Temperature is one of the seven base units. To establish a measuring scale for the temperature, we adopt the following procedure: we find a substance that has a property that varies with temperature, and we measure that property. the substance we choose is called thermometric substance, and the property that depends on temperature is called thermometric property.
Example might be the volume of a liquid (as in the common glass-bulb mercury thermometer), the pressure of a gas kept at constant volume, the electrical resistance of a wire, the length of a strip of metal, or the color of a lamp filament, all of which vary with temperature. *The choice of an individual temperature scale that is defined only for that substance and that does not necessarily agree with other independently defined temperature scales.*
Let us assume that our particular thermometer is based on a system in which we measure the value of the thermometric property X. the temperature T is some function of X, $T(X)$. We choose the simplest possible relationship between T and X, the linear function given by

$$T(X) = aX + b \tag{1}$$

where the constants a and b must be determined. this linear scale means that every interval of temperature ΔT corresponds to the same change ΔX in the value of the thermometric property. to determine a temperature on this scale, arbitrarily define the temperatures T_1 and T_2 at those points, and measure the corresponding values X_1 and X_2 of the thermometric property.
The most familiar examples of this type of scale are the Celsius and Fahrenheit scales used in common thermometers, in which the thermometric property may be its volume, observed in by means of the length of the mercury column in a thin glass tube. The linear behavior in this case means that the intervals between degree markings on the glass tube of a thermometer are a uniform size.

The Celsius and Fahrenheit Scale

In nearly all countries of the world, the Celsius scale (formerly centigrade scale) is used for all popular and commercial and most scientific measurements. The Celsisus scale was originally based on two calibration points: the normal freezing point of water, defined to be $0°C$, and the normal boiling point of water, defined to be $100°C$. These two points were used to calibrate thermometers, and other temperatures were then deduced by the interpolation or extrapolation.
The Fahrenheit scale, used in USA, employs a smaller degree than Celsius scale, and its zero is set different temperature. It was also originally based on teo fixed points, the interval between 100 degrees: the freezing point of a mixture of ice and salt, and the normal human body temperature. On this scale, the normal freezing and boiling point of water turn out to be, respectively, $32°F$ and $212°F$. the relation between Celsius and Fahrenheit scales is

$$T_F = \frac{9}{5}T_C + 32 \tag{2}$$

The degree symbol is used expressing temperatures on the Fahrenheit scale. The equivalent relation between Fahrenheit and Celsius scale is

$$9F^{\circ} = 5C^{\circ} \tag{3}$$

where F° and C° are expresses the interval on each scale, but any arbitrary temperature on both scale given by $^\circ F$ and $^\circ C$.

The Kelvin scale

On the Kelvin scale, one of the calibration points is defined to be at a temperature of zero, where the thermometric property also has a value of zero; in effect the constant in Eq. (1) is set to zero, in which case

$$T(X) = aX \tag{4}$$

To determine a temperature on this case, we need only one calibration point P. At that point, the temperature is defined to be T_P and the thermometric property has the measured value X_P. In this case

$$a = \frac{T_P}{X_P} \tag{5}$$

and so

$$T(X) = T_P \frac{X}{X_P} \tag{6}$$

By general agreement, we choose for our calibration the temperature at which ice, liquid water, and the water vapor coexist in equilibrium. This point, which is very close to the normal freezing point of water, is called the triple point of water. The temperature at

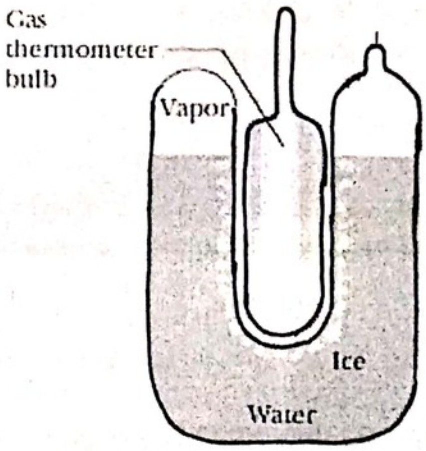

Figure 1: A triple-point cell, in which solid ice, liquid water, and water vapor coexist in thermal equilibrium. The temperature of this mixture is 273.16 K.

the triple point has been set by international agreement to be

$$T_{tr} = 273.16K$$

where K(=kelvin) is the SI unit of temperature on the absolute scale. with this choice of calibration point, Eq. 6 becomes

$$T(X) = (273.16K)\frac{X}{X_{tr}} \tag{7}$$

where X_{tr} is the thermometric property at the triple point.
The size of the degree is the same on the Celsius and Kelvin scale is defined is shifted to a more convenient value. the relationship between the Celsius temperature T_C and the the Kelvin temperature T is now set as

$$T_C = T - 273 \tag{8}$$

The Constant-Volume Gas Thermometer
The standard thermometer, against which all other thermometers are calibrated, is based

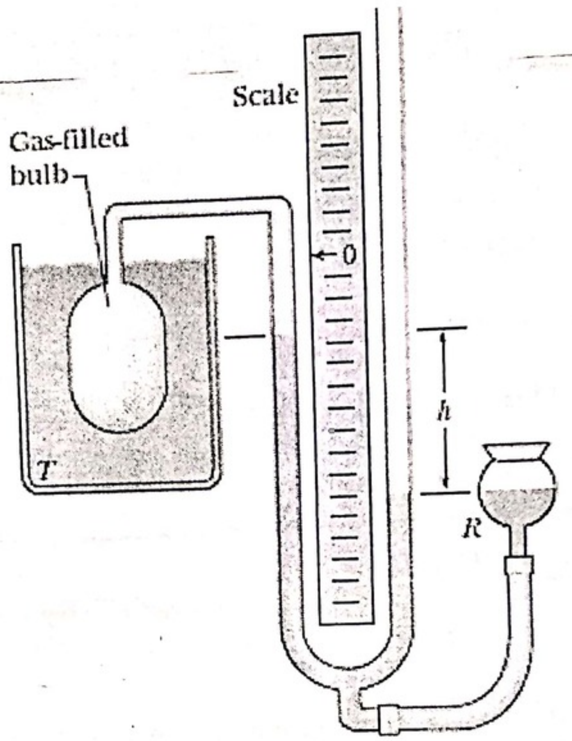

Figure 2: A constant-volume gas thermometer, its bulb immersed in a liquidwhose.temperature T is to be measured.

on the pressure of a gas in a fixed volume. Figure 2 shows such a constant-volume gas thermometer; it consists of a gas-filled bulb connected by a tube to a mercury manometer. By raising and lowering reservoir R, the mercury level in the left arm of the U-tube can always be brought to the zero of the scale to keep the gas volume constant (variations in the gas volume can affect temperature measurements).
The temperature of any body in thermal contact with the bulb (such as the liquid surrounding the bulb in Fig. 2) is then defined to be

$$T = CP \tag{9}$$

in which P is the pressure exerted by the gas and C is a constant. The pressure P is

$$P = P_0 - h\rho g \tag{10}$$

in which P_0 is the atmospheric pressure, ρ is the density of the mercury in the manometer, and h is the measured difference between the mercury levels in the two arms of the tube.* (The minus sign is used in Eq. 10 because pressure P is measured above the level at which the pressure is P_0.

If we next put the bulb in a triple-point cell (Fig. 1), the temperature now being measured is

$$T_{tr} = CP_{tr} \tag{11}$$

in which P_{tr} is the gas pressure now. Eliminating C between Eqs. 9 and 11 gives us the temperature as

$$T = T_{tr}\frac{P}{P_{tr}} = 273.16K\left(\frac{P}{P_{tr}}\right) \tag{12}$$

We still have a problem with this thermometer. If we use it to measure, say, the

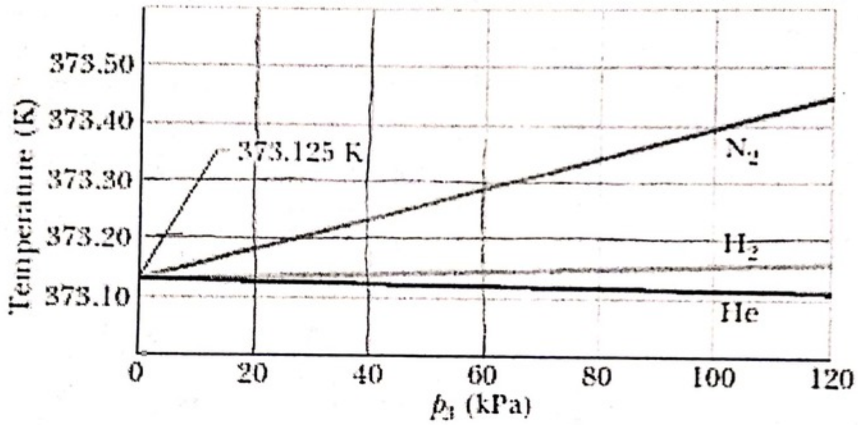

Figure 3: Temperatures measured by a constant-volume gas thermometer,with its bulb immersed in boiling water. For temperature calculations using Eq. 12, pressure $p_3 = P_{tr}$ was measured at the triple point of water.Three different gases in the thermometer bulb gave generally different results at different gas pressures, but as the amount of gas was decreased (decreasing P_tr), all three curves converged to $373.125K$.

boiling point of water, we find that different gases in the bulb give slightly different results. However, as we use smaller and smaller amounts of gas to fill the bulb, the readings converge nicely to a single temperature, no matter what gas we use. Figure 3 shows this convergence for three gases. Thus the recipe for measuring a temperature with a gas thermometer is

$$T = (273.16K)\left(lim_{gas\to 0}\frac{P}{P_{tr}}\right) \tag{13}$$

Resistance Thermometer

The resistance thermometer or resistance temperature detector (RTD) uses the resistance of electrical conductor for measuring the temperature. The resistance of the conductor varies with the time. This property of the conductor is used for measuring the temperature. The main function of the RTD is to give a positive change in resistance with temperature. The metal has a high-temperature coefficient that means their temperature increases with the increase in temperature. The carbon and germanium have low-temperature coefficient which shows that their resistance is inversely proportional to temperature.

Material used in Resistance Thermometer

The resistance thermometer uses a sensitive element made of extremely pure metals like platinum, copper or nickel. The resistance of the metal is directly proportional to the temperature. Mostly, platinum is used in resistance thermometer. The platinum has high stability, and it can withstand high temperature.

Gold and silver are not used for RTD because they have low resistivity. Tungsten has high resistivity, but it is extremely brittles. The copper is used for making the RTD element. The copper has low resistivity and also it is less expensive. The only disadvantage of the copper is that it has low linearity. The maximum temperature of the copper is about 120°C.

The RTD material is made of platinum, nickel or alloys of nickel. The nickel wires are used for a limited temperature range, but they are quite nonlinear. The following are the requirements of the conductor used in the RTDs.

1. The resistivity of the material is high so that the minimum volume of conductor is used for construction.
2. The change in resistance of the material concerning temperature should be as high as possible.
3. The resistance of the material depends on the temperature.

The resistance versus temperature curve is shown in the figure below. The curves are nearly linear, and for small temperature range, it is very evident.

Construction of Resistance Thermometer

The resistance thermometer is placed inside the protective tube for providing the pro-

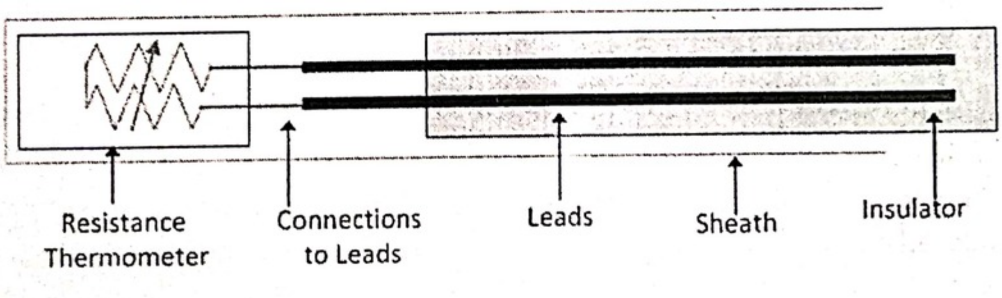

Figure 4: A schematic diagram of a resistance thermometer.

tection against damage. The resistive element is formed by placing the platinum wire on the ceramic bobbin. This resistance element is placed inside the tube which is made up of stainless steel or copper steel. The lead wire is used for connecting the resistance element with the external lead. The lead wire is covered by the insulated tube which protects it from short circuit. The ceramic material is used as an insulator for high-temperature material and for low-temperature fibre or glass is used.

Operation of Resistance Thermometer

The tip of the resistance thermometer is placed near the measurand heat source. The heat is uniformly distributed across the resistive element. The changes in the resistance vary the temperature of the element. The final resistance is measured. The below mention equations measure the variation in temperature.

$$R = R_0(1 + aT + bT^2 + ct^3 + \cdots) \tag{14}$$

Where, R_0 – resistance at temperature $T = 0$ and a, b, c, $\cdots$ are constants.

Linear Approximation

The linear approximation is the way of estimating the resistance versus temperature curve in the form of the linear equation.

$$R_T = R_0(1 + aT) \tag{15}$$

Quadratic Approximation

The quadratic approximation gives the accurate approximation of the resistance temperature curve. The approximation is expressed in the form of the quadratic equation.

$$R_T = R_0(1 + aT + bT^2) \tag{16}$$

The resistance thermometer is very less sensitive, and the metal used for making the resistive element is less expensive.