**ASSIGNMENT 3:,**
First Law of Thermodynamics,
Heat and Work in Gas Processes
Kinetic Theory of Gases

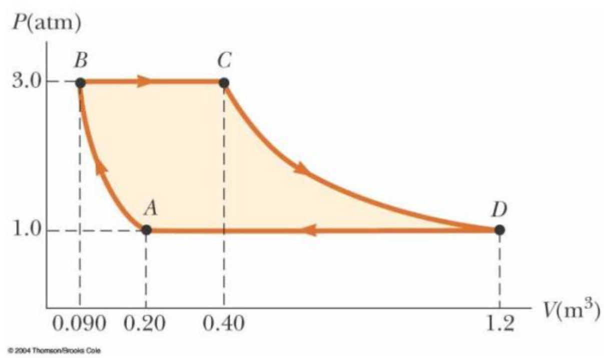
**UNIVERSITY OF OTTAWA**
**Principles of Physics**
**PHY1321/31 Fall 2018**
***Dr. A. Czajkowski***

STUDENT #: ____________________

NAME: ______________________________

**Released: Sept 28,** **Due: Oct 5** **6PM**

1 A sample of a gas goes through the process shown. From *A* to *B*, the process is adiabatic; from *B* to *C*, it is isobaric with 100 kJ of energy entering the system by heat. From *C* to *D*, the process is isothermal; from *D* to *A*, it is isobaric with 150 kJ of energy leaving the system by heat. Determine the difference in internal energy $E_{int,B} - E_{int,A}$.




$$W_{BC} = -P_B(V_C - V_B) = -3.00 \text{ atm}(0.400 - 0.0900) \text{ m}^3 = -94.2 \text{ kJ}$$

$$\Delta E_{int} = Q + W$$

$$E_{int,C} - E_{int,B} = (100 - 94.2) \text{ kJ}$$

$$E_{int,C} - E_{int,B} = 5.79 \text{ kJ}$$

Since $T$ is constant $E_{int,D} - E_{int,C} = 0$

$$W_{DA} = -P_D(V_A - V_D) = -1.00 \text{ atm}(0.200 - 1.20) \text{ m}^3 = +101 \text{ kJ}$$

$E_{int,A} - E_{int,D} = -150 \text{ kJ} + (+101 \text{ kJ}) = -48.7 \text{ kJ}$ since change of internal energy for the whole cycle is 0, we can write:

$E_{int,B} - E_{int,A} = -\left[(E_{int,C} - E_{int,B}) + (E_{int,D} - E_{int,C}) + (E_{int,A} - E_{int,D})\right]$ =-(5.79+0-48.7)kJ = 42.91kJ

**2** **A)** One mole of an ideal gas is heated slowly so that it goes from the *PV* state ($P_0$, $V_0$), to ($3P_0$, $3V_0$), in such a way that the pressure is directly proportional to the volume. How much work is done on the gas in the process?

$$|W| = 2P_0V_0 + \tfrac{1}{2}(2P_0)(2V_0) = 4P_0V_0$$

Ans: W=-$4P_0V_0$

B)As a 1.00-mol sample of a monatomic ideal gas expands adiabatically, the work done on it is –2 500 J. The initial temperature and pressure of the gas are 500 K and 3.60 atm. Calculate (iii) the final temperature, and (iv) the final pressure.

(iii) $W = nC_V(T_f - T_i)$ so that $-2\,500 \text{ J} = 1 \text{ mol}\,\frac{3}{2}\,8.314 \text{ J/mol}\cdot\text{K}(T_f - 500 \text{ K})$ and $T_f = \boxed{300 \text{ K}}$

(iv) $P_iV_i^\gamma = P_fV_f^\gamma$ and thus $P_i\left(\frac{nRT_i}{P_i}\right)^\gamma = P_f\left(\frac{nRT_f}{P_f}\right)^\gamma$ $\quad T_i^\gamma P_i^{1-\gamma} = T_f^\gamma P_f^{1-\gamma}$

$\frac{T_i^{\gamma/(\gamma-1)}}{P_i} = \frac{T_f^{\gamma/(\gamma-1)}}{P_f}$ and $P_f = P_i\left(\frac{T_f}{T_i}\right)^{\gamma/(\gamma-1)}$ $\quad P_f = P_i\left(\frac{T_f}{T_i}\right)^{(5/3)(3/2)} = 3.60 \text{ atm}\left(\frac{300}{500}\right)^{5/2} = \boxed{1.00 \text{ atm}}$

3 Use the ideal gs equation to fill the alternative expressions for work and heat below:

There are many correct entries—here are few examples (obtained using pV=nRT in substitutions)

| Process | Work | | Heat | |
|---|---|---|---|---|
| V=const | 0 | 0 | $nC_V\Delta T$ | $\frac{C_V\,V(p_f - p_i)}{R}$ |
| P=const | $-p(V_f-V_i)$ | $-nR(V_f-V_i)$ | $nC_p\Delta T$ | $\frac{C_P\,p(V_f - V_i)}{R}$ |
| T=const | $-nRT\ln\frac{V_f}{V_i}$ | $-nRT\ln\frac{p_i}{p_f}$ | $nRT\ln\frac{V_f}{V_i}$ | $nRT\ln\frac{p_i}{p_f}$ |
| Q=0 | $\frac{1}{\gamma-1}(p_fV_f - p_iV_i)$ | $\frac{nR}{\gamma-1}(T_f - T_i)$ | 0 | 0 |

**4** Using the approach demonstrated during the lecture show that for $pV^\gamma$ =const. for adiabatic gas process. (Present your derivation on the opposite site of this page). DETAILS OF THIS CALCULATION WERE GIVEN IN LECTURE.

**ASSIGNMENT 3:,**
**First Law of Thermodynamics,**
**Heat and Work in Gas Processes**
**Kinetic Theory of Gases**

**UNIVERSITY OF OTTAWA**
**Principles of Physics**
**PHY1321/31 Fall 2017**
***Dr. A. Czajkowski***

STUDENT #: ____________________

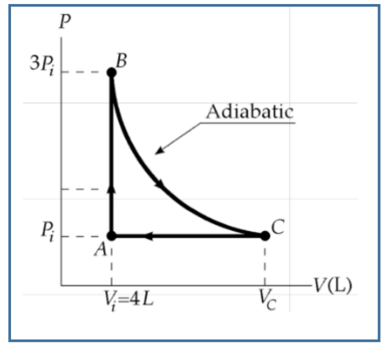
NAME:

______________________________

**Released: Sept 28,** **Due: Oct 5** **6PM**

5 A 4 liter sample of a diatomic gas with γ =1.4 confined to a cylinder, is carried through a closed cycle. The gas is initially at p=1.00atm and T=200K. First, its pressure is tripled under constant volume. Then it expands adiabatically to its original pressure. Finally the gas is compressed isobarically to its original volume.

a) draw pV diagram of this cycle
b) determine the volume of the end of the adiabatic expansion
c) find the temperature of the gas at the start of the adiabatic expansion
d) find the temperature at the end of the cycle
e) what was the net work done on the gas for this cycle




(a) See the diagram at the right.

(b) $P_B V_B^{g} = P_C V_C^{g}$ so that $3P_i V_i^{g} = P_i V_C^{g}$

so that $V_C = \left(3^{1/g}\right)V_i = \left(3^{5/7}\right)V_i = 2.19V_i$ $V_C = 2.19(4.00\text{ L}) = \boxed{8.77\text{ L}}$

(c) $P_B V_B = nRT_B = 3P_i V_i = 3nRT_i$ which gives $T_B = 3T_i = 3(200K) = 600K$

(d) After one whole cycle, $T_A = T_i = 200K$

(e) Using the expressions for work(THE TABLE!), we get:

$$W_{ABCA} = W_{AB} + W_{BC} + W_{CA} = 0 + \frac{1}{\gamma - 1}(p_C V_C - p_B V_B) - p_i(V_A - V_c)$$

$$W_{ABCA} = \frac{1}{\frac{7}{5} - 1}(p_i(3^{\frac{5}{7}}V_i) - (3p_i)V_i) - p_i(V_i - (3^{\frac{5}{7}}V_c) = 818.7J + 483.5J = -335.5J$$

(e) USING THE EXPRESSIONS FOR HEAT:

$Q_{AB} = nC_V DV = n\left(\frac{5}{2}R\right)(3T_i - T_i) = (5.00)nRT_i$, $Q_{BC} = 0$ as this process is adiabatic

$P_C V_C = nRT_C = P_i(2.19V_i) = (2.19)nRT_i$ so $T_C = 2.19T_i$,

$Q_{CA} = nC_P DT = n\left(\frac{7}{2}R\right)(T_i - 2.19T_i) = (-4.17)nRT_i$

For the whole cycle

$Q_{ABCA} = Q_{AB} + Q_{BC} + Q_{CA} = (5.00 - 4.17)nRT_i = (0.829)nRT_i$

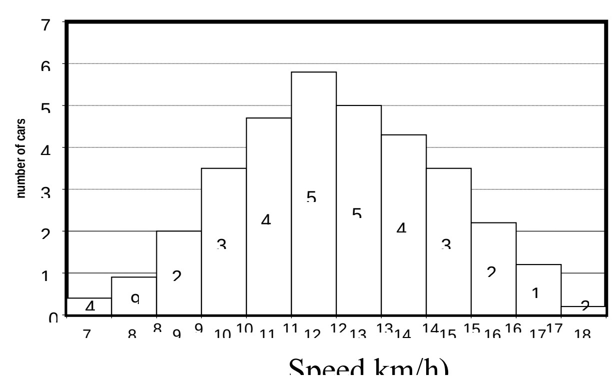
$(DE_{\text{int}})_{ABCA} = 0 = Q_{ABCA} + W_{ABCA}$

$W_{ABCA} = -Q_{ABCA} = -(0.829)nRT_i = -(0.829)P_i V_i$

$W_{ABCA} = -(0.829)(1.013 \times 10^5\text{ Pa})(4.00 \times 10^{-3}\text{ m}^3) = \boxed{-336\text{ J}}$

6 Given is distribution of speeds of cars at 417 Highway as measured by OPP.

a) Is this a discrete or continuous distribution?
b) Find the Vmp, Vrms, Vavg.
c) Find the probability that a randomly picked car will have speed larger than 125km/h.
d) Find the probability that a randomly picked car will have speed larger than 85km/h and less then 115km/h.




a) discrete
b) $V_{mp}$=120km/h; $V_{rms}$ =127km/h; $V_{avg}$=125km/h
c) P(v>125) = 0.49
d) P(85<v<115) = 0.30