Temperature

Principles of Thermometry
Practical Thermometers

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Principles of Thermometry

Temperature determines the degree of hotness or coldness of a body; it shows the direction of flow of heat when placed in thermal contact. If no heat flows between two bodies, it implies that the bodies are at the same temperature, otherwise heat will flow from the hot body to the cold body. Heat stops flowing when the two bodies have reached the same temperature.

The unit of temperature if degree Celsius (^oC); however, the SI unit is Kelvin (K).

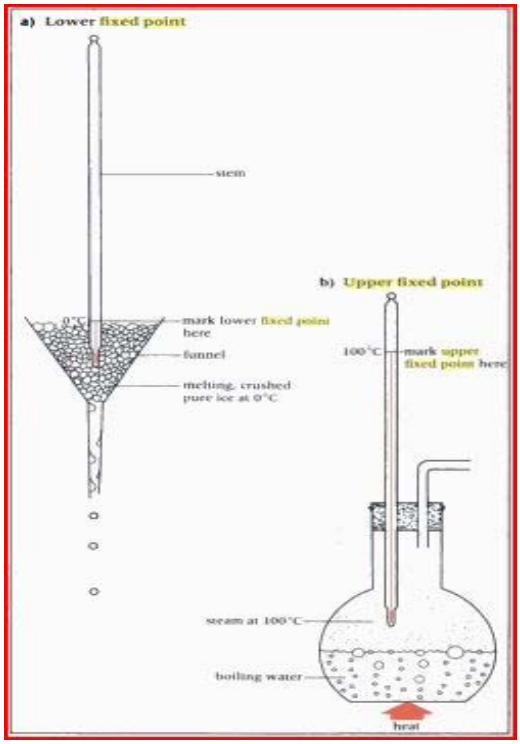
How to measure temperature? The device we used to measure temperature is called a thermometer. In the construction of a thermometer it is necessary that the substance used in the thermometer varies with temperature. All thermometers are based on the principle that some physical property (such as, volume, resistance, emf, etc) of a system changes with temperature. The thermometric substance used is anyone of the following: volume, resistance, electromotive force (emf).

The liquid-in-glass thermometer (mercury-in-glass thermometer)

In the construction of a liquid-in-glass thermometer, two fixed point are needed (in a similar way, in mathematics, you need two coordinates to draw a straight line). The two fixed points are:

- The lower fixed point or the ice point
- The upper fixed point or the steam point

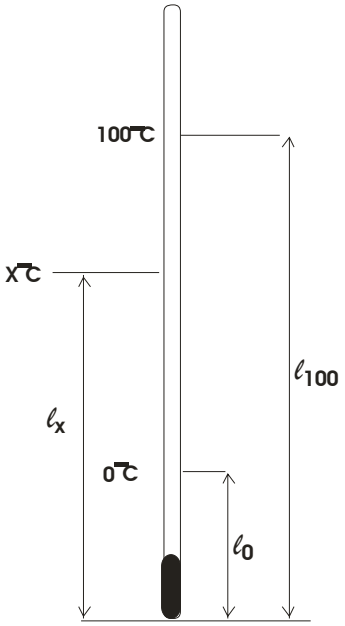
The Lower & Upper fixed points



(a) The non calibrated thermometer is immersed into the funnel containing pure melting ice. After sometime, the mercury will remain at a constant position; the thermometer is marked at this position. This is the lower fixed point and it is assigned a value of 0 ^oC.

(b) The non calibrated thermometer is now inserted into the vessel. The water is heated to boil and after sometime, the mercury will stay to a fixed position. The thermometer is marked; this is the upper fixed point and is assigned a value of 100 ^oC.

- *Task 1: Explain what is the purpose of the outlet in diagram (b)?*



Considering the lengths of the lower and upper fixed point to be l_o and l_{100} respectively, the following coordinates will be obtained:

Lower fixed point: (0, l_o)
Upper fixed point: (100, l_{100})

- *Task 2: Draw a graph of temperature against length.*

Now, the gradient of the graph will be:

$$gradient, m = \frac{l_{100} - l_o}{100 - 0}$$

Now, consider an unknown temperature X ^oC, with coordinate (x, l_x).

- ***Task 3**: Draw this coordinate on your graph*.

Since this coordinate lies on the same straight line, the gradient is the same.

Considering the following coordinates: (*0*, l_0) and (x, l_x), the gradient is:

$$gradient, m = \frac{l_x - l_o}{X - 0}$$

Equating the two equations:

$$\frac{l_{100} - l_o}{100 - 0} = \frac{l_x - l_o}{x - 0}$$

$$\frac{l_{100} - l_o}{100} = \frac{l_x - l_o}{x}$$

Therefore,

$$x = \frac{l_x - l_o}{l_{100} - l_o} 100\,^{\circ}C$$

This is an important formula that will allow you to determine an unknown temperature on the Celsius scale.

The mercury-in-glass thermometer

The mercury-in-glass thermometer consists of a glass tube in which there is a capillary tube attached to a bulb containing mercury.

Task 4: Draw a labelled diagram of a mercury-in-glass thermometer here.

Linearity of a Thermometer

As you have already seen, the formula $x = \frac{l_x - l_0}{l_{100} - l_0} 100^\circ C$ has been derived on the basis that the length of the mercury column varies linearly with temperature. That is, equal change in temeperature will bring about a similar change in the length of the mercury column. This is the case for liquids-in-glass thermometers.

Range of a Thermometer

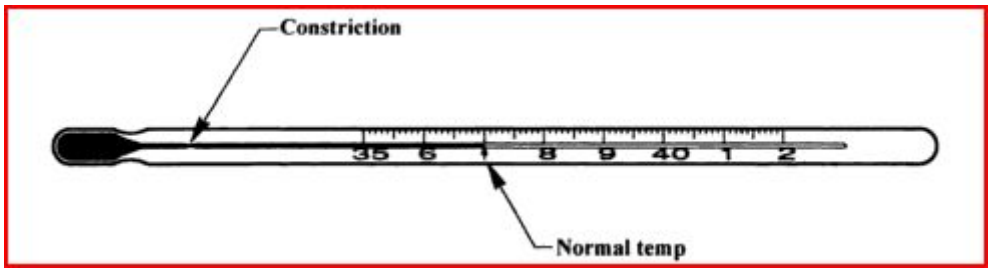
Range of a thermometer refers to the length of the stem. A thermometer with a long capillary tube or stem has a long range and therefore it will be able to measure larger value of temperature. A thermometer with range 0 - 50 ^oC has a smaller range than one with range 0 - 100 ^oC .

Sensitivity of a Thermometer

The sensitivity of a thermometer depends on the bulb size and the capillary bore. A large bulb contains more mercury and therefore expansion will be large. For a given temperature range, the sensitivity is increased by decreasing the capillary bore. Usually sensitivity is measured in mm/ ^oC. For example, a thermometer which has a sensitivity of 2 mm/ ^oC is less sensitive than one with sensitivity of 0.5 mm/ ^oC.

Clinical Thermometer

It is a thermometer used to measure the human body temperature.



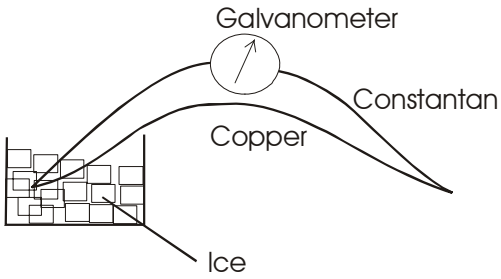
The thermometer has a constriction close to the bore that breaks the mercury column when the thermometer cools since it is removed from the patient's mouth. The mercury column can therefore not return to the bulb. Before the clinical thermometer is used again, it has to be shaken so that the mercury is restored back to the bulb. The normal body temperature is 37 ^oC.

The main requirements of a clinical thermometer are that it:

- responds quickly,
- is easy to read,
- maintains its reading after removal from the body,
- is reliable and accurate,
- is able to be cleaned and disinfected and
- is safe to use in the body.

Thermocouple

A thermocouple is a device used to measure temperature. It consists of two dissimilar metals, joined together at the two ends. When one of the two junctions is placed in melting ice (which acts as the reference point) while the other one is heated, a voltage or an emf is produced. The emf can be equated to temperature. One of the metals could be constantan whereas the other one could be copper.



Advantages of the thermocouple

- It is used to measure high temperature, up to 1750 ^{o}C.
- Since it have a minute junction, it can be used to measure the temperature of a small amount of liquid.
- It can measure rapidly varying temperatures.

SI Unit of Temperature

The SI unit of temperature is the Kelvin (K). To convert degree Celsius into Kelvin, the following formula is used:

$$T/K = 273 + t/^{o}C$$

The melting ice point of pure water is 0 ^{o}C or 273 K.

The steam point of water is 100 ^{o}C or 373 K.

Evaluation

(i) Complete tasks 1, 2, 3 & 4.

(ii) Do all the MCQ in the chapter Temperature with justifications.