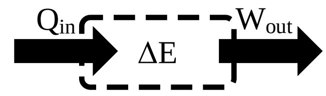
1^{st} Law for Closed System

$$\begin{bmatrix} \textit{Change in the amount} \\ \textit{of energy contained} \\ \textit{within the system} \\ \textit{during some time} \\ \textit{interval} \end{bmatrix} = \begin{bmatrix} \textit{net amount of energy} \\ \textit{transferred in across} \\ \textit{the system boundary by} \\ \textit{heat transfer during} \\ \textit{the time interval} \end{bmatrix} - \begin{bmatrix} \textit{net amount of energy} \\ \textit{transferred out across} \\ \textit{the system boundary} \\ \textit{by work during} \\ \textit{the time interval} \end{bmatrix}$$



$-W_{out}=W_{in}$

$\Delta E=Q_{in}+W_{in}$

$$\Delta E = \Delta KE + \Delta PE + \Delta U = \boldsymbol{E_2 - E_1 = Q - W}$$

Where, $KE = {}^{1}/_{2}\, mv^2$; $PE = mgh$; $U = Internal\ Energy$

$W > 0$: *work done by system*
$W < 0$: *work done on the system*
$Q > 0$: *heat transfer to the system*
$Q < 0$: *heat transfer from the system*

On Rate Bias:

$$\begin{bmatrix} \textit{Time rate of change} \\ \textit{of the energy} \\ \textit{contained within} \\ \textit{the system at} \\ \textit{time } t \end{bmatrix} = \begin{bmatrix} \textit{net rate at which} \\ \textit{energy is being} \\ \textit{transferred in} \\ \textit{by heat transfer} \\ \textit{at time } t \end{bmatrix} - \begin{bmatrix} \textit{net rate at which} \\ \textit{energy is being} \\ \textit{transferred out} \\ \textit{by work} \\ \textit{at time } t \end{bmatrix}$$

$$\frac{\mathbf{dE}}{\boldsymbol{dt}} = \frac{dKE}{dt} + \frac{dPE}{dt} + \frac{dU}{dt} = \dot{\boldsymbol{Q}} - \dot{\boldsymbol{W}}$$

$W = \int_{s1}^{s2} F \cdot ds$

$W = \int_{V1}^{V2} p \cdot dV$ rev. quasi-steady process

$W/m = \int_1^2 p \cdot dv$

$W = \int_{t1}^{t2} \dot{W} \cdot dt = \dot{W}\Delta t\ (const\ \dot{W})$

$Q = \int_{t1}^{t2} \dot{Q} \cdot dt = \dot{Q}\Delta t\ (const\ \dot{Q})$

$h = u + pv \qquad H = U + PV \qquad h = H/m$

Fraction of Total Mass that is Vapor

$$x = \frac{m_{vapor}}{m_{liquid} + m_{vapor}}$$

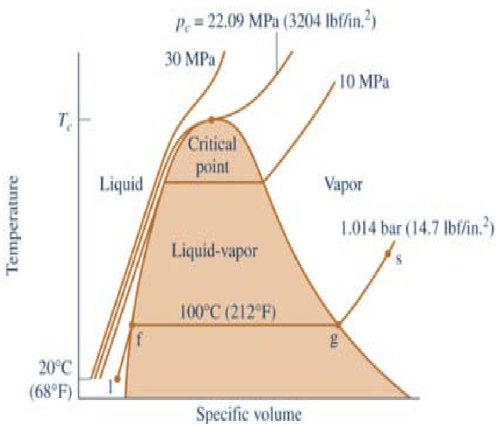
Fraction of Total Mass that is Liquid

$$1 - x = \frac{m_{liquid}}{m_{liquid} + m_{vapor}}$$

$v = (1-x)v_f + xv_g = v_f + x(v_g - v_f)$

$h = (1-x)h_f + xh_g = h_f + x(h_g - h_f)$

$u = (1-x)u_f + xu_g = u_f + x(u_g - u_f)$

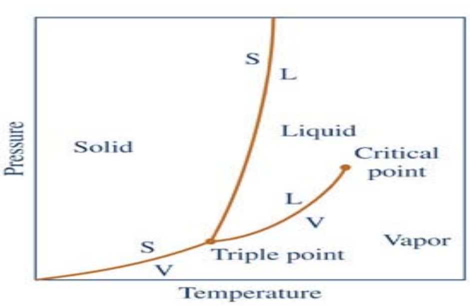


Compressed Liquid Approximation:

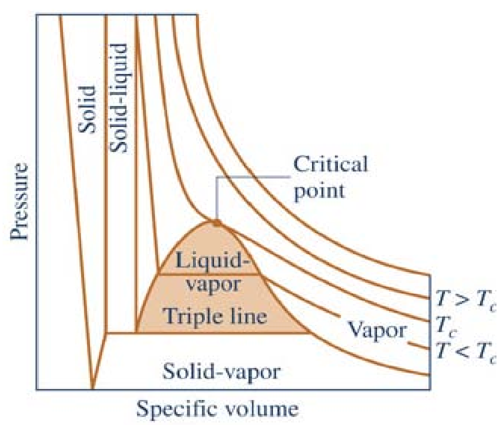
$v(T,p) \approx v_f(T)$

$u(T,p) \approx u_f(T)$

$h(T,p) \approx h_f(T) + v_f(T)[p - p_{sat}(T)]$



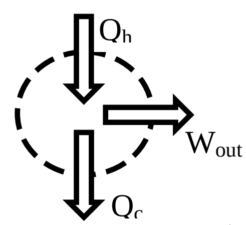
(b)



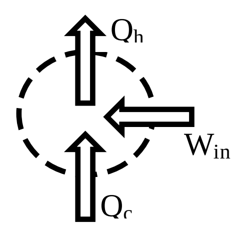
(c)

For Cycle ΔE = 0

Power



Refrig/Heat Pump



1^{st} Law:

Power	Refrig/Heat Pump
$Q_{in} = W_{out}$	$Q_{out} = W_{in}$
$\dot{Q}_{in} = \dot{W}_{out}$	$\dot{Q}_{out} = \dot{W}_{in}$
$\dot{Q}_h - \dot{Q}_c = \dot{W}_{out}$	$\dot{Q}_h - \dot{Q}_c = \dot{W}_{in}$

Efficiency:

$$\eta_{power} = \frac{\dot{W}_{out}}{\dot{Q}_h} \qquad COP_{refrig} = \frac{\dot{Q}_c}{\dot{W}_{in}}$$

$$\eta_{power} = \frac{\dot{Q}_h - \dot{Q}_c}{\dot{Q}_h} \qquad COP_{heat\ pump} = \frac{\dot{Q}_h}{\dot{W}_{in}}$$

$$\eta_{power} = \frac{what\ we\ want}{price\ we\ pay} = COP$$

Conversions

$1atm = \begin{cases} 1.01325\ bar \\ 14.696\ lbf/in^2 \end{cases}$ $1Pa = 1N/m^2 = 1.4504 * 10^{-4} lbf/in^2$ $1bar = 10^5 N/m^2; \quad 1MPa = 10\ bar$	$T(°R) = 1.8 \cdot T(K)$ $T(°C) = T(K) - 273.15$ $T(°F) = T(°R) - 459.67$ $T(°F) = 1.8T(°C) + 32$	$1lbf = 32.174\ lbm\frac{ft}{s^2}$ $g = \begin{cases} 9.80665\ m/s^2 \\ 32.174\ ft/s^2 \end{cases}$	$1BTU = 778\ ft \cdot lbf$ $1kW = 1.341\ hp$