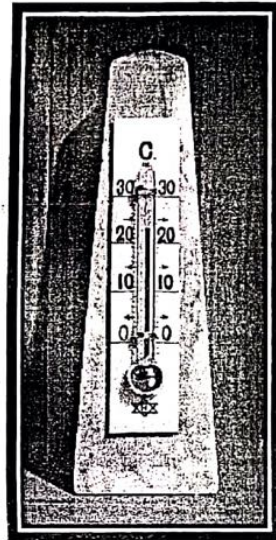


O Level Physics Syllabus Content for CAIE 2019-22 Exams

CHAPTER 9:

TEMPERATURE



Syllabus Content

- 10.1 Principles of thermometry
- 10.2 Practical thermometers

Learning outcomes

Candidates should be able to:

- (a) Explain how a physical property which varies with temperature may be used for the measurement of temperature and state examples of such properties.
- (b) Explain the need for fixed points and state what is meant by the ice point and steam point.
- (c) Discuss sensitivity, range and linearity of thermometers.
- (d) Describe the structure and action of liquid-in-glass thermometers (including clinical) and of a thermocouple thermometer, showing an appreciation of its use for measuring high temperatures and those which vary rapidly.
- (e) Describe and explain how the structure of a liquid-in-glass thermometer affects its sensitivity, range and linearity.

ABDUL HAKEEM

0300-4810136

O / AS & A Level Physics

# TEMPERATURE

## Definition

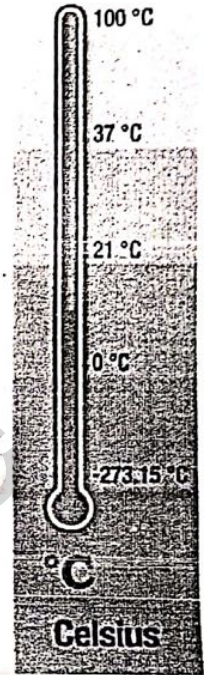
Temperature is the degree of hotness or coldness of an object. It is a measure of the average kinetic energy possessed by each molecule of the substance.

Physical quantity which changes with temperature is known as thermal property, i.e.

1. Length
2. Volume
3. Pressure
4. Resistance
5. Voltage / electro motive force

## Liquid-in-glass thermometers

The bulb of thermometer contains mercury (or coloured alcohol) which expands when the temperature rises and pushes a thread of liquid along the scale where the temperature can be read off.



## Temperature Scales

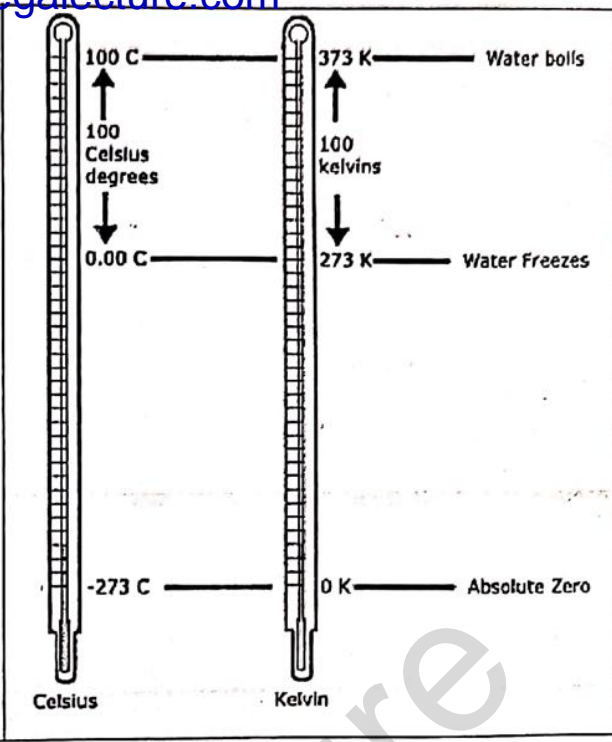
<p>(A) Two standard temperatures or fixed points are used:</p> <ol style="list-style-type: none"> <li>1. The lower fixed point is the temperature of pure melting ice. This is called <math>0^{\circ}\text{C}</math>.</li> <li>2. The upper fixed point is the temperature of steam above pure boiling water under standard atmospheric pressure. This is called <math>100^{\circ}\text{C}</math>.</li> <li>3. The space between the two fixed points is divided into 100 equal divisions or degrees of the Celsius Scale.</li> </ol>	<div style="text-align: center;"> </div> <p>Figures Calibrating a thermometer two fixed points are needed the space between them is portioned into equal divisions.</p>
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**(B) "Absolute Scale" or ""**

The lowest temperature in the universe is called "absolute zero". At this temperature, the molecules of a substance have the minimum possible energy. The absolute zero occurs at  $-273^{\circ}\text{C}$ .

The degrees on the absolute scale are called Kelvin and are exactly the same size as the Celsius degrees, i.e.  $1^{\circ}\text{C} = 1\text{K}$ .

The absolute temperature,  $T$ , is related to the Celsius temperature  $\theta$ , by

$$T (\text{K}) = \theta (^{\circ}\text{C}) + 273$$


**Properties of a Thermometer**

- The **sensitivity** is the ability of a thermometer to detect small changes in temperature. The sensitivity can be increased by:
  - Increasing the volume of the bulb, and
  - Decreasing the diameter of the tube (bore).
- The range of temperatures which can be measured by the thermometer: It is the difference between the highest and lowest values on the scale. The range can be increased by using smaller bulb and wider tube. (it is opposite to the sensitivity).
- Uniformity:** The expansion of liquid should be uniform at the different temperatures measured. The length of each degree on the scale has same value.

Megalecture  
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**Comparison between Mercury and Alcohol**

**ALCOHOL THERMOMETERS  
VERSUS  
MERCURY THERMOMETERS**

Alcohol thermometer is a type of thermometer that uses a bulb filled with alcohol as the temperature sensor	Mercury thermometer is a type of thermometer that uses a bulb filled with mercury as the temperature sensor
Liquid inside the bulb can be pure alcohol, toluene, kerosene, etc.	Liquid inside the bulb is mercury
Less toxic	Highly toxic
Suitable for measurement of low temperatures	Suitable for measurement of high temperatures
Used to measure temperatures from $-115^{\circ}\text{C}$ to $78.5^{\circ}\text{C}$	Used to measure temperatures from $-37$ to $356^{\circ}\text{C}$
Less durable because alcohol evaporates quickly	Highly durable because Mercury does not evaporate easily
Wall gets wet	Wall does not get wet
Alcohol is dyed since it is colorless	Mercury does not have to be dyed

**LABORATORY THERMOMETER  
VERSUS  
CLINICAL THERMOMETER**

Wider range as it is meant for various substances	Shorter range as it is only meant for the human body
Complex and accurate device	Simple device
Used in laboratories	Used at homes, hospitals, and clinics
Often used for liquid and gas substances	Only used for the human body
Mainly used in the scientific field	May be used by almost anybody
Its use of mercury is less dangerous	Its use of mercury is more actively discouraged
Usage depends on nature of research method	Usage relies on the condition of the patient and his suspected illness
Less accessible	More accessible

It is used to measure the temperature of the human body. It ranges from  $35^{\circ}\text{C}$  up to  $43^{\circ}\text{C}$ . It has a narrow constriction just above its bulb which stops the mercury thread from falling back into the bulb when the thermometer cools down.

The term 'sensitivity' refers to the ability of the thermometer to measure some changes in temperature. Hence a clinical thermometer is more sensitive to a laboratory thermometer. It also means that the marking of each degree is widely spaced.

'Responsiveness' refers to the time required for the thermometric substance (like mercury or alcohol) to reach the temperature of the surrounding. The shorter the time, the more responsive, it is. We say that a mercury in glass thermometer is more responsive than an alcohol thermometer as mercury is a better conductor of heat: all factors taken to be equal.

To increase range:

- (a) make the thermometer stem longer
- (b) make the bore (capillary) bigger
- (c) use a liquid with a lower expansivity

To increase sensitivity:

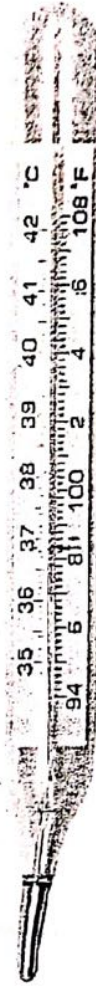
- (a) make the bore smaller
- (b) use a bigger bulb
- (c) use a liquid with a higher expansivity

To increase responsiveness:

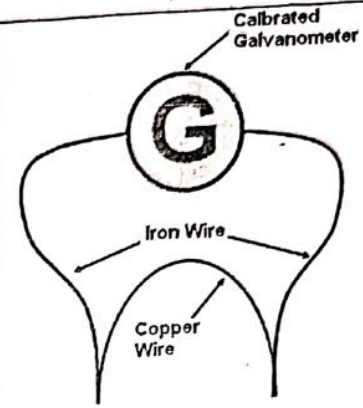
- (a) use a thin glass bulb
- (b) use a liquid that conducts heat better

### The thermocouple Thermometer

It is made by joining two different metals (e.g. copper & iron) in a circuit producing two junctions. One junction is placed in pure melting ice and the other junction is placed in the hot object. The temperature difference produces an electric voltage which deflects the galvanometer which is calibrated to temperature degrees.



<b>Thermocouple Thermometer</b>	
<p><b>Advantages</b></p> <ol style="list-style-type: none"> <li>1. simple, rugged</li> <li>2. high temperature operation</li> <li>3. low cost</li> <li>4. no resistance lead wire problems</li> <li>5. point temperature sensing</li> <li>6. fastest response to temperature</li> <li>7. It has a very large range (from <math>-200^{\circ}\text{C}</math> to <math>1500^{\circ}\text{C}</math>).</li> <li>8. It has a small thermal capacity and is used to measure rapidly changing temperatures.</li> </ol>	<p><b>Disadvantages</b></p> <ol style="list-style-type: none"> <li>1. Least stable, least repeatable</li> <li>2. Low sensitivity to small temperature changes</li> <li>3. Extension wire must be of the same thermocouple type</li> <li>4. Wire may pick up radiated electrical noise if not shielded</li> <li>5. Lowest accuracy</li> </ol>



**Precautions when reading a thermometer**

1. Mercury thread should be kept along the scale to avoid the error due to parallax.
2. Line of sight should be perpendicular to scale no. read.
3. Reading should be at the top of mercury thread.

**Alcohol-in-glass thermometers**

**Advantages of alcohol (ethanol):**

- It has a very large thermal expansion coefficient.
- Unharmful to humans and the environment (at least if you don't drink it!).
- Low freezing point ( $-115^{\circ}\text{C}$ ) makes it possible to measure very low temperatures.
- It's a bit cheaper than mercury.

**Disadvantages of alcohol (ethanol):**

- Impossible to measure high temperatures because of its low boiling point.
- It has a nonlinear expansion coefficient which results in a slide error on the measurement.
- Capillary separation (interrupted alcohol column).
- Alcohol is colourless, so dye (blue or red) must be added to make it visible.

The advantage of alcohol (ethanol) is that it has a very large thermal expansion coefficient. This results in a large change of the liquid column inside the capillary of the thermometer and contributes to the accuracy of the measurement.

## Mercury-in-glass thermometers

### Advantages of mercury:

- Mercury thermometers give accurate readings.
- Quick reaction to changes of temperatures because metal is a good heat conductor.
- Mercury has a very low saturation vapor pressure.
- Possible to measure higher temperatures as in cooking.
- Same expansion coefficient at all temperatures.
- The shiny silver color is easy to see.

### Disadvantages of mercury:

- Mercury is toxic, especially in a gaseous state.
- It's a bit more expensive than alcohol.
- Low thermal expansion coefficient.

*I guess the advantage of a very low saturation vapor pressure of mercury needs a little more explanation. So, if we consider a perfect thermometer, the volume above the liquid should be a vacuum. In reality however, this isn't the case. There will be always a small number of gas molecules present in the volume above the liquid. Since ethanol evaporates faster than mercury, more gas molecules will be present in that volume. This results in a pressure build-up above the liquid surface and a faulty indication of the thermometer.*

Mega Lecture

ABDUL HAKEEM