General Physics II Honors (PHYS 102H)

Problem set # 2 *(due February 7)*

All problems are mandatory, unless marked otherwise. Each problem is 10 points.

Q1 A container with n moles of an ideal monoatomic gas undergoes an adiabatic process. The initial state parameters of the gas are (P_i, V_i, T_i) and (P_f, V_f, T_f), correspondingly.
(a) Starting with the expression $W = \int PdV$ and using the condition $PV^\gamma = const$, show that the work done by the gas is

$$W = \frac{1}{\gamma - 1}(P_i V_i - P_f V_f).$$

(b) Starting from the first law of thermodynamics, show that the work done by the gas is equal to $nC_V(T_i - T_f)$. Explain whether these two results are consistent with each other.

Q2 The following equation describes a process in which one can neglect any energy exchange with the environment:

$$\frac{1}{2}(0.012\ \mathrm{kg})(300\ \mathrm{m/s})^2 + \frac{1}{2}(0.008\ \mathrm{kg})(400\ \mathrm{m/s})^2 =$$
$$\frac{1}{2}(0.020\ \mathrm{kg})(20\ \mathrm{m/s})^2 + (0.020\ \mathrm{kg})(128\ \mathrm{J/kg}\cdot^{\mathrm{o}}\mathrm{C})(327.3^oC - 30^oC) + m_x(2.45 \times 10^4\ \mathrm{J/kg})$$

Write a problem for which this equation appears in the solution. Describe the system and the process(s) it undergoes. Solve the problem including calculating the unknown in the equation and identifying its physical meaning. (Don't be afraid to be creative with the set up, but make sure the underlying physics is properly described).

Q3 An air rifle uses the expansion of the compressed air to accelerates pellets along the rifle barrel. Everything happens very quickly, so there is no heat exchange with the environment, and the process is essentially adiabatic. Assuming that the rifle starts with $V_0 = 15\ \mathrm{cm}^3$ of compressed air, which behaves as an ideal gas with $\gamma = 1.4$. The expanding air pushes the a $m = 1.2$g pellet with cross-section area $A = 0.03\mathrm{cm}^2$ along the $L = 55$cm long gun barrel. The pellet shoots out with a muzzle speed of $v = 140$m/s. What is the initial air pressure? Hint: the expressions from Q1 may come handy.

Q4 A new heat engine cycle can be described by an adiabatic compression ($a \rightarrow b$), and isothermal expansion ($b \rightarrow c$), and an isochoric cooling process ($c \rightarrow a$), as shown in the graph. The compression ratio is r. For a diatomic ideal gas: $c_V = \frac{5}{2}R$, $c_P = \frac{7}{2}R$, $\gamma = 1.4$.
(a) Write down the expression for the heat transferred during each process.
(b) Find an expression for the efficiency of this cycle in terms of only the compression ratio r, assuming the process is running with a diatomic ideal gas.
(c) If the compression ratio $r = 4$, what is the efficiency for this heat engine? How does this compare to the Carnot efficiency running between the reservoirs with same two temperatures?