5.02 Temperature

Sun's centre	15 000 000 °C
Sun's surface	6000 °C
bulb filament	2500 °C
butane flame	1900 °C
boiling water	100 °C
human body	37 °C
warm room	20 °C
melting ice	0 °C
food in freezer	-18 °C
liquid oxygen	-180 °C
absolute zero	-273 °C

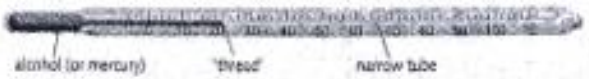
* Clinical thermometers like the one below measure the temperature of the human body very accurately. Their range is only a few degrees either side of the average body temperature of 37 °C. When removed from the body, they keep their reading until reset.

The Celsius scale

A **temperature scale** is a range of numbers for measuring the level of hotness. Everyday temperatures are normally measured on the **Celsius** scale (sometimes called the 'centigrade' scale). Its unit of temperature is the **degree Celsius** (°C). The numbers on the scale were specially chosen so that pure ice melts at 0 °C and pure water boils at 100 °C (under standard atmospheric pressure of 101 325 pascals). These are its two **fixed points**. Temperatures below 0 °C have negative (-) values.

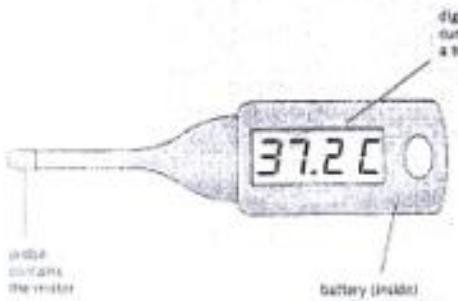
Thermometers

Temperature is measured using a **thermometer**. One simple type is shown below. The glass bulb contains a liquid – either mercury or coloured alcohol – which expands when the temperature rises and pushes a 'thread' of liquid further along the scale.

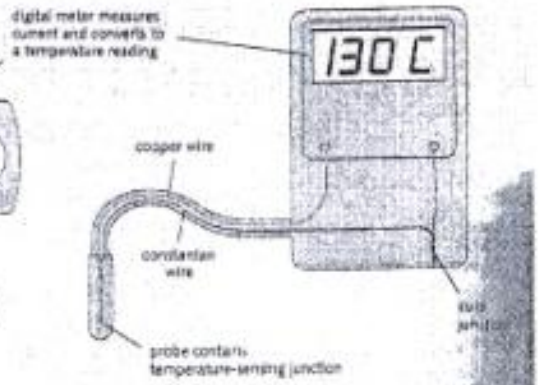


Every thermometer depends on some *property* (characteristic) of a material that varies with temperature. For example, the thermometer above contains a liquid whose volume increases with temperature. The two thermometers below use materials whose electrical properties vary with temperature.

All thermometers agree at the fixed points. However, at other temperatures, they may not agree exactly because their chosen properties may not vary with temperature in quite the same way.



Thermistor thermometer. The thermistor is a device which becomes a much better electrical conductor when its temperature rises. This means that a higher current flows from the battery, causing a higher reading on the meter.



Thermocouple thermometer. Two different metals are joined to form two junctions. A temperature difference between the junctions causes a tiny voltage which makes a current flow. The greater the temperature difference, the greater the current.

What is temperature?

In any object, the particles (atoms or molecules) are moving, so they have kinetic energy. They move at varying speeds, but the higher the temperature, then – on average – the faster they move.

If a hot object is placed in contact with a cold one, as on the right, there is a transfer of thermal energy from one to the other. As the hot object cools down, its particles lose kinetic energy. As the cold object heats up, it particles gain kinetic energy. When both objects reach the same temperature, the transfer of energy stops because the average kinetic energy per particle is the same in both.

Objects at the *same temperature* have the *same average kinetic energy per particle*. The higher the temperature, the greater the average kinetic energy per particle.

Temperature is not the same as heat. For example, a spoonful of boiling water has exactly the same temperature (100 °C) as a saucepanful of boiling water, but you could get far less thermal energy (heat) from it.

Absolute zero and the Kelvin scale

As the temperature falls, the particles in a material lose kinetic energy and move more and more slowly. At -273 °C, they can go no slower. This is the lowest temperature there is, and it called **absolute zero**. The rules of atomic physics do not allow particles to have zero energy, but at absolute zero, they would have the minimum energy possible.

In scientific work, temperatures are often measured using the **Kelvin scale**. Its temperature unit, the **kelvin** (**K**), is the same size as the degree Celsius, but the scale uses absolute zero as its zero (0 K). You convert from one scale to the other like this:

Kelvin temperature/K = Celsius temperature/°C + 273

	absolute zero	melting ice	boiling water
Celsius scale	-273 °C	0 °C	100 °C
Kelvin scale	0 K	273 K	373 K

The Kelvin scale is a thermodynamic scale. It is based on the average kinetic energy of particles, rather than on a property of a particular substance.

The constant volume hydrogen thermometer contains trapped hydrogen gas whose pressure increases with temperature. It gives the closest match to the thermodynamic scale and is used as a standard against which other thermometers are calibrated (marked).

1 -273 0 100 273 373

Say which of the above is the temperature of
a) boiling water in °C b) boiling water in K
c) absolute zero in °C d) absolute zero in K
e) melting ice in °C f) melting ice in K

2 Every thermometer depends on some property of a material that varies with temperature. What property is used in each of the following?
a) A mercury-in-glass thermometer.
b) A thermistor thermometer.

A lower temperature	B higher temperature

3 Blocks A and B above are identical apart from their temperature.
a) How does the motion of the particles in A compare with that in B?
b) In what direction is thermal energy transferred?
c) What does the transfer of thermal energy cause?

Related topics: kinetic energy 4.01 and 4.03, motion of particles in solids, liquids, and gases 5.01, Kelvin scale and particles in a gas 5.04, conduction in solids 5.09, thermistors 8.05 and 10.04