Lecture #2
Covers sections 2.3, 2.4 and 2.5

Learning Objectives

1. Be able to use the principles of conservation of mass, energy and momentum.
2. Understand the concept of temperature and various temperature scales.
3. Become familiar with different forms of energy and conversion of one form to another.

Conservation of Mass

Mass cannot be created or destroyed.

(a) Mass of a system that is totally isolated isolated from its surroundings remains constant.

(b) Accumulation of mass in a fixed volume in space through which material is flowing in and out is given by:

Mass accumulation in the volume = Mass input – Mass output.

If we are considering the mass of particular chemical specie, we must include the possibility of this specie being generated (or consumed) by chemical reaction within the volume under consideration. In this case,

Mass accumulation of the specie = Input mass of the specie – Output mass of the specie + Mass generation of the specie

Note that the mass generation term can be either positive or negative.

For Example if we are considering oxygen balance in this room, we can say

Increase in the amount of oxygen contained in the room = Oxygen that came into the room from outside – oxygen that went out from the room – oxygen that was consumed by people in the room.

Here the generation term is negative, because oxygen is being consumed not generated.

If we were considering carbon dioxide, the material balance will be

Increase in the amount of CO_2 contained in the room = CO_2 that came into the room from outside – CO_2 that went out from the room + CO_2 that was generated by people in the room.

Here the generation term is positive.

Conservation of Energy

<u>Energy cannot be destroyed or created.</u>

(a) Total energy contained in a system that is totally isolated from its surroundings remains constant.

(b) Accumulation of energy in a fixed volume in space through which energy is flowing in and out is given by:

Accumulation of energy = Energy input – Energy output

Nuclear Reactions

In Nuclear reactions mass can be converted to energy. Einstein's observed that

$$E = mC^2.$$

Conservation of $(m + E/c^2)$

When nuclear reactions are involved, we can write a combined balance for mass and energy.

Accumulation of $(m + E/c^2)$ = Input $(m + E/c^2)$ – Output $(m + E/c^2)$

Conservation of momentum

<u>In absence of an applied force, momentum of a body does not change.</u>

Momentum of a moving object is defined as mass of the object multiplied by its velocity.

$$\text{Momentum} = \text{mass} \times \text{velocity} = m \cdot u$$

When a volume that is completely isolated from its surroundings contains several objects, the sum of momentum of these objects will remain constant, even though their individual momentums can change.

2.4 Concept of temperature

Temperature refers to the sensory feeling of an object being hot or cold.
The degree of hotness or coldness can be quantified by using a temperature scale.
Such scales can be developed by using convenient cold and hot reference points.
Two such reference points are the temperature of a mixture of ice and liquid water at atmospheric pressure and the temperature of boiling water at atmospheric pressure.

In the Celsius scale, the melting ice temperature is assigned a value of zero and the boiling water is assigned a value of 100.

In the Fahrenheit scale, the corresponding values are 32 for melting ice and 212 for boiling water.

The SI unit for temperature is degrees Kelvin. In Kelvin scale the temperature of melting ice is 273.15 and that of boiling water is 373.15.

The Kelvin scale is very useful in thermodynamic calculations. It represents the absolute temperature since there are no negative readings on this scale.

The lowest possible temperature is zero degrees Kelvin, which is called absolute zero.
The counterpart of Kelvin scale in the imperial units is Rankine scale.

The temperature of melting ice in Rankine scale is 492 ^oR. The relationship between these scales can be summarized by the following equations.

$$^oF = 32 + 1.8\ ^oC$$

$$^oC = (^oF - 32)/1.8$$

$$^oK = 273.15 + {}^oC$$

$$^{o}R = {}^{o}F + 459.67$$

2.5 Interconvertibility of energy

Energy can neither be generated nor destroyed but it can be converted from one type to another.

You encounter such conversions everyday in life. The furnace that heats your house is converting the chemical energy of natural gas to heat. The light bulbs that illuminate this room are converting electrical energy into light and some heat. A hydroelectric generation unit converts the potential energy of dammed water into electricity. A solar cell, like the one you have in some of your calculators, converts light into electric current. If you rub your hands rapidly against each other, you convert mechanical energy to heat.

Internal Energy:

- Relates to the nature of a substance and its thermal state.
- Can be thought of as energy stored in a system in the form of molecular motion and bonding forces.
- Its magnitude depends on the temperature, pressure, volume and composition of the system under consideration.

Potential Energy:

- Potential energy of a system is entirely due to its position in a force field.
- In the gravitational field of earth its value depends on the elevation of an object relative to a reference elevation.

Kinetic Energy: Kinetic energy is the energy that a moving body possesses by virtue of its motion. If a system of mass m is moving at a velocity of u, its kinetic energy is given by

$$K.E. = m\,u^2/2$$

Work: Work is force acting on a body through a distance.

$$\text{Work} = \text{force x distance} = F\,.\,\Delta x$$

If the force is changing with distance traveled,

$$W = \int_0^x F dx$$

Heat: Heat is the thermal energy transferred from a hot body to a cold body.

Heat capacity

Heat capacity is defined as the amount of heat necessary to raise the temperature of a body by one degree. Specific heat is of a substance is the heat capacity per unit mass of the substance. In case of gases, you have to make a distinction between whether the increase in temperature occurs at constant pressure or constant volume.