

Name: _____

PHYS 1220-02 Quiz 3

You may use an 8.5"×11" note sheet written on both sides, a calculator of any type, and a rose hip. Please write your answers in the boxes provided. Show your work outside the boxes. If you wish to change an answer written in a box, thoroughly erase the unwanted answer and write the desired answer in its place. If a numerical answer is a physical quantity rather than a pure number, include the units with your answer.

“Multiple choice” questions, in which only one answer is correct, have circular bubbles (○): select exactly one choice. “Select all” questions, in which any number of the choices may be correct, have square bubbles (□): select all correct answers. Select your choice by filling the circle or square: please do not “X”, check, circle, or otherwise mark your choice. Do not mark bubbles for rejected options.

If the point value of a question is not indicated, it is worth one point.

Constants and equivalents

$$1 \text{ cal} = 4.184 \text{ J}$$

$$1 \text{ Cal} = 1000 \text{ cal}$$

$$1 \text{ bar} = 10^5 \text{ Pa}$$

$$\text{Specific heat capacity of liquid water: } 4184 \text{ J/kg}$$

$$\text{Universal gas constant } R: 8.31441 \text{ J/(mol}\cdot\text{K)}$$

$$\text{Boltzmann constant } k_B: 1.381 \times 10^{-23} \text{ J/K}$$

$$\text{Avogadro's number } N_A: 6.022 \times 10^{23}/\text{mol}$$

$$\text{Stefan-Boltzmann constant } \sigma: 5.670374419 \times 10^{-8} \text{ W/(m}^2\cdot\text{K}^4)$$

$$\text{Elementary charge } e: 1.602 \times 10^{-19} \text{ C}$$

$$\text{Coulomb's constant } k: 8.988 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$$

$$\text{permittivity of free space } \epsilon_0: 8.854 \times 10^{-12} \text{ C}^2/(\text{N}\cdot\text{m}^2)$$

Some metric prefixes

$$\text{nano } n \times 10^{-9}$$

$$\text{deka } D \times 10^1$$

$$\text{micro } \mu \times 10^{-6}$$

$$\text{hecta } h \times 10^2$$

$$\text{milli } m \times 10^{-3}$$

$$\text{kilo } k \times 10^3$$

$$\text{centi } c \times 10^{-2}$$

$$\text{mega } M \times 10^6$$

$$\text{deci } d \times 10^{-1}$$

$$\text{giga } G \times 10^9$$

Questions

1. An oven at 500 K transfers heat to the surrounding kitchen maintained at 285 K. The rate of transfer is 200 watts for 40 minutes.

A. What is the resulting entropy change of the oven from the heat loss?

B. What is the resulting entropy change of the kitchen from the heat gain?

C. What is the resulting entropy change of the universe from the heat transfer?

2. (2 points) A pot of 0.800 kilograms of tea cools from 92°C to 70°C. What is the resulting entropy change of the tea? Assume that the specific heat capacity of tea is the same as for water.

3. (2 points) A sample of 2.00 moles of a monatomic ideal gas at 300 K freely expands (expands into a vacuum) to 4.2 times its initial volume. What is its change in entropy?

4. Tell me the appropriate measure of performance, in terms of the quantities T_h , T_c , Q_h , or Q_c , for the following types of devices operating between high temperature T_h , and low temperature T_c .

A. A heat pump

B. A refrigerator

C. A heat engine

5. (2 points) An optimally-performing heat pump heats the air inside a building by moving heat from the air outside the building into the interior. It has a coefficient of performance of 12.0. What is the necessary relationship between the temperature of the air inside the building and the air outside the building?

6. Coulomb's law can be expressed as $F = k q_1 q_2 / r^2$, where k is a constant of proportionality. Sometimes this constant is expressed in terms of the constant ϵ_0 . What is k in terms of ϵ_0 ?

7. A carbon-12 atom contains six protons and six electrons. A mole of carbon, that is, Avogadro's number of atoms, has a mass of 0.0120 kilograms. Suppose that all of the protons in one milligram, that is, 10^{-6} kg, of carbon-12 were placed together at one point and all of the electrons were placed at 12.724×10^6 meters distant (the distance between Earth's poles).

A. Would the protons attract the electrons or repel them?

☐ a. attract

☐ b. repel

☐ c. no interaction

- B. (2 points) What would be the magnitude of the interaction force between the protons and the electrons? (Let's not even think about what it would take to hold the group of protons or the group of electrons together.)

- C. What would be the magnitude of the electric field midway between the electrons and protons?

8. A conducting hollow ball has a diameter of 0.100 meters and contains a spherical central cavity with a diameter of 0.050 meters. The ball itself bears a charge of $Q_1 = +2.00 \times 10^{-9}$ C, and at the center of the cavity is a point charge of $Q_2 = -1.00 \times 10^{-9}$ C. Figures below illustrate imaginary surfaces enclosing parts of the system.

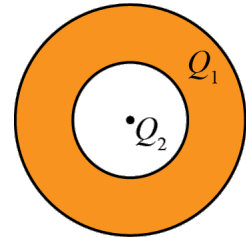
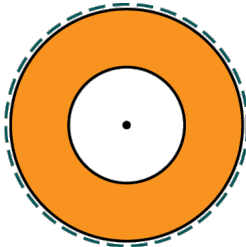


Fig. A

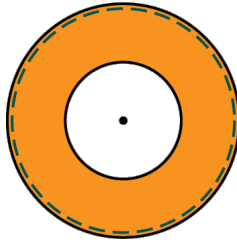


Fig. B

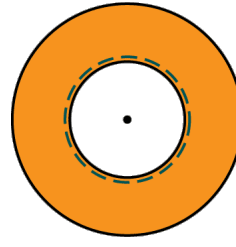


Fig. C

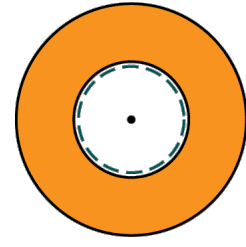


Fig. D

- A. How much charge is enclosed by a surface just outside the ball? (Fig. A)

- B. How much charge is enclosed by a surface just inside the outer skin of the ball? (Fig. B)

- C. How much charge is enclosed by a surface just outside the inner skin of the ball, just enclosing the cavity (Fig. C)?

- D. How much charge is enclosed by a surface just inside the surface of the cavity (Fig. D)?

- E. How much charge is on the inner skin of the ball (surrounding the cavity)?

- F. How much charge is between the inner and outer skins of the ball?

- G. How much charge is on the outer skin of the ball?