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

Phys 213 – University Physics: Thermal Physics

Quiz 2 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 22nd from 7-9pm in 4035 CIF - Aparna, Sarah, Zaahi

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. Consider a sealed container with a volume of 1 m^3 filled with 10^{23} helium atoms and 2×10^{23} molecules of nitrogen. Recall that helium is a monatomic 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

2. Which conditions are held constant in the following processes? (Refer to the formula sheet if you are not sure!)

a) Isothermal b) Isobaric c) Isochoric d) Adiabatic

3. What is the relationship between volume and pressure during isothermal and adiabatic processes for an ideal gas, respectively?

4. The following two questions refer to the setup described below.

A piston of volume 0.05 m^3 contains 5 moles of a monatomic ideal gas at 300 K. If it undergoes an isothermal process and expands until the internal pressure matches the external pressure, $P_E = 1$ atm.

(i) How much work is done by the gas on the environment?

a) 7.42×10^3
b) 1.12×10^4
c) -1.12×10^4
d) 1.83×10^4
e) -1.83×10^4

(ii) Suppose that the piston undergoes an adiabatic expansion instead, what is the final volume of the piston, V_f? (Values have units of cubic meters)

a) 0.086
b) 0.095
c) 0.123

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

6. Using the second law of thermodynamics, show that it is impossible for a heat engine to operate at $\epsilon = 1$.

7. Consider a balloon of volume 3 m^3 and at an initial pressure of 3 atmospheres.

(a) If the pressure is held constant and the balloon is heated up, what is the work done by the balloon on its environment given that the balloon expands to 5 m^3?

(b) If the volume is held constant, what is the new work done on the environment given that the balloon is heated up?

(c) If the pressure is not constant but now a function of volume, what is the work done on the environment given that the balloon is at 387 K and contains 283 moles of a monatomic gas, and expands to 5 m^3?

8. A Carnot heat engine (one operating at maximum efficiency) is operating between two reservoirs at T_H and T_C. Suppose that 1 kJ of heat must be added to the engine in order to produce 500 J of work and you measured the temperature of the cold reservoir to be 300 K, what is the temperature of the hot reservoir?

   a) 150 K
   b) 200 k
   c) 300 K
   d) 450 K
   e) 600 K

9. A heat pump uses 200 J of work to remove 300 J of heat from a cold reservoir. How much heat would be delivered to the hot reservoir?

10. The second law of thermodynamics states that the change in entropy is always greater than or equal to zero, yet sometimes in our calculations we can get a negative change in entropy for a piece of our system. What does a negative change in entropy represent? And how do negative changes not violate the second law?

11. Suppose we have some ocean water (which we will treat as pure water for our purposes) connected to an atmosphere. The atmosphere above contains an abundance of CO2 gas. CO2 can dissolve into water just like a solid. What is true about the total Gibbs Free Energy and Internal Energy of the ocean water system after enough CO2 has dissolved to come to equilibrium, acidifying the ocean?

12. How do you calculate the work from an isothermal process?

13. How does a heat engine's work output and efficiency scale with the temperatures of its reservoirs? If you were to design a perfect heat engine, what would be the lowest temperature you should set your cold reservoir to?

14. 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.

15. For this problem, we'll be playing around with differentials.

(a) Recall that the expression for Gibbs Free Energy is

$$G = U - TS + pV$$

Without making any substitutions, write out the full differential form of G, $\mathrm{d}G$.

(b) Determine the derivative of G with respect to volume V at fixed pressure, temperature, and number of particles. That is, find

$$\left(\frac{\partial G}{\partial V}\right)_{T,\ p,\ N}$$

and simplify as much as you can.

(c) Should G be minimized or maximized at equilibrium? What does this mean $\partial G/\partial V$ should be equal to at equilibrium?

(d) Determine a formula for the equilibrium volume V_{eq} given that this gas is not ideal, i.e.

$$S = Nk\ln(V - bN)$$

(e) Determine the equilibrium volume if $T = 340$ K, $p = 50$ kPa, $n = 4$ mol, and $b = 8.1 \times 10^{-27}$ m^3.

16. Maximizing the Entropy of the system and environment is equivalent to:

(a) Minimizing the Gibbs Free Energy of the system

(b) Minimizing the Gibbs Free Energy of the system and environment

(c) Minimizing Temperature

(d) Maximizing Work