Javier Duarte, Department of Physics
University of California San Diego
Physics 2C, Winter 2020

QUIZ 3

All students must work independently. You are allowed one page of handwritten notes only; no communication devices (cell phones, etc) permitted. Show all work; no credit will be given for answers with no derivation. Any problem asking for a vector (e.g., force) requires a vector as an answer!

Directions: Work each problem on the exam sheet provided. Put your NAME and PID on EACH sheet (one for each problem) in the space provided. If you don't have enough room on a single side of the page, finish the problem on the back of the page. $10 + 15 + 10 + 4(3) = 47$ points total for this exam.

Please keep in mind the following before you turn in your exam to avoid a 10% penalty:

- Make sure your name and PID are on each sheet in the space provided.
- Turn in all 5 pages. Do not turn in this cover page. If you absolutely could not fit a problem on the front/back of a single sheet, clearly communicate this to the proctor/TA/instructor when you turn in your exam.
- Make sure your pages are in numerical order (page 1, page 2, page 3, etc.)

This page intentionally left blank.

Name:
PID:

1. (10 points, 5 points each): A Carnot engine with 1.00 mol of Helium as the working substance operates between the temperatures 300 K and 900 K. In one cycle, 12.0 kJ of heat is delivered to the gas.

   (a) Draw an energy transfer diagram, showing what happens to every 12.0 kJ of heat that is extracted from the high-temperature reservoir. In particular, label and write numerical values for Q_H, Q_C, W_{out}, T_H (temperature of hot reservoir), and T_C (temperature of cold reservoir). What is the efficiency η of this engine?

   (b) Draw the pV diagram for this process. If the volume of the gas is V_0 at the beginning of the isothermal expansion step (point A), what is the volume of the gas at the end of this step (point B)? Your answer should be a number times V_0. (Hint: recall or rederive the work done by a gas during an isothermal expansion.)

This page intentionally left blank.

Name:	
PID:	

2. (15 points, 5 points each): A refrigerator using a diatomic gas as the working substance (with rotational but not vibrational degrees of freedom) operates via a 3-step cycle. From initial pressure p_0 and volume V_0 (point A on a pV diagram), the gas undergoes an adiabatic expansion to quadruple its volme (point B), followed by an isochoric process to return to pressure p_0 (point C), and finally an isobaric process to return to the starting point.

   (a) Draw this process on a pV diagram. Label the three corners of your cycle "A," "B," and "C." For each of the three steps (AB, BC, and CA), say whether heat is transferred to the gas, heat is transferred away from the gas, or there is no heat transfer.

   (b) What is the temperature of the gas at point B? Express your answer as a number times T_0, where T_0 is defined to be the temperature at point A.

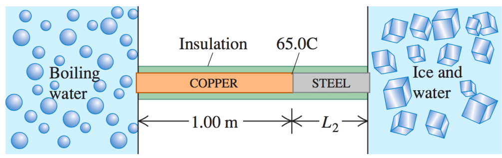
   (c) What is the coefficient of performance (COP) of this fridge? You may use the following formula, which gives the work done by a gas during an adiabatic expansion:

$$W_{\text{by,adiabat}} = \frac{p_i V_i - p_f V_f}{\gamma - 1}$$

This page intentionally left blank.

Name:
PID:

3. (10 points, 5 points each) A long rod, insulated to prevent heat loss along its sides, is in perfect thermal contact with boiling water at one end and with an ice-water mixture at the other end. The rod consists of a 1.00 m section of copper (one end in boiling water) joined end-to-end to a length L_2 of steel (one end in the ice-water mixture). Both sections of the rod have the same cross-sectional area:



The temperature of the copper-steel junction is 65.0° C after a steady state has been reached (i.e., the heat transfer rate is the same through the copper and the steel). The thermal conductivities for copper and steel are $k_{\text{Cu}} = 401$ W/(m·K) and $k_{\text{steel}} = 46$ W/(m·K), respectively.

(a) What is the length L_2 of the steel section?

(b) Suppose we remove the steel section, so that it's just the 1.00 m copper rod connecting the boiling water at one end and the ice-water mixture at the other end. Would the energy per unit time transferred through the rod increase or decease? By what factor? Explain.

This page intentionally left blank.

Name:
PID:

(12 points, 3 points each): 4 Multiple-choice questions / fill-in-the-blanks on various topics.

Directions for multiple-choice questions: COMPLETELY FILL IN THE SQUARE for the answer. Directions for fill-in-the-blank questions: Your answer should be entirely in the boxed region. Include the number of significant figures ("sig. figs.") requested in the problem.

---

4. It costs $300.00 each summer to operate a home air conditioner with a COP of 2.0. How much would it cost to cool the home in the summer after upgrading to a model with a COP of 4.0? Assume the same amount of heat is to be extracted from the house. (express your answer to the nearest dollar)

---

5. A car's internal combustion engine can be modeled as a heat engine operating between a combustion temperature of 1500°C and an air temperature of 20°C with 30% of the Carnot efficiency. The heat of combustion of gasoline is 47 kJ/g. What mass of gasoline is burned to accelerate a 1500 kg car from rest to a speed of 30 m/s?

   ☐ 1 gram
   ☐ 7 grams
   ☐ 20 grams
   ☐ 60 grams

---

6. What is the root-mean-square speed v_{rms} of oxygen molecules in your car tires? Note O_2 has a molar mass of 32.0 g/mol. Take the absolute pressure of gas in your tires to be 3.8 atm and take the temperature to be 40°C.

   ☐ 500 m/s
   ☐ 900 m/s
   ☐ 1300 m/s
   ☐ 1700 m/s
   ☐ 2100 m/s

This page intentionally left blank.

Name:
PID:

7. Two containers (A and B) initially hold N balls. Once a second, one of the balls is chosen at random and switched to the other container. After a long time has passed, you record the number of balls in each container every second. In $100,000$ s, you find 49 times when all the balls were in container A. How many balls are there?

   - ☐ 8
   - ☐ 9
   - ☐ 10
   - ☐ 11
   - ☐ 12

This page intentionally left blank.