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

**Phys 213 – University Physics: Thermal Physics**

**Midterm Worksheet**

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*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.*

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

Session 1: April 2, 4-6pm Alex and Karan    Session 2: None

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

https://care.engineering.illinois.edu/tutoring-resources/tutoring-schedule-by-course/

Solutions will be available on our website after the last review session that we host, as well as posted in the zoom chat 30 minutes prior to the end of the session

Step-by-step login for exam review session:

1. Log into Queue @ Illinois
2. Click "New Question"
3. Add your NetID and Name
4. Press "Add to Queue"
5. Join the zoom link in the staff message

**Please do not log into the zoom call without adding yourself to the queue**

Good luck with your exam!

**This worksheet mostly contains concepts for Quiz 1 of Phys 213. Problems 11 and 13 contain concepts that will be covered for Quiz 2. If studying for Quiz 1, please skip these two problems.**

1. 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, $\Delta S$, if the system changed to either of its most probable macrostates

2. Consider two containers A and B filled with the same amount of the same ideal gas. Heat is added to each one but A is held at constant volume while B is held at constant pressure. Both are heated through a temperature increase of 10 K.

a) Which of the following is true of their added heats?

A) $Q_A > Q_B$
B) $Q_A = Q_B$
C) $Q_A < Q_B$

b) Which of the following is true of their change in internal energy?

A) $\Delta U_A > \Delta U_B$
B) $\Delta U_A = \Delta U_B$
C) $\Delta U_A < \Delta U_B$

3. (This is a continuation of problem 2). Assuming the situation described above is carried out, and both containers increase their temperatures by 10 Kelvin, how much more heat must be added to container B?

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

5. 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.

6. **True or False**: For an ideal gas, the molar heat capacity at constant pressure will always be greater than the molar heat capacity at constant volume.

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

8. 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.

9. A 10 kg block of aluminum initially at 90°C is placed in contact with a 12 kg block of copper initially at 10°C. The molar heat capacities of aluminum and copper are 24.2 J/(K-mol) and 24.5 J/(K-mol), respectively.

a) When the two blocks come into thermal equilibrium, what temperature will they reach?

   A) 75.4°C
   B) 62.9°C
   C) 49.8°C
   D) 33.5°C
   E) 24.5°C

b) How does the entropy of the aluminum change during this process?

A) 0
B) +695 J/K
C) -695 J/K
D) $+3.211\times10^3$ J/K
E) $-3.211\times10^3$ J/K

10. Consider a sealed container with a volume of 1 $m^3$ filled with $10^{23}$ helium atoms and $2\times\ 10^{23}$ molecules of nitrogen. Recall that helium is a monatomic gas and nitrogen gas and nitrogen is a diatomic gas. Initially the temperature of the gas mixture is 1000 K.

a) Find the pressure inside the container (Answer in Pa).

A) 8980
B) 8290
C) 4140
D) 2250

b) Find the ratio of the total molecular rotational energy to the total translational energy (molecular and atomic) inside the container. Assume that equipartition applies.

A) 0.333
B) 0.444
C) 0.666
D) 0.777

11. Suppose we place a proton in a magnetic field B = 3 Tesla. Like electrons, protons have two possible states of their magnetic moments, either aligned or anti-aligned with the magnetic field, and we can model it as a two-state system. The energy of a proton with its magnetic moment aligned with the magnetic field is $E_{align}$ = $-\mu_p$B where $\mu_p = 1.4\times\ 10^{-26}$ J/Telsa. The energy of the anti-aligned state is $E_{anti} = +\mu$B. The proton in contact with a thermal reservoir at temperature T = 0.04K.

a) At this temperature, what is the probability that the proton has its magnetic moment anti-aligned with the magnetic field, i.e., is in the state with higher energy?

A) 0
B) 0.5
C) 0.538
D) 0.462
E) 0.481

b) At this temperature the entropy S of the system is

A) Less than k ln(2)
B) Greater than k ln(2)
C) Equal to k ln(2)

c) If we increase the magnetic field to B = 15 Tesla does the entropy of the proton system at this temperature

A) Increase
B) Stay the same
C) Decrease

d) What is the heat capacity of the two-level system near T = 0? How about at exteremly high temperatures ($T \rightarrow \infty$)?

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

13. Consider a two-state oscillator with energies $E_0 = 0$ eV and $E_1 = 0.02$ eV. Calculate the average energy of this system if it is kept at 200K.

14. A monatomic, ideal gas is contained at fixed volume under pressure P. Now suppose the pressure is tripled. What is the ratio of the intitial $v_{rms}$ to the final $v'_{rms}$? ($v_{rms}/v'_{rms}$)