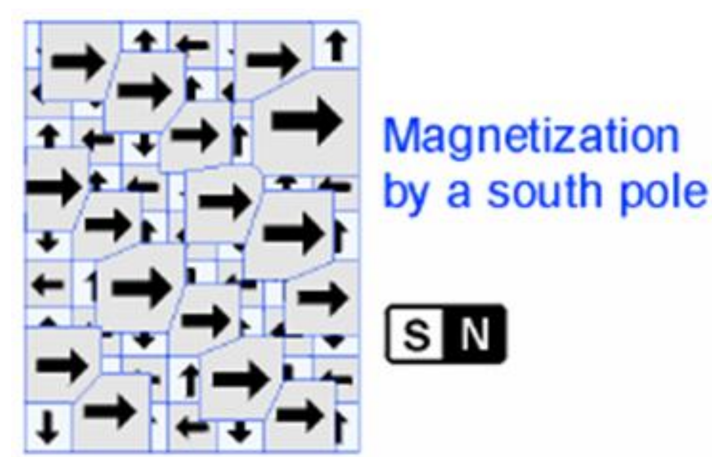
Paramagnetic refers to substances that are weakly attracted by a magnets. This would include elements like aluminum, sodium, strontium

- Magnetic domains in a ferromagnetic material will always orient themselves to attract a permanent magnet.

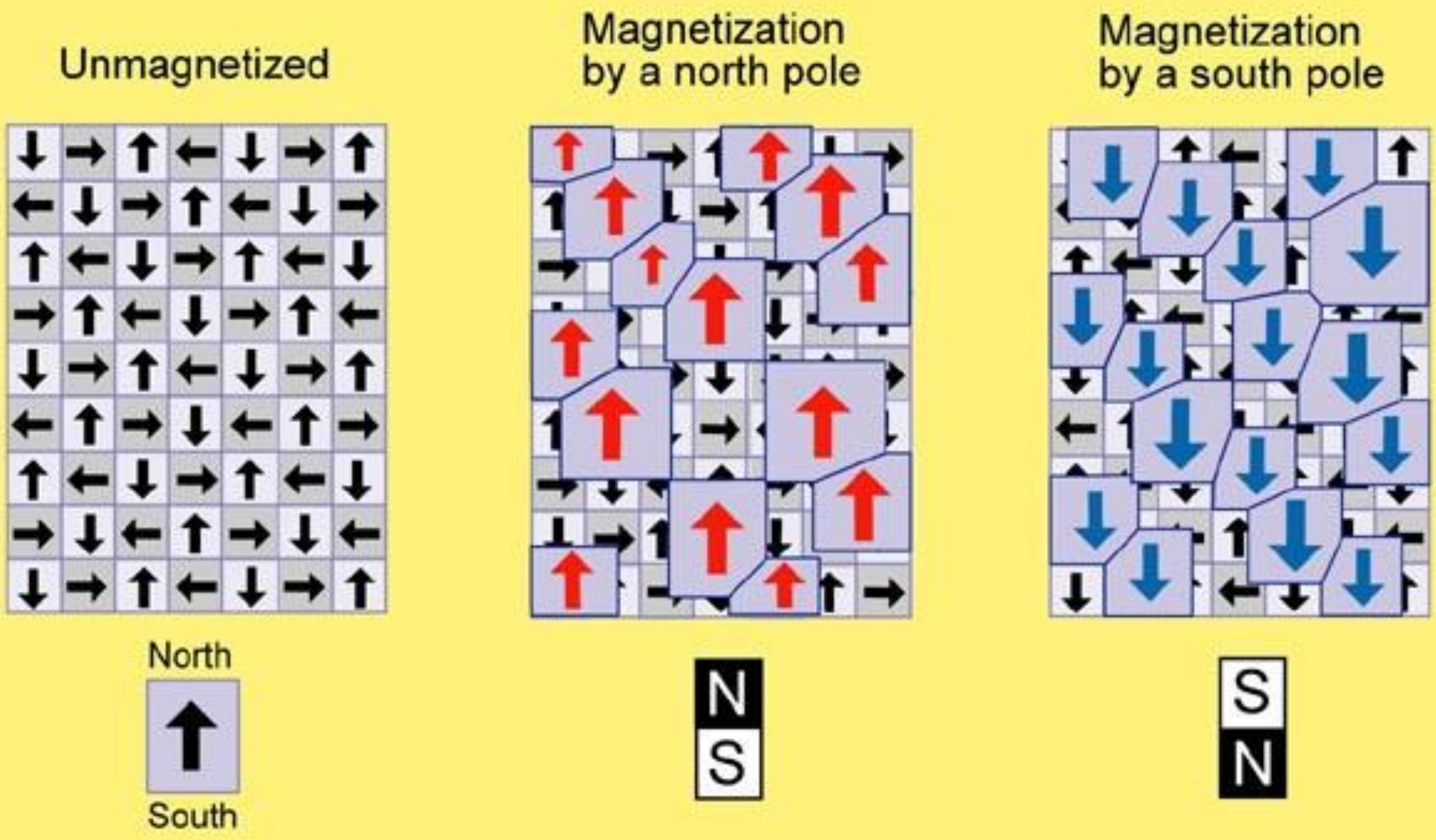
- If a north pole approaches, domains grow that have south poles facing out.

- If a south pole approaches, domains grow that have north poles facing out.



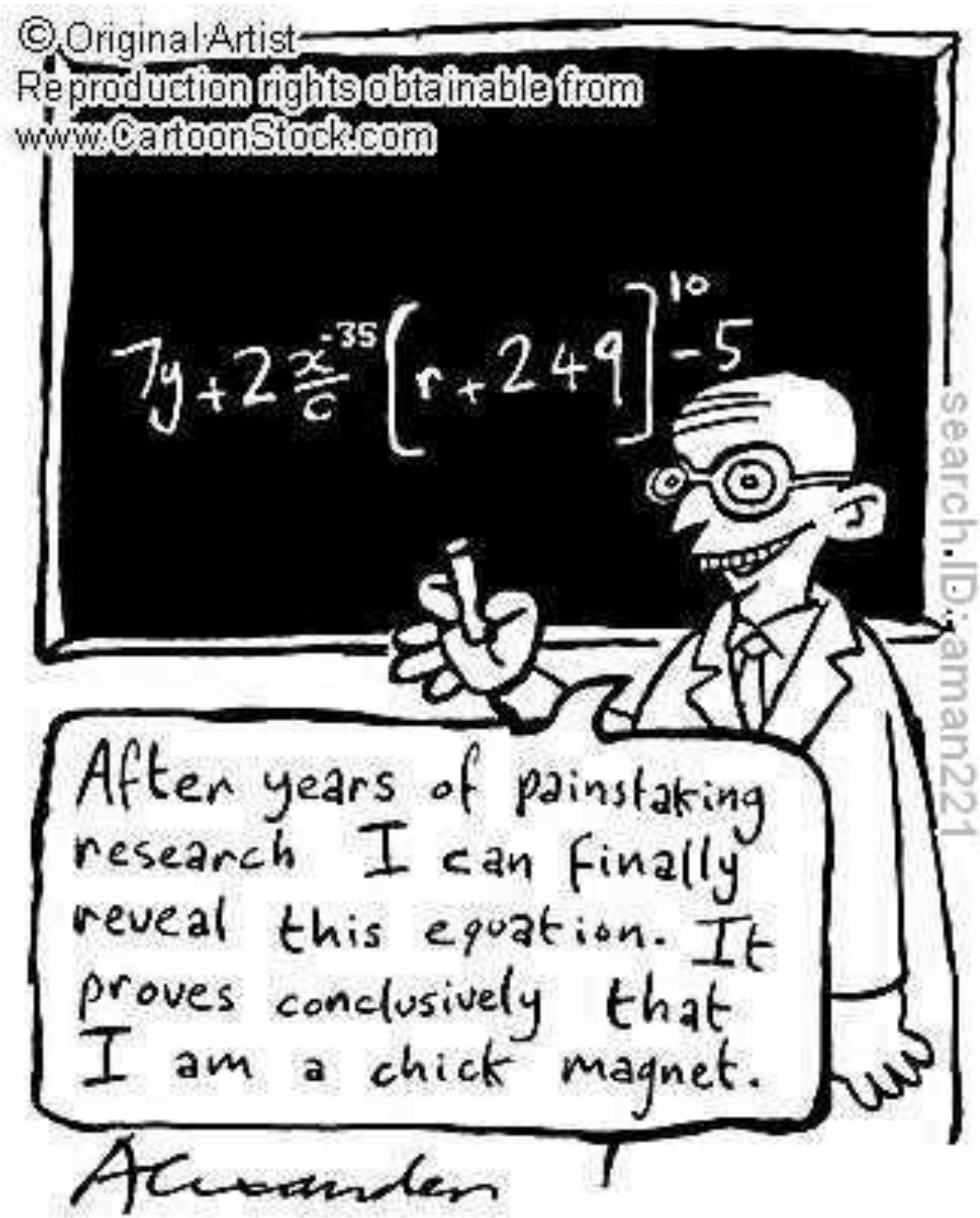


Magnetic Domains



2) Substances that are repelled

Diamagnetic refers to materials in which the electrons are oriented so their individual magnetic fields <u>cancel</u> each other out. Such substances are weakly repelled by a magnet. Examples are bismuth, zinc, silver, carbon, copper, gold and lead


© Original Artist
Reproduction rights obtainable from
www.CartoonStock.com
search ID: aman221
After years of painstaking research I can finally reveal this equation. It proves conclusively that I am a chick magnet.
Alexander

Physics 3204

Unit 3: Section 3 Electromagnetism

Magnetic Properties of Materials

Topic 4: Properties of Magnets

TEXT REFERENCE

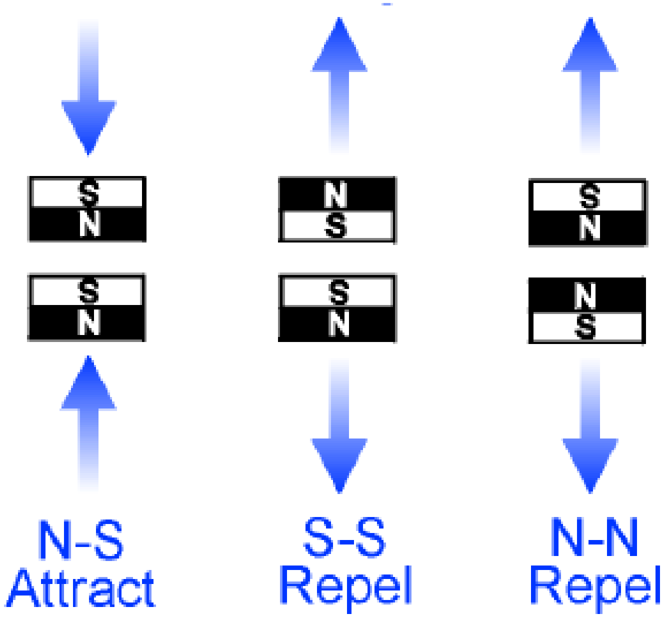

ACME
REFRIGERATORS
ACE
Magnet
Co.

Properties of Magnets

- Magnets have two opposite poles.
- **north**
- **South**

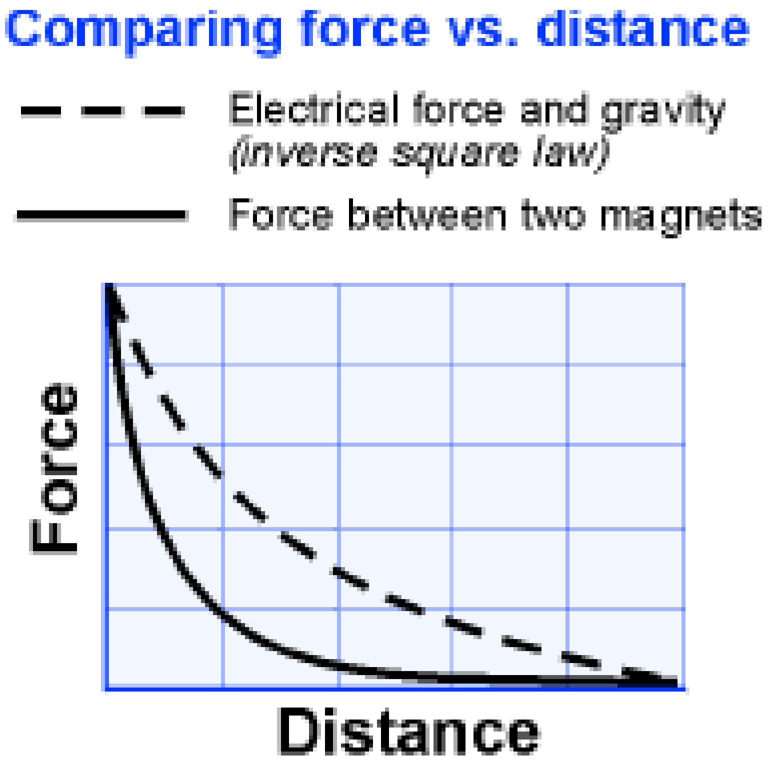
- Magnets exert forces on each other.

- The forces depend on the alignment of the poles.



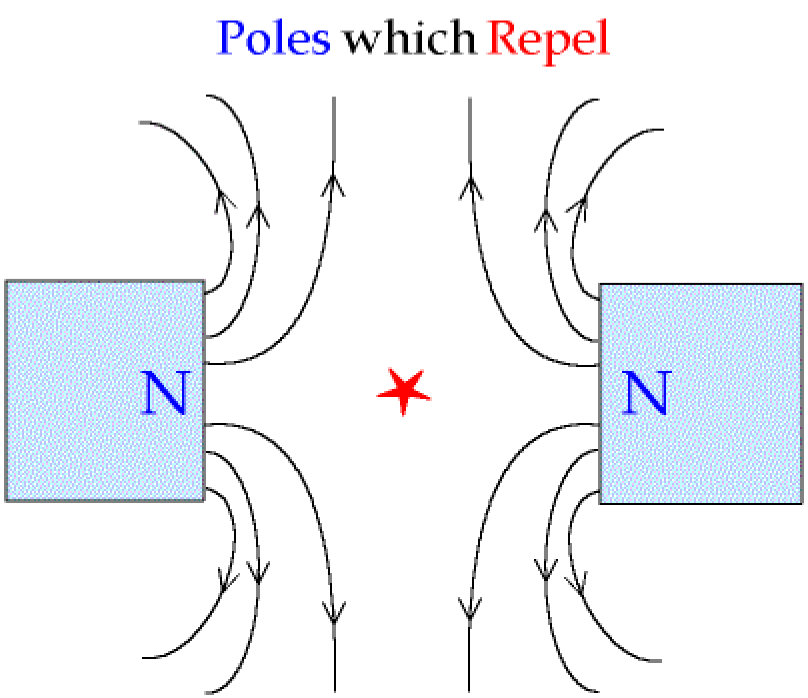
Force Between Two Magnets

- The strength of the force between magnets depends on the distance between them.
- The magnetic force decreases with distance much faster than does either gravity or the electric force.

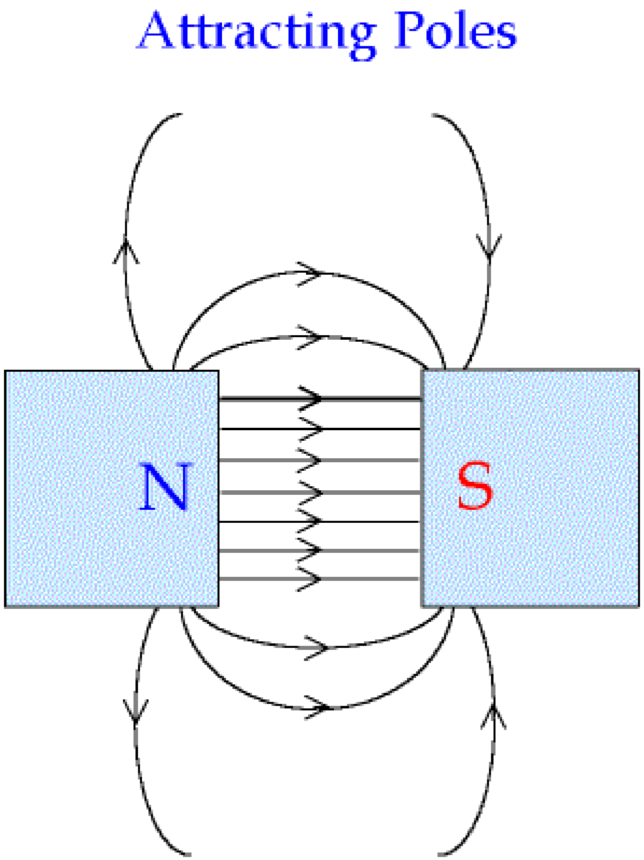


The Law of Magnetic Forces

Similar magnetic poles (north and north or south and south) *repel* one another with a force, even at a distance apart.

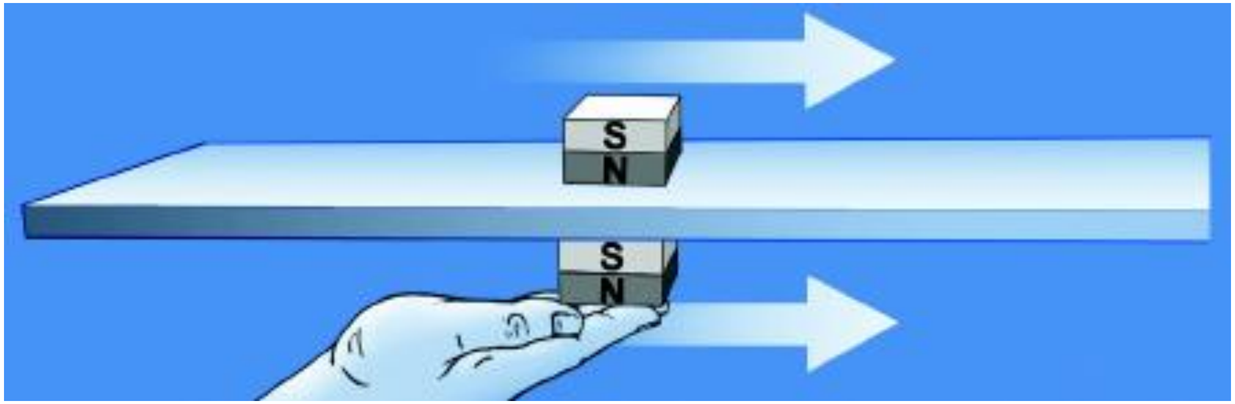


Dissimilar poles (north and south or south and north) *attract* one another with a force, even at a distance apart.



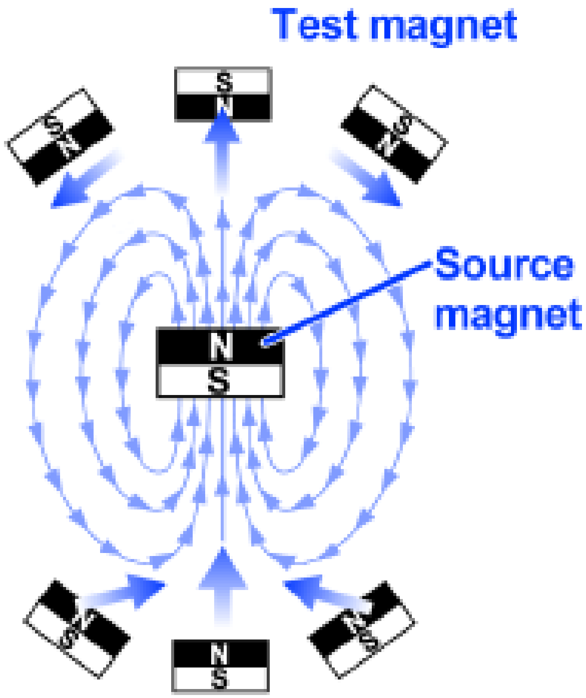
- Plastics, wood, and most insulating materials are virtually transparent to magnetic forces.

- Conducting metals, like aluminum, also allow magnetic forces to pass through, but may change the forces.



Magnetic field

Magnetic field is a region of space where a magnetic material, or a current carrying conductor or a moving charge experiences a force when placed in it.



Magnetic field :

1) **Creates forces on other magnets.**

2) **It is represent by B**

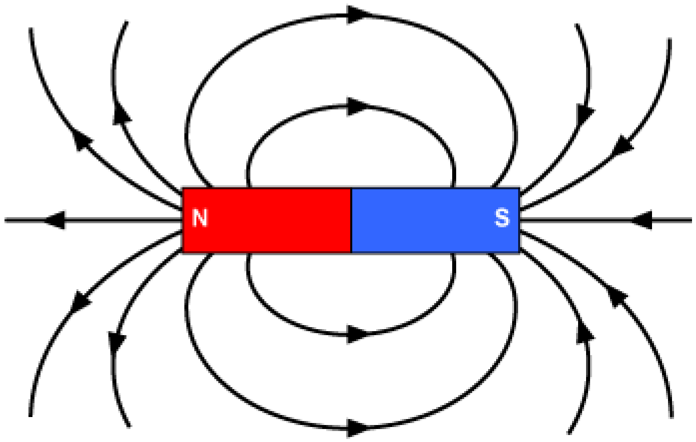
3) **It is measured in Tesla (T)**

4) **It is a vector quantity**

Physics 3204

Unit 3: Section 3 Electromagnetism

Topic 5 : Magnetic Field



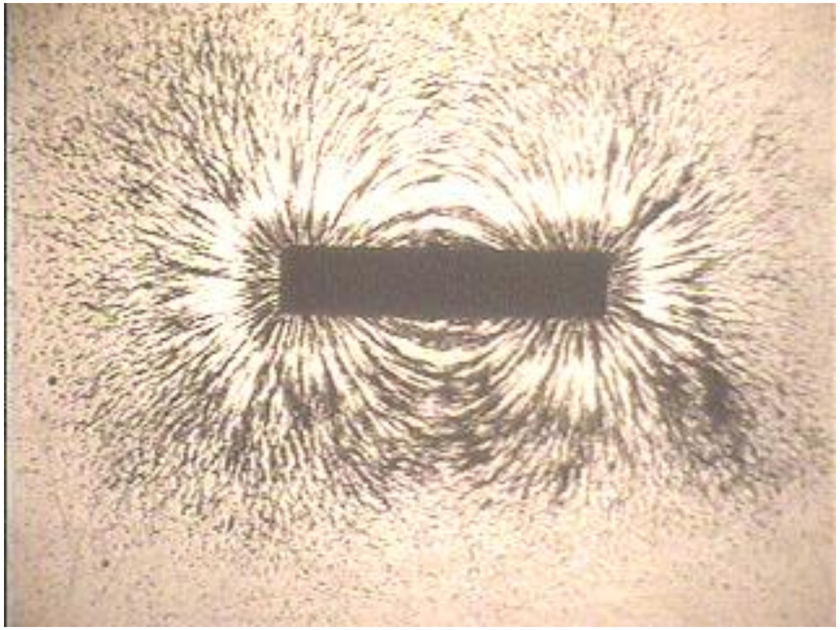
TEXT REFERENCE

BabeMagneT

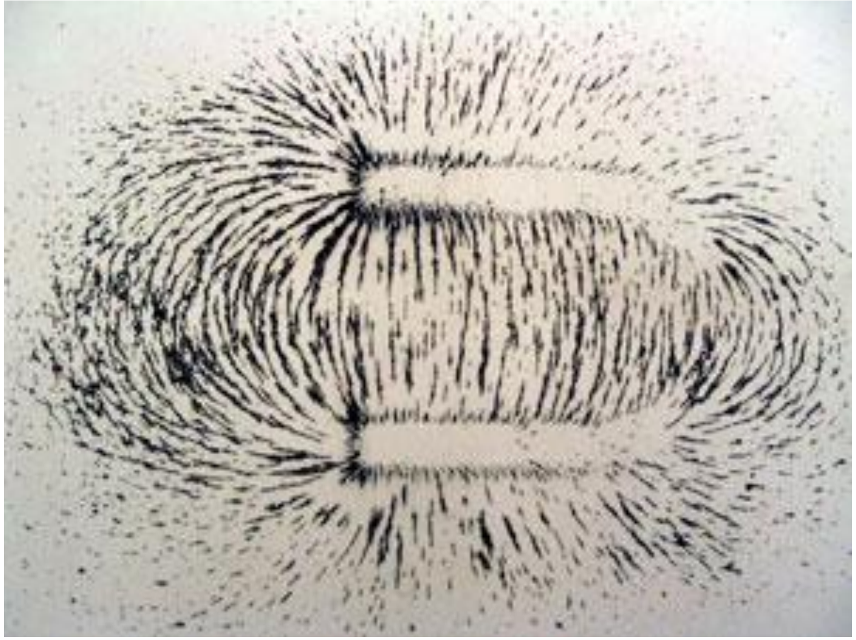
Field Lines Around a Magnet

Iron Fillings can be used to observe field lines around a magnet

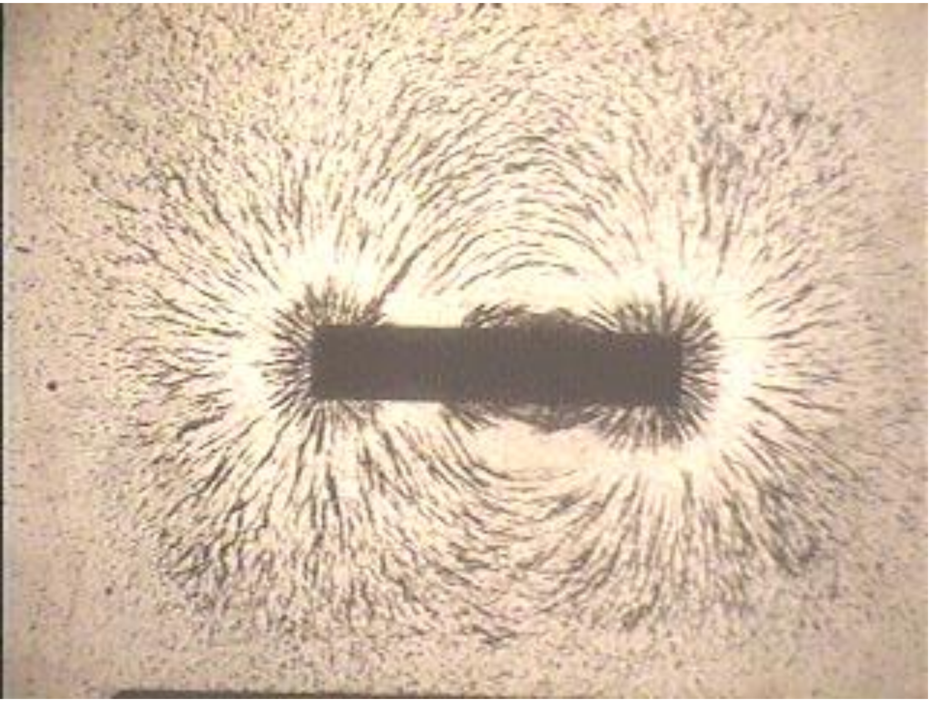
Bar Magnet

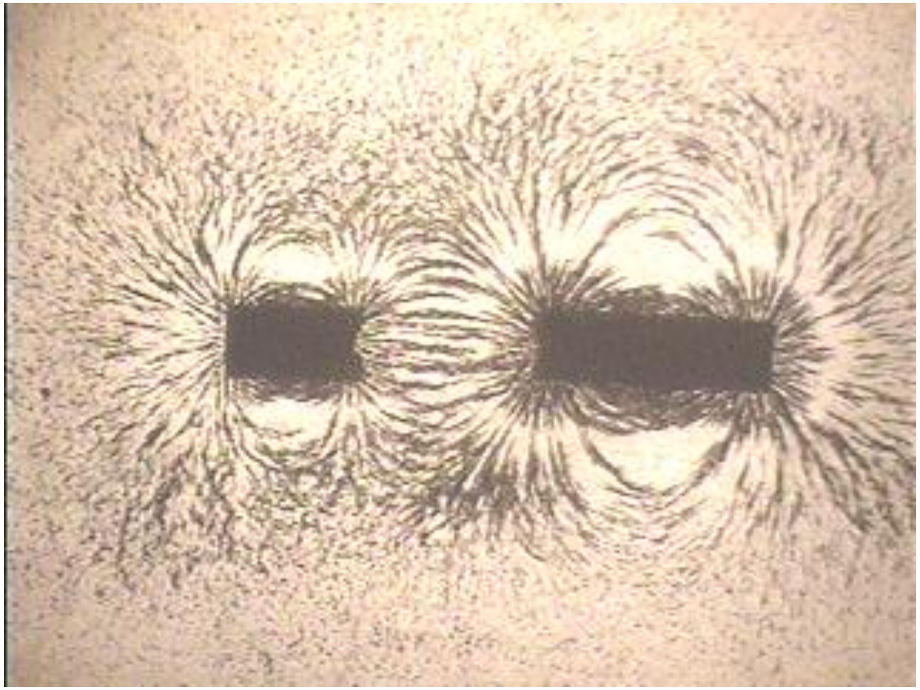


Horseshoe



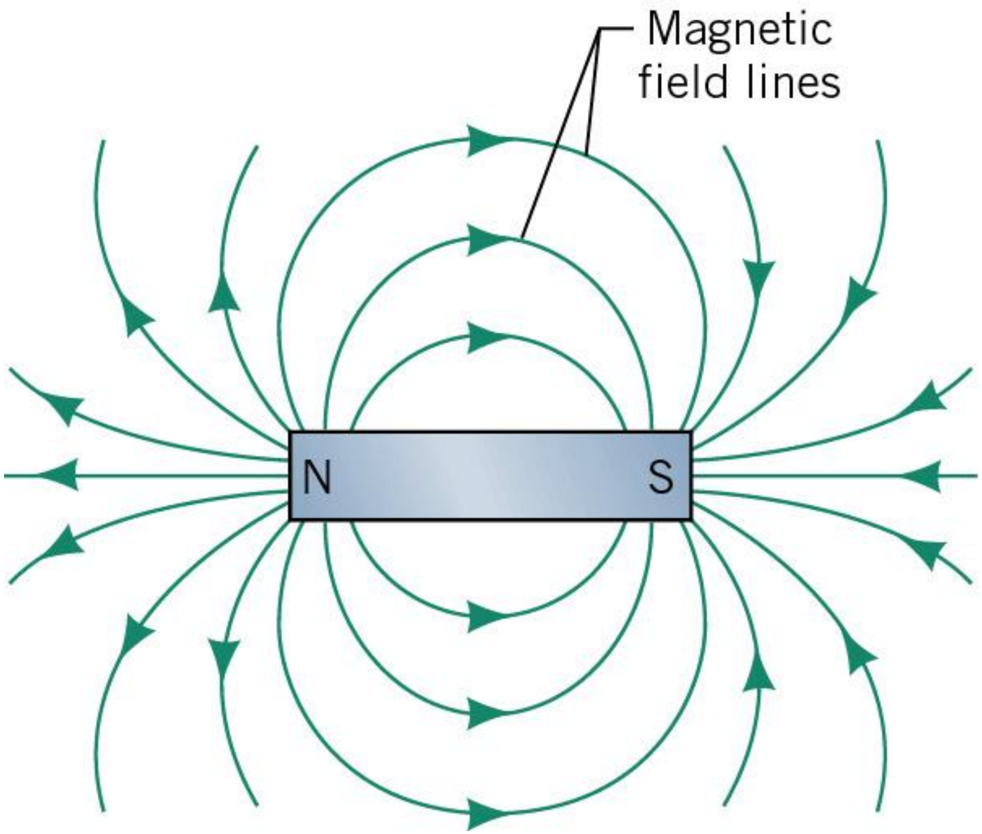
Broken Magnet



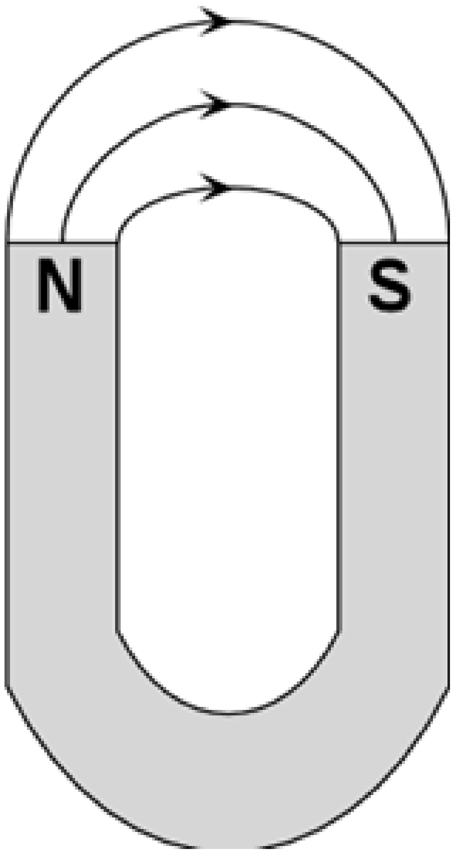


When we try to separate the two poles by breaking the magnet, we only succeed in producing two distinct dipoles (pic on right).

Magnetic field lines describe the structure of magnetic fields in three dimensions.



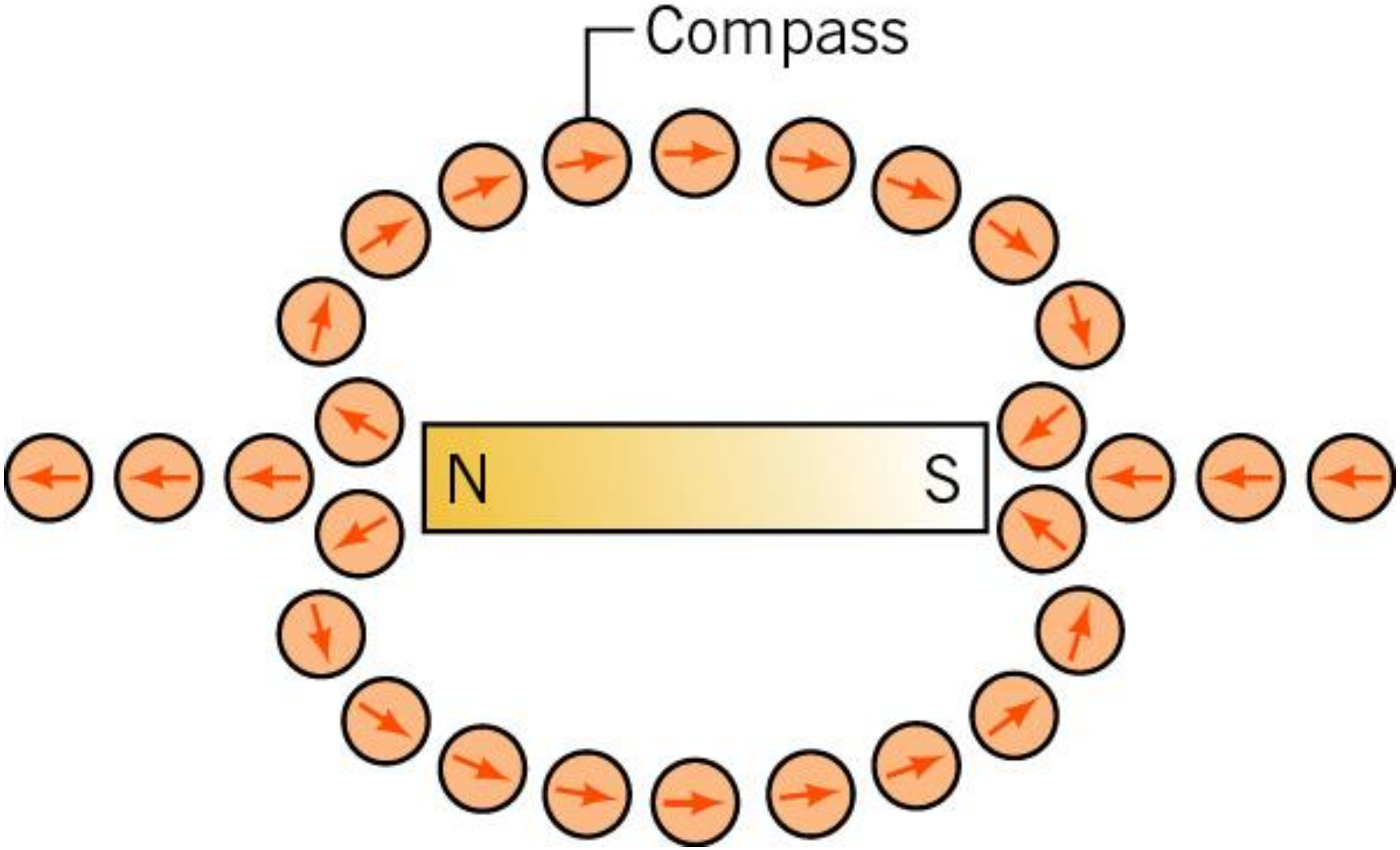
Bar Magnet



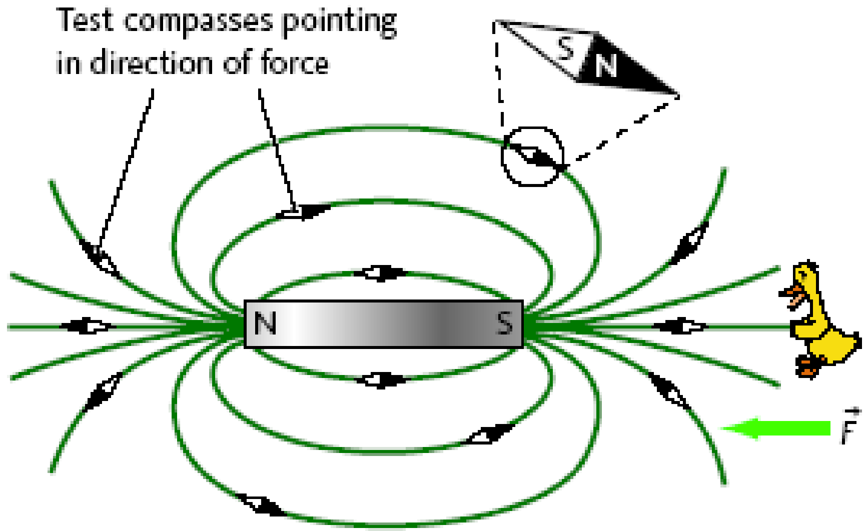
Horseshoe

Mapping Magnet Field

A compass can be used to map a magnetic field.



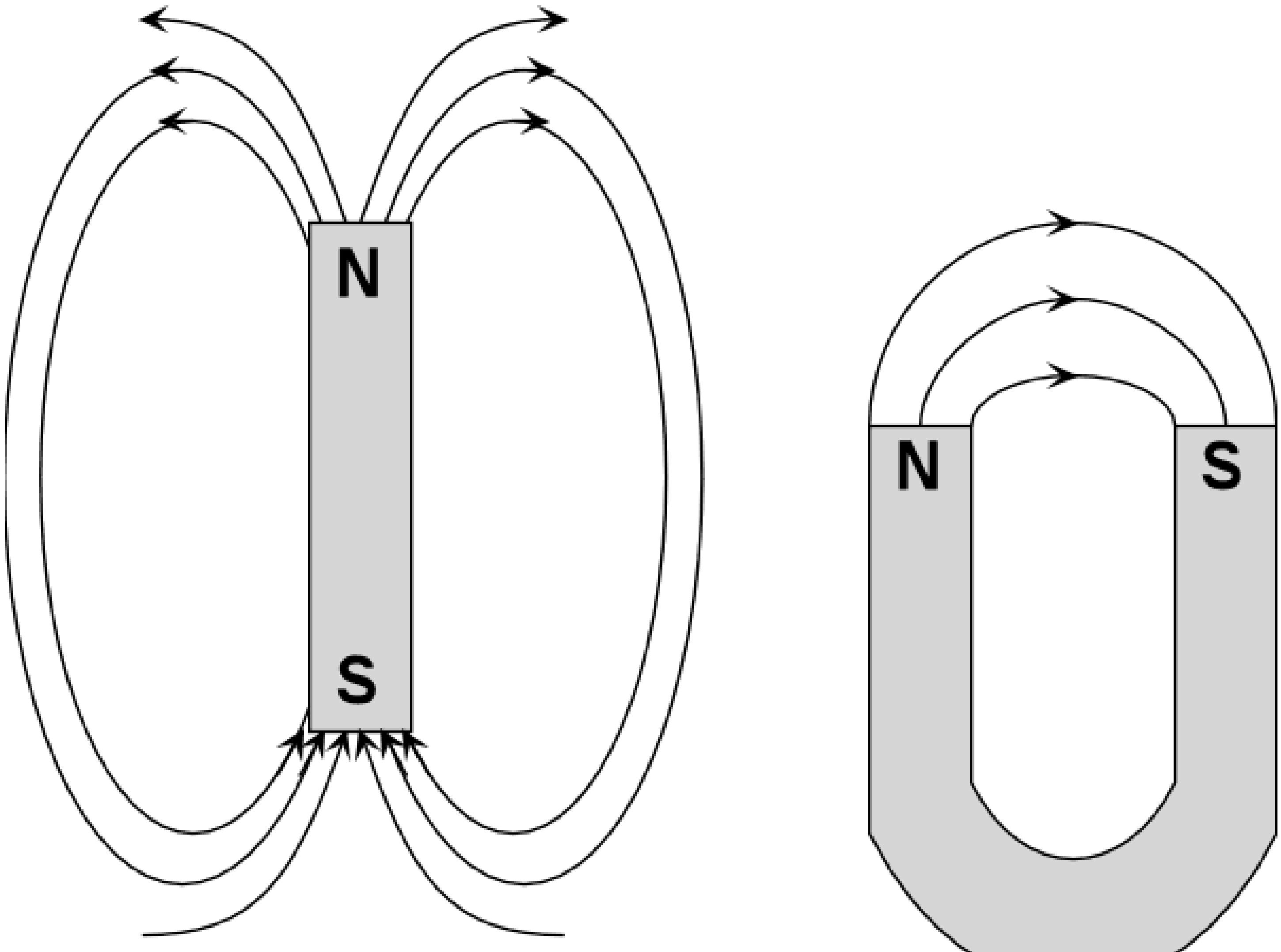
The direction of a magnetic field at a point within the field is the direction that a compass points when place at that location--in other words ***magnetic lines of force start at the north pole and end at the south pole.***



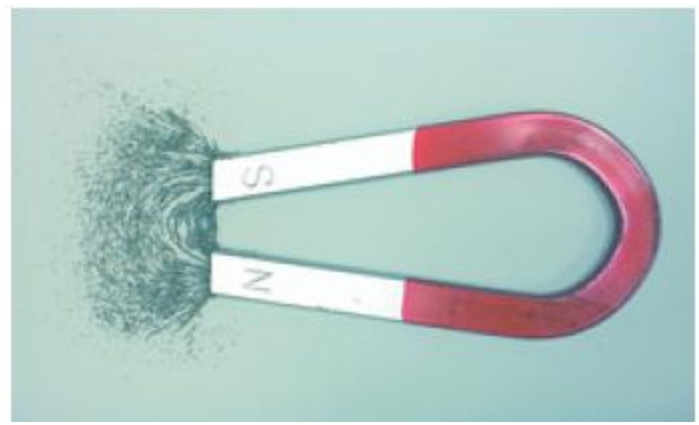
The test compass maps the field lines around a simple bar magnet by rotating its dipole to indicate the direction of force that its North end experiences in the magnetic field at that particular point in space.

Magnetic field lines are drawn tangent to the compass needle at any point. The number of lines per unit area is proportional to the magnitude of the magnetic field.

The direction of the magnetic field is defined as the direction in which the north pole of a test magnet (compass) would point when placed at that location.


N
S
N
S

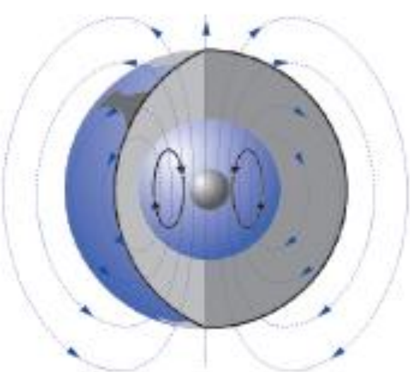
Remember: Using iron filings is equivalent to using many tiny compasses with undefined poles. Notice how the magnet is a dipole because each field line begins at one pole and flows to the corresponding point on the opposite pole. The law of magnetic forces dictates the convention that field lines flow from the north pole to the south pole of the field-creating magnet.



Physics 3204

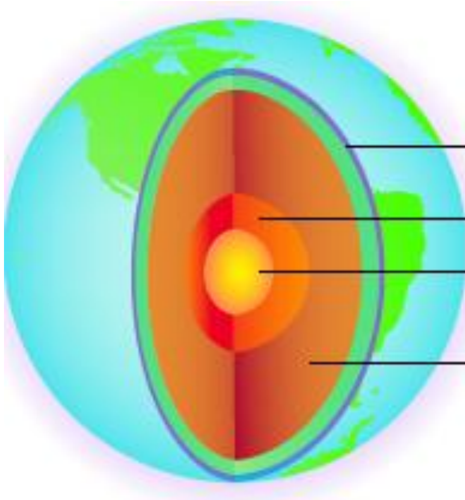
Unit 3: Section 3 Electromagnetism

Topic 6 : Earth’s Magnetic Field



TEXT REFERENCE

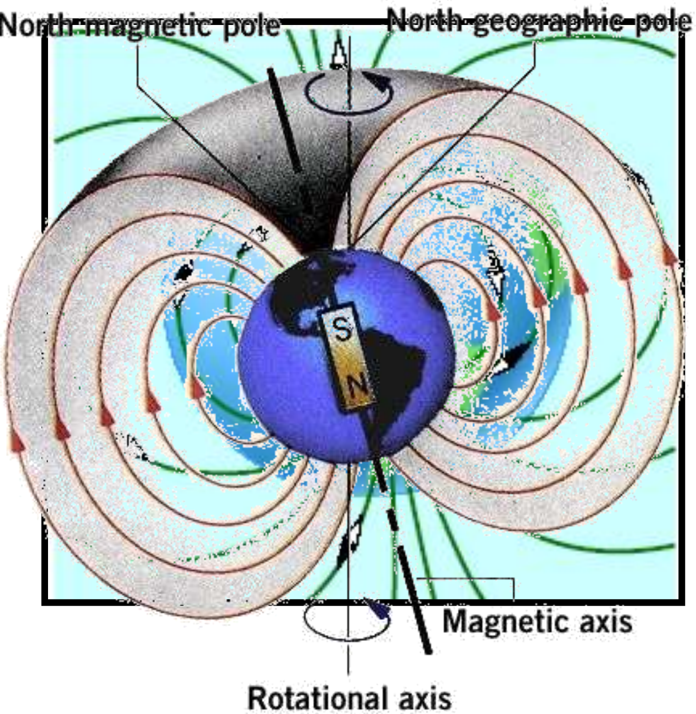
Earth's Magnetic Field



English physicist Sir William Gilbert suggested that Earth's magnetic field is created by the flowing motion of hot liquid metals under Earth's crust.

This notion led scientists to a better understanding of the cause of magnetic character at the atomic level. The interaction between a compass (a free-spinning permanent magnet) and Earth's magnetic field has been of great importance for navigators around the world.

Why is the North Pole of a Compass attracted to the Earth's North Pole?



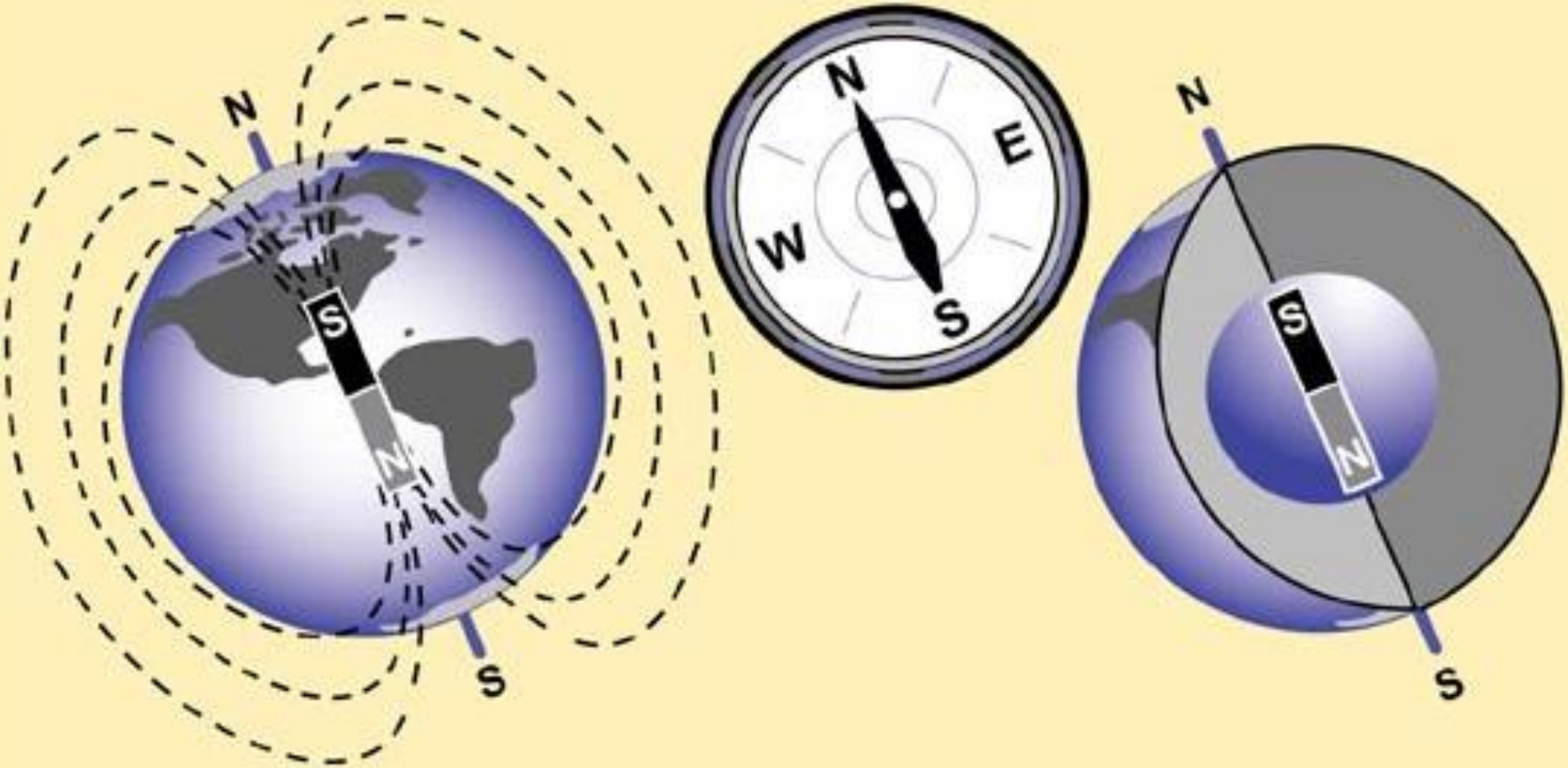
When you use a compass, the north-pointing end of the needle points toward a spot near (but not exactly at) the Earth's geographic north pole.

The Earth's magnetic poles are defined by the planet's magnetic field.

That means the south magnetic pole of the planet is near the north geographic pole.

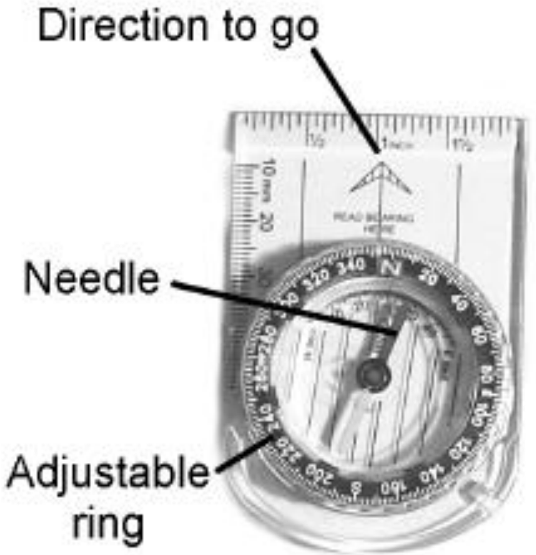
The magnetic field also varies in strength over the earth's surface. It is strongest at the poles and weakest at the equator.

How Does a Compass Work?



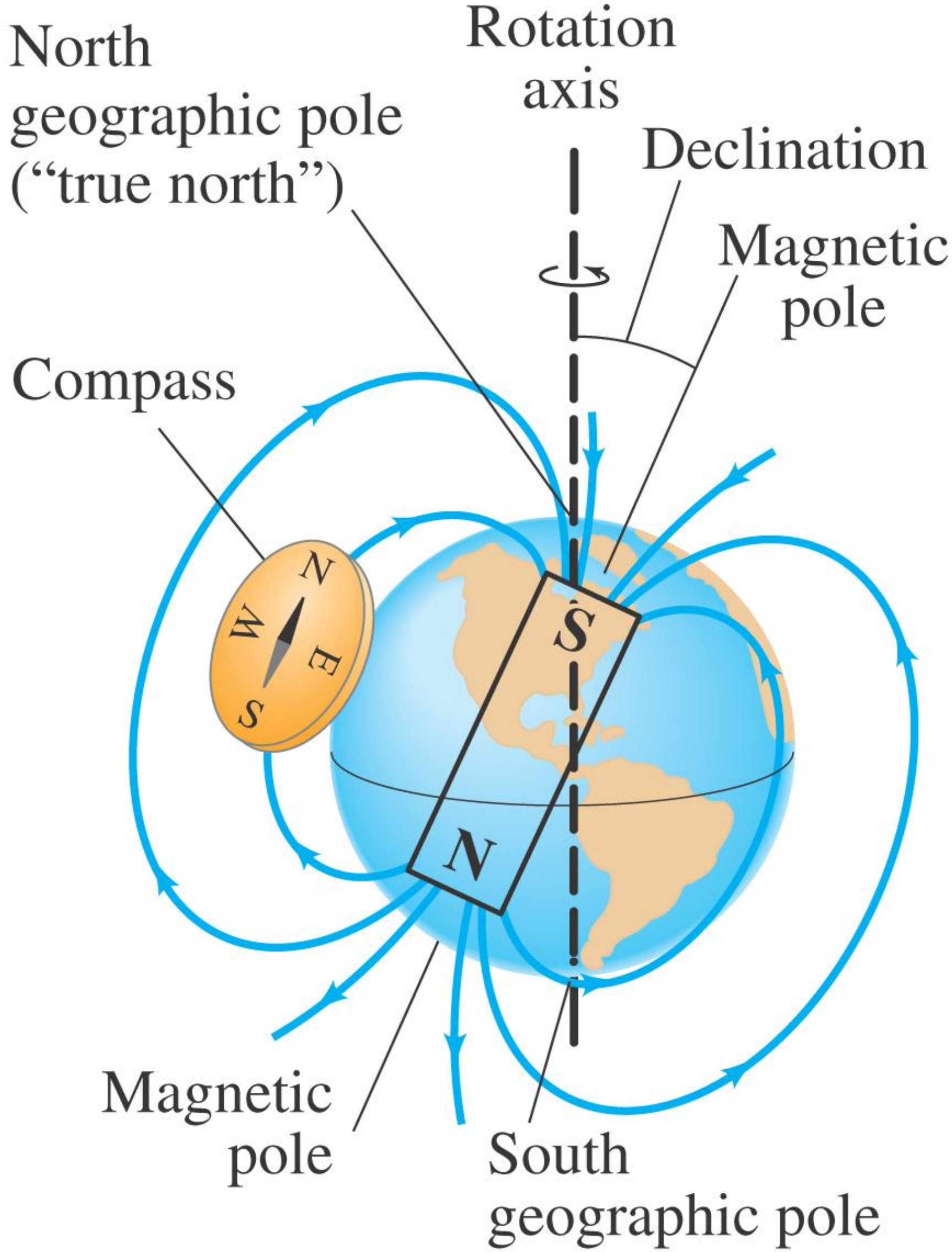
Depending on where you are, a compass will point slightly east or west of true north.

- The difference between the direction a compass points and the direction of true north is called magnetic declination.



After correcting for the declination, you rotate the whole compass until the north-pointing end of the needle lines up with zero degrees on the ring.

The large arrow points in the direction you want to go.


North
geographic pole
("true north")
Rotation
axis
Declination
Magnetic
pole
Compass
N
W
E
S
S
N
Magnetic
pole
South
geographic pole

Write 1 -5 in your exercise

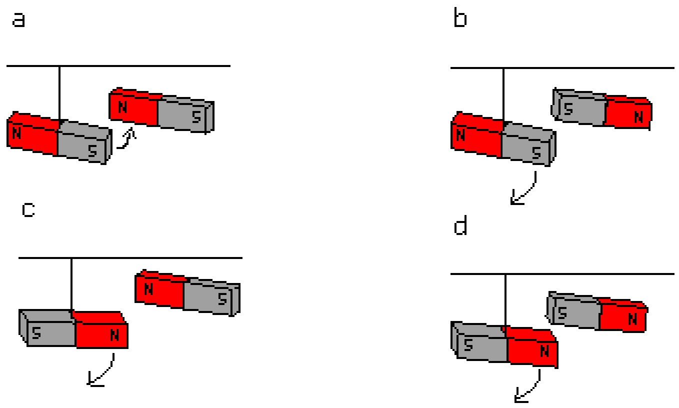
Test yourself

1. A space probe lands on the newly discovered planet Scisyhp and a magnetic probe indicates that the soil particles are repelled by both poles of a magnet. Which of the following properties best describes the soil?
    a) paramagnetic
    b) diamagnetic
    c) lodestone
    d) ferromagnetic

2. What is the proper phrase to describe the magnet that is made when a piece of iron is stroked with another magnet?
    a) permanent magnet
    b) diamagnet
    c) induced magnet
    d) electromagnet

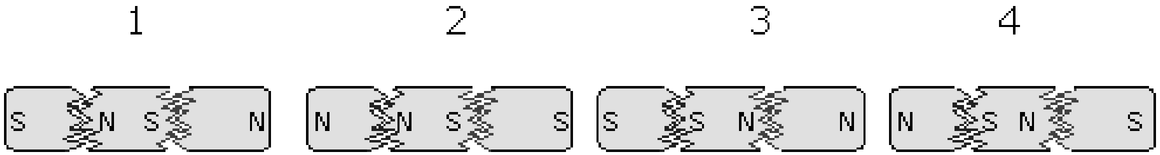
3. Which is the true statement?
    a) a domain is the smallest possible dipole
    b) in a domain all the atomic dipoles are aligned
    c) in a magnet the domains have random magnetic directions
    d) a domain is the largest possible dipole

4. Which pair of magnets are behaving incorrectly?

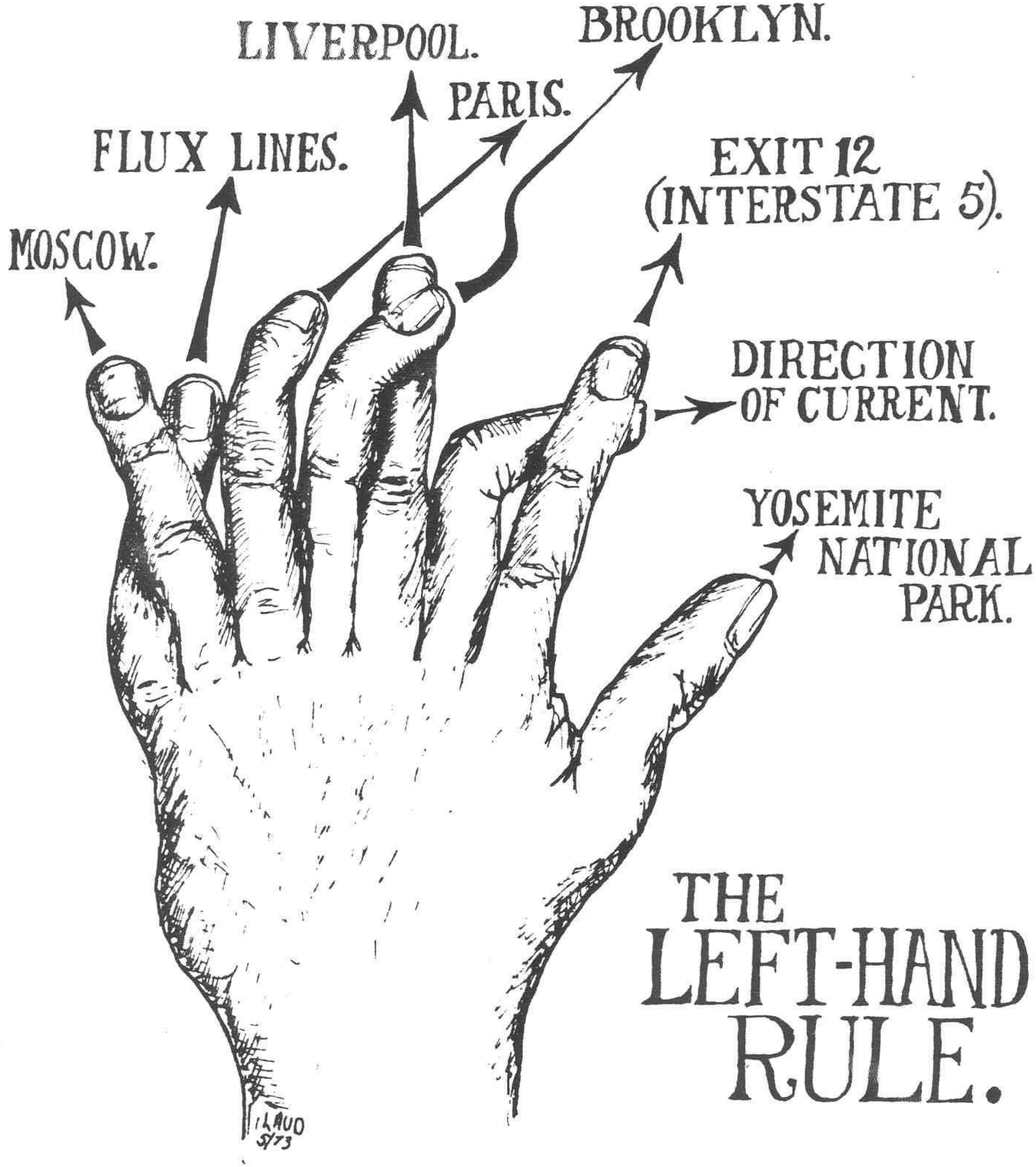


5. Which of the following pictures show a magnet incorrectly labeled after being broken into three pieces?

a) 1 & 4
b) 1 & 3
c) 1, 2, and 3
d) all 4



Click for Answers: B C B D A


LIVERPOOL.
BROOKLYN.
PARIS.
FLUX LINES.
EXIT 12
(INTERSTATE 5).
MOSCOW.
DIRECTION
OF CURRENT.
YOSEMITE
NATIONAL
PARK.
THE
LEFT-HAND
RULE.

Activity

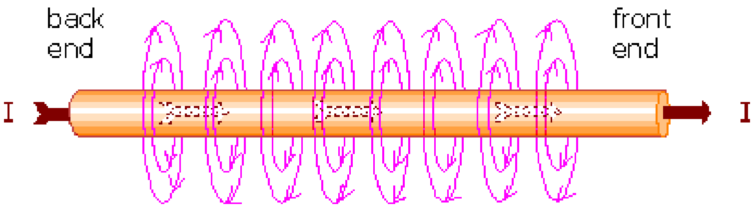
In your textbook:

- on p. 638--do #1, #2 a, d, c, f   on p. 663--do #6 - #8

Physics 3204

Unit 3: Section 3 Electromagnetism

Topic 7 : Magnetic Field Around a Straight Conductor

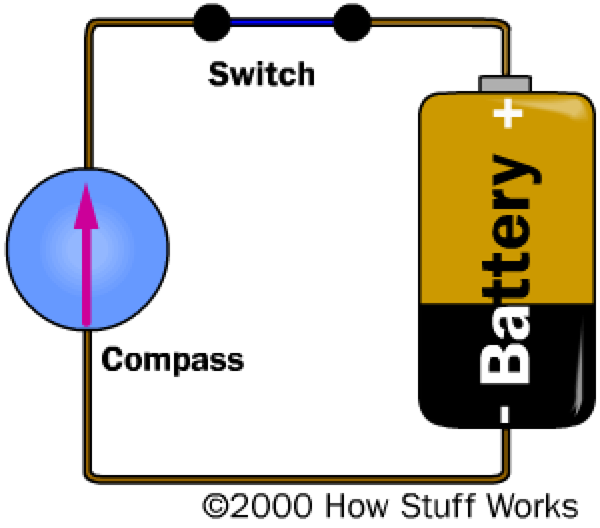


side view

TEXT REFERENCE

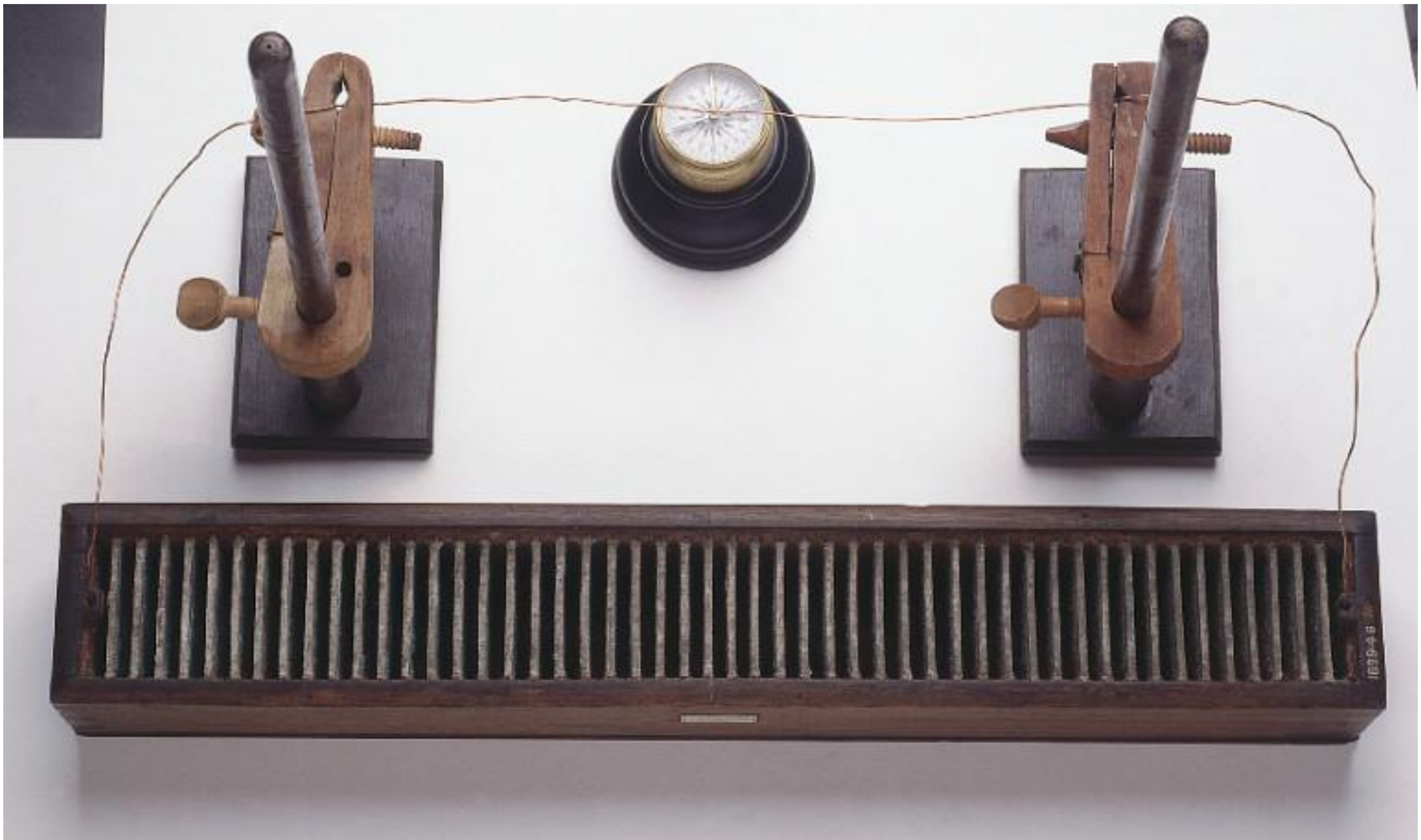
The Magnetic Field Around a Straight Conductor

Hans Oersted, (1777-1851), a Danish physicist, in 1819, discovered the deflection of a compass needle while near a current-carrying wire.

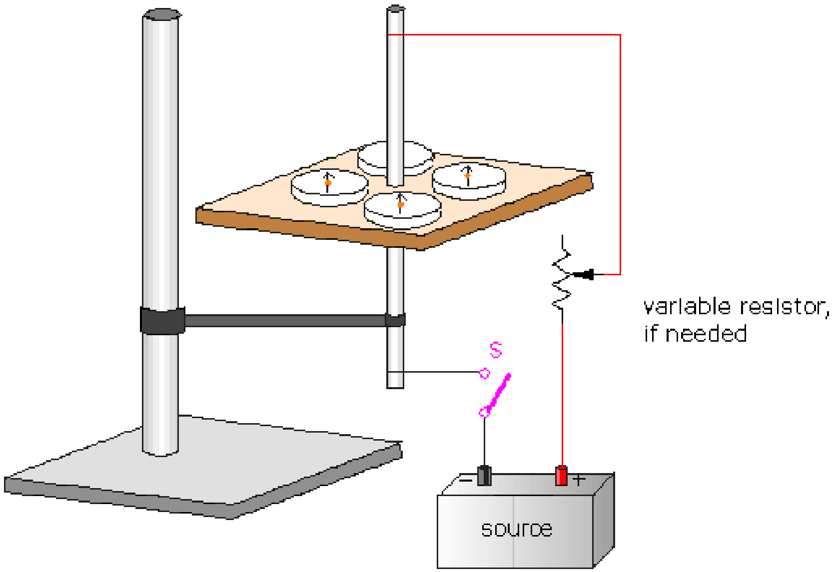


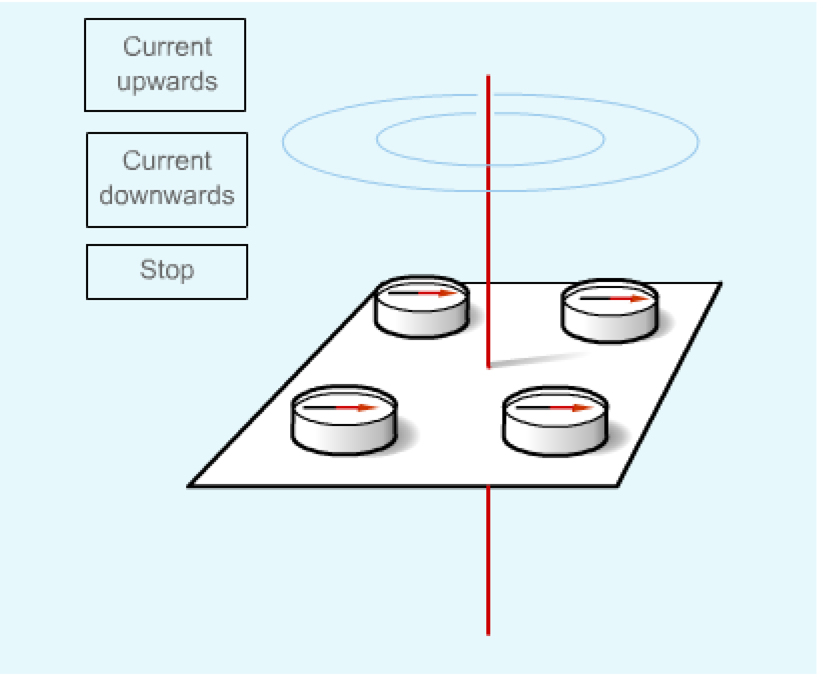
This discovery of a connection between electricity and magnetism rocked the scientific community.

Oersted's Experiment

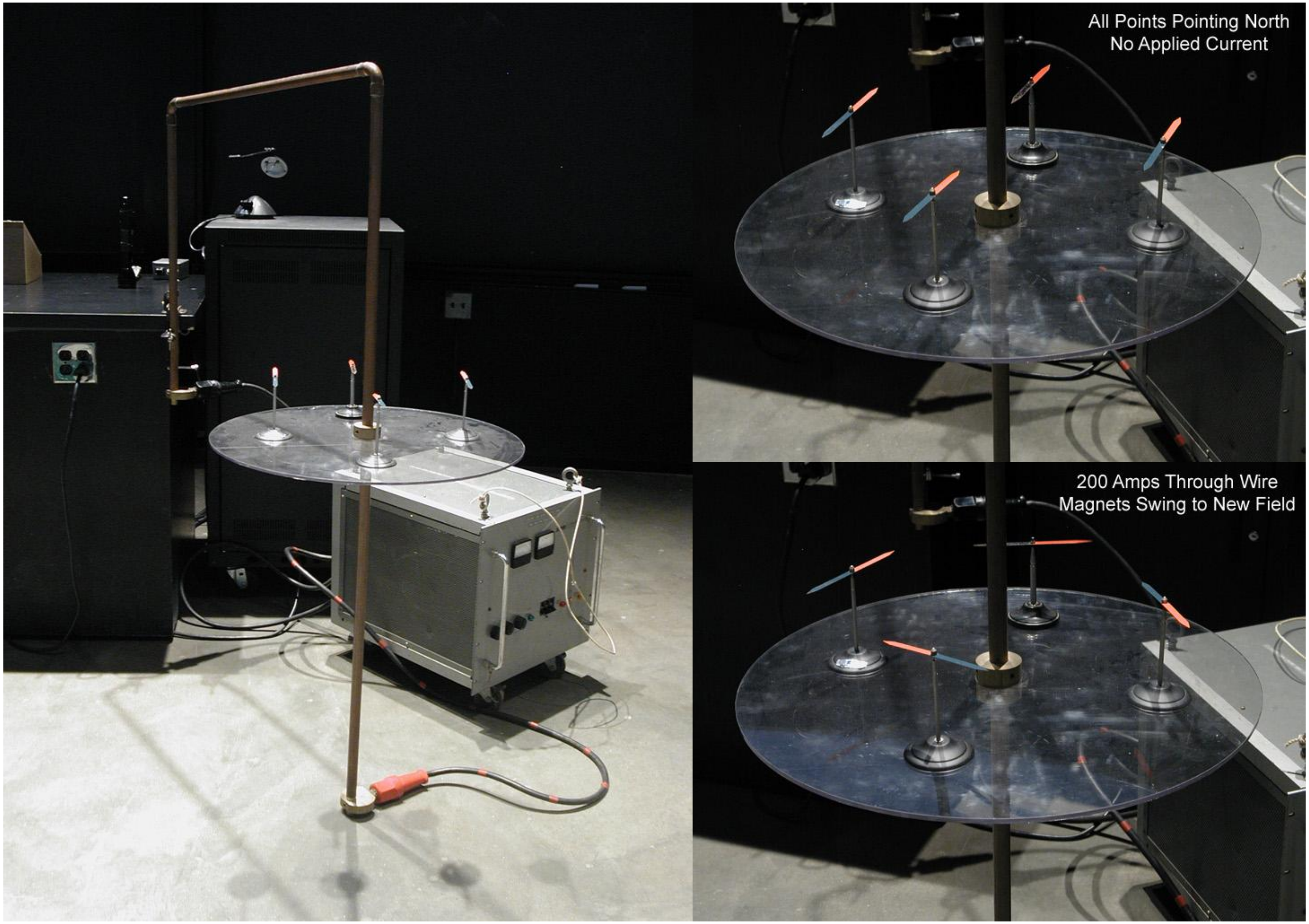


Hans Oersted's research revealed that the magnetic field lines form concentric circles around the wire. The direction of the magnetic field is perpendicular to the wire.





A current-carrying conductor produces a magnetic field around it

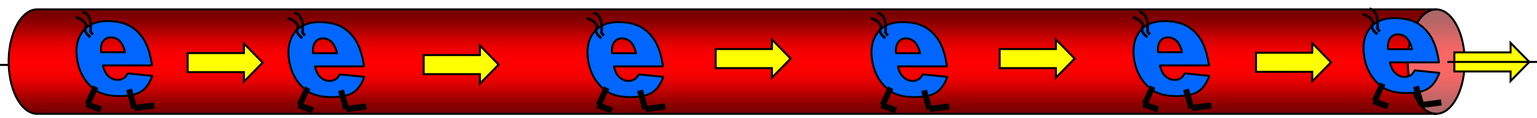


Cautionary Note

You are going to meet several left-hand rules. It is extremely important to remember that left-hand rules do not work for moving positive charges (only for moving negative charges).

Equally important, if you do physics in college or university, you will likely be using conventional current (flowing from + to - as pointed out in Section 02, Lesson 01). Left hand rules do not work for conventional current.

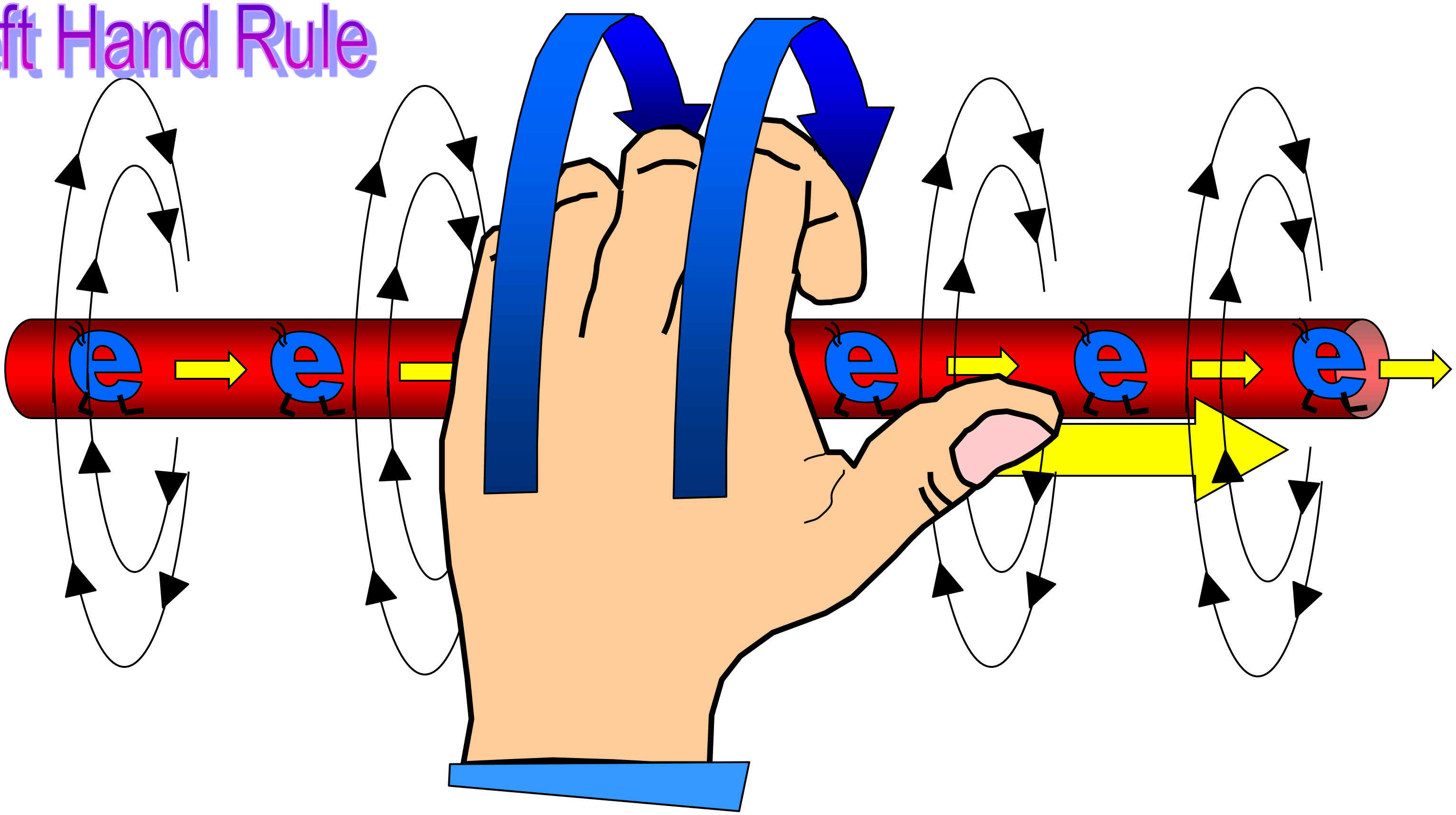
1st Left Hand Rule



Magnetic Fields

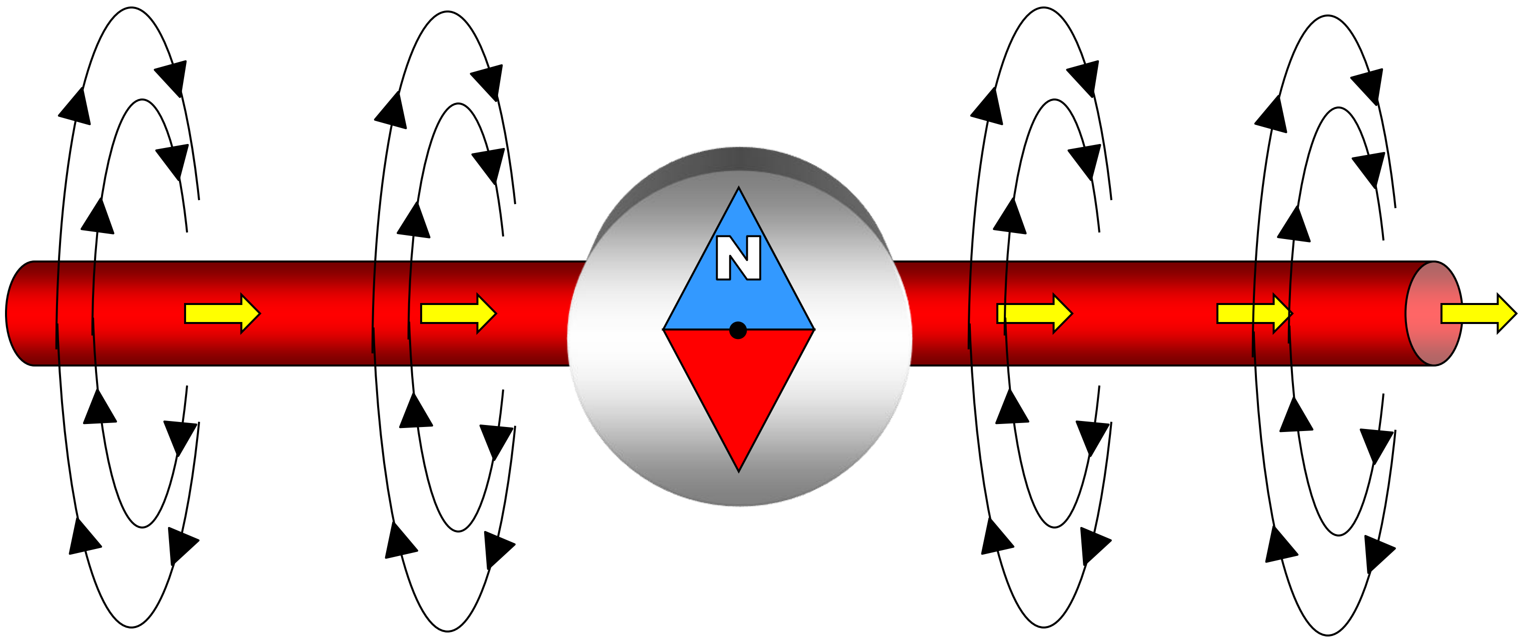
around current bearing wires

1st Left Hand Rule

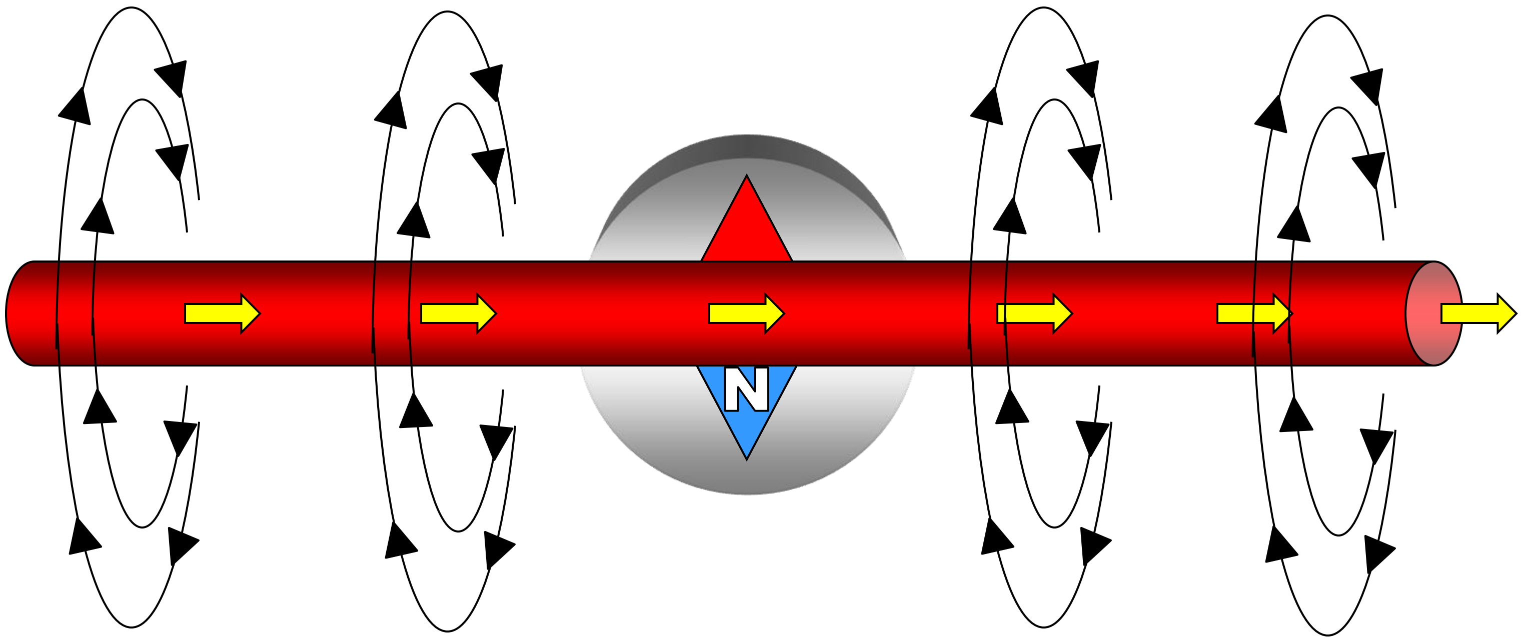


Thumb points in the direction of **electron** flow.

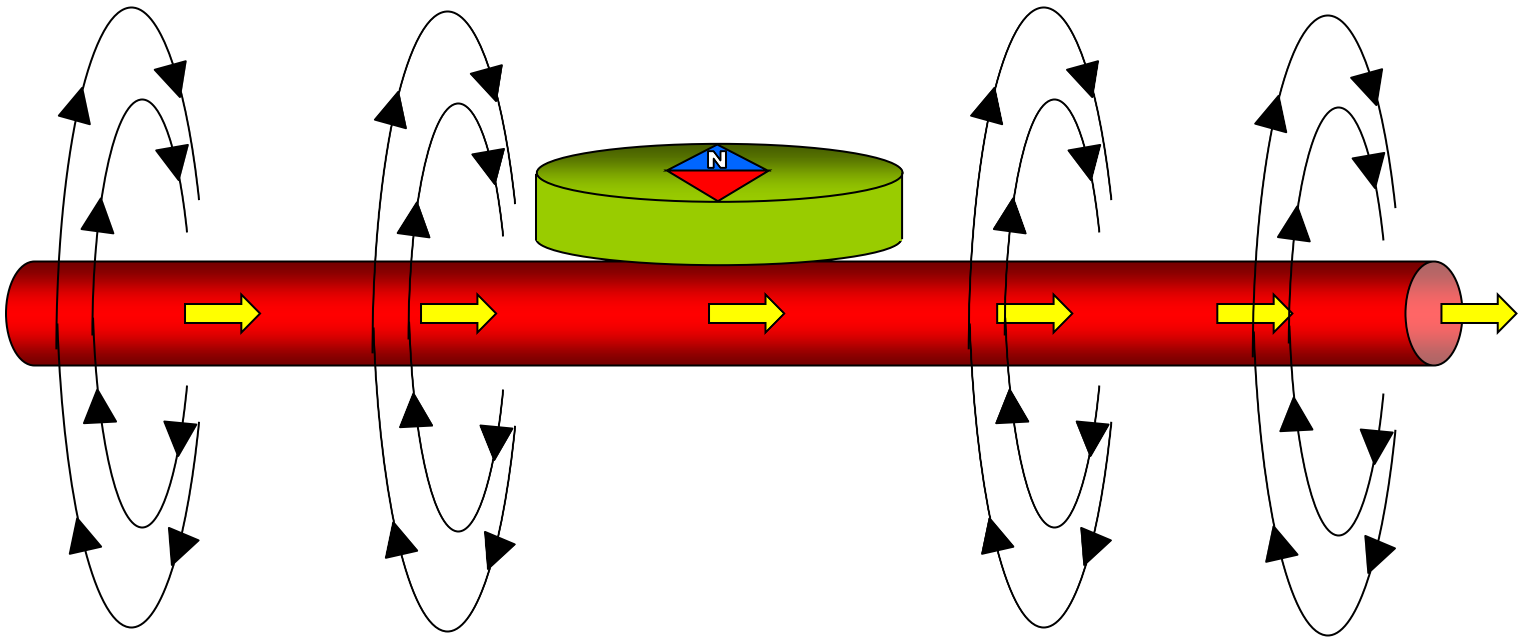
Fingers curl around the wire in the direction of the magnetic field.



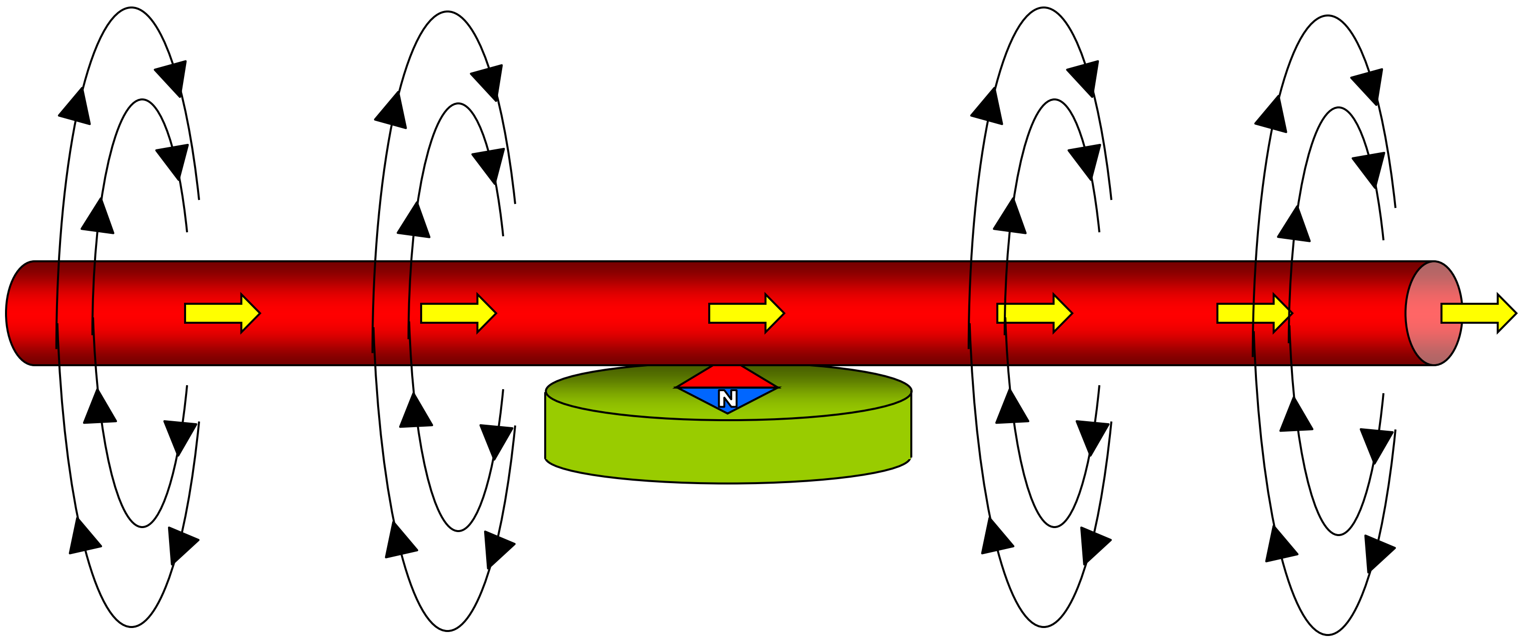
The magnetic field in front of the wire points towards the top of the page.



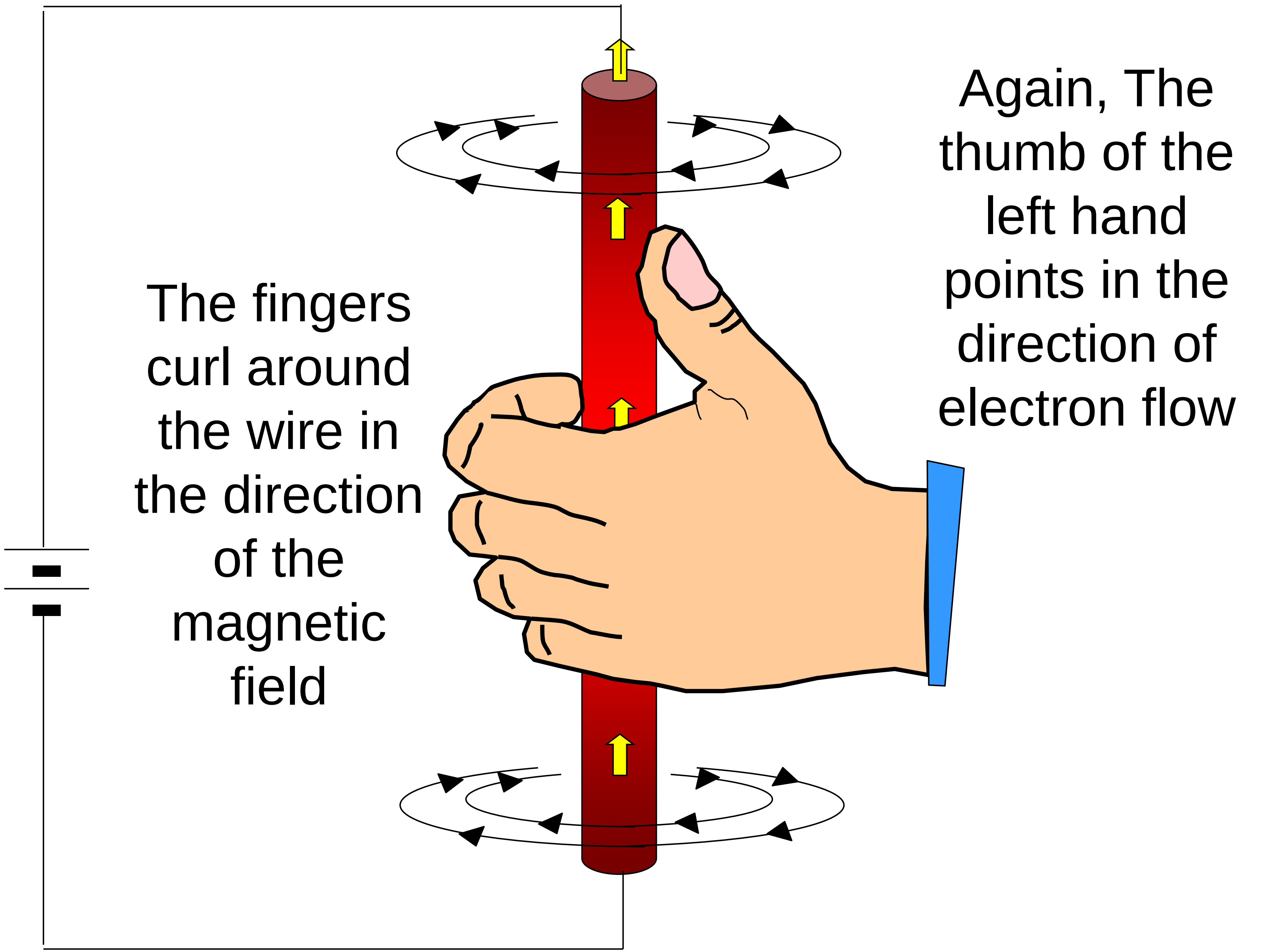
The magnetic field behind the wire points towards the bottom of the page.

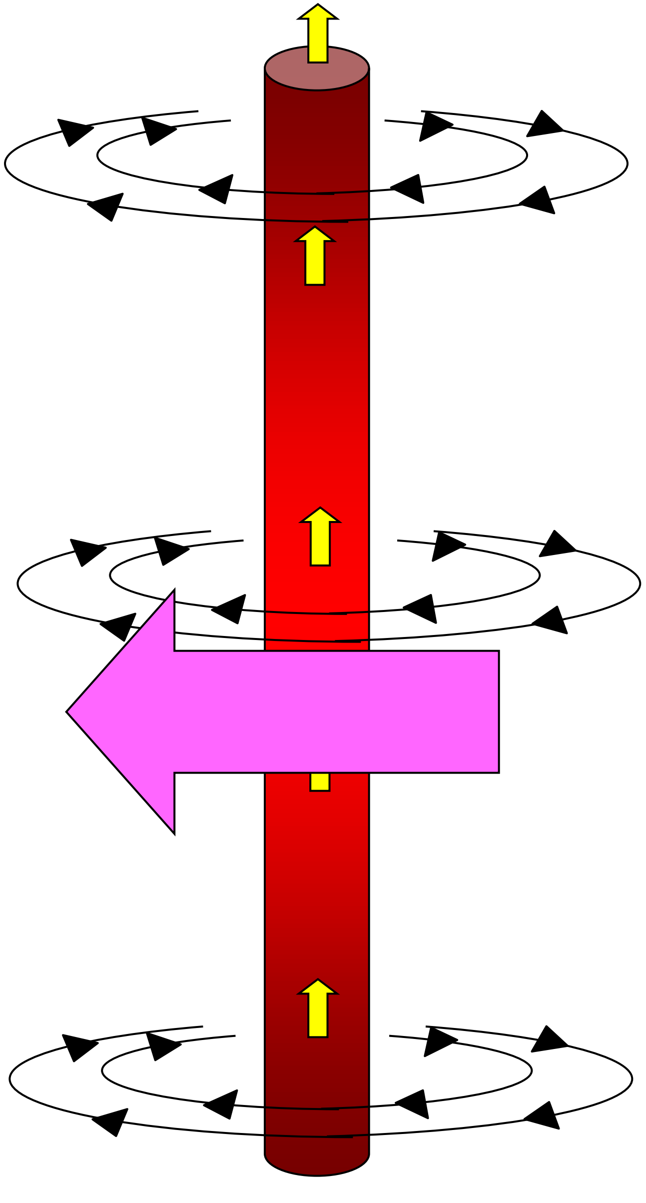


The magnetic field above the wire points into the page.



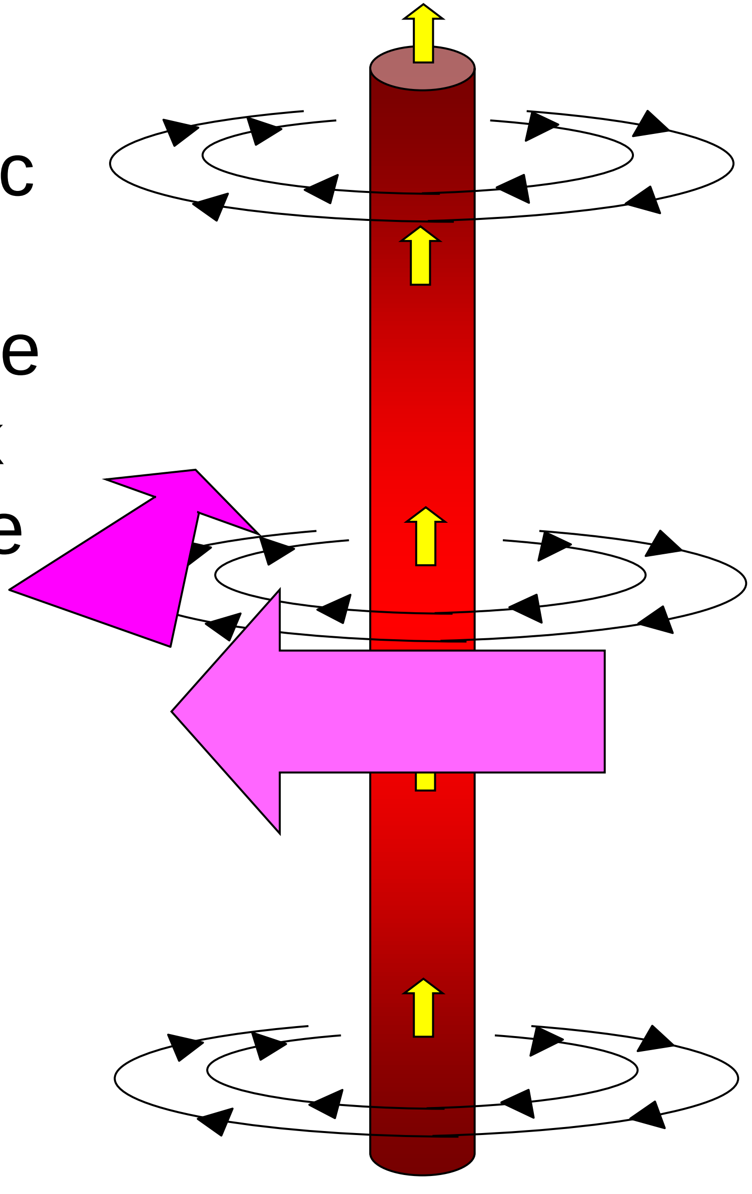
The magnetic field below the wire points out of the page.

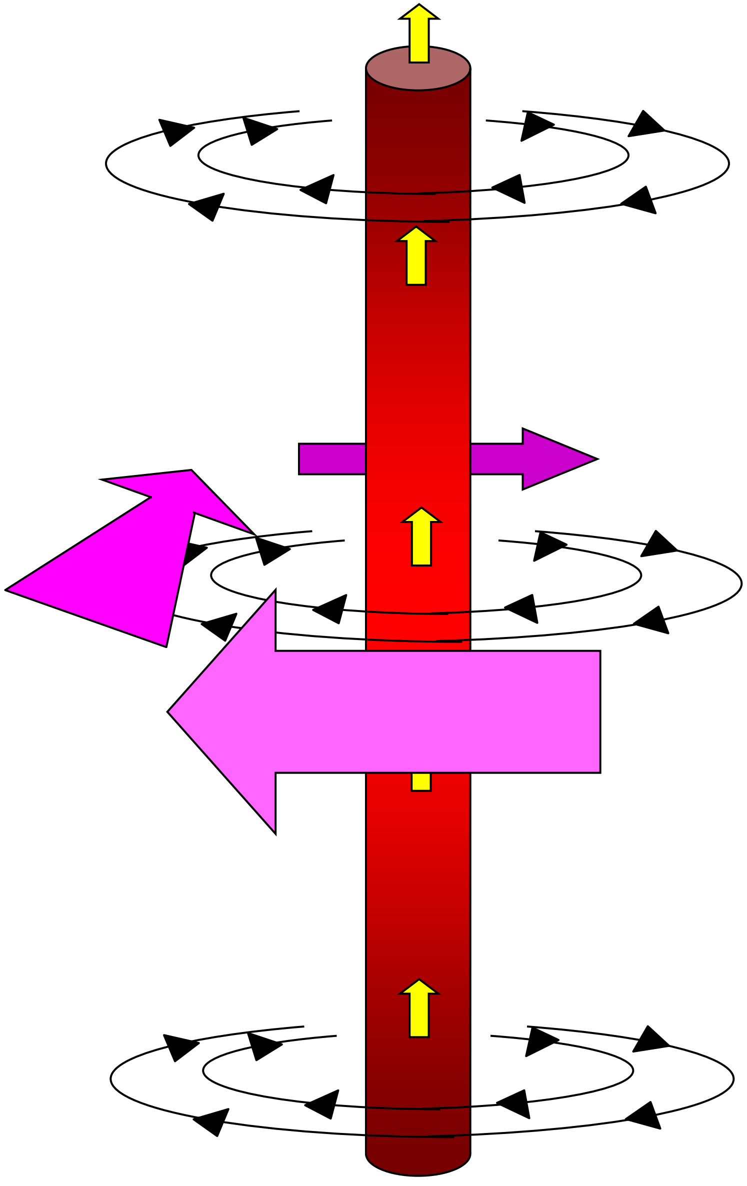

The fingers curl around the wire in the direction of the magnetic field
Again, The thumb of the left hand points in the direction of electron flow



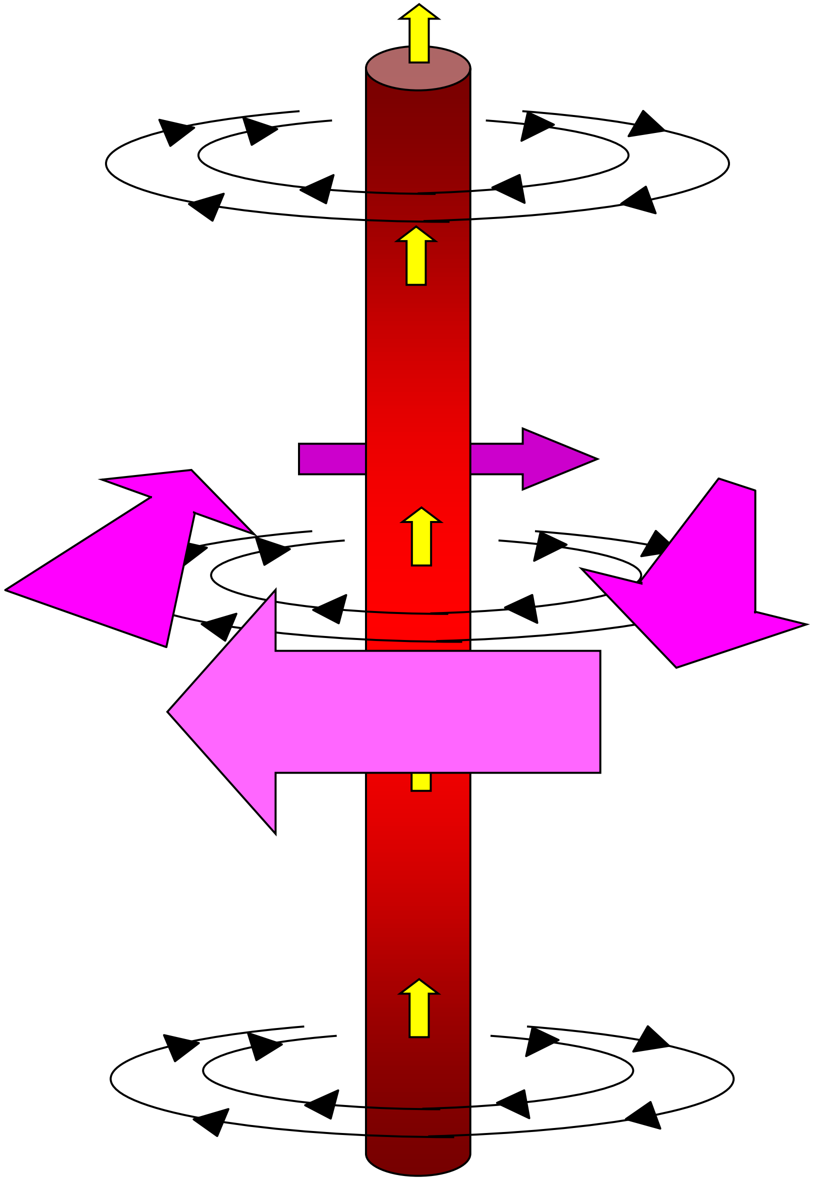
The magnetic field in front of the wire is to the left

The magnetic field on the left side of the wire is back into the page



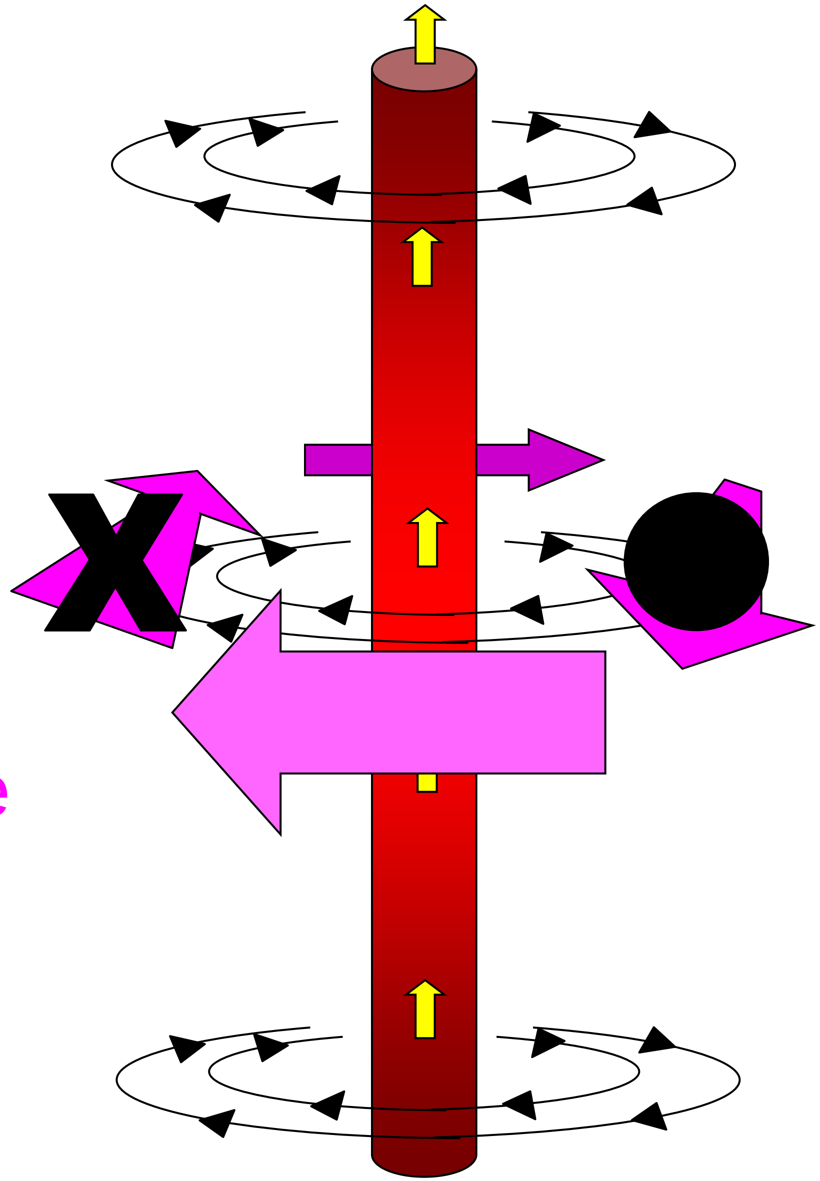


The magnetic field behind the wire is to the right

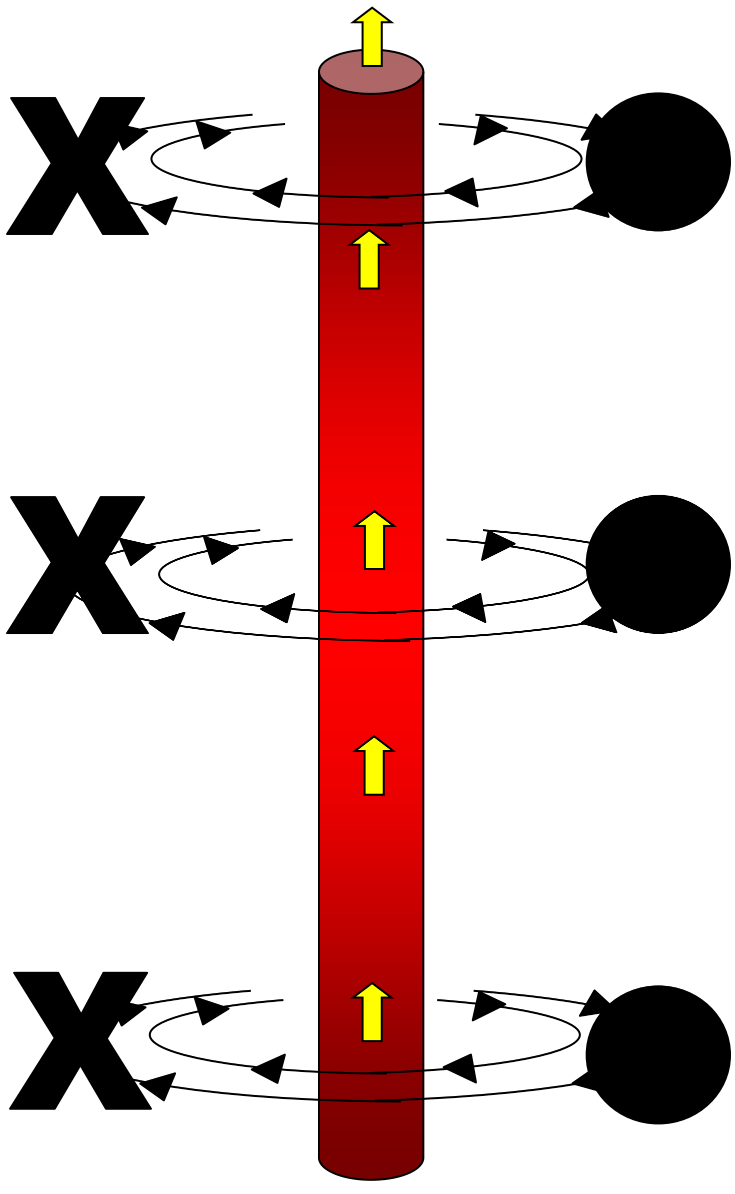


The magnetic field on the right side of the wire is pointed out of the page

Out of the page is shown by a dot

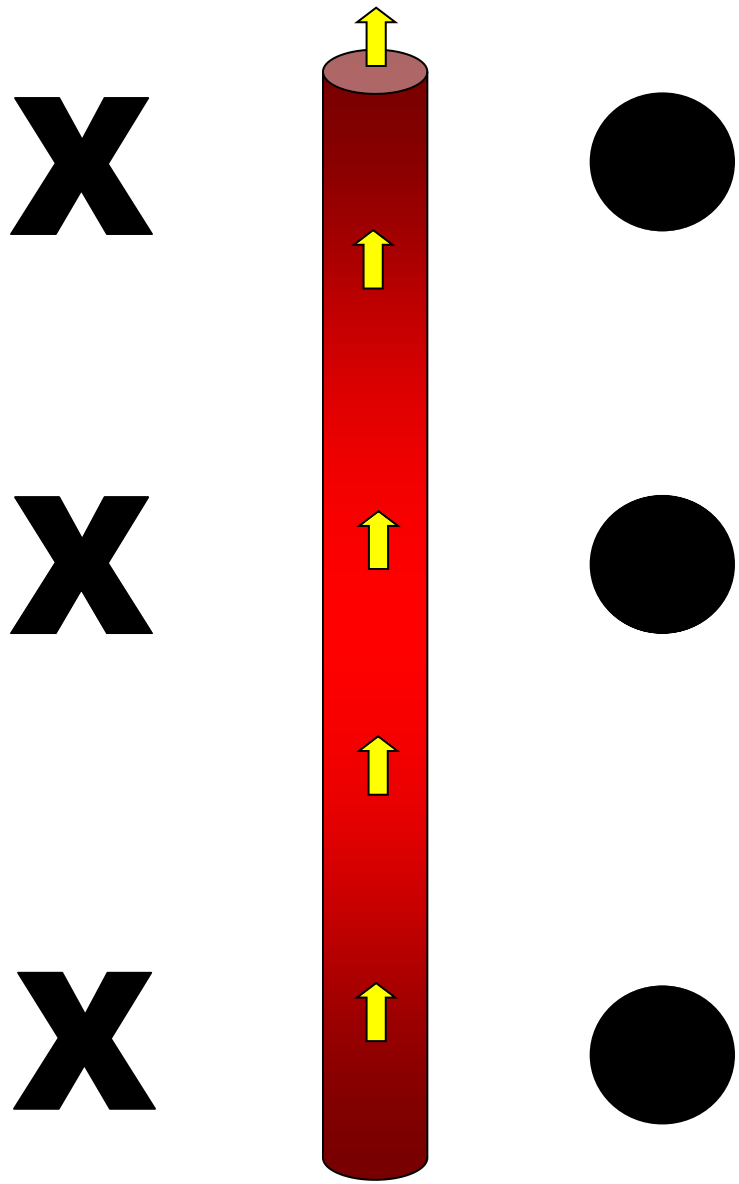


Into the page is shown by an X



Out of the page is shown by a dot

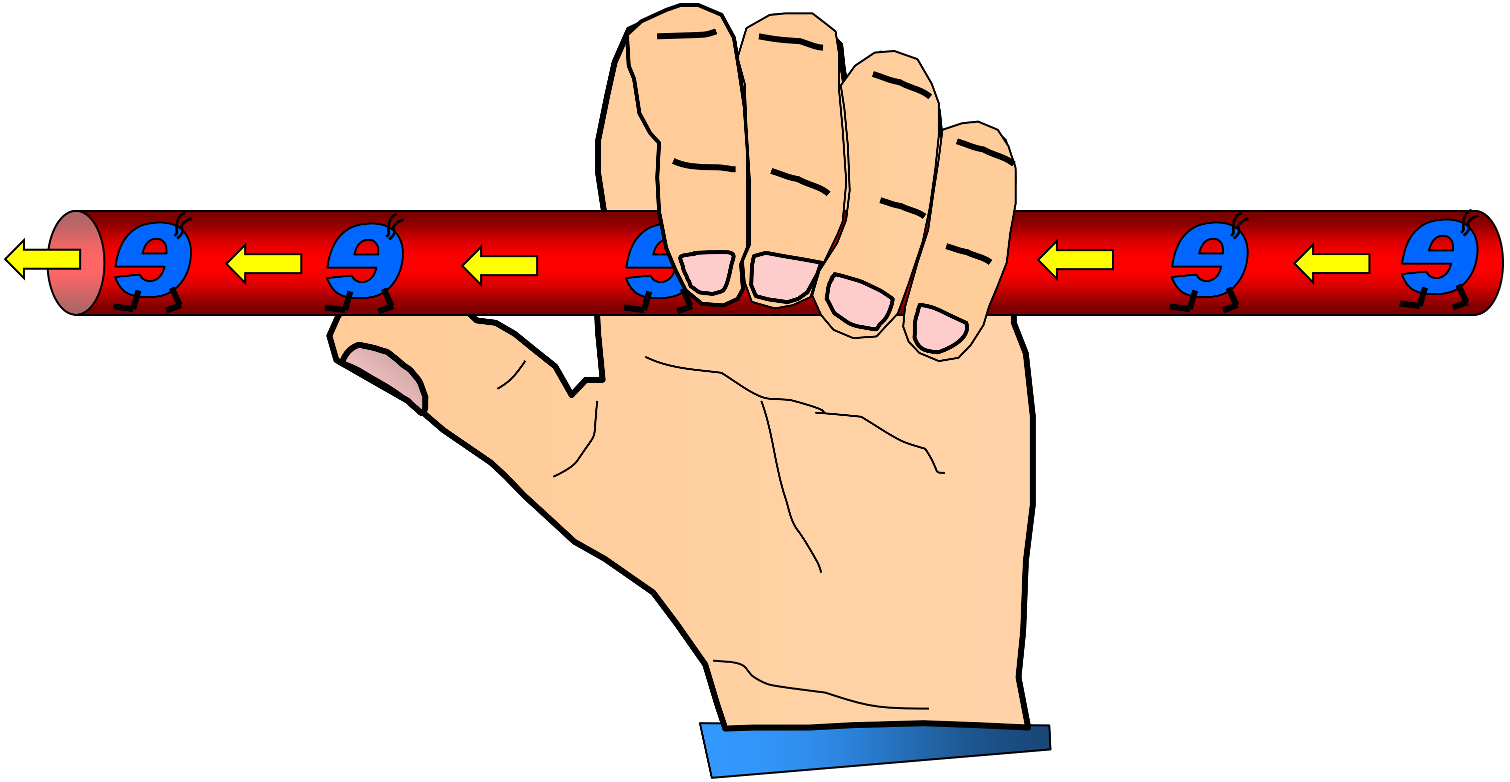
Into the page is shown by an X



Out of the page is shown by a dot

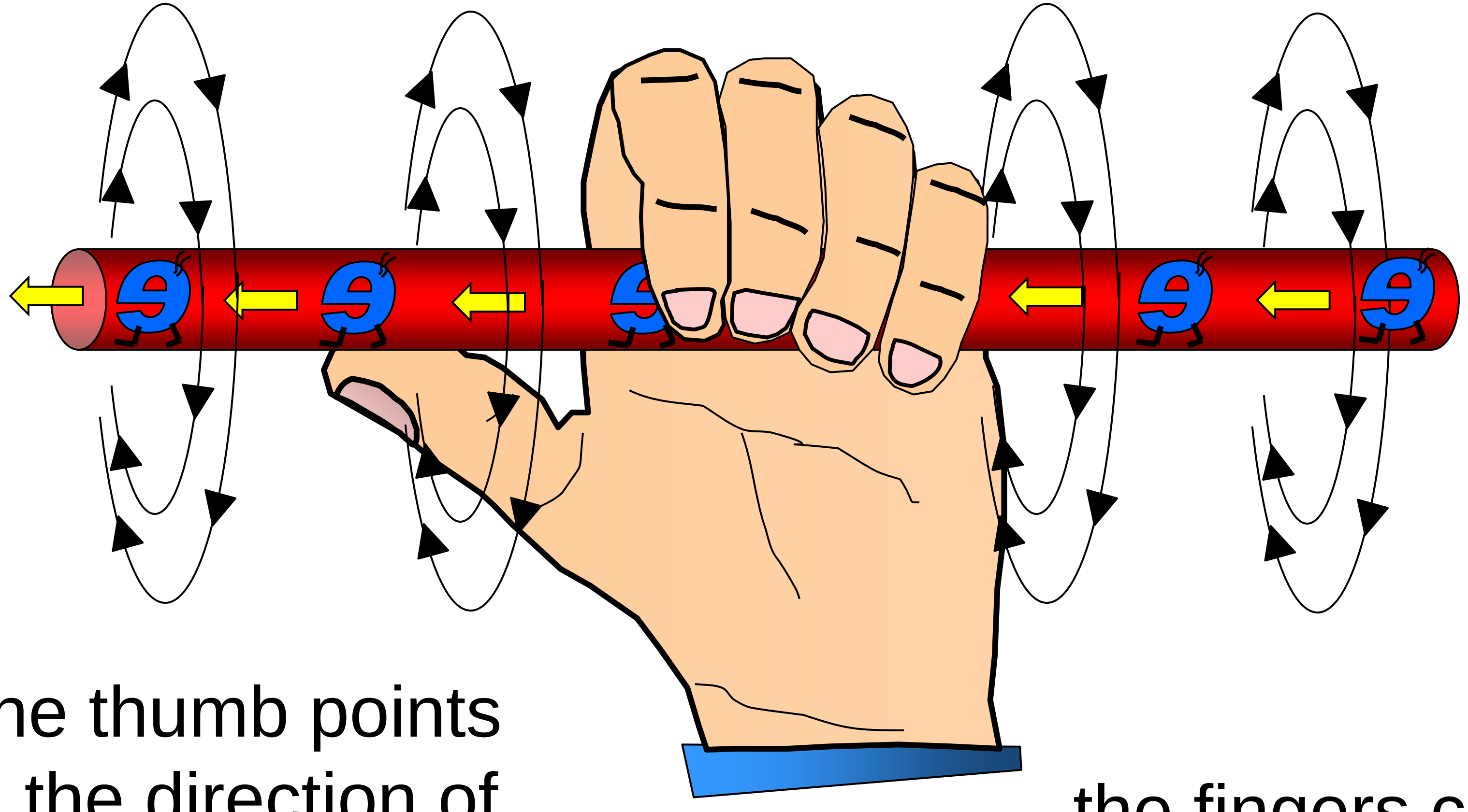
Into the page is shown by an X

The current flow is now to the left



Grasp the wire with your LEFT hand

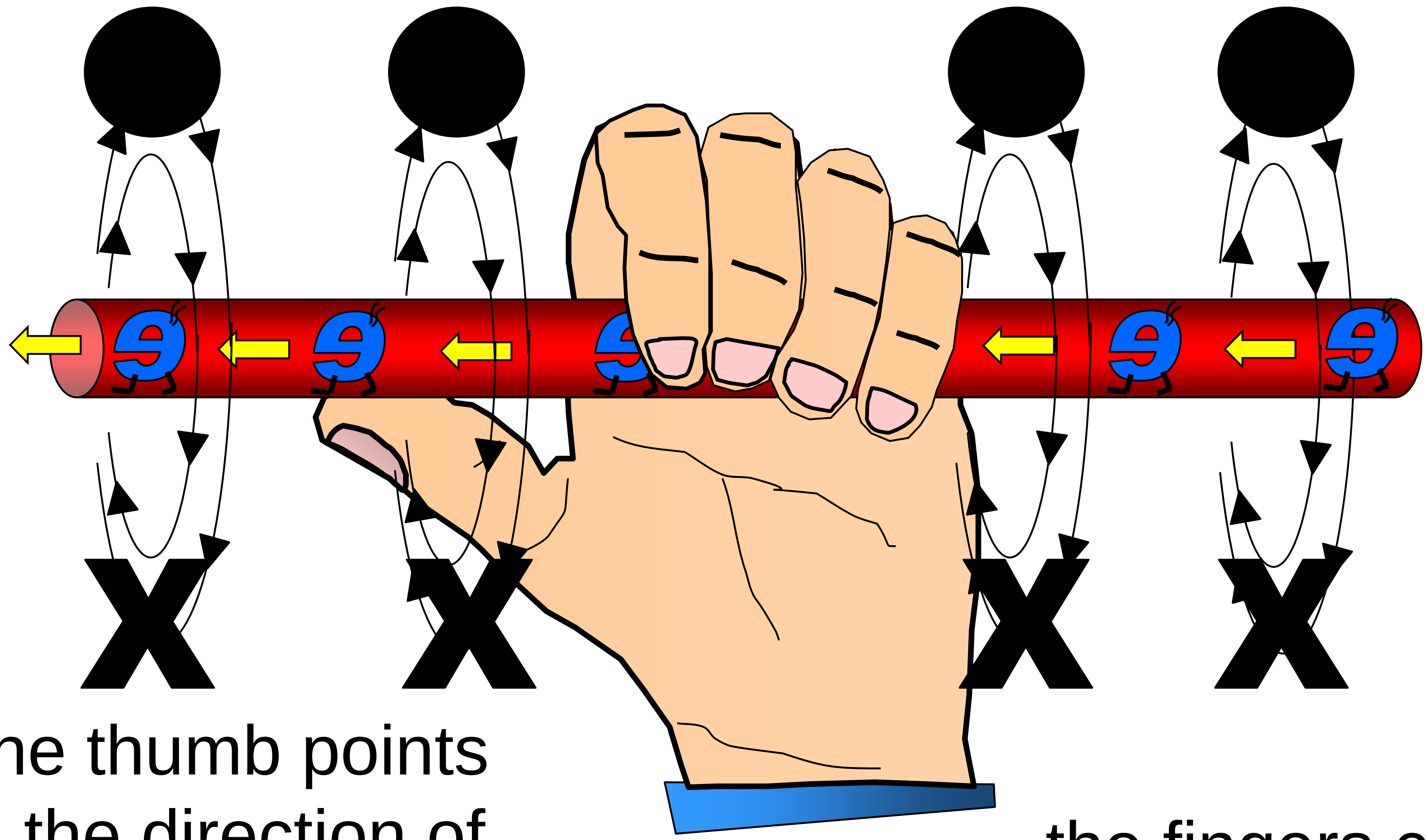
The current flow is now to the left



The thumb points in the direction of electron flow,

the fingers curl around the wire in the direction of the magnetic field.

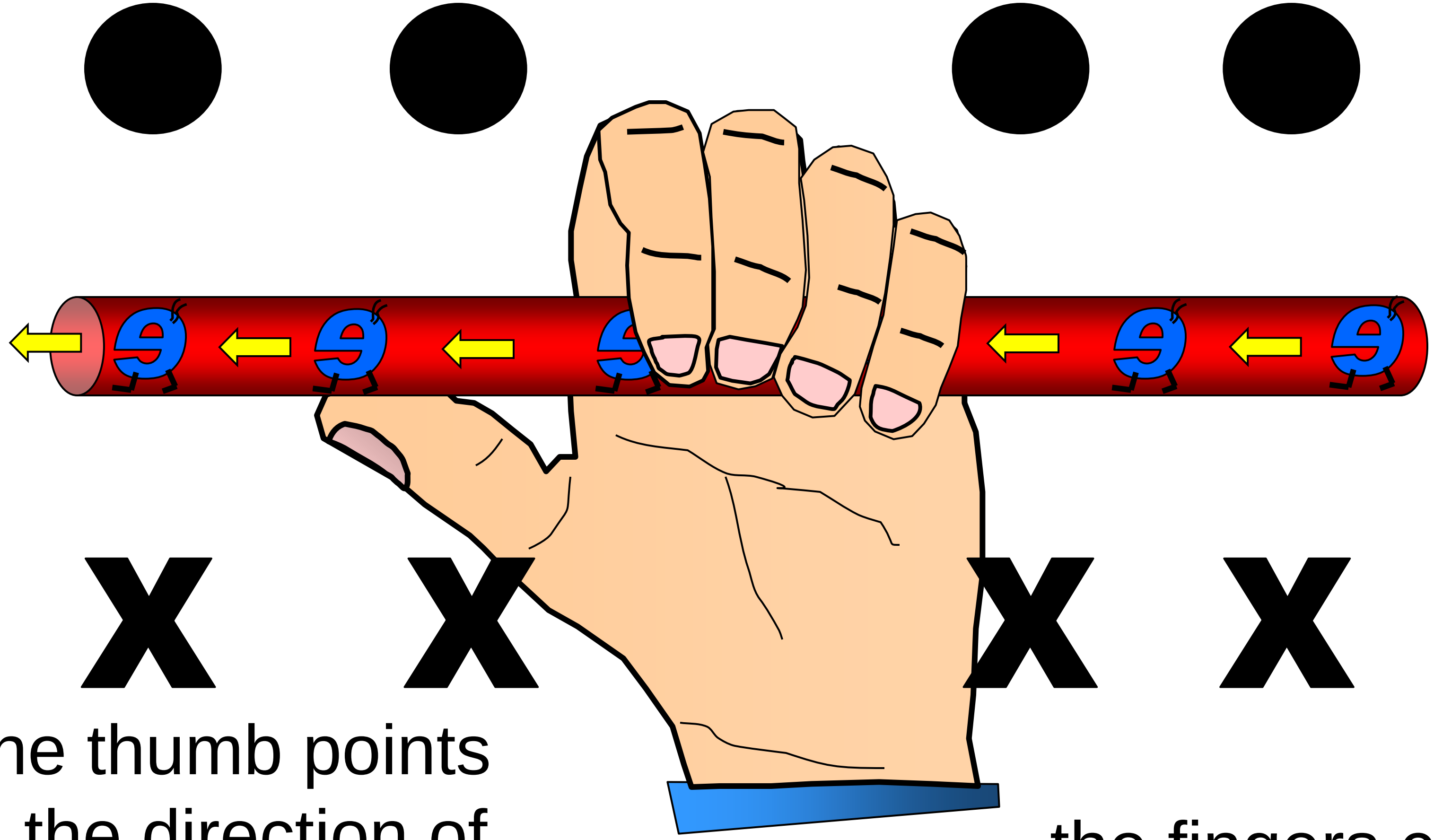
The current flow is now to the left



The thumb points in the direction of electron flow,

the fingers curl around the wire in the direction of the magnetic field.

The current flow is now to the left



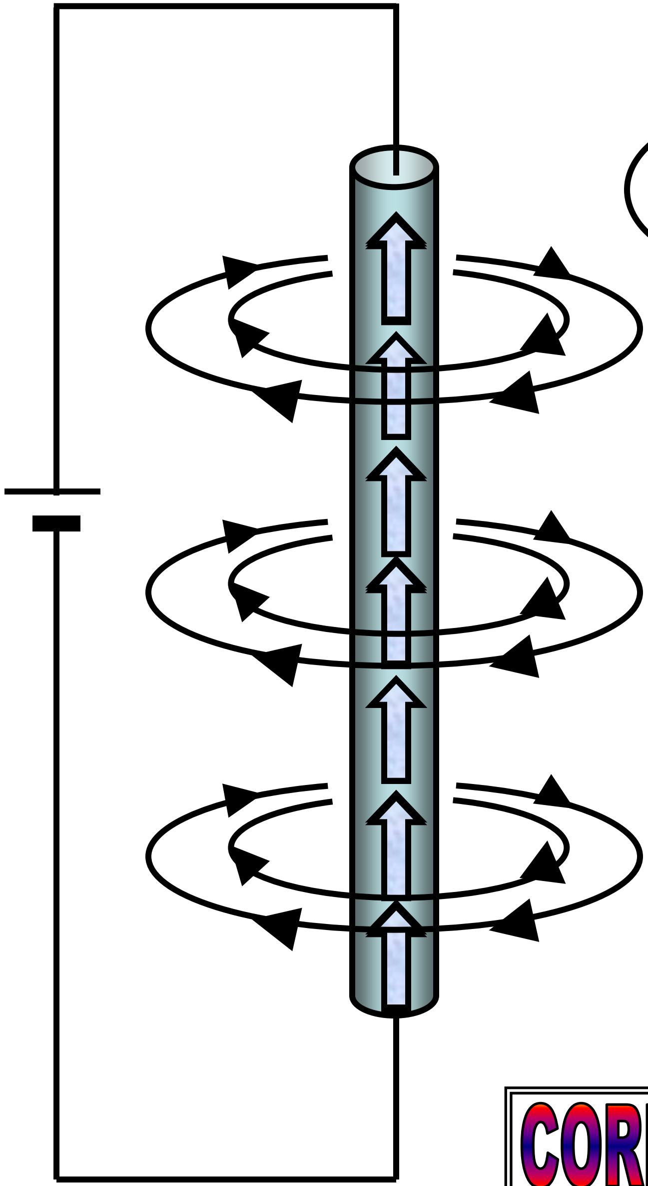
The thumb points in the direction of electron flow,

the fingers curl around the wire in the direction of the magnetic field.

Each of the following diagrams shows a section of wire that has been enlarged.

Associated with each wire is the direction of current flow and the magnetic field around the wire.

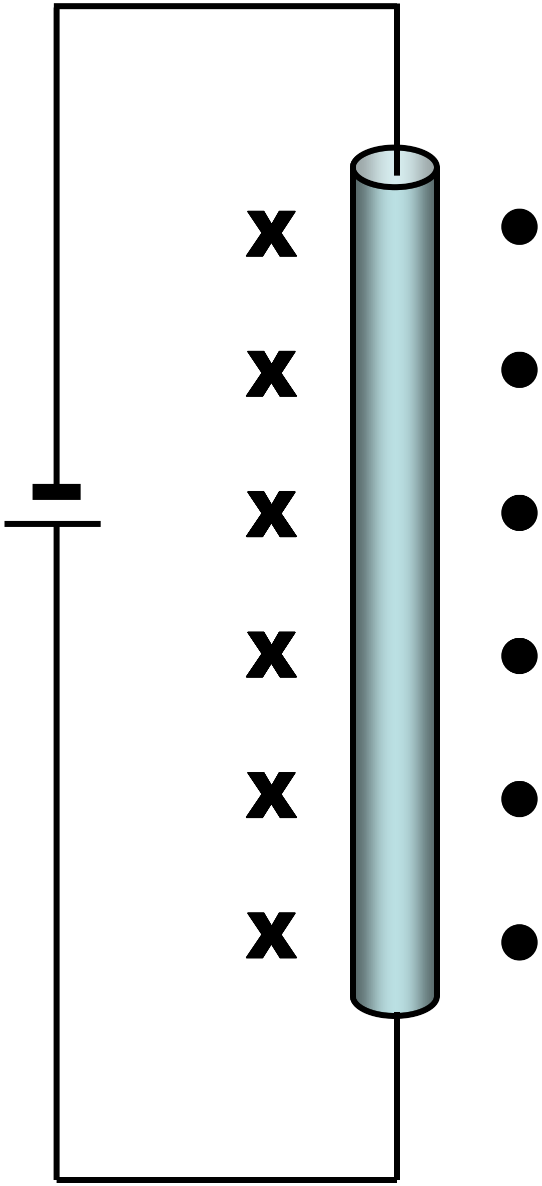
Determine which of the following diagrams are correct.



Does the diagram at the right show the correct orientation of the magnetic field around the current bearing wire?.

CORRECT

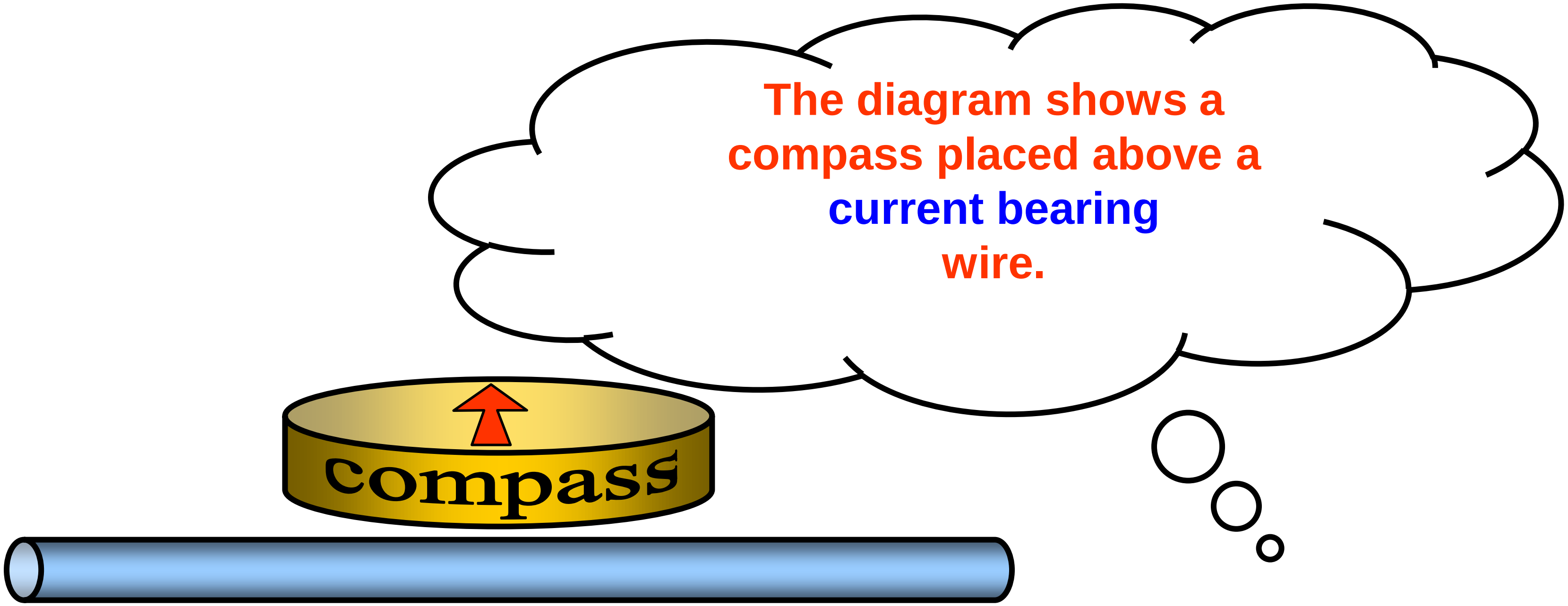
WRONG

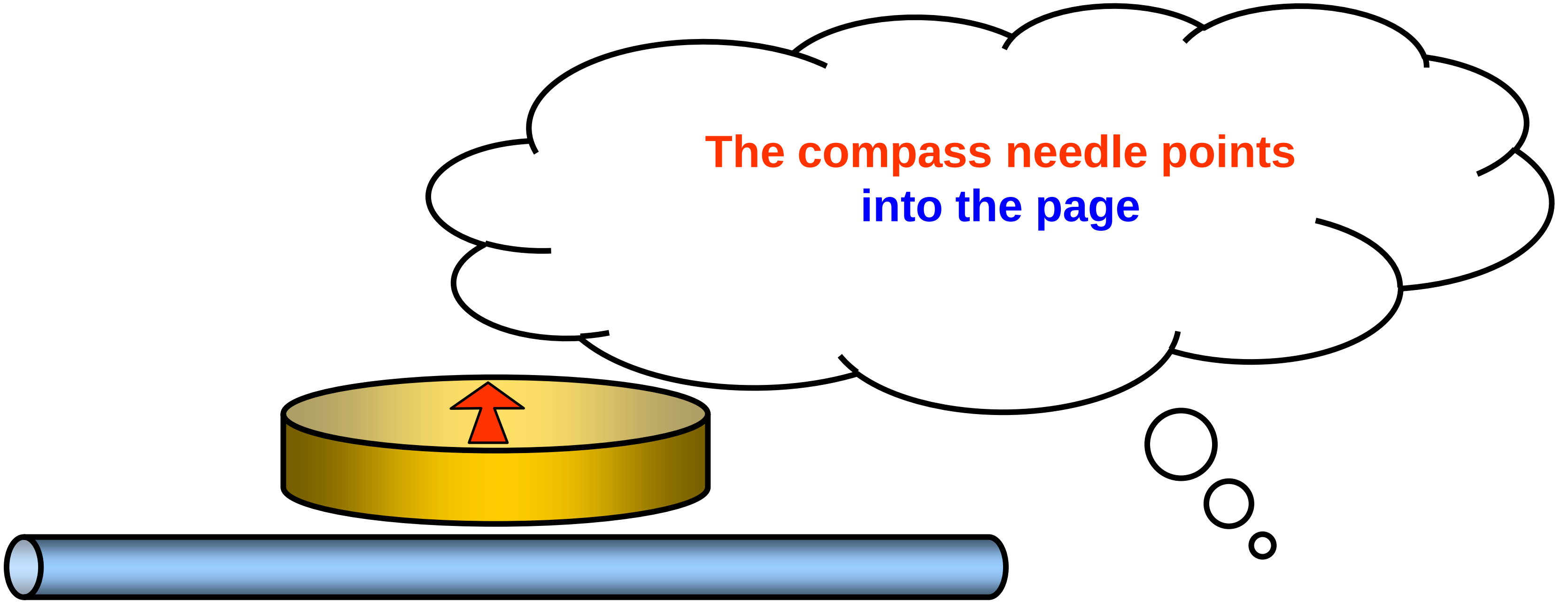


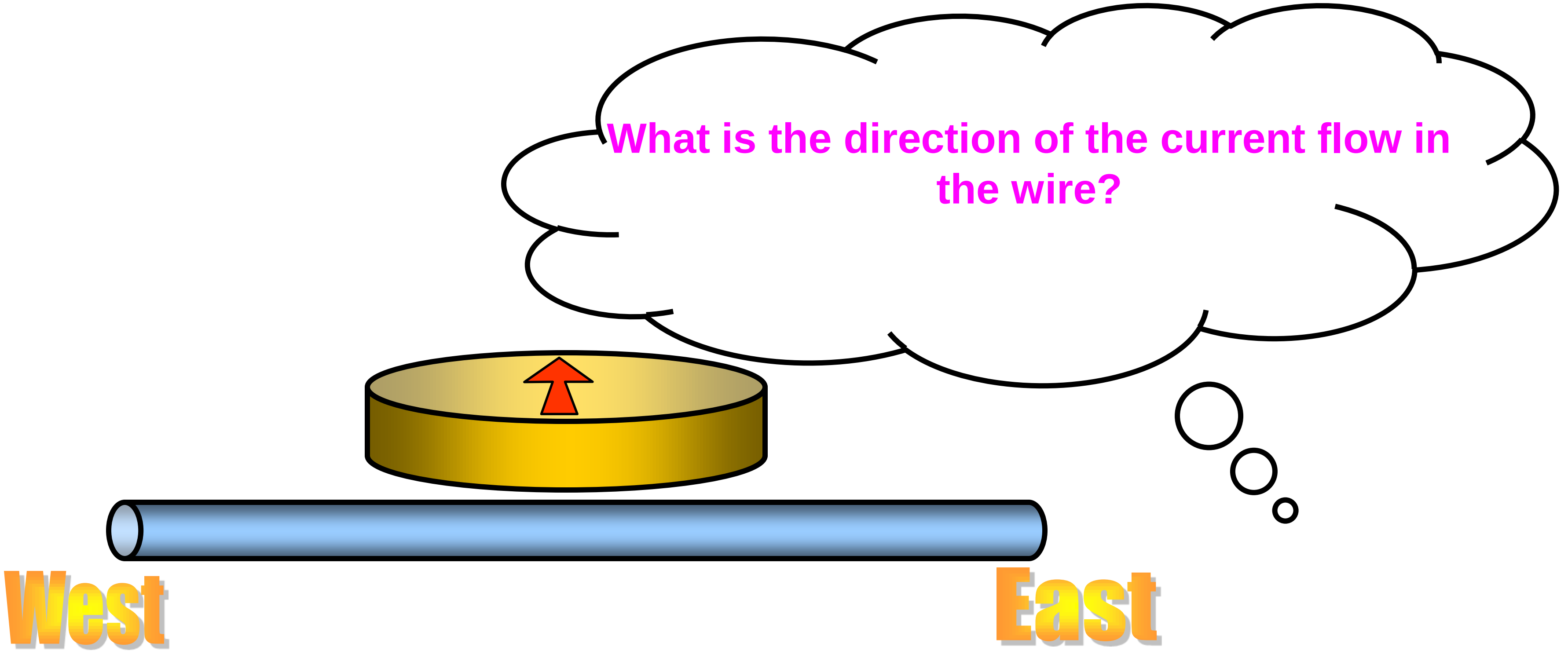
Is the diagram at the left correct?

The diagram is…

CORRECT WRONG


The diagram shows a compass placed above a current bearing wire.
compass

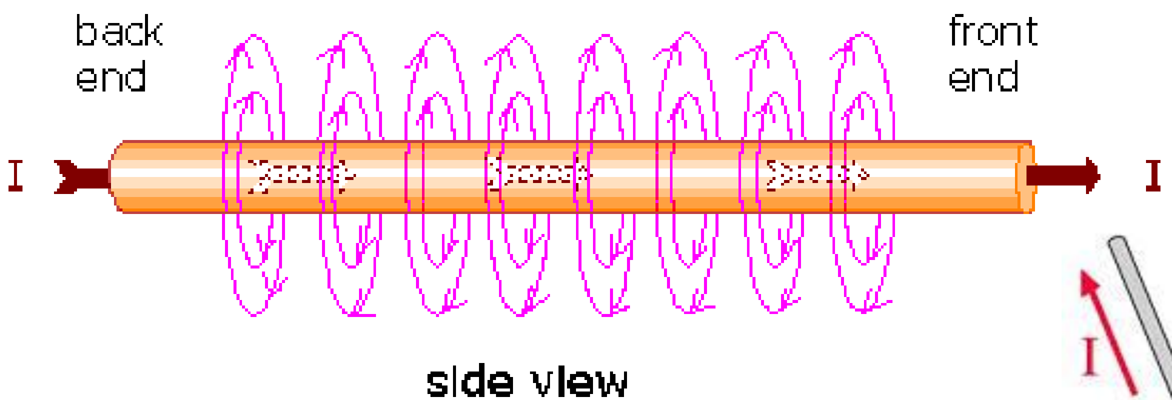

The compass needle points
into the page

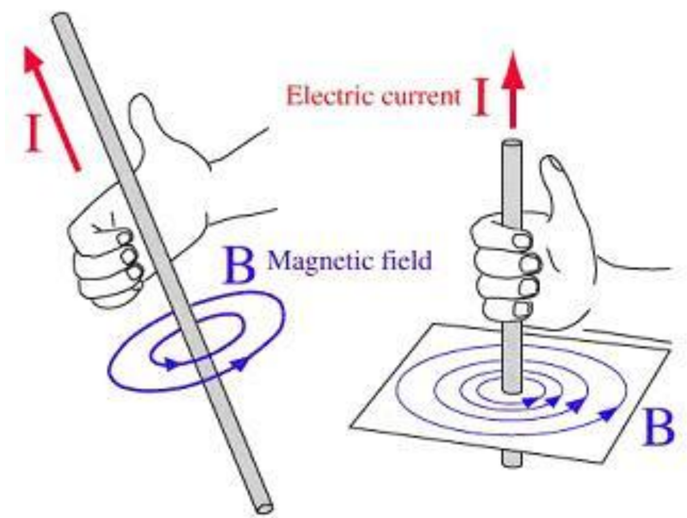


Click on your choice above.

Summary of Left Hand Rule # 1

The direction of the magnetic field is perpendicular to the wire and is in the direction the fingers of your left hand would curl if you wrapped them around the wire with your thumb in the direction of the current.

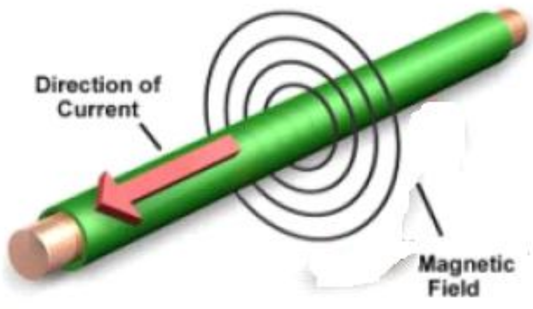




Physics 3204

Unit 3: Section 3 Electromagnetism

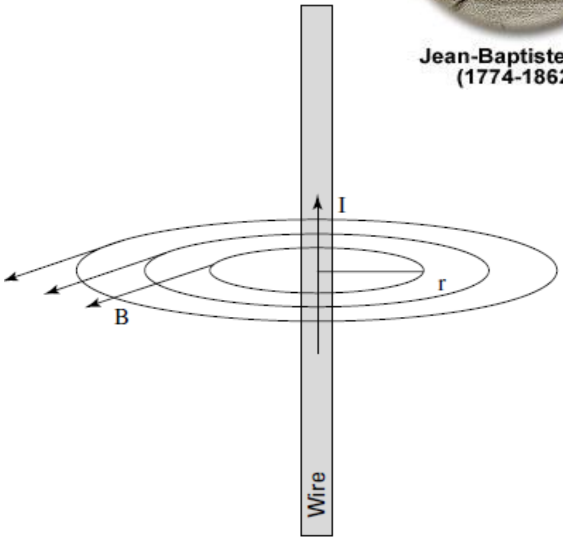
Topic 8 : Using Biot's Law to Calculate Magnetic Field



TEXT REFERENCE

Jean-Baptiste Biot (1774-1862) was able to calculate the magnetic field strength at a certain distance from a wire.

Biot Law states that the magnetic field strength (B) is directly proportional to the current in a straight conductor, and inversely proportional to the perpendicular distance (r) away from the conductor.



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

B is magnetic field =>Tesla (T)

I is current => Amperes => A

μ_o is magnetic permeability => T·m/A

If the field is in free space, the μ is written as μ_o where $\mu_o = 4\pi \times 10^{-7}$ T·m/A. Air can be considered to be free space.

Practice exercise 1

Find the magnetic field strength (B) in air 7.0 mm away from a straight conductor in which there is a current of 2.0 A.

Solution

r = 7.0 mm = 7.0 x 10-3 m

I = 2.0 A

μo = 4π x 10-7 T·m/A (air)

B = ?

Practice exercise 2

A potential difference of 12.0 V is applied to a straight conductor, the magnetic field strength (B) 2.0 cm from the conductor is 3.0×10^{-5} T. What is the resistance of the conductor?

Solution

$V = 12.0$ V

$\mu_o = 4p \times 10^{-7}$ T·m/A (air)

$R = ?$

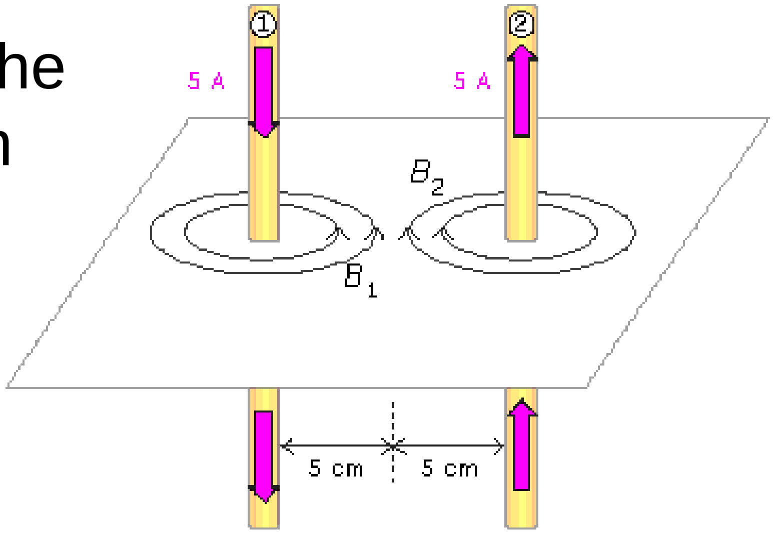
$B = 3.0 \times 10^{-5}$ T

$r = 2.0$ cm $= 2.0 \times 10^{-2}$ m

$I = ?$

Practice Exercise 3

Two parallel wires each carry 5.0 A of current in opposite directions. What is the magnetic field strength midway between the wires if the wires are 10 cm apart?



Solution

$I_1 = I_2 = I = 5\ A$

$r_1 = r_2 = r = 5.0\ cm = 5.0 \times 10^2\ m$

$\mu_o = 4p \times 10^{-7}\ T \cdot m/A$ (air)

$B_1 = ?$ $B_2 = ?$

Assigned activities

Worksheet: The Magnetic Field (B) around a Straight Current Carrying Conductor

Activity

Worksheet: Mapping Magnetic Fields

Physics 3204

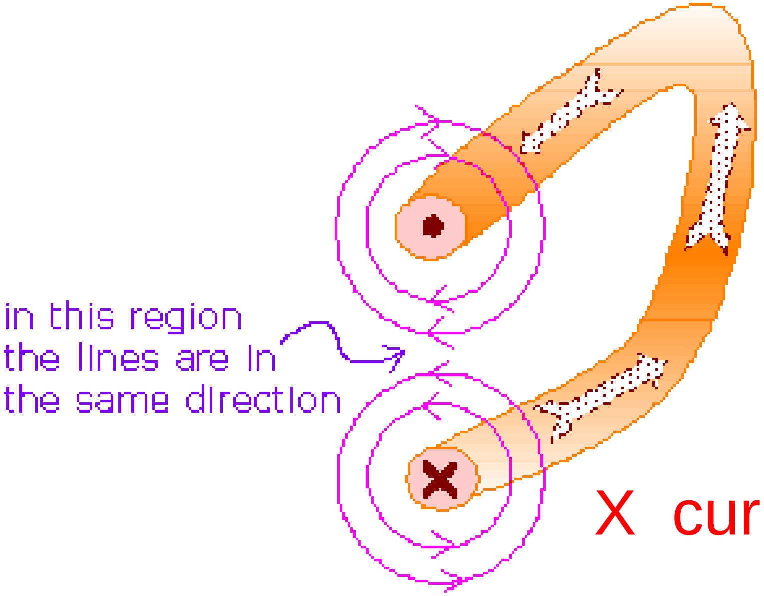
Unit 3: Section 3 Electromagnetism

Topic 9 : Solenoids and Magnetic Field

TEXT REFERENCE

Magnetic Field Around A Wire Carrying Current

Imagine that the wire is bent so the back end is on the bottom with the current going into the screen



● represent current coming out of the screen

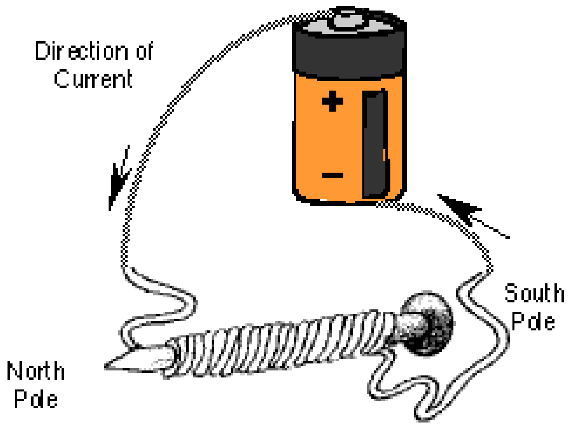
X current going into the page

left-hand rule #1 can be used to confirm that the magnetic field is in the proper direction. Note the region where the magnetic field lines are in the same direction.

Electromagnets-Solenoids

Solenoids consist of a tightly wrapped coil of wire, sometimes around an iron core. They are one of the most common electromagnets.

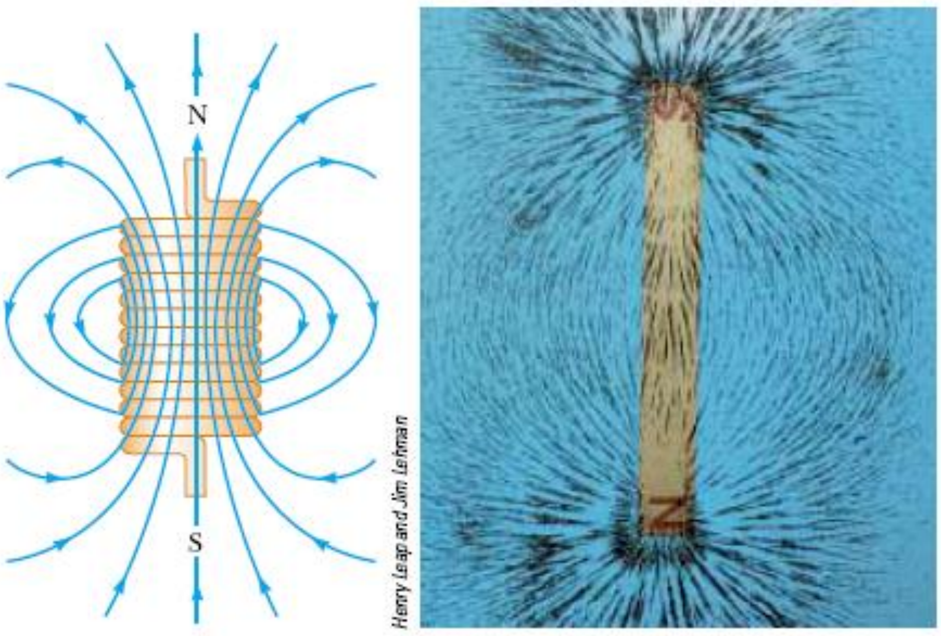
Solenoid you have seen!



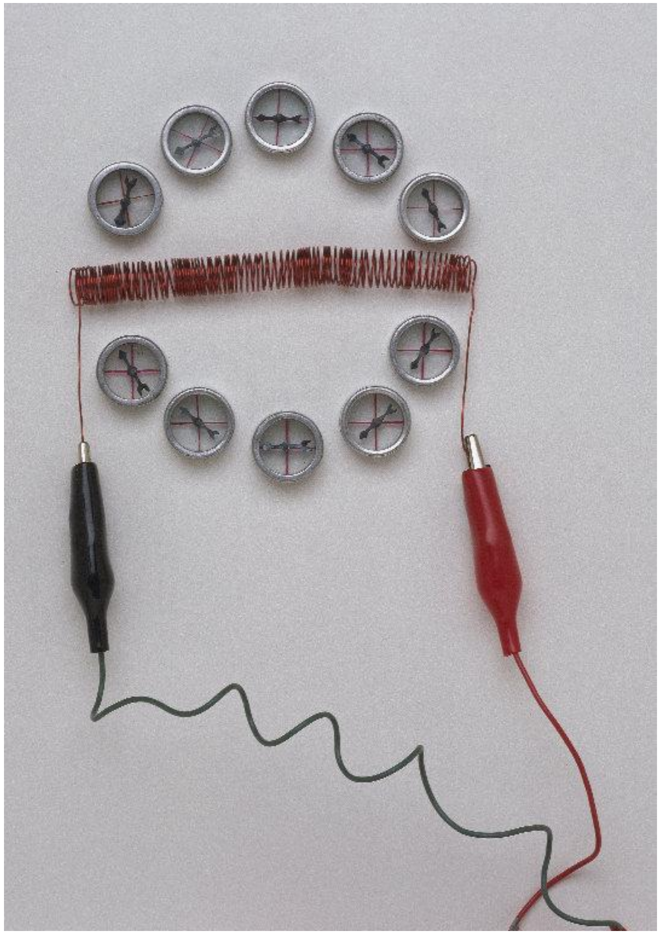
Solenoid you will you in this course!

Magnetic Filed Around a Coil

Solenoid behaves as just like a simple bar magnet but only when current is flowing.

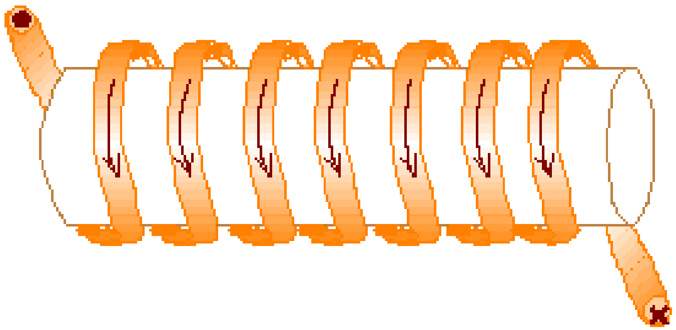


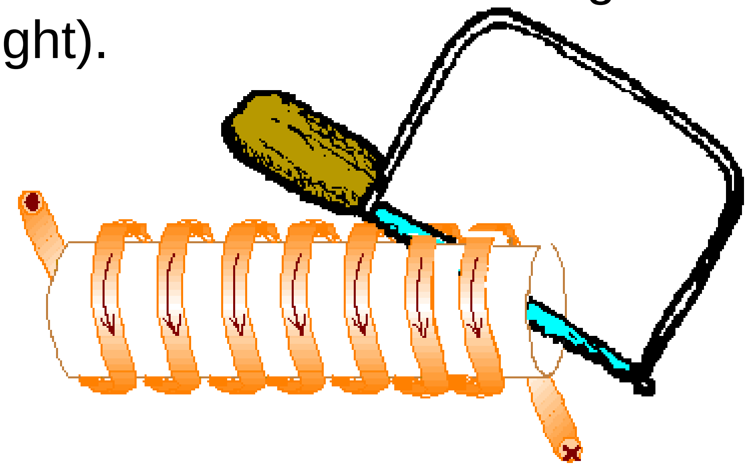
(a) (b)



How Does It Work

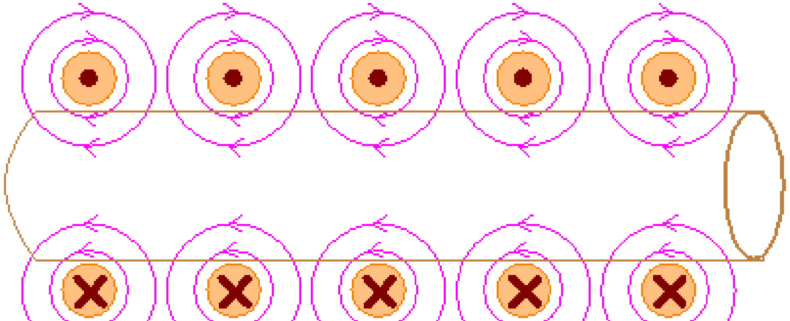
Now imagine that you have wrapped it around a cardboard centre like the one found in the centre of a roll of toilet paper. The result will be something like the picture (right).



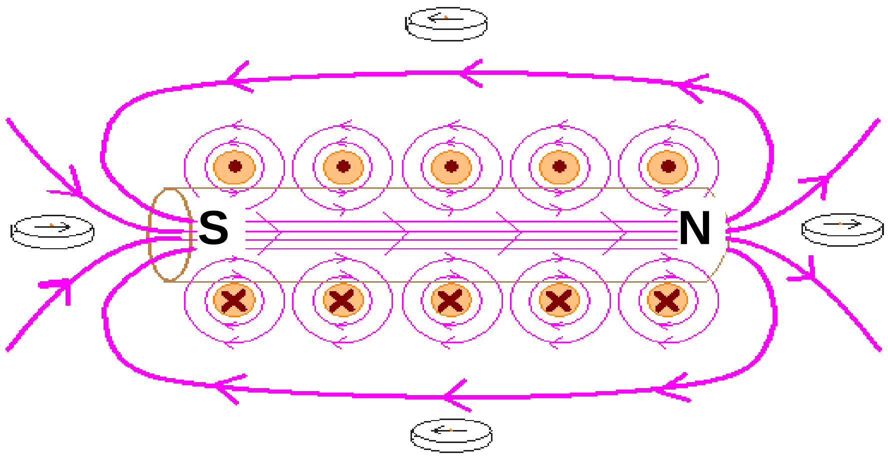


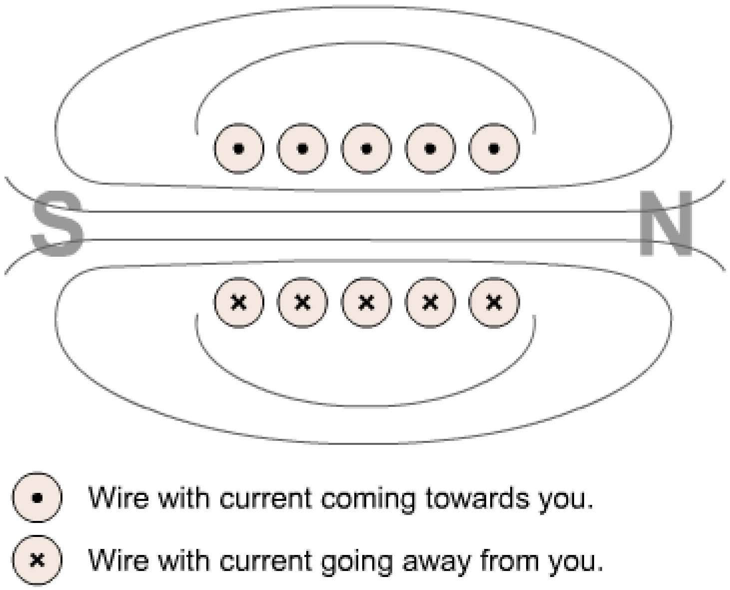
Use your imagination again, and visualize what you would "see" if the coil were sawed down the middle:

If you discard the half of the coil nearest you, will be left with something like the picture below. On the top of the coil the current is coming out of the screen , and on the bottom of the coil the current is going into the screen.



Look more closely at the way the fields of each turn add together. Inside the coil all the little fields add up to the left. On the outside of the coil all the fields add up to the right. The end result can pictured as follows.

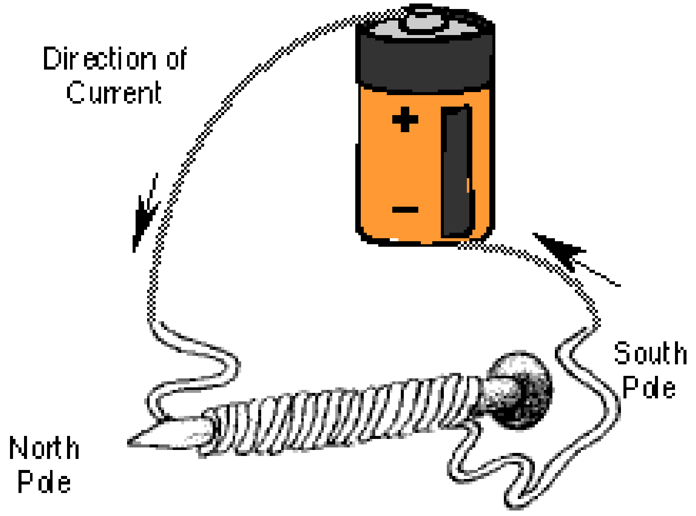




The strength of an electromagnet

In elementary school, you very probably made an electromagnet by wrapping wire around a nail or an iron bolt.

The magnetic field around such an electromagnet depends on the
direction of the current and
the direction in which coil is wound.



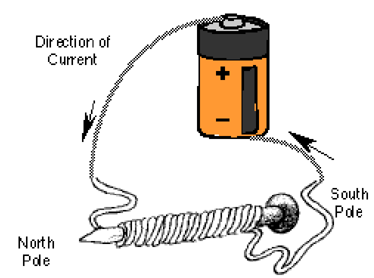
Factors that affect the strength of an Electromagnet

1. Size of the current--the bigger the current, the stronger the field

2. Size of the coil--the smaller the diameter, the stronger the field

3. Number of turns in the coil--the more tightly wound the coil is, the stronger will be the field

4. Type of core inside the coil--an electromagnet wrapped around a ferromagnetic core will be much stronger than one wrapped around a cardboard coil.



Strength of an Electromagnet

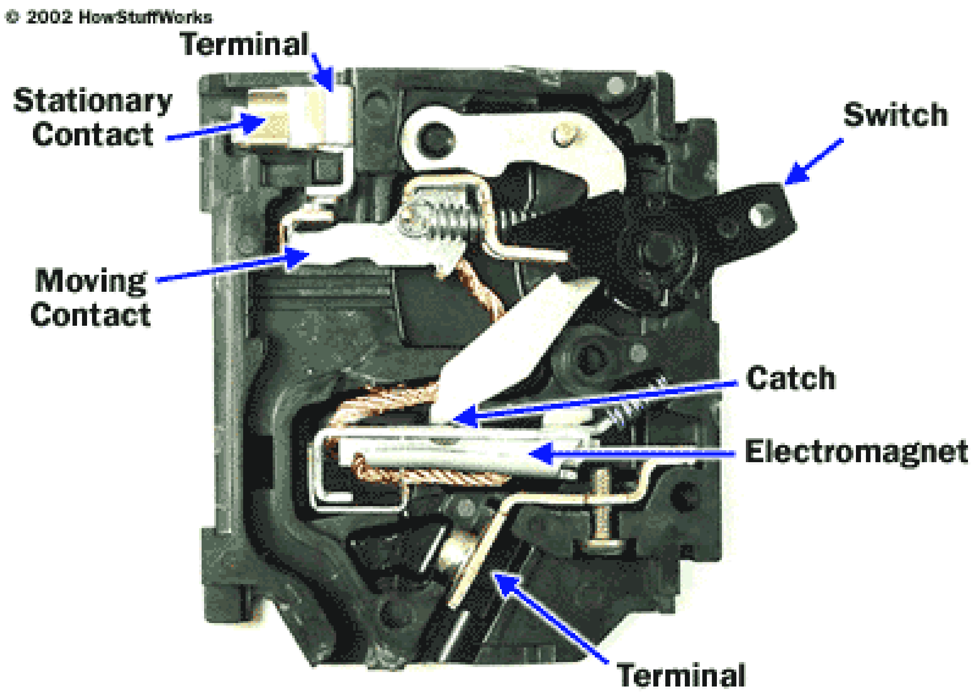
There is a term that accounts for the change in the strength of an electromagnetic according to the type of material that comprises the core. The term is magnetic permeability, and it is represented by the Greek letter mu (μ).

The relative magnetic permeability of a substance is a ratio of the strength of the magnet when the core is made of that substance to the strength when their is no core at all.

Ferromagnetic substances have a high permeability. You can find the magnetic permeability of some familiar substances in Table 15.3 on p. 637 of your textbook.

Uses of Electromagnets

1) Circuit Breaker - A safety device that switches off the electric supply when excessive current flows through the circuit. Uses an electromagnet to open the circuit.



Normal condition

The basic circuit breaker consists of a simple **switch**, connected to either a bimetallic strip or an electromagnet. The diagram on the left shows a typical electromagnet design.

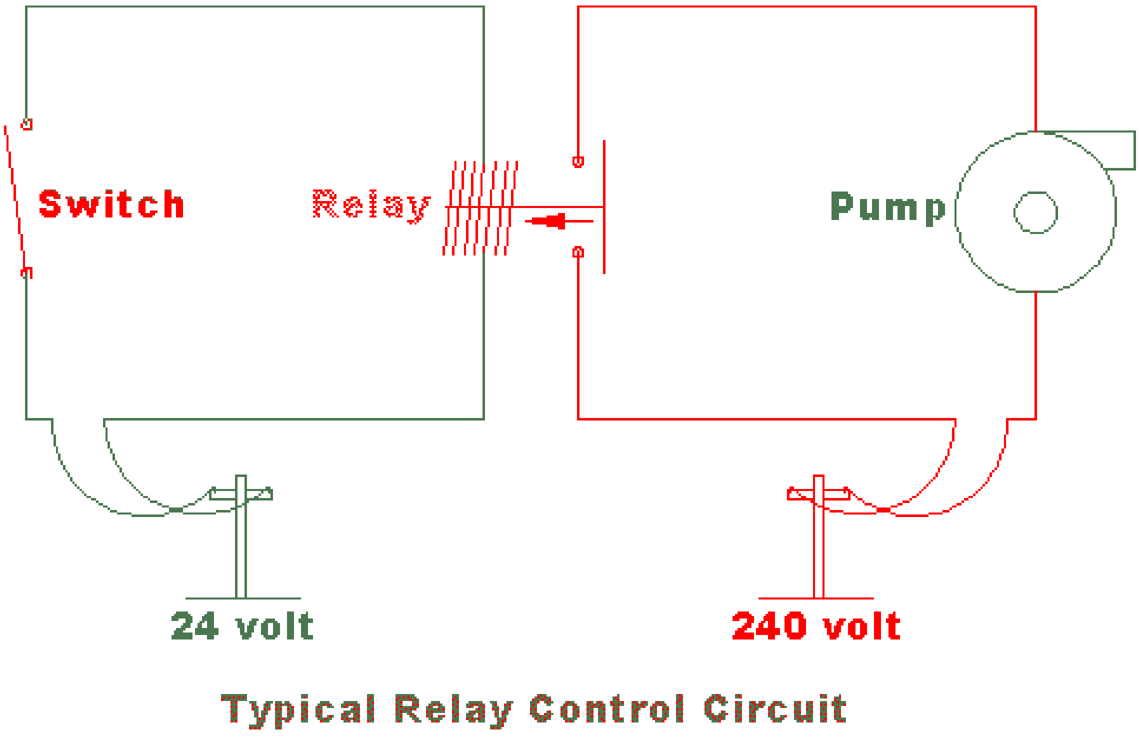
The hot wire in the circuit connects to the two ends of the switch. When the switch is flipped to the on position, electricity can flow from the bottom terminal, through the electromagnet, up to the moving contact, across to the stationary contact and out to the upper terminal.

Circuit breaker in operation

The electricity **magnetizes** the electromagnet. Increasing current boosts the electromagnet's magnetic force, and decreasing current lowers the magnetism. When the current jumps to unsafe levels, the electromagnet is strong enough to pull down a metal lever connected to the switch linkage. The entire linkage shifts, tilting the moving contact away from the stationary contact to break the circuit. The electricity shuts off.

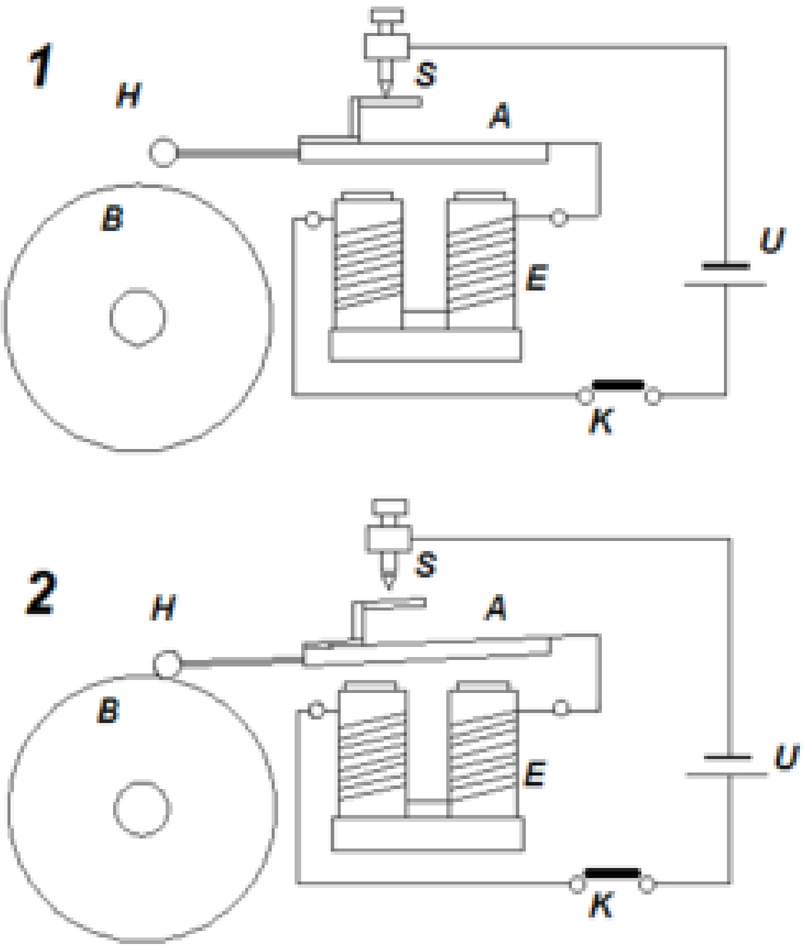
Uses of Electromagnets

2) Magnetic Relay - A device to control the switch of another circuit without any direct electrical contact between them.



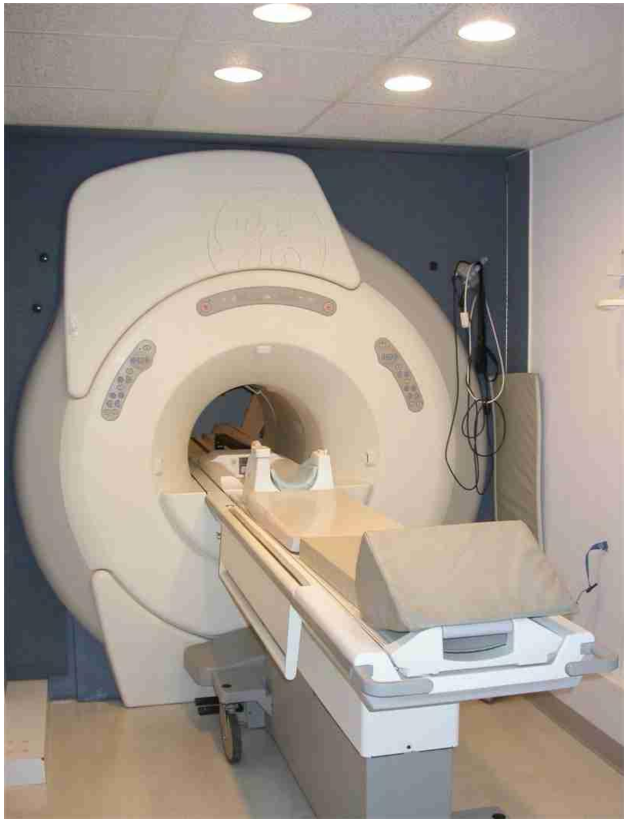
Uses of Electromagnets

3) Electric Bell - The electromagnet forms the core of the electric bell. When the bell button is pressed, the circuit is closed and current flows. The electromagnet becomes magnetised, attracting the soft iron armature and the hammer strikes the gong. However, the circuit will break and the electromagnet loses its magnetism and the springy metal strip pull back the armature and the circuit is closed again. The process repeats.



Uses of Electromagnets

4) Magnetic Resonance Imaging (MRI) - A popular method of medical imaging that provides views of tissues in the body. It is a huge scanner containing a solenoid made of superconductors.



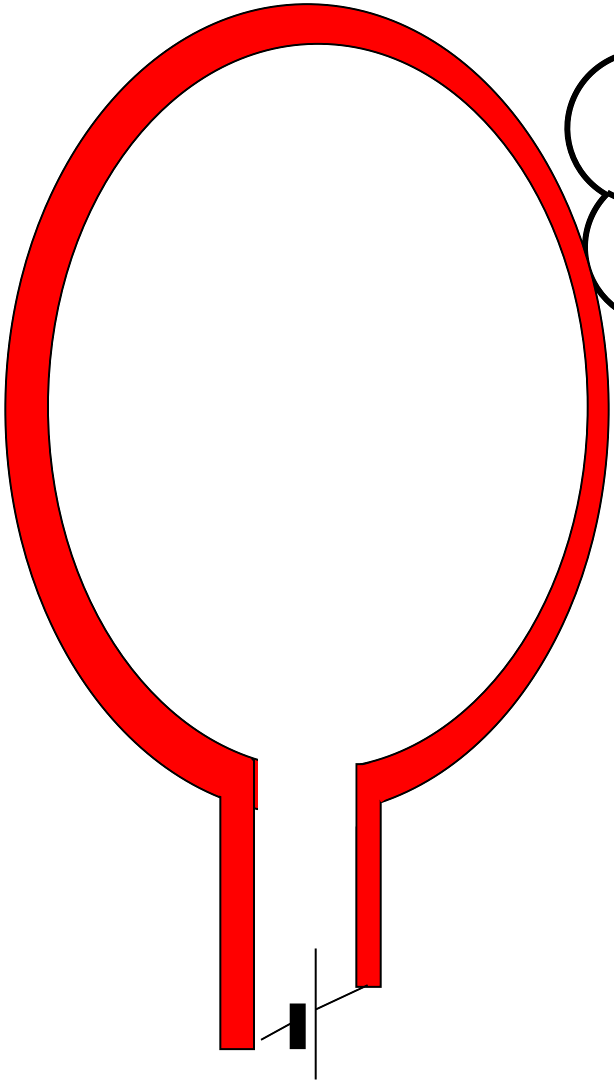
Physics 3204

Unit 3: Section 3 Electromagnetism

Topic 10 : Electromagnets and LHR #2

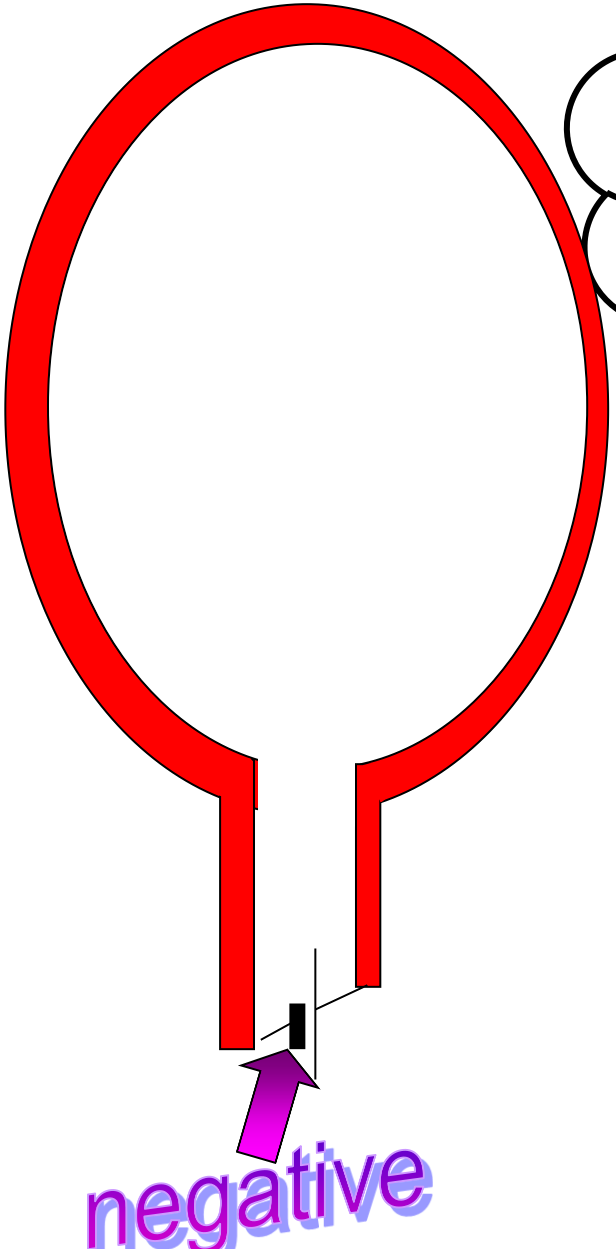
TEXT REFERENCE

Loops



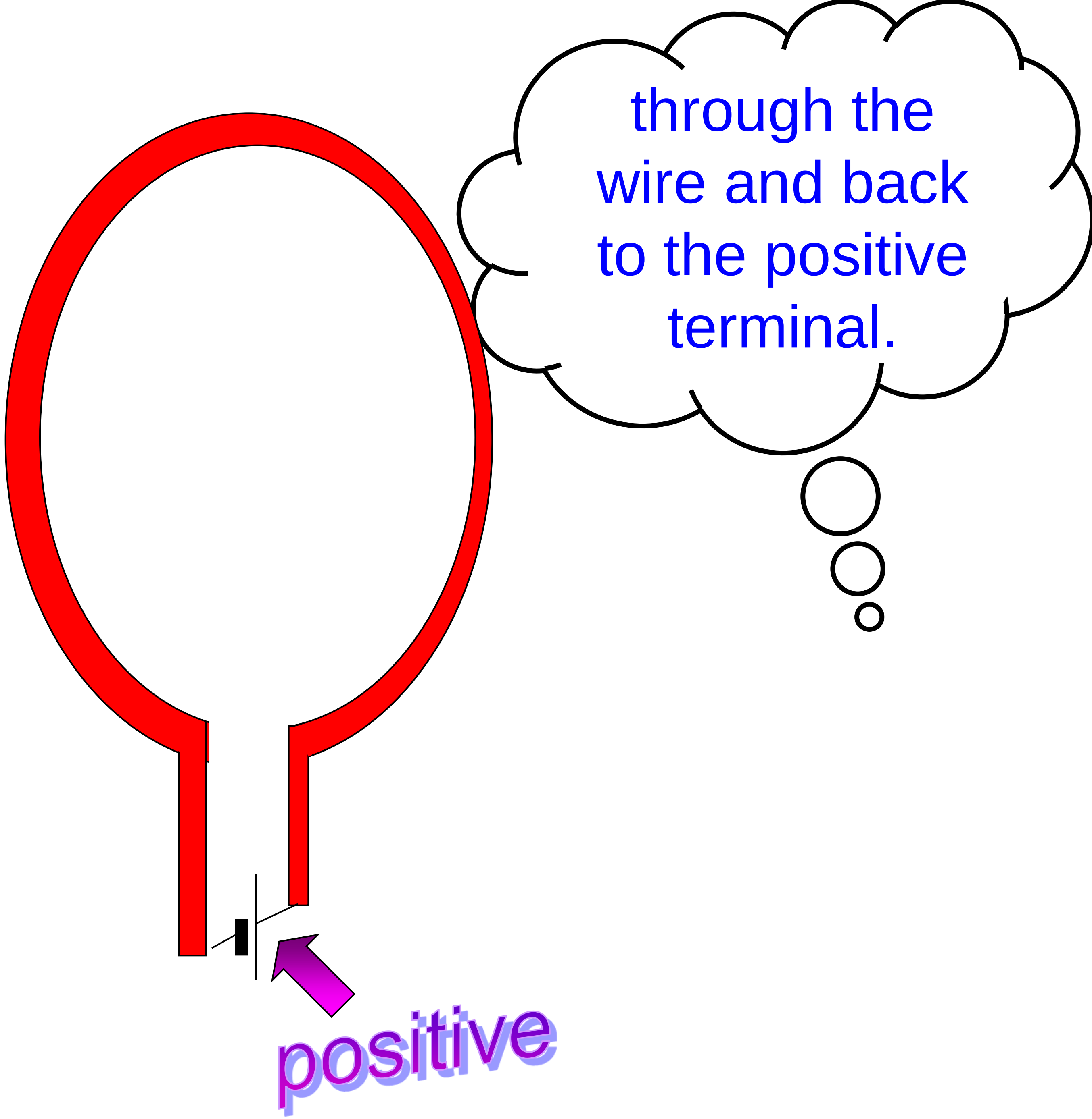
Shown here is a loop of wire connected to a potential source.

Loops

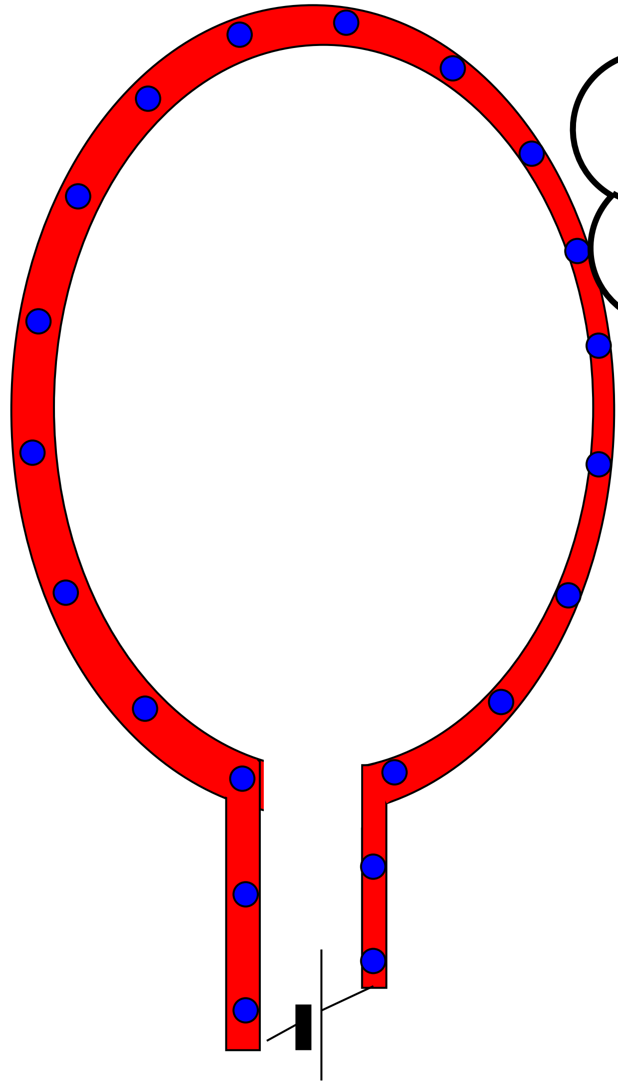


The electrons flow from the negative terminal of the battery

Loops

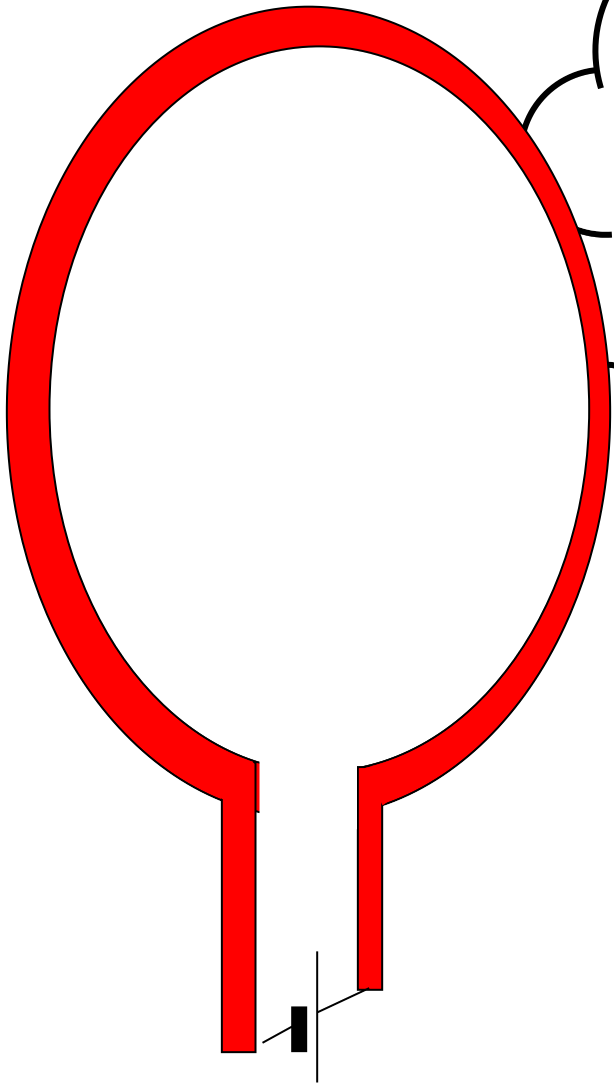

through the wire and back to the positive terminal.
positive

Loops



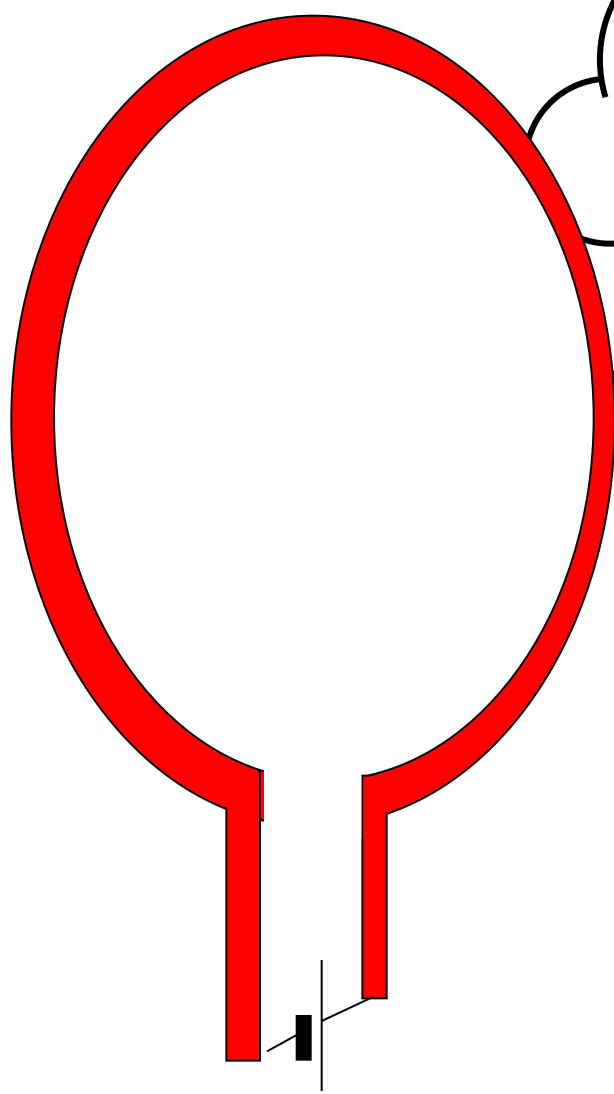
through the wire and back to the positive terminal.

Loops



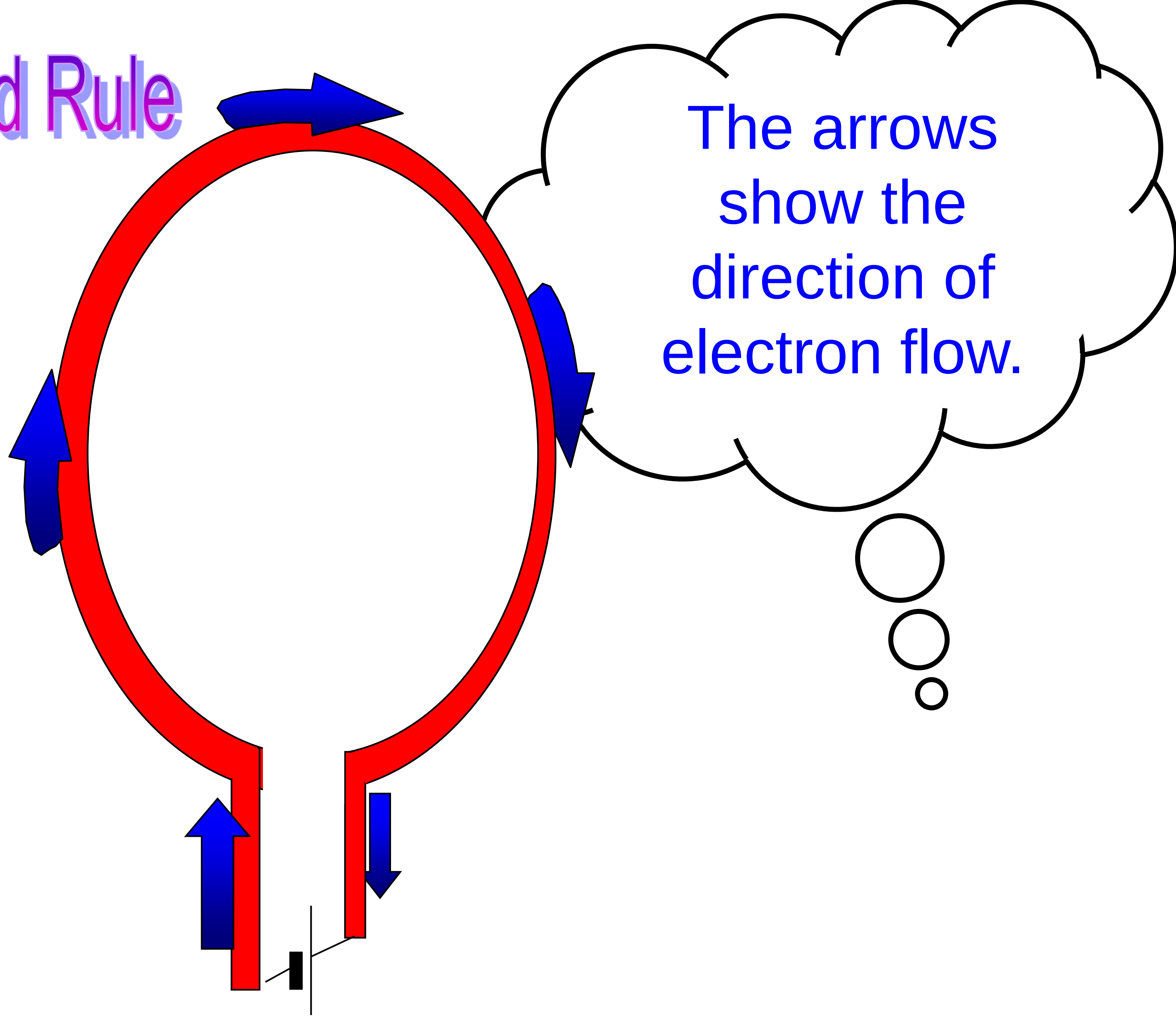
We know that when current flows through a wire a magnetic field is formed.

Loops



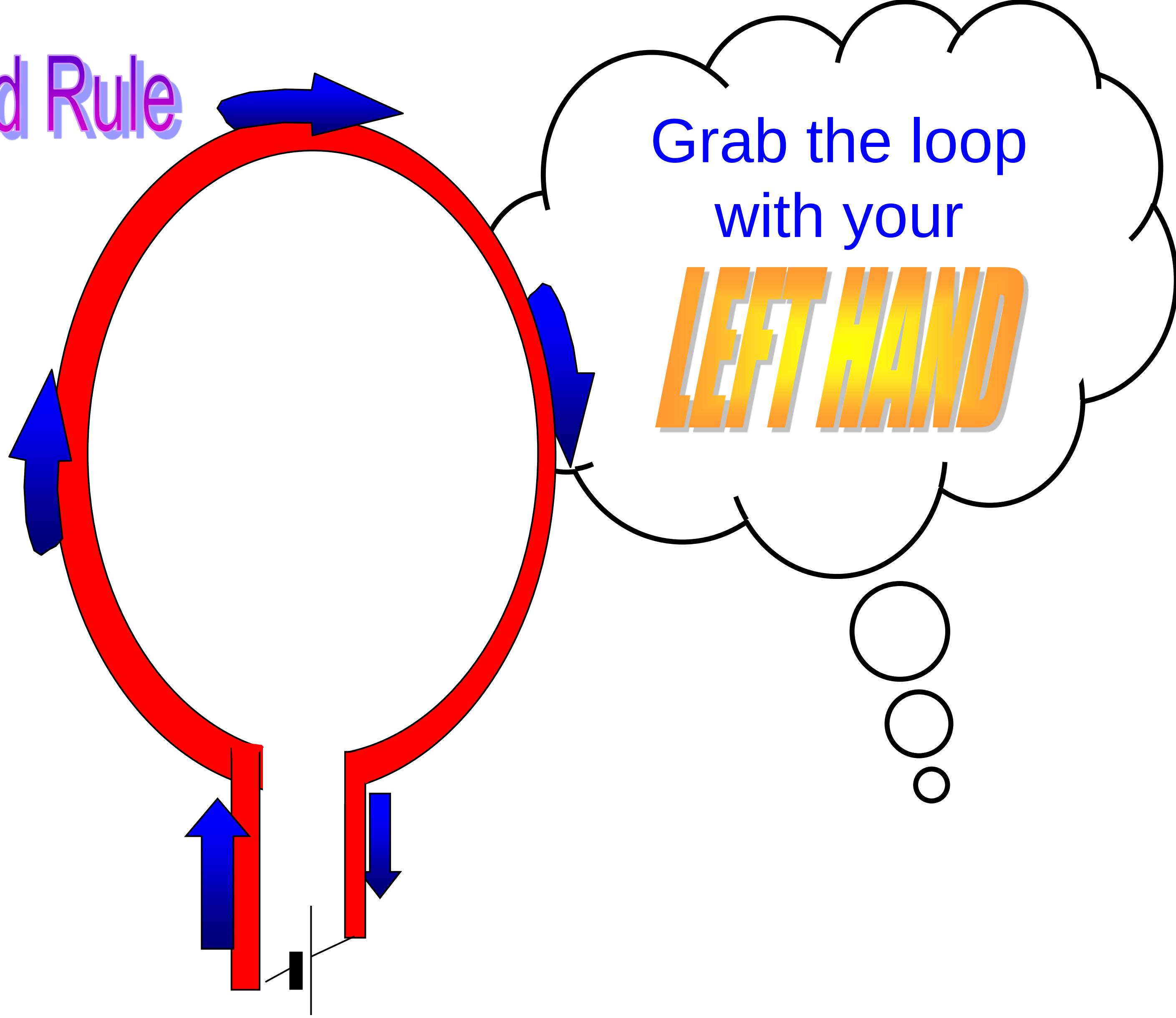
We use the 2nd Left Hand Rule to determine the direction of the magnetic field.

2nd Left Hand Rule



for Loops and Coils

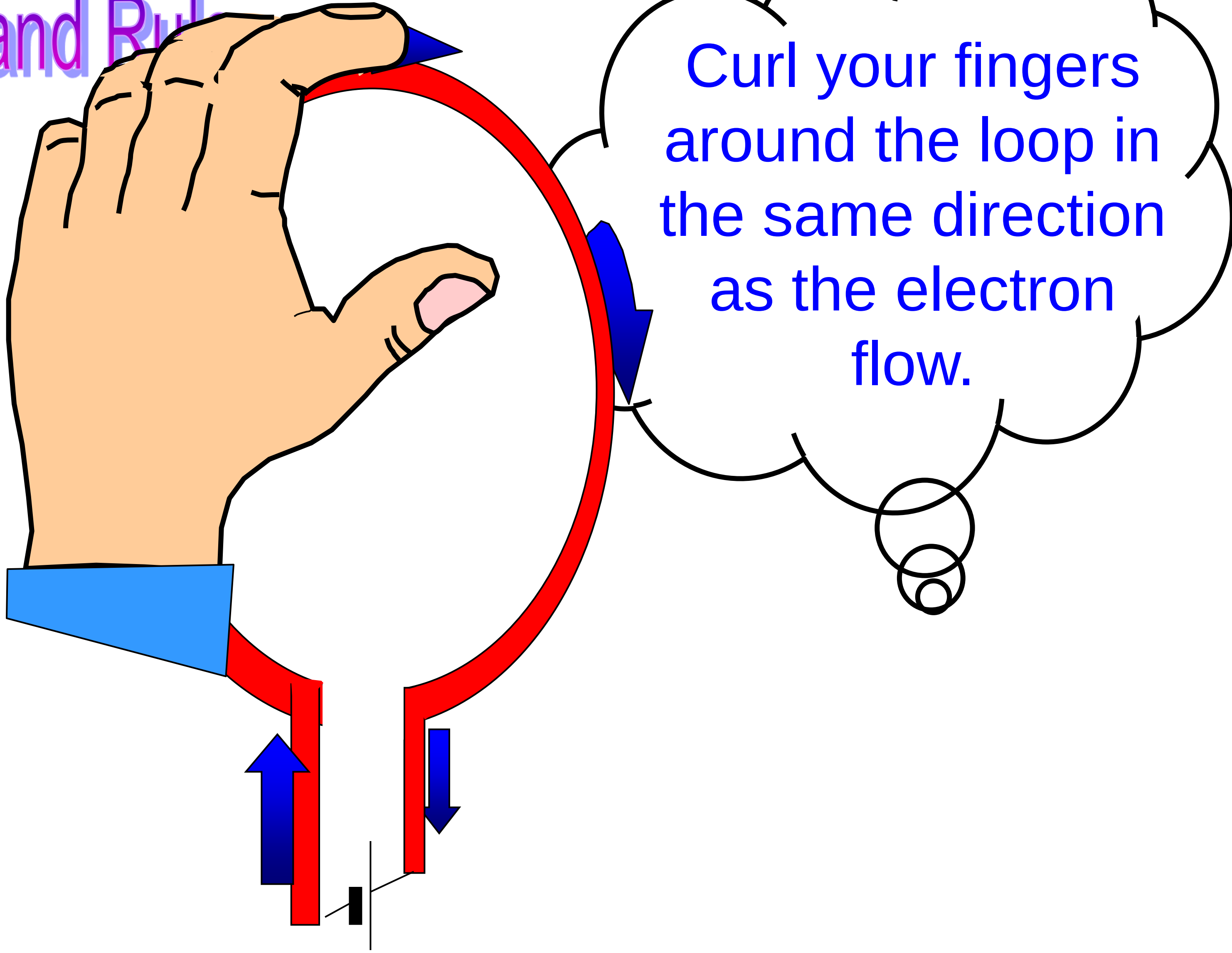
2nd Left Hand Rule



for

Loops and Coils

2nd Left Hand Rule



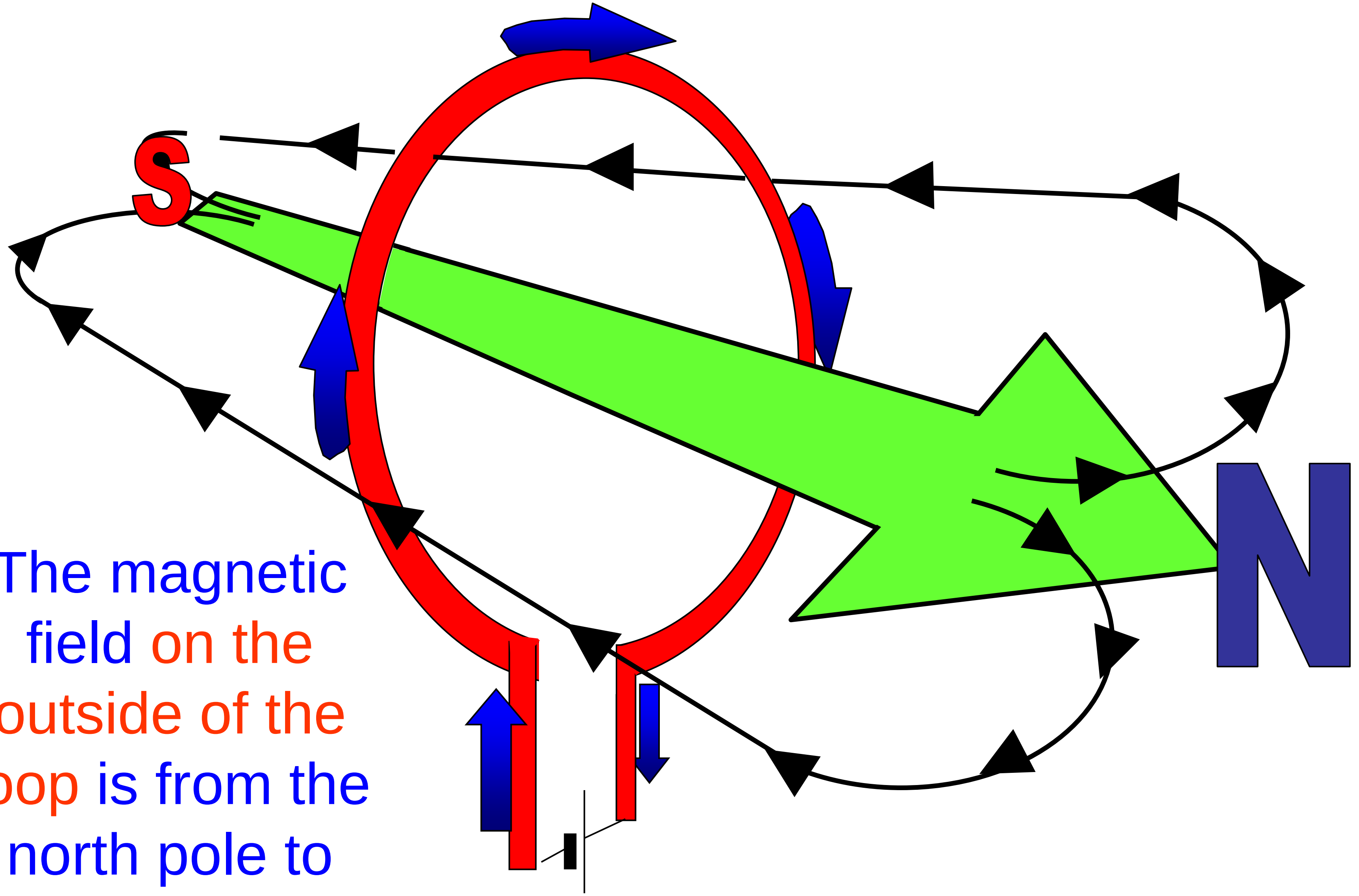
for

Loops and Coils

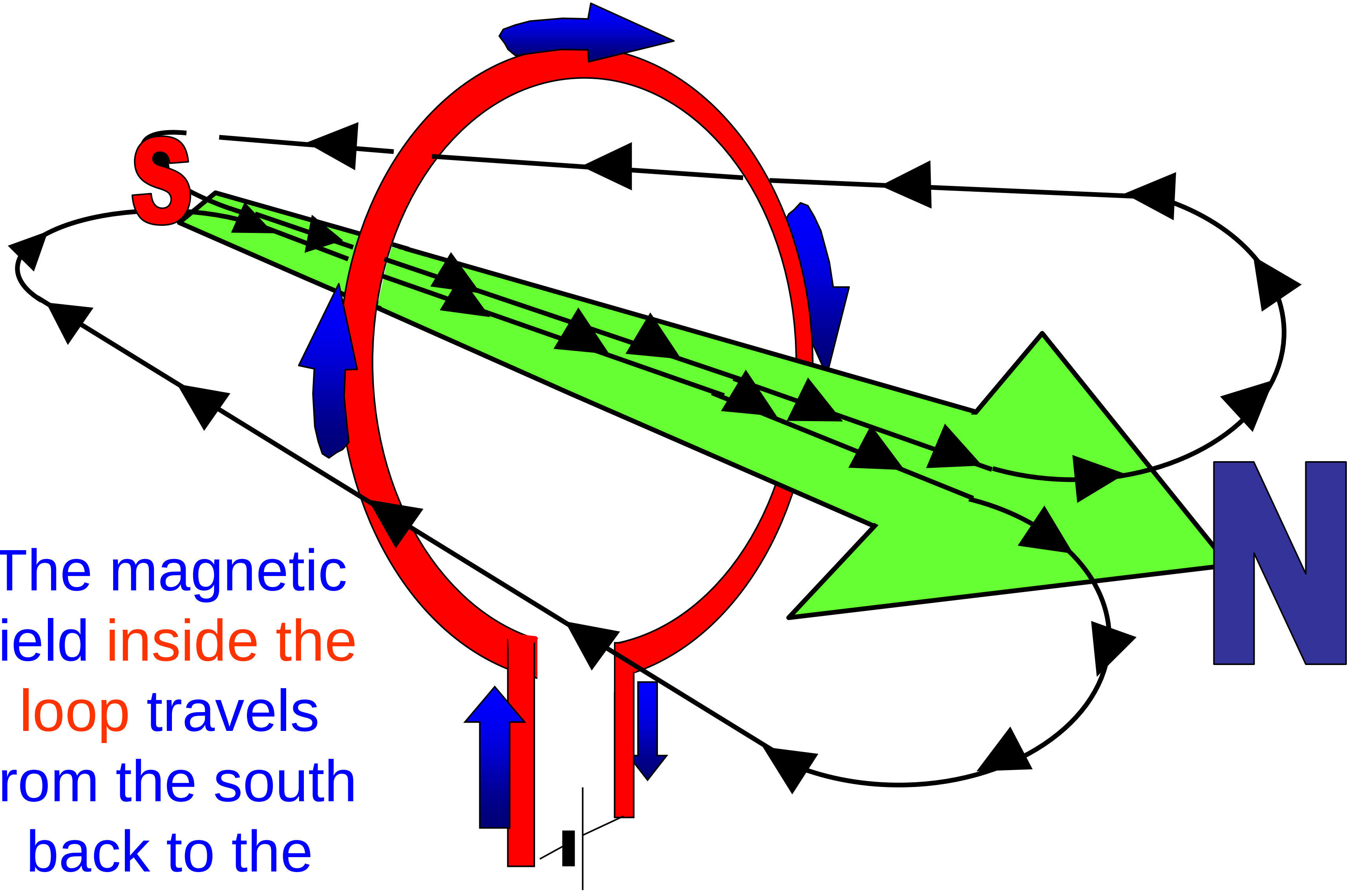
2nd Left Hand Rul

for

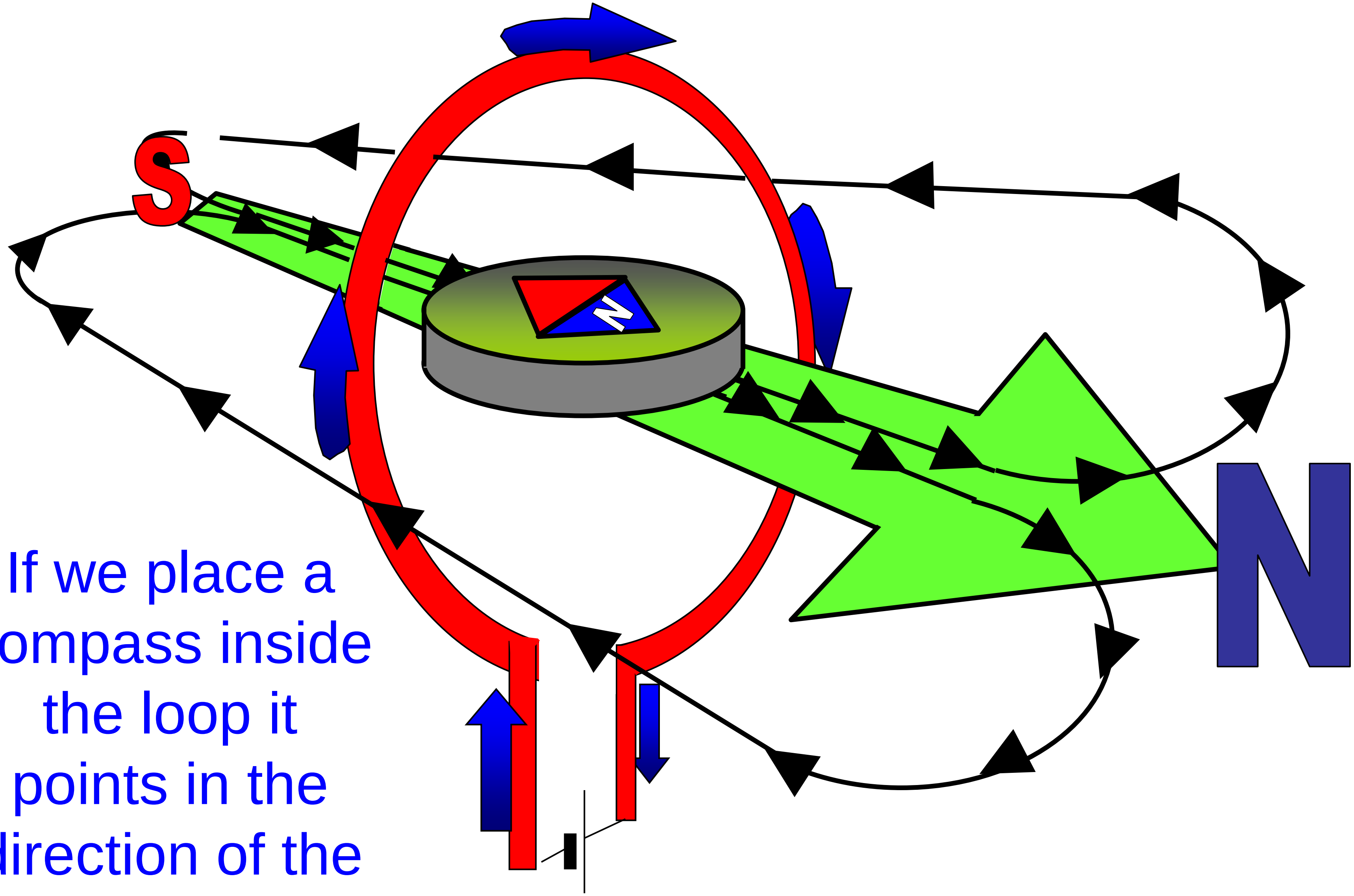
Loops and Coils



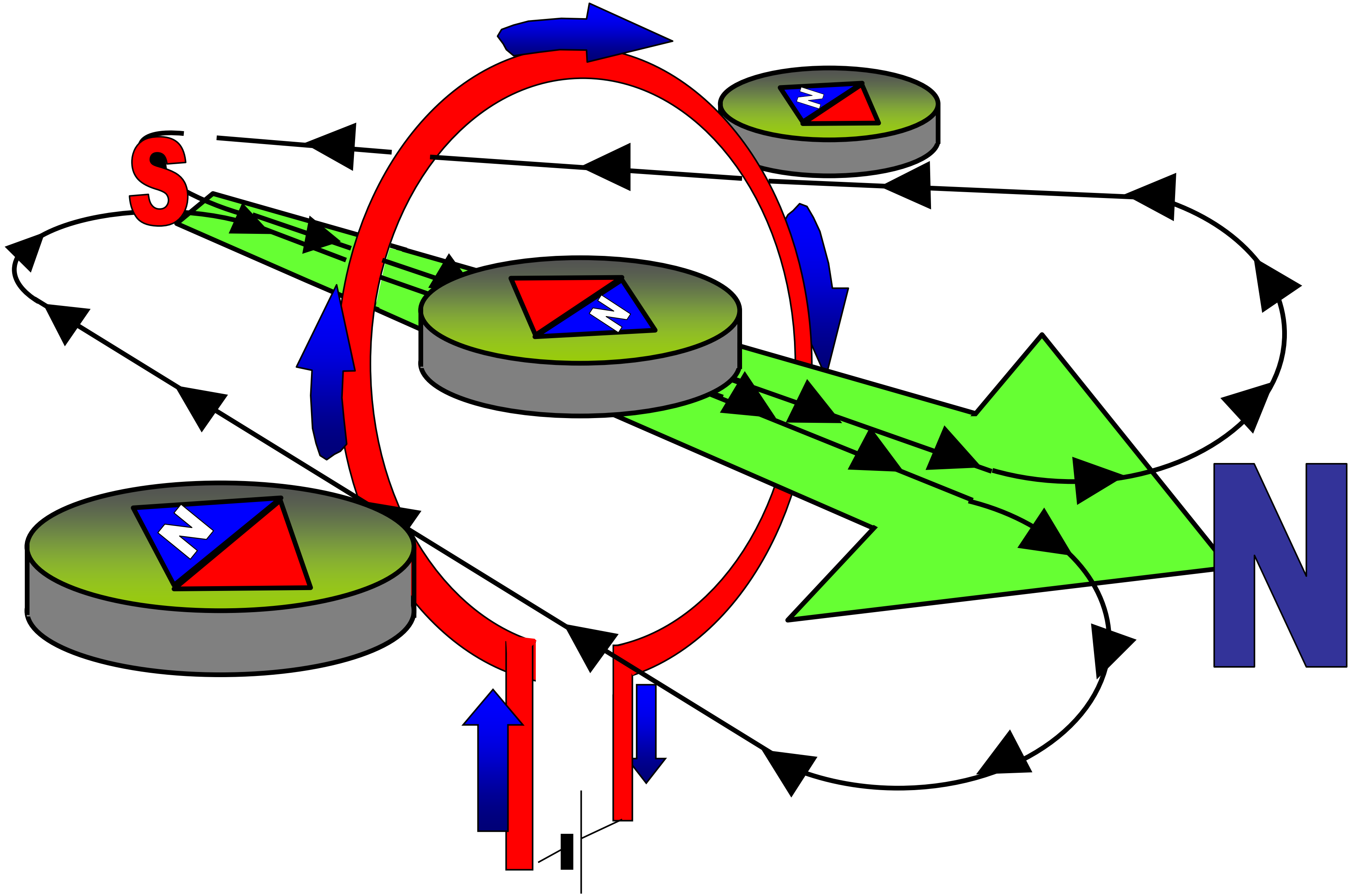
The magnetic field on the outside of the loop is from the north pole to the south pole



The magnetic field inside the loop travels from the south back to the north



If we place a compass inside the loop it points in the direction of the flux lines



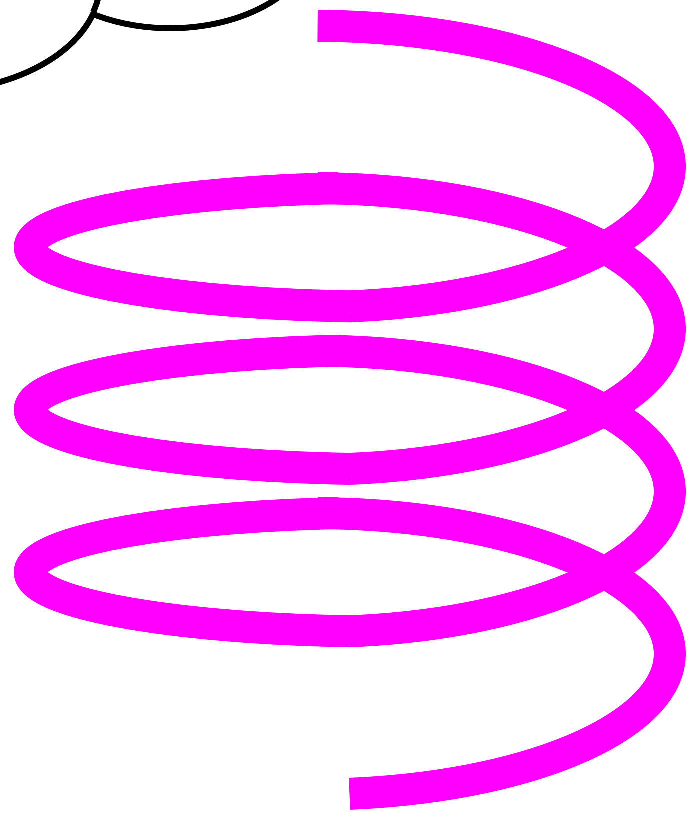
Outside the loop a compass still points in the direction of the magnetic flux lines


I'm back!

Coils

Several LOOPS of wire are called a

Coil

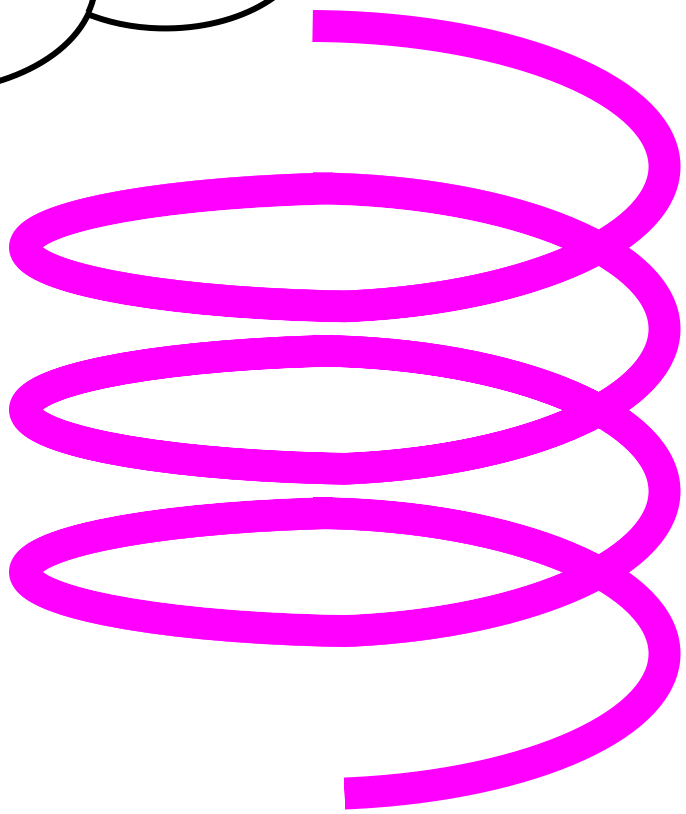


Coils

We also use the

2nd Left Hand Rule

to determine the magnetic field around a coil.



Coils

To demonstrate the

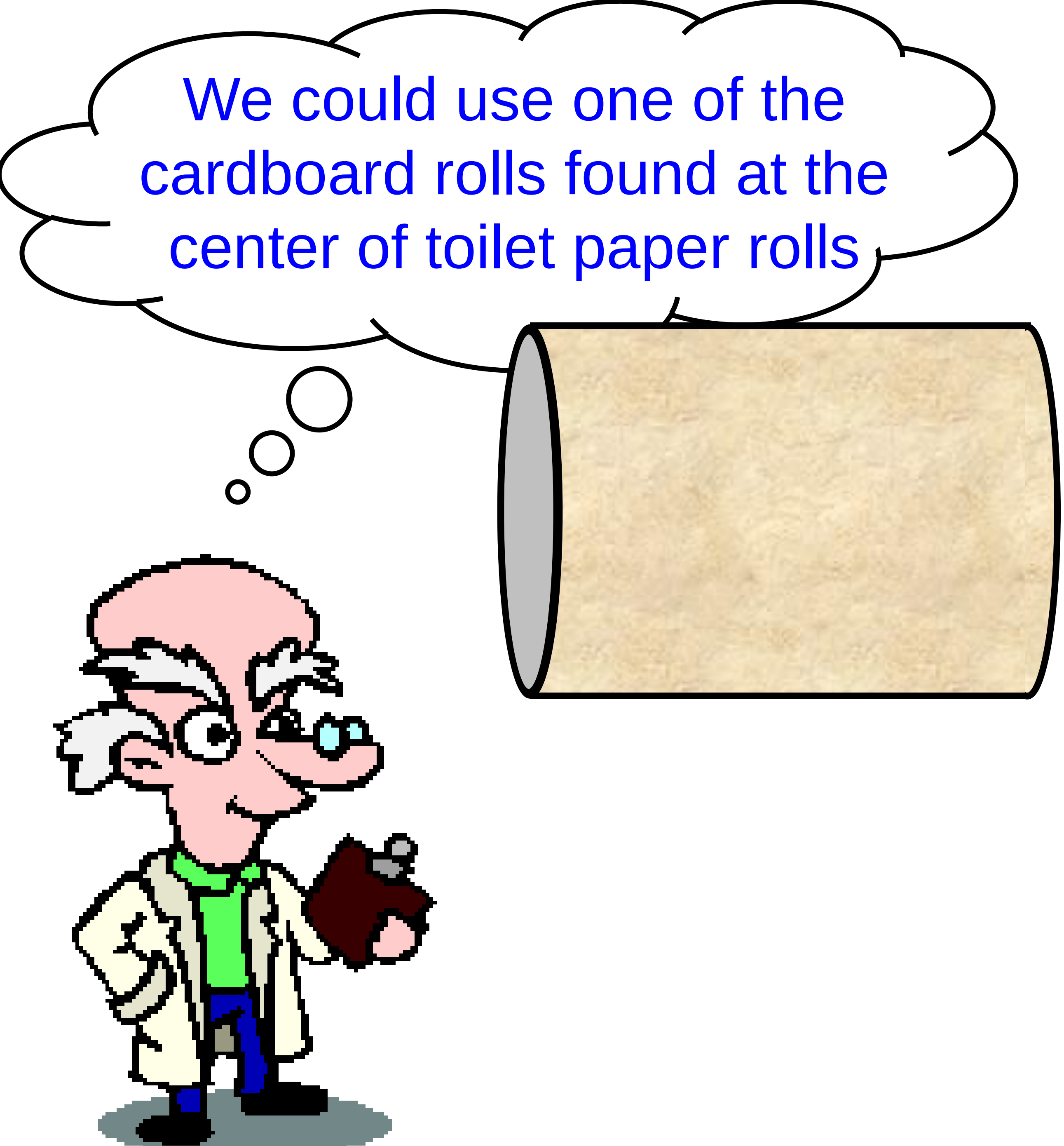
2nd Left Hand Rule

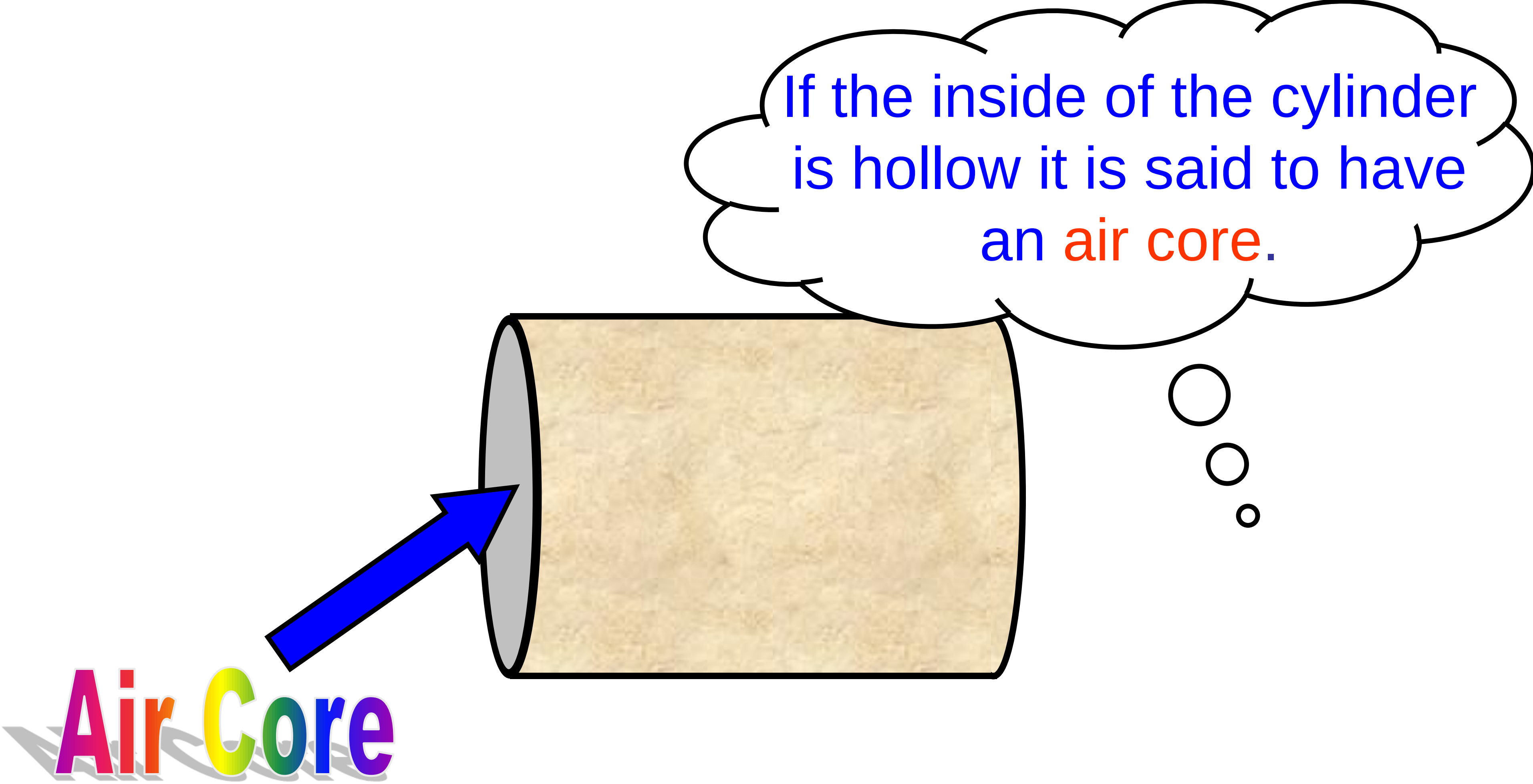
we’ll start by building an electromagnet.

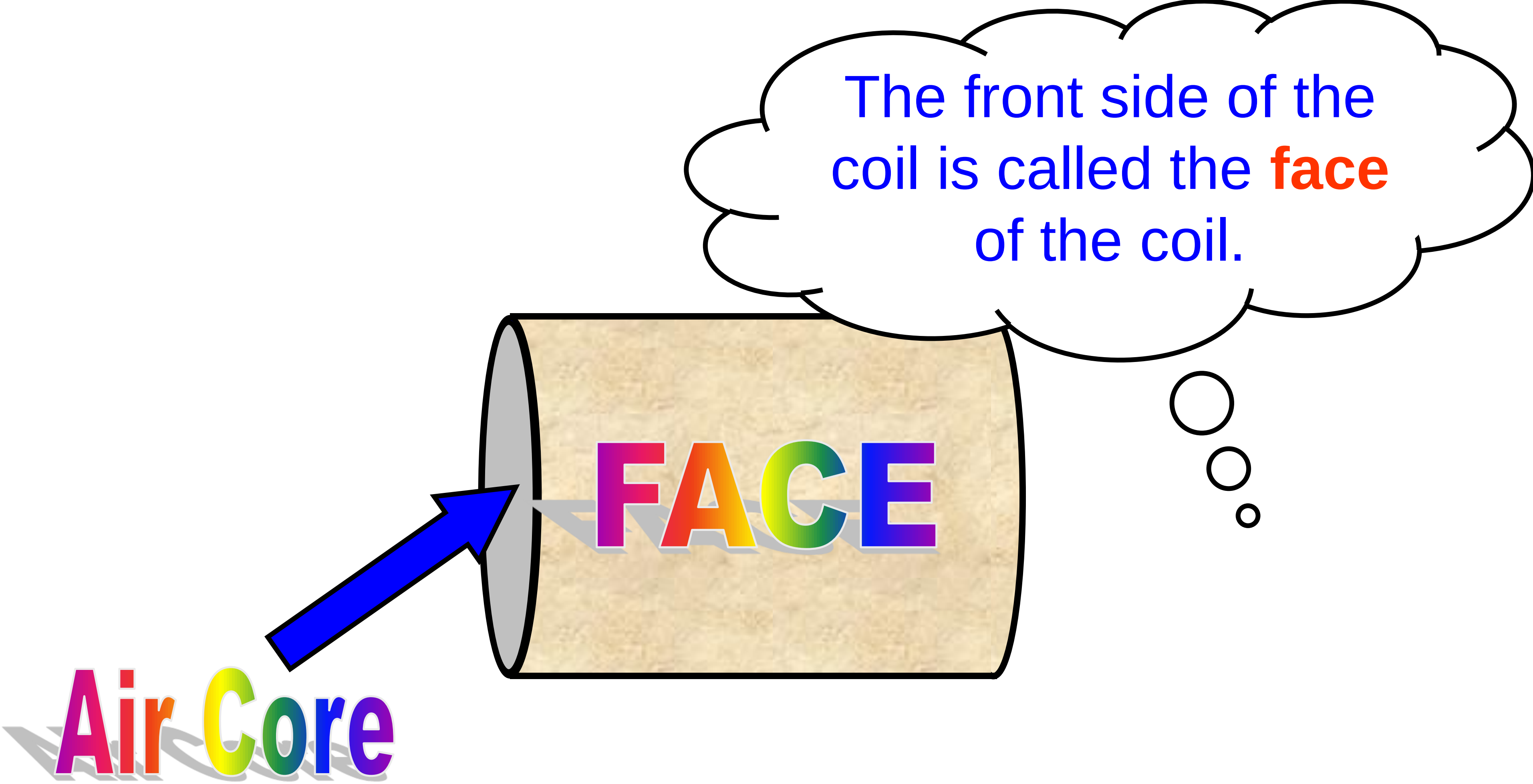
Coils

To build an electromagnet or solenoid we start with a cylinder.

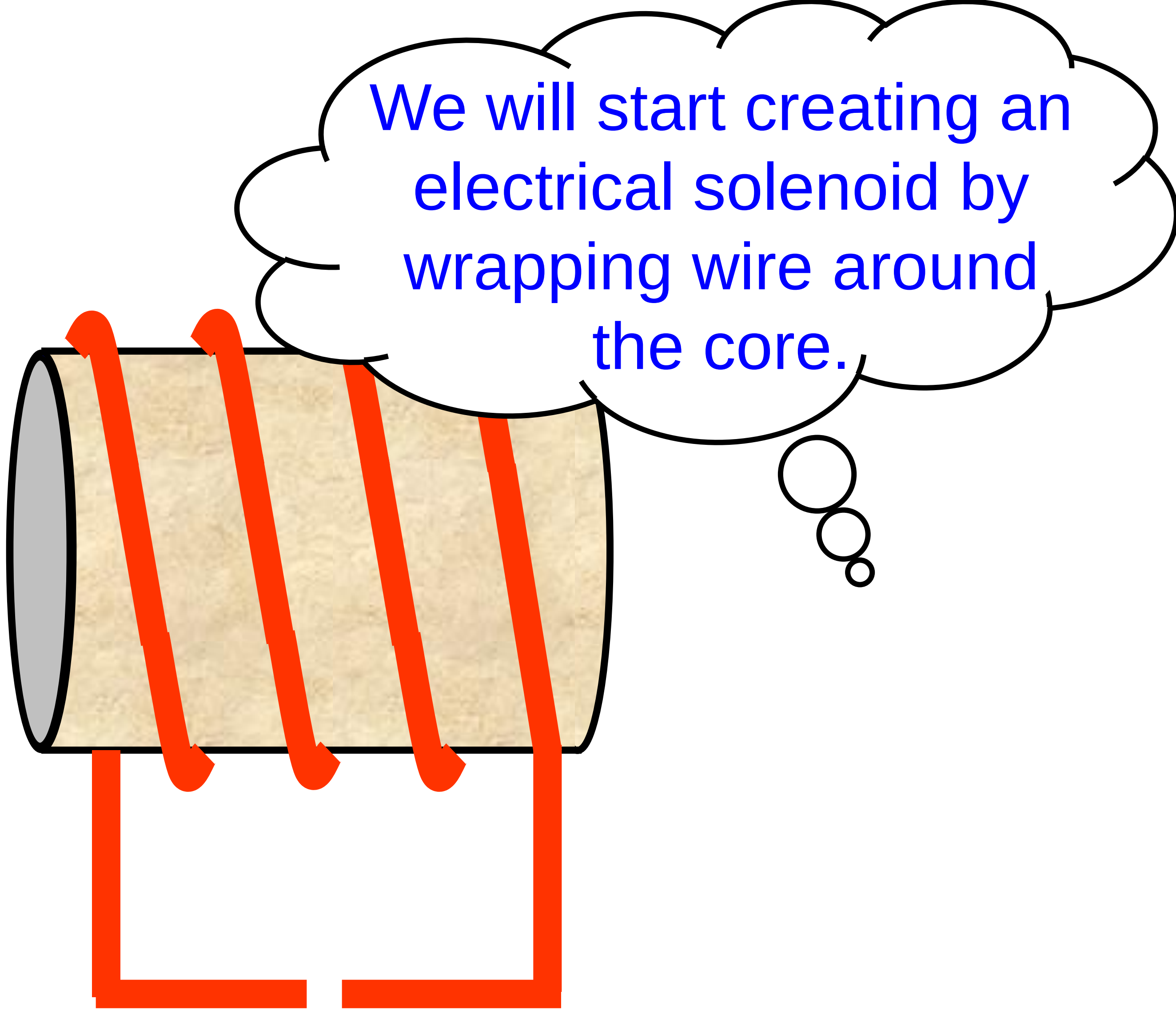
Coils

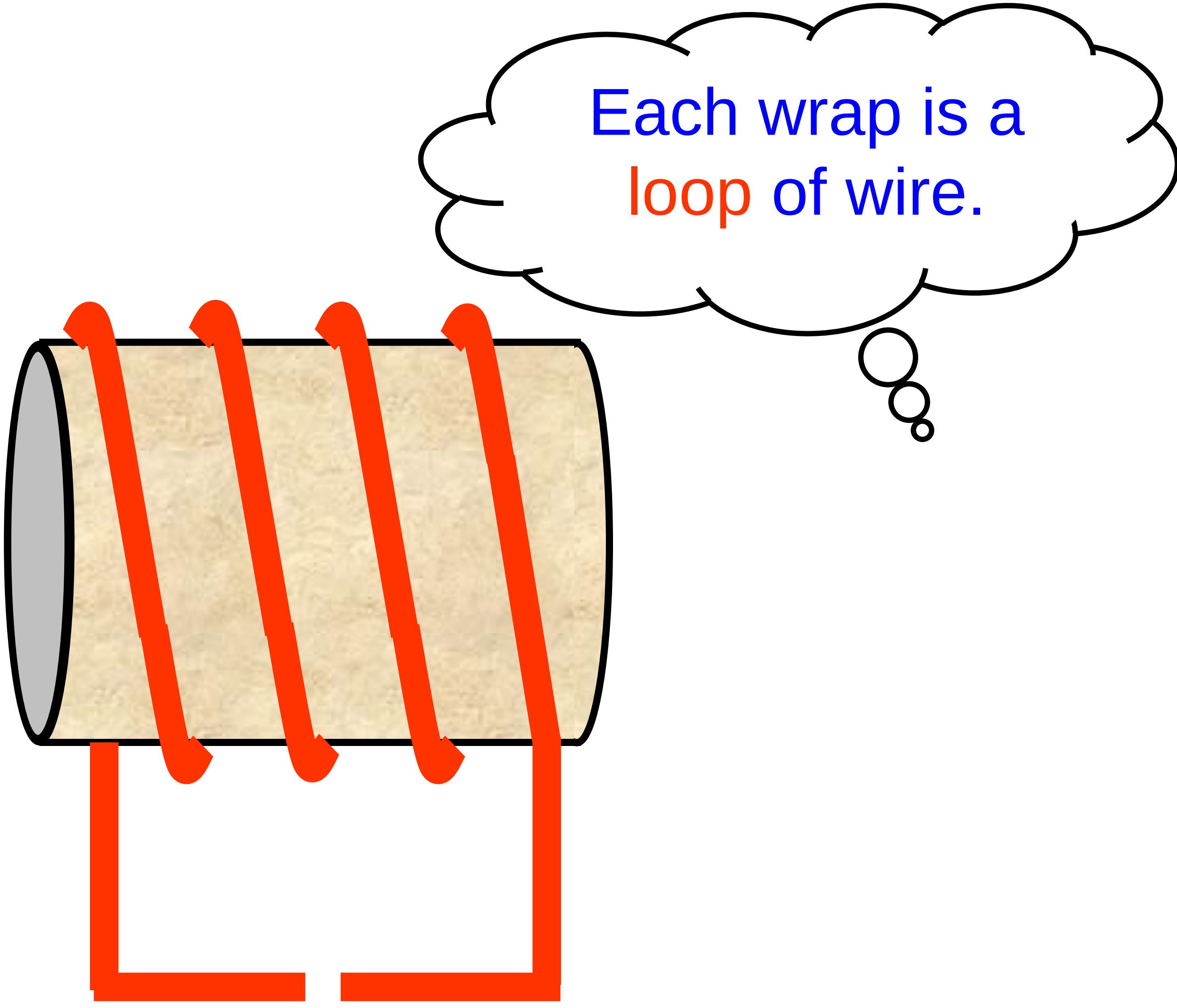

We could use one of the cardboard rolls found at the center of toilet paper rolls

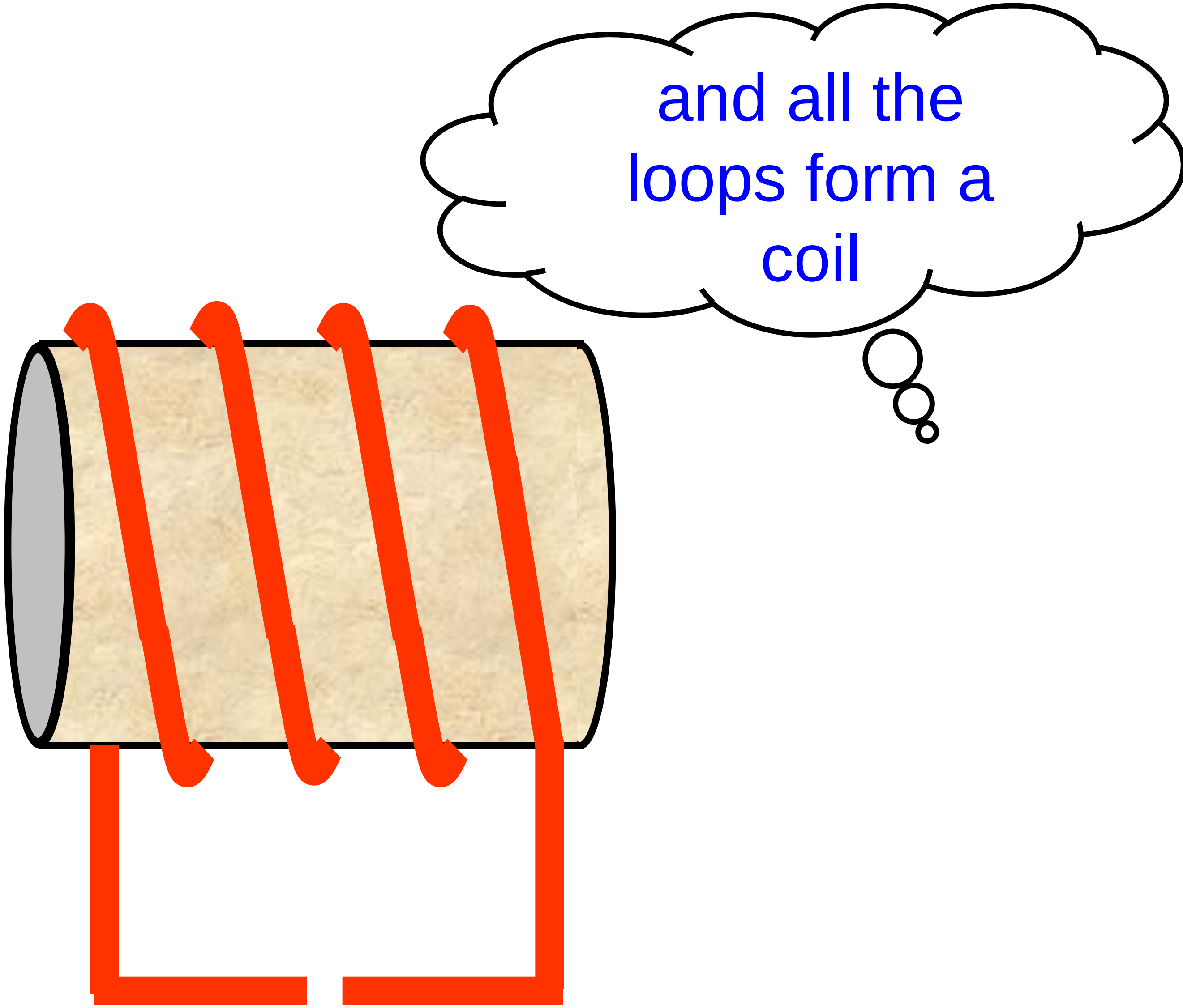

If the inside of the cylinder is hollow it is said to have an air core.
Air Core

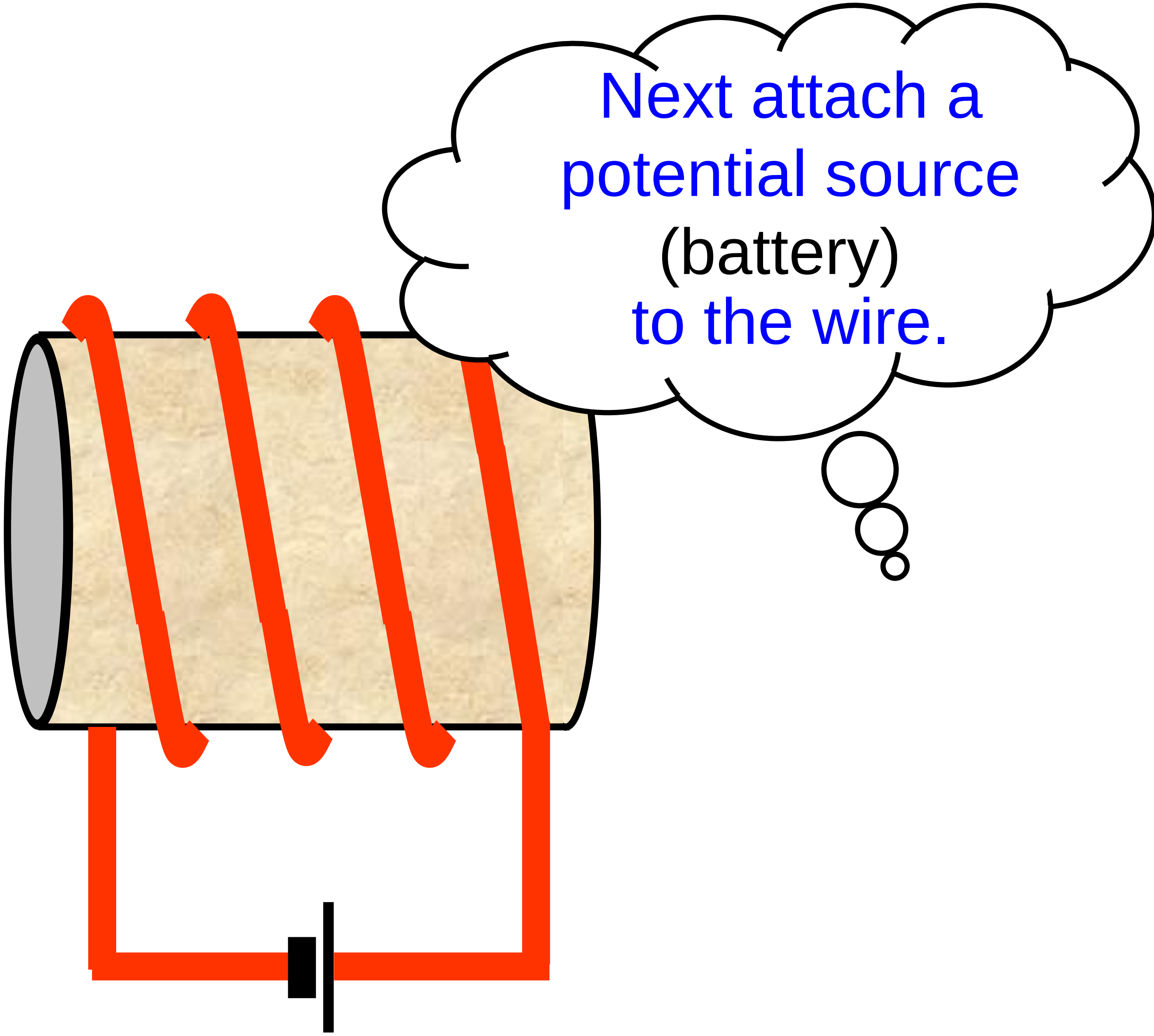


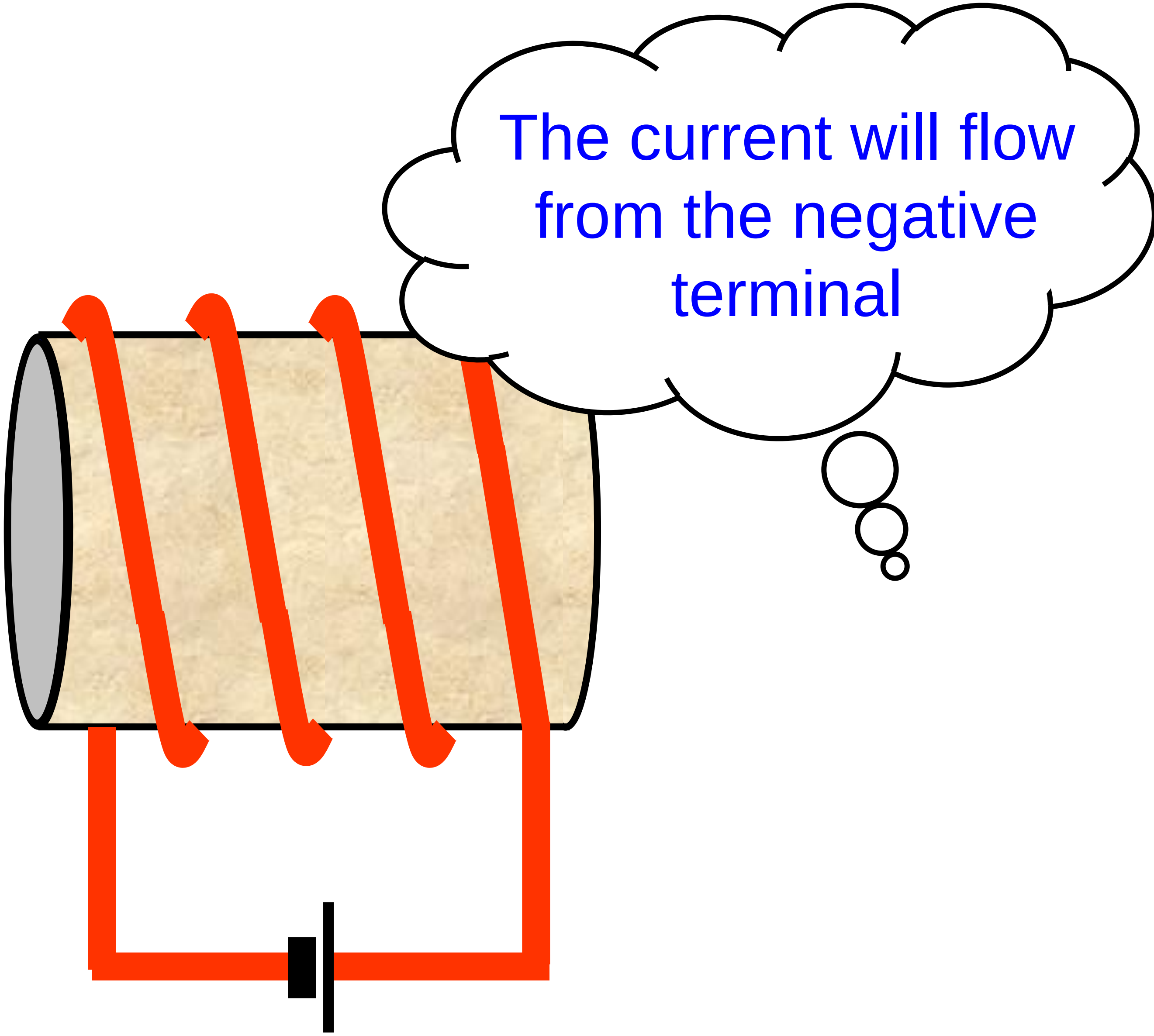
The front side of the coil is called the face of the coil.
FACE
Air Core

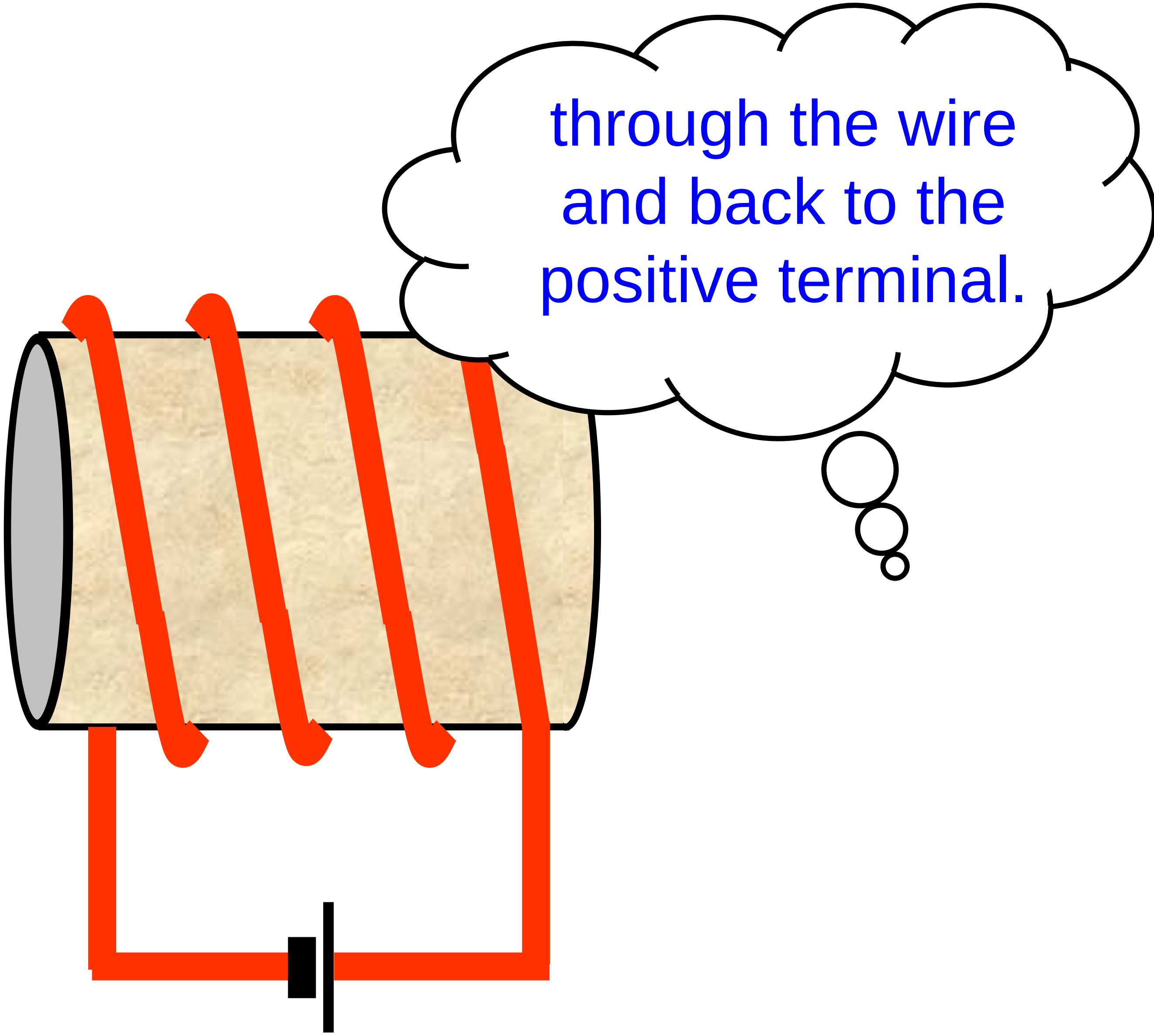

We will start creating an electrical solenoid by wrapping wire around the core.

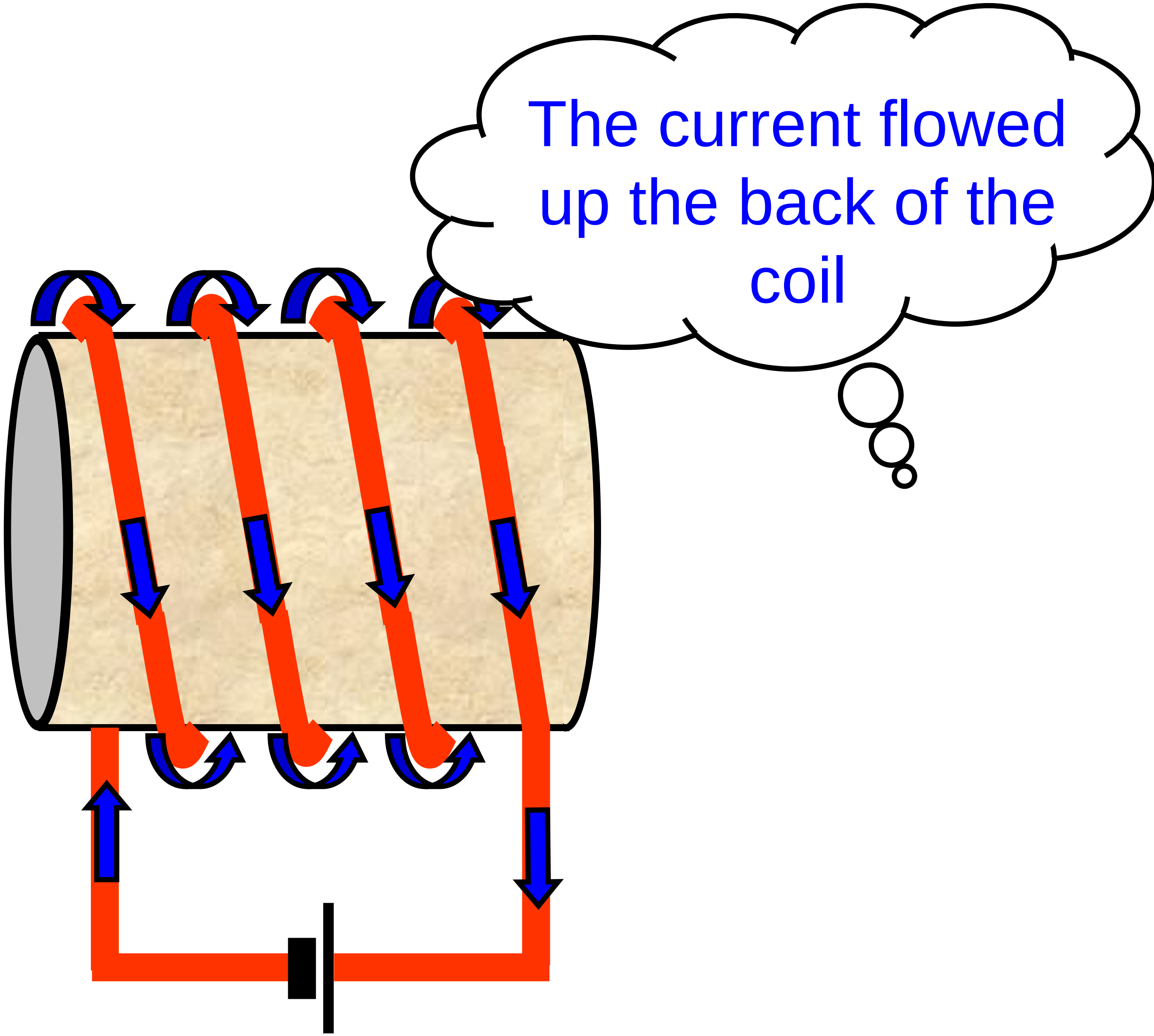

Each wrap is a
loop of wire.

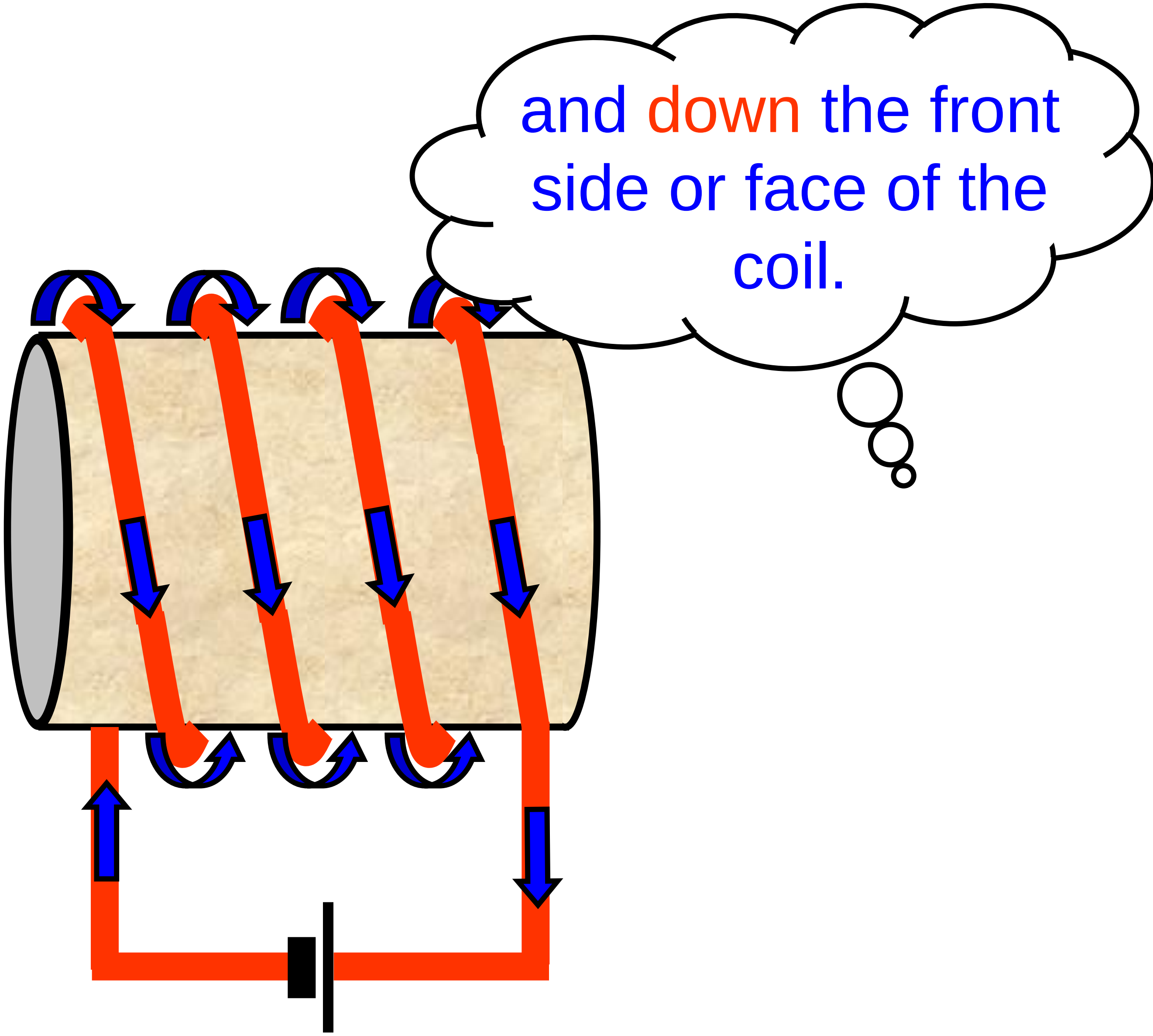

and all the loops form a coil

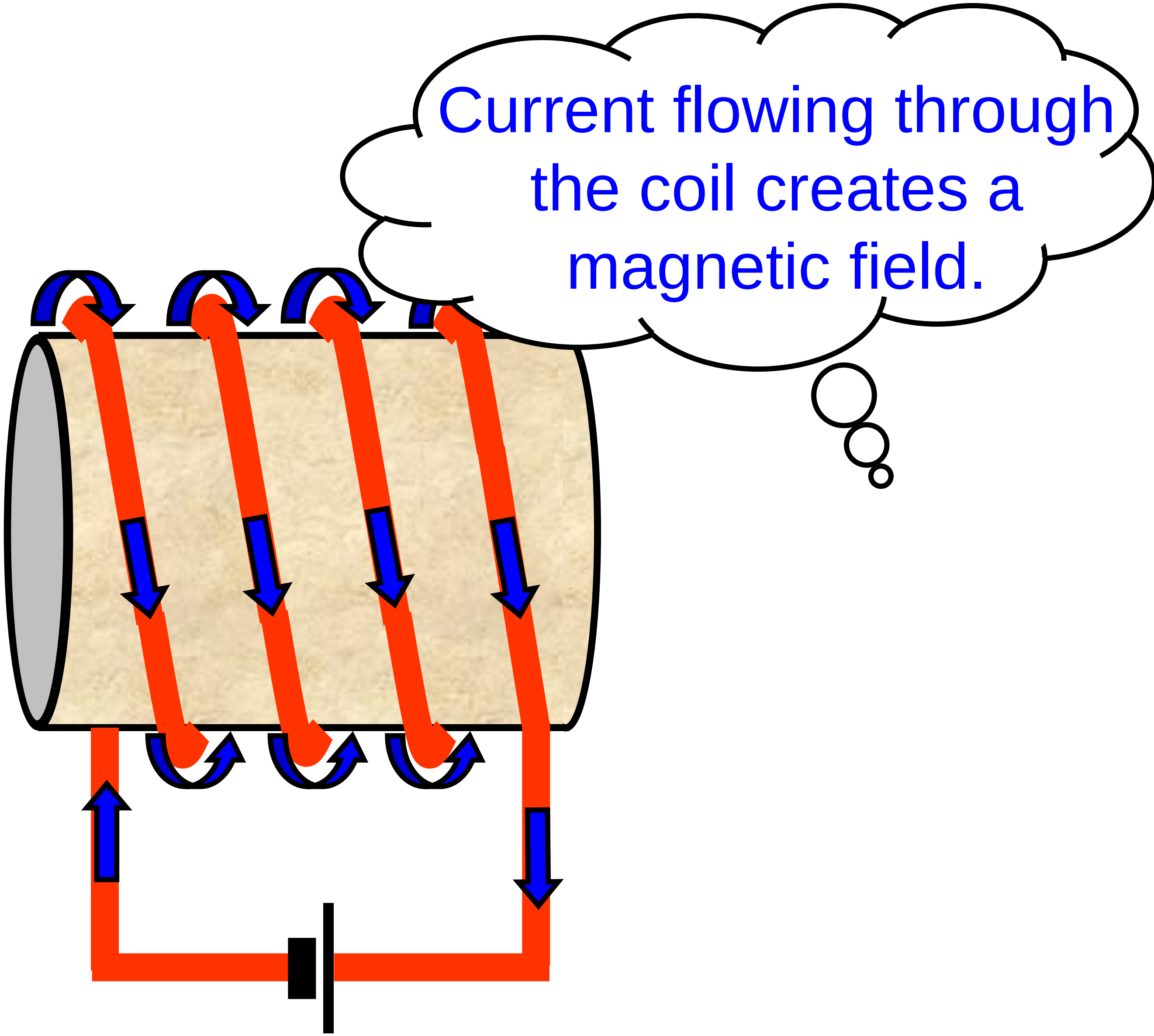

Next attach a
potential source
(battery)
to the wire.

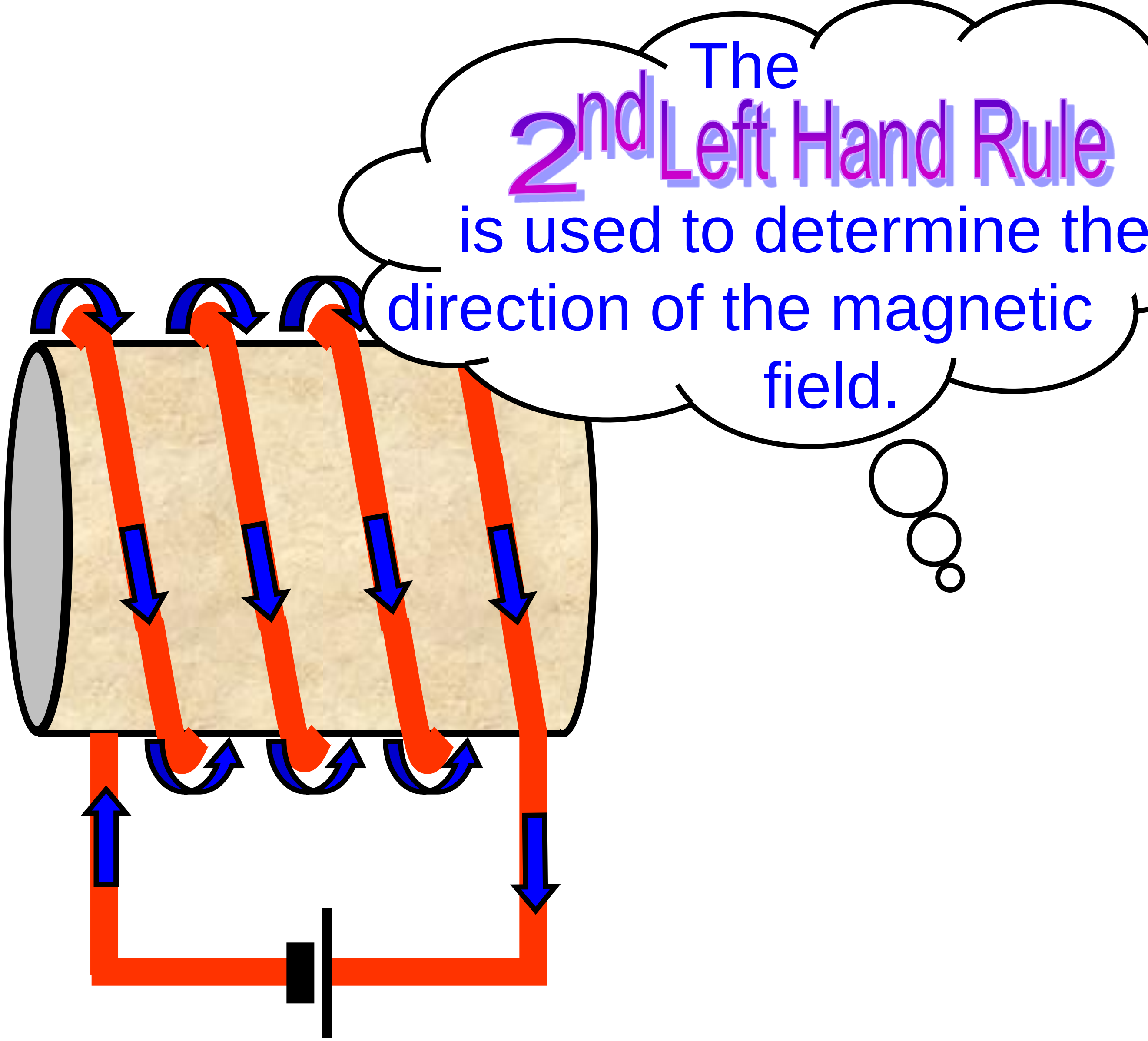

The current will flow from the negative terminal


through the wire
and back to the
positive terminal.


The current flowed up the back of the coil


and down the front
side or face of the
coil.

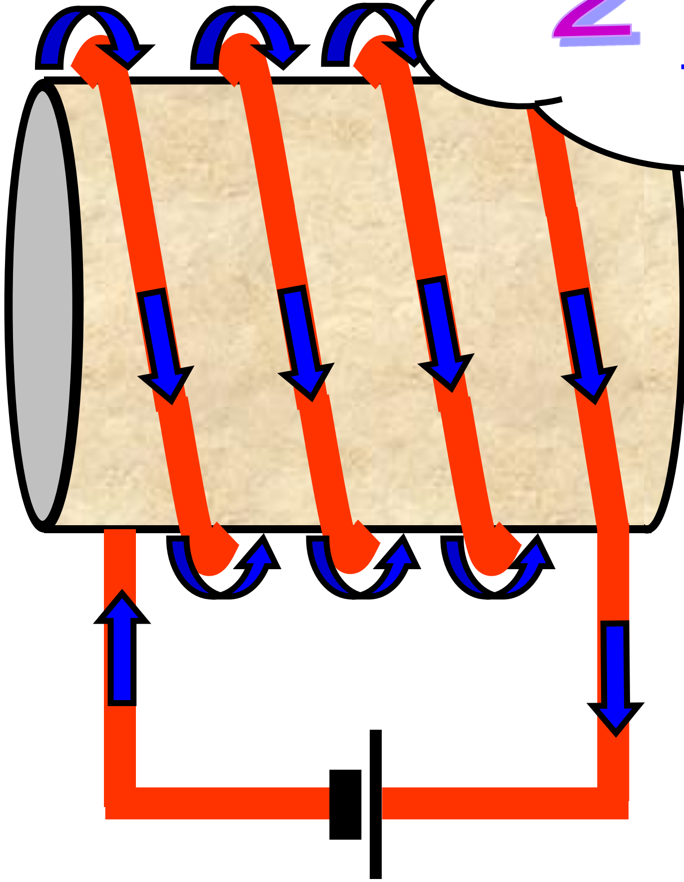

Current flowing through the coil creates a magnetic field.


The
2nd Left Hand Rule
is used to determine the
direction of the magnetic
field.

The next few slides will show how to apply the

2nd Left Hand Rule

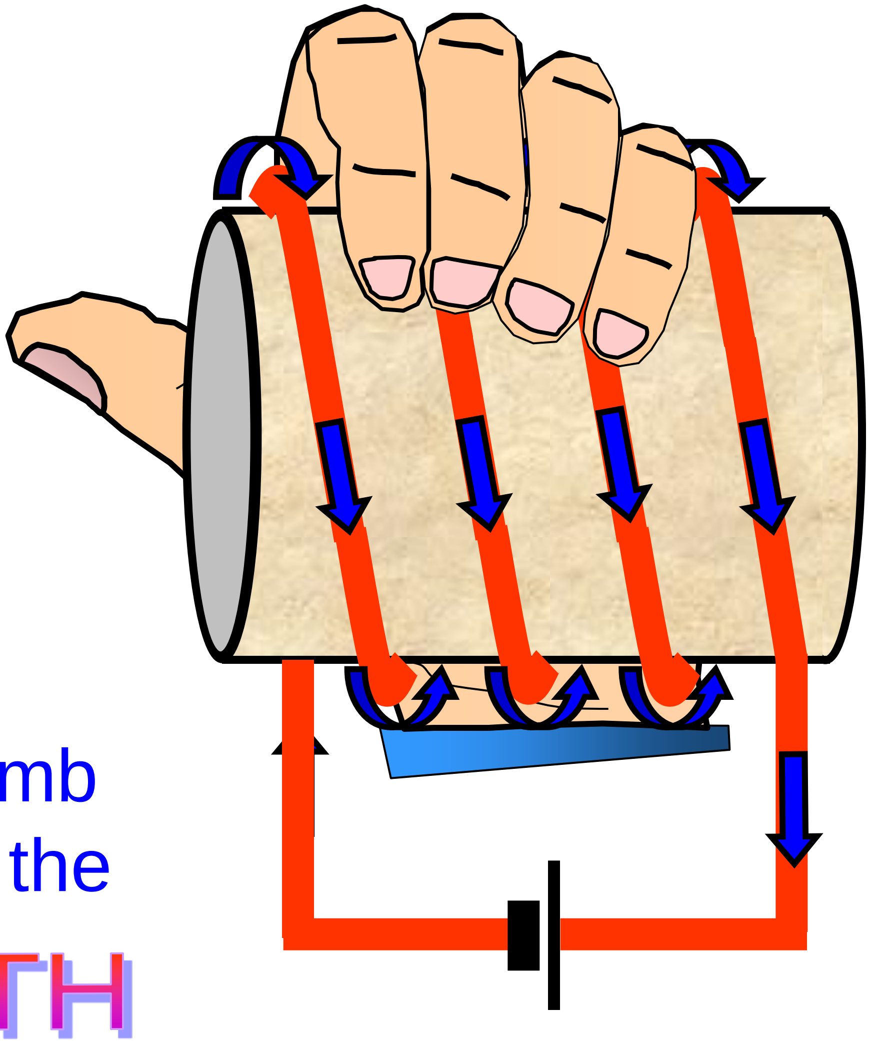
to this coil.



2nd Left Hand Rule

Grasp the coil with your left hand curling your fingers around the coil in the direction of electron flow.

N

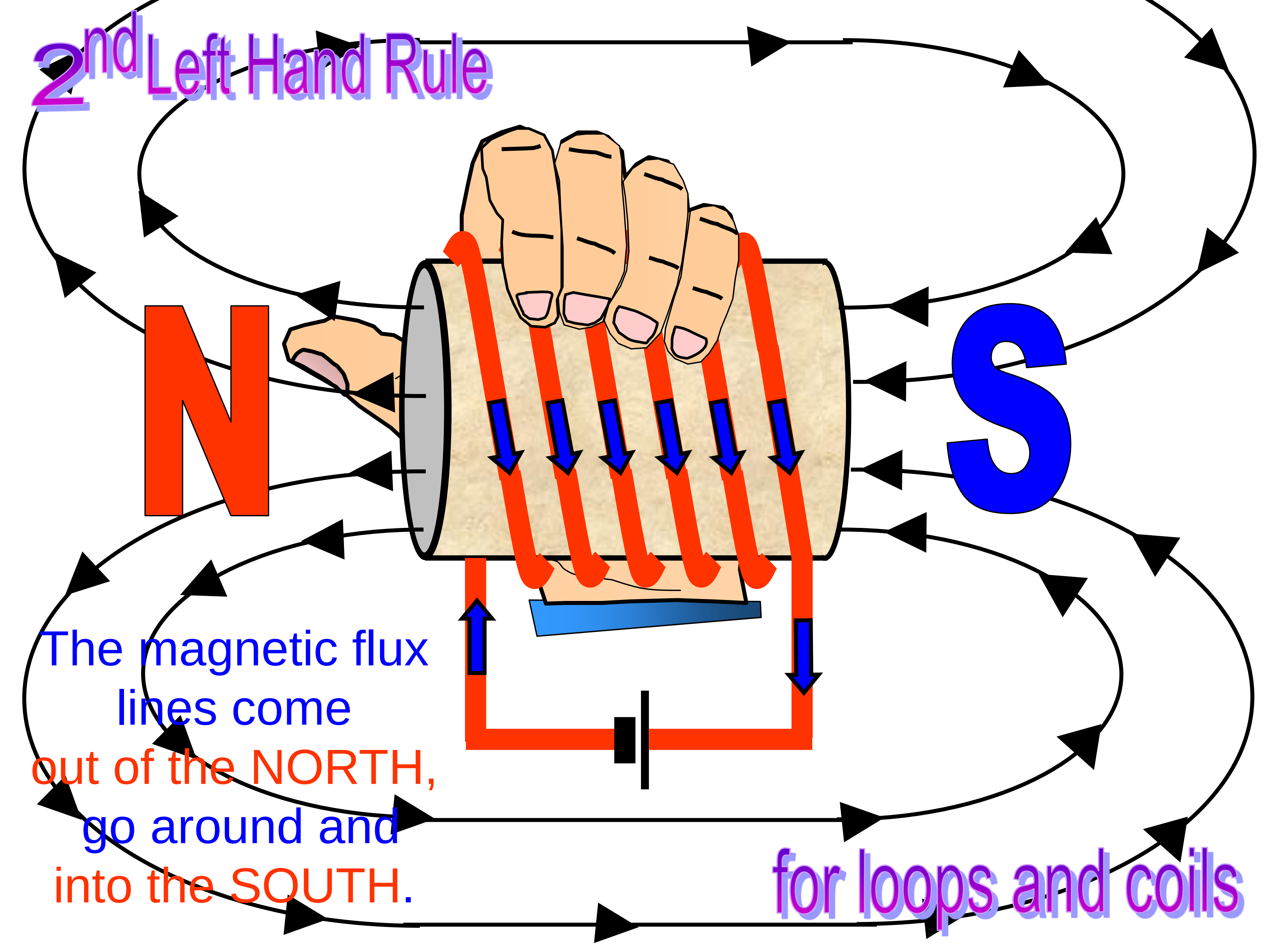


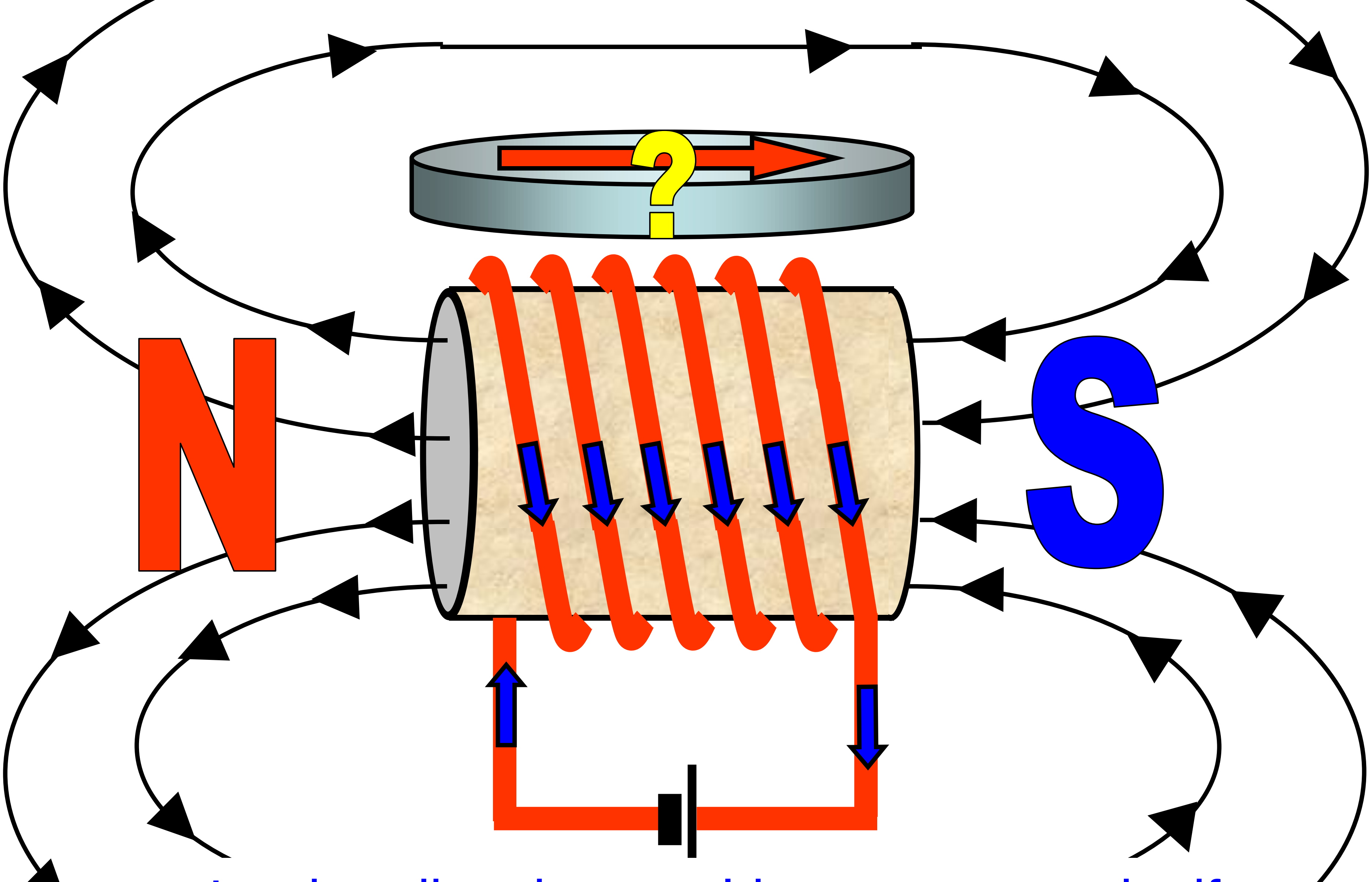
Your thumb points to the

NORTH

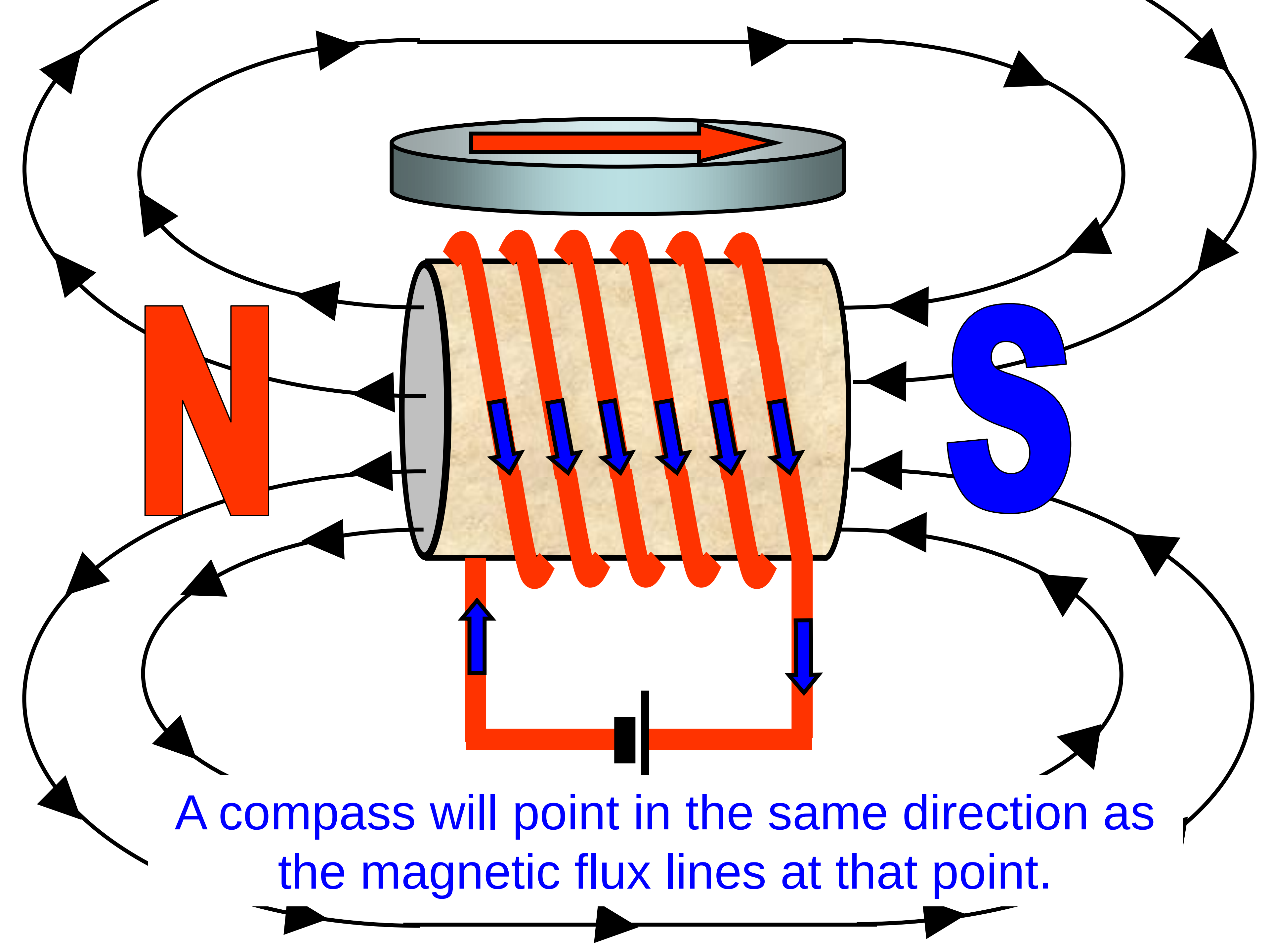
end of the coil

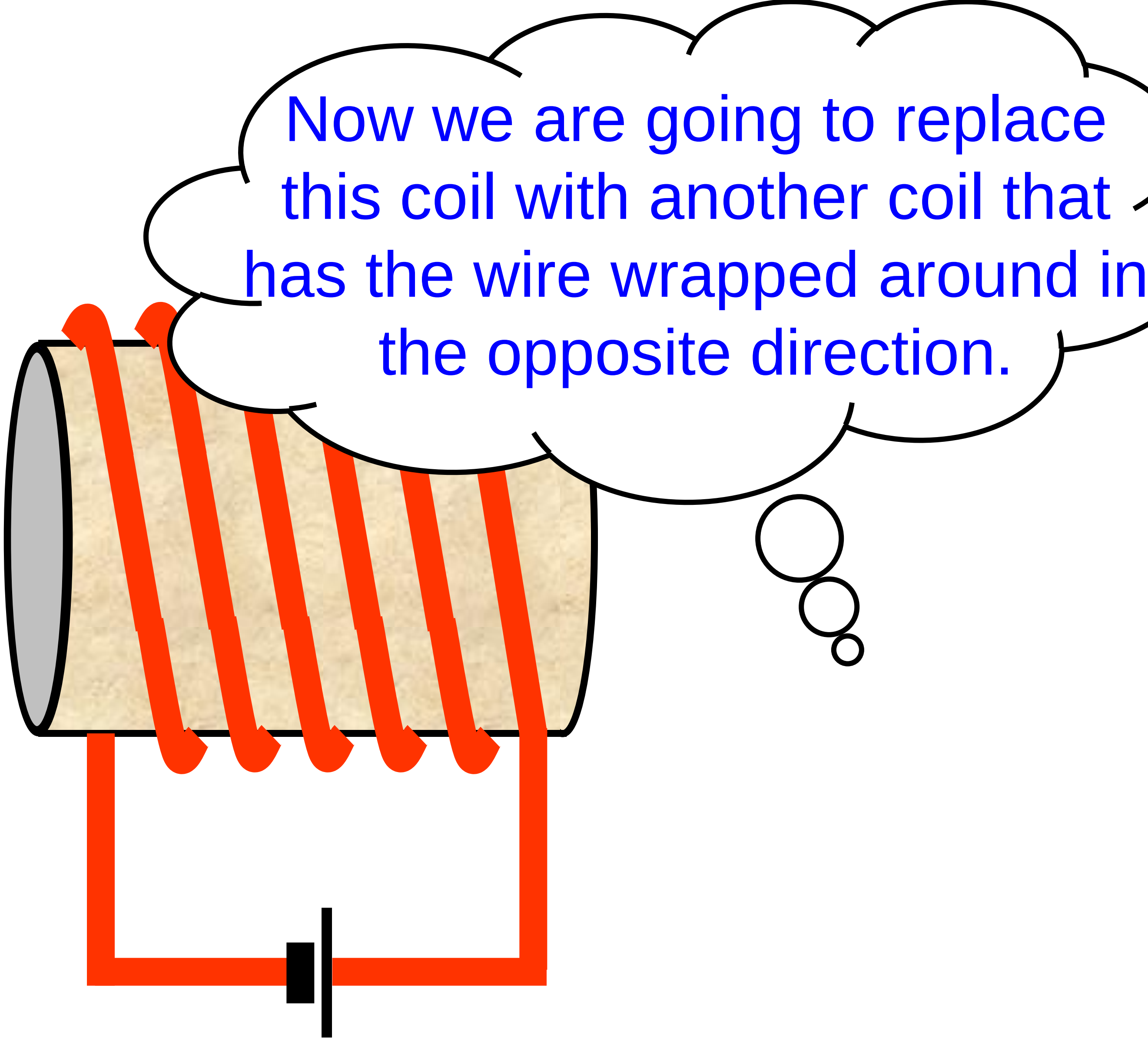
for loops and coils

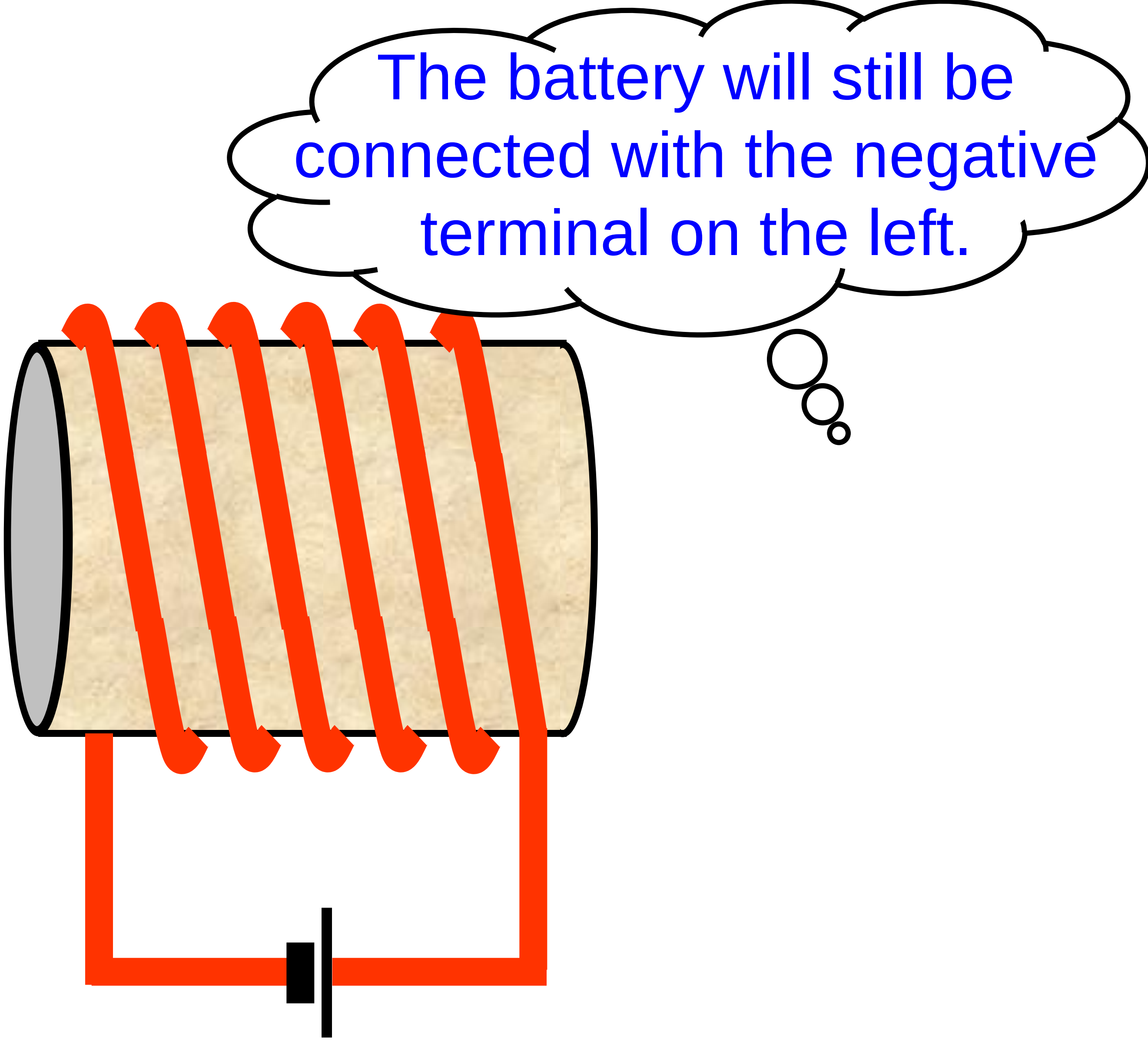

2nd Left Hand Rule
N
S
The magnetic flux
lines come
out of the NORTH,
go around and
into the SOUTH.
for loops and coils

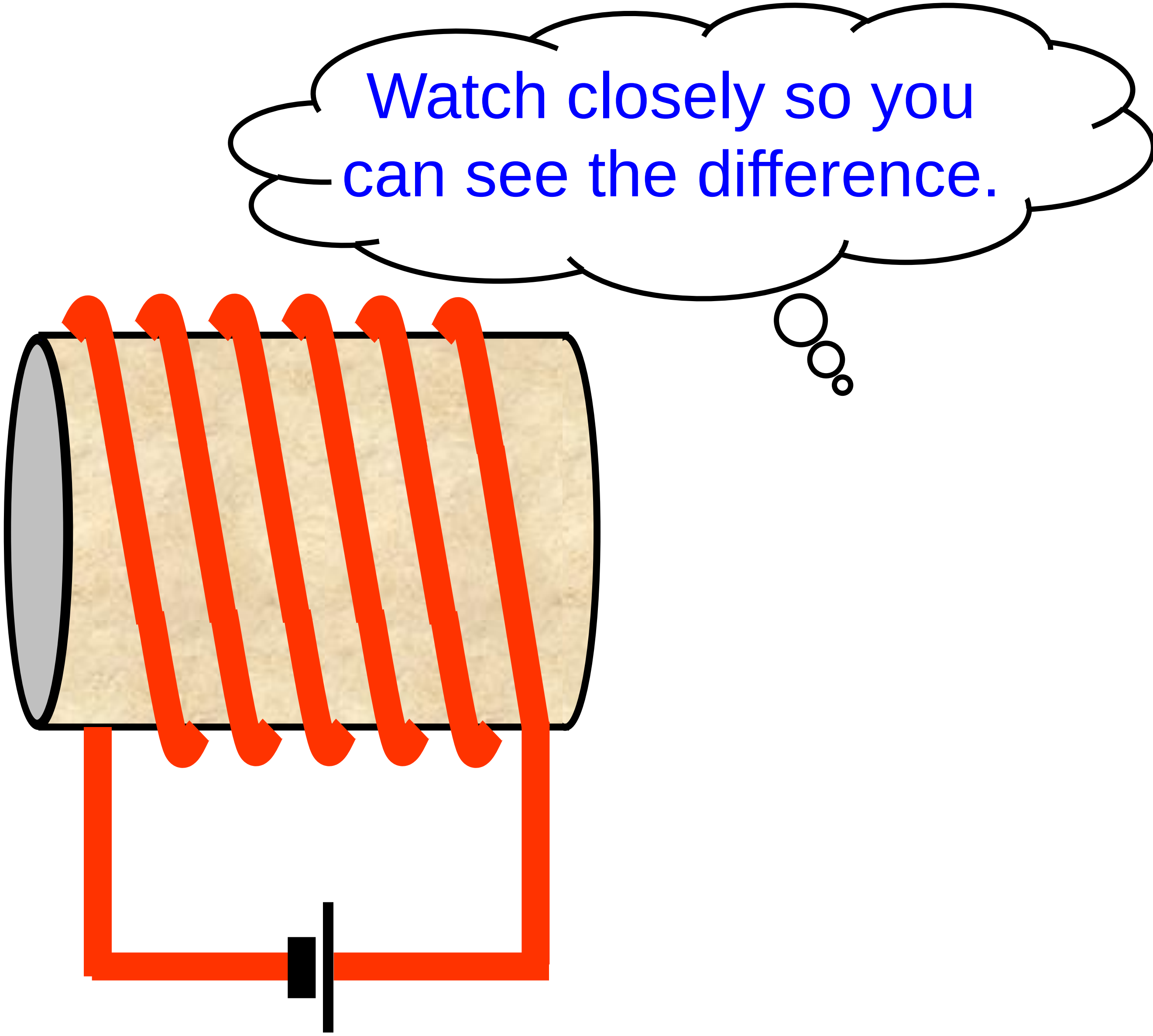


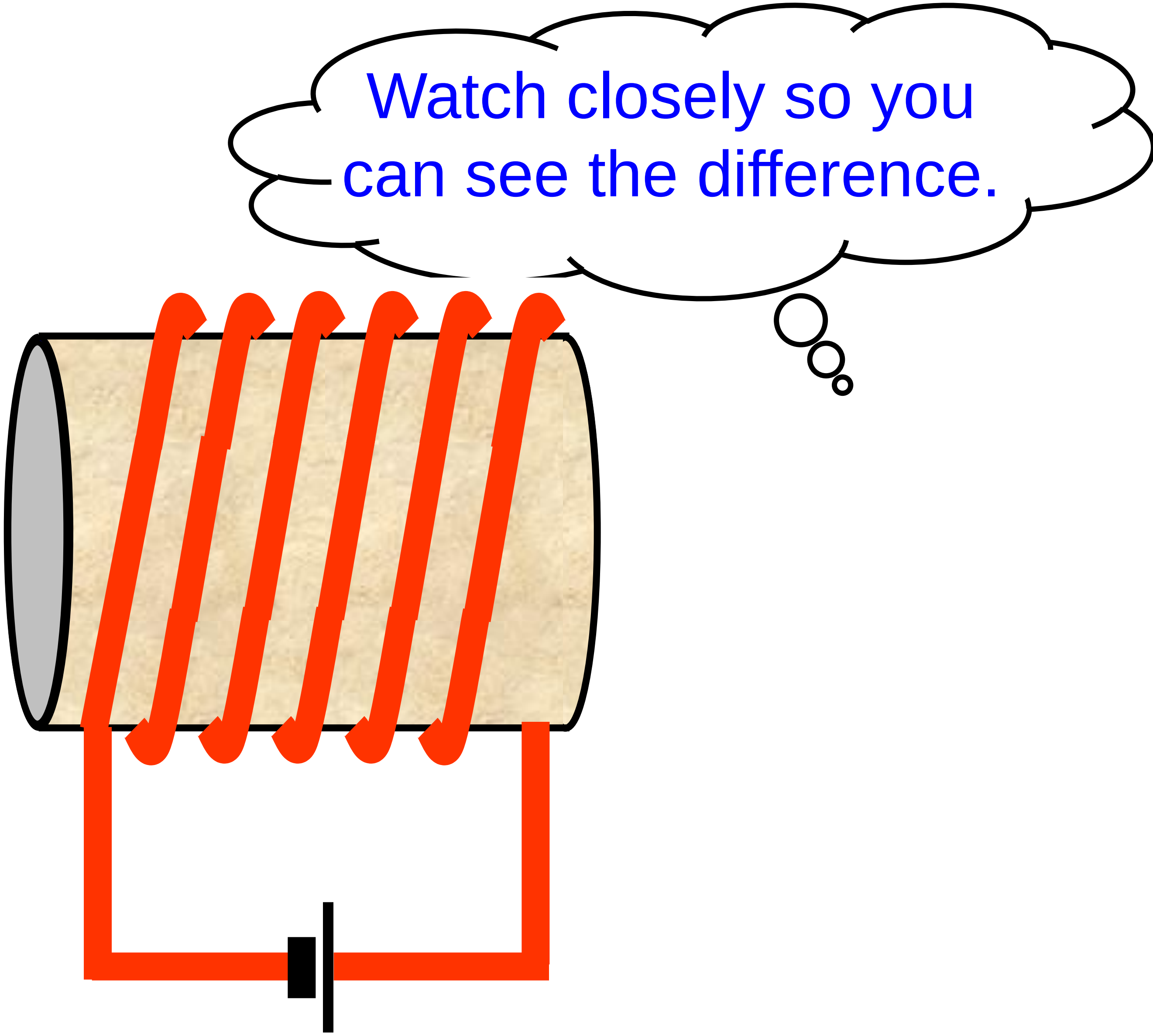
In what direction would a compass point if placed above the coil?

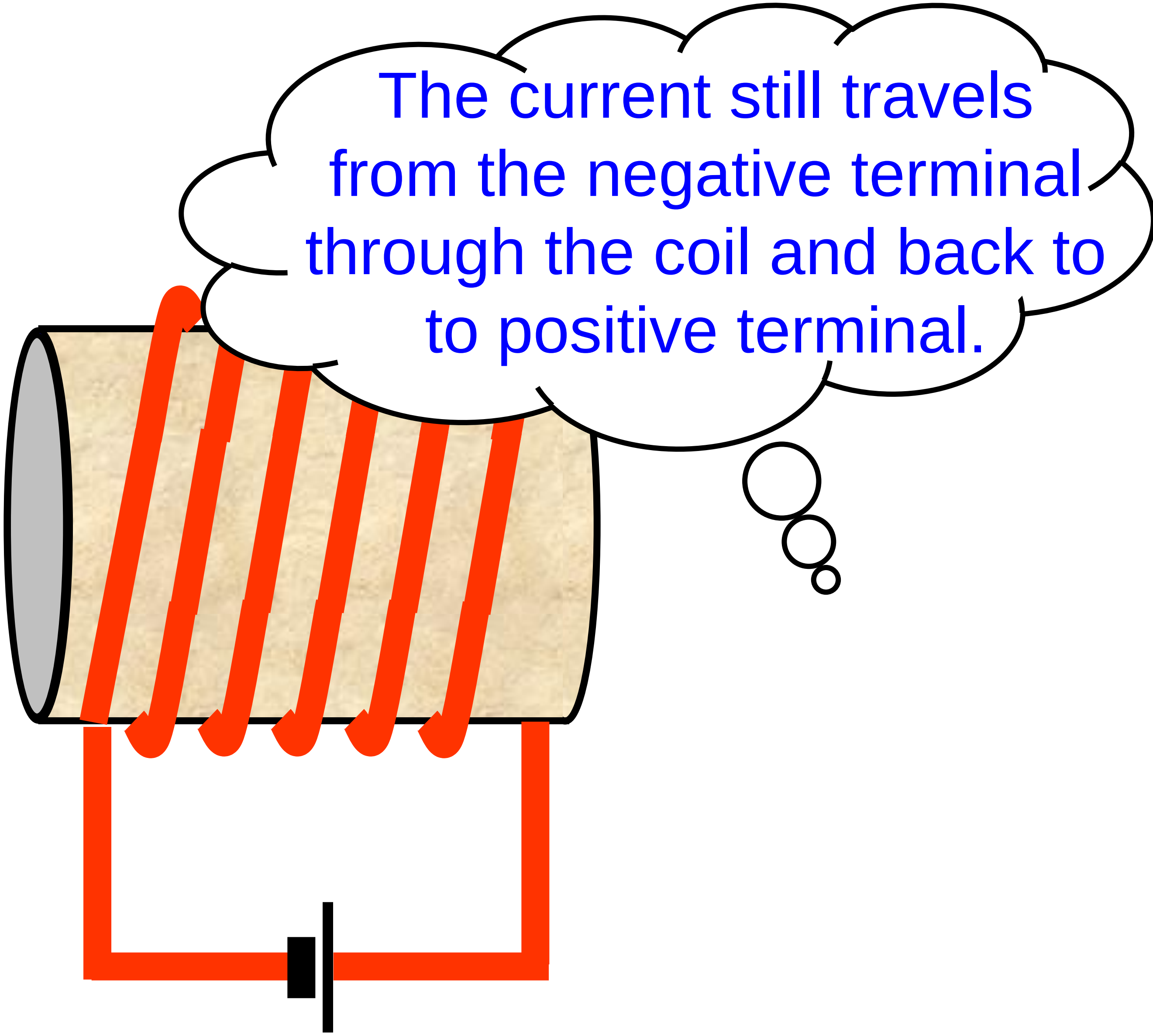

N
S
A compass will point in the same direction as the magnetic flux lines at that point.

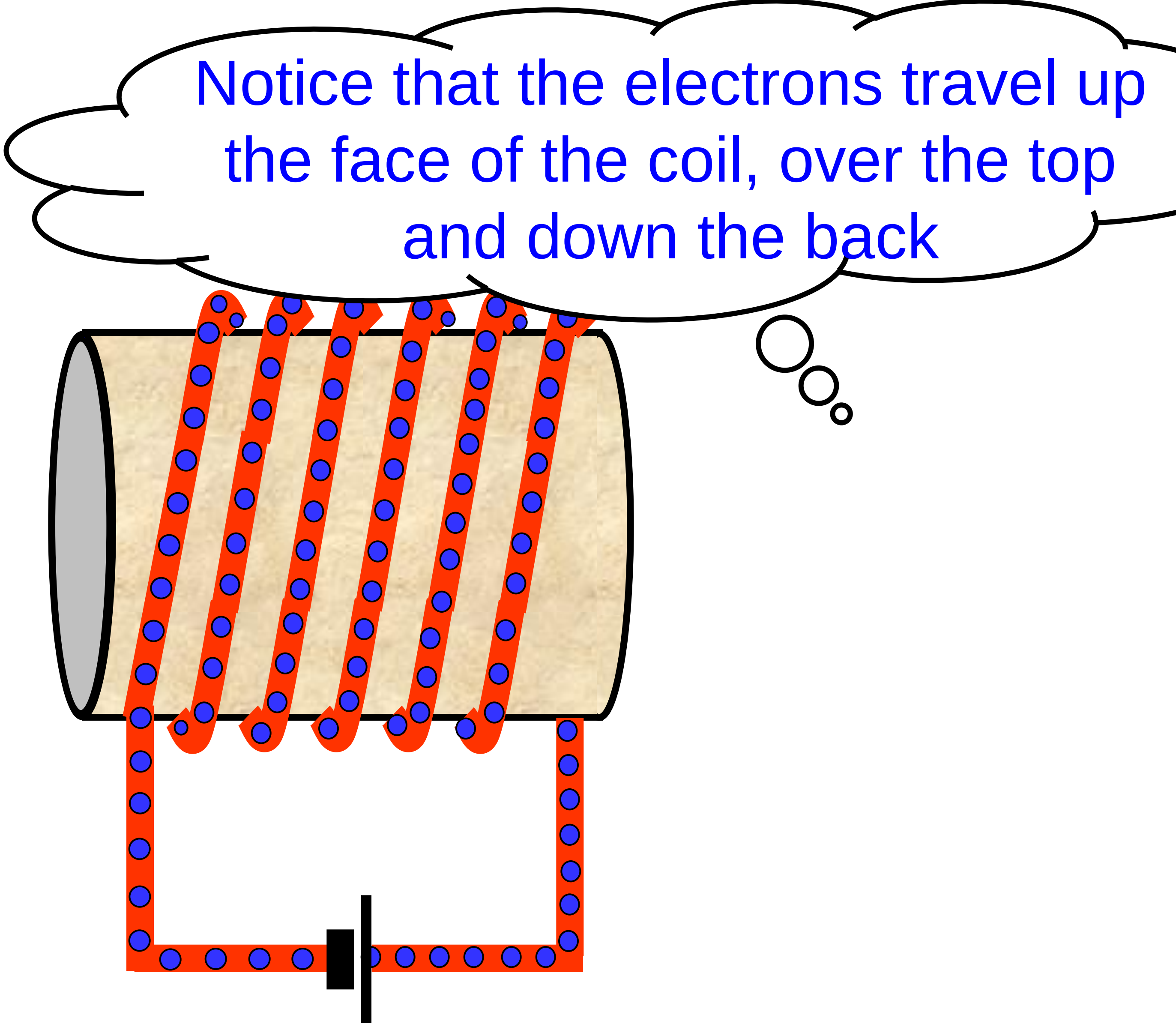

Now we are going to replace
this coil with another coil that
has the wire wrapped around in
the opposite direction.

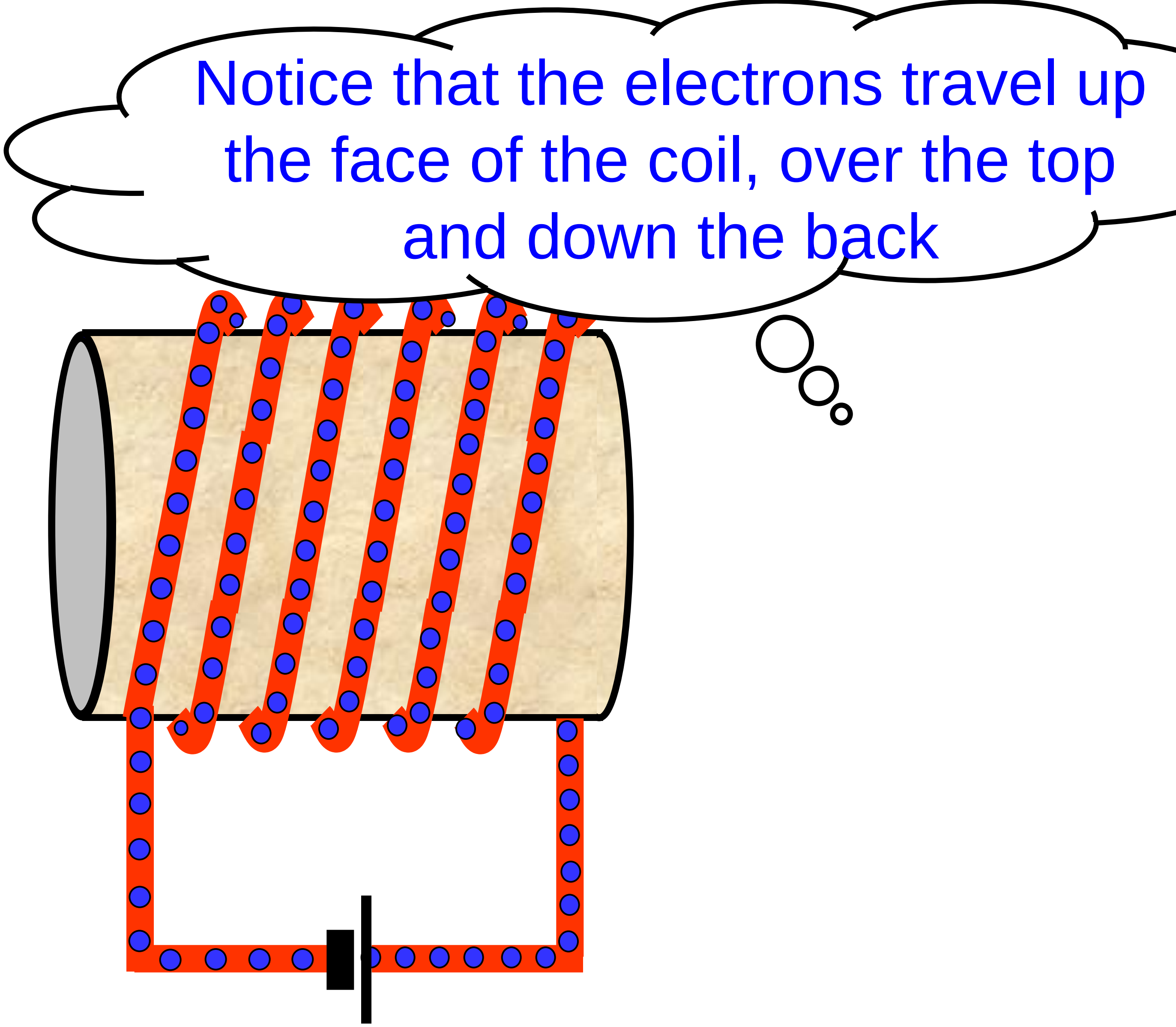

The battery will still be connected with the negative terminal on the left.

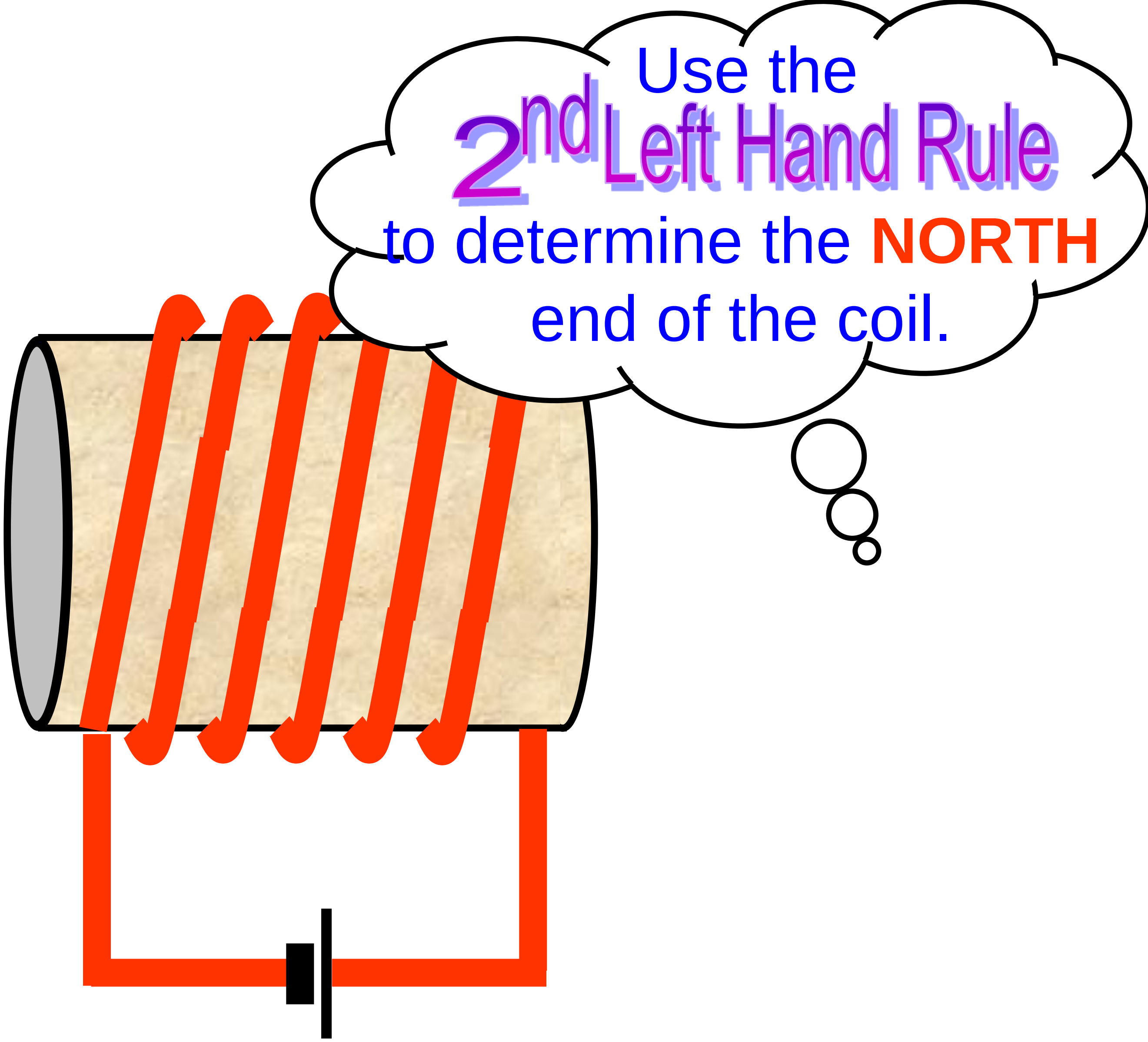

Watch closely so you can see the difference.

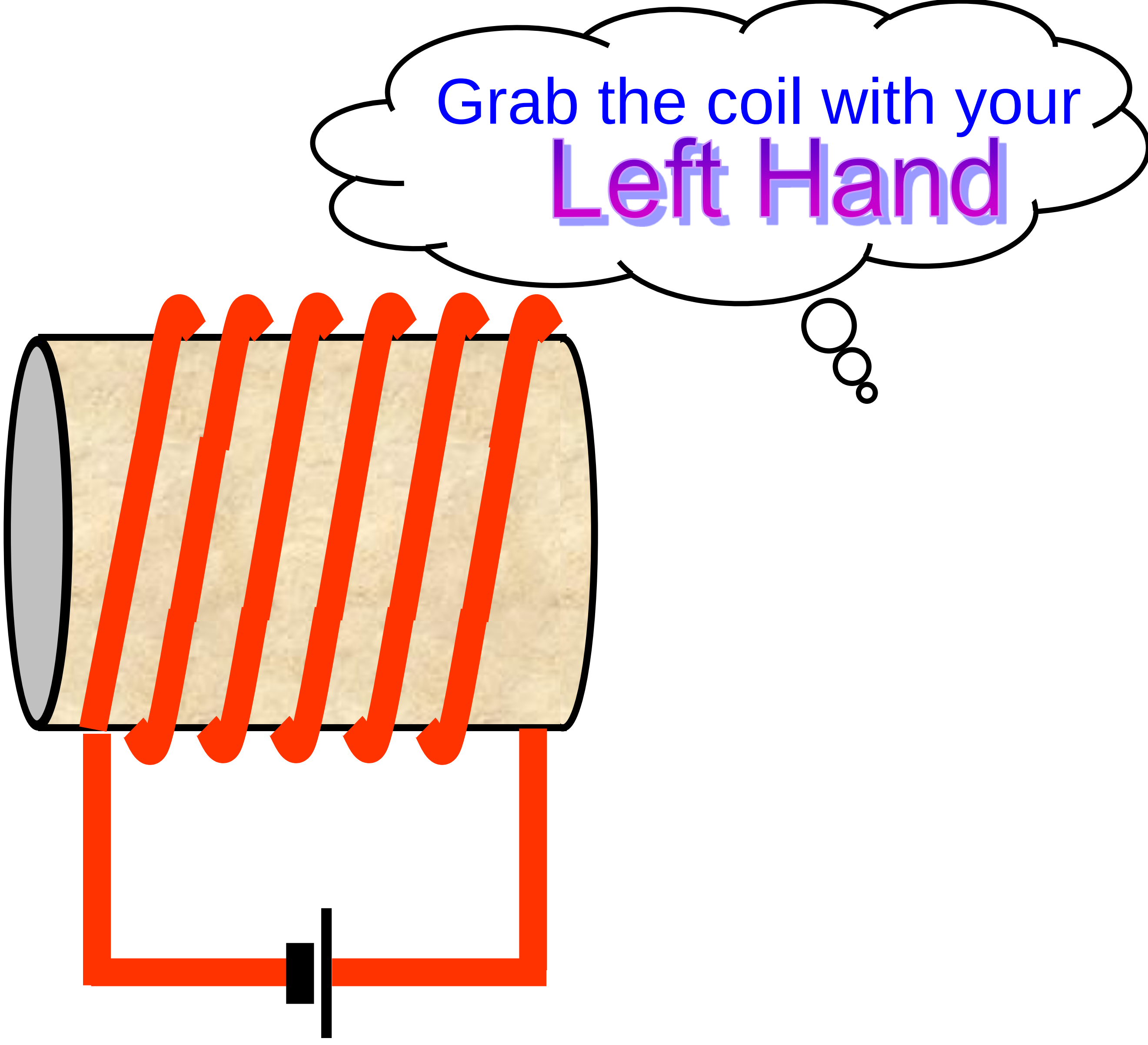

Watch closely so you can see the difference.

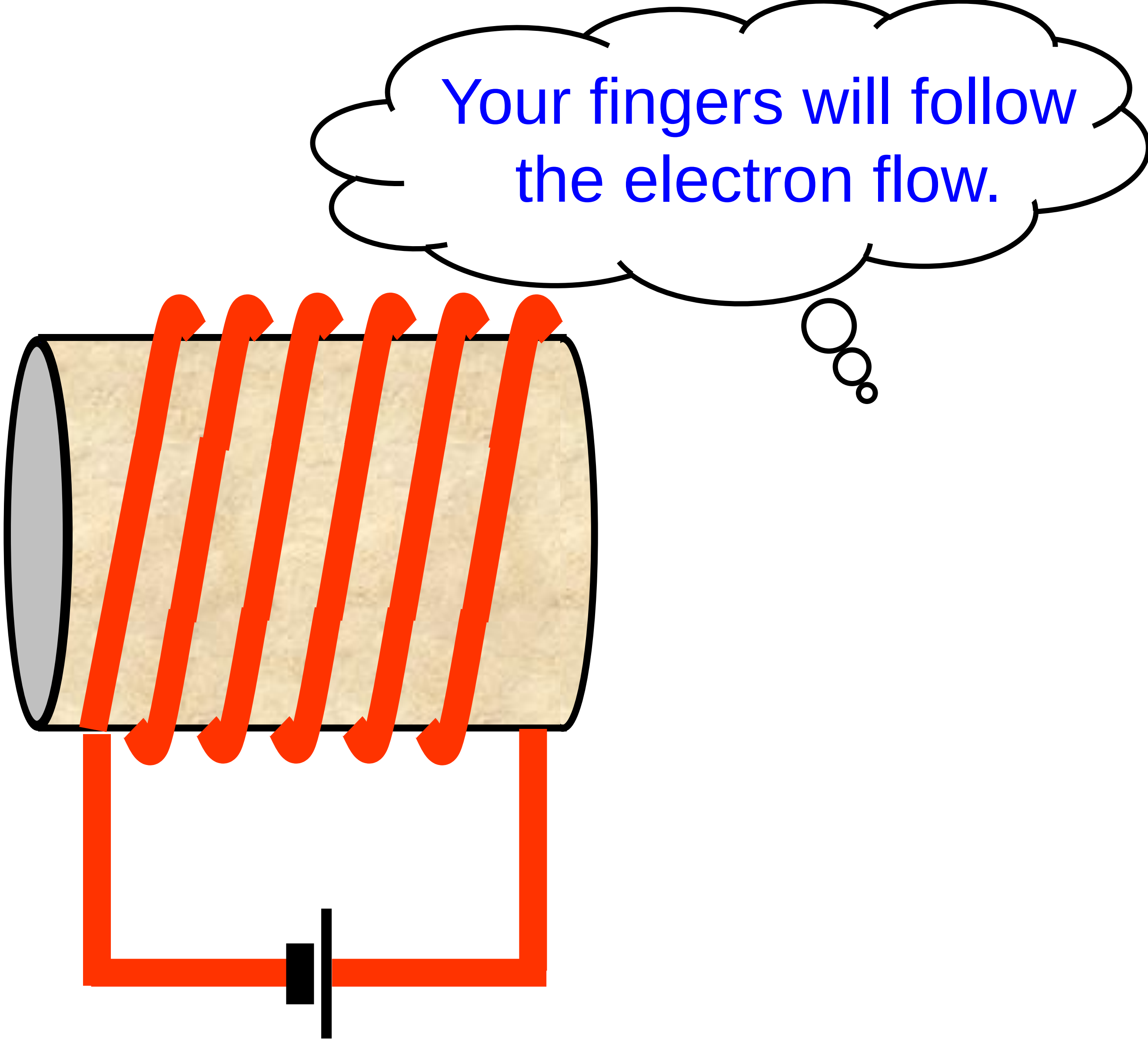

The current still travels from the negative terminal through the coil and back to to positive terminal.

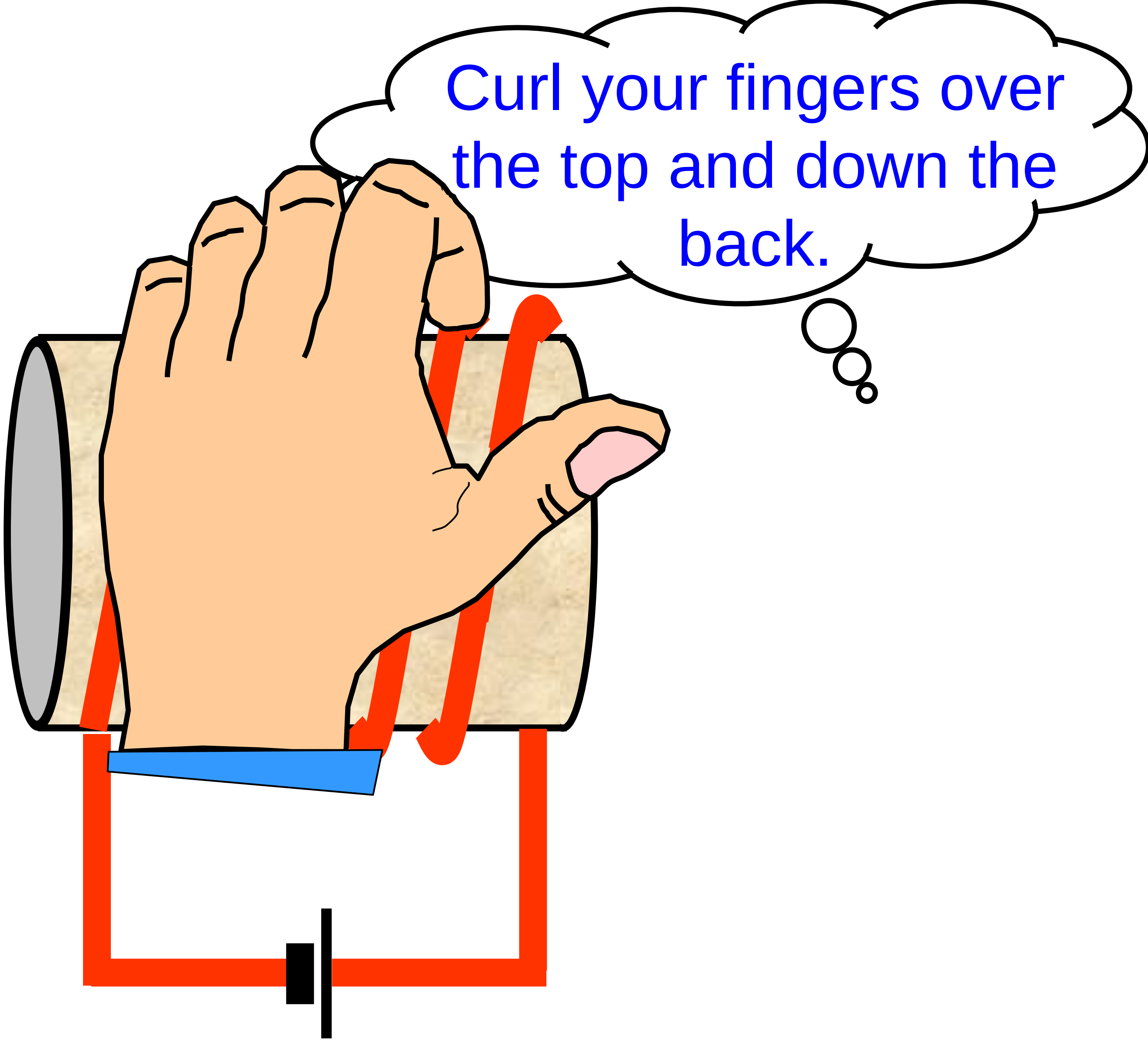

Notice that the electrons travel up the face of the coil, over the top and down the back

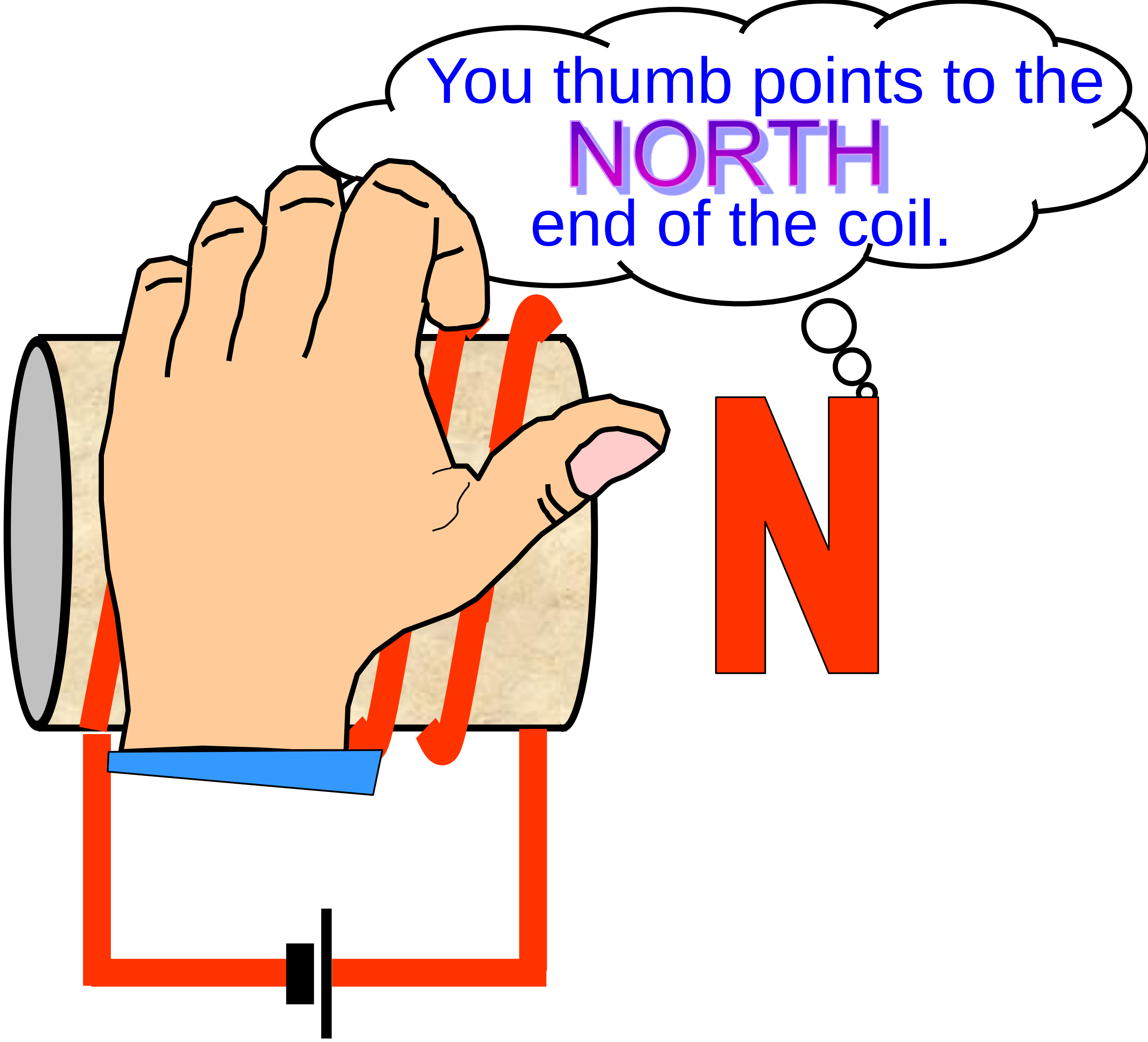

Notice that the electrons travel up the face of the coil, over the top and down the back

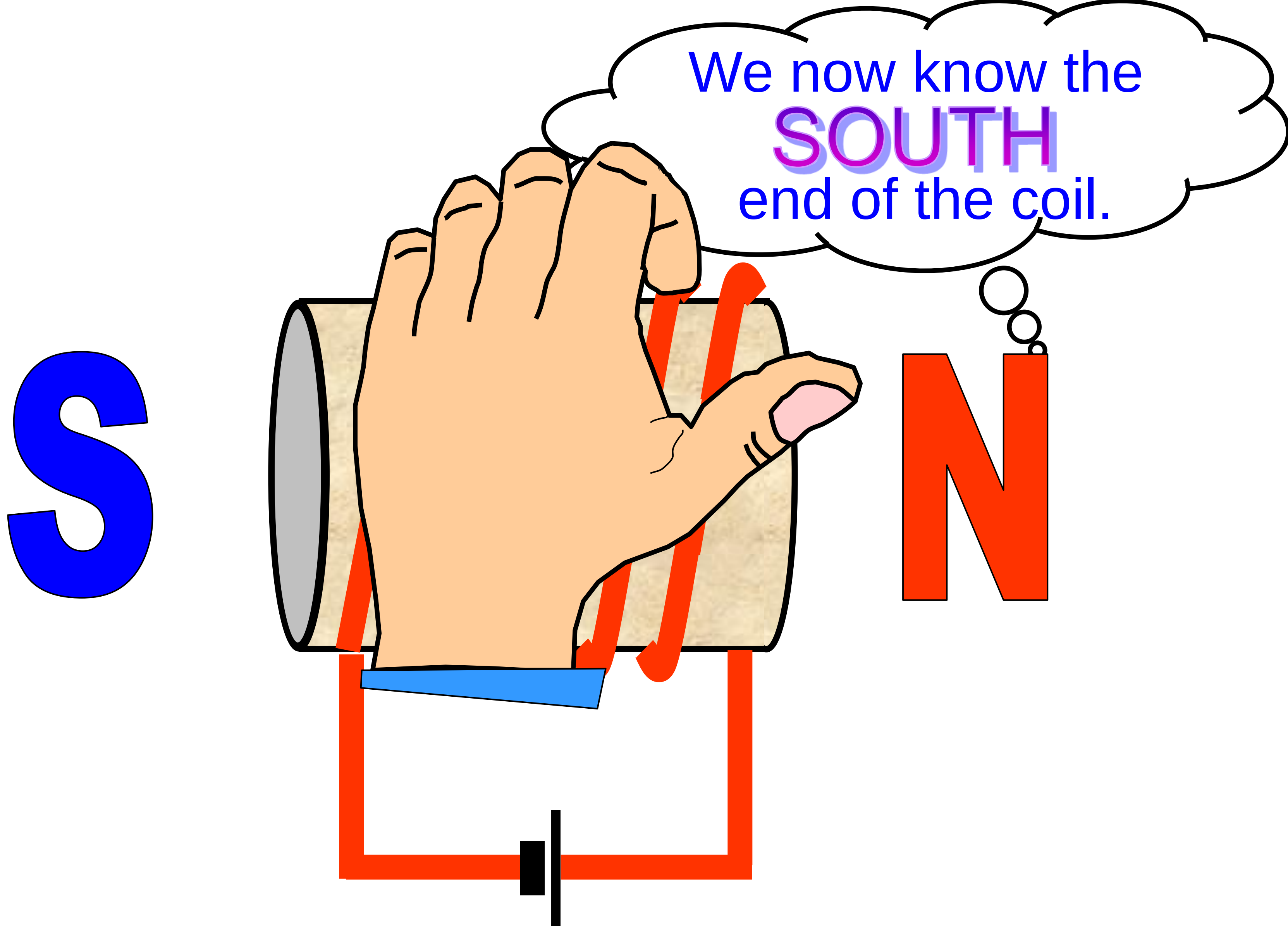

Use the
2nd Left Hand Rule
to determine the NORTH
end of the coil.

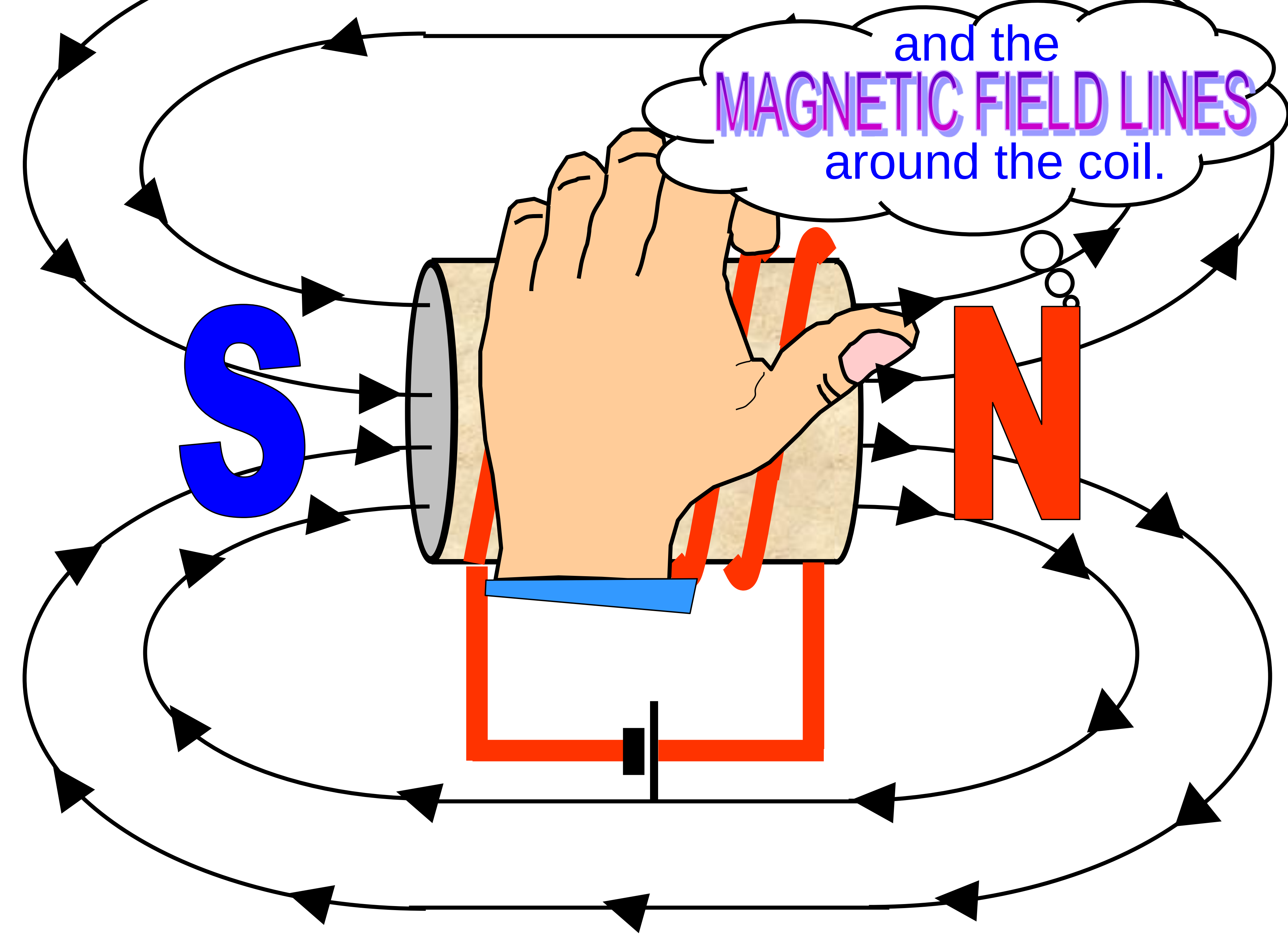

Grab the coil with your
Left Hand

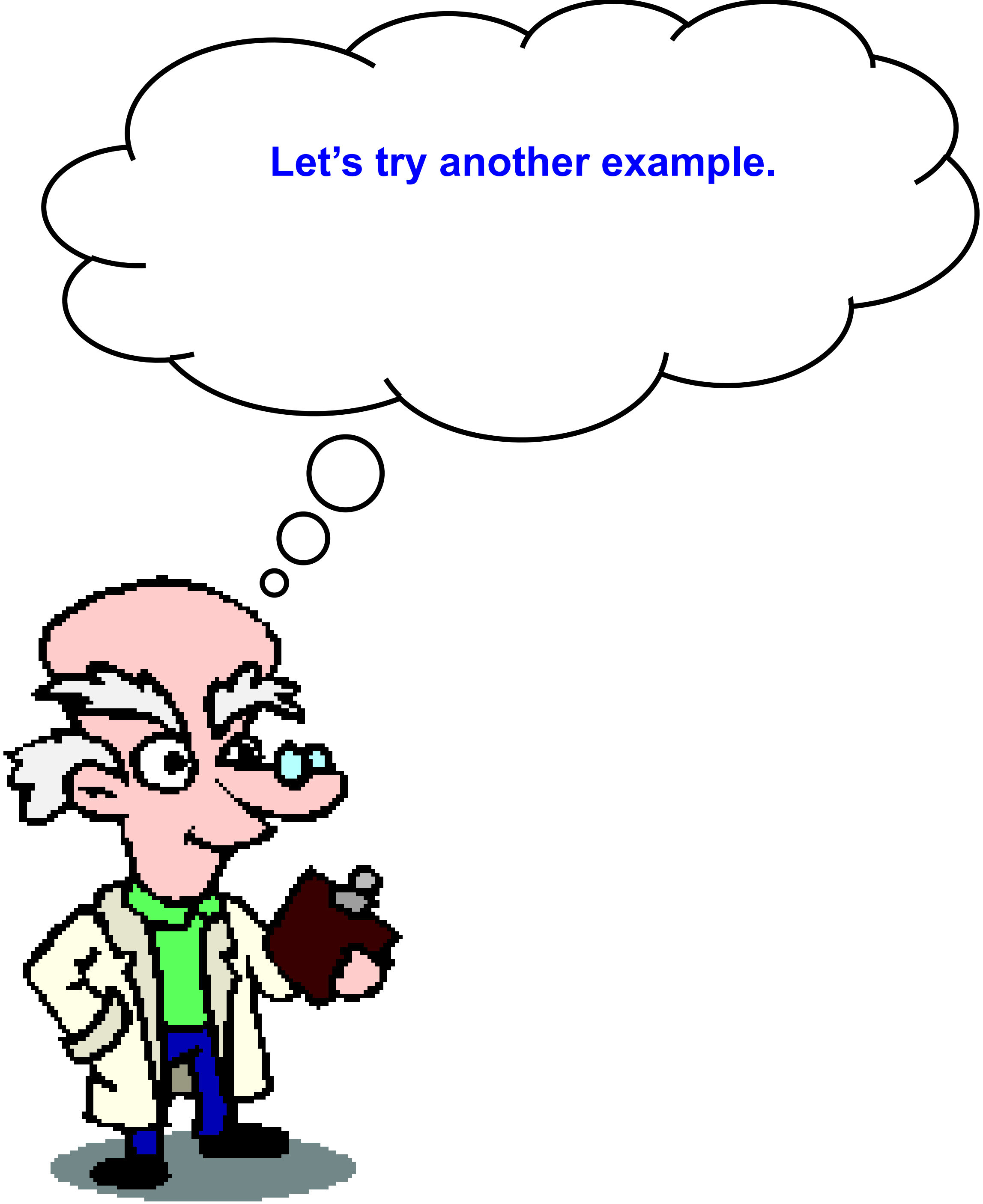

Your fingers will follow the electron flow.


Curl your fingers over the top and down the back.

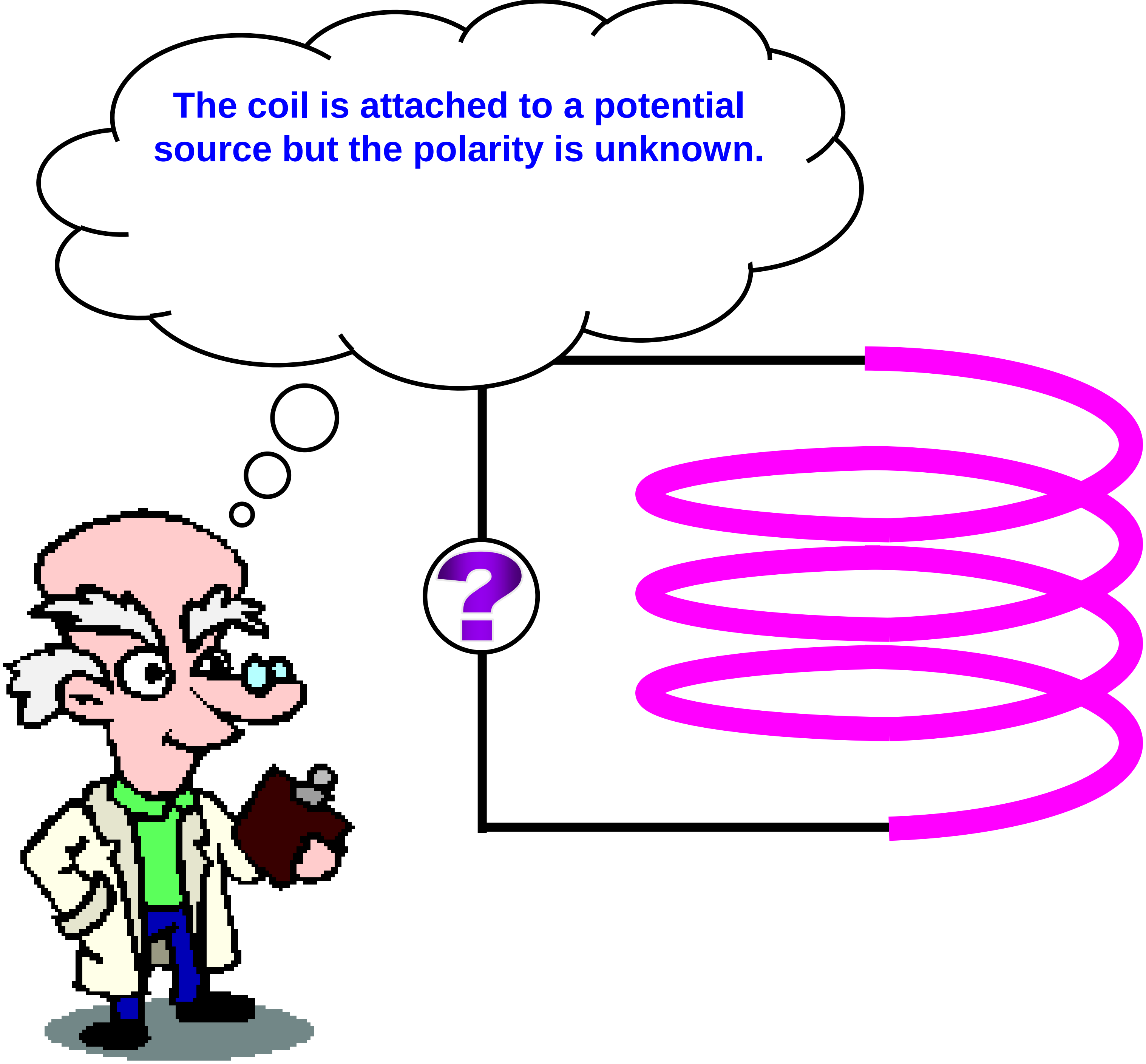

You thumb points to the
NORTH
end of the coil.
N

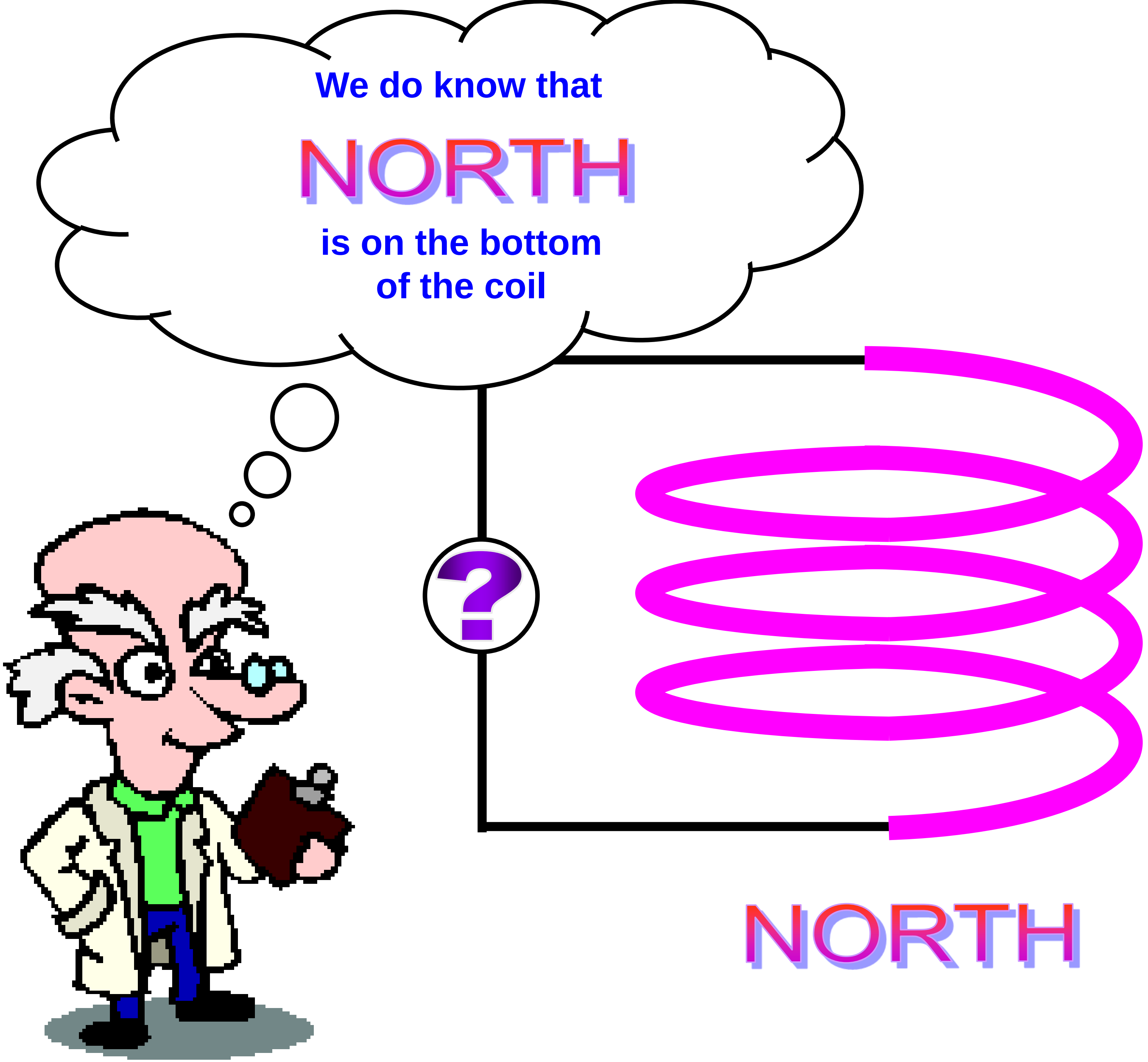

We now know the
SOUTH
end of the coil.
S
N

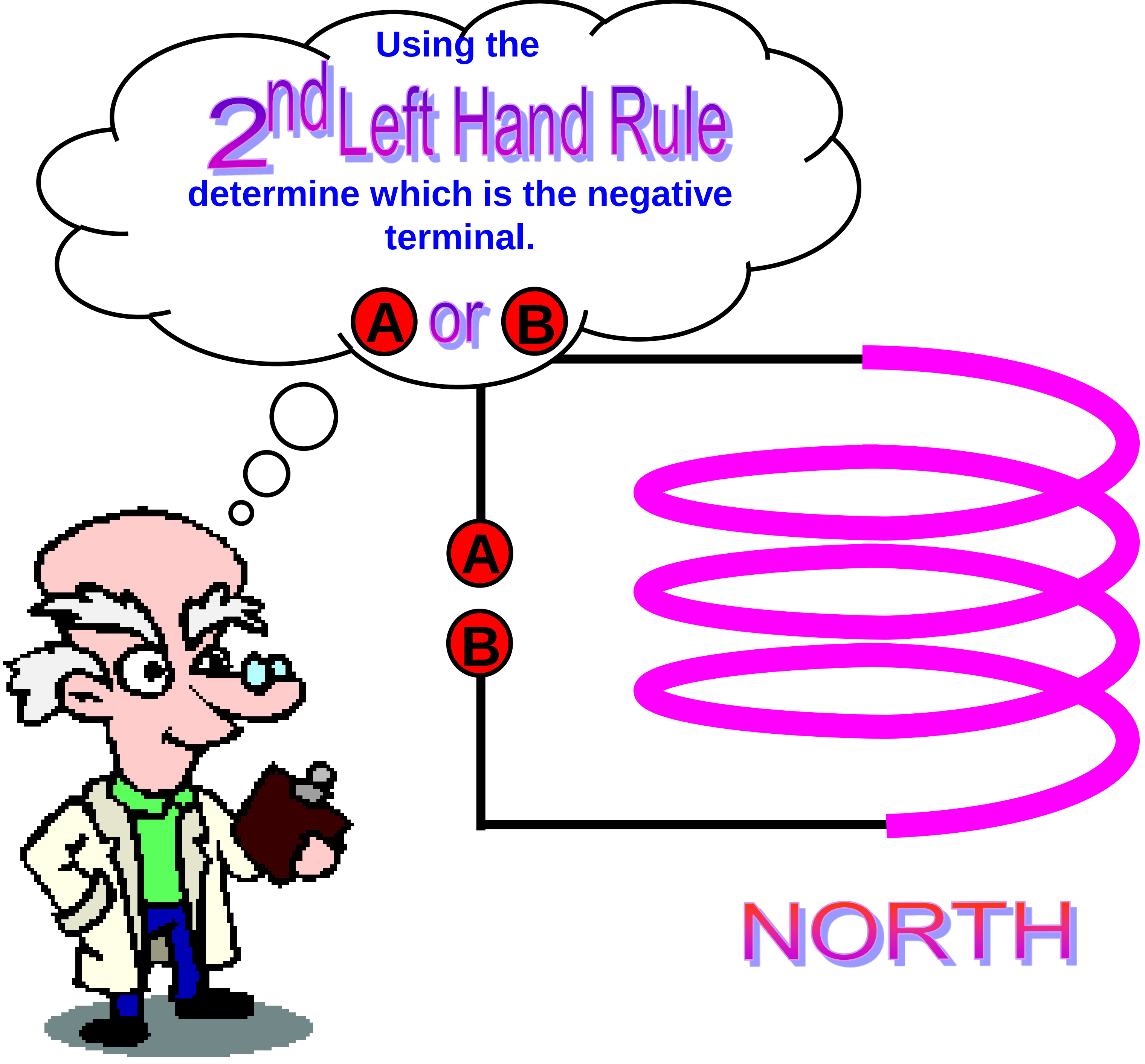

and the
MAGNETIC FIELD LINES
around the coil.
S
N


Let's try another example.

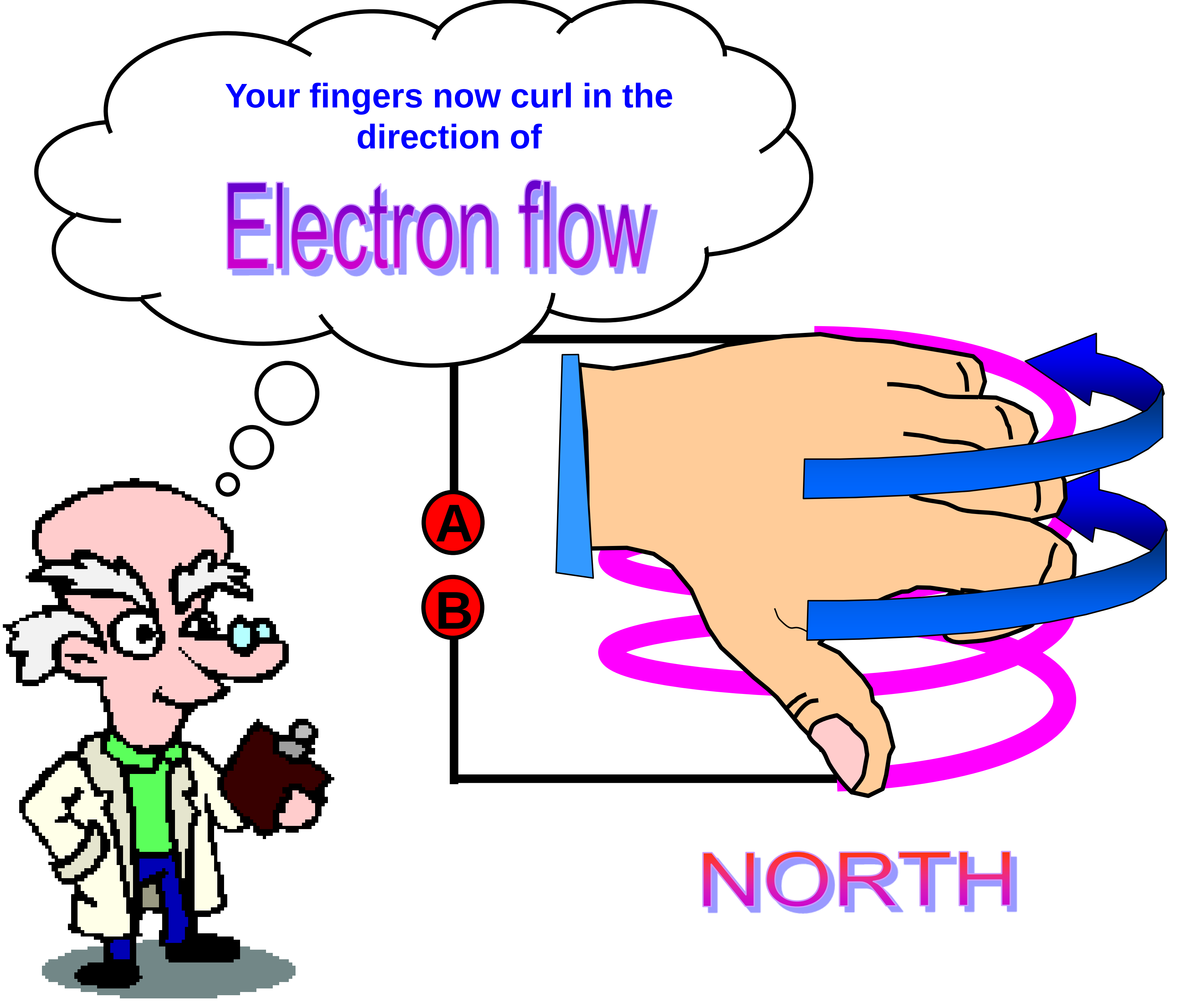

We'll start with another coil.

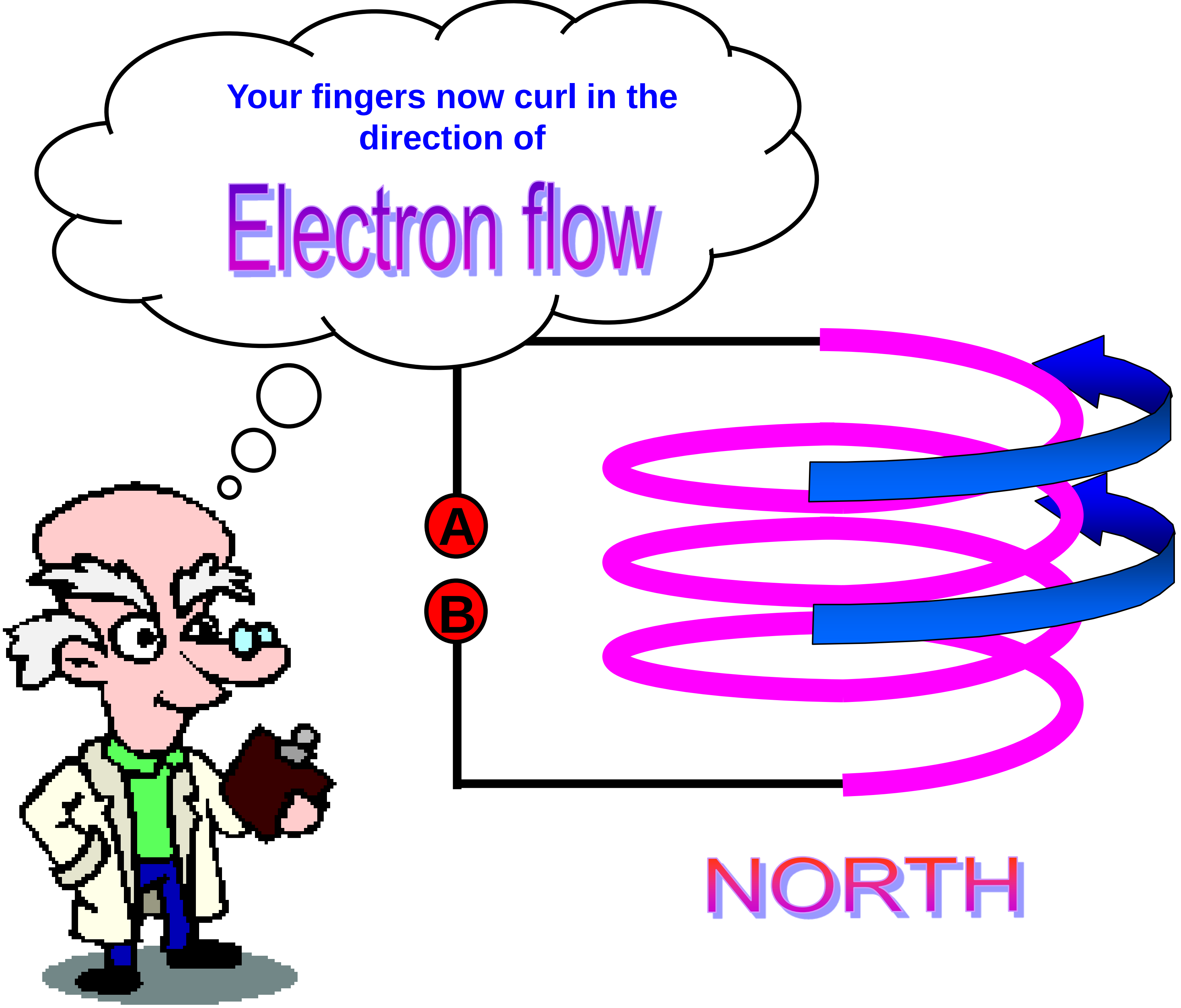

The coil is attached to a potential source but the polarity is unknown.
?

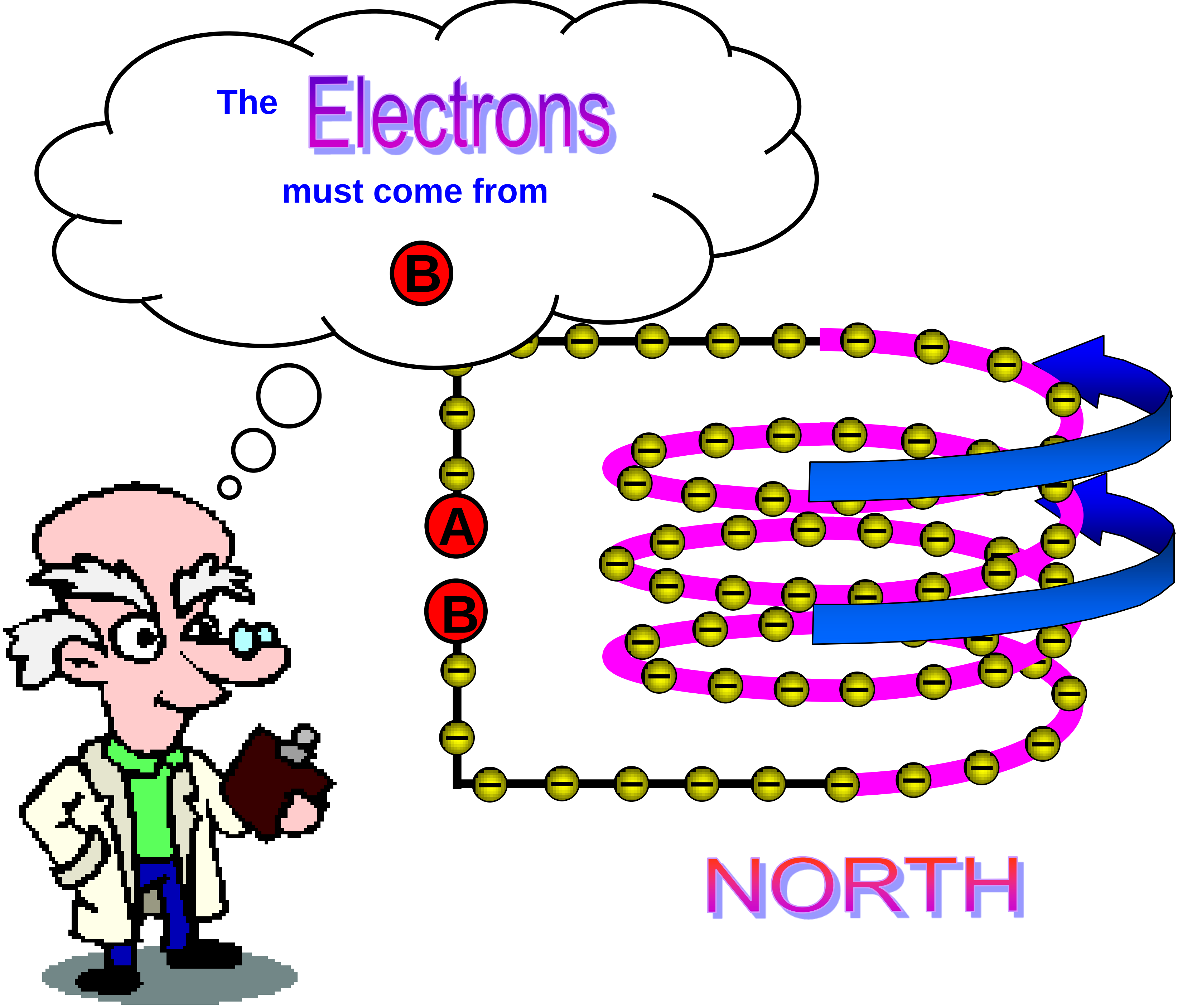

We do know that
NORTH
is on the bottom
of the coil
?
NORTH

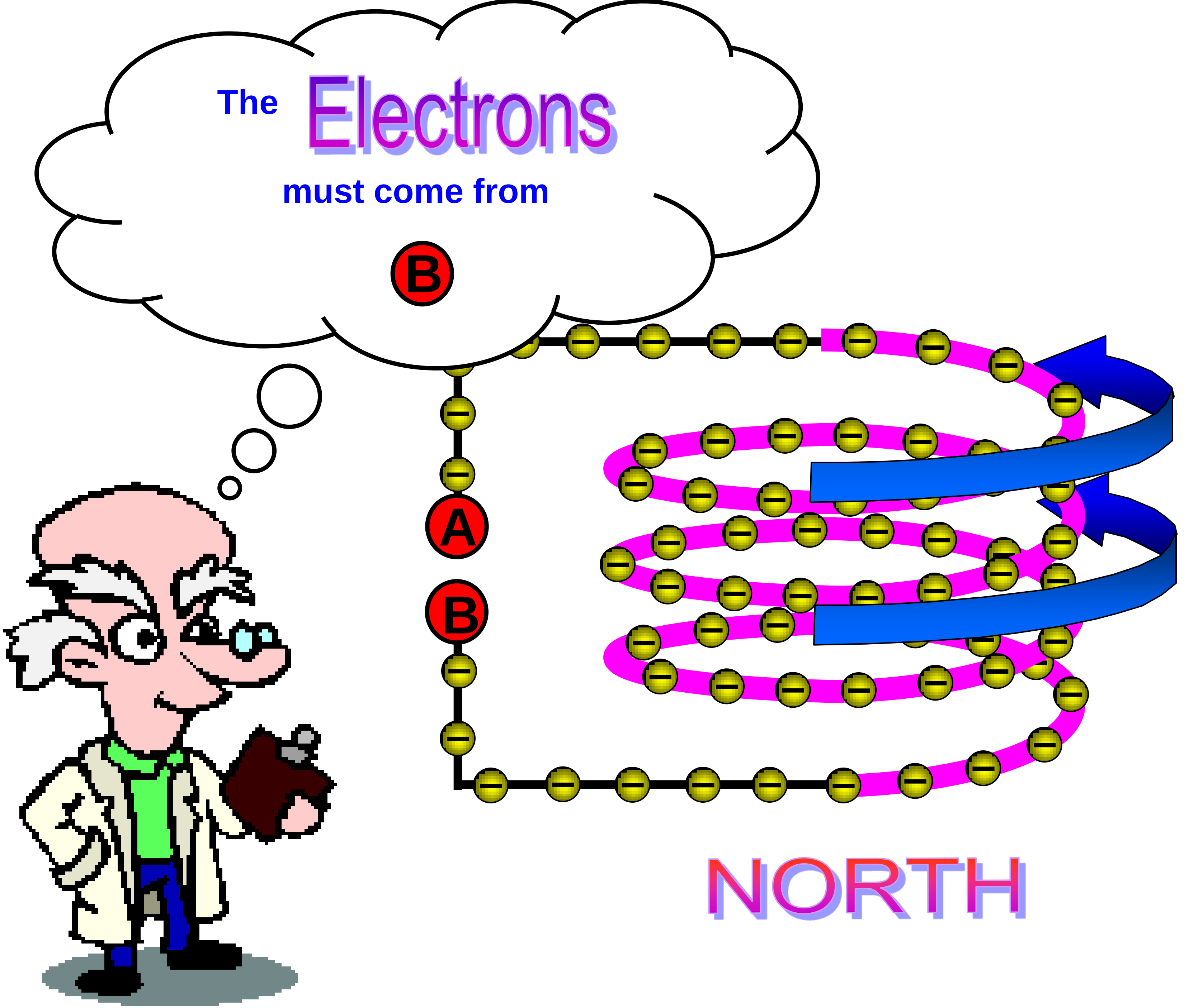

Using the
2nd Left Hand Rule
determine which is the negative terminal.
A or B
A
B
NORTH

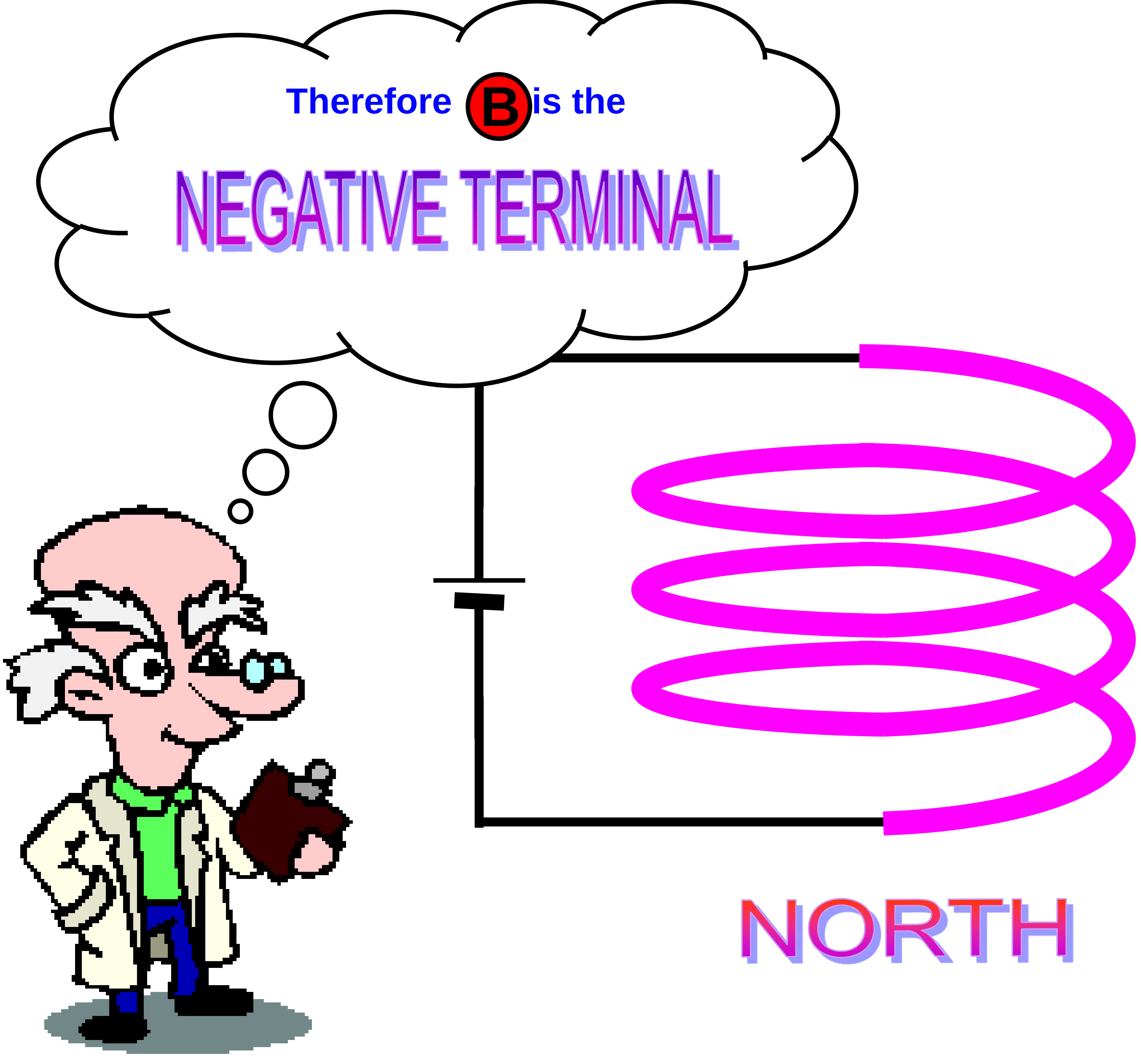

Grab the coil with your
Left Hand
so you thumb points
NORTH
A
B
NORTH


Your fingers now curl in the direction of
Electron flow
A
B
NORTH


Your fingers now curl in the direction of
Electron flow
A
B
NORTH


The Electrons
must come from
B
A
B
NORTH


The
Electrons
must come from
B
A
B
NORTH



Therefore B is the
NEGATIVE TERMINAL
NORTH

Activity

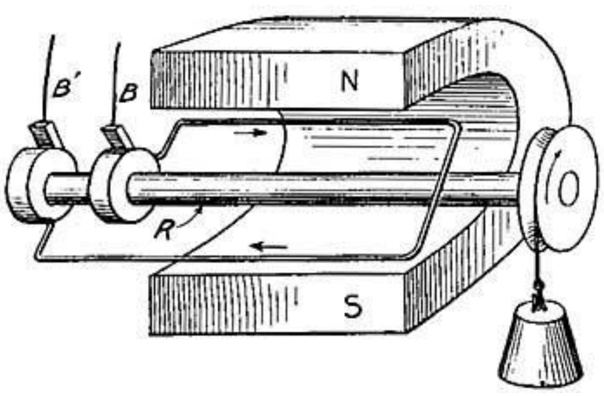
Textbook:

638-639--do #2 b, e, #3, #4.

Physics 3204

Unit 3: Section 3 Electromagnetism

Topic 9 : Motor Principle

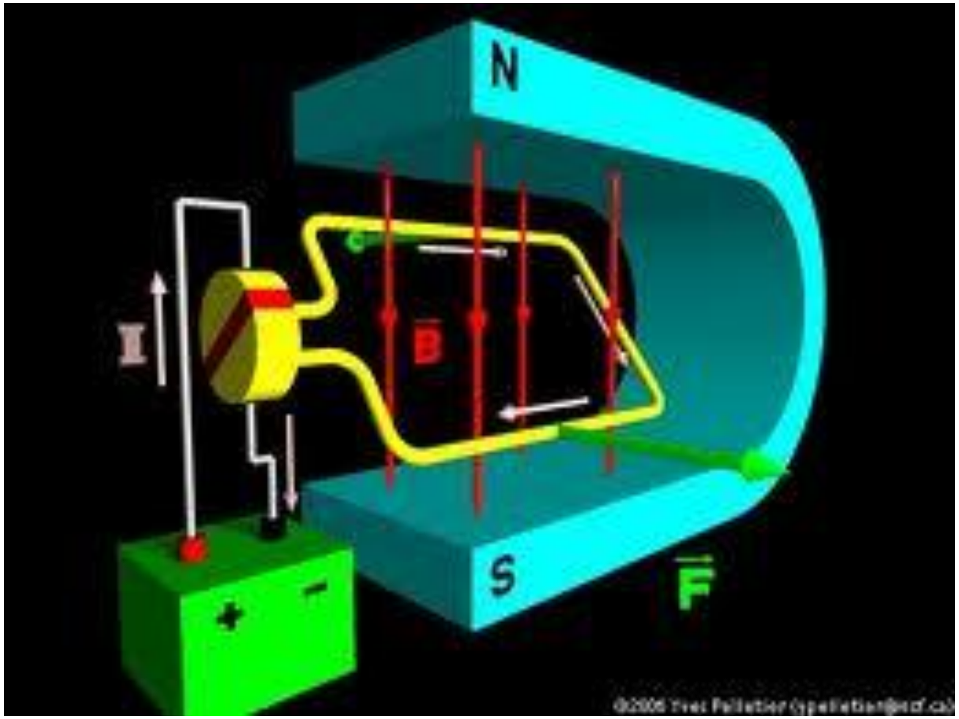


TEXT REFERENCE

Electric Motor

Electric Motor, is a machine which converts electrical energy into mechanical (rotational or kinetic) energy.

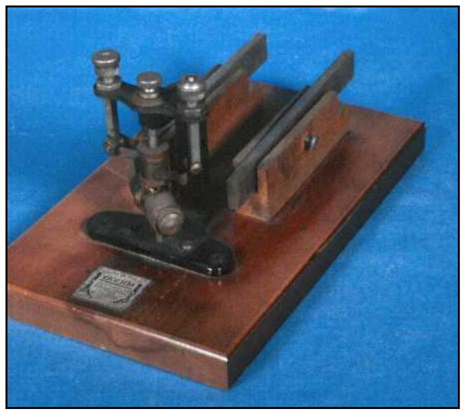
- many devices depend on the electric motor including:
- fans
- computers
- elevators
- car windows
- amusement park rides

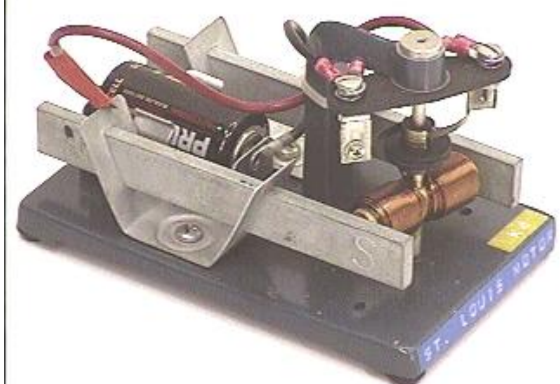


Electric motors may look complicated when you look at them, but the underlying principle is as simple as this: if two magnetic fields are in the same vicinity, they will act on each other.

This is the basic operation of a motor:
two magnetic fields make the inside part of the motor move.

St. Louis Motor



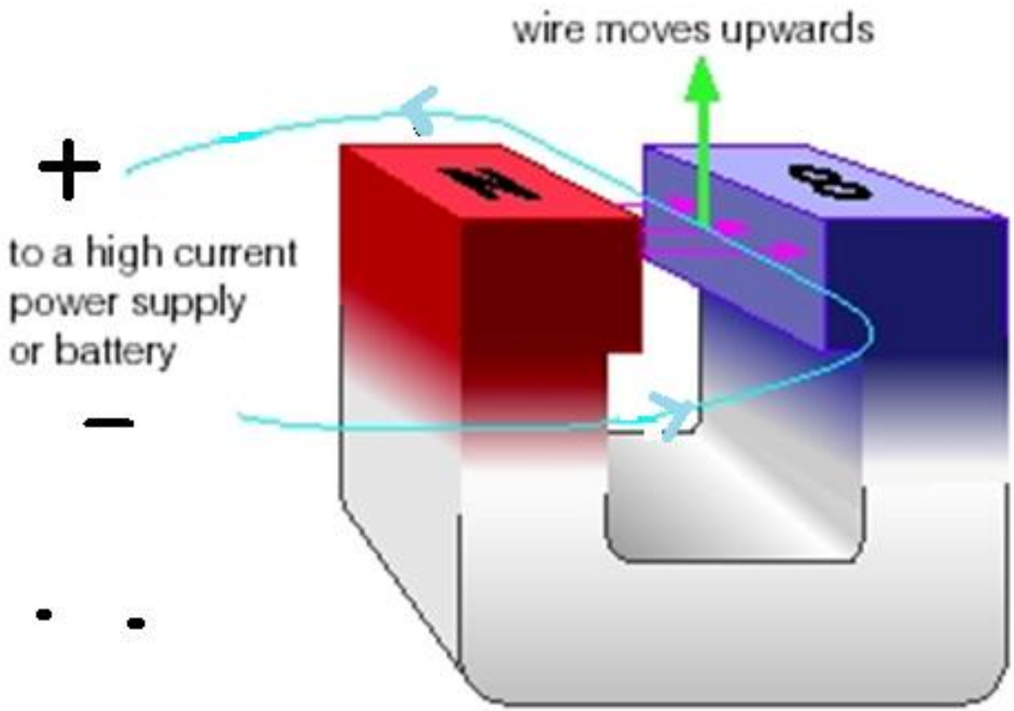


Only two magnetic fields are needed to make a motor. The are two options:

- 1. the permanent field around a permanent magnet
- 2. the field that we can start up and shut off around a conductor.

The Motor Principle

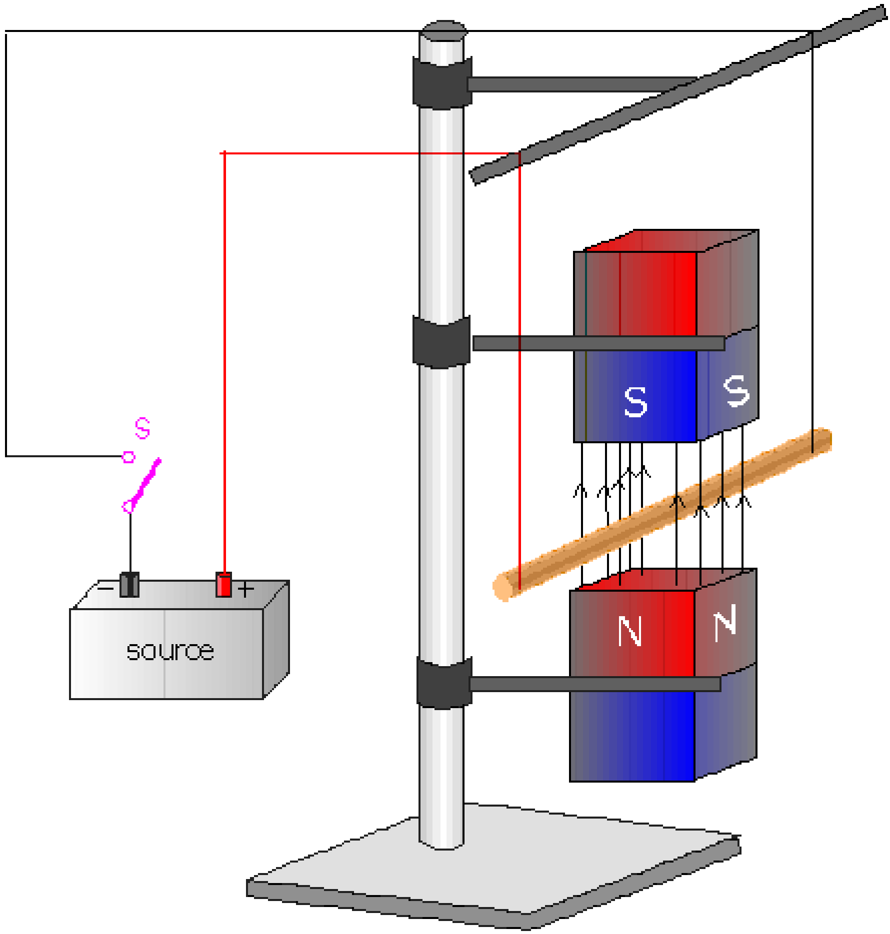
a current-carrying conductor that cuts across external magnetic field lines experiences a force perpendicular to both the magnetic field and the direction of the electric current

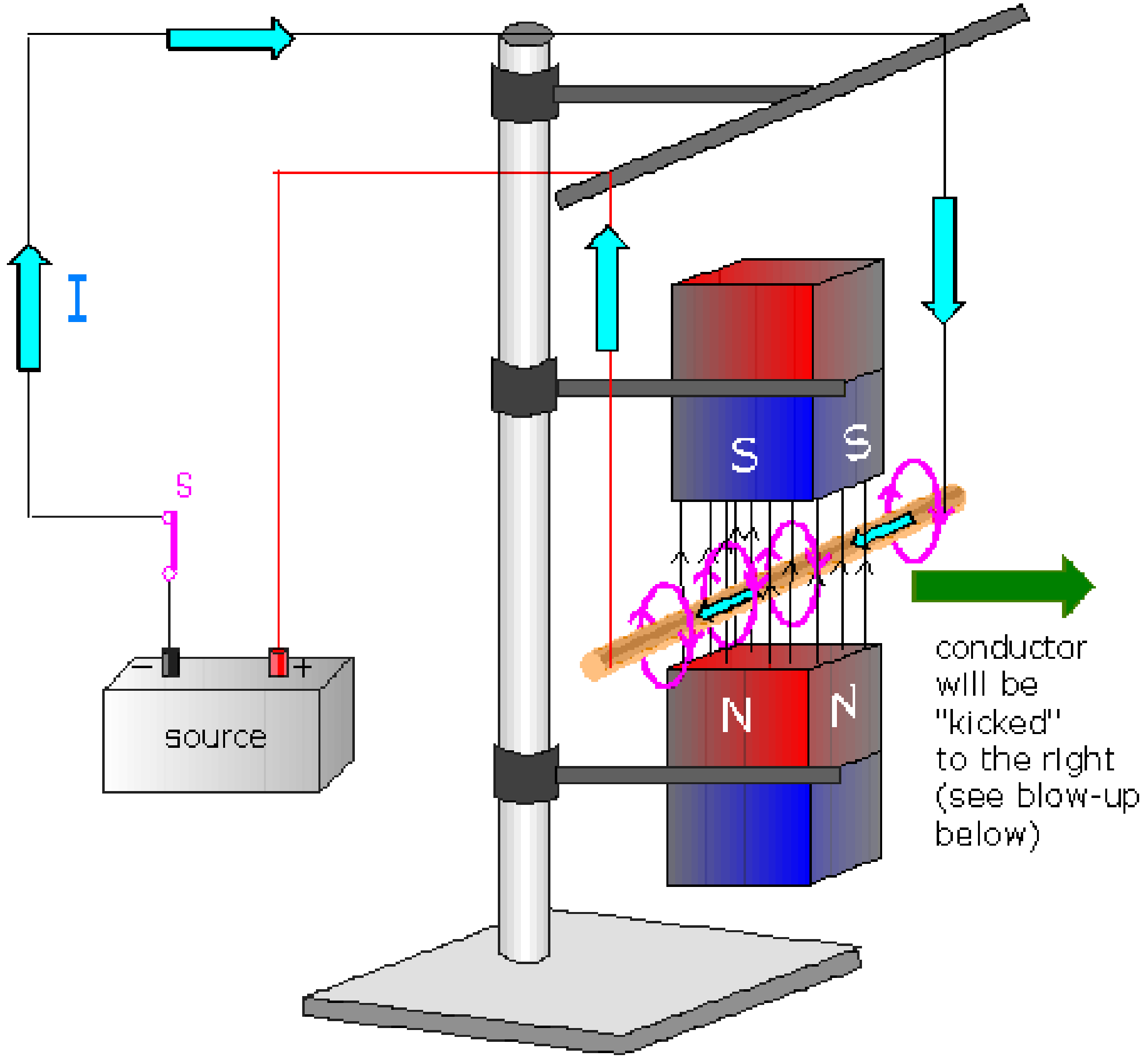


How Does The Motor Principle Work?

In the picture you can see only one magnetic field.

There is no sign of a circular field yet. This is because the switch is opened, there is no current flowing, and no circular magnetic field around the straight conductor.



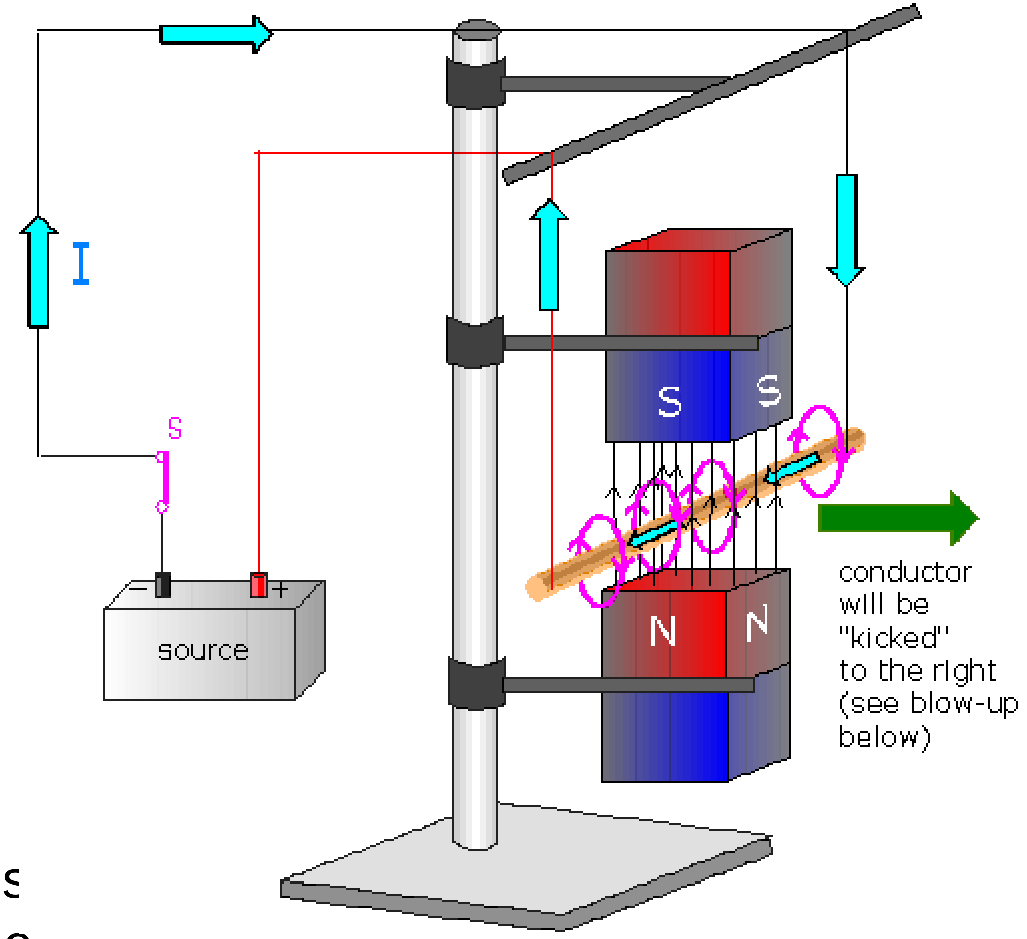


When the switch is closed, the current flows and a circular pink magnetic field is created around the conductor according to left- hand rule #1.

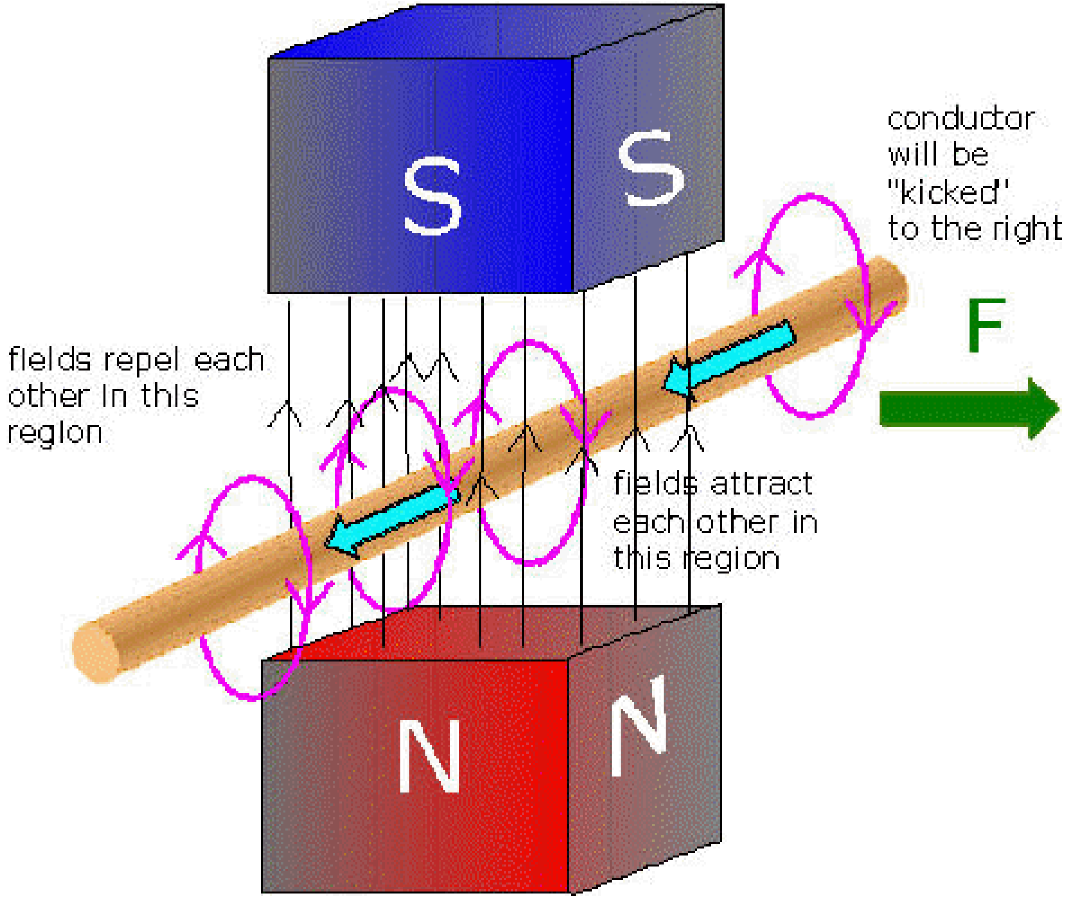
Look at the black field and the pink field to the left of the conductor. The black arrows and the pink arrows are in the same direction. This means the two fields are repelling each other to the left of the conductor.

Look at the black field and pink field to the right of the conductor. The black arrows and the pink arrows are in opposite directions. Therefore in this region the fields are attracting each other.

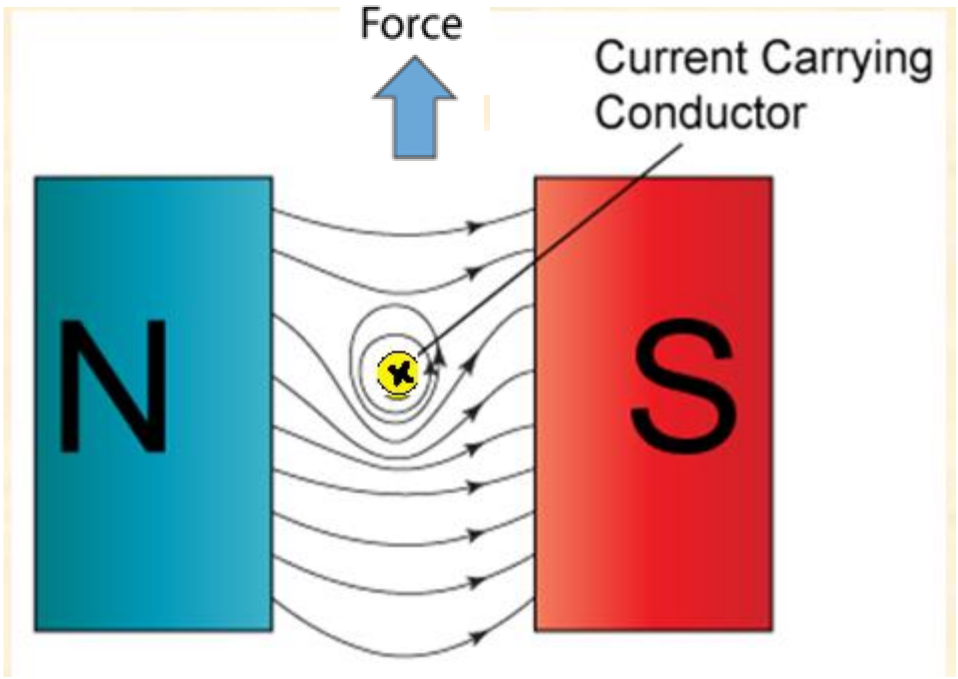
The end result is that the conductor is kicked to the right. We have made motion out of electricity and magnetism. We have created a motor!!



Study the picture until you can see the fields in the same direction to the left of the conductor (repelling); and the fields in opposite directions to the right of the conductor (attraction). The conductor will be forced to the right.

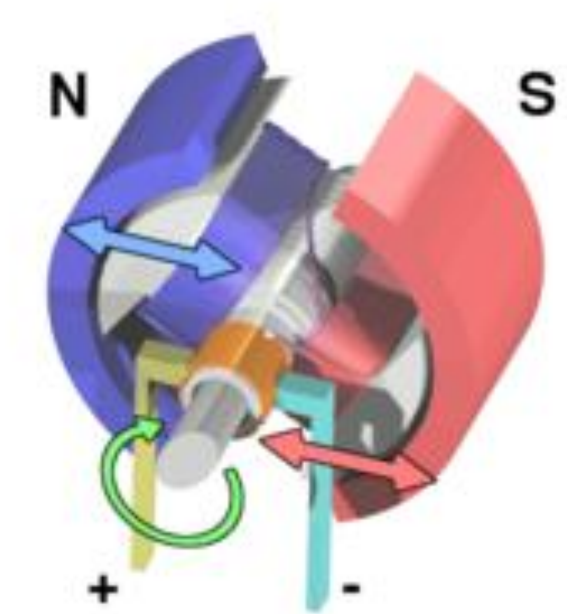


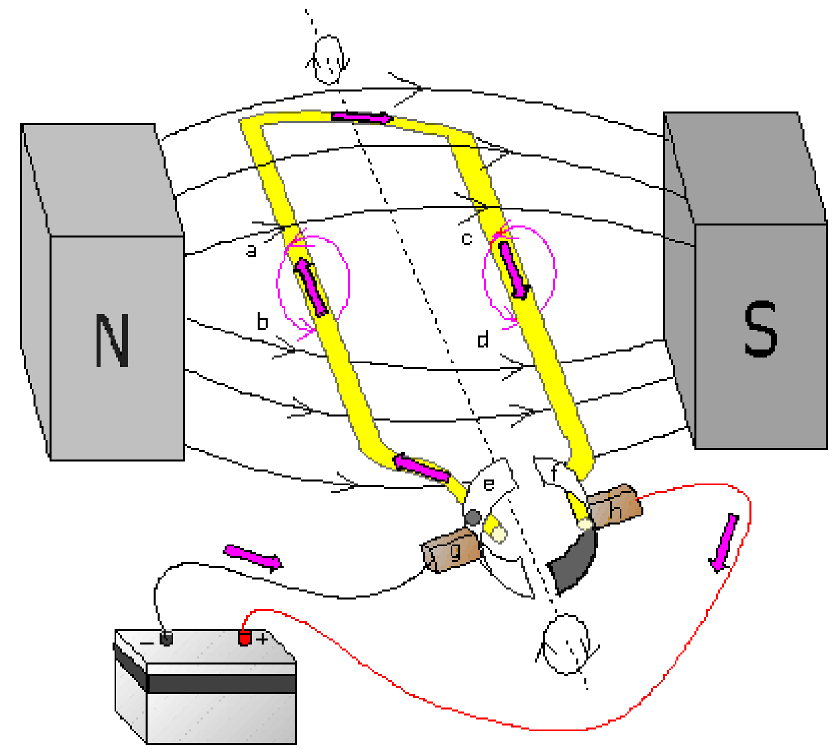
My looking at the interaction of the permanent magnetic field and the induced magnetic field of the straight carrying wire, one can determine which way the wire will be pushed.



A more complex Motor

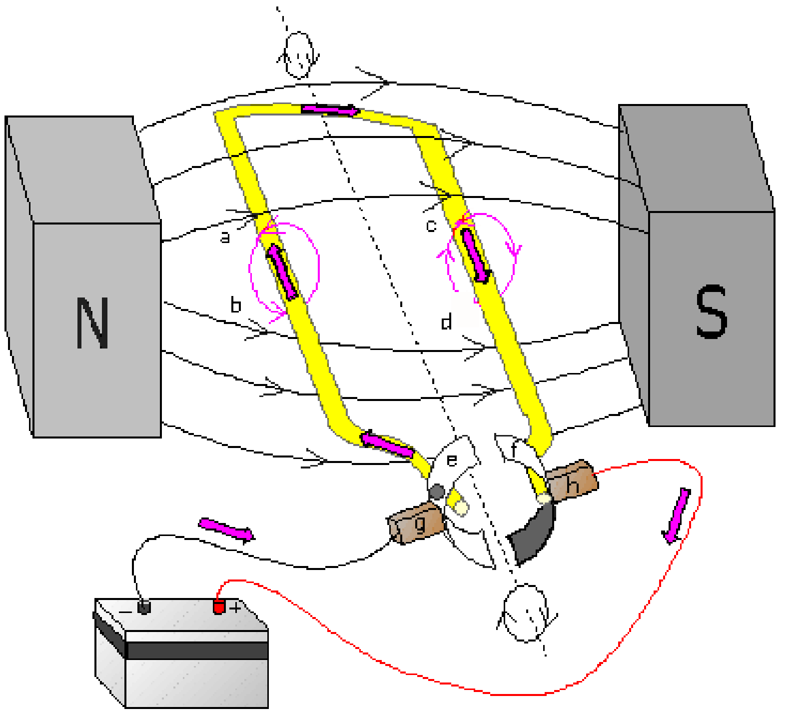
if you have ever taken a motor apart, you know that the inside piece that rotates consists of many, many turns of wire. This is too complicated to draw here, but we can show why the "rotor" rotates by looking at just one of the turns of wire.





"g" and "h" are brushes. "e" and "f" make up a split-ring commutator with a half-ring attached to each end of the loop. The brushes allow the current to pass into and out of the loop via the split rings.

In the picture the loop is more or less horizontal and a current is flowing through the loop. We have seen that the loop will rotate because of the interaction of the permanent field and the induced circular field.

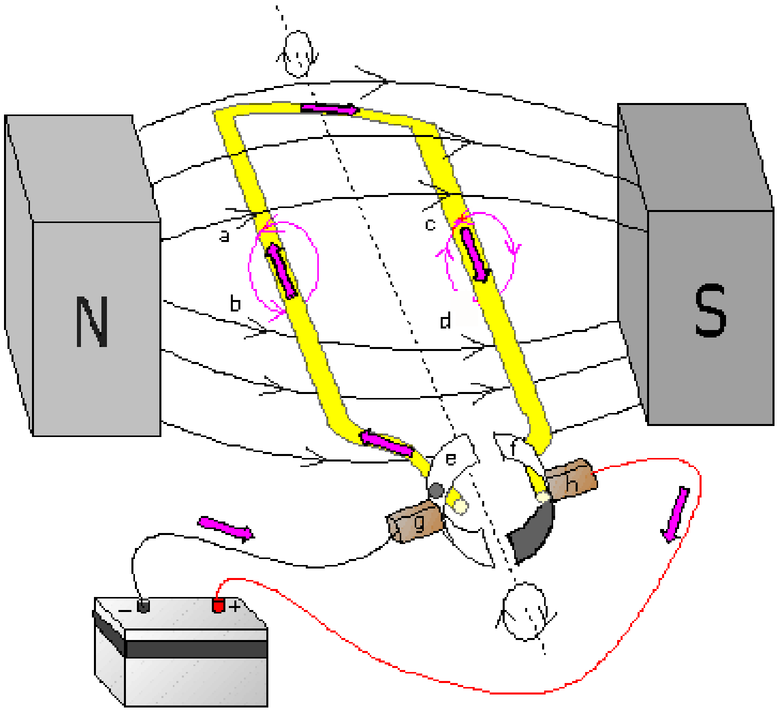


question

What can you say about the current in the loop when the loop has rotated ¼ of a complete rotation from its present position? (Look at the picture carefully).

answer

When the loop rotates 90o from its present position, the gaps between the rings will be touching the brushes. No current will flow for that split, split, split second.



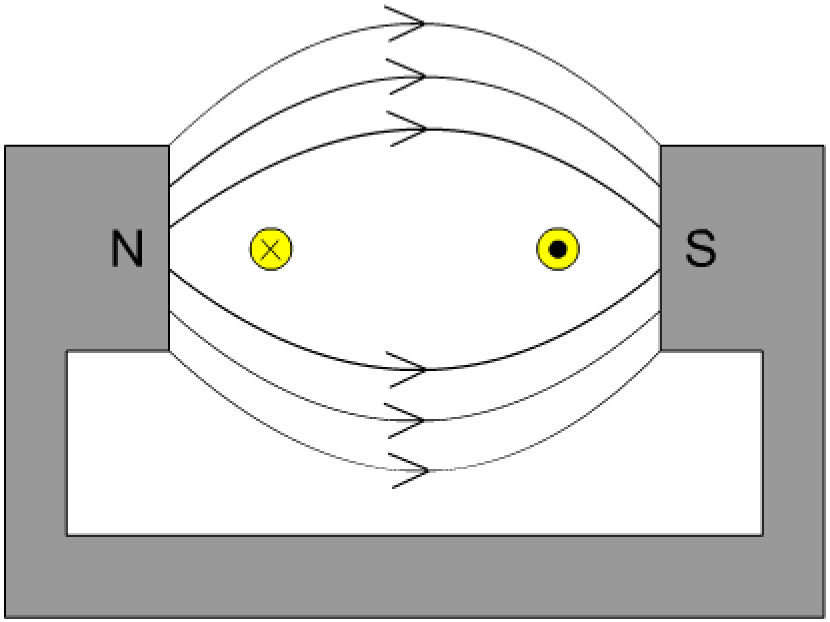
question
Will the loop stop after making ¼ turn?

answer No!! Inertia will keep it moving.

question Is the inertia required to make the loop rotate very far?
answer Hardly anywhere.

question How come?
Answer Because almost immediately split ring "e" comes in contact brush "h", and split ring "f" comes in contact with brush "g". When that happens, the current flows in the loop once more.

Below shows the "end-on" view of the same loop. You are looking directly into the screen.



The picture shows a loop of current-carrying wire inside a the field of a permanent magnet.

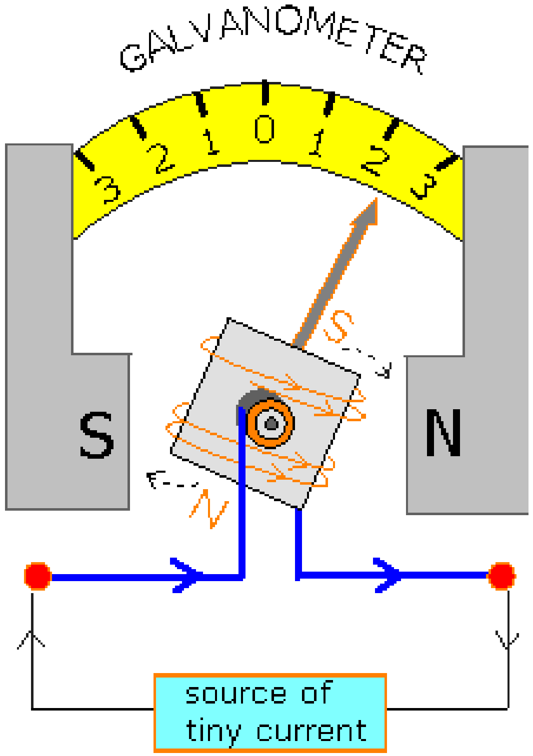
For convenience only part of the loop is shown. The circle with the x denotes the part of the loop in which the current direction is into the page. The circle with the dot denotes the part of the loop in which the current direction is out of the page.

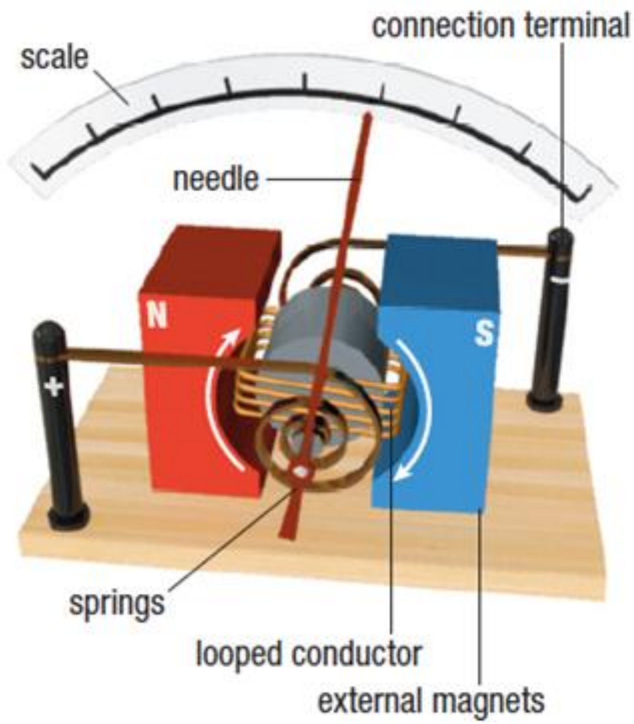
next

The Galvanometer--an Application of the Motor Principle

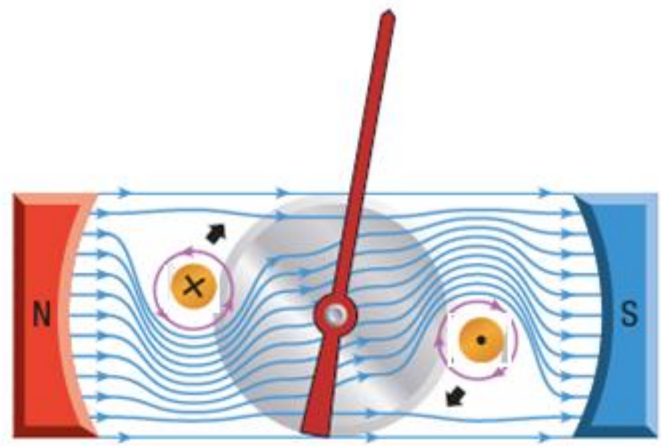
A galvanometer is an instrument used to measure very tiny currents. It consists of a small coil of wire that can rotate in the magnetic field of a permanent magnet.

In the picture. Use left-hand rule #2 to confirm that for the given current, the N and S poles of the coil are shown properly. The poles of the coil are attracted to the poles of the permanent magnet and the coil turns so that the pointer moves to the right of the zero reading. When the current is turned off, a restoring spring (not shown) pulls the pointer back to zero. If the current source is reconnected in reverse, then the N and S poles of the coil switch ends, and the pointer swings to the left of the zero position





scale
connection terminal
needle
N
S
+
springs
looped conductor
external magnets



N
S

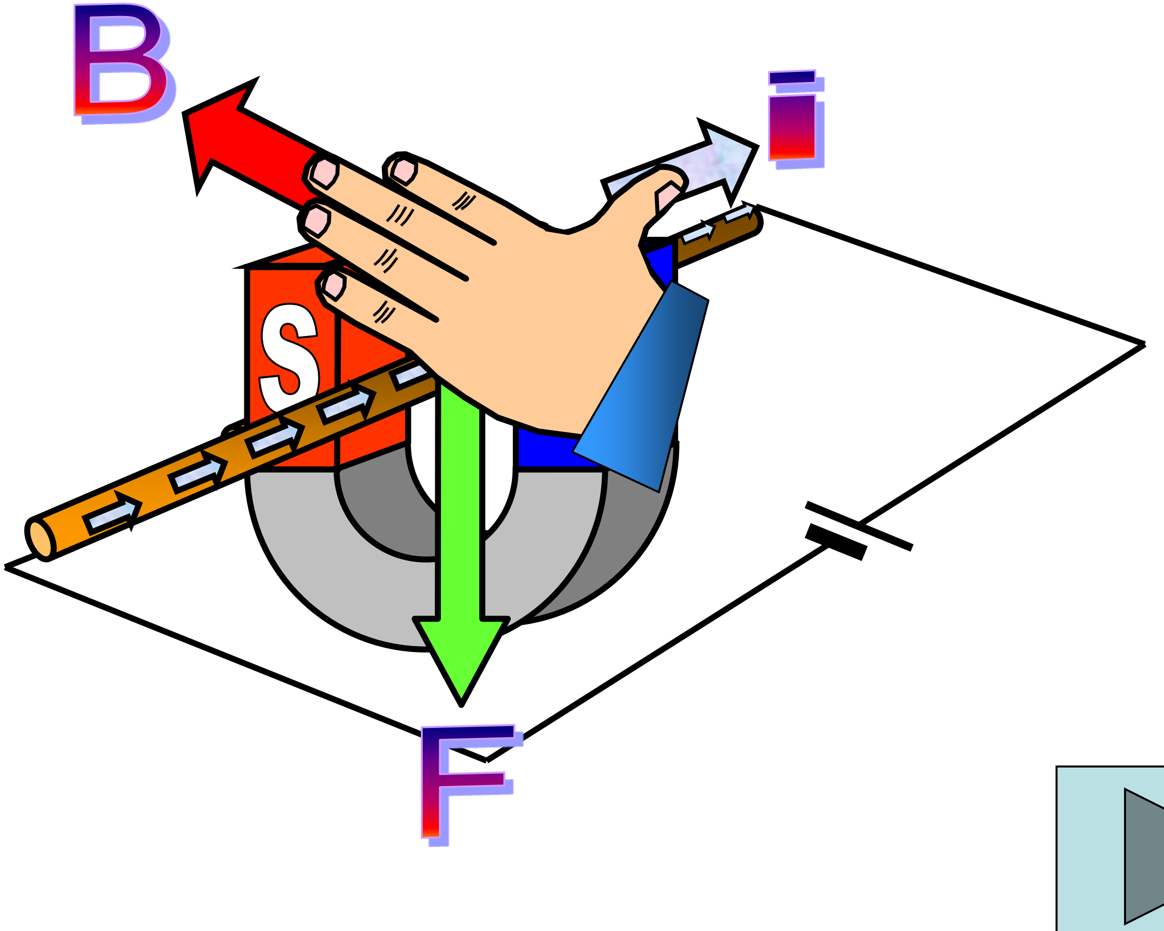
Physics 3204

Unit 3: Section 3 Electromagnetism

Topic 10 : Motor Principle and Left Hand Rule #3

TEXT REFERENCE

3rd Left Hand Rule

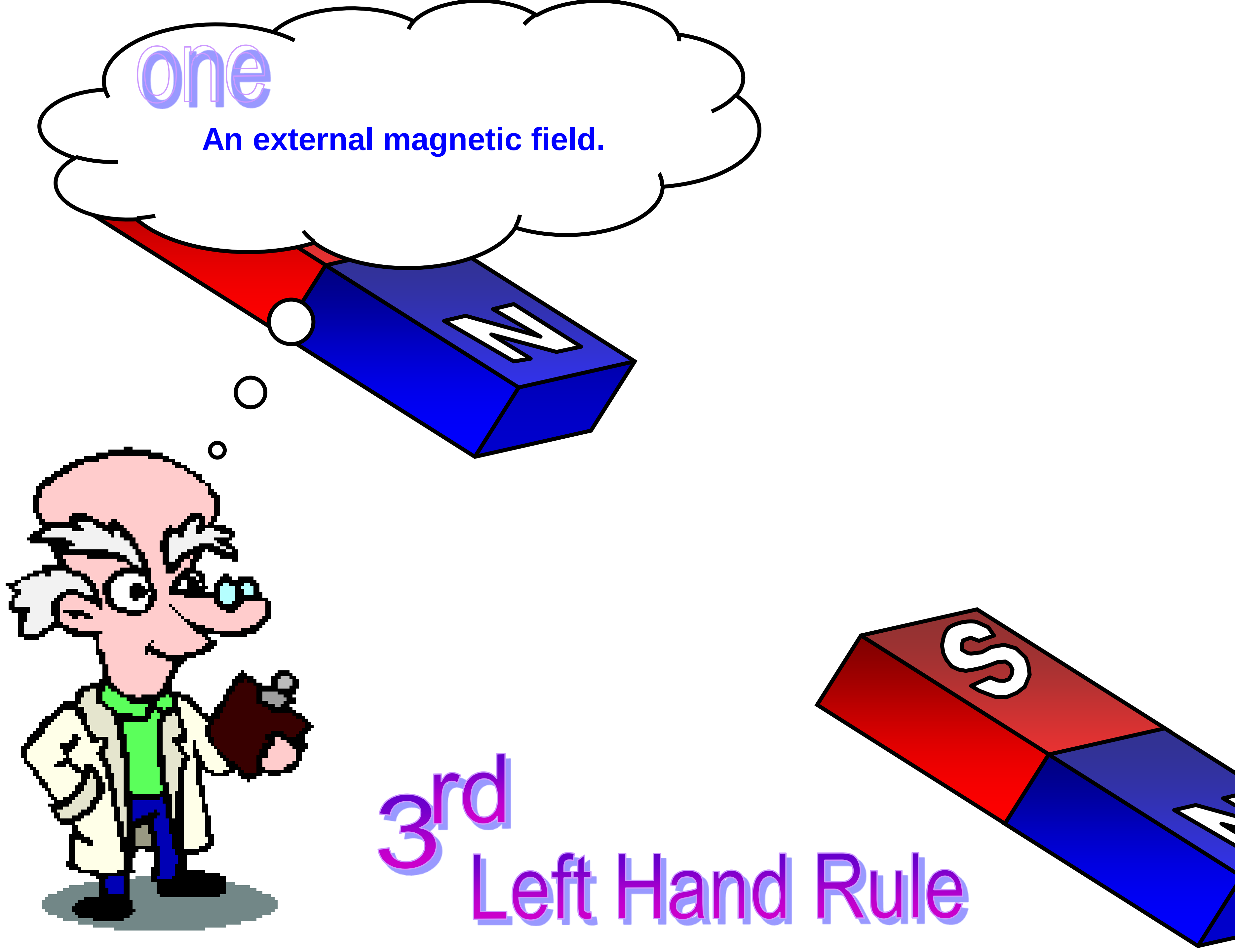


Now the

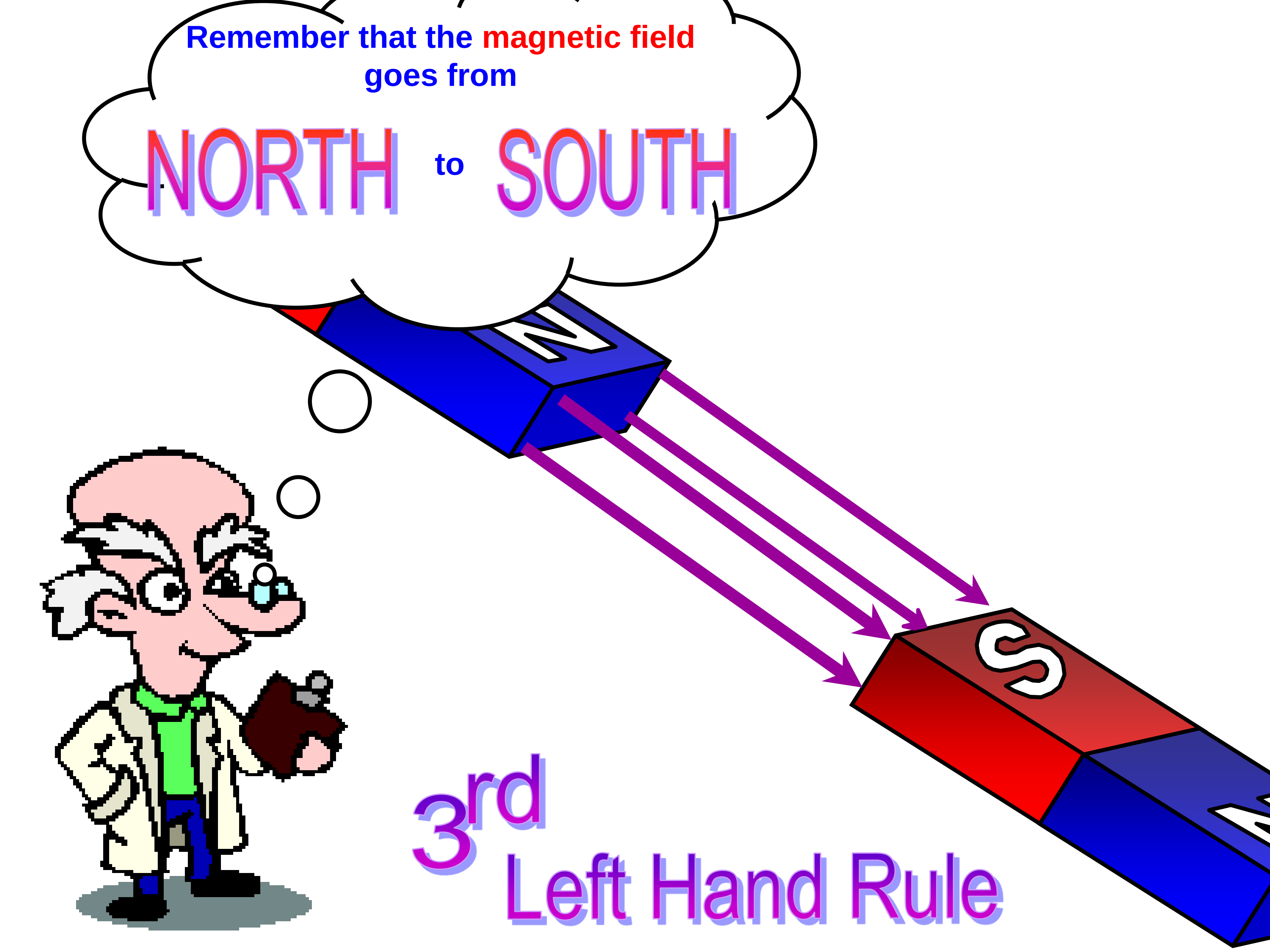
3rd Left Hand Rule

There are 3 parts to the

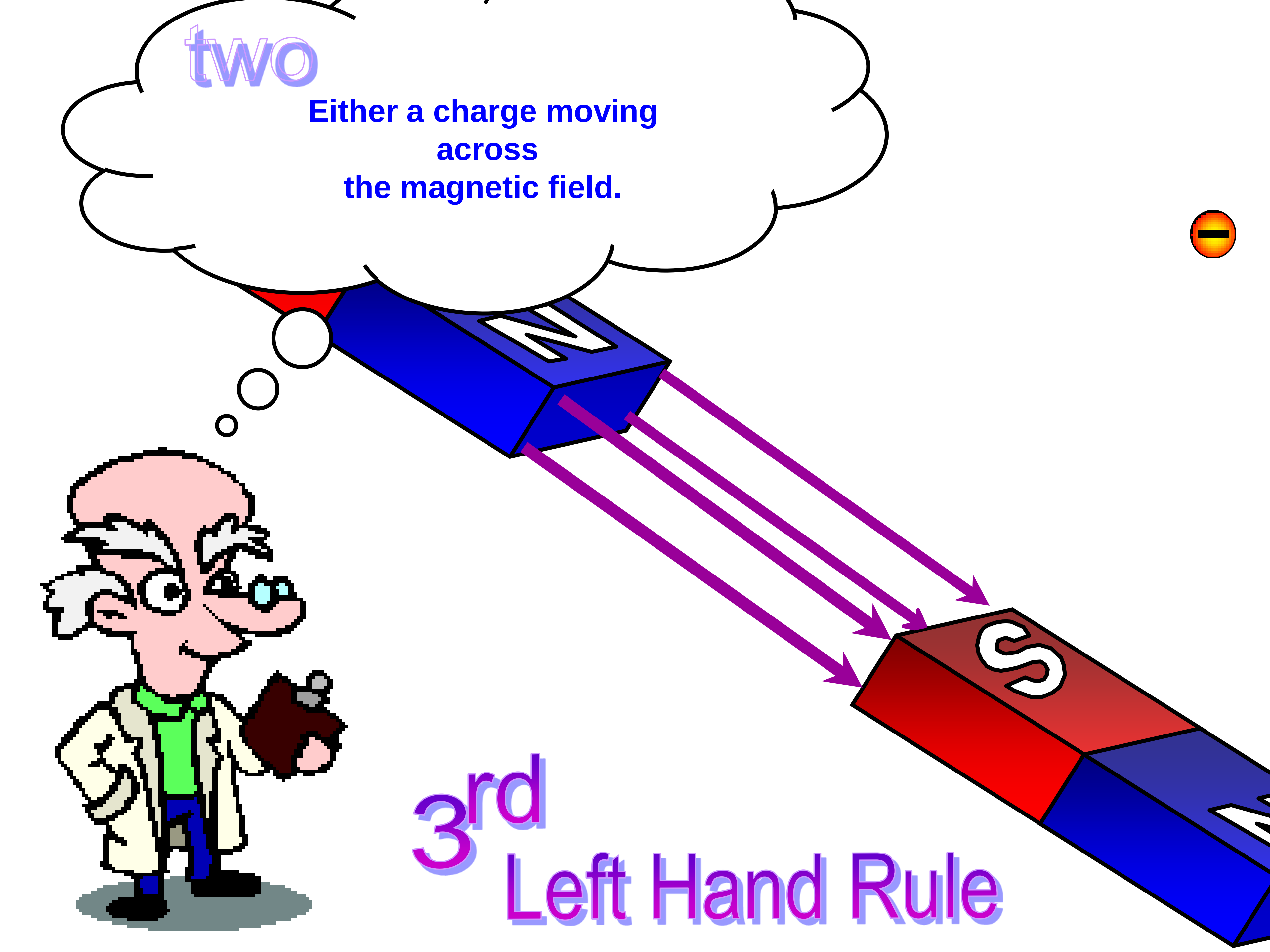
3rd Left Hand Rule

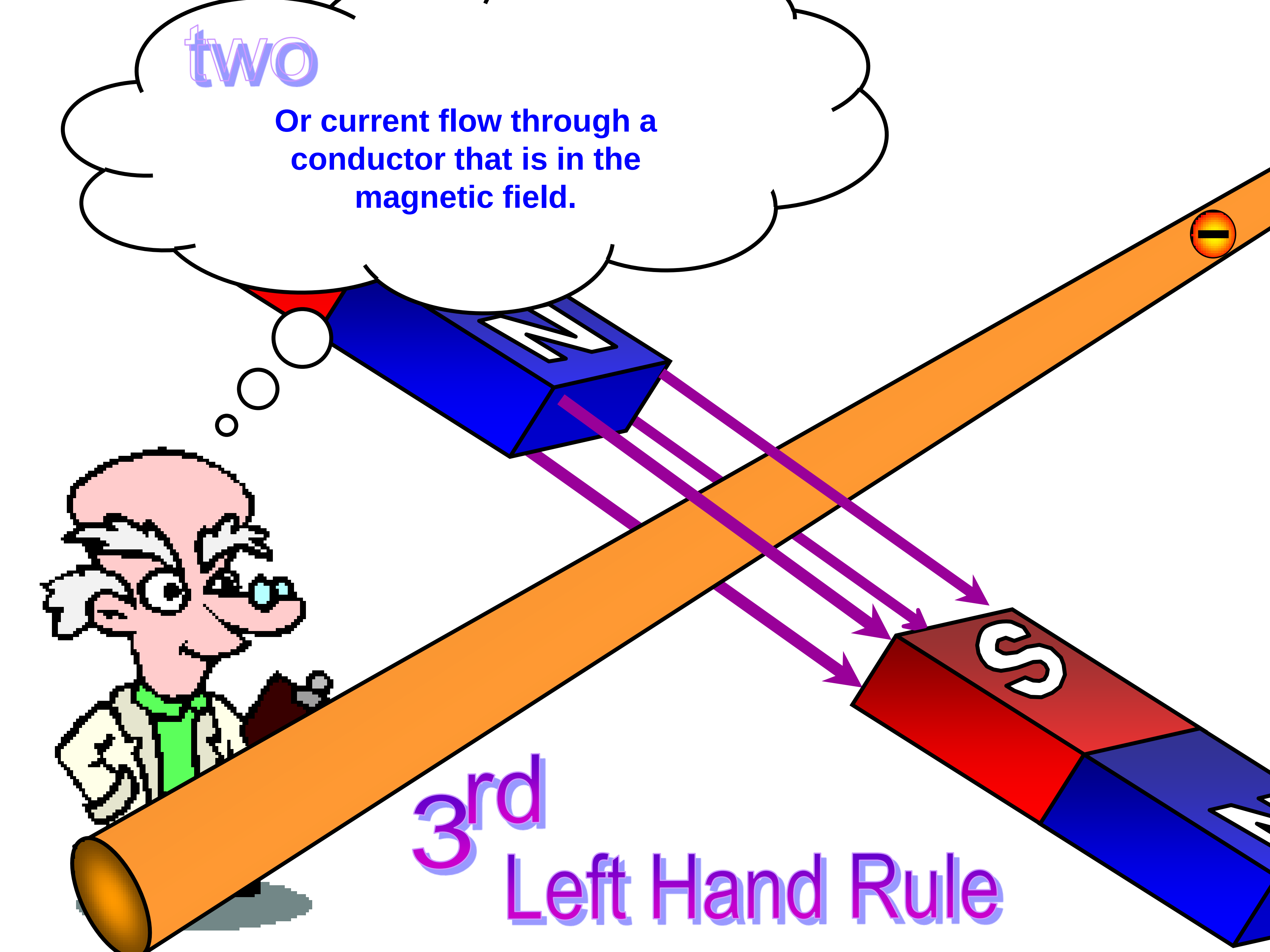


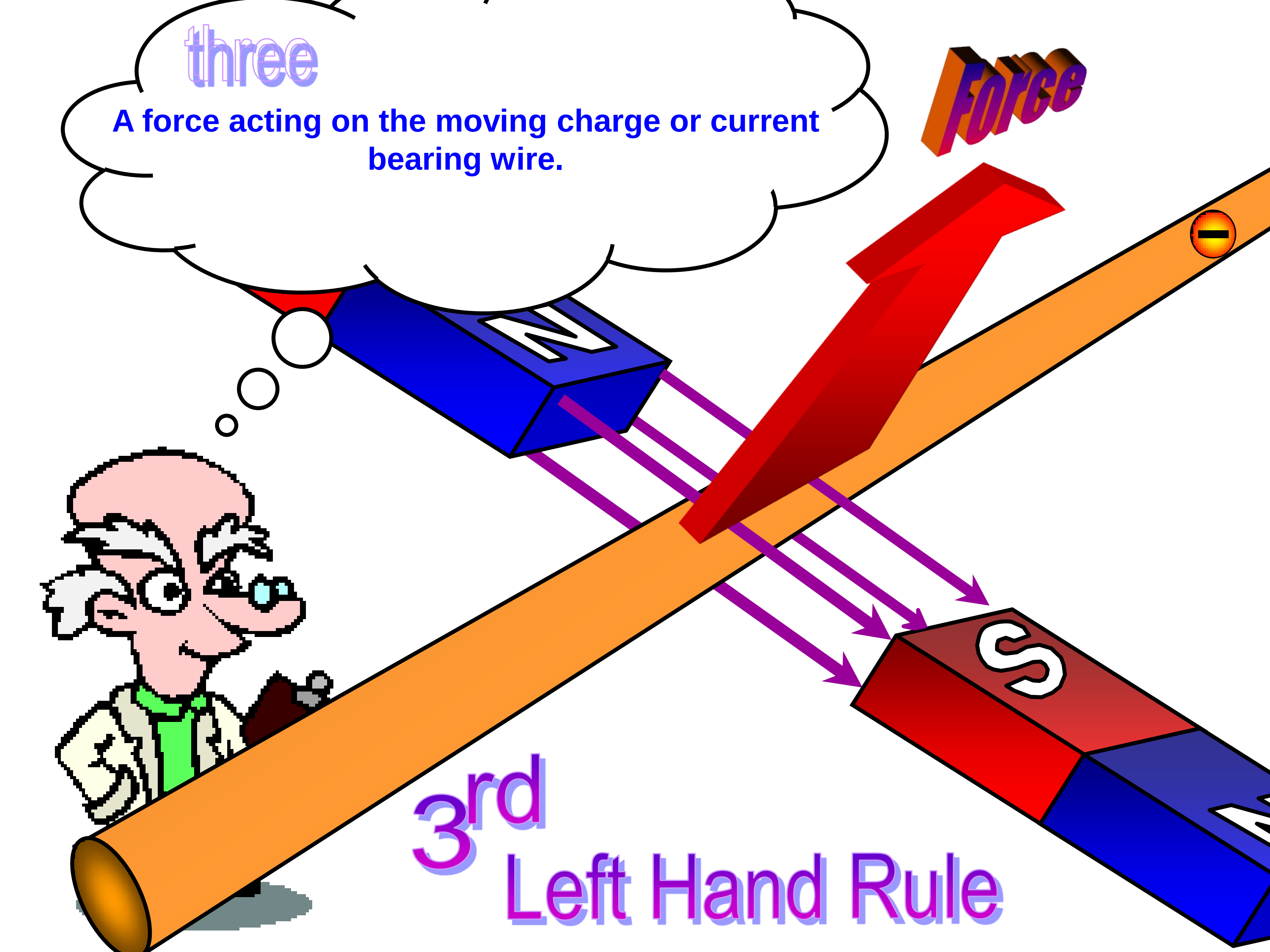
one
An external magnetic field.
N
S
3rd Left Hand Rule



Remember that the magnetic field goes from
NORTH to SOUTH
N
S
3rd Left Hand Rule

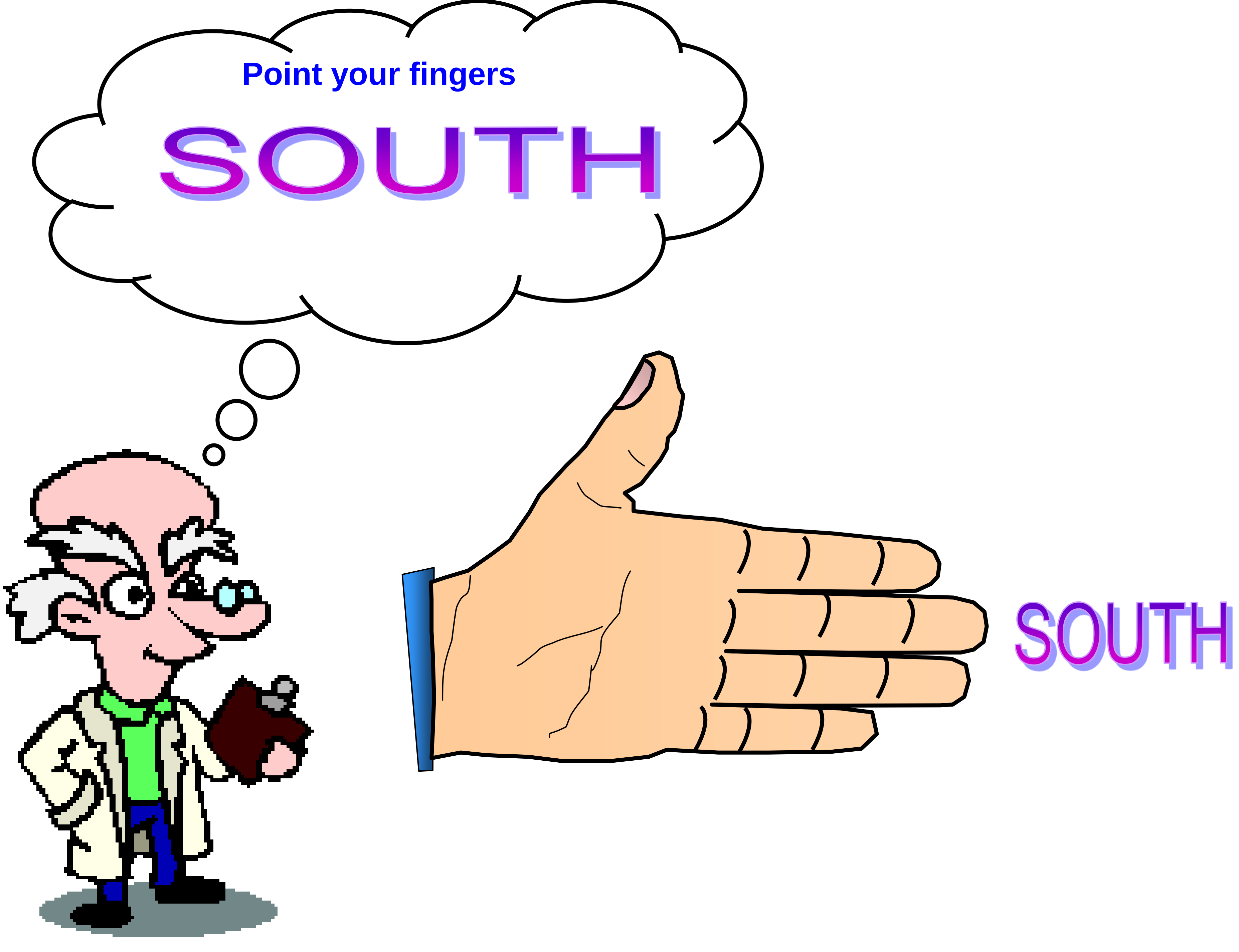

two
Either a charge moving across the magnetic field.
N
S
3rd Left Hand Rule

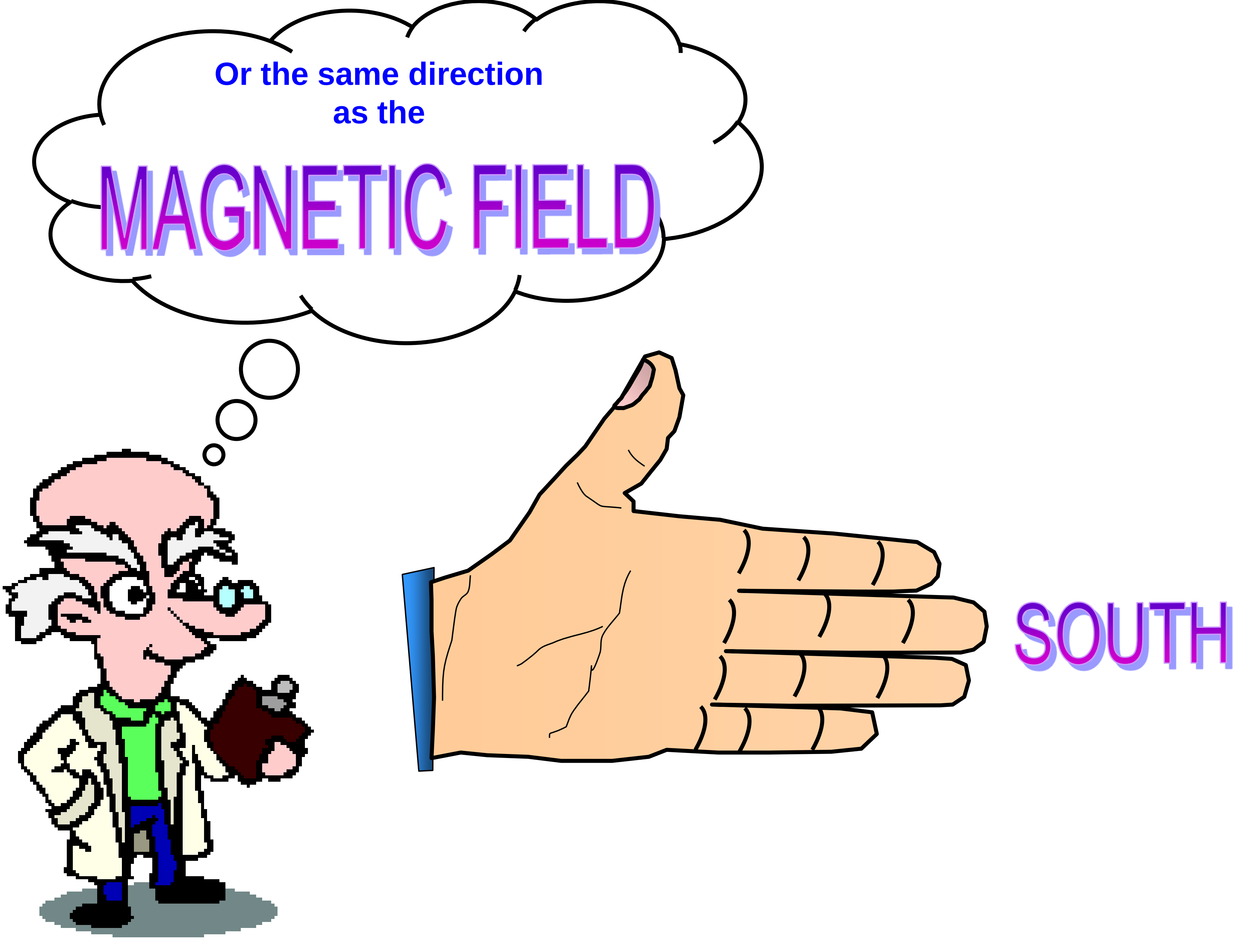

two
Or current flow through a conductor that is in the magnetic field.
N
S
3rd Left Hand Rule

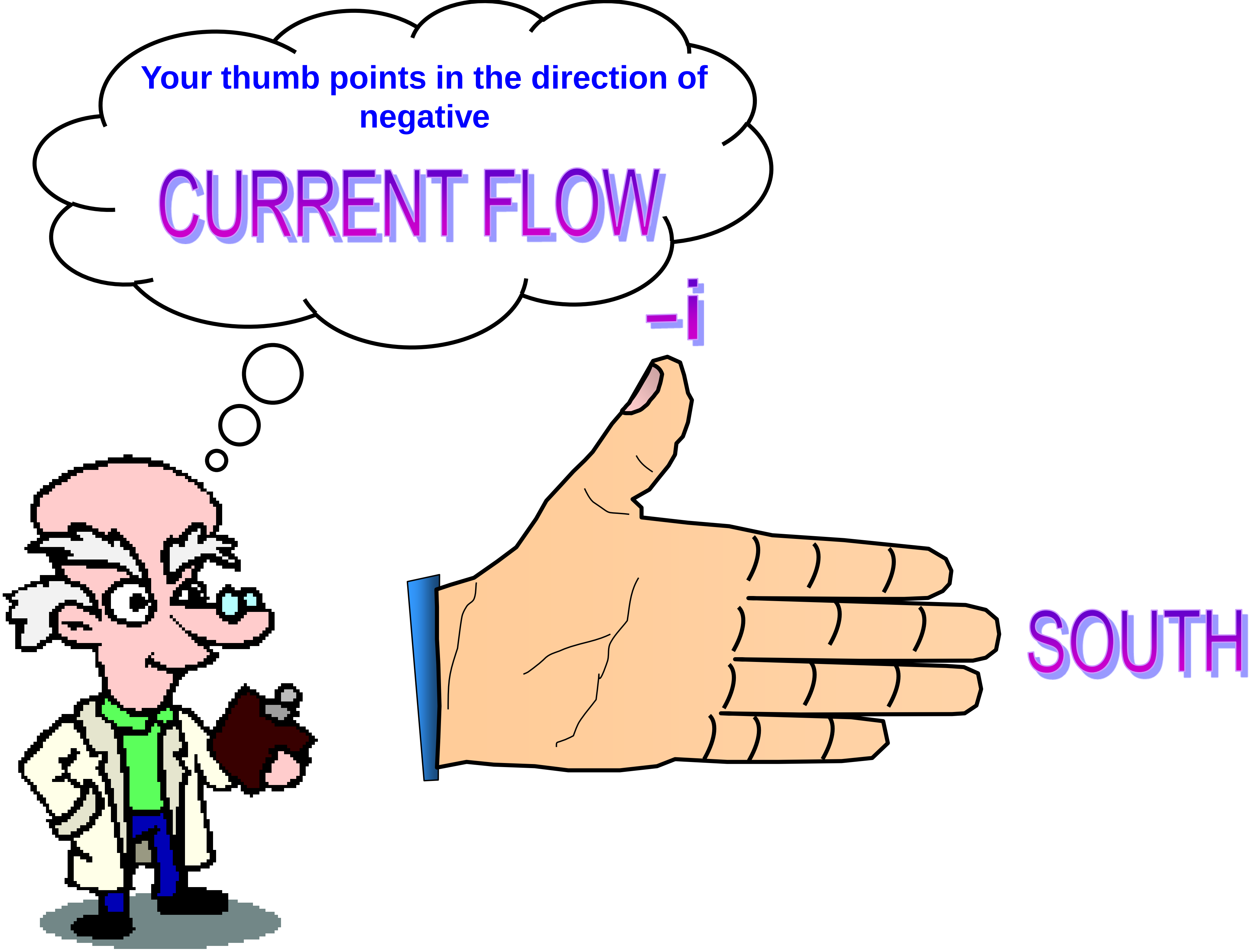

three
A force acting on the moving charge or current bearing wire.
Force
N
S
3rd Left Hand Rule

I will now show you how to apply the

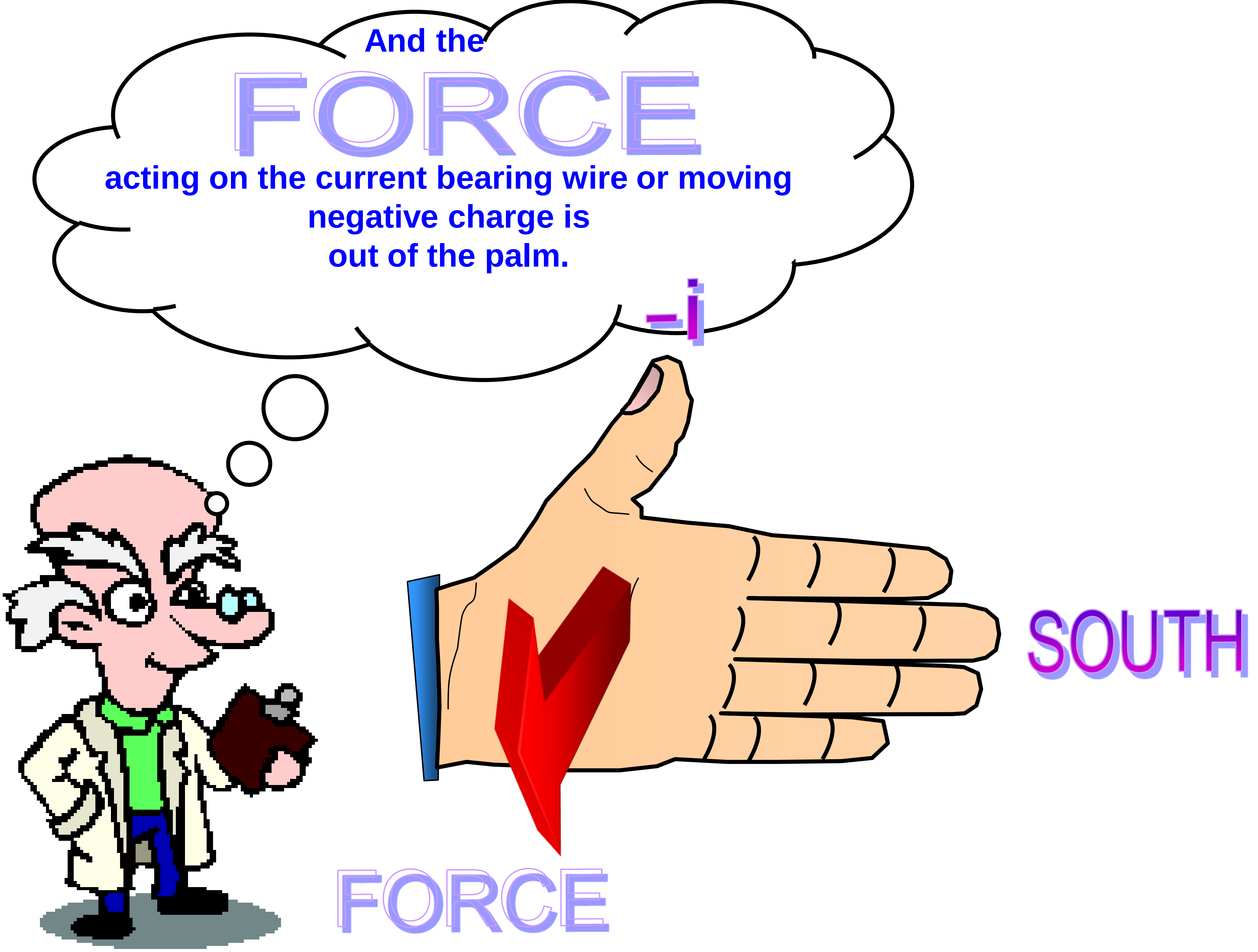
3rd Left Hand Rule

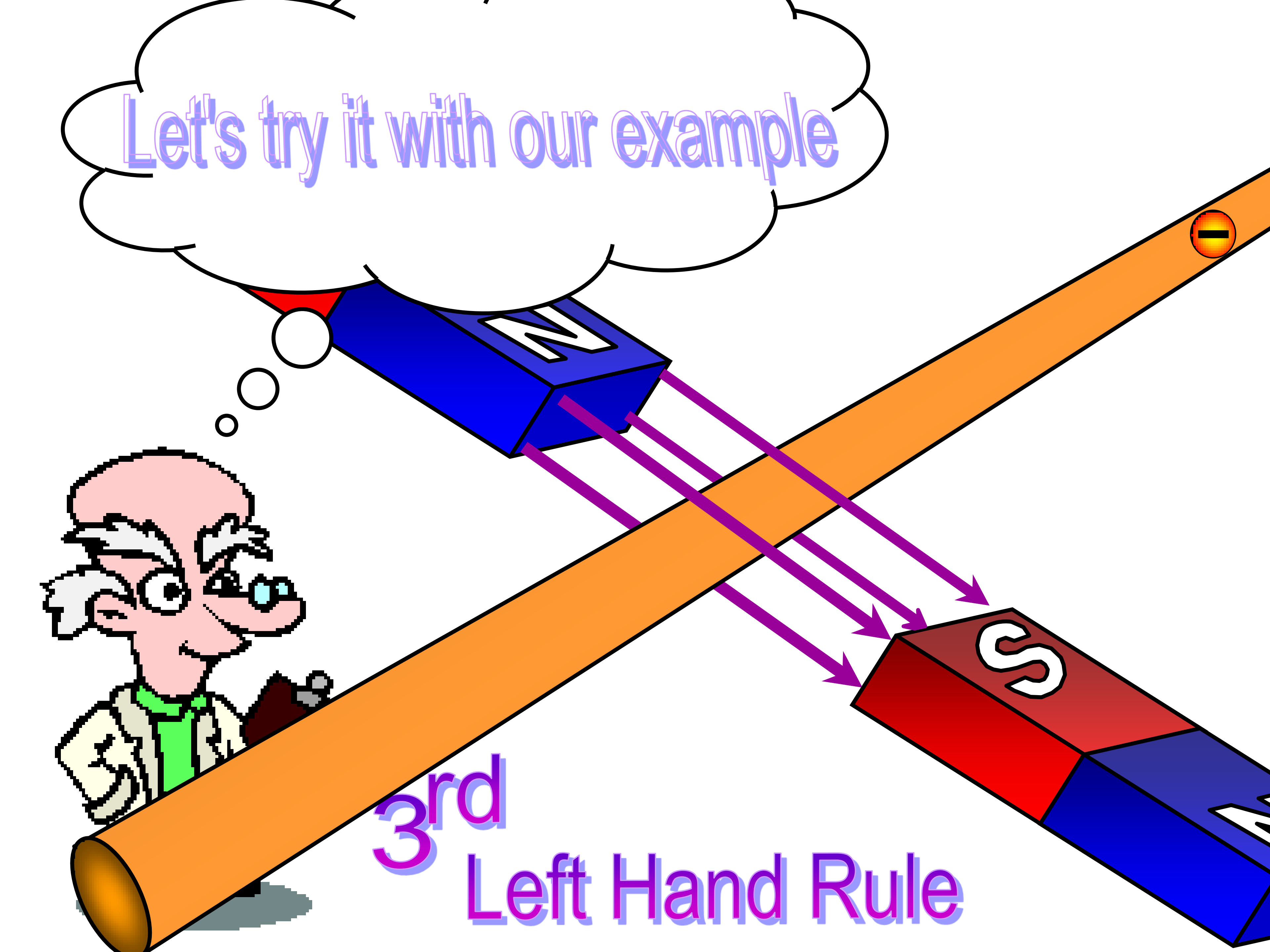

Point your fingers
SOUTH
SOUTH


Or the same direction
as the
MAGNETIC FIELD
SOUTH

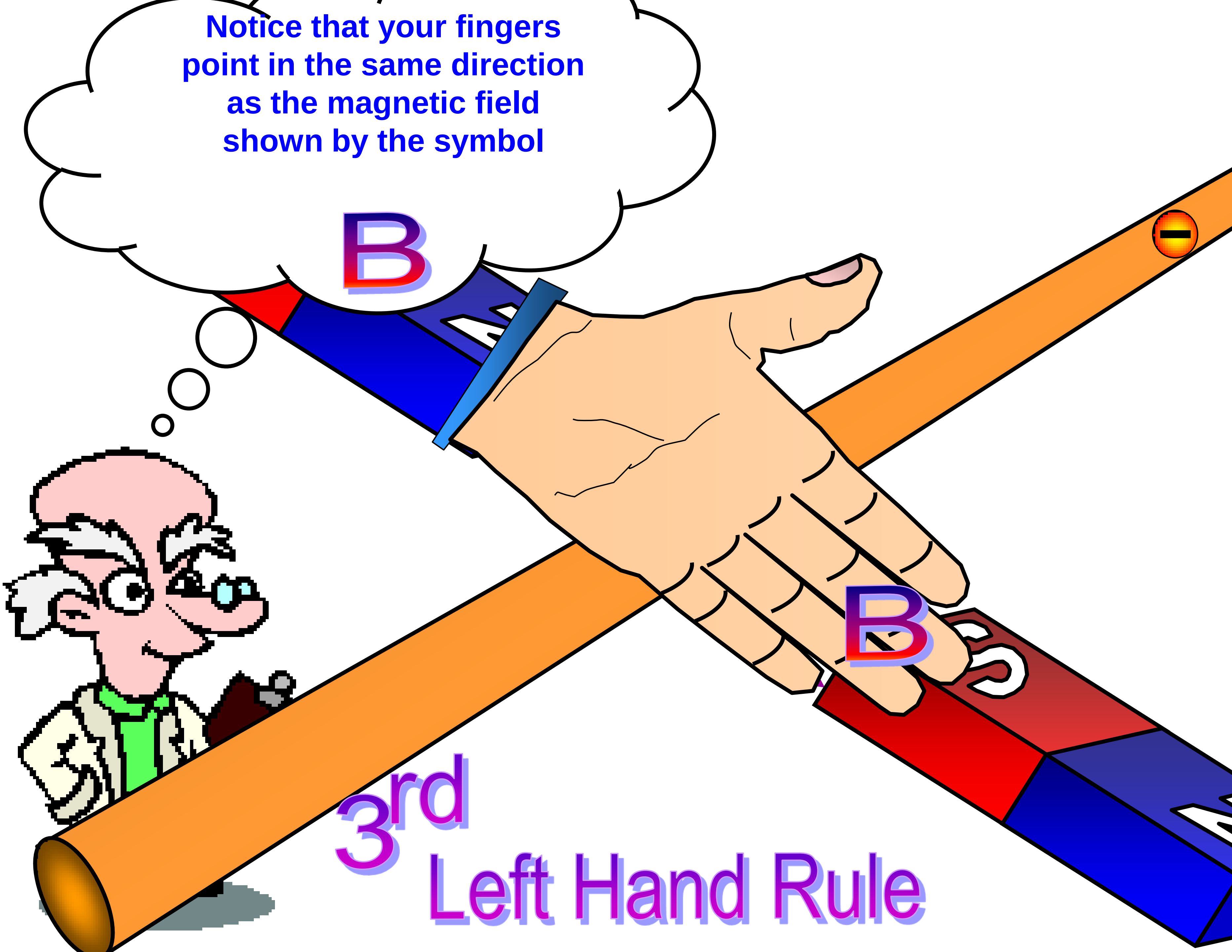


Your thumb points in the direction of negative
CURRENT FLOW
–i
SOUTH


And the
FORCE
acting on the current bearing wire or moving negative charge is
out of the palm.
-i
SOUTH
FORCE


Let's try it with our example
N
S
3rd
Left Hand Rule


First point your fingers of your left hand
SOUTH
3rd Left Hand Rule

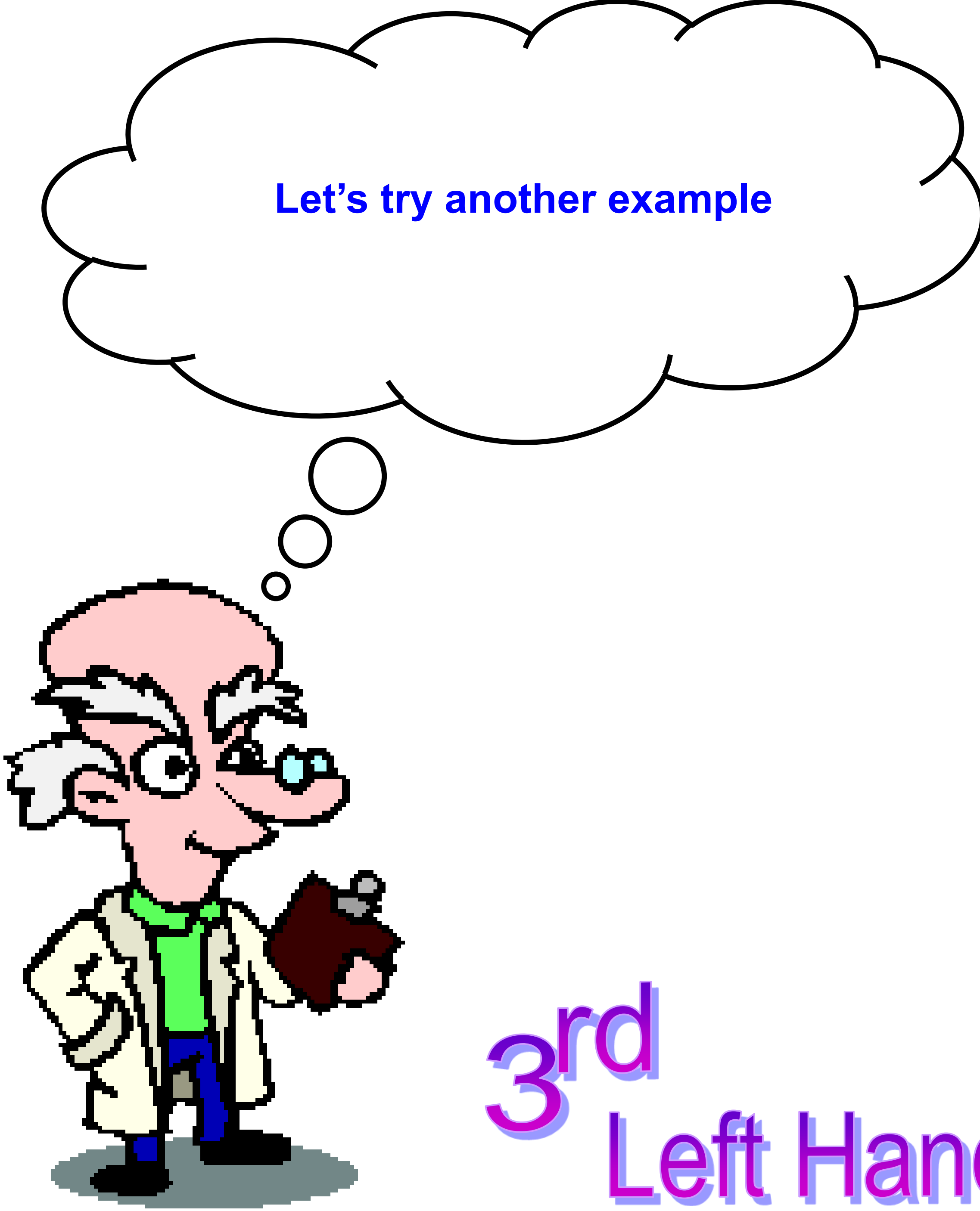


Notice that your fingers point in the same direction as the magnetic field shown by the symbol
B
B
S
3rd Left Hand Rule

Your thumb points in the direction of negative current flow
-i
-i
B
S
3rd Left Hand Rule

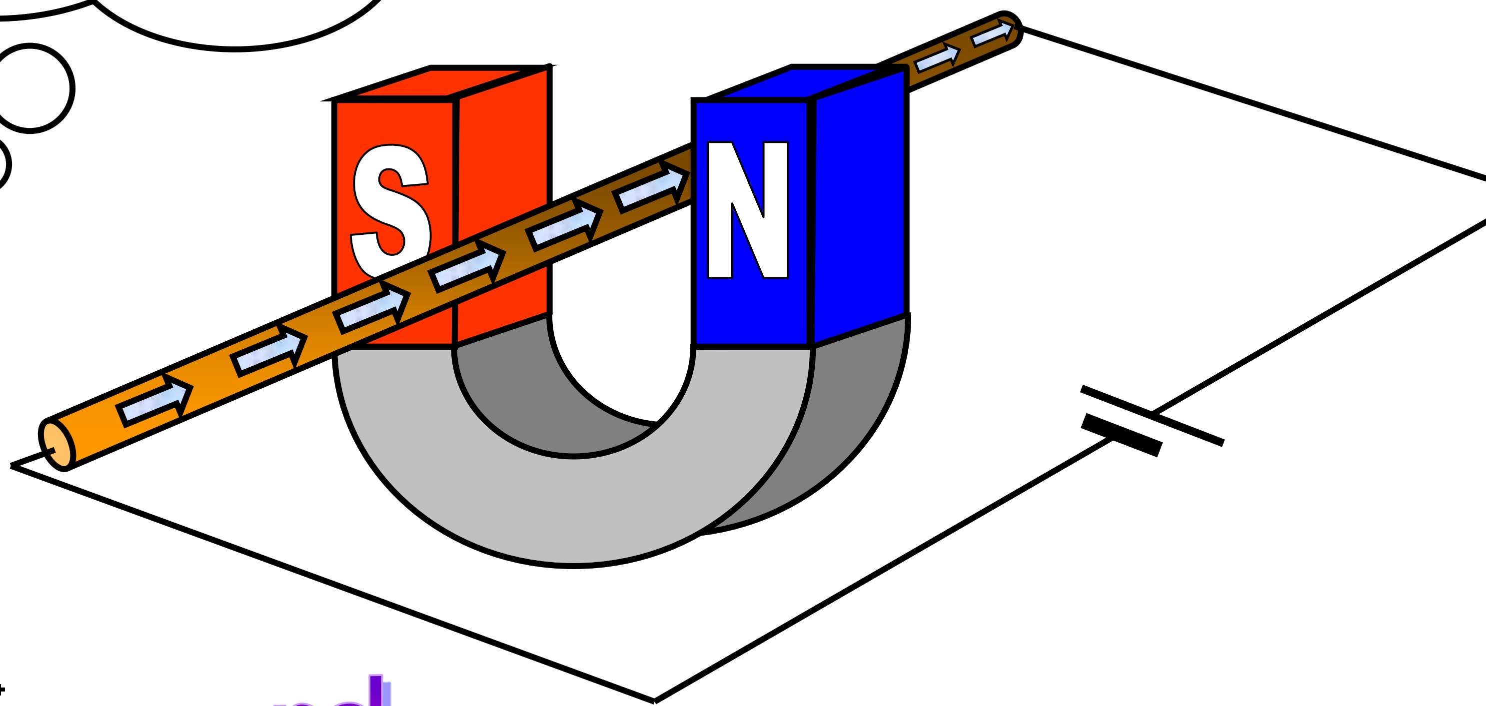

And the force acting on the moving charge or current bearing wire is out of the palm.
Force
-i
B
S
3rd Left Hand Rule

So the force acting on the wire is
UP
Force
-i
B
S
N
3rd
Left Hand Rule

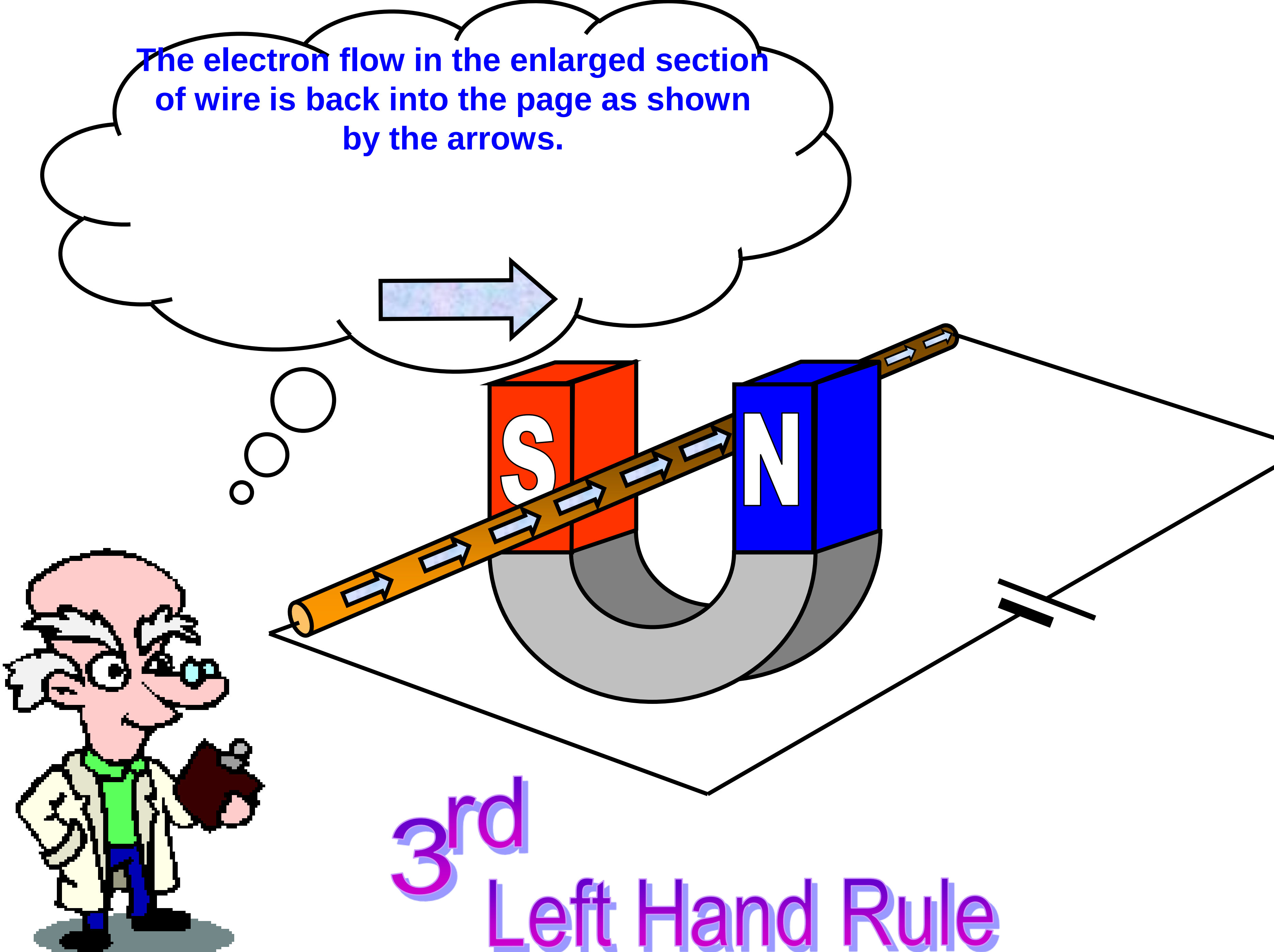


3rd Left Hand Rule

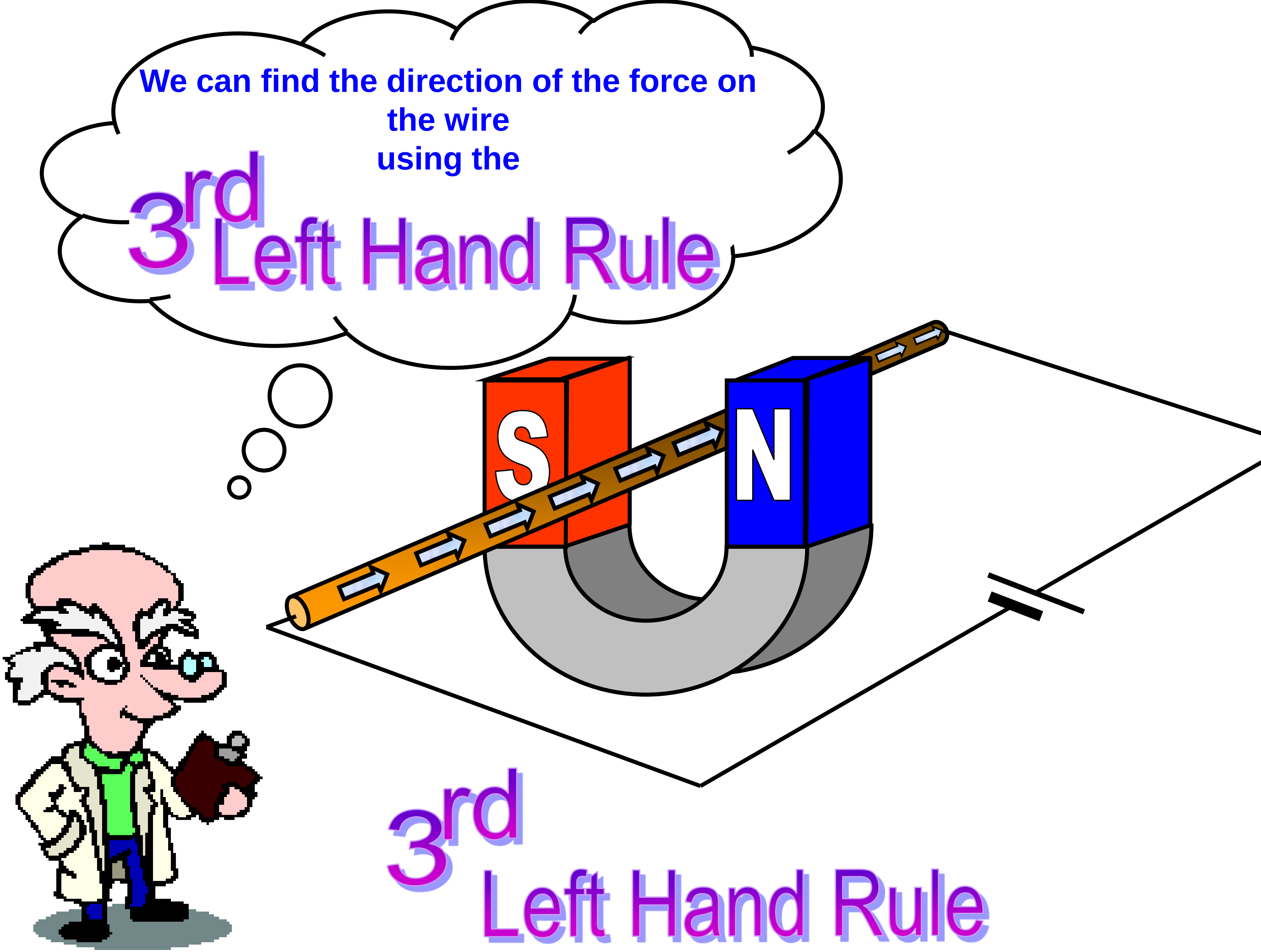
Shown here is a current bearing wire placed between the north and south poles of a horseshoe magnet.

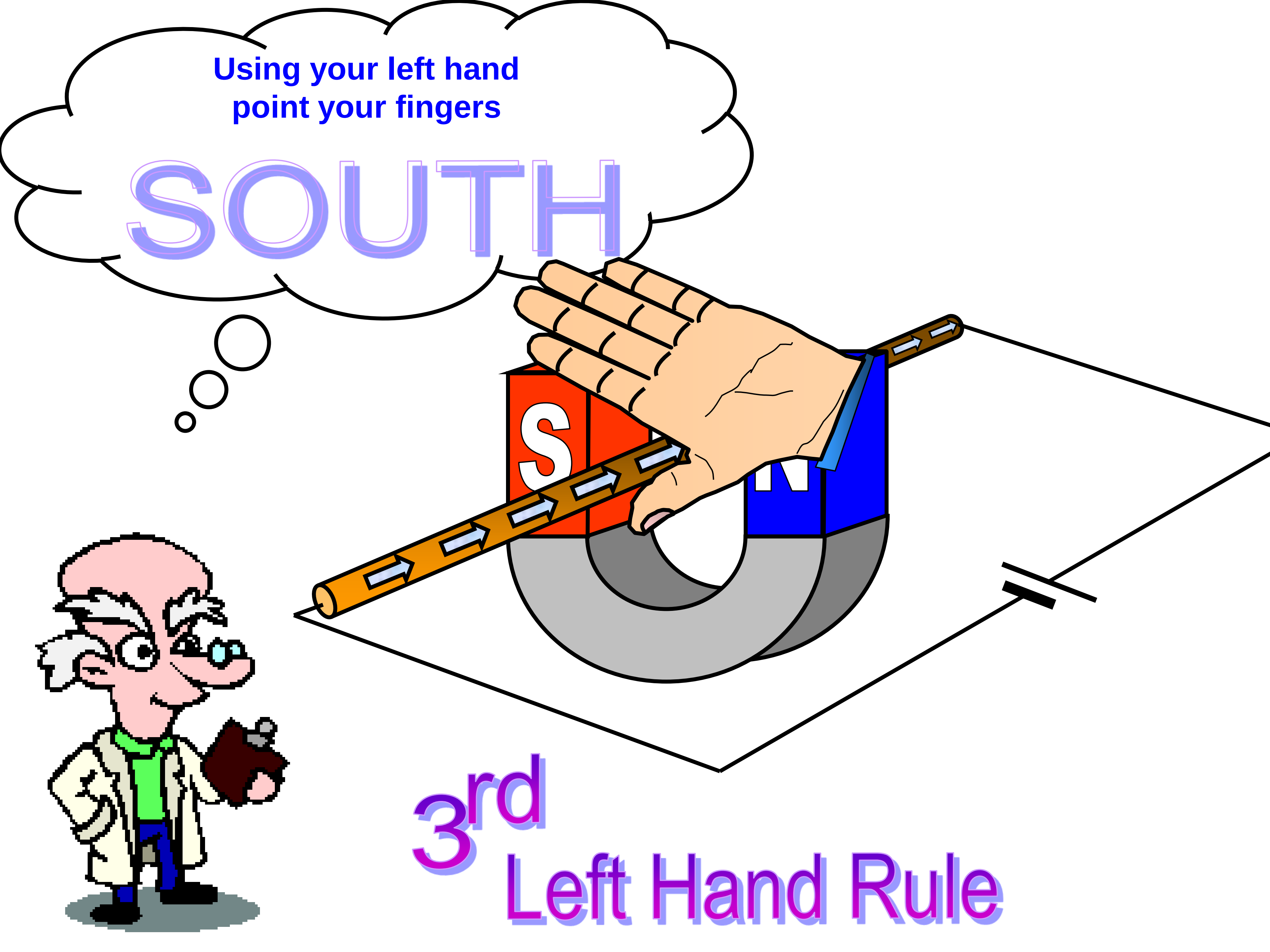


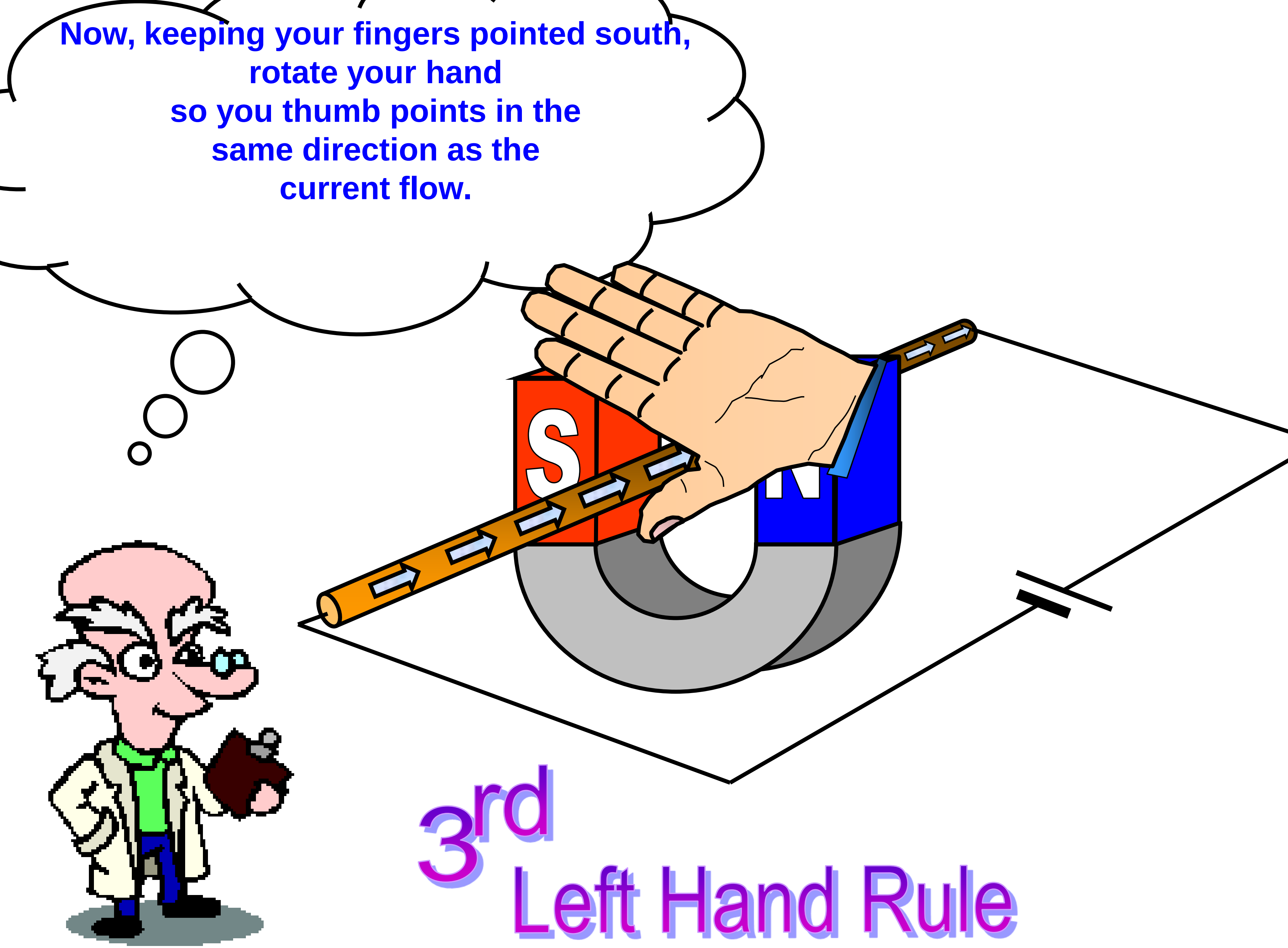
3rd Left Hand Rule

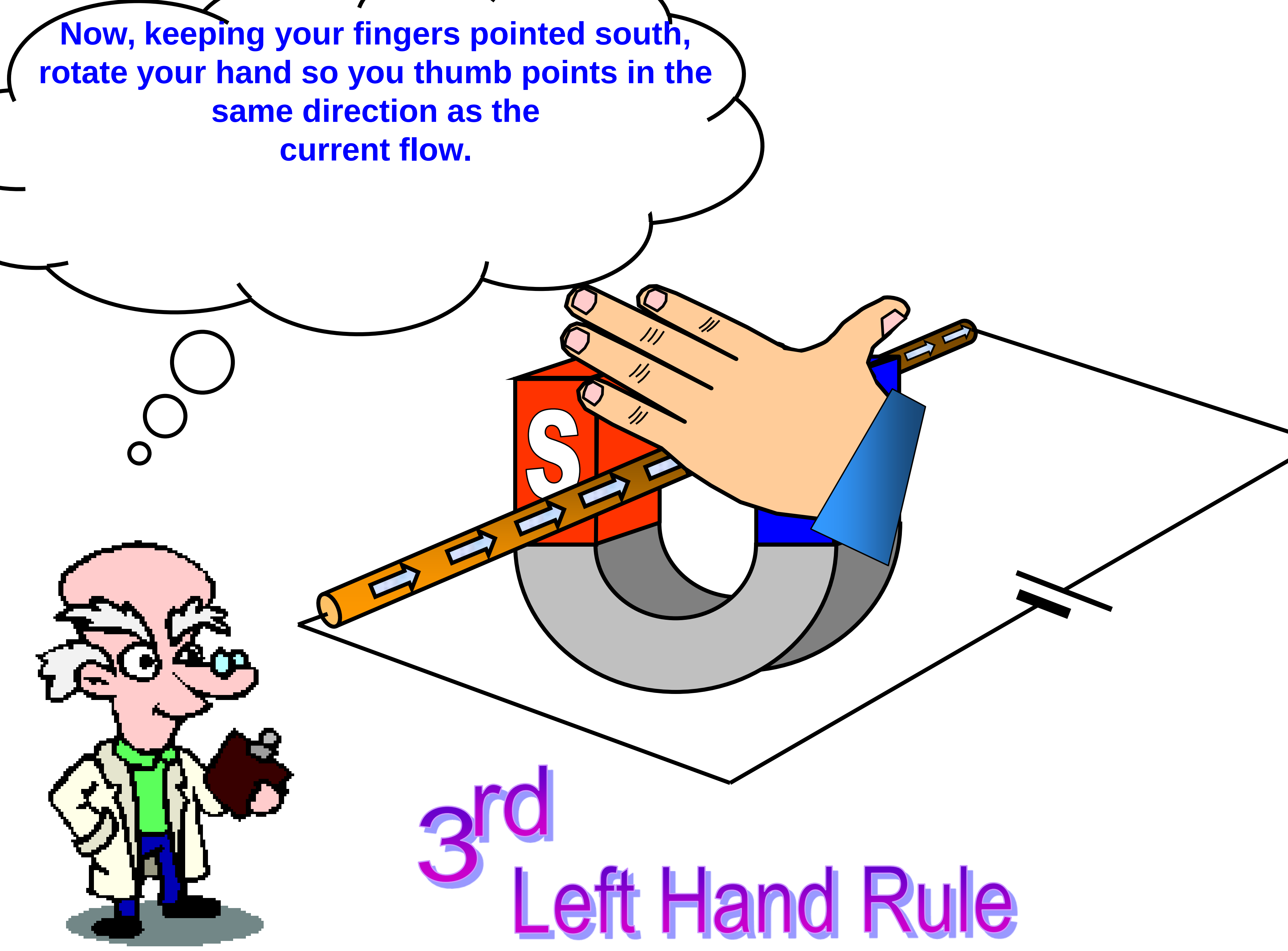


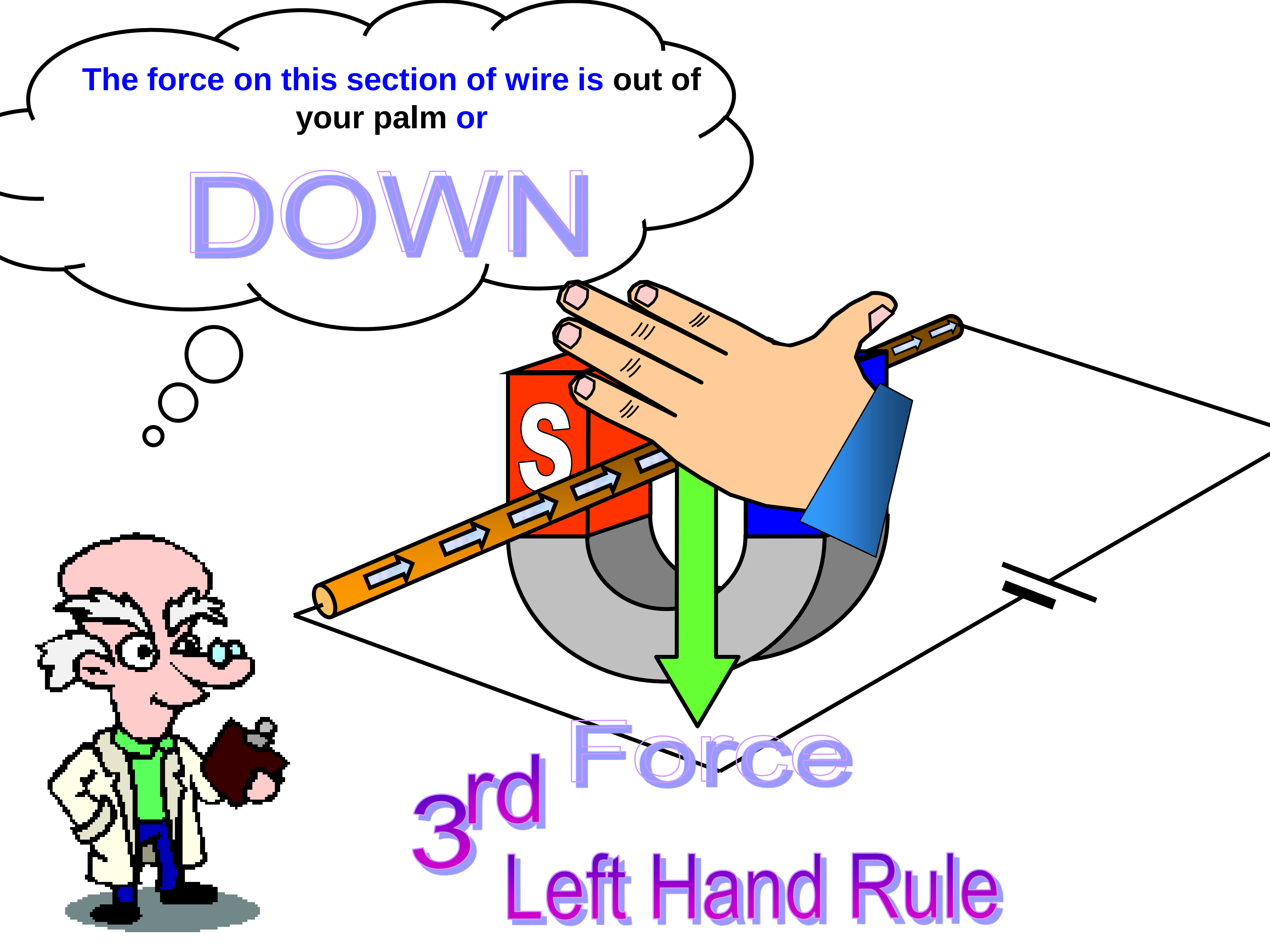
3rd Left Hand Rule


We can find the direction of the force on the wire
using the
3rd Left Hand Rule
S
N
3rd Left Hand Rule

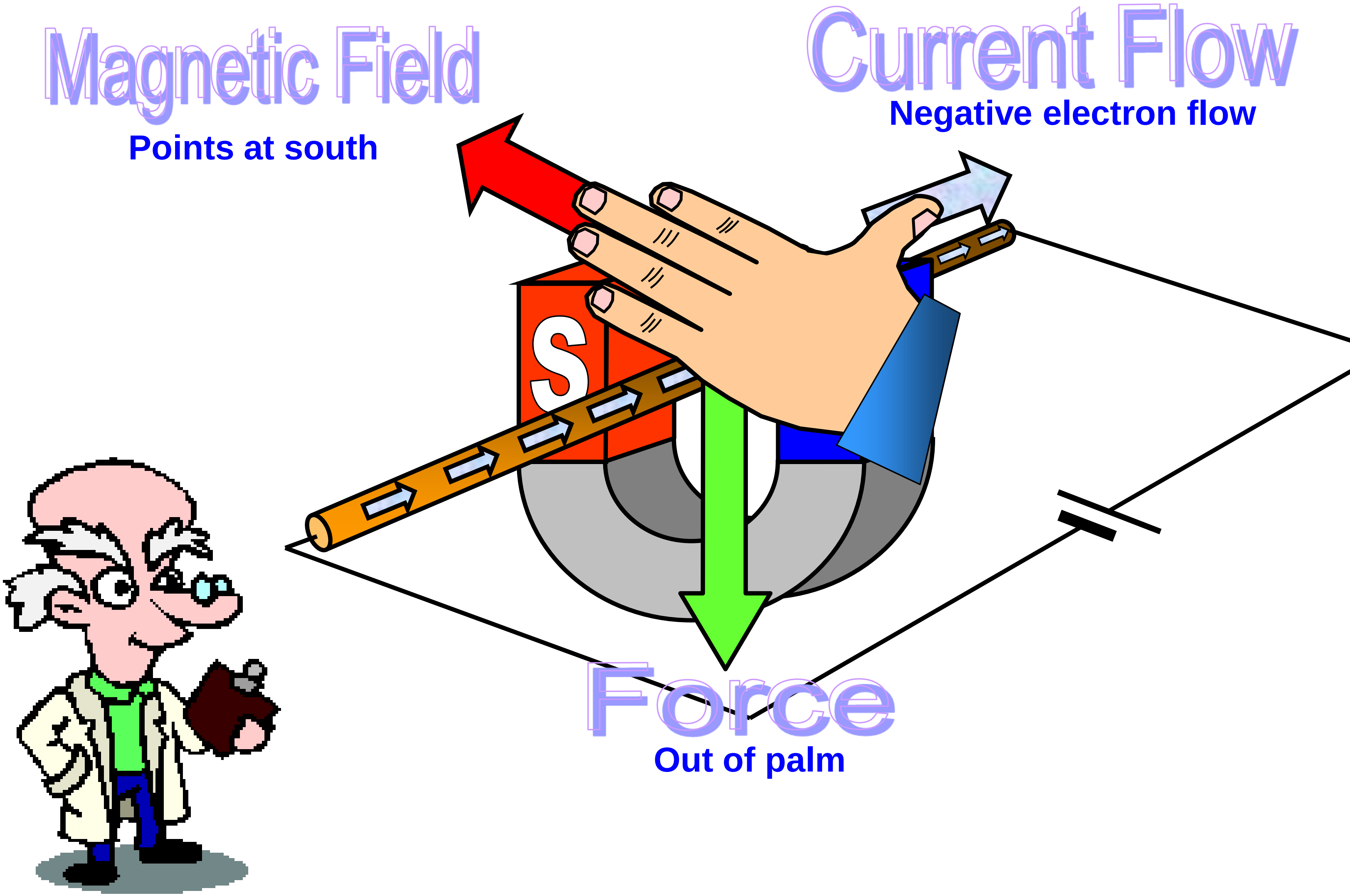

Using your left hand
point your fingers
SOUTH
S
3rd
Left Hand Rule

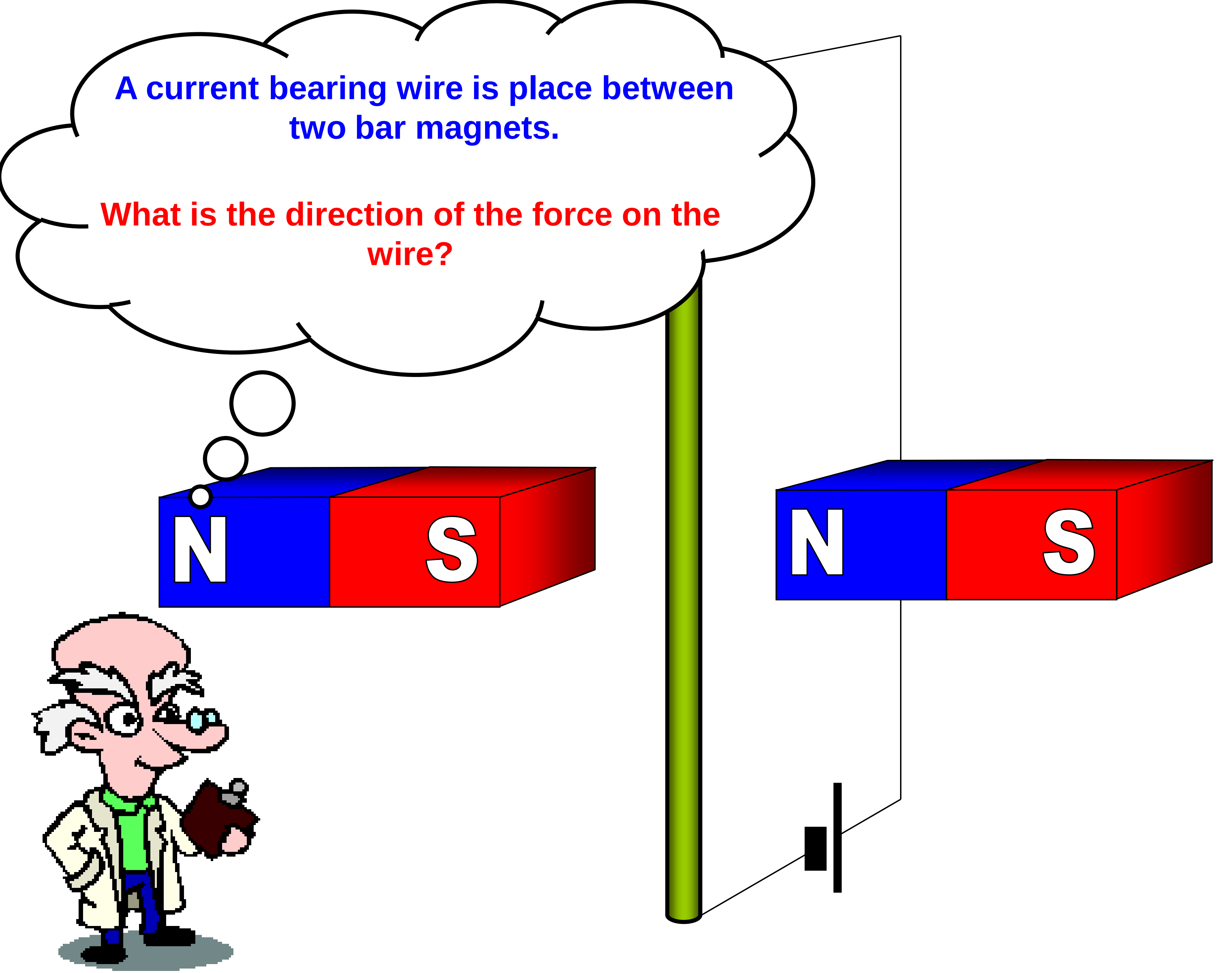

Now, keeping your fingers pointed south,
rotate your hand
so you thumb points in the
same direction as the
current flow.
S
N
3rd
Left Hand Rule


Now, keeping your fingers pointed south, rotate your hand so you thumb points in the same direction as the current flow.
S
3rd Left Hand Rule

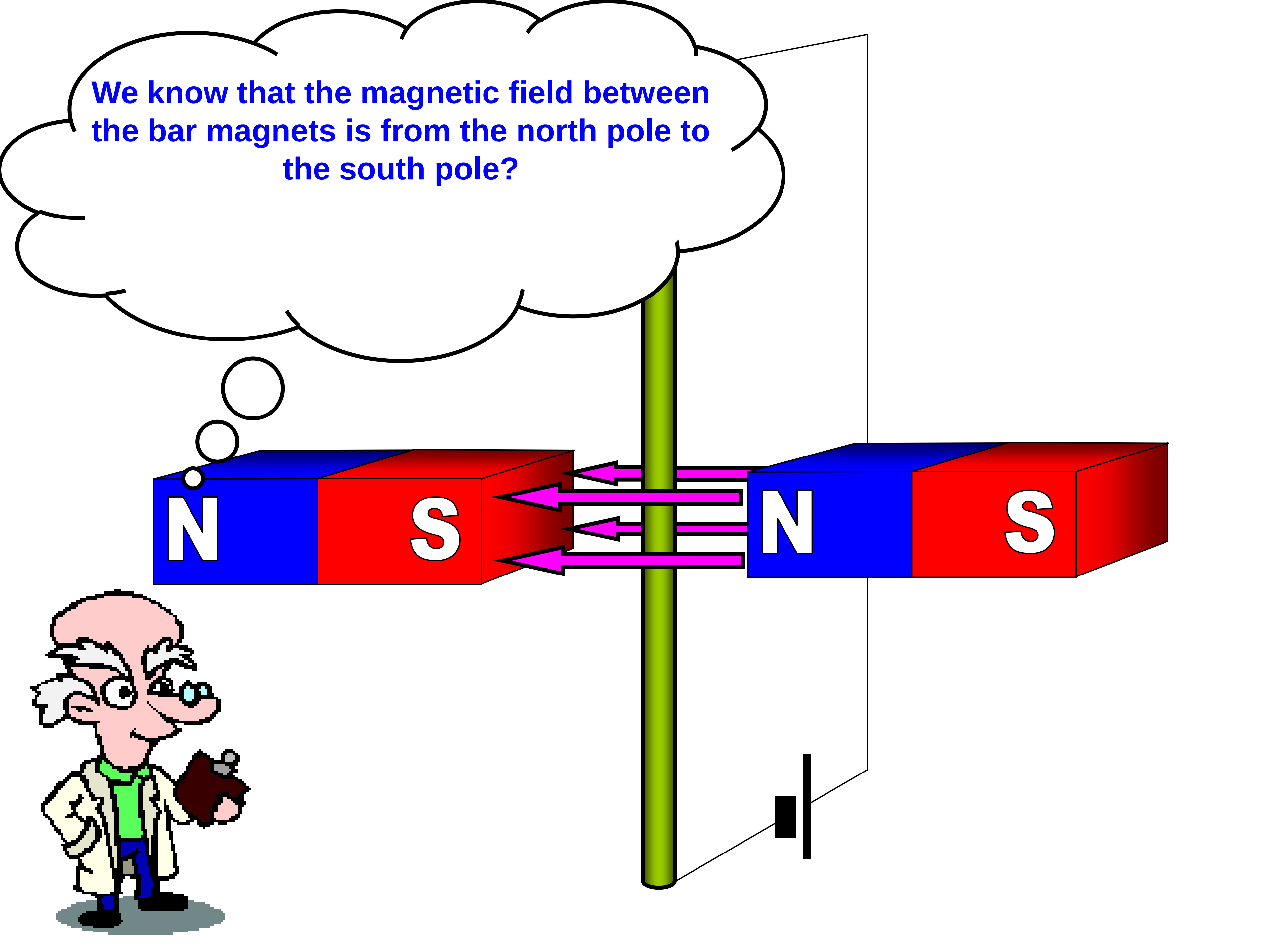


The force on this section of wire is out of your palm or
DOWN
S
Force
3rd Left Hand Rule

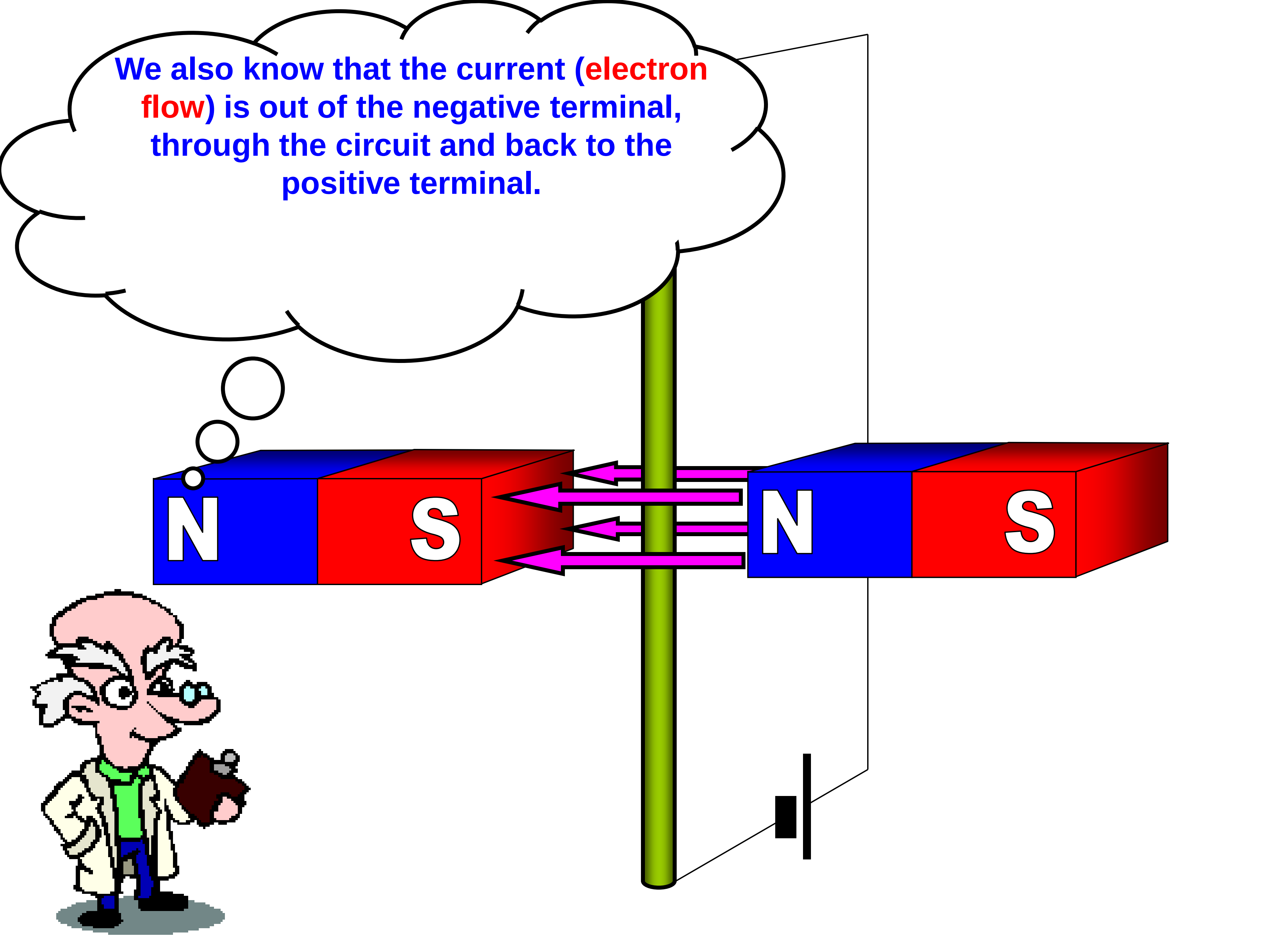

Magnetic Field
Points at south
Current Flow
Negative electron flow
S
Force
Out of palm

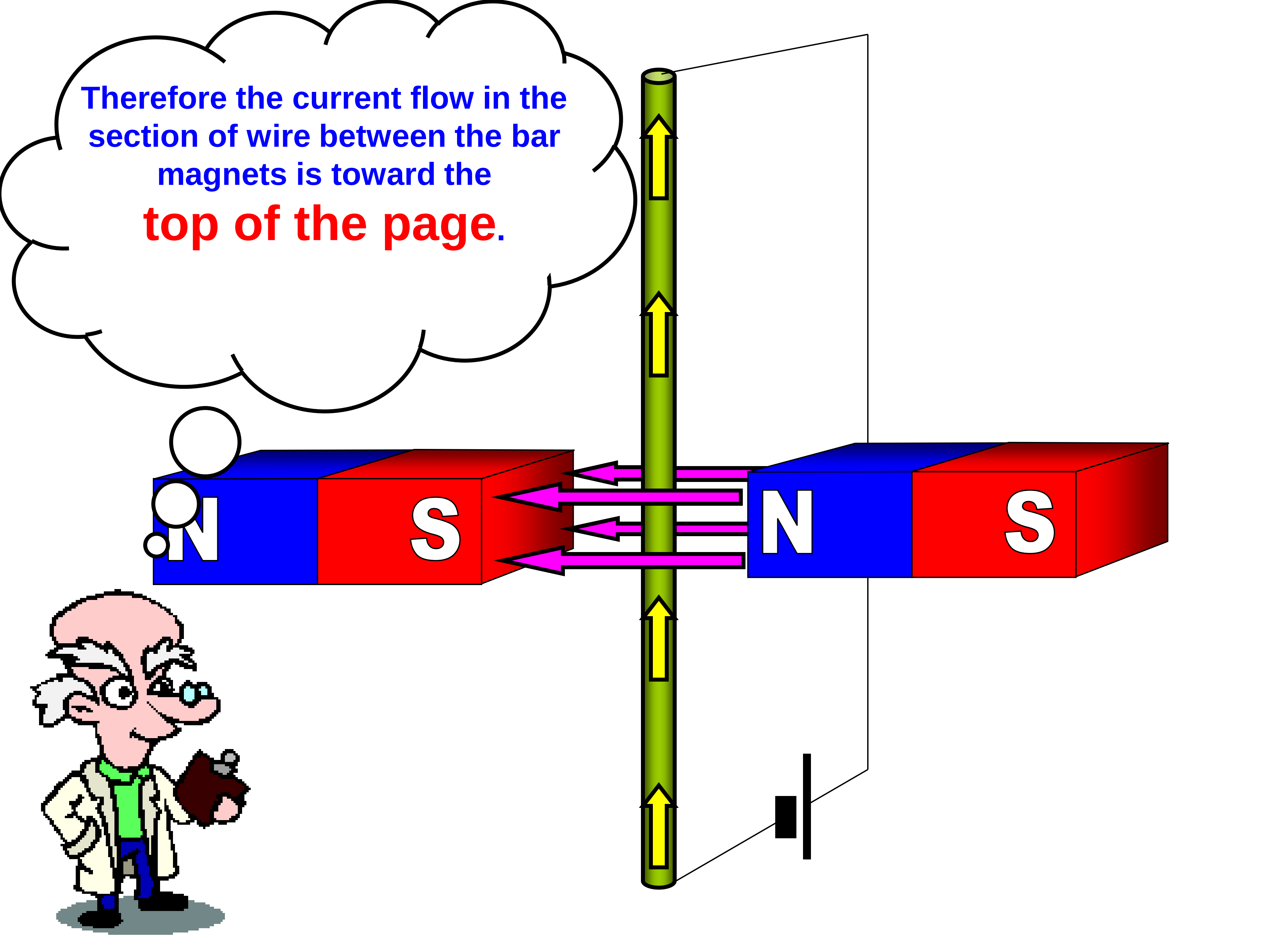


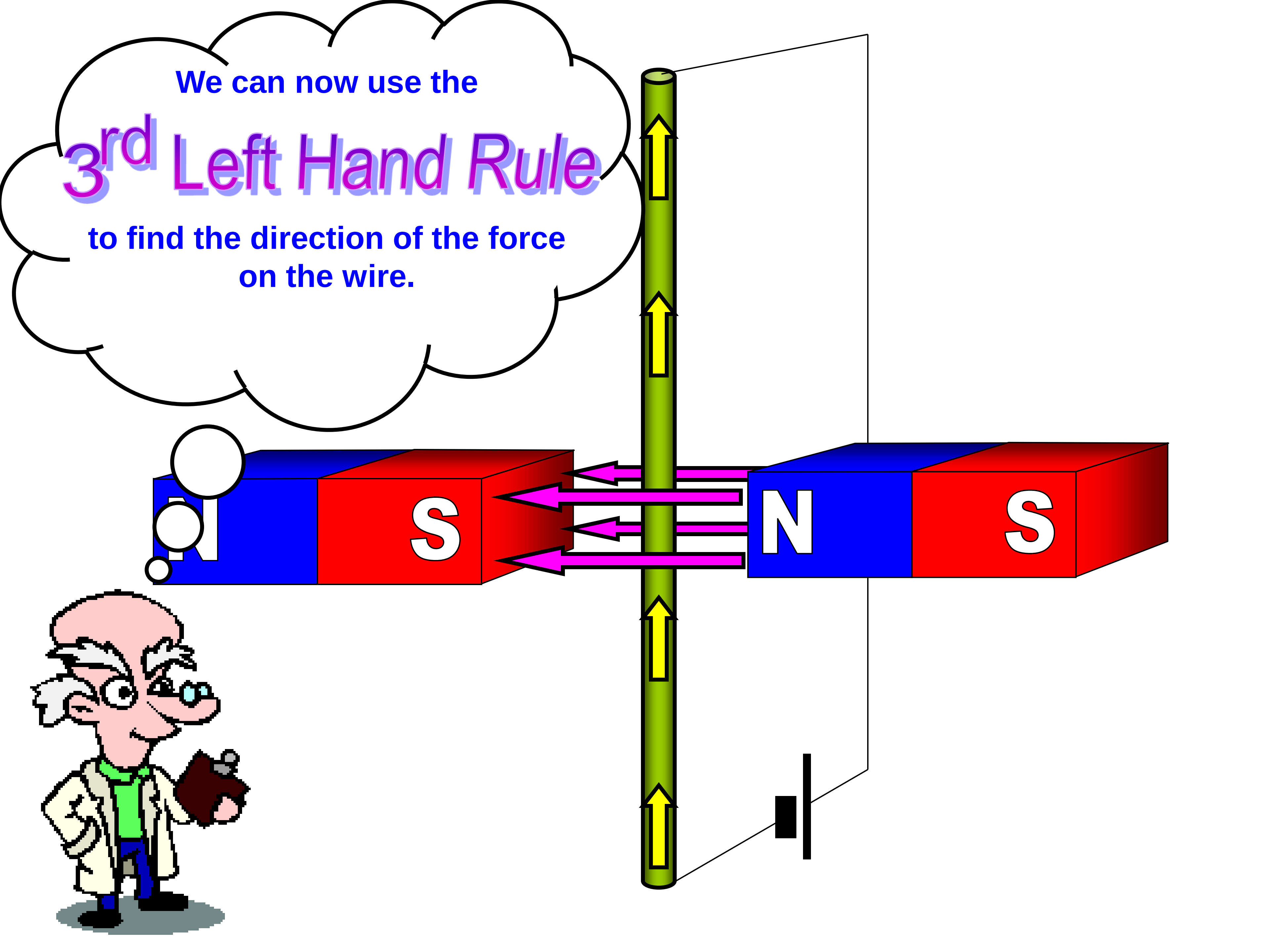
A current bearing wire is place between two bar magnets.
What is the direction of the force on the wire?
N
S
N
S

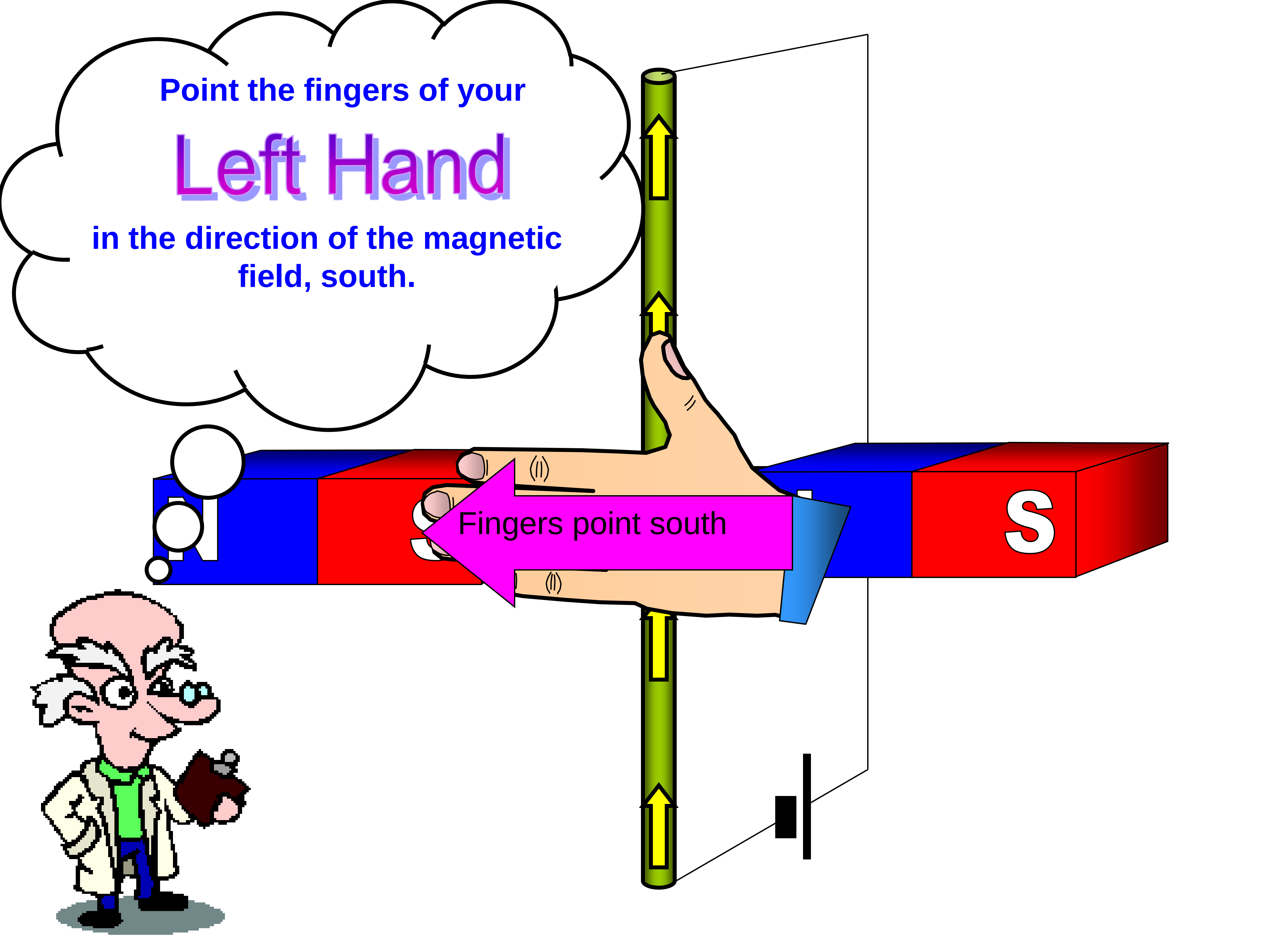


We know that the magnetic field between the bar magnets is from the north pole to the south pole?
N
S
N
S

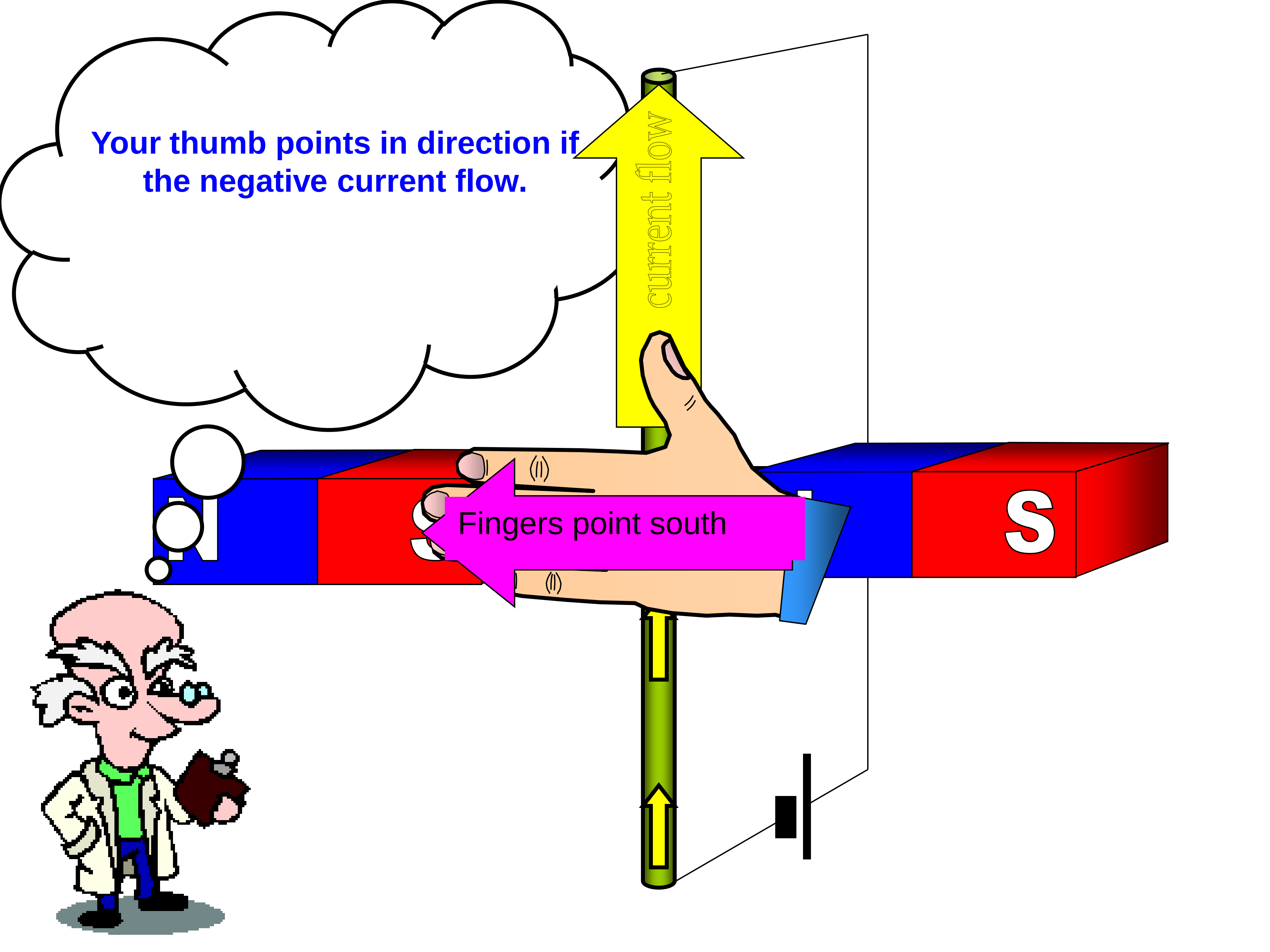

We also know that the current (electron flow) is out of the negative terminal, through the circuit and back to the positive terminal.
N
S
N
S

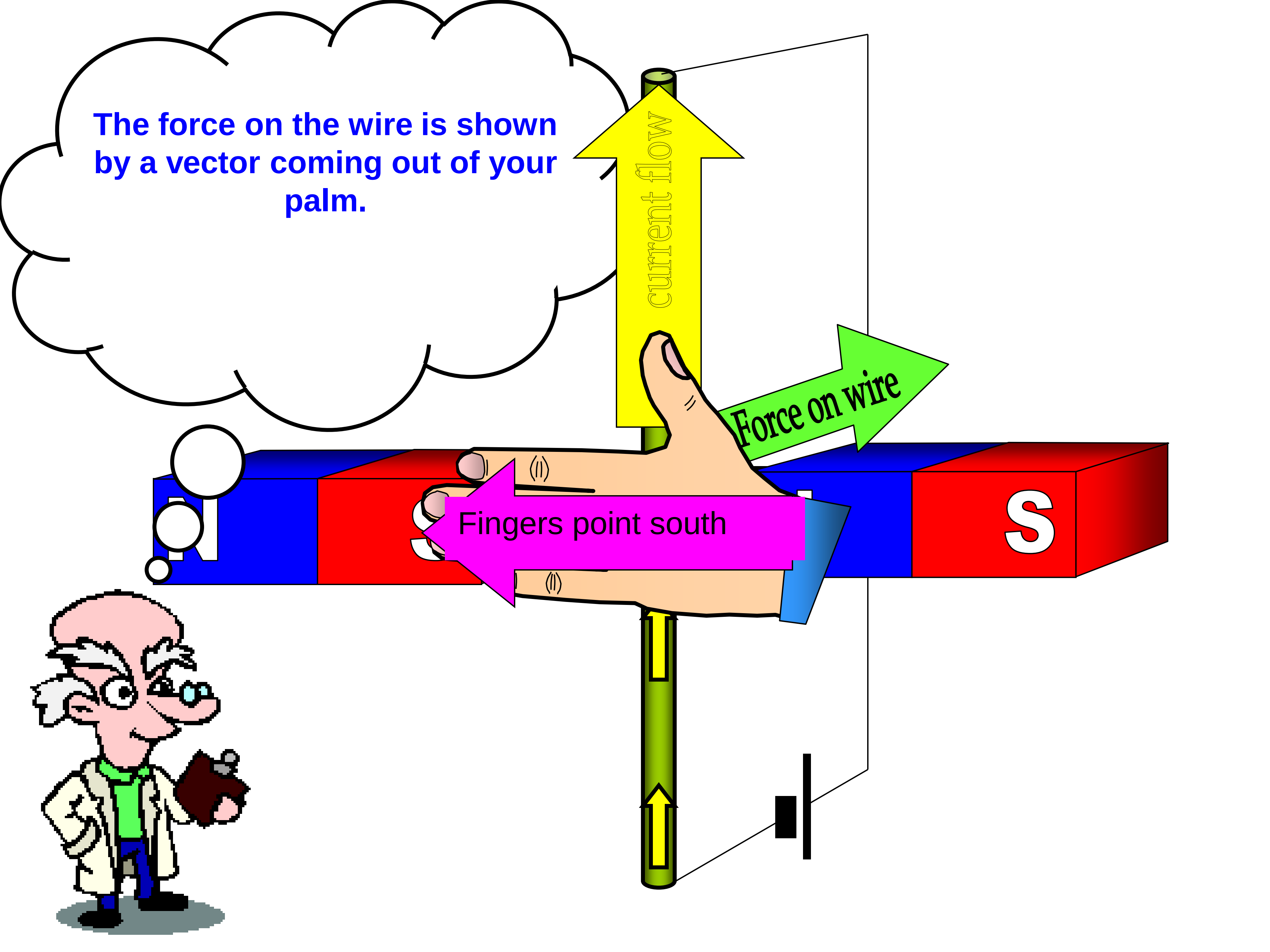

Therefore the current flow in the section of wire between the bar magnets is toward the
top of the page.
N
S
N
S

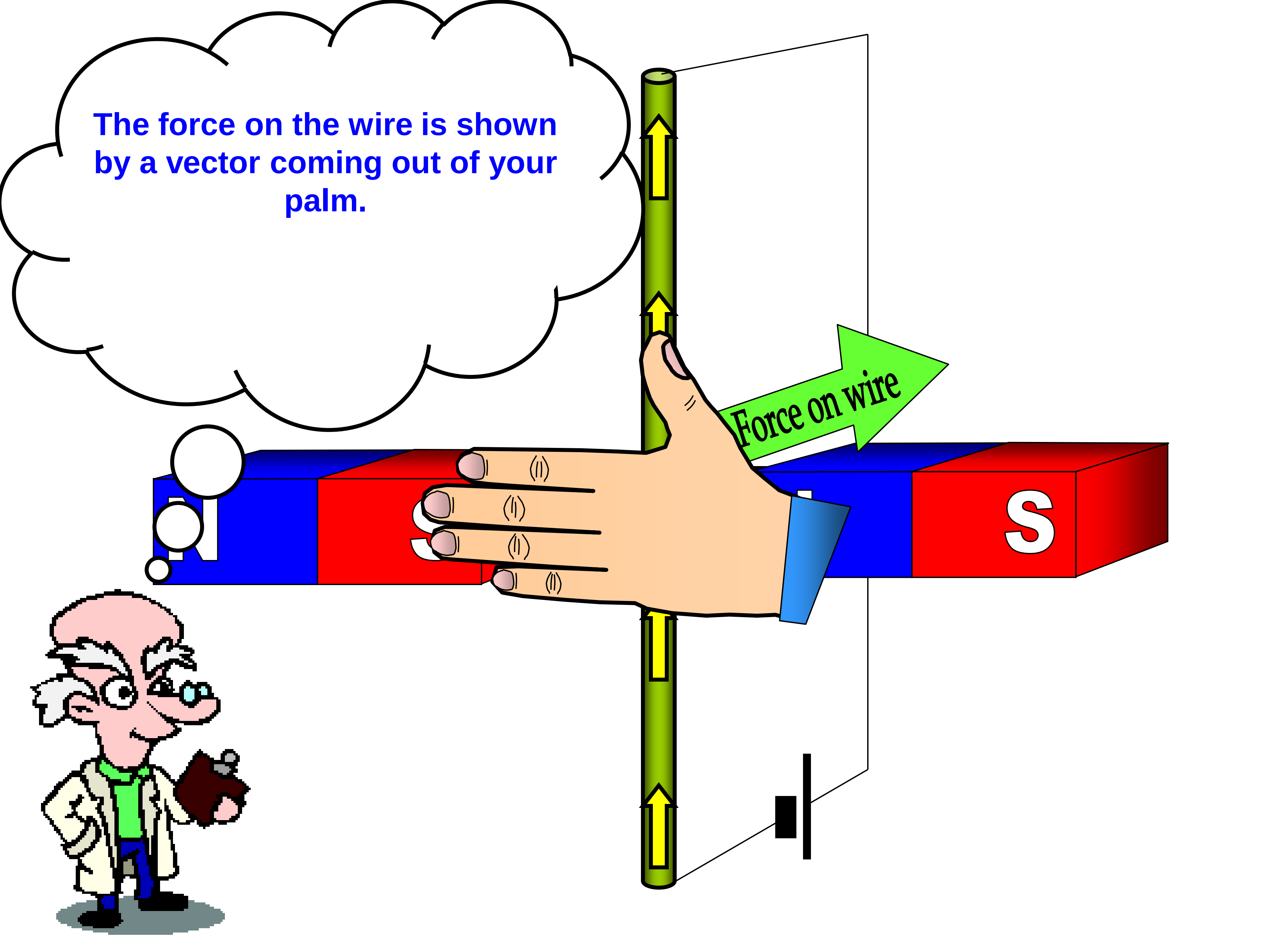

We can now use the
3rd Left Hand Rule
to find the direction of the force on the wire.
N
S
N
S

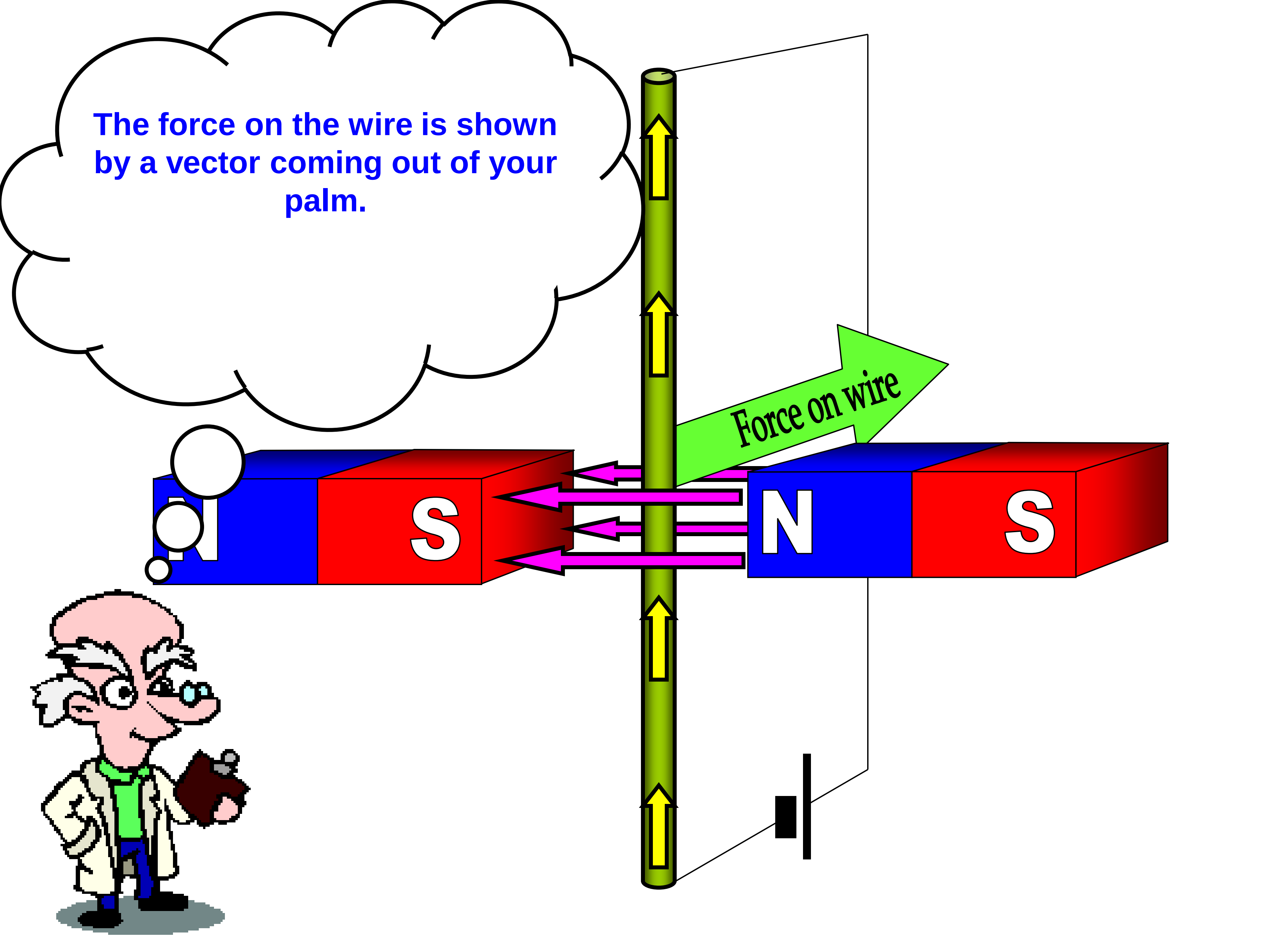


Point the fingers of your
Left Hand
in the direction of the magnetic field, south.
Fingers point south
S

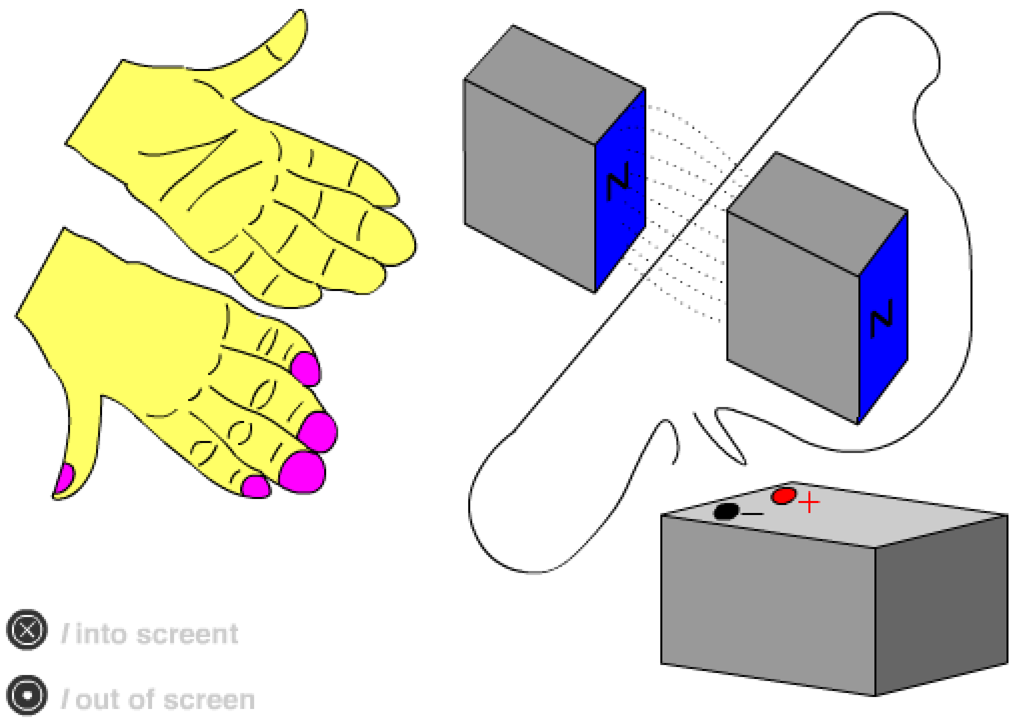

Your thumb points in direction if
the negative current flow.
current flow
Fingers point south
S


The force on the wire is shown by a vector coming out of your palm.
current flow
Force on wire
Fingers point south
N
S
S


The force on the wire is shown by a vector coming out of your palm.
Force on wire
N
S

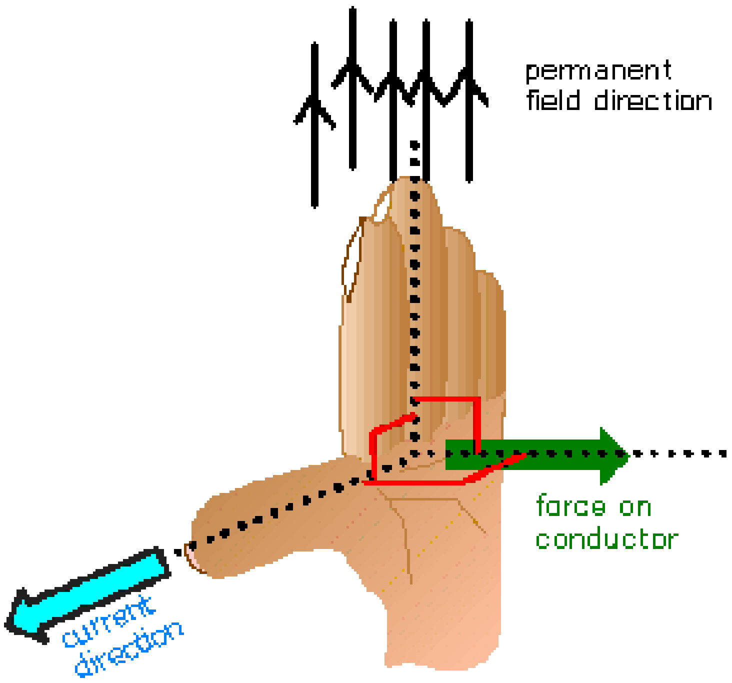

The force on the wire is shown by a vector coming out of your palm.
Force on wire
N
S
N
S

The picture below shows the action of a straight current-carrying conductor placed between the North and South poles of two bar magnets. Using left- hand rule #3 you may predict the direction of the force on the wire when (i) the current goes into the screen, (ii) the current comes out of the screen



SUMMARY OF LEFT HAND RULE #3

When a straight conductor is in a magnetic field and is carrying a current, it will experience a force. You can find the direction of that force like this: point the fingers of your left hand in the direction of the external (permanent) field. Point your thumb in the direction of the current. Then your palm points in the direction of the force on the conductor.



Left-hand rule #3
(The motor principle)

Summary Left Hand Rules

Physics 3204

Unit 3: Section 3 Electromagnetism

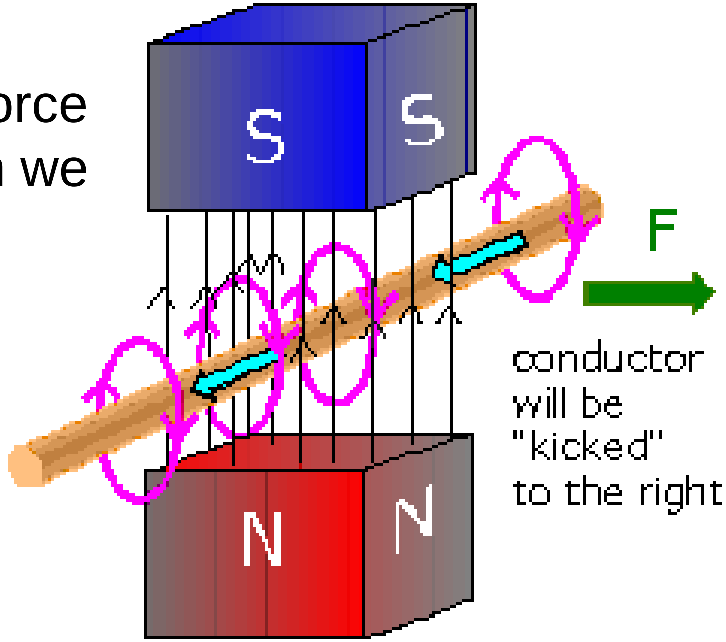
Topic 10 : Magnetic Force on a Wire

TEXT REFERENCE

The Motor Principle

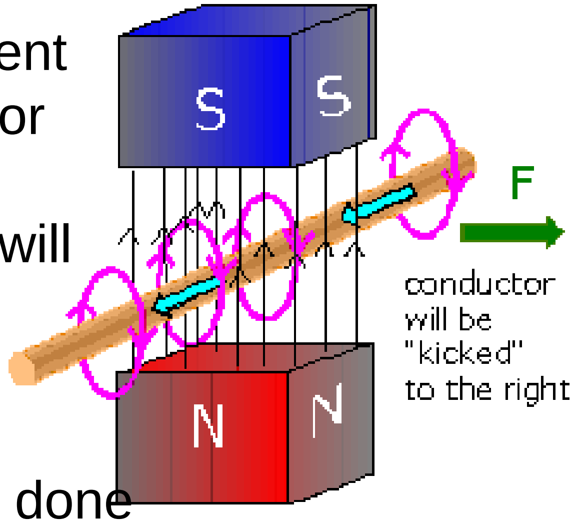
Determining the size of the force on the straight conductor

How may we increase the size of the (green) force on the straight conductor? That is, how can we make our motor more powerful?



Can you guess the FOUR ways …

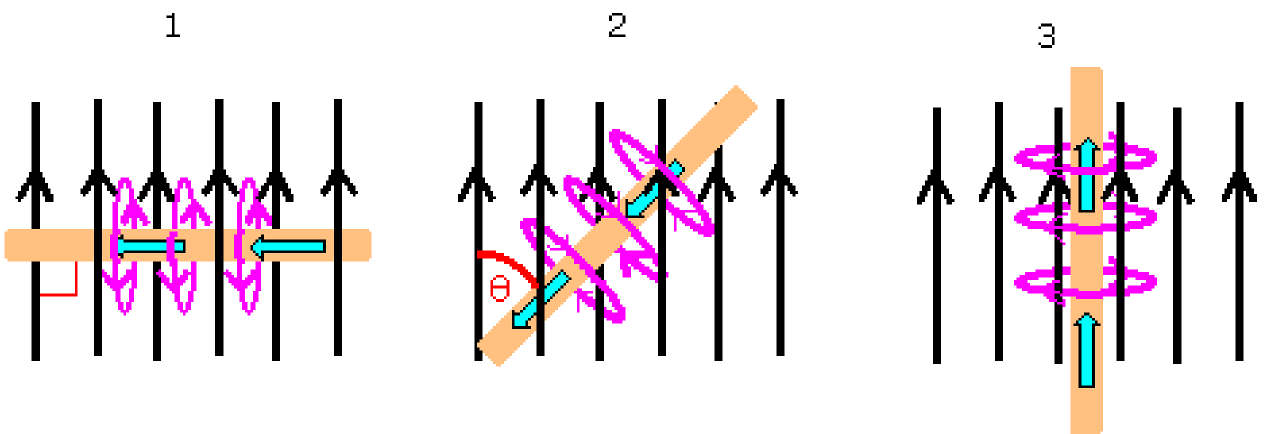
1. We can increase the size of the permanent magnets, which will in turn increase the strength of the permanent magnetic field (the vertical black lines). The symbol for magnetic field strength is B.
   The larger B is, the larger the force on the conductor will be, or F α B.



2. We can increase the size of the circular field that is induced by the current in the conductor. This may be done by increasing the current (I) in the conductor. The larger I is, the larger the force on the conductor will be, or F α I.

3. If the length (L) of the conductor is increased, the fields that interact are also effectively increased. The longer the conductor, the more circular field there will be to interact with the permanent field, therefore F α L.

4. The force F is directly proportional to the sine of the angle that the conductor makes with the permanent field: $F \propto \sin\theta$.



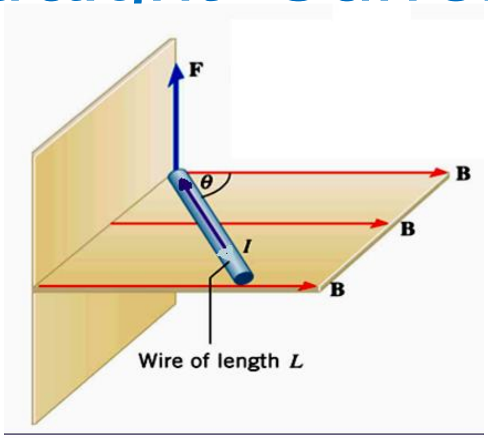
Conductor is perpendicular to field *B*. The force experienced by the conductor is MAXIMUM.

Conductor makes an angle < 90 with *B*. The component of *B* that is perpendicular to the conductor is *B* sin *θ* . The force experienced by the conductor is less than MAXIMUM, but more than ZERO.

Conductor is parallel to field *B*. The angle between the conductor and *B* is 0 degrees. There is no component of *B* perpendicular to the conductor. The force experienced by the conductor is ZERO.

Calculating Magnetic Force on a Straight Current Carrying Wire

$$\vec{F} = BIL\sin\theta$$



Force (F) exerted on a straight current-carrying conductor. Measured in Newtons (N)

Magnetic Field of Strength (B) that the wire is placed in. Measured in Tesla (T)

Current (I) passing through the conductor. Measured in Amperes (A)

Length of Conductor. Measure in meters (m).

Theta (θ) the angle between the conductor and the Magnetic Field

Practice exercise 1

Calculate the magnitude of the force on a 2.1 m wire that is carrying a current of 5.0 A perpendicular to a magnetic field of strength 1.4×10^{-4} T.

Solution

$L = 2.1$ m $\quad I = 5.0$ A

$B = 1.4 \times 10^{-4}$ T $\quad \theta = 90°$

$F = ?$

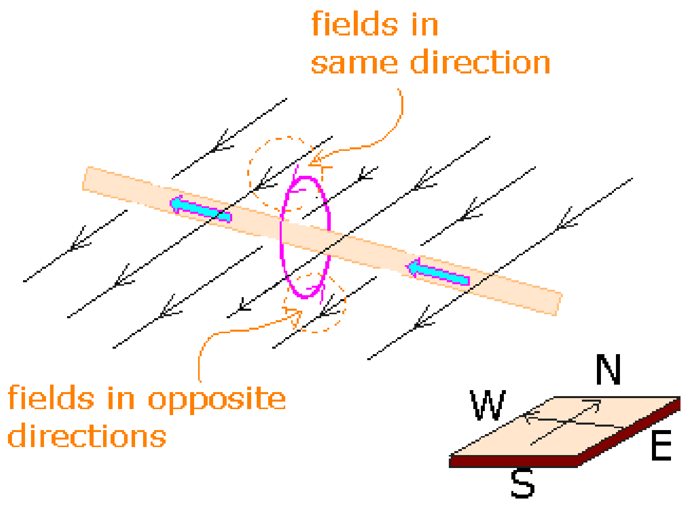
Practice exercise 2

The wire (and current) in practice exercise 1 is running from east to west. The magnetic field direction is from north to south. In which direction will the force be exerted on the conductor ?

Solution (method 1)

Left-hand rule #1 is used to draw the circular field around the conductor. The permanent (black) field and the pink circular field are in the same direction above the conductor, but in opposite directions below the conductor. Therefore, above the conductor the fields repel each other, and below the conductor the fields attract each other. The net force on the conductor is therefore downward!

Method 2
Simply use The LHR #3



Practice exercise 3

Determine by what factor the force diminishes if a conductor changes its orientation from being perpendicular to the magnetic field to a new position that makes an angle of 45° with the field.

Solution

Since the only thing that changed is the angle, we write

$L_2 = L_1$ $\quad$ $I_2 = I_2$

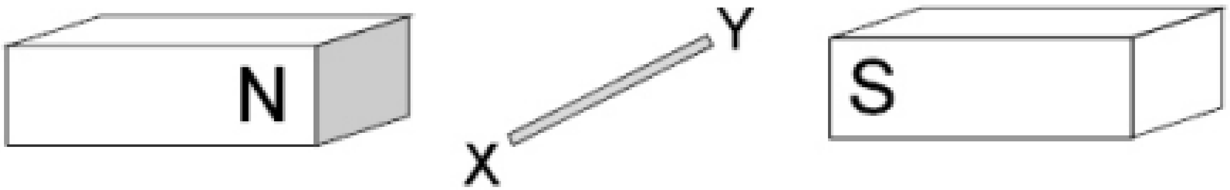
$\theta_1 = 90°$ $\quad$ $\theta_2 = 45°$

$B_1 = B_2$

Determine F_2/F_1 :

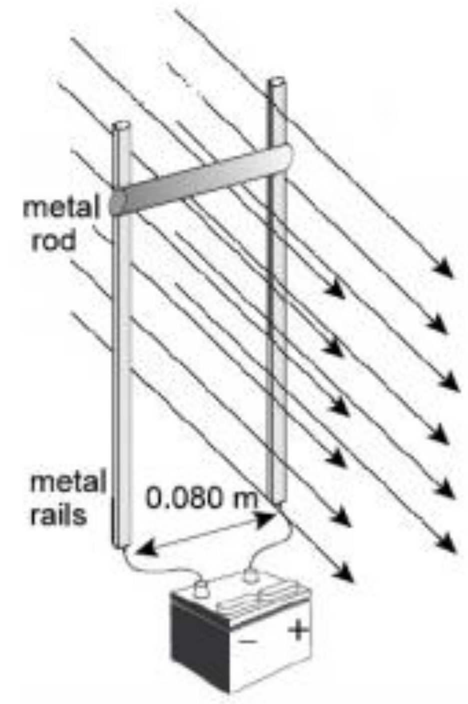
Practice exercise 4

A 0.025 m long wire segment, XY, is positioned perpendicular to a 0.750 T magnetic field as shown. When a current is passed through this wire segment, it experiences a 0.20 N force upwards. Calculate the magnitude and give the direction of the current through the wire. JUNE 2009



Practice exercise 5

A 0.16 kg metal rod is placed in a horizontal magnetic field of 0.75 T and maintains contact with two vertical metal rails that are separated by a distance of 0.080 m. Calculate the current that must flow through the rod in order for it to remain at rest.
JUNE 2008



Physics 3204

Unit 3: Section 3 Electromagnetism

Topic 11 : Magnetic Force on a Moving Charge

TEXT REFERENCE

The force on a current-carrying conductor as it sits an external magnetic field is F = BIL sinθ. The key is current-carrying. If there were no current, there would be no force on the conductor.

The conductor just provides a path for the current. If a stream of electrons were shot through a magnetic field the force on the stream would still be F = BIL sinθ, where, in this case, L would be the length of the stream that falls within the magnetic field.

Next we are going to determine the force on a single charged particle. Instead of a current of electrons passing through a magnetic field, imagine a single electron (charge q) being fired into the field. In fact the single charge could be a proton, neutron or ion.

Continue Next slide...

Think: The charge q is traveling at a speed v and takes a time of t to travel a distance L. Since distance = speed x time, we can write L = vt.

If there is a stream of electrons, and there are n charges of size q in the stream,the total charge will be Q = nq.

$$I = \frac{charge}{time}.$$

Remember current is the rate of flow of charge. That is

So now $I = \frac{nq}{t}.$

Use L = vt and I = nq/t to re-write F = BIL sin θ.

$$F = BIL \sin\theta$$

$$F = B\frac{nq}{t}vt \sin\theta$$

$$F = Bnqv \sin\theta.$$

For the force on a single charge, that is, n=1. the expression becomes

F = Bqv sin θ

Calculating Magnetic Force on a Moving Charge

$$\vec{F} = Bev\sin\theta$$

Force (F) exerted on the moving charge. Measured in Newtons (N)

Magnetic Field Strength (B) that the charge is placed in . Measured in tesla (T),

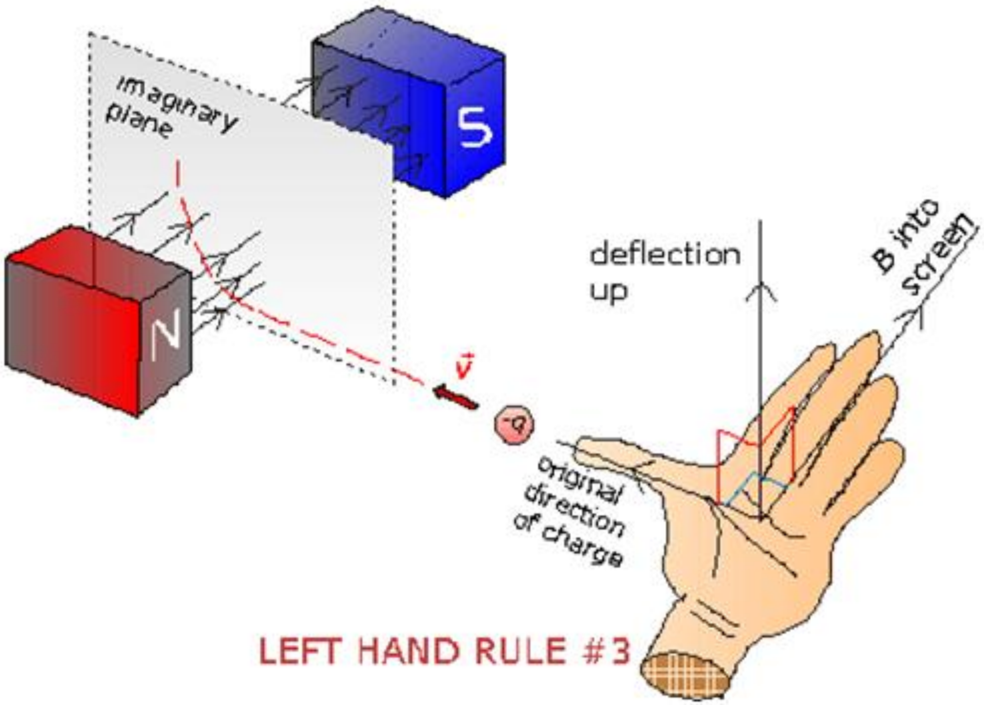
Amount of charge (e) is the magnitude of the charge. Measured in coulombs (C)

Velocity (v) is the velocity of the charged particle. Measured in meters/second (m/s)

Theta (θ) the angle between the charged particle and the Magnetic Field. Measured in degrees

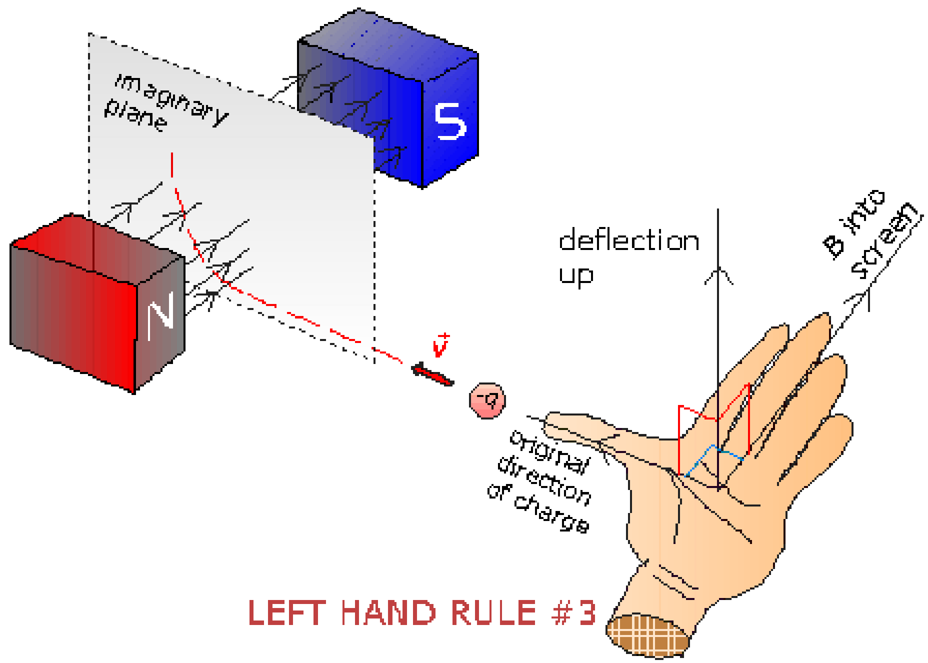
Direction of Magnetic Force on A Moving Charge

To determine the direction of the force apply left-hand rule #3 : point your fingers in the direction of the magnetic field, your thumb in the direction that the charge is moving, then the palm of your hand points in the direction of the force on the charge.



Practice exercise 2

A magnetic field of 44.0 T is directed into the screen. A particle with a negative charge of 2.0 x 10^{-18} C is shot into the field from the right, making an angle of 90^o with the field lines. If the particle is moving at 5.4 x 10^7 m/s, what magnetic force doe it experience?



Solution

$B = 44.0$ T $\quad q = 2.0 \times 10^{-18}$ C

$v = 5.4 \times 10^7$ m/s $\quad \theta = 90^o$

$F = ?$

$F = Bqv \sin \theta$

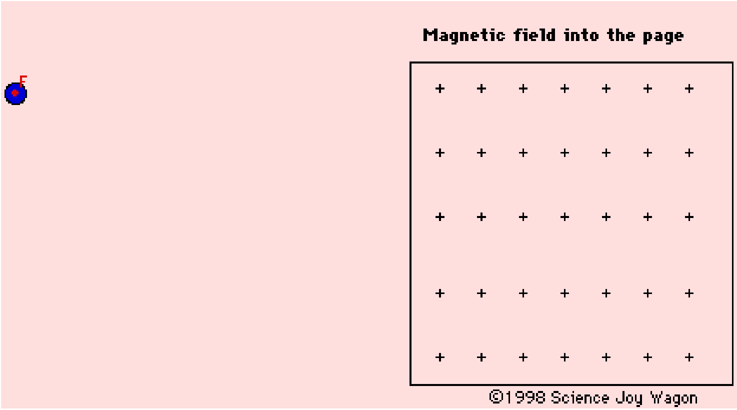
$= 44.0 \text{ T} \times 2.0 \times 10^{-18} \text{ C} \times 5.4 \times 10^7 \text{ m/s} \sin 90^o$

$= 4.8 \times 10^{-9}$ N

The magnitude of the force is 4.8 x 10-9 N. Use left hand rule #3 to determine the direction in which the particle is deflected. This means the particle is deflected towards the top of the screen.

Moving Charges Circular motion

A particle moving at constant speed in a uniform magneticfield where the field is perpendicular to the particles velocity will tracea circular path. This means that the magnetic force will provide a centripetal force to keep the particle in circular motion.



$$F_{Net} = F_{Magnetic}$$

But for UCM

$$F_{Net} = F_C$$

Therefore:

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

Which simplifies to:

$$r = \frac{mv}{Bq}$$

Where:

r: radius of curvature of particle, meters (m)

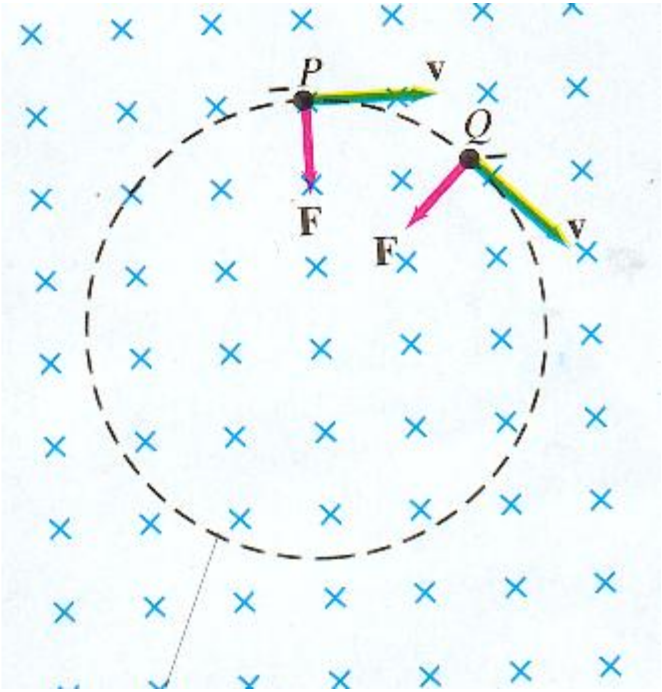
v: velocity of particle (m/s)

B: Magnetic Field Strength Tesla (T)

q: Charge on the particle (C

Practice Exercise 1

An electron travelling at 7.7×10^6 m/s enters into a uniform magnetic field at a right angle. It is deflected in a circular path with a radius of 3.5×10^{-2} m. What is the magnitude of the magnetic field it experiences? (PUBLIC EXAM, JUNE 2005)



Activity

- Worksheet: **Magnetic Force on Moving Charges**

Physics 3204

Unit 3: Section 3 Electromagnetism

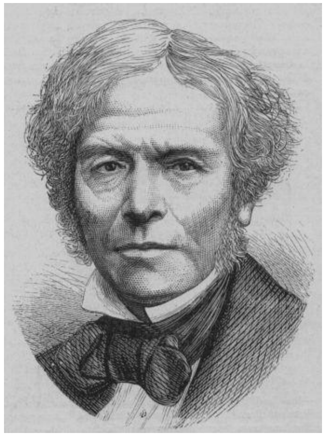
Topic 11: Inducing Current

TEXT REFERENCE

Oersted's principle: when a current passes through a straight conductor there will be a circular magnetic field around the conductor.

Hans Christian Ørsted
(1777-1851)

Micheal Faraday: discover the opposite of Oersted. It discovered that changing a magnetic field moves near a conductor it makes any free charge in the conductor move. --that is, a changing magnetic field creates a current.



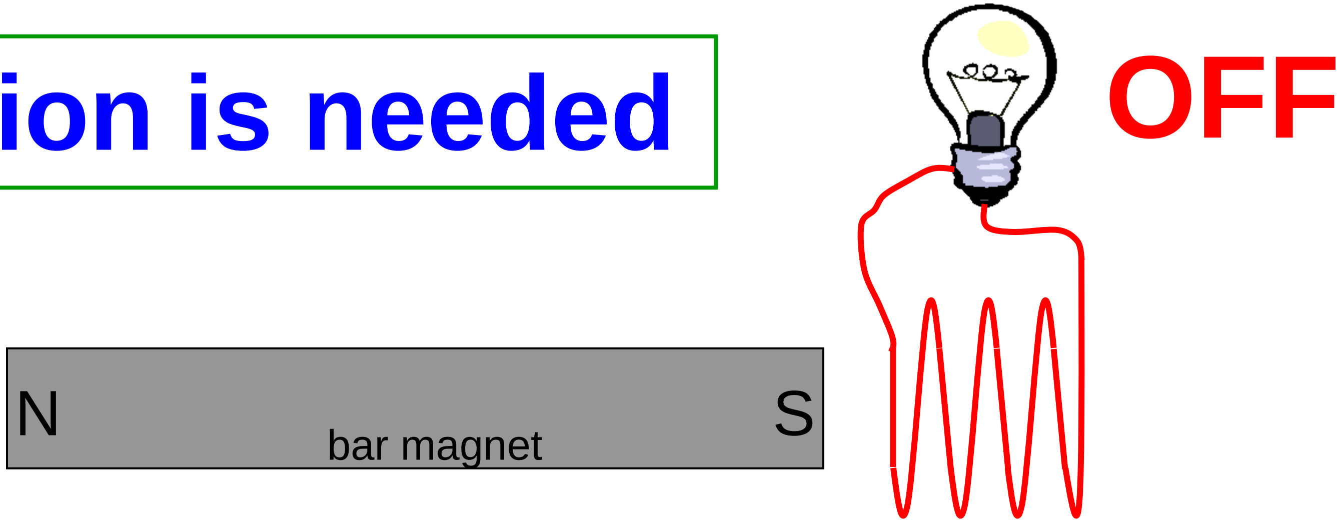
Electromagnetic Induction is the process of using magnetic fields to produce voltage, and in a complete circuit, a current.

Faraday's Law

Current is induced (created) in a wire (usually looped into coils) whenever the wire senses a **changing** (increasing and decreasing in strength) magnetic field near it

Inducing a current (Faraday's 1st method)

Motion is needed



- When a magnet is moved into coil B, a current **briefly** appears
- Current is **only present when the magnet is moving**
- As the magnet is removed from the coil, a current again **briefly** appears
- That's why we say:

  A changing magnetic field induces a current in the wire

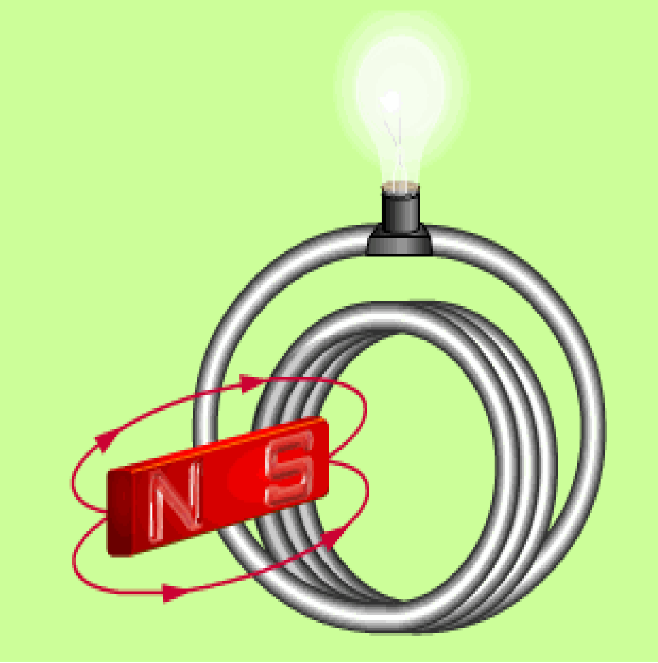
The amount of induced current depends on:

1. **Strength of magnetic field** (*use stronger magnet*)

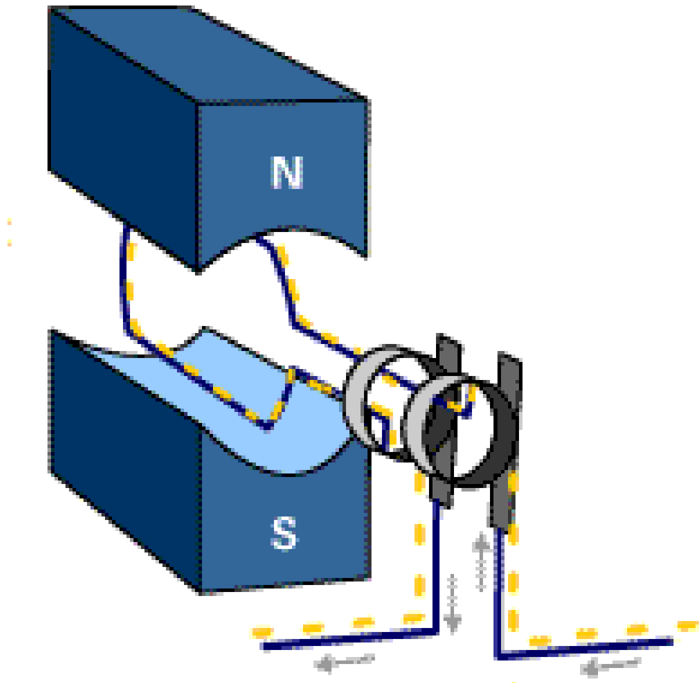
2. **Speed** of magnetic field past wire (or wire past magnetic field) (*move faster*)

3. **Area of loop** (*use larger loops*)

4. **Number of loops** (*use more loops*)



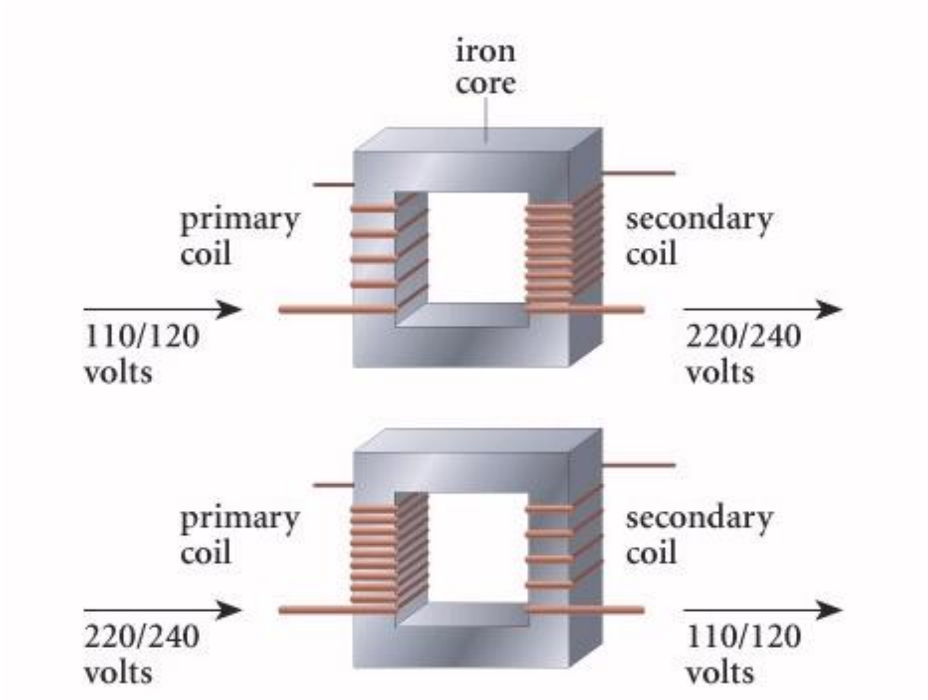
Useful Applications



AC Generators use Faraday's law to produce rotation and thus convert electrical and magnetic energy into rotational kinetic energy. This idea can be used to run all kinds of motors. Since the current in the coil is AC, it is turning on and off thus creating a CHANGING magnetic field of its own. Its own magnetic field interferes with the shown magnetic field to produce rotation.

Transformers

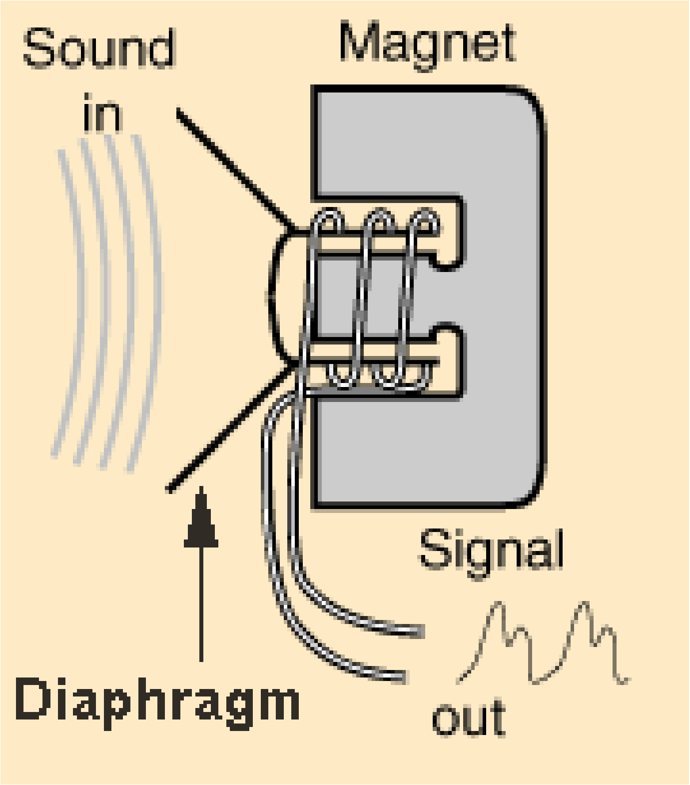
Probably one of the greatest inventions of all time is the transformer. AC Current from the primary coil moves quickly BACK and FORTH (thus the idea of changing!) across the secondary coil. The moving magnetic field caused by the changing field (flux) induces a current in the secondary coil.



If the secondary coil has MORE turns than the primary you can step up the voltage and runs devices that would normally need MORE voltage than what you have coming in. We call this a STEP UP transformer.

We can use this idea in reverse as well to create a STEP DOWN transformer.

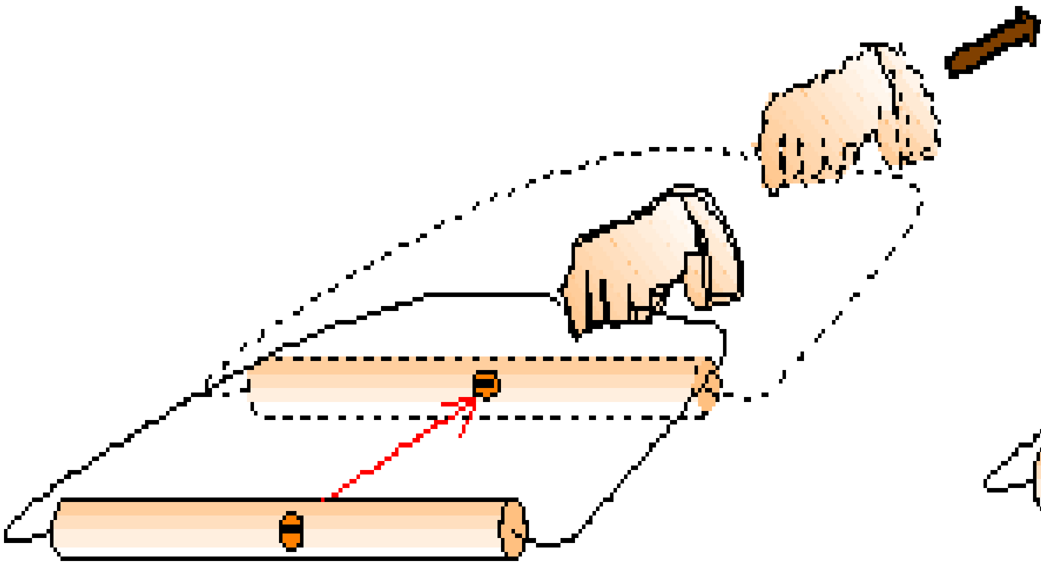
Microphones



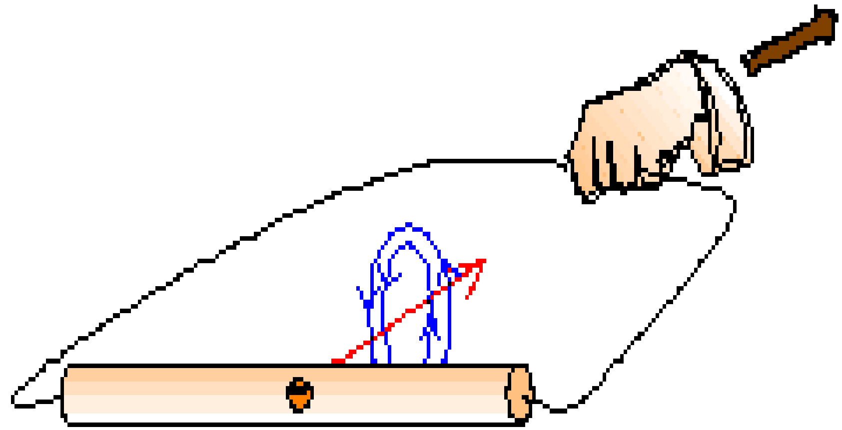
A microphone works when sound waves enter the filter of a microphone. Inside the filter, a diaphragm is vibrated by the sound waves which in turn moves a coil of wire wrapped around a magnet. The movement of the wire in the magnetic field induces a current in the wire. Thus sound waves can be turned into electronic signals and then amplified through a speaker.

How Current Is Induced In The Straight Conductor

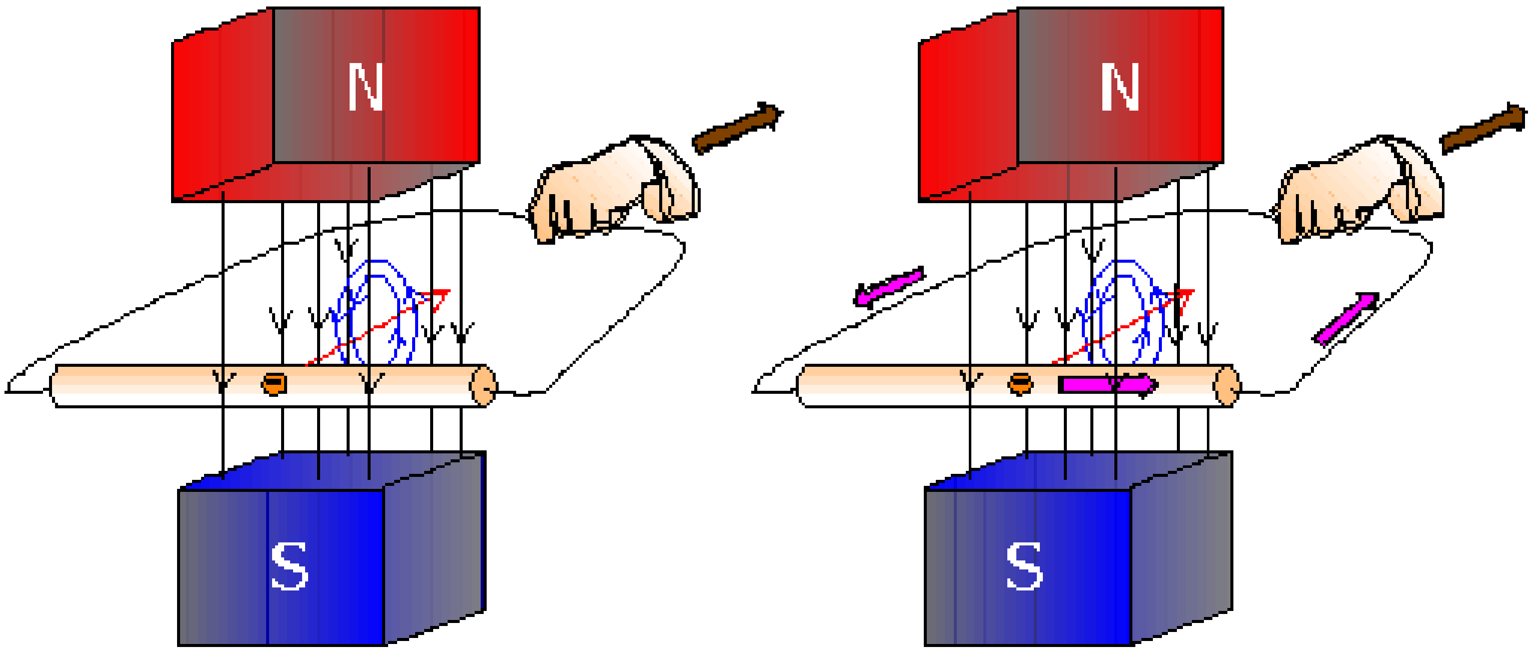
The relative motion of the conductor and the external magnetic field has induced a current in the conductor--Faraday's Law.



The electron is one of zillions being pulled in the direction of the red arrow.



Each moving electron induces a circular magnetic field about its path as described by Oersted's Principle. (Use left-hand rule #1).



On the LHS of the red path the black and blue fields repel each other

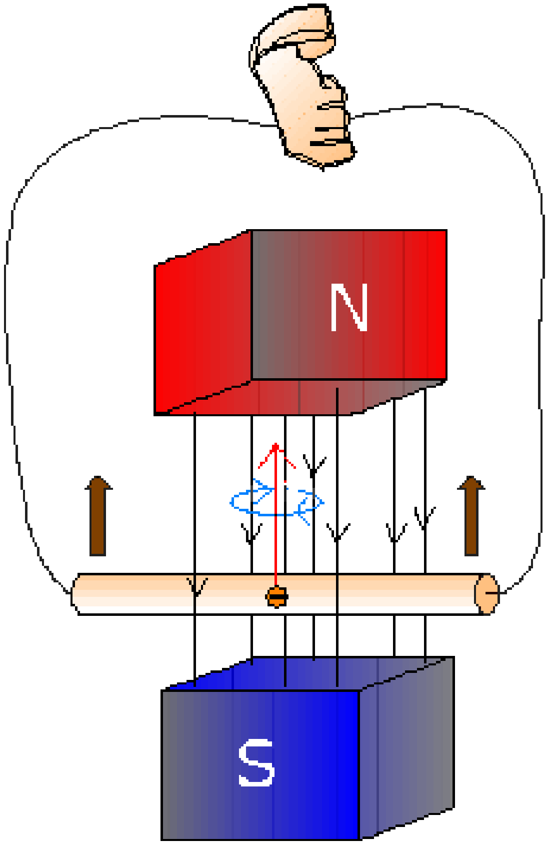
On the RHS of the red path the black and blue fields attract each other

This interaction of the black and blue fields means that the free electrons are forced to the right. That is, a current (pink arrow) has been induced by the motion

Important: either the conductor must move, or the magnetic field must move, or the magnetic field must change in intensity in order that for the current to be induced.

Here the path of the representative electron (the red arrow) is now such that the blue circular magnetic field is perpendicular to the black permanent field. Because the fields are perpendicular, they cannot interact. Therefore, the electron feels no force due to the external field, and there will be no induced current.

If the conductor is pulled through at some angle, then there will be an induced current greater than zero but less than than the maximum that results when the conductor cuts the field lines at 90^{o}



Conductor is moving parallel to the lines of force. No current Is Induced.

Physics 3204

Unit 3: Section 3 Electromagnetism

Topic 11 : AC/ DC

TEXT REFERENCE

Using Faraday's Discovery to produce Alternating Current (AC)

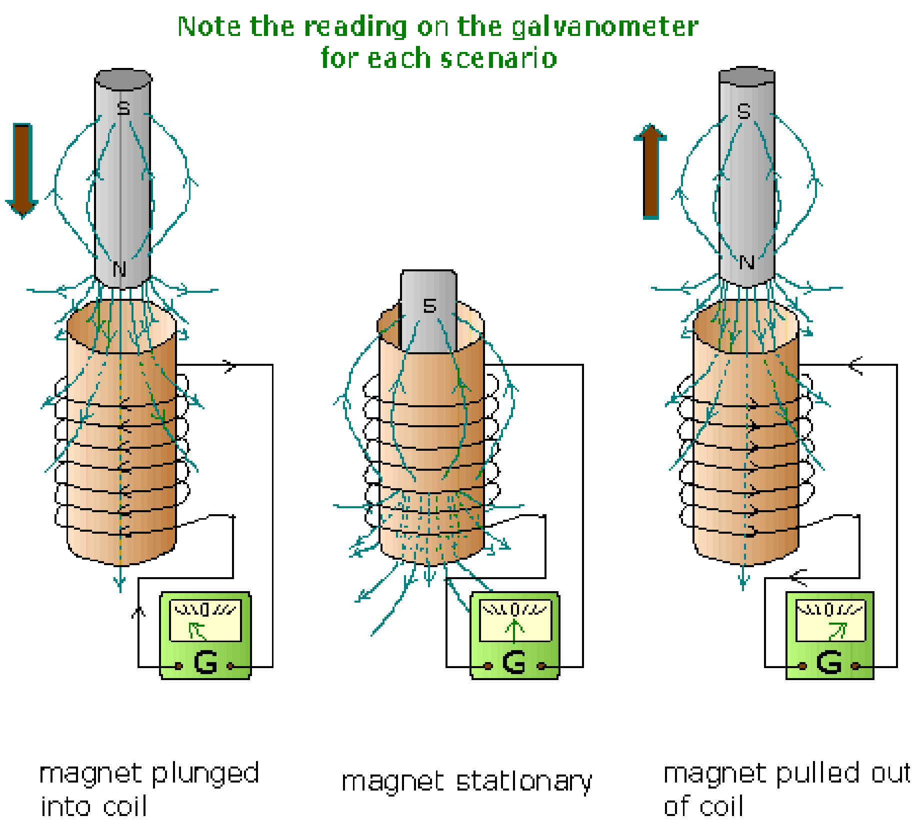
A dry cell or battery is a source of electric current that travels only in one direction. It is called direct current (DC)

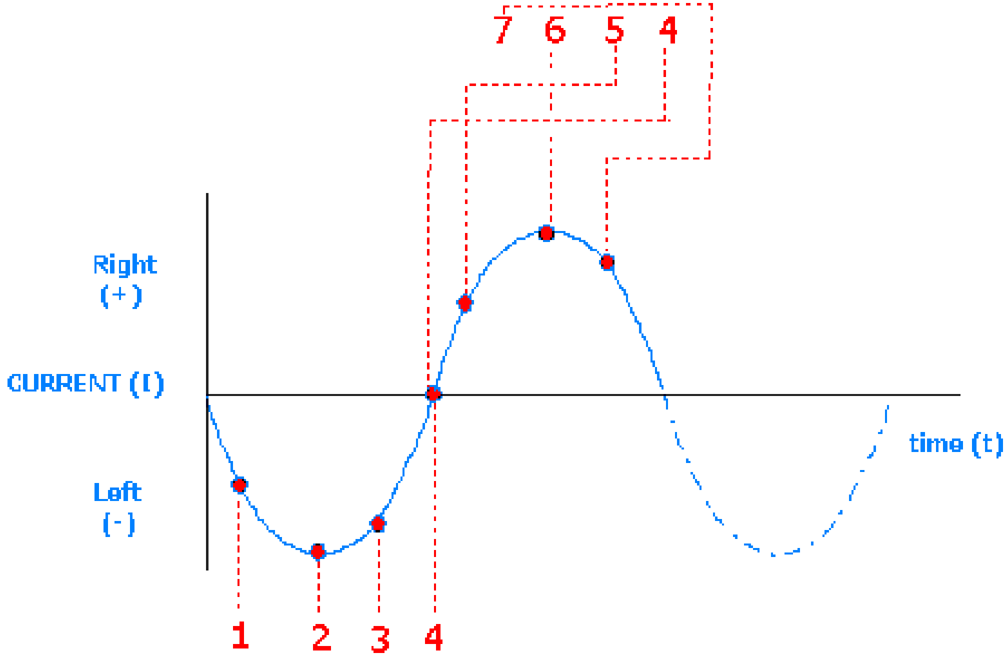
Alternating current does not travel in the same direction all the time. Neither does the current have a constant magnitude.

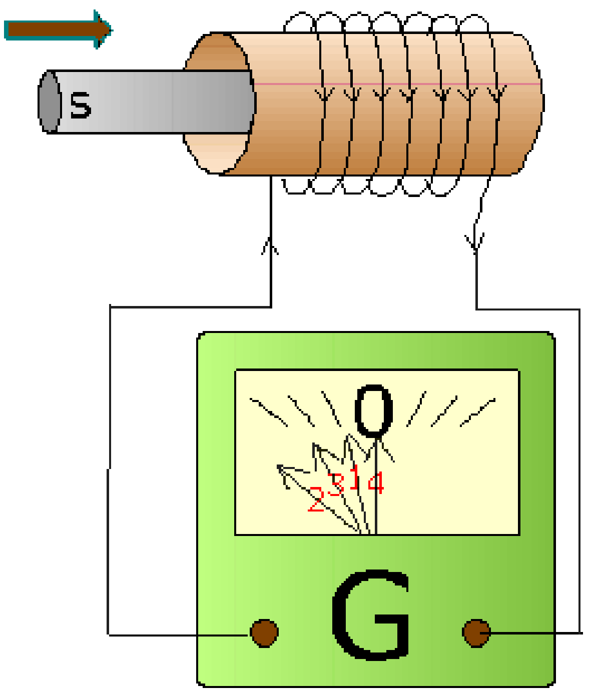
A simple way to produce AC , can be seen in Fig 16.2 on p. 670.

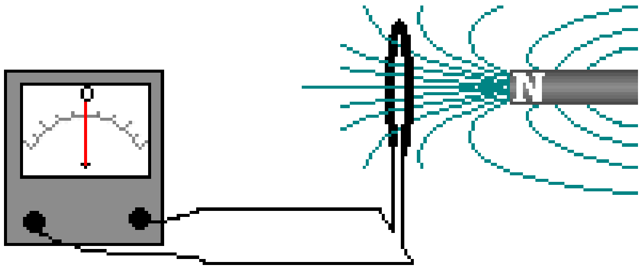
Also shown right.

As the magnet is pushed in and pulled from the coil, the galvanometer needle will show that the current reaches a maximum in one direction, then goes to zero and reaches a maximum in the other direction. This illustrates that there is an alternating current in the coil circuit.









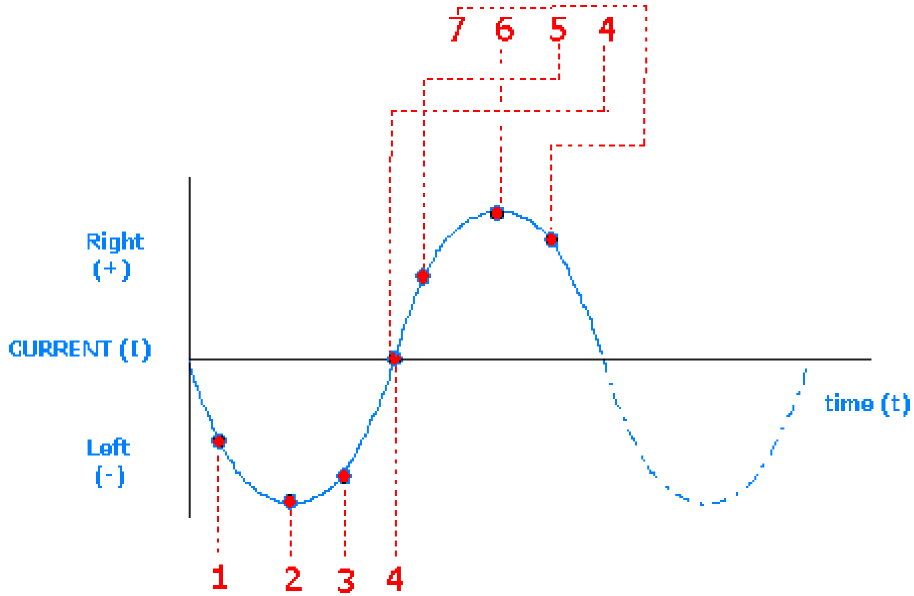
Pos. 1--the magnet is picking up speed; the needle starts to move to the left (we will say the induced current is moving to the left--in the next lesson you will learn why it is to the left).

Pos. 2--the magnet is moving at maximum speed; the current is maximum.

Pos. 3--the magnet begins to slow down; the current decreases.

Pos. 4--the magnet stops; there is no induced current

NOW GO TO THE TOP OF THE PICTURE

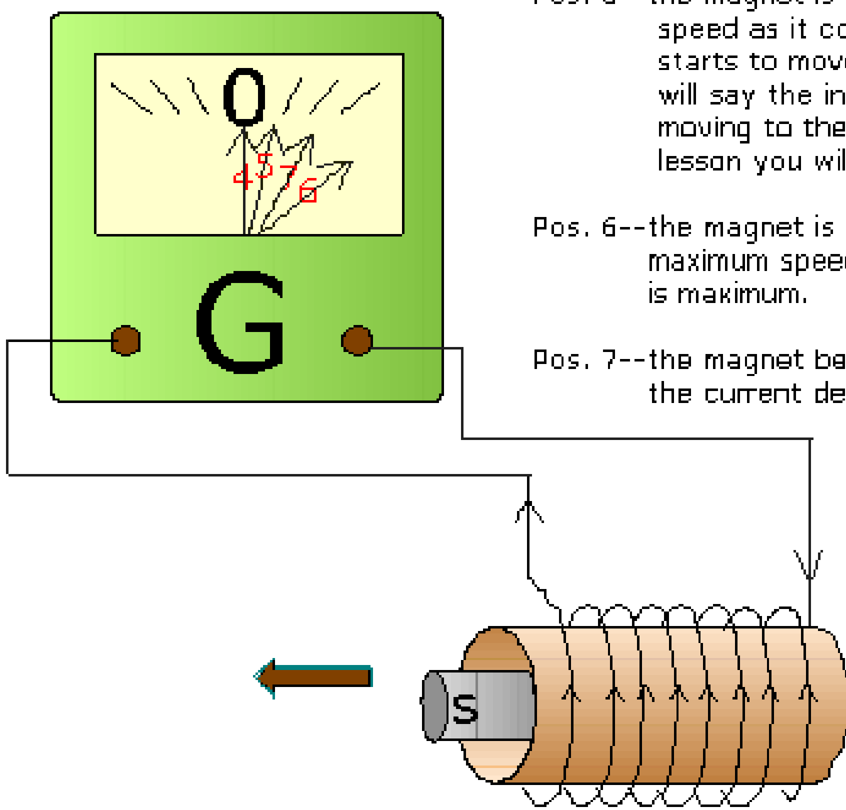


Pos. 4--the magnet is stopped inside the coil; there is no induced current.

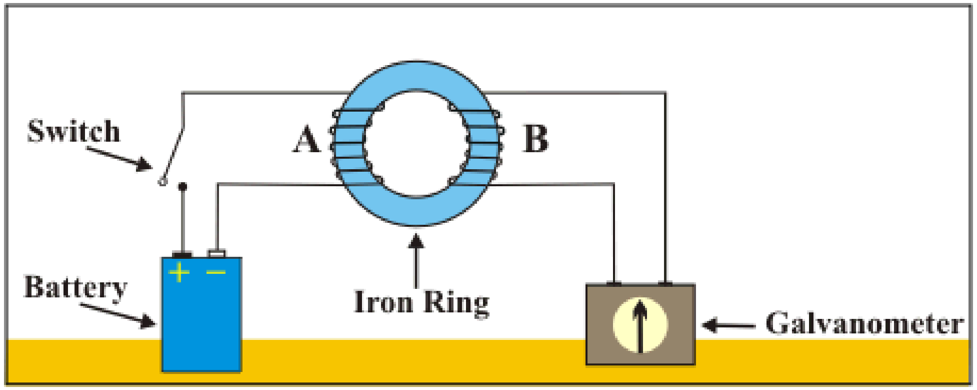
Pos. 5--the magnet is picking up speed as it comes out; the needle starts to move to the right (we will say the induced current is moving to the right--in the next lesson you will learn why).

Pos. 6--the magnet is moving at maximum speed; the current is maximum.

Pos. 7--the magnet begins to slow down; the current decreases.



Faraday's Iron Ring Apparatus



The operation of the iron ring is just an extension of the picture before where the magnet is moving in and out of the coil.

The primary coil has a current (of if you like, voltage) source, and the secondary coil does not. When the switch is closed a current begins to flow and in a split second reaches a certain maximum amount. In the short time that the current is "growing", a magnetic field will "bloom" or expand around the primary coil. The primary coil becomes, an electromagnet. As the primary field expands, its lines of force will cut through the turns of the secondary coil. According to Faraday's discovery, as the magnetic field cuts through the secondary coil, a current will be induced in the secondary coil and the galvanometer needle will move.

Remember a current is induced only as long as the magnetic field is changing, that takes only a split, split, split second for the current in the primary coil to reach some maximum reading. So, after the split second, the galvanometer drops back to zero.

Now when when the switch in the primary coil is opened, the current dies away and therefore the magnetic field collapses. The force lines are once again moving through the secondary coil, but in the opposite direction. A current will be induced again, but this time in the opposite direction. The galvanometer needle move opposite to the original deflection when the switch was closed. This deflection again lasts for the split second that it takes the current to drop to zero. After that, there is no field around the primary.

If the switch is repeatedly opened and closed, the galvanometer needle will indicate an alternating current, first one way, and then the other.

Summary

Oersted's principle: when a current passes through a straight conductor there will be a circular magnetic field around the conductor.

Michael Faraday discovered an exactly opposite phenomenon.

Faraday's Law: when a magnetic field moves near a conductor it makes any free charge in the conductor move. --that is, a changing magnetic field creates a current.

A magnetic field can change in two ways:

1. It can move physically. (i) if you move a bar magnet back and forth, then its magnetic field also moves back and forth and (ii) the magnetic field can remain stationary while the conductor itself is moved back and forth.
2. It can also change by having its intensity or strength increased or decreased. (ie. By changing the current through the coil).

Activity

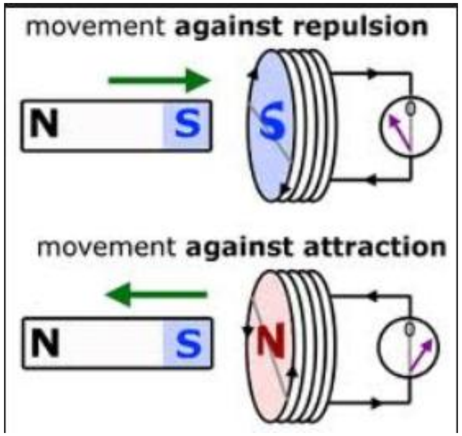
In your textbook:

p. 671--do #1-#3

p. 686--do #1--#3, #6, #9

Unit 3: Section 3 Electromagnetism

Topic 11: Lenz's Law



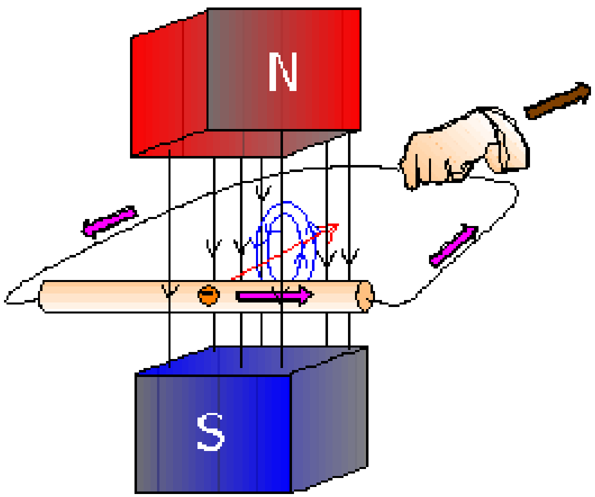
TEXT REFERENCE

Lenz's Law

The direction of the induced current creates an induced magnetic that opposes the motion of the inducing magnetic field.

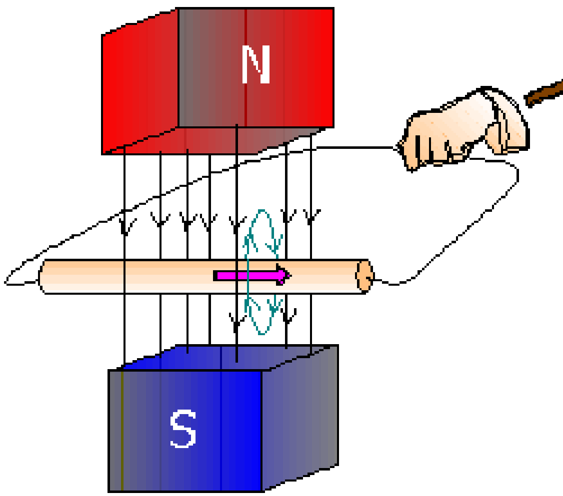
In the Picture the induced current causes a circular (green) magnetic field that interacts with the black permanent field. The side of the conductor away from you, the circular field and the permanent field are in the same direction (downward). Therefore these fields repel each other.

Picture from Lesson 09



This interaction of the black and blue fields means that the free electrons are forced to the right. That is, a current (pink arrow) has been induced by the motion

Picture for Lesson 10



The induced (pink) current now also induces another (green) magnetic field according to Oersted's Principle. Can you see that, on the side furthest from you, t green field and the black field are in the same direction (downward)and therefore repel eachother?

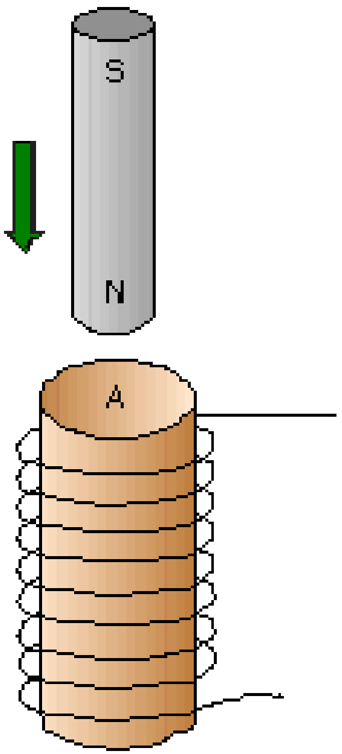
Even as the hand tries to pull the conductor through the permanent magnetic field, the induced magnetic field of the induced current is fighting the motion!
Heinrich Lenz put it this way:

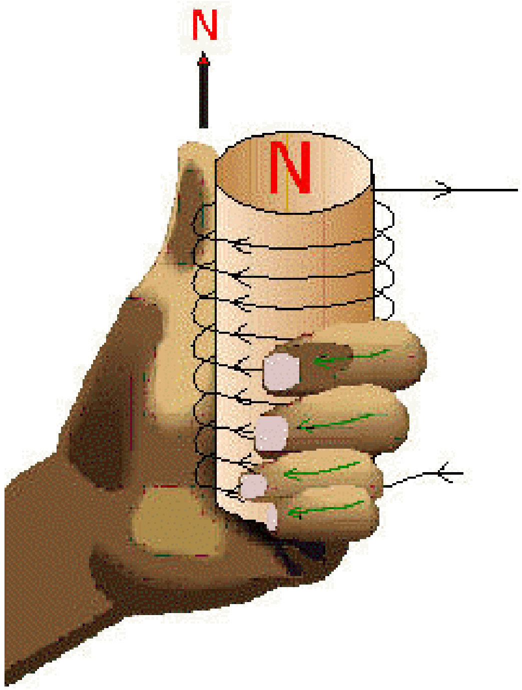
Example 1

The north pole of a bar magnet is being pushed into a coil as shown. Show the direction of the induced current in the coil.

Solution

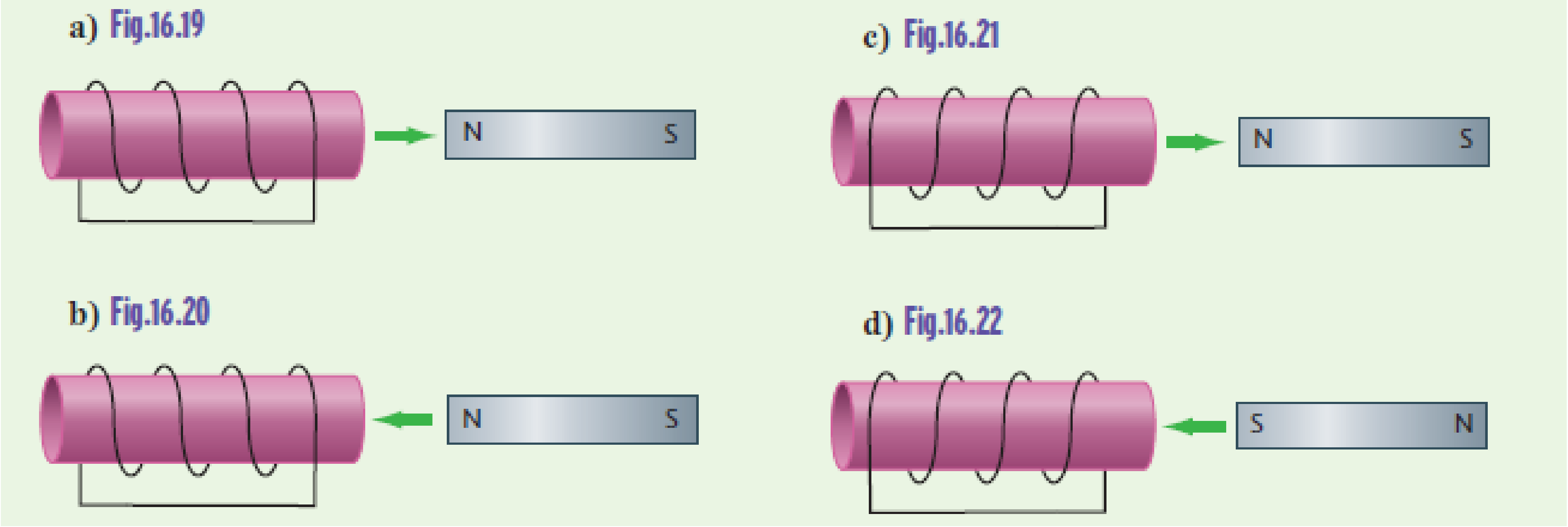
The induced current will cause a magnetic NORTH pole at position A. We know because of Lenz's Law. Now that we know the pole at end A is a N pole, just use left hand rule #2. That is, hold the coil in your left hand with your thumb pointing in the direction of the N pole and your fingers will curl in the direction of the current.





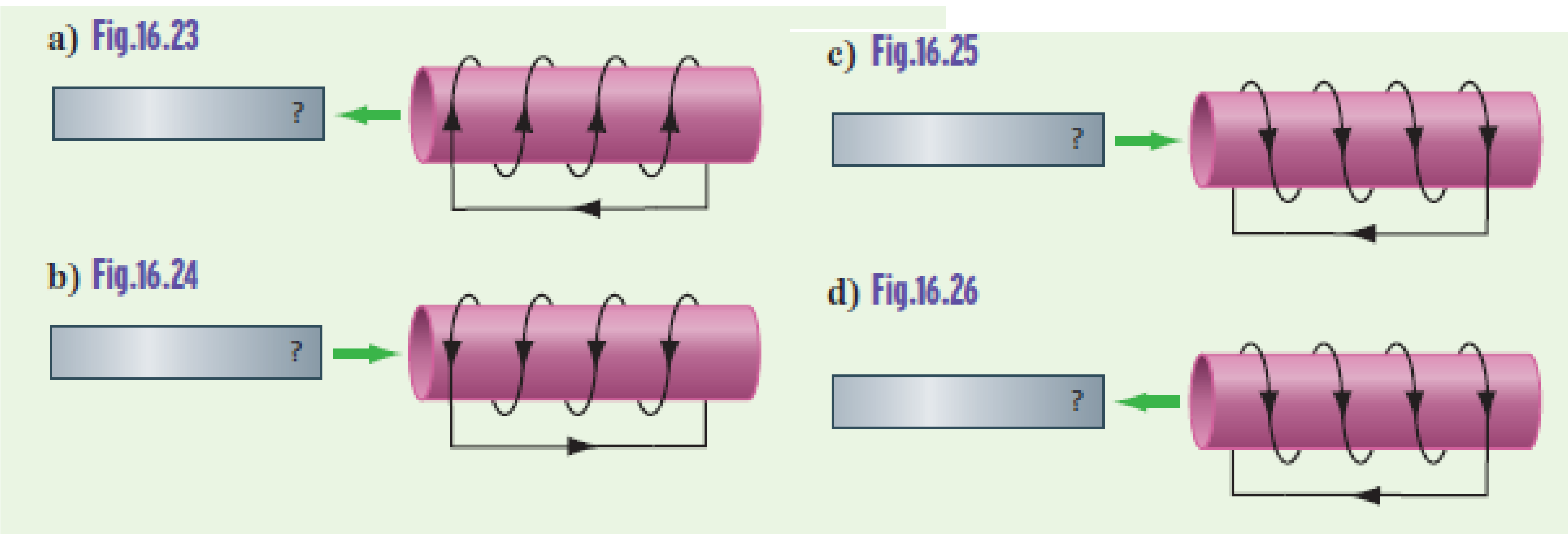
Example 2

Using Lenz's law and left hand rule #2 for solenoids (electromagnetic coils), predict the direction of the induced current flow by adding arrows to your diagrams. Add an N or S to represent the magnetic poles at each end of the coil.



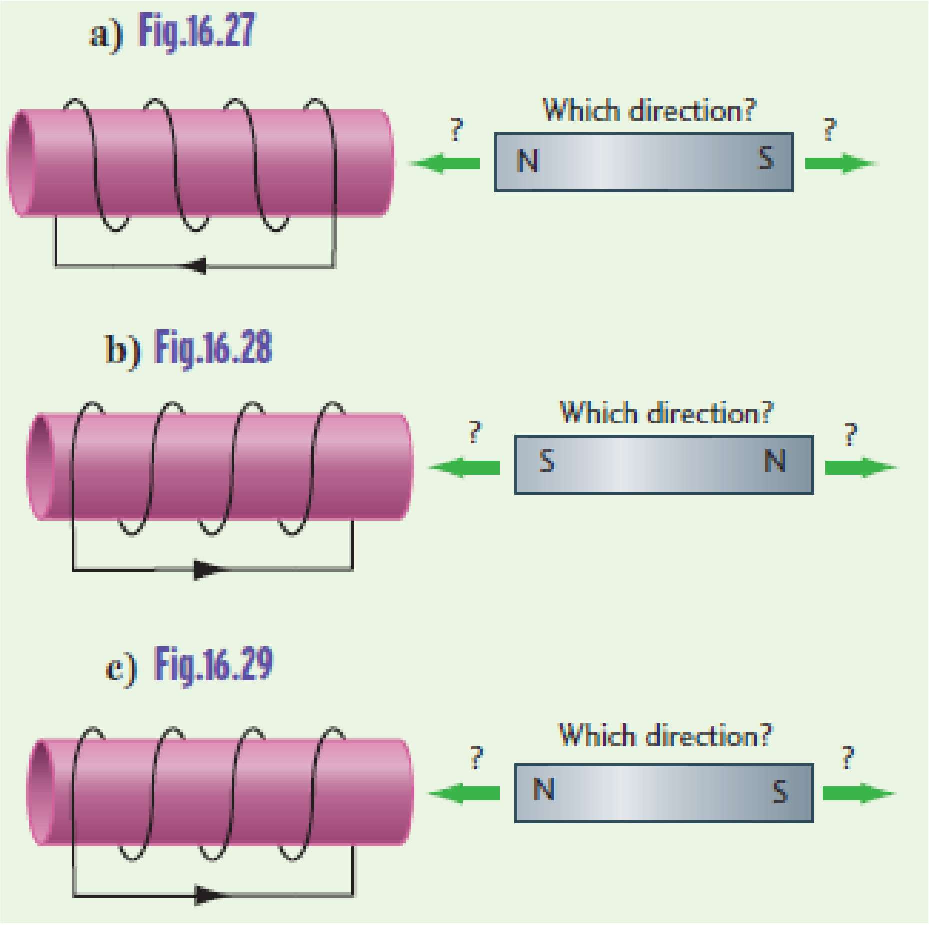
Example 3

Sketch each of the following diagrams into your notebook. Using Lenz's law and left hand rule #2 for solenoids, predict the polarity of the magnet that is being inserted or removed from the coils, as shown.



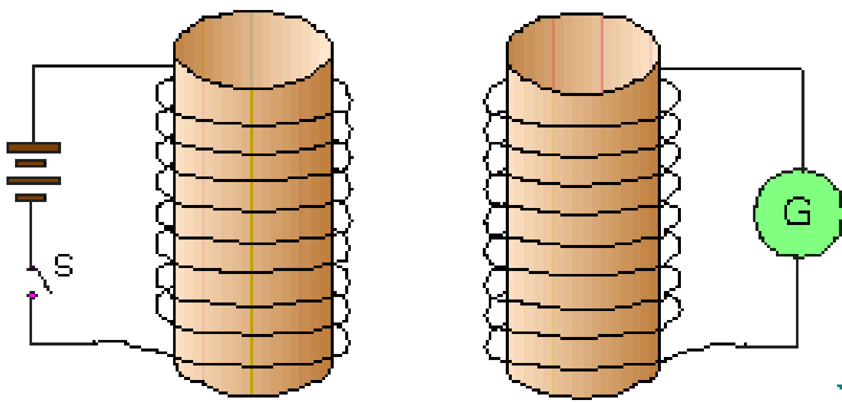
Example 4

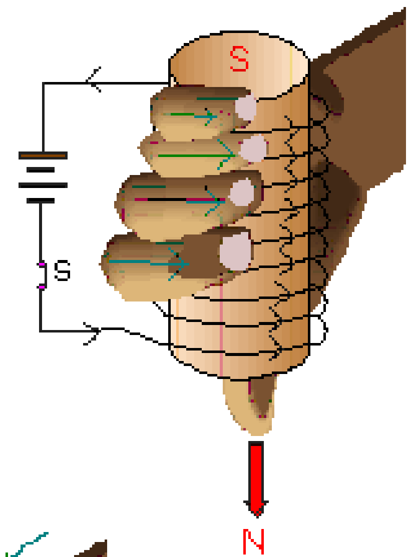
solenoids, predict the direction in which each magnet is being moved to produce the indicated current flow.

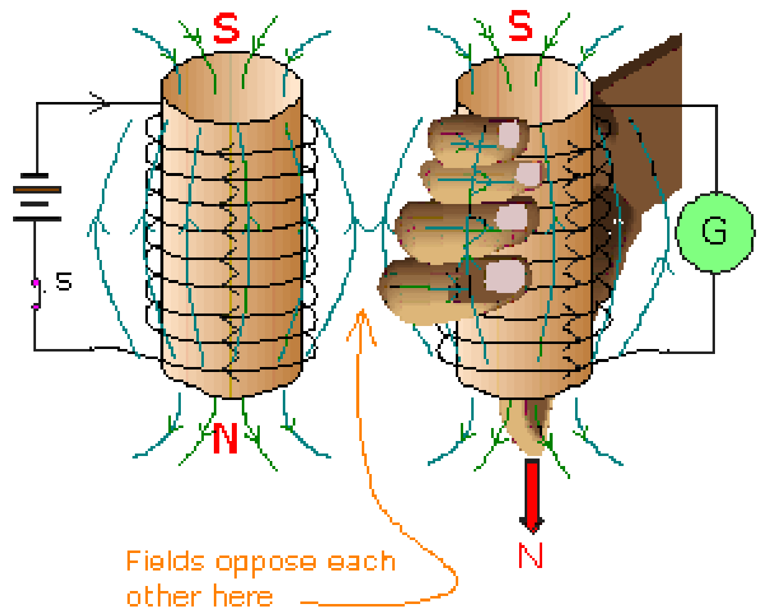


Practice exercise 2

The set-up in this exercise is similar to that of Faraday's iron ring (without the ring.). Determine the current direction in the secondary coil at the instant the the switch is closed in the primary coil.





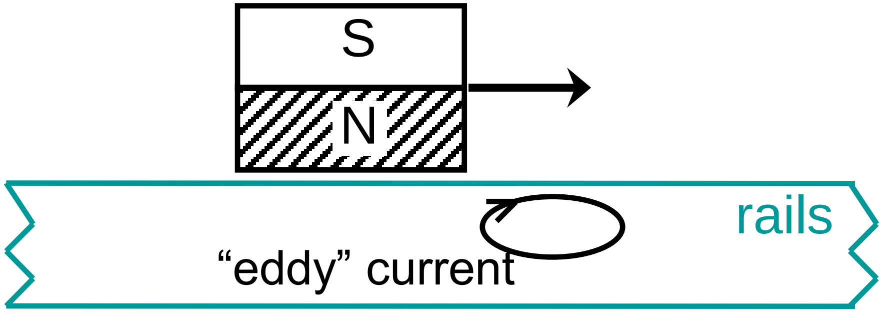


Applications of Magnetic Induction

- Magnetic Levitation (Maglev) Trains
- Induced surface ("eddy") currents produce field in opposite direction

→ Repels magnet

→ Levitates train



- Maglev trains today can travel

→ Twice the speed of Amtrak's fastest conventional train!

Activity

Work Sheet: Lenz' Law

Physics 3204

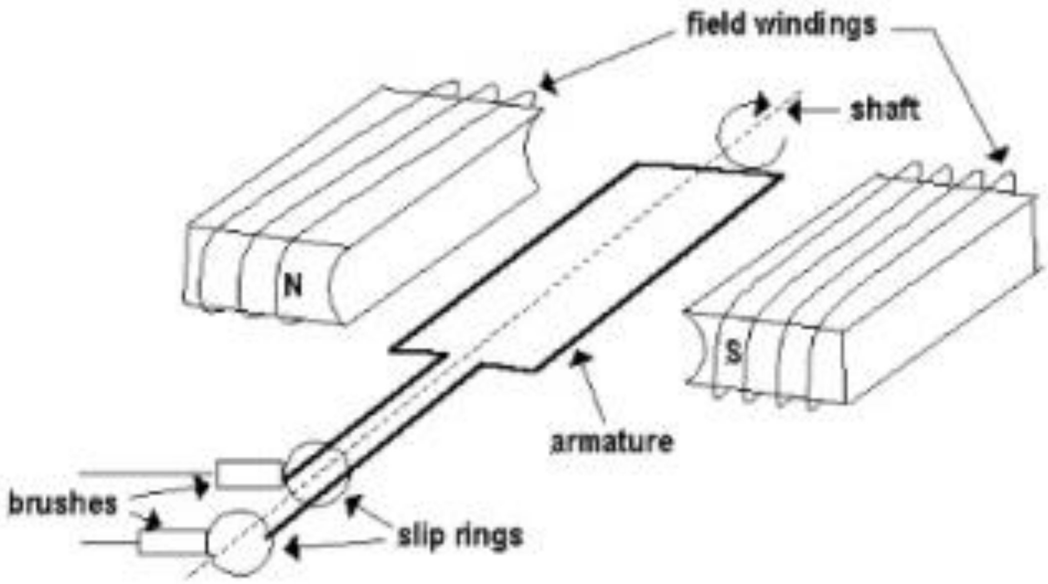
Unit 3: Section 3 Electromagnetism

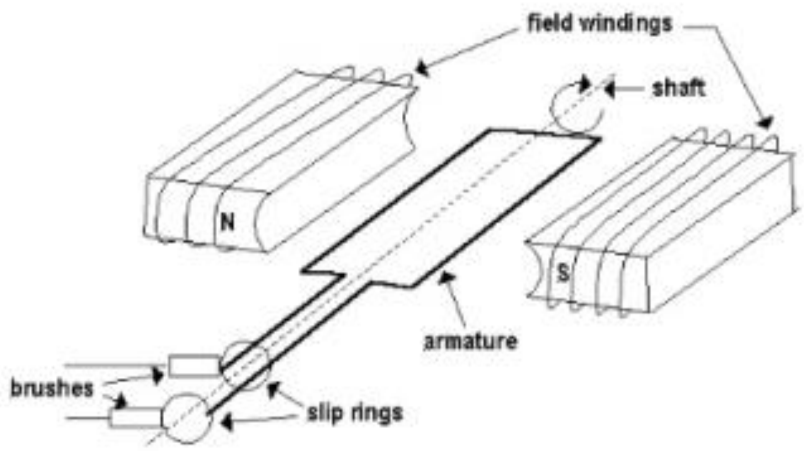
Topic 12 : AC/DC GENERATORS

TEXT REFERENCE

The AC Generator

Alternating Current Generators (AC): Electricity made by this type of generator is called alternating current, because it changes/alternates direction. AC generators produce an electric current via the motion of coils in a magnetic field or by rotating a magnet within a stationary coil





Armature – a coil wound around a metal core and mounted between the poles of an electromagnet.

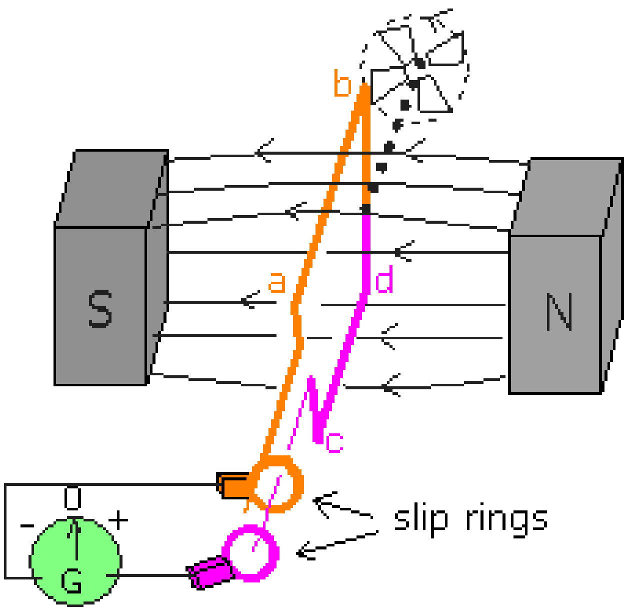
Electromagnet consisting of an iron core surrounded by a set of coi called the field windings. A steady current flows through these coils produce the required magnetic field.

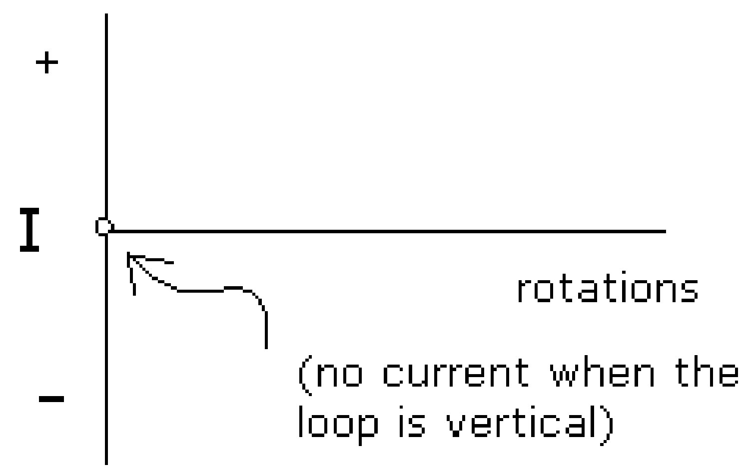
Slip rings – each end of the armature coil is connected to a metal ring. These rings are mounted on the armature shaft but are insulated from it and from each other.

Graphite brushes – these connect the slip rings to an external circuit and conduct the current induced in the armature coil to the external circuit.

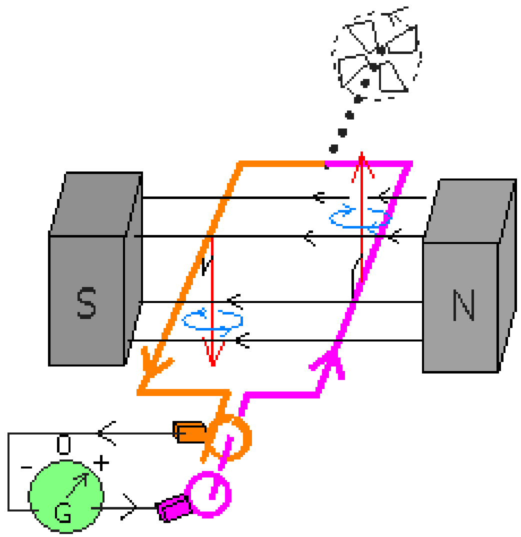
A very simple AC generator may be produced by passing a magnet in and out of a coil..producing an induced current. A more productive generator may be made by using rotary motion rather than back and forth motion and moving coil of wire while the magnet remains at rest.

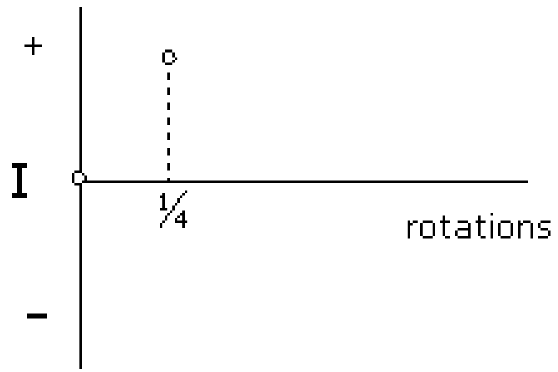
Position 1 While the loop is in the vertical position, ab and cd are not cutting any of the magnetic field lines. The sides of the loop are just moving parallel to the lines of force.





Position 2 One-quarter turn: cutting the magnetic lines in a maximum way. This makes the current maximum.





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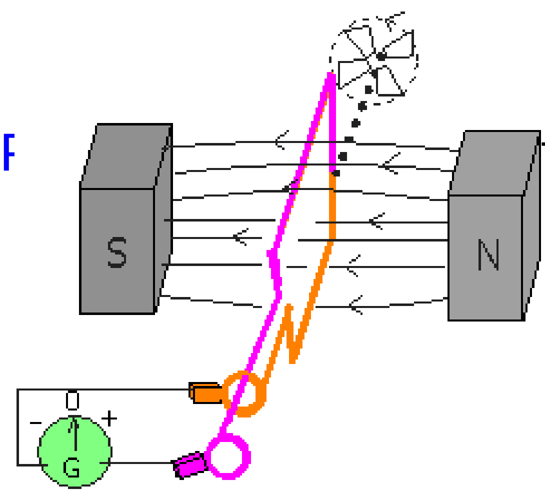
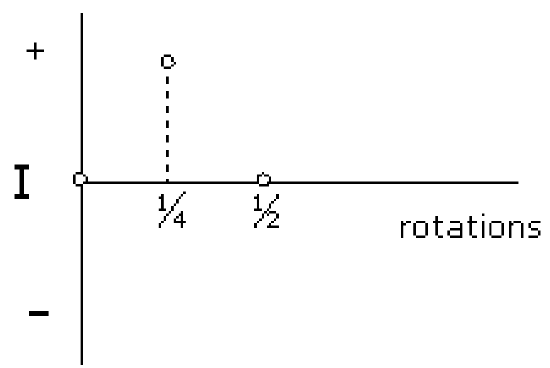
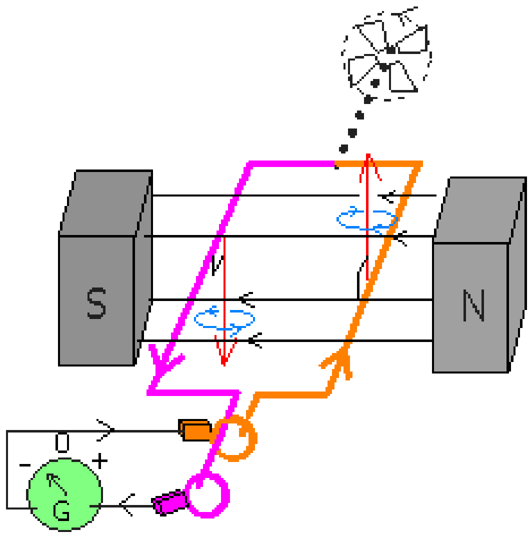
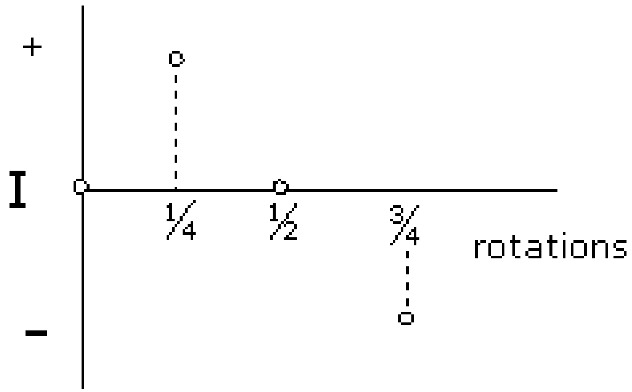


f a rotation



Position 4 Three-quarters of a rotation.

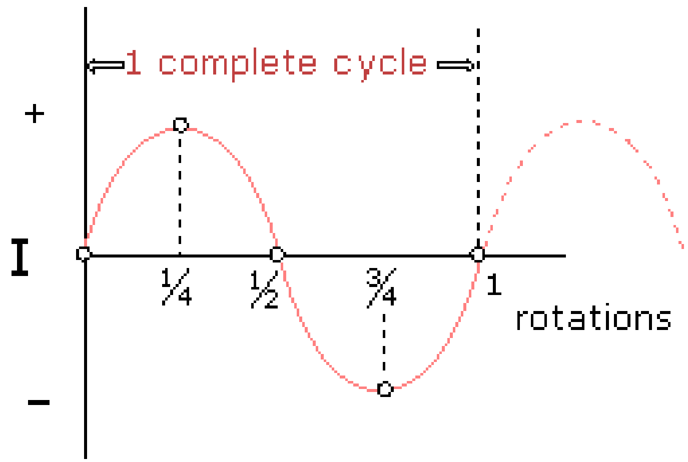




Now the pattern is clear. Here is a summing up:

As the loop rotates, there is an increase in the induced current from zero to the amount shown by the second point on the graph at 1/4 rotation. Next, as the loop approaches the second vertical position (1/2 revolution), the current gradually diminishes once again to zero.

Then the induced current increases once again to a second maximum as the loop continues to rotate and cut the magnetic lines more and more at the 3/4 rotation point. Now, however, the current is in the opposite direction.



In North America, generators turn at a controlled speed. ! Alternating current changes 120 times per second ! On a graph this current has a wave shape with 60 complete waves per second (or 60 Hz)

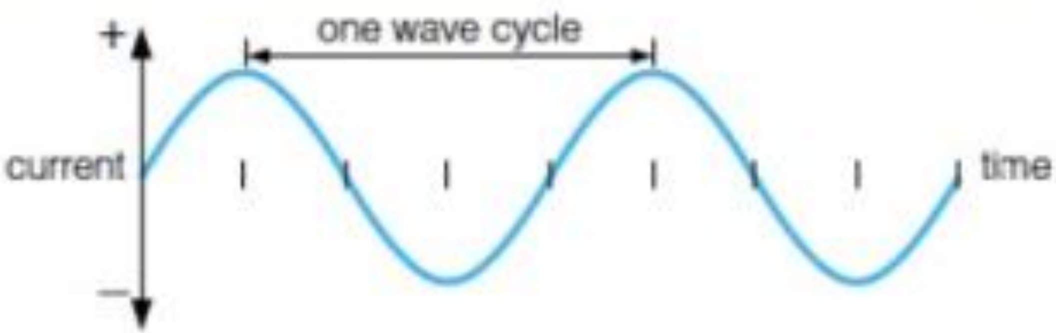
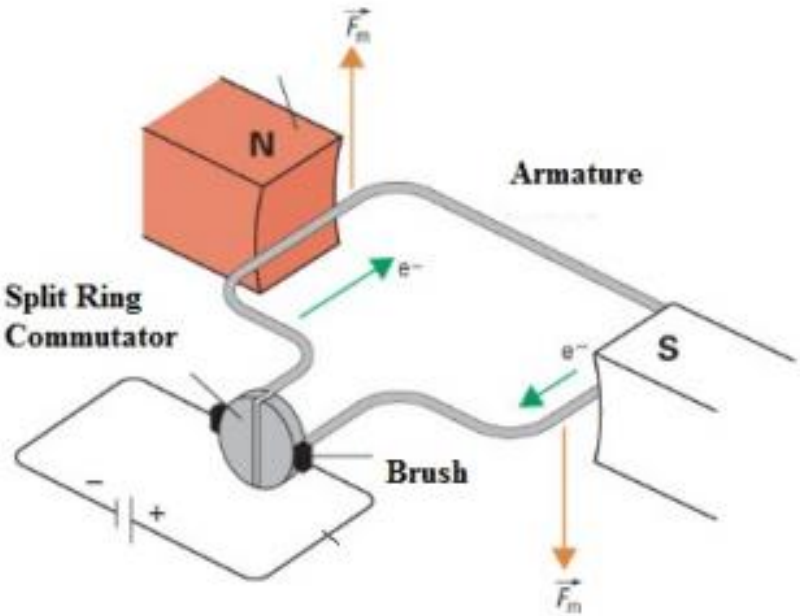


Figure 4.37 Current from an AC generator constantly varies in size and direction. Positive and negative values on the graph represent the opposite directions of the current flow.

The DC Generator

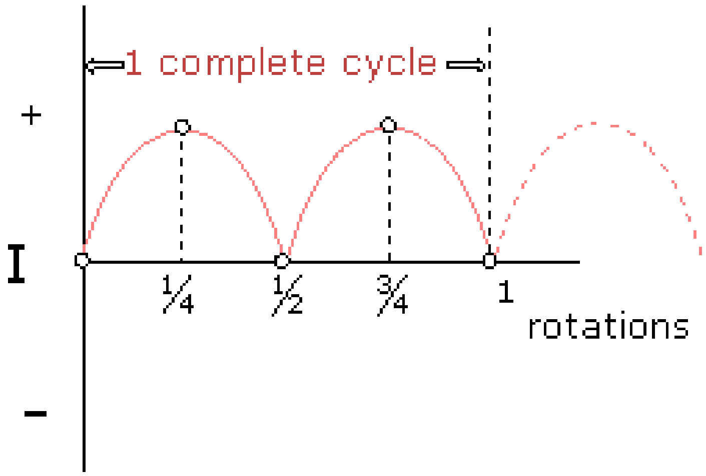
Direct Current (DC) Generators: current in only one direction. Made up of an armature (rotating loop of wire) that is connected to a circuit via split-ring commutator Generators that make direct current are often called dynamos. Device used on bike wheels to produce electricity for lights



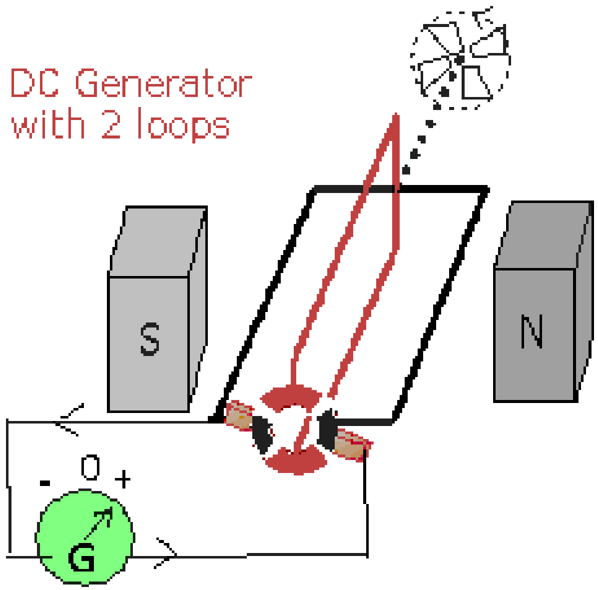
In the DC generator, the split half rings turn with the coil.

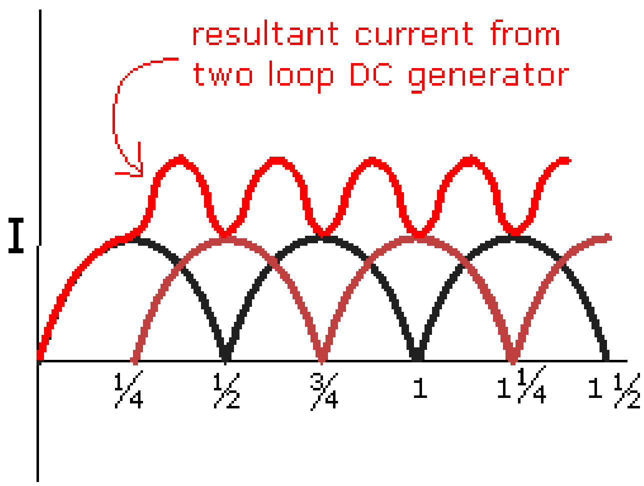
The current is always going the same way in the external circuit. The needle of the galvanometer fluctuates from 0 to the + end as the loop goes from the vertical position to either one of the horizontal positions. The current in the external circuit never reverses, even though it does reverse in the generator loops.

the current graph for a DC generator

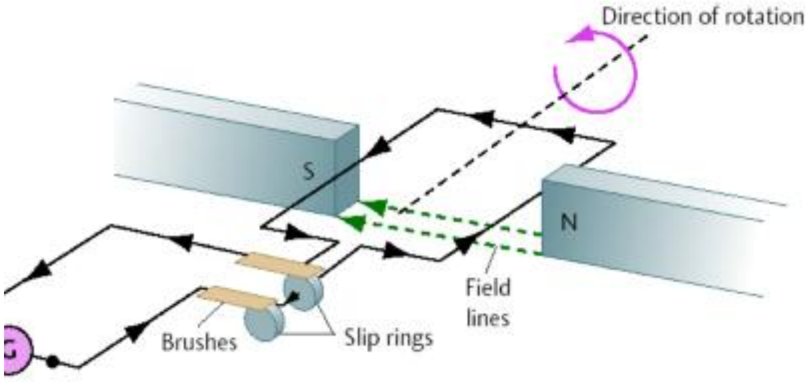


A real generator has many loops. Now look at a DC generator with two loops--one perpendicular to the other. Each loop has its own set of split rings. Notice just as the black loop loses contact with the brushes, the brown loop takes over. A plot of the current from a two-loop DC generator is shown.





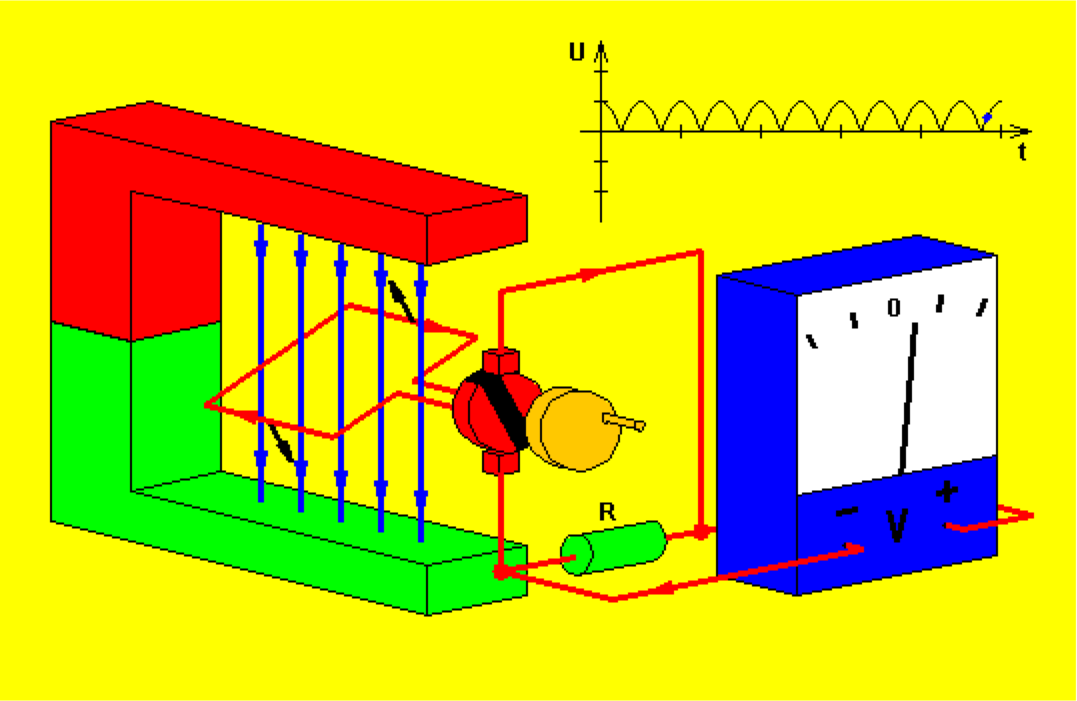
Electric Generators



HANDOUT

Generators

See applets in Applets Physics Web folder
(click on index first)



Activity

Assigned activities:

Worksheet Generators

Review for test:

- Your class notes

In your textbook:

section 5.2 "The Force of Gravity" pp. 158-159

section 5.3 "Factors affecting the force of gravity on an object" pp. 160-162

section 13.5 "Fields and field-mapping point charges" pp. 546-551

section 13.6 "Field strength" pp. 552- 556

section 15.1 "Magnetic force--another force at a distance" pp. 628

section 15.2 "Magnetic character--domain theory" pp. 629-630

section 15.3 "Mapping magnetic fields" pp. 630-632

section 15.4 "Artificial magnetic fields--electromagnetism" pp. 633-636