**U3a Physics: The physics of everyday things**

**The physics of cooking 3**

**Boiling kettle experiment**

A known volume (and therefore known mass) of water was put into the kettle and the time taken for it to boil was measured. This was then compared with the expected time calculated using this equation:

In this experiment, the heating is done electrically, so we need to know how to calculate the electrical energy supplied to the kettle.

Power (in watts) is defined as rate of change of energy i.e. power = energy /time

So the energy (in joules) can be calculated by energy = power x time

The heat energy supplied by an electric kettle of power P is equal to P x t, where t is the time (in seconds) for which the kettle is switched on.

So, **ΔQ** = Pt

Substituting into the equation **ΔQ = c m Δθ**

gives **Pt = c m Δθ**

This can be rearranged to give an expression for t:

**t = c m Δθ/P**

The initial temperature of the water was taken, and this was subtracted from 100°C to give a value for **Δθ.**

The density of water is 1kg/litre, and 1litre of water was placed in the kettle, so that the mass, **m**, of water used was 1kg.

The specific heat capacity, **c**, of water is 4200 J/kg°C

The power, **P**, of the kettle was 2500W

The initial temperature of the water was 16°C, so **Δθ** = 100 - 16 = 84°C

Substituting these values into the equation gives

t = 4200 x 1 x 84 ÷ 2500 s = 141 s = **2 min 21 s**

So, our calculation predicts that the water will take 2 min 21 s to come to the boil.

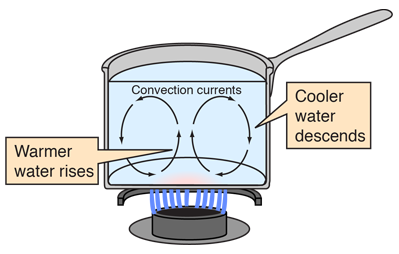
**Result**: **1 litre of water was placed in the kettle and the time taken for it to boil was found to be 2 minutes and 18 seconds.**

#### Thermal convection

Liquids and gases are fluids (because they can be made to flow). Heat energy can be transferred from one place to another by currents in the fluid.

Fluids expand when they are heated: the particles take up more space and so the warmer parts of the fluid become less dense than the cooler parts. The warmer fluid rises and the cooler fluid falls, creating a convection current, which transfers heat from place to place.

The diagram below shows convection currents within a pan of water being heated over a gas flame:



[Credit: <http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/heatra.html>]

**Radiation**

Heat can also be transferred by infrared radiation, which involves the transfer of energy via electromagnetic waves, and can happen even in a vacuum.

When a slice of bread, for example, is placed under a grill, it is warmed, and browned, because it absorbs radiation from the red-hot elements (or flames) of the grill.

Some surfaces are better than others at reflecting and absorbing **infrared radiation**.

| **Surface** | **Absorption** | **Emission** |
| --- | --- | --- |
| Dull, matt or rough | Good | Good |
| Shiny | Poor | Poor |

You can see that dull surfaces are good absorbers and emitters of infrared radiation. Shiny surfaces are poor absorbers and emitters (but they are good reflectors of infrared radiation). [Credit bbc bitesize].

**Microwave cookery**

Microwaves used in cooking have a wavelength of around 12 cm.

The microwaves are reflected within the metal interior of the oven where they are absorbed by food. Microwaves cause **water molecules in food** to vibrate, producing heat that cooks the food.

Microwave ovens are very energy-efficient – as the waves pass harmlessly through microwave-safe plastics, glass and ceramics energy is used only in heating the food, not the containers.

**Pressure Cookers**

The temperature at which a liquid boils is dependent on the surrounding pressure. At normal atmospheric pressure, water boils at 100°C, but the temperature at which water boils is higher when the pressure is raised. Inside a pressure cooker, as steam builds, the pressure increases, so that the food is heated above 100°C, and therefore cooks more quickly.

The same phenomenon explains why cooking at high altitudes can be tricky. Air pressure decreases as you move higher above sea level. At lower pressures, water boils at lower temperatures. This explains why you can’t make a decent cup of tea at the top of Mount Everest!