1

CfE Heat Energy - B McMULLEN

Three methods of heat energy transfer

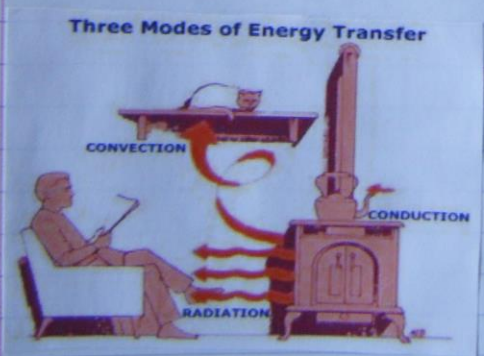
Heat energy can travel through many materials made of solids, liquids and gases.

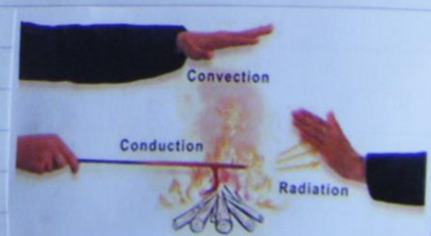
Materials that allow heat energy to travel through them are called conductors and those that don't are called Insulators.

The rate at which heat energy is transferred between an object and its surrounding depends on the difference in temperature between the two. The greater the difference in temperature, the greater the rate of heat energy transfer.

The three methods of heat energy transfer are:

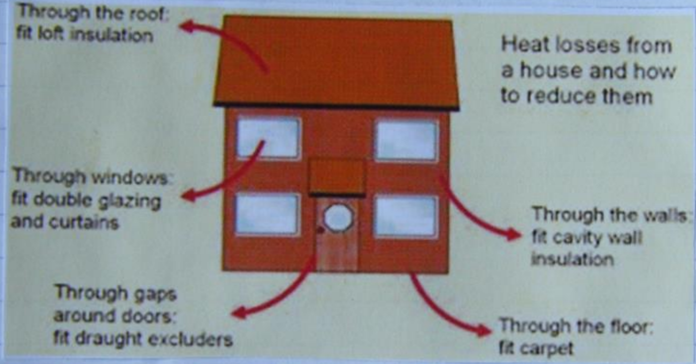
- Conduction
- Convection
- Radiation.





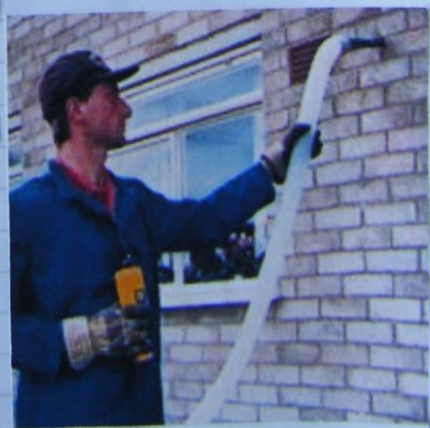
Heat Energy loss in the home

Method of Heat loss	Way it is lost	Method to prevent loss
Conduction	Through walls Through windows Through doors	Cavity wall insulation Double glazing Insulated door
Convection	Through roof	Loft insulation
Radiation	Through walls and roof in all directions	Plasterboard backed with metal foil Metal foil fixed to the wall behind radiators

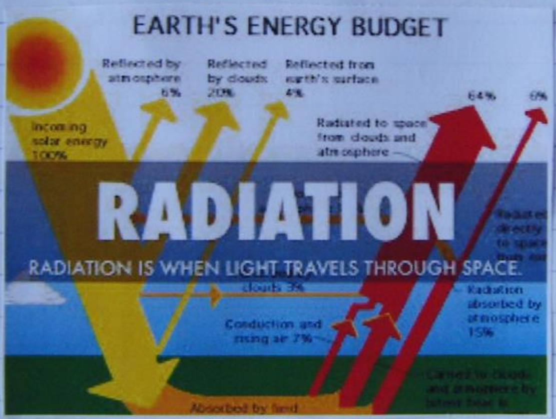


Installation of the fibre glass wool loft insulation.

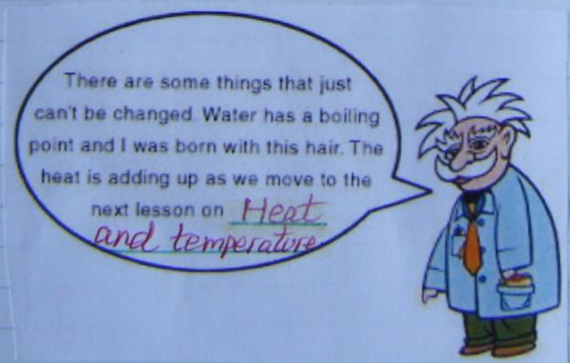
Cavity wall insulation in the cavity between the two layers of brick.



Evaporation of water from body surfaces or breathing passages cools the body.
Objects exchange radiation with each other and with the sky. Warmer objects lose heat to cooler objects.
Solar radiation
Diffused radiation
Direct radiation
Heat is lost by convection when a stream of air (wind) is cooler than body surface temperature.
Wind
Reflected radiation
Conduction is the direct transfer of heat when objects of different temperatures come into contact.



EARTH'S ENERGY BUDGET
Reflected by atmosphere 6%
Reflected by clouds 20%
Reflected from earth's surface 4%
64%
6%
Incoming solar energy 100%
Radiated to space from clouds and atmosphere
RADIATION
RADIATION IS WHEN LIGHT TRAVELS THROUGH SPACE.
Conduction and rising air 7%
Radiation absorbed by atmosphere 15%



There are some things that just can't be changed. Water has a boiling point and I was born with this hair. The heat is adding up as we move to the next lesson on Heat and temperature

Heat and Temperature

- Heat is a form of energy measured in Joules.

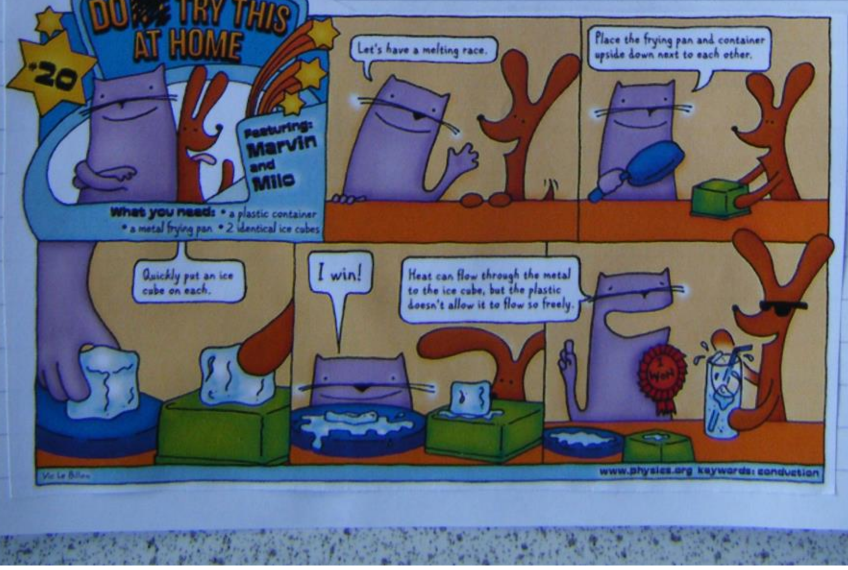
- Temperature is a measure of how hot or cold something is and it is measured in degrees celsius (°C).

- The 3 states of matter are solids, liquids and gases. (Liquids and gases are known as fluids).

Water can exist in each of the three states.

- < 0°C ⇒ Solid form ⇒ Ice
- 0°C ⇒ Ice turns to water ⇒ Solid → Liquid
- 0°C → 100°C ⇒ Water
- 100°C ⇒ Water turns to steam ⇒ Liquid → Gas.

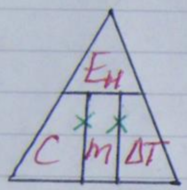
0°C ⇒ Melting point of Ice
100°C ⇒ Boiling point of Water.



Specific Heat Capacity

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

- E_H → Heat Energy (J)
- c → Specific Heat Capacity ($J\,Kg^{-1}\,{}^{o}C^{-1}$)
- m → mass (Kg)
- ΔT → Change in Temperature (°C)



1. $E_H = cm\Delta T$	2. $c = \frac{E_H}{m\Delta T}$
3. $m = \frac{E_H}{c\Delta T}$	4. $\Delta T = \frac{E_H}{cm}$

Definition ⇒ From $c = \frac{E_H}{m\Delta T}$

The specific Heat Capacity is the Heat energy required to increase the temperature of 1Kg of a substance by 1°C.

Ex1

Q. Calculate the specific heat capacity of an unknown metal of mass 250g if its temperature changes from 23°C to 43°C by absorbing 1930J of heat energy.

A. $E_H = 1930J$
$m = 250g = 0.25Kg$
$\Delta T = 43^oC - 23^oC = 20^oC$
$c = ?$

From $E_H = cm\Delta T$

$$\Rightarrow c = \frac{E_H}{m\Delta T} = \frac{1930}{0.25 \times 20} = \frac{1930}{5}$$

$$\Rightarrow c = 386\,J\,Kg^{-1}\,{}^{o}C^{-1}$$

Ex2

20,000J of heat energy is absorbed by 1·5kg of Water.

Calculate the difference in temperature of the water
(DATA REQUIRED $C_{WATER} = 4180 J kg^{-1} °C^{-1}$)

$E_H = 20{,}000 J$
$C = 4180 J kg^{-1} °C^{-1}$
$m = 1·5 kg$
$\Delta T = ?$

From $E_H = cm\Delta T$

$\Rightarrow \Delta T = \frac{E_H}{cm} = \frac{20{,}000}{4180 \times 1·5}$

$\Rightarrow \Delta T = \frac{20{,}000}{6270} = 3·2°C$

Ex3

Q. A 2kW electric heater is placed in a beaker of water for 3 minutes. If the temperature of the water increases from 19°C to 59°C then calculate or find:

a) Heat energy supplied to the water.
b) mass of the water heated.

A. a) From $P = \frac{E}{t} \Rightarrow E = Pt$

$E = ?$
$P = 2kW = 2 \times 10^3 W$
$t = 3 \text{ minutes} = 180s$

$\Rightarrow E = 2 \times 10^3 \times 180$

$\Rightarrow E = 3·6 \times 10^5 J$

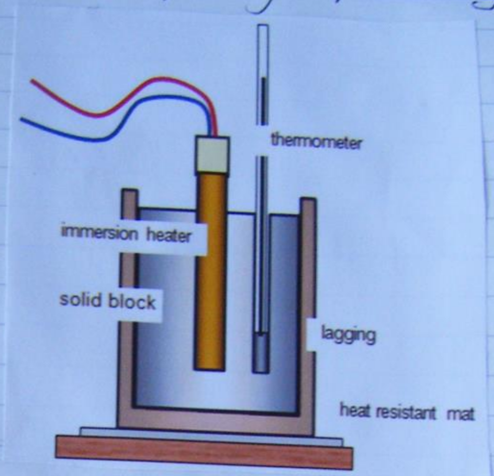
b) $E_H = 3·6 \times 10^5 J$
$C = 4180 J kg^{-1} °C^{-1}$
$m = ?$
$\Delta T = 59°C - 19°C = 40°C$

From $E_H = cm\Delta T \Rightarrow m = \frac{E_H}{c\Delta T}$

$\Rightarrow m = \frac{3·6 \times 10^5}{4180 \times 40} = 2·15 kg$

measuring specific Heat Capacity experimentally

Connect the Immersion Heater to a 12V dc power supply.



- Record the power rating of the immersion heater. (P)
- Record the mass of the solid block. (m)
- Record the initial temperature of the solid block. (T_1)
- switch on the immersion heater for a given time. (t)
- Record the final temperature of the solid block. (T_2)

From electrical energy supplied, $E_E = Pt$
If we assume that we have 100% in energy transfer. $E_E \rightarrow E_H$

As $E_H = cm\Delta T$ then

$$c = \frac{E_H}{m\Delta T}$$ where $\Delta T = T_2 - T_1$

Specific Latent Heat

This is mainly shortened to the term 'latent heat'.

This is either:

- The heat energy required to convert 1kg of a solid into a liquid at its melting point. This is the latent heat of fusion. (L_F)

OR

- The heat energy required to convert 1kg of a liquid into a gas at its boiling point. This is the latent heat of vaporisation. (L_V)

ie { Solid → Liquid, Liquid → Solid } ⇒ Latent heat of fusion.

ie { Liquid → gas, gas → liquid } ⇒ Latent heat of vaporisation.

Solid → Liquid ⇒ melting
Liquid → Solid ⇒ freezing
Liquid → Gas ⇒ boiling
Gas → Liquid ⇒ condensing.

* Changes in state do not involve a change in temperature. *

* Changes in temperature do not involve a change in state. *

Conclusion

At any particular time we can have either a change in temperature or a change in state.
However we cannot have a change in state and a change in temperature at the same time.
(ie you cannot have your cake and eat it!!).

Latent Heat Equation

$$E_H = mL$$

- L → Latent Heat (JKg^{-1})
- E_H → Heat Energy (J)
- m → mass (Kg)

Solve problems involving specific latent heat

- When the heat added or removed changes the temperature of an object, the heat is calculated using
- $E_H = CM\Delta T$

- When the heat added or removed changes the state of an object at constant temperature, the heat is calculated using
- $E_H = mL$

Applications of Specific Latent Heat in Everyday Life

- Water has a large specific latent heat of vaporization. This property enables steam to be used for cooking by the method of steaming. When steam condenses on the food, the latent heat is released directly onto the food enables the food to be cooked at a faster rate.

Ex4

Calculate the heat energy required to convert 400g of ice into water at 0°C.

(DATA L_F for ice $= 3{\cdot}34 \times 10^5 \, J \, Kg^{-1}$)

$E_H = ?$

$m = 400g = 0{\cdot}4 Kg$

$L_F = 3{\cdot}34 \times 10^5 \, J \, Kg^{-1}$

$E_H = mL_F$

$\Rightarrow E_H = 0{\cdot}4 \times 3{\cdot}34 \times 10^5$

$\Rightarrow E_H = 133{,}600 J$

Ex5

Calculate the latent heat of vaporisation of water if 1,695,000J of heat energy is used to convert 750g of water into steam at 100°C.

$E_H = 1{,}695{,}000 J$

$m = 750g = 0{\cdot}75 Kg.$

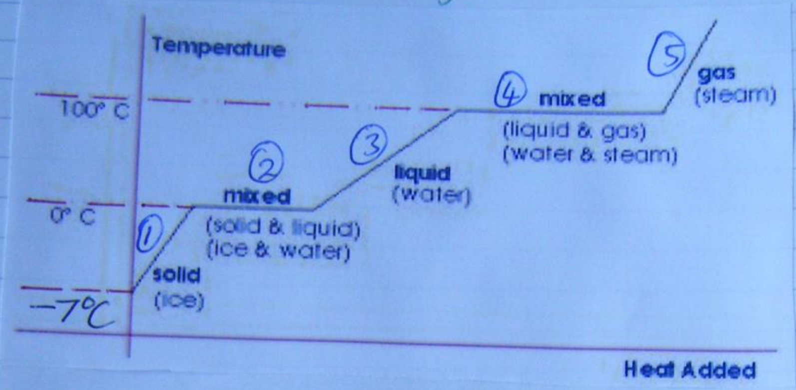
$L_V = ?$

$E_H = mL_V$

$\Rightarrow L_V = \frac{E_H}{m} = \frac{1{,}695{,}000}{0{\cdot}75}$

$\Rightarrow L_V = 2{\cdot}26 \times 10^6 \, J \, Kg^{-1}$

Gradient = 0 ⇒ change in state
Gradient ≠ 0 ⇒ change in temperature

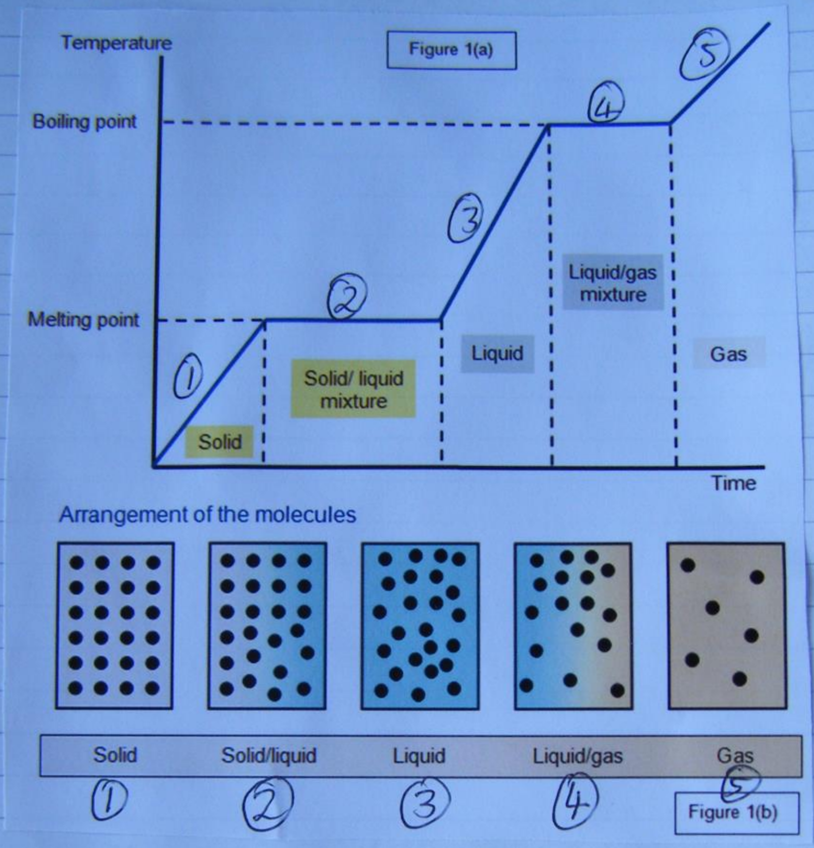


- ① Change in temperature of ice from −7°C to 0°C. ⇒ No change in state.
- ② Change in state at 0°C from ice to water ⇒ No change in temperature
- ③ Change in temperature of water from 0°C to 100°C. ⇒ No change in state.
- ④ Change in state at 100°C from water to steam ⇒ No change in temperature
- ⑤ Change in temperature of the gas from 100°C to >100°C. ⇒ No change in state.

Comparing like with like!!

A burn from steam at 100°C would be worse than a burn from water at 100°C.

Why?



The graph in Figure 1(a) matches up with the arrangement of the molecules in Figure 1(b).

Ex6

Q/ Calculate the heat energy required to convert 250g of water at 20°C into 250g of steam at 100°C.

This involves a 2 stage calculation.

- Water at 20°C → Water at 100°C
- Water at 100°C → Steam at 100°C.

A stage 1 (Change in temperature)

$E_H = ?$

Water ⇒ $c = 4180\,J\,kg^{-1}\,°C^{-1}$

$m = 250g = 0.25kg$

$\Delta T = 100°C - 20°C = 80°C$

$E_H = cm\Delta T$

$\Rightarrow E_H = 4180 \times 0.25 \times 80$

$\Rightarrow E_H = 83,600J$

Stage 2 (Change in state).

$E_H = ?$

$m = 0.25kg$

$L_V = 2.26 \times 10^6\,J\,kg^{-1}$

$E_H = mL_V$

$\Rightarrow E_H = 0.25 \times 2.26 \times 10^6$

$\Rightarrow E_H = 565,000J$

Total Heat energy required $= 83,600J + 565,000J$
$= 648,600J$

Ex7

Show that it takes a total of $1.816 \times 10^6 J$ of heat energy to convert 600g of ice at −7°C into 600g of steam at 100°C.

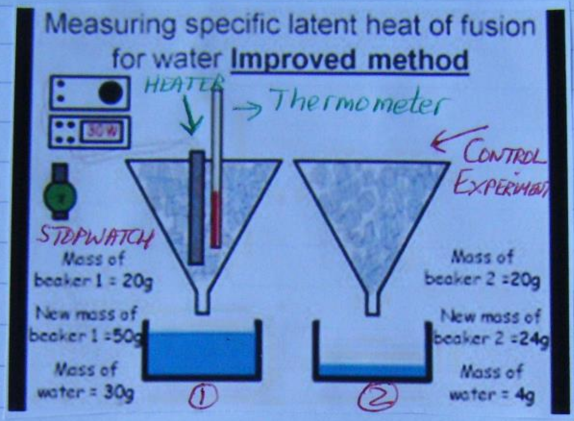
DATA REQUIRED

- $C_{ICE} = 2100\,J\,kg^{-1}\,°C^{-1}$
- $L_{F\,ICE} = 3.34 \times 10^5\,J\,kg^{-1}$
- $C_{WATER} = 4180\,J\,kg^{-1}\,°C^{-1}$
- $L_{V\,WATER} = 2.26 \times 10^6\,J\,kg^{-1}$

HINT!!!

This involves a 4 stage calculation!!

Measuring the specific latent of fusion of water experimentally



- Set up the apparatus as shown above.
- Note the power rating of the heater.
- switch on the heater for a given time that is recorded with the stopwatch.
- measure the mass of water in beaker ① when the heater is switched off.
- Measure the mass of water in beaker ② in the control experiment.
- mass of ice melted = ① − ②.
- Heat Energy supplied to the ice $E = pt$. (Assuming 100% energy transfer from $E_E \rightarrow E_H$)
- $$E_H = mL_F \Rightarrow \boxed{L_F = \frac{E_H}{m}}$$

* The control experiment takes into account the mass of ice melted naturally in the air. *