Name: _____

PHYS 1110 Exam 4

Standards 47–51

Calculators of any type are permitted. A formula sheet is provided. There is not enough room on this test paper to work out your answers: using scratch paper is recommended and encouraged.

Enter your answer inside the box provided by each question. Do not make stray marks in the box, and do not write your answer outside the box. It is a good idea to write your answers in pencil. Don't forget the units! If the question asks for a selection from provided options, fill the circle (○) or square (□) by the most correct answer. If the options for a question are preceded by circles, then mark only the one best answer. If the options are preceded by squares, select all correct answers.

1. A 25.0-kilogram ice sculpture slowly melts on a buffet table at a tropical resort. As it melts, the temperature of the ice is 0 °C (273.15 K), and the surrounding tropical air has a temperature of 27 °C (300.15 K).

   A. How much heat transfers from the air to the ice as the ice sculpture completely melts to liquid water? (Don't forget the units!)

   B. What is the entropy change of the ice during the melting process?

   C. Given that one formula for an entropy change is $\Delta S = q_{\text{rev}}/T$, what is the SI unit for entropy?

   D. What is the entropy change of the tropical air as the ice melts?

   E. What is the total entropy change of the universe as the ice melts?

   F. If a heat engine were to operate between the temperature of melting ice and the temperature of the tropical air (0 °C and 27 °C), what is the highest efficiency it could possibly have?

G. More practically, the ice must be created by freezing water in a freezer. Suppose that the interior of the freezer is kept at –15 °C (258.15 K) and the tropical surroundings are at 27 °C. What is the maximum possible coefficient of performance of the freezer?

2. A blacksmith heats a 30.0-gram (0.0300 kilogram) steel chisel to a temperature of 1000 °C in a forge. He removes it from the forge and immediately immerses it into 450 grams (0.450 kilogram) of motor oil, initially at a temperature of 25 °C. He allows the chisel and oil to come to thermal equilibrium. The specific heat capacity of steel is c_s = 490 J/(kg·°C), and the specific heat capacity of motor oil is c_o = 2000 J/(kg·°C).

A. If a quantity of heat Q is lost from a mass m_s of steel, what is the formula for the temperature change of the steel? (Choose one.)

○ $\frac{-m_s c_s}{Q}$ ○ $\frac{-c_s}{m_s Q}$ ○ $\frac{-m_s}{Q c_s}$ ○ $\frac{-Q}{m_s c_s}$

B. If the temperature of a mass m_o of oil increases by an amount ΔT, what is the formula for the heat gained by the oil? (Choose one.)

○ $\frac{m_o c_o}{\Delta T}$ ○ $\frac{m_o \Delta T}{c_o}$ ○ $\frac{m_o}{c_o \Delta T}$ ○ $m_o c_o \Delta T$

C. When the chisel and the oil reach thermal equilibrium, which has the higher temperature? (Choose one.)

○ The chisel will have the higher temperature.

○ The oil will have the higher temperature.

○ The chisel and oil will have the same temperature.

○ Not enough information is given to know both final temperatures.

D. What is the final temperature of the chisel?

○ 216.9 °C ○ 85.9 °C ○ 40.7 °C ○ 512.5 °C

3. A liquid-in-glass thermometer consists of a class bulb containing a small volume of liquid joined to a narrow glass "capillary" tube. When liquid in the bulb expands, it rises in the capillary. In the past, the liquid in thermometers was commonly liquid mercury metal, but mercury has fallen from favor because it is poisonous.

A mercury thermometer made of flint glass has a bulb containing 0.6 cubic centimeters of mercury (it's probably not helpful to convert that to cubic meters). At a temperature of 0.0 °C, the mercury just fills the bulb; as the mercury expands, it rises into the capillary. The

coefficient of linear thermal expansion for flint glass is $\alpha = 9.0\times10^{-6}/°C$, and the coefficient of volume thermal expansion for mercury is $\beta = 1.8\times10^{-4}/°C$.

A. By what volume will the thermometer bulb expand when its temperature increases from 0 °C to 20. 0 °C? (Choose one.)

○ 1.08×10^{-4} cm^3 ○ 3.24×10^{-4} cm^3 ○ 5.40×10^{-6} cm^3 ○ 1.62×10^{-5} cm^3

B. What volume of mercury expands into the capillary when the temperature rises from 0.0 °C to 20.0 °C? (Choose one.)

○ 1.03×10^{-4} cm^3 ○ 6.16×10^{-3} cm^3 ○ 1.84×10^{-3} cm^3 ○ 1.08×10^{-4} cm^3

C. To make the thermometer easy to read, the mercury column in the capillary should rise 2.0 centimeters when the temperature increases by 20.0 °C. What should be the cross-sectional area of the capillary? (Don't forget the units!)

4. Here are several questions about thermodynamic processes.

A. Which quantities determine the internal energy of a sample of an ideal gas? (Select all that apply.)

☐ Its temperature

☐ The average distance between molecules

☐ Its color

☐ The average mass per molecule

B. Which of the quantities listed below are *state variables*? (Select all that apply.)

☐ Heat ☐ Number of molecules

☐ Work ☐ Color

☐ Volume ☐ Temperature

☐ Pressure ☐ Internal energy

C. If two states have different values of temperature, pressure, volume, or number of molecules, will they have different internal energies? (Choose one.)

○ Yes, always. ○ Sometimes. ○ No, never.

D. If two states have the same values of temperature, pressure, volume, and number of molecules, will they have the same internal energy? (Choose one.)

○ Yes, always. ○ Sometimes. ○ No, never.

E. Which of the following statements are true of cyclic processes (processes that return to the starting state)? (Select all that apply.)

☐ The change in entropy of the universe is zero.

☐ The change in internal energy of the system is zero.

☐ The heat absorbed by the system is zero.

☐ The work done by the system is zero.

5. A sample of an ideal gas at an initial temperature of 300 K occupies a volume of 20 liters (0.020 cubic meters) and has a pressure of 200,000 newtons per square meter (that sounds like a lot, but it's only about twice atmospheric pressure at sea level). The gas is heated at constant pressure until its final volume is 60 liters (0.060 cubic meters). The gas absorbs 20,000 joules of heat in the process.

A. Does the gas do positive work on its surroundings in this process? (Choose one.)

○ Yes, the gas does positive work on the surroundings.

○ No, the surroundings do positive work on the gas.

○ No, no work is done in this process.

B. Does the internal energy of the gas change in this process?

○ Yes, the internal energy of the gas increases in this process.

○ Yes, the internal energy of the gas decreases in this process.

○ No, the internal energy of the gas does not change in this process.

C. What is the work done by the gas in this process?

D. What is the change in internal energy of the gas in this process?

E. Suppose that this system is a heat engine. What is the engine's efficiency?
