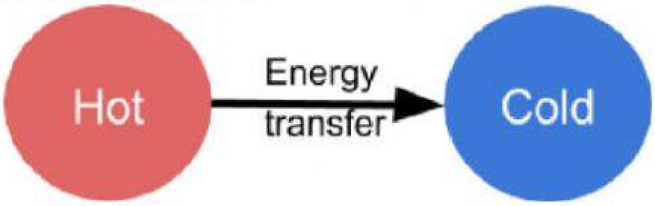
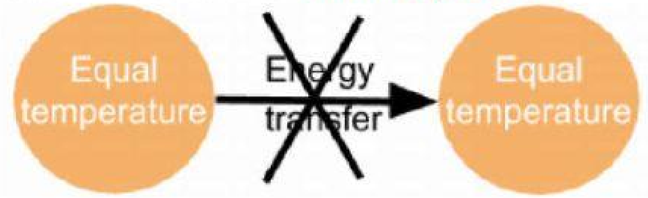
11 - Temperature (A-level only)

11.1 - Thermal Equilibrium

Thermal energy is always transferred **from an area of higher temperature to that of a lower temperature**, as shown in the diagram below.



Energy will be transferred between objects in thermal contact of different temperatures until they reach the **same** temperature. This is known as **thermal equilibrium**.



It is important to note that if object A is in thermal equilibrium with object B, and B is in thermal equilibrium with object C, then object A and C must also be in thermal equilibrium. This is known as the **zeroth law of thermodynamics**.

11.2 - Temperature Scales

Many **physical properties** vary with temperature, meaning they can be used to measure temperature. Below are some examples:

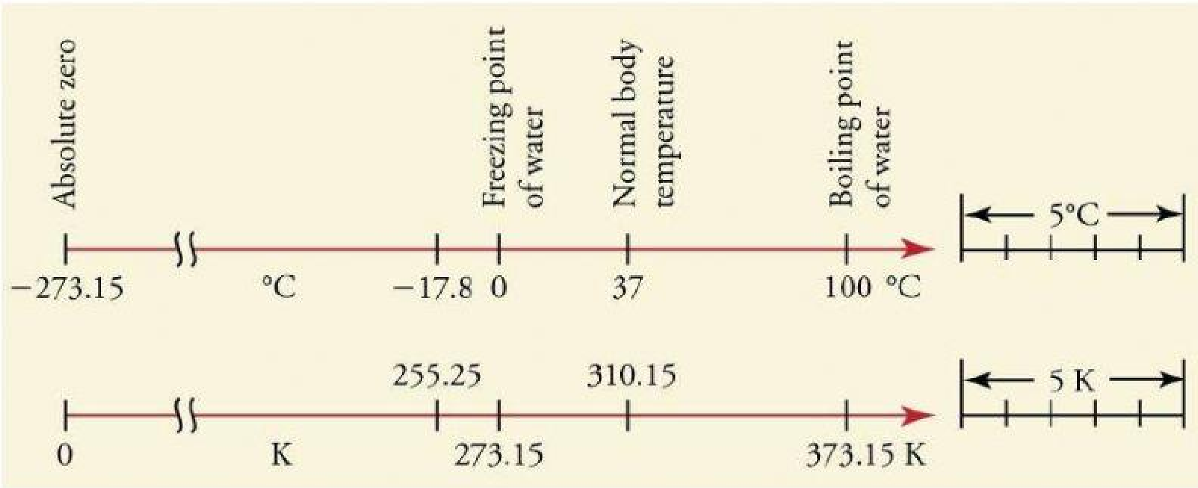
- Change in resistance of a metallic conductor or semiconductor (such as a thermistor)
- Voltage produced across a thermocouple
- Change in volume of a liquid
- Change in volume of a gas at constant pressure
- Change in pressure of a gas at constant volume

The **thermodynamic scale** or the **Kelvin scale** is an **absolute scale of temperature that does not depend on the property of any substance**, whereas the Celsius scale for instance, is dependent on the melting point (0° C) and boiling point (100° C) of pure water at atmospheric pressure.

The lowest possible temperature, **absolute zero**, is represented as 0 K on the Kelvin scale. This is the temperature at which particles have **no kinetic energy** and the **volume and pressure of a gas are zero**.

All equations in thermal physics will use temperature measured in kelvin (K). A change of 1 K is equal to a change of 1°C , and to convert between the two you can use the formula:

$K = C + 273.15$ Where K is the temperature in kelvin and C is the temperature in Celsius.



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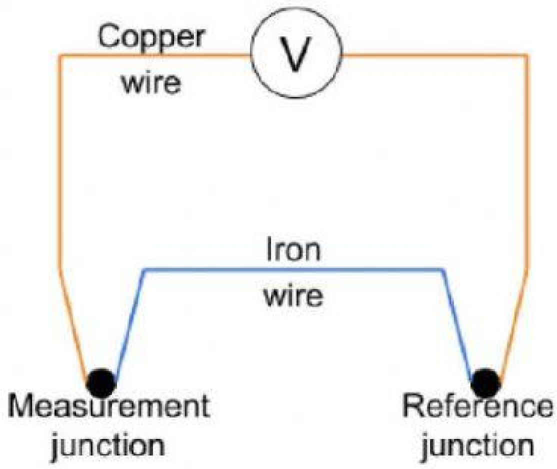
11.3 - Practical Thermometers

As shown above, many physical properties vary with temperature meaning many types of thermometers can be produced, each of which rely on a different property to measure temperature.

A **thermocouple** is a type of thermometer and its structure is shown to the right.

- The reference junction is kept at a constant temperature, whilst the measurement junction is used to measure an unknown temperature.
- If there is a temperature difference between the junctions **an emf is formed**, which is measured by the voltmeter.
- You can calculate the temperature from the recorded value of emf by using a **calibration curve**.



A **thermistor** is a semiconductor and its temperature decreases as its resistance increases. You can calculate the resistance of the thermistor and use a **calibration curve** to calculate temperature.

There are advantages and disadvantages to using a thermocouple and thermistor to measure temperature. These are summarised on the table on the next page.

Feature	Thermocouple	Thermistor
Sensitivity	Sensitivity is dependent on the choice of metals that make up the two types of wires (as shown above), therefore it can be made very sensitive.	Very sensitive but only over a narrow range of temperatures.
Range	Large	Narrow
Response time	Junctions are small so have a small thermal capacity so response time is small.	Are larger in size so have a larger thermal capacity so have a larger response time.
Stability	The wires forming the junctions of the thermocouple are subject to corrosion.	Are very stable and mostly unaffected by aging.
Ease of use	The reference junction must be kept at a constant temperature, usually through the use of ice water, which may make measurements awkward. However, for more modern thermocouples this is not true.	Much easier to use.