- ***Candidates should be able to*** :
  - ***Define*** *and* ***apply*** *the concept of* ***specific heat capacity.***
  - ***Select*** *and* ***apply*** *the equation :* $E = mc\Delta\theta$
  - ***Describe*** *an electrical experiment to determine the* ***specific heat capacity of a solid or a liquid.***
  - ***Describe*** *what is meant by* ***latent heat of fusion*** *and* ***latent heat of vaporisation.***

SPECIFIC HEAT CAPACITY

- *The* ***TEMPERATURE RISE (or FALL) (Δθ)*** *of an object depends on :*
  - The **HEAT ENERGY (E)** supplied to (or extracted from) the object.

The ***GREATER*** *the amount of heat supplied to (or extracted from) an object, the* ***GREATER*** *is the temperature rise (or fall) for a given mass.*

$$\Delta\theta \propto E$$

- The **MASS (m)** of the object.

The ***SMALLER*** *the mass of the object, the* ***LARGER*** *the temperature rise (or fall) for the same heat supplied to (or extracted from) the object.*

$$\Delta\theta \propto 1/m$$

- The **MATERIAL** of the object.

Objects of the same mass, but ***different material****, have a different temperature rise (or fall) with the same amount of heat supplied to (or extracted from) them. This fact is taken into account by a quantity called the* ***HEAT CAPACITY*** *of the object.*

The **HEAT CAPACITY** of an object is the amount of heat energy which must be supplied to (or extracted from) it, to make its temperature rise (or fall) by **1 K (or 1°C).**

So the ***GREATER*** *the heat capacity of the object, the* ***SMALLER*** *the temperature rise (or fall) for the same amount of heat supplied to (or extracted from) it.*

- ***HEAT CAPACITY*** *only relates to a* ***particular object.*** *A much more useful quantity which is a* ***property of a material,*** *is* ***SPECIFIC HEAT CAPACITY (c).***

The **SPECIFIC HEAT CAPACITY (c)** of a substance is the amount of energy needed to raise the temperature of **1 kg** of the substance by **1 K (1°C)** without a change of state.

The unit of (c) is : **J kg^{-1} K^{-1}** or **J kg^{-1} °C^{-1}**

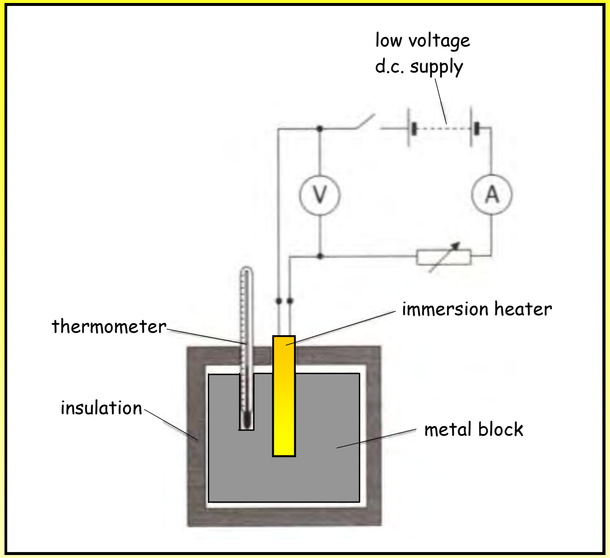
*The table below gives some typical **SPECIFIC HEAT CAPACITY** values :*

SUBSTANCE	c/J kg^{-1} K^{-1}
Aluminium	900
Concrete	850
Copper	390
Iron	490
Lead	130
Oil	2100
Water	4200

- *The amount of **ENERGY (E)** which must be supplied to a **MASS (m)** of a substance of **SPECIFIC HEATCAPACITY (c)** in order to produce a **TEMPERATURE RISE (Δθ)** is given by :*

$$\underset{(J)}{E} = \underset{(kg)}{m}\ \underset{(J\ kg^{-1}\ K^{-1})}{c}\ \underset{(K)}{\Delta\theta}$$

MEASUREMENT OF SPECIFIC HEAT CAPACITY OF A SOLID



- The **mass (m)** of the metal block is accurately measured using an electronic top-pan balance.

- The variable resistor is adjusted so as to give suitable values of **voltage (V_1)** and **current (I_1)**. The supply is then switched off and the **initial temperature (θ_i)** of the block is measured and recorded.

- The supply is then switched on and the block is heated for a fixed time (say 10 minutes). The **final temperature (θ_f)** of the block is also measured and recorded.

  Then, **temperature rise of the block,** $\Delta\theta_1 = \theta_f - \theta_i$

- After allowing the block to cool down to room temperature, the procedure is repeated using lower **voltage (V_2)** and **current (I_1)** values, as adjusted with the variable resistor. The block is heated for the same time as before and the **new temperature rise, $\Delta\theta_1$** is calculated as before.

RESULTS

Mass of block, m = kg

Time for which block is heated, t = s

Voltage across heater	V_1/V		V_2/V	
Current in heater	I_1/A		I_2/A	
Initial temperature of block	θ_i/°C		θ_i/°C	
Final temperature of block	θ_f/°C		θ_f/°C	
Temperature rise of block	$\Delta\theta_1$/°C		$\Delta\theta_2$/°C	

CALCULATIONS

electrical energy supplied to the block. = heat energy gained by the block. + heat energy lost to the surroundings.

$$V_1I_1t = mc\,\Delta\theta_1 + H \quad \text{.......................} \quad (1)$$

$$V_2I_2t = mc\,\Delta\theta_2 + H \quad \text{.......................} \quad (2)$$

(1) - (2) : $V_1I_1t - V_2I_2t = mc\,(\Delta\theta_1 - \Delta\theta_2)$

From which : $c = \dfrac{V_1I_1t - V_2I_2t}{m\,(\Delta\theta_1 - \Delta\theta_2)}$

c = ____________________________

c = J kg^{-1} K^{-1}

- **PRACTICE QUESTIONS** 3

1 Using the table of specific heat capacities given on **page 2**, calculate the **energy** which must be **supplied** (or **extracted**) to **raise** (or **lower**) the temperature of :

(a) An iron ingot of mass **12 kg** from **20°C to 190°C**.
(b) **250 g** of **water** from **18°C to 100°C**.
(c) A **copper** ring of mass 45 g from **20°C to -140°C**.

2 Calculate the **time taken** to raise the temperature of **300 g** of **oil** in an **aluminium**, deep-fat frier of mass **0.75 kg** from **20°C to 145°C**, if the electric heating element has a power rating of **3.0 kW**.

Why is your calculated time an **under-estimate ?**

3 A **3kW** electric kettle took **260 s** to heat **1.8 kg** of water from **18 °C to 100°C**.

(a) **Calculate :** (i) The **electrical energy supplied** to the **kettle** in this time.
(ii) The **internal energy gained** by the **water** in the kettle.

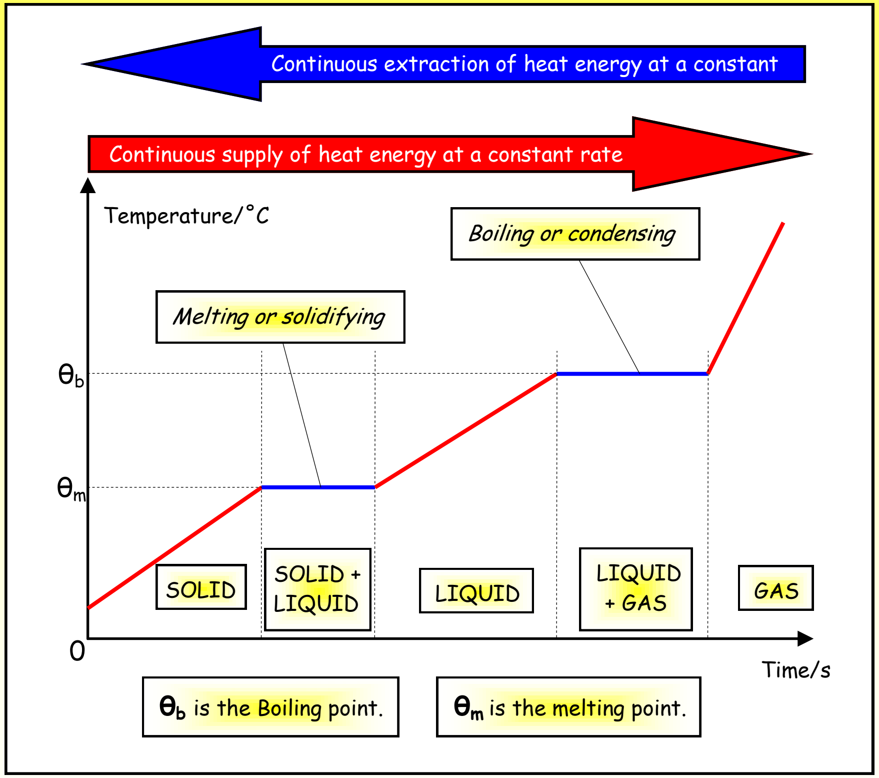
(b) The mass of the kettle was **1.2 kg** and it was made from **aluminium**.

(i) Calculate the **internal energy gained** by the **kettle**.
(ii) Account for the **difference** between the **electrical energy supplied to the kettle** and the **internal energy gained by the water and kettle**.

Use the table on **page 2** to obtain the values you need for the **specific heat capacities of water and aluminium**.

LATENT HEAT

- ***LATENT HEAT*** *is the heat energy which a body will* ***absorb*** *during* ***MELTING*** *or* ***EVAPORATION*** *and which it* ***gives out*** *during* ***SOLIDIFICATION (FREEZING)*** *or* ***CONDENSATION****. It is called latent (meaning hidden) because it produces a* ***CHANGE OF STATE, but NO TEMPERATURE CHANGE****.*



The diagram shown above illustrates what happens when a ***SOLID*** *is continuously* ***supplied*** *with heat energy, or when heat energy is continuously* ***extracted*** *from a* ***GAS****. If the diagram is read from left to right, it shows the sequence of events When heat energy is continuously added to a solid, while reading it from right to left Illustrates the reverse process of extracting heat energy from a gas.*

- *Starting from the left, with a solid well below its* ***MELTING POINT****, we see that the heat supplied causes the temperature of the solid to increase until it reaches the* ***MELTING POINT*** ***(θ_m)****.*

- *Continued heating does not cause any further increase in temperature until* ***ALL the solid has melted.***

The heat **supplied (or extracted)** to cause the phase change from **SOLID TO LIQUID (or LIQUID to SOLID)** without a change of temperature, is called the **LATENT HEAT OF FUSION.**

- *When all the solid has melted, the temperature of the resulting liquid then increases until the* ***BOILING POINT (θ_b)*** *is reached and* ***VAPORISATION*** *occurs throughout the volume of the liquid (and not just at the surface).*

  Continued heating does not cause any further increase in temperature until until ***ALL the liquid has vaporised.***

The heat **supplied (or extracted)** to cause the phase change from **LIQUID TO VAPOUR (or VAPOUR TO LIQUID)** Without a change of temperature, is called the **LATENT HEAT OF VAPORISATION.**

- *Once all the liquid has vaporised, continued heating of the gas or vapour will again cause the temperature to rise.*

The **SPECIFIC LATENT HEAT (L) OF FUSION (or VAPORISATION)** of a substance is the energy needed to change **1 kg** of the substance from **SOLID TO LIQUID (or LIQUID TO VAPOUR)** at **constant temperature.**

- *The **ENERGY (E)** which must be **supplied (or extracted)** to cause a change of state in a **MASS (m)** of a substance having a **SPECIFIC LATENT HEAT (L)** is given by :*

$$E = mL$$

(J) (kg) (J kg^{-1})

EVAPORATION AND BOILING

- ***EVAPORATION** is the name given to the process by which a liquid changes state into a gas or vapour. Evaporation occurs :*
  - ***AT ANY TEMPERATURE.***
  - ***ONLY FROM THE LIQUID SURFACE.***
- ***BOILING** is a special case of evaporation. Boiling occurs :*
  - ***AT A SPECIFIC TEMPERATURE (THE BOILING POINT).***
  - ***THROUGHOUT THE LIQUID VOLUME.** Bubbles of vapour form inside the liquid, rise to the surface and burst, releasing the vapour to the atmosphere.*

- **HOMEWORK QUESTIONS**

1 (a) **Define specific heat capacity.**

(b) **Describe** an electrical method for determining the **specific heat capacity (c)** of copper. Give a labelled diagram of the apparatus used and show how the results of such an experiment are used to calculate a value for (c).

(c) In an experiment of the type you have described in (b), a **1.5 kg** copper block was heated for **15 minutes** using an electric immersion heater which is embedded in it.

The temperature of the block was found to rise by **36°C** when the p.d. across the heater was **12.0 V** and the current in it was **2.0 A.**

When the experiment was repeated with p.d. and current values of **10.0 V** and **1.9 A** respectively and the same heating time, the new observed temperature rise was **28.5 °C.**

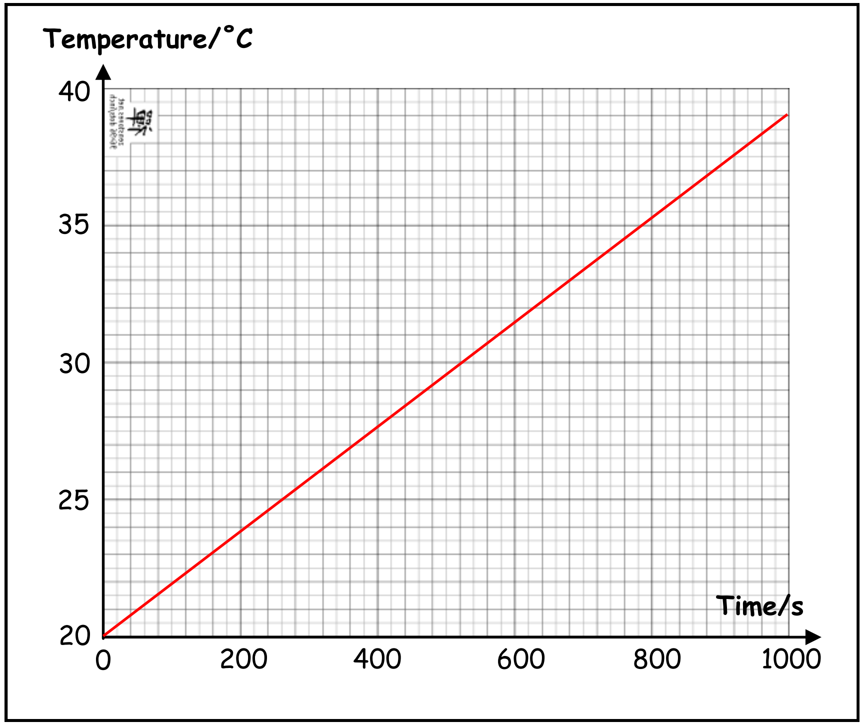
Use the two sets of results to calculate the **specific heat capacity of copper.**

2 A convector heater having a power rating of **2.5 kW** is used to heat an office whose dimensions are **6.0 m x 5.0 m x 2.8 m.** If the initial temperature of the air in the office is **12°C,** calculate the **time taken** for the heater to raise the air temperature to a comfortable **20°C.**

(Density of air at standard atmospheric pressure = **1.2 kg m^{-3}**).

Why will your calculated time be **less than** the time it will actually take to produce the required temperature change ?

3 An insulated metal cylinder of mass **1.4 kg** was heated by a **24 W** electric heater placed in a slot in the cylinder. The temperature of the metal was measured using a thermometer placed in a different slot in the metal.
The measurements obtained in the experiment were used to plat a graph of **temperature against time** as shown in the diagram below.



(a) Determine the **temperature rise per second** of the cylinder.

(b) Calculate the **specific heat capacity** of the metal of which the cylinder is made.

4 (a) Draw a well-labelled graph of **temperature against time** to show what happens when a **solid** object is continuously supplied with heat energy until some time after it has become a **gas**. 6

Indicate those sections of the graph where the object is **solid, solid + liquid, liquid, liquid + gas and gas**.
Show also the positions of the **melting** and **boiling points** on the temperature axis.

(b) **Define latent heat of fusion** and **latent heat of vaporisation.**

(c) **Explain** the difference between **evaporation** and **boiling.**