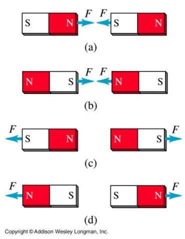
Electromagnetic

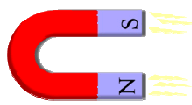
May 25, 2016 7:46 PM

Magnetic properties were discovered by the Greeks in a stone that they called magnetite. This stone would always align itself in the same direction when hung from a string. This was essentially the first compass.

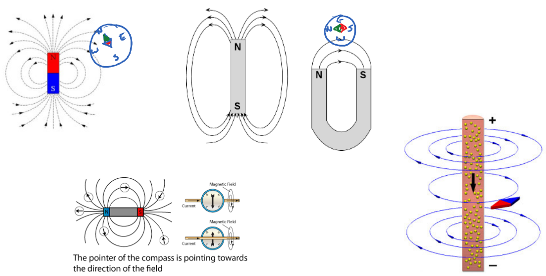
Magnets

- Always have two poles: North and South
- Like poles repel and opposite poles attract
- Only a few metals show magnetic properties: Iron, Cobalt, Nickel
- If a magnet is broken in half it, each half will have two poles. (You cannot have a single poled magnet)

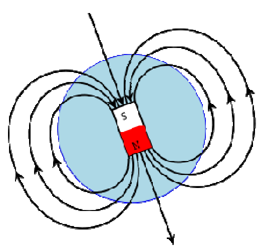


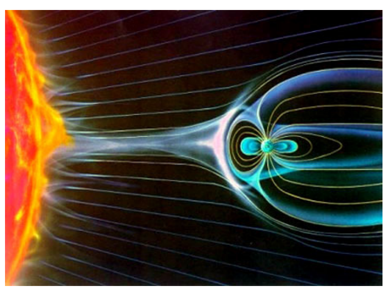


A magnetic field looks like an electric field, it comes out of the North pole and enters the South pole. It is an area where a force is exerted on an object that has magnetic properties. A compass needle POINTS in the direction of the magnetic field.



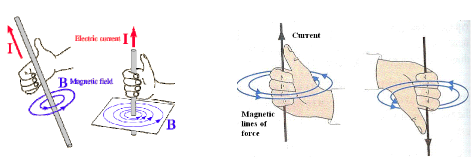
Our earth is protected by a magnetic field. This field helps block high energy particles that are emitted from the sun. Some of these particles are deflected away while others are filtered down to the earth at the poles. This is what causes the northern and southern lights.

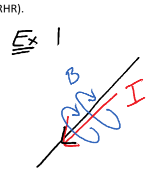




A magnetic field is a vector (also like an electric field) and the symbol is a capital $\vec{B}$.
The unit for magnetic field is a tesla (T)= $\left(\frac{N}{A\cdot m}\right)$ or gauss 1G= 10-4 T

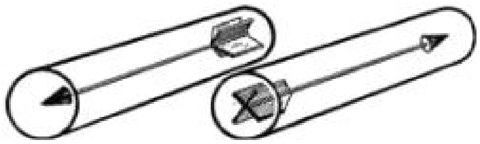
Direction and right hand rule
It was discovered that an electric current flowing in a wire creates a magnetic field (B). So a moving electron creates a magnetic field (B). Because magnetic fields (B) have direction, we use a method called the 'Right Hand Rule' (RHR).





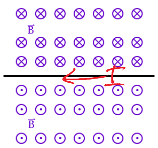
Right Hand Rule- to determine the direction of the magnetic field lines, grasp the wire with your RIGHT hand and use your thumb to point in the direction of the conventional current (from + to -). The direction your fingers are curled around the wire show the direction of the magnetic field.
(Remember that the RHR is used for conventional current. Use the 'Left Hand Rule' (LHR) for electron flow)

Notation
To represent drawings in 3-D, we use the notation :
• (the tip of an arrow) for coming out of the page.
× (the feathered end of an arrow) for going into the page.



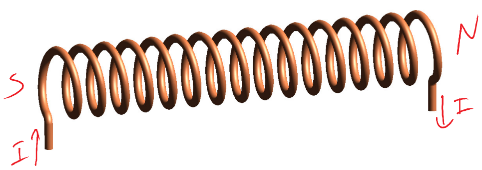
Examples

What direction is the current flowing in the wire?

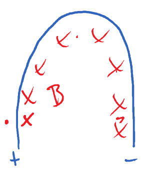


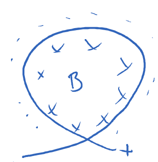
Solenoids

A solenoid is a wire that has been wrapped in a coil many times.



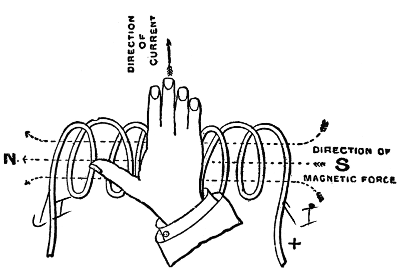
We use Solenoids to create uniform magnetic fields, in their core. Imagine wrapping your hand around the coil of wire like you would to find the magnetic field.





Right Hand Rule for Solenoids:

Wrap your fingers in the direction of the current. Your Thumb will point in the direction of the magnetic field.



Strength of Magnetic Field in a Solenoid

$$B = \frac{\mu_0 N I}{l}$$

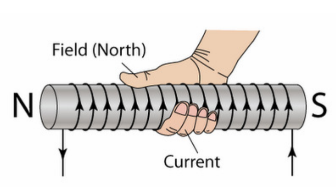
$\mu_0 = 4\pi \times 10^{-7}$ Tm/A

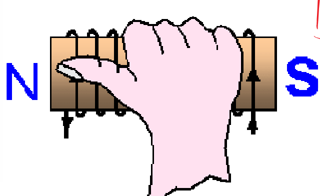
N = # of turns

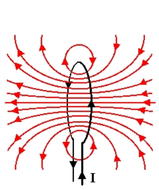
I = Current in the wire

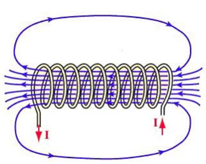
l = length of the Solenoid

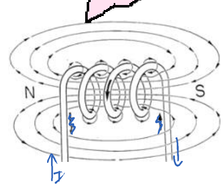
B = Magnetic Field (T)

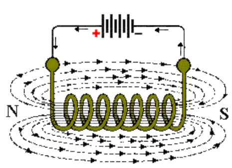




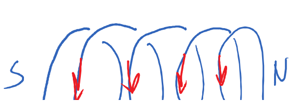


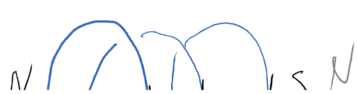


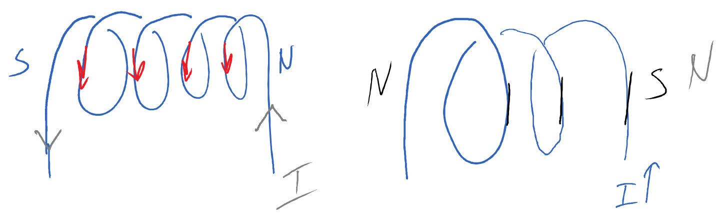


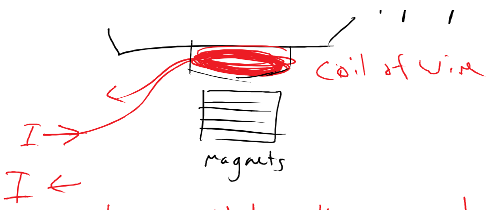


Example

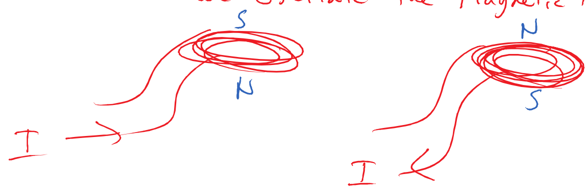






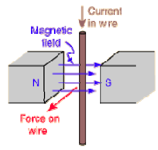


by oscilating the current direction
we oscilate the Magnetic Field direction



Forces involving magnetic Fields and Current

If we run a current through a wire that is already in an existing magnetic field, then the wire will create a new magnetic field that will interact with the existing one. This will create a force on the wire and cause it to accelerate.



The force depends on Current (I), length (l) of wire , and the magnetic field (B). The force also depends on the angle (θ) between the wire and the magnetic field (B). The force is strongest when the wire is perpendicular (90˚) to the field lines. There is no force exerted when the wire is running parallel to B.

$F=B \cdot I \cdot l \cdot \sin\theta$ (N) F_{max} when θ=90˚ because sin 90˚=1 and F=0 when θ=0˚

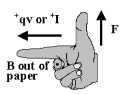
$$F = B_{\perp} \cdot I \cdot l \quad (N)$$

or $F = B \cdot I \cdot l_{\perp}$

B : Magnetic Field
I: Current
l: length in the Field
⊥ : means perpindicular Component

Right Hand Rule: Forces

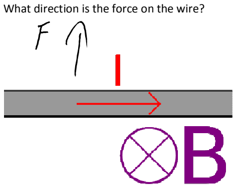
In order to determine the direction of this force we need to use YET another Right Hand Rule.



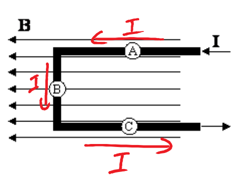
Your thumb points in the direction of the Force, your index finger points in the direction of the current or flow of positive charge, and your middle finger points in the direction of the magnetic field.

Example

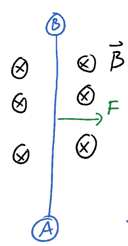
What direction is the force on the wire?



What direction is the force on the wire at points A,B, and C?



Line B: F into the page ⊗
Line A & C : No Force because I and B are parallel

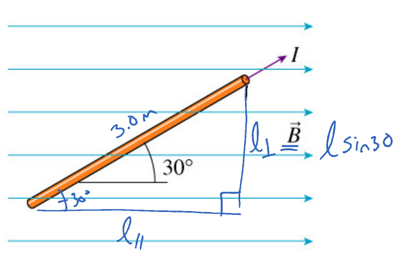


I runs from B → A

What is the magnitude of the force on the wire?

Question Details

A uniform 2.5 T magnetic field pointsto the right. A 3.0-m-long wire, carrying 15 A, is placed at an angleof 30° to the field, as shown in thefigure.



B) What is the direction of the force on the wire?

Ex

$F = B I l_{\perp}$

$F = B I l \sin 30$

$= (2.5)(15)(3) \sin 30$

$= 56.25$ N into the page

Charged Particles Moving in a Magnetic Field

Current is just charged particles moving through a wire, so we can adapt our formula above to find the force acting on a charged particle moving through a magnetic field.

From F=IlB and I=Q/t becomes F=QlB/t and v=l/t this then becomes

$$F = Q \cdot v_{\perp} \cdot \vec{B} \quad (N)$$

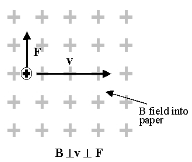
Q: charge
$V_{\perp}$: velocity of the particle } Must be perpendicular

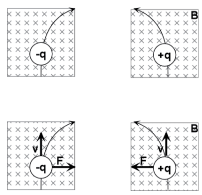
From F=IℓB and I=Q/t becomes F=QℓB/t and v=ℓ/t this then becomes

$$F = Q \cdot v_{\perp} \cdot \vec{B} \quad (N)$$

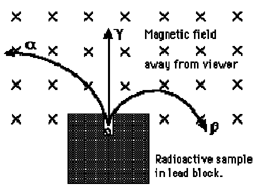
Q: charge
$V_{\perp}$: Velocity of the particle } must be perpendicular
B: Magnetic field

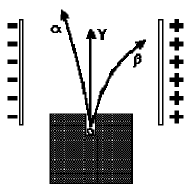
For a + charge (proton or alpha particle), the RHR works (like conventional current) but for a - charge (electron or beta particle or muon) use the LHR.





right hand for (+)
Left hand for (−)





α are positive
β are negative
γ no charge

Combining Magnetic Force with Circular Motion

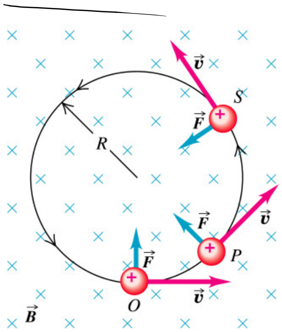
A charged particle moving through a magnetic field will experience a force acting perpendicular to the particles velocity. This is exactly what happens in circular motion. This means that the path of the charged particle will be a circle.

We can derive from our circular motion formulas the following:

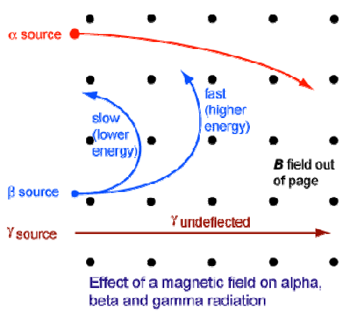
$$F = QvB \text{ and } F = \frac{mv^2}{r} \text{ so } QvB = \frac{mv^2}{r} \text{ then}$$

$$r = \frac{mv}{QB} \text{ or } r = \frac{p}{QB}$$

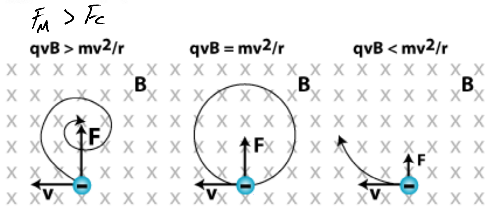
$$KE = \frac{1}{2}mv^2 = \frac{p^2}{2m}$$



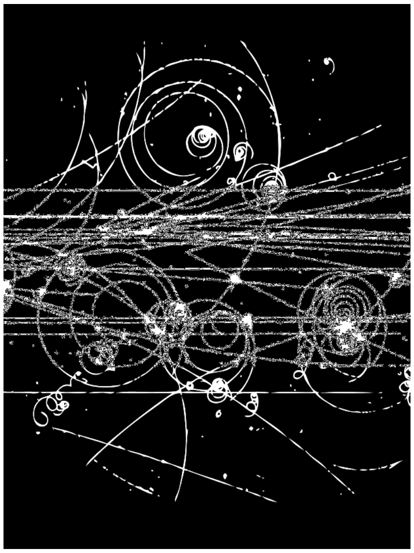
(a)



$F_M > F_c$



This understanding of how charged particles curved was used for the longest time in particle physics. Scientists would analyze the paths of particles after a collision and from looking at the path, they could determine the energy level of the particle, the charge, the mass, and ultimately what the particle was.

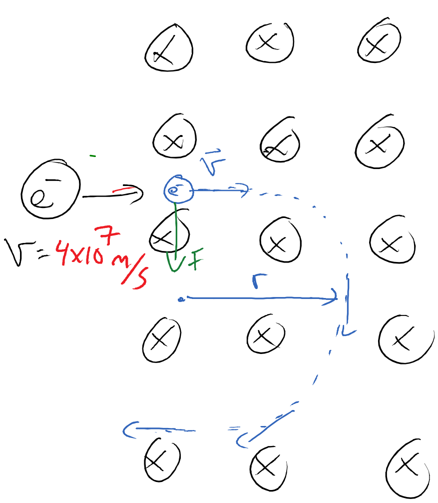


Bubble Chamber Picture of the paths of various, high energy particles.

TEST Wednesday

$B = 2500\ T$

Find r



$F = QvB$

Circular

$F_{Net} = \frac{mv^2}{r}$

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

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

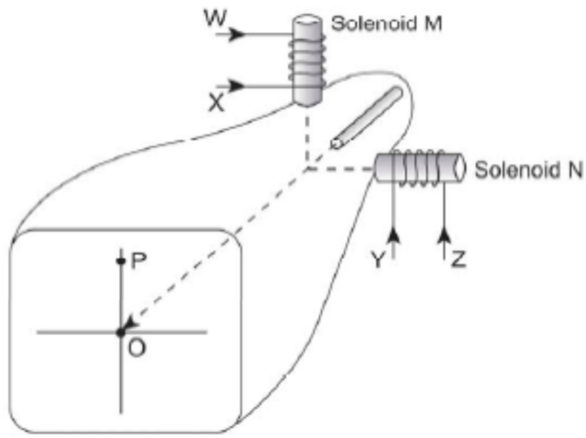
$= \frac{(9.11\times10^{-31})(4\times10^{7})}{(1.602\times10^{-19})(2500)}$

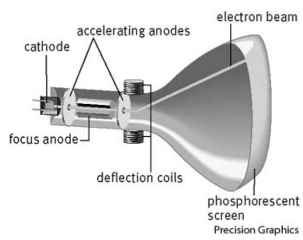
$r = 9.1\times10^{-8}\ m$

This formula is not given to you on the formula sheet but is used on every exam. It is important so know it or how to get to it.
Your RHR (+ charge) or LHR (- charge) will determine a clockwise or counterclockwise direction of curvature for the moving charge.

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

Applying the principles of electromagnetism to qualitatively explain the operation of a cathode ray tube.

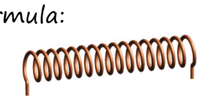




We know that when current is run through a solenoid, a magnetic field is produced. This is dependent upon the number of loops of wire, the length of the solenoid and the amount of current passing through the wire.

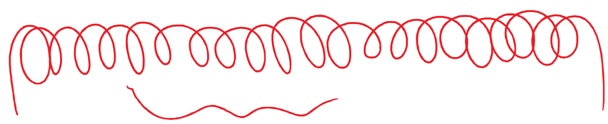
We can determine the strength of a magnetic field produced in a solenoid from the formula:

$$B = \mu_0 \left(\frac{N}{l}\right) I$$

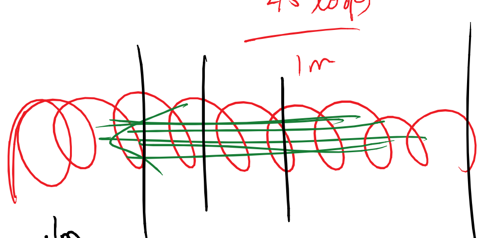


$$B = \mu_0 n I$$

where the constant $\mu_0 = 4 \cdot \pi \cdot \times 10^{-7}$ (unit T·m/A)[this is called the permittivity of free space], N = number of loops, l = length of the solenoid (m), I = current (A), and B = magnetic field (T)



45 loops / 1m



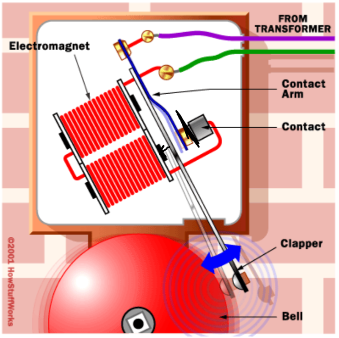
.1m

Example: A thin 10cm long solenoid has a total of 400 turns of wire and carries a current of 2.0A. What is the magnetic field?

Solution: 1.0×10^{-2} T

$B = \mu \frac{N}{l} I = 4 \times \pi \times 1 \times 10^{-7} \times 400 \times 2 = .01\ T$

Examples of practical uses for solenoids in the home and workplace:
Anything we want to move with current. Doorbells, electromagnets, speakers, switches, fire alarms (which is just a large doorbell)



Old Book	New Book
Pg 392 Q1-4 (Solenoids)	Pg 345 Q1-4
Pg 399 Q1-12 (Forces on Wire)	Pg 352 Q1-12
Pg 407 Q1-15 (Forces on Particles)	Pg 360 Q1-15