Electromagnetism #1 Name: ________________________

ELECTRIC CHARGE

We cannot say what electric charge is – we can only describe its properties and behaviour.

Experiments show that there are exactly two kinds of electric charge – these are called positive and negative respectively. Two positive or two negative charges repel each other. A positive charge and a negative charge attract each other.

Charge is always:

Cannot be created or destroyed, but it can be transferred from one object to another	Always exists as some integral multiple of a fundamental amount of charge **e** (the charge on an electron)

1 electron has a charge of:

Objects are generally electrically neutral –

But the outermost electrons of atoms are only loosely bound (particularly in metals) and can easily be added or removed from objects.

-
-

When we say the charge of a body – we really mean:

(which is only ever a very small fraction ($\approx 10^{-12}$) of the total positive or negative charge of the body).

Conductors –

Insulators –

Semiconductors –

Electromagnetism #1

COULOMB'S LAW

The magnitude of the electric force between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.

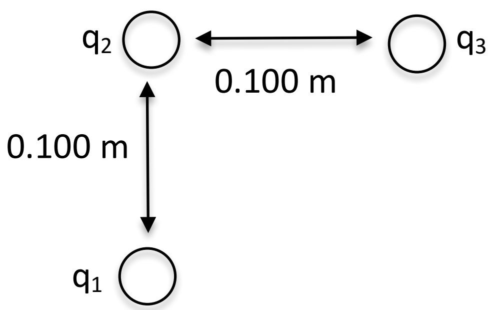
The directions of the forces exerted by the charges on each other are always along the line joining them.

If the charges have the same sign (i.e. the answer is positive):

If the charges have opposite signs (i.e. the answer is negative):

1. Find the electrical force between the electron and proton in a Hydrogen atom. The electron and proton are separated by a distance of 5.30×10^{-11} m.

2. Find the force on the charge q_3. $q_1 = q_3 = 5.00\ \mu C$ $q_2 = -2.00\ \mu C$



COULOMB'S LAW PROBLEMS

1. Calculate the electrostatic force between charges of +2.00 C and +5.00 C separated by a distance of 75.0 m in a vacuum.

[1.60×10^{7} N repulsion]

2. Two charges of +8.00 mC and -6.00 mC attract each other with a force of 3.00×10^{3} N in a vacuum. Calculate the distance between the charges.

[12.0 m]

3. Calculate what charge will repel a charge of +6.40 μC with a force of 2.70×10^{-1} N when they are separated by 0.840 m in air.

[$+3.31 \times 10^{-6}$ C]

4. Determine what happens to the force between two charged metal spheres in a vacuum if the charge on each is doubled and the distance between them multiplied by three.

[4/9 original value]

5. A metal sphere of mass 6.00×10^{-3} kg is found to just float in air above a similar metal sphere when both have a charge of 4.00 μC. Assuming that the only upwards force is electrostatic repulsion, calculate the distance between the spheres.

[1.56 m]

Electromagnetism #1

ELECTRIC FIELDS AND ELECTRIC FORCES

The electric field is a region of influence that surrounds a charged particle. Any other charged particle that enters this region of influence will ‘feel’ a force.

The electric force on a charged body is exerted by the electric field created by *other* charged bodies

The direction of an electric field at any point is:

Field Lines

Electric field lines are helpful in visualising electric fields.

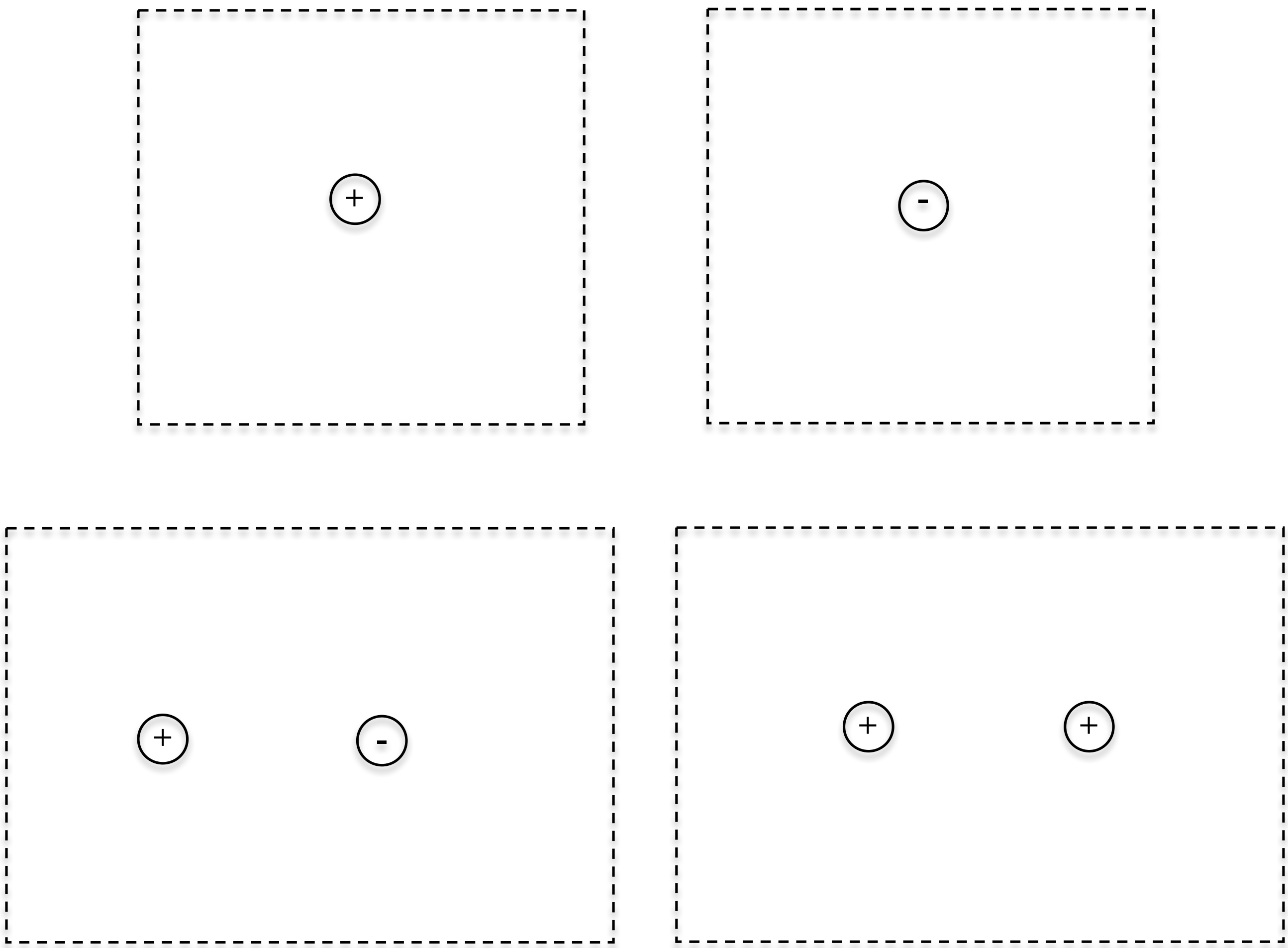
1.

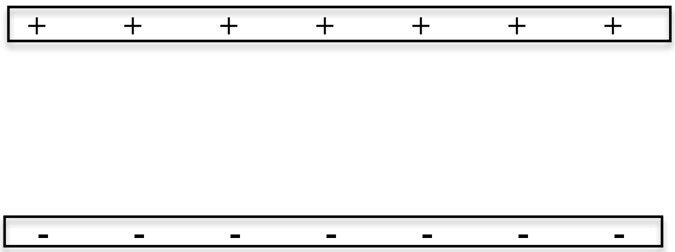
2.

3.

4.

5.





Electric Field Strength

The electric field strength (E) at a point is defined as the force exerted by the field on a unit charge placed at that point divided by the charge.

1. A charge of 7.00 C placed in an electric field experiences a force of 8.40×10^2 N. What is the electric field intensity?

2. A charge of 2.00 mC is at a point P in an electric field. It requires a force of 0.0200 N to stop it moving along a line of force. What is the electric field intensity at that point?

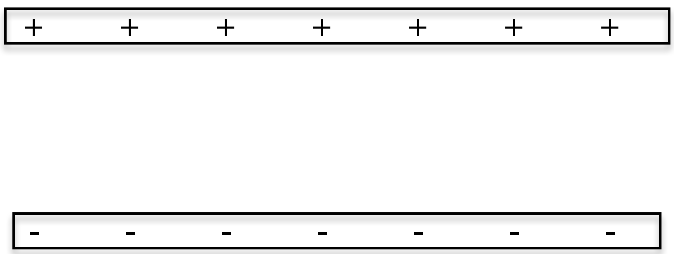
ELECTRICAL POTENTIAL DIFFERENCE

The potential difference between two points in an electric field is equal to the work done in moving a unit positive charge from the point at the lower potential (more negative) to that at the higher potential (more positive).

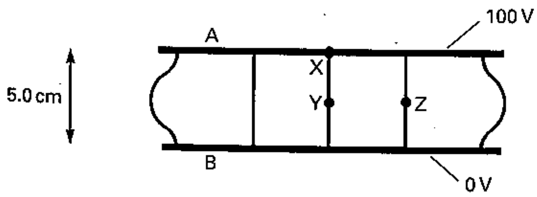
The more common term for potential difference is:

If the work done in causing one coulomb of electric charge to flow between two points is one joule, then the potential difference between the points is one volt. $1\ V = 1\ JC^{-1}$

The electric field between oppositely charged plates is uniform. If the voltage between the plates is V and the distance between them d, the strength of the uniform electric field is given by:



1. The diagram below shows the electric field lines between two parallel metal plates. Express all answers to 3 significant figures.



(a) What is the field strength at X?

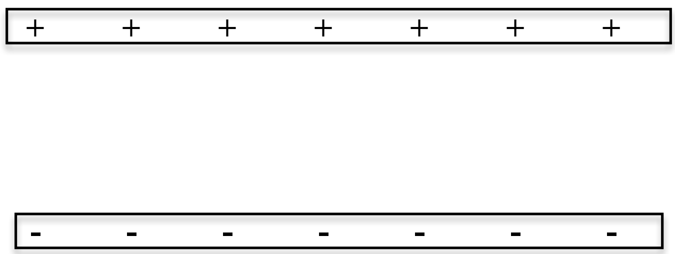
(b) What is the field strength at Y?

(c) Calculate the work done against the electric field on moving an electron from X to Y.

(d) Calculate the work done against the electric field on moving an electron from Y to Z.

(e) Calculate the force exerted on a charge of 2.00 μC placed at Y.

2. Two parallel metal plates are separated by a distance of 5.00 mm. If the voltage between the plates is 2.00×10^2 V and the top plate is positive, find:



(a) The force on a charge of +1.50 μC placed midway between the plates.

[6.00×10^{-2} N downwards]

(b) The kinetic energy gained by (i.e. the work done on) the charge when it moves to the negative plate from its position in (a).

[1.50×10^{-4} J]

Electromagnetism #1

MOTION OF CHARGED PARTICLES IN UNIFORM ELECTRIC FIELDS

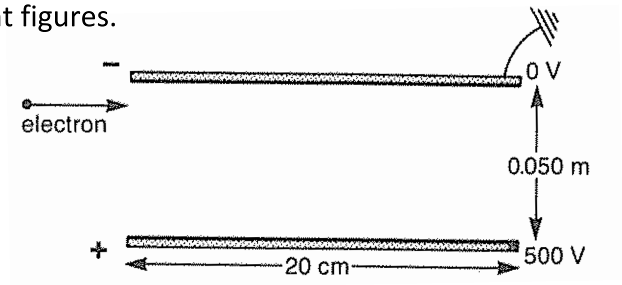
Remember: An object will only experience a change in its speed if the force exerted (or a component of the force exerted) is in the direction of motion (or in the opposite direction to the motion).

Example:

1. An electron is fired from an electron gun which accelerates the electron from rest by an accelerating potential of 2.91 kV.

(a) What is the electron's speed as it leaves the gun?

The electron gun fires the electron into a uniform field near the top plate as shown in the diagram below. Assume any contributions due to the Earth's gravitational field can be ignored. Take all values given in the diagram to be 3 significant figures.



(b) How long does it take the electron to traverse the length of the plates?

(c) How far has the electron been deviated from its straight line path when it leaves the uniform field?

Questions

1. Calculate the force between two point charges of 1.00×10^{-10} C and 1.00×10^{-12} C with centres separated by 10.0 cm in water.
(permittivity of water = 80.0 ε_0)

[1.12×10^{-12} N repulsion]

2. Two small pith balls carry charges of +3.00 nC and -12.0 nC respectively and their centres are 3.00 cm apart.

(a) Calculate the force between the charges.

[3.60×10^{-4} N attraction]

The balls are now touched together and then separated by 3.00 cm again.

(b) Calculate the force between the charges now. (Hint – the net charge will be spread equally over the spheres).

[2.02×10^{-4} N repulsion]

3. Two very small metal-coated foam spheres, each of mass 2.80×10^{-6} kg are attached to nylon threads 45.0 cm long and hung from a common point. When the spheres are given equal quantities of negative charge, each supporting thread makes an angle of 15.0° with the vertical. Calculate the charge on each sphere.

[-6.66×10^{-9} C]

4. If 98.0 J of work is done in shifting 7.00 C between two charged parallel plates, what is the potential difference between the plates?

[14.0 V]

5. The electric field strength inside a television picture tube is about $8.00 \times 10^{3}\ NC^{-1}$. What is the magnitude of the force on an electron in this field?

[1.28×10^{-15} N]

6. What power is involved in shifting 1.00×10^{-4} C across a gap of potential difference 2.00 kV in 0.0400 s?

[5.00 W]

7. Two parallel conducting plates have a uniform electric field of strength $1.60 \times 10^{2}\ NC^{-1}$ between them. Calculate the acceleration of a proton placed at the positive plate.

[$1.53 \times 10^{10}\ ms^{-2}$ towards the plate of lower potential]

8. Two parallel plate electrodes are separated by 20.0 cm and have a potential difference of 32.0 kV. An electron with an energy of 1.00 x 10^{-16} J, accelerates from the negative electrode to the positive electrode. Determine;

(a) The energy of the electron as it strikes the positive electrode.

[5.22 x 10^{-15} J]

(b) The electric field strength between the electrodes.

[1.60 x 10^{5} NC^{-1}]

(c) The force on the electron whilst between the electrodes

[2.56 x 10^{-14} N towards the positive plate]

(d) The acceleration of the electron.

[2.81 x 10^{16} ms^{-2} towards the positive plate]

9. An alpha particle travelling at 1.00×10^{6} ms^{-1} enters a uniform electric field of strength 160.0 kVm^{-1} at right angles to the field. The alpha particle has a charge twice that of a proton and it is found to take 1.00×10^{-7} s to cross the field. Given the mass of the alpha particle is 6.64×10^{-27} kg, determine;

(a) The length of the plates that produce the field.

[0.100 m]

(b) The acceleration of the alpha particle

[7.71×10^{12} ms^{-2} towards the negative plate]

(c) The velocity of the alpha particle as it leaves the field (Hint – consider the components of the velocity parallel and perpendicular to the field)

[1.26×10^{6} ms^{-1} at 37.6° from its original path towards the negative plate]

MAGNETIC MATERIALS

Basic Properties of Magnets:

1.

2.

3.

Microscopic View of Magnetism:

- All magnetic materials are magnetic because of the electrons in them.
- A moving electron will have a magnetic field associated with it - this is called a magnetic moment.
- The magnetic moment of each atom combines with those of all the other atoms in the material to give:

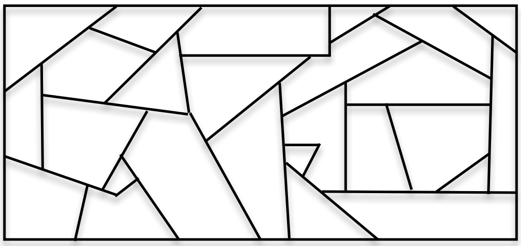
Ferromagnetic Materials

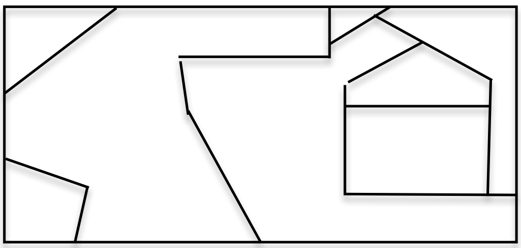
Electromagnetism #1

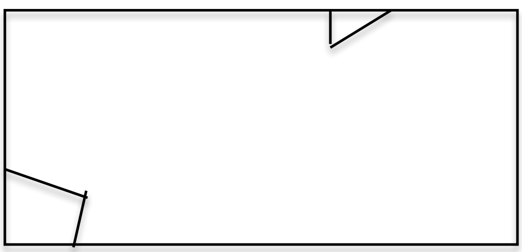
The Domain Theory of Magnetism:

- A domain is a small region of spontaneous magnetism that exists even when no external magnetic field is present.

- All magnetic moments will be aligned within a domain.







If we remove the external magnetic field, a ferromagnetic material will generally retain its magnetic field unless…….

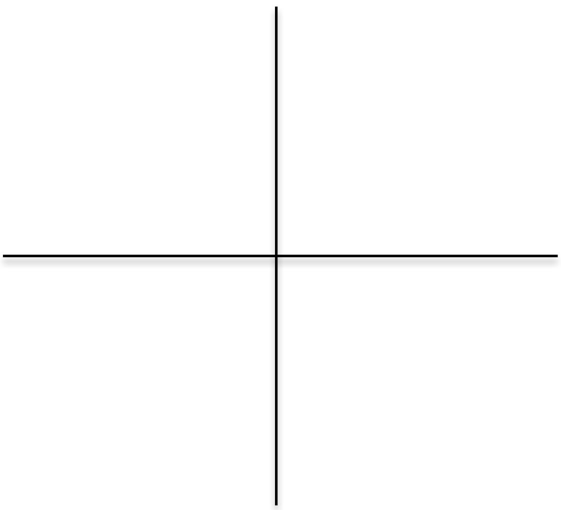
1.

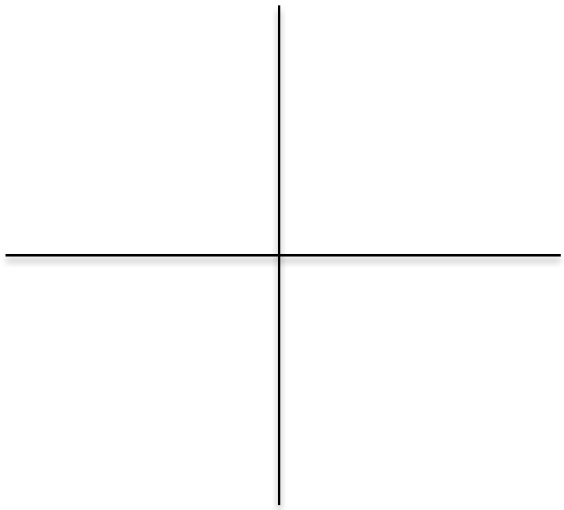
2.

3.

Hysteresis Loops:

- The area in between the hysteresis loop is equal to the amount of energy required to change the direction of magnetisation of the magnet (take it through one complete cycle).





Paramagnetic Materials

Diamagnetic Materials

MAGNETISM AND MAGNETIC FIELDS

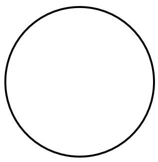
All magnets have two poles which are impossible to separate (there are no magnetic monopoles – unlike electric charges where we can have individual positive and negative charges).

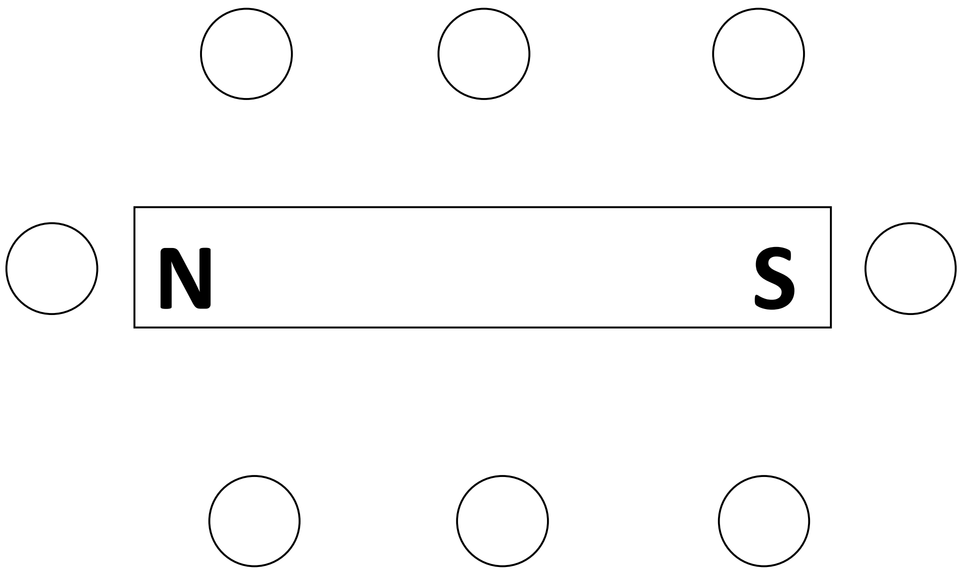
Magnetic Field

- The magnetic field is a region of influence that surrounds a magnetic material. Any other magnetic material that enters this region of influence will 'feel' a force.

Magnetic Field Lines

1. A magnetic field acts at a distance.
2. Direction:
3. The strength of the field is proportional to the density (closeness) of the lines).
4. The lines must never cross.



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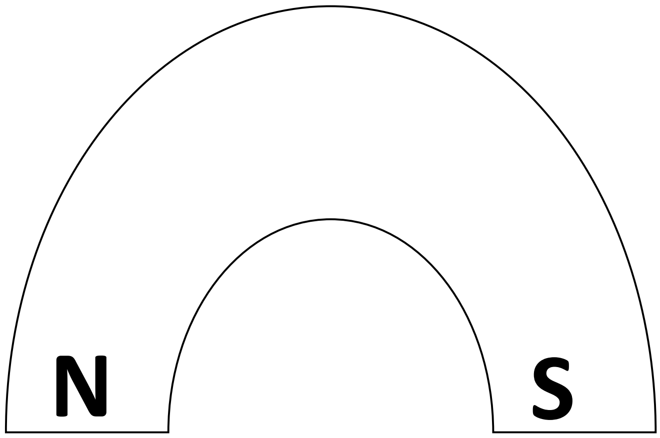
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MAGNETIC FIELDS DUE TO CHARGE CARRYING CONDUCTORS

A moving charged particle produces a magnetic field – as we have seen it is the individual magnetic moments of the (unpaired) electrons in a material that align to produce magnetism.

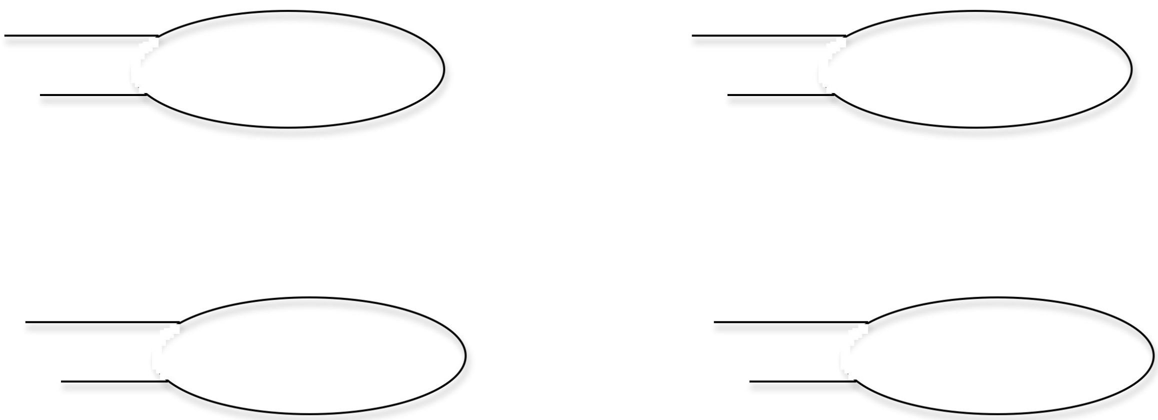
It follows then that an electric current (a flow of charged particles) should also produce a magnetic field.

Right Hand Grip Rule #1:

Long Straight Conductor:

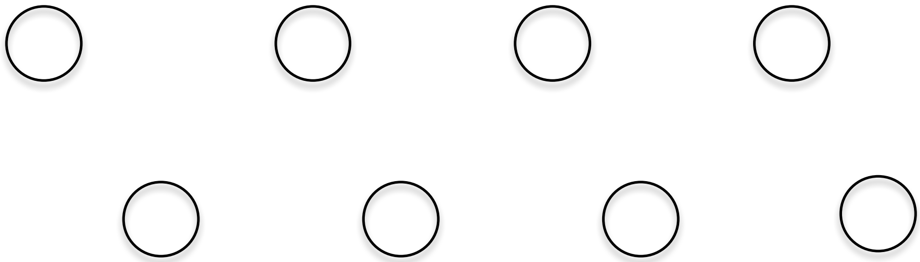
Electromagnetism #1

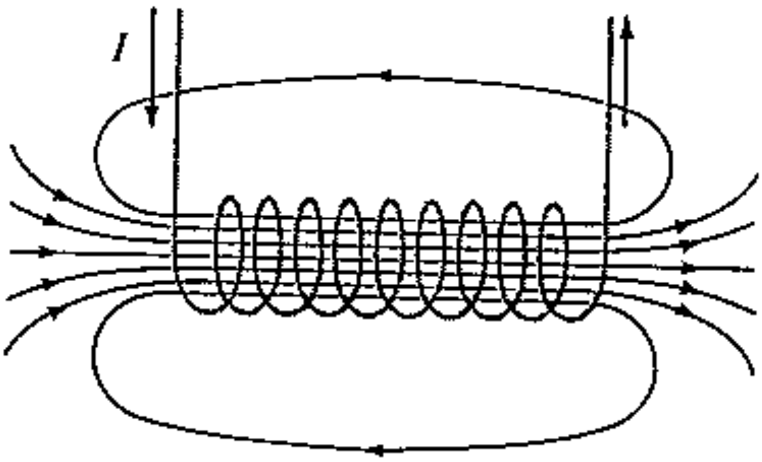
Current Carrying Loop:



Electromagnetism #1

Solenoid:





Right Hand Grip Rule #2:

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