Where Q_s heat supplied

Q_r heat rejected
W_c work of compression
W_e work of expansion

3.2.6 First Law of Thermodynamics Applied to Open Systems

The first law of thermodynamics is based on the conversation of energy within a system. Open systems are associated with those, which have a steady flow, thus the first law applied to such systems is known as the Steady Flow Energy Equation (SFEE):-

$$Q - W = (\Delta H + \Delta KE + \Delta PE)$$

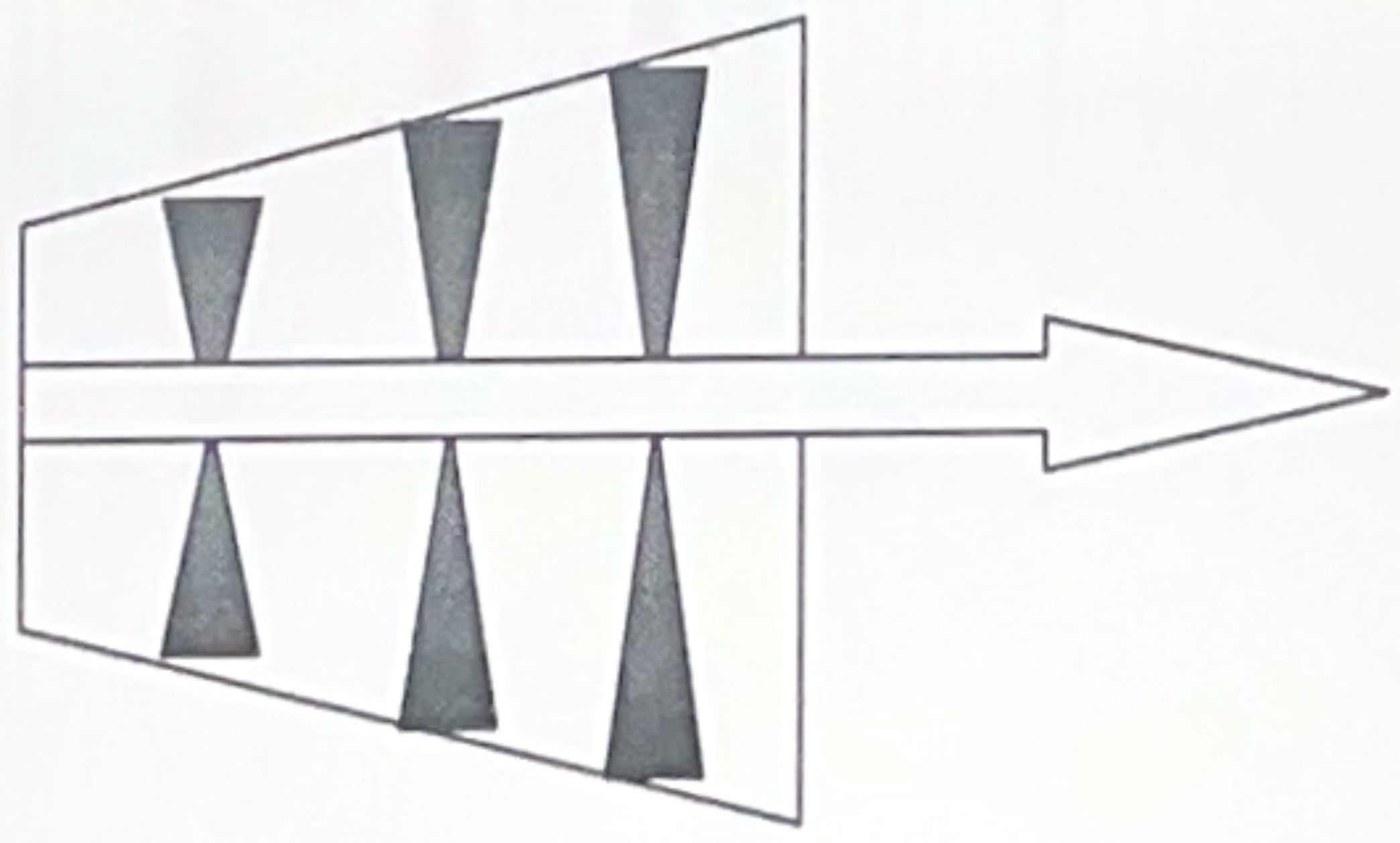
$$= m\left[(h_2 - h_1) + \frac{1}{2}\left(V_2^2 - V_1^2\right) + g\,(Z_2 - Z_1)\right] \tag{39}$$

Variable	Symbol	Units
Heat transfer	Q	W
Work transfer	W	W
Mass flow rate	m	kg/s
Specific enthalpy	h	J/kg
Velocity	V	m/s
Gravitational acceleration	g	9.81 m/s^2
Elevation above datum	z	m

3.2.6 Application of SFEE

a. Turbines or Compressors

if the SFEE is applied to the expansion of a fluid in a turbine as shown



$Q - W = m\,(\Delta h + \Delta ke + \Delta Pe)$

With the following simplifications are made

$Q = 0$,

$\Delta ke = 0$,

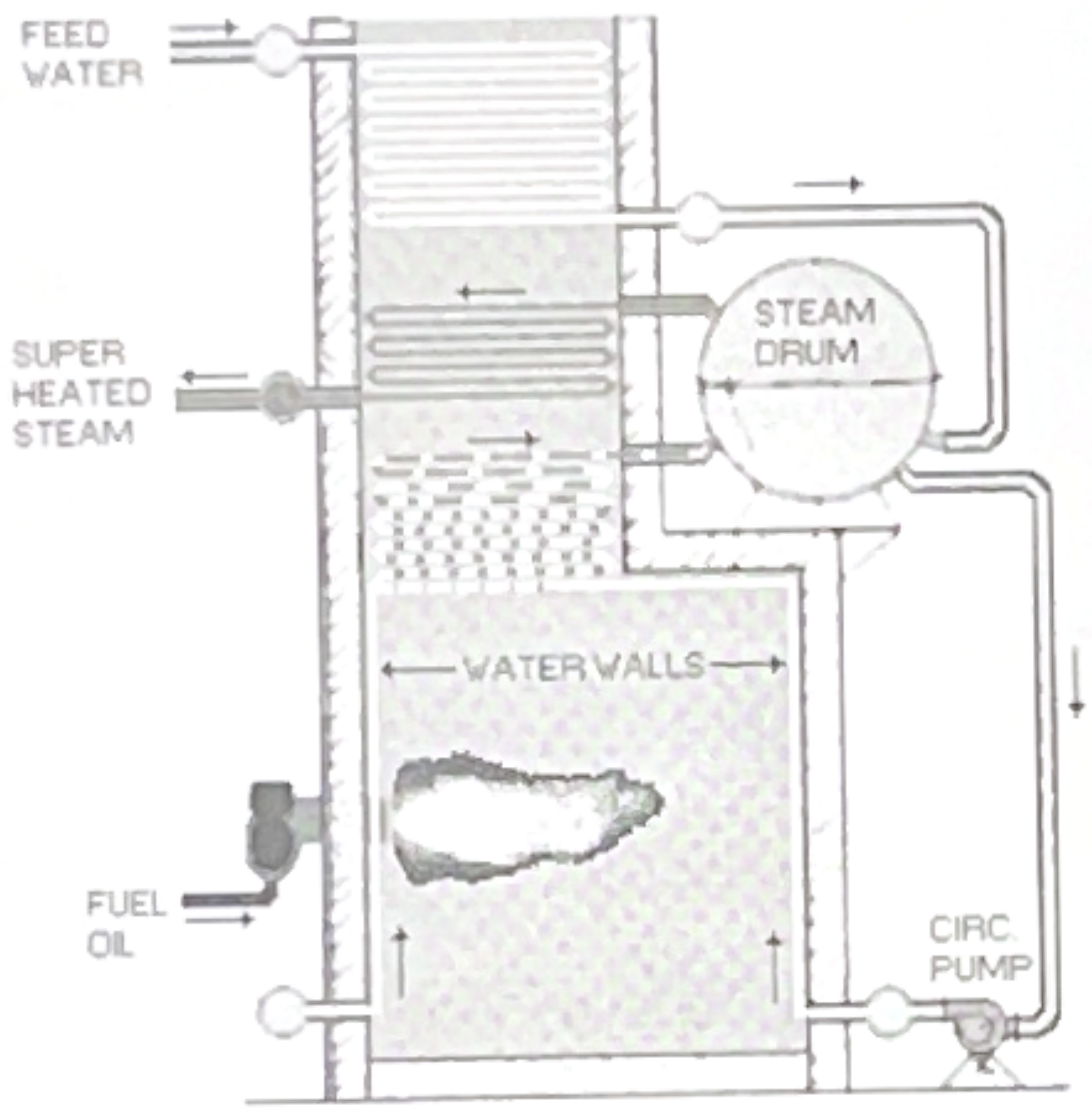
$\Delta Pe = 0$ are all neglected.

$$\therefore W = m(h_1 - h_2) \tag{40}$$

hence for a turbine, the amount of energy produced "Work " is equal to the enthalpy change between inlet and outlet.

b. Boilers or Condencors

if the SFEE is applied to the heating or cooling (evaporation or condensation) of a fluid in a boiler or condensor



$$Q - W = m(\Delta h + \Delta ke + \Delta Pe)$$

With the following simplifications are made

There is no process work on the fluid $W = 0$,

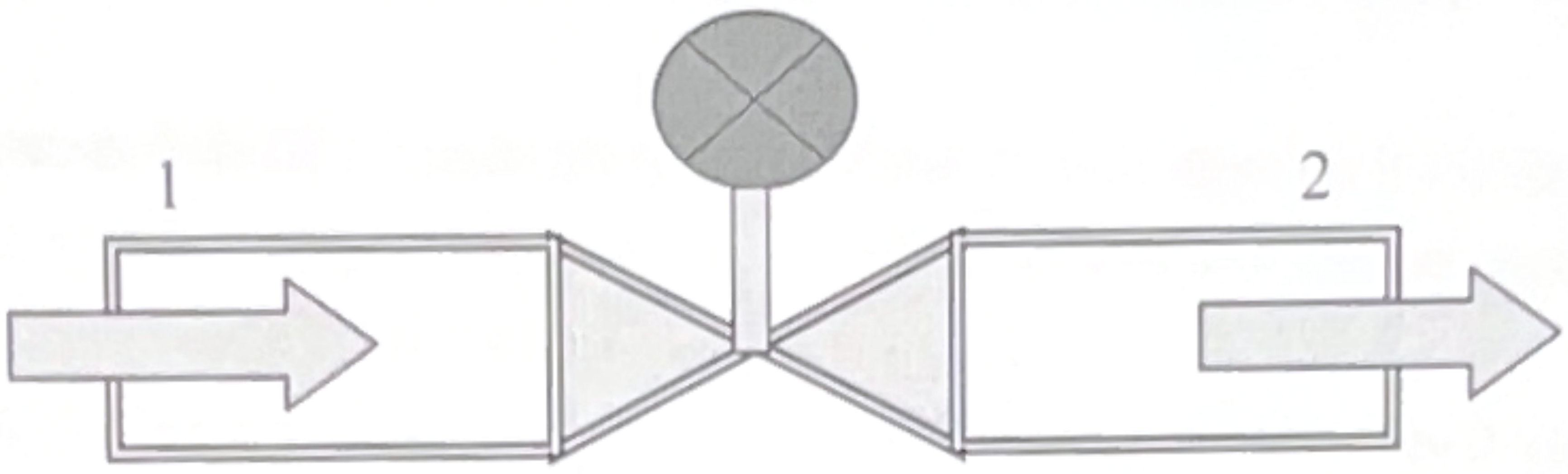
If Kinetic energy and Potential energy changes $\Delta ke = 0$, $\Delta Pe = 0$ are neglected. Then the SFEE reduces to :

$$\therefore Q = m(h_1 - h_2) \tag{41}$$

hence for a boiler or a condensor, the amount of energy supplied or exctracted from the fluid "Heat " is equal to the enthalpy change for the fluid between inlet and outlet.

c. Throttling valve

Consider the flow of fluid through a small valve as shown



if the SFEE is applied between sections 1 and 2 :

$Q - W = m (\Delta h = \Delta ke + \Delta Pe)$

$Q = 0$ Assuming adiabatic

$W = 0$	No displacement work (no work is inputted or extracted, ie no pump or turbineis attached)

$\Delta ke = 0$ Assumed (inlet and exit velocities are similar or slow)

$\Delta Pe = 0$ Assumed (entry and exit at the same or nearly the same elevation)

Hence, The SFEE, reduces to:

$\therefore \quad m\,(h2 - h1) = 0$

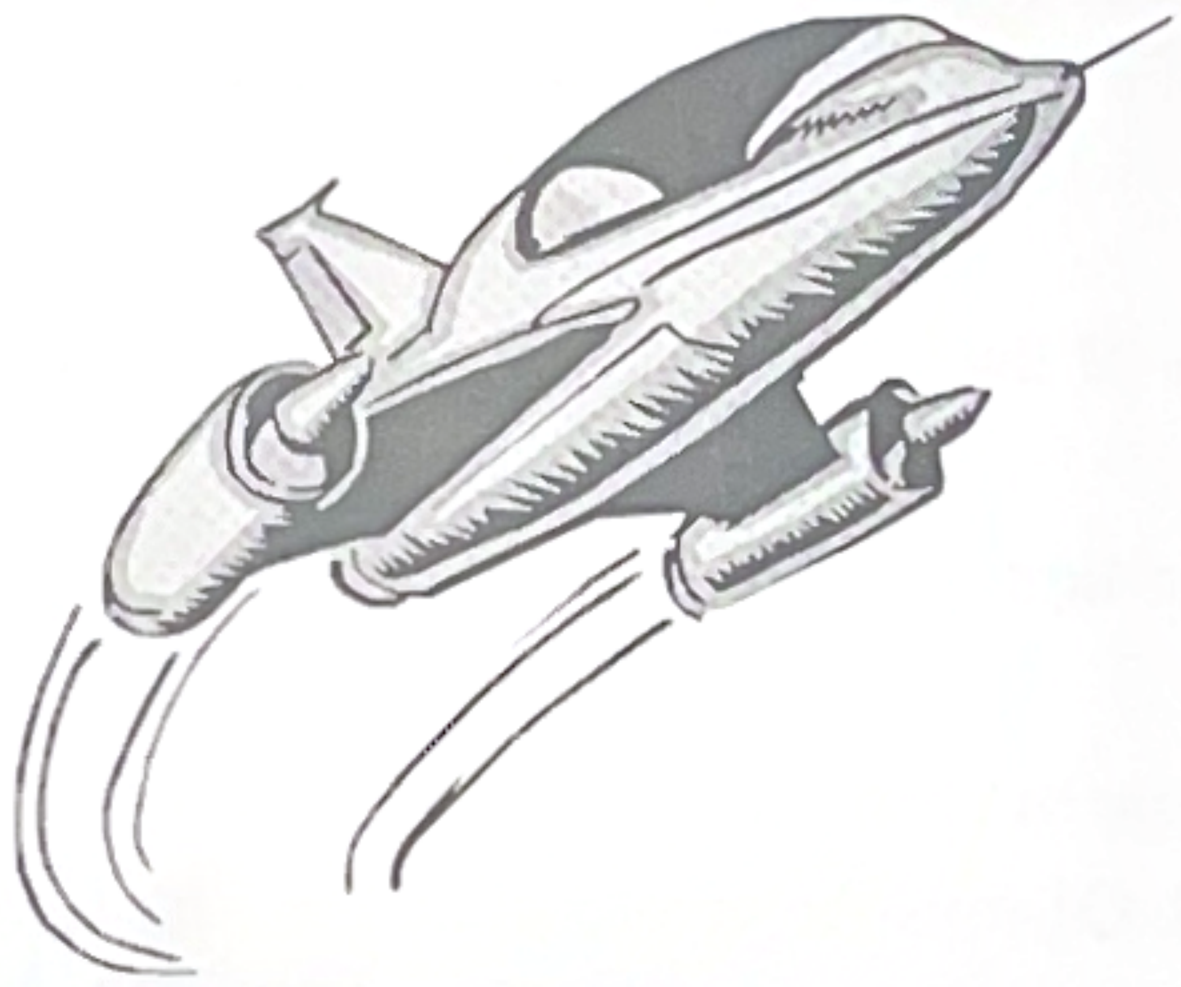
divide by the mass flow m to get:

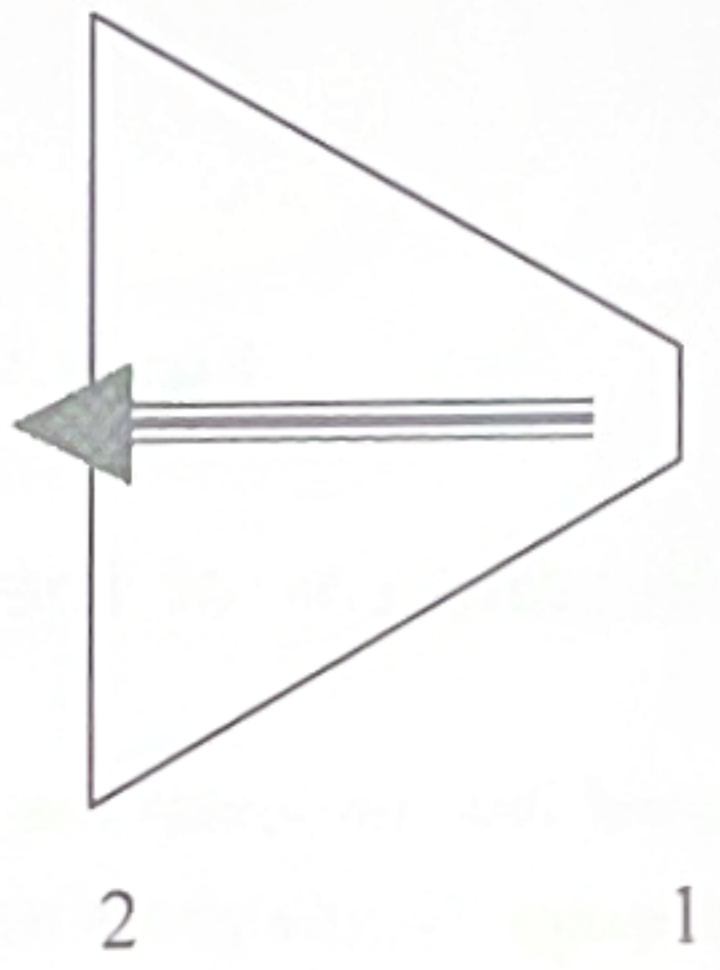
$$\therefore\ h2 = h1 \qquad (42)$$

hence for a control valve, the enthalpy of the fluid remains constant.

d. Diffuser

Consider the flow of fluid through a diffuser which is a device used in aircraft to reduce the kinetic energy of exhaust gases, as shown





if the SFEE is applied between sections 1 and 2:

$Q - W = m\,(\Delta h = \Delta ke + \Delta Pe)$

$Q = 0$	Assuming adiabatic
$W = 0$	No displacement work (no work is inputted or extracted, ie no pump or turbineis attached)

$\Delta Pe = 0$ Assumed (entry and exit at the same or nearly the same elevation)

Hence, The SFEE, reduces to:

$$\therefore \quad h_2 - h_1 = \frac{V_2^2 - V_1^2}{2} \tag{43}$$

3.3 The Second Law of Thermodynamics

The second law of thermodynamics is a general principle which places constraints upon the direction of heat transfer and the attainable efficiencies of heat engines. It's implications may be visualized in terms of the waterfall analogy.

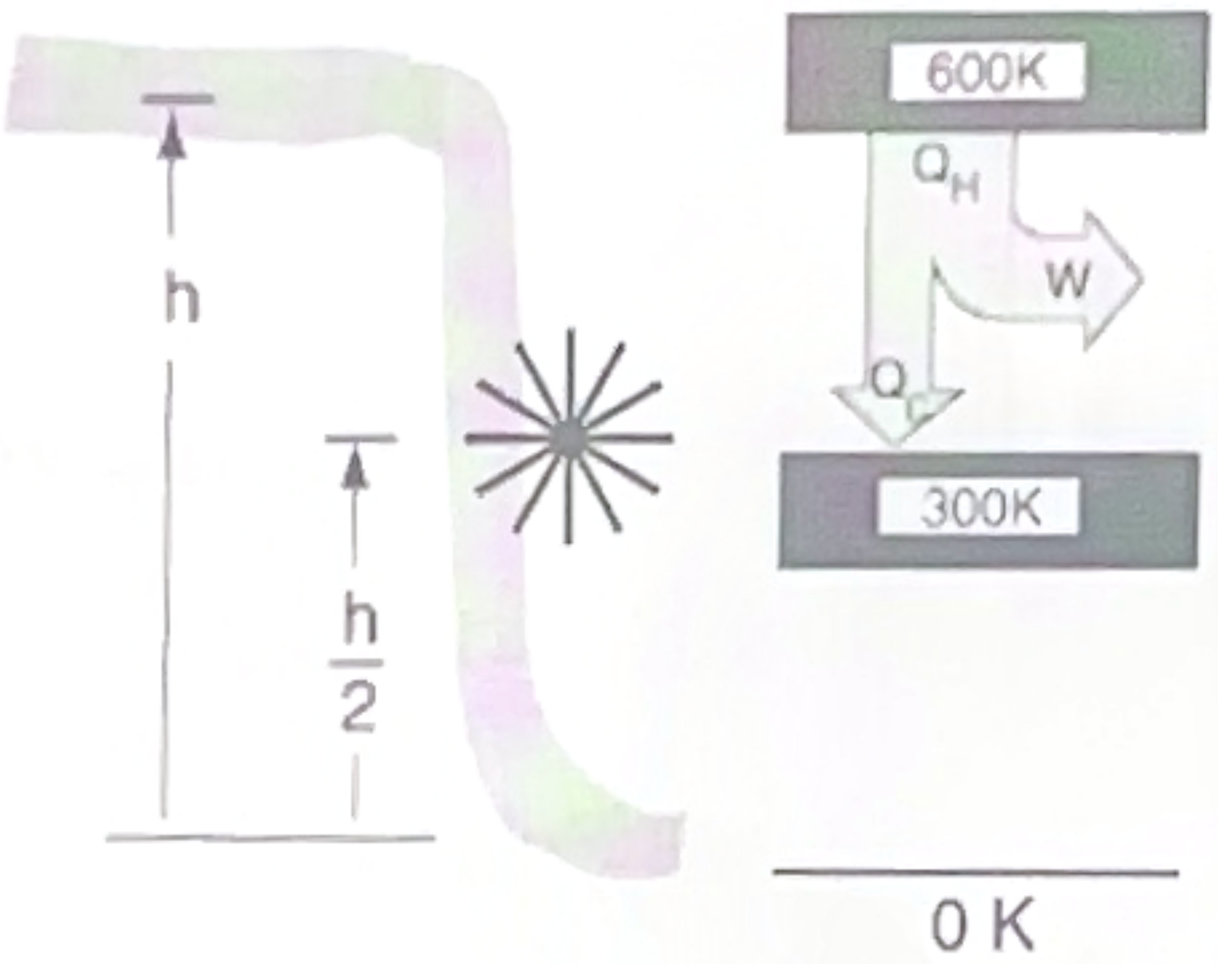


Figure 3.2: Analogy of the 2nd Law of Thermodynamics

3.3.1 Second Lay of Thermodynamics – statements:

The second law, indicates that, although the net heat supplied, Q1-Q2, in a cycle is equal to the network done, W, the gross heat supplied, Q1 must be greater than the network done; some heat must always be rejected by the system.

$Q1 > W$, or to be precise:-

$$W = Q1 - Q2 \tag{44}$$

Where, Q1 is the heat supplied and Q2 is the heat rejected.
The ratio of network output to heat supplied is known as the thermal efficiency of the system.

There are two ways in which the second law is expressed:-