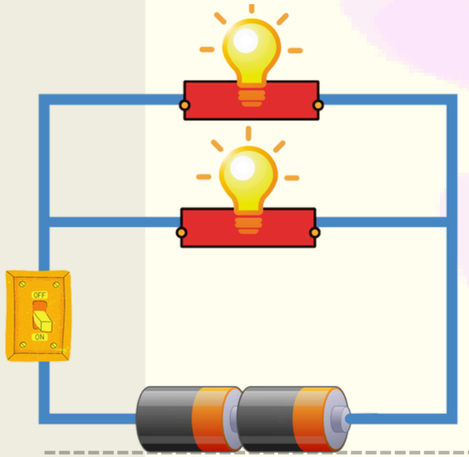
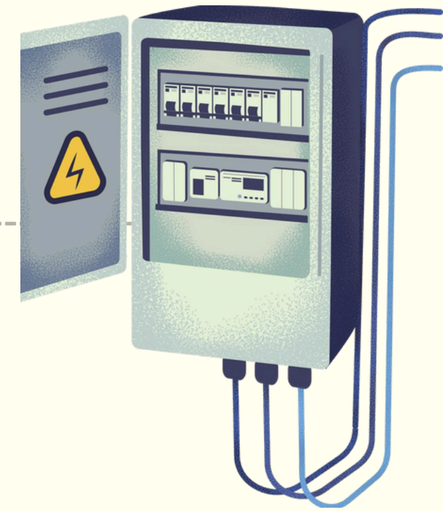
ELECTRICAL QUANTITIES



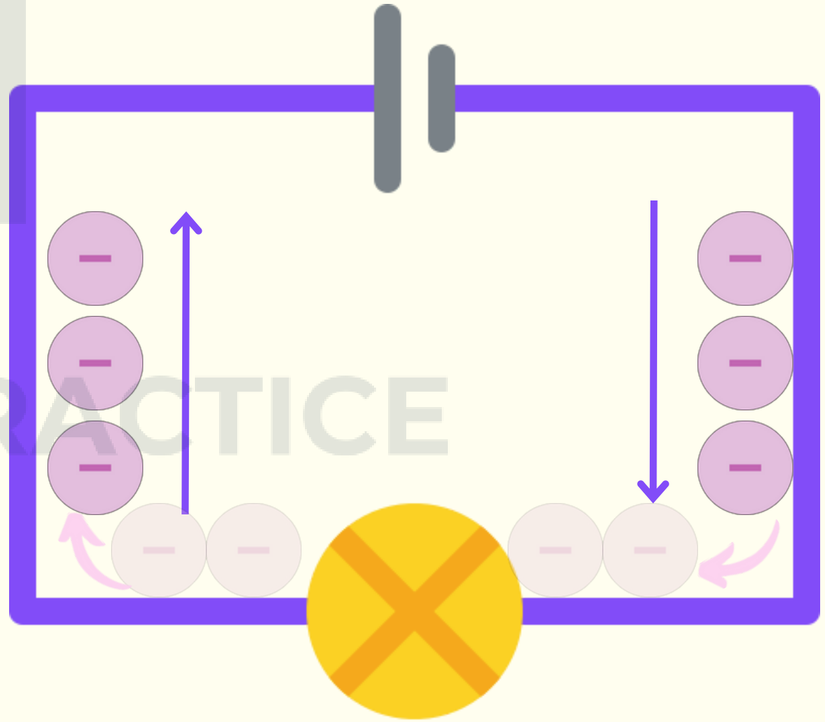


Current,
Voltage,
Resistance,
Power

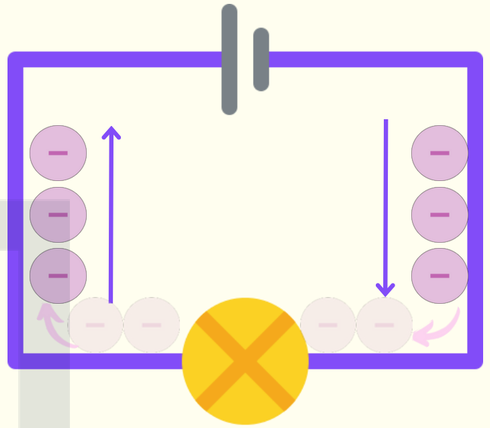
Formulas +
Work Examples

CURRENT

> Definition: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:



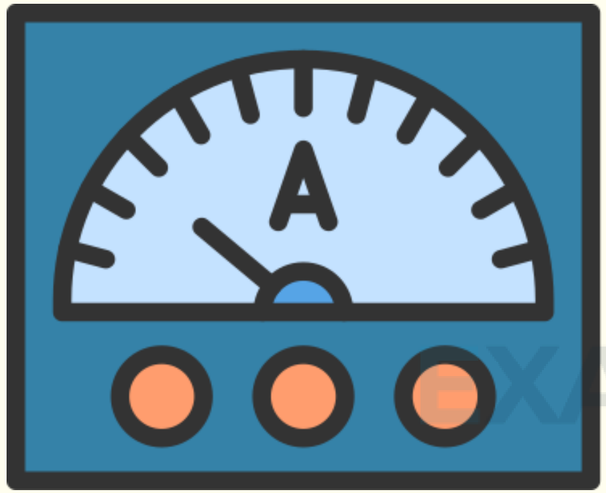
1 A complete circuit for current to flow

Metals like copper and steel form the pathway for the current to circulate. Metals are chosen because they are excellent conductors of electricity.

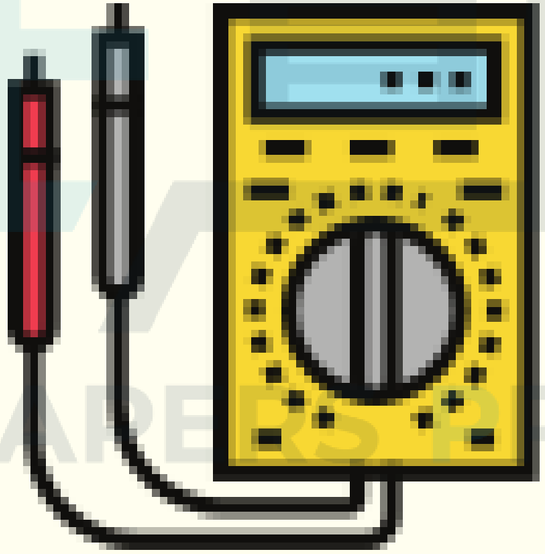
2 A source to "push" the current around the circuit:

The push can be supplied by a cell, battery, or power source.

To measure electric current, we use an ammeter,



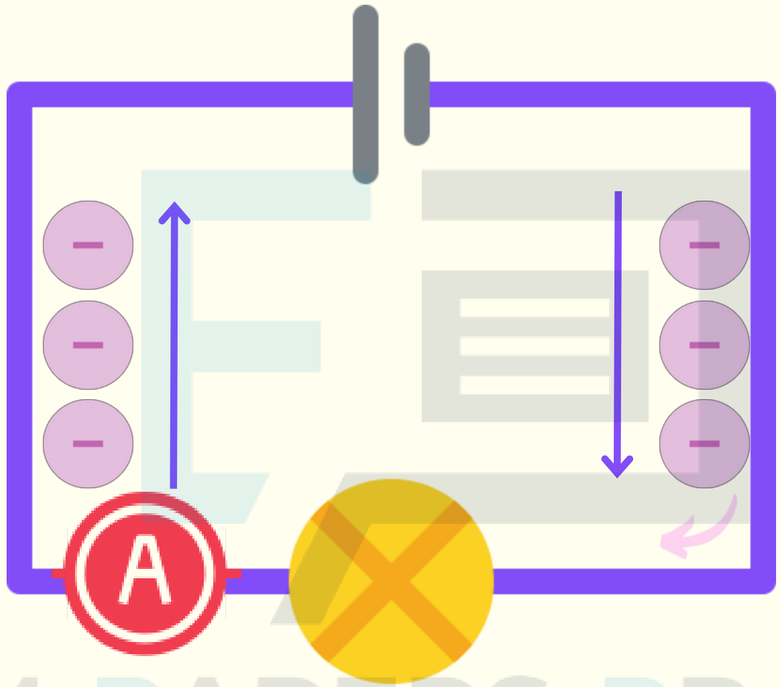
Analogue meter



digital meter

Galvanometer

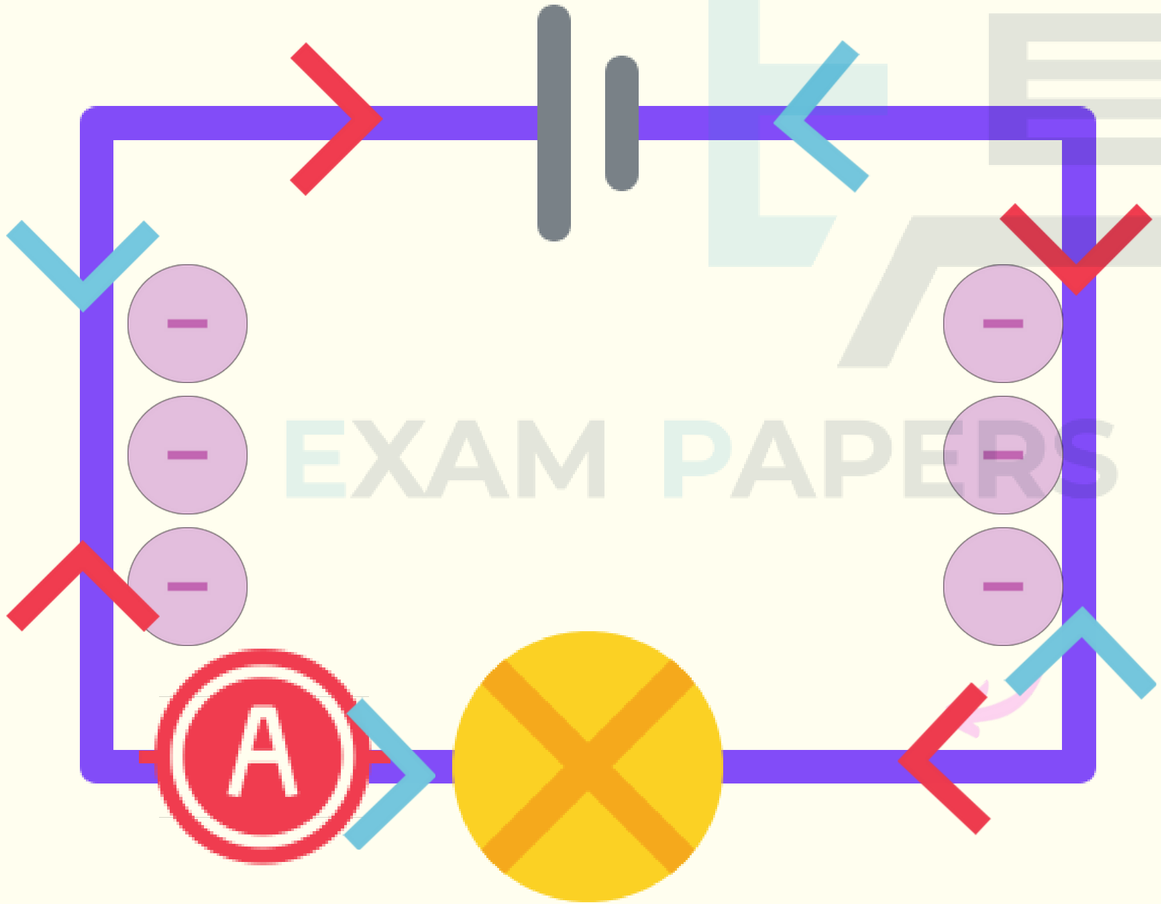
- use to measure tiny current



An ammeter is connected into a circuit in series.

The reading on an ammeter is in amperes

How current and electron move around the circuit?



Current flow

electron flow

Conventional electric current flows from the positive terminal to the negative terminal.

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 ampere

Equation

Current = Charge (Coulombs) / Time (s)

1 ampere = 1 coulombs of charge per second

WORKED EXAMPLE

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

SOLUTION

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

$$I = Q / T$$

$$Q = I * T$$

$$= 0.25 * 45$$

$$= 11.25 \text{ C}$$

WORKED EXAMPLE 2

Calculate the time tit takes for a total charge of 20 C to pass through a conductor with a current of 4 A.

WORKED EXAMPLE 2

Calculate the time t it takes for a total charge of 20 C to pass through a conductor with a current of 4 A.

$I = Q / T$

$T = Q / I$

$= 20 / 4$

$= 5s$

VOLTAGE

A.K.A POTENTIAL DIFFERENCE

DEFINITION 1

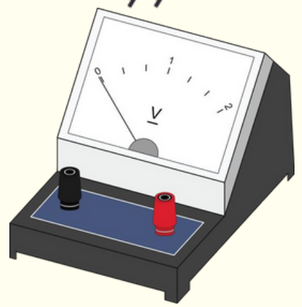
the amount of work done per unit charge to move a charge between two points in an electric field, measured in volts (V).

DEFINITION 2

The difference in electrical potential between two points.

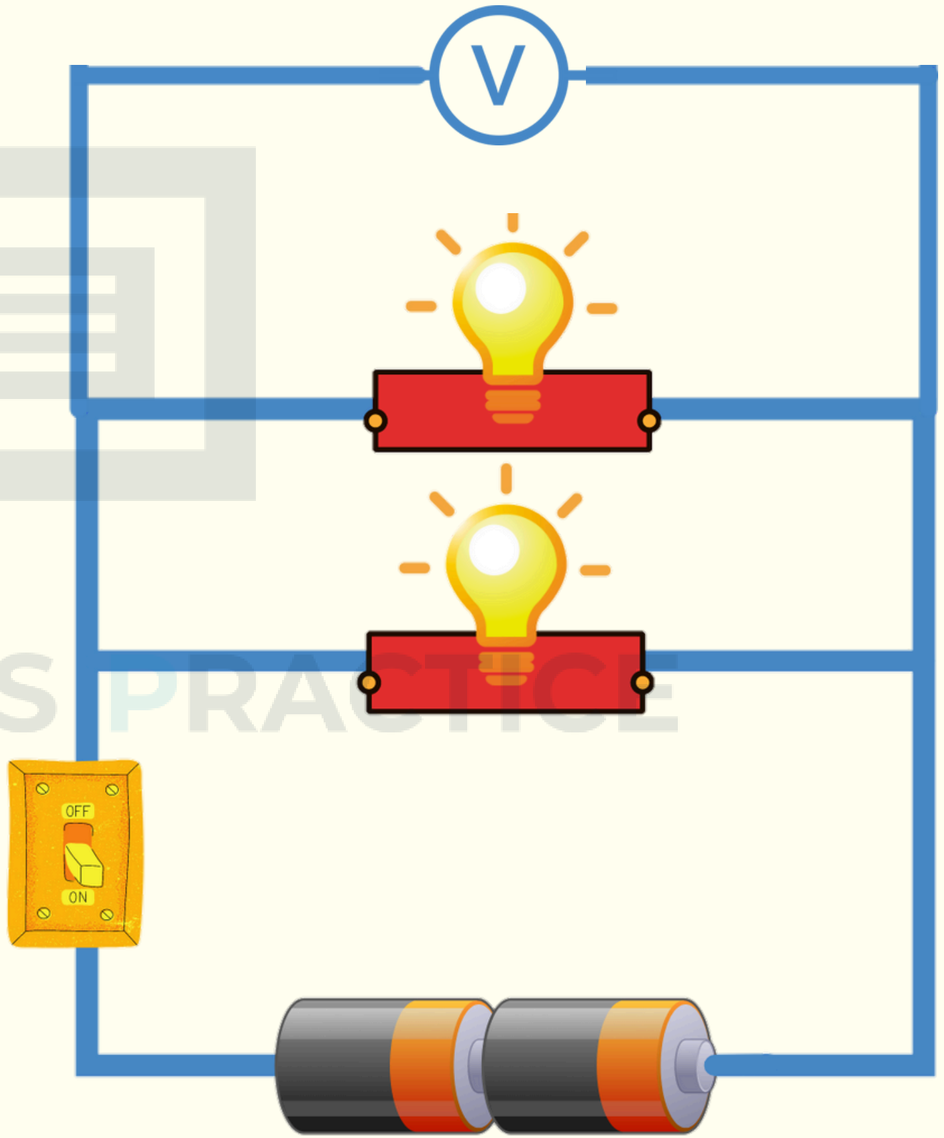
UNIT = VOLT

MEASURED BY = VOLTMETER



MEASURING VOLTAGE

A voltmeter is always connected in parallel with a component



ELECTROMOTIVE FORCE (EMF)

DEFINITION

The energy supplied by a source (such as a battery or generator) per unit charge as it moves around a complete circuit.

* IT IS ALSO MEASURED IN VOLTS

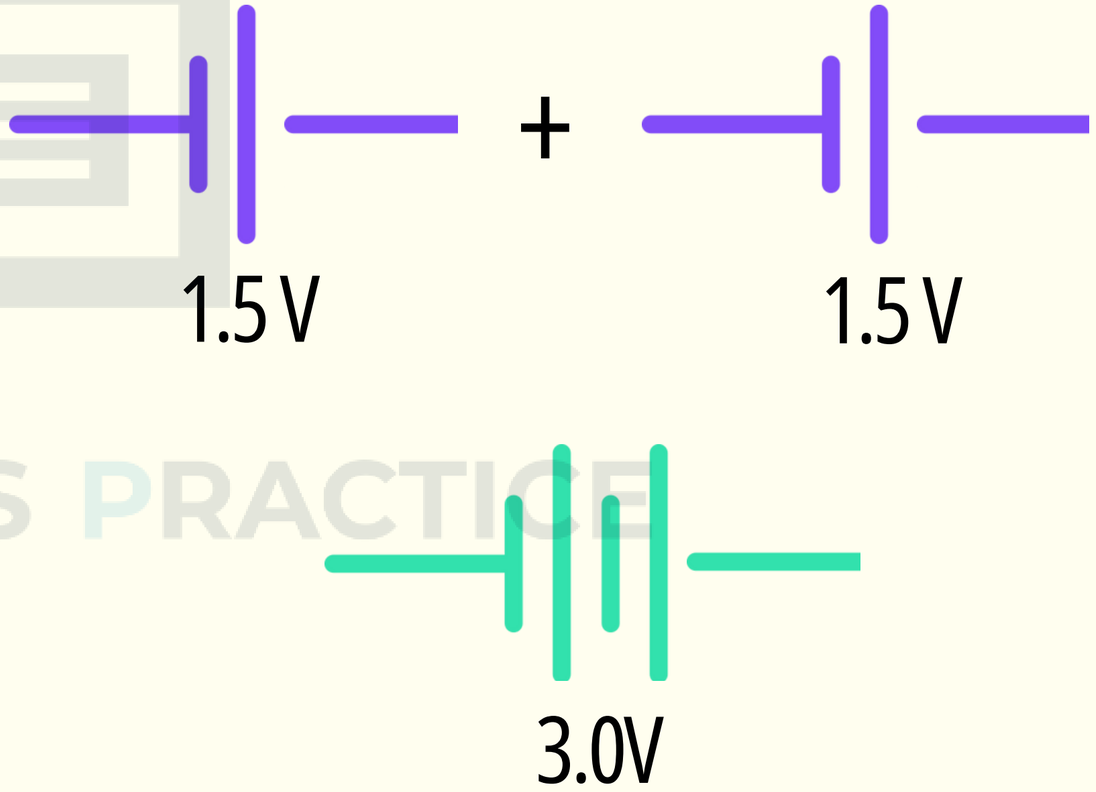
DEFINITIONS

VOLTAGE	POTENTIAL DIFFERENCE	ELECTROMOTIVE FORCE
The electric potential energy per unit charge between two points in a circuit. It is a general term for electric potential difference.	The difference in electric potential between two specific points in an electric field or circuit. It represents the work needed to move a unit charge from one point to another.	The energy supplied by a source (such as a battery or generator) per unit charge as it moves around a complete circuit.

EMF

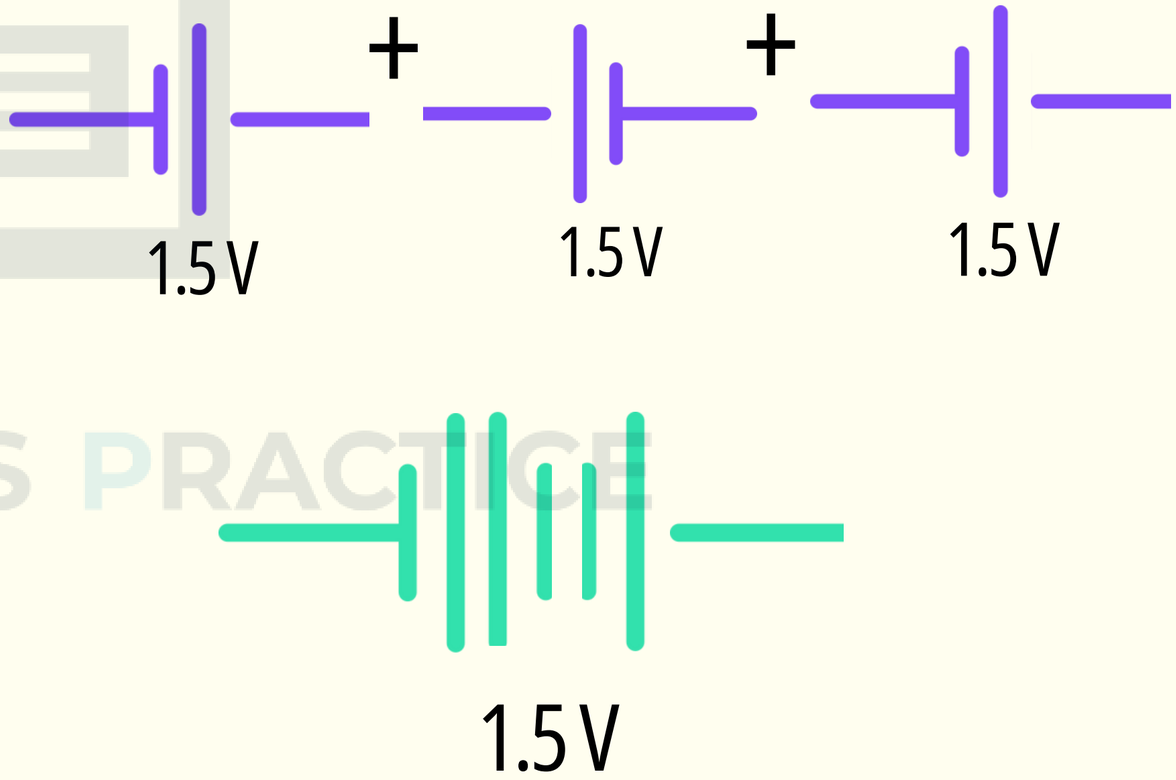
> If cells with e.m.f.s E1 and E2 are connected in series, their combined e.m.f.s is given by:

$$E = E1 + E2$$



EMF

When one cell is connected the wrong way round, the combined e.m.f is reduced.



MEASURING VOLTS

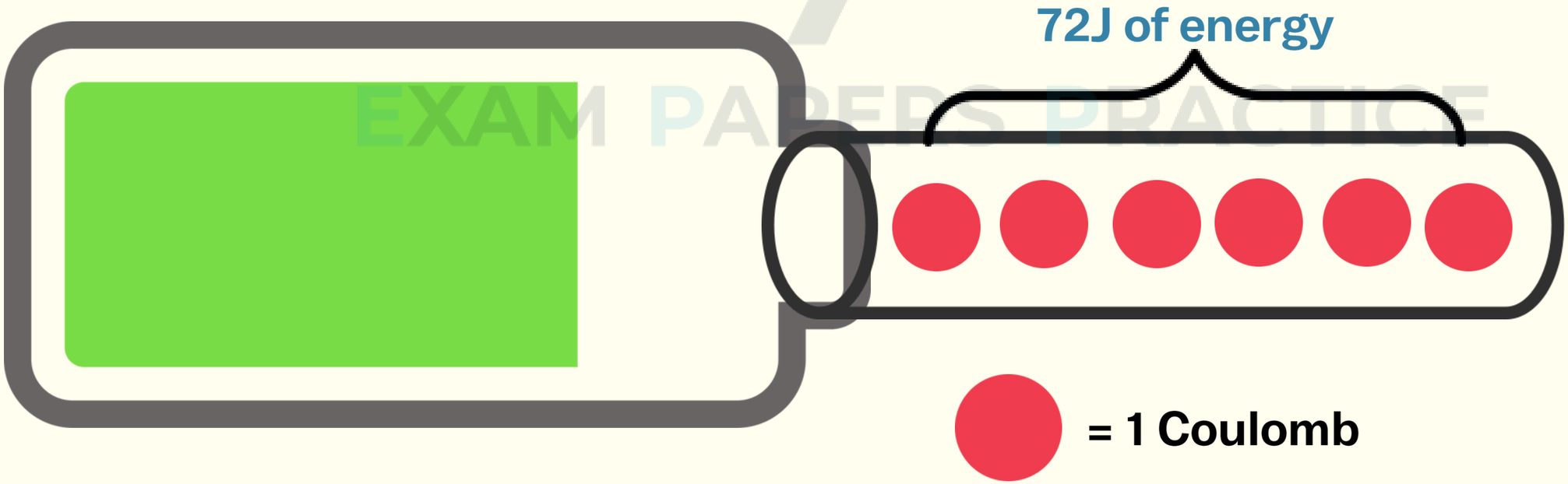
Equation

Voltage = Work done (J) / coulombs (C)

1 volt = 1 j of energy to move 1 coulombs of charge

WORKED EXAMPLE

[redacted]



SOLUTION

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

SOLUTION

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

$$V = W / Q$$
$$= 72 / 6$$
$$= 12 \text{ V}$$

WORKED EXAMPLE

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.

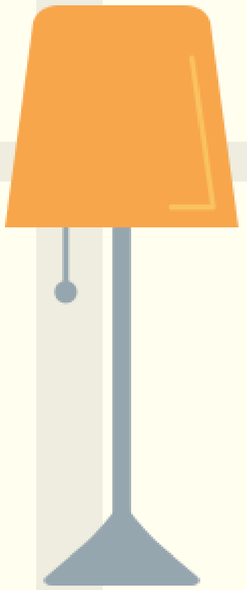
A)

V = W / Q

15 = W / 3

W = 45J

WORKDONE = ENERGY TRANSFERRED



WORKED EXAMPLE

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.

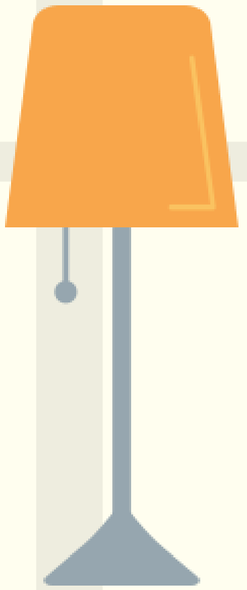
B)

$V = W / Q$

$15 = W / 6$

$W = 90J$

WORKDONE = ENERGY TRANSFERRED



WORKED EXAMPLE

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.

C) **We need to calculate the charge first.**

I = Q / T

2.5 = Q / 20

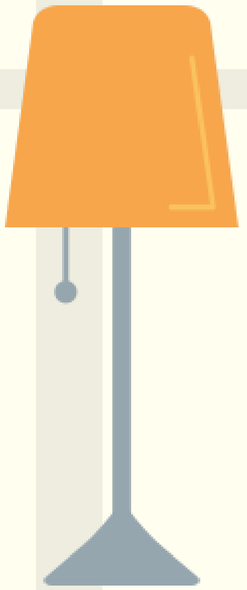
Q = 50C

THEN, FIND THE ENERGY TRANSFERRED

V = W / C

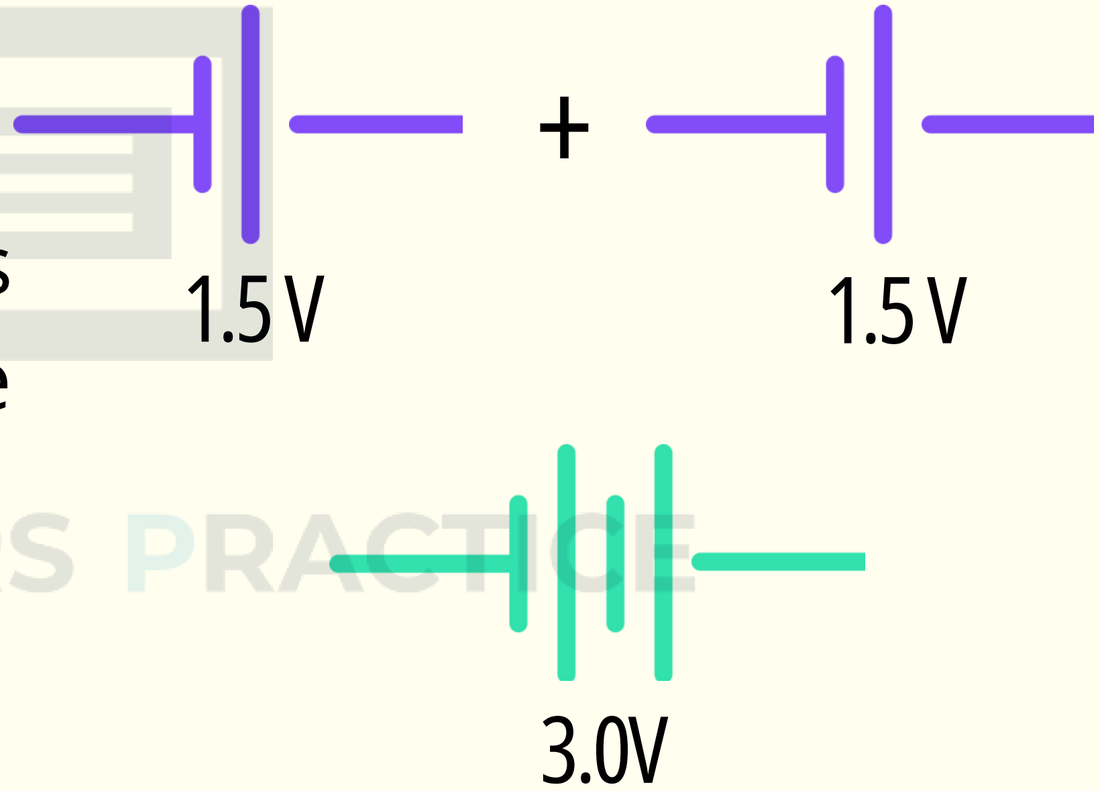
15 = W / 50

W = 750 J



WORKED EXAMPLE

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



SOLUTION

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

Combined e.m.f=

1.5V + 1.5V = 3V

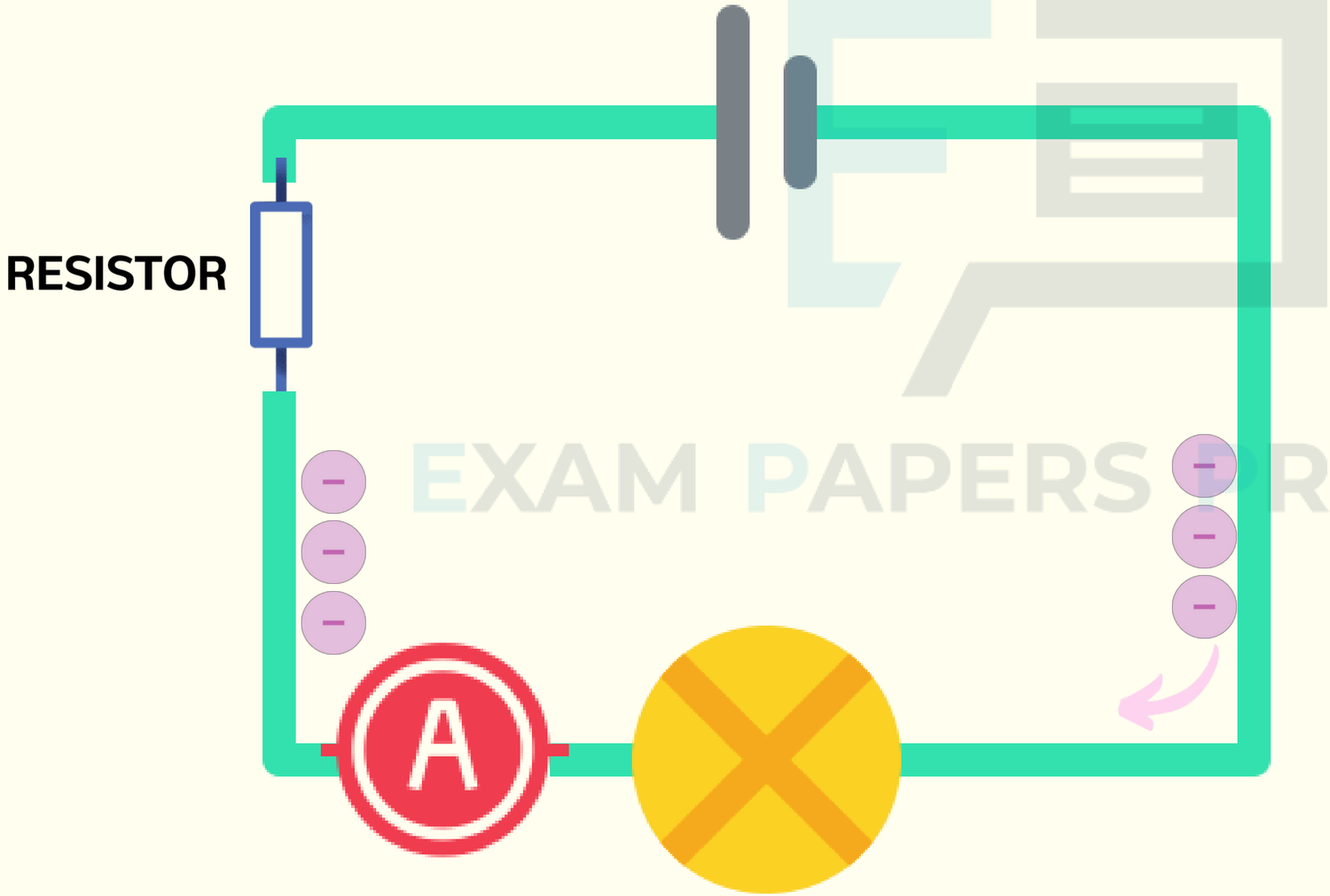
V = W / Q

3 = W / 4

W = 12J

RESISTANCE

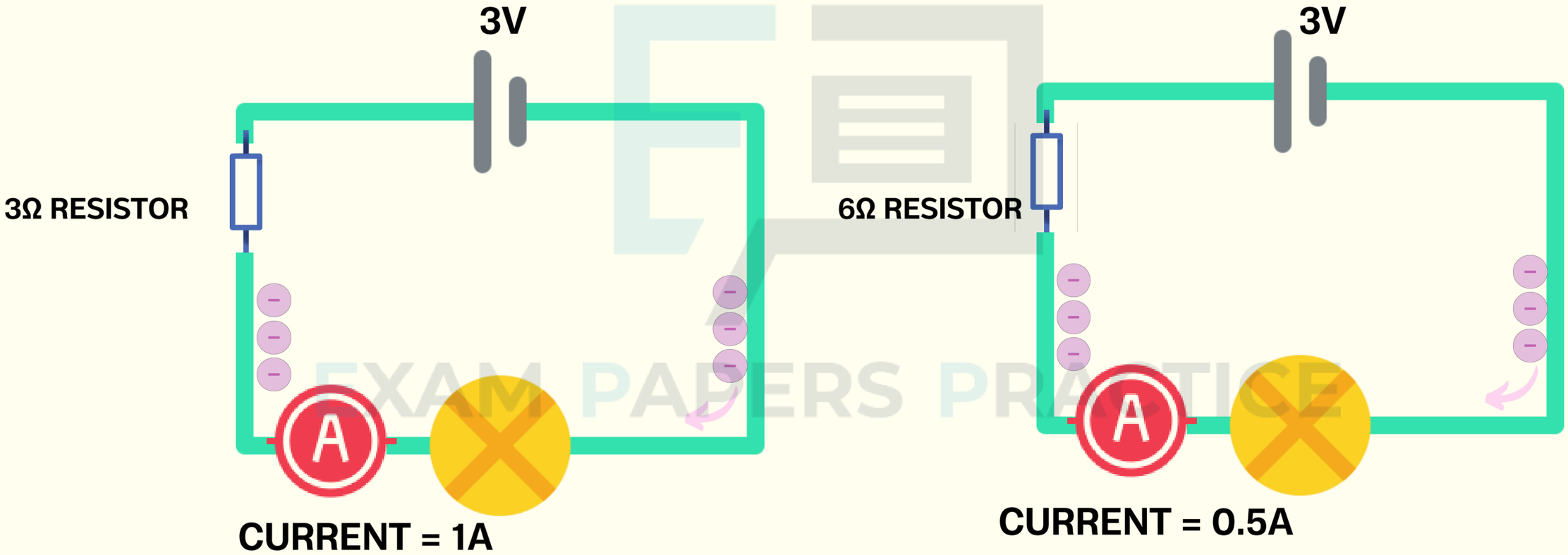
The current flowing in a circuit can be controlled by adding components with electrical resistance to the circuit.



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

RESISTANCE

The higher the resistance, the lower the amount of current that will pass through.



Ohms are used to quantify resistance (Ω). Ohms indicate the voltage required to produce a current of 1A through the resistor.

MEASURING RESISTANCE

Equation

voltage = current x resistance

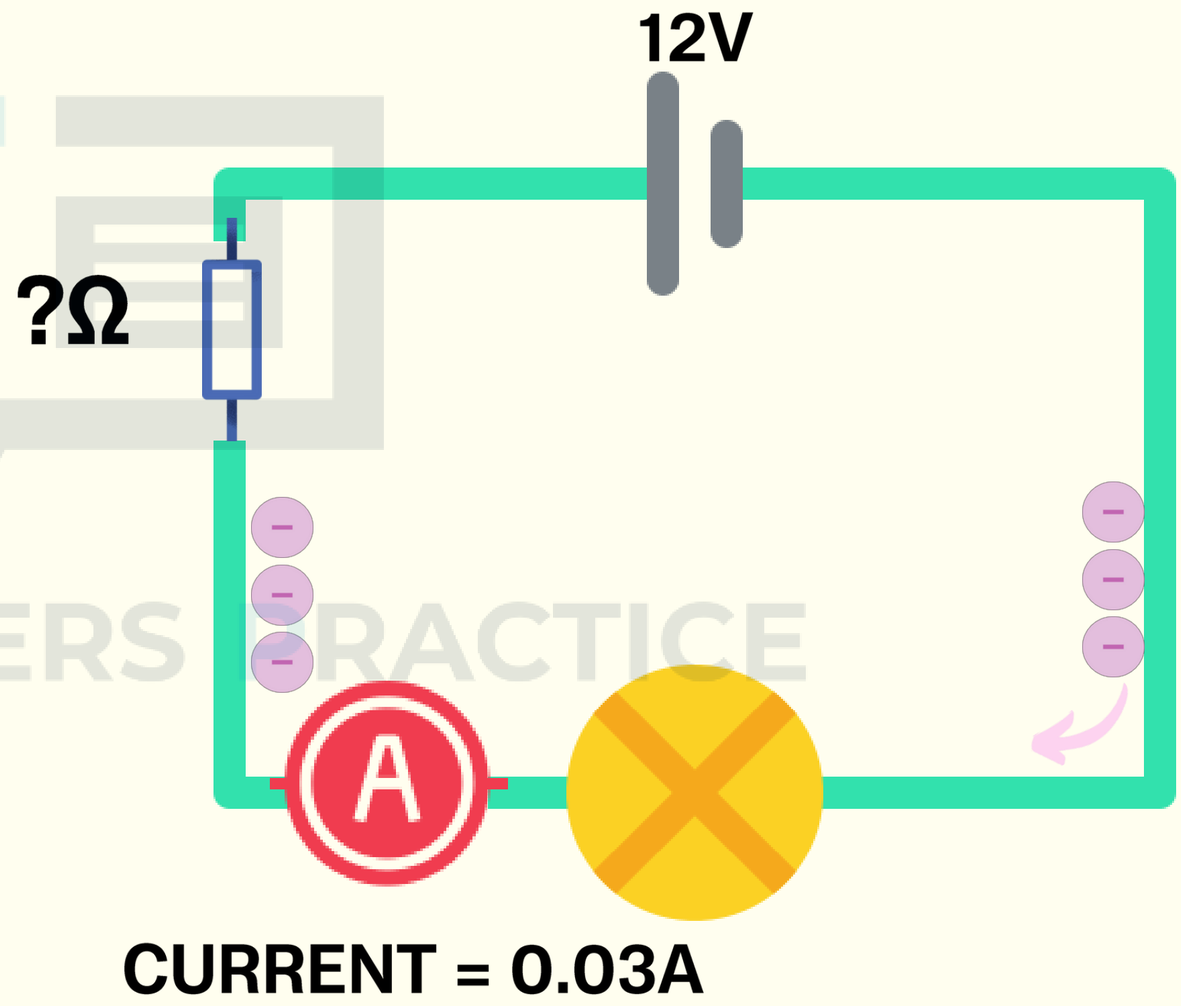
(v = ir)

or

Resistance = voltage / current

WORKED EXAMPLE

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.



SOLUTION

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.

$$V = IR$$

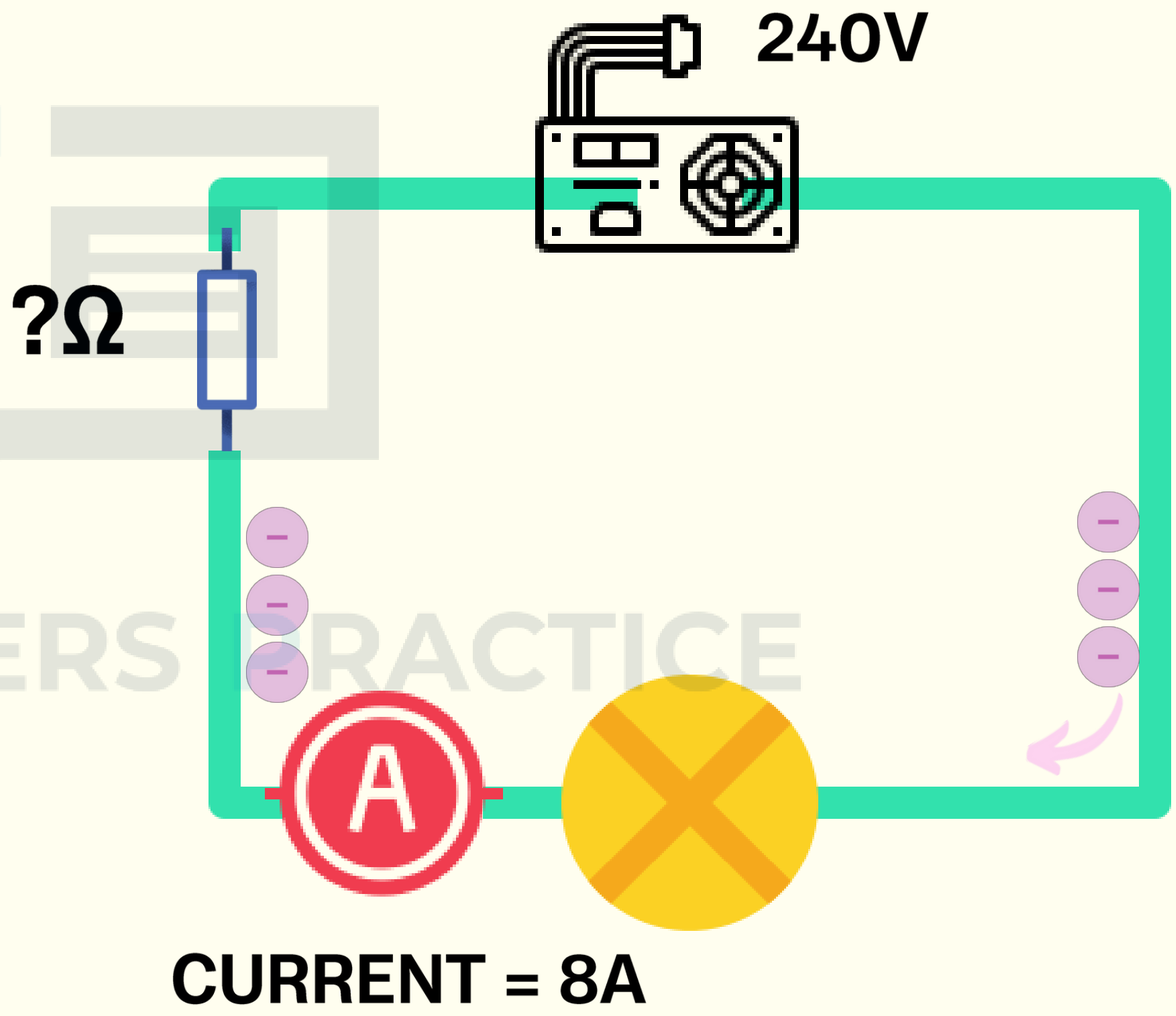
$$12 = 0.03\ R$$

$$R = 400\ \Omega$$

WORKED EXAMPLE

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.



SOLUTION

a. Determine the resistance of a lamp when a current of 8.0A passes through it while connected to a 240V supply.

$$V = IR$$

$$240 = 8\ R$$

$$R = 30\ \Omega$$

b. If the potential difference across the lamp is increased, predict whether the current flowing through it will increase or decrease.

SOLUTION

a. Determine the resistance of a lamp when a current of 8.0A passes through it while connected to a 240V supply.

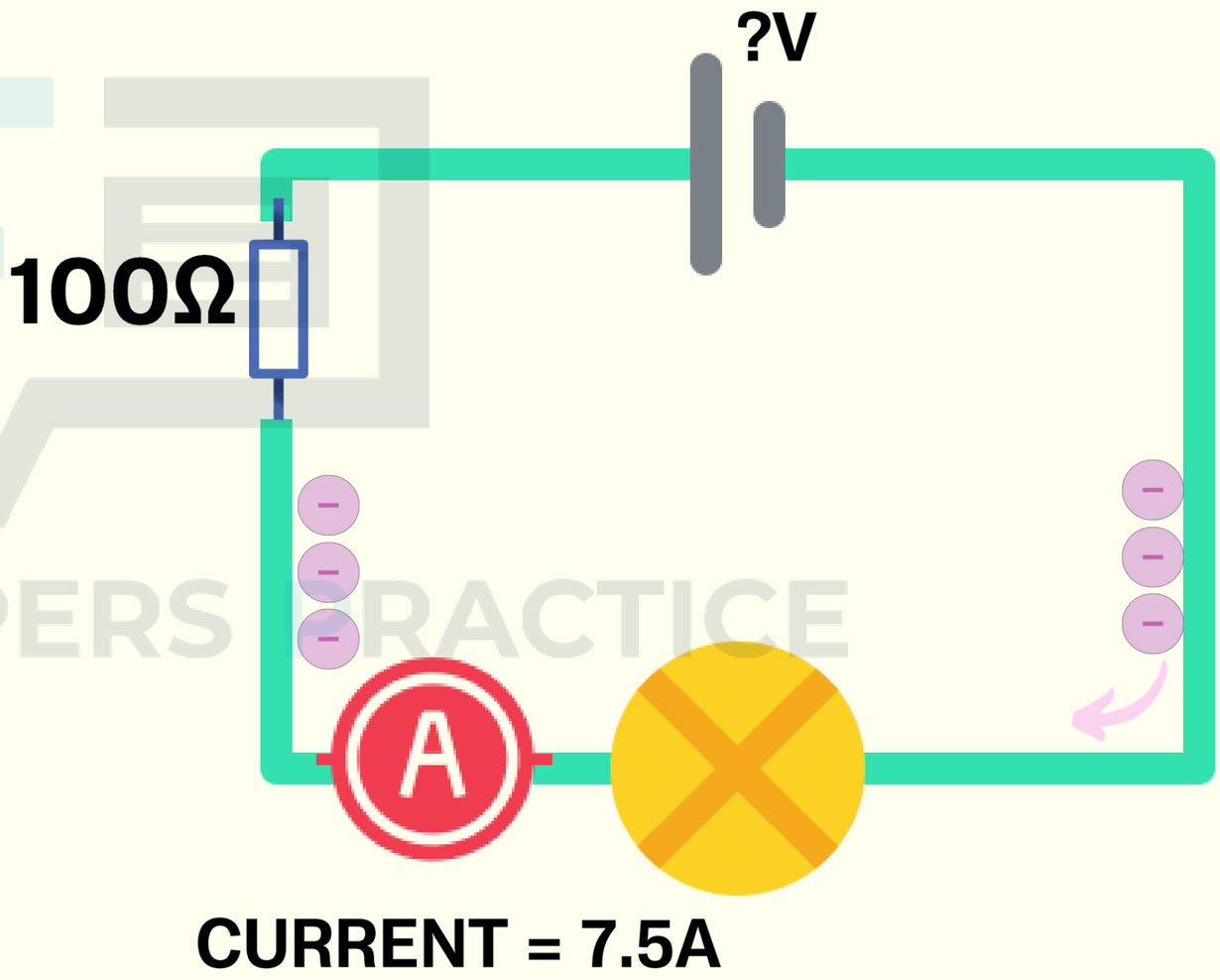
b. If the potential difference across the lamp is increased, predict whether the current flowing through it will increase or decrease.

$$V = IR$$

When V increases, I will increase too!

WORKED EXAMPLE

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



SOLUTION

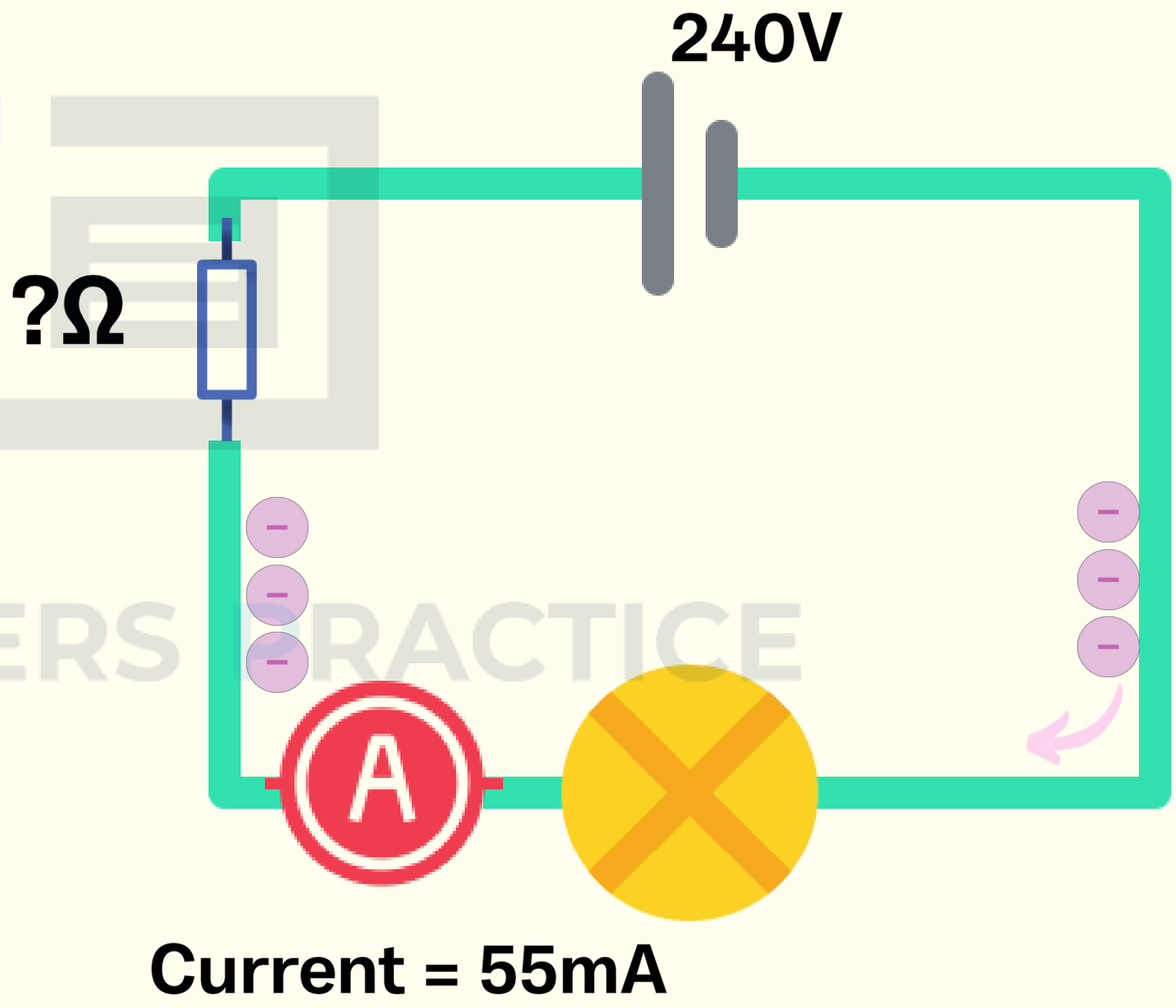
What potential difference (p.d) is required to establish a current of 7.5A through a 100Ω resistor?

$$V = IR$$
$$= 7.5 \times 100$$
$$= 750V$$

WORKED EXAMPLE

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.



SOLUTION

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

60mA = 0.06A

$V = IR$

$240 = 0.06\ R$

$R = 4000\ \Omega$

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

SOLUTION

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

From previous question:

$R = 4000\ \Omega$

$V = IR$

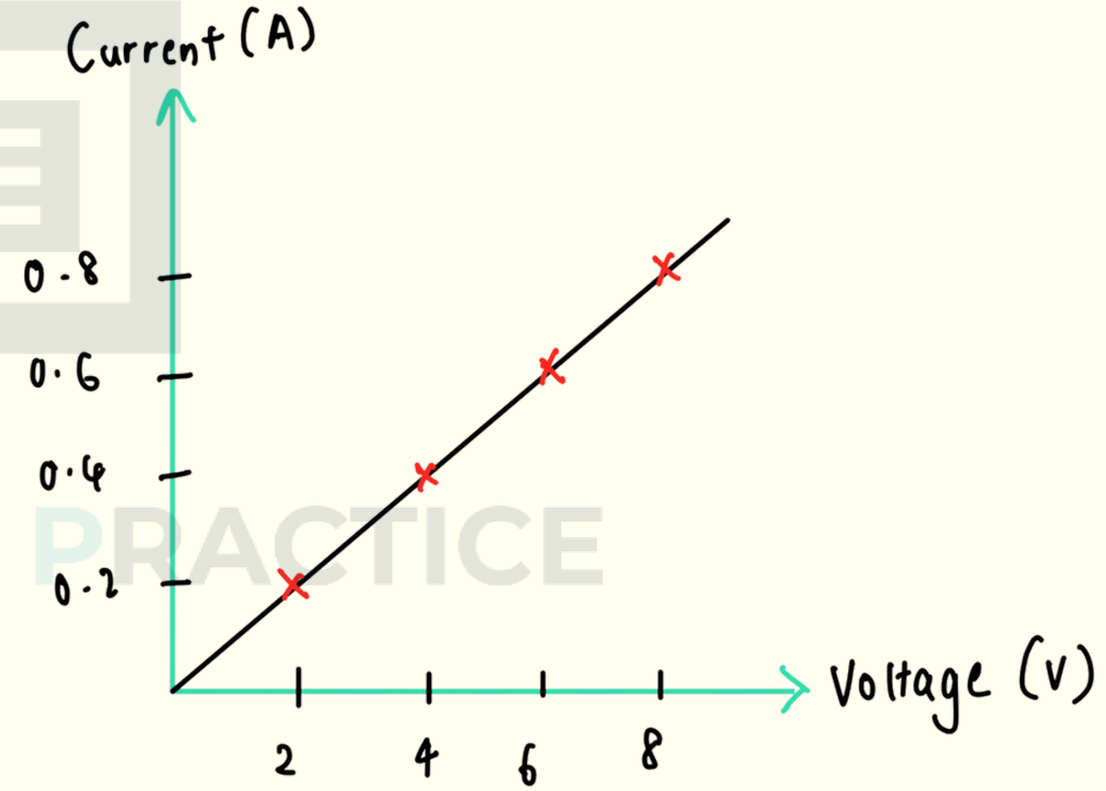
$= (0.02)(3000)$

$= 60V$

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

OHMIC RESISTOR

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.

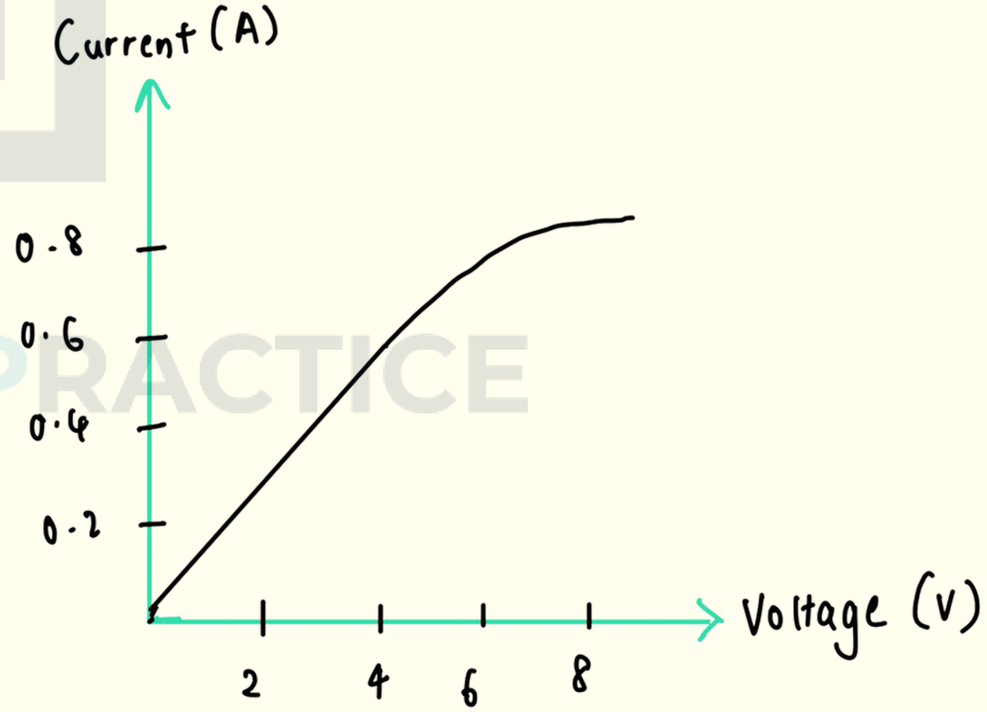


Its current-voltage characteristic is a straight line

NON-OHMIC RESISTOR

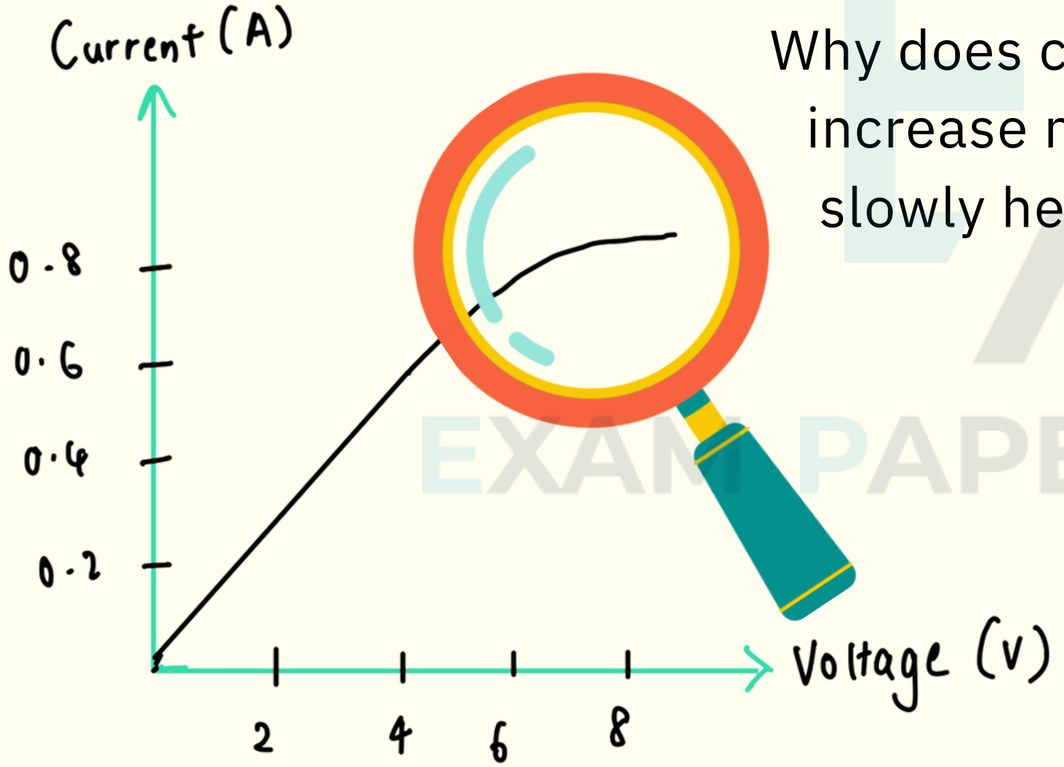
EG: FILAMENT LAMP

> 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.



NON-OHMIC RESISTOR

EG: FILAMENT LAMP



Why does current increase more slowly here?

1. As voltage rises, the filament heats up and emits brighter light.

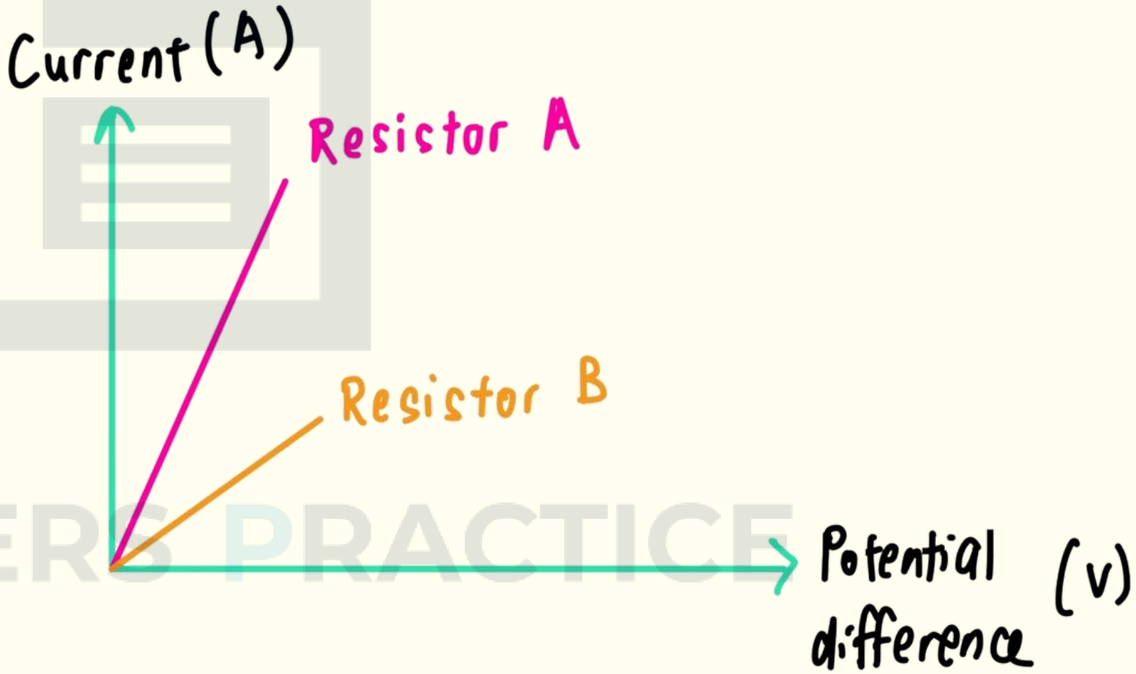
2. At elevated temperatures, the filament's resistance increases, causing the current to rise more slowly. But why?

3. a. Higher currents lead to more electrons flowing through the tungsten wire.

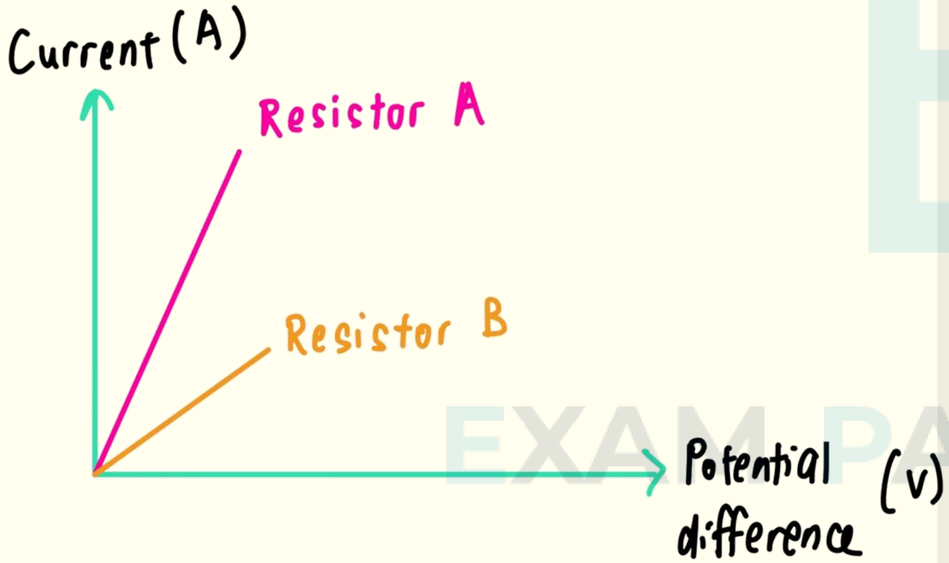
   b. This increases collisions between electrons and the lattice structure (Intuition: It's akin to navigating through a crowded space where collisions are frequent due to random movements).

WORKED EXAMPLE

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.



SOLUTION



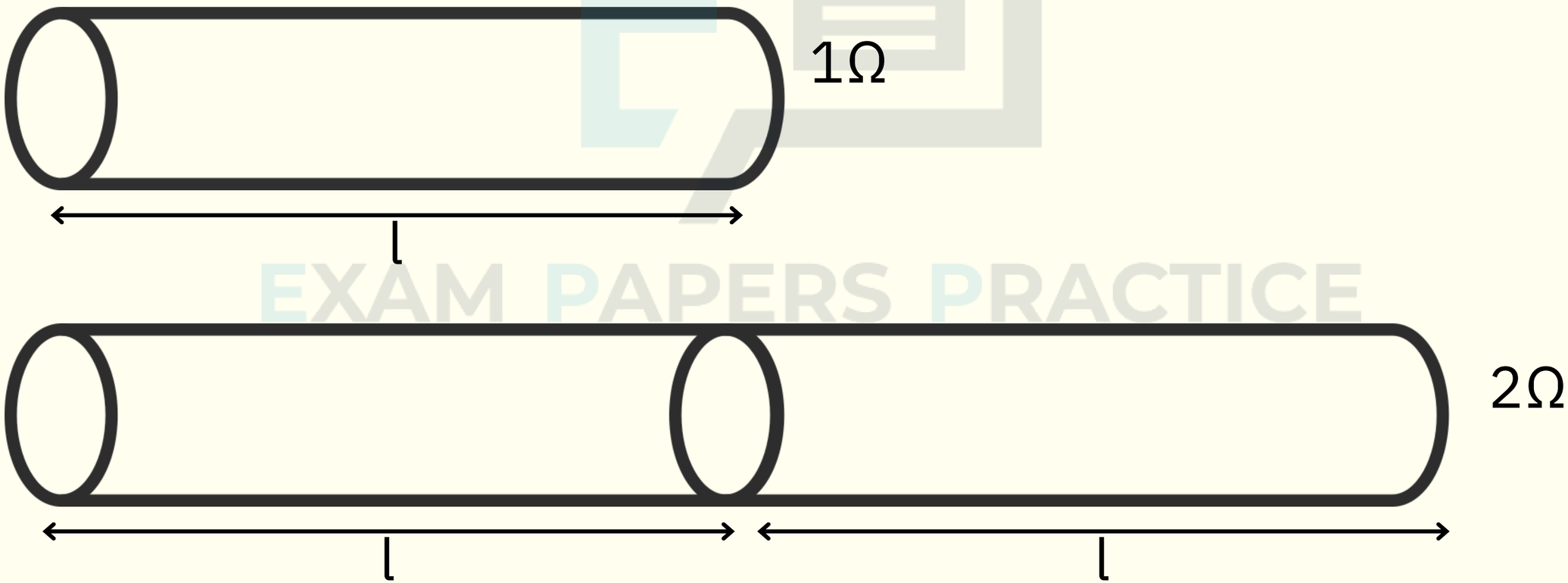
Resistor B has higher resistance.

Its current increases slower than resistor A when potential difference increases.

FACTORS (1) - LENGTH

affecting the resistance of a wire

The longer the wire, the greater its resistance -directly proportional



FACTORS (2) - DIAMETER

affecting the resistance of a wire

Doubling the radius of the wire halves the resistance

Higher resistance

Lower resistance

WORKED EXAMPLE

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.

The length of the wire is directly proportional to the resistance.

1 : 10

0.8 : 8

Answer: 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.

WORKED EXAMPLE

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.

The length of the wire is directly proportional to the resistance.

1 : 2

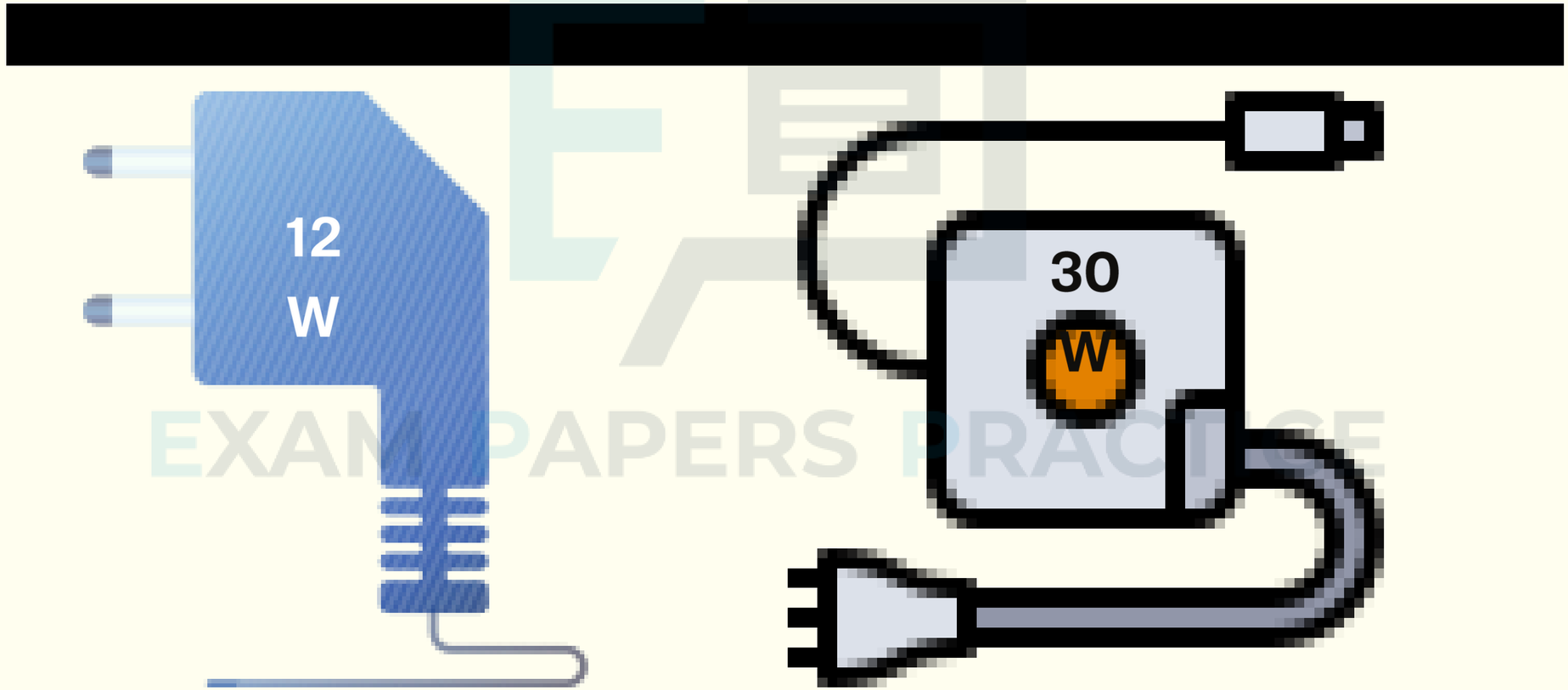
0.8 : 1.6

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.

Halving the cross sectional area of the wire double the resistance

1.6 x 2 = 3.2 Ω

ELECTRICAL APPLIANCE



Power ratings are indicated in watts (W) or kilowatts (kW).

Eg. 12 W = The appliance draws 12J of energy per second.

FORMULA

Equation

Power = voltage x current

$p = VI$

FORMULA

Equation

Power = voltage x current

$$p = VI$$

Since energy = power x time

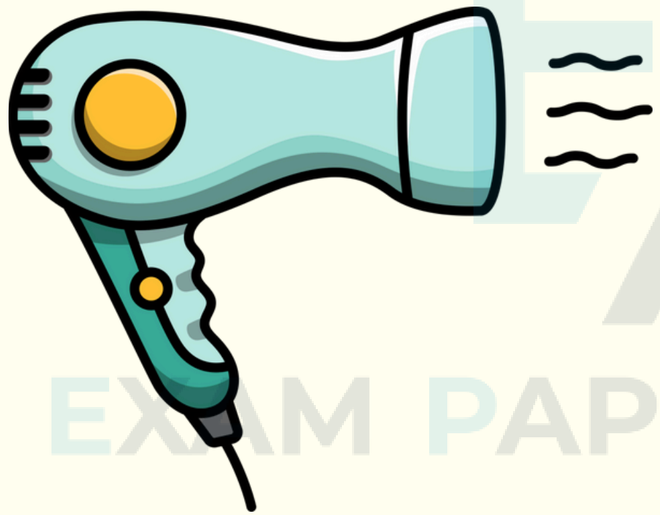
$$e = VIT$$

WORKED EXAMPLE

An 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.

WORKED EXAMPLE



$$P = VI$$
$$= 240\ (0.3)$$
$$= 72W$$

$$E = P * t$$
$$= 72 * 60$$
$$= 4320\ J$$

UNIT OF ELECTRICAL ENERGY

[redacted] kWh.

1kWh

1kW
= 1000W
= 1000 J /S

1h
= 3600s

1kWh
= 1000 x
3600

1kWh
= 3600000J

FORMULA

Equation

Energy Transferred(kWH) =

power (kW) x time (h)

WORKED EXAMPLE

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

SOLUTION

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

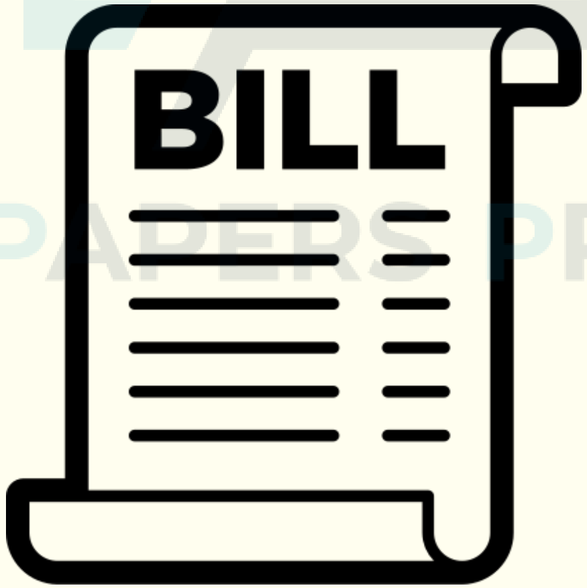
Energy transferred = Power x Time

= 0.06kW x 5h

= 0.3 kWh

WORKED EXAMPLE

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.



SOLUTION

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.

Energy used:

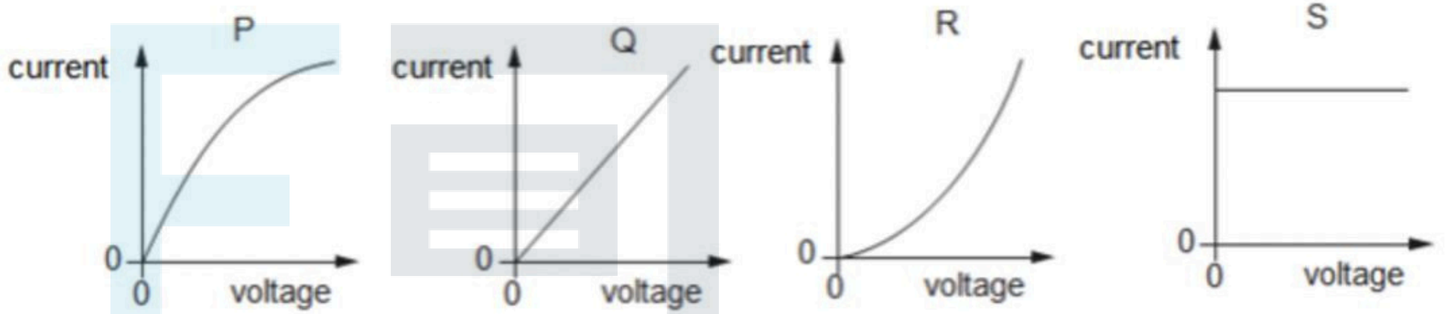
1980kWh -1800 kWh = 180 kWh

Total cost: Unit used x Unit cost

= 180 x 0.12

= £21.6

Four current-voltage graphs are given below.

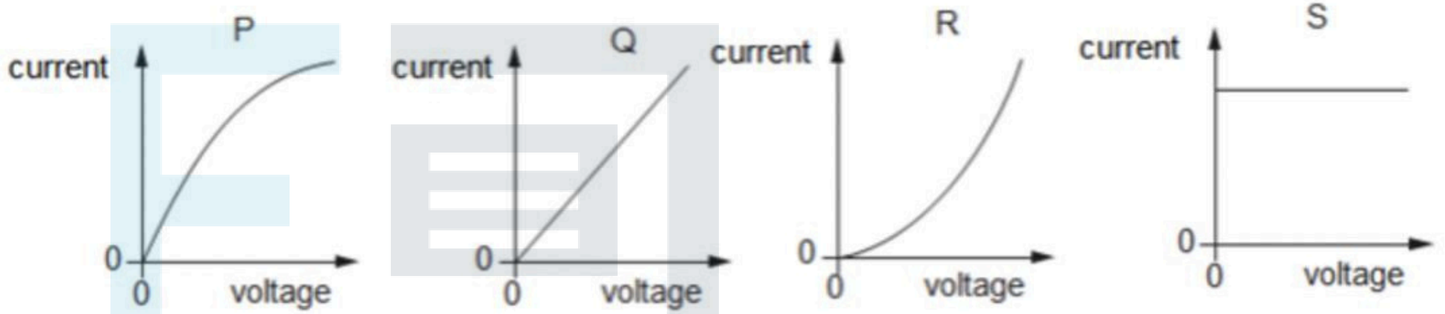


One of them is for an ohmic resistor, and another is for a filament lamp.

Which is which?

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

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

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

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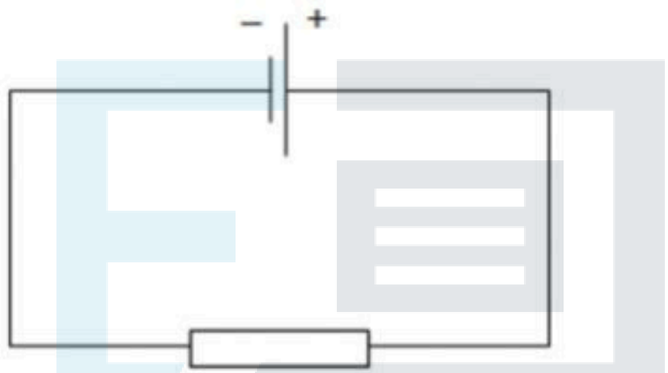
A student sets up a circuit as shown in the diagram



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

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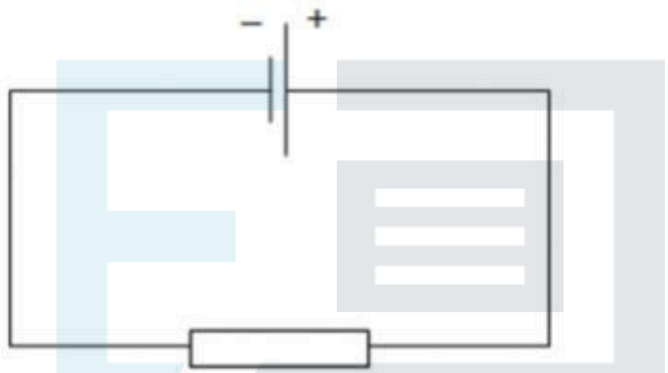

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How much power is dissipated by the resistor?

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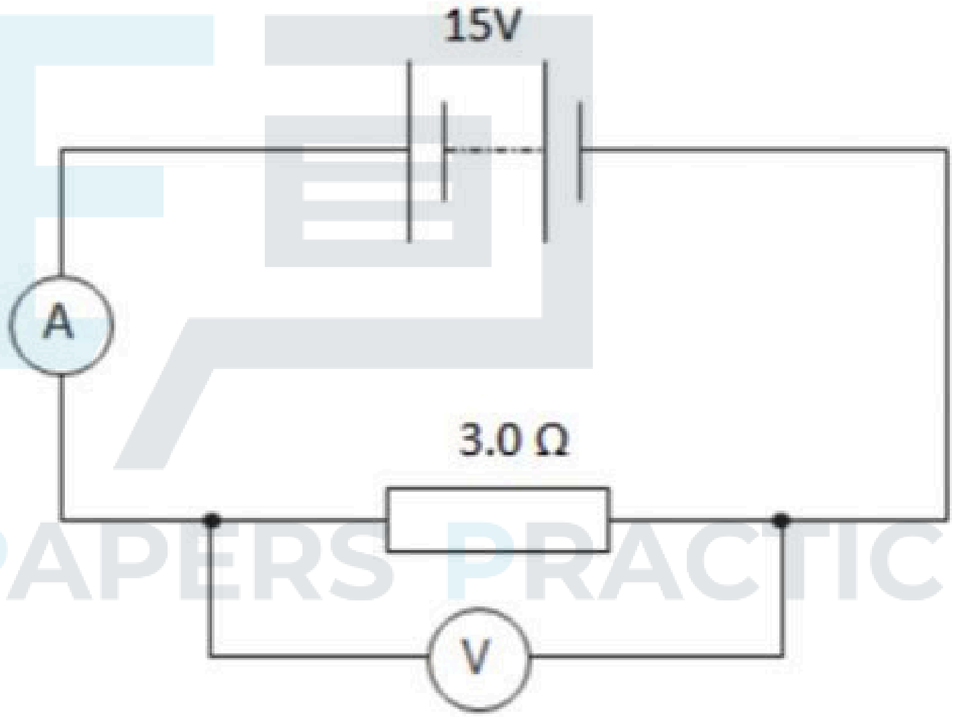

How much energy is dissipated as heat by the resistor in 2 minutes?

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

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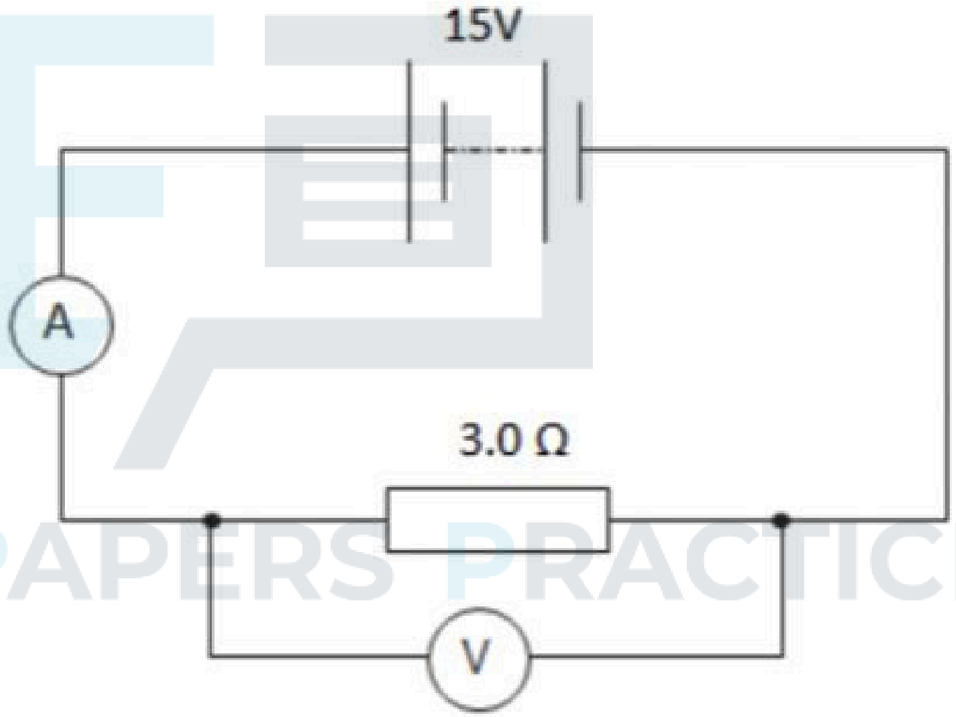

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The kinetic energy of air passing through a wind turbine every minute is 720 000 J. The electrical output of the turbine is 9.0 A at a potential difference (p.d.) of 240 V.

Calculate the efficiency (%) of the wind turbine.

efficiency = ... % [5]

[Total: 5]

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