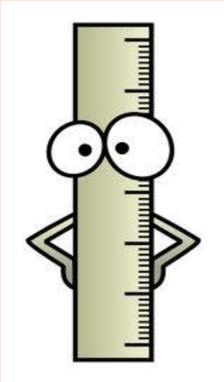
Monday, January 30, 2023

Physics - session 3



Learning Objectives:

- Electrical Circuits
- Internal resistance and EMF
- Potential dividers
- Refraction & TIR

Is your Physics brain working?

- Can you define current, voltage and resistance?
- What are Kirchhoff's 1st and 2nd Laws? How do these relate to rules for current and voltage in series and parallel circuits?
- Describe properties of transverse waves

Electrical Circuits:

Definitions:

Current is the rate of flow of charge

Charge is the physical property of matter that causes charged matter to experience a force when placed in an electromagnetic field

Potential difference is the work done per unit of charge

Resistance is the opposition to the flow of current. A high resistance means it is harder for current to flow through. Resistance is measured in **Ohms** (**Ω**)

Circuit Analysis:

The equations and rules we use are all the same as you learned in GCSE, it's just the circuits get more complex!:

V = I x R Ohm's Law - Voltage is directly proportional to current if resistance remains constant

Q = I x t   Current is the rate of flow of charge

P = E/t Power is the rate of energy transfer

P = V x I For a fixed power, current and voltage are inversely proportional

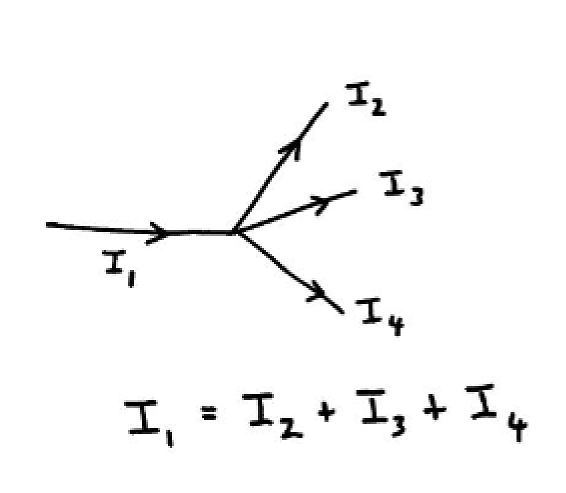
Kirchoff's Laws:

You might not have referred to them as Kirchhoff's Laws at GCSE, but you learned rules about current and voltage which use them.

Kirchhoff's First Law:

The sum of the currents entering a junction must be equal to sum of the currents leaving it.

CHARGE IS CONSERVED

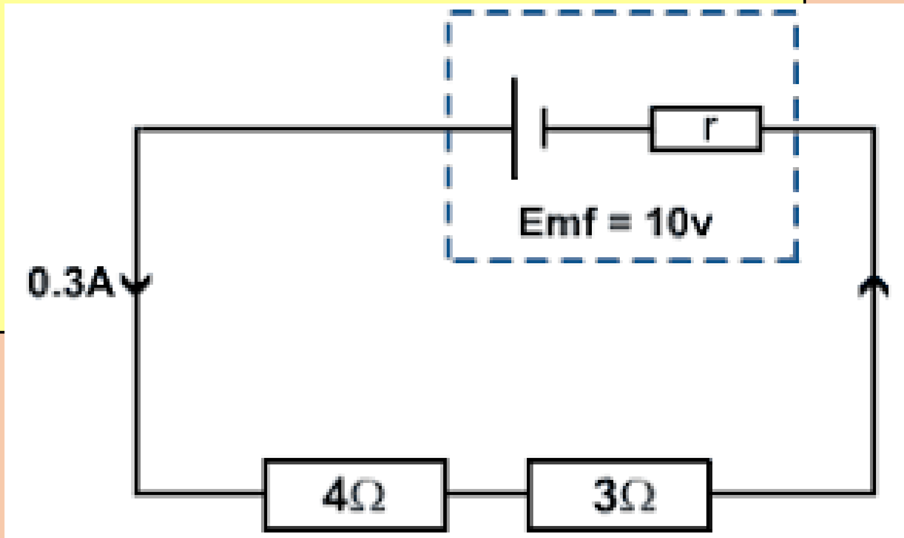


Kirchoff's Laws:

Kirchhoff's Second Law:

The sum of the **electromotive force** round any complete loop in the circuit is equal to the sum of the potential differences.

ENERGY IS CONSERVED



Circuit Laws:

What are the rules for current and voltage in series and parallel circuits?

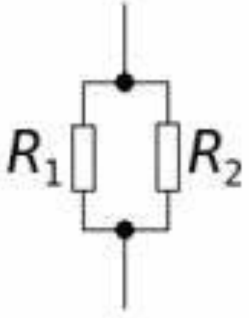
	Series	Parallel
Voltage	**Shared** between components	**Same** across each loop or branch
Current	**Same** between each component	**Shared** between each loop or branch

Circuit Laws: Let's not forget resistance

In **series**, the resistance increases as you add more resistors, as the current will be reduced.

In **parallel**, the total resistance will decrease as you add more resistors, as the charge has more routes to move through, so the overall resistance must be less.

$$R_{TOTAL} = R_1 + R_2 \ldots R_n$$

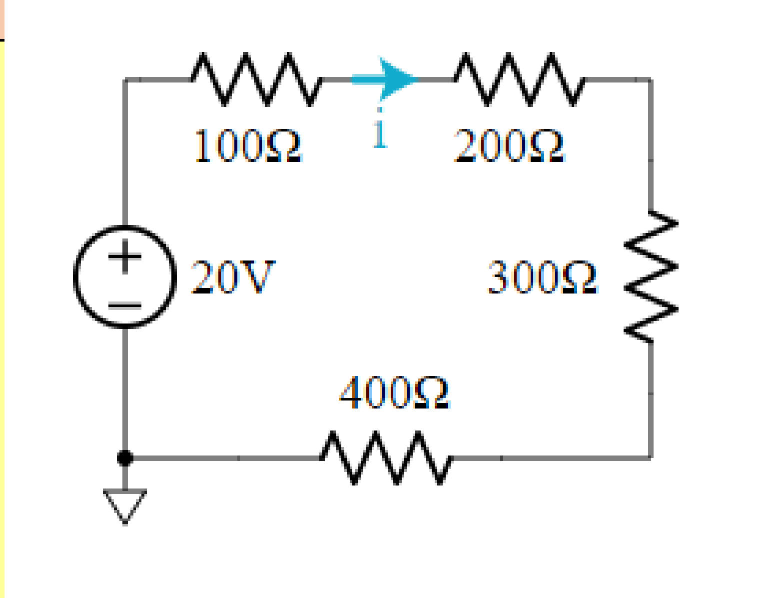


$$\frac{1}{R_{TOTAL}} = \frac{1}{R_1} + \frac{1}{R_2} \ldots \frac{1}{R_n}$$

Circuit Laws:

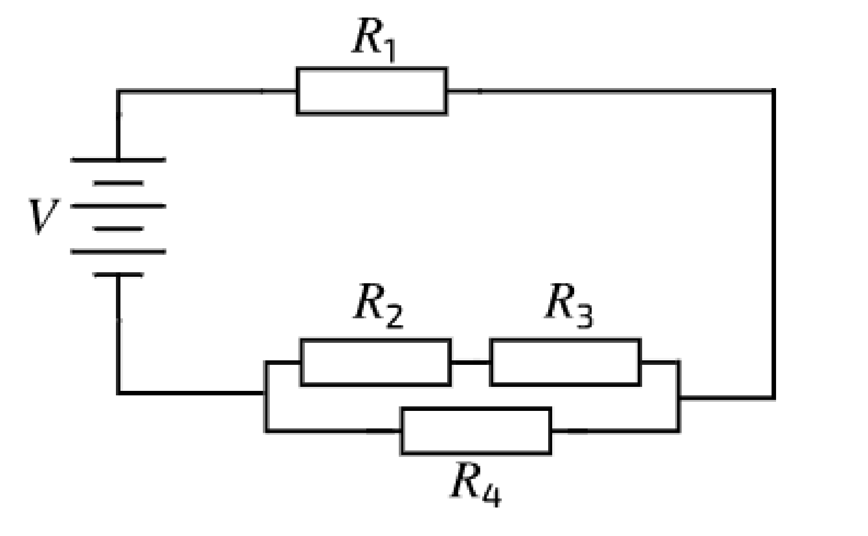
Use the circuit laws to calculate the current in this circuit.

Then calculate the voltage drop across each resistor.



Remember:
V = IR is your circuit friend. It's pretty much the only equation you will need!

Circuit Laws:



$V = 12V$

The voltage across R_1 is 6V

$R_2 = 2 \times R_3$

Find the voltage across R_3

Circuit Practice:

In the question pack – you have 10 minutes to try the first set of questions.

EMF (*Electromotive force*).

Measured in volts… looks like potential difference… but what's the difference?

It's all about energy transfer and work done.

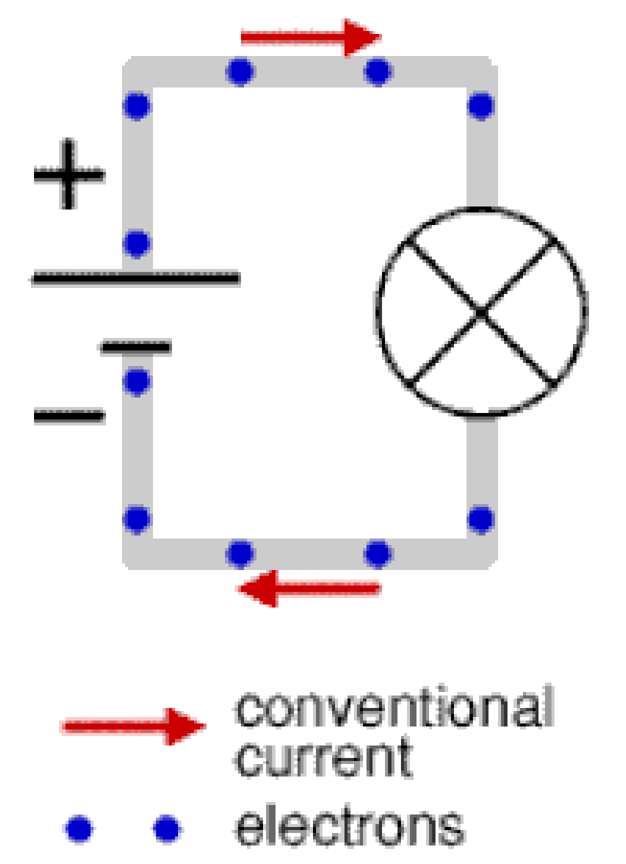
The EMF of a cell is the total **energy transferred from the cell to the charge flowing through it**. EMF is the **chemical energy transferred to electrical energy** inside the cell.

The potential difference is the **work done by the charge in the circuit.** (Terminal) Potential difference is the **electrical energy transferred into work done** in the components of the circuit.

EMF:

Chemical energy stored in the cell is transferred to electrical **energy** in the wires

$$\varepsilon = \frac{E}{Q}$$



Electrical energy is used to do **work** in the circuit (e.g. transferred to light and heat energy)

$$V = \frac{W}{Q}$$

But why is EMF not always equal to the terminal pd?

Internal Resistance:

Many questions will state that the cell has negligible internal resistance, but in reality all cells and batteries will have a certain amount of resistance to current flow.

This means that some of the energy of the cell has already been transferred before the current even leaves the cell.

How else can we define EMF?

The electromotive force can be defined as the total voltage or the potential difference across the terminals of the battery in an open circuit or in other words when no current is flowing through it.

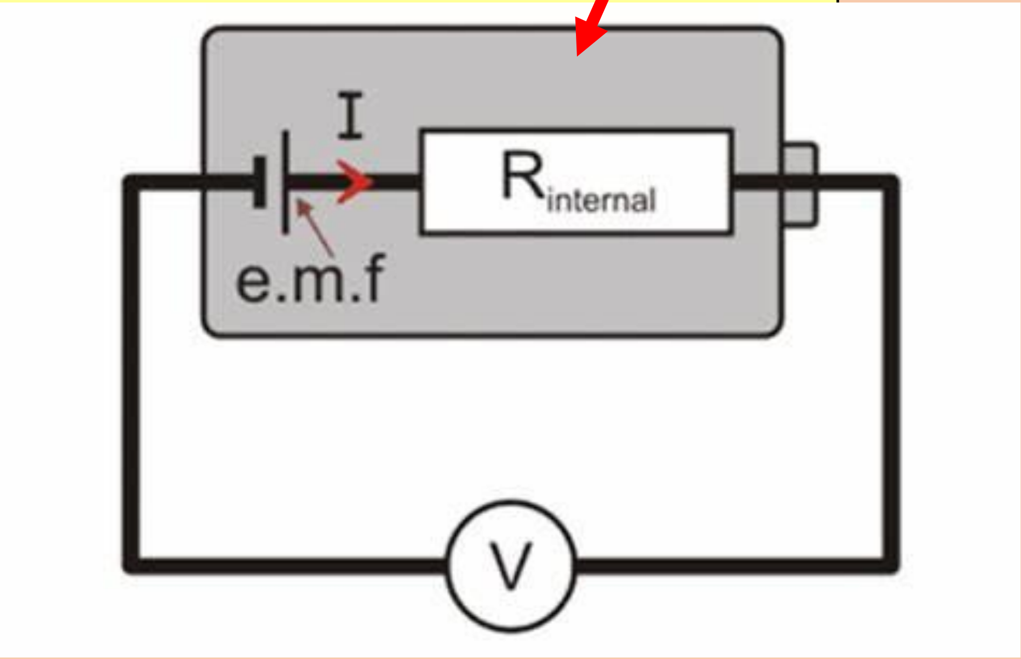
Internal Resistance:

Using Ohm's Law and Kirchhoff's 2nd Law, we can show that:

$$\mathbf{EMF = V + v}$$

$$\mathbf{EMF = (I \times R_{int}) + V}$$

Lost volts (**v**)



The difference between the **EMF** and the terminal pd (**V**) is referred to as the 'lost volts' (**v**).

Internal Resistance:

There are lots of permutations of the same equation, but they all derive from the fact that

$$\textbf{EMF = V + v}$$

Potential difference

$$V = \frac{W}{Q}$$

Resistar[...] **Edexcel**

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

emf **AQA** $\varepsilon = \frac{E}{Q}$ $\varepsilon = I(R + r)$

e.m.f and potential difference **OCR-B** $V = \mathcal{E} - Ir$

$$V = E - Ir$$

WJEC

internal resistance **OCR-A** $\mathcal{E} = I(R + r)$; $\mathcal{E} = V + Ir$

Internal Resistance:

A battery of electromotive force (e.m.f.) 6.0 V is connected across a resistor of resistance 12 Ω. The potential difference across the resistor is 4.5 V.

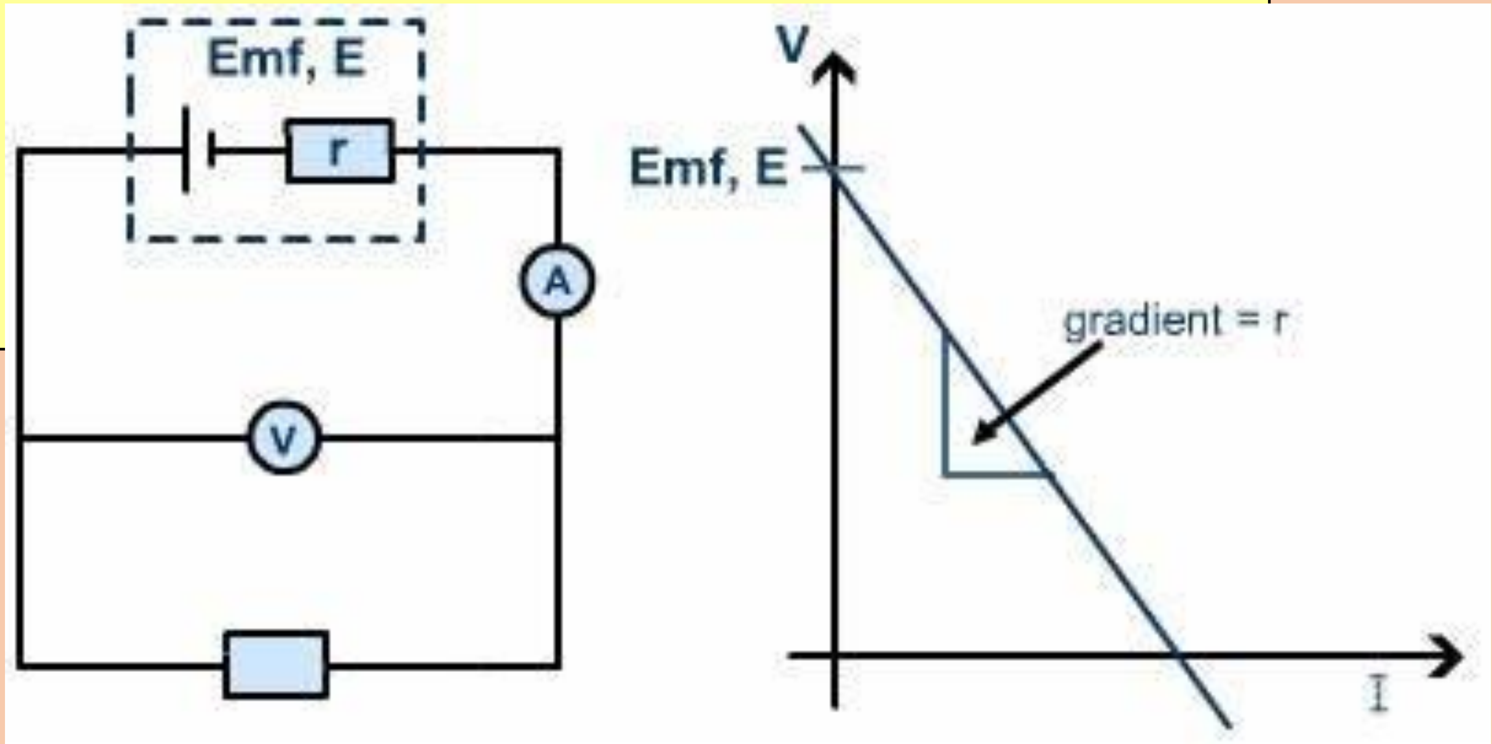
What is the internal resistance of the battery?

Determining Internal Resistance:

Plotting a graph of values of current for different values of the terminal pd will allow us to measure the internal resistance and the EMF

$$V = -Ir + \varepsilon$$

Use y = mx + c



Internal Resistance and EMF:

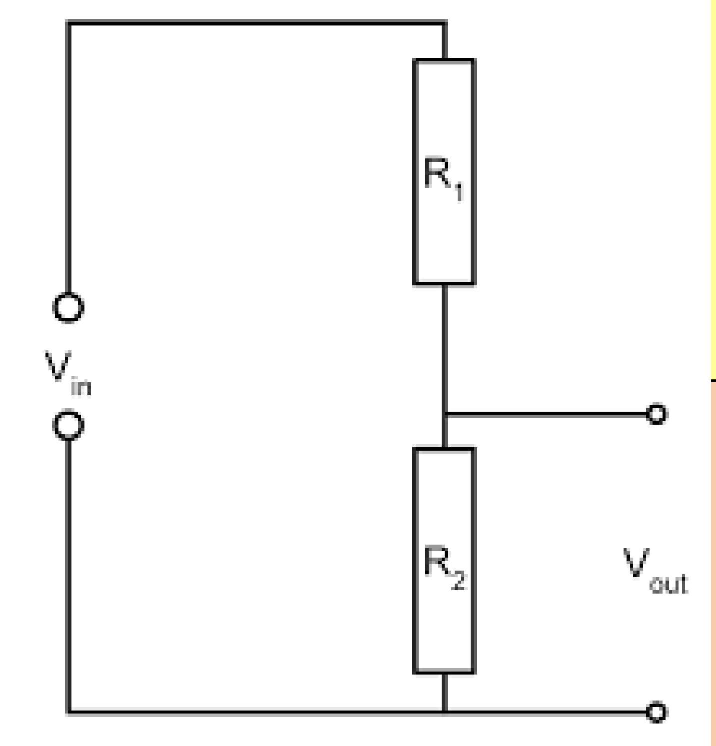
In the question pack – you have 10 minutes to try the second set of questions.

Potential Dividers

Do you find these tricky?
If so, you are not alone…

But remember – they are JUST a circuit with two resistors in series.

A potential divider is circuit that splits the potential difference provided by the power source.
Often they are sensing circuits (e.g. responding to temperature or light)



Potential Dividers

Most of the exam boards don't give equations specifically for potential dividers (except for OCR and WJEC).

Like most of the exam boards, I recommend just using V=IR and your basic circuit rules.

potential divider

OCR-A and OCR-B

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

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

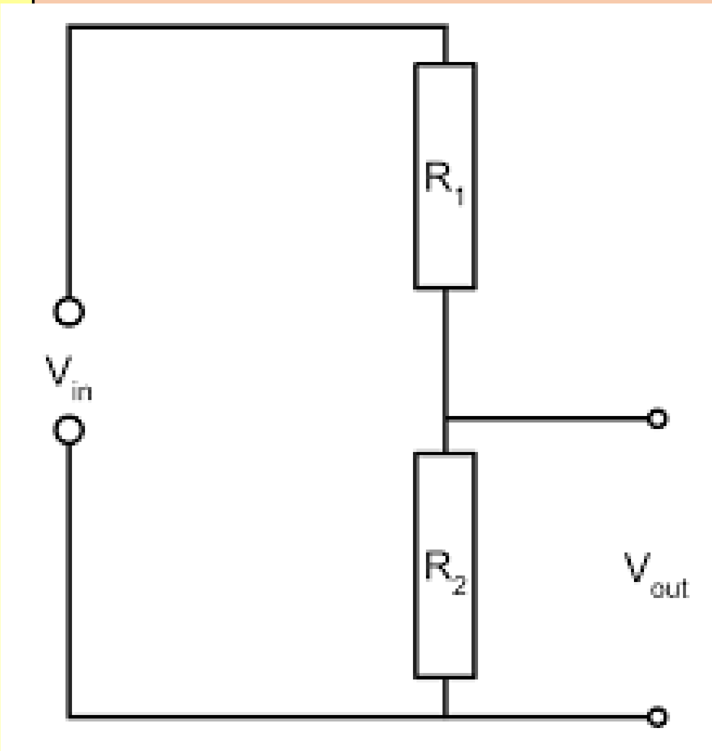
$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$$

WJEC

$$\frac{V}{V_{total}} \left[\text{or } \frac{V_{OUT}}{V_{IN}} \right] = \frac{R}{R_{total}}$$

Potential Dividers

Imagine the two resistors as a ruler. The full ruler gets the whole of the voltage from the power supply (V_{in})



As resistance increases, the voltage drop across the resistor also increases.

So the voltage is shared out between R_1 and R_2 in the same ratio as that of the resistors.

$$V_1 / V_2 = R_1 / R_2$$

The current through both resistors is the same. Which gives us:

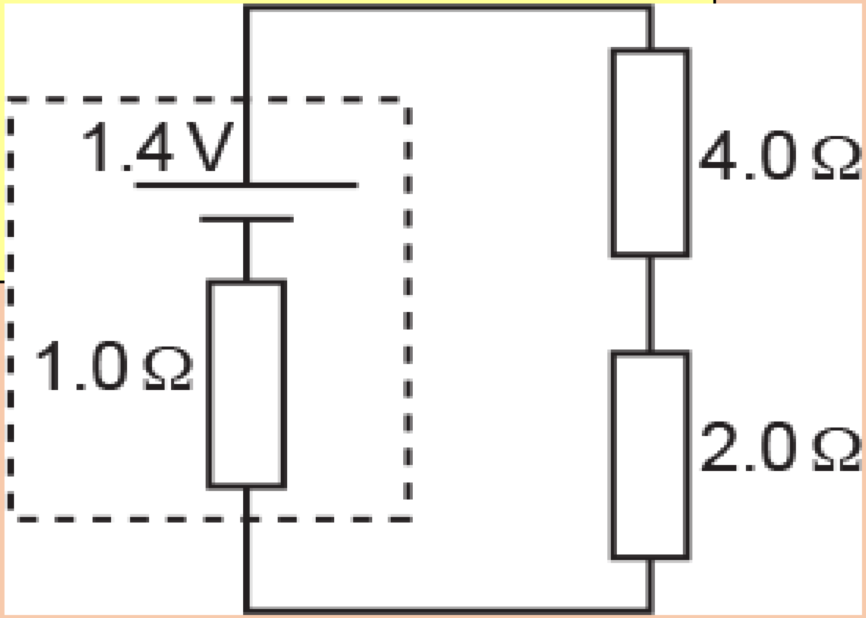
$$V_{in} /(R_1 + R_2) = V_{out} /R_2$$

Potential Dividers

Two resistors of resistances 2.0 Ω and 4.0 Ω are connected in series across the terminals of a cell of e.m.f. 1.4 V and internal resistance 1.0 Ω.

What is the potential difference across the 2.0Ω resistor?

Find total resistance (7 Ω)
Then calculate current (1.4V / 7Ω = 0.2A)
Then use V=IR to find pd.
V = 0.2 x 2 = 0.4V



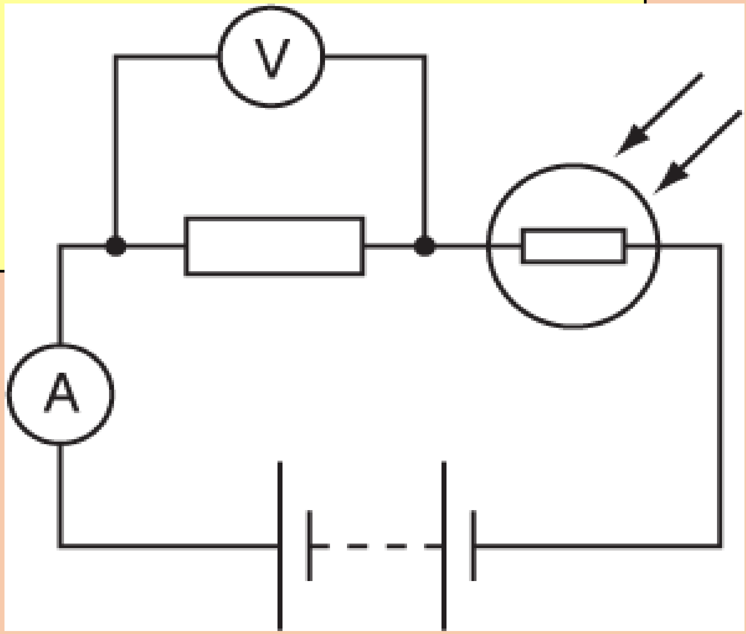
Potential Dividers

The intensity of the light incident on the LDR is reduced.

What will happen to the ammeter and voltmeter readings?
Increase? Stay the same? Decrease?

Ammeter = decrease
Voltmeter = decrease

When explaining how voltage changes, it is useful to refer to the share of the voltage



Potential Dividers

10 minutes to try some potential divider questions

Waves – Refraction and Total Internal Reflection

Recall:

Properties of transverse waves?

Which of these do not apply to longitudinal waves?

Transverse waves can…..

- Be reflected, refracted and diffracted
- Be polarised
- Travel through a vacuum

Longitudinal waves cannot…..

- Be polarised
- Travel through a vacuum

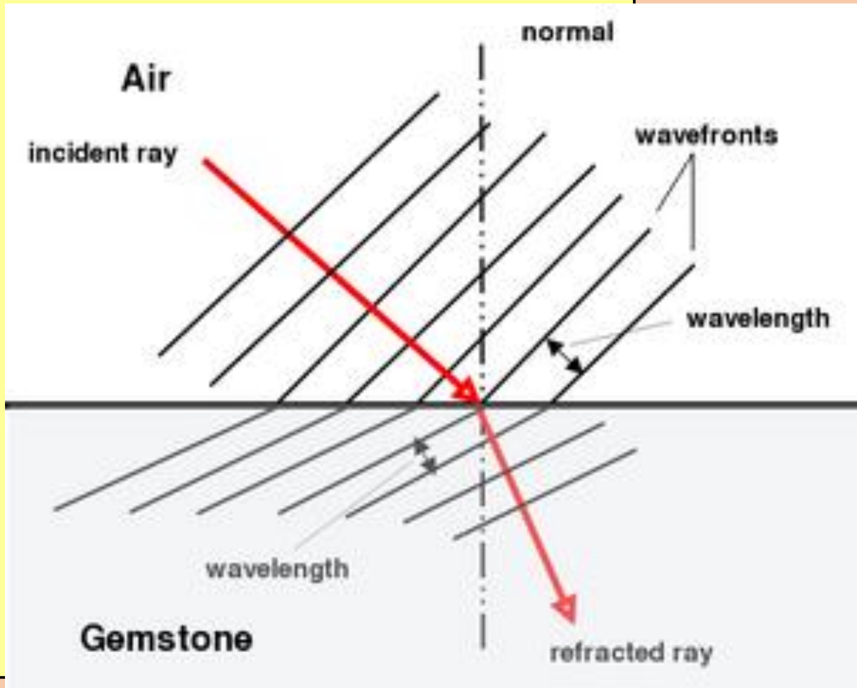
Polarised?

All waves oscillate in the same plane

Waves – Refraction

Can you explain why waves refract?
Could you use a wave front diagram?

As the wave enters the medium, the velocity reduces. Frequency remains constant (this is a property of the source, not the medium), so using v = fλ shows that the wavelength must reduce also.



Refractive index is the ratio of the speeds of the wave in each medium

$$ {}_1n_2 = \frac{c_1}{v_2} $$

Waves – Refraction

What is the relationship between the angle of incidence and the angle of refraction?
Are they directly proportional?

As the angle of incidence increases, the angle of refraction also increases.

They are not directly proportional

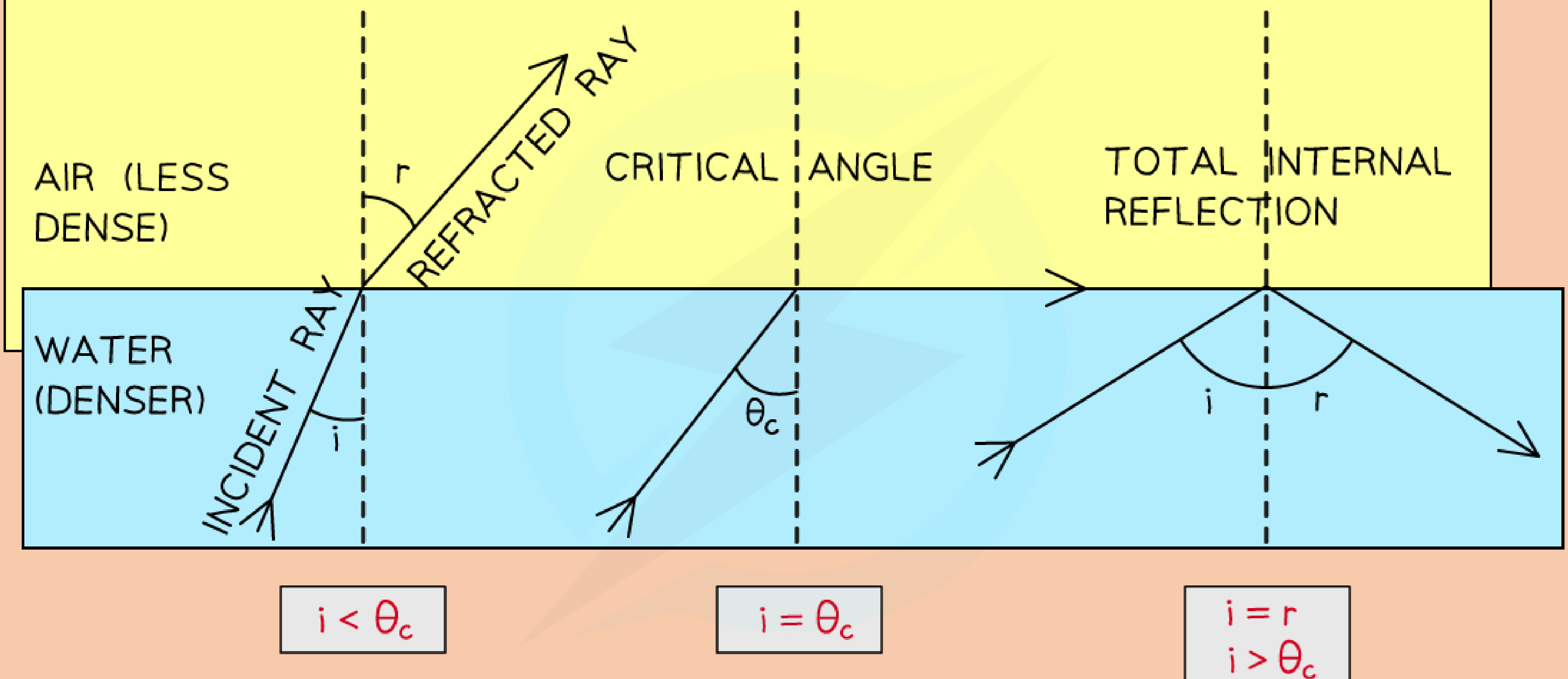
Snell's Law

$\eta \sin\theta = \text{constant}$

OR $\eta_1 \sin\theta_1 = \eta_2 \sin\theta_2$

Waves – Total Internal Reflection

As the angle of incidence is increased, provided the light is travelling from a **dense medium to a less dense one**, there comes a point where the angle of refraction reaches 90. After this the wave is totally internally reflected.



Waves – Total Internal Reflection

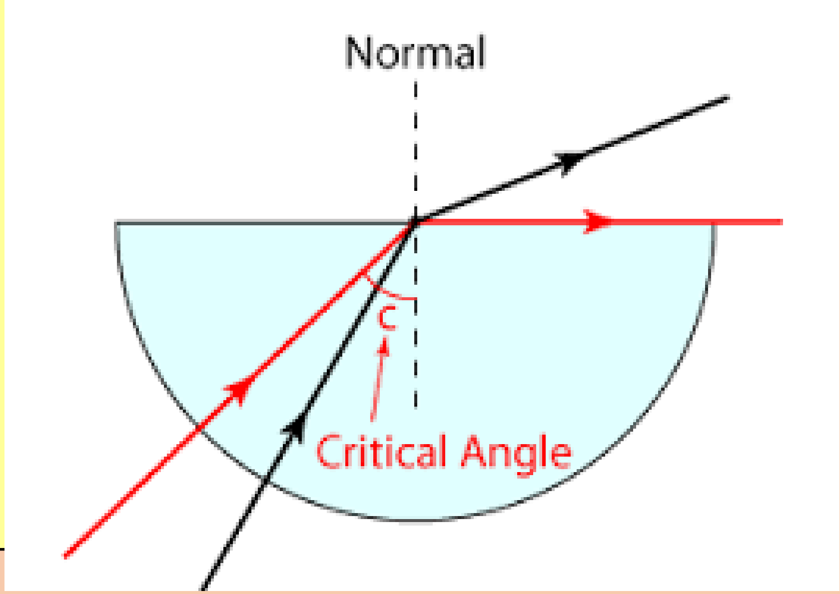
The angle of incidence when light is refracted at 90º is the critical angle.

$$\eta_1 \sin\theta_1 = \eta_2 \sin\theta_2$$

θ_1 = critical angle (c), η_2 = refractive index of air = 1 and $\sin\theta_2 = \sin(90) = 1$

$$\eta_1 \sin(c) = 1$$

So $$\eta_1 = \frac{1}{\sin(c)}$$

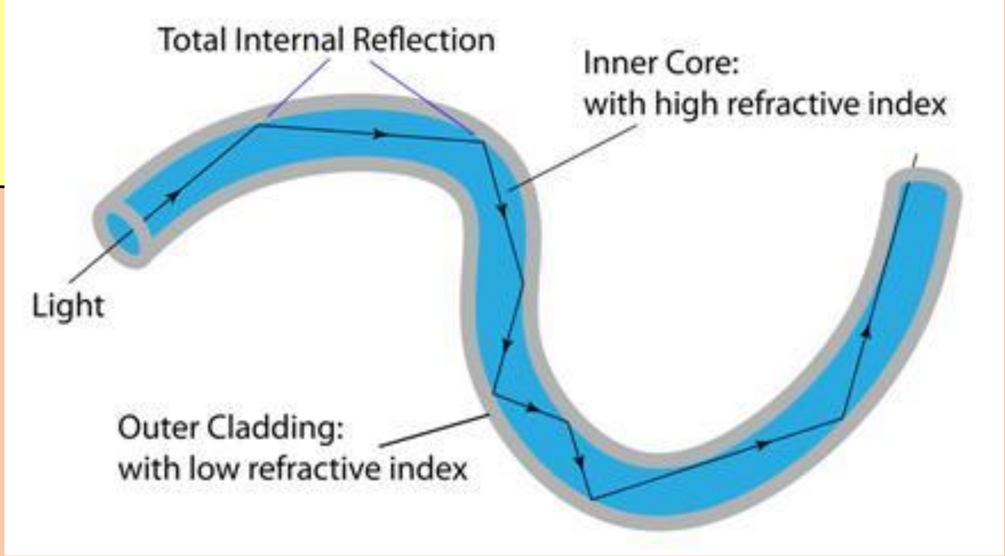


Total Internal Reflection – Fibre Optic Cables

EM waves can be passed along cables by using total internal reflection. The core has a higher refractive index than the outer cladding. This can be referred to as a **step-index**.

Dispersion (pulse broadening) can occur as the wave travels along the cable, as different wavelengths of EM wave will travel at different speeds

Shorter wavelength (blue) will travel more slowly



Total Internal Reflection & Refraction

10 minutes to try some questions on refraction

Learning Objectives:

- Electrical Circuits
- Internal resistance and EMF
- Potential dividers
- Refraction & TIR

Key Points:

- Remember that V = IR is your friend!
- Apply Kirchhoff's laws to circuits to create rules for current and potential difference
- The difference between EMF and terminal pd is all to do with energy transfers