Unit 2 – Using Electricity

2.3 – Resistance

Electrical Resistance

<u>Success Criteria</u>

By the end of the lesson, you should be able to:

- ∆ **explain** what is meant by **resistance**.
- ∆ **describe** the **energy transformation** in a **resistor**.
- ∆ **describe** what happens to the **size of current** when:
  - ➢ resistance is **increased**
  - ➢ resistance is **decreased**

Every electrical component has resistance.

Resistance is how **difficult** electric charges (a current) find it **to move** around a circuit.

A **high resistance** means the electric charges will find it __**difficult**__ to move.

A **low resistance** means the electric charges will find it __**easy**__ to move.

So when the resistance in the circuit increases, the current in the circuit will __**decrease**__, because __**the charges find it more difficult to move**__.

Resistors

A **resistor** is an electrical component that makes it **harder** for electric **charges** (a current) to **flow**.

The **circuit symbol** for a resistor is: 

The **energy transformation** that takes place in a resistor is:

electrical → **heat**

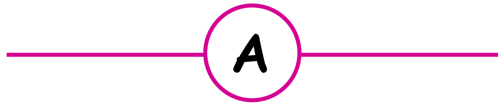
Current and Voltage

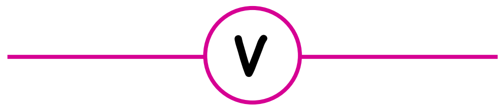
Success Criteria

By the end of the lesson, you should be able to:

- **name** the appropriate devices used to **measure current** and **measure voltage**.
- **draw** and **identify** the circuit symbols for:
  - **an ammeter**
  - **a voltmeter**
- **draw** a circuit diagram to show the **correct positions** of an **ammeter** and **voltmeter** in a circuit.

Measuring Current and Voltage

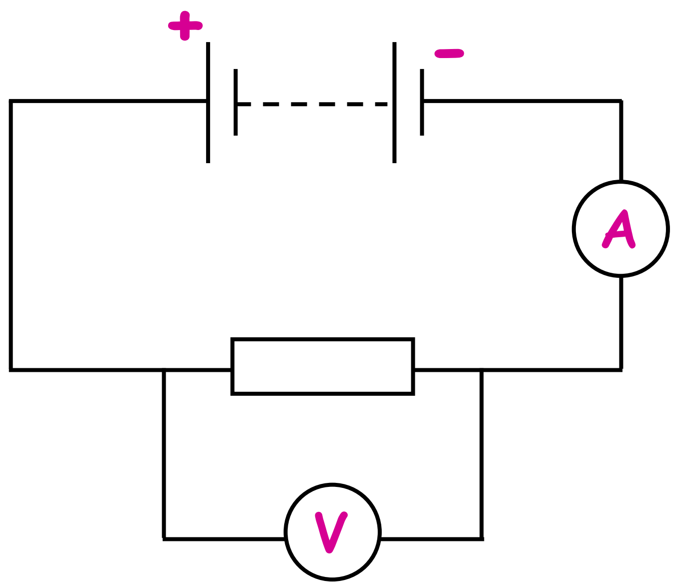
The device used to **measure current** is an **ammeter**, and has the circuit symbol: 

To **measure voltage**, a device called a **voltmeter** is used which has the circuit symbol: 

Ammeters and Voltmeters

Ammeters must always be placed in **series** (current through ammeter).

A **voltmeter** must always be in **parallel** (voltage across).



Measuring Resistance

Success Criteria

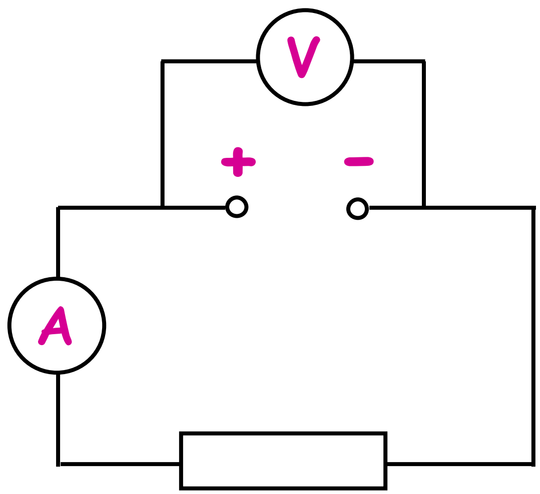
By the end of the lesson, you should be able to:

- ∆ **explain** an experiment to **measure resistance** to include:
  - ➢ a **list** of all **measurements** made
  - ➢ the **devices used** to take each measurement
  - ➢ how the **measurements** allow you to **calculate resistance**.
- ◊ ***state*** *for a resistor, how* ***voltage ÷ current*** *compares for* ***different*** *values for* ***current****.*
- ∆ **state** the equation that relates **current, voltage** and **resistance.**

Aim

To measure the resistance of a known resistor.

Circuit Diagram



Results

Current (A)	Voltage (V)	$\frac{\text{voltage}}{\text{current}}$

Conclusion

The equation relating current, voltage and resistance is:

$$\textbf{resistance} = \frac{\textbf{voltage}}{\textbf{current}}$$

Method

This must include:

- a list of all measurements made
- the devices used to make each measurement
- how the measurements allowed you to calculate resistance

Ohm's Law

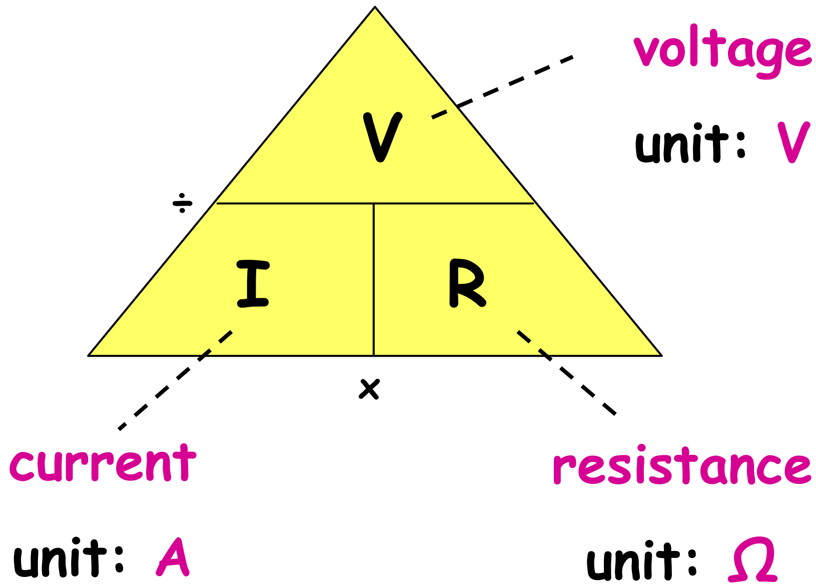
Success Criteria

By the end of the lesson, you should be able to:

- Δ carry out calculations using the relationship: $V = I R$
- Δ use correctly the unit:
  - ➢ ohms

Equation

$$V = I\,R$$



History

Ohm's Law is named after a physics teacher called Georg Ohm.

Can you guess what nationality he was?

Brandenburg Gate

Bratwurst Sausage

Andreas Hinkel

German Flag

Example 1

A 100 Ω resistor is connected to a 12 V battery.

Calculate the size of the current that flows through the resistor.

$$R = 100\ \Omega$$
$$V = 12\ \text{V}$$
$$I = ?$$

$$I = \frac{V}{R}$$
$$= \frac{12}{100}$$
$$I = 0.12\ \text{A}$$

Example 2

The heating coil of a mains electric kettle uses a current of 2.5 A.

Calculate the resistance of the heating coil.

$I = 2.5\ A$

$V = 230\ V$

voltage is 230 V as kettle uses mains voltage

$R = ?$

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

$$= \frac{230}{2.5}$$

$$R = 92\ \Omega$$

Questions

m = milli ($\times 10^{-3}$) **k = kilo ($\times 10^{3}$)**

μ = micro ($\times 10^{-6}$) **M = mega ($\times 10^{6}$)**

	voltage	current	resistance
1.	20 V	2.5 A	
2.		5 A	100 Ω
3.	125 V		25 Ω
4.		10 mA	6 MΩ
5.	2.4 kV	0.08 mA	

Variable Resistors

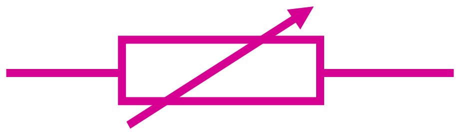
Success Criteria

By the end of the lesson, you should be able to:

- ∆ **describe** the **size of current** in a circuit when a variable resistor has:
  - ➢ a **high resistance**
  - ➢ a **low resistance**
- ∆ **state** some practical **uses** of **variable resistors**.

A variable resistor can alter the size of current in a circuit.

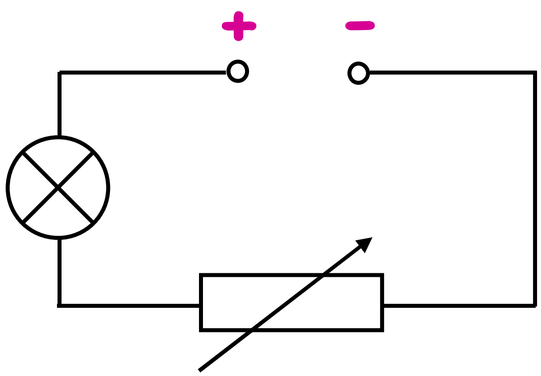
The circuit symbol for a variable resistor is:



Aim

Identify what happens to the size of current when resistance of variable resistor is changed.

Circuit Diagram



Results

resistance	brightness of bulb	current
LOW	BRIGHT	HIGH
HIGH	DULL	LOW

Conclusion

When the resistance of a variable resistor is ___increased___, the current in the circuit ___decreases___.

Practical Uses of Variable Resistors

Variable resistors are used in:

- **dimmer switches** for a light
- **volume controls** in a stereo
- **speed control** in a remote controlled car
- **petrol gauges** to show fuel level
- **temperature control** in an oven

Types of Lamp

Success Criteria

By the end of the lesson, you should be able to:

- Δ **state** examples of resistive circuits that **transform electrical** energy into **heat**.
- Δ **state** the **full energy transformation** that takes place in a **lamp**.
- Δ **state where** the **energy is transformed** in
  - ➢ a **filament lamp**
  - ➢ a **discharge tube**
- Δ **state** and **explain** which type of **lamp** is **most efficient**.

Current in Wires

When an **electric current** flows through a **wire**, **electrical** energy is transformed into **other forms** of energy.

Resistive Circuits at Home

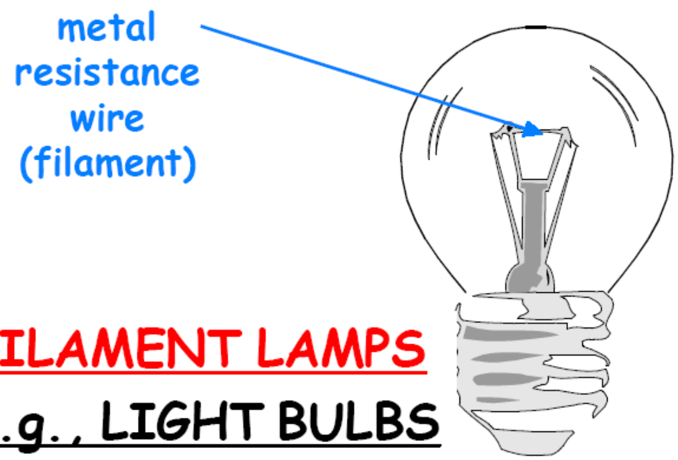
A resistive circuit changes **electrical** energy to **heat**.

This happens in **electric fires**, **cookers** and **kettles**.

Lamps

In a **lamp**, electrical energy is changed into **light** and **heat**.

Filament Lamps



FILAMENT LAMPS

e.g., LIGHT BULBS

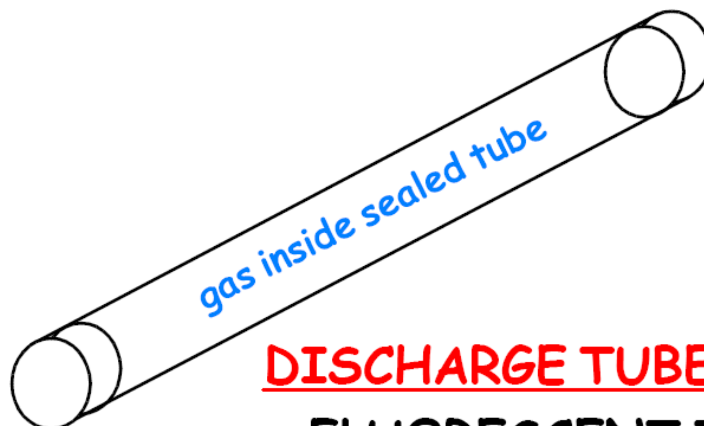
The energy change takes place in the metal resistance wire known as the filament.

A lot of heat is produced.

Discharge Tube

The energy change occurs in the gas inside a sealed tube.

Very little heat is produced.



DISCHARGE TUBES

e.g., FLUORESCENT TUBES

Efficiency

Discharge tubes are ___MORE___ efficient than filament lamps because more energy is transferred into ___light___ with less electrical energy transferred to ___heat___.

filament lamp

discharge tube

energy saving bulbs

(discharge tubes)

	Filament Lamp	Discharge Tube
Also Known As	light bulb	fluorescent tube
Energy Transformation	electrical → light + heat	electrical → light + heat
Energy Change Takes Place	in filament	in the gas
Most Efficient	No A lot of heat energy produced.	Yes More electrical energy transferred to light.
Most expensive to operate	yes	no

Measuring Power

Success Criteria

By the end of the lesson, you should be able to:

- Δ **explain** an experiment to **measure power** to include:
  - ➢ a **list** of all **measurements** made
  - ➢ the **devices used** to take each measurement
  - ➢ how the **measurements** allow you to **calculate electrical power**.

Aim

To find the power of a light bulb.

Results

power rating (W)	energy (J)	time (s)	$\frac{\text{energy}}{\text{time}}$
24	563	20	28
36	669	20	33
48	890	20	44

Conclusion

Electrical __power__ is the __energy__ used divided by the __time__ an appliance is switched on for.

$$\text{power} = \frac{\text{energy}}{\text{time}}$$

Method

This must include:

- a list of all measurements made
- the devices used to make each measurement
- how the measurements allowed you to calculate power

Power, Energy and Time

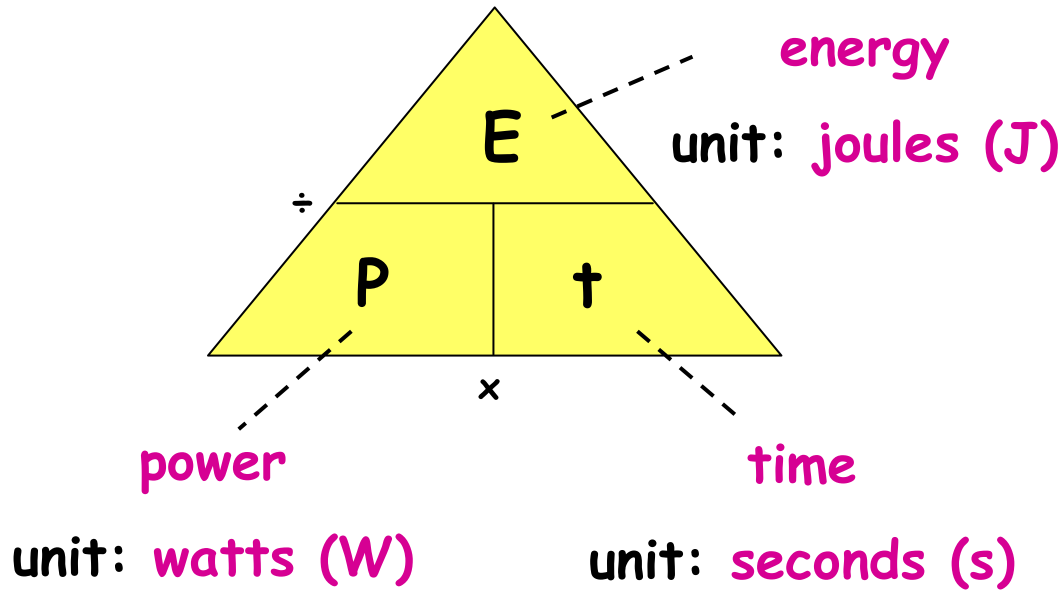
Success Criteria

By the end of the lesson, you should be able to:

- Δ **state** the relationship between **power**, **energy** and **time**.
- Δ **carry out calculations** using the relationship between **power**, **energy** and **time**.
- Δ **use** correctly the unit:
  - **joules**
  - **watts**

Equation

$$P = \frac{E}{t}$$



1 watt = 1 joule per second

A 60 W light bulb uses 60 joules of energy per second.

A 150 W television uses 150 joules of energy per second.

A 2 kW kettle uses 2000 joules of energy per second.

Example 1

A 100 W television is switched on for 30 minutes.

Calculate how much energy it uses in this time.

$$P = 100\ \text{W}$$

$$t = 30\ \text{min}$$
$$= 30 \times 60$$
$$= 1800\ \text{s}$$

$$E = ?$$

$$E = P\,t$$
$$= 100 \times 1800$$
$$= 180\,000\ \text{J}$$
$$E = 180 \times 10^3\ \text{J}$$

Example 2

A 100 W light bulb is left on and uses 54 kJ of energy.

Calculate how long the light bulb was on.

$$P = 100\ W$$

$$E = 54\ kJ$$
$$= 54 \times 10^3\ J$$

$$t = ?$$

$$t = \frac{E}{P}$$

$$= \frac{54 \times 10^3}{100}$$

$$t = 540\ s$$

Questions

m = milli ($\times 10^{-3}$) **k = kilo ($\times 10^{3}$)**

µ = micro ($\times 10^{-6}$) **M = mega ($\times 10^{6}$)**

	power	time	energy
1.	60 W	4 min	14 400 J
2.	200 W	5 min	60 kJ
3.	25 mW	600 s	15 J
4.	80 W	3×10^{-3} s	0.24 J
5.	1.3 kW	720 s	935 000 J

Power, Current and Voltage

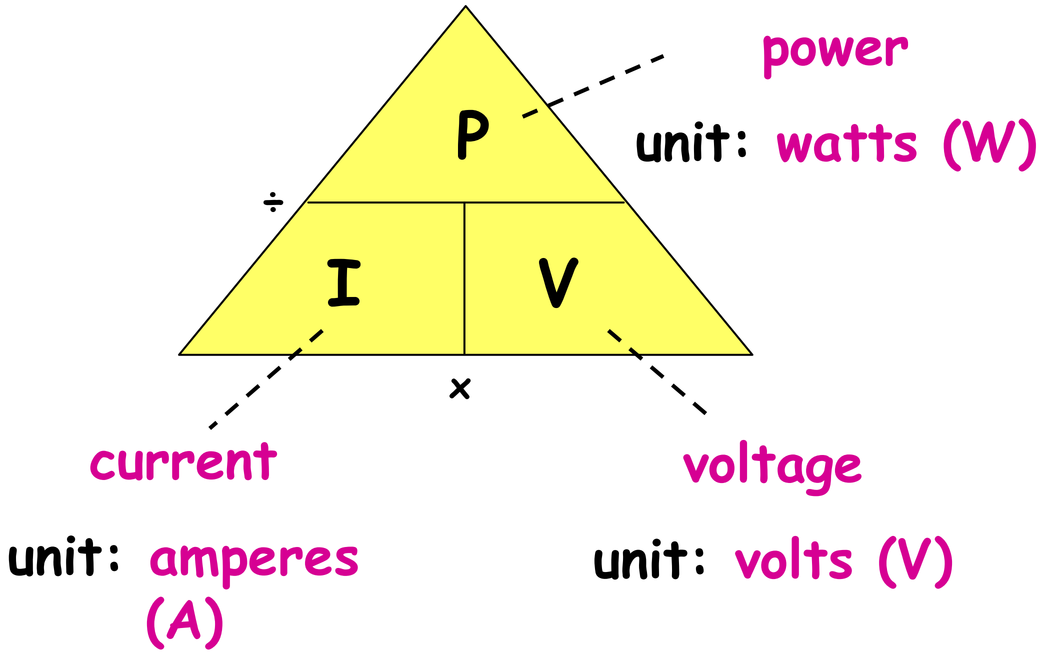
Success Criteria

By the end of the lesson, you should be able to:

- ∆ **state** the relationship between **power**, **current** and **voltage**.
- ∆ **carry out calculations** using the relationship between **power**, **current** and **voltage**.

Equation

$$P = I\,V$$



Example 1

A heater connected to the mains supply draws 20 A.

(a) Calculate the power rating of this heater.

$$V = 230\ V \qquad P = I\,V$$

$$I = 20\ A \qquad = 230 \times 20$$

$$P = ? \qquad P = 4\,600\ W$$

(b) How many joules of energy does the heater use per second.

1 watt = 1 joule per second

So the heater uses 4600 joules of energy per second.

Example 2

A 1 kW electric saw is used from the mains supply.

Calculate the size of current the saw uses.

$$P = 1\ kW$$
$$= 1 \times 10^3\ W$$

$$V = 230\ V$$

** mains voltage **

$$I = ?$$

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

$$= \frac{1 \times 10^3}{230}$$

$$I = 4.3\ A$$

Questions

m = milli ($\times 10^{-3}$)

k = kilo ($\times 10^{3}$)

μ = micro ($\times 10^{-6}$)

M = mega ($\times 10^{6}$)

	current	voltage	power
1.	3 A	5 V	15 W
2.	15 A	230 V	3.45 kW
3.	25 mA	2 kV	50 W
4.	6 μA	2000 V	12 mW
5.	2 A	15 mV	0.03 W

Combining P=IV and V=IR

<u>Success Criteria</u>

By the end of the lesson, you should be able to:

- ***show*** *how* ***P=IV*** *and* ***V=IR*** *can be* ***combined*** *to produce two new equations.*
- ***carry out calculations*** *using the relationship between* ***power****,* ***current*** *and* ***resistance****.*
- ***carry out calculations*** *using the relationship between* ***power****,* ***voltage*** *and* ***resistance****.*

Power, Current and Resistance

Consider the equations:

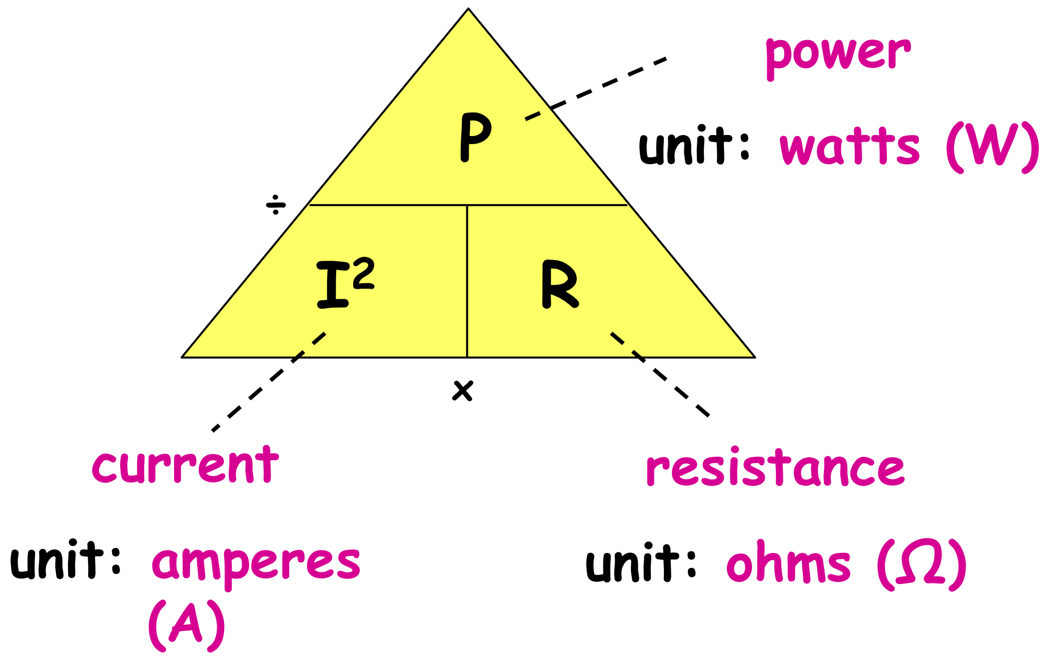
$$V = I \times R$$ and $$P = I \times V$$

Start with: $$P = I \times V$$

But: $V = I \times R$ $$P = I \times I \times R$$

So we get: $$P = I^2 \times R$$

$$P = I^2 \times R$$



P
÷
I^2
R
×
power
unit: watts (W)
current
unit: amperes (A)
resistance
unit: ohms (Ω)

Example

An electric drill has a power rating of 460 W. Whilst in operation, the drill has a resistance of 115 Ω. What is the current passing through the drill?

$$P = 460\ W$$
$$R = 115\ \Omega$$
$$I = ???$$

$$I^2 = \frac{P}{R}$$
$$= \frac{460}{115}$$
$$I^2 = 4$$
$$I = \sqrt{4}$$
$$I = 2\ A$$

Power, Voltage and Resistance

Consider the equations:

$$I = \frac{V}{R}$$ and $$P = I \times V$$

Start with:

$$P = I \times V$$

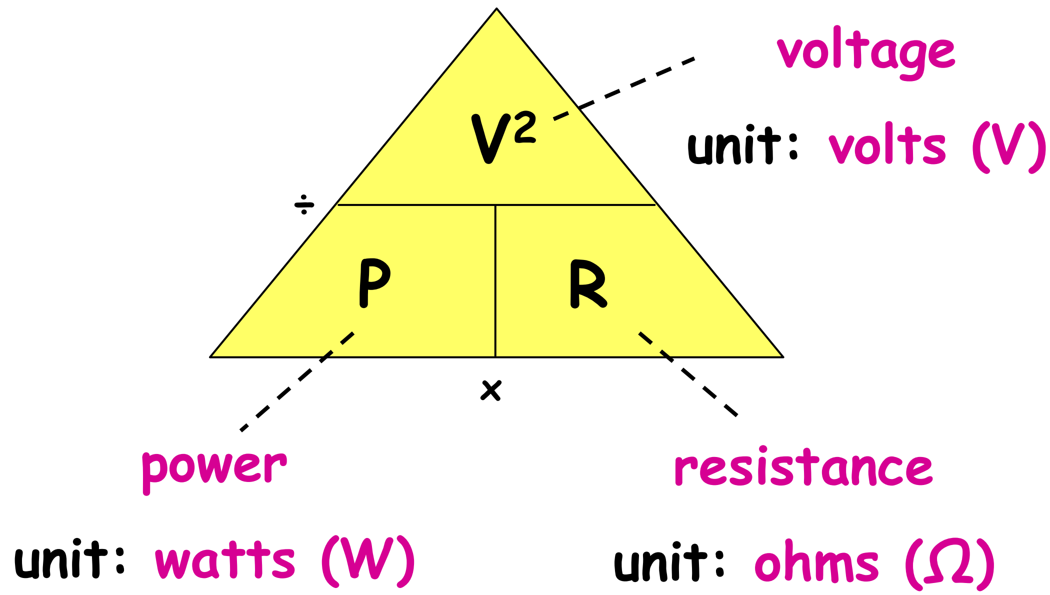
But: $I = \frac{V}{R}$

$$P = \frac{V}{R} \times V$$

So we get:

$$P = \frac{V^2}{R}$$

$$P = \frac{V^2}{R}$$


V²
P
R
÷
×
voltage
unit: volts (V)
power
unit: watts (W)
resistance
unit: ohms (Ω)

Example

A lamp has a power of 36 W and a resistance of 4Ω.

What voltage should it be connected to?

$$P = 36\ W$$

$$R = 4\ \Omega$$

$$V = ???$$

$$V^2 = P \times R$$

$$= 36 \times 4$$

$$V^2 = 144$$

$$V = \sqrt{144}$$

$$V = 12\ V$$

Questions

m = milli ($\times 10^{-3}$)	k = kilo ($\times 10^{3}$)
μ = micro ($\times 10^{-6}$)	M = mega ($\times 10^{6}$)

	power	current	resistance
1.	40 W	2 A	10 Ω
2.	6 mW	5 μA	240×10^{6} Ω
3.	5.76 kW	2.4 A	1 kΩ

	power	voltage	resistance
4.	25 000 W	5 kV	1 000 Ω
5.	16 kW	40 000 V	0.1 MΩ
6.	640 mW	800 V	1 000 kΩ