UNIVERSITY OF OTTAWA
Principles of Physics
PHY1321/31 Fall 2016
Dr. A. Czajkowski

STUDENT #: ____________________

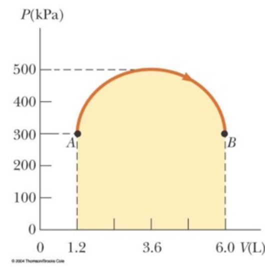
NAME: ______________________________

GROUP:

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

Released: Sept 30, Due: Oct 7 6PM

1 A sample of an ideal gas is in a vertical cylinder fitted with a piston. As 5.79 kJ of energy is transferred to the gas by heat to raise its temperature, the weight on the piston is adjusted so that the state of the gas changes from point *A* to point *B* along the semicircle shown. Find the change in internal energy of the gas.



SOLUTION:

The area of a true semicircle is ½ π r^2. The arrow in figure may looks like a semicircle but in reality we are dealing with half of the ellipsoid with a=r_V = 1.2 *l* and b=r_p =100kPa. The are of the half ellipsoind is ½ π r_V r_p.

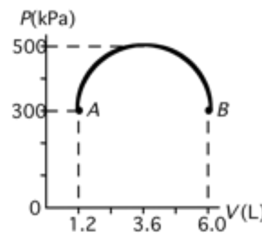
$$\frac{1}{2}\pi(2.4\text{ L})(200\text{ kPa}) = \frac{1}{2}\pi(2.4\times10^{-3}\text{ m}^3)(2\times10^5\text{ N/m}^2).$$

$$W = -\int_A^B P\,dV = -\text{area under the arch shown in the graph}$$

$$= -\left(\frac{1}{2}\pi 2.4(200)\text{ J} + 3\times10^5\text{ N/m}^2\ 4.8\times10^{-3}\text{ m}^3\right)$$

$$= -(754\text{ J} + 1\,440\text{ J}) = -2\,190\text{ J}$$

$$\Delta E_{int} = Q + W = 5\,790\text{ J} - 2\,190\text{ J} = \boxed{3.60\text{ kJ}}$$



2 **A)** One mole of an ideal gas does 3 000 J of work on its surroundings as it expands isothermally to a final pressure of 1.00 atm and volume of 25.0 L. Determine (i) the initial volume and (ii) the temperature of the gas.

(i) $W = -nRT\ln\left(\frac{V_f}{V_i}\right) = -P_fV_f\ln\left(\frac{V_f}{V_i}\right)$ s $V_i = V_f\exp\left(+\frac{W}{P_fV_f}\right) = (0.025\,0)\exp\left[\frac{-3\,000}{0.025\,0(1.013\times10^5)}\right] = \boxed{0.007\,65\text{ m}^3}$

(ii) $T_f = \frac{P_fV_f}{nR} = \frac{1.013\times10^5\text{ Pa}(0.025\,0\text{ m}^3)}{1.00\text{ mol}(8.314\text{ J/K}\cdot\text{mol})} = \boxed{305\text{ K}}$

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 $P_i\left(\frac{nRT_i}{P_i}\right)^\gamma = P_f\left(\frac{nRT_f}{P_f}\right)^\gamma$ $T_i^\gamma P_i^{1-\gamma} = T_f^\gamma P_f^{1-\gamma}$

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

4 Fill the table below:

	Degrees of Freedom	AVG Energy of single molecule	Cv	Cp	Gamma
A	1	1/2kT	½ R	3/2 R	3
B	3	3/2 kT	3/2 R	5/2 R	5/3
C	5	5/2 kT	5/2 R	7/2 R	7/5
D	11	11/2 kT	11/2 R	13/2 R	13/11
E	2	kT	R	2R	2

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

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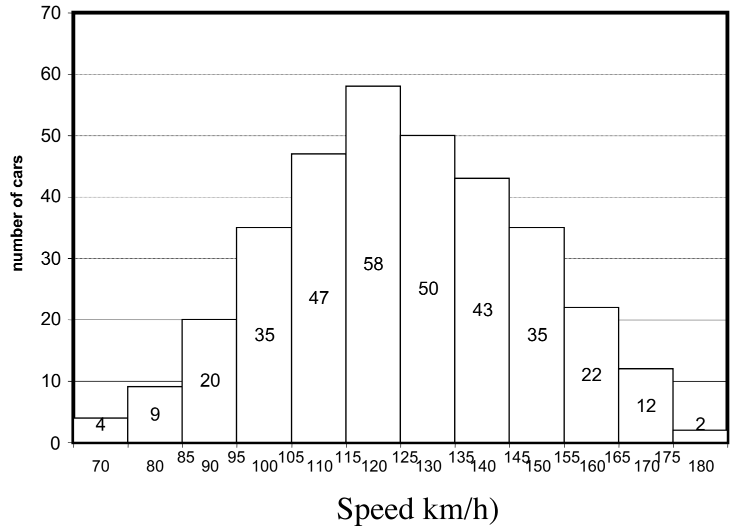
6 Given is distribution of speeds of cars at 417 Highway as measured by OPP.
a) Is this a discrete or continuous distribution?
b) Find the Vmp, Vrms, Vavg.
c) Find the probability that a randomly picked car will have speed larger than 120km/h.
d) Find the probability that a randomly picked car will have speed larger than 90km/h and less then 110km/h.



Answers:
a) discrete
b) V_{mp}=120km/h; V_{rms} =127km/h; V_{avg}=125km/h
c) 0.49
d) 0.16

7 Given is 1mole of nitrogen molecules at atmospheric pressure and temperature of 20°C.
a) Find the number of molecules having their speed between 200m/s and 201m/s N= 5.95×10^{20}

$$Since: P(v)dv = 4\pi\left[\frac{1}{2\pi}\frac{m}{kT}\right]^{\frac{3}{2}} v^2 e^{-\frac{mv^2}{2kT}}dv \quad and \quad P(v) = \frac{N}{N_A} \Rightarrow N_A = NP(v)$$

$$N = N_A 4\pi\left[\frac{1}{2\pi}\frac{M}{RT}\right]^{\frac{3}{2}} v^2 e^{-\frac{mv^2}{2kT}}dv = N_A[3.11153\cdot10^{-8}]\cdot v^2 e^{-\frac{Mv^2}{2RT}}[1m/s]$$

Answers to part a may slightly vary depending on which value was taken as the v in the formula above
(centre value as 200.5m.s or vleft =200m/s or v rigth =201m/s)

b) Find the most probable speed: ANS: 402m/s
c) Find the number of molecules with the most probable speed (within 1 m/s from it) ANS: 11. 99 $\times10^{20}$
d) Find the number of molecules with the speed of 1000m/s ANS: 0.60 $\times10^{20}$
e) Find the number of molecules with the speed of 2000m/s ANS: 7.69×10^{12}