# 3. Energy and Work

Energy has been defined as the capability to produce an effect. Energy can exist in numerous forms such as thermal, mechanical, kinetic, potential, electric, magnetic, chemical and nuclear. Energy can be stored within a system and can be transferred (as heat, for example) from one system to another. The unit of energy is Joule (J). These are some of the most important forms of energy in thermodynamics:

**1. Kinetic energy:** it is the energy that a system possesses as a result of its motion relative to some reference frame. It is denoted *KE* and is expressed as:

$$KE = \frac{1}{2}.m.C^2$$

where: *m* is the mass.

*C* is the velocity.

**2. Potential energy:** it is the energy that a system possesses as a result of its elevation in a gravitational field. It is denoted *PE* and is expressed as:

$$PE = m.g.Z$$

where: *m* is the mass.

*g* is the gravitational acceleration.

*Z* is the elevation.

**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* and it is the sum of all forms of energy within the system:

$$E = KE + PE + U = \frac{1}{2}.m.C^2 + m.g.Z + U \qquad \text{(J)}$$

The total energy of a system on a unit mass basis is denoted by *e* and is expressed as:

$$e = ke + pe + u = \frac{1}{2}.C^2 + g.Z + u \qquad \text{(J/kg)}$$

## 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:

$$H = U + PV$$

where $PV$ is the flow energy. Like internal energy, enthalpy is an extensive property and can have a specific value:

$$u = \frac{U}{m} = \frac{\text{J}}{\text{kg}}$$

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

## Work

Work, like heat, is an energy interaction between a system and its surroundings. Energy can cross the boundary of a closed system in the form of heat or work. Therefore, if the energy crossing the boundary of a closed system is not heat, it must be work. As mentioned earlier, heat is easy to recognize: Its driving force is a temperature difference between the system and its surroundings. Then we can simply say that an energy interaction that is not caused by a temperature difference between a system and its surroundings is work. More specifically, work is the energy transfer associated with a force acting through a distance. A rising piston, a rotating shaft and an electric wire crossing the system boundaries are all associated with work interactions.

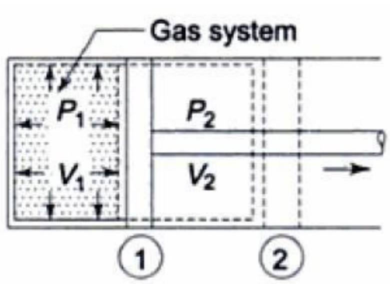
Work is also a form of energy transferred like heat and, therefore, has energy units such as J. It is denoted W. The work done per unit mass of a system is denoted *w* and is expressed as:

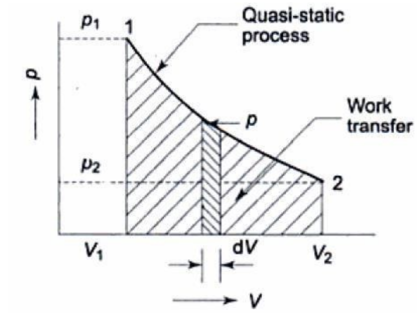
$$w = \frac{W}{m} = \frac{\text{J}}{\text{kg}}$$

The rate of doing work is called **power** and is denoted $\dot{W}$. The unit of power is J/s or Watt (W).

## $P$d$V$-Work or Displacement Work

Let the gas in the cylinder, in the figure shown, be a 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 $F = P.A$ and the infinitesimal amount of work done by the gas on the piston:




$dW = F.dl = P.A.dl = P.dV$

where $dV = A.dl$ is the infinitesimal displacement volume.

When the piston moves out from position 1 to position 2 with the volume changing from $V_1$ to $V_2$, the amount of work done by the system will be:

$$W = \int_1^2 PdV$$

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).