- U-values measure how effective a material is as an insulator.
- The lower the U-value, the better the material is as an insulator.
- Solar panels may contain water that is heated by radiation from the Sun. This water may then be used to heat buildings or provide domestic hot water.
- Different substances at the same temperature store different amounts of heat (thermal energy) for the same mass of material. This is called the specific heat capacity (c).
- Heat transferred = mass x specific heat capacity x temperature change

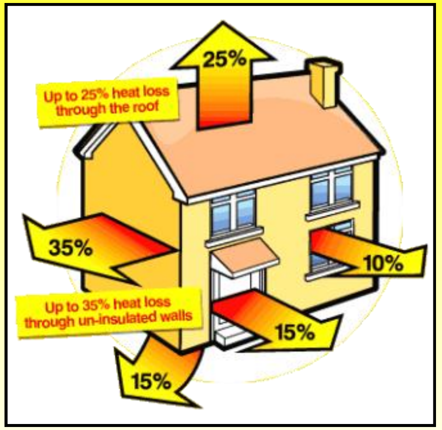
$$E = m \times c \times \theta$$

(joule, J) (kilogram, kg) (joule/kilogram °C, J/kg °C) (°C)

HEAT LOSS FROM BUILDINGS

- When we turn on the central heating in our homes, schools and places of work, we want to make sure that heat loss from the building is as low as possible i.e. we want our buildings to be **energy efficient**.

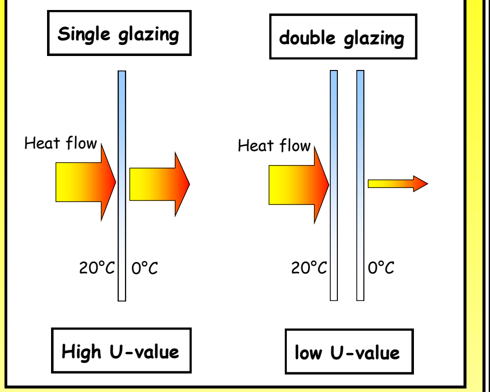
  In order to achieve this, buildings need to be specifically designed or modified so as to minimise the rate at which thermal energy is transferred from the inside to the outside.



Conduction is the main thermal energy transfer process by which heat is lost from a building. The leakage of heat occurs through the walls, windows and roof and it can be reduced by the use of building materials which are **good thermal insulators**.

U-VALUE

- The **U-VALUE** is a measure of the thermal (heat) energy flow through a building element.
- This is illustrated by the diagram opposite which shows that more heat flows out of a single-glazed window than a double-glazed one.



- The **higher** the U-value, the **more** heat flows through, so **a good U-value is a low one.**

In a **cold** climate a building element with a **low U-value** will reduce **heat loss to the outside** and in a **hot** climate it will reduce **heat gain from outside.**

- The **U-VALUE** physically describes how much thermal energy in **watts (W)** is transferred through a building component with an area of **1 metre^2 (m^2)** at a temperature difference of **1 degree celcius (°C).**

  Thus the unit for U-values is : **W/m^2 °C**

- The **rate of heat loss (H)** through each particular component of a building can be calculated using the following equation (NOTE : You are not required to know this) :

Rate of heat loss = U-value x area x temperature difference

$$H = U \times A \times T$$

(W) (W/m^2 °C) (m^2) (°C)

- The table below shows some typical U-values for building components Before and after insulation measures have been taken :

BUILDING COMPONENT	U-VALUE (W/m² °C)
Doors (without draught excluders) Doors (with draught excluders)	5.0 3.0
Windows (single glazed) Windows (double glazed)	5.0 2.5
Cavity wall (air-filled gap) Cavity wall (foam-filled gap)	1.0 0.5
Floor (without carpeting) Floor (with carpeting)	1.0 0.3
Roof (without insulation) Roof (with insulation)	2.0 0.3

- Given the areas shown opposite and the corresponding U-values in the table above, we can now calculate the **rate of heat loss (H)** for a house :

(a) Without insulation,

(b) With insulation,

When there is a temperature difference of **15 °C** between the inside and the outside.

Area of doors = 10 m^2.

Area of windows = 30 m^2.

Area of brick wall = 200 m^2.

Area of floor = 100 m^2.

Area of ceiling /roof = 100 m^2.

(a) WITHOUT INSULATION

Doors → **H =** =

Windows → **H =** =

Walls → **H =** =

Floor → **H =** =

Roof → **H =** =

Total heat loss (H_T) = W = kW

(a) WITH INSULATION

Doors → **H =** =

Windows → **H =** =

Walls → **H =** =

Floor → **H =** =

Roof → **H =** =

Total heat loss (H_T) = W = kW

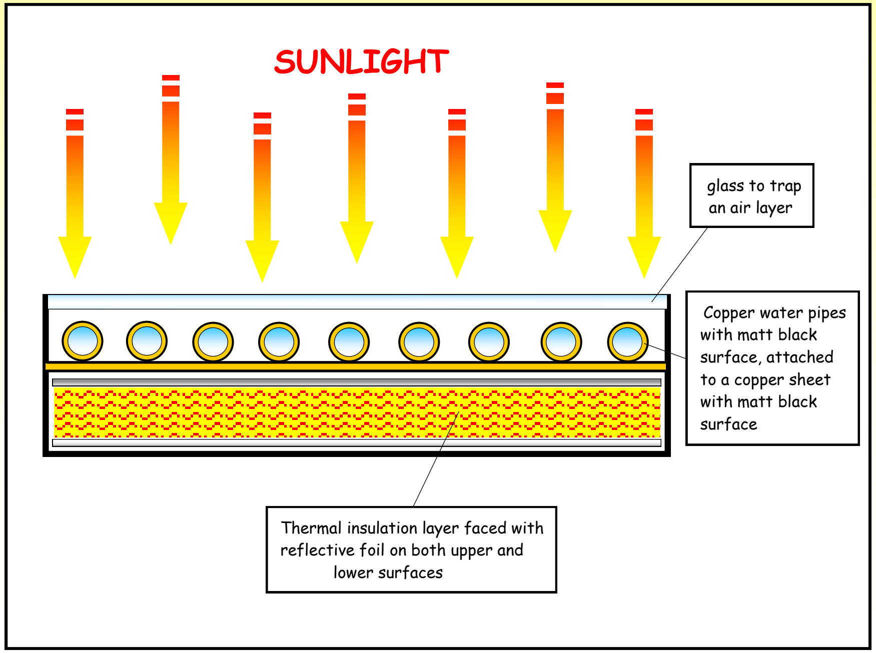
- The above calculation shows that the rate of heat loss from a house can be substantially reduced by the installation of appropriate insulation.

SOLAR PANELS

- Solar heating panels absorb infrared radiation and use it to heat water. The panels are placed to receive the maximum amount of the Sun's energy.

  In the northern hemisphere, they must face south and be angled so that the Sun's rays falls on them as directly as possible for as long as possible.

- The structure of a typical solar heating panel is illustrated in the cross-sectional view shown below.



- Water is pumped through **copper** pipes fixed onto a **copper** sheet. **Copper** is used because it is an **excellent thermal conductor**. The surfaces of the sheet and the pipes have a **matt black**, powder-coated finish as this is the **best absorber** of infrared radiation.

  The glass traps a layer of air above the pipes so as to help **insulate** the unit and retain the heat. The **thermal insulating layer with reflective foil** is also specifically designed to stop heat escaping to the surroundings.

  This kind of panel is quite efficient and the energy produced is more cost effective than that from photoelectric cells.

SUPPLYING HEAT ENERGY

- When **heat energy (E)** is supplied to an object, the **temperature rise (ΔT)** of the object depends on :

  The amount of **heat energy (E)** supplied to the object.

  *The **greater** the amount of heat energy supplied to an object, the **greater** is the temperature rise for a given mass.*

  $\Delta T \propto E$

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

  *The **smaller** the mass of the object, the **greater** is the temperature rise for the same amount of heat supplied to the object.*

  $\Delta T \propto 1/m$

- The **material** of the object.

  *Objects of the same mass, but **different material**, have a different temperature rise with the same amount of heat supplied to them. This fact is taken into account by a quantity called the **specific heat capacity (c)** of the object.*

  *The **greater** the specific heat capacity of the object's material, the **smaller** is the temperature rise for the same amount of heat supplied to it.*

  $\Delta T \propto 1/c$

The **specific heat capacity (c)** of a substance is the amount of heat energy needed to raise the temperature of **1 kg** of the substance by **1°C**.

The unit of (c) is : **J/kg °C**

- 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 **heat energy (E)** which must be supplied to a **mass (m)** of a substance of **specific heat capacity (c)** in order to produce a **temperature rise (ΔT)** is given by :

Heat energy = mass × specific heat capacity × temperature rise

$$E = m \times c \times \Delta T$$

(J) (kg) $(J\ kg^{-1}\ K^{-1})$ (K)

EXAMPLE

*Calculate the amount of heat energy which must be supplied to heat **150 kg** of water in a bath from **17 °C** to **41 °C**. Given that the specific heat capacity of water is **4200 J/kg °C**.*

$$E = m \times c \times \Delta T$$

$$E = 150 \times 4200 \times (41 - 17)$$

$$E = 15\ 120\ 000\ J = 15.12\ MJ$$

- Water has a **very high specific heat capacity.** This means that it absorbs a large amount of heat energy when it is heated and gives out a large amount of heat energy when it cools down.

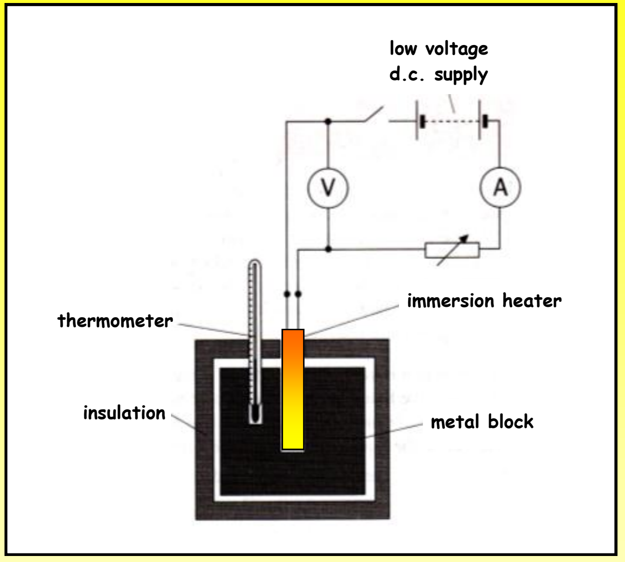
- Water's very high specific heat capacity is useful in the following ways :

  - The human body is mostly water, so if we indulge in vigorous exercise and our muscles produce a lot of heat, we don't overheat too quickly.

  - Water is used as the heat carrier in solar heating panels because it can absorb large amounts of heat energy which can then be used to provide heating and hot water in a home.

  - Because it can absorb a lot of heat energy, water is used as the coolant in most car engines.

PRACTICAL WORK - 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 (T_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 (T_f)** of the block is also measured and recorded.

  Then, **temperature rise of the block**, $\Delta T_1 = T_f - T_i$

- 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**, ΔT_2 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	T_i/°C		T_i/°C	
Final temperature of block	T_f/°C		T_f/°C	
Temperature rise of block	ΔT_1/°C		ΔT_2/°C	

CALCULATIONS

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

$$V_1 I_1 t = m c \Delta T_1 + H \quad \text{.......................} \quad (1)$$

$$V_2 I_2 t = m c \Delta T_2 + H \quad \text{.......................} \quad (2)$$

(1) - (2) : $V_1 I_1 t - V_2 I_2 t = m c (\Delta T_1 - \Delta T_2)$

From which : $c = \dfrac{V_1 I_1 t - V_2 I_2 t}{m (\Delta T_1 - \Delta T_2)}$

c = ________________________

c = ______ J/kg °C

- PRACTICE QUESTIONS

1 How much heat is needed to raise the temperature of **2.5 kg** of a substance of specific heat capacity **240 J/kg °C**, from **15 °C** to **70 °C ?**

2 The same amount of heat was supplied to different masses of three substances, **A, B** and **C**. The temperature rise in each case is shown in the table below.

material	mass / kg	heat supplied / J	temp. rise / °C
A	1.0	2000	1.0
B	2.0	2000	5.0
C	0.5	2000	4.0

Calculate the **specific heat capacities** of **A, B** and **C**.

3 **(a)** The table shows how much **energy** is needed to make the temperature of **1 kg** of Different substances rise by **1 °C**.

SUBSTANCE	ENERGY / J
copper	390
mercury	140
silver	240
steel	450

Which substance has the **highest specific heat capacity?** Give a reason for your answer.

(b) A microwave oven is used to heat a cold mug of coffee. In a few seconds the temperature of the coffee rises by **70 °C**.

Showing clearly how you work out your final answer, calculate the **heat energy in joules gained by the coffee.**

Take the mass of the coffee to be **0.2 kg** and the specific heat capacity of the coffee to be **4000 J/kg °C**.

- HOMEWORK QUESTIONS

1 **(a)** Explain what is meant by the term **U-value.**

(b) With regard to insulating a house, is it better for a building component to have a **high** U-value or a **low** one? **Explain** your answer.

2 **(a)** What are solar heating panels used for?

(b) Referring to the diagram of a cross-sectional view of a solar heating panel shown on page **25** :

(i) Explain why **water** is used to carry the heat absorbed by the panel.

(ii) Why are the pipes made of **copper** and why do they have a **matt black** outer coating?

(iii) Why does the insulating layer beneath the pipes have a **reflective foil** outer covering?

(iv) Why does the panel have a **glass cover**?

3 Referring to the apparatus used to measure the **specific heat capacity** of a metal, which is shown diagrammatically on page **27** :

(a) If the immersion heater has a power of **50 W**, how many **joules of energy does it supply each second?**

(b) The immersion heater is switched on for **10 minutes** and during this time the temperature of the block rises from **20 °C** to **45 °C**.

(i) Calculate the **energy in joules** supplied to the metal block during this time.

(ii) If the block has a mass of **2.0 kg**, calculate the **specific heat capacity of the metal.**

(iii) When this experiment is performed, the **measured temperature rise** of the block is **smaller** than expected. Why do you think this is?