Electromagnetism #1 Name: SOLUTIONS

ELECTRIC CHARGE

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

Symbol: q Units: Coulombs C — SI derived — 1 Ampere = 1 C/s

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.

NEGATIVE – ELECTRONS

POSITIVE – PROTONS

Charge is always:

CONSERVED	QUANTISED
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: -1.60×10^{-19} C

$n = \frac{q}{e}$ ← NOT on data sheet

number of electrons = $\frac{\text{charge}}{\text{charge of an electron}}$

Objects are generally electrically neutral – NUMBER OF ELECTRONS = NUMBER OF PROTONS

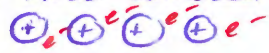
But the outermost electrons of atoms are only loosely bound (particularly in metals) and can easily be added or removed from objects.

- A POSITIVELY CHARGED OBJECT HAS HAD ELECTRONS REMOVED
- A NEGATIVELY CHARGED OBJECT HAS HAD ELECTRONS ADDED

When we say the charge of a body – we really mean: NET CHARGE (ONLY A SMALL FRACTION ~10^{-12} OF TOTAL CHARGE OF A BODY)

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

Conductors – PERMIT THE EASY MOVEMENT OF CHARGE THROUGH THEM
THEY ARE USUALLY METALS WITH FREE CONDUCTION ELECTRONS

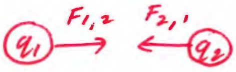


Insulators – DO NOT PERMIT EASY MOVEMENT OF CHARGE THROUGH THEM.
THEY ARE USUALLY NON-METALS WITH NO OR FEW FREE ELECTRONS

Semiconductors – INTERMEDIATE PROPERTIES BETWEEN CONDUCTORS & INSULATORS

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.



$F_{1,2} = F_{2,1}$

$$F_e = \frac{k q_1 q_2}{r^2} \Rightarrow F_e = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$k = \frac{1}{4\pi\varepsilon_0}$$

$k = 8.99 \times 10^9\ NC^{-2}m^2$

ε_0 = permittivity of free space $= 8.85 \times 10^{-12}\ C^2N^{-1}m^{-2}$ or Fm^{-1}

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): THE FORCE IS REPULSIVE

If the charges have opposite signs (i.e. the answer is negative): THE FORCE IS ATTRACTIVE

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.

$q_e = -1.60 \times 10^{-19}\ C$

$q_p = 1.60 \times 10^{-19}\ C$

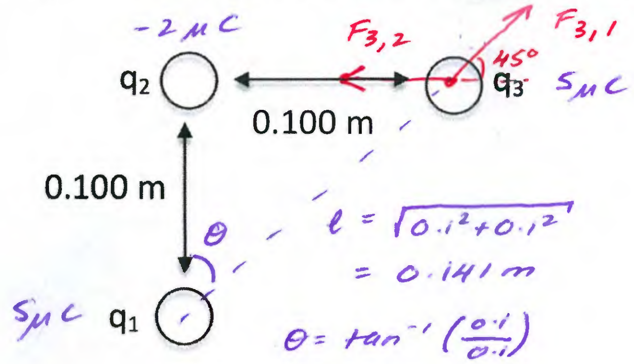
$r = 5.30 \times 10^{-11}\ m$

$$F_e = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} = \frac{1}{4\pi(8.85\times10^{-12})}\frac{(1.6\times10^{-19})(-1.6\times10^{-19})}{(5.30\times10^{-11})^2}$$

(2: remember!)

$= -8.20 \times 10^{-8}\ N \Rightarrow 8.20 \times 10^{-8}\ N$ ATTRACTION

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



F on q_3 due to q_1

$l = \sqrt{0.1^2 + 0.1^2} = 0.141\ m$

$\theta = \tan^{-1}\left(\frac{0.1}{0.1}\right) = 45°$

$$F_e = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

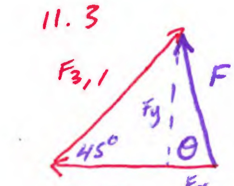
$$F_{3,1} = \frac{1}{4\pi(8.85\times10^{-12})}\frac{(5\times10^{-6})(5\times10^{-6})}{0.141^2}$$

$= 11.3\ N$ $45°$ ABOVE HORIZONTAL TO RIGHT

$$F_{3,2} = \frac{1}{4\pi(8.85\times10^{-12})}\frac{(5\times10^{-6})(-2\times10^{-6})}{0.100^2}$$

$= -8.99\ N = 8.99\ N$ LEFT

USING COMPONENTS



COULD USE COSINE OR SINE RULE

$F_{3,1}y = 11.3 \sin 45°$

$F_{3,1}x = 11.3 \cos 45°$

$$\tan\theta = \frac{7.99}{1.00}$$

$\theta = 82.9°$

$F_x = -8.99 + 11.3\cos 45° = -1.00\ N$

$F_y = 11.3 \sin 45° = 7.99\ N$

$F = \sqrt{7.99^2 + 1.00^2} = 8.05\ N$ at $82.9°$ ABOVE HORIZONTAL TO LEFT

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]

$$F_e = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$= \frac{1}{4\pi(8.85\times10^{-12})}\frac{(2\times5)}{75^2}$$

$$= 1.60\times10^7\ N\ \text{REPULSION}$$

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.

ATTRACTION ∴ −ve

[12.0 m]

$$F_e = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$r = \sqrt{\frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{F_e}} = \sqrt{\frac{1}{4\pi\times8.85\times10^{-12}}\frac{(8\times10^{-3})(-6\times10^{-3})}{-(3\times10^3)}}$$

$$= 12.0\ m$$

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.

+ve

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

$$F_e = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$q_1 = \frac{F_e r^2 (4\pi\varepsilon_0)}{q_2}$$

$$= \frac{(2.70\times10^{-1})(0.840)^2(4\pi\times8.85\times10^{-12})}{(6.40\times10^{-6})}$$

$$= 3.31\times10^{-6}\ C$$

POSITIVE

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]

$$F_e \propto \frac{q_1 q_2}{r^2} \quad \text{ORIGINAL}$$

$$F_e \propto \frac{(2q_1)(2q_2)}{(3r)^2} \quad \text{NEW}$$

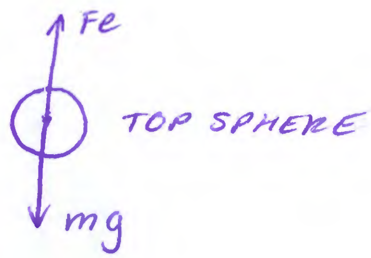
$$= \frac{4 q_1 q_2}{9 r^2}$$

$$= \left[\frac{4}{9}\right] F_{e\,\text{ORIGINAL}}$$

$$\Rightarrow \frac{4}{9} \text{ TIMES ORIGINAL}$$

5. A metal sphere of mass 6.00 x 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]



$$\Sigma F = 0$$

$$F_e = mg$$

$$F_e = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$r = \sqrt{\frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{mg}}$$

$$= \sqrt{\frac{1\,(4.00\times10^{-6})(4.00\times10^{-6})}{4\pi(8.85\times10^{-12})\,(6.00\times10^{-3})(9.8)}}$$

$$= 1.56\,m$$

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

➡ AN ELECTRICALLY CHARGED PARTICLE DOES NOT 'FEEL' ITS OWN ELECTRIC FIELD

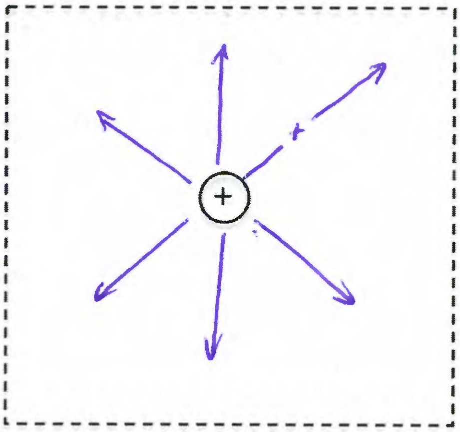
The direction of an electric field at any point is:

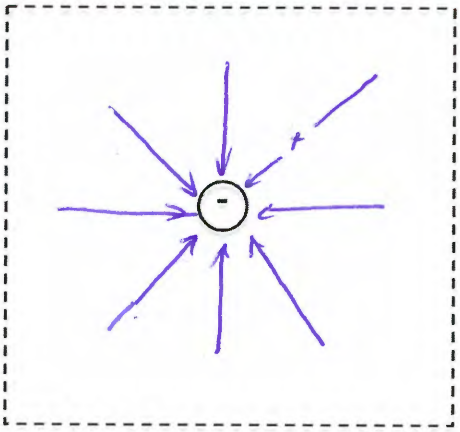
THE DIRECTION IN WHICH A SMALL POSITIVE TEST CHARGE WOULD MOVE IF PLACED AT THAT POINT.

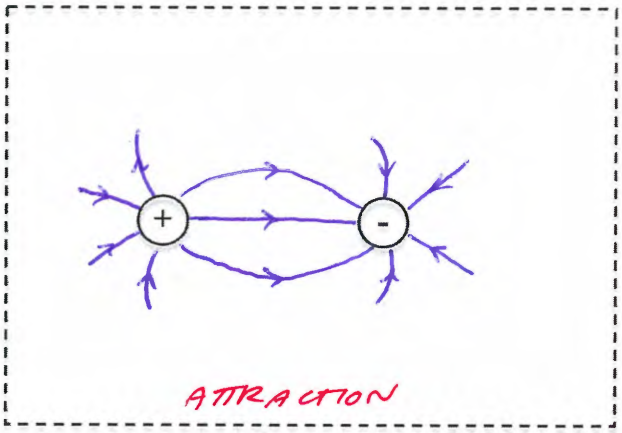
Field Lines

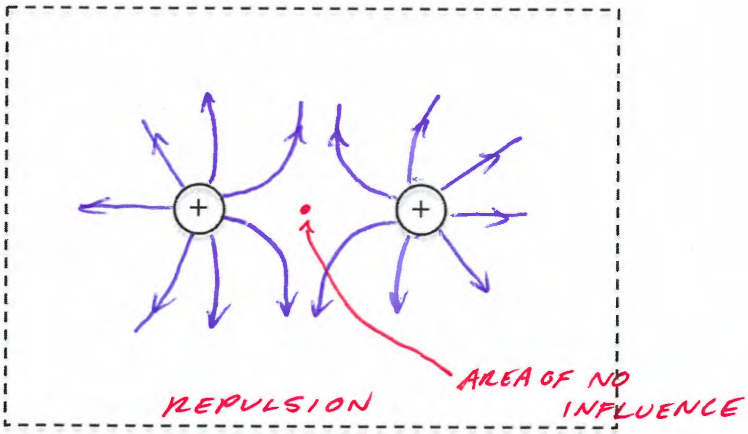
Electric field lines are helpful in visualising electric fields.

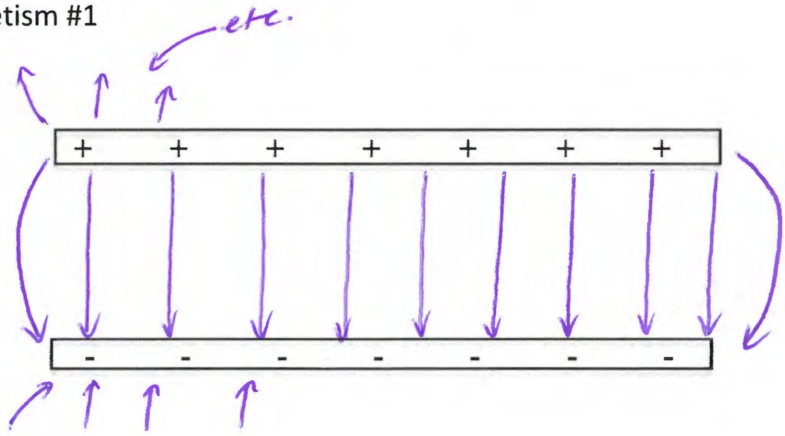
1. FIELD LINES CAN NEVER CROSS
2. LINES CLOSER TOGETHER IMPLY A STRONGER ELECTRIC FIELD
3. LINES MUST ENTER & EXIT A CHARGED BODY AT RIGHT ANGLES
4. LINES ARE ALWAYS DIRECTED AWAY FROM POSITIVE CHARGES AND TOWARDS NEGATIVE CHARGES.
5. IN A UNIFORM FIELD, LINES ARE STRAIGHT, PARALLEL AND UNIFORMLY SPACED











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.

$$E = \frac{F}{q}$$

F is Fe (N)

q is charge (C)

E - Field strength /Intensity (NC^{-1})

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?

$$E = \frac{F}{C} = \frac{8.40 \times 10^2}{7.00}$$

$$= 1.20 \times 10^2 \, NC^{-1}$$

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?

$$E = \frac{F}{q}$$

$$= \frac{0.02}{(2 \times 10^{-3})}$$

$$= 10.0 \, NC^{-1}$$

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).

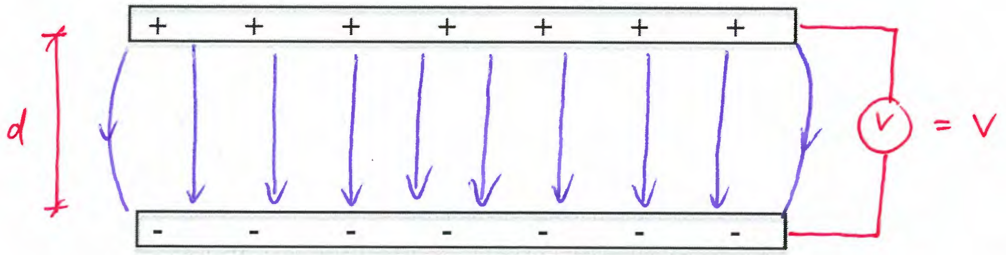
The more common term for potential difference is: VOLTAGE (QTY) — NOT THE SAME THING! — UNITS: VOLTS (V) (UNITS)

$$V = \frac{W}{q} \qquad 1V \equiv 1\,JC^{-1}$$

WORK PER UNIT CHARGE

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:



WORK = FORCE × DISPLACEMENT $(W = Fs)$

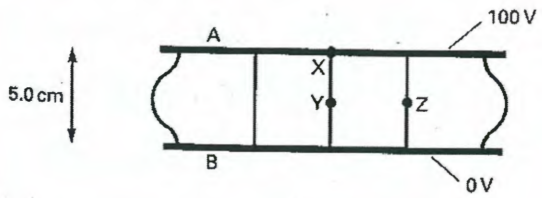
$F = Eq$ ← ELECTRIC FIELD STRENGTH

$= Eq \times \text{displacement}$

$$E = \frac{W}{q \times \text{displacement}} = \frac{Vq}{q \times \text{displacement}}$$

$$E = \frac{V}{d} \quad [\text{UNITS } Vm^{-1}]$$

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?

$$E = \frac{V}{d} = \frac{100}{0.05} = 2.00 \times 10^{3}\ Vm^{-1}$$

(b) What is the field strength at Y?

$E = \frac{V}{d} = \frac{50}{0.025} = 2.00 \times 10^{3}\ Vm^{-1}$

SAME AS a) BECAUSE IT IS A UNIFORM FIELD BETWEEN THE PLATES.

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

$W = Fs$

$F = Eq$
$= (2000)(1.6 \times 10^{-19})$
$= 3.2 \times 10^{-16}\ N$

$W = Fs$
$= (3.2 \times 10^{-16})(0.025)$
$= 8.00 \times 10^{-18}\ J$

OR

$W = Vq$
$= 50\ (1.6 \times 10^{-19})$
$= 8.00 \times 10^{-18}\ J$

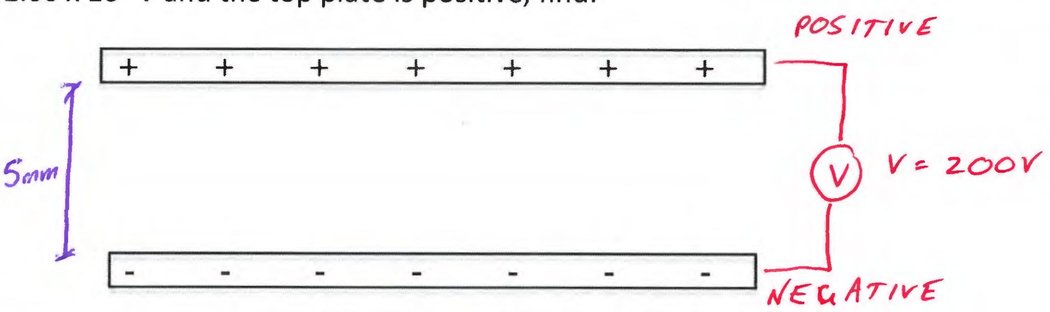
(d) Calculate the work done against the electric field on moving an electron from Y to Z.

ZERO – NO CHANGE IN POTENTIAL

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

$F = Eq$
$= (2000)(2 \times 10^{-6}) = 4.00 \times 10^{-3}\ N$ TOWARDS PLATE B

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]

$E = \frac{V}{d} = \frac{200}{0.005}$ (or $\frac{100}{2.5 \times 10^{-3}}$)
$= 40.0\ kVm^{-1}$

$F = Eq$
$= 40 \times 10^{3}\ (1.5 \times 10^{-6})$
$= 6.00 \times 10^{-2}\ N$ DOWN

(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]

$\Sigma E_i = \Sigma E_f$ — charge does work
$E_p \Rightarrow E_K$

$W = Vq$
$= (100)(1.50 \times 10^{-6})$
$= 1.50 \times 10^{-4}\ J$

POTENTIAL CONVERTED TO E_K
$W = \Delta E_K$

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.

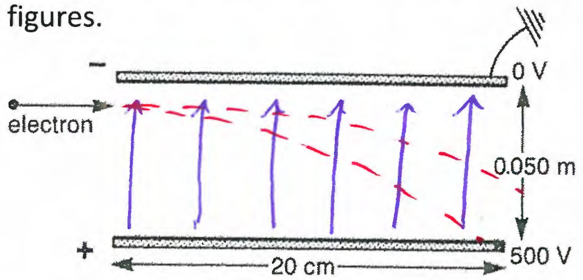
(a) What is the electron's speed as it leaves the gun?

$W = qV$
$= (1.60\times10^{-19})(2.91\times10^{3})$
$= 4.66\times10^{-16}\ J$

$Work = \Delta E_K = \frac{1}{2}mv^2 - 0$

$v = \sqrt{\frac{2W}{m}} = \sqrt{\frac{2(4.66\times10^{-16})}{(9.11\times10^{-31})}}$
$= 3.20\times10^{7}\ m/s$

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.



LIKE PROJECTILE MOTION, HORIZONTAL SPEED DOES NOT CHANGE.

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

$s = tv$

$t = \frac{s}{v} = \frac{0.2}{3.20\times10^{7}} = 6.25\times10^{-9}\ s$

(assuming it does not hit plate)

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

VERTICAL SPEED STARTS AT 0 THEN INCREASES

↓ DOWN +ve

$E = \frac{V}{d} = \frac{500}{0.05}$
$= 10{,}000\ Vm^{-1}$

$E = \frac{F}{q}$

$F = Eq = (10000)(1.6\times10^{-19})$
$= 1.60\times10^{-15}\ N$

$F = ma$

$a = \frac{F}{m} = \frac{1.60\times10^{-15}}{9.11\times10^{-31}}$
$= 1.76\times10^{15}\ m/s$

$s = \cancel{ut}^{\,0} + \frac{1}{2}at^2$
$= \frac{1}{2}(1.76\times10^{15})(6.25\times10^{-9})^2$
$= 0.0343\ m$

ASSUMPTION CORRECT.

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]

$$F_e = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}$$

$\varepsilon = 80\,\varepsilon_0$

$$= \frac{1}{4\pi(80)(8.85\times10^{-12})}\frac{(1\times10^{-10})(1\times10^{-12})}{(0.1)^2}$$

$$= 1.12\times10^{-12}\text{ N REPULSION}$$

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]

$$F_e = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$= \frac{1}{4\pi(8.85\times10^{-12})}\frac{(3\times10^{-9})(-12\times10^{-9})}{(3\times10^{-2})^2}$$

$$= -3.60\times10^{-4}\text{ N}$$

$$= 3.60\times10^{-4}\text{ N ATTRACTION}$$

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 ~~attraction~~ REPULSION]

ONCE TOUCHED

$$q_{net} = (3-12)\times10^{-9}$$

$$= -9\times10^{-9}\text{ C}$$

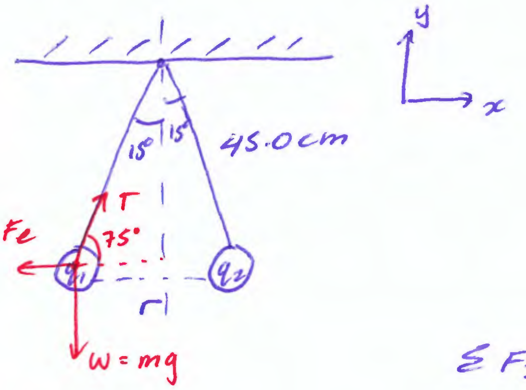
$$q_{each} = \frac{q_{net}}{2} = \frac{-9\times10^{-9}}{2} = -4.50\times10^{-9}\text{ C}$$

$$F_e = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} = \frac{1}{4(\pi)(8.85\times10^{-12})}\frac{(-4.50\times10^{-9})^2}{(3\times10^{-2})^2}$$

$$= 2.02\times10^{-4}\text{ N REPULSION}$$

3. Two very small metal-coated foam spheres, each of mass 2.80 x 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.

[-6.6~~3~~6 x 10^{-9} C]



$\Sigma F_y = 0$

$T\sin 75° - mg = 0$

$T = \dfrac{mg}{\sin 75°} = \dfrac{(2.80\times10^{-6})(9.8)}{\sin 75°}$

$= 2.841 \times 10^{-5}$ N

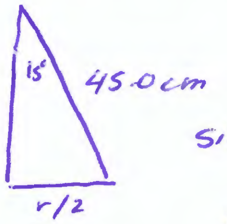
$\Sigma F_x = 0$

$T\cos 75° - F_e = 0$

$F_e = T\cos 75°$

$= 2.841\times10^{-5}(\cos 75)$

$= 7.353 \times 10^{-6}$ N



$\sin 15° = \dfrac{(\frac{r}{2})}{0.45}$

$r = 0.2329$ m

$F_e = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1 q_2}{r^2}$ $\quad q_1 = q_2$

$|q| = \sqrt{F_e r^2 (4\pi\varepsilon_0)}$

$= \sqrt{(7.353\times10^{-6})(0.2329)^2(4\pi \times 8.85\times10^{-12})} = 6.66\times10^{-9}$ C

$q = -6.66\times10^{-9}$ 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]

$W = qV$

$V = \dfrac{W}{q} = \dfrac{98}{7}$

$= 14.0$ V

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

[1.28 x 10^{-15} N]

$F = Eq$

$E = 8.00 \times 10^3\ NC^{-1}$

$F = 8.00 \times 10^3 (1.6 \times 10^{-19})$

$= 1.28 \times 10^{-15}\ N$

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

[5.00 W]

$P = ?$

$q = 1.00 \times 10^{-4}\ C$

$V = 2.00 \times 10^3\ V$

$t = 0.0400\ s$

$P = \frac{W}{t} \quad W = qV$

$P = \frac{qV}{t}$

$= \frac{(1.00 \times 10^{-4})(2.00 \times 10^3)}{(0.0400)}$

$= 5.00\ W$

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

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

$E = 1.60 \times 10^2\ NC^{-1}$

$a = ?$

$u = 0$

$F = Eq$

$F = ma$

$m_p = 1.67 \times 10^{-27}\ kg$

$q = +1.60 \times 10^{-19}\ C$

$a = \frac{Eq}{m}$

$= \frac{1.60 \times 10^2 \times 1.60 \times 10^{-19}}{1.67 \times 10^{-27}}$

$= 1.53 \times 10^{10}\ m/s^2$

TOWARDS 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 1.00×10^{-16} J, accelerates from the negative electrode to the positive electrode. Determine;

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

[5.22×10^{-15} J]

$\Delta E = W$

$W = Vq$

$= 32 \times 10^{3} \times 1.6 \times 10^{-19}$

$= 5.12 \times 10^{-15}$ J

$E_f = E_i + W$

$= 1.00 \times 10^{-16} + 5.12 \times 10^{-15}$

$= 5.22 \times 10^{-15}$ J

(b) The electric field strength between the electrodes.

[1.60×10^{5} NC^{-1}]

$E = \frac{F}{q}$

$W = Fs$

$E = \frac{\left(\frac{W}{s}\right)}{q} = \frac{\left(\frac{5.12 \times 10^{-15}}{0.2}\right)}{1.6 \times 10^{-19}}$

$= 1.60 \times 10^{5}$ NC^{-1}

$E = \frac{V}{d}$

$= \frac{32 \times 10^{3}}{0.2}$

$= 1.60 \times 10^{5}$ NC^{-1}

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

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

$F = Eq$

$= 1.60 \times 10^{5} (1.60 \times 10^{-19})$

$= 2.56 \times 10^{-14}$ N TOWARDS POSITIVE ELECTRODE

(d) The acceleration of the electron.

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

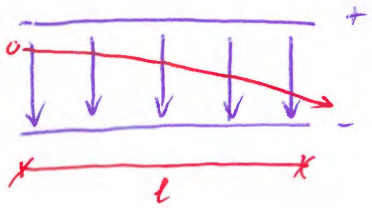
$F = ma$

$a = \frac{F}{m} = \frac{2.56 \times 10^{-14}}{(9.11 \times 10^{-31})} = 2.81 \times 10^{16}$ m/s^2 TOWARDS POSITIVE ELECTRODE

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]



HORIZONTAL DIRECTION

$v = u = 1.00 \times 10^6$ m/s

$v = \frac{s}{t}$

$l = vt = (1.00 \times 10^6)(1.00 \times 10^{-7})$

$= 0.100$ m

(b) The acceleration of the alpha particle

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

$F = ma$

$q = 2e$

$a = \frac{F_e}{m}$

$F_e = Eq$

$= 160 \times 10^3 (2 \times 1.60 \times 10^{-19})$

$= 5.12 \times 10^{-14}$ N

$a = \frac{5.12 \times 10^{-14}}{6.64 \times 10^{-27}}$

$= 7.71 \times 10^{12}$ m/s^2 TOWARDS 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 x 10^6 ms^{-1} at 37.6° from its original path towards the negative plate]

VERTICAL

+ ↓

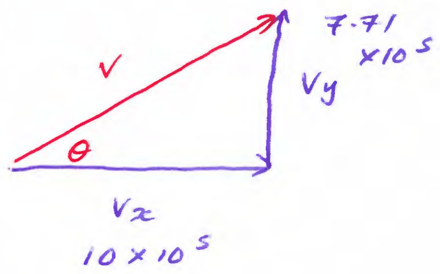
$v = u + at$ (u = 0)

$= 7.71 \times 10^{12} (1.00 \times 10^{-7})$

$= 7.71 \times 10^{5}$ m/s

HORIZONTAL

$v = 1.00 \times 10^{6}$ m/s



$v = \sqrt{v_x^2 + v_y^2}$

$= \sqrt{(1.00 \times 10^{6})^2 + (7.71 \times 10^{5})^2}$

$= 1.26 \times 10^{6}$ m/s

$\tan\theta = \frac{7.71 \times 10^{5}}{1.00 \times 10^{6}}$

$\theta = 37.6°$

⇒ $v = 1.26 \times 10^{6}$ m/s at 37.6° BELOW HORIZONTAL TOWARDS NEGATIVE PLATE

(HORIZONTAL = PARALLEL TO PLATE)

MAGNETIC MATERIALS

Basic Properties of Magnets:

1. ALL MAGNETS HAVE TWO POLES (DIPOLAR) WHICH ARE IMPOSSIBLE TO SEPARATE.
'NORTH' 'SOUTH'

2. UNLIKE POLES ATTRACT
LIKE POLES REPEL

3. FORCES DUE TO MAGNETS ACT AT A DISTANCE
-PHYSICAL CONTACT IS NOT REQUIRED.
→ MAGNETIC FIELD

Microscopic View of Magnetism:

- All magnetic materials are magnetic because of the electrons in them. ↗ DUE TO
  - ORBITAL MOTION
  - 'SPIN'
- 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:

A NET MAGNETIC MOMENT

A MATERIAL WITH A NET MAGNETIC MOMENT ($\neq 0$) IS SAID TO DISPLAY MAGNETIC PROPERTIES

Ferromagnetic Materials

MATERIALS WE COMMONLY CONSIDER TO BE MAGNETIC

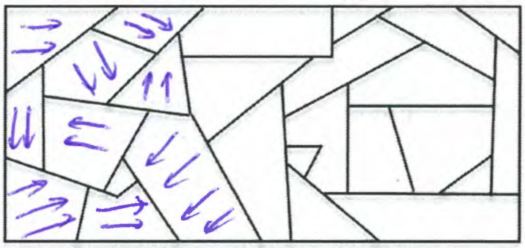
- COBALT
- IRON
- NICKEL

THESE MATERIALS EXHIBIT STRONG & PERMANENT MAGNETIC EFFECTS.

The Domain Theory of Magnetism:

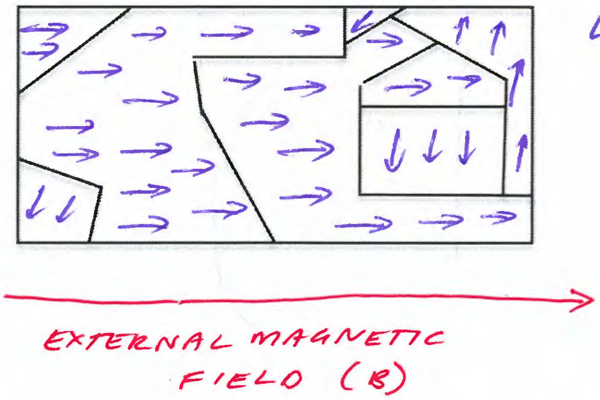
- A domain is a small region of spontaneous magnetism that exists even when no external magnetic field is present.

- All magnetic moments will be aligned within a domain.



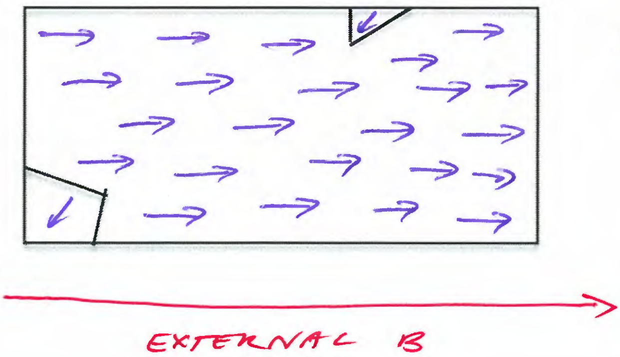
← EACH AREA IS CALLED A DOMAIN

NO NET MAGNETIC MOMENT IN THE MATERIAL



← THE MAGNETIC MOMENTS ALIGN THEMSELVES WITH THE EXTERNAL FIELD.

→ FAVOURABLY ALIGNED DOMAINS GROW BIGGER.



← THE MAJORITY OF THE MAGNETIC MOMENTS ARE ALIGNED

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

↳ MAGNETIC MEMORY
HYSTERESIS

1. HIT, DROP, BANG

→ KNOCKS THE MAGNETIC MOMENTS OUT OF ALIGNMENT

2. REMAGNETISE WITH ANOTHER EXTERNAL MAGNETIC FIELD IN THE OPPOSITE DIRECTION.

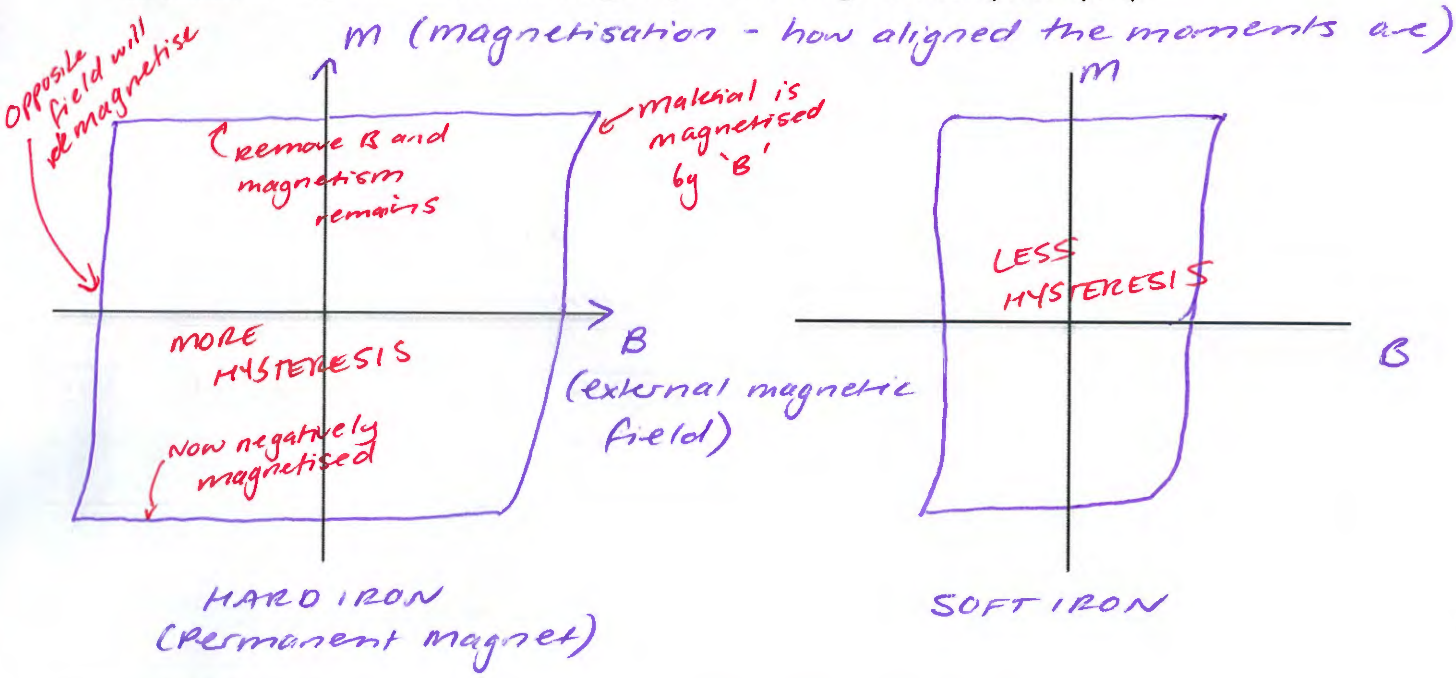
3. EXPOSE IT TO HEAT

→ THERMAL AGITATION KNOCKS MAGNETIC MOMENTS OUT OF ALIGNMENT

T_c - CURIE TEMPERATURE (NOT MAGNETIC ABOVE T_c)

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

- unpaired electrons

WILL ALIGN THEMSELVES WITH A MAGNETIC FIELD

VERY WEAK EFFECT

e.g. Al, U, Pt, Na, O_2

Diamagnetic Materials

- Paired electrons

WILL ALIGN THEMSELVES PERPENDICULAR TO A MAGNETIC FIELD

VERY WEAK EFFECT

e.g. Bi, Hg, Ag, Diamond, Pb, NaCl, Cu, Glass, Organics

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).

LIKE POLES REPEL

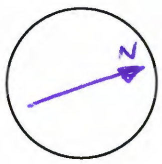
UNLIKE POLES ATTRACT N ♥ S

Magnetic Field

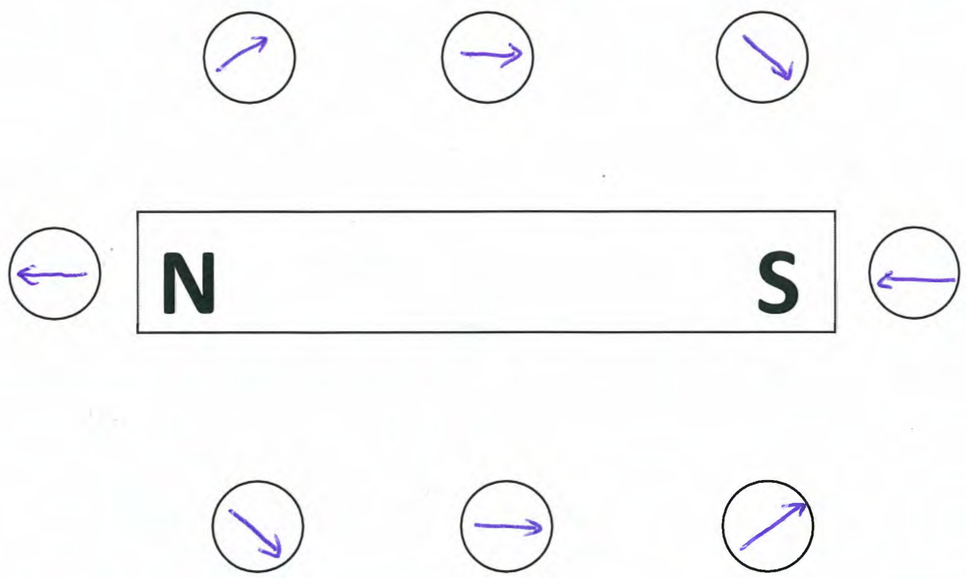
- The magnetic field is a region of influence that surrounds a magnetic material. Any other magnetic material that enters this region of influence will 'feel' a force.

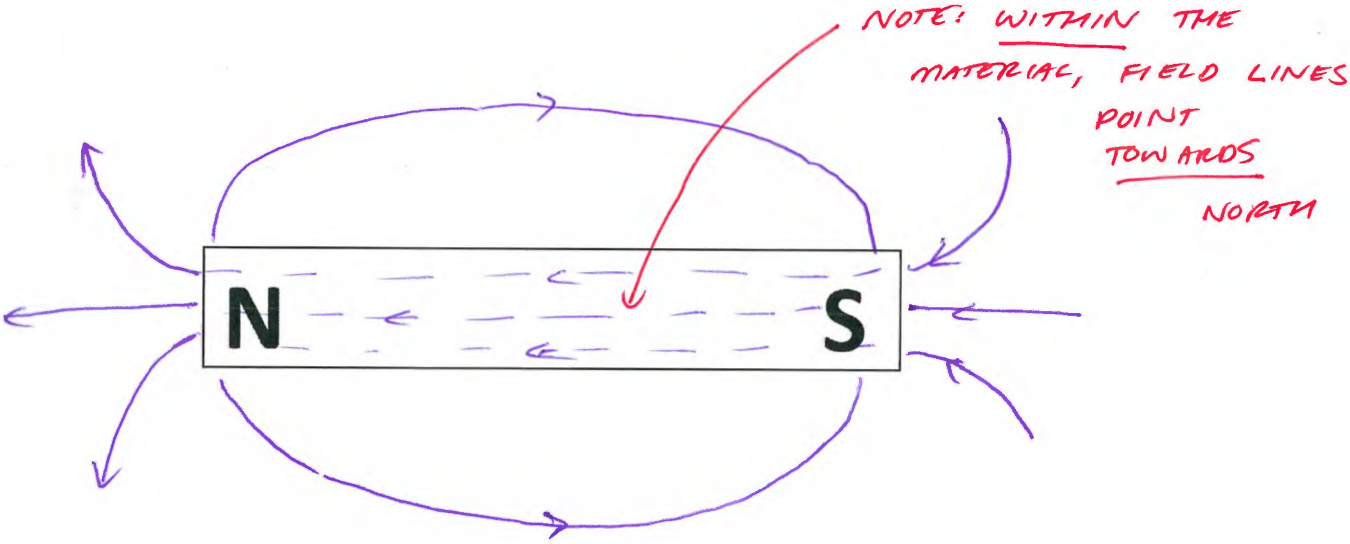
Magnetic Field Lines

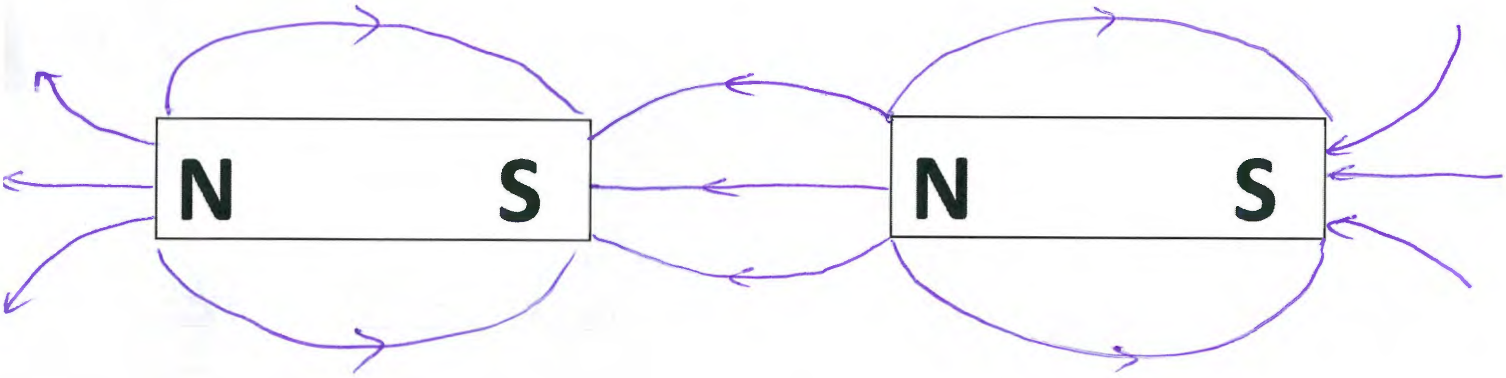
1. A magnetic field acts at a distance.
2. Direction: FROM NORTH TO SOUTH.
   THE DIRECTION THE NORTH END OF A COMPASS NEEDLE WOULD POINT
3. The strength of the field is proportional to the density (closeness) of the lines.
4. The lines must never cross.



COMPASS NEEDLE
- POINTS TOWARDS GEOGRAPHIC NORTH
- POINTS TOWARDS MAGNETIC SOUTH




NOTE: WITHIN THE MATERIAL, FIELD LINES POINT TOWARDS NORTH
N
S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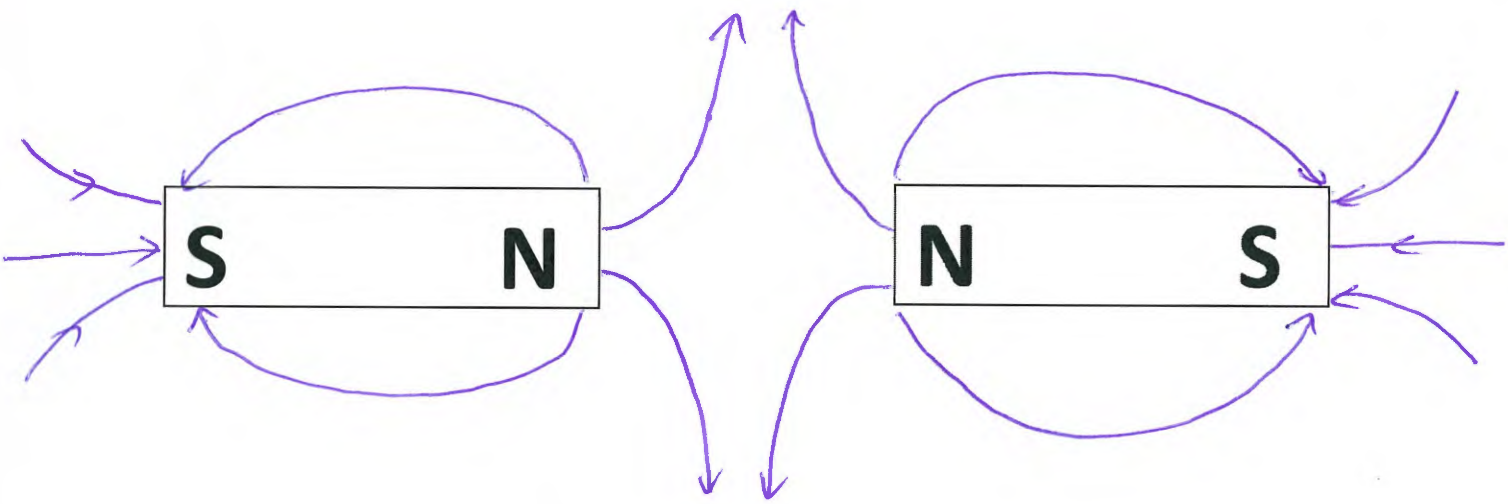
S
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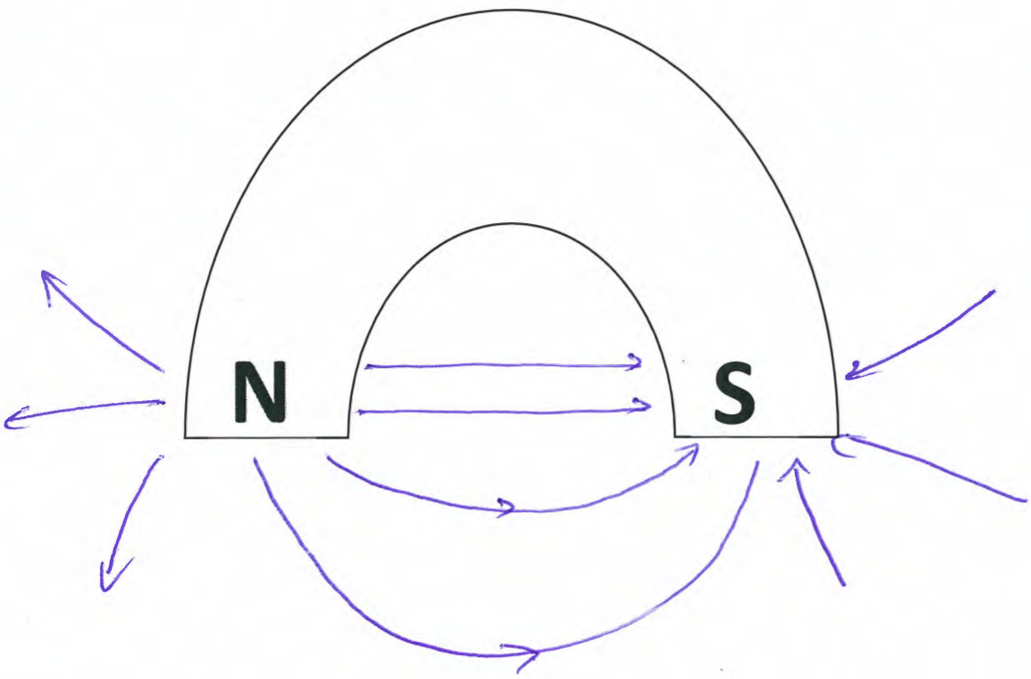
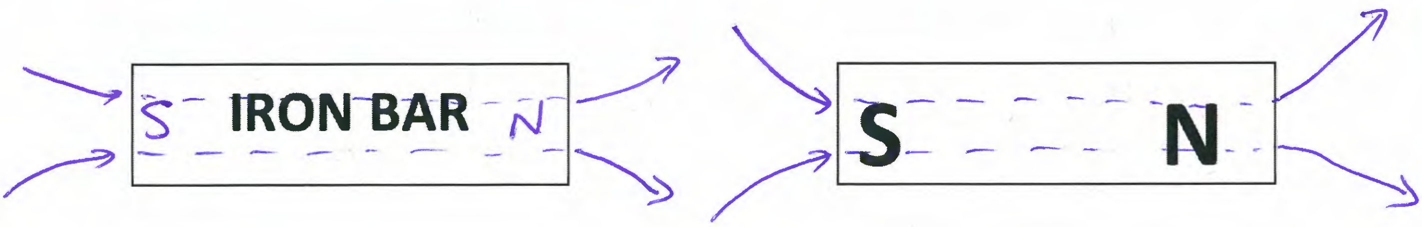




MAGNETIC MOMENTS IN THE IRON BAR ALIGN THEMSELVES WITH THE EXTERNAL MAGNETIC FIELD

→ IRON BAR IS ATTRACTED TO THE MAGNET.

Electromagnetism #1

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.

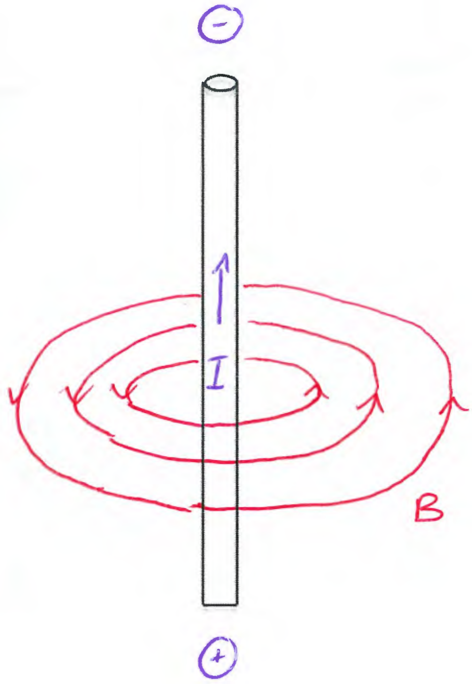
It follows then that an electric current (a flow of charged particles) should also produce a magnetic field.

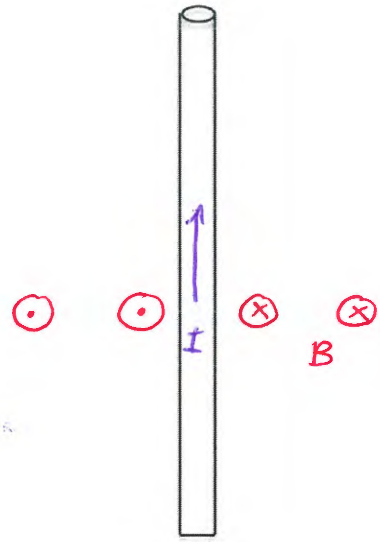
THERE IS ALWAYS A MAGNETIC FIELD ASSOCIATED WITH A MOVING CHARGED PARTICLE & HENCE ALWAYS A MAGNETIC FIELD ASSOCIATED WITH AN ELECTRIC CURRENT.

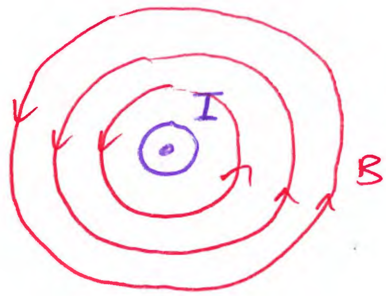
Right Hand Grip Rule #1:

- THUMB POINTS IN THE DIRECTION OF THE CURRENT (CONVENTIONAL)
- FINGERS CURL IN THE DIRECTION OF THE MAGNETIC FIELD LINES

Long Straight Conductor:







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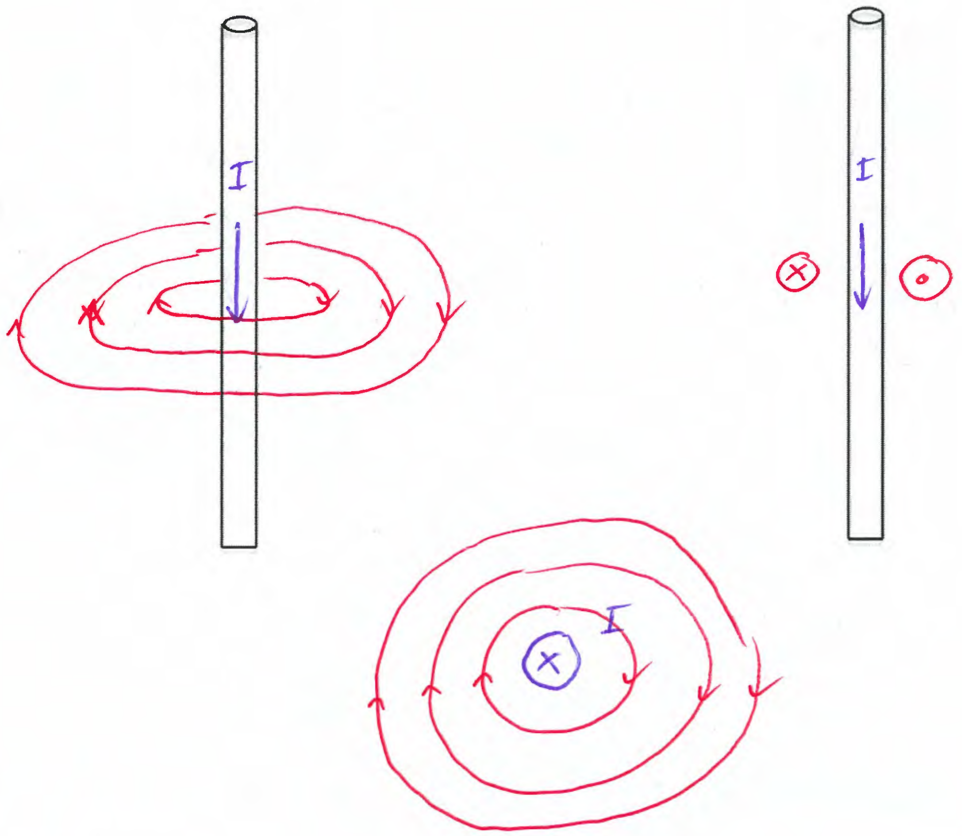
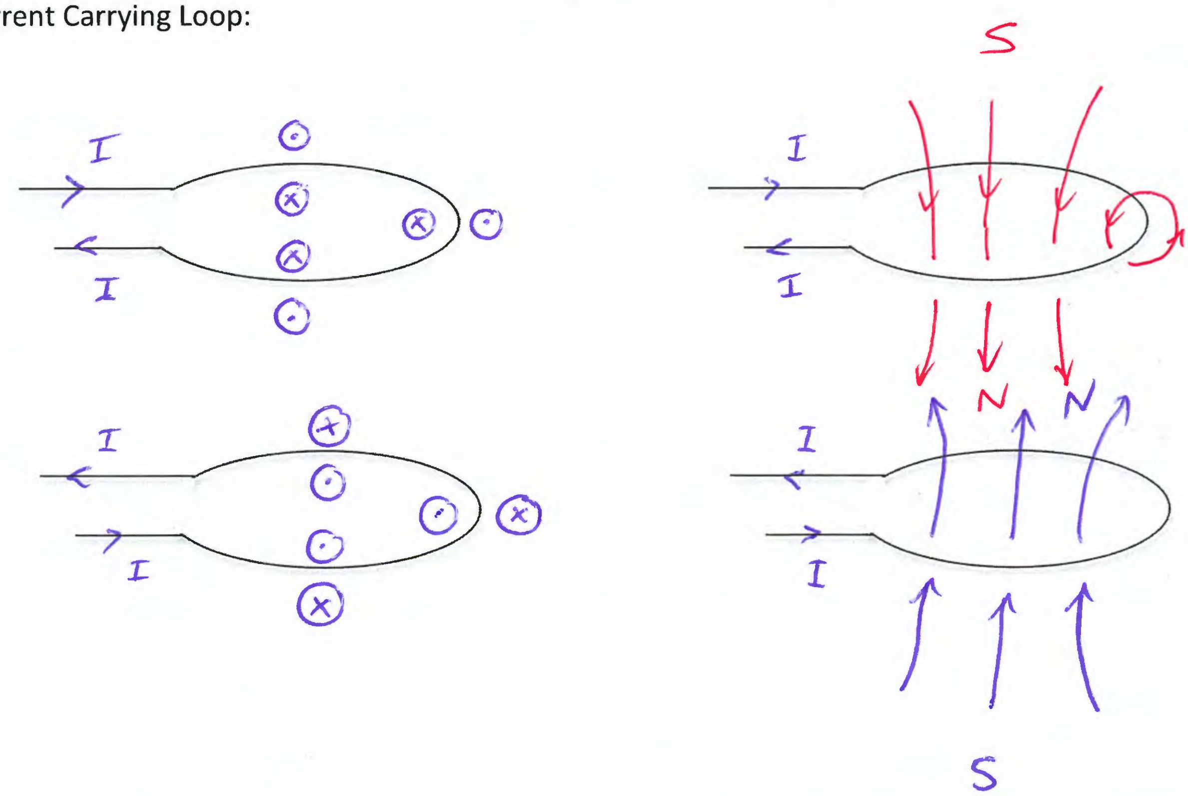
Electromagnetism #1



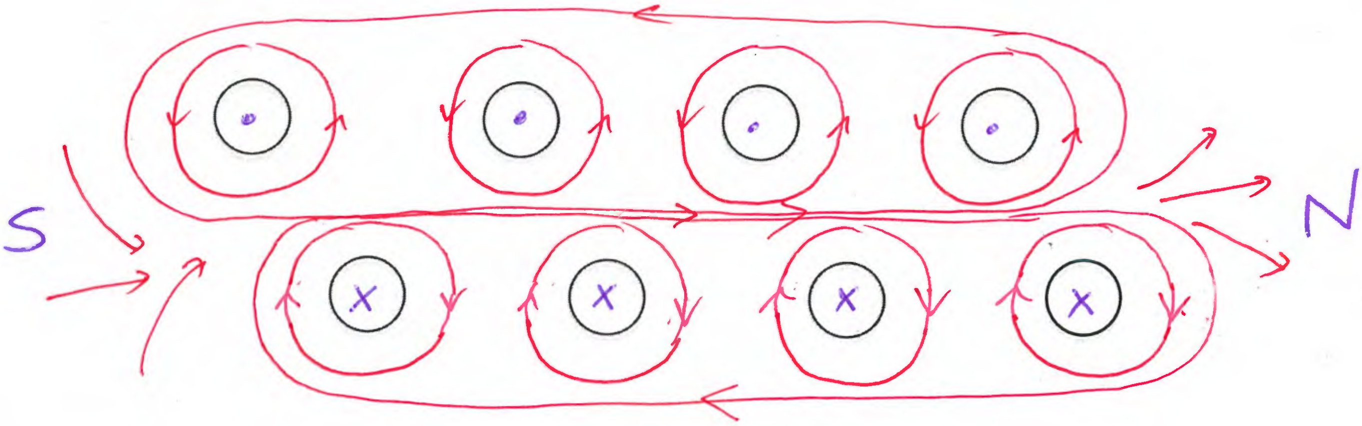
Current Carrying Loop:

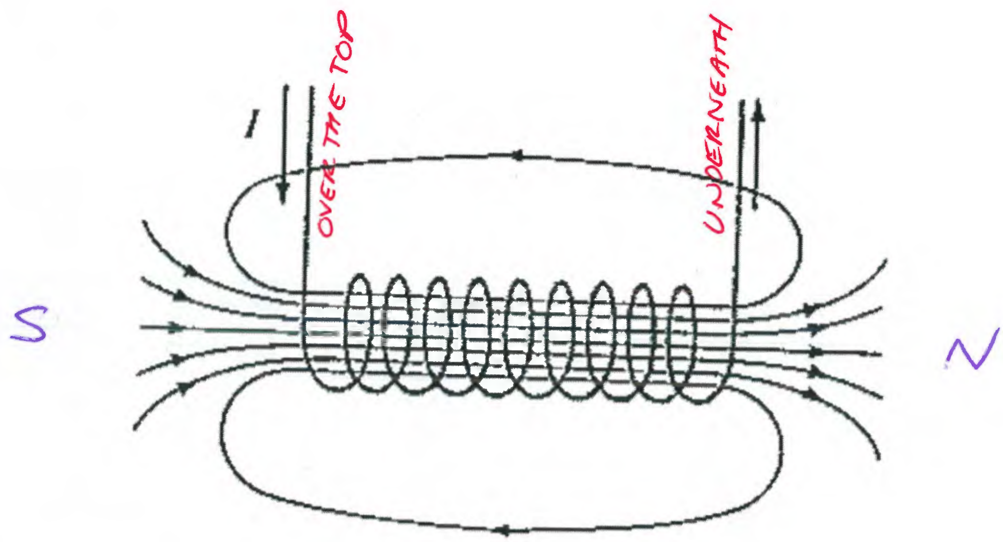


Electromagnetism #1

Solenoid: LONG COIL OF WIRE CONSISTING OF MANY LOOPS.

↓ CROSS SECTION OF A SOLENOID





Right Hand Grip Rule #2:

- FINGERS CURL IN DIRECTION OF CONVENTIONAL CURRENT
- THUMB POINTS IN THE DIRECTION OF THE FIELD LINES (i.e. TO THE NORTH POLE)