# 5. ENERGY, WORK, HEAT AND POWER

## 5.1 ENERGY

Energy is defined as the ability to do work. It comes in different forms, heat (thermal), light (radiant), mechanical, electrical, chemical, and nuclear energy. All these energies we need to live our busy lives. Energy is a general term include energy in transition and stored energy. The stored energy of a substance may be in the forms of mechanical energy and internal energy (other forms of stored energy may be chemical energy and electrical energy). The unit of energy is Joule (J). There are three types of energy:

**1. POTENTIAL ENERGY (P.E):** It is the energy stored in a system (mass) as a result of its location in a gravitational field, and its magnitude is given by:

$$P.E = m.g.Z \qquad \text{.............................. (7)}$$

where: m is the mass (kg).
g: is the gravitational acceleration ($m/s^2$).
Z: is the elevation (m).

**Forms of Potential Energy are:**

**a. CHEMICAL ENERGY:** is the energy stored in food, wood, coal, petroleum, and other fuels.

**b. MECHANICAL ENERGY:** is the energy possessed by an object due to its stored energy of position. Rubber bands and springs are good examples.

**c. NUCLEAR ENERGY:** is the energy locked in the nucleus of the atom. Nuclear power plants split atoms in process called fission.

**d. GRAVITATIONAL ENERGY:** is the energy stored as a result of gravitational forces concentrated by the earth for the object. Water held back by a dam is an example.

Email (esam.muhe@uomus.edu.iq)

**2. KINETIC ENERGY:**

It is the energy that a system possesses as a result of its motion relative to some reference frame. It is denoted (K.E) and is expressed as:

$$K.E = \frac{1}{2} .m.V^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

where: m is the mass (kg).
V: is the velocity (m/s).

**Forms of Kinetic energy are:**

**a. ELECTRICITY**: is the energy produced when something upsets the balancing force between electrons and protons in atoms.

**b. LIGHT OR RADIANT ENERGY**: waves that omit energy. Examples include radio and television waves. Gamma rays and x-rays.

**c. HEAT OR THERMAL ENERGY:** is the energy created by heat.

**d. MOVEMENT:** as the power of potential energy uncoils, it transforms the energy source into kinetic energy.

**3. INTERNAL ENERGY**:

It is the sum of all energy associated with molecules which may have translational, vibrational and rotational motions etc., and respective energies causing these motions. It is denoted (U).

The total energy of a system is denoted (E) in (J) and it is the sum of all forms of energy within the system:

$$E = K.E + P.E + U = \frac{1}{2} m.V^2 + m.g.Z + U \qquad \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

The total energy of a system on a unit mass basis is denoted by (e) in (J/kg) and is expressed as:

$$e = Ke + Pe + u = \frac{1}{2} V^2 + g.Z + u \qquad \ldots\ldots\ldots (10)$$

## 5.2 WORK

Work is defined as the product of a force and the distance moved in the direction of the force and is denoted by (W). Consider a simple closed system as a gas trapped between a piston and cylinder, as shown in the Figure (2), the system having initially the pressure ($P_1$) and volume ($V_1$). The system is in thermodynamic equilibrium, the state of which is described by the coordinates ($P_1$) and ($V_1$). The piston is the only boundary which moves due to the gas pressure. Let the piston move out to a new final position (2), which is also a thermodynamic equilibrium state specified by pressure ($P_2$) and volume ($V_2$). At any intermediate point in the travel of the piston, let the pressure be ($P$) and the volume be ($V$). This must also be an equilibrium state, since macroscopic properties ($P$) and ($V$) are significant only for equilibrium states. When the piston moves an infinitesimal distance ($dl$), and if ($A$) is the area of the piston, the force acting on the piston ($F$) and the infinitesimal amount of work done by the gas on the piston:

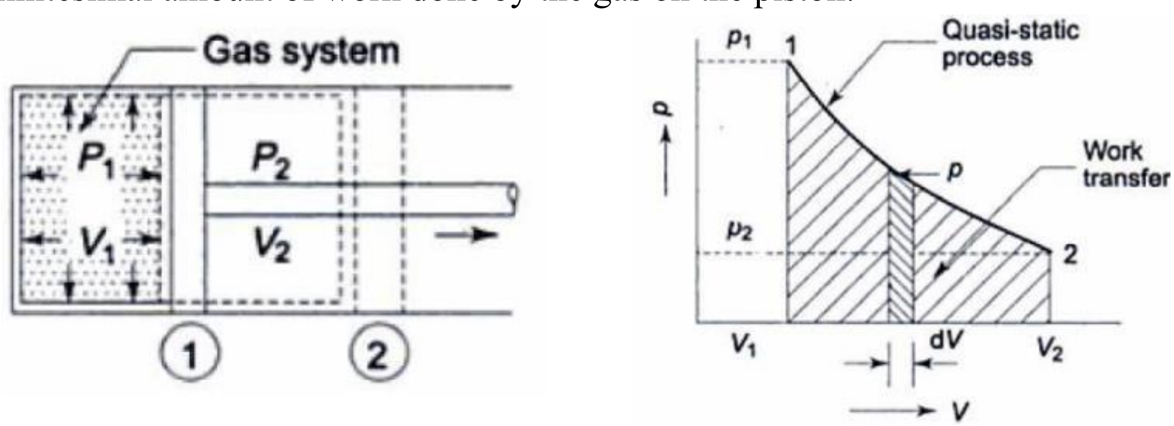


**Figure (2) Closed System and PV-Diagram.**

$$dW = F.dl = P.A.dl = P.dV \qquad \text{.....................(11)}$$

where $F = P.A$ is the force acting on the piston.

$dV = A.\, dl$ is the infinitesimal displacement volume.

When the piston moves out from position (1) to position (2) with the volume changing from ($V1$) to ($V2$), the amount of work done by the system will be:

$W = \int_1^2 P\,dV$ ……………………..(12)

The magnitude of the work done is given by the area under the path 1-2, as shown on the (P-V) diagram. It should be noted that when work is done by the system, it will have a positive sign, and when work is done on the system, it will have a negative sign, (i.e. $W$ out is positive and $W$ in is negative).

**5.3 HEAT**

Heat is the energy transferred without transfer of mass across the boundary of the system due to the difference in temperature between the system and its surroundings. It is denoted ($Q$). If there is no temperature difference there is no heat transfer, thus heat is not a property. The unit of heat is Joule (J = N.m).

For one kilogram of the substance is the specific heat and denoted ($q$):

$q = Q/m = J/kg$ ………………………… (13)

**5.4 POWER**

Power is the time rate of energy transfer by work, or work done per unit time, and is denoted by ($\dot{W}$).

$\dot{W} = W/t = J/s = watt$ …………………..(14)

**6. SPECIFIC HEAT CAPACITY**

The specific heat capacity of a substance is defined as the amount of heat which transfers into or out of a unit mass of the substance, while the temperature of the substance changes by one degree. Thus if:

$C$: Specific heat capacity of the substance.

$m$: Mass of the substance.

$Q$: Heat transfer.

$T_1$: Initial temperature.

$T_2$: Final temperature.

Then: $Q_{1\text{-}2} = m\,C\,\Delta T = m\,C\,(T_2 - T_1)$ …………(15)

Email (esam.muhe@uomus.edu.iq)

Specific heat capacity may vary with temperature. It should also be noted that when heat is transferred to the system, it will have a positive sign, and when

it is transferred from the system, it will have a negative sign, (i.e. $Q$ gained is positive and $Q$ rejected is negative).

**Example (2):** An unknown metal weighing (0.9 kg) at an initial temperature of (140 °C) is placed into an insulated container holding (3 kg) of water at an initial temperature of (60 °C). After thermal equilibrium the water rose to (65 °C). Knowing that ($C_{\text{water}}$ = 4186 J/kg.°C), what is the specific heat capacity of the metal?

**Solution**:

The amount of heat lost by the metal equals the amount of heat gained by the water, thus:

$$Q_{\text{Lost}} = Q_{\text{Gained}}$$

$$-m_{\text{m}}\, C_{\text{m}}\, \Delta T_{\text{m}} = m_{\text{w}}\, C_{\text{w}}\, \Delta T_{\text{w}}$$

$$-0.9 \times C_{\text{m}} \times (65 - 140) = 3 \times 4186 \times (65 - 60)$$

$$C_{\text{m}} = 930\ J/kg.°C$$

**Example (3):** A (10 g) iron bar at (80 °C) is dropped into (70 g) of water at (25 °C). Knowing that ($C_{water}$ = 4.186 kJ/kg.°C) and ($C_{iron}$ = 0.47kJ/kg.°C), what is the final temperature after thermal equilibrium?

**Solution:**

The amount of heat lost by the iron bar equals the amount of heat gained by the water, thus:

$Q_{Lost} = Q_{Gained}$

$-m_i\, C_i\, \Delta T_i = m_w\, C_w\, \Delta T_w$

$-10 \times 0.47 \times (T_f - 80) = 70 \times 4.186 \times (T_f - 25)$

$T_f = 25.87\ °C$

## 7. ENTHALPY

Enthalpy is a property of a substance and a form of energy. It is denoted (H) and is equal to the combined internal energy and flow energy:

$$H = U + P.V \qquad \text{..........................(16)}$$

where

U: is the internal energy.

P.V is the flow energy.

Like internal energy, enthalpy is an extensive property and can have a specific value:

$$\text{h} = \text{H}/m = J/kg \qquad \text{.............................. (17)}$$

Enthalpy is equivalent to the total heat content of a system and it is a dependent property.