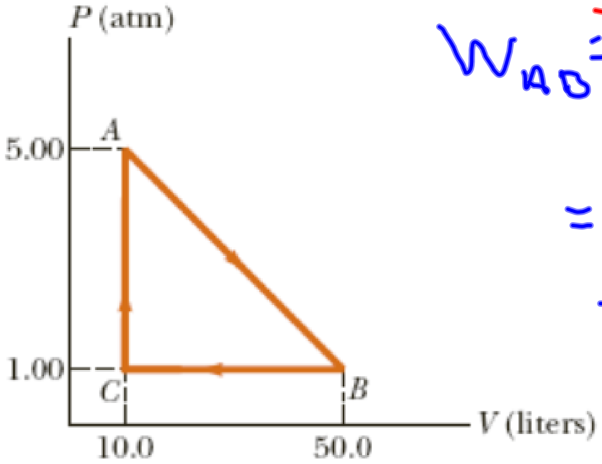
Reminders 12-3-07:
-Quiz on Heat Transfer and 1st Law Wednesday
-Thermodynamics Conceptual Questions due 12/5
-Turn in Heat Engine Worksheet Wednesday
-Homework 12 Due 12/9
-Exam 4 12/10.

Objectives:
-First Law of Thermodynamics Examples
-Second Law of Thermodynamics
-Heat Engines and Carnot Engine

A substance undergoes the cyclic process shown in Figure P12.51. Work output occurs along path AB while work input is required along path BC, and no work is involved in the constant volume process CA. Energy transfers by heat occur during each process involved in the cycle.



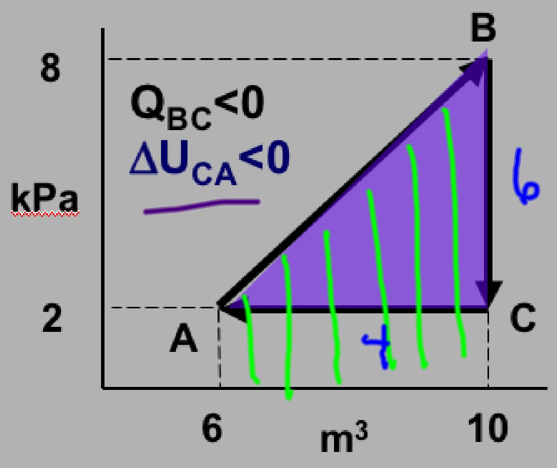
$$W_{AB} = -\left[\tfrac{1}{2}(4\,\text{atm})(40\,L) + (1\,\text{atm})(40\,L)\right]$$
$$= -[80\ L\text{-atm} + 40\ L\text{-atm}]$$
$$= -[120\ L\text{-atm}]$$
$$= -120\ L\text{-atm}$$

(a) What is the work output during process AB?
12200 J
(b) How much work input is required during process BC?
4050 J
(c) What is the net energy input Q during this cycle?
8150 J

$$-120\ L\text{-atm} \cdot \left(101{,}300\ \tfrac{Pa}{atm}\right)\left(\frac{1\ m^3}{1000\ L}\right)$$
$$= -12{,}200\ J$$

$$W_{BC} = (40\ L\text{-atm})(101300)\left(\frac{1\ m^3}{1000\ L}\right)$$
$$= 4050\ J$$

$$Q_{input} = 12{,}200 - 4050$$
$$= 8150\ J\,!$$



Consider the process shown. Determine the signs of Q, W, and ΔU associated with each process.

Answer: $W_{AB}<0$, $W_{BC}=0$; $W_{CA}>0$
$W_{AB}=-20J$, $W_{BC}=0$; $W_{CA}=+8J$
$Q_{AB}>0$; $Q_{CA}<0$
$\Delta U_{AB}>0$, $\Delta U_{BC}<0$
$\Delta U_{cycle}=0$; $W_{cycle}<0=-12J$; $Q_{cycle}>0=12J$

$W = -P\Delta V$ Better yet

W = negative of area under curve

$W_{AB} < 0$, $W_{BC} = 0$ $W_{CA} > 0$

$W_{AB} = -12 + -8$

$W_{cycle} = W_{AB} + W_{BC} + W_{CA}$

$W_{AB} = -20\,kJ$

$W_{cycle} < 0$

$W_{CA} = +8\,kJ$

$W_{cycle} = -\frac{1}{2}(6\,kPa)(4) = -12\,kJ$

$\Delta U_{cycle} = 0$ $\Delta U_{cycle} = Q_{cycle} + W_{cycle}$

$Q_{cycle} = -W_{cycle}$

$Q_{cycle} = +12 kJ$

Given $Q_{BC} < 0$ $W_{BC} = 0$

$\Delta U_{BC} = Q_{BC} + W_{BC}$

so $\Delta U_{BC} < 0$

from $C \to A$

$W_{CA} > 0$ $\Delta U_{CA} < 0$

$\Delta U_{CA} = Q_{CA} + W_{CA}$

$Q_{CA} < 0$

$Q_{cycl} = Q_{AB} + Q_{BC} + Q_{CA}$

$Q_{AB} > 0$ since $Q_{cycle} > 0$

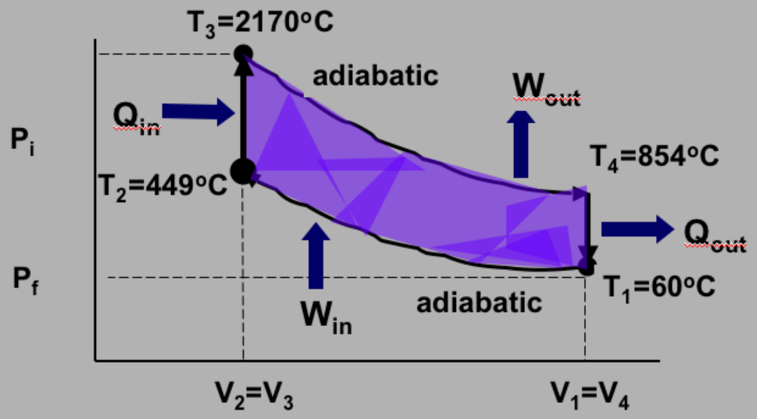
$\Delta U_{cycle} = \Delta U_{AB} + \Delta U_{BC} + \Delta U_{CA}$

$\Delta U_{cycle} = 0$, $\Delta U_{CA} < 0$

$\Delta U_{BC} < 0$

so $\Delta U_{AB} > 0$

PV diagram of Internal Combustion Engine Cycle



Otto Cycle (1876)

Internal Combustion Engine Cycle Continued

Given Information

P_1=1atm; T_1=60°C;n=1
P_2=15atm; T_3=2170°C
$\gamma=C_p/C_v=1.4$ (diatomic ideal gas)
$V_2=V_3$; $V_1=V_4$
$P_i (V_i^{\gamma}) = P_f (V_f^{\gamma})$
$TP^{(\gamma-1)/\gamma}$=constant
$TV^{(\gamma-1)}$=constant

Calculated Values

T_2=449°C; T_4=854°C
W_{in}=-8.13kJ
Q_{in}= 36.0kJ
W_{out}=27.5kJ
Q_{out}= -16.6kJ
W_{cycle}=19.4kJ

$e=W_{cycle}/Q_{in}$=19.4J/36.0J=0.54

$$T_1 V_1^{(r-1)} = T_2 V_2^{(r-1)}$$

From ideal gas law $PV = nRT$

$$V = \frac{nRT}{P}$$

$$T_1 \left[\frac{nRT_1}{P_1}\right]^{r-1} = T_2 \left[\frac{nRT_2}{P_2}\right]^{r-1}$$

$$T_1^{1} \left(\frac{T_1^{r-1}}{P_1^{r-1}}\right) = T_2 \left(\frac{T_2^{r-1}}{P_2^{r-1}}\right)$$

$$\frac{T_1^{r}}{P_1^{r-1}} = \frac{T_2^{r}}{P_2^{r-1}} \Rightarrow T_1^{r} P_1^{1-r} = T_2^{r} P_2^{1-r}$$

$1-r$

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$$\left(\frac{T_1}{T_2}\right)^r = \left(\frac{P_2}{P_1}\right) = \left(\frac{15}{1}\right)^{1-r} = 15^{(-0.4)}$$

$$\left(\left(\frac{T_1}{T_2}\right)^r\right)^{1/r} = \left[15^{(-0.4)}\right]^{\frac{1}{r}}$$

$$\frac{T_1}{T_2} = \left[15^{(-0.4)}\right]^{\frac{1}{1.4}}$$

solve for T_2

- A heat engine absorbs 200J of heat from a hot reservoir, and exhausts 160J to a cold reservoir. What is the efficiency of this engine?

$Q_{in} = 200J$

$Q_{out} = 160$

$W = 40$

$e = \frac{40}{200} = .2$ or 20%

$= \frac{W_{out}}{Q_{in}} = \frac{Q_H - Q_{out}}{Q_{in}} = 1 - \frac{Q_{out}}{Q_{in}}$