Physics 7B, Fall 2009, Sections 2 and 3, Instructor: Professor Adrian Lee

# First Midterm Examination

Thursday October 1, 2009

Please do work in your bluebooks. You may use one double-sided 3.5″ × 5″ index card of notes. Test duration is 90 minutes.

1) Three Independent Questions [30 pts total]

a) **Heat Conduction.** A copper rod and an aluminum rod of the same length L and cross-sectional area are attached end-to-end to form one long rod of length 2L. The tip of the copper end of the combined rod is placed in a furnace maintained at a temperature $T_H$ and tip of the aluminum end is held at $T_L$. What is the temperature of the middle of the combined rod where the two rods are joined? The values of k for aluminum and copper are $k_{Al}$ and $k_{Cu}$. What is the temperature if $k_{Al} = k_{Cu}$? What is the temperature if $k_{Al} = \frac{1}{2}k_{Cu}$? (10 pts)

b) **Radiative transfer.** *(This problem is challenging, you may want to save it for last.)* A spherical solid mass with radius R, density $\rho$, with specific heat C, and emissivity e, is released from a space ship to float in the vacuum of space. The sphere is initially at temperature $T_0$. How long does it take to cool to a lower temperature $T_1$? The temperature change is large enough that $T^4$ can not be approximated as constant. (10 pts)

c) **Kinetic theory of gases (Giancoli 18-10).** Show that the rms speed of molecules in a gas is given by $v_{rms} = \sqrt{3P/r}$, where P is the pressure of the gas and r is the gas density. (10 pts)

2) **Heat Engine (Giancoli 20-69 4th ed).** [30 pts total]

The operation of a heat engine takes an ideal monatomic gas through a rectangular cycle on a PV diagram (see board). The boundaries of the box are at $P_0$, $3P_0$, $V_0$, and $2V_0$.

a) During which parts of the cycle is heat flowing in from the high temperature? Calculate the contributions to $Q_H$ and the total $Q_H$. (10 pts)

b) Calculate the total work done by this engine and then determine the efficiency of this engine. Express the answer in terms of $w_T$ and $Q_H$ for partial credit. The answer should be a number. (10 pts)

c) Compare the efficiency of this engine to that of a Carnot engine operating between $T_H$ and $T_L$, the highest and lowest temperatures achieved by the rectangular engine. ($e = 1 - T_L/T_H$ for a Carnot engine). The final answer should be a number. (10 pts)

3) **Entropy.** [20 pts total]

a) Why would you expect the total entropy change in a Carnot cycle to be zero? Discuss both the gas and the environment. A simple one line answer for each is sufficient. (5 pts)

b) Calculate the entropy change and show that it is zero. There is more than one way to do this problem, and you are allowed to use derived expressions for the efficiency of a Carnot engine such as that given in 2c. (15 pts)