Laws of Thermodynamics

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Laws of Thermodynamics

- First Law of T.D.
- Energy Equation
- About Conservation of energy

$$E = me = U + \mathrm{KE} + \mathrm{PE} = m(u + ke + pe) \qquad (3.1)$$

m=Mass, e=energy per unit mass, Joule/kg
E=total energy
U=Internal Energy, for example, Heating water until you reach boiling point.
KE= Kinetic Energy, Water once reach boiling point, vapor escapes from the container.
PE= Potential Energy, For example, Storing water on a storage tank at an elevation.

$$E = mu + \frac{1}{2}m\mathbf{V}^2 + mgZ \qquad (3.2)$$

u=Internal energy per unit mass, Joule/kg
V=Velocity
Z=Elevation
g=Gravity

Forms of Internal Energy Equation

$$E_2 - E_1 = {}_1Q_2 - {}_1W_2 \tag{3.5}$$

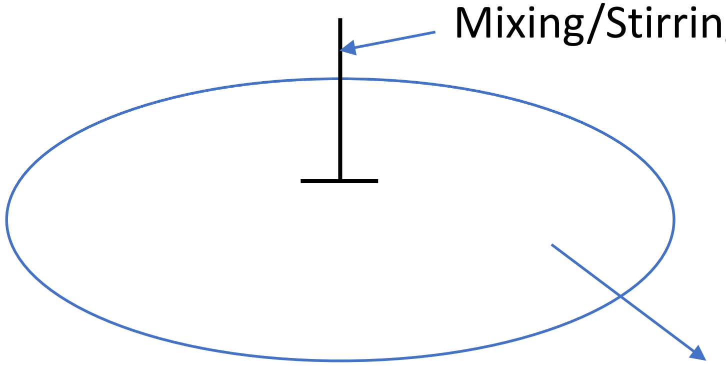
accompanied by

$$E_2 - E_1 = U_2 - U_1 + \frac{1}{2}m(\mathbf{V}_2^2 - \mathbf{V}_1^2) + m(Z_2 - Z_1)$$

E2-E1= Change in energy between state 1 and 2, For example, In case of boiling water, before boiling point state 1, after boiling Point state 2.

Example on Internal energy

A tank containing a fluid is stirred by a paddle wheel. The work input to the paddle wheel is 5090 kJ. The heat transfer from the tank is 1500 kJ. Consider the tank and the fluid inside a control surface and determine the change in internal energy of this control mass.



Mixing/Stirring, 5090 KJ input

Heat Transfer, 1500 KJ

The energy equation is (Eq. 3.5)

$$U_2 - U_1 + \frac{1}{2}m(\mathbf{V}_2^2 - \mathbf{V}_1^2) + mg(Z_2 - Z_1) = {}_1Q_2 - {}_1W_2$$

Since there is no change in kinetic and potential energy, this reduces to

$$U_2 - U_1 = {}_1Q_2 - {}_1W_2$$

$$U_2 - U_1 = -1500 - (-5090) = 3590 \text{ kJ}$$

U =Q-W=-1500-(-5090)=-1500+5090=3590 kJ
Q output, so it is negative
W Input, so it is negative
So, Internal Energy is going up

General Notion:
W Out is positive, W input is negative
Q output is negative, Q Input is Positive

If fluid mass is 15 kg, find the internal energy per unit mass→3590/15=239.3 kJ/kg

First Law of Thermodynamics with U=0

going through several processes that are repeated. As the substance returns to its original state, there is no net change in the control volume's total energy and the rate of change is thus zero. The net sum of the right-hand-side terms gives the energy equation as

$$0 = \oint \delta Q - \oint \delta W \tag{3.10}$$

The symbol $\oint \delta Q$, which is called the cyclic integral of the heat transfer, represents the net heat transfer in the cycle and $\oint \delta W$ is the cyclic integral of the work representing the net

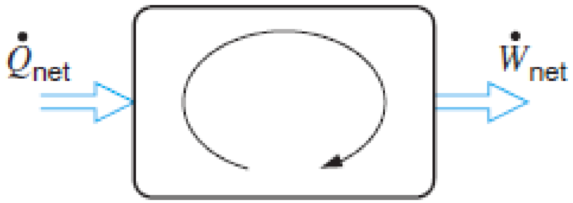


FIGURE 3.3 A cyclic machine.

work given out during the cycle. Rewriting the equation as

$$\oint \delta Q = \oint \delta W \tag{3.11}$$

- There is no net change in internal energy.

Energy Conservation Example

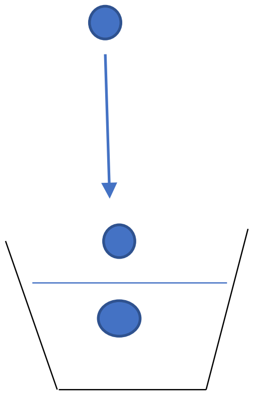
Consider a stone having a mass of 10 kg and a bucket containing 100 kg of liquid water. Initially the stone is 10.2 m above the water, and the stone and the water are at the same temperature, state 1. The stone then falls into the water.

Determine ΔU, ΔKE, ΔPE, Q, and W for the following changes of state, assuming standard gravitational acceleration of 9.806 65 m/s^2.

a. The stone is about to enter the water, state 2.

b. The stone has just come to rest in the bucket, state 3.

c. Heat has been transferred to the surroundings in such an amount that the stone and water are at the same temperature, T_1, state 4.



Given, m_s=10 kg, m_w =100 kg
Z=10.2 m
g=9.8 m per sec^2

Solution:

$$\Delta U + \Delta KE + \Delta PE = Q - W$$

Case a. $\Delta U = 0, \quad {}_1Q_2 = 0, \quad {}_1W_2 = 0$

Del (KE)=-Del (PE)=-m_s*g*Z=10*9.8*10.2
=1000 J

Case b. $\Delta PE = 0, \quad {}_2Q_3 = 0, \quad {}_2W_3 = 0$

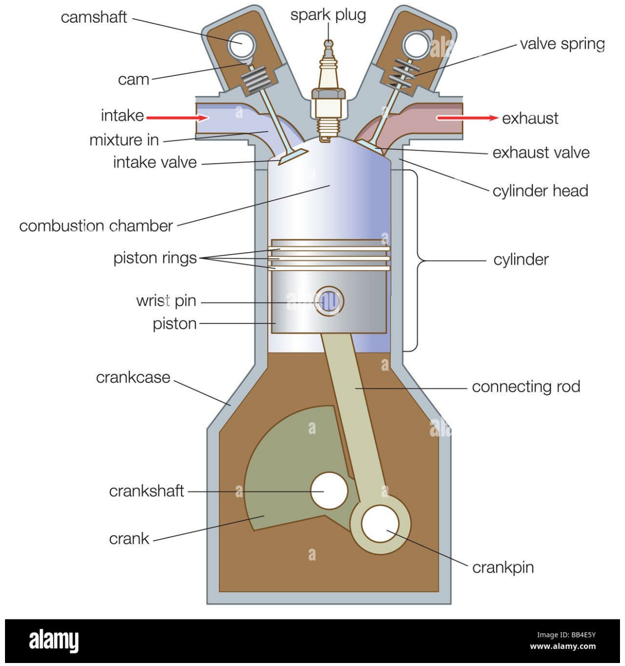
Del(U)=-Del (KE)=-1000 J

Case c. $\Delta U = -1\ kJ, \quad \Delta KE = 0, \quad \Delta PE = 0, \quad {}_3W_4 = 0$

Q=Del (U)=-1000 J=-1 KJ

Enthalpy from 1st law of TD

- H, h, delta h
- kJ, kJ/kg
- Enthalpy is a measure of heat of a system at constant pressure



energy (U) of a system is equal to the heat and work done on the system.

Q=U+W

If we use a Piston-Cylinder case as an example, we find that, W= Force*distance

=F*Del (d)

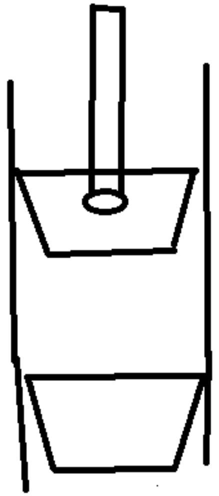
At constant Pressure, W=P*Del(V)

Heat Transferred at Constant Pressure, is enthalpy, therefore,

$$\Delta H = Q_p$$

Therefore, at constant pressure

$$\Delta H = \Delta U + P\Delta V$$



Example Problem

Calculate the Enthalpy change for a gas phase reaction at 1.2 atm if the change in internal energy is 47kJ and the volume increase by 1.1 L to 41.0 L. Note 1L-atm =101.325J

Ans- 52 kJ