





Electric circuits



Emf (E) and Potential difference

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1) Electromotive force [Emf (E)]

- The maximum amount of work done per unit charge which a cell can produce.
- $E = \frac{W_{\max}}{Q}$
- It is measured with a voltmeter when no current is flowing in the circuit.
- The emf of a cell cannot change
- Unit: Volts (V)

2) Potential difference (V)

- The work done per unit positive charge.
- $V = \frac{W}{Q}$
- The potential difference measured across the terminals of a battery when a current is flowing through the battery is called the terminal potential difference
- Unit: Volts (V)
- A Voltmeter is used to measure the potential difference of given element (conductor, battery or resistor) is ALWAYS connected in parallel for the element of interest.

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Electric current (I)

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➤ Electric current (I)

- The rate of flow of charge.

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

- Measured in Ampere (A)

➤ Conventional current

- It is regarded as the flow of positive charges in a conductor from the positive terminal of a source through the circuit to the negative terminal of the source.
- Ammeter is used to measure the current through an element of interest (conductor, battery or resistor) and is **ALWAYS** connected in series

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Resistance (R)

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- Resistance is defined to have a current inversely proportional to it.
- A conductor has a resistance of one ohm if a current of one ampere passes through when a potential difference of one volt is maintained between its ends.
- $R = \frac{V}{I}$
- Measured in ohms (Ω)
- Resistance is a material's opposition to the flow of electric charge (or current)
- **Factors influencing resistance of a conductor:**
 1. Type of material used.
 2. Length of the conductor ($R \propto l$)
 3. Thickness of the conductor ($R \propto \frac{1}{A}$)
 4. Temperature of the conductor ($R \propto T$)

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Factors influencing resistance of a conductor

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1) **Type of material used**

- Different materials have different resistance to the flow of charge

2) **Length of the conductor**

- Electric resistance (R) is directly proportional to the length of the conductor
- The longer the conductor, the more collisions the charges will make with its atoms

3) **Thickness (cross-sectional area) of the conductor**

- Electric resistance (R) is inversely proportional to the thickness (cross sectional area) of the conductor
- The greater the diameter of the conductor, the more current the conductor can carry

4) **Temperature of the conductor**

Electric resistance (R) is directly proportional to the temperature of the conductor

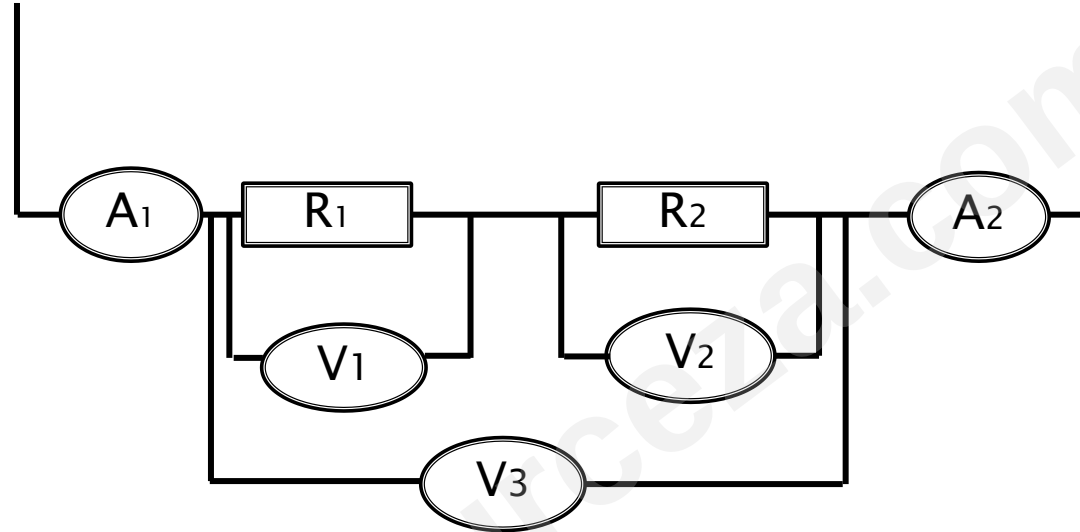
According to the Kinetic Molecular Theory atoms vibrate more rapidly at higher temperature, the charges moving through the conductor (electrons) collide more frequently. Thus increasing the resistance of the conductor

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Resistors connected in Series

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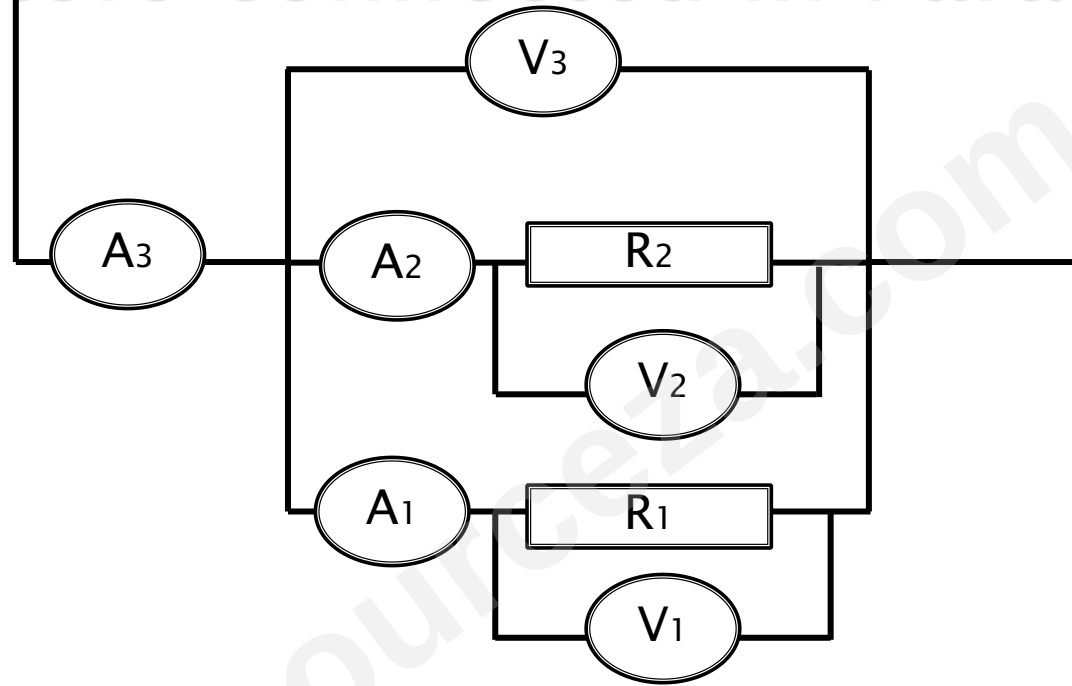
- Current remain the same. ($I_1 = I_2 = \text{constant}$)
- Divide the potential difference proportionally ($V_3 = V_1 + V_2$)
- The larger the resistance the greater the potential difference
- The more resistors in series, the bigger the resistance and the smaller the current
- Mathematically: $R_s = R_1 + R_2 + \dots$

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Resistors connected in Parallel

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- Potential difference remains constant ($V_1 = V_2 = V_3$)
- Divide the current inversely proportionally ($I_3 = I_1 + I_2$)
- The larger the resistor, the smaller the current.
- The more resistors in parallel, the smaller the resistance and the greater the current

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Mathematically: $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$



Ohm's Law

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- The potential difference across a conductor is directly proportional to the current in the conductor at constant temperature.
- In symbolic form: $R = \frac{V}{I}$
- **Ohmic and non-Ohmic materials**
- An *Ohmic* conductor would have a **linear relationship** between the current and the Potential difference.

- Materials that obey Ohm's law is said to be ohmic

➤ Ohmic	Non-ohmic
• Metallic conductors	Diodes, Transistors, Semiconductors and light bulbs

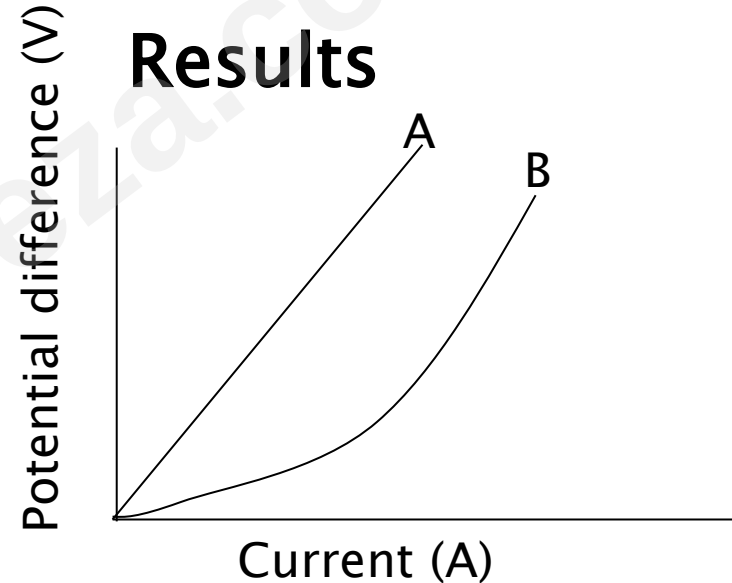
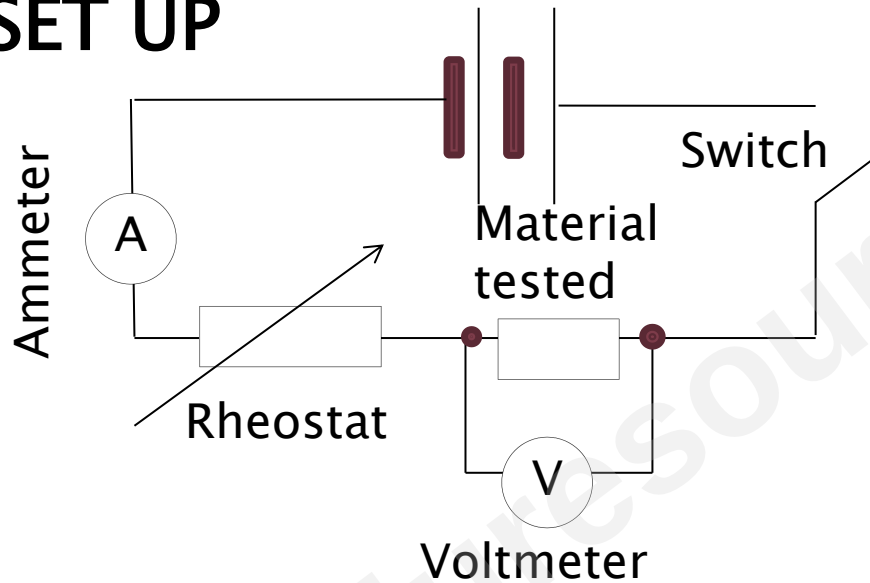
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Ohm's law

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Investigation: SET UP



- The gradient of the graph represents the resistance
- If the **gradient is constant, A**, then the material is said to be ohmic
- If the **gradient is not constant, B**, then the material is said to be non-ohmic

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Power

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- The rate at which work is done.
- Symbolic form: $P = \frac{W}{\Delta t}$
- SI Unit: Watt (W)
- Combining 1) $P = \frac{W}{\Delta t}$, 2) $V = \frac{W}{Q}$ and 3) $I = \frac{Q}{\Delta t}$
- Yields: $P = VI$
- Electrical power dissipated in a device is equal to the product of the potential difference across the device and the current flowing through it.
- Combining 1) $P = VI$ and 2) $R = \frac{V}{I}$
- Yields: $P = \frac{V^2}{R}$ and $P = I^2 R$

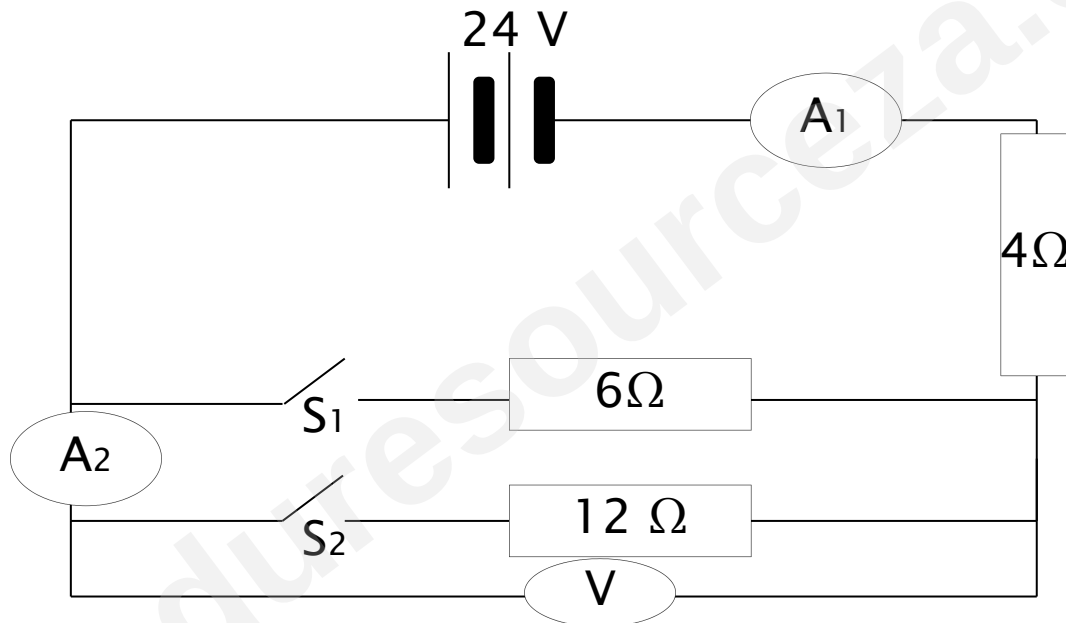
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Example 1

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In the accompanying circuit the 24 V battery has no internal resistance and the resistance of the ammeters are negligible.



- 1) What is the reading on Voltmeter V when both switches S1 and S2 are open?
- 2) Calculate the total resistance of the circuit when both S1 and S2 are closed.
- 3) Calculate the reading on the ammeters if both switches S1 and S2 are closed.
- 4) How would the energy produced by the battery, change when one of the switches is open? Give a reason for your answer.

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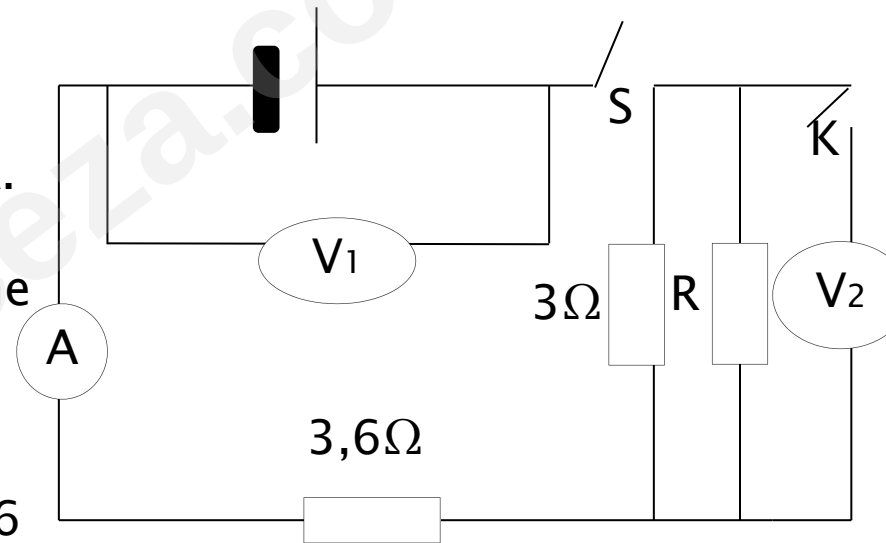


Example 2

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A circuit is set up as shown in the circuit diagram. With switches S and K open, Voltmeter V_1 reads 18,0 V. Switch S and K are now closed. The ammeter A reads 3,0 A.

1. Switch K is now also closed. Why does the reading on A not change noticeably?
2. Calculate the reading on voltmeter V_2 .
3. Calculate the resistance of resistor R.
4. Calculate the power dissipated by the $3,6\ \Omega$ resistor



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Class exercise 1

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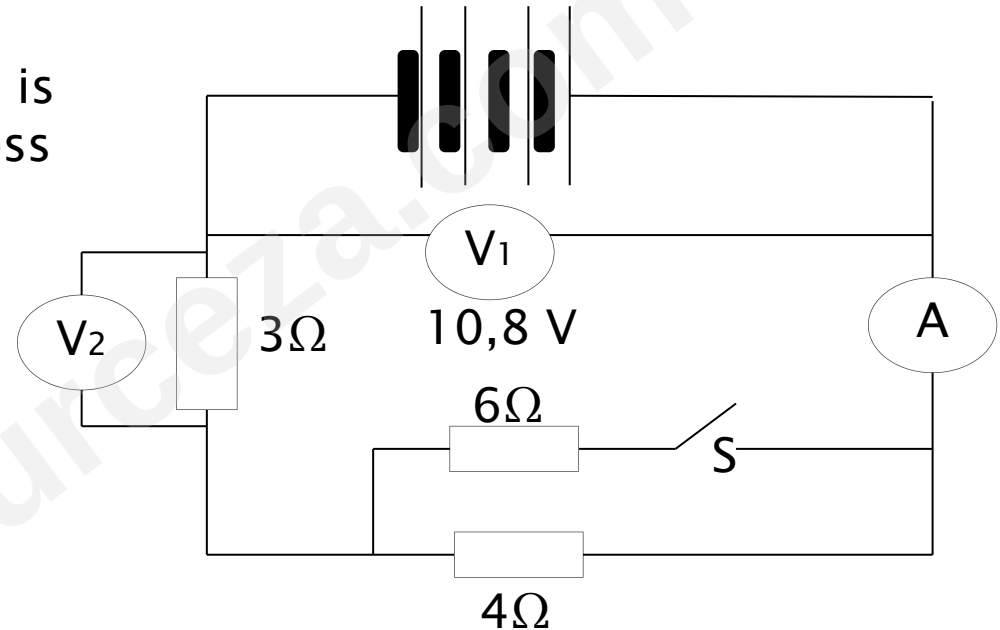
The diagram shows a circuit containing four cells. When switch S is closed, voltmeter V_1 connected across the battery reads 10,8 V.

Calculate the :

1. Reading on the ammeter.

The switch S is now opened.

- 2 Is the current through the ammeter A greater than, less than or the same as before? Explain your answer.
- 3 Calculate the reading on voltmeter V_2 with Switch S open



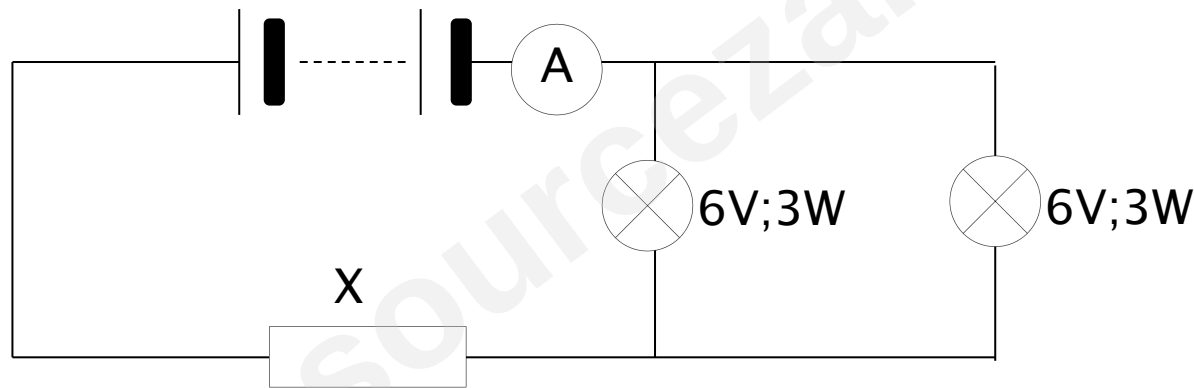
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Class exercise 2

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In the accompanying circuit, a battery with an emf of 24 V is connected in series with a resistor X and two identical light bulbs connected in parallel. The battery has negligible internal resistance. Each bulb is marked: 6 V; 3 W.



- 1) Calculate the current which should flow in each bulb when it is used at its specified voltage rating.
- 2) Calculate the resistance that X should have to ensure that each bulb operates at its specified power rating.
- 3) Will the ammeter reading increase or decrease if:
 - 3.1) Another identical light bulb is connected in parallel to the existing two? Give a reason for your answer
 - 3.2) Another resistor is connected in series with X? Give a reason for your answer.

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Cost of electricity usage

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- ▶ Eskom is the main provider of electricity in South Africa
- ▶ We are billed for the energy use per hour.
- ▶ The longer an appliance or device is used, the more energy it converts and the more we pay.
- ▶ Energy consumption units at home is measured in kilowatt hour (kWh).
- ▶ That is the use of 1 kilowatt of electricity for 1 hour
- ▶ $P = \frac{W}{\Delta t} \rightarrow W = P\Delta t$
- ▶ Therefore the Cost (R) = cost per kWh × Power rating in kilowatt × time in hours

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Examples

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- 1) A heater is marked 2 000W/3 000W is switched on for 4 hours. For the first hour, it is on the highest setting and for the last 3 hours, it is on the lowest setting.
 - 1.1) How much energy does it transfer to the room in kWh?
 - 1.2) What is the cost of heating the room if electricity cost 70c per kWh?
- 2) You are buying a new vacuum cleaner. There are three models from which to choose. All are marked 220 V. One vacuum cleaner is marked 450 W while the other two are marked 1200 W and 1600 W.
 - 2.1) What do the marked values mean?
 - 2.2) Which vacuum cleaner is likely to work most effectively?
 - 2.3) Which vacuum cleaner will be the cheapest to run?

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