NEW LOWER SECONDARY CURRICULUM PHYSICS TOPIC: TEMPERATURE MEASUREMENT.

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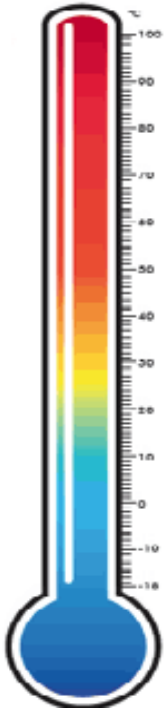
TEMPERATURE MEASUREMENT



100 °C Boiling Water

37 °C Body Temperature

8 °C Food Storage

5 °C Fridge Temperature

-18 °C Freezer Temperature

MAIN OBJECTIVES

***By the end of this chapter, you should be able to*:**

- understand the difference between heat and temperature.
- understand how temperature scales are established.
- calibrate a thermometer and use it to measure temperature.
- compare the qualities of thermometric liquids.
- describe causes and effects of the daily variations in atmospheric temperature.

KEY WORDS

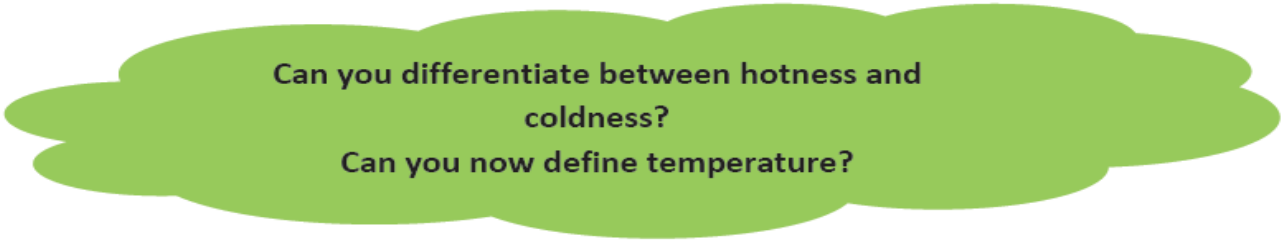
- Temperature
- Temperature scales
- Thermometric property
- Upper fixed temperature
- Lower fixed temperature
- Clinical thermometer
- Digital thermometer
- Conduction
- Radiation
- Convection
- Expansion
- Bimetallic strip
- Convection currents
- Durnal temperature changes

INTRODUCTION

In Chapter One, you learnt that physics deals with the study of matter and its relation with energy. One of the forms of energy is heat. Heat has different effects on matter. One of the effects is the change in temperature. In this chapter, you will learn how temperature is measured and how the environmental temperature changes with time.

HEAT AND TEMPERATURE

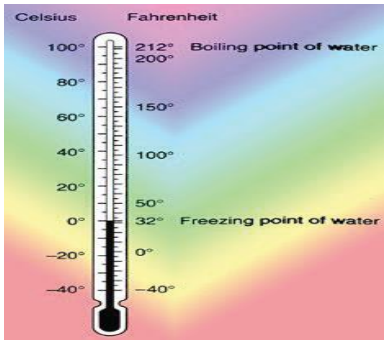
- **Heat** is a form of energy. When a body absorbs heat, it becomes hotter; and when an object loses heat, it becomes colder. Therefore, the amount of heat in a body influences the body's temperature.



- Have you heard statements like 'it is very cold today' or 'It is hot'? Do such statements make sense? How hot is hot, and how cold is cold? All these are related to the temperature of bodies.

TEMPERATURE

- **Temperature** – it is the degree of hotness of a body on some chosen scale. It is measured using a thermometer.



- The SI unit of temperature is the Kelvin (K). Other units include degrees Celsius (^{0}C), Fahrenheit, F. Temperature is a basic physical quantity as well as a scalar quantity.

MEASURING TEMPERATURE

- How good are you at estimating temperature? Can you estimate the temperature of:

1. a hot day?
2. a cup of hot tea?
3. warm bathwater?
4. normal human body temperature?

The following are some common temperature estimates:

- A comfortable temperature for working is 25°C.
- A cold morning is about 19°C to 21°C.
- A hot day is about 29°C.

THERMOMETER SCALES

- A temperature of $100℃$ is equivalent to $212°$For 373 K.
- From this illustration, it can be seen that the temperature of a body depends on the scale used.

Thermometer scales.

There are 3 thermometer scales commonly used

(i) Celsius / centigrade scale ($℃$)

(ii) Fahrenheit scale ($°F$)

(iii) Kelvin scale/ absolute (K)

- Relation between Celsius and Fahrenheit

CONVERSIONS

There are 3 thermometer scales commonly used have the following relation.

Relation between Celsius and Fahrenheit

$$°F = \frac{9}{5}°C + 32$$

Relationship between Celsius scale and Kelvin scale.

$$K = 273 + {}^{0}C$$

Where C is temperature in Celsius scale and K is temperature in Kelvin scale.

EXAMPLES

1. Convert each of the following from Celsius to Kelvin (Hint: use T(K)=θ(℃)+273.)

a) -20 ℃

T=-20+273=253K

b) 0 ℃

T=0+273=273K

c) 10 ℃

T=10+273=283K

d) -273 ℃

T=-273+273=0K

2. Convert each of the following from Kelvin to 0C (Hint: use θ(℃)=T(K)-273.)

a) 0K

θ=0-273= -273

b) 167K

θ=167-273=-106 ℃

c) 283K

θ=283-273=10℃

d) 3450K

θ=3450-273=3177

EXAMPLES

1. Convert each of the following from Celsius to Fahrenheit scale (Hint: use $°\mathrm{F} = \frac{9}{5}°\mathrm{C} + 32$*)*

a) *100℃*

b) *0℃*

c) *542℃*

d) *99℃*

2. Convert each of the following from Fahrenheit scale to Celsius(Hint: use $°\mathrm{F} = \frac{9}{5}°\mathrm{C} + 32$*)*

a) *212*°F

b) *614*°F

c) *32*°F

d) *614*°F

THERMOMETERS

- *A thermometer is an instrument used to measure temperature. There are many types of thermometers, each designed for a specific use.*
- The thermometer makes use of a physical property of a substance which changes continuously and uniformly with temperature. The physical property is referred to as thermometric property.

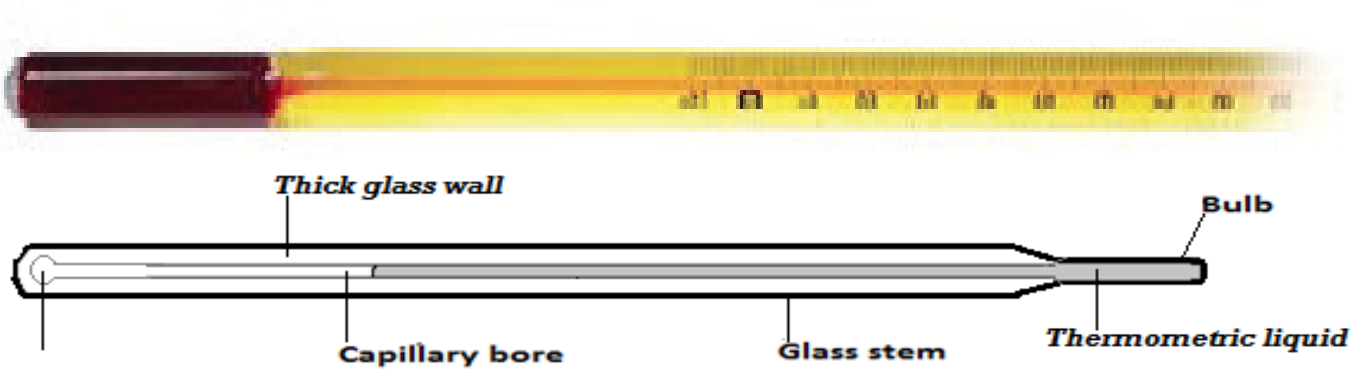
TYPES OF THERMOMETERS

Examples of thermometric properties

Thermometric property	*Type of thermometer*
Volume expansion of a liquid (length)	Liquid-in-glass thermometer
Volume expansion of a gas	Gas thermometer
Electrical resistance	Platinum Resistance thermometer
Electromotive force(E.M.F))	Thermocouple

A LIQUID-IN-GLASS THERMOMETER WORKS

- A liquid-in-glass thermometer consists of a tube with a bulb and a narrow capillary or bore. When the thermometer is put in a warm or hot substance, the liquid in the bulb expands forcing its way in the bore to a length that corresponds with the temperature of the substance.



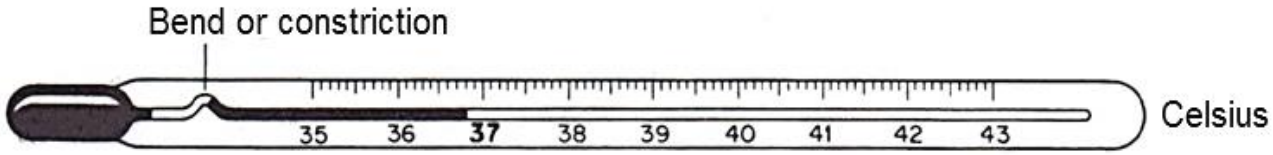
PARTS AND FUNCTIONS

Bulb:	It stores the liquid
Bore:	It gives the liquid a route of travel as it expands and contracts. It is very narrow to make the thermometer more sensitive and accurate.
Stem:	This surrounds the bore in the thermometer. It is also a magnifying glass to enable easy reading of temperature.
Expansion Chamber:	This provides space where gases and air inside the capillary collect as the liquid rises.

A thermometer is said to be sensitive if it can record very small temperature changes. The sensitivity of the thermometer can be increased by using a large bulb and a narrow capillary tube.

CLINICAL THERMOMETER

- This is the thermometer, doctors and nurses normally use in the hospitals to measure the temperature of the human body. It is a liquid-in-glass type of thermometer.



These thermometers are suitable for measuring body temperature because:

i) Mercury, which is used as the liquid, is very sensitive to temperature changes.

ii) the scale is limited between 35°C to 43°C, the only range needed for medical purposes.

iii) there is a constriction or bend which breaks the mercury column and prevents its backflow. This allows enough time for a reading to be taken.

DIGITAL THERMOMETERS

- Digital thermometers detect body temperature with simplicity. The display allows for easy reading of the detected temperature (oral, under arm and rectal). They are flexible and more comfortable to use.

- They emit a beep to indicate when the temperature measurement is complete and stores the last measurement taken for a short time.

DIGITAL THERMOMETERS

TEMPERATURE SCALES

To determine a temperature scale, fixed points are chosen. A fixed point is a well-defined temperature which can be used as a reference point in measuring other values of temperature. In the Celsius scale of temperature, there are two fixed points.

Lower fixed point:	This is the temperature of pure melting ice at standard atmospheric pressure.
Upper fixed point:	This is the temperature of steam from pure water boiling under standard atmospheric pressure.

ACTIVITY ; DETERMINING THE LOWER FIXED POINT

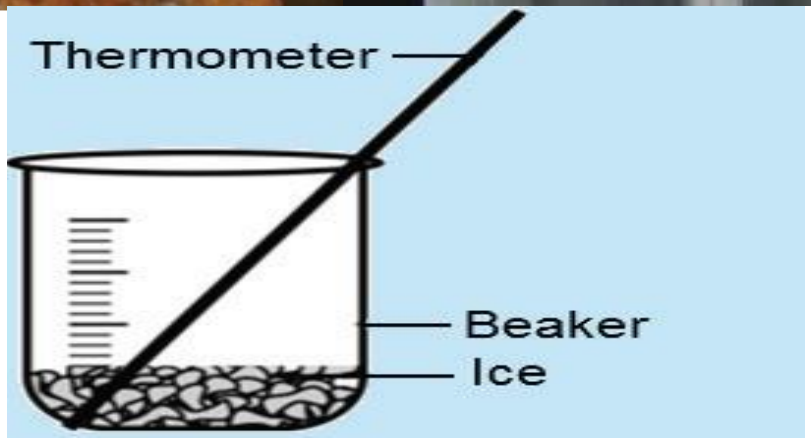
a) Fill a beaker with cracked ice as shown in When water begins forming from melting ice, place the bulb end of the thermometer well into the ice but leave the stem above the melting ice so that you can read and record the temperature of melting ice.

b) Gently stir for five minutes. What do you observe?

c) Read and record this observed temperature of the melting ice in data table.

d) Repeat the entire procedure for a second and third trial, while recording all results in the table.


20
10
0
-10


Thermometer
Beaker
Ice

RESULTS:

1st trail	2nd trail	3rd trail	Average

1. Are all the values in each of the three trials the same?

2. Is the lower fixed point of the thermometer accurate? If not, give a possible explanation for the difference.

ACTIVITY : DETERMINING THE UPPER FIXED POINT

a) Pour water in the beaker until it is half full. Put the beaker over a heat source as shown below and boil the water for some time.

b) When the water begins to boil vigorously, what do you observe about the mercury level in the thermometer?

c) Remove the thermometer from the water and hold it in the steam.

d) Read and record this observed temperature of the boiling point in the data table below, for three trials.

RESULTS:

1st trail	2nd trail	3rd trail	Average

1. Are all the values in each of the three trials the same?

2. Is the lower fixed point of the thermometer accurate? If not, give a possible explanation for the difference.

CALIBRATION OF THE THERMOMETER

Calibration refers to the process of graduating an instrument to give quantitative measurements that allow scientists to produce accurate readings. The following steps are taken to calibrate a thermometer:

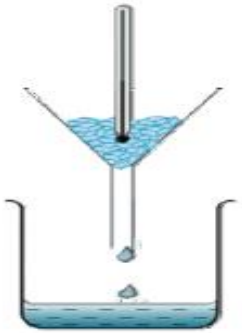
i) Determine the lower fixed point of the thermometer. Mark the point on the thermometer.

ii) Determine the upper fixed point of a thermometer. Mark the point on the thermometer.

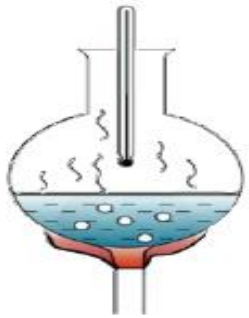
iii) Divide the difference between the two points into 100 equal points.

Mark the points as a scale along the stem either in Celsius scale or Kelvin or both.

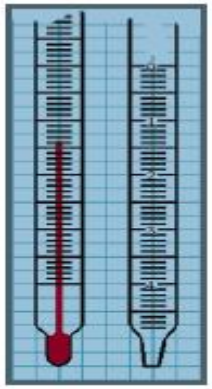
iv) Measure the temperature of various objects using your thermometer.



Freezing point of water (0°C)



Boiling point of water (100°C)



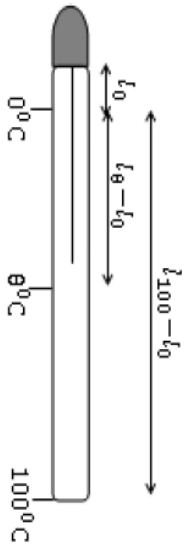
Make 100 divisions

- If l_0 is the length of the mercury thread above the bulb at melting ice, l_{100} is the length of the mercury thread of steam at 760 mmHg and l_θ is the length of mercury thread for the object being measured.
  - Then the required temperature θ°Cis given by $\theta =$

$$\left(\frac{l_\theta - l_o}{l_{100} - l_o}\right) \text{x } 100°\text{C}$$

OR

$$\theta = \left(\frac{X}{Y}\right) \text{x } 100°\text{C}$$



$X = l_{\theta - l_o}$ AND $Y = l_{100 - l_o}$

Y is called the fundamental interval

CALCULATIONS

1. A mercury thermometer is calibrated by immersing it in pure melting ice and then in steam above boiling pure water. If the mercury columns are at 6 cm and 16 cm marks respectively, find the temperature when the mercury column is 8 cm long.

6 cm corresponds to 0℃

16 cm corresponds to 100℃

8 cm corresponds to θ ℃

θ = ?

$\theta = (\frac{l_{\theta} - l_o}{l_{100} - l_o})$x 100℃

$\theta = (\frac{8-6}{16-6})$x 100℃

$\theta = (\frac{2}{10})$x 100℃

$$\theta = 20℃$$

2. In an un calibrated mercury thermometer, the length of the mercury thread above the bulb is 18mm at a temperature of melting ice and 138mm at a temperature of steam at 760mm Hg. When placed in a hot liquid the length of the mercury thread is 118mm. calculate the temperature of the liquid.(θ=83°C)

3. Find the unknown temperature θ given the following lengths of mercury.

-Length of steam = 25cm

-Length of ice point = 1cm

-Length of known temperature θ= 19cm (θ=75°C)

4. Find the temperature in °Cif the length of mercury thread is 7cm from the point and fundamental interval is 20cm. (θ=35°C)

1.The length of a mercury column of a thermometer at ice point and steam point are 2.0 cm and 22.0 cm respectively. What is the reading of the thermometer when the mercury column is 9.0 cm long?

- What will be the mercury length in the column at 60°C?

2. Study the table below and fill the gaps.

TEMPERATURE(°C)	TEMPERATURE(K)	TEMPERATURE(°F)
0		
		32
-32		
	350	
	370	
100	373	212

Note

1. The Celsius scale on a common laboratory thermometer ranges from 0 °C which is the freezing point of pure water to 100°C which is the boiling point of pure water. The interval between these two points is divided into 100 equal parts for which each part represents a change of 1 °C.

2. In the Kelvin or absolute scale, the freezing point of water is 273 K and the boiling point of water is 373 K. The Kelvin (K) is the S.I Unit of temperature.

THERMOMETRIC LIQUIDS

Liquids whose volumes vary continuously with temperature are called thermometric liquids and they are used to make good liquid thermometers.

Examples of thermometric liquids include mercury and alcohol.

Properties of a liquid that make it suitable for thermometer
(Qualities of a good thermometric liquid).

It should be opaque so as to be readily seen.

It's expansion should be regular, i.e. expansion per degree should be the same at different point on the temperature scale.

It should have high boiling point and low melting point so that both high and low temperature can be measured.

It should be able to expand so much for a small temperature change.

It should be a good conductor so that it responds rapidly to the temperature change.

It must not stick to the inside of the tube.

Must not be poisonous.

The most commonly used liquid is mercury although coloured alcohol can also be used. Water does not meet all the above desirable properties

TABLE 5.4: COMPARING THERMOMETRIC LIQUIDS

MERCURY	ALCOHOL
It is opaque and makes reading easy.	It is coulorless and makes reading difficult. It needs coloring.
It expands regularly.	It has a somewhat irregular expansion
It has a high boiling point, 357 ^{o}C.	It boils at 78 ^{o}C .
It freezes at -39 ^{o}C.	It freezes at -115 ^{o}C .
It has a lower expansivity than alcohol.	It has a higher expansivity than that of mercury.

EASY EXERCISE FOR GOOD READERS

1. State reasons why mercury is usually preferred to alcohol as a thermometric liquid.
2. What are the advantages of alcohol over mercury as a thermometric liquid?
3. Suggest reasons why water is never used as a thermometric liquid although it is fairly abundant.

VARIATIONS IN DAILY AND ATMOSPHERIC TEMPERATURE

- Have you ever wondered why it is normally colder at night than during the day? The difference between the temperature of the day and of the night is called **diurnal change in temperature.**
- *The change in temperature from day to night is brought about by the* daily rotation of the earth. The earth receives heat during the day by solar radiation, but continually loses heat by surface radiation. Warming and cooling depend on an imbalance of solar and surface radiation. During the day, solar radiation exceeds surface radiation and the surface becomes warmer.

At night, solar radiation ceases, but surface radiation continues and cools the surface. Cooling continues after sunrise until solar radiation again exceeds terrestrial radiation. Minimum temperature usually occurs after sunrise, sometimes as much as one hour after. The continued cooling after sunrise is one reason why fog sometimes forms shortly after the sun is above the horizon.

Atmospheric temperature is a measure of temperature at different levels of the earth's atmosphere. It is governed by many factors , including incoming solar radiation, humidity and altitude. The amount of solar energy received by any region varies with seasons, latitude and time of day. These differences in solar energy create temperature variations. Temperatures also vary with differences in relief and altitude.

The amount of ground-level atmospheric temperature ranges depends on several factors, such as:

- Average temperature
- Average humidity
- Regime of winds
- Proximity to large bodies of water, such as the sea It is hotter near the earth's surface because heat from the earth warms this air. As the altitude increases the number of air molecules decreases, thus the average of their kinetic energy decreases. However, temperature increases with altitude above a certain height because of increasing amounts of ozone

ACTIVITY OF INTEGRATION

The daily activities of school are being affected by the weather variation, especially temperature. as a physics student you have been tasked to prepare a temperature chart and the message about how the chart will be useful