Electricity

WHAT IS ELECTRICITY?

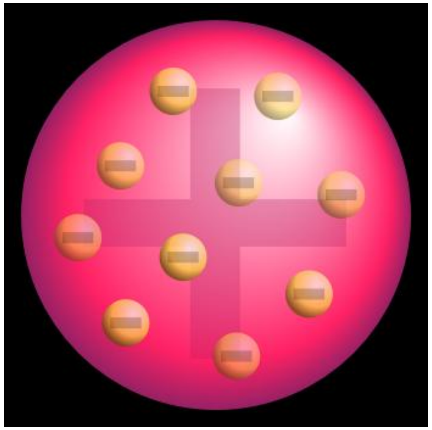
- Key words: electrons, conductors,
- insulators, charge, current

- By the end of this lesson you will be able
- to:

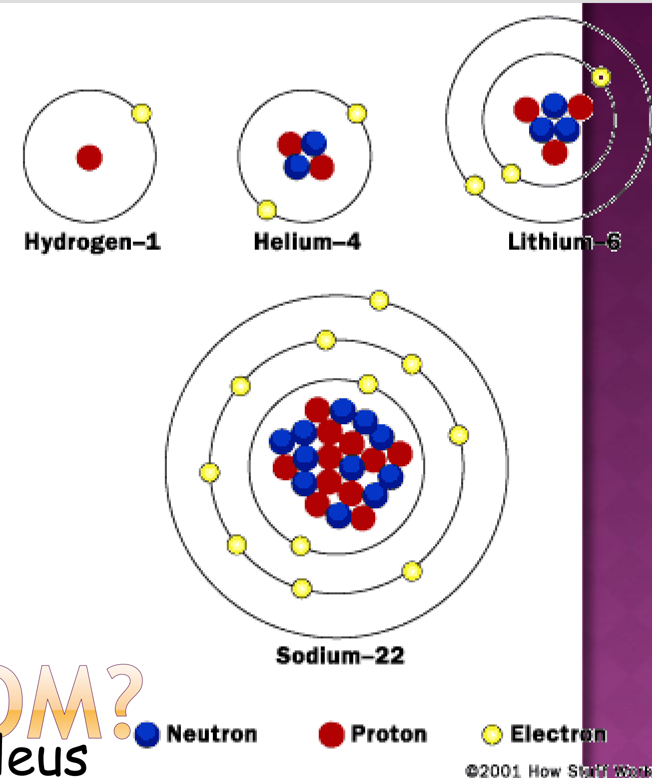
- State that electrons are free to move in a
- conductor
- Describe the electrical current in terms of
- movement of charges around a circuit
- Distinguish between conductors and insulators
- and give examples of each.
- Carry out calculations involving $Q = It$

WHAT IS INSIDE AN ATOM?

Thomson's Plum pudding model

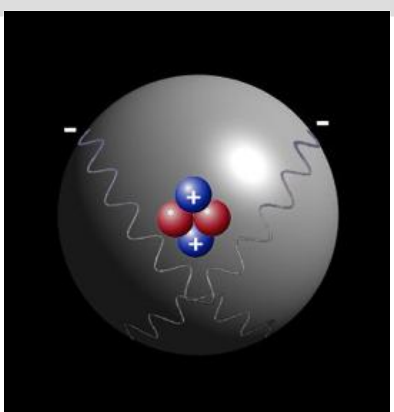


Rutherford Bohr model

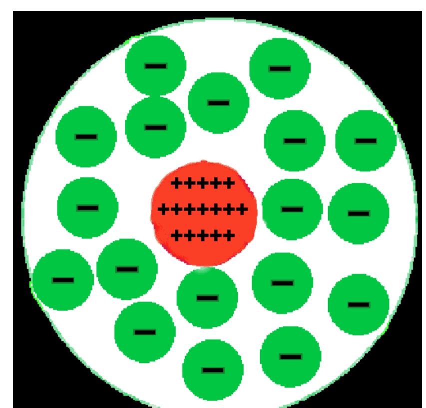


Quantum model of the nucleus

Charge cloud model



Rutherford model



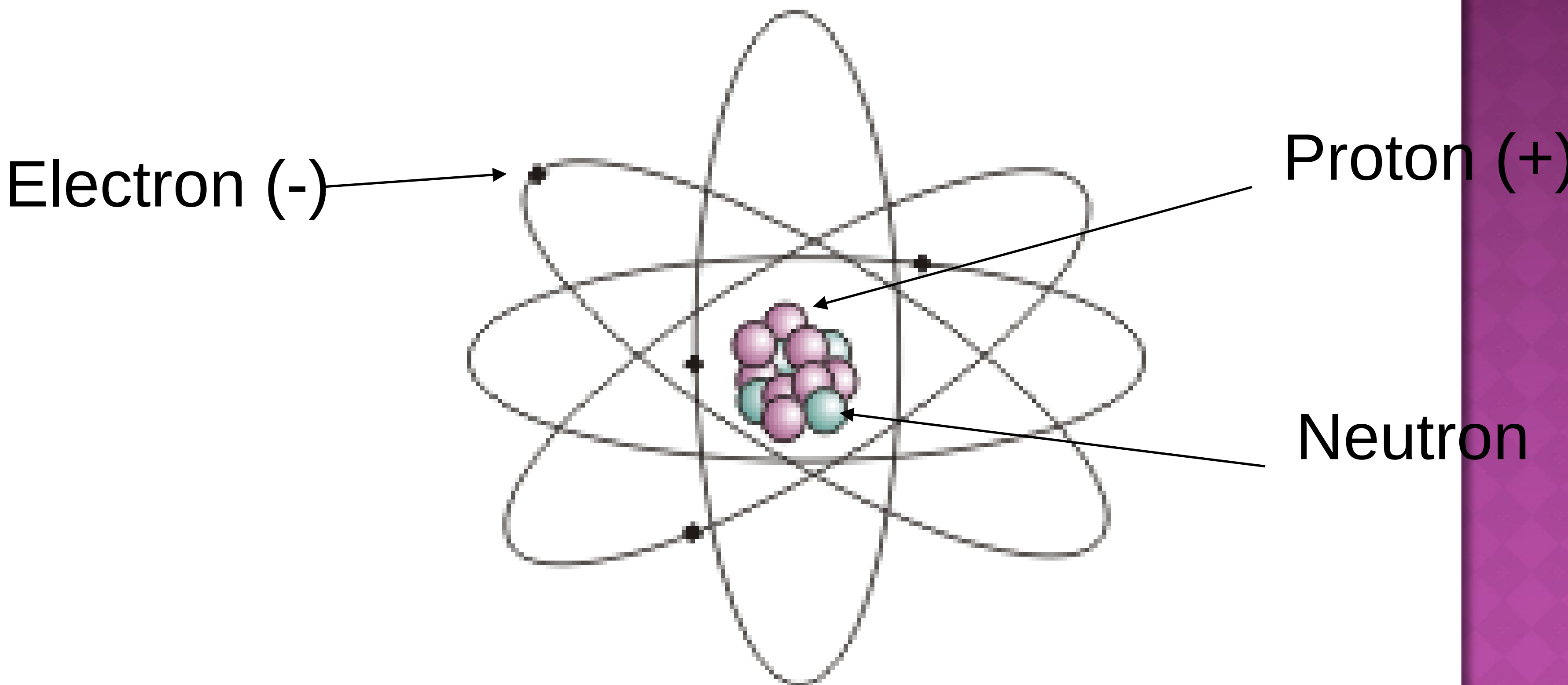
THE ATOM

- An atom is a fundamental unit of matter
- made up of

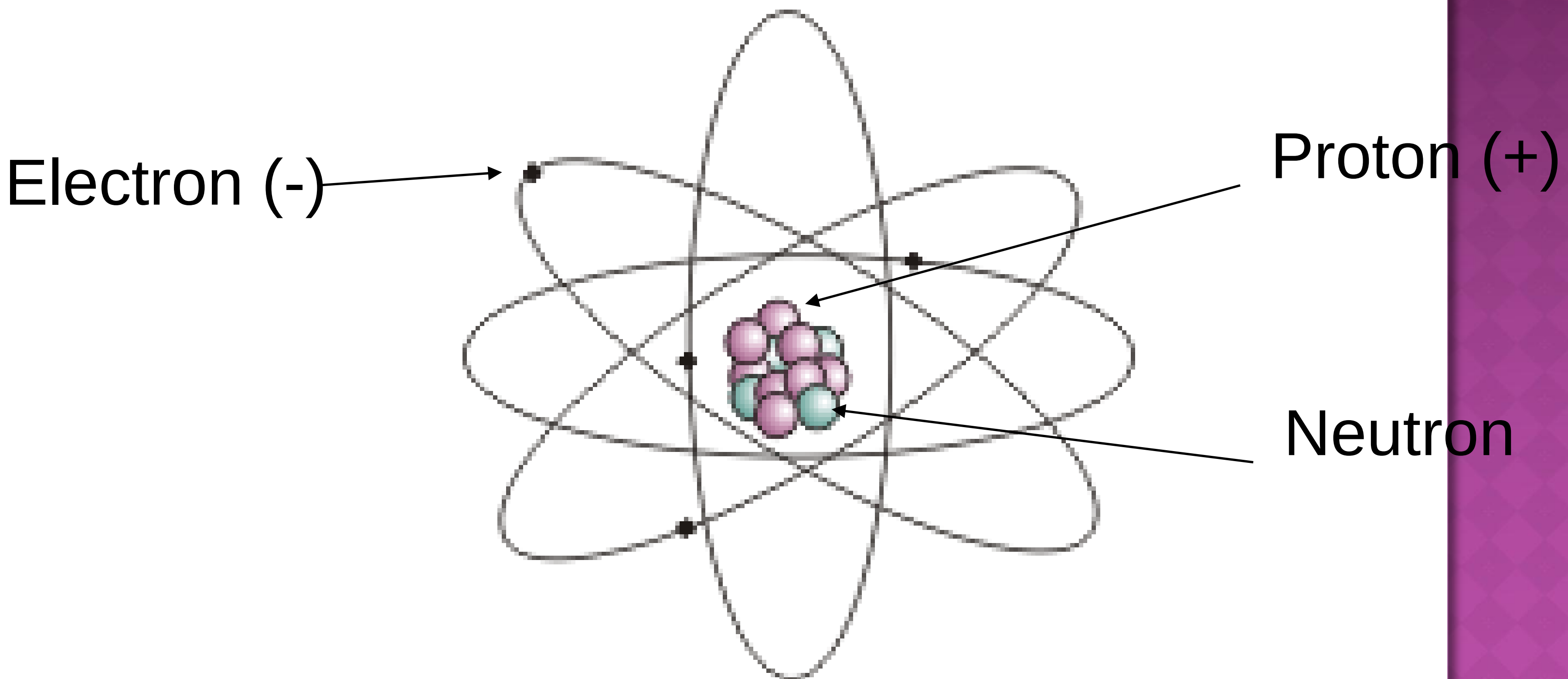
- protons (with a positive charge)
- neutrons (neutral – no charge)
- electrons (with a negative charge)

WHAT IS ELECTRICITY?

- Everything is made of atoms which contain POSITIVE particles called PROTONS and NEGATIVE particles called ELECTRONS.



- An atom will usually have the same number of positives and negatives
- This makes the atom NEUTRAL.



ELECTRICAL CHARGE

- Electric charge is given the symbol
- Q
- Electrons are the charge carriers
- that flow in an electrical circuit
  –
- from the negative to positive
- terminals.

ELECTRICAL CHARGE

- Charge is measured in
  - Coulombs
- which is given the symbol
  - C

ELECTRICAL CHARGE

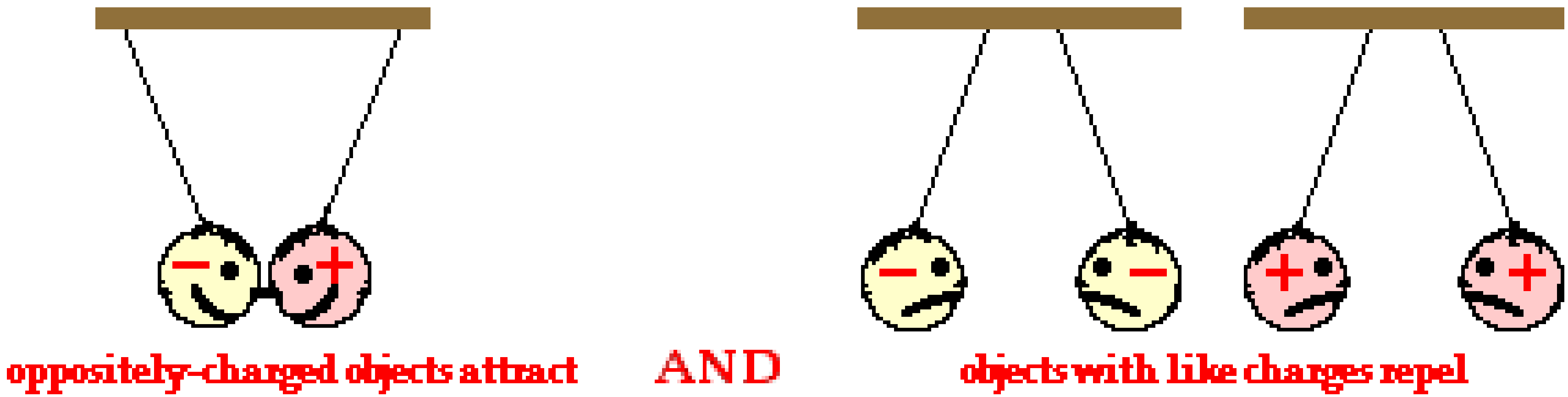
- The charge on a proton is
  - 1.6×10^{-19}C

- which is the same size as the charge on an
- electron.

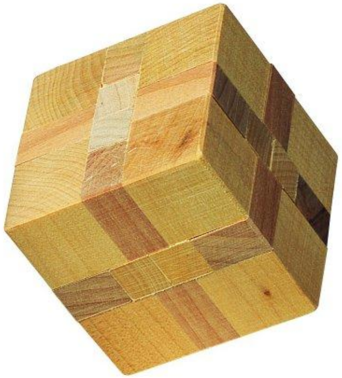
What is Electricity?

Electrons have a negative charge (Q) measured in coulombs (C).

Electrons move round a circuit from negative to positive (remember like charges repel, opposites attract) giving rise to an electric current.


oppositely-charged objects attract
AND
objects with like charges repel

What is a conductor?



Name some conductors and insulators

What makes them effective conductors / insulators?

What is an insulator?

CONDUCTORS & INSULATORS

- What makes something a good conductor?

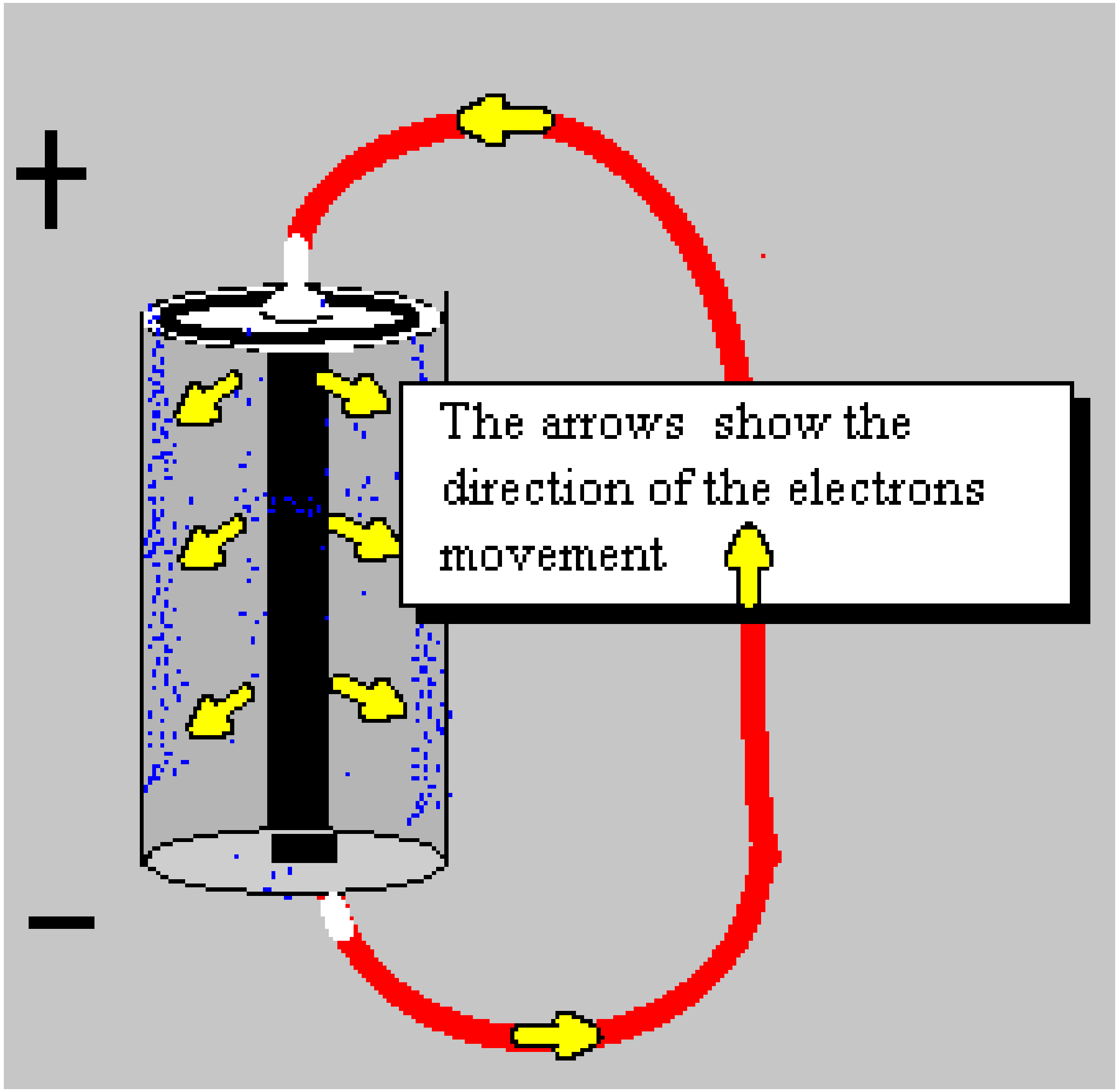
- Good conductors allow electrons to move
- through them easily. Insulators do not
- allow electrons to move easily.

WHAT IS ELECTRICITY?

So electricity is…

movement of charge round a circuit.

We call this electric current.


+
−
The arrows show the direction of the electrons movement

CHARGE, CURRENT & TIME

- Electric current is given the symbol
- I
- Electric current is the movement of
- negative charges (electrons) in a
- circuit

CHARGE, CURRENT & TIME

- Current is the amount of charge flowing
- per second and is given the unit
    - Amps (A)

CHARGE, CURRENT & TIME

so a current of 1 A is 1 C of charge transferred in 1 s.

$$I = \frac{Q}{t}$$

Charge transferred in coulombs (C)

Current in Amps (A)

time in seconds (s)

Charge, Current & Time

- This can be rearranged as

$$Q = It$$

- or

$$t = \frac{Q}{I}$$

- Key words: series, current, ammeter, voltmeter,
- battery, resistor, variable resistor, fuse, switch, lamp,
- voltage

- By the end of this lesson you will be able
- to:

- Draw circuit diagrams to show the correct positions of
- an ammeter in a series circuit.
- Draw and identify the circuit symbols for an
- ammeter, voltmeter, battery, resistor, variable
- resistor, fuse, switch and lamp.
- State that in a series circuit, the current is the same at
- all positions.

DIFFERENT TYPES OF CIRCUIT

- There are different ways in which you can
- connect cells and components (such as
- lamps) to create a circuit:

- series
- parallel
- a mixture of both

SERIES CIRCUIT

- A series circuit has only one electrical path.
- You can trace from one side of the battery to the other, through each component, without lifting your finger from the page.

DIFFERENT TYPES OF CIRCUIT

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SERIES CIRCUIT

- A series circuit has only one electrical path.
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[Physics Animations – Series Circuits]

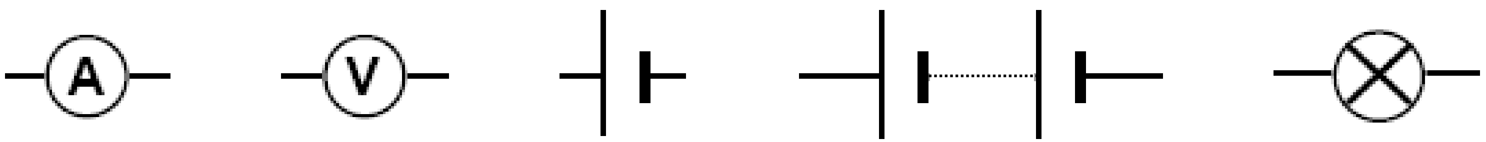
NAME THAT COMPONENT

Resistor

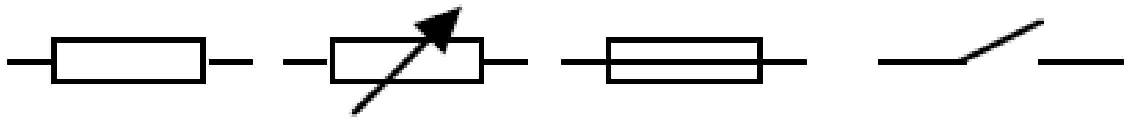
Fuse

Battery

Ammeter



On the back of p2 carefully draw each symbol and label – in pencil!



Voltmeter

Switch

Cell

Lamp

Variable resistor

BUILD A SERIES CIRCUIT

- On the worksheet you will find four
- building circuit activities.

- Follow the instructions carefully!
- Answer each question as you go.
- Make careful observations.

- Lesson 2 build a series circuit.pub

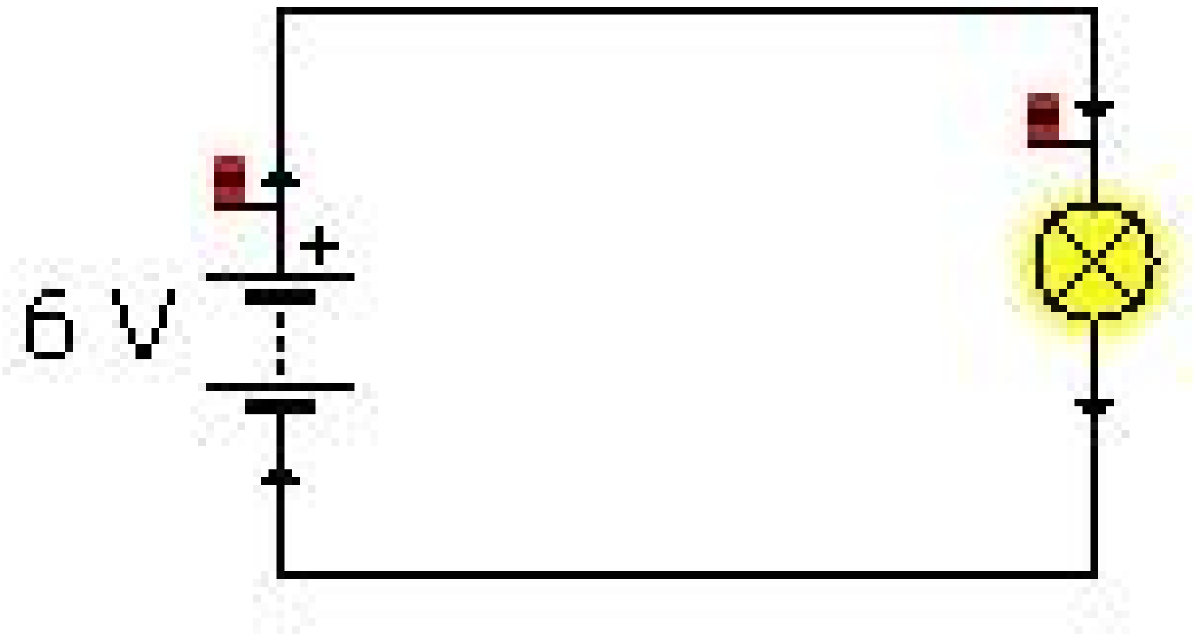
BUILD A SERIES CIRCUIT

- Build a series circuit which contains a
- 6V battery pack, three 3.5 V lamps in
- lamp holders, and a meter used for
- measuring current.

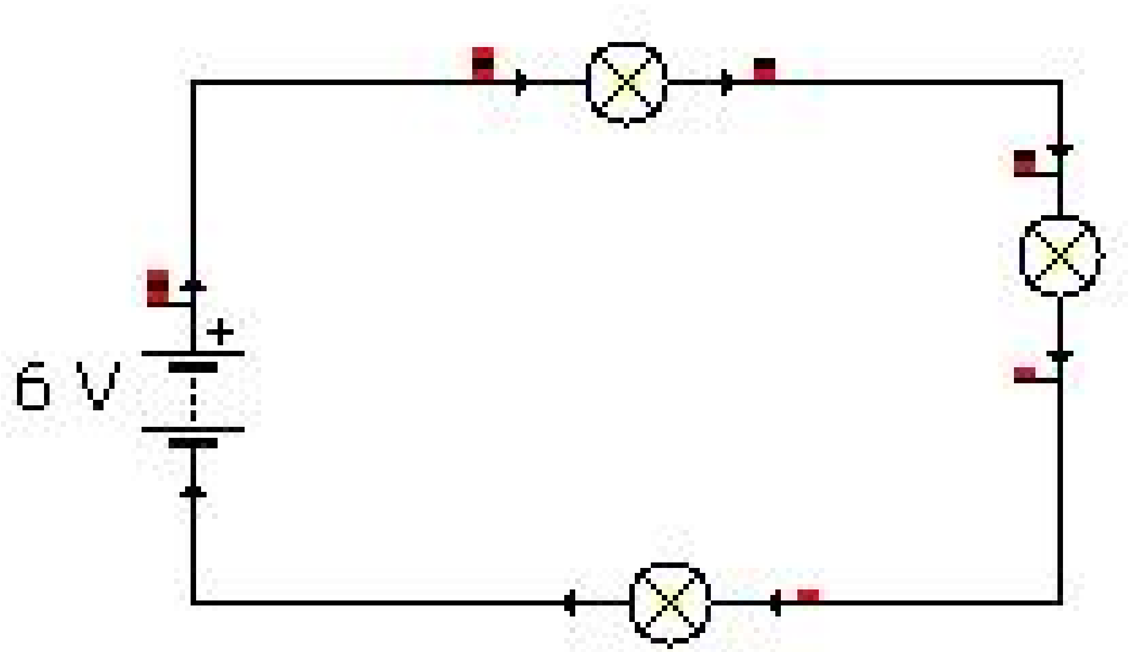
- What is the meter called?

- Where is it positioned in the circuit?

ACTIVITY 1



ACTIVITY 2



Bulbs are much dimmer!

ACTIVITY 3 - CHANGE YOUR CIRCUIT…

- Move your ammeter to different positions
- in the series circuit.

- Make a note of the positions each time,
- and of the current at each position.

- What can you say about the current in a
- series circuit?

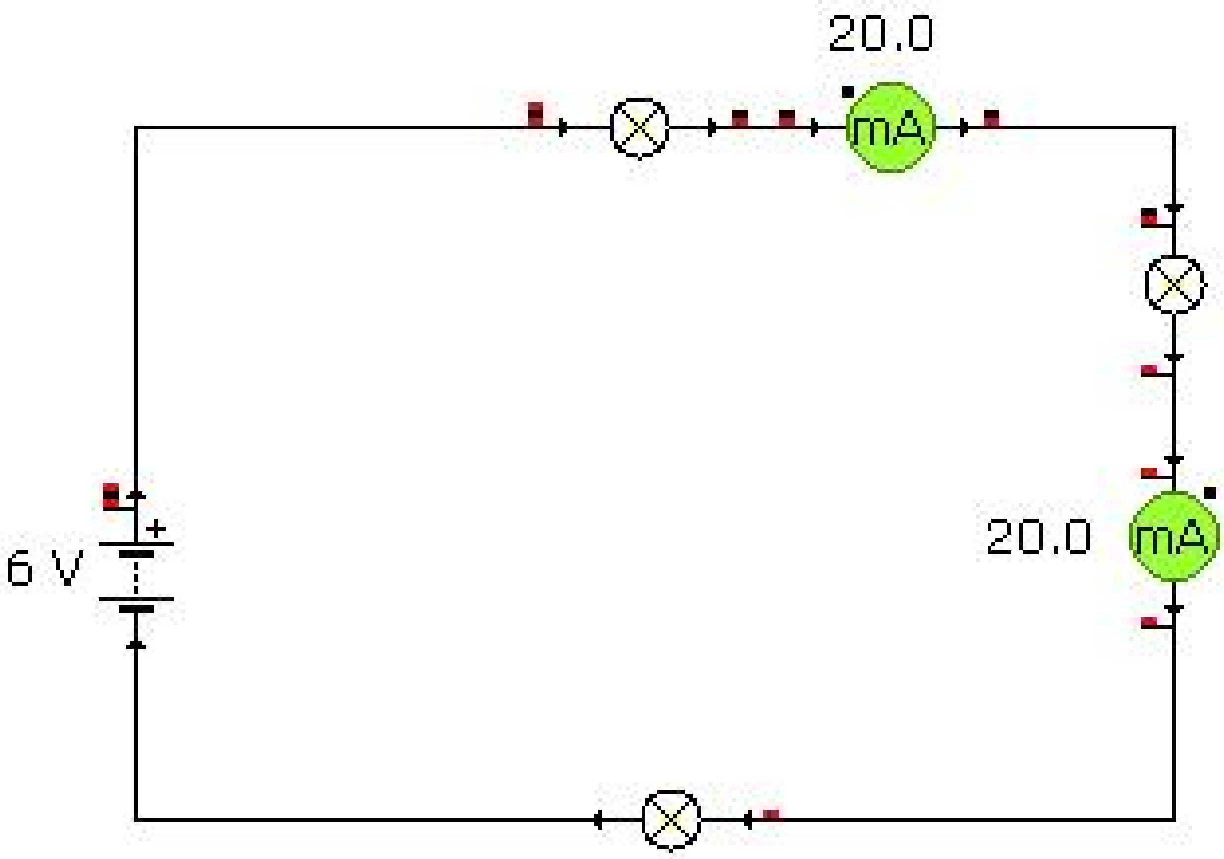
SUCCESSFUL CIRCUIT DIAGRAMS

- On your worksheet you have drawn a circuit
- diagram.

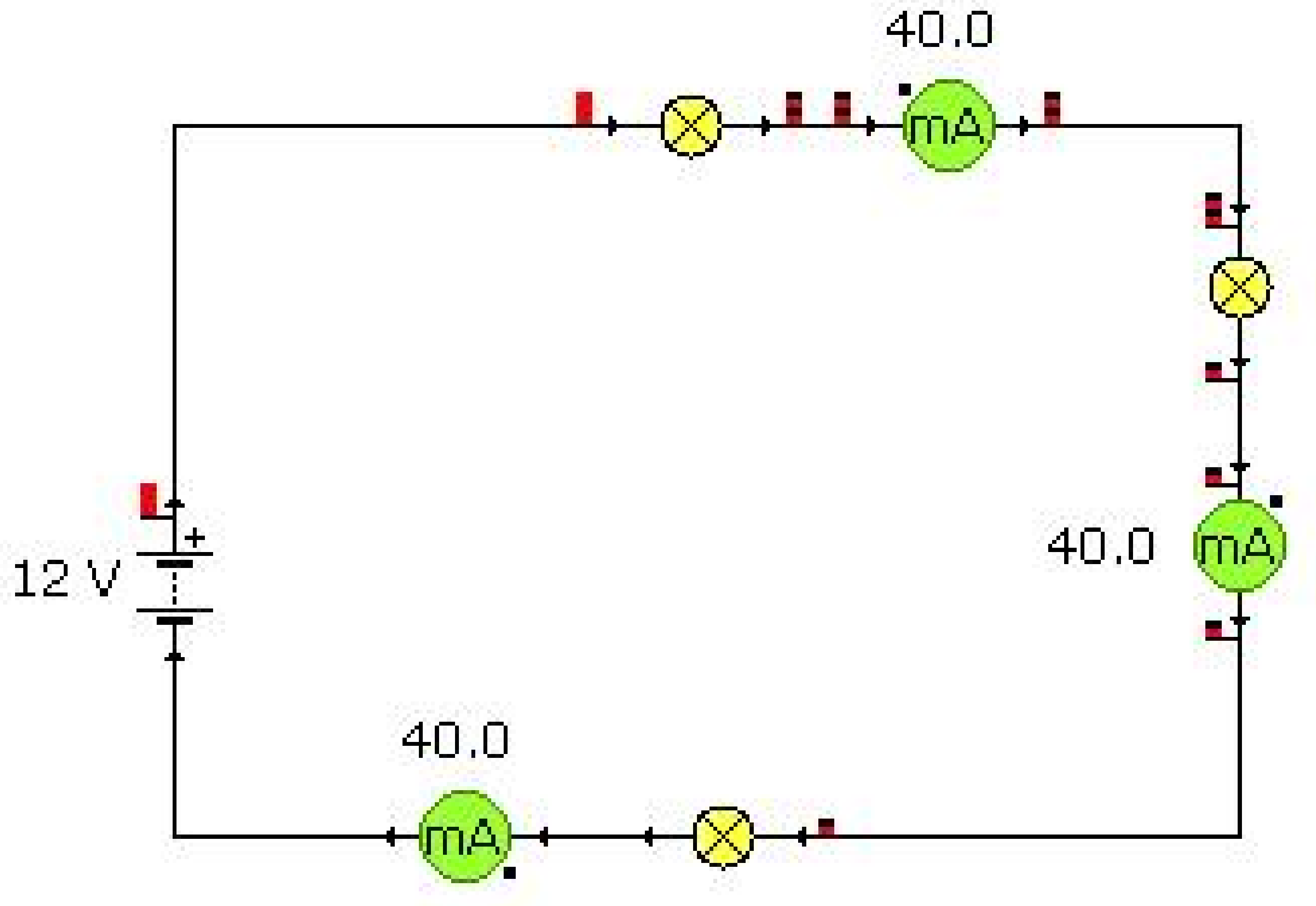
- To be successful at circuit diagrams:
  - use a ruler and pencil
  - draw components carefully
  - draw wires as straight lines (with corners as
  - right angles!)
  - make sure all components are correctly draw
  - and joined in the circuit.

YOUR CIRCUIT DIAGRAM...

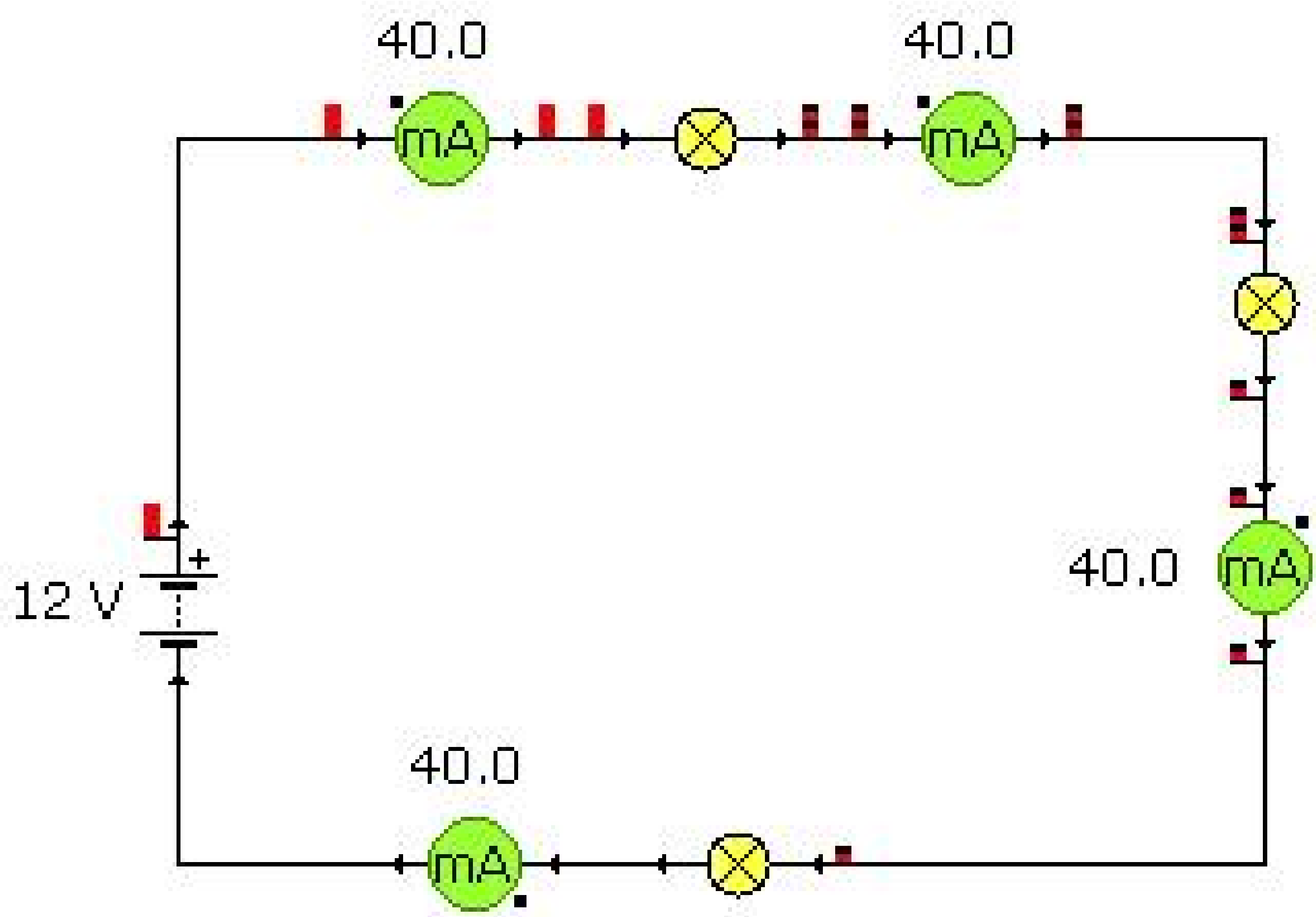
- should look like this:



Notice in this circuit, current is the same at all points



Notice in this circuit, current is the same at all points



SERIES CIRCUITS AND CURRENT

- We are measuring the current I in a series circuit.
- What have we observed?
- We find that the current is the same at
- all points.

- How can this be written mathematically?
  - $I_1 = I_2 = I_3 = I_4$ and so on

THINK…

- How could you make use of a series circuit
- to investigate which materials are
- conductors and which materials are
- insulators?

- Which components would you need?
- What would you observe?

…AND LEARN

- components and names
- formulae and symbols
- what is a series circuit?
- current in series circuit
- drawing a series circuit diagram

WHAT HAVE I LEARNED?

- Key words: series, parallel, ammeter, current,

- By the end of this lesson you will be able
- to:

- Draw circuit diagrams to show the correct positions of an
- ammeter in a parallel circuit.
- Draw and identify the circuit symbols for an ammeter, and
- lamp.
- State that in a series circuit, the current is the same at
- all positions.
- State that in a parallel circuit, the sum of the current in
- the branches adds up to the current drawn from the
- supply.

QUICK QUIZ

- What is a series circuit?
- What is the symbol for current?
- What are the units of current?
- What is the relationship between current and
- time?
- What do we know about the current in a series
- circuit?
- How do we measure current?
- Draw the symbol for this.
- Describe how to measure current in a series
- circuit.

BUILD ANOTHER CIRCUIT

- Build a series circuit which includes a 6V
- battery, a 6V lamp and an ammeter.

- Draw the circuit diagram for your circuit:

BUILD ANOTHER CIRCUIT

- We will now take one of your series
- circuits, and “add it” to someone else’s.
- Another ammeter has been added.

- What do you notice about the readings on
- the ammeter?

BUILD ANOTHER CIRCUIT

- We will now “add” another series circuit.

- What do you notice about the readings on
- the ammeter?

WHAT SORT OF CIRCUIT IS THIS?

- We have constructed a parallel circuit.

- What does the circuit diagram look like?

- Try drawing it on Crocodile Physics.

DRAW THE CIRCUIT DIAGRAM BELOW

PARALLEL CIRCUIT

- We have constructed a parallel circuit.
- This is a circuit with different branches.
- When it reaches a junction, the current
- can divide and take different branches.

PARALLEL CIRCUITS AND CURRENT

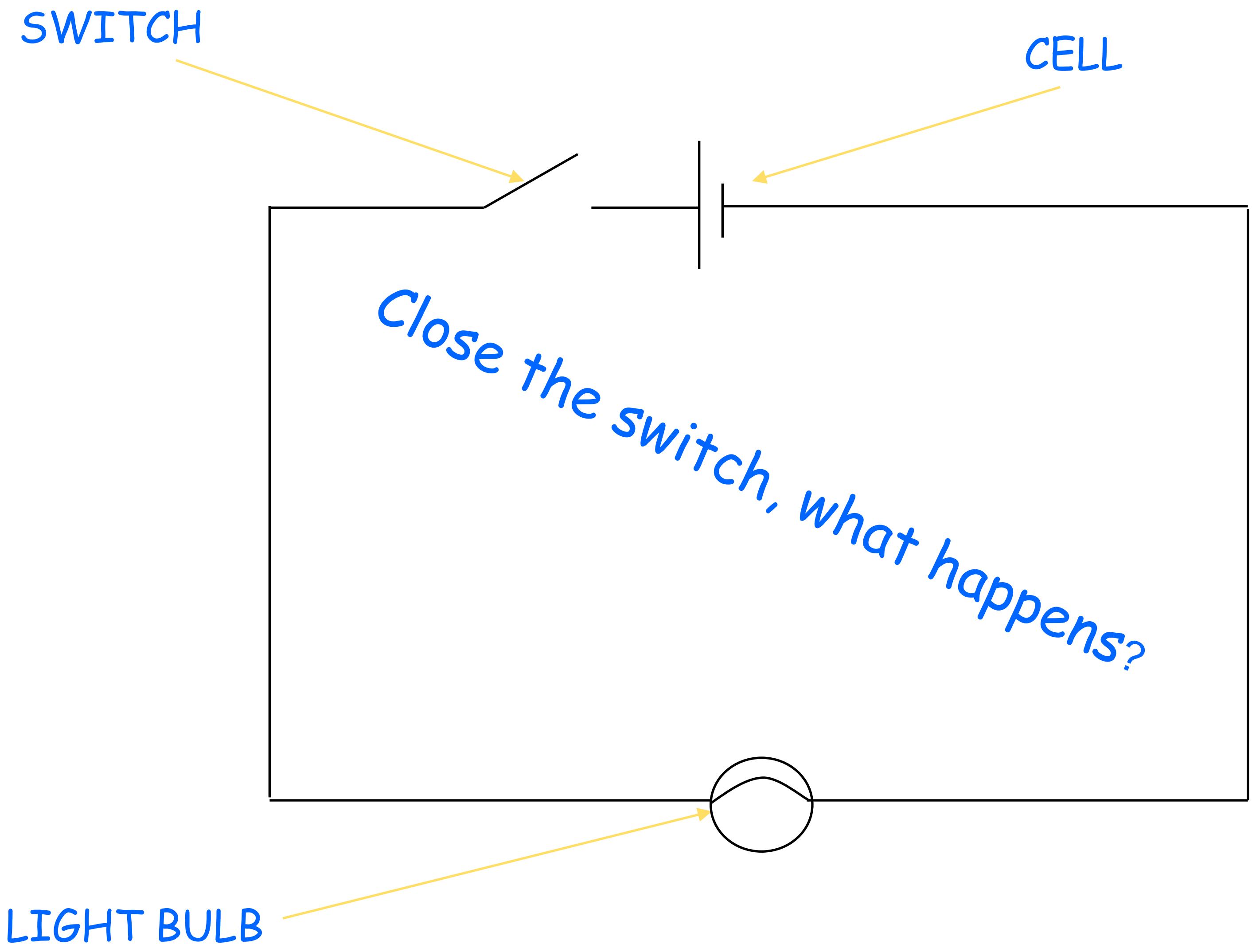
- We are measuring the current I in a
- parallel circuit.

- What have we observed?
- We find that the current in each of the
- branches adds up to the total current.
- How can this be written mathematically?
  - $I_T = I_1 + I_2 + I_3$ and so on

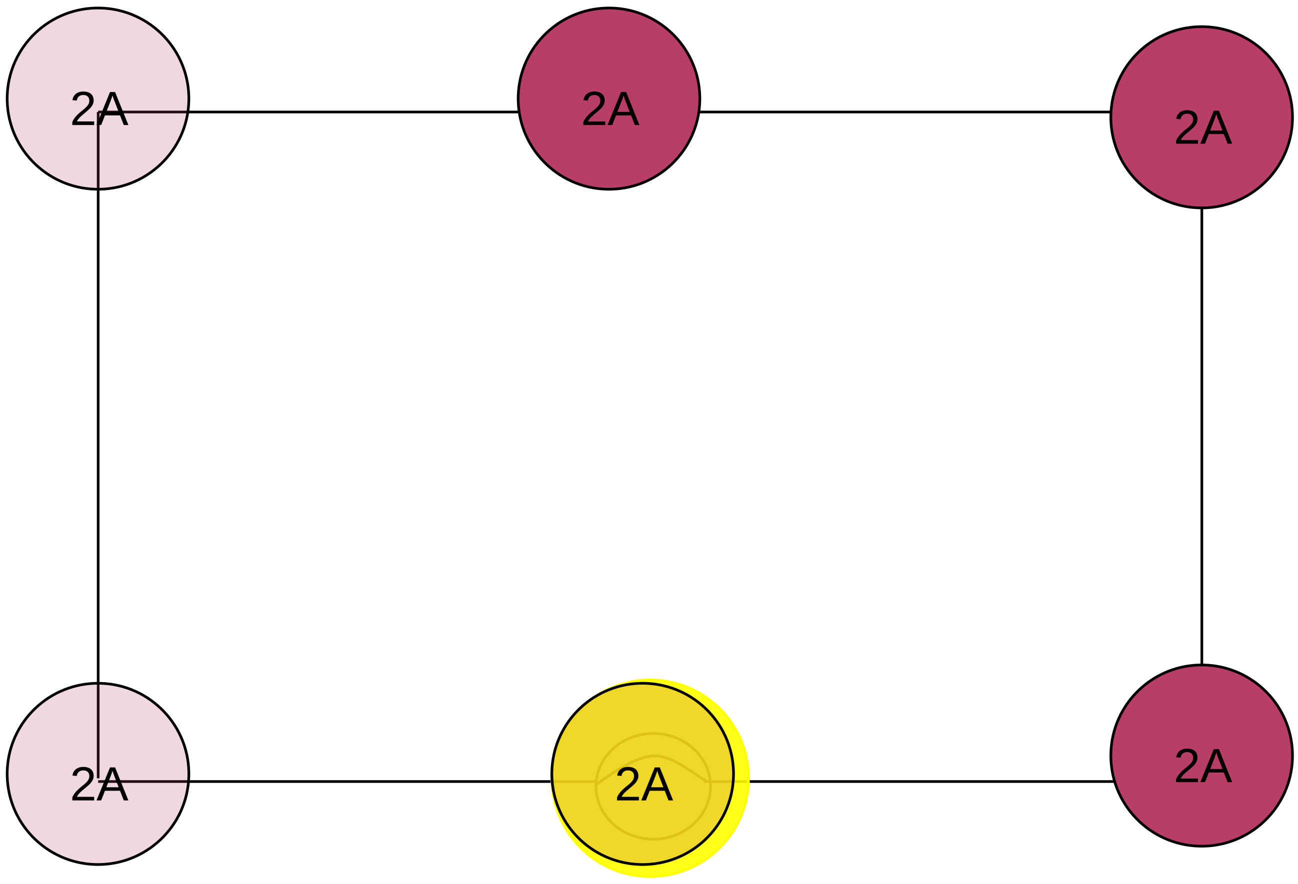
ELECTRIC CIRCUITS

How many ways can you make two light bulbs work?

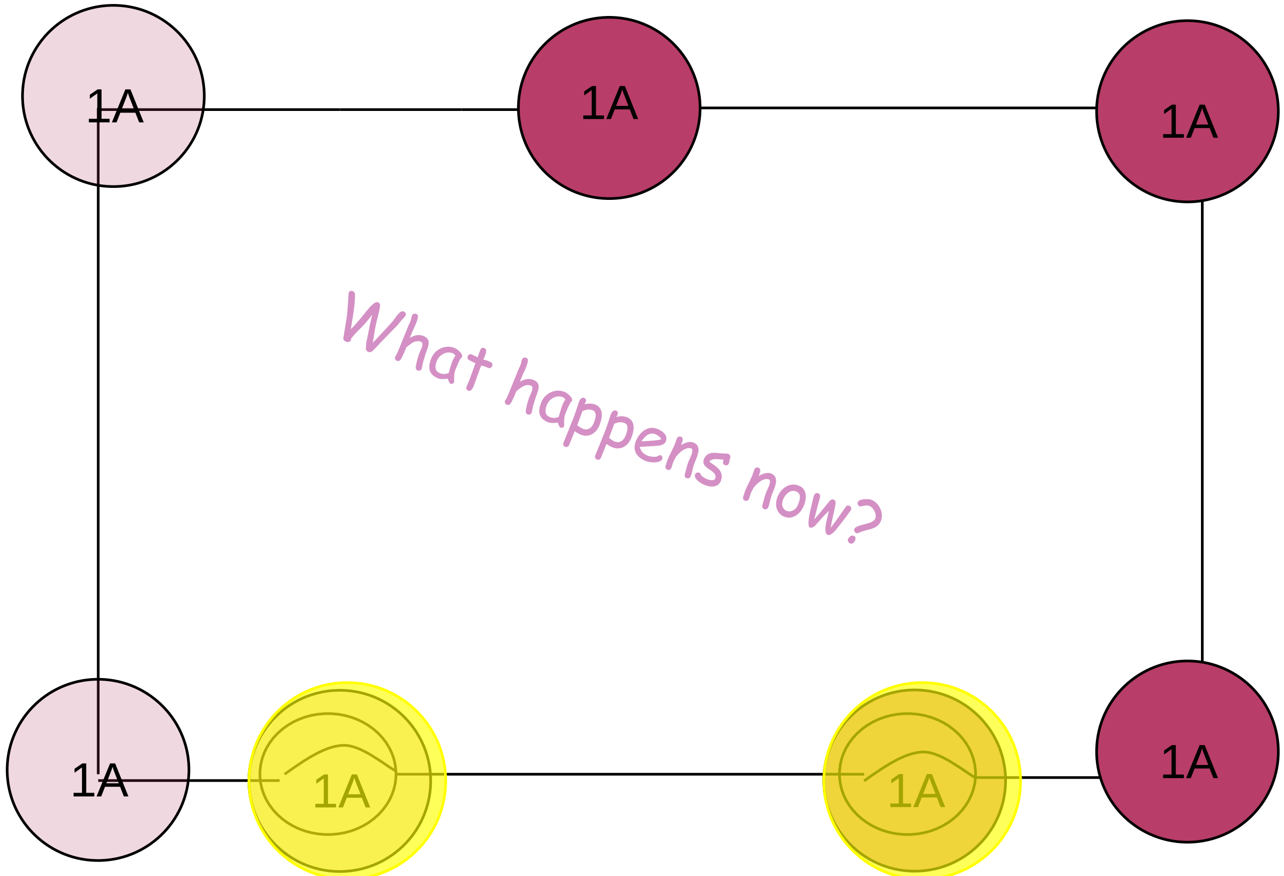
A SIMPLE CIRCUIT



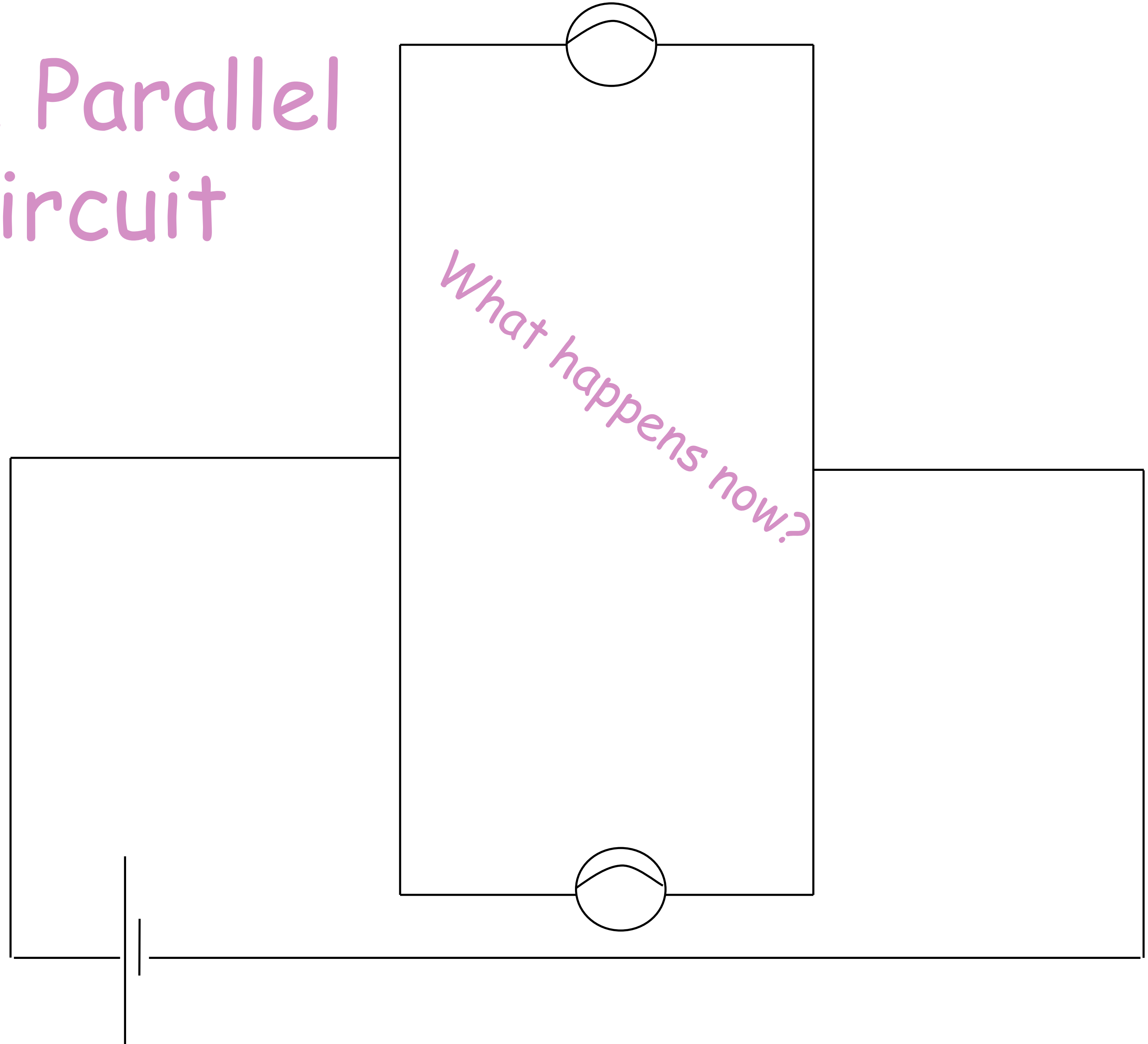
A SIMPLE CIRCUIT



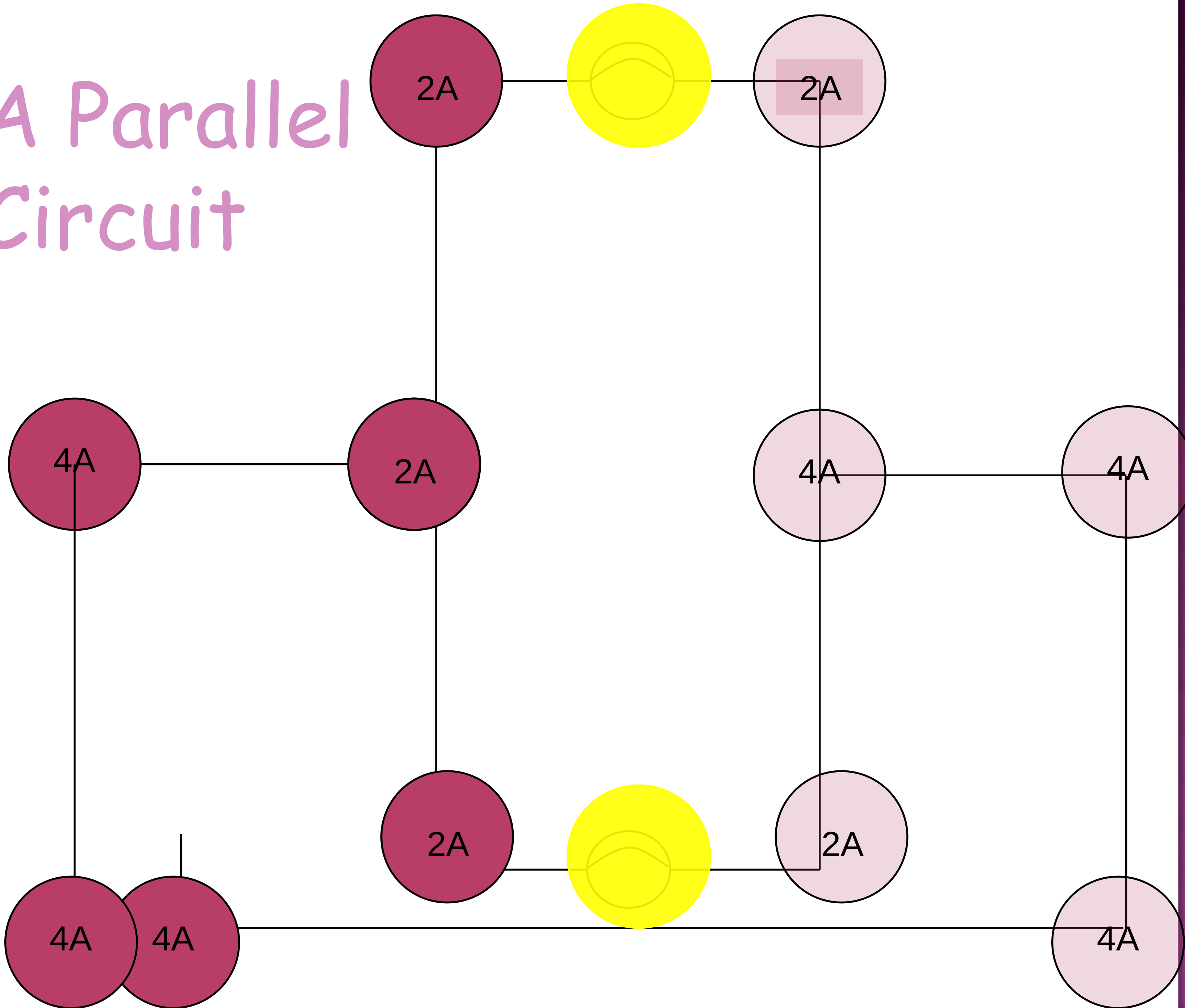
A Series Circuit



A Parallel Circuit



A Parallel Circuit



WHAT HAVE YOU LEARNED TODAY?

- Key words: voltage, potential difference,
- voltmeter, series, parallel

- By the end of this lesson you will be able
- to:

- Draw and identify the circuit symbols for a
- voltmeter, battery, and lamp
- State that the voltage of a supply is a measure
- of the energy given to the charges in a circuit.
- Draw circuit diagrams to show the correct positions of a
- voltmeter in a circuit.
- State that the sum of potential differences across the
- components in series is equal to the voltage of the
- supply.
- State that the potential difference across components
- in parallel is the same for each component.

WHAT IS A VOLTAGE?

WHAT IS A VOLT?

Discussion
Demonstration
Voltage in series and parallel

WHAT IS THE ENERGY CHANGE WHICH TAKES PLACE IN A BATTERY?

Chemical to Electrical

WHEN A BATTERY IS IN A CIRCUIT…

- The electrical energy is carried by the
- electrons that move round the circuit.

- It is converted into others forms of
- energy.

- If there is a bulb in the circuit, it is
- converted from
- to

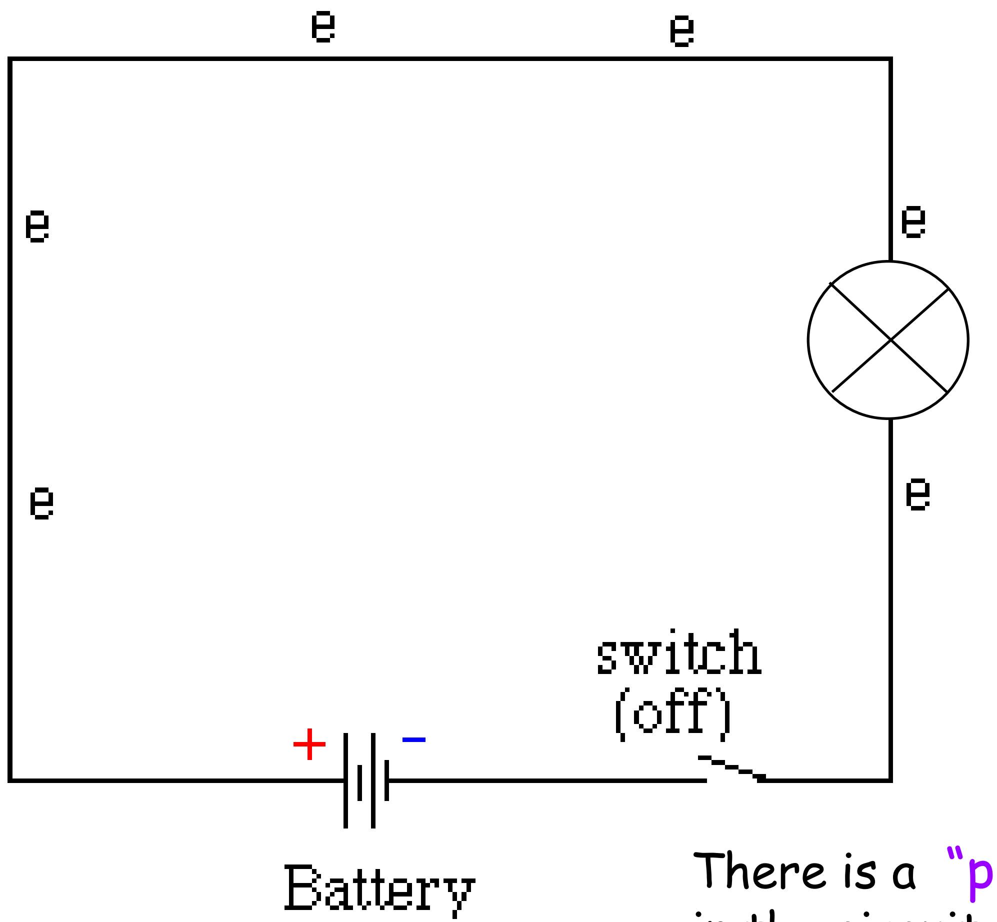
http://www.members.shaw.ca/len92/current_animation.gif

- The amount of electrical energy the
- electrons have at any point in a circuit is
- known as their “potential”.

- As they move the electrons transfer energy
- into other forms.

- This means at any two points the electron has
- different amounts of energy.

Electrons start with (for example) 6J of energy. They have "potential".



As they pass through the bulb, some of the energy is converted to light.

Electrons which have passed through the bulb have less energy. Or less "potential".

There is a "potential" difference in the circuit

WHAT HAS "POTENTIAL DIFFERENCE" GOT TO DO WITH VOLTAGE?

- It is the same thing!

- The potential difference (p.d.), or voltage,
- of a battery is a measure of the electrical
- energy given to one coulomb of charge
- passing through the battery.

POTENTIAL DIFFERENCE OR VOLTAGE (V)

- A 9 V battery will give how much energy
- to each coulomb of charge passing
- through the battery?

- 9 J

POTENTIAL DIFFERENCE OR VOLTAGE (V)

- A 1.5 V battery will give how much energy
- to each coulomb of charge passing
- through the battery?

- 1.5 J

POTENTIAL DIFFERENCE OR VOLTAGE (V)

- A battery with a p.d. of 6V will give how
- much energy to each coulomb of charge
- passing through the battery?

- 6 J

VOLTAGE OR P.D.

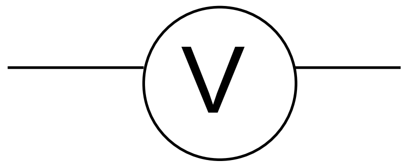
- Voltage (or p.d.) is measured in
- volts
- and is given the symbol
- V

SUMMARY OF UNITS

Quantity	Symbol	Units	Symbol
charge			C
	t		s

HOW CAN WE MEASURE VOLTAGE?

- Voltage (or p.d.) can be measured using a
- voltmeter.



- An ammeter is connected in the circuit
- but a voltmeter must be connected across
- the component.

You can't measure voltage…

- in a circuit
- through a circuit
- through a component
- flowing

BUILD A SERIES CIRCUIT

- Build a series circuit which contains a
- 6V battery, two 6V lamps, and a meter
- used for measuring potential difference
- across each lamp.

- What is the meter called?

- Where is it positioned in the circuit?

DRAWING A CIRCUIT DIAGRAM

- Now draw a circuit diagram of the series
- circuit which you built.

- Remember to use a ruler and pencil, draw
- components carefully, draw wires as
- straight lines (with corners as right
- angles!), and make sure all components are
- correctly draw and joined in the circuit.

SERIES CIRCUITS AND VOLTAGE

- We are measuring the potential difference (V) in a series circuit.
- What have we observed?
- We find that the
- How can this be written mathematically?

PARALLEL CIRCUIT

- Now use the same components to
- construct a parallel circuit.

- This is a circuit with different branches.

PARALLEL CIRCUITS AND VOLTAGE

- We are measuring the potential
- differences in a parallel circuit.

- What have we observed?

- How can this be written mathematically?

TASKS & HOMEWORK

- Yellow Practice Questions: 2.10, 2.11
- Numerical Questions: p33-36 qu 5-14
- Complete for homework for Tuesday 27th
- November

WHAT HAVE YOU LEARNED TODAY?

QUICK QUIZ
WHAT HAVE WE LEARNED?

WHAT HAVE YOU LEARNED TODAY?

- Key words: electrical resistance, voltage,
- current, Ohm’s law, ohms, resistor,
- variable power supply

- By the end of this lesson you will be able to:
- State that V/I for a resistor remains
- approximately constant for different currents.
- State that an increase in resistance of a circuit
- leads to a decrease in the current in that
- circuit.
- draw the symbol or a variable power supply and
- resistor.

- Key words: electrical resistance, voltage,
- current, Ohm’s law, ohms, resistor,
- variable power supply

- By the end of this lesson you will have
- practised:
- building a series circuit
- using an ammeter and a voltmeter to find
- current and voltage.
- graphing results

RESISTORS

The symbol for a resistor is

RESISTORS

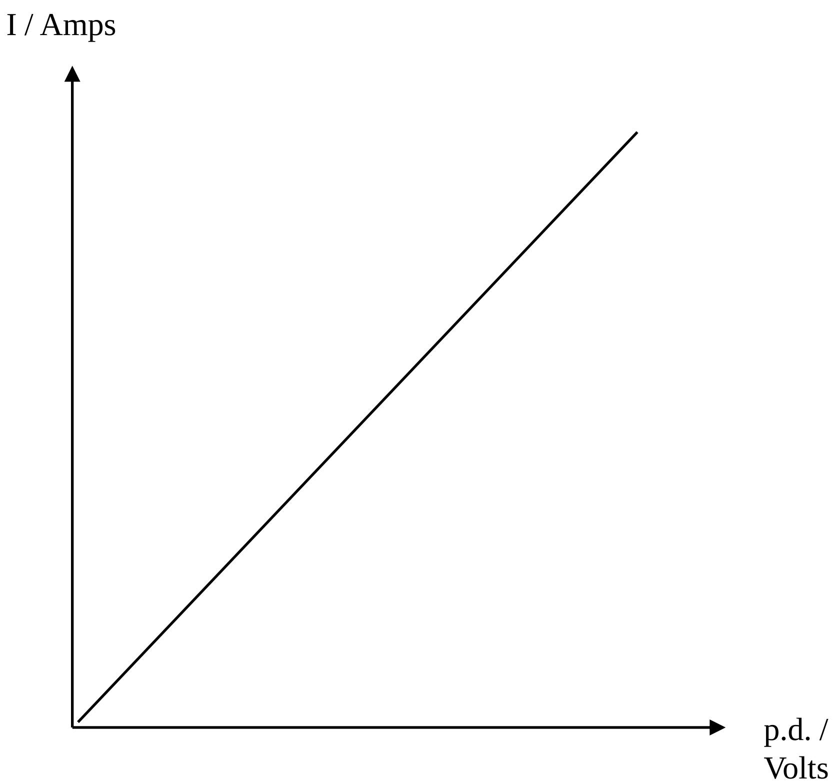
- Resistors C
- flow of electric current. They have a
- property called re
  which
- is measured in O

WHAT IS THE RELATIONSHIP BETWEEN CURRENT AND VOLTAGE IN A RESISTOR?

- Current is measured using an an
- Voltage is measured using a volt

- Investigation: relationship between
- current and voltage in a resistor.

RELATIONSHIP BETWEEN CURRENT AND VOLTAGE IN A RESISTOR



Straight line through the origin tells us that current is

directly proportional to voltage

The ratio V/I is constant and is equal to resistance in the circuit.

RELATIONSHIP BETWEEN CURRENT AND VOLTAGE IN A RESISTOR

$\frac{V}{I}$ is approximately constant

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

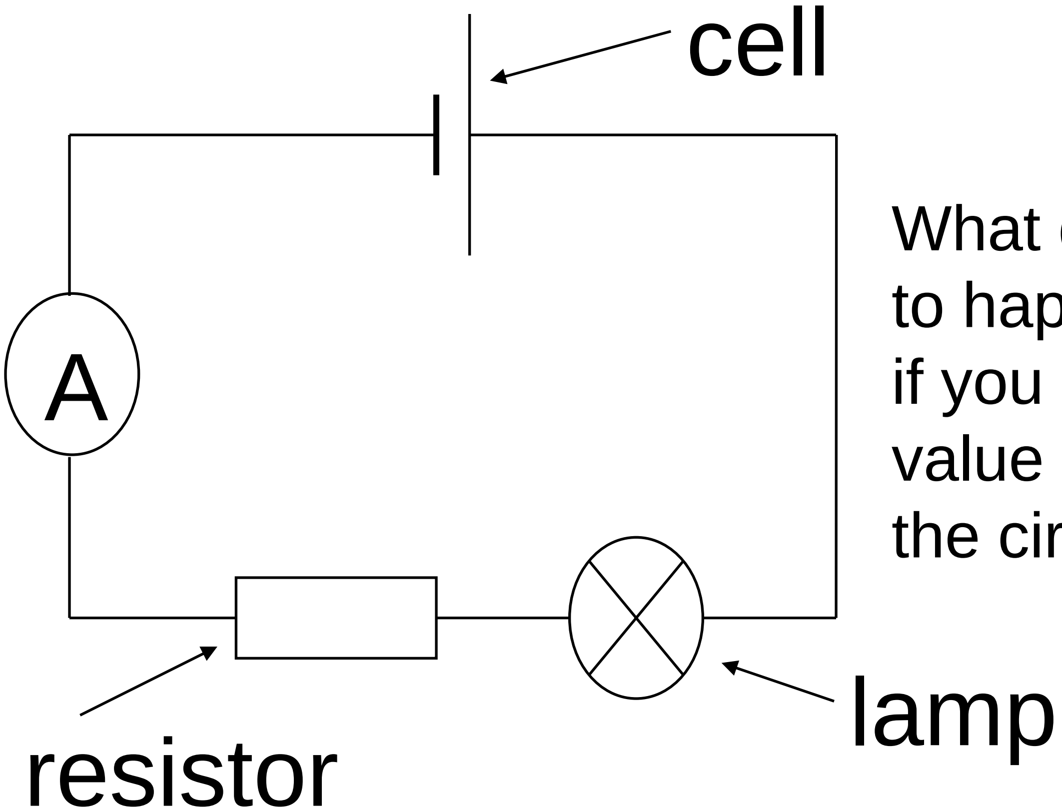
RELATIONSHIP BETWEEN CURRENT AND VOLTAGE IN A RESISTOR

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

Ohm's Law

$$V = IR$$

RESISTORS



What do you expect to happen to the current if you increase the value of the resistor in the circuit shown?

Demonstration

CALCULATE

- For a voltage of 12V, calculate the
- current for a resistant of

(i) 1 Ω
(ii) 2 Ω
(iii) 4 Ω
(iv) 24 Ω
(v) 1 k Ω

- What can you say about current and
- resistance for a fixed voltage? Complete
- the sentences.

- As resistance increases, the current

- As resistance decreases, the current

VARYING RESISTANCE

- The opposition to current or resistance
- of a material (measured in Ω) depends
- on several things.

- Think and discuss what some of these
- might be.

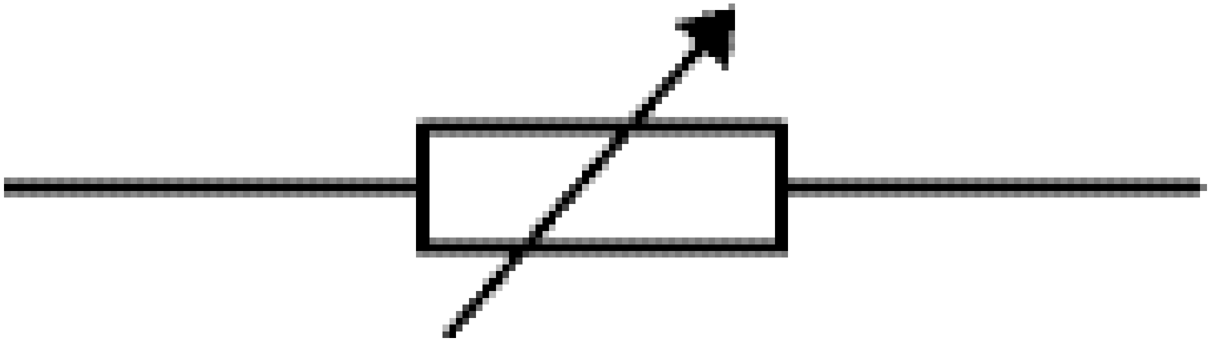
VARYING RESISTANCE

- The opposition to current or resistance of
- a material (measured in Ω) depends on

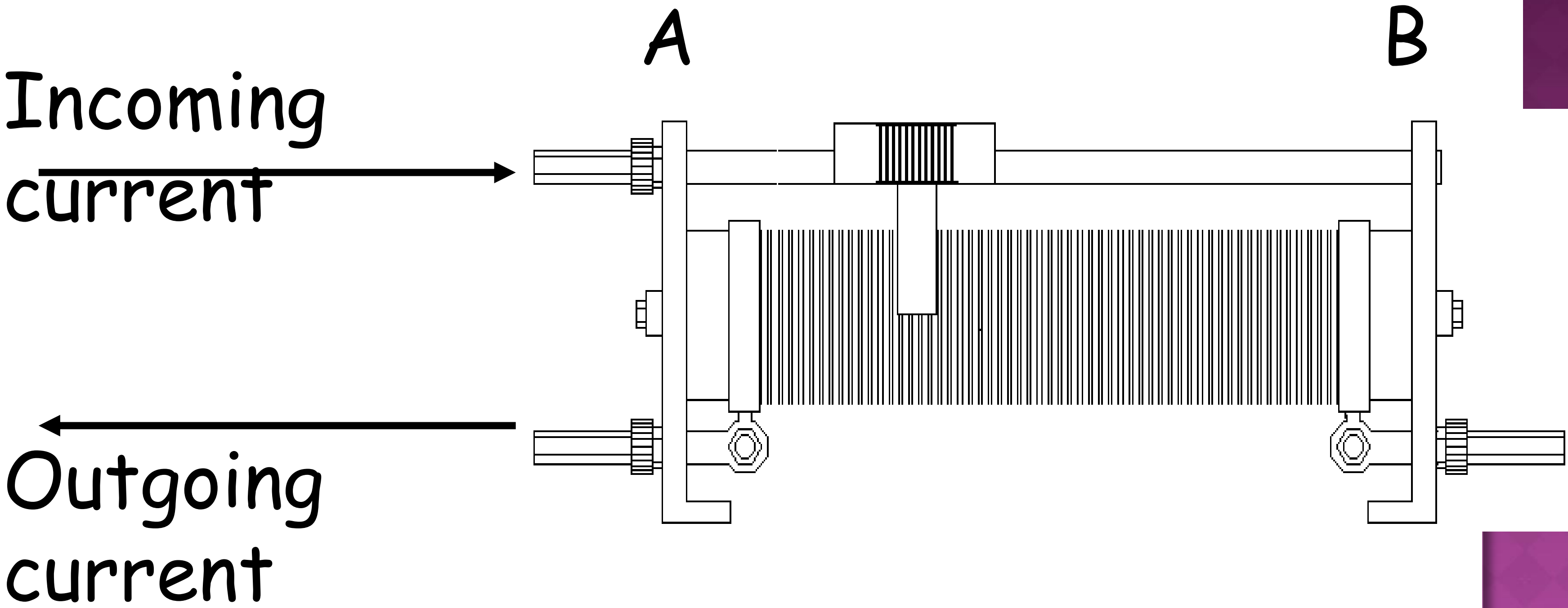
- type of material (the better the conductor, the lower the resistance)
- length of material (the longer the material, the higher the resistance)
- thickness of material (the thinner the material, the higher the resistance)
- temperature of material (the higher the temperature, the higher the resistance)

VARYING RESISTANCE

- The relationship between length of the
- material and resistance allows us to make
- a
- variable resistor (or rheostat).



VARIABLE RESISTOR



Demonstration

VARIABLE RESISTORS

- In the above diagram, if the
- slider is moved in the direction
  A to B the resistance will
- increase because the length
  of
- wire through which the current

USES OF VARIABLE RESISTORS?

- Variable resistors can be used

- as volume or brightness controls on
- televisions
- volume control on MP3 players
- light dimmer switches.

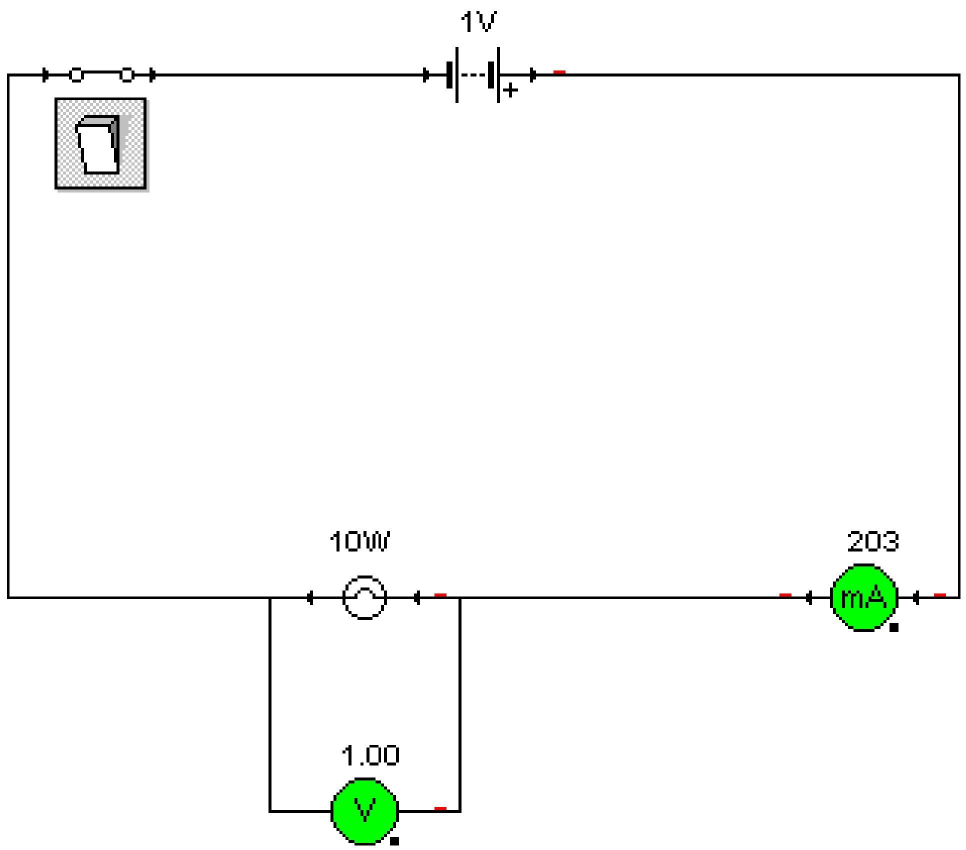
- Key words: resistance, series, parallel,
- ohms, ohmmeter
- By the end of this lesson you will be able
- to:
- State the relationships between total
- resistance and individual resistances in
- series and parallel circuits
- Carry out calculations involving the
- relationships between resistors in series
- and in parallel

- Key words: resistance, series, parallel,
- ohms, ohmmeter

- By the end of this lesson you will have
- practised:
- building a series circuit
- building a parallel circuit
- drawing circuit diagrams
- using an ohmmeter to measure resistance
- in a circuit

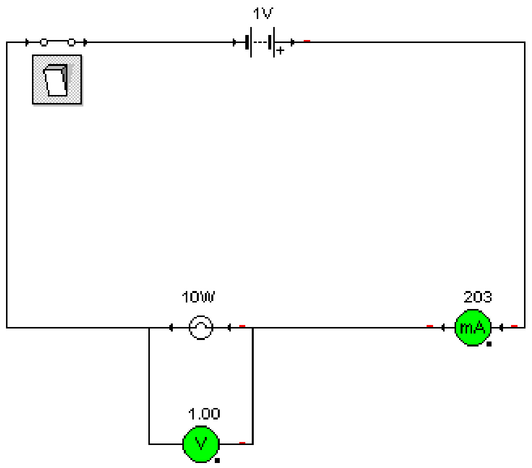
VARIATION OF RESISTANCE AND CURRENT FOR A LAMP FILAMENT

- Look at the circuit diagram below:



Handout

* Name each of the components



* Is this a series or parallel circuit?

* As the voltage across the lamp increases, what do you expect to happen to the current?

* Sketch a graph of your prediction of the relationship between current and voltage.

- In the resistor, current and voltage are
- directly proportional.

- But in a filament lamp, heat is generated.
- We know that resistance increases as
- temperature increases. So we see that as
- voltage increases, temperature increases,
- resistance increases and current
- increases – but more slowly than we might
- predict.

MEASURING RESISTANCE

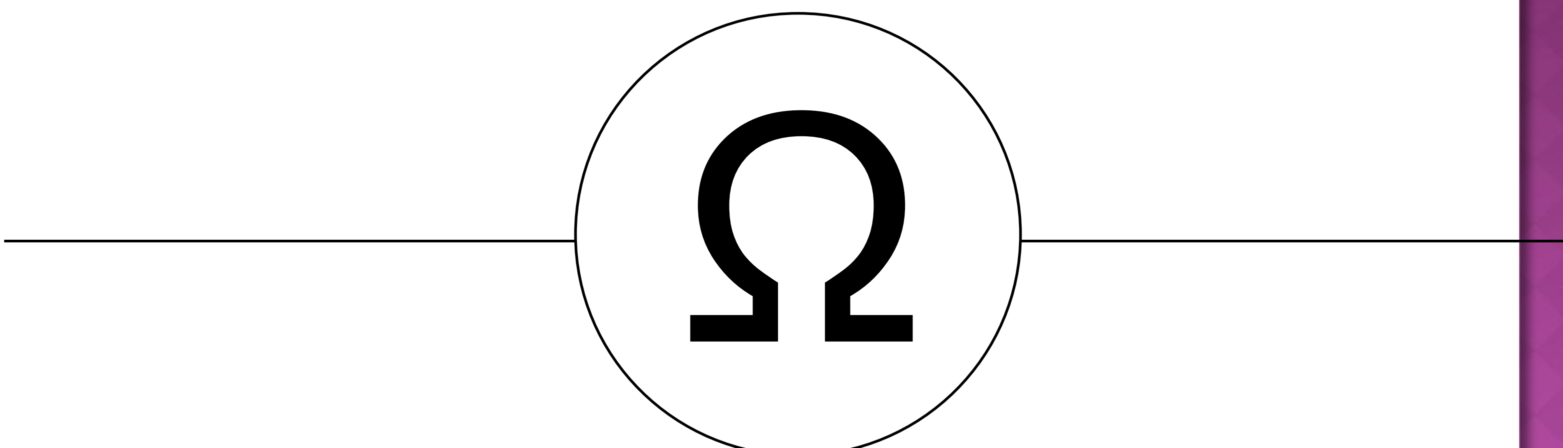
- We can find the resistance of a
- component by measuring

- voltage across the component using
- a voltmeter

- current through the component using
- an ammeter

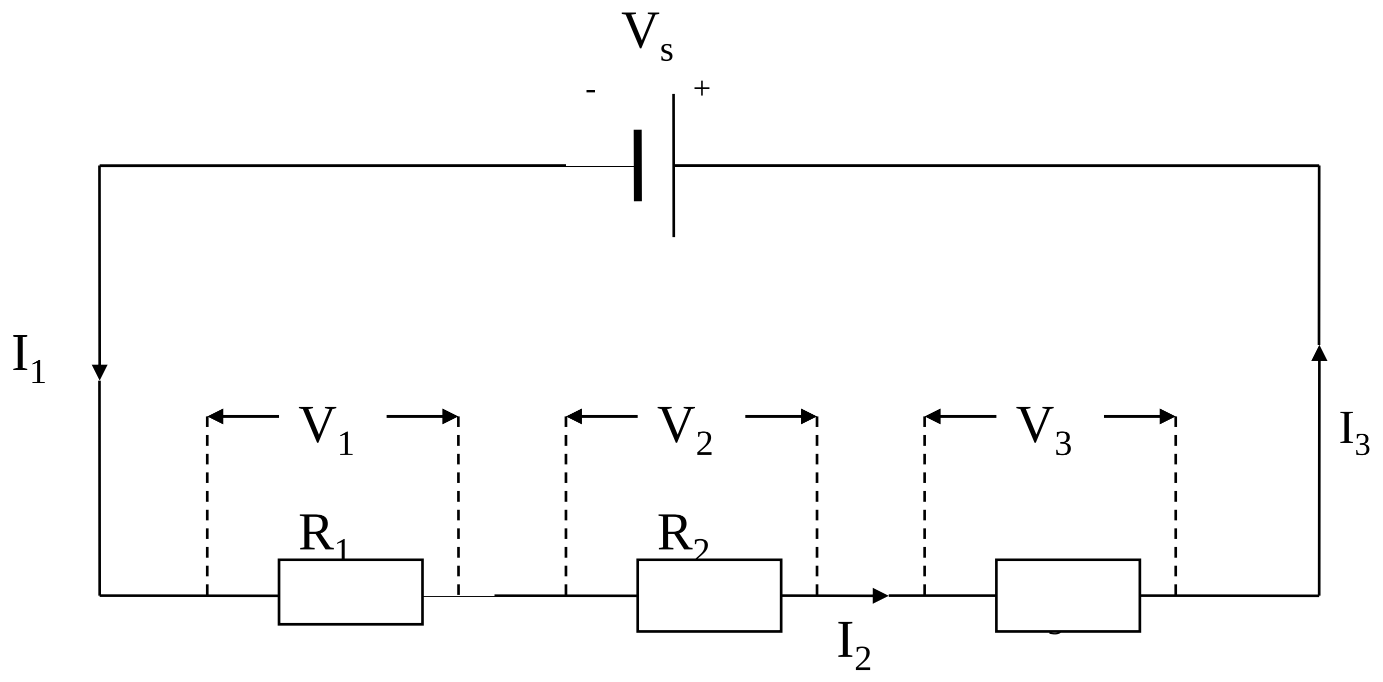
MEASURING RESISTANCE

- or we can measure it directly using an
- ohmmeter

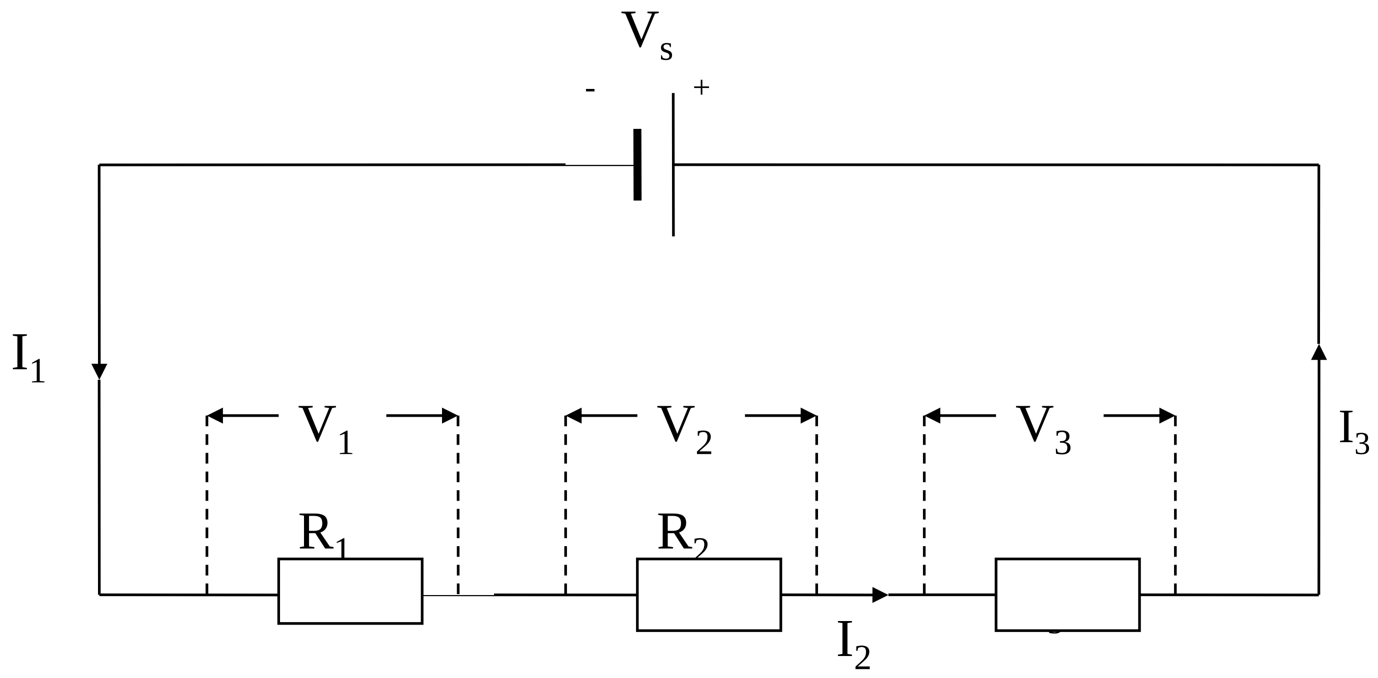


eriment

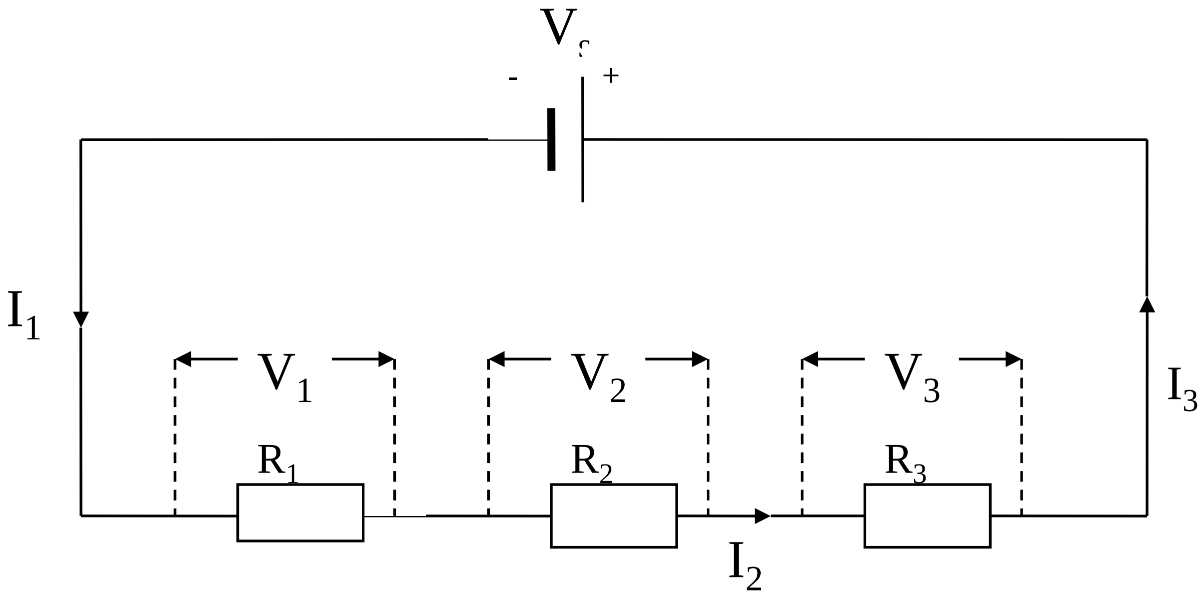
SERIES AND PARALLEL CIRCUITS VOLTAGE, CURRENT AND RESISTANCE



What type of circuit is this?



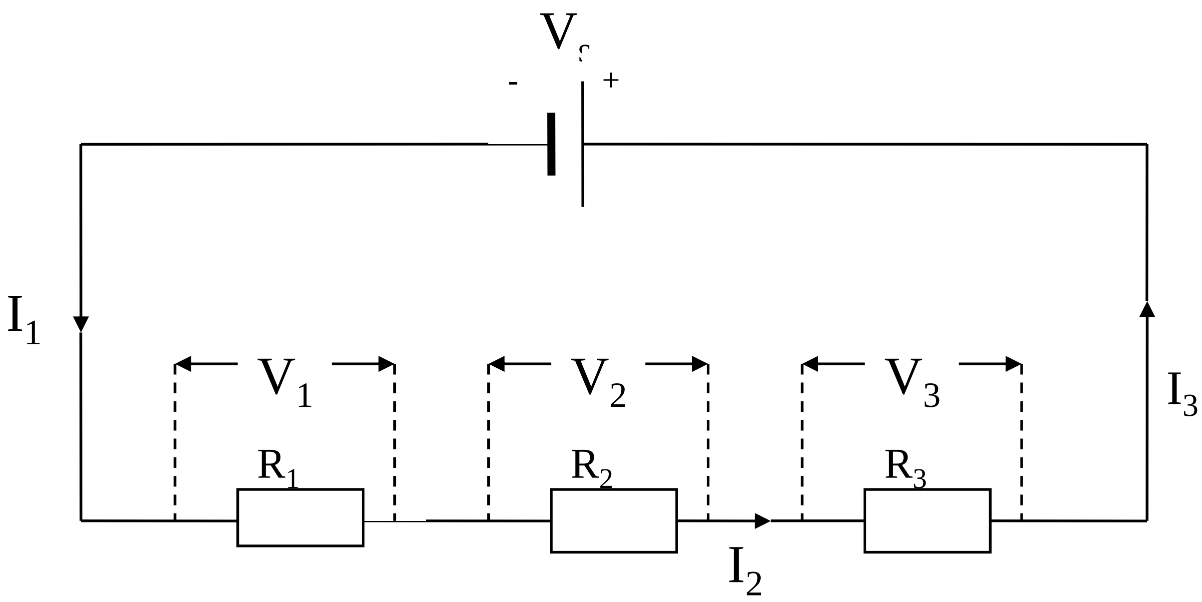
One electrical path from negative to positive therefore series.



What is the relationship between the three currents?

The current is the same at each point.

$$I_1 = I_2 = I_3$$



What is the relationship between the four voltages?

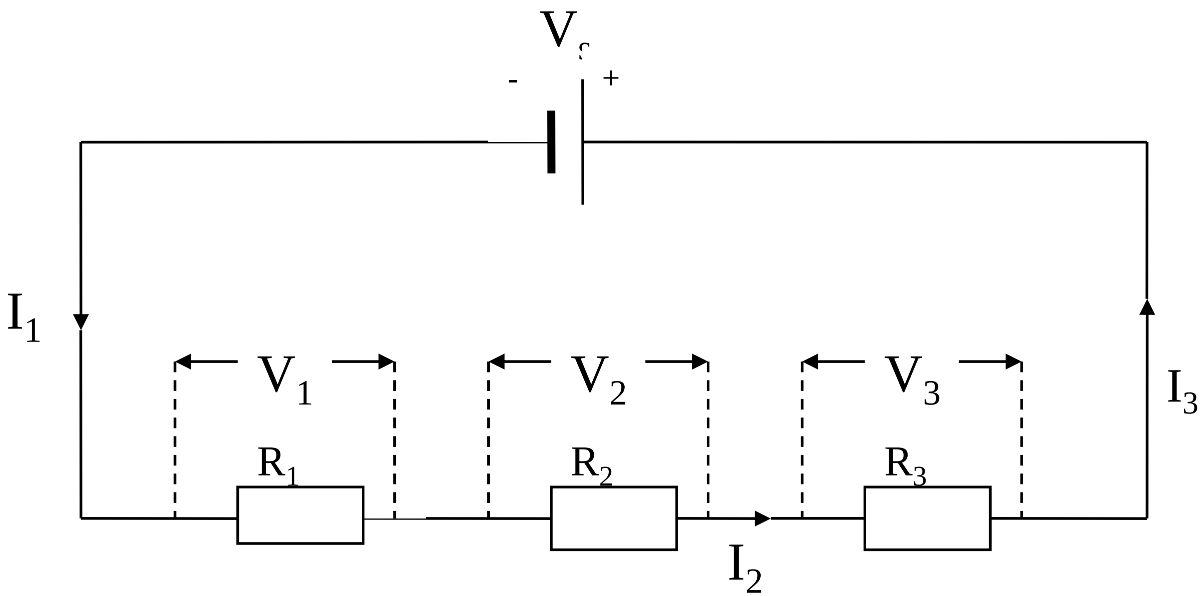
They add to equal the supply voltage.

$$V_s = V_1 + V_2 + V_3$$

DISADVANTAGES OF SERIES CIRCUITS?

- When one component fails the whole circuit
- fails.

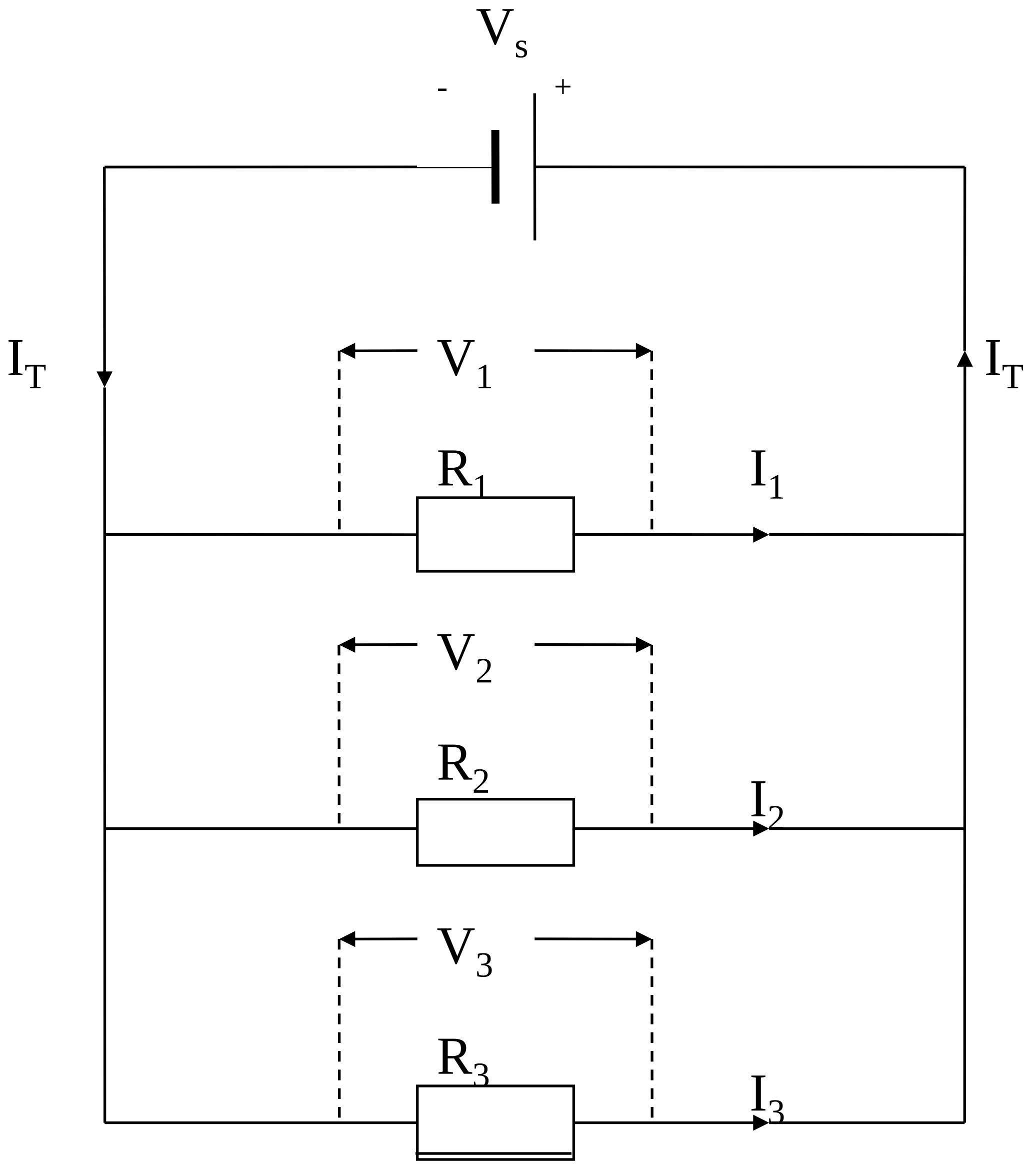
- The current is the same at all points and the
- voltage is divided between the bulbs. The
- more bulbs added the dimmer each one is.



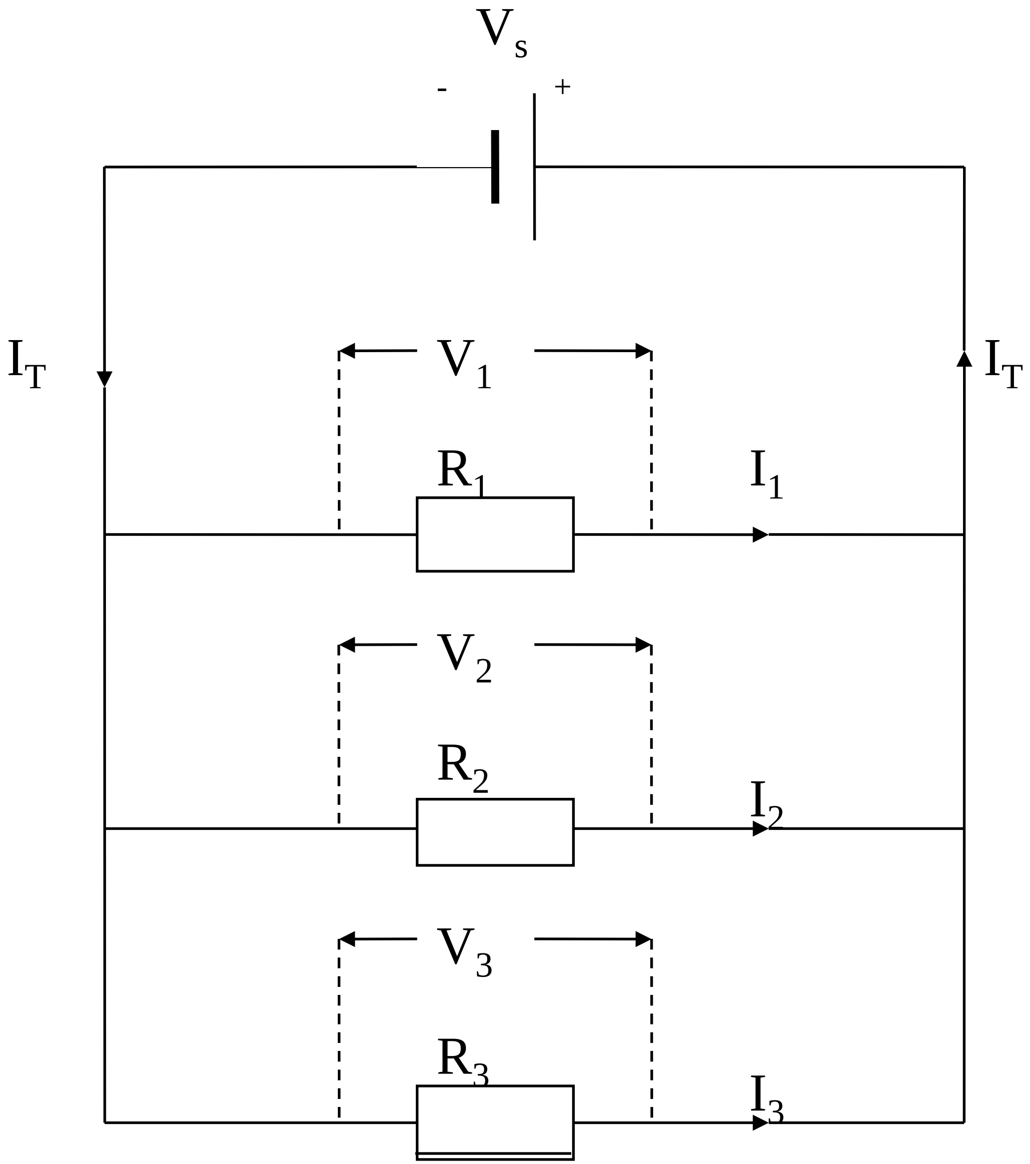
How do you find total resistance in series?

Add each resistance together.

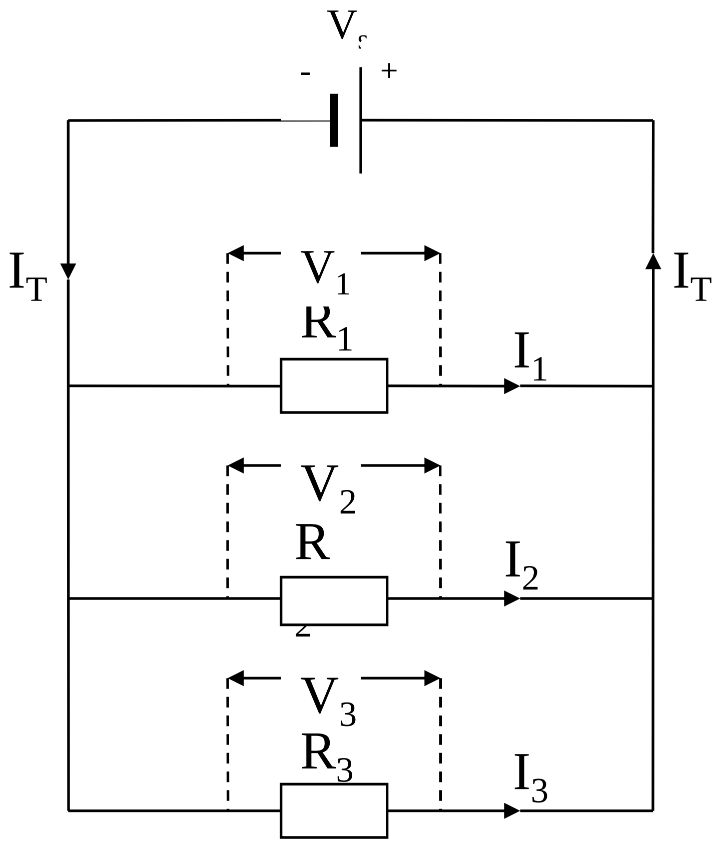
$$R_{total} = R_1 + R_2 + R_3$$



What type of circuit is this?



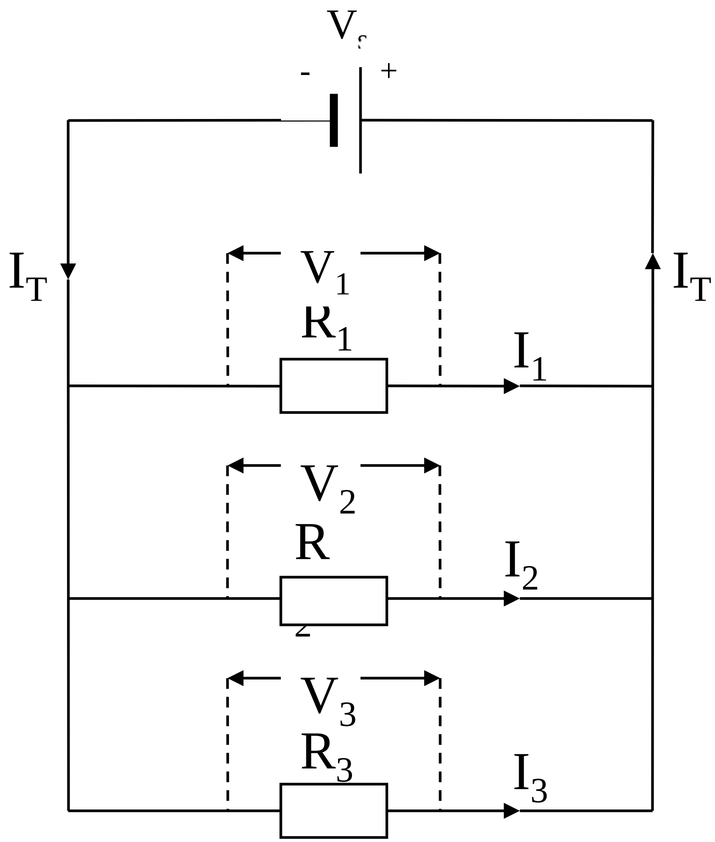
More than one electrical path – components connected on different branches therefore parallel.



What is the relationship between the four currents?

The four currents add to give the total current.

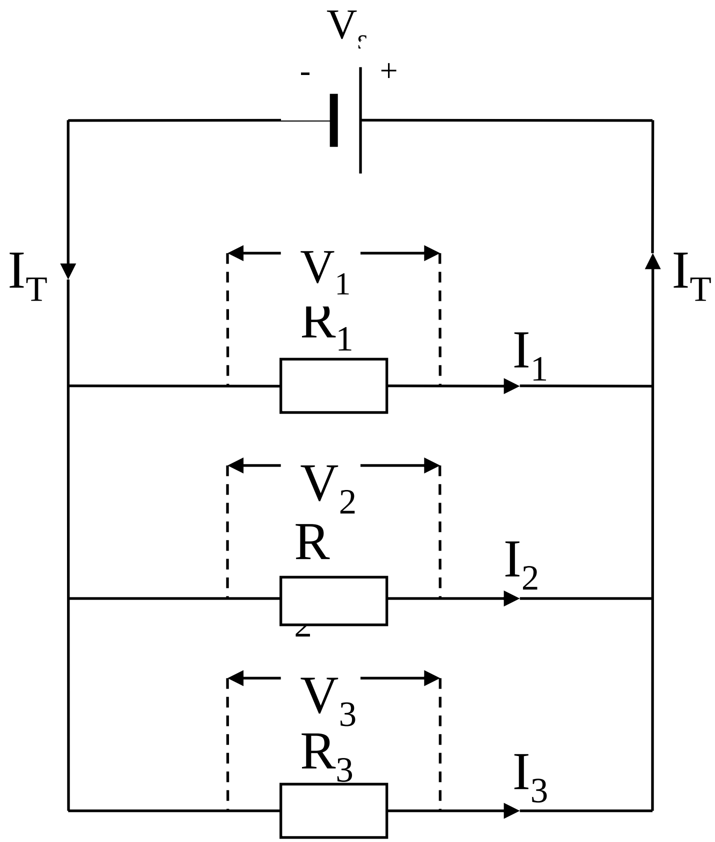
$$I_T = I_1 + I_2 + I_3$$



What is the relationship between the four voltages?

Each voltage is equal to the supply voltage.

$$V_S = V_1 = V_2 = V_3$$



The resistance in parallel?

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

If more resistors are connected in parallel the total resistance will always

decrease

This is because there are more branches through which the electricity can flow.

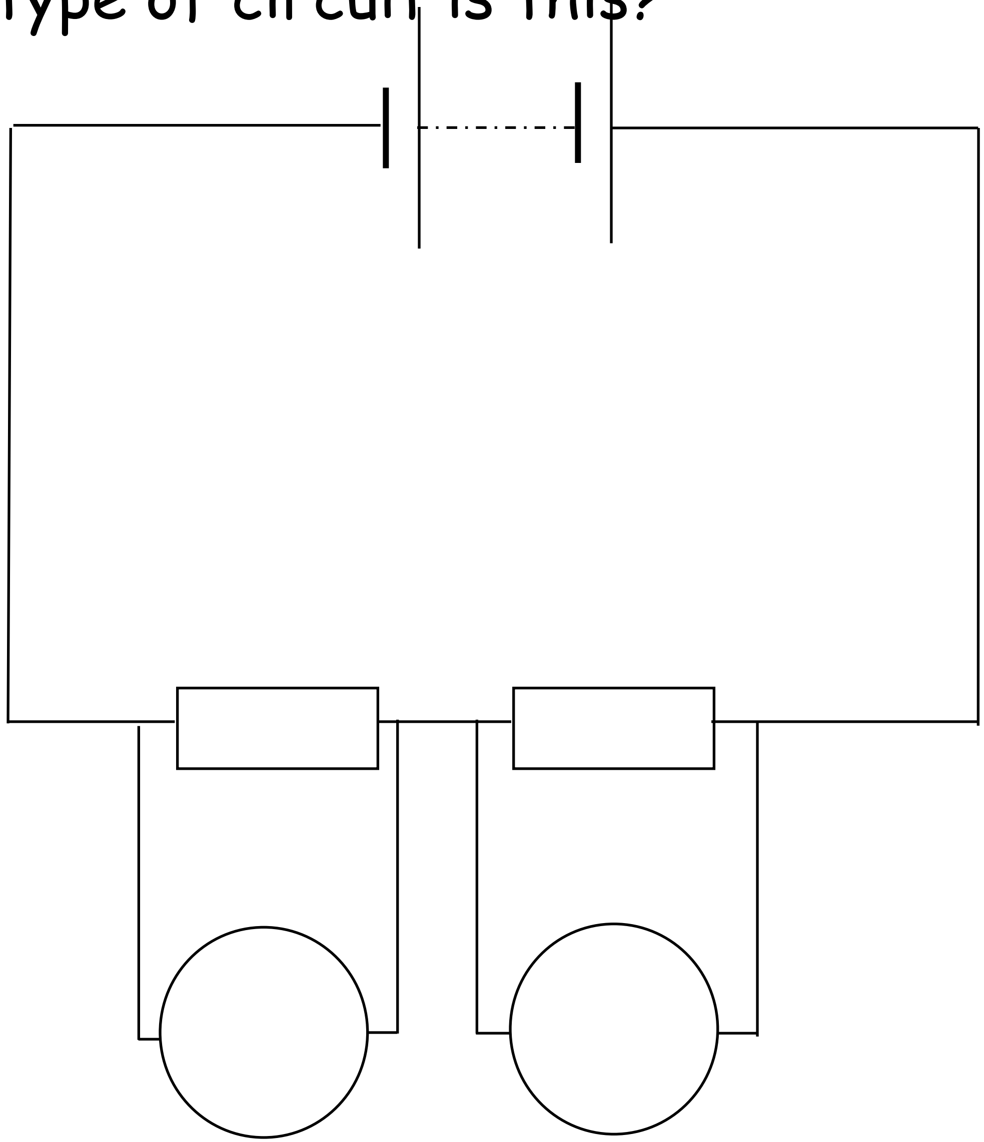
ADVANTAGES OF THE PARALLEL CIRCUIT?

- When one bulb fails the rest of the circuit
- continues to work.

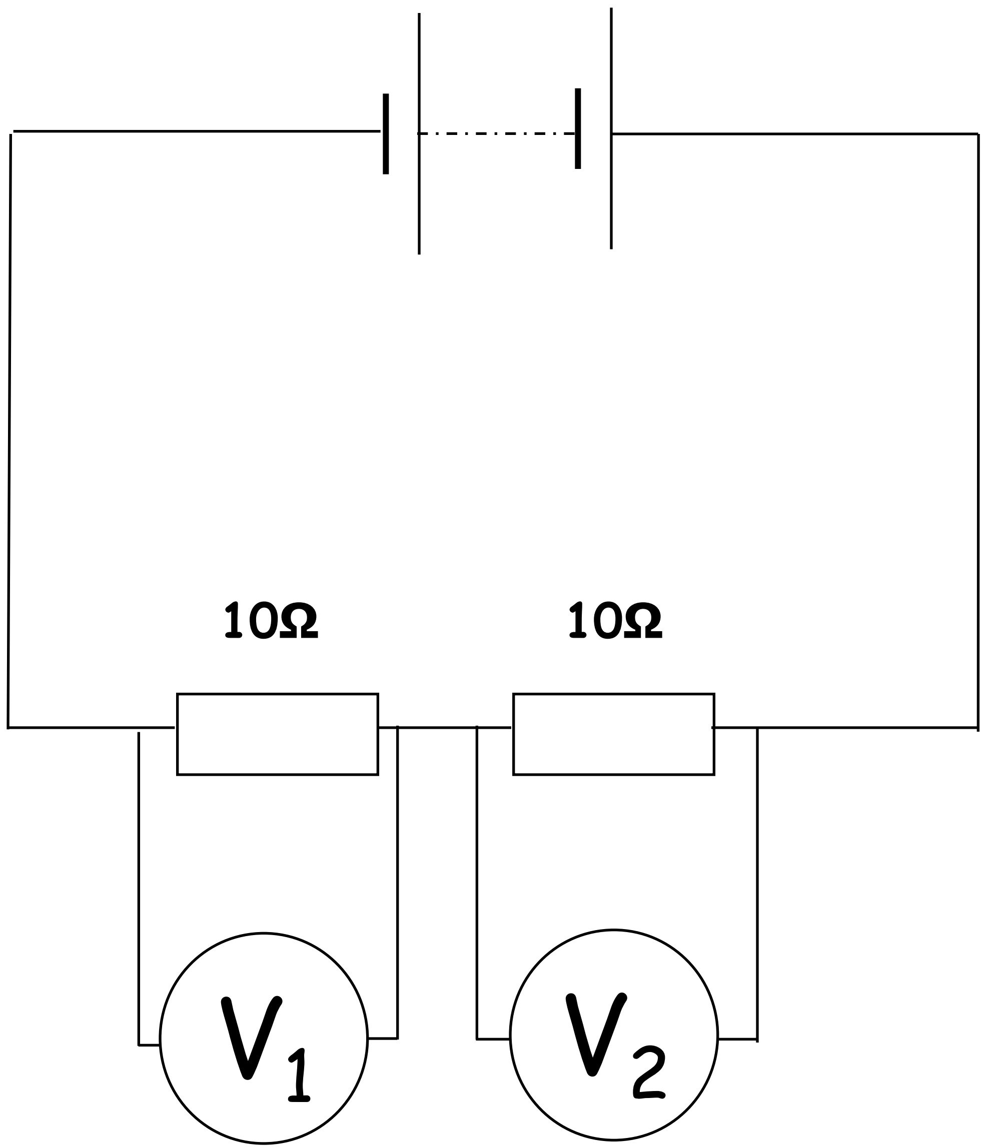
- The more components, the lower the
- resistance. The total current drawn
- increases. Voltage in each branch is the same as
- the supply voltage therefore bulbs in parallel
- will each be as bright as a single bulb.What have you learned today?

- Key words: resistor, resistance, series,
- potential, potential divider
- By the end of this lesson you will be able
- to:
- State that a potential divider circuit
- consists of a number of resistors, or a
- variable resistor, connected across a
- power supply.
- Carry out calculations involving potential
- differences and resistance in a potential
- divider.

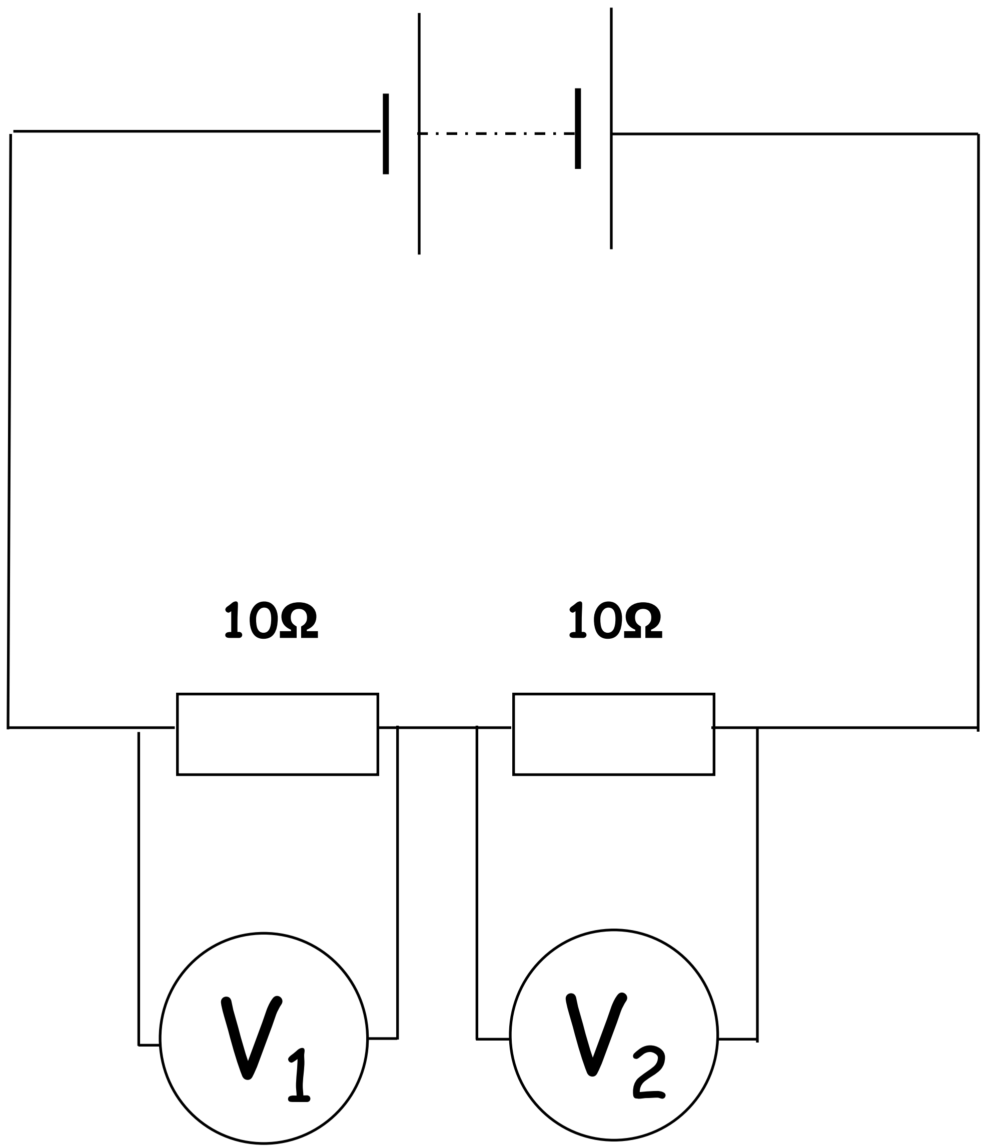
Name each component.
What type of circuit is this?



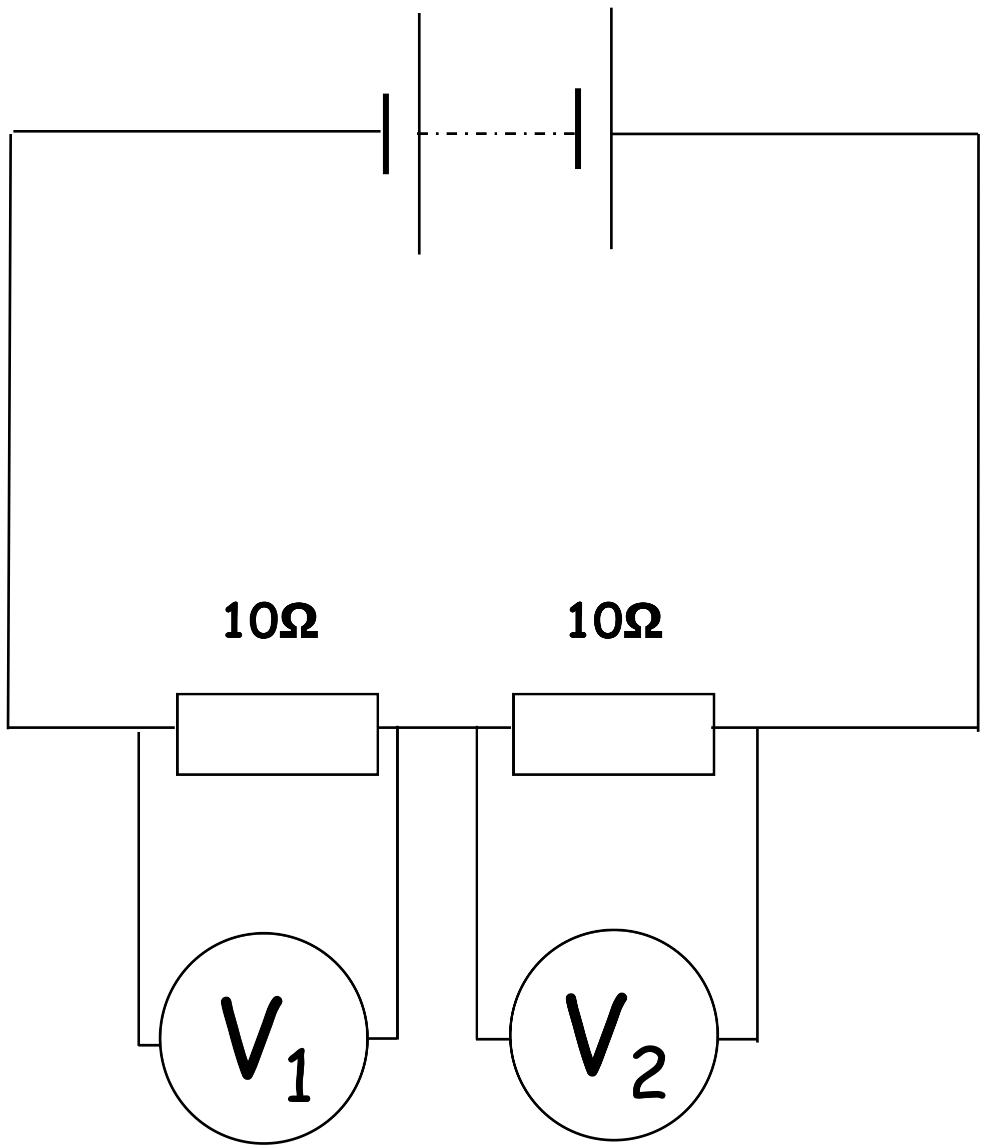
The supply voltage is 6V. What is voltage V_1? V_2?



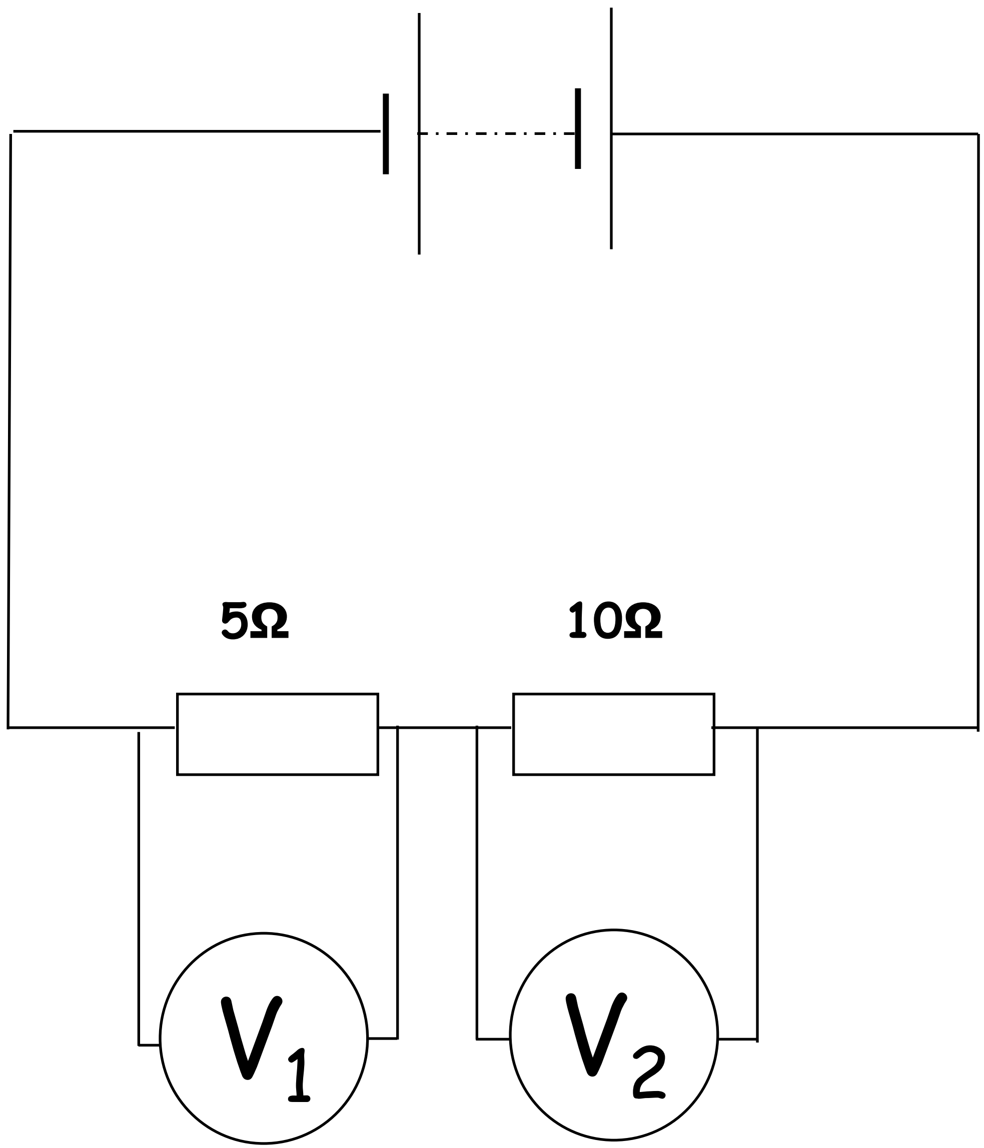
The supply voltage is 10V. What is voltage V_1? V_2?



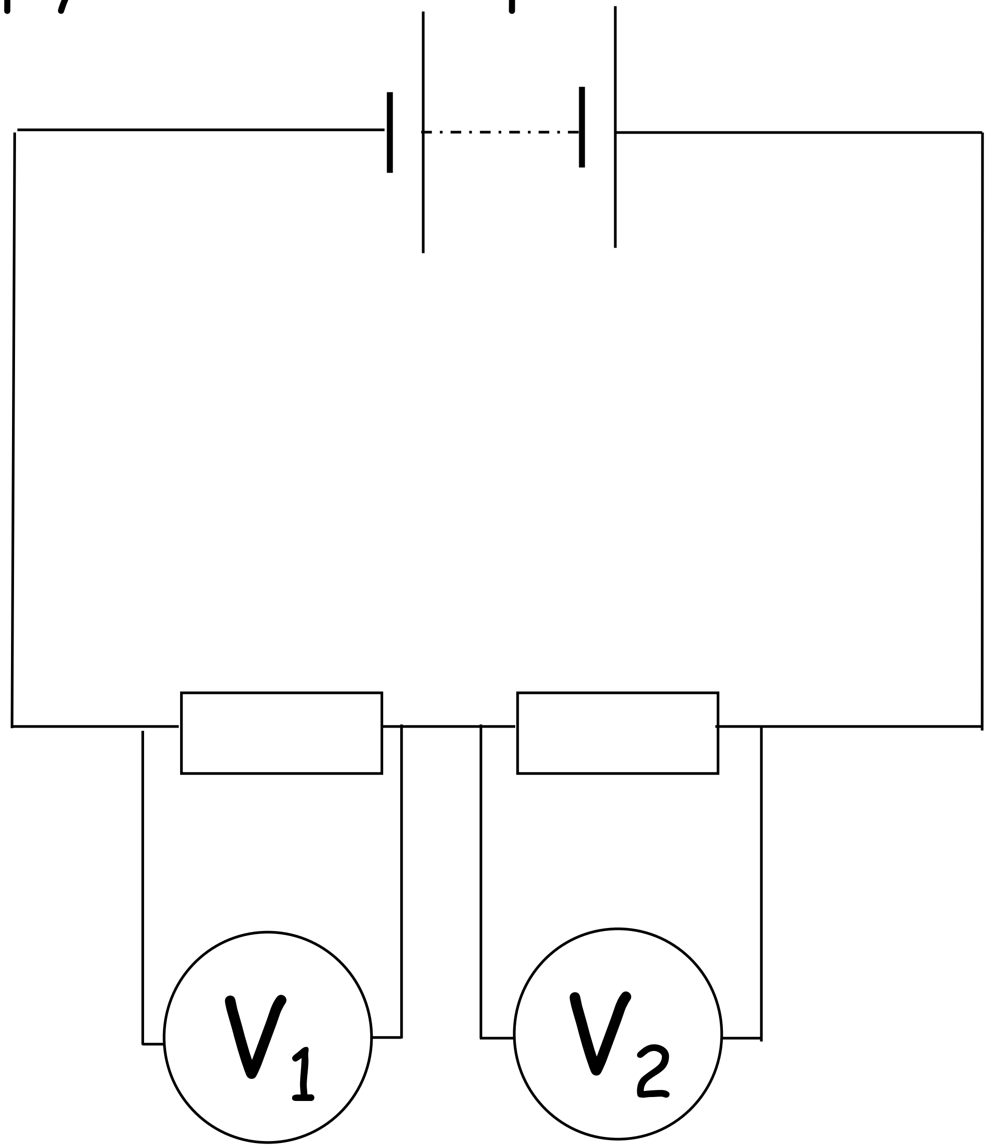
The supply voltage is 5V. What is voltage V_1? V_2?



The supply voltage is 6V. What is voltage V_1? V_2?



A series circuit with two resistor and a power supply is known as a potential divider.



Why is it called a potential divider?

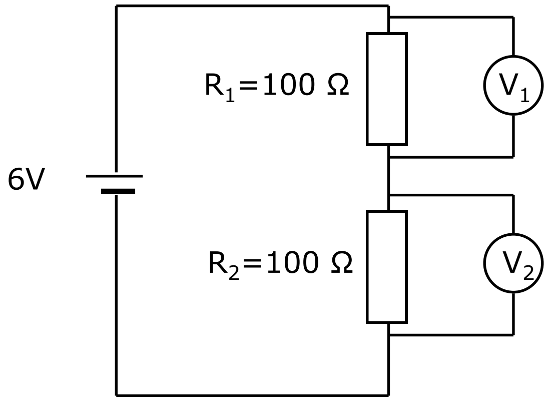
- The potential difference of the supply is
- divided between the two resistors.

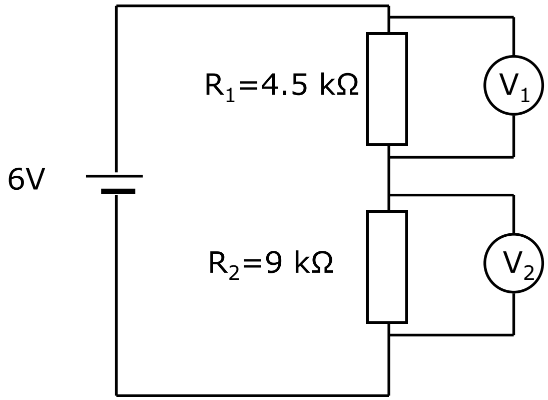
- When the two resistors are identical (i.e.
- have the same value of resistance), the
- potential difference is split equally.

Investigating Potential Dividers

POTENTIAL DIVIDER CIRCUITS

- A voltage divider consists of two devices, usually resistors, connected in series.





- The current in each resistor is calculated
- using Ohm's Law:

- What can we say about the current in a
- series circuit?

- It stays the same throughout the circuit.

$$I_1 = \frac{V_1}{R_1}$$

- In a voltage divider circuit

$$\frac{V_1}{R_1} = \frac{V_2}{R_2}$$

- This can also be written

$$\frac{V_1}{R_1} = \frac{V_2}{R_2}$$

- If the resistance of one resistor
- is increased, the voltage across this
- resistor will

- This means the other voltage must

POTENTIAL DIVIDERS

$$V_1 = \frac{R_1}{R_1 + R_2} V_S$$

What do the symbols mean?

$$V_2 = \frac{R_2}{R_1 + R_2} V_S$$

$$V_1 = \frac{R_1}{R_T} V_S$$

$$V_2 = \frac{R_2}{R_T} V_S$$

POTENTIAL DIVIDERS

$$V_1 = \frac{R_1}{R_1 + R_2} V_S$$

$$V_2 = \frac{R_2}{R_1 + R_2} V_S$$

$$V_1 = \frac{R_1}{R_T} V_S$$

$$V_2 = \frac{R_2}{R_T} V_S$$

Look again at the worksheet.

Use the formula to calculate V_1 and V_2 for each circuit.

The answers found using the formula match the values measured using the voltmeter.

POTENTIOMETER

- The **potentiometer** is a special type of
- voltage divider.

- It is a **variable resistor** with a sliding
- contact.

- What range of output is it possible to
- obtain from a potentiometer?

- Range of output voltages 0V to supply
- voltage.

- Key words: electrical energy, power,
- voltage, current, resistance
- By the end of this lesson you will be able
- to:
- State that when there is an electrical current
- in a component there is an energy
- transformation and give some examples.
- State the relationship between energy and
- power.
- Carry out calculations using $E = Pt$
- State that in a lamp electrical energy is
- transformed into heat and light.
- State that the energy transformation in an
- electrical heater occurs in the resistance wire.

WHAT IS A VOLTAGE?

WHAT IS A VOLT?

WHAT IS "POTENTIAL DIFFERENCE" ? WHAT IS VOLTAGE?

- It is the same thing!

- The potential difference (p.d.), or voltage,
- of a battery is a measure of the electrical
- energy given to one coulomb of charge
- passing through the battery.

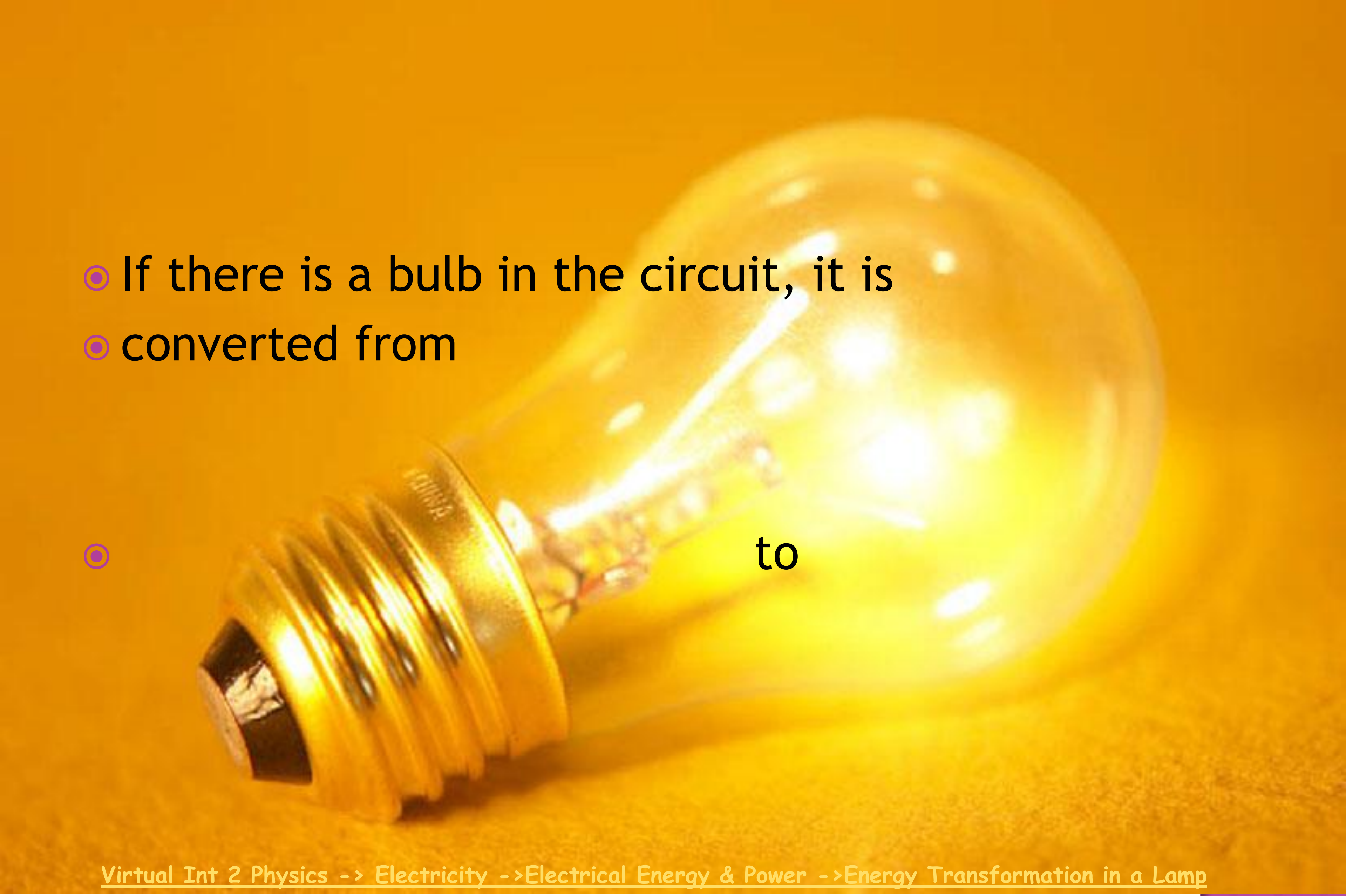
WHAT IS THE ENERGY CHANGE WHICH TAKES PLACE IN A BATTERY?

Chemical to Electrical

WHEN A BATTERY IS IN A CIRCUIT…

- The electrical energy is carried by the
- electrons that move round the circuit.

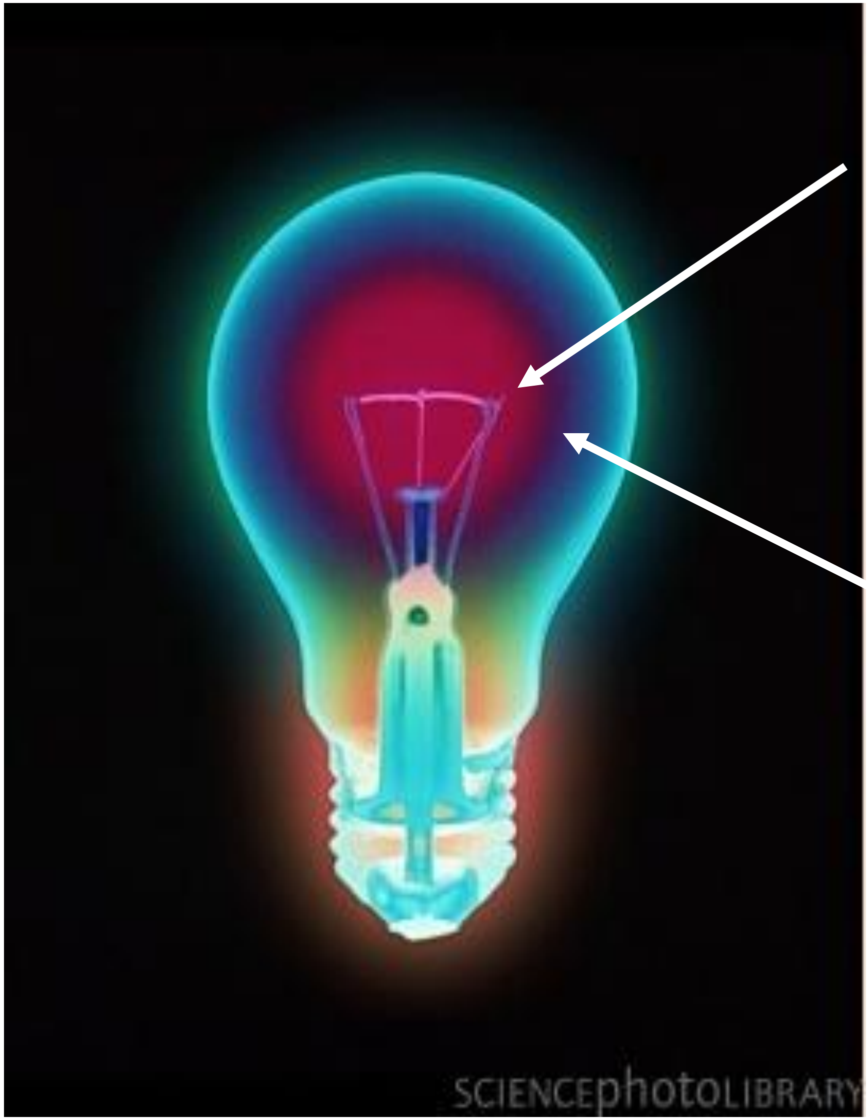
- It is converted into others forms of
- energy.



- If there is a bulb in the circuit, it is
- converted from
- to

[Virtual Int 2 Physics -> Electricity ->Electrical Energy & Power ->Energy Transformation in a Lamp]()

FILAMENT LAMPS



- Filament of tungsten wire

Glass

How does it work?

FILAMENT LAMP

Tungsten (metal) filament becomes so hot it glows.

Why isn't oxygen used inside the bulb?

FILAMENT LAMPS

- Electric current
- passes through the
- resistance wire which
- is made of tungsten.
- Electrical energy is
- changed into heat
- energy and the
- wire glows white hot.

- Filament lamps
- produce both heat and
- light.

- In an electric fire, energy is converted
- from
- to

RESISTANCE IN A WIRE

We have learned that when a voltage is applied across a lamp, the resistance increases.

What happens to the temperature?

RESISTANCE IN A WIRE

As current passes through a resistance wire, the wire gets hot.

This is how electric fires and filament lights work.

The filament becomes hot enough to glow and emit light. The bar of the electric fire is a length of wire which also glows when hot.

What are the energy changes taking place in these appliances?

POWER AND ENERGY

- Electrical energy has the symbol
- and is measured in

POWER

- The power rating of an appliance or a
- component is defined as
- the amount of energy used by the
- component / appliance in one
- second

POWER

- The power rating tells us the rate at
- which energy is transformed, that is the
- energy transformed each second.

POWER

- For example, an appliance with a power
- rating of 250 W converts 250 Joules of
- electrical energy into another form each
- second.

POWER

- How can this be written as a formula?

Power in Watts (W)

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

Energy in Joules (J)

time in seconds (s)

Demonstration / experiment

Investigating Energy and Power

Connect the joule meter to the voltage supply and a ray box bulb to the joule meter.

Set the supply voltage at 6V and switch on. You'll see the counter on the joule meter increasing (note each time the counter increases by **1, this is 100J of energy)**.

Record the number of joules used in 50s and 100s. Calculate the number of joules used per second.

Power is energy used per second, in watts. Write the formula:

If the supply voltage was increased to 12V, what would you expect to happen?

Increase supply voltage to 12V and repeat the experiment.

Worksheet / experiment

POWER AND ENERGY

Ray box bulb, 6V supply		Ray box bulb, 12V supply	
Number of joules used in 50 s?		Number of joules used in 50 s?	
Number of joules used in 100 s?		Number of joules used in 100 s?	
Number of joules used each second?		Number of joules used each second?	
Power (W)		Power (W)	

Were your results as expected?

1 watt is equivalent to the transfer of 1 joule per second.

POWER & ENERGY EXAMPLE

If an electric fire uses 1.8 MJ of energy in a time of 10 minutes, calculate the power output of the fire.

POWER & ENERGY EXAMPLE

$P = ?$

$E = 1.8\ MJ = 1.8x10^6\ J$

t=10 minutes = 600 s

FORMULA?

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

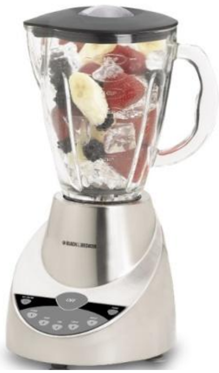
POWER RATINGS OF APPLIANCES

- Different appliances have different
- power ratings.

- What is meant by power?

WATT'S MY POWER RATING?









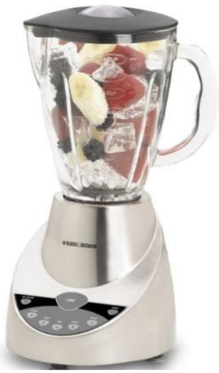

500 W, 150 W, 1200 W, 100 W, 3000 W, 300 W, 800 W, 1500 W, 30 W, 60 W, 11 W

WATT'S MY POWER RATING?

WHAT HAVE YOU LEARNED TODAY?

- Key words: electrical energy, power,
- voltage, current, resistance
- By the end of this lesson you will be able
- to:
- State that the electrical energy
- transformed each second = VI
- Carry out calculations using P=IV and E=Pt
- Explain the equivalence between VI, I^2R
- and V^2/R.
- Carry out calculations involving the
- relationships between power, current,
- voltage and resistance.

WATT'S MY POWER RATING?



500 W, 150 W, 1200 W,
100 W, 3000 W, 300 W,
800 W, 1500 W, 30 W, 60 W,
11 W

WATT'S MY POWER RATING?

CURRENT THROUGH APPLIANCES

- Different appliances have different
- power ratings.

- $P = IV$

- For appliances which use the mains supply
- V =

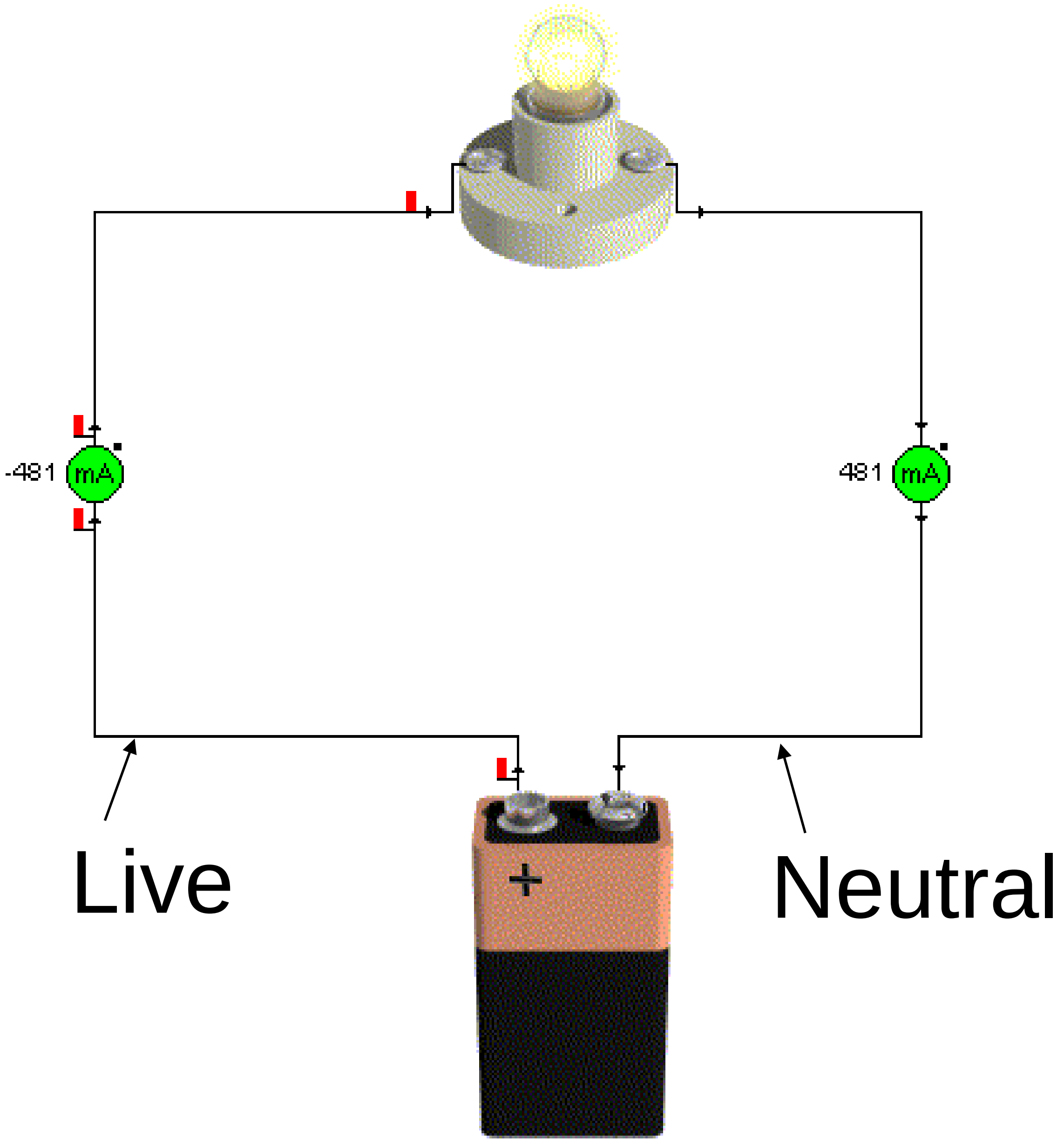
CURRENT THROUGH APPLIANCES

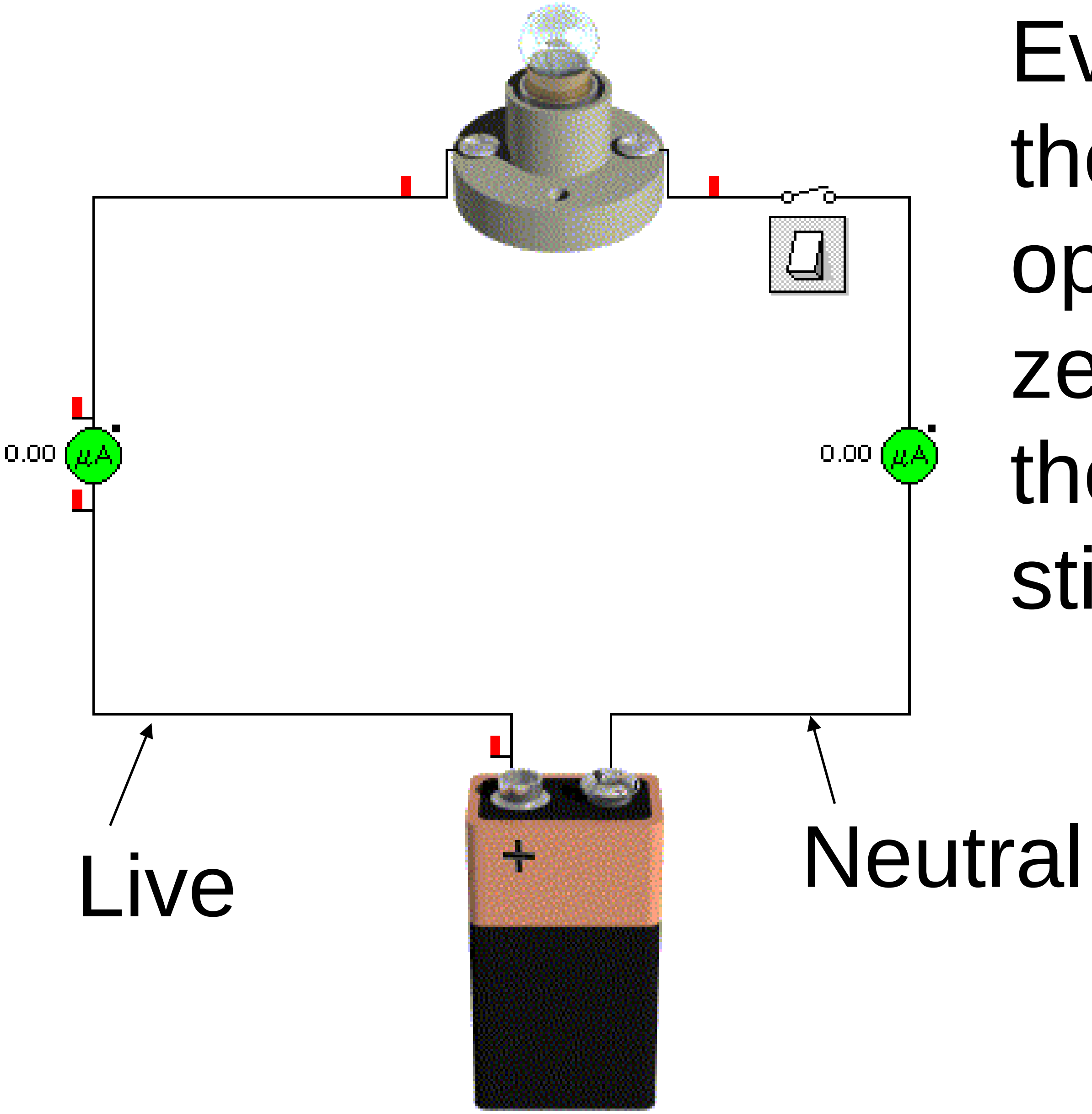
- As power increases for a fixed voltage,
- what happens to the current?

- As power increases the current

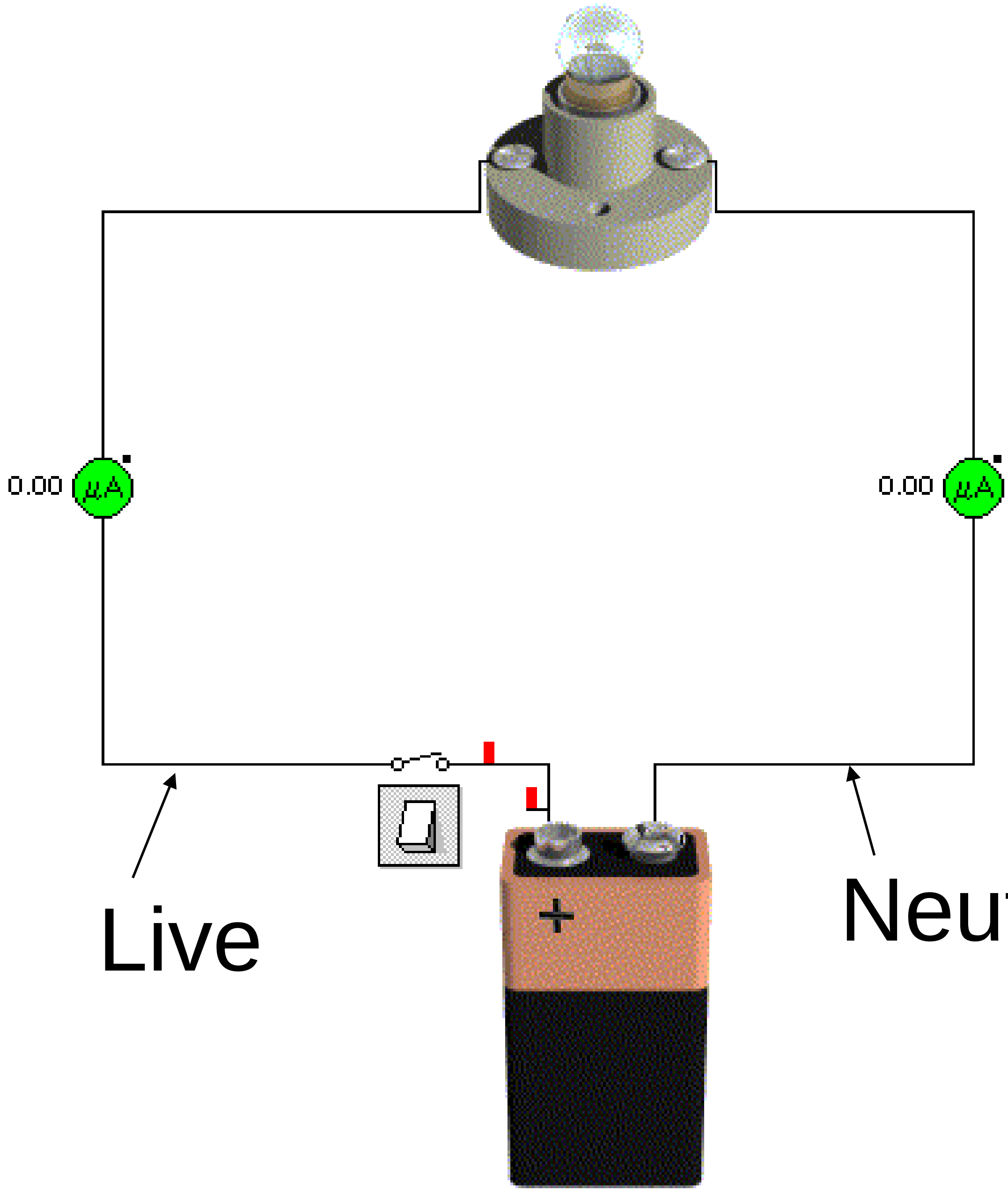
  -

Red flag indicates 9V.

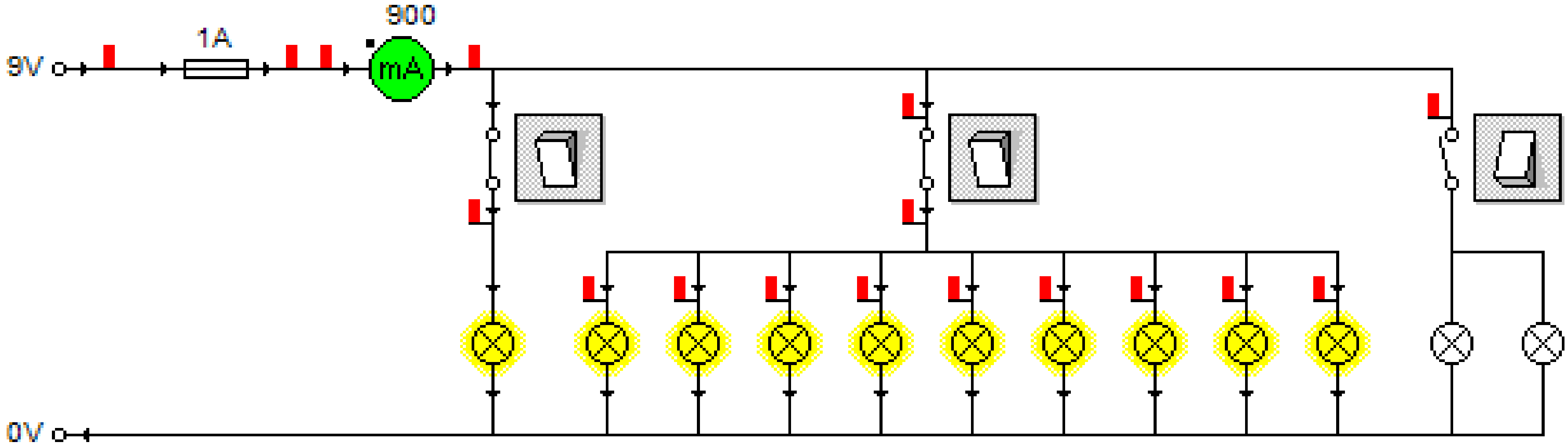




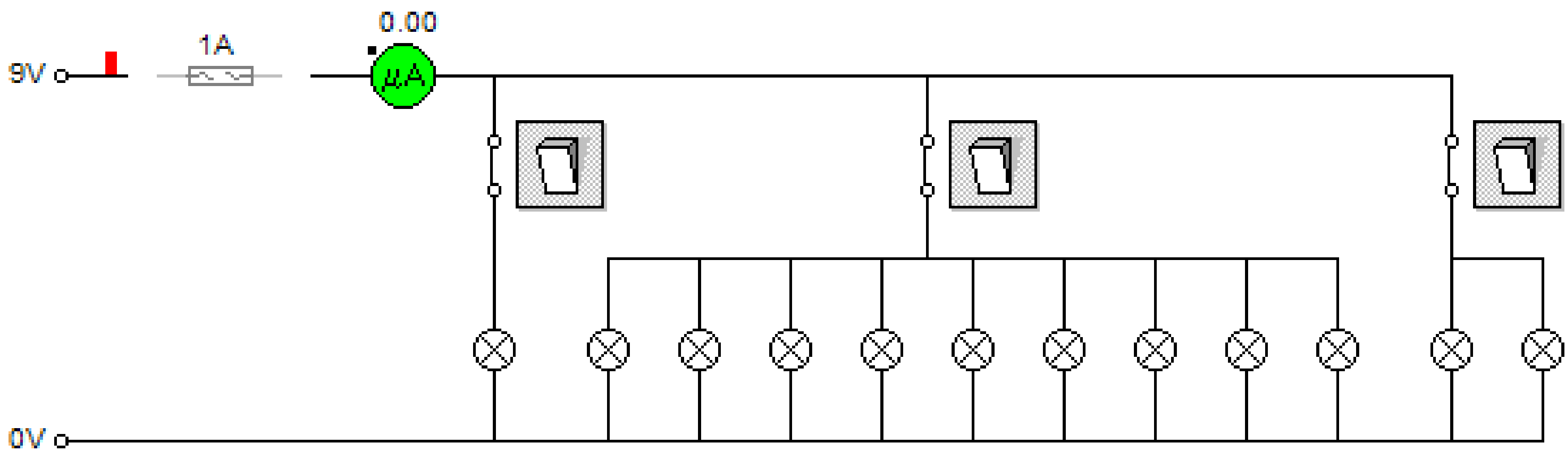
Even with the switch open and zero current the lamp is still at 9V.



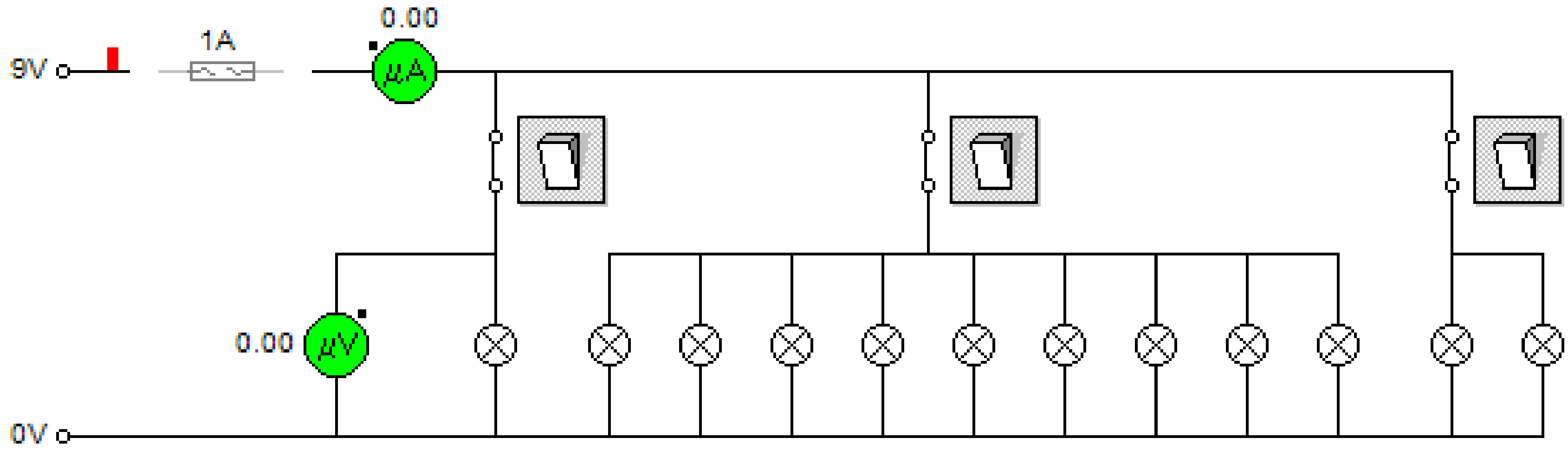
This time, when the switch is open, the lamp is at 0V and is safe to touch.



The red flags indicate that voltage at these points is 9V.

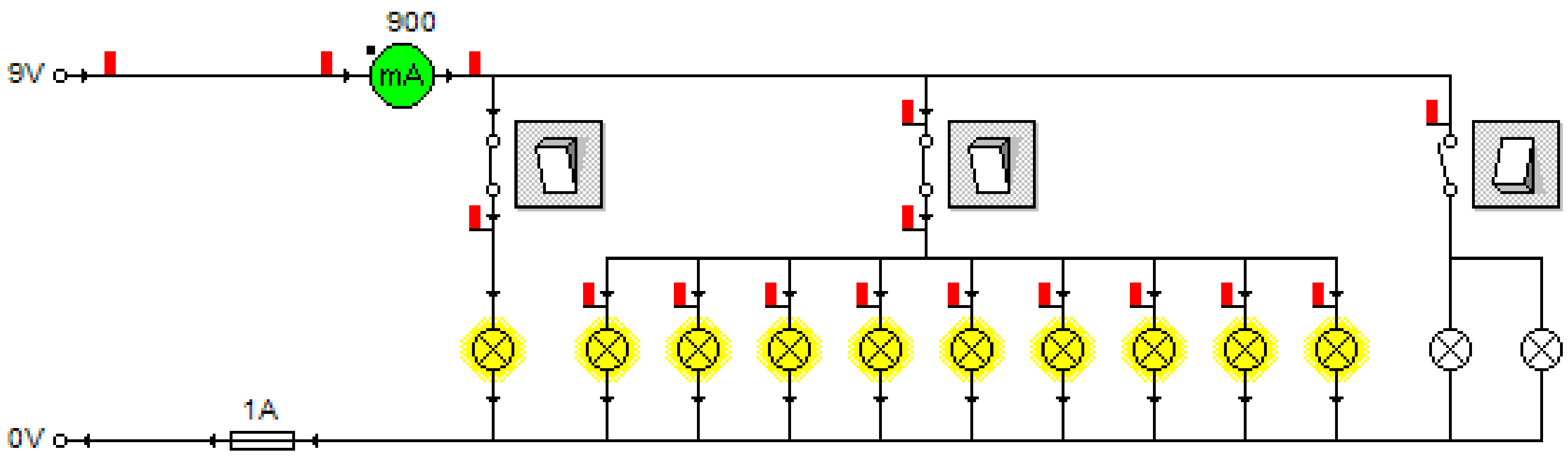


Closing the third switch results in a current greater than 1A, blowing the fuse.

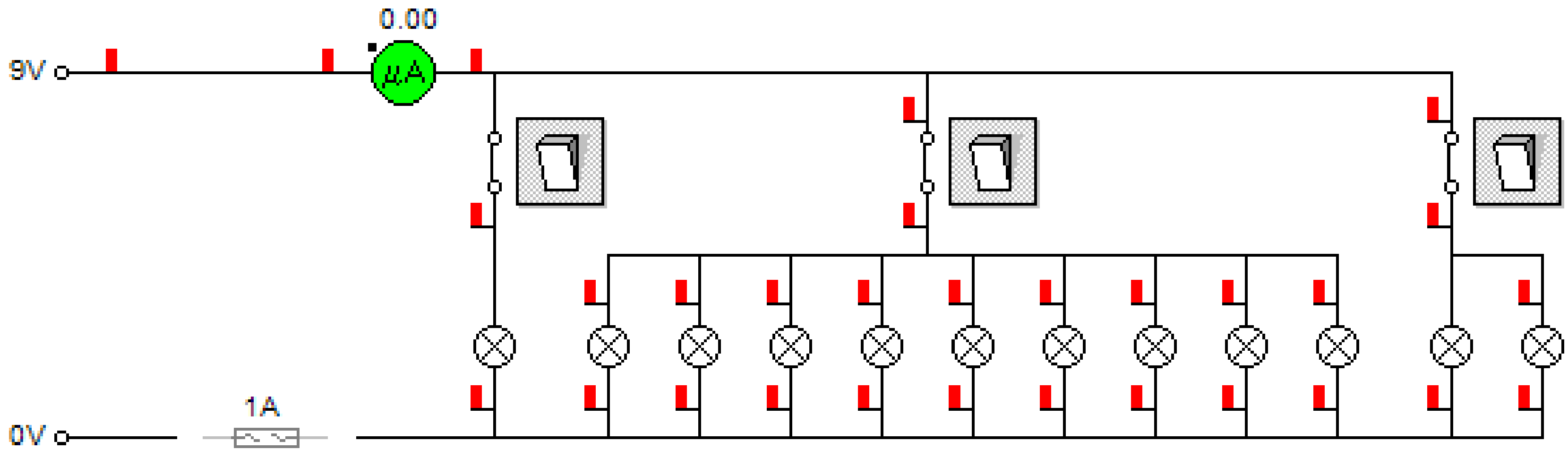


Inserting a voltmeter across a bulb shows that the bulbs are at zero volts.

If you touch them, you won't receive an electric shock as they are isolated from the voltage supply.



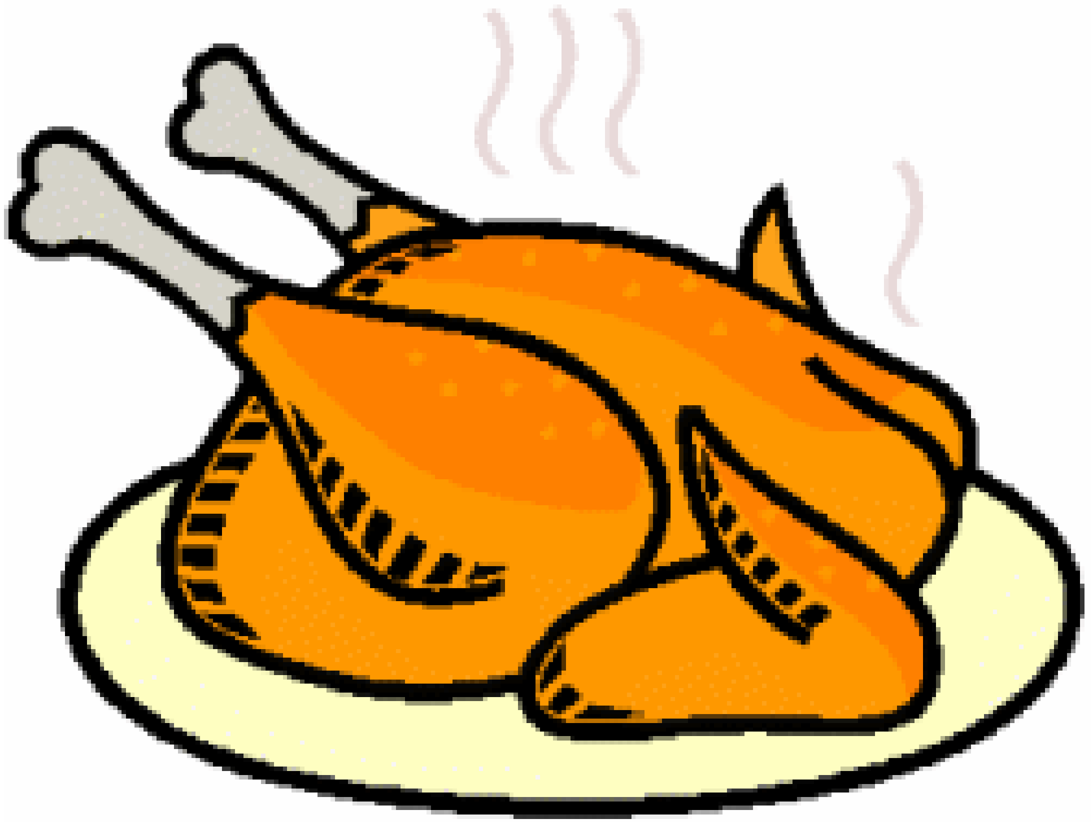
The red flags indicate that voltage at these points is 9V. The fuse is now in the neutral wire.



Closing the third switch results in a current greater than 1A, blowing the fuse.
The red flags show that at these points the voltage is still at 9V.
If you touch this now, you'll complete the circuit and receive an electric shock – you become the "neutral wire" and allow electricity to flow through you.

Why can a bird sit safely on this high voltage power line?

What will happen if the bird spreads its wings and touches the pylon?



WHICH FUSE TO USE?

- How would you calculate which fuse is required for an appliance?
- An appliance operating from the mains supply has a supply voltage of 230V.
- The rating plate gives you information on the power of the appliance.

- The formula which links voltage, power and current:

- $$P = VI$$

- The general rule for fuses

The fuse value needs to be just above the normal operating current

If the appliance has a power rating of:	Fuse value should be:
Less than 700W	3A
More than 700W	13A

EXAMPLE

- What is the appropriate choice of fuse for a
- mains appliance with a power rat
- 330 W?

$V = 230V$

$P = 330W$

$I = ?$

EXAMPLE

- What is the appropriate choice of fuse for a
- mains appliance with a power rat
- 330 W?

$$V = 230V$$

$$P = 330W$$

$$I = ?$$

POWER RATINGS OF APPLIANCES

- Which type of appliances tend to have the
- highest power ratings?

POWER RATINGS OF APPLIANCES

- Which type of appliances draw the
- highest current?

POWER RATINGS OF APPLIANCES

- Which type of appliances need the largest
- value of fuse?

- Examples of
- rating plates

AC 230 V ~ 50 Hz

75 W

230 V ~ 50 Hz

2000 W

230 V ~ 50 Hz

350 W

WHAT HAVE YOU LEARNED TODAY?

- Key words: electrical energy, power,
- voltage, current, resistance
- By the end of this lesson you will be able
- to:
- State that the electrical energy
- transformed each second = VI
- Carry out calculations using P=IV and E=Pt
- Explain the equivalence between VI, I^2R
- and V^2/R.
- Carry out calculations involving the
- relationships between power, current,
- voltage and resistance.

- Investigating…
- power, voltage, current and
- resistance.
- What do you notice about

$$IV, I^2R, \frac{V^2}{R}$$

Worksheet / experiment

- Power can be calculated from the voltage across the appliance and the current flowing through it. Written as an equation:

- $P = IV$

RELATIONSHIP BETWEEN POWER, CURRENT, VOLTAGE AND RESISTANCE

- Our experiments showed that

$$IV$$

RELATIONSHIP BETWEEN POWER, CURRENT, VOLTAGE AND RESISTANCE

EQUATIONS FOR POWER

$$P = VI \text{ and } V = IR$$

$$Substituting$$

$$P = IxRxI$$

$$P = I^2R$$

EQUATIONS FOR POWER

$$P = VI \text{ and } V = IR$$

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

$$Substituting$$

$$P = Vx\frac{V}{R}$$

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

WHAT HAVE YOU LEARNED TODAY?

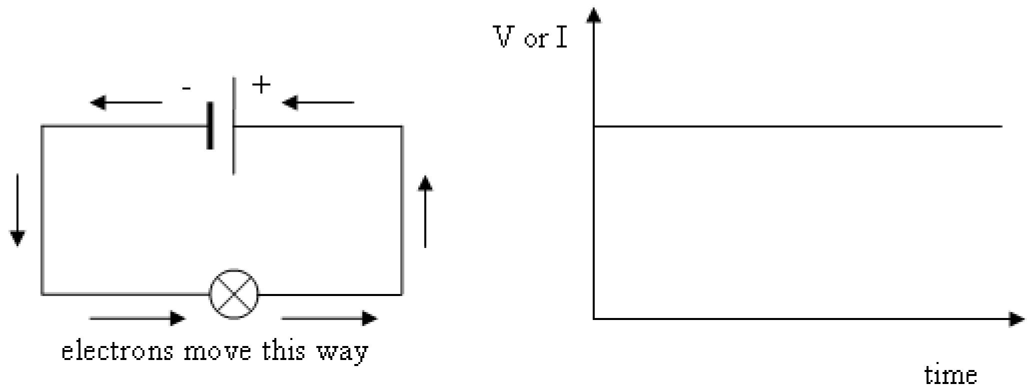
- Key words: alternating current, direct
- current, mains supply, frequency
- By the end of this lesson you will be able
- to:

- Explain in terms of current the terms a.c. and d.c.
- State that the frequency of the mains supply is 50Hz.
- State that the quoted value of an alternating voltage is
- less than its peak value.
- State that a d.c. supply and an a.c. supply of the
- same quoted value will supply the same power to
- a given resistor.

DIRECT CURRENT (D.C.)

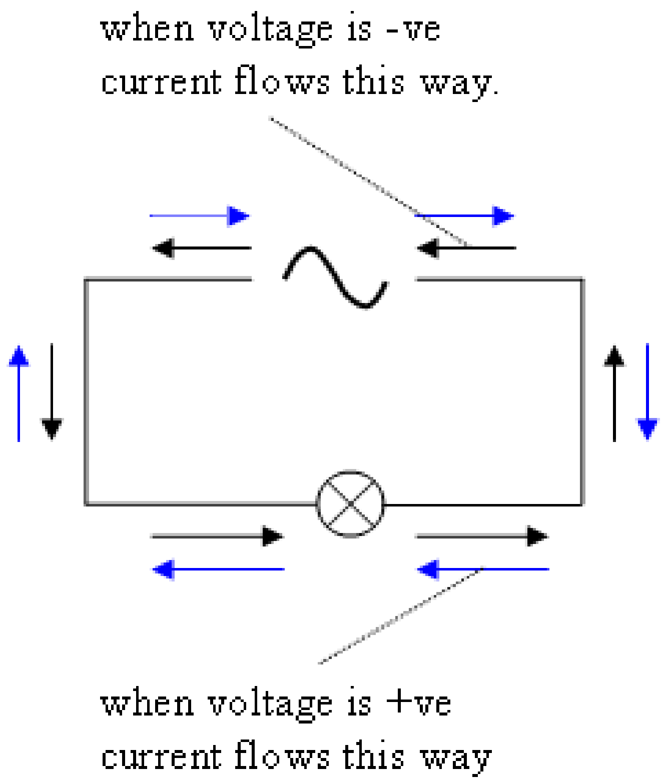
- The voltage drives a steady or direct current.
- The electrons move in one direction.
- The current (or voltage) does not change with time.

DIRECT CURRENT



ALTERNATING CURRENT (AC)

- An alternating current is continually changing direction
- The alternating voltage and current has a distinctive waveform



ALTERNATING CURRENT

- Using the oscilloscope, we can measure the peak voltage of the a.c. supply.

- The declared, quoted or “effective”, voltage is always less than the peak voltage.

CALCULATING DECLARED VOLTAGE

- The declared (or effective) voltage can be calculated from the peak voltage.

- The quoted voltage is ~ 0.7 x peak voltage.

- The declared voltage is the value of a.c. voltage which gives the same heating or lighting effect as d.c. voltage.

MAINS SUPPLY

- What is the frequency of the mains supply?
-

MAINS SUPPLY

- What is meant by the frequency of the supply?

Alternating current flows one way then the other. It is continually changing direction. The rate of the changing direction is called the frequency and it is measured in Hertz (Hz) which is the number of forward-backward cycles in one second.

MAINS SUPPLY

- Voltage pushes the current. The voltage changes polarity causing the current to change direction.

MAINS SUPPLY

- What is the declared value of the mains supply voltage?

230V

- What is meant by the voltage of the supply?

The **voltage** of a power supply or battery is a measure of how much "push" it can provide and how much energy it can give to the electrical charge.

MEASURING EFFECTIVE VOLTAGE / CURRENT IN AN A.C. CIRCUIT

- The effective voltage or current in an a.c.
- circuit can be measured using a.c.
- voltmeter or ammeter.

MEASURING PEAK A.C. VOLTAGE USING AN OSCILLOSCOPE

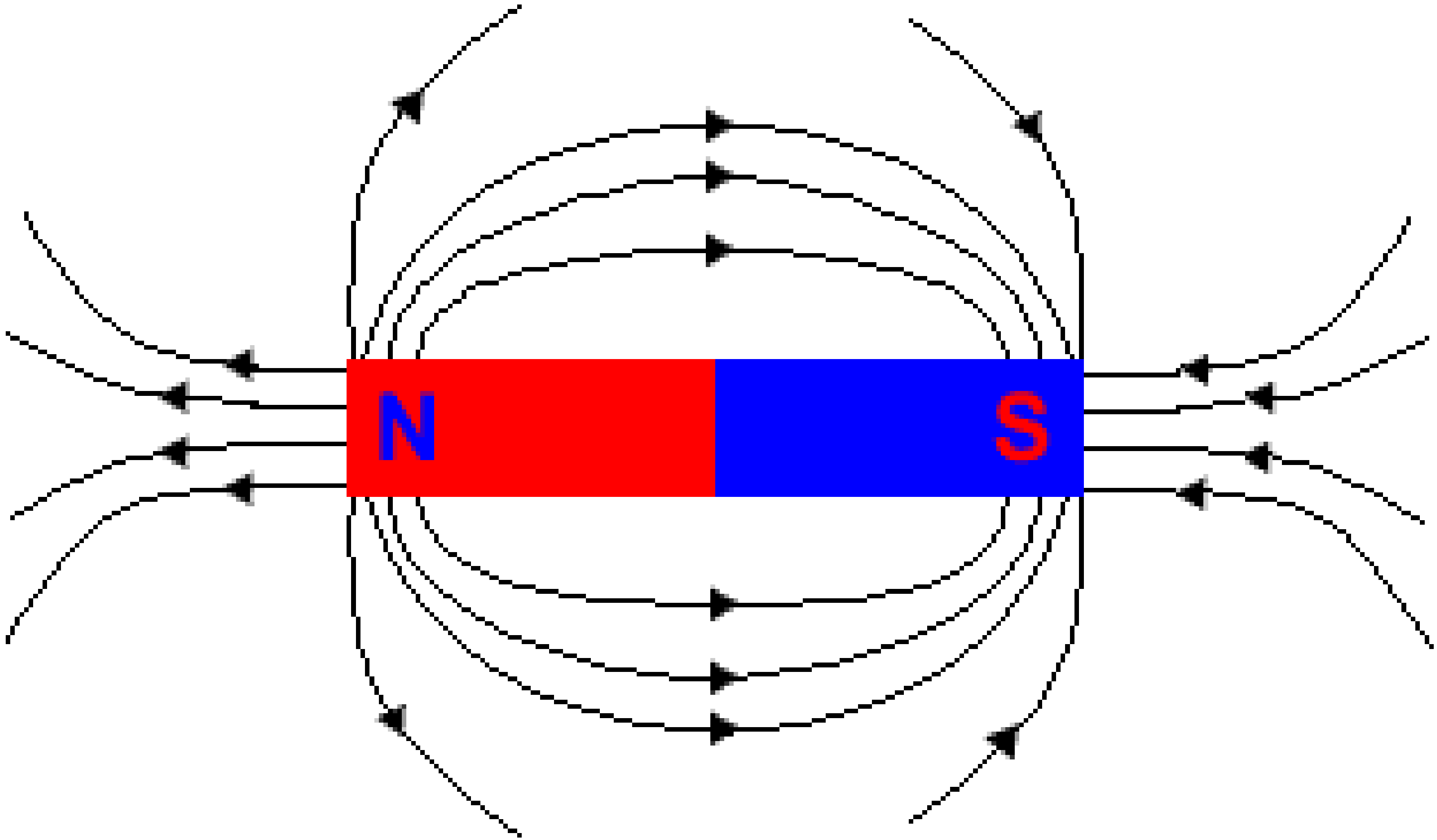
1. Adjust the position so the trace is central on the screen.
2. Adjust the volts/div so the trace fills the screen.
3. Count the number of boxes from the axis to the peak.
4. Multiply the number of boxes by the volts / div.

WHAT HAVE YOU LEARNED TODAY?

- Key words: electromagnetism, induced
- voltage, field strength, turns.
- By the end of this lesson you will be able to:
- State that a magnetic field exists around
- a current carrying wire.
- Identify circumstances in which a voltage
- will be induced in a conductor.
- State the factors which affect the size
- of the induced voltage i.e. field strength,
- number of turns on a coil, relative
- movement.

PERMANENT MAGNETS

- A magnetic field is the region around a
- magnet in which a magnetic force can be
- detected.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MAGNETIC FIELD AROUND A CURRENT CARRY WIRE

- What happens when the direction of the
- current is reversed?

- The direction of the magnetic field is
- reversed

ELECTROMAGNETS

- When an electric current passes through a
- wire which is coiled around an iron core, the
- core becomes magnetised and an
- electromagnet is produced.

- When an a.c. current is used, the current
- changed direction and so the magnetic field
- changes direction.

e-m demo

ELECTROMAGNETS

- Strength of electromagnet with/without iron
- core?

- Effect of increasing current through the coil?

- Effect of increasing number of turns in the
- coil (while keeping current constant)?

HOW IS AN ELECTROMAGNET CONSTRUCTED?

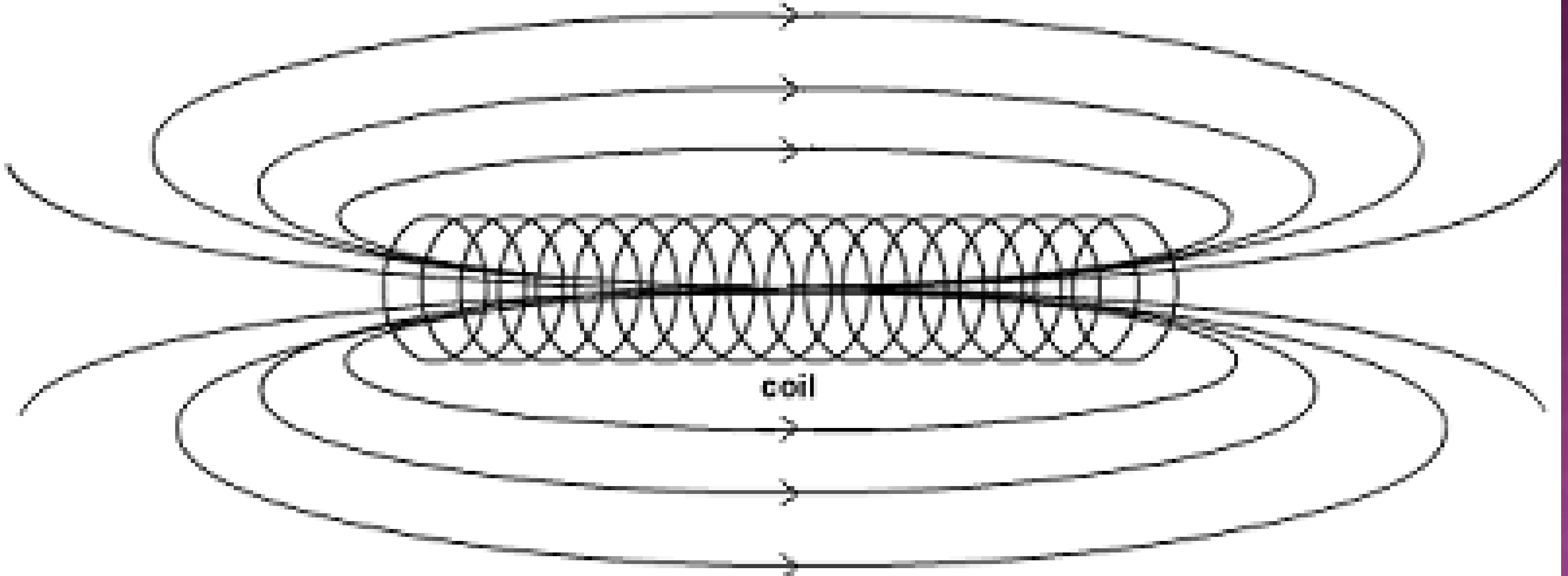
- A current through a wire can be used to
- create an electromagnet.

http://micro.magnet.fsu.edu/electromag/java/compass/index.html

HOW IS AN ELECTROMAGNET CONSTRUCTED?

- A conducting wire is wound round an iron core.

- When a current passes through the
- conductor there is a magnetic field around
- the conductor. By wrapping it round a soft
- iron core, the magnetic field is concentrated.


coil

HOW CAN THE STRENGTH OF AN ELECTROMAGNET BE INCREASED?

- By increasing the current through the
- coil.

- By increasing the number of turns on the
- coil of wire.

WHAT ARE THE ADVANTAGES OF AN ELECTROMAGNET OVER A PERMANENT MAGNET?

- The electromagnet can be switched off.

- The magnetic field strength can be varied
- (how?)

- The electromagnet provides a much stronger
- magnet field for the same size than a
- permanent magnet.

ELECTROMAGNETIC INDUCTION

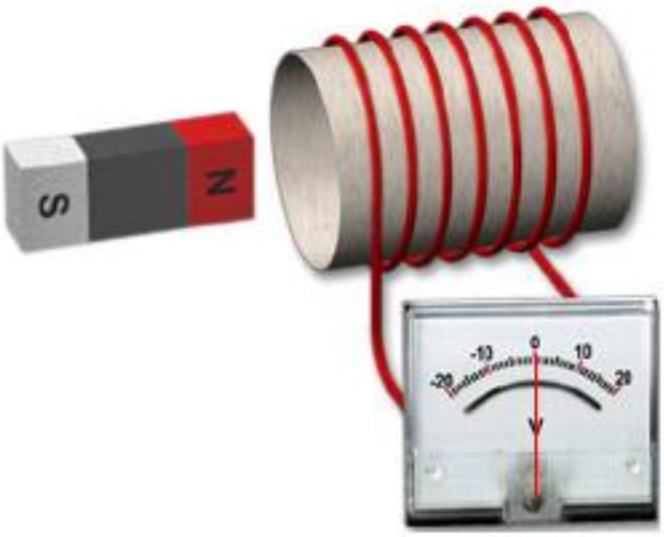
- What happens when a wire is moved in a
- magnetic field?

- A voltage is created – or induced. For this
- reason we call this electromagnetic
- induction.

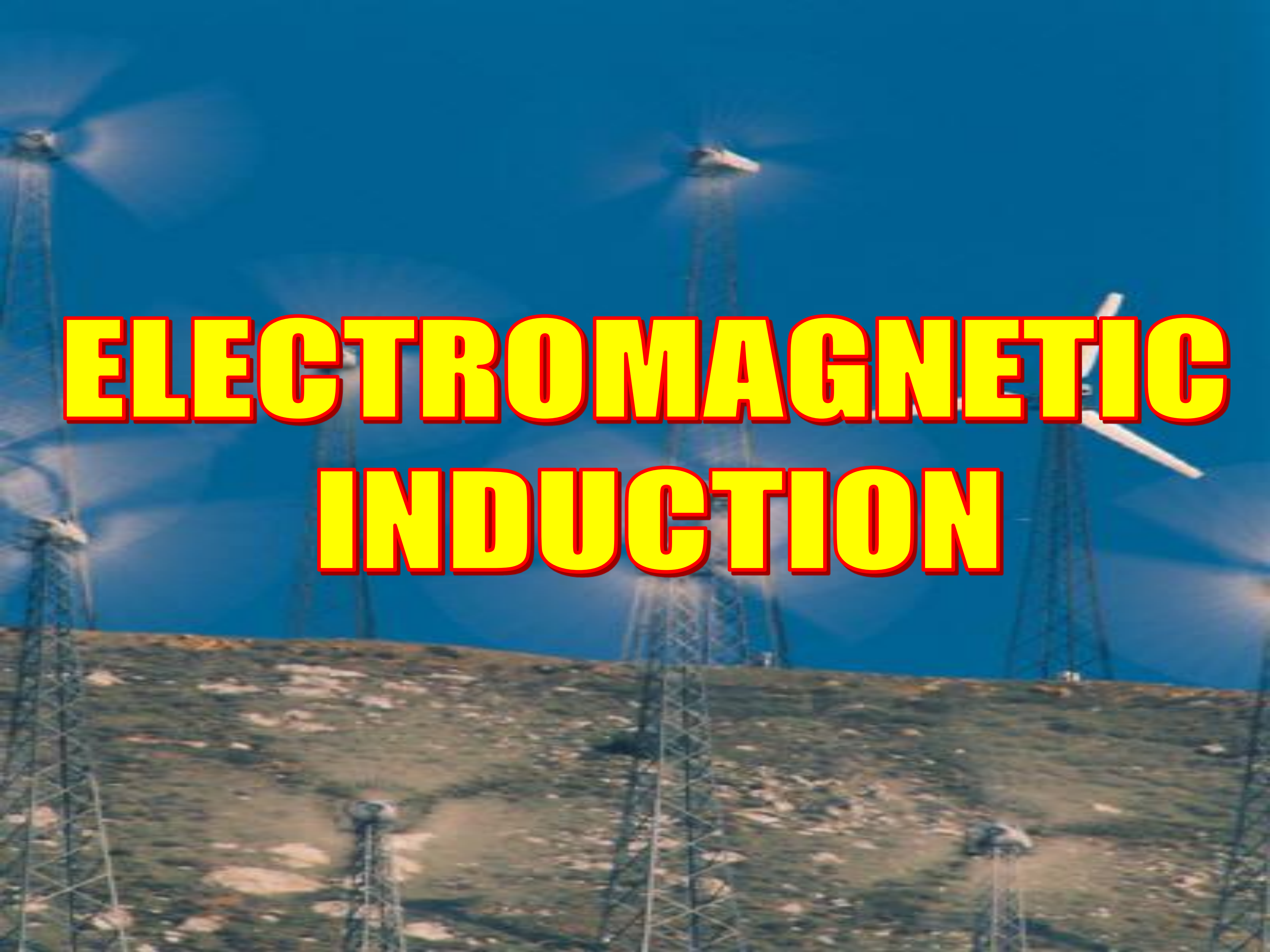
ELECTROMAGNETIC INDUCTION

- http://micro.magnet.fsu.edu/electromag/java/faraday2/

- What happens when a permanent magnet
- is moved towards or away from a coil of
- wire?



ELECTROMAGNETIC INDUCTION



WHAT DO WE KNOW SO FAR?

- When a current passes through a coil of
- wire, there is a magnetic field around the
- wire.

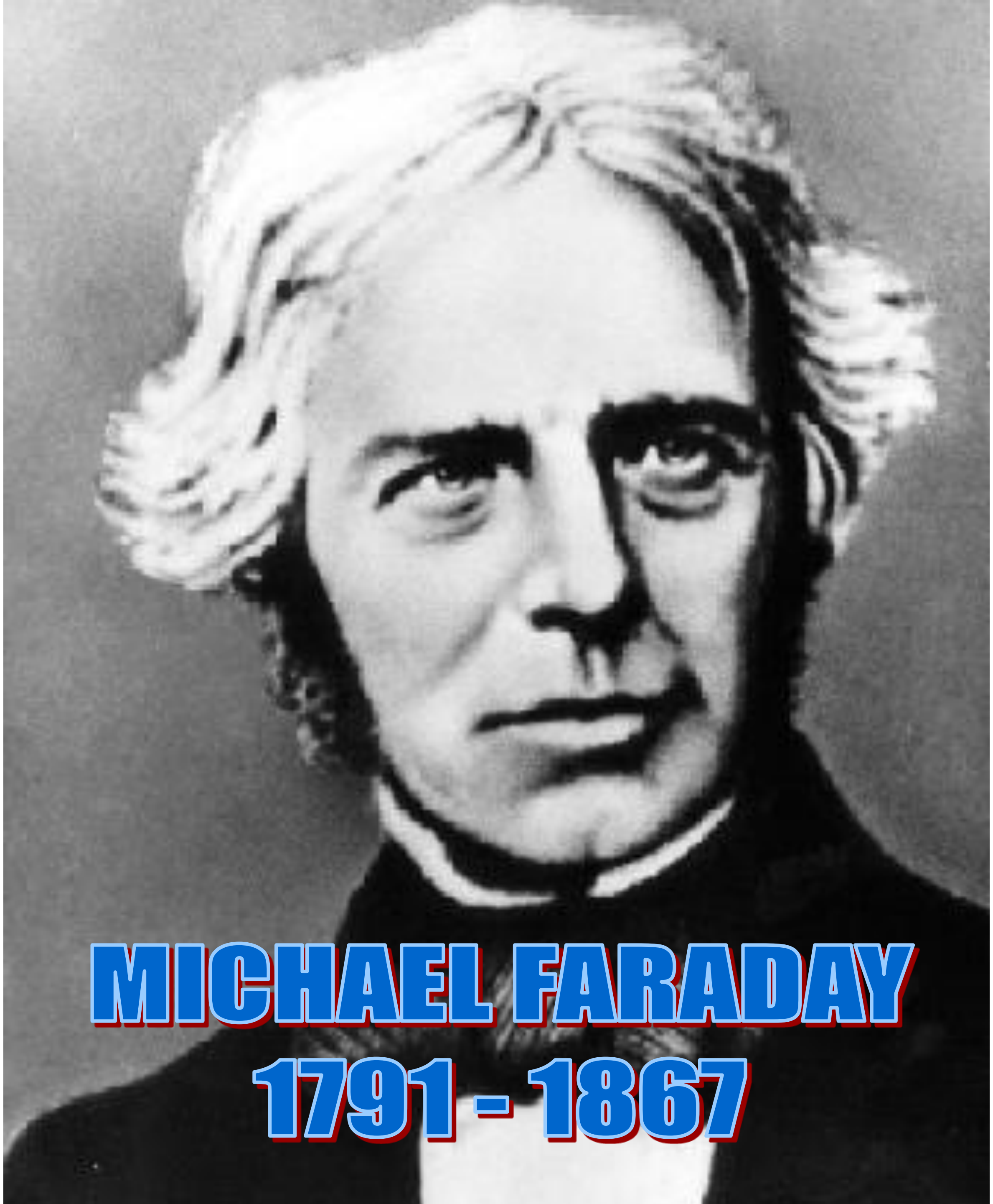
- Changing direction of the current changes
- the direction of the magnetic field.

WHAT DO WE KNOW SO FAR?

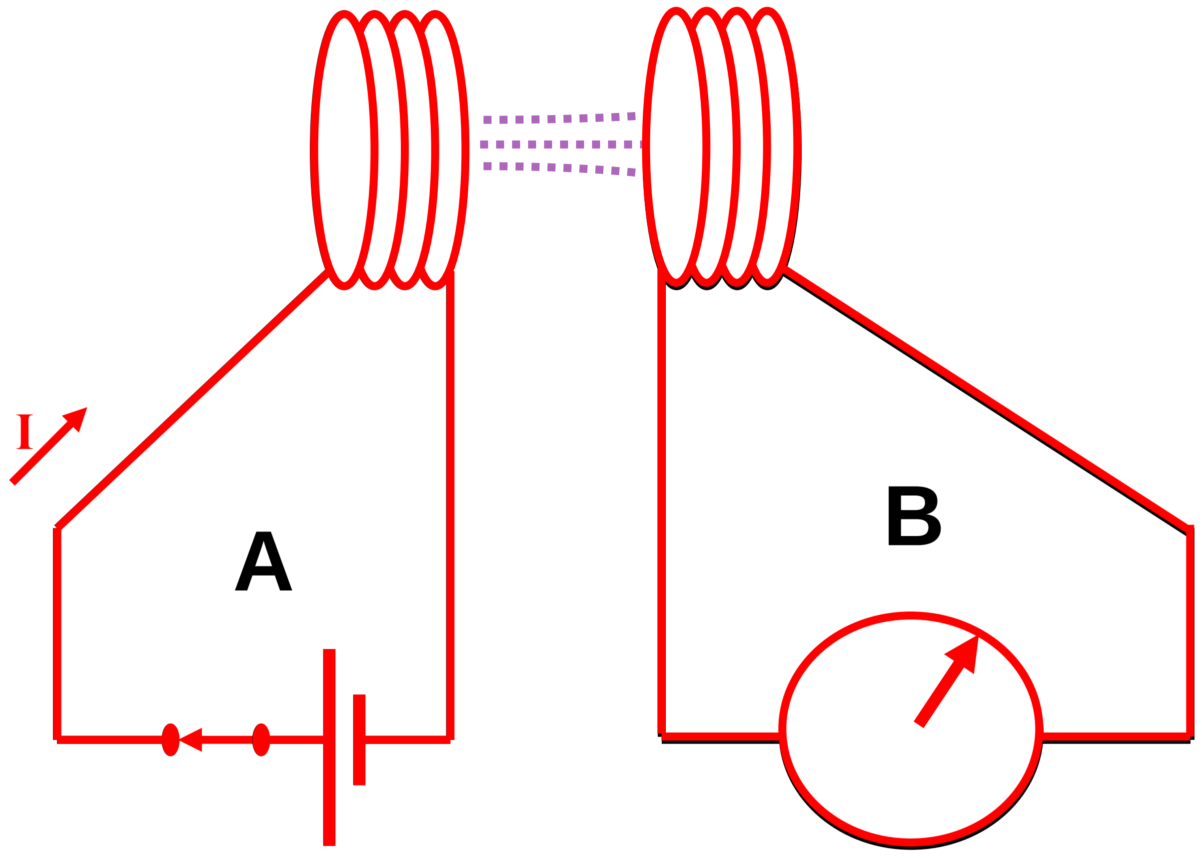
- When we move a wire in a magnetic field,
- voltage is induced.

- When we move a magnet in a coil of wire,
- a voltage is induced.

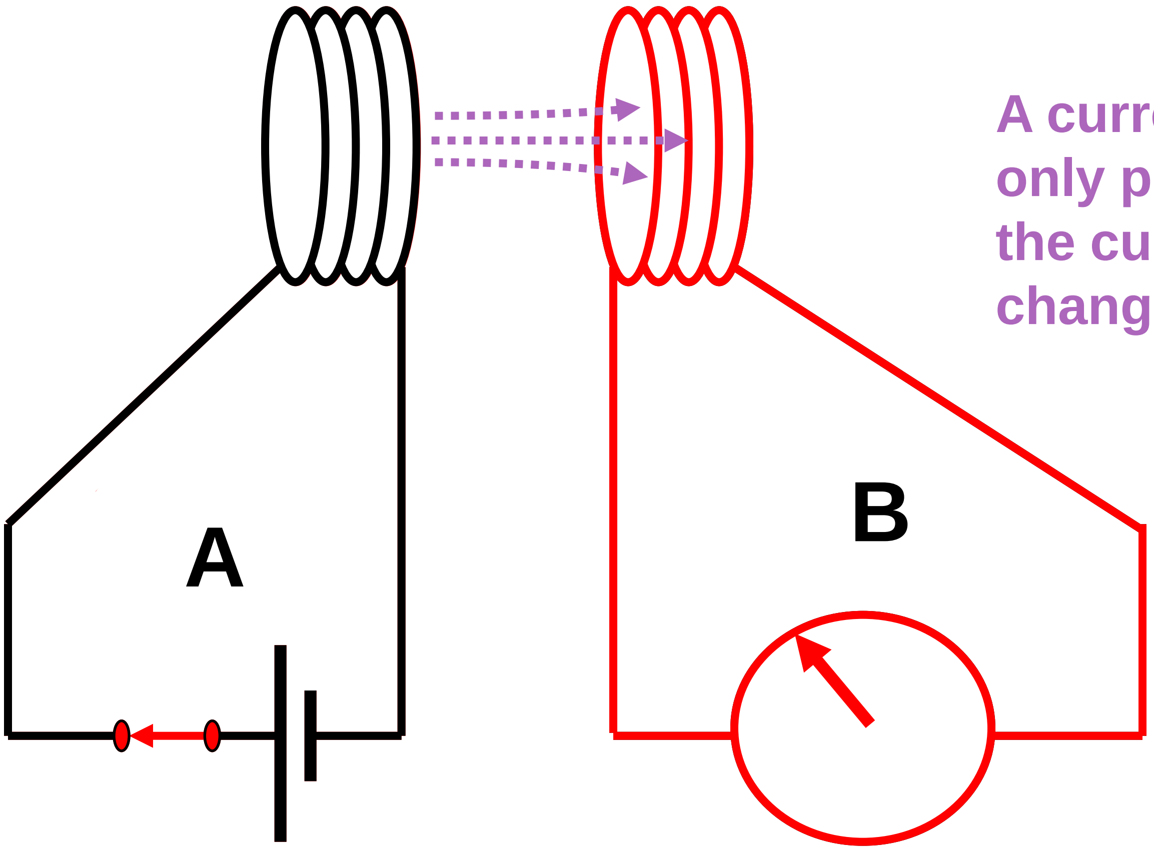
- What do we have in common? Changing
- magnetic field leading to electricity!


MICHAEL FARADAY
1791 - 1867

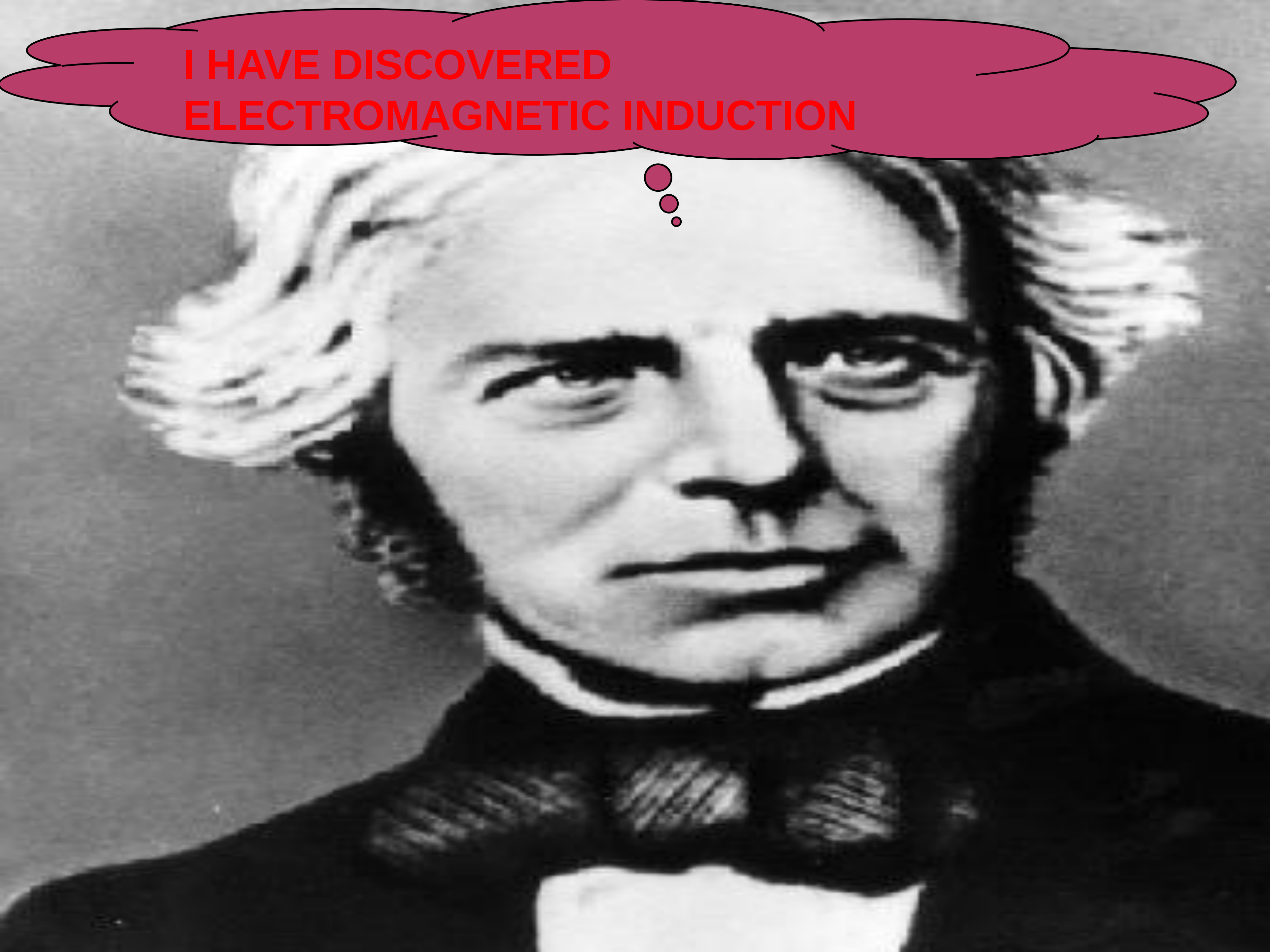
FARADAY'S EXPERIMENT 1832



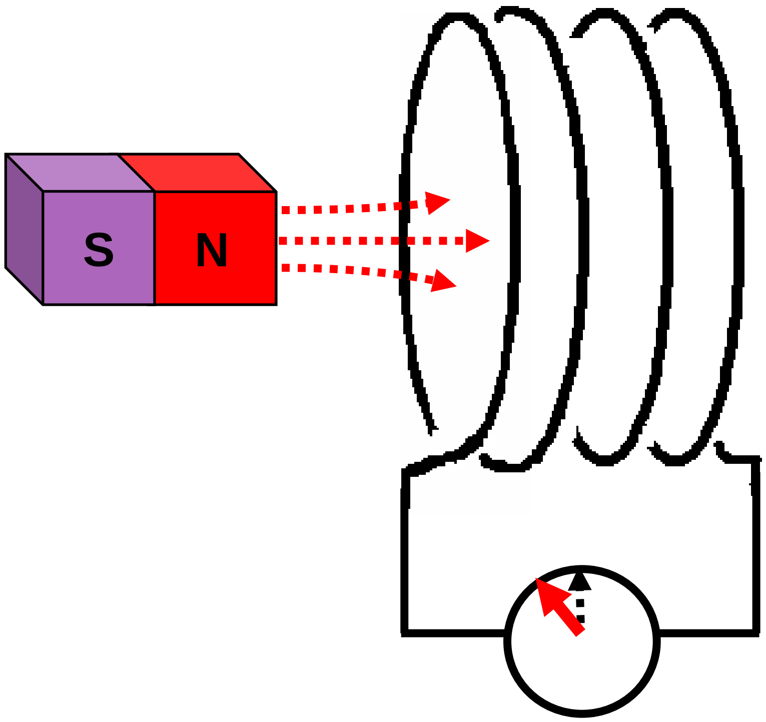
FARADAY'S EXPERIMENT 1832



A current in B is only present when the current in A is changing.


I HAVE DISCOVERED
ELECTROMAGNETIC INDUCTION


Now I understand!
VOLTAGE IS ONLY INDUCED WHEN THERE IS RELATIVE MOTION BETWEEN A CONDUCTOR AND A MAGNETIC FIELD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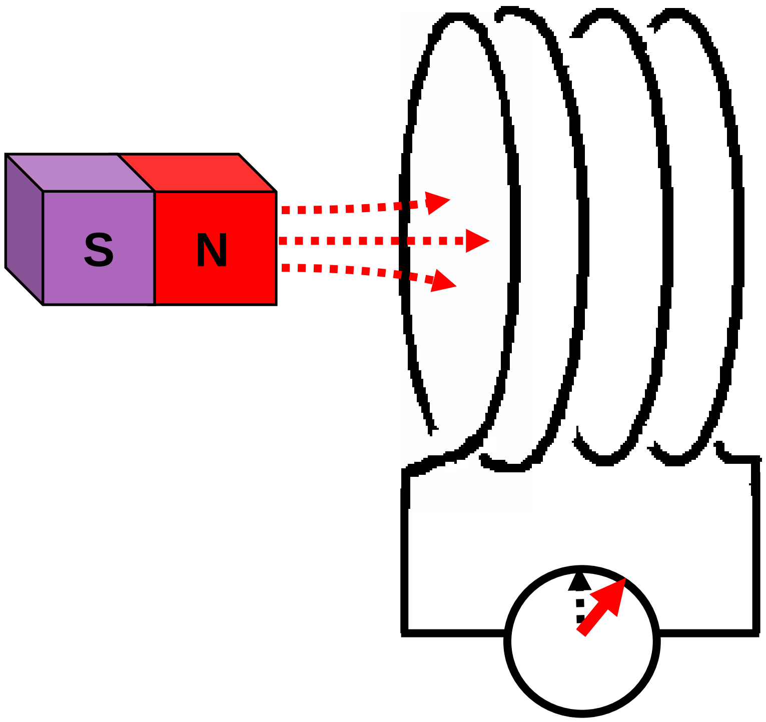
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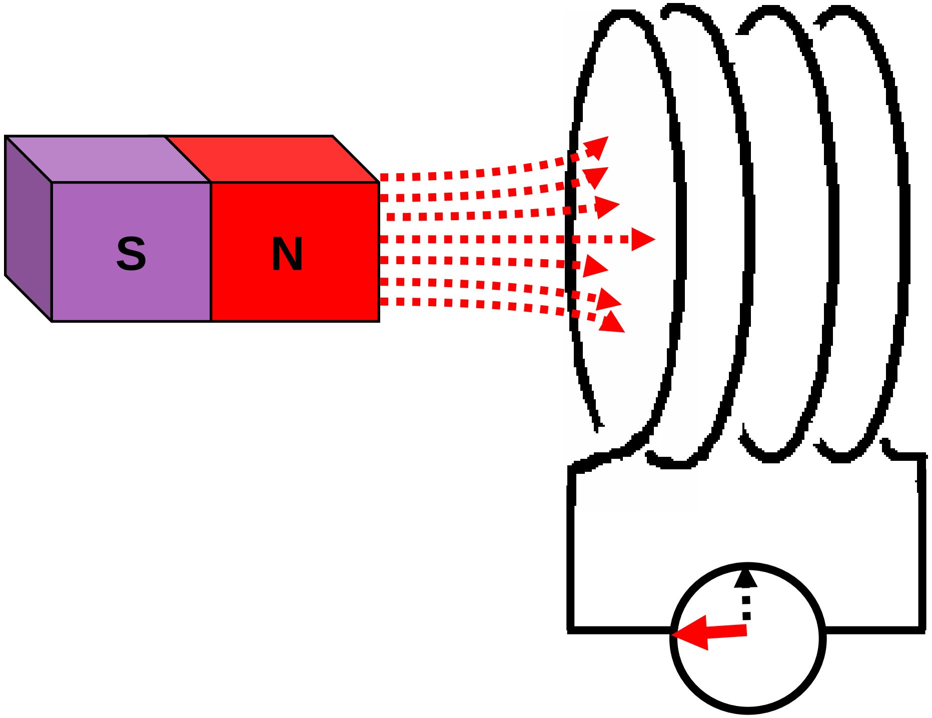
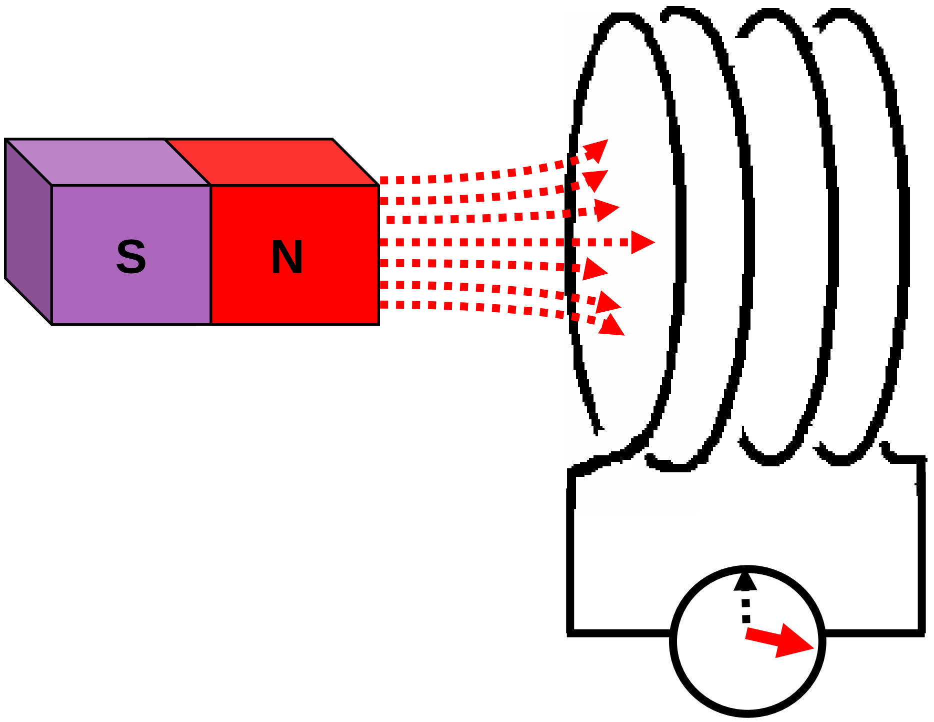
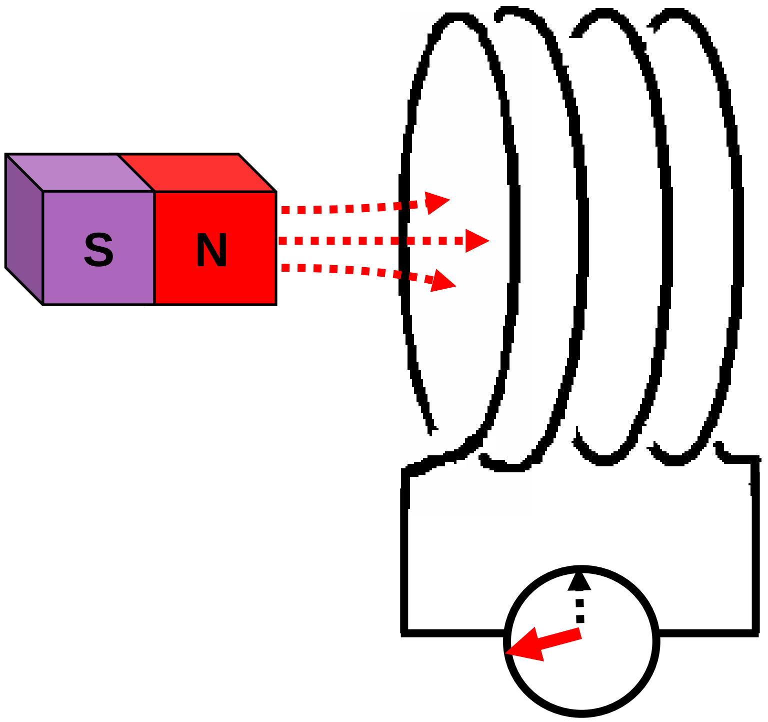
STRONGER FIELD (B)



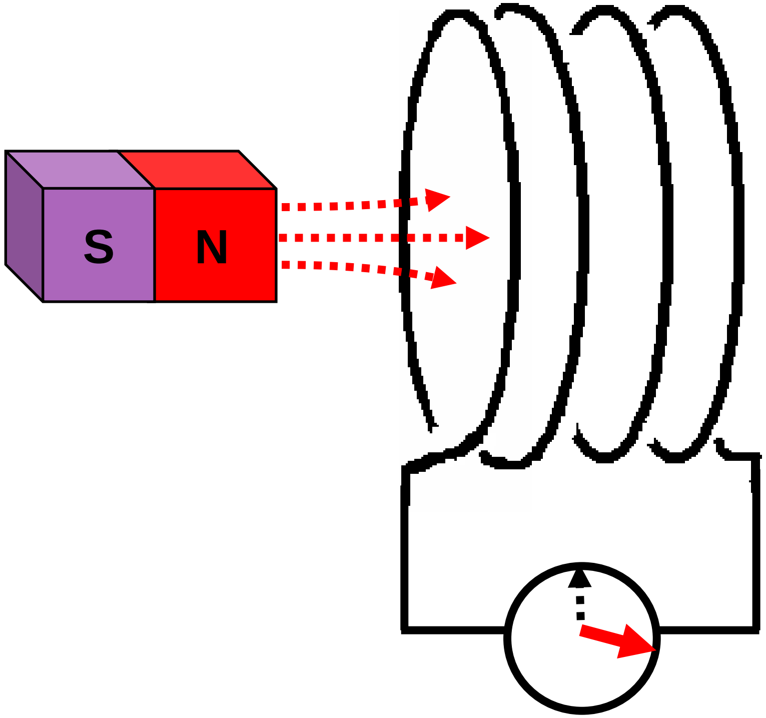
STRONGER FIELD (B)

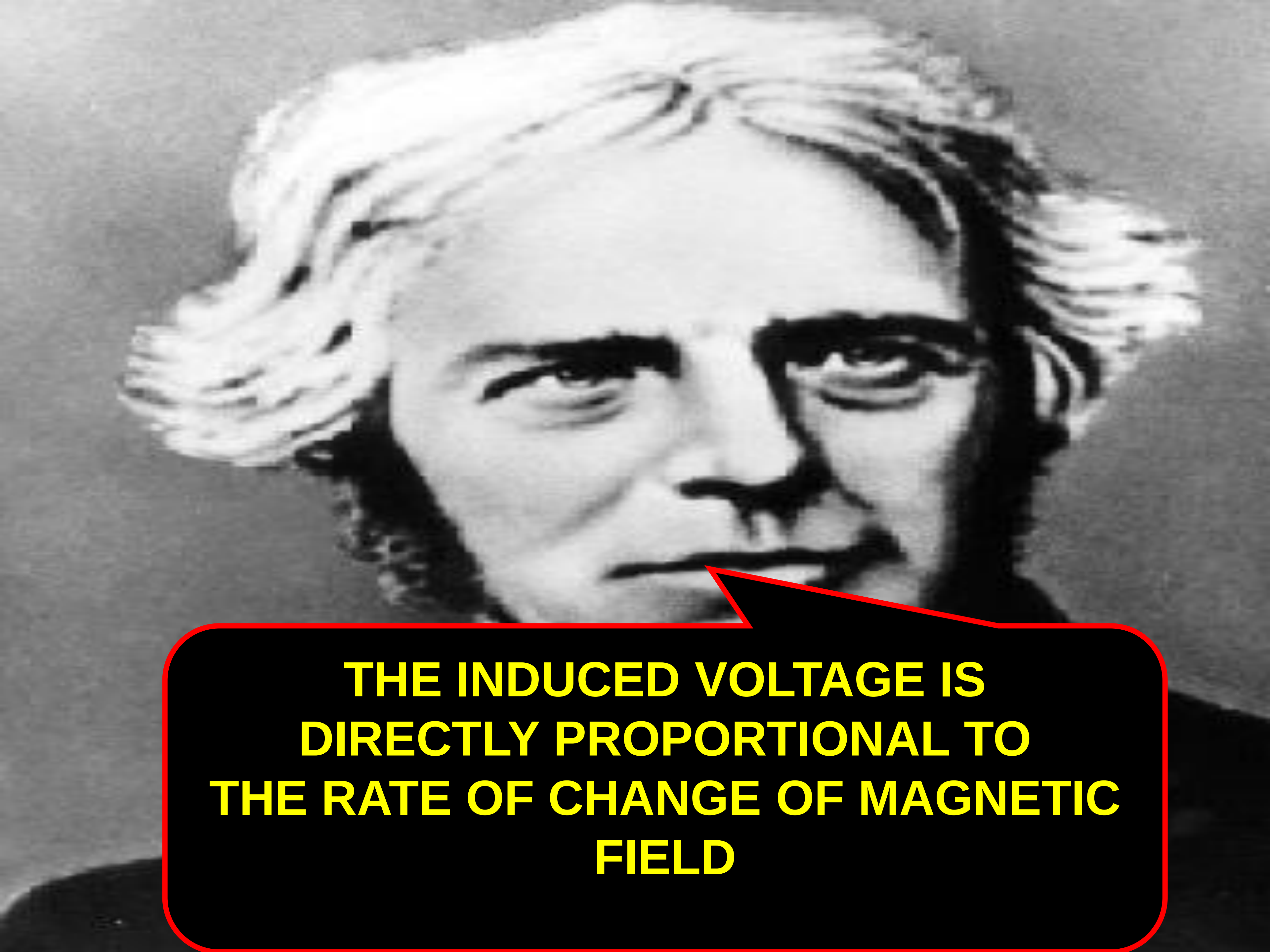


FASTER



FASTER




THE INDUCED VOLTAGE IS DIRECTLY PROPORTIONAL TO THE RATE OF CHANGE OF MAGNETIC FIELD

WHAT IS OBSERVED WHEN…

- the magnet is stationary next to the coil?
- Nothing! No voltage is induced.

- The magnet is moved in the opposite
- direction (towards the coil instead of
- away from it)?
- The voltage produced has opposite polarity.

WHAT IS OBSERVED WHEN…

- the magnet is moved backwards and
- forwards?
- Voltage induced which has a changing polarity.

- What does this mean for the current?
- The current will change direction – it is
- a.c.!

GENERATING ELECTRICITY

- A voltage can be induced in a coil of wire
- if a magnet is moved towards (or away
- from the coil).

- This effect is known as induction.

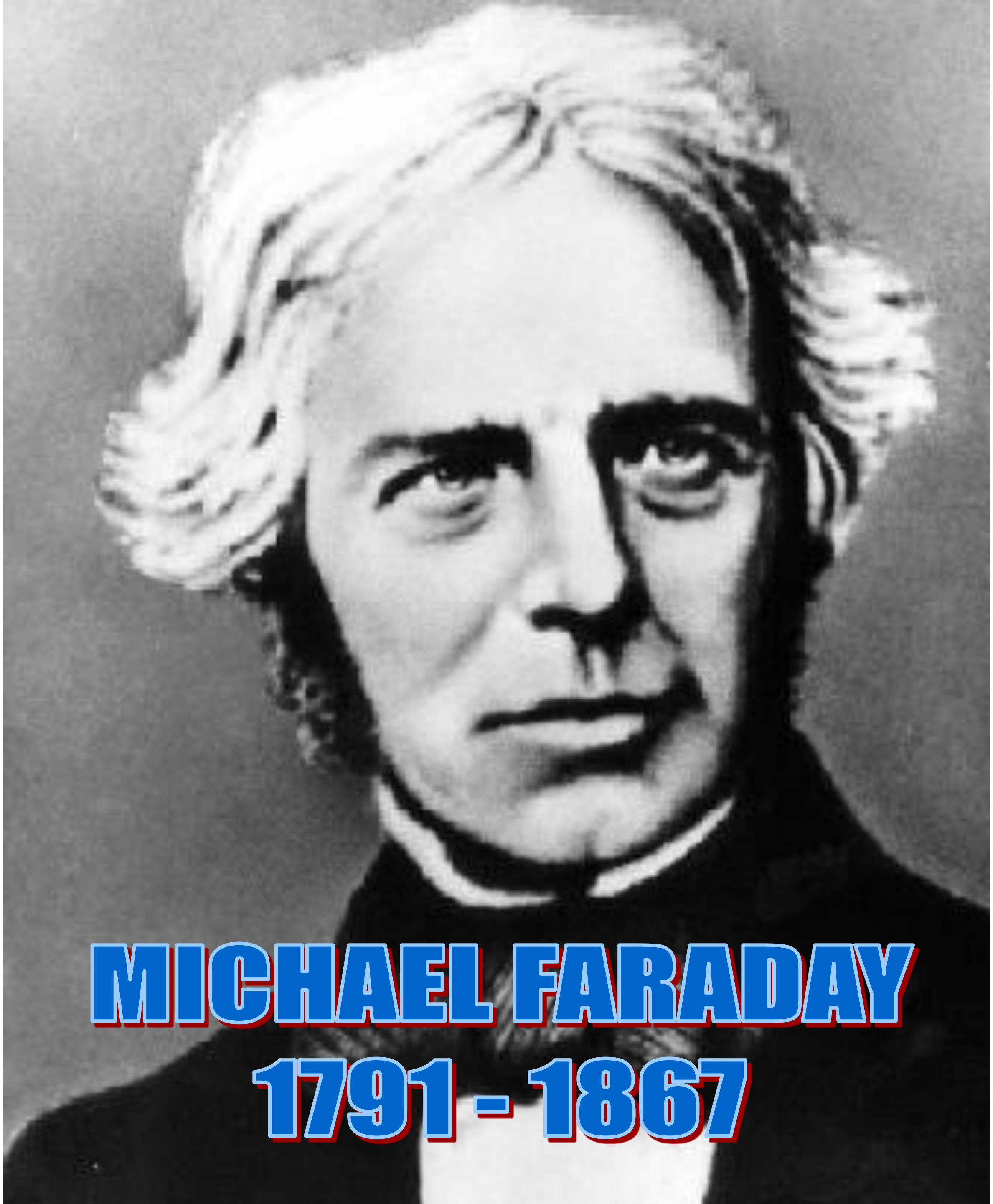
- What does the induced voltage depend
- on?

GENERATING ELECTRICITY

- Induced voltage depends on:
- strength of the magnetic field (the stronger the greater the induced voltage)
- speed of movement (the faster the greater the induced voltage).
- number of turns in the coil (the more turns of wire on the coil the greater the induced voltage).

GENERATING ELECTRICITY

- To summarise:
- A voltage is induced across the ends of a wire
- coil is the coil experiences a changing magnetic
- field.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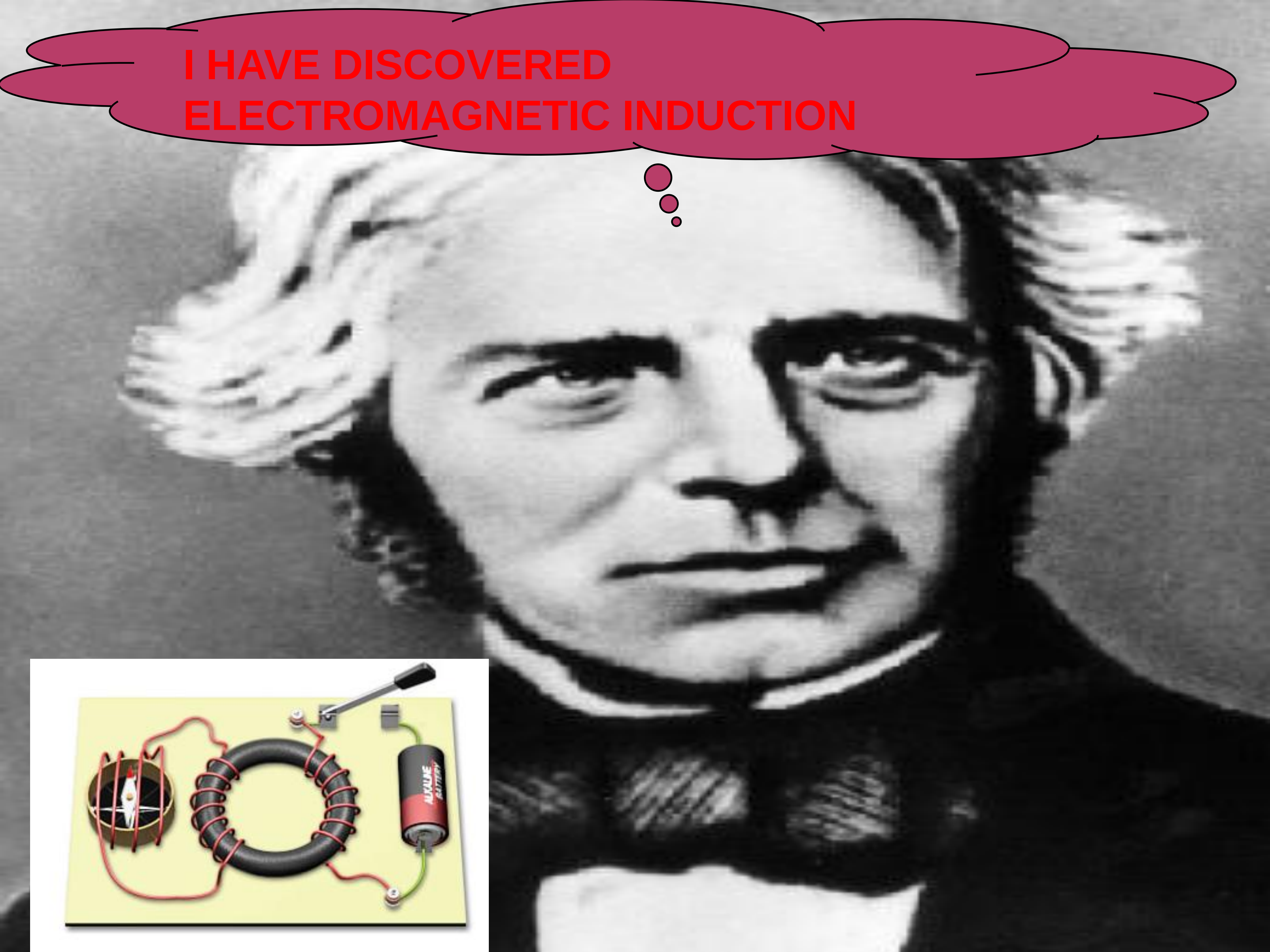
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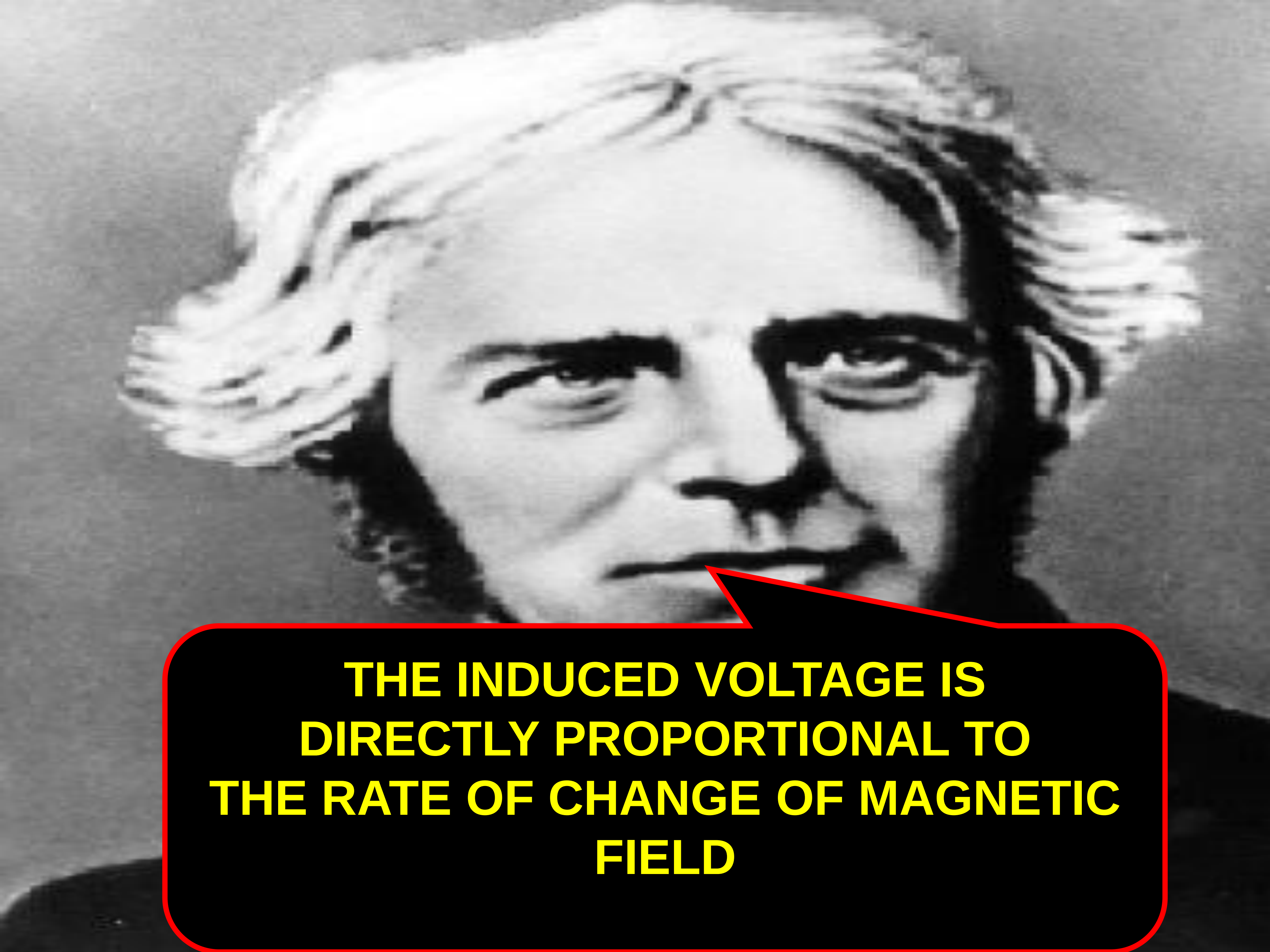

THE INDUCED VOLTAGE IS
DIRECTLY PROPORTIONAL TO
THE RATE OF CHANGE OF MAGNETIC
FIELD

Generating Electricity

- How do we "create" electricity?

A SIMPLE GENERATOR

- A current can be passed through a wire to
- result in movement (a motor!).

- Electrical energy was changed to kinetic
- energy.

A SIMPLE GENERATOR

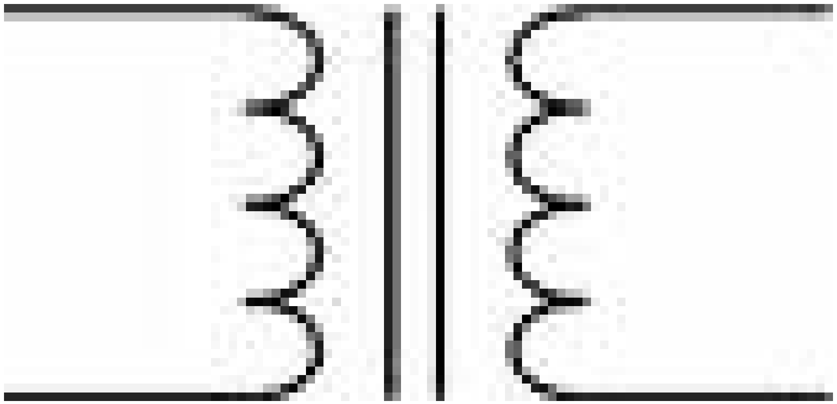
- The motor can work “in reverse”.

- Kinetic energy can be used to create
- electricity in a dynamo or simple
- generator.

TRANSFORMERS

- What is a transformer?

- Demonstration.



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TRANSFORMERS

- A transformer consists of two separate coils of
- wire wound on the same iron core.

- The first coil, the primary, is connected to an a.c.
- voltage supply. There is therefore a changing
- magnetic field around the core.

- This changing field induces a voltage across the
- other coil, the secondary. A current flows as a
- result of the induced voltage.

TRANSFORMER TERMS

- We talk about

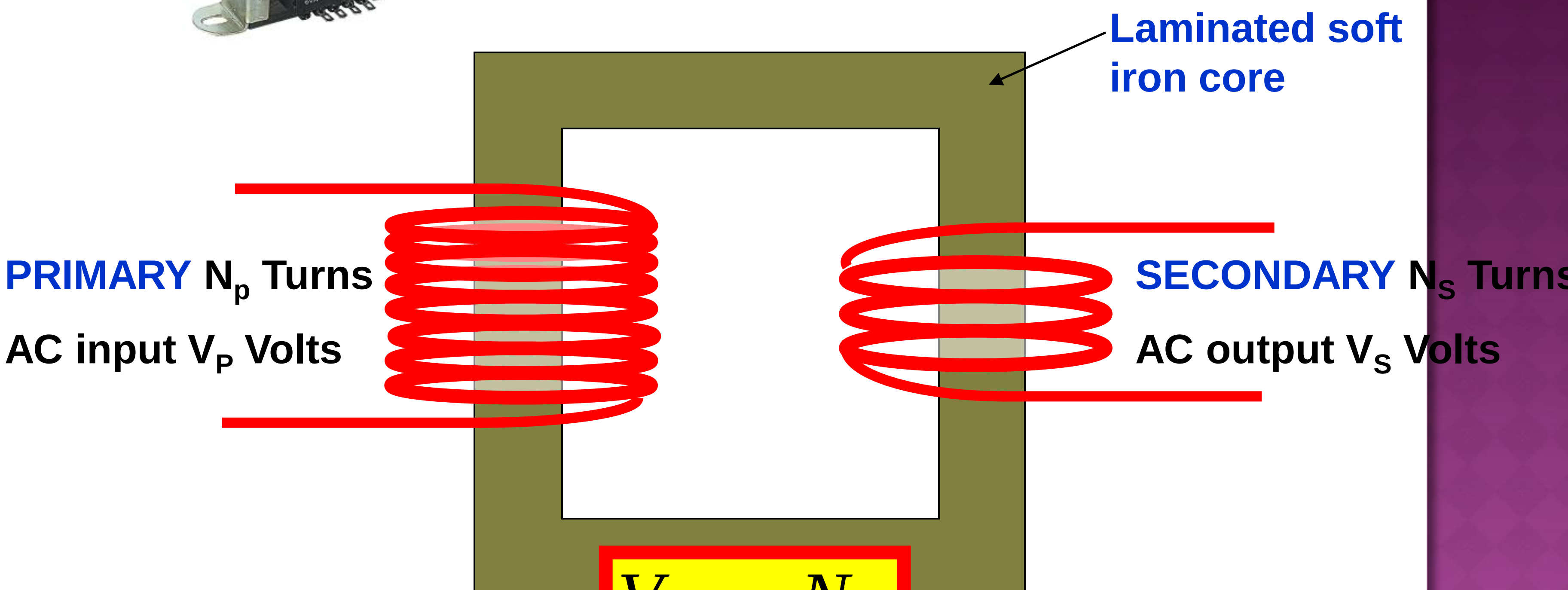
- Primary coil (the first one – connected to
- a.c. voltage)
- Secondary coil (the second one – voltage
- is induced)
- Number of turns – number of “loops” of
- wire in coil

TRANSFORMER TERMS

- We talk about

- N_p – the number of turns on the primary coil
- N_s – the number of turns on the secondary coil
- V_p – the voltage applied to the primary coil
- V_s – the voltage induced across secondary coil
- I_p – the current in the primary coil

THE TRANSFORMER



$$\boxed{\frac{V_S}{V_P} = \frac{N_S}{N_P}}$$

EQUIPMENT

- 2 coils
- 1 x a.c. voltmeter
- Four wires
- A variable power supply.

- Set your power supply to 2V. YOU
- MUST NOT EXCEED 2V as the
- primary voltage.

- Measure the output voltage for a 2V input
- for each of the combinations of number
- of turns in the primary and secondary.

- Record your results in your table.

- Calculate $\frac{V_S}{V_p}$ and $\frac{N_S}{N_p}$
- and record your results in your table.

INVESTIGATING TRANSFORMERS

V_P	N_P	V_s	N_s	$\frac{V_s}{V_p}$	$\frac{N_s}{N_p}$
2V	125		125		
2V	125		500		
2V	125		625		
2V	500		125		
2V	500		500		
2V	500		625		

TRANSFORMERS

V_P	N_P	V_s	N_s	$\frac{V_s}{V_p}$	$\frac{N_s}{N_p}$
2 V					
2 V					
2 V					
2 V					
2 V					
2 V					

TRANSFORMERS

- A step-up transformer is one in which the secondary voltage is greater than the primary.
- A step-up transformer has more turns on the secondary coil than the primary coil.
- Which of the transformers are step-up?

TRANSFORMERS

A step-down transformer is one in which the secondary voltage is less than the primary.

A step-down transformer has fewer turns on the secondary coil than the primary coil.

Which are step-down transformers?

WHAT WOULD HAPPEN IF A D.C. SUPPLY WAS CONNECTED TO A TRANSFORMER?

- At the moment of switching on, there is a
- changing magnetic field which would induce
- a voltage in the secondary coil. The same at
- the moment of switching off.

- Once switched on, no changing magnetic
- field (since steady current) and therefore no
- induced voltage.

STEP-UP TRANSFORMER

- What is a step up transformer?

- What can you say about the relationship
- between the number of turns in the secondary
- and primary? $N_s > N_P$

- and the voltage in the secondary and
- primary? $V_s > V_P$

STEP-DOWN TRANSFORMER

- What is a step down transformer?

- What can you say about the relationship
- between the number of turns in the secondary
- and primary? $N_s < N_P$

- and the voltage in the secondary and
- primary? $V_s < V_P$

ENERGY LOSSES IN TRANSFORMERS

- For calculations, we often assume that
- the transformer is 100% efficient.
- however in reality they are about 95%
- efficient.

- What causes the energy losses?

ENERGY LOSSES IN TRANSFORMERS

- Heating effect of current in coils (coils are long length of wire with resistance hence electrical energy changed to heat)
- Iron core being magnetised and demagnetised
- Transformer vibrating -> sound
- Magnetic field “leakage”

VOLTAGE AND CURRENT IN TRANSFORMERS

- Assuming an ideal transformer with no
- energy losses total energy input must
- equal total energy output.

- Since rate of energy input is power:

- power input = power output

VOLTAGE AND CURRENT IN TRANSFORMERS

- Power is given as
-
- so
- which can be rearranged as

VOLTAGE AND CURRENT IN TRANSFORMERS

$$\frac{V_s}{V_P} = \frac{I_P}{I_S}$$

In a step-up transformer, the voltage in the secondary is greater than the primary. What happens to the current?

VOLTAGE AND CURRENT IN TRANSFORMERS

$$\frac{V_s}{V_P} = \frac{I_P}{I_S}$$

The current in the coils is in the reverse ratio to the voltage therefore as voltage increases, current decreases.

VOLTAGE AND CURRENT IN TRANSFORMERS

$$\frac{V_s}{V_P} = \frac{I_P}{I_S}$$

In a step-down transformer, the voltage in the secondary is less than the primary. What happens to the current?

VOLTAGE AND CURRENT IN TRANSFORMERS

$$\frac{V_s}{V_P} = \frac{I_P}{I_S}$$

The current in the coils is in the reverse ratio to the voltage therefore as voltage decreases, current increases.

Transformers

$$\frac{n_p}{n_s} = \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

n_p = number of turns on primary coil
n_s = number of turns on secondary coil
V_p = voltage across primary coil
V_s = voltage across secondary coil
I_p = current in primary coil
I_s = current in secondary coil

Type of transformer	Turns ratio?	Effect on VOLTAGE?	Effect on CURRENT?
Step-up			
Step-down			

WHAT HAVE YOU LEARNED TODAY?

- Key words: electromagnetism, induced
- voltage, field strength, turns.
- By the end of this lesson you will be able to:
- State that high voltages are used in the
- transmission of electricity to reduce
- power loss.

- Carry out calculations involving power loss
- in transmission lines.

TRANSMITTING ELECTRICAL ENERGY

- Transformers are used by the National
- Grid system through which electrical
- energy is transmitted.

- Demonstration

Electricity Transmission

Electrical energy is transferred from the power station to the consumer via the **National Grid**.

- Electricity is sent for many kilometres along transmission lines on pylons.

TRANSFORMERS IN ELECTRICAL TRANSMISSION

- What happens as current flows through
- the wires?

- The length of the wires means large

TRANSFORMERS IN ELECTRICAL TRANSMISSION

- Energy is changed from electrical to heat resulting in large power losses in the wires.
- Relationship between power, current and resistance?

Transformers in Electrical Transmission

- At the power station, a step-up transformer is used to increase the voltage.

- Why?

TRANSFORMERS IN ELECTRICAL TRANSMISSION

$$\frac{V_s}{V_P} = \frac{I_P}{I_S}$$

- As voltage stepped up, current stepped down by the same factor. And since $P = I^2 R$ by reducing current the power losses due to heating are reduced.

TRANSFORMERS IN ELECTRICAL TRANSMISSION

- This stepping up of the voltage and hence stepping down of the current makes the transfer much more efficient. The losses due to heating are reduced.

TRANSFORMERS IN ELECTRICAL TRANSMISSION

- At the consumer end, a step-down transformer reduces the voltage to 230V, increasing the current.

ELECTRICAL QUANTITIES AND UNITS

CHARGE

- Base unit = coulomb
  - also the base unit for current and voltage
- Symbol = Q
- Abbreviation = C

CURRENT

- Electric current – movement of charged particles in a specific direction
  - Electrons, pos ions, neg ions
  - Speed of light (186,000 miles per sec.)
- Symbol – I (intensity of the electricity)
- Unit of current – ampere (amp)
  - Coulombs per second
  - 1A = 1 coulomb/sec

CURRENT

- Direct current
  - Dc
  - Current travels in same/one direction
  - Flashlight cells, and batteries
- Alternating current
  - Ac
  - Current periodicallly reverses the direction in which it is moving
  - In your house (every 1/120 of a sec)
  - In tv receiver (every 1/67,000,000 of a sec)

VOLTAGE

- Electric pressure that causes current flow
  - Electromotive force (emf)
- Symbol = V
- Types of energy
  - Kinetic energy
    - Energy in motion, energy doing work, or energy being converted into another form
  - Potential energy
    - Energy that can be stored for a long period of time in its present form
    - Capable of doing work

RESISTANCE

- Opposition a material offers to current
- Symbol – R
- Unit of resistance – omega symbol
  - Measured in ohms
- Converts electric energy into heat energy when current is forced through a material