Thermodynamics Review Problems – Physics 2

1. A certain automotive tire contains a volume of 55 L filled with pure nitrogen to a gauge pressure of 32 psi when the temperature is 22 °C. (a) Determine the number of molecules contained. (b) Determine the average speed (rms) of the nitrogen molecules. (c) Assuming the volume is unchanged, the same tire would measure what pressure if the temperature drops to 0.0 °C? (d) Determine the change in translational kinetic energy of the nitrogen as the temperature drops. (e) How would the heat for the nitrogen compare to the value calculated in the previous question? Explain.
2. A certain quantity of monatomic ideal gas has total internal energy U at absolute pressure P. Derive an expression for the volume of this gas in terms of P, U, and any appropriate constants.
3. A puffy down-filled winter jacket is warm because of the "loft" – *i.e.* the fluffy feathers help create pockets of air, which is a good insulator. Suppose the jacket has average thickness 6.0 cm and covers 1.1 m^2 of the person's torso and arms. (a) Given the thermal conductivity of air 0.023 $Js^{-1}m^{-1}K^{-1}$, determine the rate of heat loss through the coat for a person with body temperature 37.0 °C on a very cold day that is −10.0 °C. (b) What thickness of air would have the same rate of heat loss at normal room conditions 20.0 °C? (c) Does the answer seem reasonable based on the typical attire we wear for room conditions?
4. Neon in the atmosphere has a certain distribution of speeds at 300 K. (a) Given the mass of neon is 20.0 u determine the "average speed" (v_{rms}). (b) Argon atoms, mass 40.0 u, would move at the same speeds at what temperature? (c) If these two gases are then mixed together, initially at these two temperatures, is energy transferred from one to the other (even though the speed distributions are the same)? Explain.
5. A cylindrical container with a piston contains 100.0 cm^3 of an ideal monatomic gas that is initially at 300 K and 1.00 atm pressure. Four processes then occur: 1. The pressure is increased to 2.00 atm while the temperature remains constant at 300 K. 2. The volume increases to 90.0 cm^3 as the pressure remains constant at 2.00 atm. 3. The gas expands adiabatically, reaching a temperature of 503 K as it returns to its original volume of 100.0 cm^3. 4. The temperature returns to its original value of 300 K while the volume remains fixed at 100.0 cm^3. The efficiency of the entire cycle is 14.5 %.
   (a) Determine the number of atoms contained in the cylinder.
   (b) Determine the maximum temperature that occurs during the cycle.
   (c) Determine the pressure of the gas at the beginning of the isochoric process.
   (d) Determine the work done on the gas for each process.
   (e) Determine the heat for each process.
   (f) Determine the change in internal energy for each process.
   (g) Make a sketch of a *PV* diagram illustrating this cycle.
   Hints: It is not necessarily best to work through the cycle in the order given. And, it is possible to find all heat and work values *exactly* without using any calculus.

Answers

1. a. 4.4×10^{24}
   b. 510 m/s
   c. 29 psi (200 kPa)
   d. −2.0 kJ
   e. The absolute value of the heat would be a greater number of joules because molecular nitrogen has other forms of kinetic energy that would also decrease with the temperature. The decrease in internal energy of the nitrogen is greater than calculated and there is no work done, so the heat value Q must satisfy $Q < -2.0$ kJ.
2. $V = \frac{2U}{3P}$
3. a. 20 W
   b. 2.2 cm
   c. Everyday clothing will trap a layer of air a centimeter or so thick, so this does indeed seem like a reasonable estimate.
4. a. 612 m/s
   b. 600 K
   c. Yes, heat would flow from the higher temperature argon to the lower temperature neon. Even though the speeds are "the same", any collisions of the more massive argons with the less massive neon would tend to result in kinetic energy transferring to the neon.
5. a. 2.45×10^{21}
   b. 540 K
   c. 1.68 atm
   d. $W_1 = 7.04$ J $W_2 = -8.10$ J $W_3 = -1.87$ J $W_4 = 0$
   e. $Q_1 = -7.04$ J $Q_2 = 20.3$ J $Q_3 = 0$ $Q_4 = -10.3$ J
   f. $\Delta U_1 = 0$ $\Delta U_2 = 12.2$ J $\Delta U_3 = -1.87$ J $\Delta U_4 = -10.3$ J
   g.