Temperature

Learning Outcomes

Candidates should be able to:

(a) explain how a physical property which varies with temperature, such as volume of liquid column, resistance of metal wire and electromotive force (e.m.f.) produced by junctions formed with wires of two different metals, may be used to define temperature scales

(b) describe the process of calibration of a liquid-in-glass thermometer, including the need for fixed points such as the *ice point* and *steam point*

Some definitions

Temperature	Temperature is a measure of the degree of hotness or coldness of an object It determines the **direction** of net thermal **energy transfer** between two objects SI unit: Kelvin
Heat or thermal energy	It refers to the amount of **thermal energy** that is being transferred from a hotter to a colder region. SI unit: Joule
Temperature scale	Method used to quantify the variable which is temperature
Fahrenheit scale	Used in America Has 2 fixed points ice point (32°F) and steam point (212°F)
Celsius scale	Has 2 fixed points ice point (0°C) and steam point (100°C)
Thermodynamic scale	Temperature in kelvin = Temperature in °C + 273

Thermometric substances

- Thermometric substances have physical (thermometric) properties that vary **uniformly** and **continuously** with temperature.

Thermometric properties	Examples of thermometers
Volume of a fixed mass of liquid	Mercury-in-glass thermometer; alcohol-in-glass thermometer
Electrical resistance of a piece of metal	Resistance thermometer
Electrical voltage or electromotive force (e.m.f.)	Thermocouple thermometer
Pressure of a fixed mass of gas at constant volume	Constant volume gas thermometer

A good thermometer generally

- has an easy-to-read scale;
- is safe to use;
- is responsive to temperature changes;
- is sensitive to small temperature changes;
- is able to measure the required range of temperatures.

Calibration of a liquid-in-glass thermometer

Step 1: Choose an appropriate thermometric substance. → Mercury or alcohol

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Step 2: Choose two fixed points. (These are used as reference points to set up the scale for temperature measurement.) → **Ice** point – lower fixed point; **Steam** point – upper fixed point

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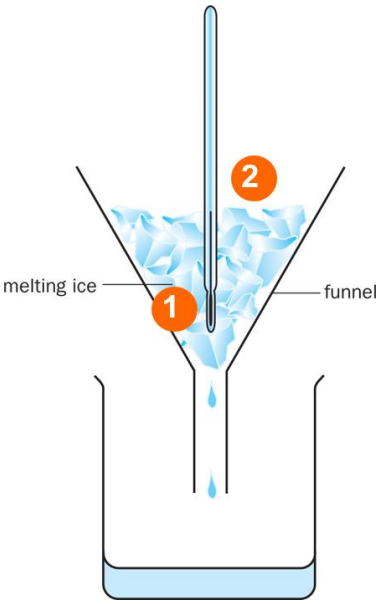
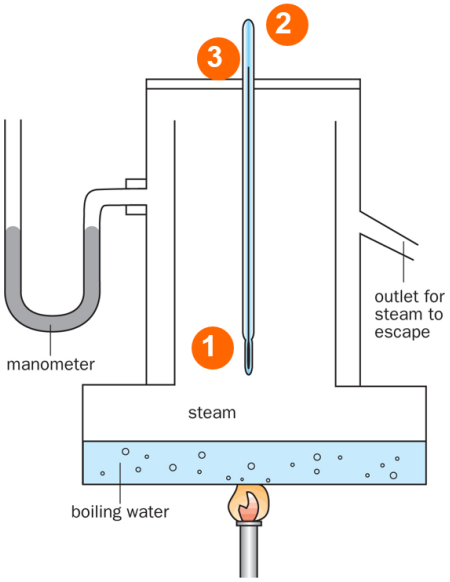
Step 3: Divide the interval between the ice point and steam point into 100 equal parts. Each interval is 1°C. → Change in length of mercury thread is proportionate to temperature change

Determining the fixed points

- Melting point of pure ice and boiling point of water is chosen as the fixed points because they are **common physical phenomena**, which are **easily reproducible**.

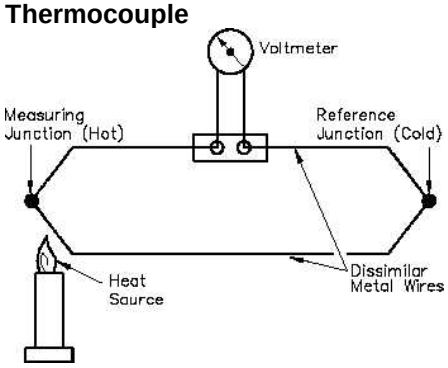


- Immerse the bulb and the lower part of the thermometer stem into a funnel containing **pure melting ice**.
- When the mercury level in the thermometer stem is steady, make a mark l_0 at that level on the stem. This is the ice point.



- Insert the thermometer into the apparatus. The bulb should be **just above the boiling water**.
- The stem of the thermometer should protrude from the top of the apparatus.
- When the mercury level in the thermometer stem remains steady, make a mark l_{100} at that level on the stem. This is the steam point.

Thermocouple



- Consists of **two wires made of different metals** such as iron and copper
- The wires are joined to form two junctions, which produce a small electromotive force when there is a **temperature difference** between them.

Advantages

- Wire junction is small and needs very little heat to warm it up. Responds very quickly to temperature changes and can be used in very small or precise locations.
- Output is an electrical signal which can be used to operate electrical equipment capable of giving warnings of sudden temperature changes or keeping continuous records of temperatures. (e.g. in airplanes)
- Depending on the metals chosen, temperatures up to 1500˚C can be measured.

Questions

The resistance of a piece of platinum wire is 450 Ω when placed in pure melting ice and 560 Ω when placed in steam above boiling water. Determine the temperature of a molten substance if the resistance of the wire is found to be 1260 Ω when placed in the substance.

The range of a mercury-in-glass thermometer is from −10°C to 110°C. The length of the mercury thread between the −10°C and 110°C marks on the stem is 20 cm. Determine the temperature when the length of the mercury thread is 12 cm from the −10°C mark.

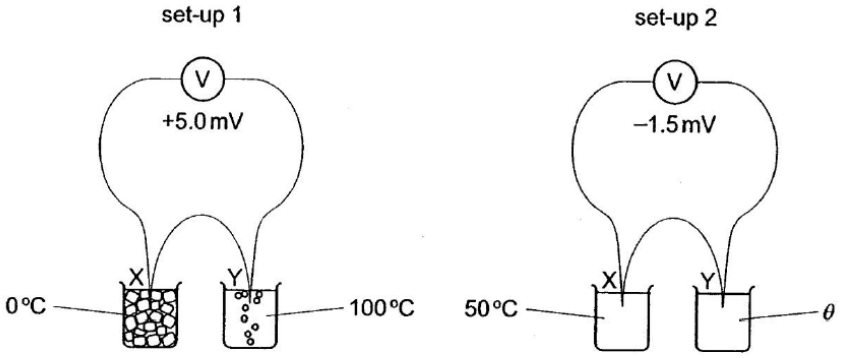
A thermocouple is used to measure the temperature in a gas turbine. An e.m.f. of 45 mV is obtained when junction X is kept at 0°C and junction Y is kept at 100°C. The e.m.f. changes to 65 mV when the hot junction is placed in the gas turbine.

(a) Why is the thermocouple suitable for measuring the temperature in a gas turbine?

(b) Calculate the temperature in the gas turbine.

16 A thermocouple is placed with its junction **X** and **Y** in

set-up 1	melting ice and boiling water
set-up 2	liquids at temperatures 50 °C and θ



In set-up 1 the voltmeter reads +5.0 mV, and in set-up 2 the voltmeter reads −1.5 mV.

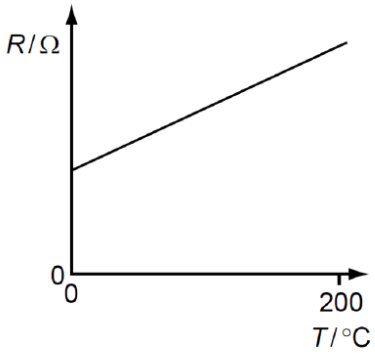
Assuming that the thermocouple has a linear response, what is the temperature θ?

A 20 °C **B** 30 °C **C** 70 °C **D** 80 °C

26. A student is given a centigrade scale thermometer. If the lengths of the mercury thread when placed in melting ice is 2.0 cm and in a liquid of 30 °C is 5.0 cm, calculate the length of mercury when placed in steam.

A 8.0 cm **B** 10.0 cm
C 12.0 cm **D** 15.0 cm

16 The electrical resistance of a metal wire varies with temperature as shown.



The resistance of the wire at 0 °C is 1.00 Ω and at 100 °C is 1.40 Ω.

What is the resistance of the wire at 200 °C?

A 1.80 Ω **B** 1.96 Ω **C** 2.00 Ω **D** 2.80 Ω

13. A cup is filled with 0.3 kg of water at 50 °C and a pail is filled with 5.0 kg of water at 30 °C. Which of the following is false?

A The water in the cup has a higher temperature than the water in the pail.
B There is more mass of water in the pail than in the cup.
C There is more thermal energy stored in the pail than in the cup.
D When the cup is placed together with the pail, heat will flow from the pail to the cup.

14. The resistance of an alloy wire is 25 Ω when it is placed in a cup of pure melting ice. At room temperature of 28 °C, the resistance is 38 Ω. If the wire is put in boiling water at 100 °C, what will be the resistance?

A 28 Ω **B** 46 Ω **C** 71 Ω **D** 152 Ω

18. In an uncallibrated thermometer, the length of a mercury thread is 3 cm when immersed in pure melting ice, and 28 cm when surrounded by steam from boiling water under normal atmospheric pressure. The thermometer is then placed in a liquid of temperature T °C and the length of the mercury thread is 18 cm.

Find T.

A. 37.5
B. 40
C. 57
D. 60