Introduction to Physical Science

Temperature

Presented by Robert Wagner

Temperature

- Temperature to humans can be a matter of perception.
  - If you place one hand in hot water and another hand in cold water. What happens when you place both hands in room temperature water?
- Scientifically, temperature is a measure of the average velocities of the particles in a substance
  - This is what is measured with a thermometer

Linear Thermal Expansion

- The change in length of a substance depends on the temperature, material and the length itself:
  -
  - is the coefficient of linear expansion
- Coefficient of linear expansion
  - Depends on the properties of the materials involved

Material	Coefficient of linear expansion α(1/°C)	Coefficient of volume expansion β(1/°C)
Solids		
Aluminum	25×10^{-6}	75×10^{-6}
Brass	19×10^{-6}	56×10^{-6}
Copper	17×10^{-6}	51×10^{-6}
Gold	14×10^{-6}	42×10^{-6}
Iron or Steel	12×10^{-6}	35×10^{-6}
Invar (Nickel-Iron alloy)	0.9×10^{-6}	2.7×10^{-6}
Lead	29×10^{-6}	87×10^{-6}
Silver	18×10^{-6}	54×10^{-6}
Glass (ordinary)	9×10^{-6}	27×10^{-6}
Glass (Pyrex®)	3×10^{-6}	9×10^{-6}
Quartz	0.4×10^{-6}	1×10^{-6}
Concrete, Brick	~12×10^{-6}	~36×10^{-6}
Marble (average)	7×10^{-6}	2.1×10^{-5}
Liquids		
Ether		1650×10^{-6}
Ethyl alcohol		1100×10^{-6}
Petrol		950×10^{-6}
Glycerin		500×10^{-6}
Mercury		180×10^{-6}
Water		210×10^{-6}
Gases		
Air and most other gases at atmospheric pressure		3400×10^{-6}

Image Credit: OpenStax College Physics - Table 13.2 CC BY 4.0

Example

- Room temperature is generally considered to be about . What would this be in ? In Kelvins?
  - Draw a sketch
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

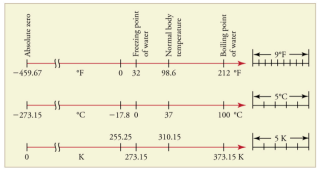
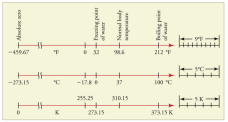


Figure 13.6 Relationships between the Fahrenheit, Celsius, and Kelvin temperature scales, rounded to the nearest degree. The relative sizes of the scales are also shown.

Image Credit: OpenStax College Physics - Figure 13.6 CC BY 4.0

Example



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$$T(^oC) = 25.0^oC$$

$$T(^oF) = \frac{9}{5}T(^oC) + 32$$

$$T(^oF) = \frac{9}{5}(25.0) + 32 = 77.0^oF$$

$$T(K) = T(^oC) + 273.15$$

$$T(K) = 25.0 + 273.15 = 298K$$

Image Credit: OpenStax College Physics - Figure 13.6 CC BY 4.0

Thermal Equilibrium

- If two systems, A & B are in thermal equilibrium with each other, and B is in thermal equilibrium with a third system, C, then A is also in thermal equilibrium with C.
  - The Zeroth Law of Thermodynamics
- Heat will flow from hotter object to cooler objects, equalizing their temperatures.
  - This is how a thermometer measures temperature

Image Credit: OpenStax College Physics - Figure 8.8

Thermal Expansion

- Thermal expansion is related to the change in temperature
  - Greater temperature change means greater expansion
- The amount of expansion also depends on the material
  - Alcohol in a thermometer expands more than the glass

Image Credit: Ingolfson, Public domain, via Wikimedia Commons

Example

- The span of a bridge is 1275 m long at its coldest. The bridge is exposed to temperatures ranging from to . What is the change in length between these temperatures if the bridge is made of steel?
  - Draw a sketch
  - Identify known values
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$$L = 1275\ m\ ;\ \Delta T = 55^oC\ ;\ \alpha(steel) = \frac{12x10^{-6}}{^oC}$$

$$\Delta L = \alpha L \Delta T$$

$$\Delta L = (\frac{12x10^{-6}}{^oC})(1275\ m)(55^oC)$$

$$\Delta L = 0.84\ m$$

Thermal Expansion in Two and Three Dimensions

- Two Dimensions:
  -
- Three Dimensions
  -
    - is the coefficient of volume expansion

Example

- Suppose a 60.0 L steel gasoline tank is full. The gas and tank have a temperature of 15.0ºC. How much gasoline will spill by the time they warm to 35.0ºC?
  - Draw a sketch
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

$$V = 60.0\ L\ ;\ \Delta T = 20.0^oC\ ;\ \beta(steel) = \frac{35x10^{-6}}{^oC}$$

$$\beta(gas) = \frac{950x10^{-6}}{^oC}$$

$$\Delta V_s = \beta_s \Delta T\ ;\ \Delta V_{gas} = \beta_{gas} V_{gas} \Delta T$$

$$V_{spill} = \Delta V_{gas} - \Delta V_s\ ;\ V_{gas} = V_s$$

$$V_{spill} = (\beta_{gas} - \beta_s) V \Delta T$$

$$V_{spill} = \frac{(950 - 35)x10^{-6}}{^oC}(60.0\ L)(20.0^oC) = 1.10\ L$$

Thermal Stress

- Thermal stress is caused by expansion and contraction as the temperature changes.
  - Damage to roads - potholes
  - Weathering of rocks
  - Rupturing of tank
  - Glass cooking pans
  - Dental fillings

Summary

- Temperature is a measure of the average kinetic energies of the particle in a substance
- Objects in contact will reach thermal equilibrium as heat is transferred from a hotter object to a cooler one
- Thermal stress occurs when changes in temperature are rapid or when material in unable to expand and contract freely