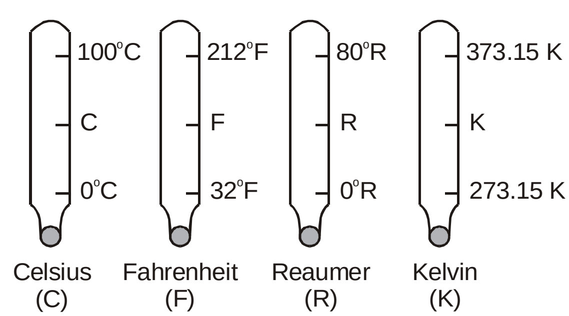
TEMPERATURE

1. temperature mark the beginnings of the science of thermodynamics.
2. The temperature of a body is a state which determines the direction of flow of heat or the degree of hotness of a body.
3. Heat is the cause and temperature is the effect.
4. A body at a higher temperature need not necessarily contain more heat.
5. Two bodies at the same temperature may contain different amounts of heat.
6. Two bodies containing the same amount of heat may be at different temperatures.
7. The direction of flow of heat from a body does not depend on its heat content but depends on its temperature.
8. In principle, any system whose properties change the temperature can be used as a thermometer.
9. There are four scales of temperature. They are Celsius scale, Fahrenheit scale, Reaumer scale and Kelvin (or Absolute or thermodynamic temperature) scale.
10. The most fundamental scale of temperature called Kelvin scale is based on the laws of thermodynamics.
11. The melting point of ice at standard atmospheric pressure is taken as the lower fixed point.
12. The boiling point of water at standard pressure is taken as the upper fixed point. The upper fixed point is determined by using Hypsometer.
13. The distance between the lower and upper fixed points is divided into definite equal divisions.
14. Different scales of temperature.
15. The reading on one scale can be readily converted into corresponding one or the other by the relation $\frac{K-273}{100}=\frac{C}{100}=\frac{F-32}{180}=\frac{R}{80}$
16. If in a certain arbitrary scale of temperature, p° is the lower fixed point and q° is the upper fixed point, any temperature x in this scale can be converted to Celsius or Fahrenheit scale by using the formula $\frac{C}{100}=\frac{x-p}{q-p}=\frac{F-32}{180}$
17. The differences of temperature on different scales can be converted using the formula $\frac{\Delta K}{100}=\frac{\Delta C}{100}=\frac{\Delta F}{180}=\frac{\Delta R}{80}$
18. Different types of thermometers and their ranges :
    Clinical thermometer –95°F to 110°F
    Mercury thermometer –38°C to 350°C

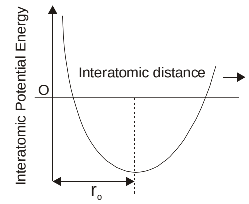
Alcohol thermometer	–110°C to 78°C
Hydrogen gas thermometer	–260°C to 1600°C
Platinum resistance thermometer	–200°C to 1200°C
Pyrometer	very high temperatures

19. Advantages of mercury as a thermometric fluid.
    i) Mercury remains as a liquid over a wide range of temperature
    ii) Pure mercury can be readily and easily obtained.
    iii) Its vapour pressure at ordinary temperature is negligible.
    iv) It has high conductivity and low thermal capacity. So it quickly attains the temperature of the body by taking a negligibly small quantity of heat.
    v) It does not wet glass and is opaque.
20. Of all the thermometers, gas thermometers are more sensitive because of their high volume expansion. They have the same scale for all gases.
21. Using a constant volume hydrogen thermometer, temperatures ranging from –200°C to 1100°C can be measured. It is generally used to calibrate other thermometers.
22. To have more surface contact with heat, the thermometric bulb will be in the shape of a cylinder.
23. To determine the maximum and minimum temperatures attained during a day at a place, Six's maximum and minimum thermometer is used.
24. If X is any thermometric property such as pressure or volume or resistance which has values at 0°, 100° and t° on any scale as X_0, X_{100} and X_t, then $t = \left(\frac{X_t - X_0}{X_{100} - X_0}\right)100$.
25. Temperatures on the Celsius scale denoted by the symbol °C (read "degrees Celsius"). Temperature changes and temperature differences on the Celsius scale are expressed in C° (read "Celsius degrees"). For eg: 20°C is a temperature and 20 C° is a temperature difference. In general, all substances whether they are in the form of solids, liquids or gases expand on heating except water between 0°C and 4°C and some aqueous solutions. This is known as thermal expansion.

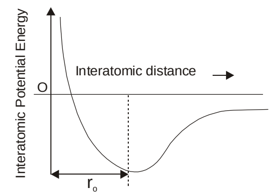


EXPANSION OF SOLIDS

26. Solids expand on heating due to increased atomic spacing.
27. A solid can be considered as periodic arrangement of atoms in the form of lattice.
28. At any particular temperature, the atoms are in a specific state of vibration about a fixed point called as equilibrium position in the lattice.
29. As the temperature increases, the amplitude of vibration of the atoms increases.
30. If the lattice vibrations are purely harmonic the potential energy curve is a symmetric parabola and there is not thermal expansion.



31. If the lattice vibrations are an harmonic, the potential energy of an oscillator is an asymmetric function of its position and thermal expansion is observed.



32. Coefficient of linear expansion (α) : The ratio of increase in length per one degree rise in temperature to its original length is called coefficient of linear expansion.

    $$\alpha = \frac{l_2 - l_1}{l_1(t_2 - t_1)}$$

    Unit of α is $C^{o^{-1}}$ or K^{-1}
33. The change in length is calculated using $\Delta L = L\ \alpha\ \Delta t$
34. Coefficient of area or superficial expansion (β) : The increase in area per unit area per one degree rise in temperature is called coefficient of areal expansion.

    $$\beta = \frac{a_2 - a_1}{a_1(t_2 - t_1)}$$

    Unit of β is $C^{o^{-1}}$ or K^{-1}
35. The change in area is calculated using formula $\Delta a = a\ \beta\ \Delta t$.
36. The coefficient of volume or cubical expansion (γ) is the increase in volume per unit volume per degree rise in temperature.

    $$\gamma = \frac{V_2 - V_1}{V_1(t_2 - t_1)}$$

    Unit of γ is $C^{o^{-1}}$ or K^{-1}
37. The change in volume is calculated using formula $\Delta V = V\ \gamma\ \Delta t$.
38. For all isotropic substances (solids which expand in the same ratio in all directions) $\alpha : \beta : \gamma = 1:2:3$ or $\gamma = 3\alpha$; $\beta = 2\alpha$; $\gamma = \alpha + \beta$.

39. If α_x, α_y and α_z represent the coefficients of linear expansion for an isotropic solids (solids which expand differently in different directions) in x, y and z directions respectively, then $\gamma=\alpha_x+\alpha_y+\alpha_z$ and the average coefficient of linear expansion $\alpha=\frac{\alpha_x+\alpha_y+\alpha_z}{3}$.
40. The numerical value of coefficient of linear expansion of a solid depends on the nature of the material and the scale of temperature used.
41. The numerical value of coefficient of linear expansion of a solid is independent of physical dimensions of the body and also on the unit of length chosen.
42. The increase in length or linear expansion of a rod depends on nature of material, initial length of rod and rise of temperature.
43. The numerical value of α or β or γ in the units of per °C is 9/5 times its numerical value in the units of per °F.
44. α per °F=$\frac{5}{9}.\alpha$ per °C.
45. α per °R=$\frac{5}{4}.\alpha$ per °C.
46. Variation of density with temperature : The density of a solid decreases with increase of temperature. $d_t=\frac{d_o}{1+\gamma t}$ or $d_t \approx d_o(1-\gamma t)$ where d_o is density at 0°C.
47. If R_1 and R_2 are the radii of a disc or a plate at t_1°C and t_2°C respectively then $R_2=R_1(1+\alpha(t_2-t_1))$.
48. A metal scale is calibrated at a particular temperature does not give the correct measurement at any other temperature.
   a) When scale expands correction to be made $\Delta l=L\ \alpha\ \Delta t$, correct reading=$L+\Delta l$
   b) When scale contracts correction to be made $\Delta l=L\ \alpha\ \Delta t$, correct reading=$L-\Delta l$. L=measured value.
   c) $L_{measured}=L_{true}[1-\alpha(\Delta t)]$
49. When a metal rod is heated or cooled and is not allowed to expand or contract thermal stress is developed.

   Thermal force $F=YA\ \alpha\ (t_2-t_1)$

   Thermal force is independent of length of rod.

   Thermal stress $\sigma=Y\ \alpha\ (t_2-t_1)$

   Y=Young's modulus

   α=coefficient of linear expansion

   t_2-t_1=difference of temperature

A=area of cross-section of the metal rod.
For same thermal stress in two different rods heated through the same rise in temperature, $Y_1\alpha_1=Y_2\alpha_2$.

50. Barometer with brass scale :
    Relation between faulty and actual barometric height is given by $h_2=h_1[1+(\alpha_s-Y_{Hg})(t_2-t_1)]$
    h_1=height of barometer at t_1°C where the scale is marked
    h_2=height of barometer at t_2°C where the measurement is made
    γ_{Hg}=real coefficient of expansion of mercury
    α_s=coefficient of linear expansion of scale
51. Pendulum clocks lose or gain time as the length increases or decreases respectively.
    The fractional change=$\frac{\Delta T}{T}=\frac{\alpha\Delta t}{2}$.
    The loss or gain per day=$\frac{\alpha\Delta t}{2}$x86400 seconds.
52. The condition required for two rods of different materials to have the difference between the lengths always constant is $L_1\alpha_1=L_2\alpha_2$.
53. A hole in a metal plate expands on heating just like a solid plate of the same size.
54. A cavity of a solid object expands on heating just like a solid object of the same volume.
55. If a hollow pipe and a solid rod of same dimensions made of same material are heated to the same rise in temperature, both expand equally.
56. If a thin rod and a thick rod of same length and material are heated to same rise in temperature, both expand equally.
57. If a thin rod and a thick rod of same length and material are heated by equal quantities of heat, thin rod expands more than thick rod.
58. A rectangular metal plate contains a circular hole. If it is heated, the size of the hole increases and the shape of the hole remains circular.
59. A metal plate contains two holes at a certain distance apart from each other. If the plate is heated, the distance between the centers of the holes increases.
60. The change in the volume of a body, when its temperature is raised, does not depend on the cavities inside the body.

Applications of linear expansion

61. Platinum (or monel) is used to seal inside glass because both have nearly equal coefficients of linear expansion.
62. Iron or steel is used for reinforcement in concrete because both have nearly equal coefficients of expansion.
63. Pyrex glass has low α. Hence combustion tubes and test tubes for hating purpose are made out of it.
64. Invar steel (steel+nickel) has very low α. So it is used in making pendulum clocks, balancing wheels and measuring tapes. (Composition of invar steel is 64% steel and 36% nickel).
65. Metal pipes that carry steam are provided with bends to allow for expansion.
66. Telephone wires held tightly between the poles snap in winter due to induced tensile stress as a result of prevented contraction.
67. Thick glass tumbler cracks when hot liquid is poured into it because of unequal expansion.
68. Hot chimney cracks when a drop of water falls on it because of unequal contraction.
69. A brass disc snuggly fits in a hole in a steel plate. To loosen the disc from the hole, the system should be cooled.
70. To remove a tight metal cap of a glass bottle, it should be warmed.
71. While laying railway tracks, small gaps are left between adjacent rails to allow for free expansion without affecting the track during summer. Gap to be left $(\Delta l)=\alpha l\Delta t$=expansion of each rail.
72. Concrete roads are laid in sections and expansion channels are provided between them.
73. Thermostat is a device which maintains a steady temperature.
74. Thermostats are used in refrigerators, automatic irons and incubators.
75. Thermostat is a bimetallic strip made of iron and brass. The principle involved is different materials will have different coefficients of linear expansion.
76. A bimetallic strip is used in dial-type thermometer.
77. If an iron ring with a saw-cut is heated, the width of the gap increases.
78. Barometric scale which expands or contracts measures wrong pressure. On expansion the true pressure is less than measured pressure.
    $P_{true}=P_{measured}[1-(\gamma-\alpha)t]$

where γ=coefficient of cubical expansion of mercury
α=coefficient of linear expansion of the material used in making the scale
t=rise of the temperature

79. When a straight bimetallic strip is heated it bends in such a way that the more expansive metal lies on the outer side. If d is the thickness of the each strip in a bimetallic strip, then the radius of the compound strip is given by R=$\frac{d}{(\alpha_2 - \alpha_1)\Delta t}$.