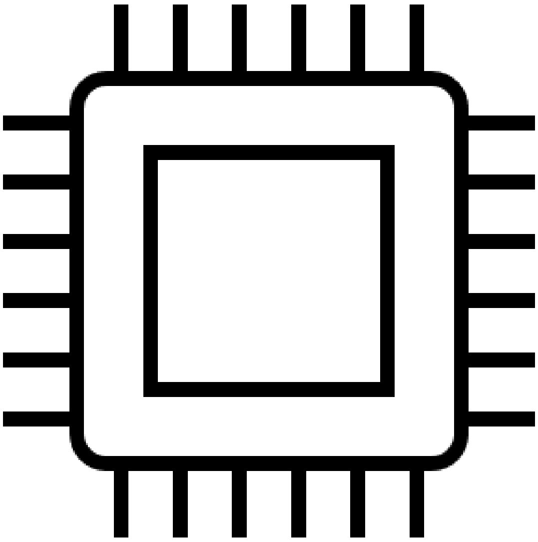
Circuit Components



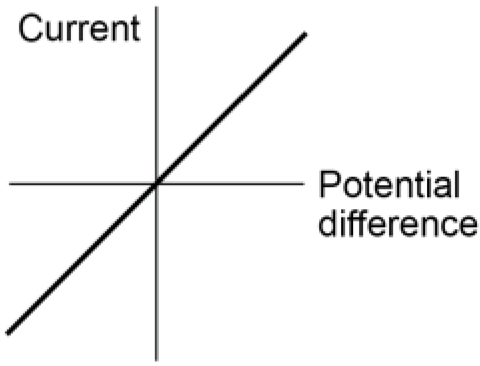
L1 Resistors

Resistors and Resistance

Resistors are components used in electrical circuits to control the flow of current. Think of them as obstacles that electric current must pass through, slowing it down. The resistance of a resistor is a measure of how much it resists the flow of current. It’s measured in ohms (Ω).

For some resistors, the value of resistance (R) stays the same no matter what. These are called **ohmic conductors**. However, other resistors can change their resistance when the current passing through them changes. Let's explore these different types of resistors and how their behaviour can be shown on a graph.

Ohmic Conductors



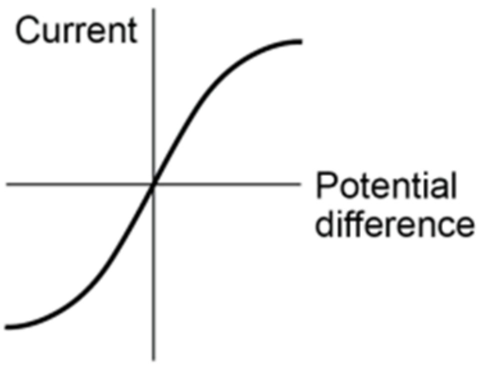
An **ohmic conductor** is a resistor that follows Ohm's Law. Ohm's Law states that the current (I) through a resistor at a constant temperature is directly proportional to the voltage (V) across it. This means if you double the voltage, the current will also double. The formula for this is:

$V=I\times RV=I\times R$

Here, R (resistance) is constant.

On an IV graph (a graph showing current vs. voltage), an ohmic conductor will appear as a straight line passing through the origin (0,0). This straight line indicates that as the voltage increases, the current increases at a constant rate. The slope of this line represents the resistance. If the line is steeper, the resistance is lower because the current increases more for a given increase in voltage.

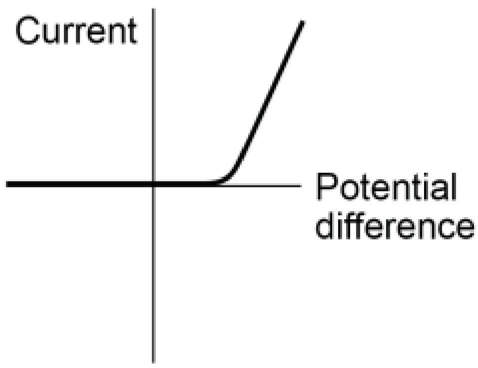
Filament Lamps



A **filament lamp** is different from an ohmic conductor. As more current flows through the filament, it heats up and the temperature of the filament increases. When the filament gets hotter, its resistance also increases. This means that as the current increases, the resistance doesn't stay constant; it increases too.

On an IV graph for a filament lamp, the curve starts off steep (indicating low resistance) but then flattens out as the voltage increases. This curve shows that at higher voltages, the current increases more slowly because the resistance is higher due to the increased temperature of the filament.

Diodes

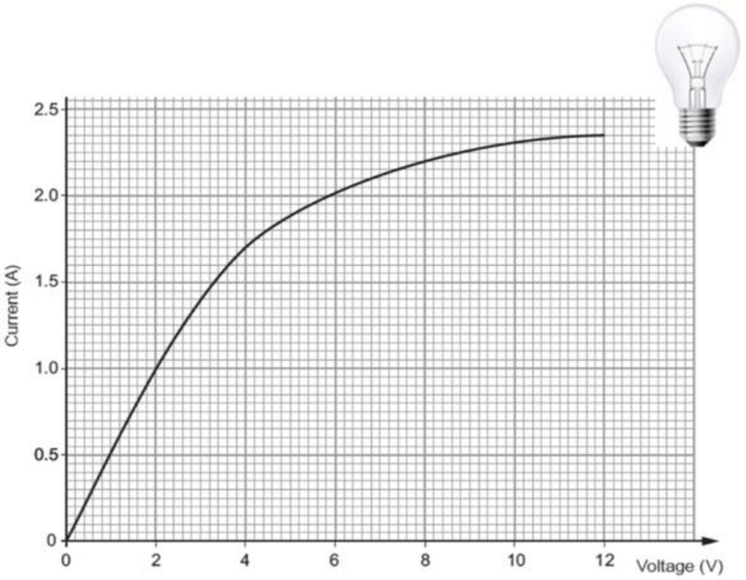


A **diode** is a special component that allows current to flow in only one direction. It has very low resistance when current flows in the forward direction and very high resistance in the reverse direction. This property is used in many electronic devices to control the direction of current flow.

On an IV graph, a diode's behavior looks quite different from an ohmic conductor or a filament lamp. In the forward direction (positive voltage), the current doesn’t increase much until a certain voltage threshold is reached. Once this threshold is crossed, the current increases rapidly, showing a steep upward curve. In the reverse direction (negative voltage), the current is almost zero, indicating very high resistance. This is shown as a flat line near the horizontal axis on the negative side of the graph.

Independent practice

1. Describe the relationship between current and voltage for an ohmic conductor. What does this relationship look like on an IV graph?
2. Explain why the resistance of a filament lamp increases as the current through it increases. How is this shown on an IV graph?
3. What is the key characteristic of a diode's IV graph that distinguishes it from ohmic conductors and filament lamps?
4. If a resistor has a constant resistance of 5 ohms, sketch the IV graph for this resistor and explain the shape of the graph.
5. How does the behaviour of a filament lamp's resistance differ from that of an ohmic conductor when the current increases? Illustrate your answer with an IV graph.
6. Describe what happens to the current through a diode when the voltage is applied in the reverse direction. How is this depicted on an IV graph?
7. The voltage across a bulb is measured for various currents, with the results plotted opposite.



   a) At what voltage does the lamp stop acting like an Ohmic conductor (i.e. when does it stop following Ohm's law and being a straight line)?
   b) What is the current when the Voltage is:
      i) 2V. ii) 6V. iii) 12V.
   c) Calculate the resistance of the lamp at:
      i) 2V. ii) 6V. iii) 12V.
   d) What do you notice happens to the resistance of the lamp as the voltage increases?
   e) Why does this happen to the resistance of the lamp?

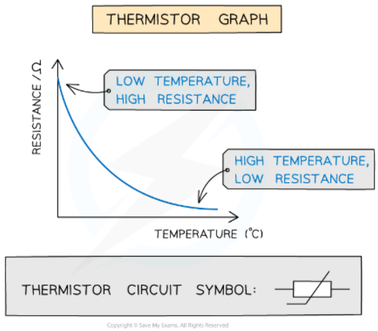
L2 Thermistors

A thermistor is a type of resistor whose resistance changes significantly with temperature. The most common type, a Negative Temperature Coefficient (NTC) thermistor, decreases in resistance as the temperature increases. Understanding how thermistors work and how they are used in everyday devices can be fascinating and very useful.

How Thermistors Work

To start with, a resistor is a component that resists the flow of electric current in a circuit. The amount of resistance determines how much it limits the current. Unlike ordinary resistors, thermistors change their resistance based on the temperature around them.

In an NTC thermistor, when the temperature goes up, the resistance goes down. This happens because higher temperatures provide energy to the thermistor's materials, allowing more electrons to move freely. More free electrons mean better conductivity and lower resistance.



Applications of Thermistors

Thermistors are used in many devices to measure and control temperature. Here are a few common applications:

1. **Thermostats**
   - **Home Heating Systems**: In a home heating system, a thermostat can use a thermistor to measure the room temperature. When the temperature drops below a set point, the thermistor's resistance increases, signalling the system to turn on the heat. As the room warms up and the thermistor's resistance decreases, it signals the system to turn off the heat.
   - **Refrigerators**: Thermostats in refrigerators use thermistors to keep the temperature within a specific range. If the temperature rises too high, the thermistor's resistance drops, and the thermostat turns on the cooling system.
2. **Digital Thermometers**
   - Digital thermometers use thermistors to measure body temperature. When you place the thermometer under your tongue, the thermistor senses the temperature change, and the digital display shows your body temperature.
3. **Overheat Protection**
   - **Computers**: Inside a computer, thermistors help prevent overheating by monitoring the temperature of critical components like the CPU. If the temperature gets too high, the thermistor's resistance changes, triggering fans or shutting down the system to prevent damage.
   - **Batteries**: In devices like smartphones and laptops, thermistors monitor battery temperature. If the battery gets too hot, the thermistor helps manage charging rates to protect the battery and the device.
4. **Automotive Applications**
   - **Engine Management**: Cars use thermistors in their engine management systems to monitor the temperature of engine coolant. The thermistor's readings help the car's computer adjust the fuel mixture and ignition timing for optimal performance.

- **Climate Control**: In the car's climate control system, thermistors measure the temperature of the air coming into the cabin, ensuring the air conditioning, or heating system maintains the desired temperature.

Understanding Circuit Design with Thermistors

When designing circuits that use thermistors, engineers often connect them with other components to create a voltage divider. A voltage divider helps to measure the voltage drop across the thermistor, which changes with temperature. This voltage can then be read by a microcontroller or other control system to make decisions based on the temperature.

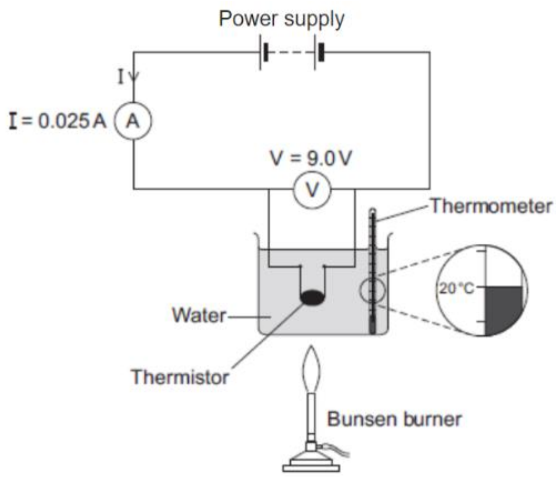
For instance, in a simple thermostat circuit, a thermistor and a fixed resistor are connected in series. The voltage across the thermistor is measured, and as the temperature changes, so does the voltage. This information can be used to turn a heating or cooling device on or off.

Conclusion

Thermistors are versatile components essential in many modern electronic devices. Their ability to accurately respond to temperature changes makes them perfect for applications like thermostats, digital thermometers, and overheat protection systems. Understanding how thermistors work and their applications can give you a better appreciation of the technology behind everyday devices and inspire you to explore further in the field of electronics.

Independent practice

1. How does the resistance of an NTC thermistor change with temperature?
2. What role does a thermistor play in a home heating system's thermostat?
3. How do thermistors help prevent overheating in computers?
4. Why are thermistors used in digital thermometers?
5. Describe how thermistors are used in car engine management systems.
6. What is a voltage divider and how is it used with thermistors in circuit design?
7. The figure opposite shows the apparatus used to obtain the data needed to calculate the resistance of a thermistor at different temperatures.

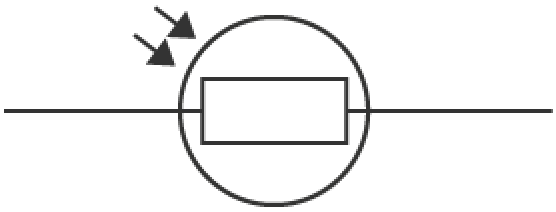


   a) Use the data given in the figure to calculate the resistance of the thermistor at 20 °C.
   b) Using a ruler and pencil for the axes, sketch a graph that shows how the resistance of the thermistor would change as the temperature increases from 20 °C to 100 °C.
   c) Give an example of a circuit that is likely to contain a thermistor.
   d) The ammeter used in the circuit has a very low resistance. Why is it important that ammeters have a very low resistance?
   e) A student plans to investigate how the resistance of an LDR changes with light intensity. The student starts with the apparatus show in the figure but makes three changes to the apparatus. One of the changes is to replace the thermistor with an LDR. Describe what other changes the student should make to the apparatus.
   f) Draw a circuit diagram of the new apparatus (with LDR instead of thermistor).

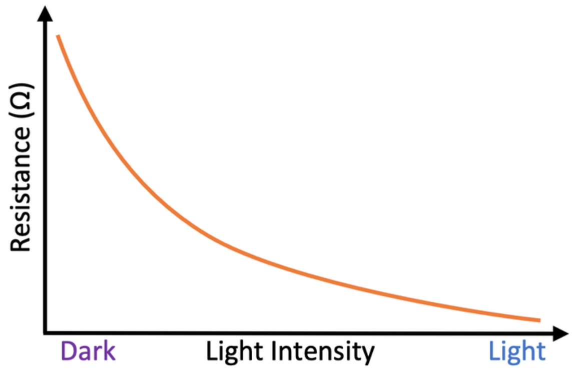
L3 LDR's

Imagine you're in a room with a lamp that turns on automatically when it gets dark. How does it know when to turn on? This is where a special component called a Light Dependent Resistor, or LDR, comes into play.

What is an LDR?
A Light Dependent Resistor (LDR) is a type of resistor whose resistance changes based on the amount of light it is exposed to. In simple terms, it can detect light levels. Resistors are components in circuits that limit the flow of electrical current, but LDRs are special because their resistance varies with light intensity.



How Does an LDR Work?
An LDR is made from a semiconductor material. Semiconductors are materials that can conduct electricity under certain conditions. When light hits the surface of an LDR, it gives energy to the electrons in the material. With more light, more electrons get enough energy to move, reducing the resistance.



Bright Light: When the LDR is in bright light, its resistance is low. This means it allows more electrical current to flow through.
Dim Light or Darkness: When the LDR is in darkness or low light, its resistance is high. This means it restricts the flow of electrical current.

Practical Uses of LDRs
LDRs are incredibly useful in many everyday devices. Here are a few examples:

Street Lights: Many street lights use LDRs to detect the level of light outside. As it gets dark, the LDR's resistance increases, triggering the lights to turn on. In the morning, when it gets light again, the LDR's resistance decreases, and the lights turn off.
Smartphones: Some smartphones use LDRs to adjust the screen brightness based on the surrounding light, making the screen easier to see in bright conditions and saving battery in darker conditions.
Burglar Alarms: LDRs can be used in security systems to detect changes in light levels, such as a shadow moving across a sensor, which might indicate an intruder.
How to Use an LDR in a Circuit
To see an LDR in action, you can set up a simple circuit with a battery, an LDR, and a light bulb or LED. Here’s a basic idea of how you can do it:

Connect the LDR: Place the LDR in the circuit. One end should be connected to the positive terminal of the battery.

Add a Resistor: Connect a fixed resistor to the other end of the LDR. This helps to protect the circuit and control the current.

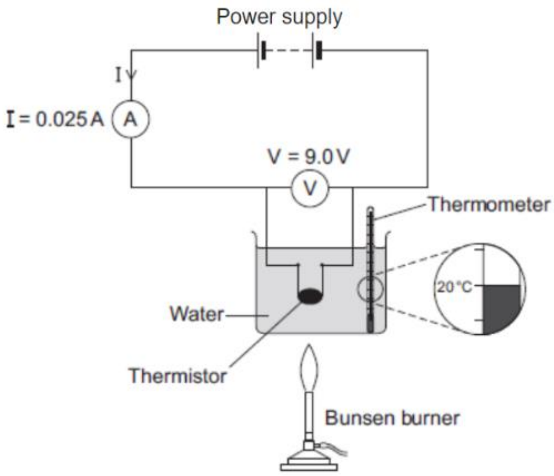
Connect the LED: Attach the LED or light bulb in the circuit so that it will light up when current flows through it.

Complete the Circuit: Connect everything to the negative terminal of the battery to complete the circuit.

When you shine light on the LDR, the LED should light up because the resistance of the LDR is low, allowing current to flow. In darkness, the LED will turn off because the high resistance of the LDR prevents current from flowing.

<u>Independent practice</u>

1. What is a Light Dependent Resistor (LDR) and what makes it special compared to regular resistors?
2. How does the resistance of an LDR change with varying light conditions?
3. Explain how an LDR works when exposed to bright light and in darkness.
4. List three practical uses of LDRs mentioned in the text.
5. Describe the basic steps to set up a simple circuit using an LDR, a battery, a resistor, and an LED.
6. Why are LDRs useful in devices like streetlights and smartphones?
7. What is the significance of learning about LDRs in understanding modern technology.
8. A student plans to investigate how the resistance of an LDR changes with light intensity. The student starts with the apparatus show in the figure but makes three changes to the apparatus. One of the changes is to replace the thermistor with an LDR. Describe what other changes the student should make to the apparatus.

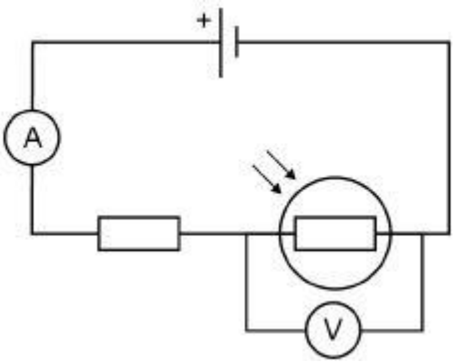


9. Draw a circuit diagram of the new apparatus (with LDR instead of thermistor).

10. The student builds a different circuit.

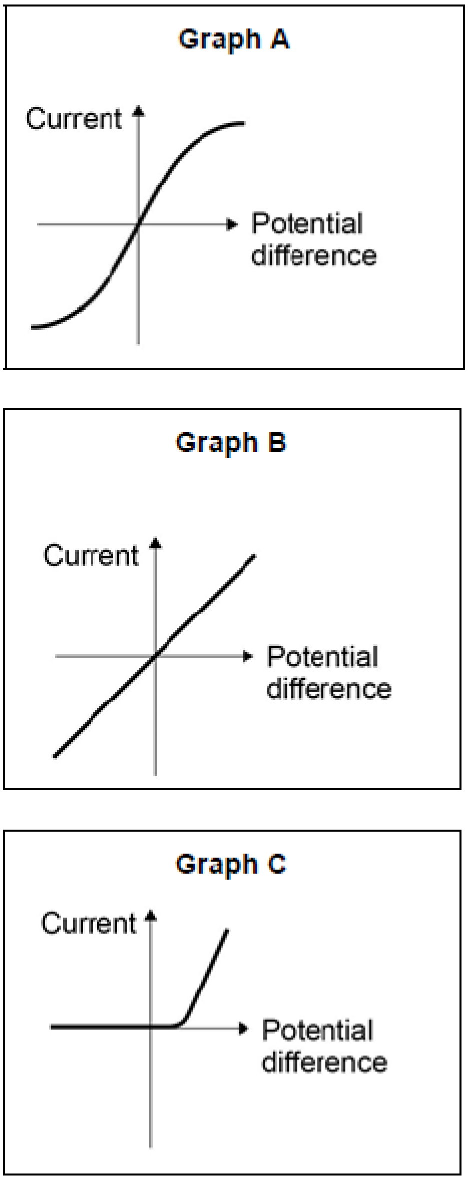
Figure 3 shows the circuit.

Figure 3



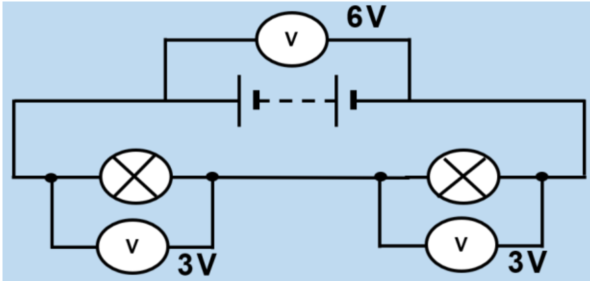
Explain how the readings on both meters change when the environmental conditions change.

Figure 2



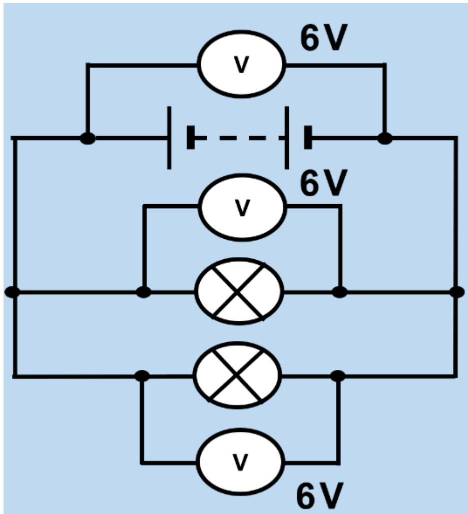
(3)
(Total 11 marks)

L4 Total resistance and Voltage in

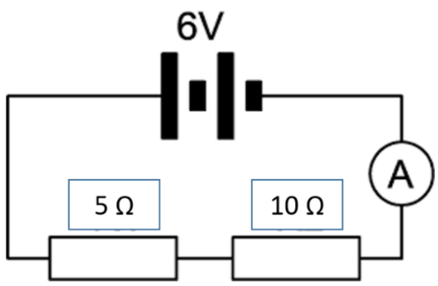


In a series circuit, the voltage supplied by the battery is **shared** by the components. So, the sum of the potential difference across the components equals the battery voltage.
This is because the **work** done by the battery on the charge must always equal the work done on the components. Otherwise, energy would be lost.

As more bulbs are added in series, each bulb has less potential difference and so the bulbs become dimmer.
The component with the highest resistance will have the largest potential difference because the higher the resistance, the more work is done by the charge passing through it.
In a parallel circuit, the potential difference across each bulb is the **same** as the potential difference across the battery.
This means that all the bulbs have the same brightness, and they are brighter than the same number of bulbs in a series circuit. However, this also means that the battery will run down faster in a parallel circuit.



Example question. What is the potential difference across each of these resistors?
STEP 1: Calculate the total resistance
$R_{TOT} = R_1 + R_2 = 5 + 10 = 15\ \Omega$
STEP 2: Calculate the total current in the circuit
$I = V \div R = 6 \div 15 = 0.4$ A
STEP 3: Calculate the potential difference across both of the resistors
5 Ohm resistor: $V = I \times R = 0.4 \times 5 = 2$V
10 Ohm resistor: $V = I \times R = 0.4 \times 10 = 4$V



Note that these potential differences add up to give the total potential difference across the battery (6V).

Basic

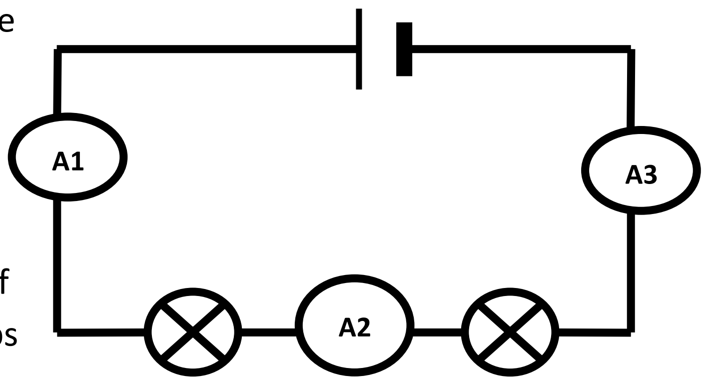
1. A 1.5 V cell is connected to a 3.0 Ω resistor and a 2.0 Ω resistor in series with each other.
   A. Draw a circuit diagram for this circuit
   B. Calculate:
      (I) The total resistance of the two resistors
      (II) The current through the resistors
      (III) The potential differences across each resistor

Medium

2. A circuit contains a battery of two cells, with each cell providing 1.5 V. The circuit also has two resistors connected in series. Resistor P has a resistance of 2 Ω and resistor Q has a resistance of 10 Ω.
   A. Draw a circuit diagram for this circuit.
   B. Calculate the total resistance of the two resistors
   C. Calculate the total potential difference provided by the battery
   D. Show that the current through the battery is 0.25 A
   E. Calculate the potential difference across each resistor
3. A circuit contains a 6 V battery and three resistors connected in parallel with each other and with the battery.
   R_1 = 2 Ω
   R_2 = 3 Ω
   R_3 = 6 Ω
   a. Draw a circuit diagram for this circuit
   b. Suggest a value for total resistance.
   c.

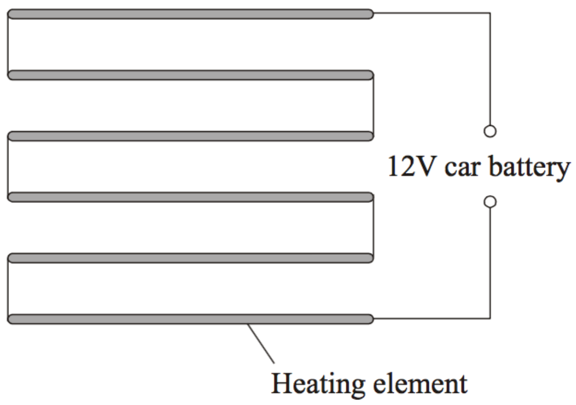
Hard

4. The battery in this circuit has a potential difference of 12V, each bulb has a resistance of 5Ω, calculate the current in A1, A2 and A3
5. The two bulbs are identical, calculate the voltage over them
6. What would happen to the brightness of the bulbs if you added another bulb in series with the first two?
7. What would happen to the brightness of the bulbs if you added another two bulbs in parallel to the first two?



The diagram shows a simple type of car rear window heater. The six heating elements are exactly the same and are connected in **series**.

Each heating element has a resistance of 5 Ω. The current passing through each element is 0.4 A.



(a) Calculate the total resistance of the six heating elements. Show clearly how you work out your answer. **(2)**

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(b) Why is the current passing through each element the same? **(1)**

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(c) What is the total current passing through the whole circuit? **(1)**

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(d) How is the 12-volt potential difference of the car battery shared between the six heating elements? **(1)**

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L5 Circuit measurements

Investigating the I–V (current-voltage) characteristics of different circuit elements is a fundamental part of understanding how electrical circuits work. Here's how you can set up and understand these experiments using circuit diagrams. We'll look at three elements: a filament lamp, a diode, and a resistor at constant temperature.

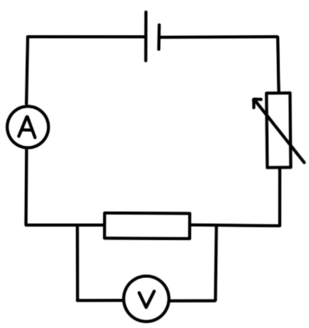
What You'll Need

1. **Power Supply**: A variable DC power supply.
2. **Ammeter**: To measure current (I).
3. **Voltmeter**: To measure voltage (V).
4. **Resistor**: A simple resistor with a known resistance.
5. **Filament Lamp**: A small light bulb.
6. **Diode**: A semiconductor device that allows current to flow in one direction.
7. **Connecting Wires**: To build your circuits.
8. **Breadboard**: To easily assemble and modify your circuits.

1. Resistor at Constant Temperature

Objective: To understand the I–V characteristics of a resistor.

Circuit Diagram:



1. **Connect the Resistor (R)**: Place the resistor in series with the ammeter (A).
2. **Measure Voltage (V)**: Place the voltmeter across the resistor.
3. **Adjust the Power Supply**: Gradually increase the voltage from the power supply and record the current (I) using the ammeter for each voltage (V) reading.
4. Switch the power supply to get the negative values.

Expected Result: For a resistor, the I–V graph is a straight line, showing that current is directly proportional to voltage (Ohm's Law: V = IR). This means the resistor's resistance stays constant.

2. Filament Lamp

Objective: To observe the I–V characteristics of a filament lamp.

1. **Connect the Filament Lamp**: Place the filament lamp in series with the ammeter.
2. **Measure Voltage (V)**: Place the voltmeter across the filament lamp.
3. **Adjust the Power Supply**: Gradually increase the voltage and record the current.

Expected Result: The I–V graph for a filament lamp curves upwards. Initially, the lamp behaves like a resistor, but as the filament heats up, its resistance increases, causing the curve to bend.

3. Diode

Objective: To understand the I–V characteristics of a diode.

1. **Connect the Diode**: Place the diode in series with the ammeter. Ensure the diode is forward-biased (positive voltage to the anode and negative to the cathode).
2. **Measure Voltage (V)**: Place the voltmeter across the diode.
3. **Adjust the Power Supply**: Gradually increase the voltage and record the current.

Expected Result: The I–V graph for a diode shows that very little current flows until a certain threshold voltage (about 0.7V for silicon diodes). Once this threshold is reached, current increases rapidly.

Systematic Errors:

- The voltmeter and ammeters should start from zero, to avoid zero error in the readings

Random Errors:

- In practice, the voltmeter and ammeter will still have some resistance, therefore the voltages and currents displayed may be slightly inaccurate
- The temperature of the equipment could affect its resistance. This must be controlled carefully
- Taking multiple readings of the current for each component will provide a more accurate result and reduce uncertainties

Understanding the Results

- **Resistor**: The straight line confirms Ohm’s Law (V = IR).
- **Filament Lamp**: The curve indicates increasing resistance with temperature.
- **Diode**: The sharp increase in current at the threshold voltage shows the diode’s unique property of allowing current to flow in only one direction.

By following these steps and using the circuit diagrams, you’ll be able to investigate and understand the I–V characteristics of different electrical components. This hands-on experience will help you grasp fundamental electrical concepts and prepare you for more advanced studies in physics and electronics.

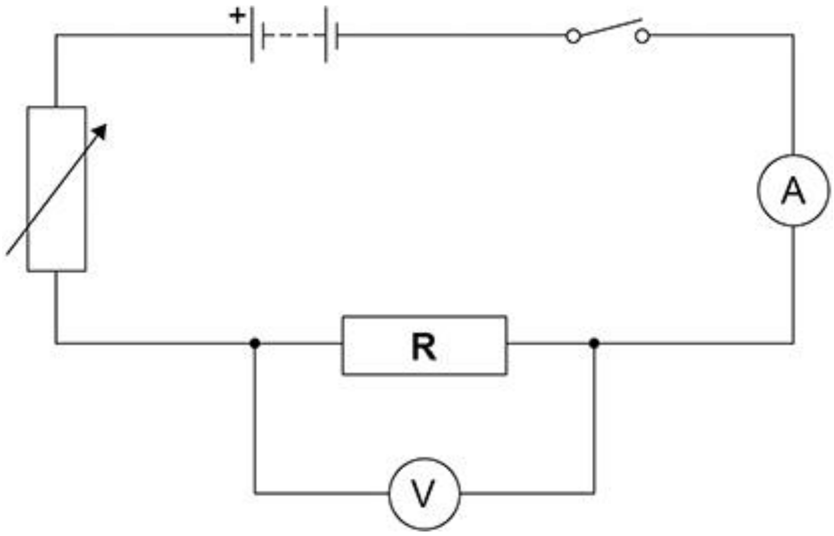
Independent practice

1. What is the expected shape of the I-V graph for a resistor and which law does this demonstrate?
2. Describe the process for setting up the circuit to measure the I-V characteristics of a filament lamp. What result should you expect from this experiment?
3. Explain the procedure for investigating the I-V characteristics of a diode. What is the significance of the threshold voltage in this experiment?
4. Identify at least two types of errors that might occur during these experiments and explain how they could affect the results.
5. How does the behaviour of a filament lamp differ from that of a simple resistor when plotted on an I-V graph, and what causes this difference?
6. Why is it important to take multiple readings of the current for each component during these experiments? What benefit does this provide?
7. Student A investigated how the current in resistor R at constant temperature varied with the potential difference across the resistor.

   Student A recorded both positive and negative values of current.

   Figure 1 shows the circuit Student A used.

   Figure 1



   (a) Describe a method that Student A could use for this investigation. (6)

   (b) Student B repeated the investigation.

   During Student B’s investigation the temperature of resistor R increased.

   (c) Explain how the increased temperature of resistor R would have affected Student B’s results. (2)