Temperature

Temperature is a measure of the average kinetic energy of particles in a substance, indicating how hot or cold it is. It is an intensive property, meaning it does not depend on the amount of material, and is measured in units like Celsius (°C), Fahrenheit (°F), or Kelvin (K).

Heat

Heat is the energy transferred between objects due to a temperature difference. It is an extensive property, meaning it depends on the mass and specific properties of the material. Heat is measured in Joules (J) and flows from hotter to cooler objects until equilibrium is reached.

- Temperature is an attempt to measure the "hotness" or "coldness" on a scale you devise.
- A device to do this is called a **thermometer** and is usually calibrated by the melting and freezing points of a substance. This is most often water with orrections for atmospheric pressure well known.
- The **thermometer** is often a container filled with a substance that will expand or contract as heat flows in its surroundings.

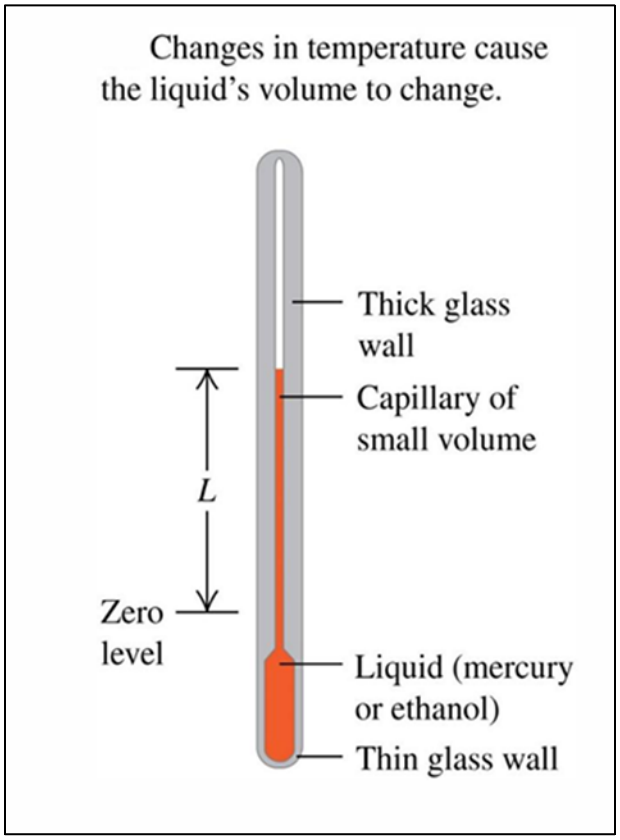


Figure: The illustration shows a thermometer that uses a column of liquid (usually mercury or ethanol) to measure air temperature.

To convert from…	Use this equation…
Celsius to Fahrenheit	$T_F = \frac{9}{5}T_C + 32$
Fahrenheit to Celsius	$T_C = \frac{5}{9}(T_F - 32)$
Celsius to Kelvin	$T_K = T_C + 273.15$
Kelvin to Celsius	$T_C = T_K - 273.15$
Fahrenheit to Kelvin	$T_K = \frac{5}{9}(T_F - 32) + 273.15$
Kelvin to Fahrenheit	$T_F = \frac{9}{5}(T_K - 273.15) + 32$

Zeroth law of thermodynamics

when two objects are in thermal equilibrium with a third object, they are in thermal equilibrium with one another.

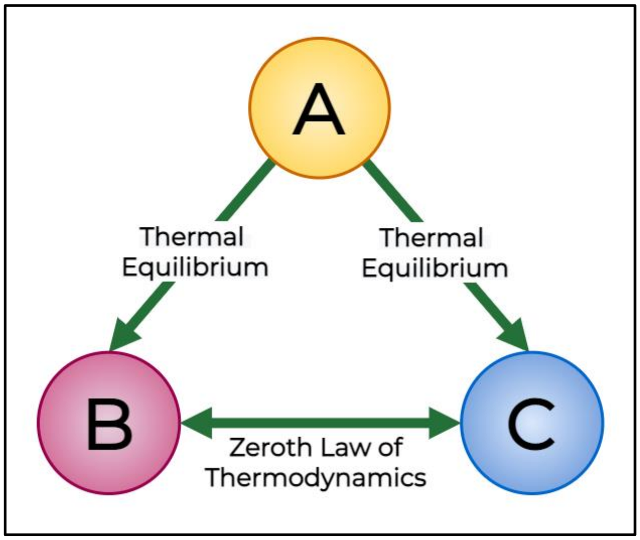


Figure : If System A is in thermal equilibrium with System C (TA = TC), and, if System B is in thermal equilibrium with System C (TB = TC), then, System A is in thermal equilibrium with System B (TA = TB).

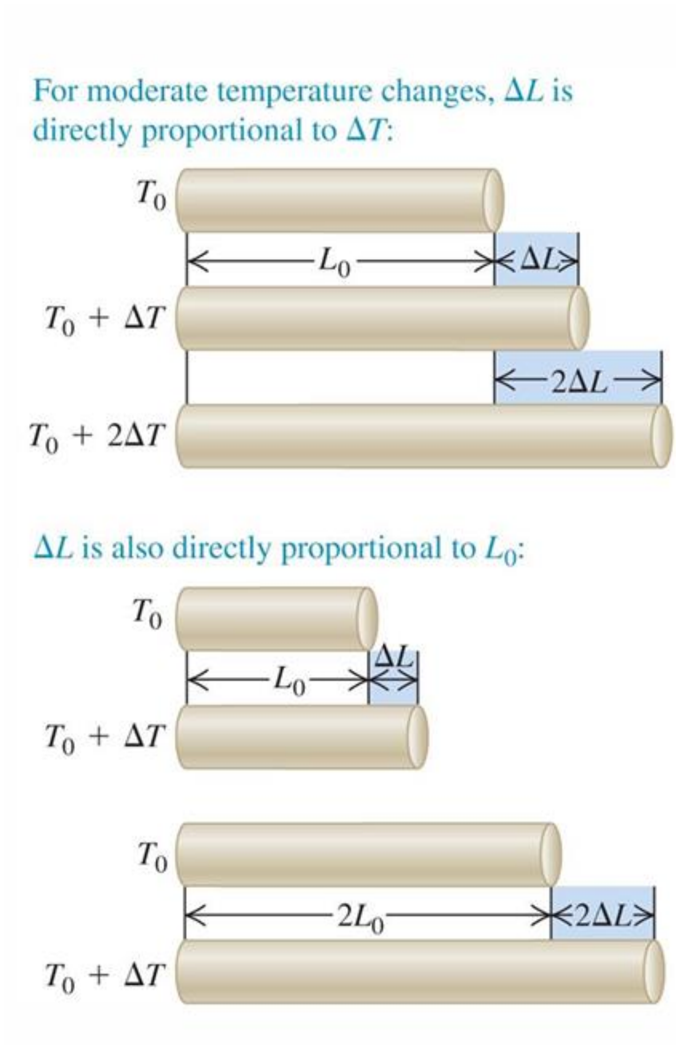
The Zeroth Law provides the foundation for defining temperature and using thermometers to measure it. The law establishes temperature as a measurable and comparable property of systems.

Internal energy

Internal energy is the sum of all microscopic forms of energy associated with the random motion and interaction of particles (atoms and molecules) within a system.

Thermal expansion

Thermal expansion is the tendency of a material to change its dimensions (length, area, or volume) in response to a change in temperature. This occurs because particles in a substance move more vigorously as temperature increases, causing the material to expand.



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Under a moderate change in temperature:

- Length change is proportional to the original length.
- Length change is proportional to temperature change.

$$\underbrace{\Delta L}_{length} = \alpha L_o \underbrace{\Delta T}_{temperature}$$

Here; α is coefficient of linear expansion $[K^{-1}$or $C^{-1}]$ (Fractional change in length during one degree temperature change)

EXAMPLE

Calculating Linear Thermal Expansion

The main span of San Francisco's Golden Gate Bridge is 1275 m long at its coldest. The bridge is exposed to temperatures ranging from $-15\ °C$ to $40\ °C$. What is its change in length between these temperatures? Assume that the bridge is made entirely of steel.

Strategy

Use the equation for linear thermal expansion $\Delta L = \alpha L \Delta T$ to calculate the change in length, ΔL. Use the coefficient of linear expansion α for steel from Table 1.2, and note that the change in temperature ΔT is $55\ °C$.

Solution

Substitute all of the known values into the equation to solve for ΔL:

$$\Delta L = \alpha L \Delta T = \left(\frac{12 \times 10^{-6}}{°C}\right)(1275\ m)(55\ °C) = 0.84\ m.$$

Volumetric Expansion

$$\Delta V = \beta V \Delta T.$$

where β is the coefficient of volume expansion.

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Specific Heat

The specific heat of a substance is defined as the amount of heat required to raise a unit mass of the substance through a unit rise in temperature. The symbol C will be used for specific heat.

$$C = \frac{Q}{m\Delta T} \qquad \text{J/kg K.}$$

- For gases, if the process is at constant pressure, it is c_p, and if the process is at constant volume, it is c_v.
- For solids and liquids, however, $c_p=c_v=c$, as they are incompressible.

Example

Calculating the Required Heat

A 0.500-kg aluminum pan on a stove and 0.250 L of water in it are heated from 20.0 °C to 80.0 °C. (a) How much heat is required? What percentage of the heat is used to raise the temperature of (b) the pan and (c) the water?

Strategy

We can assume that the pan and the water are always at the same temperature. When you put the pan on the stove, the temperature of the water and that of the pan are increased by the same amount. We use the equation for the heat transfer for the given temperature change and mass of water and aluminum. The specific heat values for water and aluminum are given in Table 1.3.

Solution

1. Calculate the temperature difference:

$$\Delta T = T_f - T_i = 60.0\ °\text{C}.$$

2. Calculate the mass of water. Because the density of water is $1000\ \text{kg/m}^3$, 1 L of water has a mass of 1 kg, and the mass of 0.250 L of water is $m_w = 0.250\ \text{kg}$.

3. Calculate the heat transferred to the water. Use the specific heat of water in Table 1.3:

$$Q_w = m_w c_w \Delta T = (0.250\ \text{kg})(4186\ \text{J/kg °C})(60.0\ °\text{C}) = 62.8\ \text{kJ}.$$

4. Calculate the heat transferred to the aluminum. Use the specific heat for aluminum in Table 1.3:

$$Q_{Al} = m_{Al} c_{Al} \Delta T = (0.500\ \text{kg})(900\ \text{J/kg °C})(60.0\ °\text{C}) = 27.0\ \text{kJ}.$$

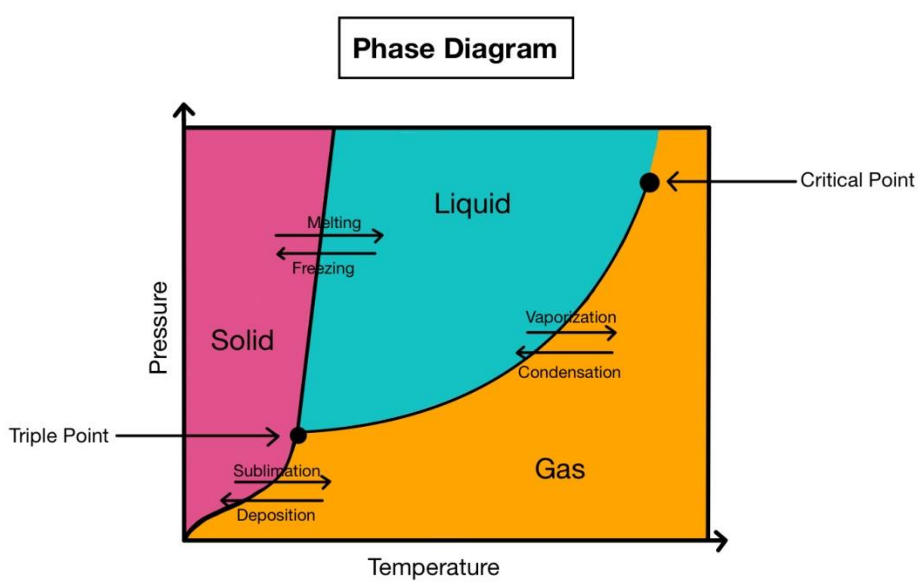
5. Find the total transferred heat:

$$Q_{Total} = Q_W + Q_{Al} = 89.8\ \text{kJ}.$$

Phase transitions

Phase transitions play an important theoretical and practical role in the study of heat flow. In melting (or "fusion"), a solid turns into a liquid; the opposite process is freezing. In evaporation, a liquid turns into a gas; the opposite process is

condensation.A substance melts or freezes at a temperature called its melting point, and boils (evaporates rapidly) or condenses at it boiling point. These temperatures depend on pressure. High pressure favors the denser form, so typically, high pressure raises the melting point and boiling point, and low pressure lowers them. For example, the boiling point of water is 100 °C at 1.00 atm. At higher pressure, the boiling point is higher, and at lower pressure, it is lower. The main exception is the melting and freezing of water, discussed in the next section.



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Latent heat

Latent heat is the amount of heat required to change the phase of a substance without changing its temperature.During phase transitions, such as melting, freezing, boiling, or condensation, the substance absorbs or releases energy, but its temperature remains constant.

$$Q = mL_f \text{(melting/freezing)}$$

$$Q = mL_v \text{(vaporization/condensation)}$$

where the latent heat of fusion Lf and latent heat of vaporization Lv are material constants that are determined experimentally. (Latent heats are also called latent heat coefficients and heats of transformation.) These constants are "latent," or hidden, because in phase changes, energy enters or leaves a system without causing a temperature change in the system, so in effect, the energy is hidden.

Mechanisms of Heat Transfer

Just as interesting as the effects of heat transfer on a system are the methods by which it occurs. Whenever there is a temperature difference, heat transfer occurs. It may occur rapidly, as through a cooking pan, or slowly, as through the walls of a picnic ice chest. So many processes involve heat transfer that it is hard to imagine a situation where no heat transfer occurs. Yet every heat transfer takes place by only three methods:

1. Conduction is heat transfer through stationary matter by physical contact. (The matter is stationary on a macroscopic scale—we know that thermal motion of the atoms and molecules occurs at any temperature above absolute zero.) Heat transferred from the burner of a stove through the bottom of a pan to food in the pan is transferred by conduction.

2. Convection is the heat transfer by the macroscopic movement of a fluid. This type of transfer takes place in a forced-air furnace and in weather systems, for example.

3. Heat transfer by radiation occurs when microwaves, infrared radiation, visible light, or another form of electromagnetic radiation is emitted or absorbed. An obvious example is the warming of Earth by the Sun. A less obvious example is thermal radiation from the human body.

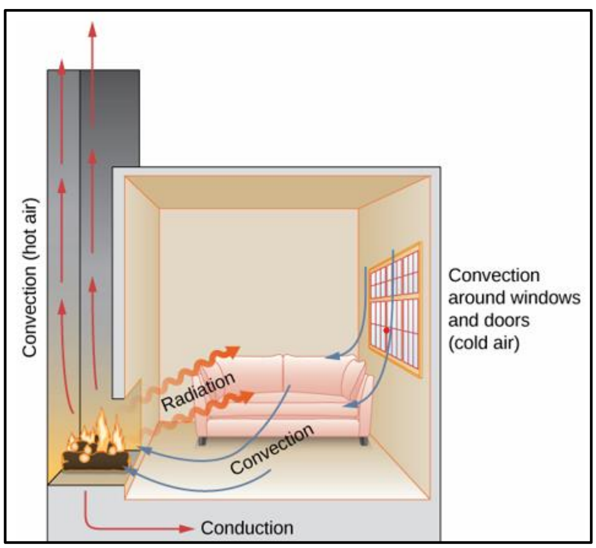

Figure: In a fireplace, heat transfer occurs by all three methods: conduction, convection, and radiation.

(Show Figure above) Radiation is responsible for most of the heat transferred into the room. Heat transfer also occurs through conduction into the room, but much slower. Heat transfer by convection also occurs through cold air entering the room around windows and hot air leaving the room by rising up the chimney.

Global warming and the greenhouse effect

Global Warming: Refers to the increase in Earth's average temperature due to higher concentrations of greenhouse gases from human activities. This leads to the enhanced greenhouse effect, which exacerbates warming.

Effects of Global Warming:

1.Rising sea levels due to thermal expansion and melting ice caps.

2.Changes in wind patterns affecting rainfall distribution, leading to floods and droughts.

3.Increased insect populations, impacting agriculture and health.

4.Disruption of water supplies.

Control Measures:

1.Reduce deforestation and promote sustainable agriculture.

2.Implement CO_2 absorption technologies.

3.Increase tree planting.

4.Utilize renewable energy sources.

The Greenhouse Effect

Greenhouse Effect: Solar energy passes through the atmosphere, with one-third reflected back into space and two-thirds absorbed by the Earth's surface. This energy is re-emitted as infrared radiation, some of which is absorbed and re-emitted by greenhouse gases, warming the Earth and lower atmosphere.

Importance:

1.Maintains average global temperatures.

2.Helps regulate sea levels.

3.Preserves polar ice caps.

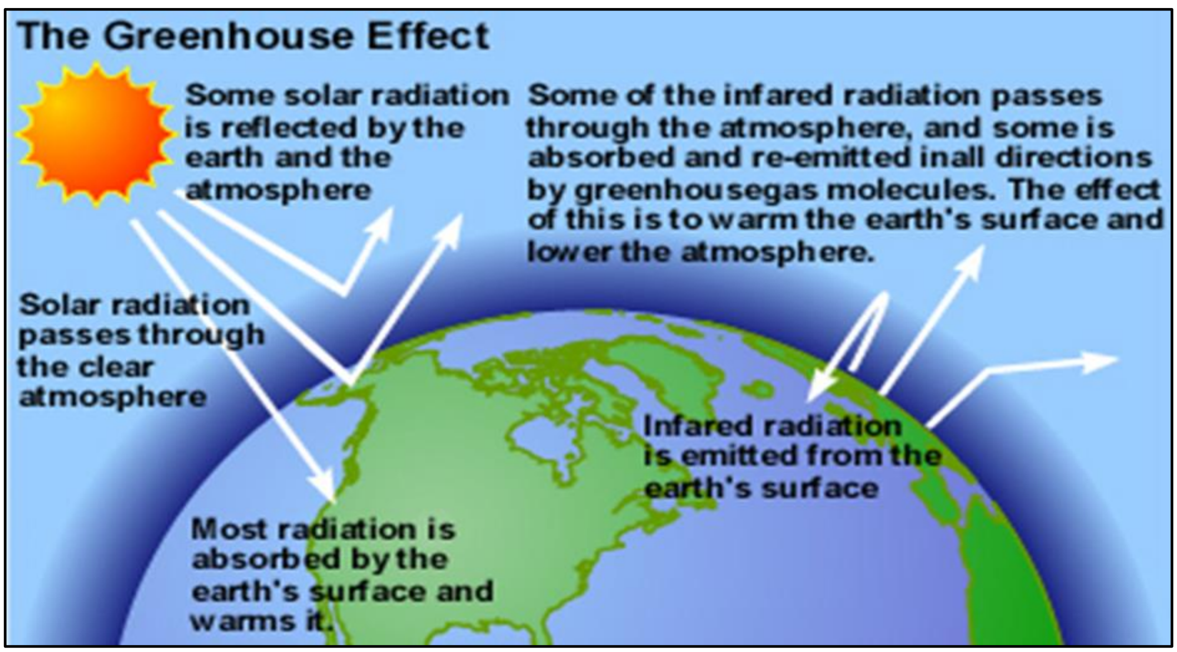

Figure : The Greenhouse effects.

Major greenhouse gases are:

Greenhouse Gas	symbol	Sources
Water vapor	H_2O	Naturally occurring. Rising global temperatures may act to increase water vapor in the atmosphere.
Carbon Dioxide	CO_2	Naturally occurring. Also it occurs as a result of human activities such as burning of coal, oil, and natural gases.
Methane	CH_4	It produces by both the natural and human process. It is produced when plants decay and where there is very little air. It is also called swamp gas because it is abundant around the water and swamps.
Nitrous Oxide	N_2O	Generated by burning fossil fuels, in the manufacture of nitrogen fertilizer and by use of this fertilizers in agricultural
Ozone	O_3	Naturally occurring. Ultraviolet radiation and oxygen interacted to form ozone in atmosphere. Ozone layer helps to protect the earth from ultra-violet radiation
Chlorofluorocarbon, CFCs	Various compounds	Increasing the use of CFCs tend to destroy ozone in the upper atmosphere causing depletion the ozone layer