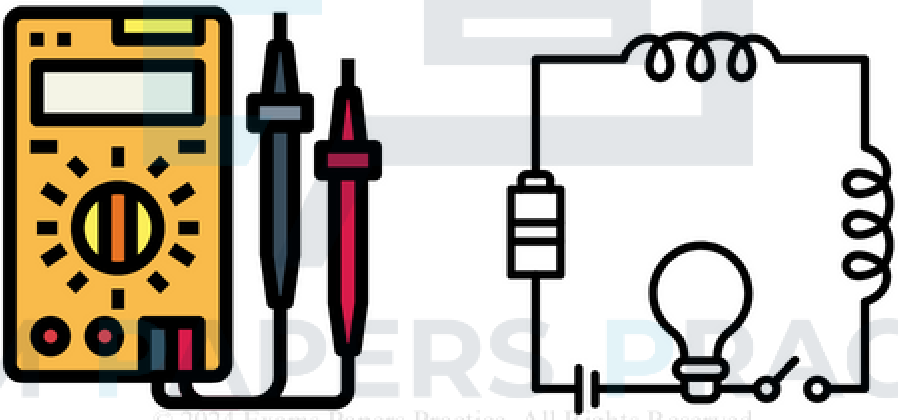
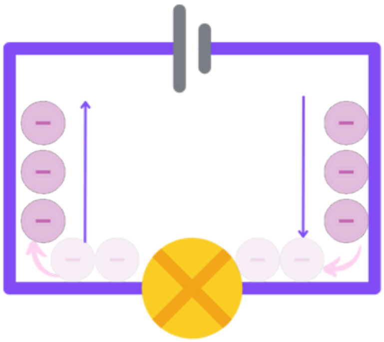
Chapter 18

Electrical Quantities



18.1 Current

Drawing a simple circuit:



Definition of current:

Electric current is the flow of electric charge through a conductor, typically measured in amperes.

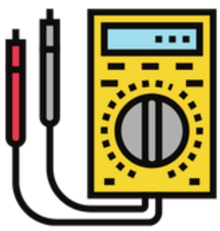
For an electric current to flow, two things are needed:

1. A complete circuit for the current to flow:
    a. Metals like copper and steel form the pathway for the current to circulate.
    b. Metals are chosen because they are excellent conductors of electricity.
2. A source to "push" the current around the circuit:
    c. The push can be supplied by a cell, battery, or power source.

Measuring electric current

1. To measure electric current, we use an ammeter. There are two types:
    a. Analogue meter
    b. Digital meter
2. An ammeter is connected in series within a circuit.
3. The reading on an ammeter is measured in amperes.

ANALOGUE METER



DIGITAL METER

GALVANOMETER
- USE TO MEASURE TINY CURRENT

How current and electron move around the circuit

1. Conventional electric current flows from the positive terminal to the negative terminal.
2. However, it is now understood that in metals, negatively charged electrons move, leaving the negative terminal of the cell and flowing towards the positive terminal.

Measuring electric current: Ampere

1. The electric current is defined as the charge passing a point in the circuit per unit of time.
2. Equation:

I = Q / T

Worked Example 1:

An electric motor draws a current of 250 mA for 45 seconds. How much electric charge passes through the motor during this time?

18.2 Voltage in electric circuit

1. Voltage, also known as potential difference

Definition:

Voltage is defined as the amount of work done per unit charge to move a charge between two points in an electric field, measured in volts (V).

The difference in electrical potential between two points.

(Unofficial): How much "push" a battery provides the push the current.

Unit	Volt
Measured using:	Voltmeter

2. Voltmeter
   - A voltmeter is always connected in parallel with a component.
   - A voltmeter can have either an analogue display or a digital display.

3. Electromotive force
   - A special name for potential difference across a cell
   - It is also measured in volts

Electromotive force (emf) is defined as the amount of work done by a source in moving a unit charge through the entire circuit.

EXAM PAPERS PRACTICE

Combining e.m.f.

1. If cells with e.m.f.s E1 and E2 are connected in series, their combined e.m.f.s is given by:

$$E = E1 + E2$$

Measuring Volts

1. A volt is a joule per coulomb of charge.
2. Formula to measure voltage:

V = W / Q

V can be the e.m.f from the cell, or the potential difference across the device.

3. Work done is also the energy transferred.

Worked Example 2:

Calculate the electromotive force (e.m.f) of a battery that transfers 72 J of energy to a charge of 6 C.

Worked Example 3:

Given a potential difference of 15V across a resistor, calculate the energy transferred when:

a. A charge of 3C passes through it.
b. A charge of 6C passes through it.
c. A current of 2.5A flows for 20 seconds.

Worked Example 4

In a circuit with two 1.5V cells connected in series, calculate the energy gained by 4C of charge passing through the cells.

18.3 Electrical Resistance

1. The current flowing in a circuit can be controlled by adding components with electrical resistance to the circuit.
2. Definition of resistance:

Resistance is the measure of opposition to the flow of electric current through a material, typically measured in ohms (Ω).

3. The higher the resistance, the lower the amount of current that will pass through.
4. Ohms are used to quantify resistance (Ω). Ohms indicate the voltage required to produce a current of 1A through the resistor.

Measuring resistance:

1. Equation:

V = IR

2. To measure the resistance of a resistor, we need to know the:
   a. Potential difference
   b. Current

Worked Example 5

Calculate the resistance of a resistor when a current of 0.03A flows through it and there is a potential difference of 12.0V across its ends.

Worked Example 6

a. Determine the resistance of a lamp when a current of 8.0A passes through it while connected to a 240V supply.
b. If the potential difference across the lamp is increased, predict whether the current flowing through it will increase or decrease.

Worked Example 7

What potential difference (p.d) is required to establish a current of 7.5A through a 100Ω resistor?

Worked Example 8

a. Determine the resistance of a resistor when a potential difference of 240 V results in a current of 60 mA flowing through it.

b. Calculate the potential difference required to produce a current of 20 mA through the resistor.

Ohmic resistor

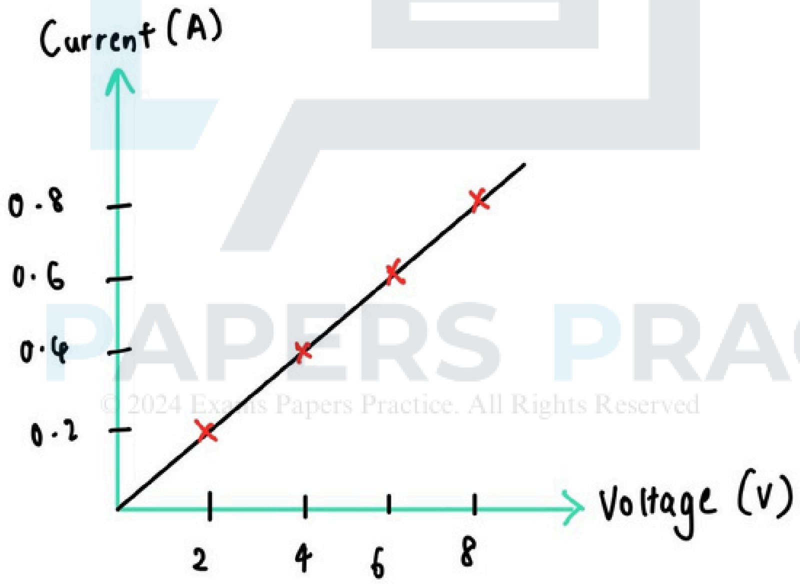
1. An ohmic resistor is a resistor that:

An ohmic resistor, also known as an ohmic device or ohmic conductor, is a component that obeys Ohm's law, meaning its resistance remains constant regardless of the applied voltage or current within its operational limits.

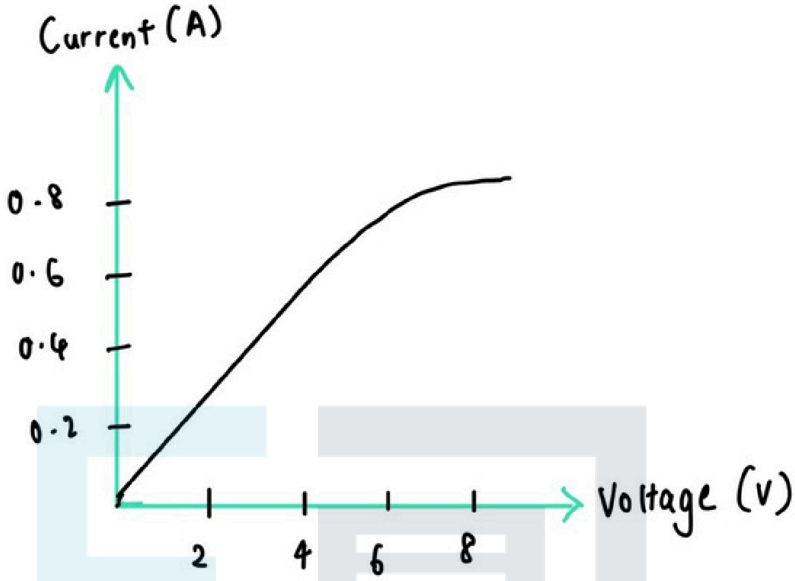
Its current-voltage characteristic is a straight line

2. Current-voltage characteristic:

A graph of current on the vertical axis and voltage on the horizontal axis.



3. The current-voltage characteristic of a non-ohmic resistor (eg. Filament lamp)



• Initially, the graph shows a linear relationship (current increases proportionally with voltage).

• At higher voltages, the graph begins to curve upwards. The rate of current increase slows down as voltage increases.

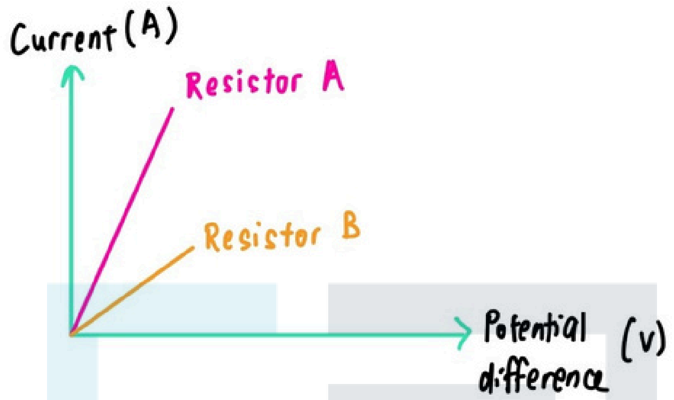
Reasons:

1. As voltage rises, the filament heats up and emits brighter light.
2. At elevated temperatures, the filament's resistance increases, causing the current to rise more slowly. But why?
    a. Higher currents lead to more electrons flowing through the tungsten wire.
    b. This increases collisions between electrons and the lattice structure (Intuition: It's akin to navigating through a crowded space where collisions are frequent due to random movements).

Worked Example 9:

The diagram below shows the current-voltage characteristic of a two ohmic resistors.

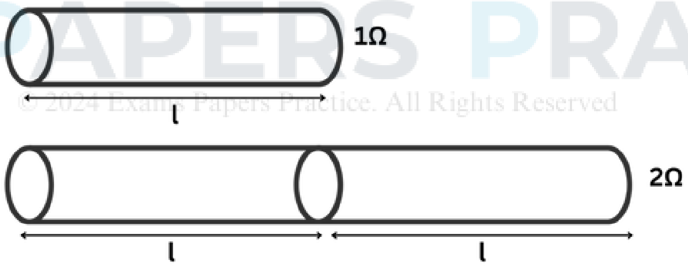
Which resistor, A or B, has a higher resistance? Give your reason.



Answer:

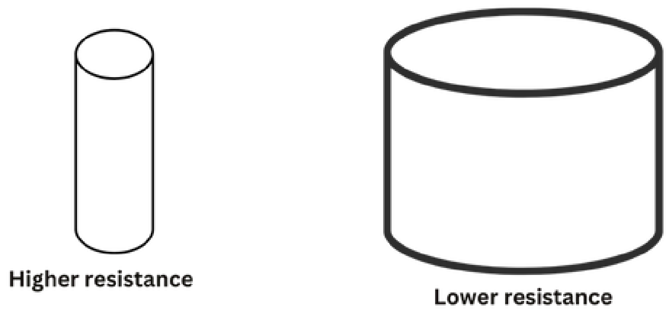
Factors affecting the resistance of wires

a. Length – The longer a wire, the greater its resistance



b. Diameter / cross sectional area – The greater the diameter of a wire, the less its resistance

- Doubling the radius halves the resistance again.



Worked Example 10:

a. Determine the resistance of a piece of wire that is 10.0 m long, made of the same material as a 1 m length which has a resistance of 0.8 Ω.

b. Calculate the resistance of a 2.0 m wire that has half of the cross-sectional area of the original wire but is made of the same material.

Extra notes for Paper 6

Experiment 1 – Measuring resistance

1. Use a variable power supply (voltage is adjustable).
2. For each voltage value, measure the current with an ammeter.
3. Calculate the R values using the formula:

$R = V/I$

4. Average the R values to find the true value of R.

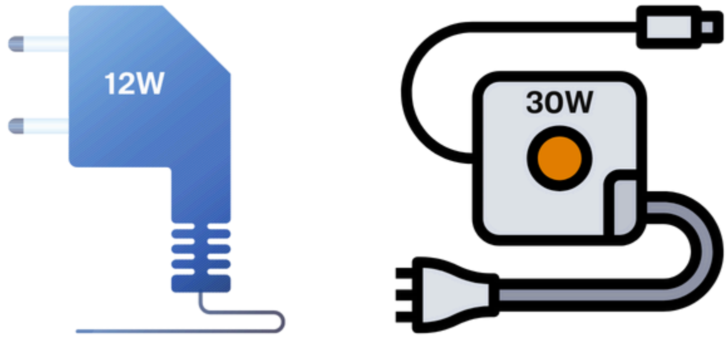
Experiment 2 – Investigate the relationship between thickness and length of wire and resistance of a circuit

1. Use a wire of different length for each experiment. Make the voltage a constant.
2. Measure the current using an ammeter.
3. Calculate the resistance of the circuit.

You should see that the longer/thicker a wire, the higher the resistance of a circuit.

18.4 Electrical energy, work and power

1. Most electrical appliances have a label that shows their power rating.



2. Power ratings are specified in watts (W) or kilowatts (kW).
3. An appliance's power rating denotes how quickly it transfers energy and signifies the maximum electrical power it draws from the main supply.
4. Equation:

Power = energy transferred (J) / time taken (s)

5. Equation relating Power to Current and P.d:

P = VI

6. Since energy = power x time, we can use derive an equation for electrical energy transferred E in terms of current and voltage.

   Equation:

E = VIt

Worked Example 11:

A hair dryer operates from a 240 V main supply. It consumes a current of 0.30 Calculate the rate at which electrical energy is transferred by the hair dryer. Also, determine the total energy transferred in one minute.

Unit of electrical energy

1. We use electricity because it is a good way of transferring energy from place to place.
2. The unit we use to calculate the amount of energy transferred electrically is kWh.
3. One kWh is equal to 3.6 x 106 J of energy:

1kW = 1000 W = 1000 J of energy per second

1h = 3600s

1kWh = 3600 x 1000

= 3.6 x 106 J

4. Equation to calculate kWh:

Energy Transferred (kWh) = Power (kW) x Time (hour)

Worked Example 13

A light bulb with a power rating of 60 watts operates for 5 hours. How much energy does it consume in kilowatt-hours (kWh)?

Worked Example 14

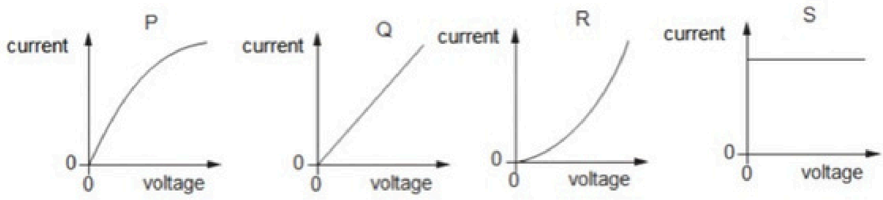
Tom checks his electricity bill for a three-month period. The meter reading at the start was 1800 kWh and at the end, it was 1980 kWh. Electricity costs 12 cents per kilowatt-hour (kWh). Calculate his electricity bill for this period.

Past Year Questions

No

1

Four current-voltage graphs are given below.



One of them is for an ohmic resistor, and another is for a filament lamp.

Which is which?

	filament lamp	ohmic resistor
A	Q	S
B	R	Q
C	P	Q
D	Q	R

2

A student muses on the concept of the resistance of a wire.

She wonders whether changing the diameter of the wire and the length of the wire would affect the resistance.

Since you have studied this in physics, you know the answer!

Choose the row from the table in which changes are made to both the diameter and the length that would each **decrease** the resistance of a wire.

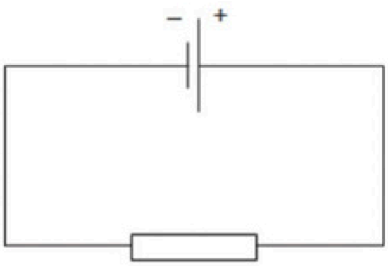
	change to length	change to diameter
A	increase	increase
B	increase	decrease
C	decrease	increase
D	decrease	decrease

3

What is the unit of electromotive force?

A Joule **B** Volt **C** Ampere **D** Watt

4	A student sets up a circuit as shown in the diagram



A charge of 4.9 C flows through the lamp in 0.7 s.

What is the current through the resistor, which direction do electrons flow through the resistor, and what is the direction of the conventional current through the resistor?

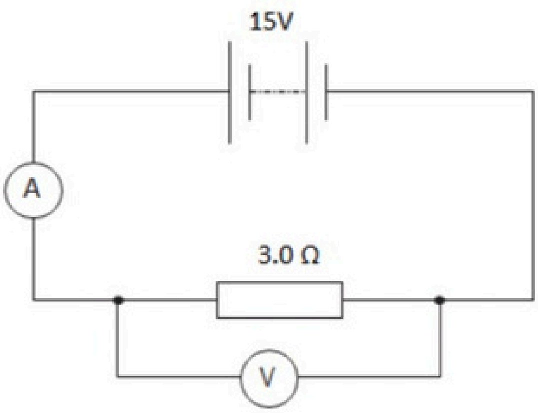
	current / A	direction of electron flow	direction of conventional current
A	7.00	Left to right	Right to left
B	3.43	Left to right	Right to left
C	7.00	Right to left	Right to left
D	3.43	Right to left	Right to left

5 A student connects a 6 V power supply to a 3 Ω resistor. The resistor is left connected to the power supply for 1 minute.

How much power is dissipated by the resistor?

A 2 W **B** 12 W **C** 720 J **D** 18 W

6 A 3.0 Ω resistor is connected to a 15 V power supply as shown in the diagram. The ammeter reads 5 A throughout the experiment.

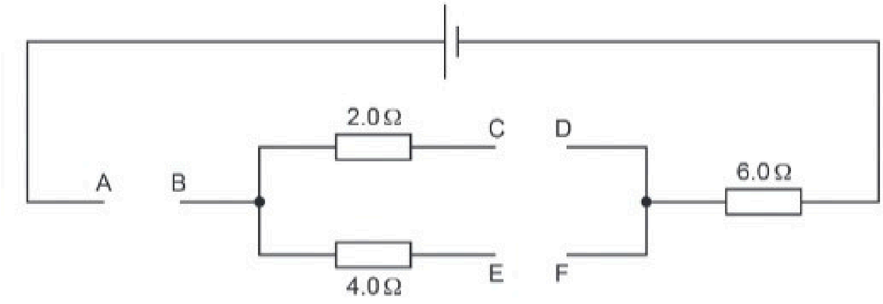


How much energy is dissipated as heat by the resistor in 2 minutes?

A 9.0 kJ **B** 150 J **C** 600 J **D** 5 J

7

The diagram shows an incomplete electrical circuit.



(a) A student completes the circuit and measures the current in the 6.0 Ω resistor.

On the diagram, draw an ammeter symbol in one gap and straight lines to indicate wires in the other gaps to show how the student should do this. [1]

(b) A voltmeter is connected to measure the potential difference (p.d.) across the 4.0 Ω resistor.

On the diagram, draw a voltmeter symbol connected in the correct position. [2]

recognisable ammeter in gap AB **AND** straight lines in CD **AND** EF	**1**
recognisable voltmeter across 4 Ω (1) correct voltmeter symbol used (1)	**2**

8

The kinetic energy of air passing through a wind turbine every minute is 720 000 J. The electrical output of the turbine is 9.0 A at a potential difference (p.d.) of 240 V.

Calculate the efficiency (%) of the wind turbine.

efficiency = ... % [5]

[Total: 5]

EXAM PAPERS PRACTICE

Question	Answer	Marks
1	(output) $P = VI$ **or** $E = VIt$ **or** $E = Pt$ in any form words, symbols or numbers **OR** (P =) VI **OR** (P =) 240 × 9 **OR** (P =) 2160 (W) **OR** (E =) 240 × 9 × 60 = 129 600 (J) (1) (rate of energy input = 720 000 / 60 =) 12 000 (J / s) **OR** energy input = 720 000 (J) (1) (efficiency =) (100 ×) output power / input power **OR** (100 ×) output energy / input energy words, symbols or numbers (1) (efficiency =) $100 \times \frac{2160}{12\ 000}$ (1) (efficiency =) 18(%) (1)	5