TEMPERATURE

Principles of thermometry

Practical thermometers

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Principles of thermometry

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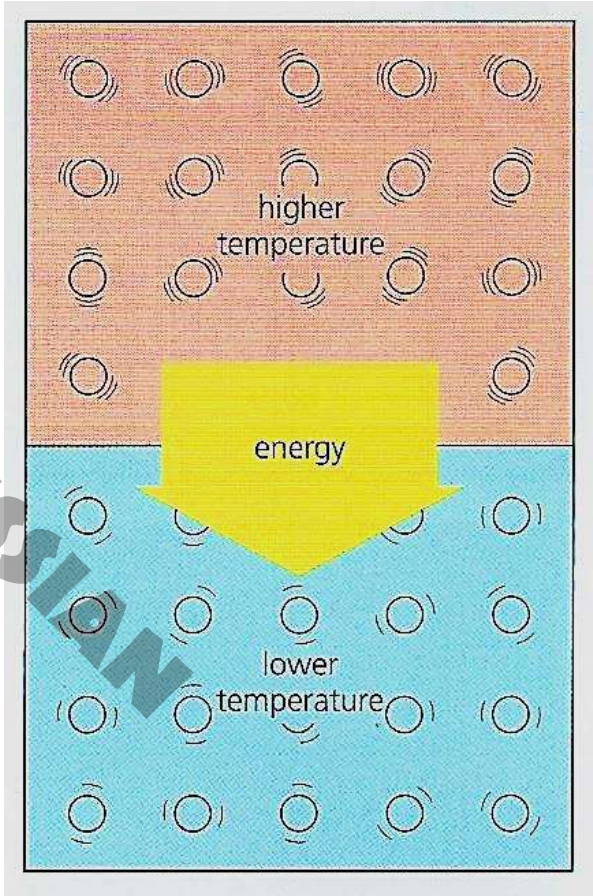
- Explain how a physical property which varies with temperature may be used for the measurement of temperature and state examples of such properties.
- Explain the need for fixed points and state what is meant by the ice point and steam point.

WHAT IS TEMPERATURE?

- The temperature of an object is a measure of the **average kinetic energy** of its particle.
- If a hot object is placed in contact with a cold one, there is a transfer of thermal energy from one to the other.
- When both objects reach the same temperature, the transfer of energy stops because the average per particle is the same in both.



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PRINCIPLES OF THERMOMETRY

- A **thermometer** is any instrument which is used to measure temperature.
- The thermometer needs a scale to be used effectively.
- There are several types of thermometers.
- The choice of which to use is depend on
  - the range of temperature to be measured,
  - the accuracy required, and
  - the physical conditions in which the thermometer will be used.

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Physical Properties	Thermometer
Volume of a fixed mass of liquid	Liquid-in-glass thermometer
Electrical resistance of a metal wire	Resistance thermometer
Electromotive force (e.m.f.)	Thermocouple
Pressure of a fixed mass of gas at constant volume	Constant volume gas thermometer

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- **Step 1: Choose a physical property** which changes continuously with temperature.

Physical Properties
Volume of a fixed mass of liquid
Electrical resistance of a metal wire
Electromotive force (e.m.f.)
Pressure of a fixed mass of gas at constant volume

- **Step 2: Choose two fixed points.** The upper fixed point and lower fixed point
- **Step 3: Divide the temperature between two fixed points** into many equal divisions.

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CONSTRUCTING LIQUID IN GLASS THERMOMETER

1. Selection of the tube - the smaller the bore (capillary tube), the greater will be the sensitiveness of the thermometer

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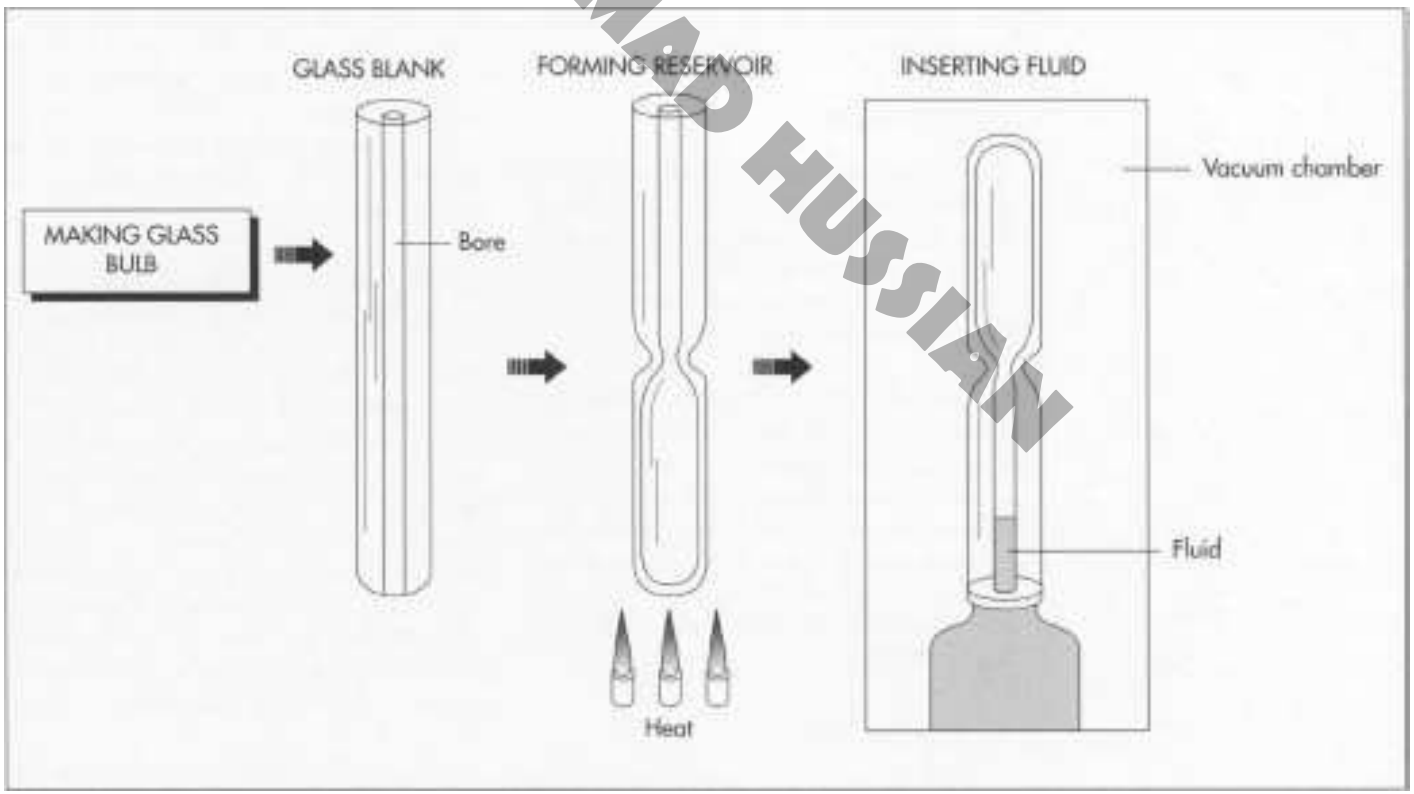

2. Determination of the Fixed Points - thermometric scale that correspond to the melting of pure ice in distilled water, and the boiling point of water at standard atmospheric pressure.

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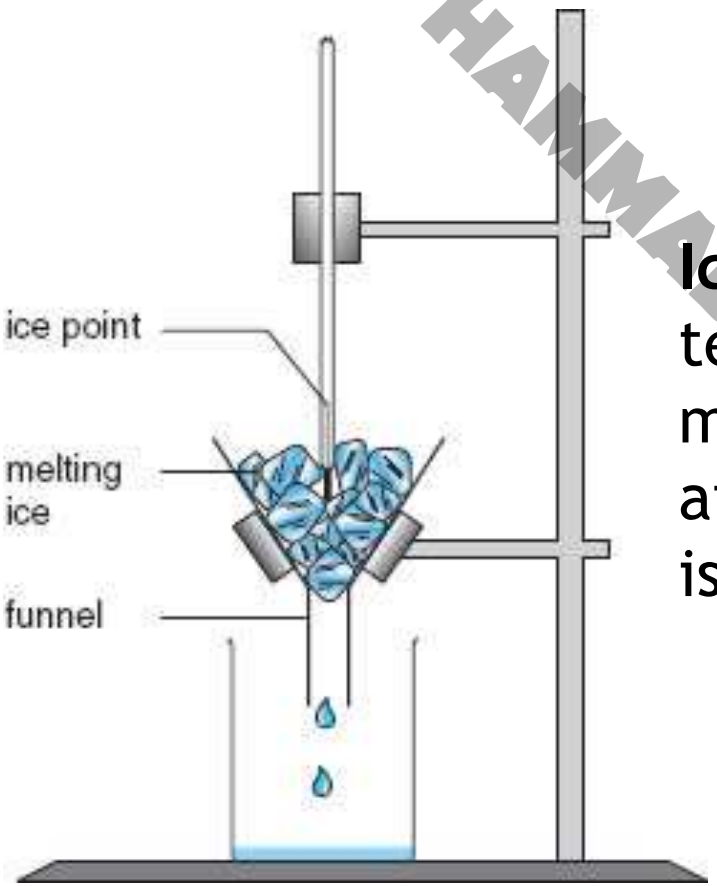

Ice point is the temperature of pure melting ice at standard atmospheric pressure, and is assigned a value of 0 °C.

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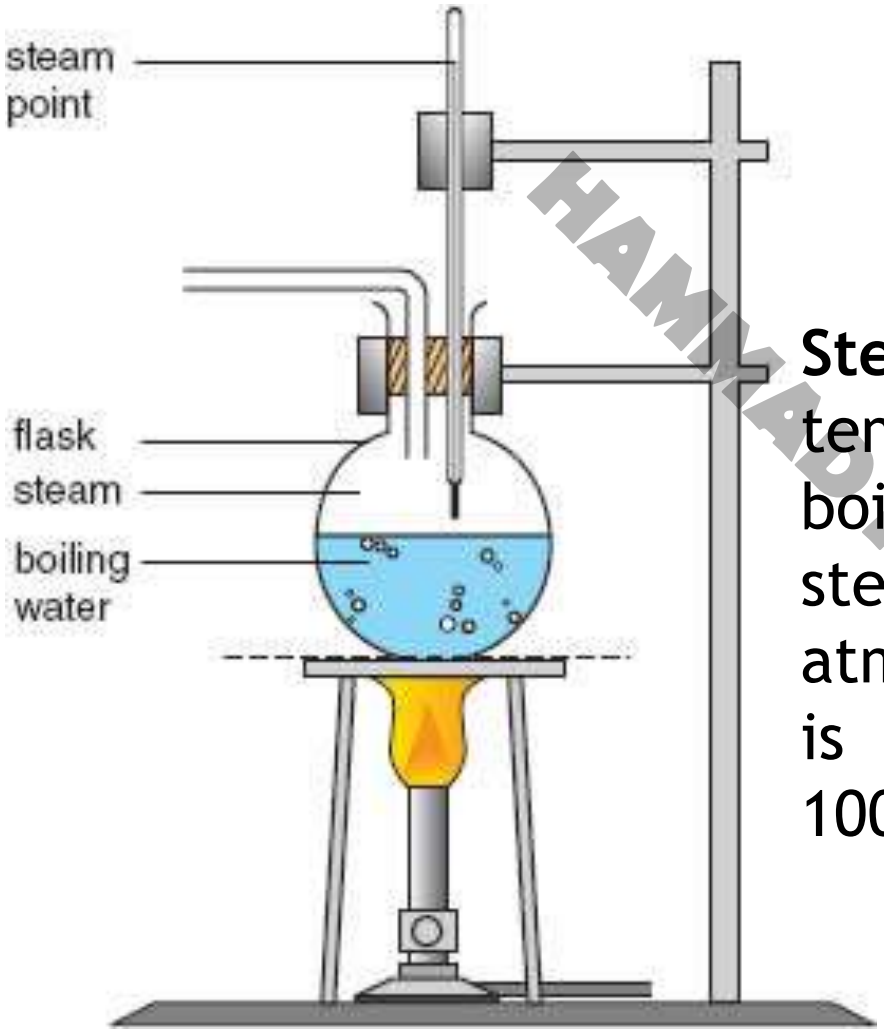

Steam point is the temperature at which boiling water changes into steam at standard atmospheric pressure, and is assigned a value of 100°C.

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3. On the **Celsius scale**, the interval between the ice point and the steam point is divided into 100 equal divisions for easy reading. Each division is equal to one degree Celsius (°C).

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- If the two fixed points are marked, intermediate temperatures can be calculated.

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- If the lengths of mercury thread at ice point (0 °C), at steam point (100 °C) and when immersed in a liquid of unknown temperature θ are l_0, l_{100} and l_θ respectively, the temperature θ can be calculated as follows:

$$\theta = \frac{l_\theta - l_0}{l_{100} - l_0} \times 100°\text{C}$$

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- The equation can be modified when the thermometer uses other physical properties. For a resistance thermometer, the equation can be written as

$$\theta = \frac{R_\theta - R_0}{R_{100} - R_0} \times 100°\text{C}$$

  - R_0 is the resistance of platinum wire at ice point (0 °C),
  - R_{100} is the resistance of platinum wire at steam point (100 °C)
  - R_θ is the resistance of platinum wire at an unknown temperature (θ °C)

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EXAMPLE 1

1. The bulb of mercury-in-glass thermometer is placed in turn in melting ice, in steam and in a liquid X. The lengths of the mercury thread above the bulb are 20 mm, 170 mm and 50 mm respectively. What is the temperature of X?
2. The length of the mercury thread in a thermometer is 20 mm when it is in pure melting ice and 180 mm when it is in steam above boiling water. When the thermometer is placed in a liquid, the length of the mercury thread is 68 mm. What is the temperature of the liquid?

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3. In an unmarked mercury thermometer, it was found experimentally that the length l_0 was 5 cm and the length l_{100} was 25 cm. What is the temperature when l_θ is (i) 14 cm, (ii) 3 cm?
4. The length of the mercury column in a non-calibrated mercury thermometer is 2 cm when its bulb is immerse in melting ice and 20 cm when the bulb is in steam above boiling water. What would the temperature be if the length of the mercury column is 11 cm?
5. An uncalibrated thermometer is attached to a centimetre scale and reads 5.0 cm in pure melting ice and 30.0 cm in steam. When the thermometer is immersed in the liquid y, the length of the mercury column is 15.0 cm. What is temperature of liquid y?

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Practical thermometers

- Discuss sensitivity, range and linearity of thermometers.

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THERMOMETRIC PROPERTIES

- Some materials have properties that changes with temperature:
  - Liquids can expand if the temperature increases, or contract if it decreases;
  - Metals and alloys also expand and contract if the temperature changes;
  - Some substances change their colours when the temperature increases
  - Some substances change their electrical conductivity when its temperature rises

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- In understanding the features of the thermometer a few consideration should be taken:
  - Responsiveness – It refers to how fast the thermometer can respond to the temperature changes and register the new reading.
    - the larger the bulb, the less responsive it is, since there is more liquid in the larger bulb.
    - the bulb wall are usually made to be thin so that conduction of heat energy can occur as quickly as possible.

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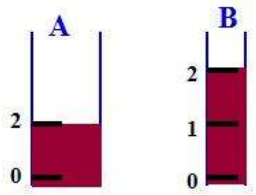

- Sensitivity – this measure the amount of change in thermometric property per unit change in temperature.
  - a thermometer with a thicker bore will be less sensitive since the change in length of the thermometric liquid is lesser.
- Range – refers to scope of temperature it can measure.
  - the longer the length of the stem, the larger the range of the thermometer
- Linearity – is the uniform expansion of the liquid to temperature which give the reading.
  - mercury expand at a steady rate as it is heated.

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Practical thermometers

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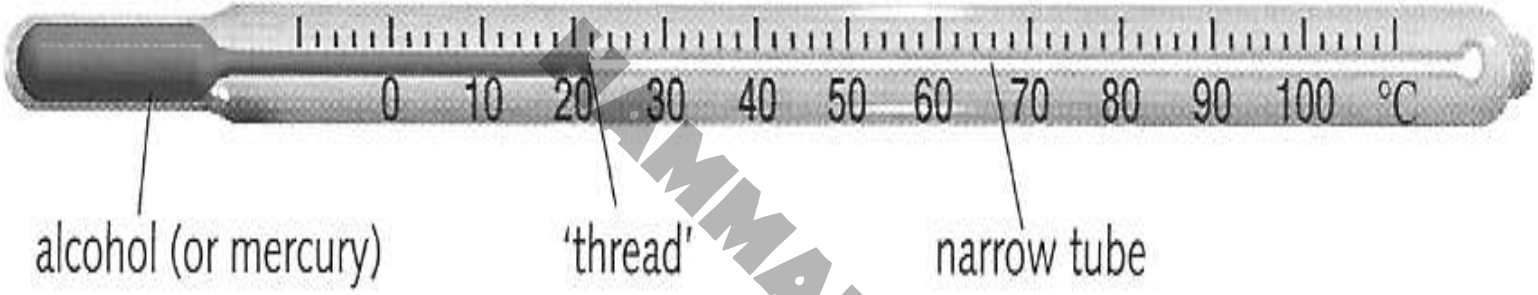
- Describe the structure and action of liquid-in-glass thermometers (including clinical) and of a thermocouple thermometer, showing an appreciation of its use for measuring high temperatures and those which vary rapidly.

LIQUID-IN-GLASS THERMOMETER



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- It is made by filling the glass bulb and the capillary tube with mercury or alcohol.
- After heating to drive out all the air, the capillary tube is then sealed.
- As the liquid cools and contracts, the space above it in the capillary becomes practically a vacuum.

Thin-wall glass bulb	• To allows conduction of heat quickly through glass to the liquid
Small bulb	• Small amount of liquid responds more quickly to a change in temperature
Fine and uniform bore	• To allow noticeable movement of liquid • To ensures even expansion of liquid
Thick-wall tube	• Act as magnifying glass for easy reading
Smaller size	• More portable and cheap to produce

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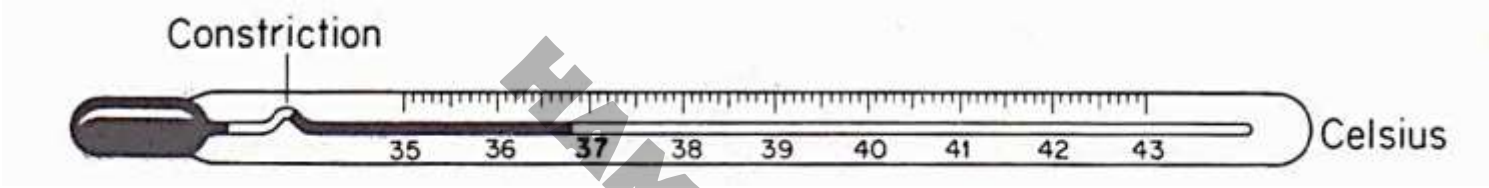
CLINICAL THERMOMETER



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- It is smaller in size than the laboratory thermometer.
- It has a constriction in the fine capillary tube. This prevents the mercury from contracting and flowing back when it is removed from human body (temperature of surroundings being lower).
- The scale ranges between 35°C to 43°C. This enables the scale to be divided into smaller intervals for greater accuracy

CLINICAL THERMOMETER

Thin-wall glass bulb	• To allows conduction of heat quickly through glass to the liquid
Very fine bore capillary	• Large change in length for small change in temperature
Small range	• For greater accuracy • Stem can be made short
Narrow constriction	• Prevents contracting mercury from flowing back into the bulb
Pear-shape stem	• Act as magnifying glass

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THERMOCOUPLE THERMOMETER

- A **thermocouple** consists of two wires of different metals joined together at the ends to form two junctions.

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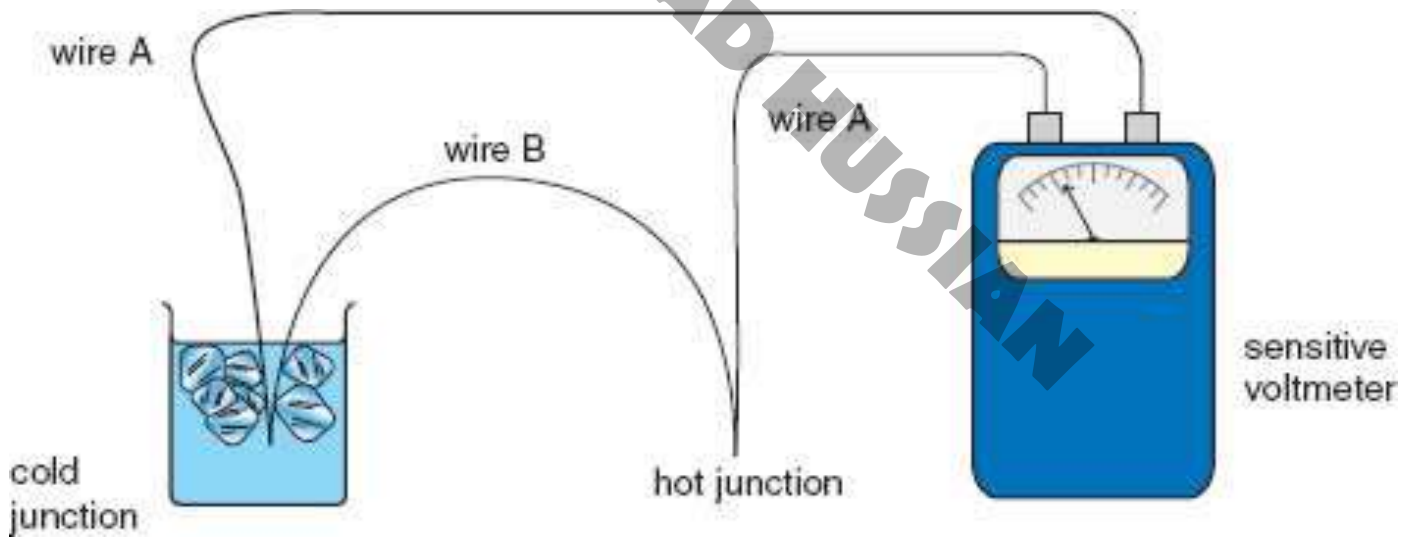

- If the junctions are at different temperatures, a small electromotive forces or e.m.f. (voltage) is produced.
- The larger the temperature difference, the larger is the e.m.f. produced.
- The temperature range over which a thermocouple operates depends on the two metals used for wires (e.g. copper and constantan).

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- Advantages of a thermocouple
  - Thermocouple can operate over a very **wide range of temperatures** from −200 °C to 1700 °C. It can be used to measure high temperature.
  - As the wire junctions are very small, the thermocouple can be used to **measure the temperature at a point.**
  - Due to small mass and small thermal capacity of the thermojunctions, the thermocouple can be used to **measure temperatures that change rapidly.**

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1. To calibrate a thermometer, without using another thermometer, fixed points are required.

   Which statement is correct?

   A. Any temperatures can be used as fixed points.
   B. Both a lower fixed point and an upper fixed point are required.
   C. Only a lower fixed point is required.
   D. Only an upper fixed point is required.

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2. To mark a temperature scale on a thermometer, fixed points are needed.

   Which is a fixed point?

   A. the bottom end of the thermometer tube
   B. the top end of the thermometer tube
   C. the temperature of pure melting ice
   D. the temperature of pure warm water

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3. To mark a temperature scale on a thermometer, standard temperatures known as fixed points are needed.

   Which of these is a fixed point?

   A. room temperature
   B. the temperature inside a freezer
   C. the temperature of pure melting ice
   D. the temperature of pure warm water

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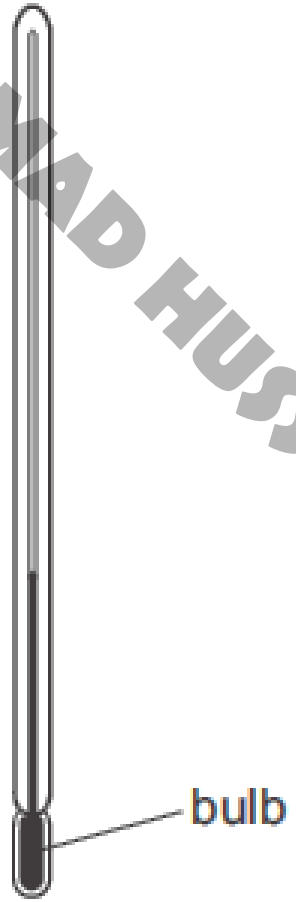
4. The thermometer in the diagram has no scale.



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Where must the bulb be placed so that 0 °C can be marked on the stem?

A. in boiling water
B. in cold water
C. in a freezer
D. in melting ice

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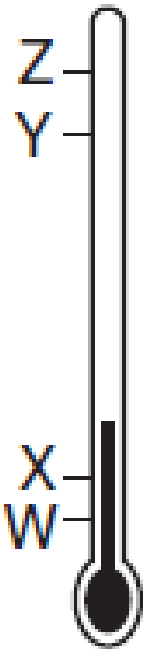
5. The top of the mercury thread in a mercury-in-glass thermometer reaches point X at 0 °C and point Z at 100 °C.



Where might it be at a temperature below the ice-point?

A. point W
B. point X
C. point Y
D. point Z

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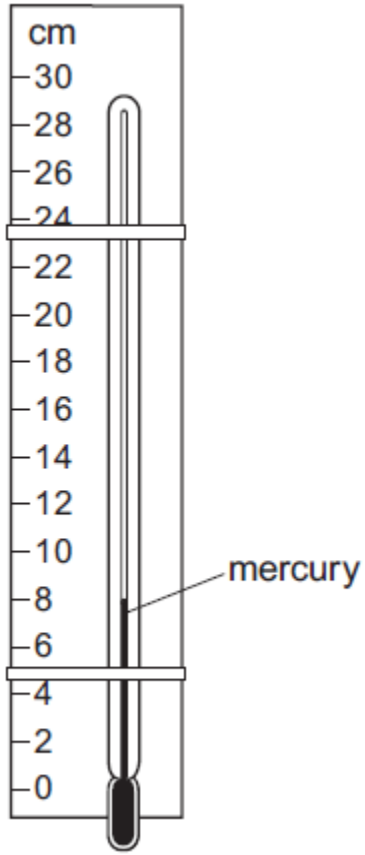
6. A thermometer with no scale is taped to a ruler as shown. When placed in steam, the mercury level rises to 22 cm. When placed in pure melting ice, the mercury level falls to 2 cm.

   Which temperature is shown by the mercury level in the diagram?

   A. 6 °C
   B. 8 °C
   C. 30 °C
   D. 40 °C



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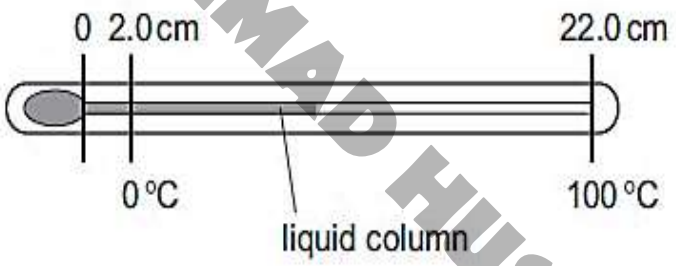
7. The diagram shows a liquid-in-glass thermometer.



At 0 °C, the length of the liquid column is 2.0 cm. At 100 °C, the length of the liquid column is 22.0 cm.

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What is the length of the liquid column at 40 °C?

A. 6.0 cm
B. 8.0 cm
C. 8.8 cm
D. 10.0 cm

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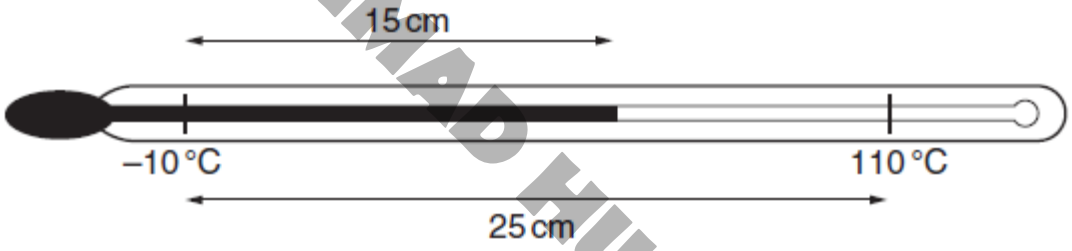
8. The diagram shows a mercury-in-glass thermometer. The distance between the –10 °C and the 110 °C markings is 25 cm.



At which temperature is the end of the mercury thread 15 cm from the –10 °C mark?

A. 50 °C
B. 60 °C
C. 62 °C
D. 72 °C

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9. The sensitivity of a liquid-in-glass thermometer depends on the volume of liquid used and the diameter of the bore of the thermometer.

Which changes will produce the greatest increase in sensitivity?

	volume of liquid	bore diameter
A	decrease	decrease
B	decrease	increase
C	increase	decrease
D	increase	increase

C

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10. What makes a thermometer sensitive to small changes in temperature?
    A. a bulb with a thin glass wall
    B. a shiny liquid in its bore
    C. a stem with a thick glass wall
    D. a very narrow bore

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11. A new liquid is tested to decide whether it is suitable for use in a liquid-in-glass thermometer.

    It is found that the liquid does not expand uniformly with temperature.

    What will be the effect of this on the scale of the thermometer?

    A. It has a short range.
    B. It is not linear.
    C. The markings are too close together.
    D. The markings are too far apart.

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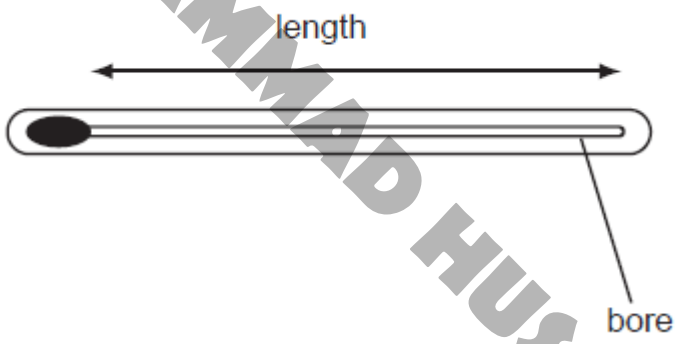
12. Four mercury-in-glass thermometers are made with different dimensions.



Which will have the greatest sensitivity?

A. 10 cm long and bore 0.75 mm wide
B. 15 cm long and bore 0.50 mm wide
C. 25 cm long and bore 0.10 mm wide
D. 30 cm long and bore 0.25 mm wide

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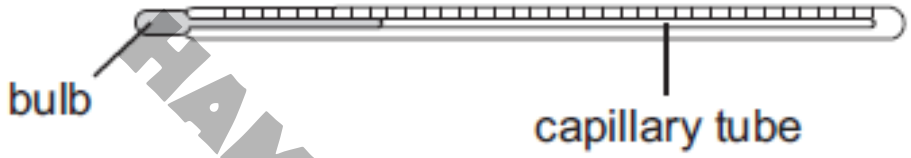
13. A liquid-in-glass thermometer consists of a bulb containing a liquid. The liquid can expand into a very thin capillary tube.



The liquid in the thermometer is replaced by another liquid that expands more for the same temperature rise.

The new thermometer will have

A. greater sensitivity and greater range.
B. greater sensitivity but less range.
C. the same sensitivity and the same range.
D. the same sensitivity but greater range.

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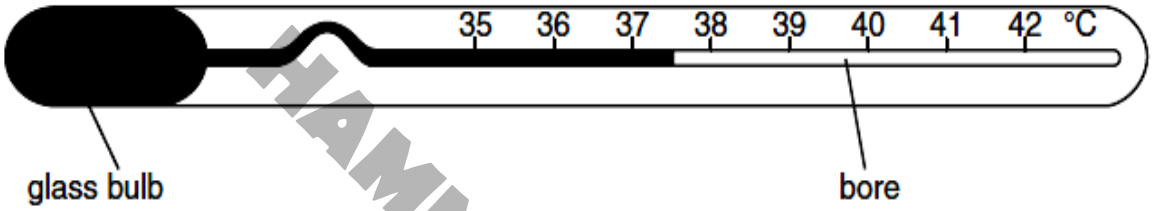
14. A clinical thermometer is designed to respond quickly to a change in temperature and to have a high sensitivity.



Which design features should the clinical thermometer have?

	bulb	bore
A	thick glass	narrow
B	thick glass	wide
C	thin glass	narrow
D	thin glass	wide

C

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15. A thermocouple thermometer uses a voltmeter to measure the e.m.f. generated between two junctions. The junctions are at temperatures t_1 and t_2. To calibrate the thermometer, fixed points are needed.

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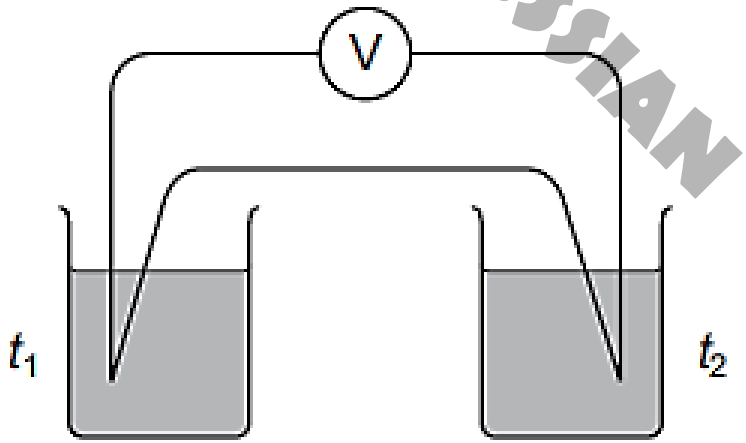

What are the values of t_1 and t_2 when the thermometer is calibrated at the steam point?

	t_1	t_2
A	0 °C	0 °C
B	0 °C	100 °C
C	25 °C	0 °C
D	25 °C	125 °C

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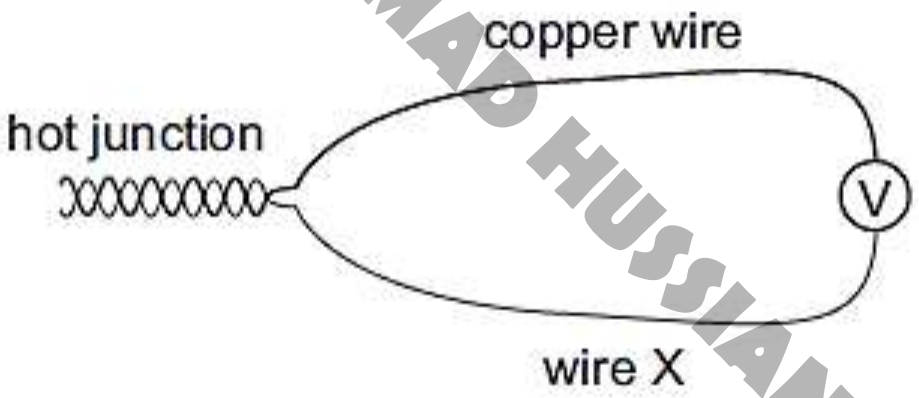
B

16. A thermocouple thermometer is made from two wires connected to a voltmeter.



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Which arrangement gives a reading on the voltmeter?

	temperature of voltmeter	wire X
A	colder than hot junction	copper
B	colder than hot junction	iron
C	same as hot junction	copper
D	same as hot junction	iron

B

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17. Which thermometer is the best for measuring rapidly-changing temperatures?
    A. a clinical thermometer
    B. a liquid-in-glass thermometer
    C. a thermocouple
    D. all thermometers are equally good

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