Problem Set 2 PS2 due Friday May 19

PS2-1 A thermodynamic system undergoes a cycle consisting of four processes according the data in the following table. The units are Btu. Determine the missing units in the table and also determine whether the cycle is a power or a refrigeration cycle.

Process	U change	KE change	PE change	E change	Q, heat	W, work
1-2	72	-5	-6		0	
2-3	64	0			90	
3-4	-97		0			92
4-1		0	3			0

PS2-2

Is the following cycle, which consists of three processes, a power cycle or a refrigeration cycle? Sketch a pressure-volume and temperature-entropy property diagram of the cycle.

1) a compression process with p V= constant, with no change in internal energy, from p=1 bar, V= 1.6 m^3 to V= .2 m^3
2) a constant pressure process to V=1.6 m^3
3) a constant volume process with an internal energy change of -3549 kJ

PS2-3 For refrigerant R-134a complete the following table.

Temperature, C	pressure, kPa	volume, m^3/kg	phase
-8	500		
30		.022	
	320		saturated vapor
100	600		

PS1-1

Process	ΔU	ΔKE	ΔPE	ΔE	Q	W
$1-2$	$+72$	-5	-6		0	
$2-3$	$+64$	0			$+90$	
$3-4$	-97		0			$+92$
$4-1$		0	3			0

Cycle Definition:

$$\sum_{\text{cycle}} \Delta U = 0, \quad \sum_{\text{cycle}} \Delta KE = 0, \quad \sum_{\text{cycle}} \Delta PE = 0, \quad \sum_{\text{cycle}} \Delta E = 0$$

$$\Delta E_{\text{process}} = \Delta U + \Delta KE + \Delta PE$$

First Law for a Process:

$$Q = \Delta E + W$$

First Law for a Cycle:

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

PS1-1

Process	ΔU	ΔKE	ΔPE	ΔE	Q	W
1 – 2	+ 72	- 5	- 6	61	0	- 61
2 – 3	+ 64	0	+ 3	+ 67	+ 90	+ 23
3 – 4	- 97	+ 5	0	- 92	0	+ 92
4 - 1	- 39	0	3	- 36	- 36	0
$\sum_{\text{cycle}}$	0	0	0	0	+ 54	+ 54

54 Btu is added to the system and 54 Btu of work is done.

The cycle is a power cycle.

$$\sum_{\text{cycle}} \Delta U = 0, \qquad \sum_{\text{cycle}} \Delta KE = 0, \qquad \sum_{\text{cycle}} \Delta PE = 0$$

$$\Delta E_{\text{process}} = \Delta U + \Delta KE + \Delta PE$$

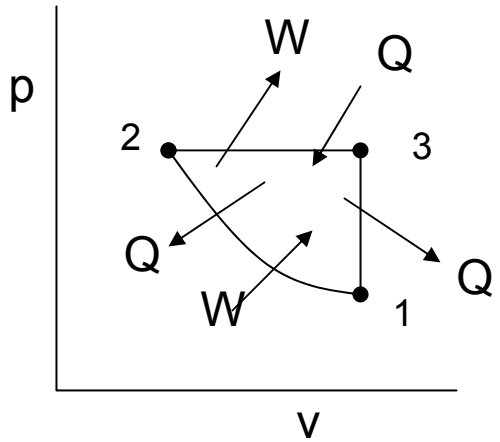
$$\text{Check}: \sum_{\text{cycle}} \Delta E = 0$$

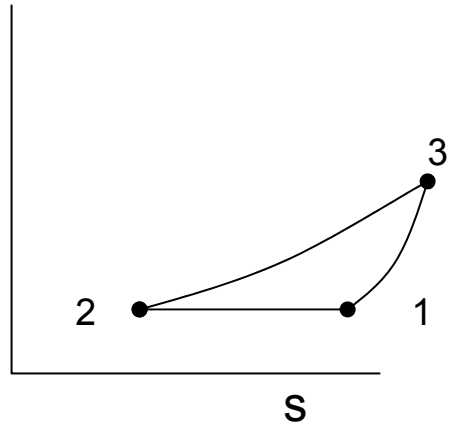
First Law for a Process $\quad Q = \Delta U + W$

First Law for a Cycle $\qquad \oint \delta Q = \oint \delta W$

PS2-1

$$Q = \Delta E + W$$
(Q added +, W done +)
$$W = \int p dv$$
$$\int_{\text{cycle}} E = 0$$





$$W_{31} = \int p dv = \int p0 = 0$$
$$Q_{31} = \Delta E_{31} + W_{31}$$
$$Q_{31} = -3549 \text{ kJ heat rejected}$$

$$E_{12} + E_{23} + E_{31} = 0$$
$$0 + E_{23} - 3549 = 0$$
$$E_{23} = +3549 \text{ kJ}$$

$$Q_{23} = \Delta E_{23} + W_{23}$$
$$W_{23} = \int p dv = p_2 (V_3 - V_1)$$
$$p_1 v_1 = p_2 v_2$$
$$p_2 = p_1 \frac{v_1}{v_1} = 100 \text{ kPa} \times 1.6/1.2 = 800 \text{ kPa}$$
$$W_{23} = 800 \times (1.6 - .2) = +1120 \text{ kPam}^3, \text{kJ}$$
$$Q_{23} = 3549 + 1120 = +4669$$

$$pv = C$$
$$p_1 v_1 = C$$
$$p = \frac{p_1 v_1}{v}$$

$$W_{12} = \int p dv$$
$$W_{12} = p_1 v_1 \int \frac{dv}{v} = p_1 v_1 \ln\left(\frac{V_2}{V_1}\right)$$
$$W_{12} = 100 \text{ kPa} \times 1.6 \text{ m}^3 \times \ln\left(\frac{.2}{1.6}\right)$$
$$W_{12} = 1600 \times -2.097 = -327.7 \text{ kPam}^2 \text{or kJ}$$
$$E_{12} = 0$$
$$Q_{12} = 0 + W_{12} = -327.7 \text{ kJ}$$

$W_{12} -327.3$	$Q_{12} = -327.7$
$W_{23} = +1120$	$Q_{23} = +4669$
$W_{31} = 0$	$Q_{31} = -3549$
$+792.3$	$= \quad +792.3$

$$\int W = \int Q$$
Net Heat added Net Work done $\Rightarrow$ PowerCycle

PS2-3 For refrigerant R-134a complete the following table.

Temperature, C	pressure, kPa	volume, m^3/kg	phase
-8	500	(.0007569)	(compressed liquid)
30	(770.06)	.022	(saturated mixture)
(2.46)	320	(.0632)	saturated vapor
100	600	(.04790)	(superheated vapor)