Aim

The overall aim of this Physics Coursework is to investigate into the factors which affect the speed of the cooling of water.

Background Information

There are many factors that affect the cooling of hot water. I have listed some of these below:

1) Shape of the container and surface area. This could be weather the container is short or fat, or tall or thin.
2) Room temperature. This could vary from about 10°C to 30°C.
3) Insulation. Does covering the container several times make any difference to the speed of the cooling of hot water?

I will look for information about conduction, convection, radiation and evaporation.

Heat Transfer

Heat and Temperature

All objects contain heat energy within them. Heat energy is caused by particles within the object moving around via kinetic energy. The diagram below shows atoms of gas like Neon and Argon.

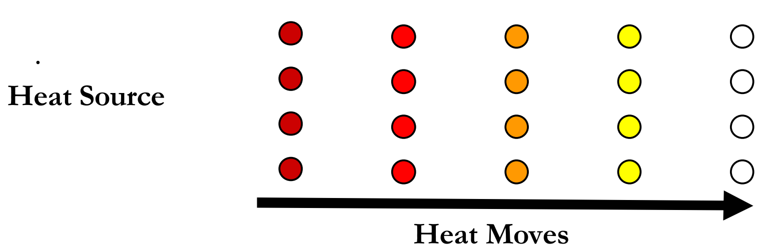
The arrows in the diagram show that the atoms have different speeds in different directions. If the temperature is increased, the average speed of the atoms also increases, therefore more kinetic energy is created. This then means more heat energy is being created.
In 1869, James Clerk Maxwell provided a useful equation for this kinetic theory.

$$PV = \frac{1}{3}nmc^2$$

Where: **P** = pressure
V = Volume
n = number of molecules
m = mass of molecule
c = velocity of the molecules

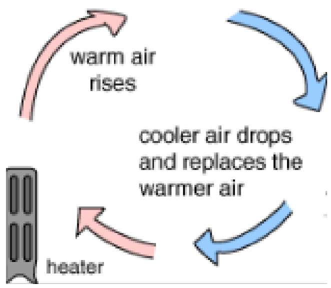
Conduction

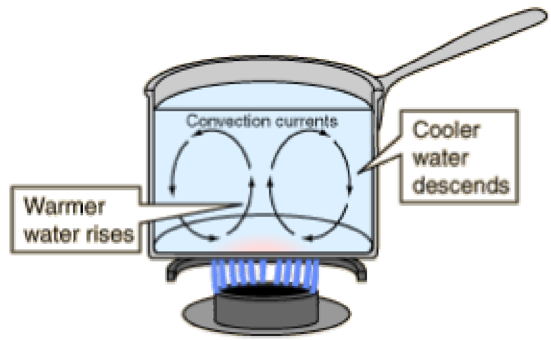
Heat conduction is the transmission of heat across matter. Heat transfer is always directed from a higher to a lower temperature. Denser substances are usually better conductors; metals are the best conductors of heat
The extra heat energy is passed from atom to atom through the solid. This caused by the vibrations of the atoms and moving streams of electrons.



Convection

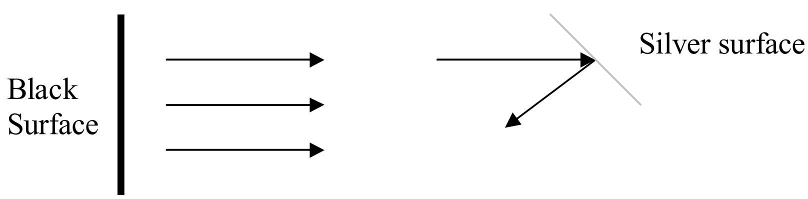
Convection is the transfer of heat by currents within a fluid, i.e.: liquids and gases. This is when heat moves as a substance as a whole. It may arise from temperature differences either within the fluid or between the fluid and its boundary, which would affect density. For example hot air is less dense than cold air so hot air moves above cold air. This is how heat spreads through water in kettles and the air in a room (shown below).





Radiation

Hot objects give off electromagnetic radiation called infra red rays (heat rays). Dull black surfaces radiate more heat energy than shiny white surfaces at the same temperature, whilst shiny silver surfaces reflect heat.



Evaporation

Evaporation is the process in which atoms or molecules in a liquid state gain sufficient energy to enter the gaseous state. A liquid cools when it is stirred or blown because fast moving particles in the liquid are escaping into the air. The particles that leave by evaporation take latent heat from the other particles, causing them to cool down. The particles left in the liquid, on average, are moving more slowly, therefore the temperature of the liquid cools down.

Scientific Laws

Energy is conserved. It cannot be created from anything and it cannot be lost. Heat is only transferred.
When energy is used to do work, some of it gets side tracked: not all energy supplied does useful work. The missing energy usually ends up spread over a large number of particles (it is lost to its surroundings by heat).

A Sankey diagram can illustrate these laws. This one below shows the energy transfers through a car engine.

The output energy equals the input energy from the fuel. This shows that no energy has been lost in this process. Only 19% is used to move the car.

Specific Heat Capacity

This is the heat energy taken in or given out when 1kg of a substance changes temperature by 1k.
It is the property of the substance alone – there is a set value for each substance.
Specific Heat Capacity of water is 4200kJ per Kg per ˚C or K. (0˚C = 273K and 25˚C = 298K)

Equation

$Q = m\,s\,\Delta T$ or $Q = m\,s\,(t - t)$

$Q = m \times s\,(SHC) \times \Delta t$

- Q → Heat gained or lost
- m → Mass amount of liquid
- s (SHC) → Specific Heat Capacity
- Δt → Temperature rise or fall

Endothermic Reaction
Chemical reaction where the energy content of the products is more than that of the reactants; heat is taken in by the system.

Exothermic Reaction
Chemical reaction where the energy content of the products is less than that of the reactants; heat is given out from the system.

Predictions
I predict that the temperature of the surroundings will affect the cooling of the hot water. I think that the hot water will cool down faster when the surrounding air is very cold. I think that hot water will cool down slowly when the air is very hot.

I also think that the material that the container is made out of will affect the cooling. I predict that two polystyrene cups will retain more heat than one cup of the same material. I also predict that three polystyrene cups will retain more than in the other two situations.

Furthermore, I believe the movement of the liquid will affect the cooling of hot water. I think that any hot liquid in cold liquid will rise to the top. This is due to convection. All liquids should be stirred to keep their temperatures steady.

Experiment
The aim of my experiment is to investigate into one factor which will affect the cooling of hot water. I have chosen to investigate:

The insulation of the container: one cup thickness, two cup thickness and three cup thickness.

Hypothesis
I predict that the heat loss will decrease as the number of cups used increases. Therefore, I predict that the less polystyrene cups used, the faster it would be for the water to cool down.

Apparatus

- ☺ 9 Polystyrene cups. $100cm^3$ capacity
- ☺ Electric kettle to warm the water
- ☺ Stop watch- measuring seconds and minutes
- ☺ Three -10 to +110°C thermometers
- ☺ $100cm^3$ measuring cylinder
- ☺ 3 lids made of plastic

Diagram

Fair Test

I must make sure I carry out this experiment fairly. If not, I could end up with insufficient and unreliable results. To make this a fair test i am going to ensure that:

- ☺ The material of the cups are the same – all polystyrene
- ☺ The thickness of the polystyrene cups are the same
- ☺ All the cups have the same shape
- ☺ All the cups are the same colour

Safety

I must ensure I carry this experiment out safely. If safety is ignored in any experiment, many dangerous things could occur. To ensure safety I must wear goggles at all times and also wear gloves so not to get burnt from the hot water being used.

Plan of Method – insulation of the container

1) I will begin this experiment by collecting and setting up the apparatus as shown in the previous diagram.
2) I will then measure $100cm^3$ of hot water previously heated in an electric kettle to about 80 ˚ C, using the appropriate measuring cylinder.
3) This water will be transferred to a polystyrene cup and a thermometer will be used to check its temperature. A stop clock is then started and the temperature will be noted down every minute for 10 minutes.
4) This same process will be repeated for two concentric polystyrene cups, and then again for three concentric polystyrene cups
5) I will then either repeat the whole experiment another two times or, if time is running out, I will compare my set of results with another students. This will mean I can rule out any outliers and check if my results are fair.
6) This will then allow me to make an average for all 3 experiments – 1 cup, 2 cups, and 3 cups.
7) I will then put my results into the following chart:

	Insulation											
	1 Polystyrene cup / °C				2 Polystyrene cup/ °C				3 Polystyrene cup/ °C			
Time (mins)	Exp 1	Exp 2	Exp 3	Average	Exp 1	Exp 2	Exp 3	Average	Exp 1	Exp 2	Exp 3	Average
00.00												
01.00												
02.00												
03.00												
04.00												
05.00												
06.00												
07.00												
08.00												
09.00												
10.00												
Net Temp change												
Net Heat Loss /J												

Actual Method

I followed my plan exactly and did not need to change any parts of the method. However, in my chart (as shown above) I included the formula $Q = ms\Delta T$ to work out the heat loss of water in each of my containers.
I also drew up a graph of my results to make them more visual and notice ant patterns.

Results

Please see following pages.

Conclusion

From looking at my graph of results, I notice that the water cooled down much more rapidly with only one polystyrene cup, than with two or three polystyrene cups. The graph shows that the heat loss using just one cup, is much greater than that of using three cups. The cooling down of water using three polystyrene cups was very steady and the heat loss was much less than that of two cups and three cups.

From the table of results I worked out the net temperature change and net heat loss for each repeated experiment. I calculated that the average net temperature change for one polystyrene cup (21) was higher than that of three polystyrene cups, which was 17. Also, the net heat loss of one cup was 8778J whilst it was just 7106J for three polystyrene cups. This shows that using two or three polystyrene cups, insured good insulation. One polystyrene cups did not have sufficient enough insulation, therefore the water cooled down much more quickly than if there were 2 or 3 cups used.

My hypothesis was that using one cup would mean the water would cool down quicker than if we were to use two or three cups, as this provides good insulation. The graph shows that the line for one polystyrene cup has a much steeper gradient than the line for 3 polystyrene cups. Therefore, my prediction for this experiment has been proved correct. Less heat was lost in 10 minutes as the number of polystyrene cups was increased.

Both the graph and table are good ways of finding out the results for this experiment. they both clearly show a pattern between the number of cups and the heat loss. From lookin at the graph we can clearly see that the water gets cooled down quicker uing just one cup than using three cups, just by looking at the gradient. The formulas on the table also show this, but using numbers instead of using visual content such as the graph.

Evaluation

I think that my experiment was very successful as I obtained results which proved my hypothesis. This experiment was very time consuming as several repeats were necessary. However, I think I done them as well as I could do them.

If I was able to spend more time on this experiment I would investigate further into factors which could affect the cooling of hot water such as the colour of the container, insulation like cotton wool and bubble wrap, and containers made of different materials such as glass and aluminium.

Undertaking this experiment outside instead of inside the science classroom would make a difference to the cooling of the water. As there would be more wind and a cold atmosphere, the speed that the water cools down would increase.

Bibliography

1. CGP revision guides
2. www.bbc.co.uk/schools/gcsebitesize