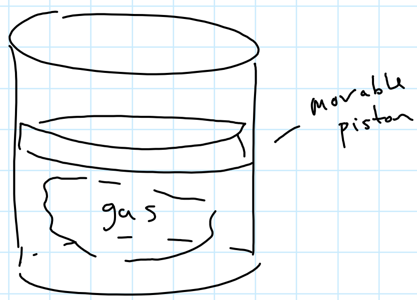
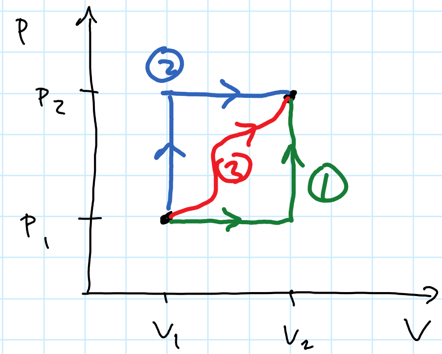
Phy 2B 3/11

Wednesday, March 11, 2015 9:48 AM

1st Law of Thermodynamics: $\Delta U = Q - W_{\text{by system}}$





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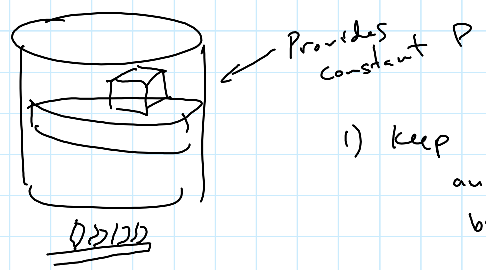


1) keep P constant and increase V by adding heat

2) Lock the piston in place (fix V) add heat to increase P

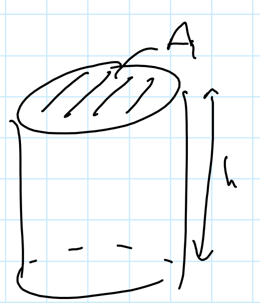
2 Reverse the order of 1

3 OR some combination of 1 & 2

Area under PV curve is work done by the gas

$$P = \frac{F}{A}$$

$$W = Fd = (PA)\,h = PV$$



Volume = Ah

4 common thermal Processes:

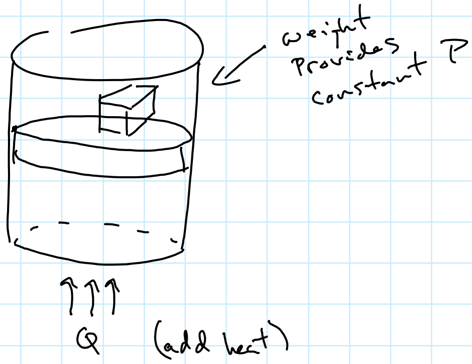
1) Isobaric - constant Pressure

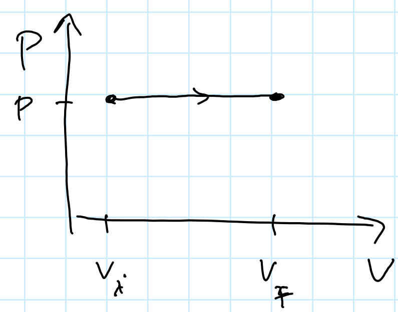
2) Isochoric - constant Volume

3) Isothermal - constant temperature

4) Adiabatic - No transfer of heat ($Q = 0$)

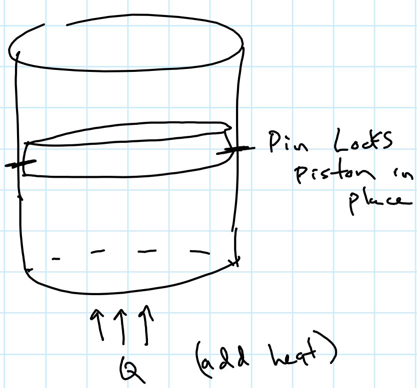
1) Isobaric:

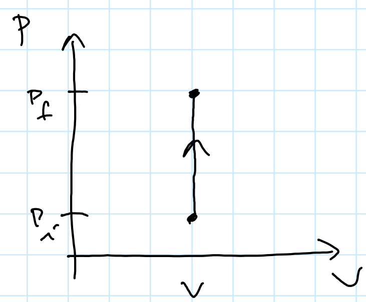




$$W = P\,\Delta V = P(V_f - V_i)$$

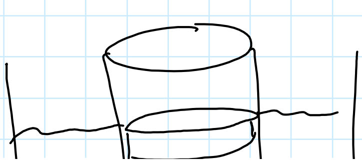
2) Isochoric

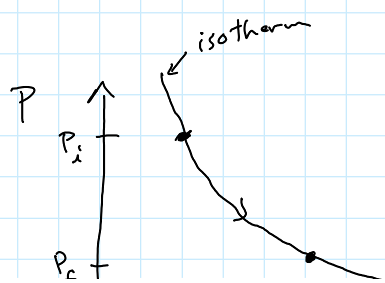


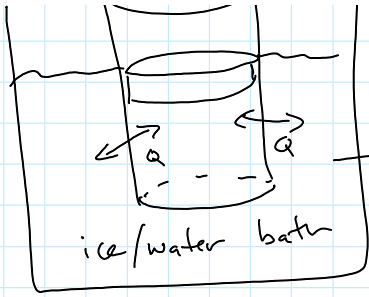


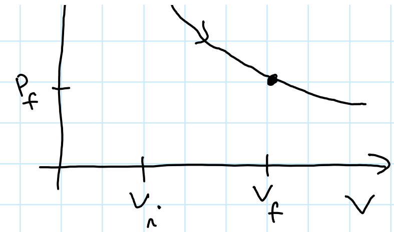
$$W = 0$$

3) Isothermal







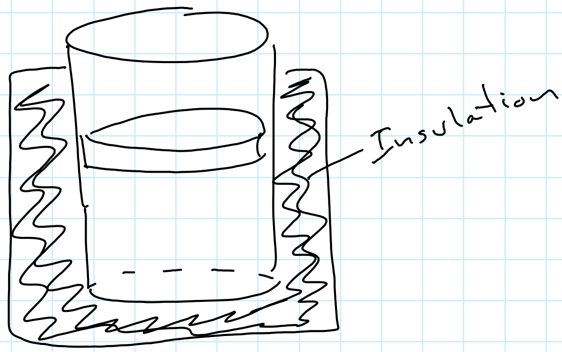


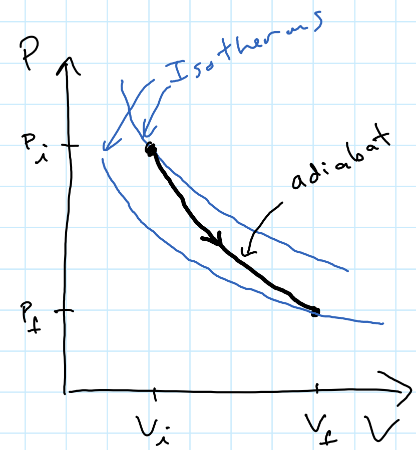
because heat can leave / enter the gas

T stays the same as we move the piston

$$W = nRT \ln\left(\frac{V_f}{V_i}\right)$$

4) Adiabatic





heat cannot enter or leave the system

$$Q = 0$$

$$\Delta U = \cancel{Q}^{\,0} - W$$

$$U_f - U_i = -W$$

$$U = \frac{3}{2} nRT$$ for a monatomic ideal gas

$$W = \frac{3}{2} nR \left(T_i - T_f\right)$$

$$P_i V_i^{\gamma} = P_f V_f^{\gamma}$$

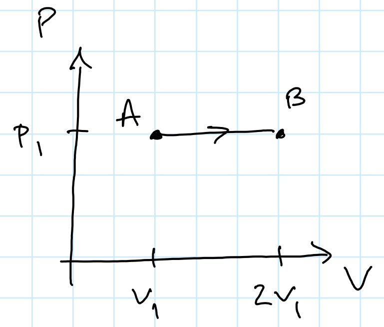
$\gamma = \frac{5}{3}$ for a monatomic ideal gas

Example 1

given: 2 moles of monatomic ideal gas go through the following process from A to B

$P_1 = 5 \times 10^5$ Pa

$T_A = 400°C$



States
(Think $PV = nRT$)

	A	B
P	5×10^5 Pa	5×10^5 Pa
V	2.24×10^{-2} m^3	4.48×10^{-2} m^3
T	$400°C$ = 673 K	1346 K
U	16,778 J	33,556 J

Find V_A:

$$PV = nRT$$

$$V_A = \frac{nRT_A}{P_A}$$

$$= \frac{(2\ \text{mol})(8.31\ \frac{J}{mol\ K})(673\ K)}{5 \times 10^5\ Pa}$$

$$= 2.24 \times 10^{-2}\ m^3$$

Processes
($\Delta U = Q - W$)

	A → B
ΔU	+ 16,778 J
Q	+ 27,978 J
W_{By}	+ 11,200 J

Find T_B:

$$T_B = \frac{P_B V_B}{nR}$$

$$= 1346\ K$$

$$U = \frac{3}{2} nRT$$

Find $\Delta U = U_f - U_i$

Find $W = P \Delta V$

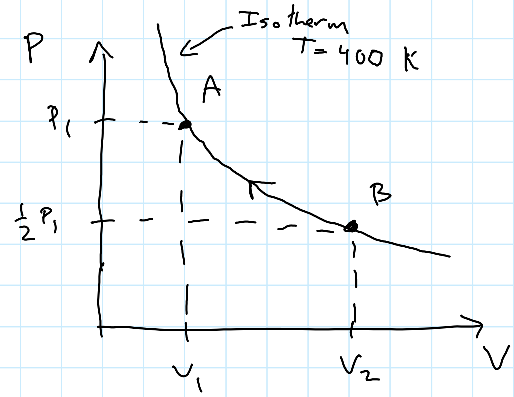
Find Q using $\Delta U = Q - W$

...le 2 given: 2 moles of an ideal monatomic gas

Example 2

given: 2 moles of an ideal monatomic gas go through the follwing thermal process from B to A

$V_1 = 8.3 \times 10^{-3}\ m^3$



States
(think $PV = nRT$)

	A	B
P	8.0×10^5 Pa	4.0×10^5 Pa
V	$8.3 \times 10^{-3}\ m^3$	$1.66 \times 10^{-2}\ m^3$
T	400 K	400 K
U	9,972 J	9,972 J

1) Find P_A using $PV = nRT$

$$P_A = \frac{(2\ mol)\left(8.31\ \frac{J}{mol\ K}\right)(400\ K)}{8.3 \times 10^{-3}\ m^3}$$

$$= 8.0 \times 10^5\ Pa$$

2) $P_B = \frac{1}{2} P_A$

3) $T_B = T_A$ isotherm

4) Find V_B using $PV = nRT$

5) $U = \frac{3}{2} nRT$

6) Find $\Delta U = U_f - U_i$

7) Find W using:

$$W = nRT \ln\left(\frac{V_f}{V_i}\right)$$

$$= -4608\ J$$

8) Find Q using:

$$\cancel{\Delta U}^{\,0} = Q - W$$

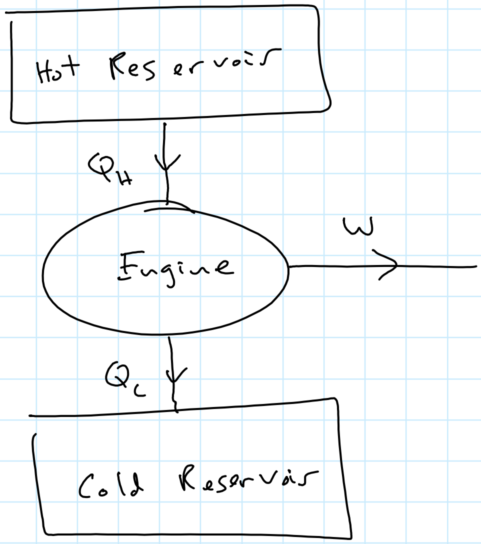
$$Q = W$$

Processes
(think $\Delta U = Q - W$)

	B → A
ΔU	0
Q	−4608 J
W	−4608 J

2nd Law: Heat flows from hot to cold

Heat Engine:



$$Q_H = W + Q_c$$

what goes in equals what comes out

efficiency of a heat engine:

$$e = \frac{\text{Work done}}{\text{Input heat}} = \frac{W}{Q_H} = \frac{Q_H - Q_c}{Q_H}$$

using $Q_H = W + Q_c$

Maximum efficiency if for a reversible Process:

$$e_{max} = 1 - \frac{T_c}{T_H}$$

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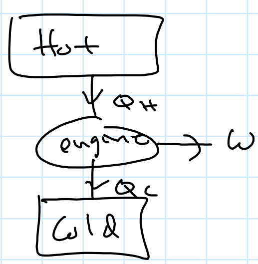
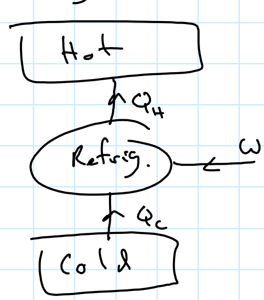
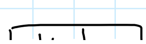
Heat engine



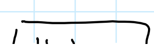
Refrigerator



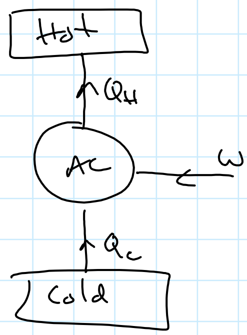
Air Conditioner



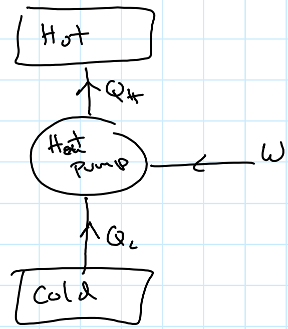
Heat Pump



Air Conditioner



Heat Pump



Like efficiency of an engine:

$$COP = \frac{Q_c}{W}$$ for refrigerator

$$COP = \frac{Q_H}{W}$$ for heat pump

Entropy:

$$\Delta S = \frac{Q}{T}$$

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worksheet p. 268

Top: all same P

bottom: $n_A = n_B > n_c = n_D$

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Top: $PV = nRT$

$T \propto PV$

	P	V	$P*V$
A	$3P_0$	V_0	$3P_0V_0$
B	$3P_0$	$2V_0$	$6P_0V_0$
C	$3P_0$	$4V_0$	$12P_0V_0$
D	P_0	$4V_0$	$4P_0V_0$
E	$2P_0$	V_0	$2P_0V_0$

$$T_c > T_B > T_D > T_A > T_E$$

bottom : similar to top

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a) $W_{ab} > W_{ef}$

$W_{ab} = 3P_0V_0$ area under curve

$W_{ef} = 2P_0V_0$

b) $W_{bc} = W_{fg} = 0$

c) $W_{abcd} = W_{efgh}$

$W_{abcd} = W_{ab} + W_{bc} + W_{cd}$

$= 3P_0V_0 + 0 - 2P_0V_0$

$= P_0V_0$

d) $W_{abcda} = W_{abcd}$

same as part c