

Demonstrate understanding of aspects of heat

Heat Transfer

- Temperature - temperature is a measure of the average kinetic energy of the particles making up an object (measured in °C or K)
- 0 K = -273°C (absolute zero – temperature at which all molecular motion ceases). 273 K = 0°C, 373 K = 100°C. To convert K to °C subtract 273; To convert °C to K add 273!
- A temperature change of 1 degree Kelvin (1 K) is the same as a temperature change of 1 degree celcius or centigrade (1°C)
- Heat - heat is a measure of the total energy of an object (measured in joules)
- Heat energy - thermal energy. It is transferred from one thing to another thing because of the temperature difference between them. Direction of energy flow is always from a warmer to a cooler thing. Heat won't transfer between objects at the same temperature.
- Latent heat - is the term used to describe energy which causes a change of state/phase without change of temperature. During a phase change, the heat energy goes into the work of breaking bonds and separating molecules, rather than increasing the temperature.
- The Specific Latent Heat of a Substance (L) is the quantity of energy needed to change the state of 1 kg of a substance without a change in temperature.



<p>The specific latent heat of fusion is the amount of heat required to convert 1 kg of a solid into the liquid without a change in temperature.</p>	<p>The specific latent heat of vaporisation is the amount of heat required to convert 1kg of a liquid into the vapour without a change in temperature.</p>

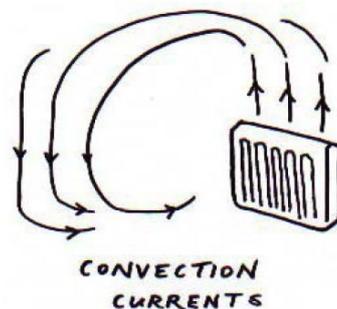
- The specific latent heat of fusion of ice at 0°C, for example, is 334000 J kg⁻¹. This means that to convert 1 kg of ice at 0°C to 1 kg of water at 0°C, 334000 J of heat must be absorbed by the ice. Conversely, when 1 kg of water at 0°C freezes to give 1 kg of ice at 0°C, 334000 J of heat will be released to the surroundings.
- Specific heat capacity. The specific heat capacity of a substance is the quantity of energy needed to change the temperature of 1 kg of the substance by 1°C. The specific heat capacity of water is high compared with most other substances: $c_{\text{water}} = 4200 \text{ J kg}^{-1} \text{ } ^\circ\text{C}^{-1}$

The greater the specific heat capacity of a substance, the more energy must be transferred to it or taken from it to change the temperature of a given mass of it.

Conduction, convection, radiation

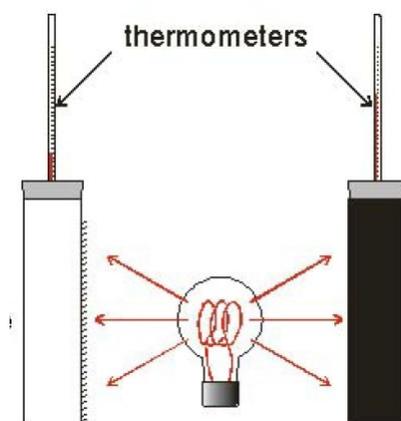
☐ Conduction – Atoms in a substance are always vibrating. If a substance gets hotter, the atoms vibrate more. The atoms don't swap places, or move around, they just vibrate more on the spot. Heat spreads by conduction when atoms increase their vibrations, and pass this energy on to those nearby. Metals have a 'sea' of delocalised electrons, which move at random inside them. In metals, these free electrons carry energy faster than the atomic vibrations and transfer it by colliding with other electrons and atoms. Because of this, metals are the best conductors of heat energy. Metal objects feel cold if you touch them because they carry heat away from your hand. In non-metals there are very no free electrons to do the conduction quickly, so the process is slow. Solids are better at conducting than liquids and gases because the atoms are closer together. If the atoms are too spaced out it makes it harder for the atoms to pass the energy along. Everything conducts to some extent - liquids and gases also conduct heat but only very slowly. Water is a very poor conductor. Air is a terrible conductor, and this is why clothes which trap air are warm – e.g. fleeces. Fibreglass traps air and is used as 'lagging' to insulate water pipes, ovens, fridges and roofs of houses.

☐ Convection. Gases (and many liquids) have low thermal conductivity. However, energy can be transported through a fluid (liquid or gas) by convection currents. Imagine a Bunsen heating a beaker of water. The temperature of the water near the flame increases. This water expands & so its density is less than the water surrounding it. The higher temperature water therefore rises upwards transferring energy through the liquid. Cooler water sinks to take its place. A convection current is established. DON'T say "Heat rises!!"



A similar situation exists when a room is heated by a (badly named!) "radiator".

☐ Radiation. Radiation does not need any matter to be present and can travel through a vacuum (how heat reaches us from the sun). IR (infrared radiation) is emitted by all objects hotter than their surroundings. Some surfaces absorb radiation better than others, for example, black, dull surfaces are best at absorbing radiation. White and shiny surfaces are poor absorbers, and instead of absorbing they make good reflectors of radiation. When radiation hits an object three things happen: Part gets reflected, part is transmitted through the object and part is absorbed. It is the bit that is absorbed that raises the temperature of the object. If an object is hotter than its surroundings it will lose energy to the surroundings by radiation. Some surfaces also give out, or emit, radiation better than others. A dull black surface is a better emitter of radiation than the shiny one.



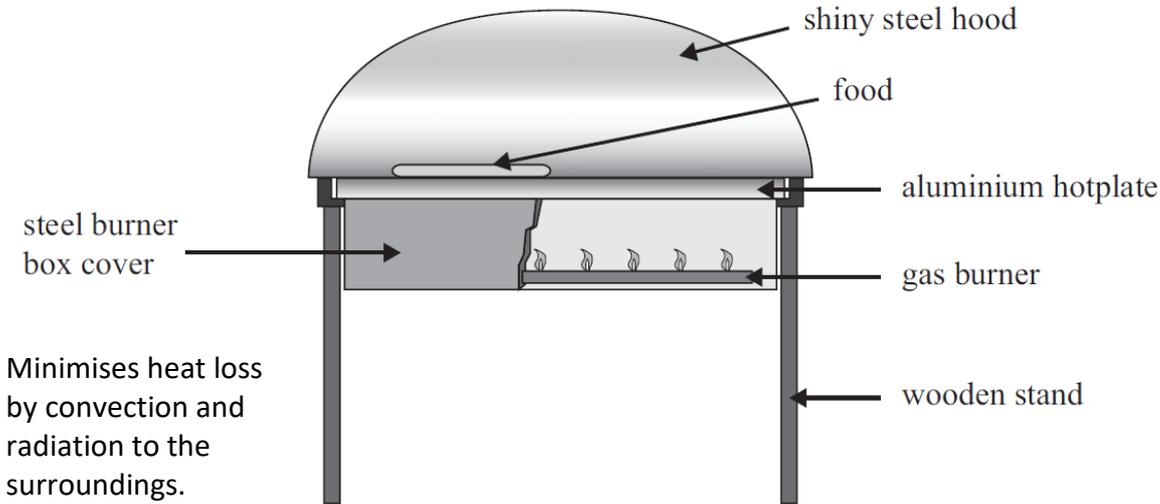
Dark coloured or dull surfaces both emit and absorb radiation better than light coloured or shiny surfaces. But in a question think... What is the hotter object? Should I be writing about absorbing or emitting heat energy? This is a common error!!! And don't say "BLACK ATTRACTS HEAT!!"

☐ Efficiency of heating

- Energy cannot be created or destroyed, only be transferred from one form to another. Energy that is 'wasted', like the light energy from a fire, does not disappear but is transferred into the surroundings. It becomes very difficult to do anything useful with it. The efficiency of a device can be calculated: $\text{efficiency} = \text{useful energy output} \div \text{useful energy input}$.

- Some of the heat efficiency features of a barbeque include the burner box cover, the shiny steel hood, steel hood and its wooden stand.

Traps air reducing heat loss by convection AND reflects heat back minimising heat loss by radiation



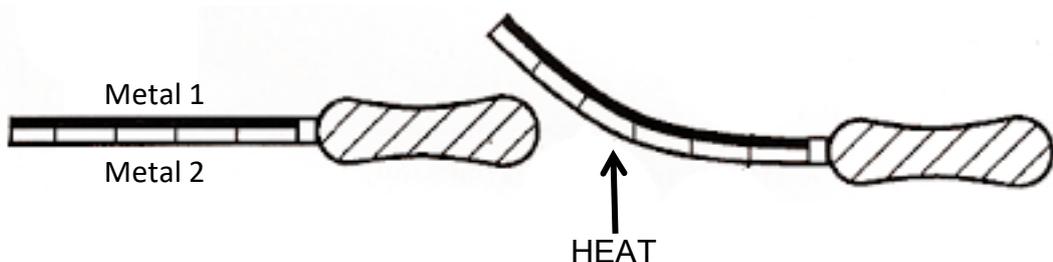
Minimises heat loss by convection and radiation to the surroundings.

Insulator – not much heat lost from the plate by conduction to the frame.

- ☐ Insulation – insulation reduces unwanted energy transfer (and can keep warm things warm or cold things cool). Most insulating materials work by trapping air within fibres, or bubbles or similar cavities in a material like fibre glass or polystyrene. Air is a poor conductor of heat and the layer of air is a barrier to the transfer of heat. Insulation cuts down the loss of heat by reducing the effect of conduction & convection.

☐ Thermal expansion

- Expansion is due to an increase in the average distance between atoms in the substance.
- The atoms themselves do not expand; they simply move further away from their neighbours. (NEVER say “particles expand” in the exam!)
- The expansion occurs due to the increased kinetic energy of the particles involved which then vibrate more and move further apart.
- Some effects and applications of expansion and contraction in everyday life include riveting, gaps in bridges, overhead power and telephone lines, and thermostats.
- Not all materials expand by the same amount for the same temperature change. E.g. bimetallic strip. Metal 2 expands more (has a *higher coefficient of thermal expansion*) than Metal 1 in the diagram below so the strip bends.



☐ $Q = mc\Delta T$

- What this means is: Heat energy received or given out = mass of substance x specific heat capacity x temperature change:
- Q = energy (in J)
- m = mass (kg)
- c = specific heat capacity ($J/(kg^{\circ}C)$, also written $J\ kg^{-1}\ ^{\circ}C^{-1}$)
- ΔT is the temperature change ($^{\circ}C$)

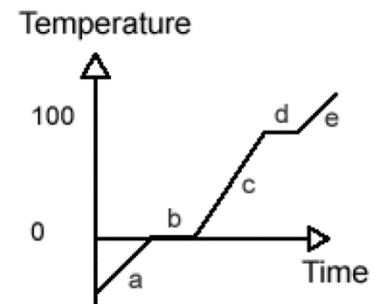
The value of 'c' is the same if you are cooling rather than heating the substance. In other words you get as much heat back out of the substance when you cool it as you put in when you heated it.

☐ $Q = mL$ The Specific Latent Heat of a Substance (L). This is the quantity of energy needed to change the state of 1 kg of a substance without a change in temperature, units $J\ kg^{-1}$. For water, the specific latent heat of fusion, $L = 334\ 000\ J\ kg^{-1}$. The specific latent heat of vaporisation is rather higher, $L = 2.3 \times 10^6\ J\ kg^{-1}$. The latent heat of vaporisation is therefore almost 7 times the latent heat of fusion; this indicates more energy is needed to separate the molecules in going from water to steam than to break up the lattice structure in going from ice to water.

- Liquid to gas and vice versa – latent heat of vaporisation (d)
- Solid to liquid and vice versa – latent heat of fusion (b)
- Solid to gas and vice versa – latent heat of sublimation (you don't often come across that)

a, c and e – Heat energy goes to change the temperature. Specific heat capacity equations apply.

b and d – Heat energy goes to change the state. Specific latent heat equations apply.



☐ $P = E / t$ (P = power in **W**, E = energy in **J**, t = time, in **s**).

Eg 1. A 2 kW electric jug. $2\ kW = 2000\ W = 2000\ J\ s^{-1}$.

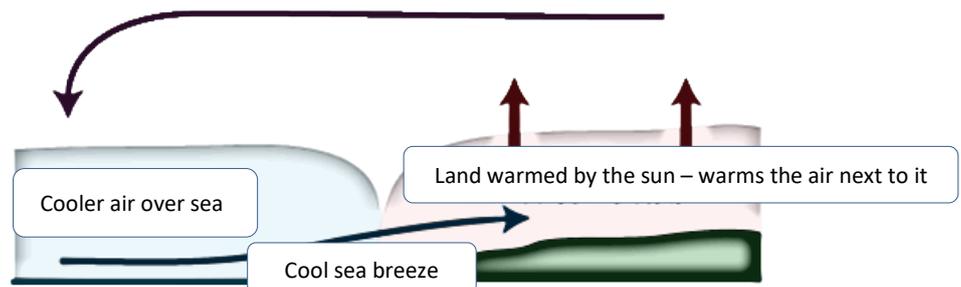
Eg 2. Power output of nuclear reactor is 120 kW. $120\ kW = 120000\ W = 120000\ J\ s^{-1}$.

- Power = energy / time
- Time = energy / power

SOME EXPLANATIONS

Onshore & Offshore Breezes

During the day, the ground heats up more quickly than the sea; this occurs because water has a larger specific heat capacity. The air in contact with the warm ground is heated by conduction. That air expands, becoming less dense than the surrounding cooler air. As a result, the warm air rises and other air moves horizontally (winds) to fill the space - creating an onshore sea breeze. Cooler air descends, and a convection current is set up, which transfers heat away from the land.



At night, the ground loses its heat more quickly, and the water surface is warmer than the land. As a result, the breeze is offshore.

The Thermos Flask

The thermos flask is designed to minimise heat transfer by conduction, convection and radiation. It is used to store either hot or cold liquids for long periods of time. It has a double wall of glass with a silvered inner wall. The space between the walls is evacuated to minimise heat transfer by conduction and convection. By reflecting most of the radiant heat, the silvered surface minimises heat transfer by radiation. The plastic or cork stopper in its neck prevents heat loss by convection and conduction.



Satellites



It is necessary to protect the sensitive electronic instruments in orbiting space satellites. In half of its orbit around the Earth, a satellite is exposed to intense radiation from the Sun, and in the other half it is in the Earth's cold shadow. Without protection, its interior would be subjected to tremendous extremes of heating and cooling. The interior of the satellite is wrapped with blankets of highly reflective aluminium foil. The foil's shiny surface reflects away much of the Sun's radiation while the satellite is in the unshaded part of the orbit, and helps retain interior heat while the satellite is in the Earth's shadow.

Wool sweaters and down jackets

These garments keep us warm by trapping the warmer air in regions close to our bodies and hence reducing heat loss by convection and conduction. What keeps us warm is not the clothing itself but the air trapped in the clothing.

