Edexcel GCSE Physics

Your notes

Energy Transfers in Circuits

Contents

Heating in Circuits

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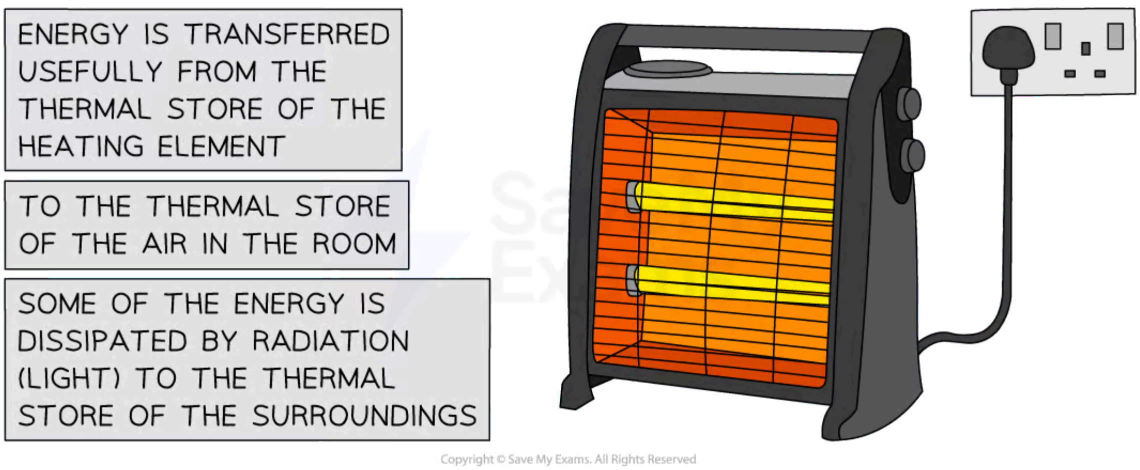
The Heating Effect of Current

- When charge passes through a component, such as a resistor, some of the energy is transferred from the electrons to the component by heating, therefore increasing its temperature
  - The energy will dissipate (spread out) into the environment via thermal conduction, convection and radiation
- This is used to an advantage to by devices like electric heaters



The heating effect of current can be used for many applications such as electric heaters

- However, wasted thermal energy makes a device less **efficient** and if too much current flows through a component, the heating effect can be very dangerous
  - This can burn someone if they touch it or cause a fire

Dissipation of Thermal Energy

- When an electrical current does work against electrical resistance:
  - Electrical energy is **dissipated as thermal energy** in the surroundings
  - The heat that is produced will dissipate via thermal conduction, convection and radiation
- The amount of heat produced depends on two factors:
  - **Current:** The greater the current, the more heat that is produced

- **Resistance:** The higher the resistance, the more heat that is produced (for a given current)
- Note that reducing the resistance can cause the current to increase
    - This could actually **increase** the amount of heat produced

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Reducing Heating in Circuits

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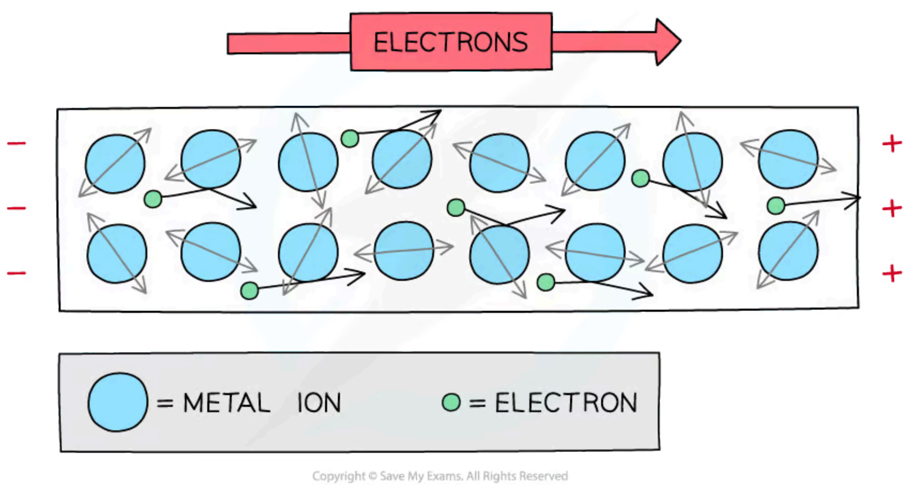
Explaining Heating in Circuits

- When electricity passes through a component, there is energy transferred to **heat**
- This is due to **collisions** between:
  - **Electrons** flowing in the conductor, and
  - The **lattice of atoms** within the metal conductor
- Electricity, in metals, is caused by a **flow of electrons**
  - This is called the **current**
- Metals are made up of a **lattice** of ions
- As the electrons pass through the metal lattice they **collide** with ions
  - The ions **resist** the flow of the electrons



As electrons flow through the metal, they collide with ions, making them vibrate more

- When the electrons collide, they lose some energy by giving it to the ions, which start to vibrate **more**
  - As a result of this, the metal **heats up**
- This heating effect is **utilised** in many appliances, including:
  - Electric heaters

- Electric ovens
- Electric hob
- Toasters
- Kettles

Reducing Heating in Circuits

- In most electrical appliances, the heat is not wanted
  - As well as being unwanted, it can also be dangerous
- The amount of heat created in wires can be reduced in a couple of ways:
  - Reduce the **current** in the wires
  - Uses wires with a **lower resistance**
- Copper is usually used in electrical wiring as it has a relatively low resistance and is fairly cheap
  - Lower resistance alternatives exist, but they are more expensive

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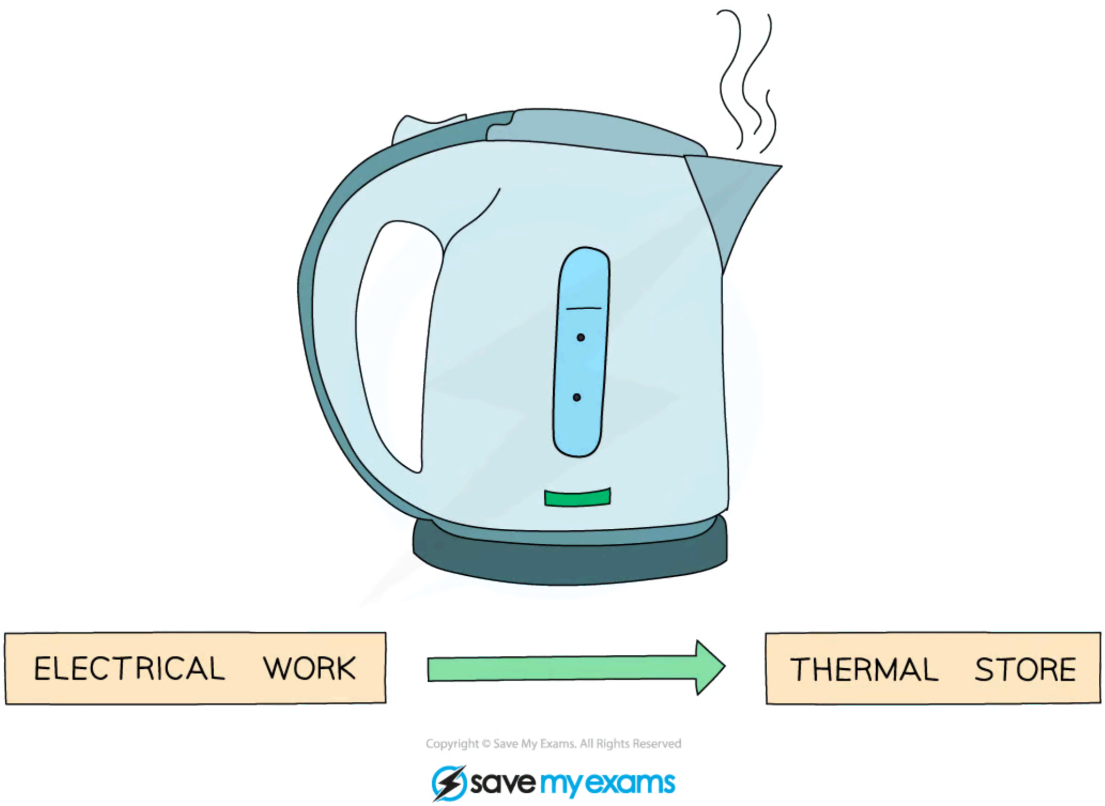
Uses & Dangers of Electric Heating

Advantages & Disadvantages

Advantages of the Heating Effect

- The heating effect is very useful in appliances which are **intended** to heat up, such as:
  - Electric kettles
  - Electric ovens
  - Domestic heating
  - Electric toasters



A kettle converts electrical work to a thermal energy store

Disadvantages of the Heating Effect

- It results in energy loss, reducing efficiency
  - For example, **waste heat** in a light bulb or **overheating** in a computer
- It can pose a fire hazard – many domestic fires are caused by too much current passing through low-quality wiring
  - For example, sparks or **excessive heat** in an electric motor

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Calculating Electric Energy

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Calculating Electric Energy

- **Work** is done when charge flows through a circuit
  - Work done is equal to the **energy transferred**
- The amount of energy transferred by electrical work in a component (or appliance) depends upon:
  - The **current**, *I*
  - The **potential difference**, *V*
  - The amount of **time** the component is used for, *t*
- When charge flows through a resistor, for example, the energy transferred is what makes the resistor **hot**
- The energy transferred can be calculated using the equation:

$$E = P \times t$$

- Where:
  - E = energy transferred in joules (J)
  - P = power in watts (W)
  - t = time in seconds (s)
- Since $\boldsymbol{P = IV}$, this equation can also be written as:

$$E = I \times V \times t$$

- Where:
  - I = current in amperes (A)
  - V = potential difference in volts (V)
- When charge flows around a circuit for a given time, the energy supplied by the battery is equal to the energy transferred to all the components in the circuit

Worked Example

Calculate the energy transferred in 1 minute when a current of 0.7 A passes through a potential difference of 4 V.

Answer:

Step 1: Write down the known quantities

- Time, t = 1 minute = 60 s
- Current, I = 0.7 A
- Potential difference, V = 4 V

Step 2: Write down the relevant equation

$$E = I \times V \times t$$

Step 3: Substitute in the values

$$E = 0.7 \times 4 \times 60 = \mathbf{168\ J}$$

Examiner Tips and Tricks

'Energy transferred' and 'work done' are often used interchangeably in equations, don't panic, they mean the same thing!Always remember that the time t in the above equations must always be converted into **seconds**

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Energy & Power

Energy & Power

- Power is defined as the **energy transferred per second**
  - Power is measured in **watts**
- Since power is energy transferred per second, the watt can also be defined as **1 joule per second**

1 W = 1 J / s

- 1 kilowatt (1 kW) is equal to 1000 watts, or 1000 joules of energy transferred per second (1 kJ / s)

Calculating Energy Transfers

- Power is defined as the **energy transferred per unit time**:

$$\text{Power} = \frac{\text{Energy transferred}}{\text{Time}} = \frac{E}{t}$$

- Power can also be defined as the **work done per unit time**:

$$\text{Power} = \frac{\text{Work done}}{\text{time}} = \frac{W}{t}$$

- Where:
  - *E* or *W* = The energy transferred, or work done, measured in **joules** (J)
  - *t* = time measured in seconds (s)
  - *P* = power measured in **watts** (W)
- This equation can be rearranged with the help of a formula triangle:

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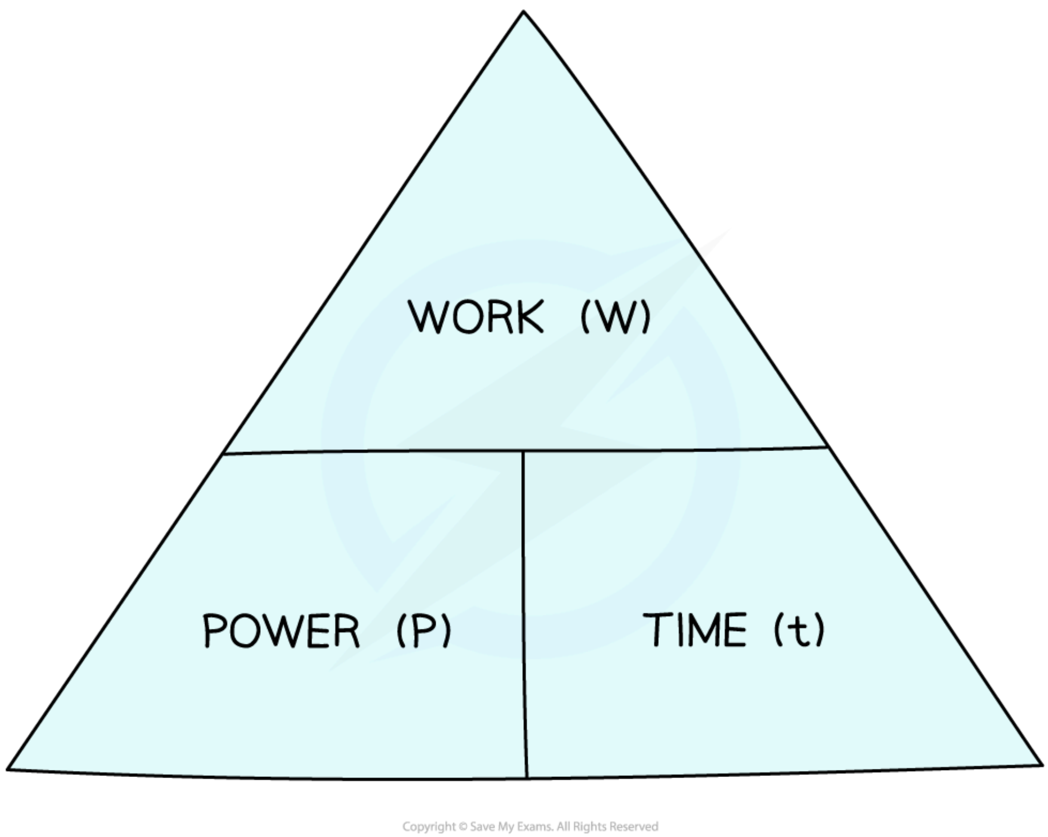

Work, power, time formula triangle

Worked Example

Calculate the energy transferred if an iron of power 2000 W is used for 5 minutes.

Answer:

Step 1: List the known values

- Power, P = 2000 W
- Time, t = 5 minutes = 5 × 60 = 300 s

Step 2: Write down the relevant equation

$$\text{Power} = \frac{\text{Energy transferred}}{\text{Time}} = \frac{E}{t}$$

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Step 3: Rearrange for energy transferred, *E*

$$\text{Energy transferred} = \text{power} \times \text{time}$$

$$E = Pt$$

Step 4: Substitute in the values

$$E = 2000 \times 300 = \mathbf{600\,000\ J}$$

Examiner Tips and Tricks

Think of power as “energy per second”. Thinking of it this way will help you to remember the relationship between power and energy

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Electricity & Power

Electrical Power

- Power is defined as

  The rate of energy transfer or the amount of energy transferred per second

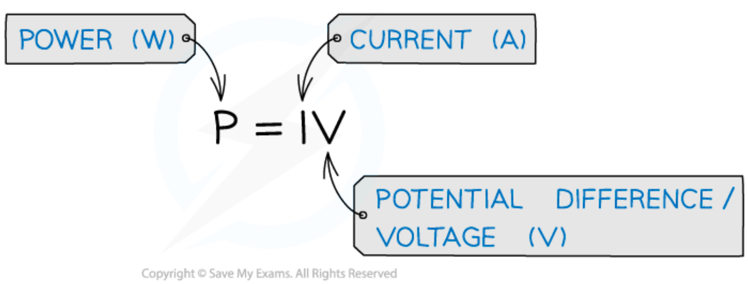
- The power of a device depends on:
  - The **voltage** (potential difference) of the device
  - The **current** of the device

Examiner Tips and Tricks

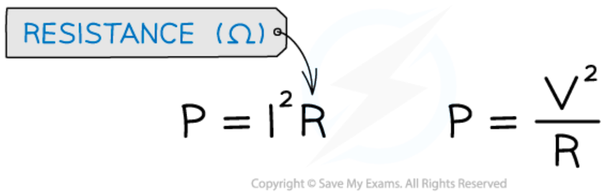
Remember: Power is just energy **per second**. Think of it this way will help you to remember the relationship between power and energy

Calculating Electrical Power

- The power of an electrical component (or appliance) is given by the equation:



- The unit of power is the watt (W), which is the same as a joule per second (J/s)
- Combining the equations ***P = IV*** with ***V = IR***, power can be written in terms of resistance, *R*:



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- Where:
  - P = power in watts (W)
  - I = current in amps (A)
  - V = voltage in volts (V)
  - R = resistance in ohms (Ω)
- This equation can be rearranged with the help of a formula triangle:

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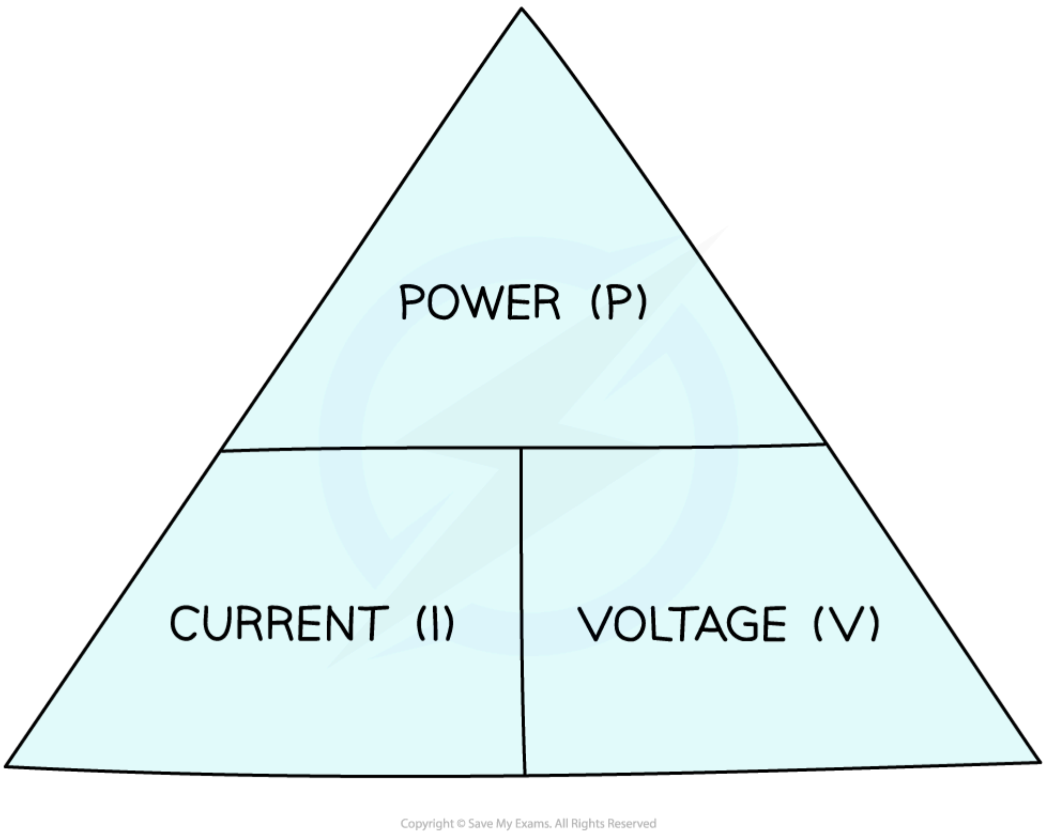

Power, current, voltage formula triangle

Worked Example

Calculate the potential difference through a 48 W electric motor with a current of 4 A.

Answer:

Step 1: List the known quantities

- Power, P = 48 W
- Current, I = 4 A

Step 2: Write down the relevant equation

$$P = IV$$

Step 3: Rearrange for potential difference, *V*

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

Step 4: Substitute in the values

$$V = \frac{48}{4} = \mathbf{12\ V}$$

Worked Example

Calculate the power through a 20 Ω resistor with a current of 6 A through it.

Answer:

Step 1: List the known quantities

- Resistance, R = 20 Ω
- Current, I = 6 A

Step 2: Write down the relevant equation

$$P = I^2R$$

Step 3: Substitute in the values

$$P = (6)^2 \times 20 = \mathbf{720\ W}$$

Examiner Tips and Tricks

You can use the mnemonic “Twinkle Twinkle Little Star, Power equals I squared R” to remember whether to multiply or divide by resistance in the power equations Which equation to use will depend on whether the value of current or voltage has been given in the question You can remember the unit of power by the phrase: “**Watt** is the unit of **power**?”

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Energy Transfers in Appliances

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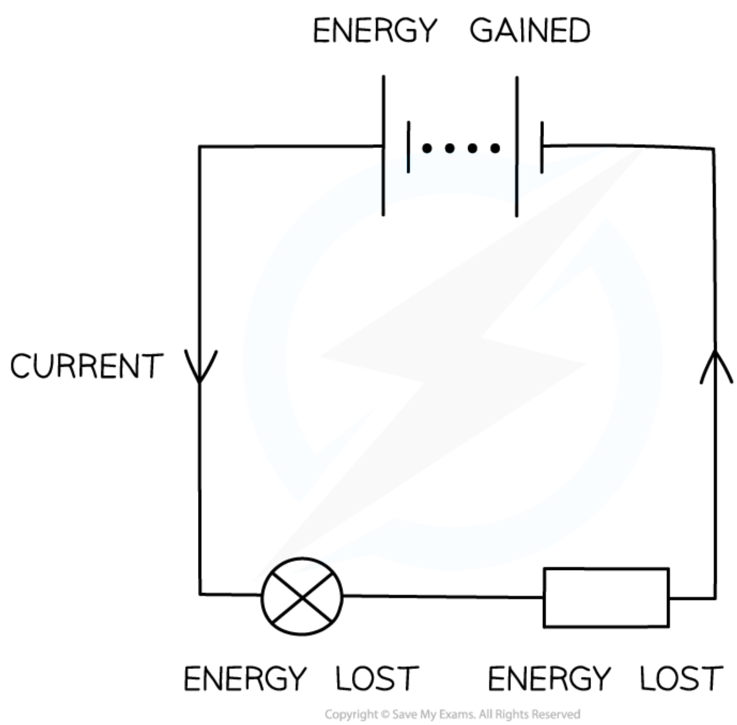
Energy Transfers in Appliances

- Everyday appliances transfer energy electrically from the mains supply to the appliance
  - For example, in a heater, energy is transferred to the **thermal store** of the heating element
- The amount of energy an appliance transfers depends on:
  - The **time** the appliance is switched on for
  - The **power** of the appliance
- A 1 kW iron uses the **same** amount of energy in 1 hour as a 2 kW iron would use in 30 minutes
- A 100 W heater uses the **same** amount of energy in 30 hours as a 3000 W heater does in 1 hour
- As charge (electrons) flows around a circuit, energy is transferred from the power source to the various components
  - As the electrons pass through the power supply, energy is transferred to the electrons
  - As the electrons pass through each component, energy is transferred from the electrons to the components



The flow of charge transfers energy from the power source to the components

- Different domestic appliances transfer energy electrically from the chemical store of the DC cells and batteries, such as a remote control
- Most household appliances transfer energy electrically from the AC mains supply
- The energy can be transferred to the **kinetic store** of an **electric motor**
- Motors are used in:
  - Vacuum cleaners - to create the suction to suck in dust and dirt off carpets
  - Washing machines - to rotate the drum to wash (or dry) clothes
  - Refrigerators - to compress the refrigerant chemical into a liquid to reduce the temperature
- Or, the energy can be transferred to the heating element of **heating** devices
- Heating is used in:
  - Toasters - to toast bread
  - Kettles - to boil hot water

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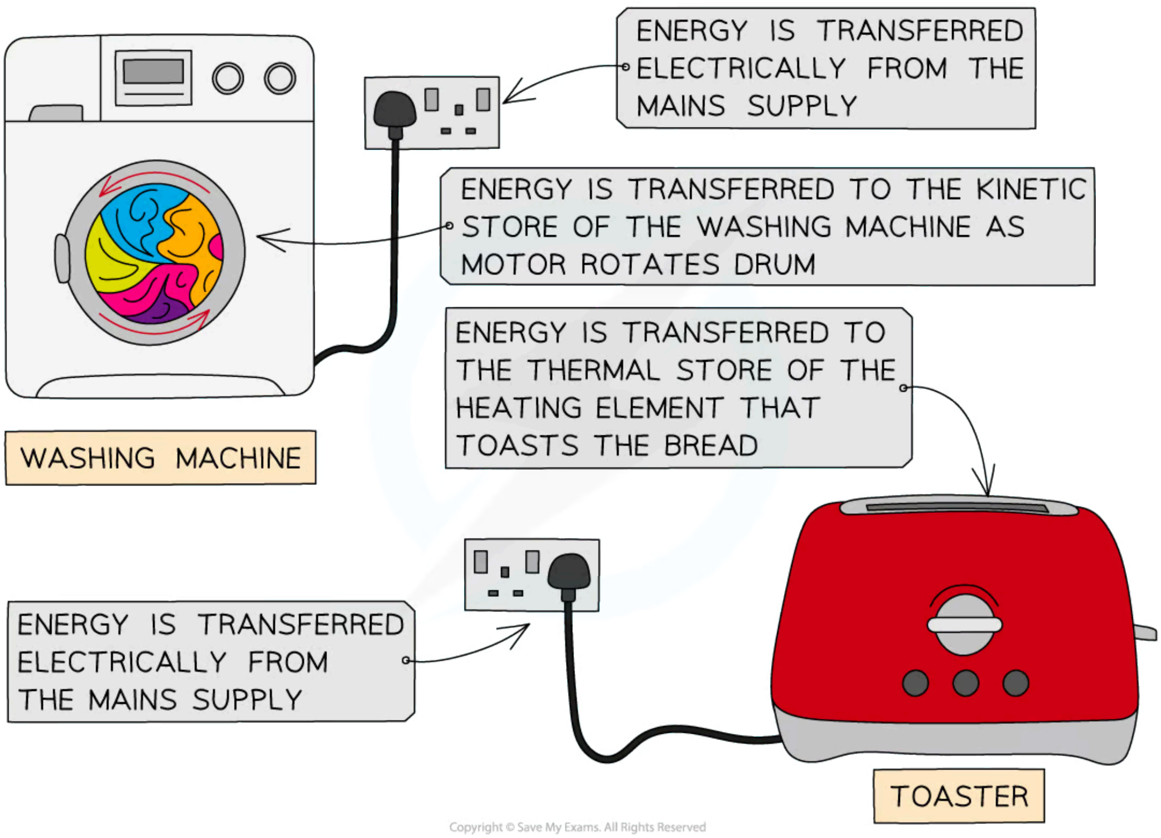
- Radiators - hot water is pumped from the boiler so the radiator can heat up a room



Energy transfers for a washing machine and toaster

Power Ratings

- The power of an appliance is the **amount of energy it transfers by electrical work every second**
- Every electrical appliance has a **power rating,** which tells you how much energy it needs to work
- The power rating for domestic electrical appliances is normally given on a label
- This will include:
  - The **potential difference** required (eg. 230 V in the UK)
  - The **frequency** of the supply (eg. 50 Hz in the UK)
  - The **power rating** in Watts (this varies for each device)
- The higher the power rating, the quicker the change in stored energy

- For example, a 2000 W kettle means the kettle transfers 2000 J of energy **per second** from one store to another
- The different power ratings of various household appliances are listed in the table below as examples:

Power Ratings Table

Appliance	Power in W
Clock	10
Lamp	50
Drill	800
Iron	1,250
Kettle	2,400
Hot water heater	3,000
Electric oven	12,000

- Care must be taken not to plug an appliance into a mains that is has a voltage that is much higher than stated on the label, for example in another country that has a higher mains voltage
  - This could cause the appliance to fuse or set fire and become damaged

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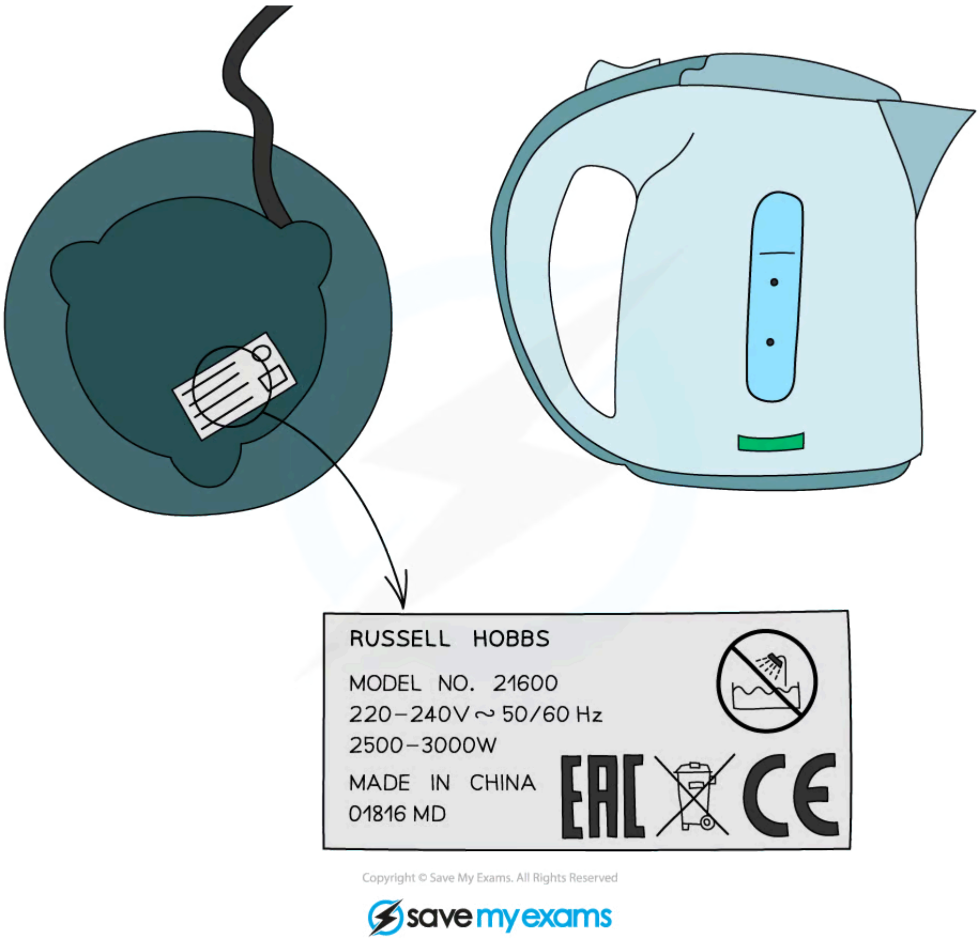

Mains electric appliances, such as this kettle, are fitted with labels that list important information such as the power and voltage of the appliance