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

**The physics of cooking 2**

**Heat Transfer**

Heat energy can be transferred by **conduction**, **convection** or **radiation**.

**Conduction in solids**

The atoms/molecules of a solid are fixed in place but vibrate about their fixed positions. When part of a solid absorbs heat energy the atoms vibrate faster and with bigger amplitude. These vibrations pass from atom to atom as they bump into one another, transferring heat energy as they do so. This process happens in all solids when heated but is a slow process.



**Conduction in metals**

Metals contain free electrons. The metal atoms without their electrons are positively charged ions.

When the free electrons absorb heat energy, they move much faster (their kinetic energy increases).

As it moves through the metal, an electron may bump into an ion and some of its kinetic energy will be absorbed by the ion, which vibrates faster and with greater amplitude. In this way, the energy is passed along the piece of metal.

This process is very much faster than conduction caused by just passing vibrations from atom to atom. So, conduction in metals is faster than in non-metals.

**Insulators**

A good insulator is a poor conductor. Air is a very good insulator, so any material that contains trapped pockets of air would be a good insulator:

* Wool feels warm because it traps a lot of air
* The air trapped between layers of clothing helps keep us warm, so several thin layers of clothes are better than one thick layer.(String vests!)
* Double glazing: air is trapped between layers of glass
* Materials like polystyrene contain bubbles of air
* Animals are helped to keep warm by air trapped in their fur or feathers.
* Wood is a good insulator because it contains air pockets within its cellular structure.

**Implications for cooking**:

* Metal saucepans conduct heat to the food inside them more quickly than, for example, glass or pyrex pans (glass is not a good conductor of heat).
* A metal handle of a saucepan will become hot more quickly than a wooden or plastic handle.
* Plastic, rubber, wood, and ceramics are good insulators. These are often used to make kitchen utensils, such as saucepan handles, to stop heat from flowing up to burn the cook's hand.
* Baked Alaska: Meringue contains air, so it is a poor conductor of heat. Not enough heat is transferred to melt the ice cream in the time it takes for the meringue to cook.

 Different metals conduct heat at different rates. For example, copper is a better conductor than aluminium.

**Specific Heat capacity**

Like all forms of energy, heat is measured in joules (J).

Different substances need different amounts of energy to raise their temperature by the same amount.

* 1kg of liquid water needs 4200J to raise its temperature by 1°C
* 1kg of aluminium needs 880J to raise its temperature by 1°C

 These values are the **specific heat capacities** of the substances.

Some other examples of specific heat capacities are:

| **Material** | **Specific heat capacity (J/kg/°C)** |
| --- | --- |
| Brick | 840 |
| Copper | 385 |
| Lead | 129 |

Lead will warm up and cool down faster because it doesn’t take much energy to change its temperature. Brick will take much longer to heat up and cool down. This is why bricks are sometimes used in storage heaters as they stay warm for a long time. (credit bbc bitesize)

Definition: The **specific heat capacity** of a substance is the amount of energy (in J) needed to raise the temperature of 1kg of the substance by 1°C

The unit of specific heat capacity is J/kg°C (or J/kg K)

**Energy needed = specific heat capacity x mass x change in temperature**

Units: J J/kg°C kg °C (or K)

In symbols, this equation is:

 **ΔQ = c m Δθ**

This equation can also be used to calculate how much heat energy a substance loses when its temperature drops.

**Examples**

**1.** How much energy is needed to heat 100g of water from 10°C to 30°C?

Answer: Using the formula ΔQ = c m Δθ

 ΔQ = 4200 x 0.1 x 20 (100g = 0.1 kg)

 = **8400 J**

**2.** How much energy is lost by a 200g block of copper as it cools from 60°C to 10°C?

 ΔQ = c m Δθ

 ΔQ = 385 x 0.2 x 50 (200g = 0.2 kg)

 = **3850 J**

**3.** A 2kg block of iron is given 10kJ of energy and its temperature rises by 10°C. Calculate the specific heat capacity of iron

Rearranging the formula ΔQ = c m Δθ

 gives c = ΔQ/m Δθ

 so c = 10000 **÷** (2 x 10) (10 kJ = 10000 J)

 = **500 J/kg°C**

**Jam Tarts**

You may have noticed that, when eating a jam tart fresh from the oven, you are likely to burn your tongue on the jam, but the pastry, at exactly the same temperature, doesn’t have the same effect. This can be explained by the fact that jam has a higher specific heat capacity than pastry.

This means that, in a given interval of time, more heat is transferred to your tongue from the jam than from the pastry, and so the jam burns you while the pastry doesn’t.