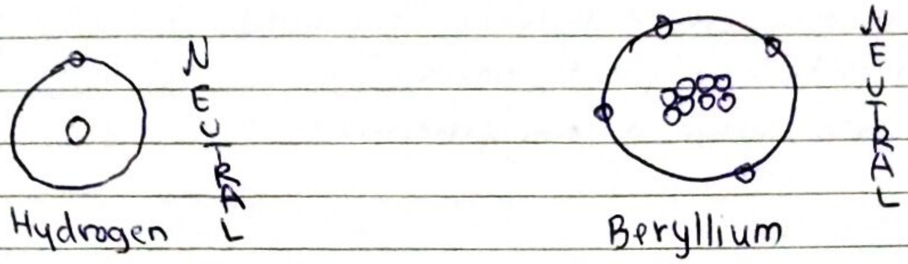
5. Electricity and Magnetism

Date

5.1 Electric fields

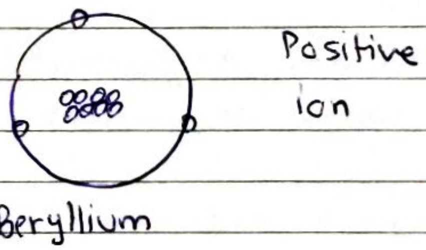
1) Essential idea - when charges move, an electric current is created.

2) Electrons orbit a central nucleus.

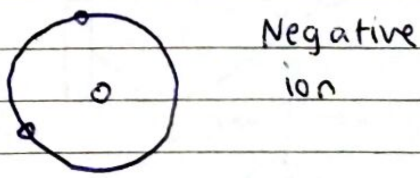


3) If electrons = protons, charge is 0 or the atom is neutral.

4) If an electron is removed from an atom, it becomes a positive ion. (+)



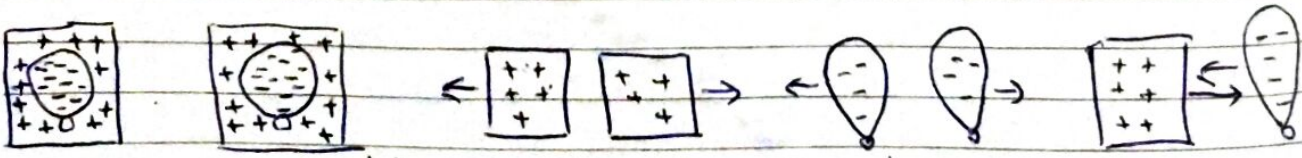
5) If an electron is added ~~from~~ to an atom, it becomes a negative ion. (−)



6) Elementary charge e.

1 electron = 1.60×10^{-19} Coulomb	the elementary charge

7) If we rub a balloon and wool, the balloon strips off some electrons from the wool.



Like charges repel.
Unlike charges attract.

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8) For every (-) transferred to the balloon, there is exactly one (+) left behind on the wool.

Total (or net) charge = ZERO

WE CREATED NO NET CHARGE IN THE PROCESS.

9) Law of conservation of charge

Charge can be neither created nor destroyed.

It can be transferred from one object to another. We can have a (-) on a ~~wool~~ balloon, but leaving behind behind an equal (+) charge on the wool.

Example A balloon has picked up 150µC of charge from Albert the cat.

a) How ~~may~~ many electrons have been transferred?

$$1e = 1.60 \times 10^{-19}$$

$$\frac{-150 \times 10^{-6}}{-1.60 \times 10^{-19}} = 9.4 \times 10^{14} e^-$$

b) What is the charge on Albert?

~~$q_{albert} = 150 \mu C$~~ $q_{albert} = +150 \mu C$

10) Materials

1) Conductors- easily transfer electrons without capturing them
2) Non conductors or insulators- capture or impede (delay) electrons
3) Semiconductors- lie between conductors & insulators.

Metals are generally good conductors, non metals are insulators, and metalloids are good semiconductors.

11) Electroscope

You place a charge on the ball. Since each leaf has some of the original charge, they repel. Can't tell if + or - charge.

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12. Electric current I is the time rate Δt at which charge Δq moves past a particular point in a circuit.

$I = \Delta q / \Delta t$	Electric (A)
Current $= \frac{\Delta \text{ charge}}{\Delta \text{ time}}$	$(C s^{-1})$ current (Ampere)

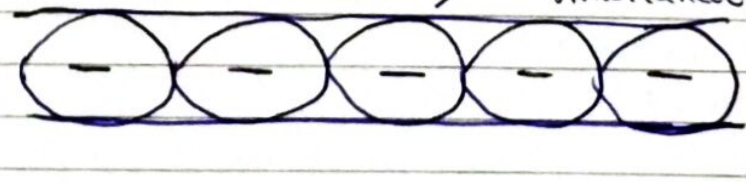
Example: Houses have 20 ampere service. How many electrons per second is this?

$1e = 1.60 \times 10^{-19}$ C

$20\text{ A} = 20\ C s^{-1}$

$\frac{20}{1.60 \times 10^{-19}} = 1.25 \times 10^{20}\ e^- = 1.3 \times 10^{20}\ e^-$

13) Think that conductors are pipes. The chemical cell pushes an electron out of the (−) side. This electron pushes the next, & so on, because like charges repel. The "electromotive" force is transferred simultaneously to every charge in the circuit.



14) Explain why when a wire is cut current stops everywhere and does not "leak" into the air.

- Freeing an e^- from a conductor takes a lot of energy. This is why you don't get electrocuted by outlets (the voltage is low). So, when you cut the wire e^- do not leak out into the surrounding environment. Finally, when chain is broken the push stops, so currents stops everywhere.

15) Coulomb's law, (electric force F between two point charges q_1 & q_2 separated by distance r.

$F = \frac{k q_1 q_2}{r^2}$	Coulomb's law	where $k = 8.99 \times 10^9\ Nm^2C^{-2}$	k = Coulomb's constant

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There is an alternate form of Coulomb's law:

$F = \left(\frac{1}{4\pi\varepsilon_0}\right)\left(\frac{q_1 q_2}{r^2}\right)$	Coulomb's law	ε_0 = permittivity of free space
where $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2 N^{-1} m^{-2}$	$k = \frac{1}{4\pi\varepsilon_0}$	

Example

Show that $\frac{1}{4\pi\varepsilon_0}$ equals k.

$k = 8.99 \times 10^9$ ~~$Nm^{2}C^{-2}$~~ $Nm^2 C^{-2}$

$$\frac{1}{4\pi \times 8.85 \times 10^{-12}} = 8.99 \times 10^9 = k$$

Either of the 2 equations can be used. The first is easier though.

Practice

Find the Coulomb force between $2e^-$ located 1.0cm apart.

$F = \frac{kq_1q_2}{r^2}$

$$F = \frac{8.99 \times 10^9 \times (1.60 \times 10^{-19})^2}{0.01^2} = 2.3 \times 10^{-24}\ N$$

The electrons repel.

Practice If the 2 electrons were embedded in a chunk of quartz, having a permittivity of $12\varepsilon_0$, what will the Coulomb force be between them if they are 1.0 cm apart?

$$\frac{q_1q_2}{4\pi\varepsilon_0 \times r^2} = 2.3 \times 10^{-24}$$

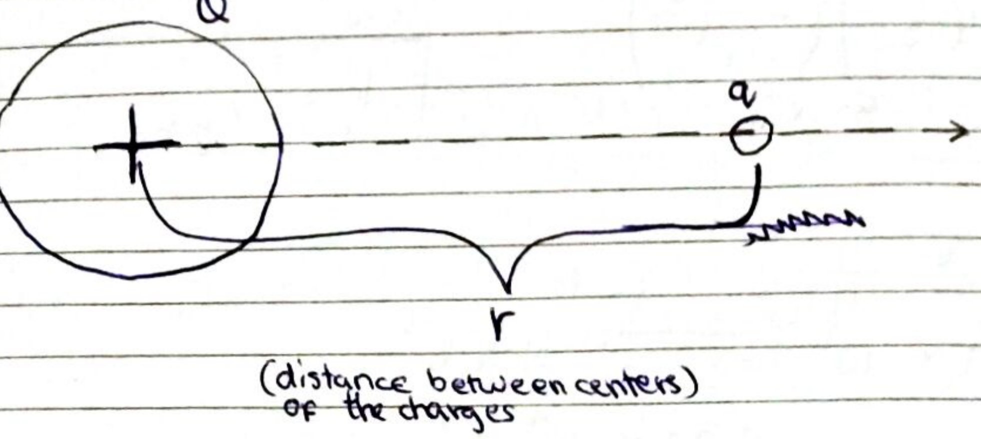
$$\frac{\frac{q_1q_2}{4\pi \times \cancel{8}\varepsilon_0 \times r^2}}{\frac{12}{\frac{q_1q_2}{4\pi\varepsilon_0 \times r^2}}} = \frac{\cancel{x}F_1}{2.3 \times 10^{-24}} = \frac{1}{\cancel{8}12}$$

~~$x\ F_1 = \frac{2.3 \times 10^{-24}}{12\ 8} = 2.88 \times 10^{-25}$~~ N

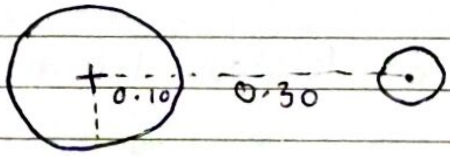
$$F_1 = \frac{2.3 \times 10^{-24}}{12} = 1.92 \times 10^{-25}\ N$$

KIKY

16) Coulomb's law work for any spherical distribution of charge at any radius.



Example A conducting sphere of radius 0.10m holds an electric charge of $Q = +125\mu C$. A charge $q = -5.0\mu C$ is located 0.30m from the surface of Q. Find the electric force between the two charges.



$\mu = \times 10^{-6}$

$$F = \frac{kq_1q_2}{r^2}$$

$$F = \frac{(8.99\times10^9)(125\times10^{-6})(-5.0\times10^{-6})}{0.40^2}$$

$= \cancel{-0.000035\ N}$

$= \cancel{-35\times10^{-5}}\ -35\ N$

17) Suppose a charge q is located at a distance r from another charge Q.

Electric field strength E is the force per unit charge acting on q due to the presence of Q.

$E = F/q$	Electric field strength	Newtons per Coulomb (NC^{-1})

E.g. Find the electric-field strength 1.0 cm from an electron.

$F = \frac{(8.99\times10^9)(1.60\times10^{-19})^2}{0.01^2} = 2.3\times10^{-24}$; $E = \frac{2.3\times10^{-24}}{1.6\times10^{-19}} = 1.4\times10^{-5}\ NC^{-1}$

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Example

Let q be a small charge located a distance r from a larger charge Q. Find the electric field strength due to Q at a distance r from the center of Q.

$$F = \frac{(8.99\times10^{9})(Q)(q)}{r^2}$$

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

$$\boxed{F = Eq}$$

$$Eq = \cancel{8.99\times10}\ \frac{kQq}{r^2}$$

$E = \dfrac{kQ}{r^2}$	Electric field strength at a distance r from the center of charge Q.

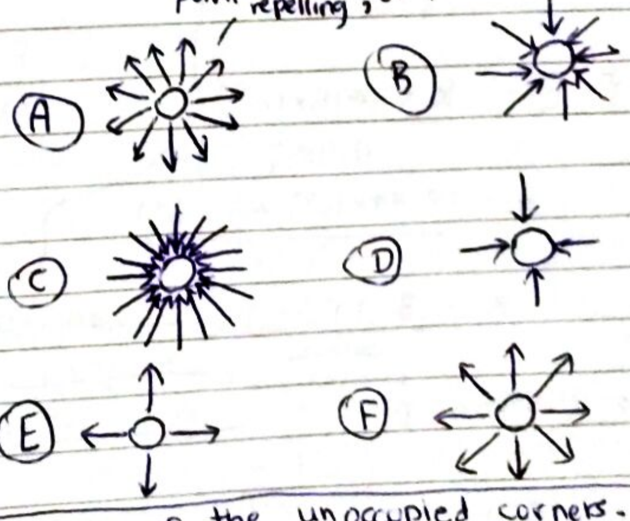
~~17) Albert Einstein Fastest thing on Earth is light. Travels at $3.00\times10^{8}\ ms^{-1}$.~~

18) The space surrounding a nucleus is distorted by its charge in such a way that the electron "knows" how to act.

Electrons know which way to curve in their orbits by knowing the local curvature of their immediate environment.

Test charges are by definition (+) charges.

Point charges repelling, so positive charge.



Example

a) Largest negative charge? C

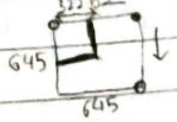
b) Largest positive charge? A

c) Smallest negative charge? D

d) Smallest positive charge? E

Example Two charges of −0.225C each are located at opposite corners of a square having a side length of 645m. Find the electric field vector at

a) the center of the square



$$E = \frac{kQ}{r^2} = \frac{8.99\times10^{9}\times(-0.225)}{456^2}$$

$$= -9724\ NC^{-1}$$

But, they cancel out.

(KKY) $E = 0\ NC^{-1}$

b) one of the unoccupied corners.

$$E = \frac{8.99\times10^{9}\times(-0.225)}{645^2}$$

$E_1 = -4860\ N/C^{-1} \downarrow$ $E_2 = -4860\ NC^{-1} \leftarrow$

$E^2 = E_1^2 + E_2^2 = 2(4860)^2$, $E = 6880\ NC^{-1}$

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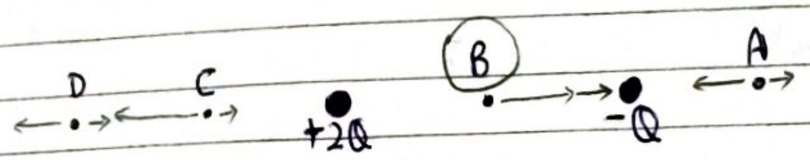
Practice:

Two stationary charges are shown. At which point is the electric field strength the greatest?

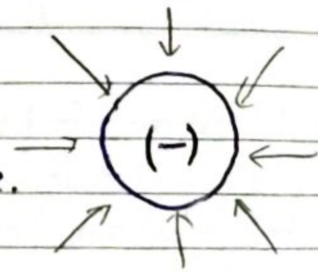


- Sketch in the field due to each charge at each point.
- Fields diminish as $1/r^2$.
- Fields point away from (+) and toward (-).
- The only place the fields add is point B.

Practice:

An isolated metal sphere of radius 1.5cm has a charge of -15nC placed on it.

a) Sketch the electric field lines outside the sphere.



b) Find the electric field strength at the surface of the sphere.

radius $r = 1.5\text{cm}$

charge $= -15\text{nC}$

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

$$E = \frac{k \times (-15\times10^{-9})}{0.015^2}$$

$$= \frac{(8.99\times10^{9})(-15\times10^{-9})}{0.015^2}$$

$$= \frac{(8.99)(-15)}{0.015^2} = \cancel{-53940\ NC^{-1}} = \cancel{-54000\ NC^{-1}} = \cancel{-5.4\times10^{4}\ NC^{-1}}$$

$= 599333\ NC^{-1}$

$= 600000\ NC^{-1}$

$= 6.0\times10^{5}\ NC^{-1}$

c) An electron is placed on the outside surface of the sphere and released. What is its initial acceleration?

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

~~Fe = Eq~~

The electron feels force Eq,

$= (6.0\times10^{5})(1.6\times10^{-19}) = 9.6\times10^{-14}$

$F = ma$

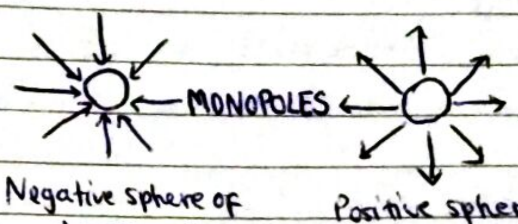
$9.6\times10^{-14} = ma$

$$\frac{9.6\times10^{-14}}{9.11\times10^{-31}} = a = 1.1\times10^{17}\ ms^{-2}$$

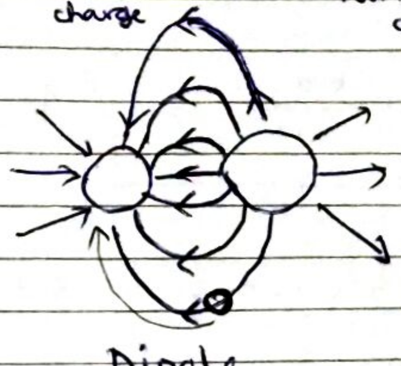
Date

19) Electric monopoles & dipoles

A single charge is called a monopole.

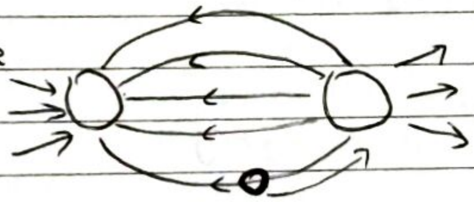


If two opposite electric monopoles are near enough to each other.



Dipole

If the charges are negative



Practice

If the charge ~~of~~ on a 25cm radius metal sphere is +150 μC, calculate

a) Electric field strength at the surface.

$$E = \frac{kQ}{r^2}$$

$$E = \frac{8.99 \times 10^9 \times \cancel{0.25}\ 150 \times 10^{-6}}{0.25^2} = 2.2 \times 10^7\ NC^{-1}$$

b) Field strength 25 cm from the surface

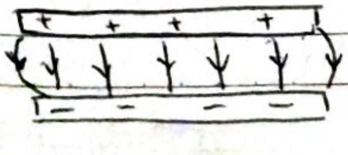
$$\frac{8.99 \times 10^9 \times 150 \times 10^{-6}}{0.50^2} = 5.4 \times 10^6\ NC^{-1}$$

c) Force on a $-0.75\ \mu C$ charge placed 25 cm from the surface

$$F = Eq = 5.4 \times 10^6 \times (-0.75 \times 10^{-6}) = -4.05\ N = -4.1\ N$$

(It is an attractive force. (- sign))

Example If we take 2 parallel plates of metal & give them equal & opposite charge, what does the electric field look like between the plates?



$E = \frac{V}{d}$	Electric Field strength	For parallel plates

V = Potential difference
d = distance between plates.

(KKY)

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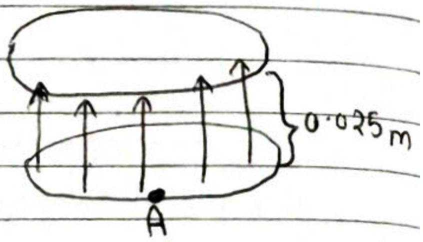
Practice

Uniform Electric field strength is 275 NC^{-1}. A +12 μC charge having a mass of 0.25 g is placed in the field at A & released.



a) Electric force acting on the charge?

$$F = \frac{k q_1 q_2}{r^2} = Eq$$

$$\cancel{= 8.99 \times 10^{9} \times 12 \times 10^{-6} \times}$$

$$275 \times 12 \times 10^{-6} = 3.3 \times 10^{-3} N$$

b) Weight of the charge

$$Weight = 0.00025 kg \times 9.81$$
$$= 0.0025 N$$

c) Acceleration of the charge?

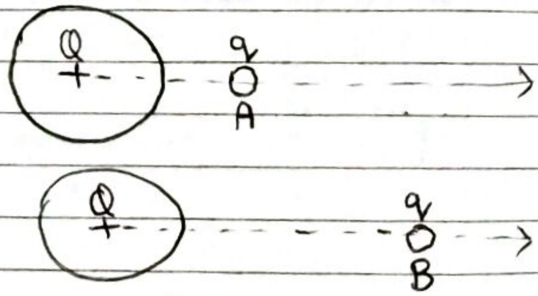
$$F_{net} = ma$$
$$F = 0.00025 \times a$$

$$0.0008 = 0.00025 \times a$$
$$a = 3.2 \; ms^{-2} (\uparrow)$$

2) **Potential difference**

Because electric charges experience the electric force, when one charge is moved in the vicinity of another, work W is done.

(area) or (district)



(W)

Potential difference (V) - amount of work done per unit charge in moving a point charge from one point to another.

$V = \frac{W}{q}$	Potential Difference	Volts = JC^{-1} = V

Practice

$q = {}^{+}15 \mu C$ moved from point A, having a voltage of 25.0 V to point B, having a voltage of 18.0 V.

a) what is the P.D. undergone by the charge?

$$V = V_B - V_A = 18 - 25 = -7.0 V.$$

b) What is the work done in moving the charge from A to B?

$$-7.0 = \frac{W}{\cancel{1.6 \times 10^{-19}} \; 15 \times 10^{-6}}, \quad W = 1.1 \times 10^{-4} J$$

(KIKY)

ΔV or V are same.

Date

1) Joules are too large and awkward.

Electronvolt (eV) - work done when an elementary charge e is moved through a potential difference V.

$W = qV$

$1\ eV = eV = (1.60 \times 10^{-19})(1\ V) = 1.60 \times 10^{-19}\ J$

$1 eV = 1.60 \times 10^{-19} J$	Electronvolt conversion

Practice

An electron is moved from point A, having a voltage (potential) of 25.0 V, to Point B, having a voltage (potential) of 18.0 V.

a) What is the work done (in eV and in J) on the electron by the external force during the displacement?

Scalar value

$V = \frac{W}{q}$ OR $-7 = \frac{W}{e}$

$-7 = \frac{W}{-1.6 \times 10^{-19} C}$ $7\ eV = W$

$W = 1.12 \times 10^{-18}\ J$

$= 7\ eV$

b) If the electron is released from Point B, what is its speed when it reaches point A?

$\Delta E_K + \Delta E_P = 0$

$\Delta E_P = -1.12 \times 10^{-18}\ J$

$1.12 \times 10^{-18} = (\frac{1}{2} \times mv^2) - \frac{1}{2} mu^2$

$= \frac{1}{2} m v^2 - \frac{1}{2} m(0)^2$

$1.12 \times 10^{-18} = \frac{1}{2}(9.11 \times 10^{-31}) v^2$

$2.5 \times 10^{12} = v^2$

~~v = 1.57~~ ~~v = 1.6 x~~

$v = 1.57 \times 10^6\ ms^{-1}$

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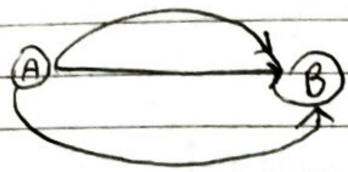
22) Potential difference - path independence

Example

A charge of $q = +15.0\,\mu C$ is moved from point A, having a voltage (potential) of 25.0 V to point B, having a voltage (potential) of 18.0 V, in 3 different ways. What is the work done in each case?



$$18.0 - 25 = -7\ V$$

$$-7 = \frac{W}{q}$$

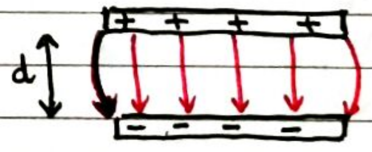
$$-7 = \frac{W}{-15 \times 10^{-6}}$$

$$W = 1.05 \times 10^{-4}\ J$$

Work is independent of the path because the electric force is a conservative force.

~~E.g. A charge of q = +15.0 μC is moved from Point A, having a voltage (potential) of 25.0 V to poin B, having a voltage (potential) of 18.0 V, in 3 different ways. What is the work done in each case?~~

$$\boxed{W = (Eq)d = Fd\cos 0^\circ}$$



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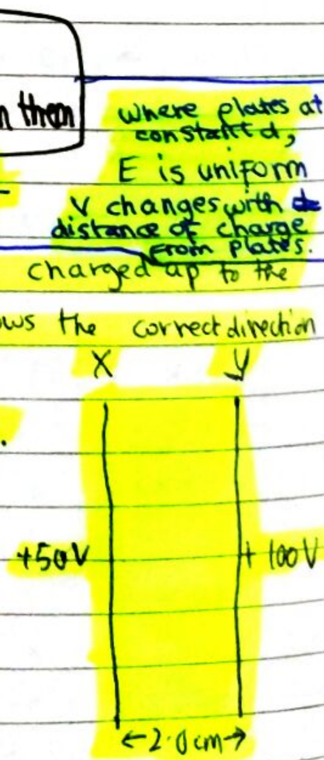
$\boxed{V = Ed}$ For parallel plates with a P.D., d is the separation between them

Voltage = Electric field x displacement

$E = \frac{V}{d}$ where plates at constant d, E is uniform, V changes with distance of charge from plates.

Practice: Two parallel plates with plate separation 2.0 cm are charged up to the potential difference shown. Which one of the following shows the correct direction and strength of the resulting electric field?

a) $X \rightarrow Y$, $25\ Vcm^{-1}$
b) $X \rightarrow Y$, $100\ Vcm^{-1}$
c) $Y \rightarrow X$, $25\ Vcm^{-1}$ ✓
d) $Y \rightarrow X$, $100\ Vcm^{-1}$



Always + to − or less positive.

Y has higher positive, so electric field from Y → X.

$$V = Ed$$

$$100 - 50 = E \times \cancel{0.02}\ 2$$

$$\frac{50}{2\ \cancel{0.02}} = E = 25\,Vcm^{-1}$$

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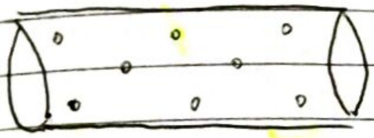
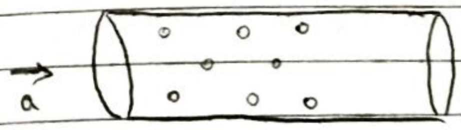
Identifying sign and nature of charge carriers in a metal

23) Charge carriers in a metal are electrons. (-)

24) Assuming the charge carriers in a conductor are free to move, if a conductor is suddenly accelerated, the electron would "pool" at the trailing side due to inertia, and a P.D. measured by a voltmeter would be set up between the ends.



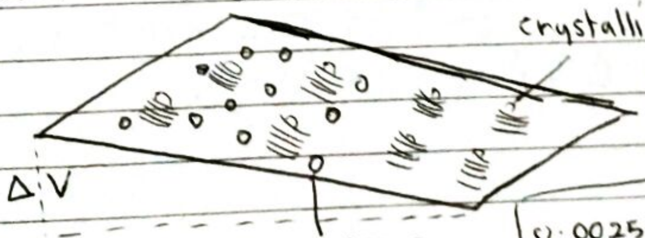
Now the conductor gets accelerated...



There is a potential difference between the ends, measured by a voltmeter.

25) Drift velocity

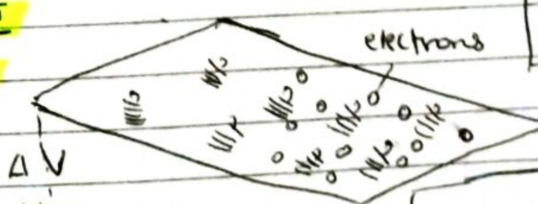
If we place that same portion of conductor under the influence of a potential difference, we have a slow drifting of the velocities towards the lower potential.



- Net current is not zero

- Electrons still have a high velocity, but this time the net migration is in the direction of the lower potential.

Then!



- Speed of this net migration is called drift velocity.

PRACTICE

Drift velocity is $0.0025\ ms^{-1}$ for your house wiring. If wire between your light switch & light bulb is 6.5m, how long does it take an electron to travel from the switch to the bulb?

$v = d/t$

$0.0025 = 6.5/t$

$t = 6.5/0.0025$

$t = 2600$ seconds

$= 43.3$ min

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Date

$\boxed{I = nAvq}$ Current vs. dript velocity

Current I = No of free charges per units volume X cross-sectional area X drift velocity X charges

Number density

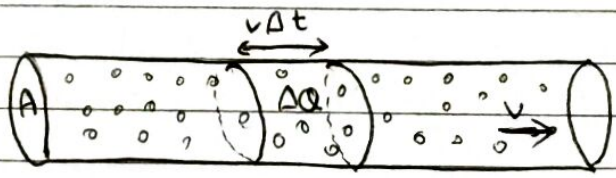
Practice

Suppose the current in a 2.5mm diameter copper wire is 1.5A and the no. density of the free electrons is $5.0 \times 10^{26}\ m^{-3}$. Find the drift velocity.

$$I = nAvq$$

$$1.5 = 5 \times 10^{26} \times (\pi \times 0.00125^2) \times v \times 1.6 \times 10^{-19}$$

$$v = \frac{1.5}{5 \times 10^{26} \times 0.00125^2 \pi \times 1.6 \times 10^{-19}} = 0.00382\ ms^{-1} = 3.8 \times 10^{-3}\ ms^{-1}$$



Through any time interval Δt, only the charges ΔQ between the two black Cross-sections will provide the current I.

The volume containing the ~~current~~ charge ΔQ is $V = Av\Delta t$.

Thus $\Delta Q = nVq = \cancel{nAv\Delta tq}\ nAv\Delta tq$.

Finally, $I = \Delta Q / \Delta t = nAvq$.

KIKY

5.2 Heating effect of electric currents

Date

Resistance

Partially made of carbon.
The lesser the carbon, the more the resistance.

Wire-wound resistors, variable resistors, potentiometers, thermistors, LDRs

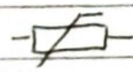
Definition
1) Electrical resistance R is a measure of how hard it is for current to flow through a material. (Ω) (ohms) Measured using ohm-meter.
~~2) Resistance R of a material is the ratio of the potential difference~~

2)

Fixed-value resistor


potentiometer


variable resistor


thermistor
Temperature ↑, resistance ↓


Light-dependent resistor (LDR)

Brightness ↑ resistance ↓
(whatever, just remember it.)

3) Resistance (R) of a material is the ratio of the P.D. V across the material to the current I flowing through the material.

4) $\boxed{R = V/I}$ Electric resistance

$V A^{-1} = \Omega$

E.g.
Fixed resistor has current 18.2 mA when it has a 6.0 V P.D. across it.
What is its resistance?

$$R = \frac{V}{I} = \frac{6.0}{0.0182} = 330\ \Omega$$

5) Factors affecting resistance
① $\boxed{R \propto L}$ (Length)
② $\boxed{R \propto \frac{1}{A}}$ (Area)

$R \propto \frac{L}{A}$

③ Resistance also depends on material. (material) (ρ is material)
ρ = proportionality constant
$\boxed{R = \frac{\rho L}{A} \text{ or } \rho = \frac{RA}{L}}$ Resistance equation
ρ is different for all materials.

④ Temperature
As temperature increases, resistance increases.

Date

Practice

What is the resistance of a 0.00200 m long carbon core resistor having a core diameter of 0.000100 m? Temperature is 20°C, assume. ρ of carbon $= 3600 \times 10^{-8}\ \Omega m$

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

$$R = \frac{\rho \times 0.002}{\pi (0.00005)^2}$$

$$R = \frac{3600 \times 10^{-8} \times 0.002}{\pi (0.00005)^2}$$

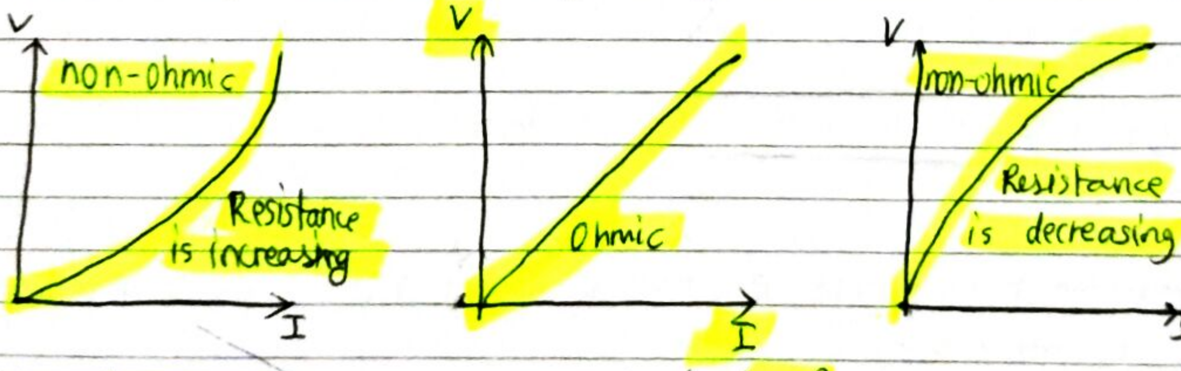
$$= 9.17\ \Omega$$

6) Ohm's Law

IF TEMPERATURE IS CONSTANT, RESISTANCE IS CONSTANT.
Voltage is directly proportional to current.

$V \propto I$ or $\frac{V}{I}$ = CONSTANT or $V = IR$	Ohm's law

7) A material is ohmic if it follows Ohm's law. In other words, its resistance stays constant as voltage changes.



8) Why does a bulb not follow Ohm's law?

- Hotter the filament, the higher the R.
- But, the more current, the hotter a filament ~~lamp~~ burns.
- Thus, the bigger the I, the bigger the R.
  NOT an Ohmic conductor because resistance is not constant.

KIKY

No.

Date:

9) Power dissipation

Power - rate at which work is being done.

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

we learnt that $W = qV$

Thus. $P = \frac{W}{t} = \frac{qV}{t}$

$$= \left(\frac{q}{t}\right)V$$

$$\boxed{P = IV}$$

Energy per unit time delivered to, or consumed by, an electrical component with Current I and Potential difference V.

$$R = \frac{V}{I}$$

$= V = IR$

$P = IV = I \times IR = I^2R$

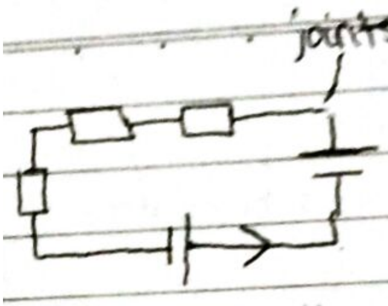
$P = I^2R$	Electrical power

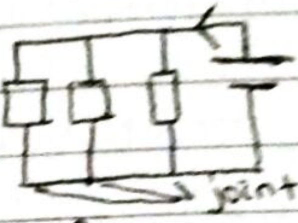
$$R = \frac{V}{I}$$

$$I = \frac{V}{R}$$

$$P = IV = \frac{V}{R} \times V = \frac{V^2}{R}$$

$P = \frac{V^2}{R}$	Electrical power

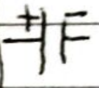


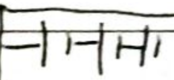
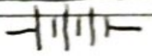


Series circuit
Single - loop

Parallel circuit
Triple - loop

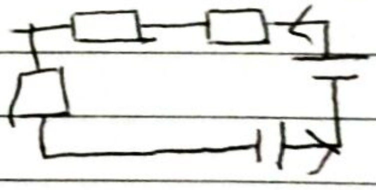
Current flows from + to −.

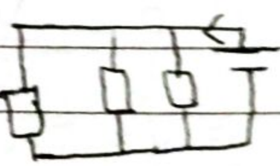
 cell

 or  battery

 resistor

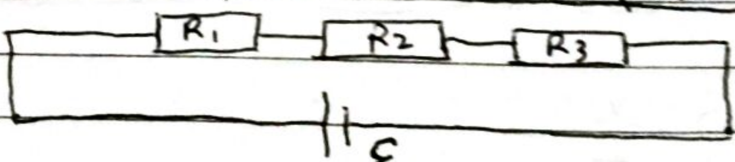
Example





b) Series Circuits

I is the same for all series components.



$\mathcal{E}$ E.M.F symbol

Conservation of energy tells us that:

$q\mathcal{E} = qV_1 + qV_2 + qV_3$ (workdone).

$\mathcal{E} = IR_1 + IR_2 + IR_3$ from Ohm's law. $V = IR$

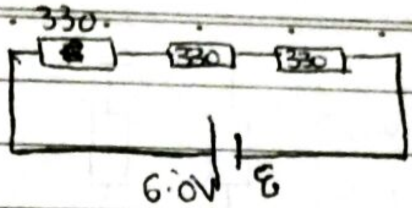
$= I(R_1 + R_2 + R_3)$ Equivalent

$\boxed{R = R_1 + R_2 + R_3 + \ldots}$ Resistance in series

No.

Date:

Example



a) What is the circuit's equivalent resistance?

$330\,\Omega \times 3 = 990\,\Omega$

b) Current in the circuit?

$V = IR$

$I = \frac{6}{990} = 0.61 \times 10^{-2}\ A$

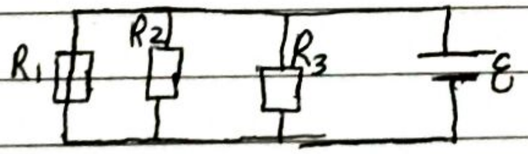
$= 0.0061\ A$

c) Voltage on each resistor?

$V = 0.0061 \times 330$

$= 2.0V$

II) Parallel circuits



V is the same for all parallel components.

$\varepsilon = V_1 = V_2 = V_3 \equiv V$

There are 3 currents though. I_1, I_2, I_3

$I = I_1 + I_2 + I_3$

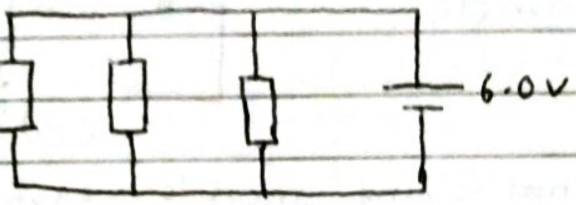
OR

$\frac{\varepsilon}{R} = \frac{V_1}{R_1} + \frac{V_2}{R_1} + \frac{V_3}{R_3}$ $\quad I = \frac{V}{R}$

$\frac{V}{R} \rightarrow \boxed{\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots} \rightarrow$ Equivalent resistance in parallel

Example

a) Circuit's resistance?



Ans $\frac{1}{R} = \frac{1}{330} + \frac{1}{330} + \frac{1}{330}$

330 Ω each.

$\frac{1}{R} = \frac{3}{330}$

$\frac{R}{1} = \frac{330}{3}$

$R = 110\ \Omega$

b) What is the voltage on each resistor?

Ans 6.0 V

c) Current in each resistor?

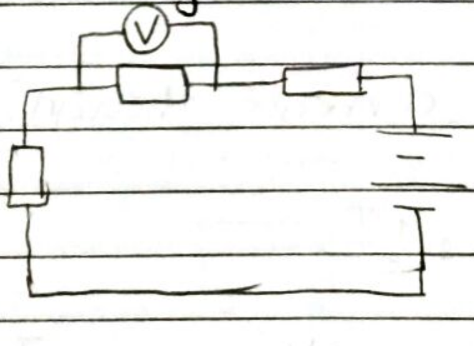
$I_1 = \frac{V_1}{R_1} = \frac{6.0}{330} = 0.0182$

$= 0.018\ A$

$I_2 = \frac{6.0}{330} = 0.018A$

$I_3 = \frac{6.0}{330} = 0.018A$

12) Voltmeter is always connected to a circuit in parallel.



09.4
Voltmeter

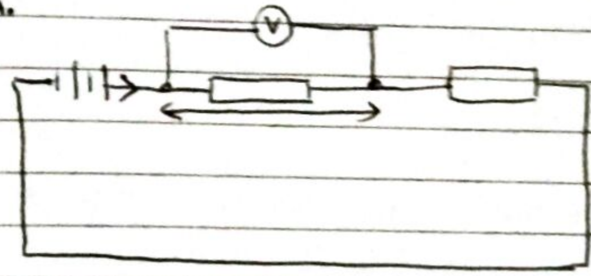
Uncertainty? $= \pm 0.1V$

Fractional error $= \frac{0.1}{9.4} = 0.011$ or 1.1%

When using a voltmeter, red wire is always placed at the point of highest potential. (+)

13) Ammeter is connected in series.

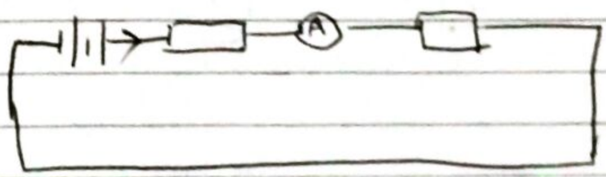
14) Voltmeter only reads the voltage of the component it is parallel with.



Battery supplies current to the circuit itself & voltmeter.

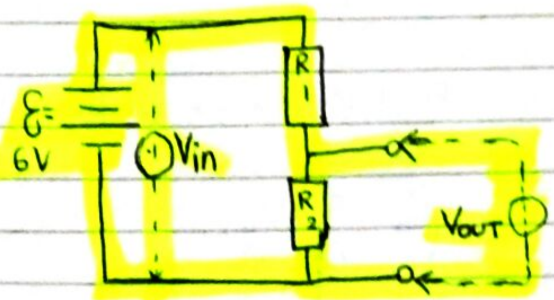
Voltmeter have high resistance to minimize their current.

15) Ideal ammeters have very ~~high~~ low resistance to minimize effect on the current.



16) Potential divider - a circuit made of two (or more) series resistors that allows us to tap off ~~we want to~~ voltage.

How to obtain 3V from a 6V battery?



Input voltage is the emf of the battery.
Output voltage is the voltage drop across R_2.

$R = R_1 + R_2$, series

$I = \frac{V_{in}}{R} = \frac{V_{in}}{R_1 + R_2}$

$V_{OUT} = V_2 = IR_2$

$V_{OUT} = IR_2$

$= \frac{V_{in}}{R_1 + R_2} \times R_2 = V_{in} \times \frac{R_2}{R_1 + R_2} = 6 \times \frac{R_2}{R_1 + R_2}$

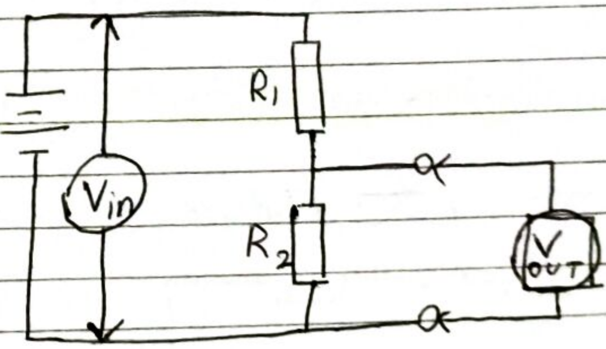
$V_{OUT} = V_{IN} [R_2 / (R_1 + R_2)]$	Potential Divider

Date

Practice : ~~Find the output voltage~~.

Example

Find the output voltage if the battery has an e.m.f. of 9.0 V, R_1 is a 2200 Ω resistor, and R_2 is a 330 Ω resistor.

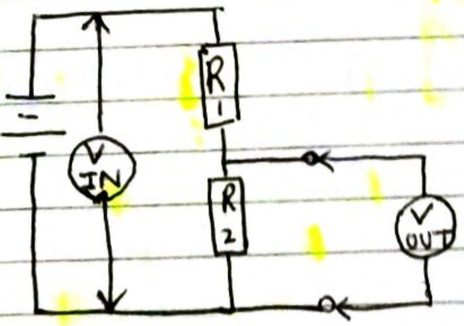


$$V_{OUT} = V_{IN} \times \frac{R_2}{R_1+R_2}$$

$$= 9.0 \times \frac{330}{2200+330} = \frac{27}{23} = 1.17\,V = 1.2\,V$$

Example

We want an output voltage of 6V. Find the value of R_2.



$\mathcal{E} = 9.0V$
$R_1 = 2200\,\Omega$
$V_{OUT} = 6V$

$$V_{OUT} = V_{IN} \times \frac{R_2}{R_1+R_2}, \quad 6 = 9.0 \times \frac{R_2}{2200+R_2}$$

$$\frac{2}{3} = \frac{R_2}{2200+R_2}$$

$$\frac{4400}{3} + \frac{2}{3}R_2 = R_2$$

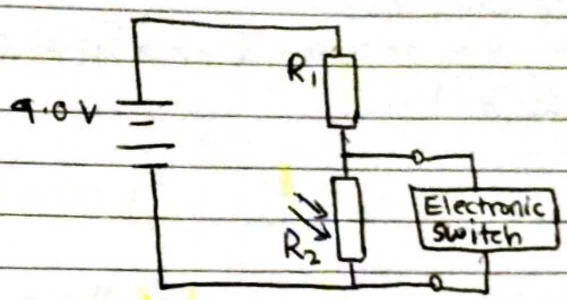
$$\frac{4400}{3} = \frac{1}{3}R_2 \qquad R_2 = 4400\,\Omega$$

KIKY

Date

Practice

A LDR has $R = 25\ \Omega$ in bright light and $R = 22000\ \Omega$ in low light. An electronic switch will turn on a light when its P.D. is above 7.0V. What should the value of R_1 be?



$$V_{OUT} = V_{IN} \times \frac{R_2}{R_1 + R_2}$$

$$7 = 9 \times \frac{22000}{R_1 + R_2}$$

$$7 = 9 \times \frac{22000}{R_1 + 22000}$$

$$\frac{7}{9} \times (R_1 + 22000) = 22000$$

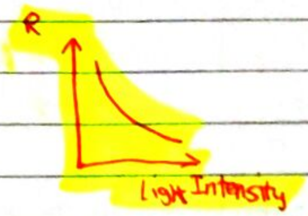
$$\frac{7}{9} R_1 + \frac{7}{9}(22000) = 22000$$

$$R_1 = 6285.7\ \Omega$$
$$= 6\,300\ \Omega$$

$$7 = 9\left(\frac{22000}{\cancel{20}R_2 + 22000}\right)$$

$$\frac{7}{9} = \frac{\cancel{20}22000}{22000 + R_2}$$

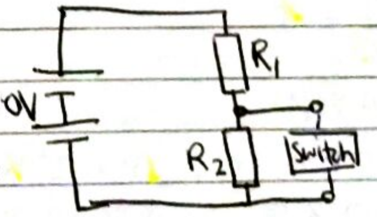
Solve.



Practice

Thermistor has a R $250\ \Omega$ when it is in Fire and R $6500\ \Omega$ when at room temperature. An electronic system will turn on a sprinkler system when its P.D. is above 7.0V.

a) Should the thermistor be R_1 or R_2?



We want high voltage at high temperature where resistance is lower, so it should be R_1. If R_2, then voltage would increase with resistance.

$$\cancel{7 = 9\left(\frac{250}{}\right)}$$

b) What should R_2 be?

$R_1 = 250\ \Omega$ in fire

$$7.0 = 9.0 \times \frac{R_2}{250 + R_2}$$

$$\frac{7}{9} \times (250 + R_2) = R_2$$

$$\frac{7}{9}(250) = \frac{2}{9} R_2$$

$$1750 = 2R_2$$

$$875\ \Omega = R_2$$

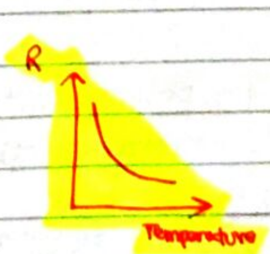
$$880\ \Omega = R_2$$

$$7 = 9\left(\frac{R_2}{250 + R_2}\right)$$

$$1750 + 7R_2 = 9R_2$$

$$1750 = 2R_2$$

$$R_2 = 875\ \Omega$$

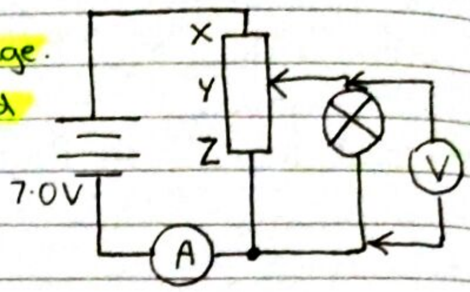


KIKY

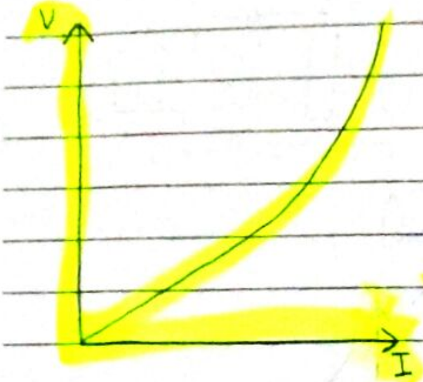
Date

Practice

A filament lamp is rated at "4.0V, 0.80W" on its package. The potentiometer has a resistance from X to Z of 24 Ω and has linear variation.



a) Sketch V vs. the current I for a typical filament lamp. Is it ohmic?



It is not ohmic as Ohmic means linear.

b) The potentiometer is adjusted so that the meter shows 4.0V. Will it's contact be above Y, below Y, or exactly on Y?

Ans It will be above Y because $V_{OUT} = 4.0V$ and $V_{IN} = 7.0\,V$. So, it is above Y as more than half of the resistance is required.

c) The potentiometer is adjusted so that the meter shows 4.0V. What is the current and the resistance of the lamp at this instant?

Ans. $V = 4.0V$

$P = 0.80\,W$

$P = VI = 4.0 \times I$

$\frac{0.80}{4.0} = I$

$= 0.20A$

$V = IR$ OR $P = I^2R$

$4 = 0.2 \times R$ $0.80 = 0.04 \times R$

$\frac{4}{0.2} = R$ $\frac{0.8}{0.04} = 20\,\Omega = R$

$R = 20\,\Omega$ $R = 20\,\Omega$

d) The potentiometer is adjusted so that the meter shows 4.0V. What is the resistance of the Y-Z portion of the potentiometer?

$V_{OUT} = V_{IN} \times \frac{R_2}{R_1 + R_2}$

R_2 = Y-Z portion, R_1 = X-Y portion

$4.0 = 7.0 \times \frac{R_2}{24}$

$\frac{4}{7} \times 24 = R_2 = 13.7\,\Omega = 14\,\Omega$

e) What is the current in the Y-Z portion when meter shows 4.0

$I = V_{OUT}/R$

$I = 4/14$

$= \cancel{0.30}\ 0.29\,A$

KIKY

Date

f) What is the current in the ammeter?

~~I = V_IN~~

There are 2 currents being supplied.

0·29A (c) 0·20A

$0.29 + 0.20 = 0.49\text{ A}$

Q A battery is connected to a 25W lamp. Resistance? Voltmeter show 1·4V

$25\text{ W} = 1.4 \times I$

$\frac{25}{1.4} = 17.9\text{ A}$

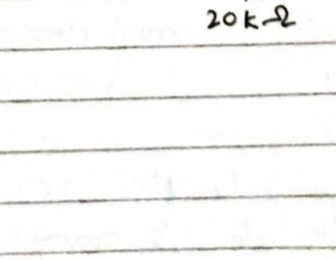
$P = I^2 R$

$25 = 17.9^2 \times R$

$R = 0.078\ \Omega$

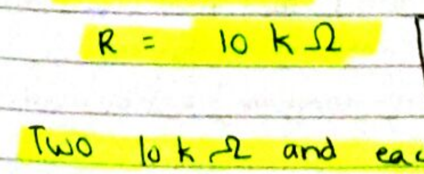
PRACTICE

A non-ideal voltmeter is used to measure the p.d. of the 20 kΩ resistor as shown. What will its reading be?



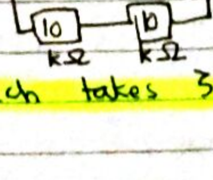
Solution

There are 2 currents flowing because voltmeter's resistance isn't high enough.



$\frac{1}{R} = \frac{1}{20} + \frac{1}{20}$

$R = 10\text{ k}\Omega$



Two 10 kΩ and each takes 3V each.

$V = 3\text{ V}$

(KIKY)

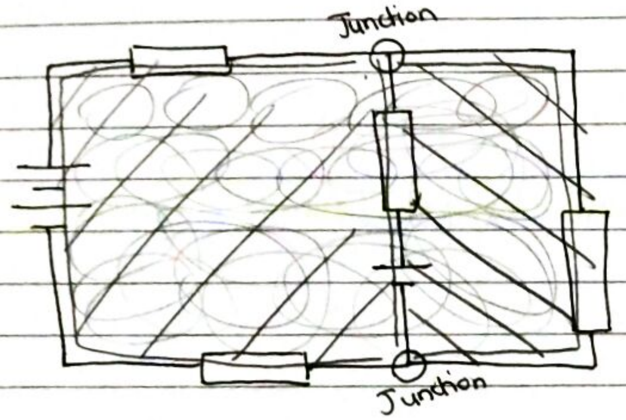
Date

17) Kirchhoff's rules - junction, branch and loop

A junction is a point in a circuit where three or more ~~points~~ wires are connected together.

A branch is all the wire and components connecting 1 junction to another.

A loop is all the wire & components in a complete circle.



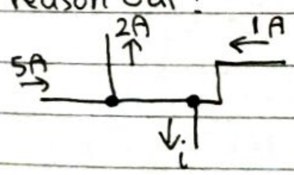
O Junction
— Branch
/// Loop

Solving a circuit. You must find the voltages and currents of all its components.

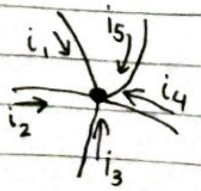
STEP 1 : Assign a current to each branch.
You can choose an arbitrary direction if you don't know which way it flows.
FORGET IT !

Kirchhoff's Laws - Khan Academy

Try reason out !



What is i?
6 A flows into the node, 5 ~~For~~ → and 1 ←. So, 6A must flow out.
$i = 4A$



i_1 flows into the node. But, it can't stay inside the nod & i_1's charge can't jump off the wires into thin air. Current must flow out of the node through 1 or more other branches.

$$i_1 + i_2 + i_3 + i_4 + i_5 = 0$$

If i_1 is positive current, some currents must be negative.

KIKY

Date

Kirchoff's current law - the sum of all currents flowing into a node is zero. (A node connects 2 or more elements)

$$\boxed{\sum_n i_n = 0}$$

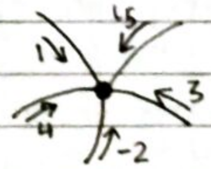
n is the branches attached to the node.

The law can also be - the sum of all currents flowing out of a node is zero.

$$\boxed{\sum i_{in} = \sum i_{out}}$$

You have to look at the arrows in the circuit.

Example

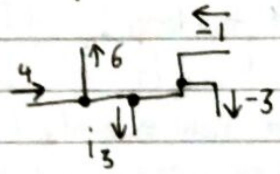


$i_5 = ?$

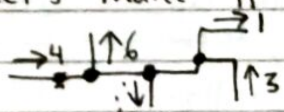
$1 + 3 + 4 - 2 + i_5 = 0$

$i_5 = -6\ A$

Example



Let's make it simpler.

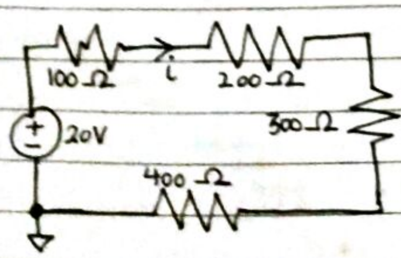


$4 + 3 = 7$

$7 = 6 + 1 + i_3$

$i_3 = 0\ A$

Voltage around a loop



$R_{series} = 100 + 200 + 300 + 400 = 1000\ \Omega$

$\text{Current} = \frac{20}{1000} = 0.02\ A$

Now, find voltage across each resistor.

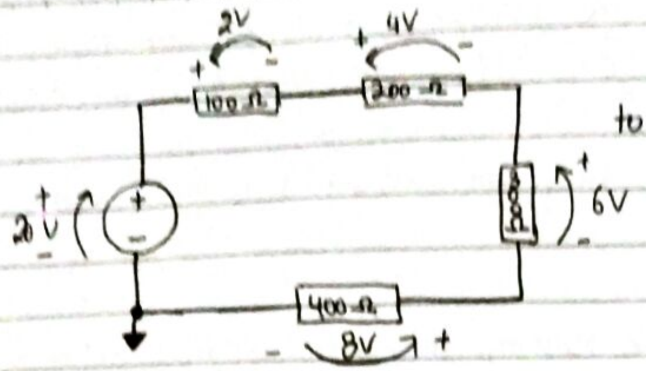
$V_{R_1} = 0.02 \times 100 = +2\ V$

$V_{R_2} = 0.02 \times 200 = +4\ V$

$V_{R_3} = 0.02 \times 300 = +6\ V$

$V_{R_4} = 0.02 \times 400 = +8\ V$

The circuit is now solved.



The individual resistor voltages add up to the ~~sor~~ source voltage. ~~Ha~~

Now go around the loop and add them.

Procedure : Add Element voltages around a loop

Step 1 : Pick a starting node.

Step 2 : Pick a direction to travel around the loop (clockwise or anti-)

Step 3 : Walk around the loop. (Imagine yourself walking around it.)
Include element voltages in a growing sum according to these rules:

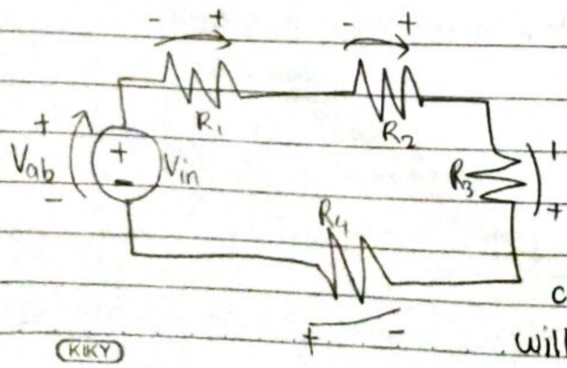
- When you encounter a new element, look at the voltage sign as you enter the element.
- If sign is +, there will be a voltage drop through the element. + to -. Subtract the element voltage.
- If the sign is -, there will be a voltage rise through the element. - to +. Add the element voltage.

Step 4 : Continue around the loop until you reach the starting point, including element voltages all the way around.

Applying the loop procedure.
Already applied at the top of the page in the diagram.

$$v_{loop} = 20 - 2 - 4 - 6 - 8 = 0$$

This happens because electric force is conservative.



$$V_{ab} + V_{R_1} + V_{R_2} + V_{R_3} + V_{R_4} = 0$$

How can they all be positive and = 0 ?
The voltage arrows & polarity signs are just reference directions for voltage. When the circuit is complete, one or more elements will have negative voltages with respect to the voltage arrow.

Date

Kirchhoff's Voltage Law - the sum of voltages around a loop is zero.

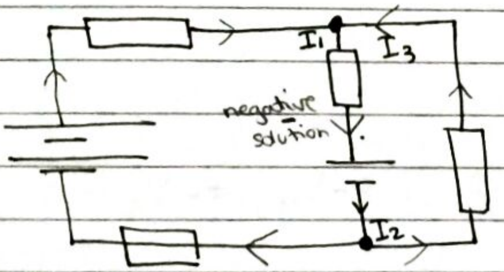
$$\boxed{\sum_n V_n = 0} \quad \text{OR} \quad \boxed{\sum V_{rise} = \sum V_{drop}}$$

The law has some nice properties:

- Walk around the loop and end up at the starting point, the sum of the voltages around the loop adds up to zero.
- You can go clockwise or anti-clockwise.
- If a circuit has multiple loops, Kirchhoff's Voltage law is true for every loop.

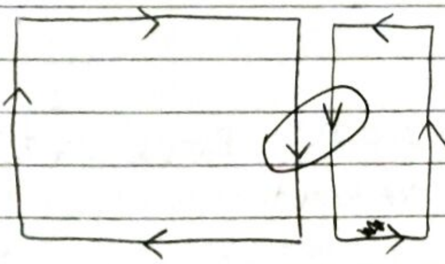
Back to Powerpoint

STEP 1 Assign a current.



Let's say now, if the current enters a junction, +. If it leaves, −.

I_3 & I_1 are + in TOP junction.
I_2 is −.



BOTTOM JUNCTION
I_1 is −, I_3 is −, I_2 is +

Separate loops

Conservation of charge.
∴ Sum of currents at each junction is zero.

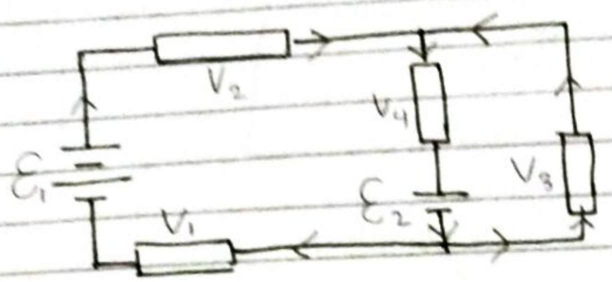
$$\boxed{\sum I = 0 \text{ (Junction)}} \boxed{\text{Kirchhoff's rule for } I}$$

TOP: $I_1 - I_2 + I_3 = 0$

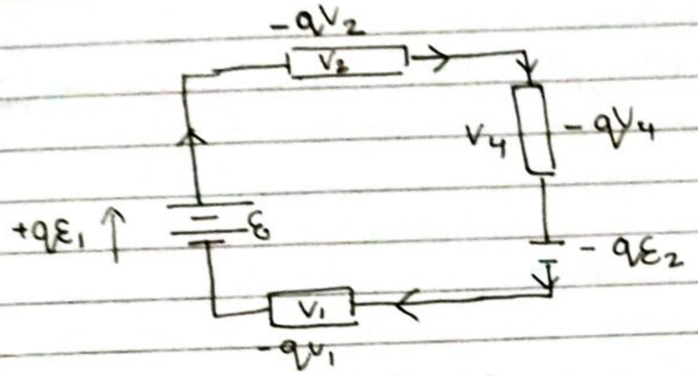
BOTTOM: $-I_1 + I_2 - I_3 = 0$

Turn over for some more complex shiz...

Give each battery an emf $\mathcal{E}$ and each resistor a voltage V.



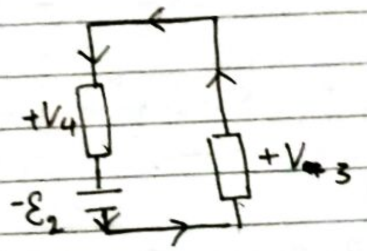
Cells and battery increase energy of the current.
Resistors decrease the energy.



$\Sigma V = 0$ (loop)

$-V_1 + \mathcal{E}_1 + (-V_2) + (-V_4) + (-\mathcal{E}_2) = 0$

Write equation for other loop.



$-\mathcal{E}_2 - V_4 - V_3 = 0$

Suppose each resistor is $R = 2.0\,\Omega$. Emfs $\mathcal{E}_1 = 12V$, $\mathcal{E}_2 = 6.0V$.
Find the voltages and the currents of the circuit.

$I_1 - I_2 + I_3 = 0$

$-V_1 + -V_2 + -V_4 + \mathcal{E}_1 + -\mathcal{E}_2 = 0$

$-\mathcal{E}_2 - V_3 - V_4 = 0$

$-2I_1 + -2I_1 + -2I_2 + 12 - 6 = 0$

$-6 - 2I_3 - 2I_2 = 0$

1) $I_3 = I_2 - I_1$ 2) $3 = 2I_1 + I_2$ 3) $3 = -I_2 + -I_3$

$3 = 2I_1 + I_2$

$3 = -2I_2 + -I_3$

$3 = -I_2 + -(I_2 - I_1) \Rightarrow 3 = -2I_2 + I_1$

$I_1 = 3 + 2I_2$

$3 = 2(3 + 2I_2) + I_2$

$I_2 = -0.6$ A

$I_1 = 1.8$ A

$I_3 = -2.4$ A

We chose wrong directions. Redraw currents

$V_1 = 1.8 \times 2 = 3.6V$

$V_2 = 1.8 \times 2 = 3.6V$

$V_3 = 2.4 \times 2 = 4.8V$

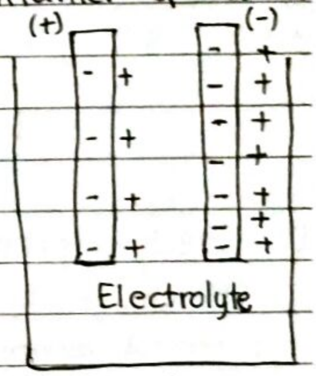
$V_4 = 0.6 \times 2 = 1.2V$

5.3 - Electric cells

1) Electric cells allow us to store chemical energy.

2) The terminal P.D. of a typical practical electrical cell loses its initial value quickly, has a stable and constant value for most of its lifetime, followed by a rapid decrease in 0 as the cell discharges completely.

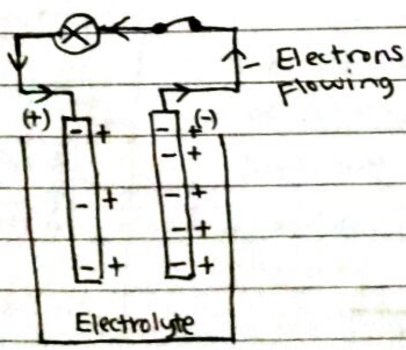
3) Cells
- To make an electric cell, or battery, take a container of weak acid, and two electrodes made of different metals.
- Different metals dissolve at different rates.
- As they dissolve, they enter the acid as positive ions, leaving behind electrons.
- Weak acid is the electrolyte.
- Least negative metal is + terminal.
- Most negative metal is − terminal.



The chemical cell

4) Think of a chemical cell as a device that converts chemical energy into electrical energy.

5) If we connect conductors & a light bulb to the (+) & (−) terminals, we see that electrons begin to flow in an electric current.



6) Each time an electron leaves, the acid creates another. Each time an electron enter the (+), the acid neutralizes an electron.

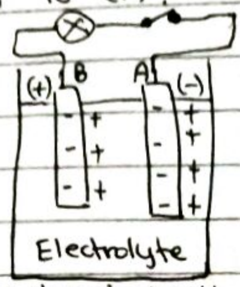
7) Eventually, the metals or the electrolyte is used up.

8) Primary cell can't be recharged. Secondary cell can be recharged by applying external voltage, reversing the chemical reaction.

KKY

Date

9) Why do electrons flow from (-) to (+) ?
They feel a higher <u>repulsive force</u> at (-) terminal than at (+), so, they move from (-) to (+).

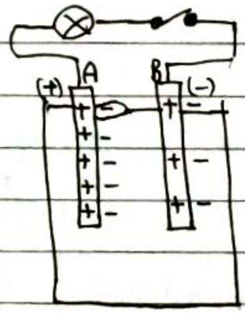


The chemical cell

10) Potential energy
B has already travelled and is returning to the cell. It can't do work on the bulb anymore. Thus the electron at A has more potential energy.

11) Conventional current - positive charge flow (+) to (-).

WE WILL ONLY USE CONVENTIONAL CURRENT, SO:

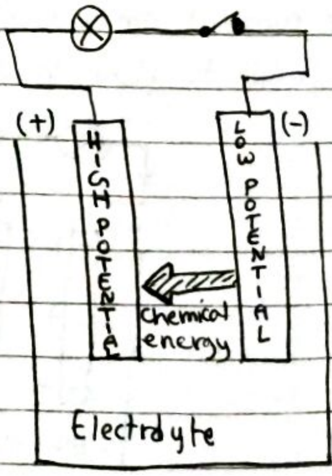


Charge at B has already travelled and can't do anymore work on the bulb.
Charge A can still do work on the bulb.
Charge A has more potential energy

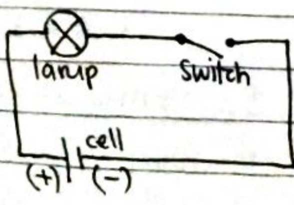
12) Electric potential difference ΔV - amount of work done in moving a (+) charge q from a point of lower potential energy to a point of higher potential energy.

$\Delta V = \dfrac{\Delta E_p}{q} = \dfrac{\text{Change in Potential energy}}{\text{Charge}}$ (p.d.)	Potential difference $V = JC^{-1}$

13) Think like this.
Battery is an engine.
It uses chemical energy to take positive charges and move them from low to high potential within the cell so that they can do work outside the cell in the external circuit. The charges lose energy as they work and the process repeats.



Schematic diagram:



Date

Example

200 μC of charge is brought from 2.0V to 14V through a car battery. What is the change in potential energy of the charge?

$\Delta V = 12V$

$q = 200\mu C$

$12 = \frac{\Delta E_p}{200\mu C}$

$\Delta E_p = 0.0024 J$ (Potential energy increases. makes sense!)

14) Electromotive force ε (emf) - amount of chemical energy converted into electrical energy per unit charge. Volts

Example How much chemical energy is converted to electrical energy by a 1.6V EMF cell if a charge of 15 μC is drawn by the voltmeter?

$\varepsilon =$ Energy converted per unit charge

$\varepsilon = 1.6V$

~~$E = \frac{1.6}{15\times10^{-6}} = 106666.7 = 1.1\times10^{5} J$~~

$E = 1.6 \times (15\times10^{-6}) = 2.4\times10^{-5} J$

Energy converted from chemical to electrical = $\varepsilon \times q$	Not on the presentation.

15) Internal resistance r in a cell or battery causes the cell's voltage to drop when there is an external demand for the cell's electrical energy.
Good cells have small internal resistances.

16) Internal resistance is why a battery becomes hot when there is demand for current from an external circuit. (Think practically. It makes sense!)

Cell heat is produced at the rate

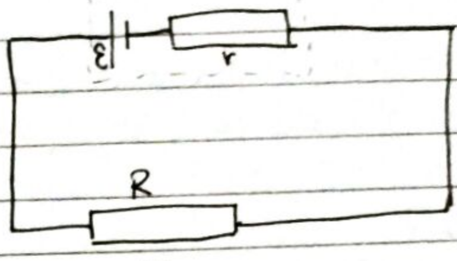
$P = I^2 r$ r = cell internal resistance	cell heat rate

Example Battery's internal resistance = 1.25 Ω. Find rate of heat production if it is supplying an external circuit with a current of $I = 2.00 A$?

$P = I^2 r = 4\times1.25 = 5 Js^{-1} = 5W$

Date

17) If we wish to consider the internal resistance of a cell, we can use the cell & resistor symbol :



Since, $E_p = qV$

Deduce, $\underline{E_p = q\mathcal{E}}$

in the previous formula

Electric energy → Heat energy = $E_{p,R} = qV_R$

$+$

$E_{p,r} = qV_r$

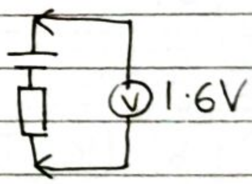
$$\cancel{q}\mathcal{E} = \cancel{q}V_R + \cancel{q}V_r$$

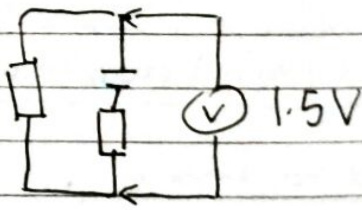
$$V_R = IR \qquad V_r = Ir$$

$\mathcal{E} = IR + Ir = I(R+r)$	emf relationship

Example

A cell got unloaded voltage 1·6V. Loaded voltage 1·5V when a 330 Ω resistor is connected as shown.





a) Find ε.

$\mathcal{E} = 1{\cdot}6\,V$

b) Find I.

$$I = \frac{V}{R} = \frac{1{\cdot}5}{330} = 0{\cdot}0045\,A = 0{\cdot}0045\,A = 4{\cdot}5 \times 10^{-3}\,A$$

c) Find the cell's internal resistance.

$$\mathcal{E} = IR + Ir$$
$$1{\cdot}6 = (0{\cdot}0045)(330) + (0{\cdot}0045)(r)$$
$$\cancel{r = 23.5\,\Omega} \qquad 0{\cdot}1 = 0{\cdot}0045r$$
$$r = 22\,\Omega$$

d) What is the terminal potential difference t.p.d. of the cell?

t.p.d. depends on the load.

t.p.d = 1·6V when unloaded.

t.p.d = 1·5V when loaded.

(KIKY)

5.4 Electricity and Magnetism
5.4 Magnetic effects of electric currents

Date

1) Magnetism arises when one charge moves in the vicinity of another charge.

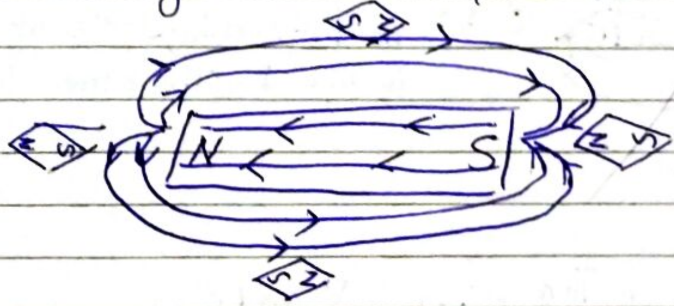
2) $\boxed{\text{Like poles repel. Unlike poles attract.}}$ **POLE LAW.**

3) "North" = north-seeking pole
"South" = south-seeking pole

4) Magnetic field lines - lines along which the magnets align themselves.

5) B - magnetic flux density - Tesla (T) - B is a vector.

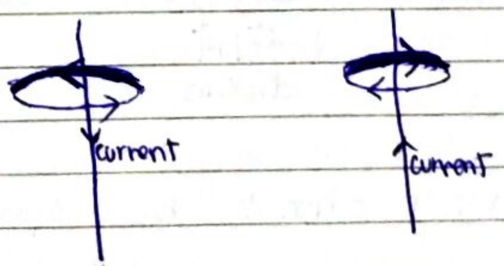
6) B-field is greatest at the poles.



7) A bar magnet is a magnetic dipole. Two poles.

An electric monopole is a charge.
But, we can't split a magnet and isolate the poles.

Right-hand rule



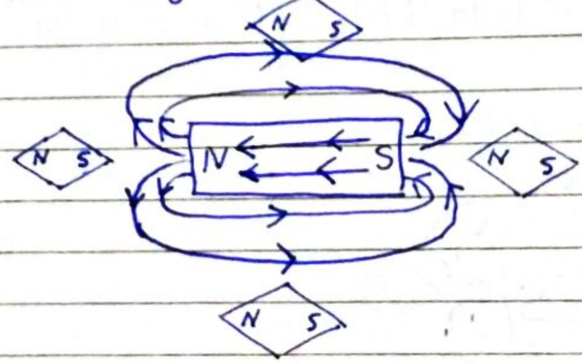
5.4 Magnetic Effects of electric currents

1) $\boxed{\text{Pole Law}}$: Like poles repel. Unlike poles attract.
Charge law is same!

2) Magnetic field lines - lines along which the magnets align themselves

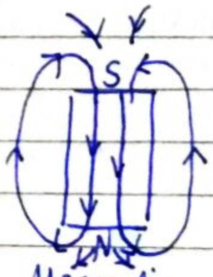
B = magnetic flux density, Tesla (T)
It is a vector!

3) B-field is greatest at the poles.

4) 

The direction of magnetic field lines is the direction a north-seeking pole would point if placed within the field.

5) Magnet is a <u>dipole</u>. Two poles N and S.

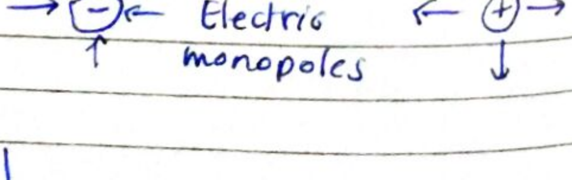


Magnetic dipole

Electric dipole

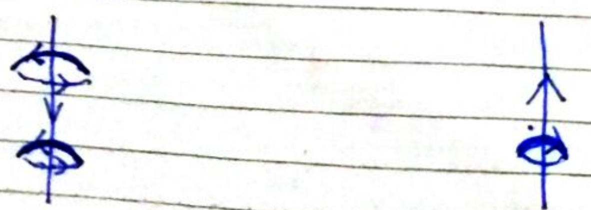
In magnetic dipole, internally, S → N magnetic field.
But, in electric dipole, + → - both ~~inside & outside~~ internally & externally.

6) Poles of a magnet cannot be separated.



Electric monopoles

7) Right-hand rule



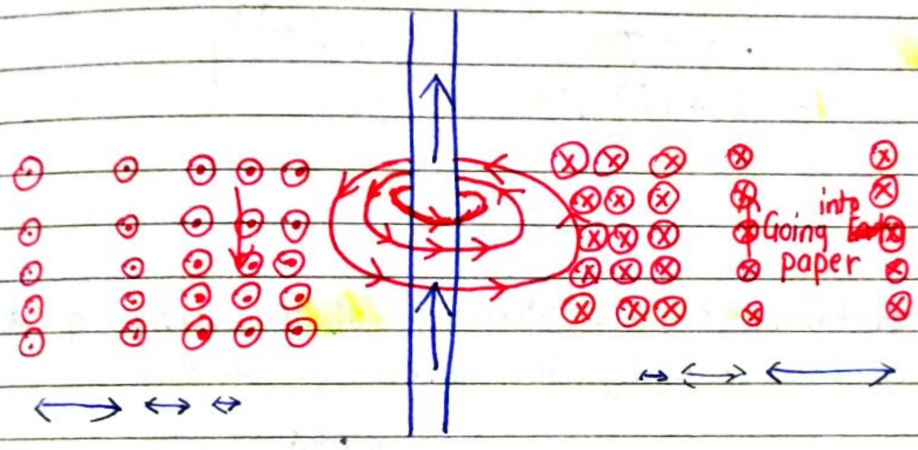
Date

7) View from head of B-field.

• or ⊙

View from tail of B-field.

x or ⊗



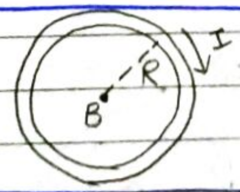
Field gets weaker the farther from the wire.

8) Magnetic field strength a distance d from a current-carrying wire

$$B = \frac{\mu_0 I}{(2\pi d)}$$

Magnetic field strength in the center of a current-carrying loop of radius R

$$B = \frac{\mu_0 I}{2R}$$



- $\mu_0 = 4\pi \times 10^{-7}\ TmA^{-1}$, permeability of free space.
- I = current (amp) • d : distance (m)
- R = radius (m)

BTW, $\varepsilon_0 : 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$ is permittivity of free space.

Date

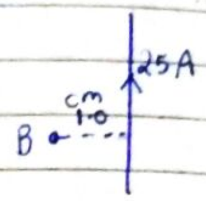
Practice

Find the magnetic flux density 1.0 cm from a straight wire carrying a current of 25 A.

Solution

Magnetic flux density is just a big ass name for B.

$$B = \frac{\mu_0 I}{2\pi d} = \frac{4\pi \times 10^{-7} \times 25}{2\pi \times 0.01}$$

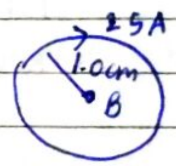


$$B = \frac{0.0000314}{0.02\pi} = 0.0005\ T$$
$$= 5 \times 10^{-4}\ T$$

Practice

Find the ~~magnetic flux density~~ B-field strength at the center of a 1.0 cm radius loop of wire carrying a current of 25 A.

Solution

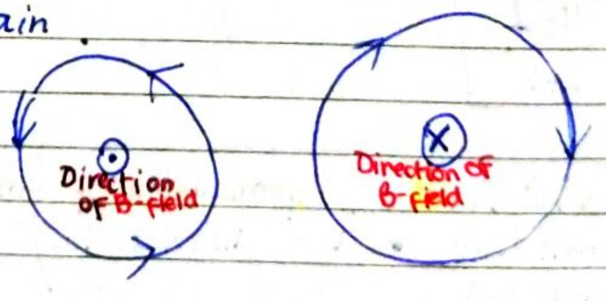


$$B = \frac{\mu_0 I}{2R} = \frac{4\pi \times 10^{-7} \times 25}{2 \times 0.01}$$
$$= 0.0016\ T$$
$$= 1.6 \times 10^{-3}\ T$$

π times stronger!

3) Magnetic field direction in a loop

Right-hand rule again.



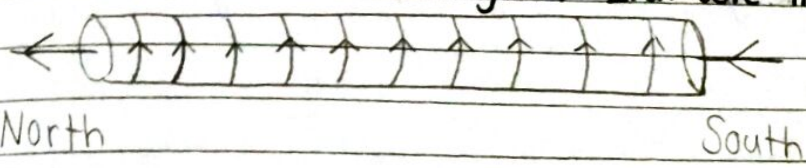
(KIKY)

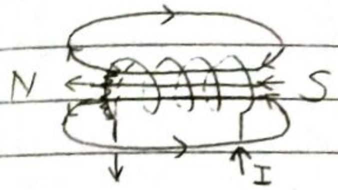
Date

9) Solenoid - series of loops stretched
L coil of wire acting as a magnet
when carrying electric current.

RHR for Solenoids

This is an electromagnet. Iron core inside a solenoid.





Strength of an electromagnet is affected by:
1) Number of loops
2) Current
3) Nature of material of core
4) Shape and size of core

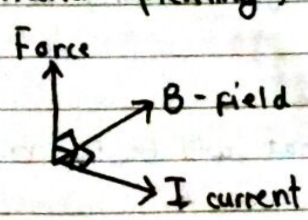
10) Determining the force on a charge moving in a B-field

A moving charge produces a magnetic field. So, if this moving charge is in an external magnetic field, it will feel a magnetic force due to the pole law.
But, a stationary charge in an external magnetic field won't feel a magnetic force because it doesn't have its own magnetic field.

The Force F felt by a charge q, traveling at velocity v through a B-field of strength B is given by

$F = qvB\sin\theta$	where θ is the angle between v and B	Force on q due to presence of B

11) Left-hand Fleming's rule



KIKY

Date

Practice

A 25 μC charge traveling at 150 ms^{-1} to the north enters a uniform B-field having a strength of 0.050 T and pointing to the west.

a) Magnitude of ~~magnitude~~ the magnetic force acting on the charge?

$F = qvb\sin\theta$

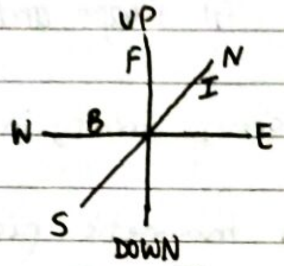
$F = 25 \times 10^{-6} \times 150 \times 0.050 \times \sin 90$

$= 0.0001875\ N$

$= 1.9 \times 10^{-4}\ N$

b) Which way will the charge be deflected?

Up



c) Explain why the magnetic force cannot change the magnitude of the velocity of the charge while it is being deflected.

F is perpendicular to v, so only v's direction will change, not the magnitude.

d) How do you know that the charge will be in uniform circular motion?

q, v, B are constant. So, F is constant. So, a is constant.

Constant acceleration perpendicular to the charge's velocity is the definition of UCM.

e) If the mass of charge is 2.5×10^{-5} kg, what will be the radius of its circular motion?

$F = 1.9 \times 10^{-4}$

$F = 2.5 \times 10^{-5} \times a$

$a = 7.6\ ms^{-2}$

$a = \frac{v^2}{r}$

$7.6 = \frac{150^2}{r}$

$r = 2961\ m$

$= 3000\ m$

$= 3.0 \times 10^3\ m$

12) $F = qvB\sin\theta$

$v \perp B$, $\sin 90 = 1$

$F = qvB$

$ma = qvB$

$m\left(\frac{v^2}{r}\right) = qvB$

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

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

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

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

13) The magnitude of the magnetic force F acting on a wire of length L and carrying a current of I in a magnetic field B is given by this formula:

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

$F = BIL\sin\theta$	where θ is the angle between I and B	Force on wire of length L due to B

Direction of I is the same as direction of q as it flows through the wire.

14) $F = qvB\sin\theta \rightarrow F \quad BIL\sin\theta$

$F = qvB\sin\theta$

$F = q(L/t)B\sin\theta$ (v = distance / time)

$F = (It)(L/t)B\sin\theta$ $I = \frac{q}{t}$

$F = ILB\sin\theta$

$F = BIL\sin\theta$

PRACTICE

A 25-m long wire carrying a 15 A current to the north is immersed in a magnetic flux density of 0.076 T which points downward.

Find the magnitude & direction of the magnetic force acting on the wire.

$F = BIL\sin\theta$

$F = 0.076 \times 15 \times 25 \times \overset{\sin 90}{\cancel{\sin 180}}$

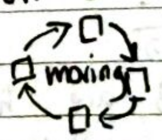
$F = 28.5\ N$

$= 29\ N$ to the West

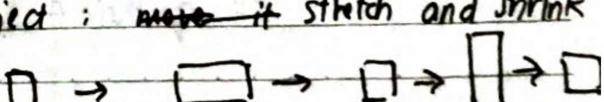
14) Both electric field and magnetic field were manifestations of a single force - electromagnetic wave.

Electromagnetic & gravitational forces travel as waves through space at the speed of light.

Effect of an electromagnetic disturbance on an object : move it around in time with the wave.



Effect of gravitational disturbance on an object : ~~move it~~ stretch and shrink it in time with the wave.



Changing shape

(KKY)

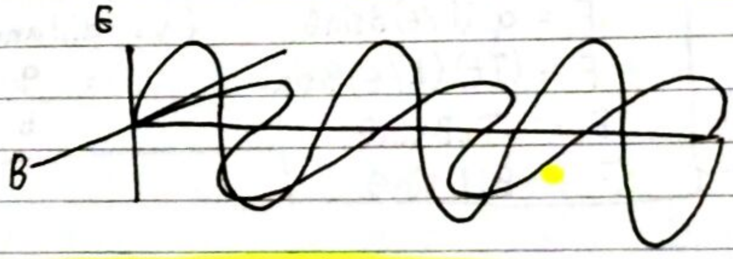
$$\frac{1}{\sqrt{\varepsilon_0 \mu_0}}$$

$$= \frac{1}{\sqrt{8.85 \times 10^{-12} \times 4\pi \times 10^{-7}}}$$

$$= 2.9986 \times 10^{8} \, ms^{-1}$$

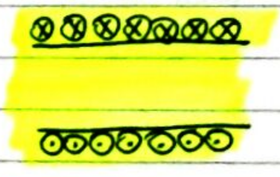
$$C = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$$, c = speed of light

15) Electric field & magnetic field are related in the electromagnetic radiation.



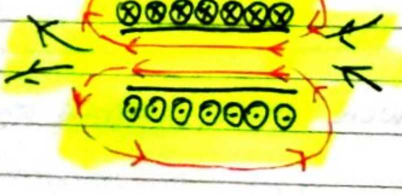
They are perpendicular and in phase.

Practice

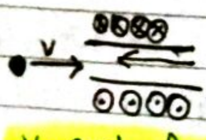


Current - carrying solenoid.

a) Sketch in magnetic field lines inside and outside of each end of the solenoid.



b) A positive charge comes from the left. Direction of magnetic force.

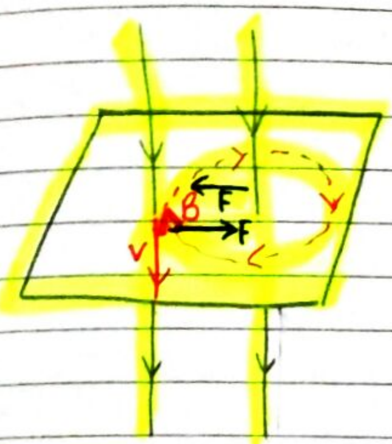


v and B are having 180°. F = 0N

$F = qvB\sin\theta$, $\sin 180° = 0$, $F = 0N$

PRACTICE

Sketch in the force acting on each wire.

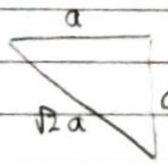


1 : Right hand rule on the right rope.

2 : Left-hand fleming on left rope.

3 : Repeat

Questions



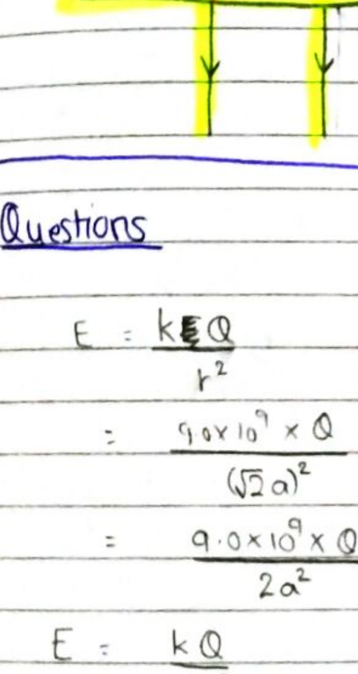
1)a i) $E = \frac{kQ}{r^2}$

$= \frac{9.0\times10^9 \times Q}{(\sqrt{2}a)^2}$

$= \frac{9.0\times10^9 \times Q}{2a^2}$

$E = \frac{kQ}{2a^2}$

ii)



iii) $E = \frac{kQ}{r^2}$

$E = \sqrt{\left(\frac{2kQ}{2a^2}\right)^2 + \left(\frac{2kQ}{2a^2}\right)^2}$

+Q & -Q   +Q and -Q

$E = \sqrt{\frac{4k^2Q^2}{4a^4} + \frac{4k^2Q^2}{4a^4}}$

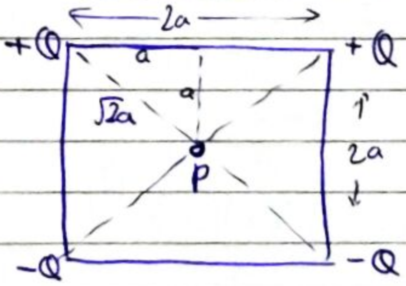
$= \sqrt{\frac{8k^2Q^2}{4a^4}}$

$= \sqrt{\frac{2k^2Q^2}{a^4}}$

$= \sqrt{2}\,\frac{kQ}{a^2}$

Explanation

i)



+Q is at distance of $\sqrt{2}a$.

So, $E = \frac{kQ}{(\sqrt{2}a)^2} = \frac{kQ}{2a^2}$

ii) Charge flows from + to - generally. So, repelled from +. Attracted to -. The E from Q^+ on left repels it to $-Q$ at the right. $-Q$ attracts. The E from Q^+ on right repels it to Q^- on left and $-Q$ attracts. Overall, it goes down.

iii) The left Q^+ and right Q^- work together having E in same direction. Same for other two components. Add the Q^+ & Q^- E field: $E_1 = \frac{2kQ}{2a^2}$ $E_2 = \frac{2kQ}{2a^2}$

Now Pythagoras theorem because they have different directions.

Answer is $\sqrt{2}\,\frac{kQ}{a^2}$