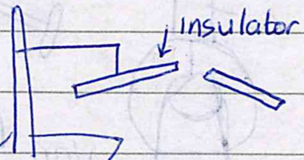
STATIC ELECTRICITY (static ⇒ can't move if its on an insulator)

Friction causes electrons to leave one material and go onto another. ē leaving ⇒ material ⊕, ē joining ⇒ materials ⊖ /

Demonstration:

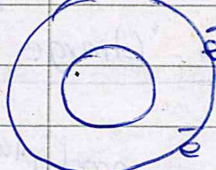


(only ē move!!)

like charges repel
unlike charges attract

Polythene + wool becomes ⊖ — ē go from wool → Polythene

Cellulose acetate + wool becomes ⊕ — ē go from acetate → wool



Atom is neutral, then ē leave ⇒ more ⊕ than ⊖.

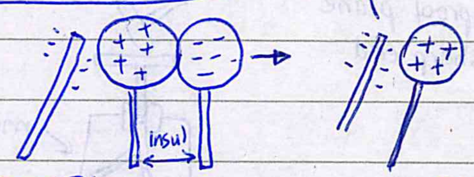
Unit of Electric Charge = Coulomb (C)   1C = 1Amp x 1sec $I = \frac{Q}{t}$

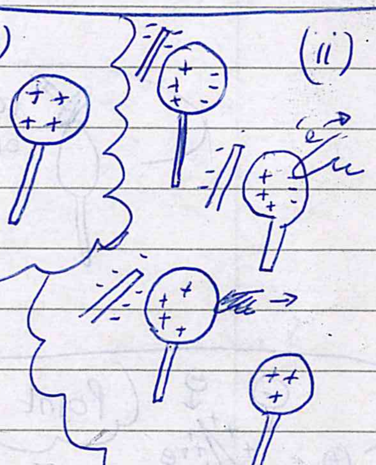
charge on ē = $1.6 \times 10^{-}$ C

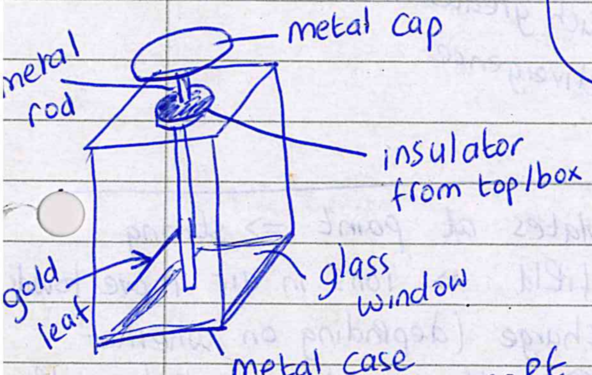
Insulators of electricity do not allow electrons to flow through them

Conductors allow electrons to flow through

(Charge by induction →



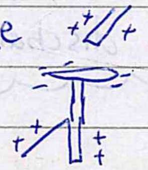




GOLD LEAF ELECTROSCOPE

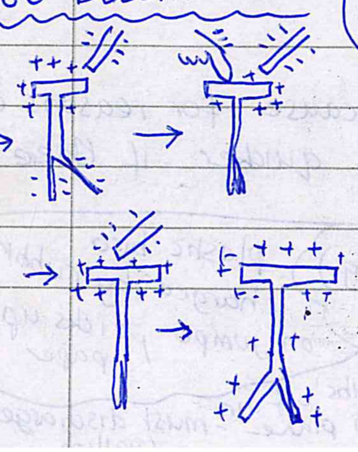
Gold leaf Electroscope:

a.) Detects charge (leafe diverges)



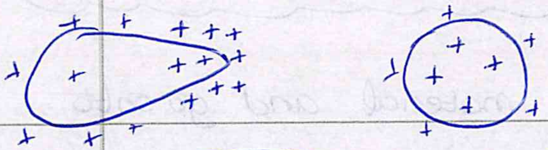
b.) Indicates Size (approx) of charge
greater charge ⇒ greater divergance

TO CHARGE ELECTROSCOPE:



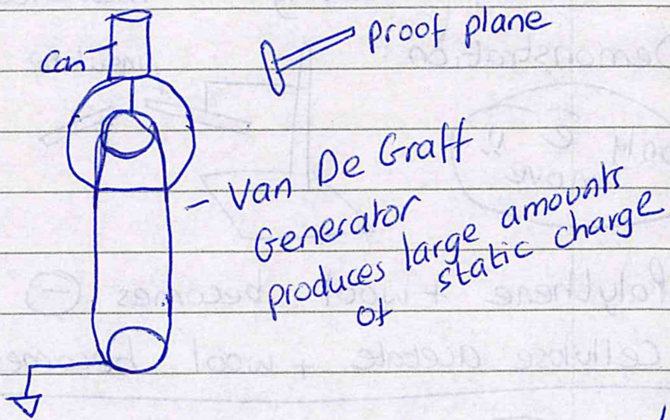
c.) Indicates Sign of charge (+) or (−)
(i) Charge electroscope
(ii) Bring object over near
(iii) If leaf diverges more ⇒ object + electroscope same charge
(iv) If leaf Collapses then object + electroscope opp. charge

d.) Tests for conduction
(i) Charge electroscope, (ii) Touch object off cap
(iii) If leaf ~~diverges~~ collapses object is conductor

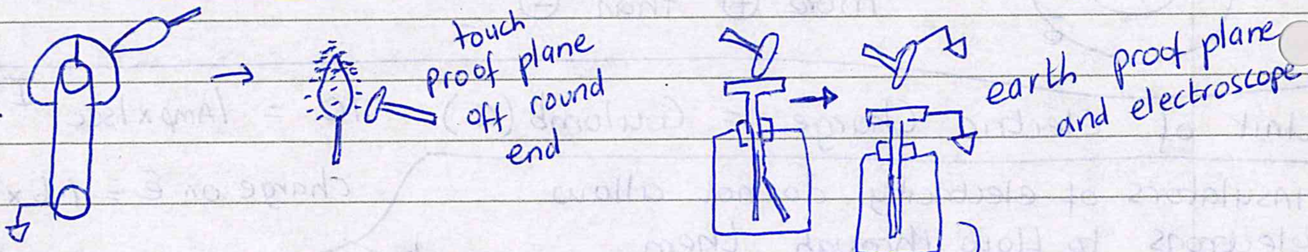


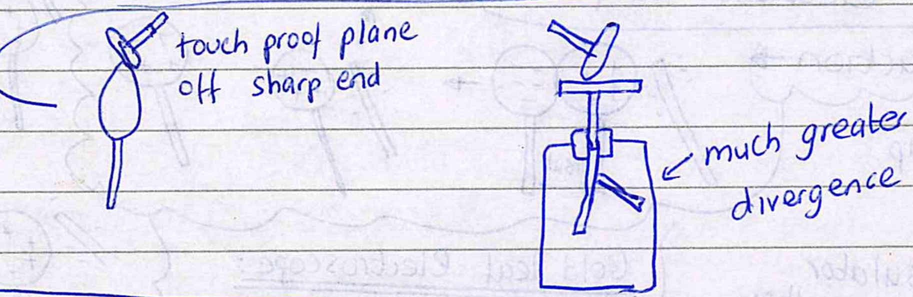
Can use a Van De Graff generator to show charge on a conductor accumulates on the most pointed part

All static charge resides on outside of a hollow metal conductor

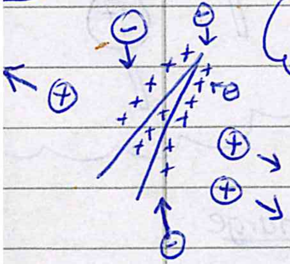


(i) Set up as shown
(ii) Connect proof plane to inside of can
(iii) Bring near electroscope
(iv) NOTHING happens (no charge) leafes won't diverge
(v) Touch proof plane to outside of can (vi) leaf diverges. Charge only on outside

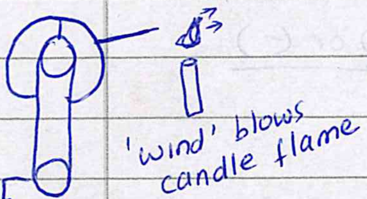




(Point discharge)



Charge accumulates at point => strong electric force field => ions in air move towds or away from charge (depending on whether they are ⊕ or ⊖). They, in turn collide with atoms in air making more ions. The ions with opposite charge move to the point and neutralise the charge. Ions of opposite charge create an 'electric wind'.



Used to discharge objects because for reasons above a charged object loses its charge quicker if there are points on it.

STATIC electricity Effects: (Clothes crackling (charges moving quickly through air)) (plastic biro charged by rubbing on jumper, picks up paper)

sparks can be dangerous if fine dust (sawmills), or fuel (airplane)
airplane picks up static e when it 'rubs' off air
tyres are rubber so charge stays on plane – must discharge before [illegible]

Lightening = charge building up on clouds. This gets discharged when clouds rub off each other or when discharge occurs between cloud + ground. There can be a huge flow of electrons (lightening) so a lightening rod is used to protect buildings (metal rod with point to point discharge reduces voltage between clouds & rod)

Coulomb's law: Force between 2 electrical static charges

$$F = \frac{Q_1 Q_2}{4\pi \epsilon d^2}$$

d = distance between Q_1, Q_2

ϵ = constant related to material (permittivity)

Inverse square law

$\varepsilon_r = \varepsilon / \varepsilon_0$ — ε_r: relative permitivity; ε_0: permitivity of vaccume

$\varepsilon = \varepsilon_r \varepsilon_0$

Electric field strength at a point = strength of Electric field = force a ⊕1C charge would experience if placed at that point. $E = \frac{F}{Q}$ →

E at $Q_2 = \frac{F_{Q_1Q_2}}{Q_2}$

Q_1 ←d→ Q_2

$E = N/C$ or NC^{-1}

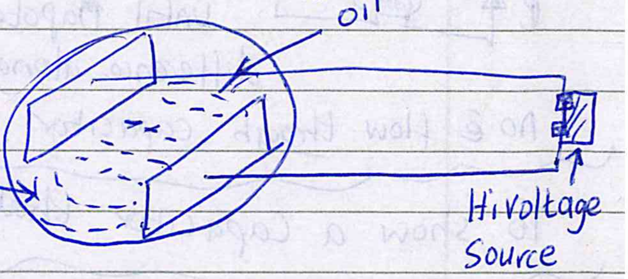
Q_1 ⊕ $E = \frac{Q_1(1)}{4\pi \epsilon d^2}$

ELECTRIC FIELD = any region of space where a static electric charge experiences a force other than the force of gravity + always caused by other charges in the vicinity.

Electric field lines point in the direction a ⊕ charge would move if it was placed at that point in the field.

* strong field means lines of field are close
* weak field means lines of field are far apart

To demonstrate E-field patterns



Applications of E fields:

Electrostatic Precipitators

Photocopiers

E-fields affect integrated circuits. Static can build up on person they are human conductor. When they touch i/circuit the static charge flows from them thro circuit to earth

POTENTIAL DIFFERENCE between 2 points is work done in bringing 1C charge from one point to the other.

UNIT = J/C or Volt

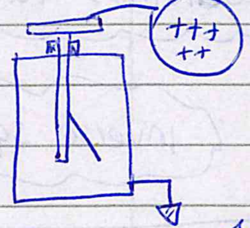
$$V = \frac{W}{Q}$$ Work per unit charge

1 Volt = 1 Joule per Coulomb

Potential difference is SCALAR

MEASURE VOLTAGE/POTENTIAL DIFF using electroscope:

amount of divergence of leaf ∝ potential difference



ELECTRIC CURRENT is the flow of electric charge

electrons will flow from ⊖ to ⊕ until there is no charge difference

So therefore, all points on a conductor carrying static charge are at same voltage/potential

CAPACITANCE of a conductor = ratio of charge on the conductor to its potential

$$C = \frac{Q}{V}$$ (Const)

(measure of how much charge it can hold for a particular potential)

Unit of CAPACITANCE = Farad. $C = \frac{Q}{V} = \frac{C}{V}$

so 1 Farad = 1 Coulomb per volt

$1\mu F = 1\times10^{-6}F$, $1nF = 1\times10^{-9}F$, $1pF = 1\times10^{-12}F$

PARALLEL PLATE CAPACITOR

(insulator) dielectric material

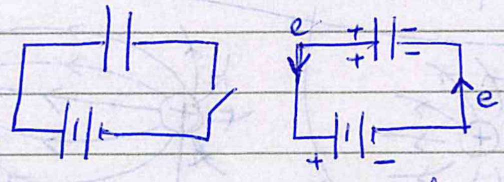
metal plates

$$C = \frac{\varepsilon_0 A}{d}$$

The capacitance of PP capacitor

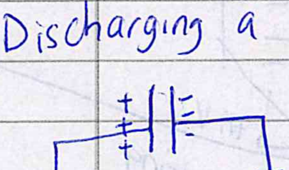
$$C = \frac{Q}{V}$$ Q ← charge on one plate; V: potential difference between plates

Charging a Capacitor



electrons flow until no potential difference. no ē flow through capacitor!

Discharging a Capacitor:



Bulb flashes as electrons flow until no potential difference along wire.

No ē flow through capacitor!

To show a capacitor that is charged stores energy

To show the capacitance of PP capacitor depends on
(1) Distance between plates
(2) Area of overlap
(3) Nature of Dielectric

Energy stored in a Capacitor = $W = \frac{1}{2}CV^2$

CURRENT and CHARGE

3 Effects of electric current Demo
– Magnetic, Electrical, Heating

In a metal conductor some e^- are free to wander from atom to atom → they will move if there is a potenial difference between ends of metal

Size of current = amount of charge passing any point per sec

$I = Q/t \qquad Q = It$

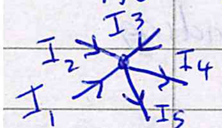
1 electron has a charge of $1 \cdot 6 \times 10^{-19}$ C → 1 Coulomb = $\frac{1}{1 \cdot 6 \times 10^{19}}$ electrons $= 6 \cdot 25 \times 10^{18}$

Conventional current moves in <u>opposite</u> direction to electrons (+) → (−)

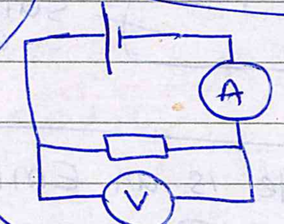
Alternating current changes direction 100 times/sec ∿ ×50 (50Hz

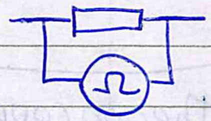
Direct current moves in one direction – measured with (mA) (A) (μA) Ammeters
galvanometer → (↗)

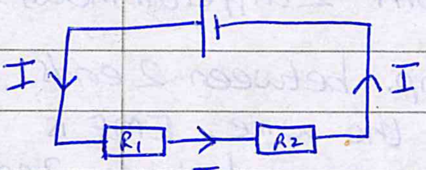
At a junction sum of currents entering = sum of currents leaving



$I_1 + I_2 + I_3 = I_4 + I_5$







Series Circuit

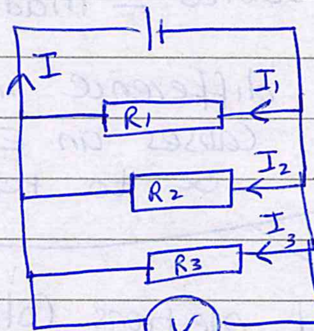
$V = V_1 + V_2$

$V = IR_1 + IR_2$

$V = I(R_1 + R_2)$

$\frac{V}{I} = (R_1 + R_2)$ ←

$R = R_1 + R_2$



Parallel circuit

$I = I_1 + I_2 + I_3$

$= \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$

$I = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$

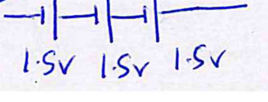
$\frac{V}{I} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ OR $R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$

Potential difference between 2 points in a circuit is the amount of energy converted from electrical to other forms between the 2 points when 1C of charge passes any point on the circuit
= energy lost by one coulomb as it moves from one point to other

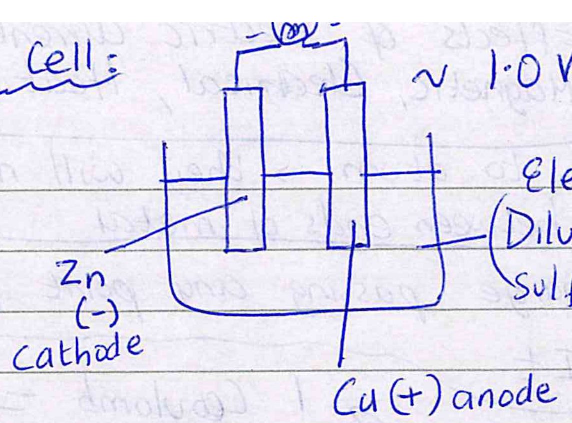
Power dissipated between A and B = $V_{AB} I_{AB}$

Batteries in series



= 4·5V

Simple Cell:



~ 1.0 V

Electrolyte (Dilute H_2SO_4 sulfuric acid)

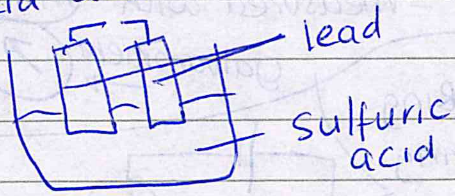
Zn becomes ⊖
Cu becomes ⊕
So when wire is connected electrons flow thro metal from ⊖ to ⊕ until chemicals used up.

Primary cell = cell that cannot be recharged

Dry batteries → the electrolyte = paste
Zinc-carbon, alkaline manganese

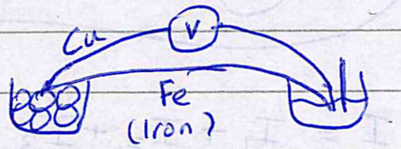
Secondary cell = cell that can be recharged
or Accumulator

Lead acid accumulator = 2 lead plates – used in CAR !!



- Charged by passing current through
- discharges in use
- can be recharged by sending current through backwds

Thermocouple is an EMF source – made from 2 different metals



difference in temp. between 2 ends causes an EMF in the wire. EMF is ∝ to temp. difference between 2 ends.

Mains electricity, AC, 230V

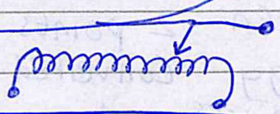
RESISTANCE = $\frac{V}{I}$ | In a metal electrons collide with atoms of material & get slowed down → material resists movement of charge

Ohm's law:
At constant temp, the resistance of a conductor $R = \frac{V}{I}$ = constant = SCALAR

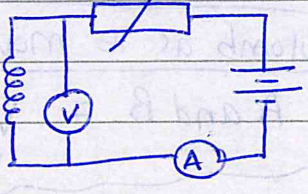
Ohm (Ω) = Resistance of conductor if current is 1 amp thro it when V (p.d) = 1V

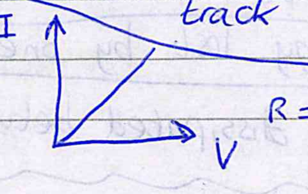
Ohmmeter measures R, also moving coil ohmmeter * zero ohmmeter – when probes are connected together
or measure R

Ohmic conductors obey Ohm's law | Circuit symbols – log tables

Variable resistor ⇒ rheostat  or potentiometer

To demonstrate Ohm's law:
vary R, measure V, I



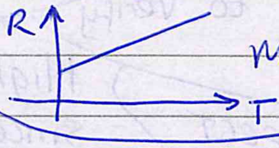


$R = \frac{1}{m}$

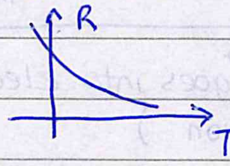
Resistance depends on T, l, C.S.A, Material

Metallic Conductor: R>>> T>>> Carbon, Semiconductors $R \propto \frac{1}{T}$ R<<< T>>>

Metal: As T>>> atoms vibrate more and get in the way of the current so as T>>>> R>>>



Insulators, Semi Conductors As T>>> electrons in material become 'free' for conduction so R<<<



SEMICONDUCTOR

MANDATORY EXPS = Variation of Resistance of metallic conductor with temp / Semi conductor

THERMISTOR = semiconductor whose resistance decreases rapidly with T>>>
~~Nickel~~, Cobalt, iron nickel oxides

RESISTIVITY = ρ

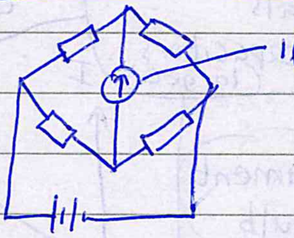
$R = \rho \frac{L}{A} \leftrightarrow \rho = \frac{RA}{L}$

If A is Constant $R \propto L$

RESISTIVITY = resistance of material of length 1m, C.S.A 1m²

Mandatory experiment to measure Resistivity (no bends in wire, zero ohmmeter)

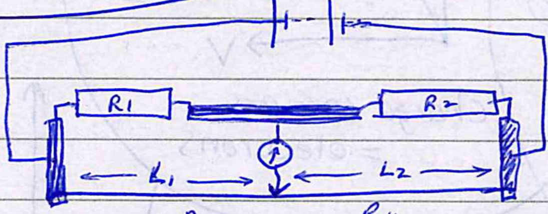
Wheatstone bridge



If no I thro galvanometer, then

$\frac{I_1 R_1}{I_1 R_2} = \frac{I_2 R_3}{I_2 R_4} \Rightarrow \frac{R_1}{R_2} = \frac{R_3}{R_4}$

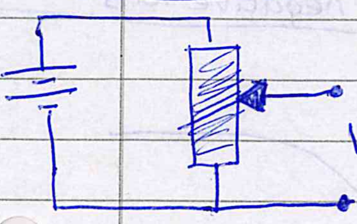
Meter bridge



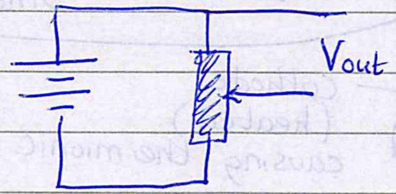
$\frac{R_1}{R_2} = \frac{R_3}{R_4} = \frac{\rho L_1/A_1}{\rho L_2/A_2}$

$\frac{R_1}{R_2} = \frac{L_1}{L_2}$

Wheatstone / Meter bridge → used as temperature control → current will flow in galvanometer if R changes - can be used to control a heater / cooler to restore temp.
also a fail safe device in a boiler - thermistor near pilot flame.
If flame goes out fuel supply can be shut off

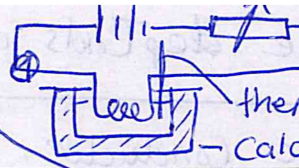


or



Voltage divider Circuit using a Rheostat (or can use potentiometer)

To show Heating effect of $\bar{e}$ current :



~~Joules~~ ~~Power~~ $W \propto I^2 R t$ $\quad W = I^2 R t$

Joule's law : $P \propto I^2$ rate at which heat is produced $\propto I^2$ (for constant Resistance)

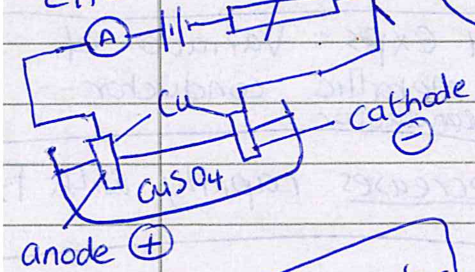
Mandatory Exp to verify Joule's law

High voltage used in transmission lines (Extra High Tension EHT)

Since $P = VI$ so make I small V big

Then small I means I^2 small means less heat lost in wires

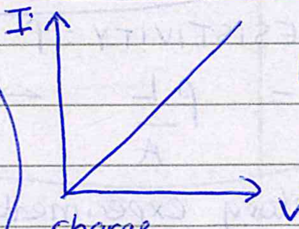
CHEMICAL EFFECT



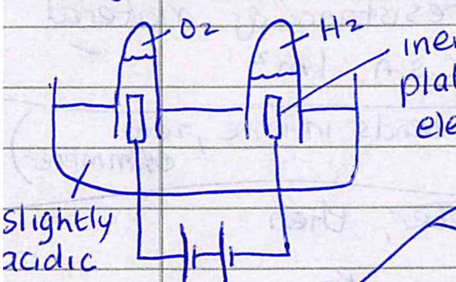
Anode: $Cu \rightarrow Cu^{2+} + 2\bar{e}$ (Cu^{2+} goes into electrolyte; ↑ ion)

Cathode: Cu^{++} in electrolyte takes $2\bar{e}$ from cathode to become Cu (plates onto cathode)

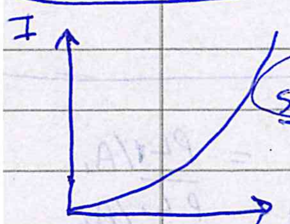
$Cu^{2+} + 2\bar{e} \rightarrow Cu$



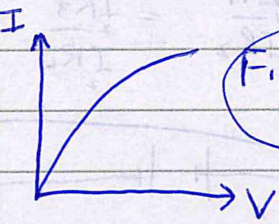
or Hydrolysis of water



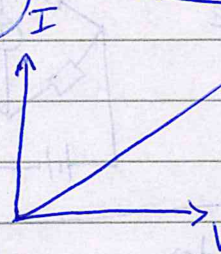
chemical effect used in
- electroplating
- extracting metals from their ores
- purifying metals
- making electrolytic capacitors (large C)

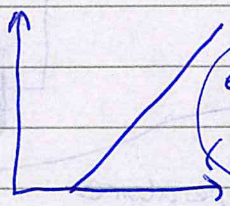


Charge carriers = holes, electrons

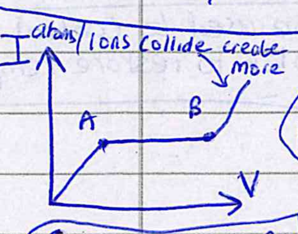


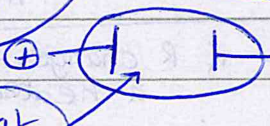
Charge carriers = electrons





charge carriers = IONS





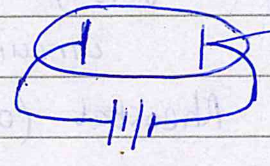
Gas at low pressure

background ions

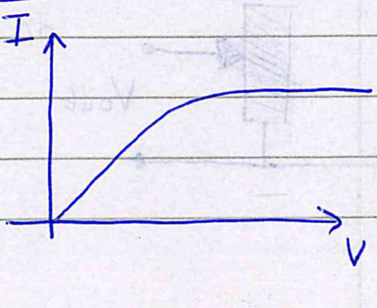
charge carriers = positive ions, electrons, small few negative ions

SODIUM VAPOUR lamp / NEON lamp

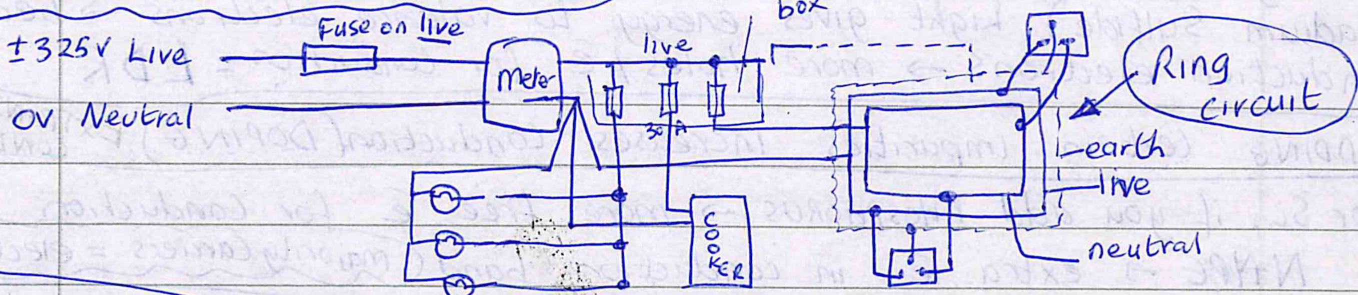
vaccuum tube



cathode (heated) causing thermionic emission



DOMESTIC ELECTRIC CIRCUITS:



Appliances taking a large current have separate live & neutral wire & large fuse — RADIAL Circuit

Lights connected in parallel

Switch should always be connected to live wire so when it is open it is disconnected from live.

Fuse: designed to melt if current too large
** Connect live wire so live gets disconnected

M.C.B = Miniature Circuit Breaker
contains a bimetallic strip (small currents) and electromagnet (large currents)

RESIDUAL CURRENT DEVICE
* faster than fuse to react
* can be reset by flicking a switch

R.C.D. detect difference between live and neutral and trips very quickly - faster than MCB or fuse

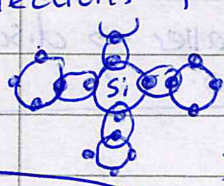
Live = Brown → right
Neutral = Blue → left
Earth = green/yellow

EARTHING
Connects appliance to earth thro metal wire so if live touches the appliance then current flows through to earth not through person

KILOWATT HOUR = unit of electricity
= amount of energy used by a 1000W appliance in 1 hour (1W = 1J/s)
(1kWh = 1 E.S.B. unit)

SEMICONDUCTORS = substance whose resistivity is between that of a good conductor and a good insulator
silicon, germanium, cadium sulfide

not many electrons free to move - they are in bonds (covalent) with 4 other Si atoms (valence electrons)



Some few bonds can break and few ē can be free to move → (conduction electrons)

INTRINSIC CONDUCTION

HOLE = gap left behind by an electron that has broken free. Other valence ē can move into this leaving behind a hole ○ ← ē ← ē
(as if holes were moving)

Intrinsic conduction = conduction in pure semiconductor due to ē moving from ⊖ to ⊕ and an equal no. of holes moving from ⊕ to ⊖

As T >>> more valence electrons break free from covalent bonds and become conduction electrons (free to move). They leave behind holes
This increases the conductivity → holes + electrons are the charge carriers

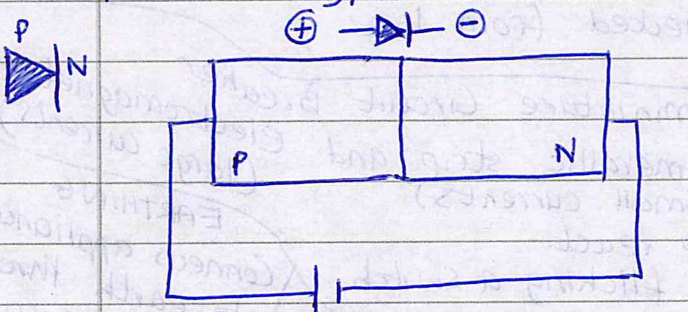
Shining light on some semiconductors increase their conductivity (Cadium Sulfide). Light gives energy to valence electrons → become conduction electrons → more holes / $\bar{e}$ for conduction = LDR

ADDING certain impurities increases conduction (DOPING) EXTRINSIC CONDUCTION

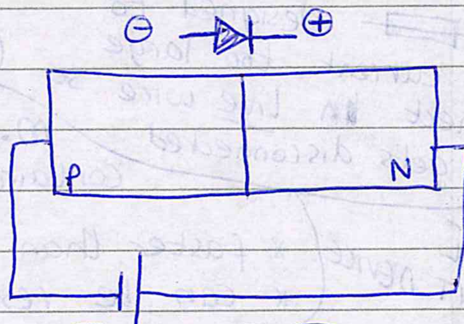
For Si, if you add PHOSPHORUS → more free $\bar{e}$ for conduction
N TYPE → extra $\bar{e}$ in conduction band (majority carriers = electrons)

For Si, if you add BORON → more holes available at valence level → allows conduction (majority carriers = holes)

Join P and N type together to make a diode:

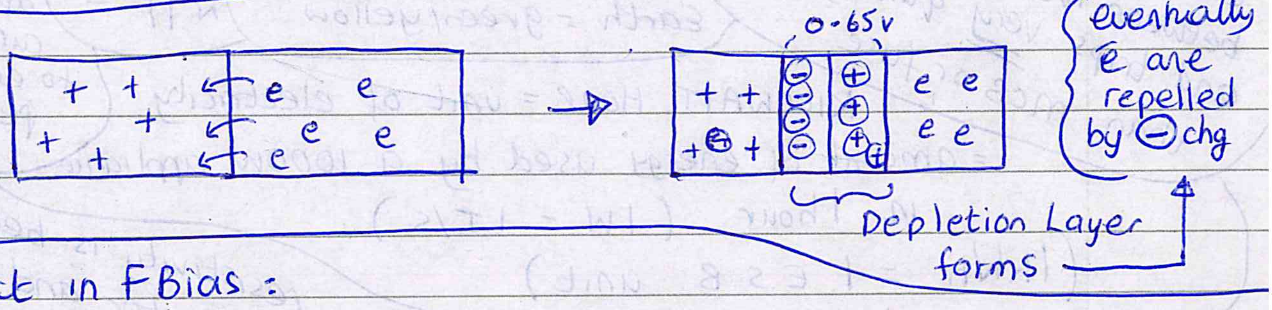


(Forward Biased)

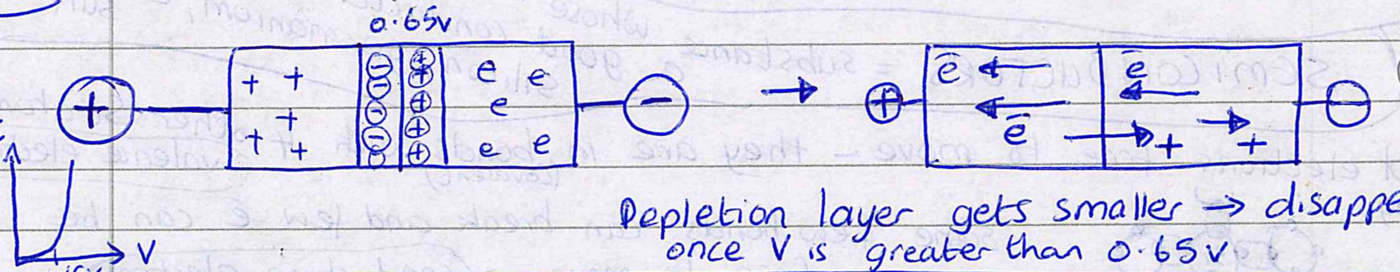


(Reverse Biased)

join P and N:

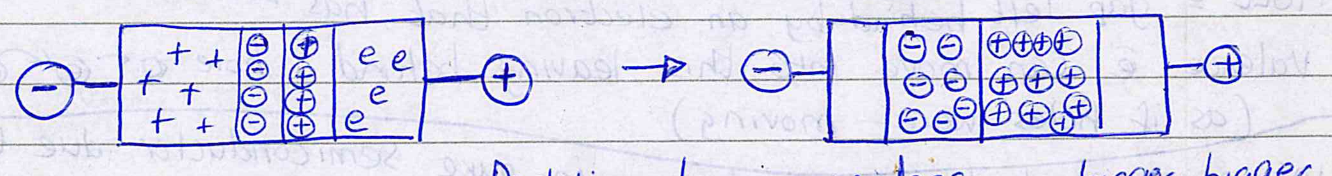


(NOW) Connect in F Bias:



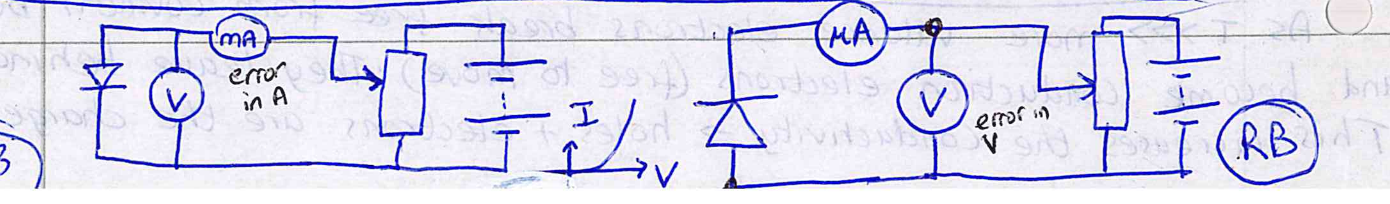
Depletion layer gets smaller → disappears once V is greater than 0·65V

Connect in R. bias

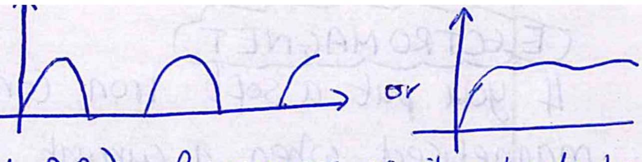


Depletion layer widens → bigger, bigger until breakdown occurs when depletion layer is full length

**



Diode Rectification (AC → DC)

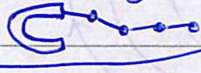


Diodes used in rectifiers ↗
also in light detector circuits (LDR) — R increases as it gets dark
R decreases as it gets bright
also L.E.Ds to emit light

* normally get a resistor in series with diode to protect it from current that is too large.

MAGNETISM: lodestone, magnetite is naturally magnetised

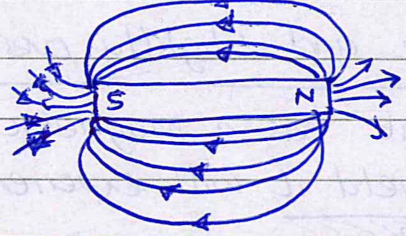
Ferromagnetic materials are attracted to magnets (e.g. iron) (nickel, cobalt).
A magnet magnetises ferromagnetic materials when they are close (eg. Pins

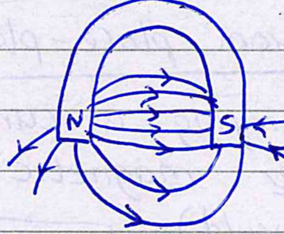


A magnetic field:
space around a magnet or any region of space where magnetic force can be felt.

DIRECTION of magnetic field = direction of the force a North pole would experience at that point. ⊘ plotting compass

Magnetic Field Line: Line drawn so that the tangent to it at any point shows the direction of the magnetic field at that point.



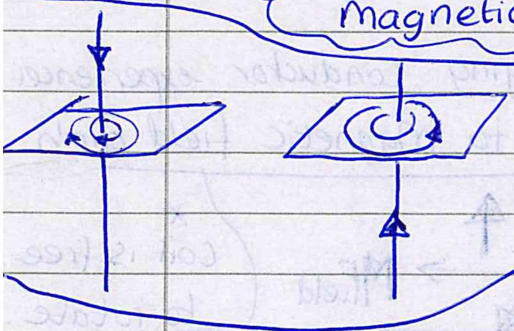


can use iron filings or plotting compasses

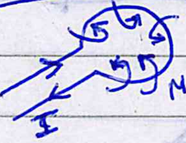
In 1819 Hans C. Oersted discovered that a current carrying wire has a magnetic field around it → only when current flows. DEMO!

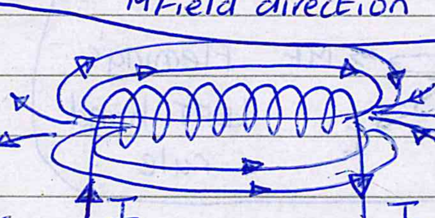
Needle deflects whenever current changes value (or direction)

* EVERY current carrying conductor has a magnetic field around it caused by current



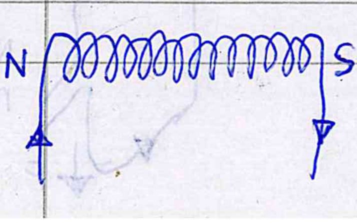
Right hand grip rule





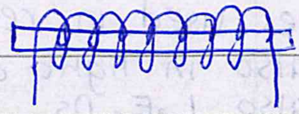
look into loop. If I moves clkwise your end is south

solenoid (coil whose length is much longer than radius)

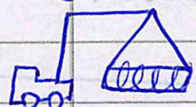


ELECTROMAGNET

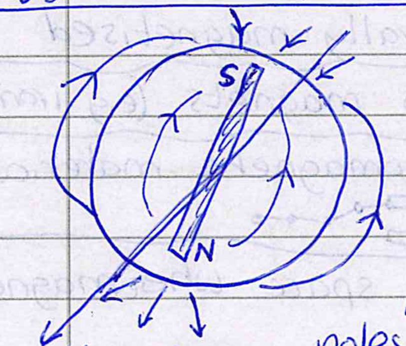
If you put a soft Iron Core <u>into</u> Solenoid, then it becomes magnetised when a current flows in solenoid



Large No of turns (N) & large current ⇒ Strong magnet.



electromagnet used in Scrapyards (& M.C.B's)

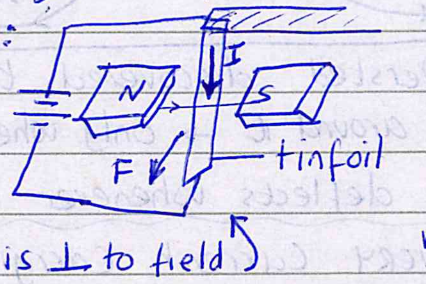


earth's axis

Earth's Magnetic Field: Due to circulating electric currents in core.

As if there is a huge bar magnet at centre. The end that all magnet(N)'s point to <u>is</u> a south pole but this is called 'NORTH' as the north poles of magnets point to it. The Earths 'magnet' is not aligned fully with North - South axis. So there is a difference between true North and magnetic North as per compass. The angle between true North and magnetic North = magnetic declination / variation. Amount of declination varies from place - place <u>and</u> slightly over time.

Because a Conductor carrying a current has a magnetic field, if you put it in <u>another</u> magnetic field it will experience a force (just like 2 magnets would):



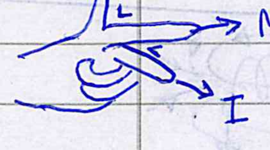
when current flows tinfoil moves as it gets a force due to its magnetic field interacting with magnets mag. field.

⊛ If tinfoil was placed parallel to magnetic field it would <u>NOT</u> experience a force. Here it is ⊥ to field

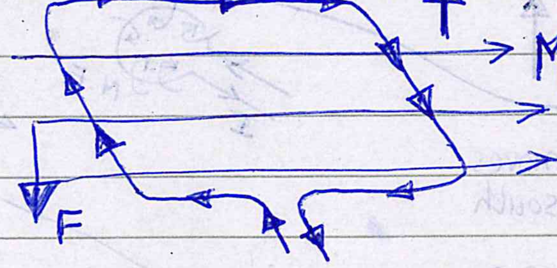
---

⊛ The Direction of the Force a current carrying conductor experiences is <u>always</u> (i) ⊥ to current direction (ii) ⊥ to Magnetic field dir'n

---



Fleming's LEFT hand rule



* Coil is free to rotate.

With I in direction shown, coil will rotate anticlockwise. If I changes direction It rotates other way.

No rotation