Physics 4C Spring 2018 Test 2

Name: _____

May 14, 2018

Please show your work! Answers are not complete without clear reasoning. When asked for an expression, you must give your answer in terms of the variables given in the question and/or fundamental constants.

Answer as many questions as you can, in any order. Books and notes are not allowed. Use any blank space to answer questions, but please make sure it is clear which question your answer refers to.

The last question, question 3, is worth the most points.

$g = 9.8\ \text{ms}^{-2}$

$P_0 = 1.013 \times 10^5\ \text{Pa} = 1\ \text{atm}$

$R = 8.314\ \text{J mol}^{-1}\ \text{K}^{-1}$

$k_B = 1.38 \times 10^{-23}\ \text{J/K}$

$N_A = 6.022 \times 10^{23}$

$m_p = 1.67 \times 10^{-27}\ \text{kg}$

$\sigma = 5.6696 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$

$1\ \text{cal} = 4.186\ \text{J}$

$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$

Fahrenheit to Celsius:
$([^\circ\text{F}] - 32) \div 1.8 = [^\circ\text{C}]$

Celsius to Fahrenheit:
$([^\circ\text{C}] \times 1.8) + 32 = [^\circ\text{F}]$

$e = 1 - \frac{1}{(V_1/V_2)^{(\gamma-1)}}$

$\int_v^{v+\text{dv}} N_v\,\text{dv} = \int_v^{v+\text{dv}} 4\pi N \left(\frac{m_0}{2\pi k_B T}\right)^{3/2} v^2 e^{-m_0 v^2/2k_B T}\,\text{dv}$

1. **[12pts]** A sample of a solid substance has a volume V_0 and a density ρ_0 at a temperature T_0. The specific heat capacity of the sample is c and the coefficient of volume expansion is β. The solid sample is heated at in air at constant pressure P_0. If the temperature of the substance is increased by an amount ΔT and it remains a solid,

   (a) find and expression for the new density of the substance. [4 pts]

   (b) what is the work done on the sample as it is heated? [4 pts]

   (c) what is the change in the internal energy of the sample? [4 pts]

2. **[15pts]** Initially, a container of volume V contains n moles of helium gas at a pressure P. Suppose the pressure is of the gas is increased to $4P$ while the volume is unchanged.

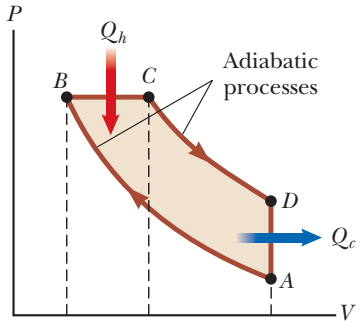
   (a) By what factor does the average kinetic energy of the helium atoms change? [4 pts]

   (b) By what factor does the root-mean-square (rms) speed of the atoms change? [2 pts]

   (c) By what factor does the most probable speed of the atoms change? [2 pts]

   (d) On the same (labeled) axes, sketch the distribution of molecular speeds for each pressure. Label the most probable speed and the rms speed on each distribution. [7 pts]

3. **[23pts]** An idealized diesel engine operates in the cycle shown. Fuel is sprayed into the cylinder at the point of maximum compression, B. Combustion occurs during the expansion $B \to C$, which is modeled as an isobaric process. The gas in the cycle has n moles, a molar heat capacity at constant pressure of C_p, and a molar heat capacity at constant volume of C_v, and ratio γ. T_A, T_B, T_C, and T_D are the temperatures at points A, B, C, and D, respectively.



(a) What is the heat transferred to the gas in processes C $\to$ D and A $\to$ B? [2 pts]

(b) Show that the efficiency of an engine operating in this cycle is [5 pts]

$$e = 1 - \frac{1}{\gamma}\left(\frac{T_D - T_A}{T_C - T_B}\right)$$

(c) What is the entropy change in the process B $\to$ C? [3 pts]

(d) What is the entropy change in the process D $\to$ A? [3 pts]

(e) Show that [5 pts]

$$\frac{T_D}{T_A} = \left(\frac{T_C}{T_B}\right)^{\gamma}$$

(f) Using your results from (c), (d), and (e), find/confirm the net change in entropy of the working fluid going clockwise around the cycle from A $\to$ A. [5 pts]

–Extra Workspace–