Center for Academic Resources in Engineering (CARE) Peer Exam Review Session

Phys 213 – University Physics: Thermal Physics

Quiz 1 Worksheet

The problems in this review are designed to help prepare you for your upcoming exam. Questions pertain to material covered in the course and are intended to reflect the topics likely to appear in the exam. Keep in mind that this worksheet was created by CARE tutors, and while it is thorough, it is not comprehensive. In addition to exam review sessions, CARE also hosts regularly scheduled tutoring hours.

Tutors are available to answer questions, review problems, and help you feel prepared for your exam during these times:

Tuesday, April 8th, 7-9 pm Alex, Luke, and David

Can't make it to a session? Here's our schedule by course:

`https://care.grainger.illinois.edu/tutoring/schedule-by-subject`

Solutions will be available on our website after the last review session that we host.

Step-by-step login for exam review session:

1. Log into Queue @ Illinois: https://queue.illinois.edu/q/queue/844
2. Click "New Question"
3. Add your NetID and Name
4. Press "Add to Queue"

Please be sure to follow the above steps to add yourself to the Queue.

Good luck with your exam!

1 Here are some warm-ups to get you started!

1. Copper has a specific heat capacity of 376.812 J / kg K. Consider a copper ingot of mass 12 kg and at a temperature of 274.5 K. Given 3.67 kJ of energy delivered to the ingot:

(a) the heat capacity of the ingot

(b) the molar heat capacity of the ingot

(c) Calculate the ingot's final temperature

2. Below you are given an substance and its number of moles. Determine its heat capacity. Hint:

$$U = \frac{N_{\text{DOF}}}{2} NkT \implies C = \frac{N_{\text{DOF}}}{2} Nk$$

(a) N_2 gas, 4 moles

(b) solid aluminum, 6 moles

(c) argon gas, 8 moles

3. Below you are given heat capacity functions as well as initial and final temperatures. Using the definition of temperature, determine the overall change in entropy. Hint:

$$\frac{1}{T} = \frac{\partial S}{\partial U} \implies \Delta S = \int \frac{\mathrm{d}U}{T} \implies \Delta S = \int_{T_i}^{T_f} \frac{C\mathrm{d}T}{T}$$

(a) $C(T) = 24$ J/K, $T_i = 300$ K, $T_f = 350$ K

(b) $C(T) = \alpha T^2$, $\alpha = 0.05$ J/K^2, $T_i = 300$ K, $T_f = 200$ K

(c) $C(T) = \beta T^4$ J/K, $\beta = 0.0001$ J/K^5, $T_i = 10$ K, $T_f = 130$ K

4. Let's do some combinatorics! Find the number of possible combinations for N coin tosses resulting in t tails :

(a) N = 10, t = 10

(b) N = 20, t = 4

(c) N = 100, t = 74

2 Regular Problems

5. Label each statement as True or False.

(a) One mole of nitrogen gas has a different heat capacity than one mole of hydrogen gas.

(b) It is possible for the entropy of a single object to decrease.

(c) Equilibrium is defined as the point at which the entropies of each object in a system are all equal.

(d) As you keep adding internal energy to an object, it becomes harder and harder to increase its entropy.

(e) A copper block weighing 1 kg has a different heat capacity than a copper block weighing 2 kg.

6. Consider 5 coins, each initially starting on heads.

(a) What is the entropy, S, of this system in its current configuration?

(b) List all the macrostates available to this system.

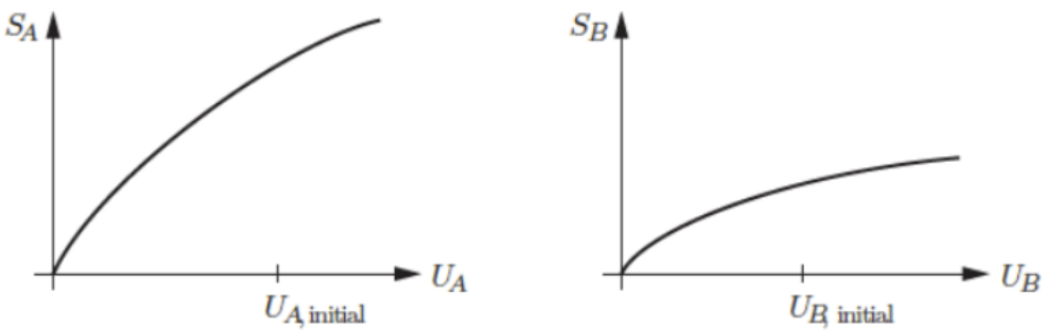
(c) Identify the most probable macrostates. Hint: there are two.

(d) How many microstates would lead to the macrostates identified above?

(e) Calculate the change in entropy, ΔS, if the system changed to either of its most probable macrostates.

7. The heat capacity of a solid is linear with temperature. How does its entropy change with temperature?

8. The figure below shows entropy S vs. internal energy U graphs for two objects, A and B. Both graphs are on the same scale. The internal energies of these two objects initially have the values indicated in the figure below.



(a) The objects are then brought into thermal contact with each other. Determine which of the following will happen.

i. Heat will transfer from object A to object B.

ii. Heat will not transfer between the objects.

iii. Heat will transfer from object B to object A.

(b) Which of the following is a correct statement?

i. $\Delta S_A = 0$, $\Delta S_B = 0$

ii. $\Delta S_A > 0$, $\Delta S_B > 0$

iii. $\Delta S_A < 0$, $\Delta S_B > 0$

iv. $\Delta S_A > 0$, $\Delta S_B < 0$

9. What is the difference between heat capacity, specific heat capacity, and molar heat capacity?

10. Substance A has a heat capacity of 3 J/K while substance B has a heat capacity of 5 J/K. Starting from the same temperature, which one cools at a faster rate.

11. Explain why the heat capacity at constant volume of an ideal solid is twice that of the same amount of a monatomic ideal gas.

12. A sealed container with a mass of 2.7 kg is filled with 4 moles of helium gas. Initially, the helium gas is at a temperature of 140°C and the container is at 38°C. The helium-container system is thermally isolated.

    Note that the specific heat of the material making the container is 386 J/(kg·K) and the molar specific heat of helium is 12.5 J/(mol·K).

    Find the equilibrium temperature of the system in Celsius and Kelvin.

13. (Note: this question uses fictional elements.) Consider a block of Wesleyium connected to a block of Vedhamite. A cylinder of Matthewide (thermal conductivity 10 $\frac{\text{m J}}{\text{s K}}$ and length 2 m) connects the two. The Matthewide cylinder has a cross-sectional area of 1 m^3. The temperature difference between the two blocks is 20 degrees Celsius, and approximately 51 Joules of heat is transported between the two blocks through the cylinder. How long does this process take?

14. Let's say I have a gas of diatomic molecules such that at a high enough temperature, $T_{\text{crit}} =$ 500 K, the number of degrees of freedom for each molecules increases from 5 to 7. If I have 6 moles of this gas, determine the amount of energy I would need to add to it to go from $T_i = 200$ K to $T_f = 800$ K.

15. Suppose we have a box of two gases as the same temperature in an insulating chamber partitioned by an impermeable membrane. This membrane is free move back and forth, changing the left and right volumes, V_A and V_B. The entropy of gas A and B can be described with the following equations:

$$S_A = N_A k \ln(V_A) + f(U_A, N_A)$$
$$S_B = N_B k \ln(V_B - bN_B) + f(U_A, N_A)$$

Here, $N_A = 4$ mol $N_B = 3$ mol, and $b = 6 \times 10^{-5}$ m^3/mol. The total volume of the container is 6 m^3.

(a) Find the volumes V_A^f and V_B^f that result from the system achieving equilibrium.

(b) We are told the initial volumes were $V_A^i = 1$ m^3 and $V_B^i = 5$ m^3. Determine the change in total entropy ΔS, and confirm that this value is positive.

(c) Let's say that instead of a moving impermeable membrane, we had an *immovable permeable* membrane with the same initial volumes. How would the entropy maximization process change? What would stay constant, and what would change to maximize entropy? Do we have enough information to do this? (You don't have to do any math, just explain in words.)