WORK

Work is energy in transit, from one thermodynamic system to another thermodynamic system, in which the sole effect of the energy transfer can be reduced to raising a weight. Work can also be understood as a force acting against a resistance through a distance.

Work= Force x Distance

1J=1N x 1 m   1 ft lb = 1 lb x 1 ft

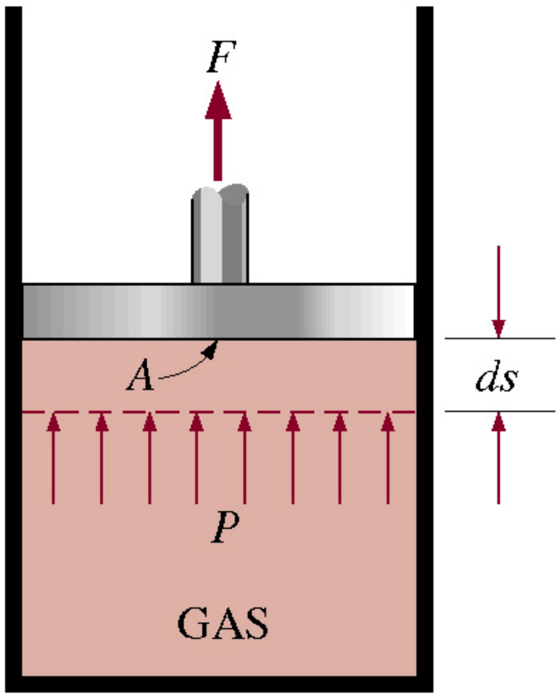
$$W = \int Fds \text{ from Mechanics}$$

$$N \times m$$

$$lbf \times ft$$

$$W = \int \frac{F}{A} Ads$$

$$W = \int pdv$$



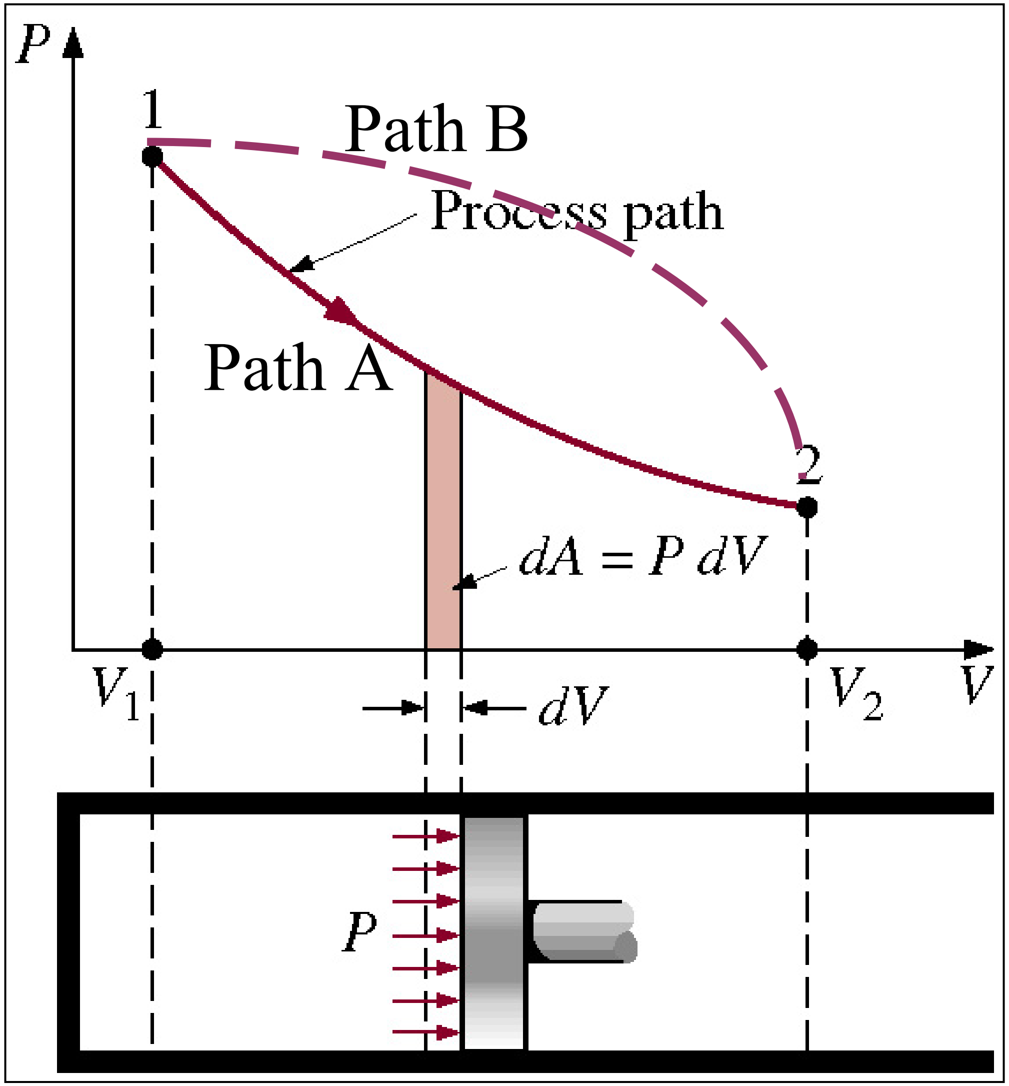
Work is not a property.

Work is a path function.

Work depends on the path taken between the initial and final state points.

Work is not an exact differential.

$$\int_A pdv \neq \int_B pdv$$



HEAT

Heat is energy in transit from one thermodynamic system to another thermodynamic system due to a temperature difference between the two thermodynamic systems.

1BTU= 1 lb water at 60 F raised 1 degree F.
1 kJ=4.1816 kg water at 15 C raised 1 degree C.

CONDUCTION $Q = -kA\frac{dT}{dx}$ (2.52)

CONVECTION $Q = -hA(T - T_o)$ (2.53)

RADIATION $Q = \sigma\varepsilon A\left(T_2^4 - T_1^4\right)$ (2.57)

A area

k conductivity

h convection heat transfer coefficient

ε emissivity

σ Stephan Boltzman constant

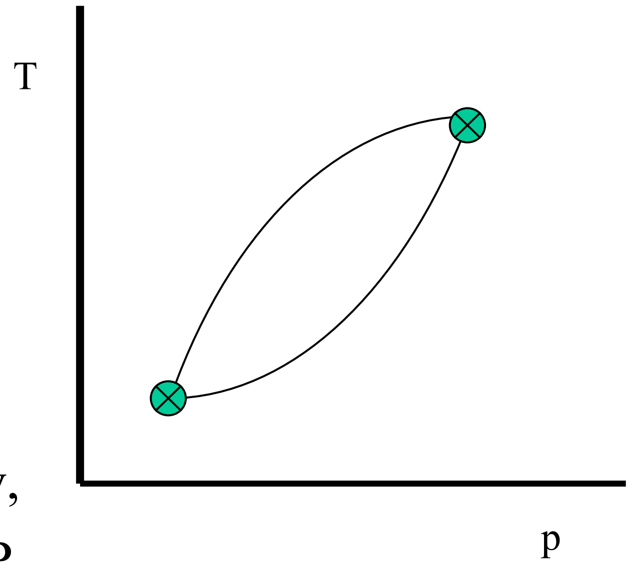
$5.67 \times 10^{-8}\ \mathrm{W/m^2\ K^4}$

$.1713 \times 10^{-8}\ \mathrm{Btu/\ hr\ ft^2\ R^4}$

HEAT AND WORK

Both Heat and Work are:

- energy in transit
- dependent on the path or process
- ARE NOT exact differentials
- ARE NOT fluid properties



Properties are exact differentials. Internal energy, u, is a function of temperature, T, and pressure, P.

$$du = \left(\frac{\partial u}{\partial T}\right)_p dT + \left(\frac{\partial u}{\partial p}\right)_T dp$$

The same change in internal energy results from any path taken between (p, T) state points.

Heat and work can also be functions of T and P however Heat and Work are not exact differentials. Heat and Work depend on the path taken between the (p, T) state points.

First Law of Thermodynamics

Observations:

work can be transferred into heat

more friction = more heat

$$\sum \delta Q \propto \sum \delta W$$

Examples:

rubbing you hands together

friction in a wheel bearing

braking a wheel

Experiments:

$$\sum Q = C \sum W$$

$$\oint \delta Q = C \oint \delta W$$

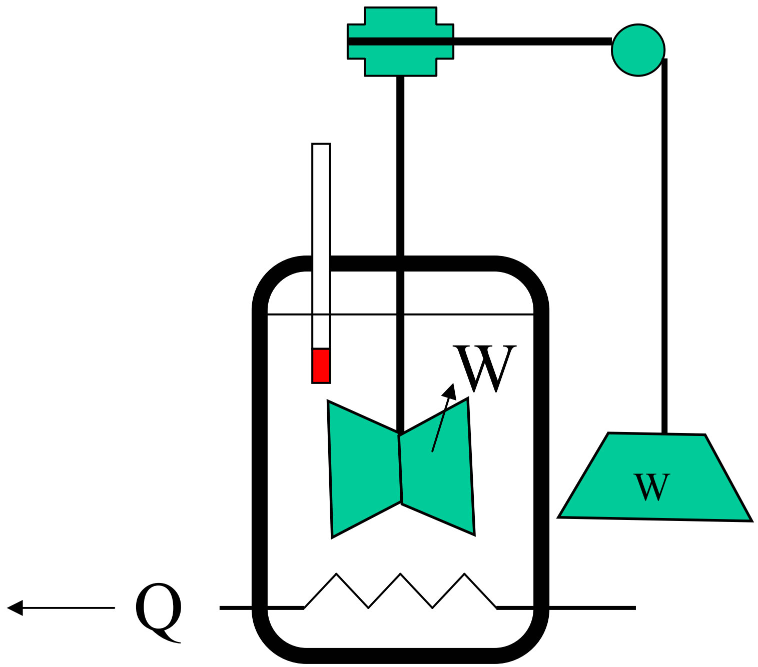
$$1\ \text{BTU} = 778\ \text{ft}\ \text{lb}_f$$

$$1\ \text{calorie} = .427\ \text{kg}\ \text{m}$$

First Law for a Cycle

$$\oint \boldsymbol{\delta Q} = \oint \boldsymbol{\delta W}$$

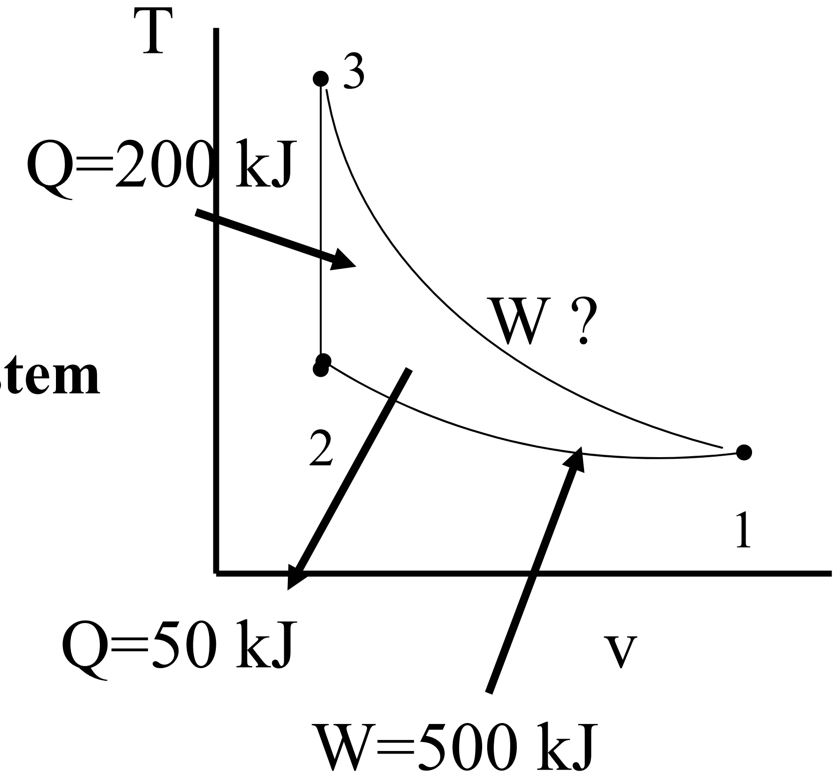
$$\oint (\boldsymbol{\delta Q} - \boldsymbol{\delta W}) = \mathbf{0}$$



JOULE EXPERIMENT

The First Law is a fundamental observation of nature, an axiom, which can not be proved but has never been found to be violated

With the following energy flows, in a closed sysem what is the work done in process 3 → 2?



$\mathbf{W_{1\to 2} = 500\ kJ}$ **done on the system**

$\mathbf{Q_{1\to 2} = 50\ kJ}$ **removed from the system**

$\mathbf{Q_{2\to 3} = 200\ kJ}$ **added to the system**

$\mathbf{Q_{3\to 1} = 0\ kJ}$

First Law for a Cycle

$$\sum Q = \sum W$$

$$-Q_{1\to 2} + Q_{2\to 3} = -W_{1\to 2} + W_{3\to 1}$$

$$-50 + 200 = -500 + W_{3\to 1}$$

$$W_{3\to 1} = 650\text{ kJ done by the system}$$

First Law of Thermodynamics

$$\oint \delta Q = \oint \delta W \quad \text{First Law for a Cycle}$$

$$\oint (\delta Q - \delta W) = 0$$

Cycle $A \Rightarrow B$ $\quad {}_A\int (\delta Q - \delta W) - {}_B\int (\delta Q - \delta W) = 0$

Cycle $A \Rightarrow C$ $\quad {}_A\int (\delta Q - \delta W) - {}_C\int (\delta Q - \delta W) = 0$

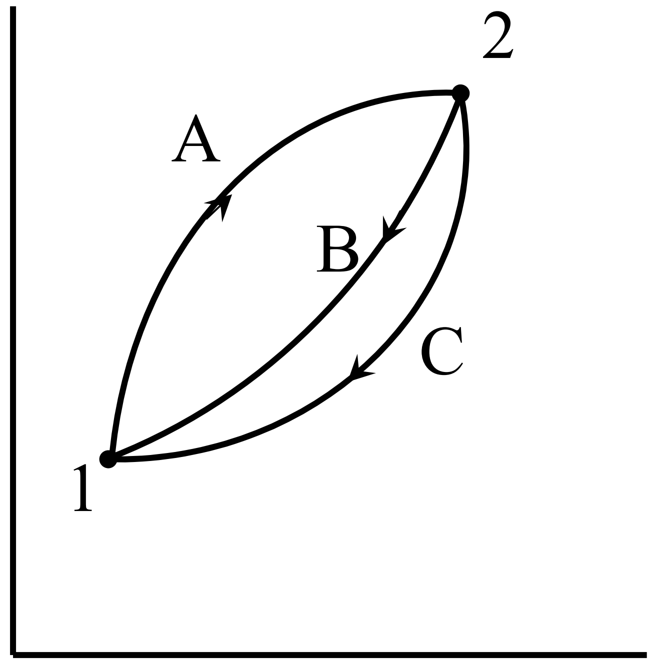
Processes B and C $\quad {}_B\int (\delta Q - \delta W) - {}_C\int (\delta Q - \delta W) = 0$

$${}_B\int (\delta Q - \delta W) = {}_C\int (\delta Q - \delta W)$$

$\int (\delta Q - \delta W)$ is independent of path and therefore a property. Define E as energy in all forms, KE + PE + U(T).

$$E_1 - E_2 = \int_2^1 (\delta Q - \delta W) = Q - W$$

By convention for this equation form
heat added to system is positive, $Q +$
work done by system is positive, $W +$



First Law for a Processes

$$\mathbf{Q = \Delta E + W}$$

$$\boldsymbol{\delta Q = dE + \delta W}$$

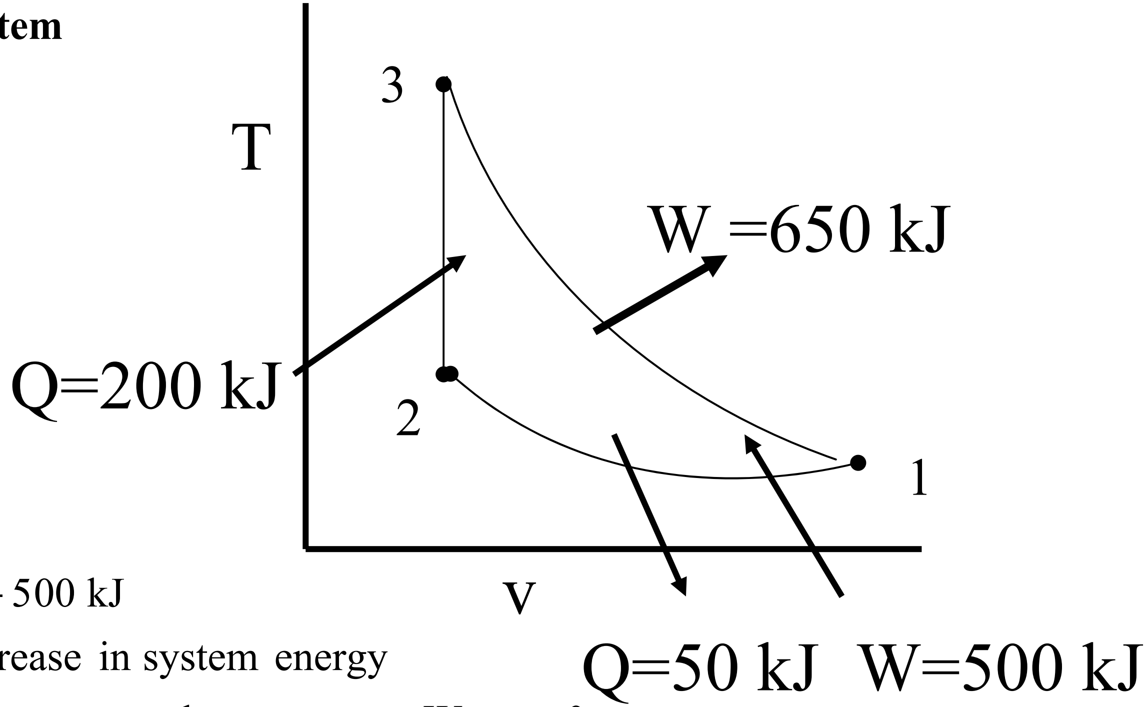
With the following energy flows, in a closed system what is the energy change in each process?

$\mathbf{W_{1\to2}}$ **= 500 kJ done on the system**

$\mathbf{Q_{1\to2}}$ **= 50 kJ removed from the system**

$\mathbf{Q_{2\to3}}$ **= 200 kJ added to the system**

$\mathbf{W_{3\to1}}$ **= 650 kJ done by system**



First Law for a Process

$Q = \Delta E + W$

$\mathbf{Q_{1\to2} = \Delta E_{1\to2} + W_{1\to2}}$ $\quad -50\text{ kJ} = \Delta E_{1\to2} - 500\text{ kJ}$

$\Delta E_{1\to2} = 450\text{ kJ increase in system energy}$

$\mathbf{Q_{2\leftarrow3} = \Delta E_{2\to3} + W_{2\to3}}$ $\quad \text{since } 2\to3 \text{ is a constant volume process } W_{2\to3} = 0$

$\Delta E_{2\to3} = 200\text{ kJ increase in system energy}$

$Q_{3\to1} = \Delta E_{3\to1} + W_{2\to3}$ $\quad Q_{3\to1} = \Delta E_{3\to1} + 650$

$\Delta E_{3\to1} = -650\text{ kJ}$

$\text{For: } Q = \Delta E + W.$

Q added to the system is +

W done by the system is +

First Law for a Cycle

$\mathbf{\Delta E_{1\to2} + \Delta E_{2\to3} + \Delta E_{3\to1}} = 0$ $\quad 450\text{ kJ} + 200\text{ kJ} - 650\text{ kJ} = 0$

$$\oint \delta Q = \oint \delta W$$

$\mathbf{Q_{1\to2} + Q_{2\leftarrow3} + Q_{3\to1}} =$

$\mathbf{W_{1\to2} + W_{2\to3} + W_{2\to3}}$ $\quad -50\text{ kJ} + 200\text{ kJ} + Q_{3\to1} = -500\text{ kJ} + 0\text{ kJ} + 650\text{ kJ}$

$Q_{3\to1} = 0$

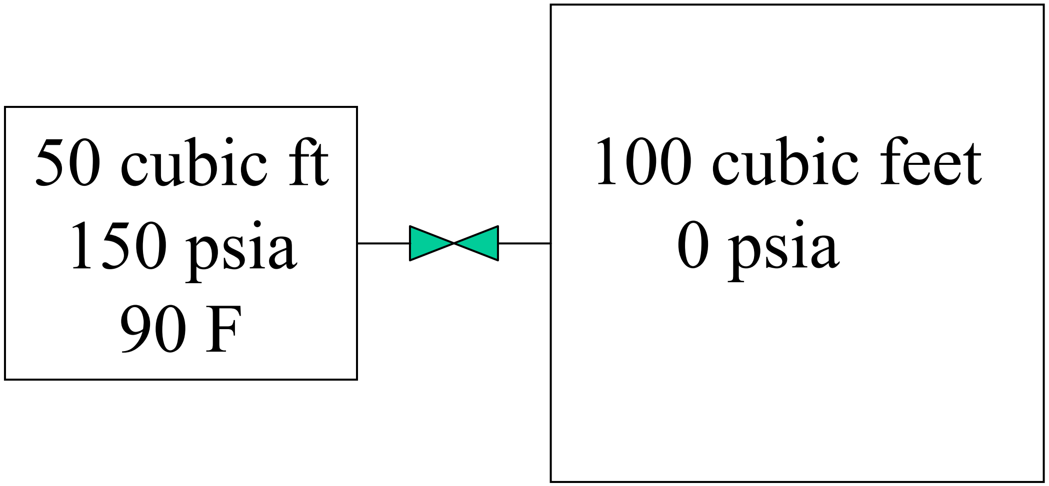
An insulated tank containing 50 cu ft of air at 150 psia and 90 degrees F is connected to another insulated tank of 100 cu ft, assumed to be a complete vacuum , by a short pipe and valve. The valve is opened and the air pressure allowed to equalize between the tanks.

1)What is the initial pressure in the tanks?

2) What is the final temperature in the tanks?

3) What is the change in enthalpy?

4) What is the work done by the system?



The thermodynamic system is the mass in the pressurized tank.There is no mass in the evacuated tank and thus no system to transfer heat or work to. Neither heat or work are transferred to the system outside the two tanks. Work=0. It is given that Q=0

$$Q = \Delta U + W$$

$$0 = \Delta U \Rightarrow \Delta T = 0$$

1) $pV = mR$

$pv = RT$

$$p_1 v_1 = p_2 v_2$$

$$150 \times 50 = p_2 \times 150$$

$$p_2 = 50\text{psia}$$

2)

$$0 = \Delta U = mc_v (T_2 - T_1)$$

$$T_2 = 90\ {}^\circ F$$

3)

$$\Delta h = c_p \Delta T = 0$$

4)

$$\text{Work} = 0$$