

HOOR TEST #2

.....
HONOR PLEDGE:

In completing this test, I have neither given nor received unauthorized assistance.

(signature)
.....

- This is a closed-book, closed-notes test. No written material is allowed.
- You are permitted to use an electronic calculator only to assist with numerical work.
- Assume that the given quantities are accurate enough to justify three (and only three) figures in your final answers.
- **Show your work, especially on the problems!** Credit, especially partial credit on problems where your final answer is incorrect, will depend on the work shown.

The test consists of 15 questions and 2 problems. Perfect score is 100.

Questions 1-15 count 4 points each. (60%)

Problems 1-2 count 20 points each. (40%)

Possibly useful information.

terrestrial acceleration due to gravity: $g = 9.80 \text{ m/s}^2$
 $\pi = 3.14159265$ $e = 2.71828183$ $\log_{10}e = 0.43429448$
 $1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$ $1 \text{ year} = 3.156 \times 10^7 \text{ sec}$
astronomical unit (AU) = $1.496 \times 10^{11} \text{ m}$
speed of light in vacuum: $c = 2.998 \times 10^8 \text{ m/s}$
constant of gravitation: $G = 6.673 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$
Planck's constant: $h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s} = 4.136 \times 10^{-15} \text{ eV}\cdot\text{s}$
"h-bar" $\hbar \equiv h/2\pi = 1.055 \times 10^{-34} \text{ J}\cdot\text{s} = 6.583 \times 10^{-16} \text{ eV}\cdot\text{s}$
Boltzmann constant: $k = 1.381 \times 10^{-23} \text{ J/K} = 8.617 \times 10^{-5} \text{ eV/K}$
Avogadro's number $N_A = 6.022 \times 10^{23} \text{ particles/mole}$
Universal gas constant: $R = N_A k = 8.315 \text{ J/(mol}\cdot\text{K)}$
Stefan-Boltzmann constant: $\sigma = 5.671 \times 10^{-8} \text{ W/(m}^2\text{K}^4)$
unified mass unit (dalton): $(1 \text{ u}) = 1.661 \times 10^{-27} \text{ kg}$
energy equivalent of 1 dalton: $(1 \text{ u})c^2 = 1.493 \times 10^{-10} \text{ J} = 931.9 \text{ MeV}$
proton (rest) mass: $m_p = 1.673 \times 10^{-27} \text{ kg}$
rest energy of proton: $m_p c^2 = 1.504 \times 10^{-10} \text{ J} = 938.6 \text{ MeV}$
electron (rest) mass: $m_e = 9.109 \times 10^{-31} \text{ kg}$
rest energy of electron: $m_e c^2 = 9.187 \times 10^{-14} \text{ J} = 0.5111 \text{ MeV}$
elementary unit of charge: $e = 1.602 \times 10^{-19} \text{ C}$
product of h and c: $hc = 1.987 \times 10^{-25} \text{ J}\cdot\text{m} = 1.240 \times 10^{-6} \text{ eV}\cdot\text{m} = 1240 \text{ eV}\cdot\text{nm}$
standard temperature: $T = 0^\circ\text{C} = 273.15 \text{ K}$
standard pressure: $P = 1.000 \text{ atmosphere} = 1.013 \times 10^5 \text{ N/m}^2$

Questions 1-15. (4 points each) On most of these questions, partial credit is not available. You are not required to show your work.

Q1-3. Consider a traveling pressure wave described by the following equation:

$$\Psi(x,t) = (1.20 \times 10^{-2} \text{ Pa}) \cos[(5.00 \text{ rad/m})x - (1.80 \times 10^3 \text{ rad/s})t + 0.300 \text{ rad}]$$

Q1. This wave is traveling in the _____.

(A) +x direction

(B) -x direction

(C) The direction of travel cannot be determined without additional information.

Q1. _____

Q2. What is the speed of this wave? (Include correct SI units.)

Q2. _____

Q3. What is the period of this wave? (Include correct SI units.)

Q3. _____

Q4. Two sinusoidal waves are interfering to produce 5 beats per second. One of the sinusoidal waves has a frequency of 440 Hz. What are the two possible frequencies for the other sinusoidal wave?

Q4. _____ Hz **OR** _____ Hz

Q5. At $T = 273 \text{ K}$, a metal bar has a length of 2.00 m . When the bar is cooled to $T = 223 \text{ K}$, its length shrinks by $1.50 \times 10^{-3} \text{ m}$. Determine the coefficient of thermal expansion for this metal, including appropriate SI units.

Q5. _____

Q6. What is the defining characteristic of a thermal reservoir?

Q7. In the equation $\frac{\delta Q}{dt} = -kA \frac{dT}{dx}$, what are the correct SI units for the quantity k?

Q7. _____

Q8. In the quasi-static adiabatic expansion of an ideal gas, the entropy of the gas _____.

- (A) increases
- (B) decreases
- (C) remains the same
- (D) This cannot be determined without additional information.

Q8. _____

Q9. Both helium (atomic mass 4.00) and argon (atomic mass 39.9) are monatomic gases. In a gas which is a mixture of helium and argon, what is the ratio of the average speed of the helium atoms to the average speed of the argon atoms?

- (A) 0.0101
- (B) 0.100
- (C) 0.316
- (D) 3.16
- (E) 9.98
- (F) 99.5
- (G) It cannot be determined without knowing the temperature of the mixture.

Q9. _____

Q10. In the simplest model of a monatomic solid, there are 6 active degrees of freedom per atom. On the basis of this model, the predicted molar specific heat (at constant volume) of the solid is _____.

- (A) 3R
- (B) 6R
- (C) 9R
- (D) 12R

Q10. _____

Q11. In a typical diatomic gas at room temperature, the adiabatic exponent $\gamma = 7/5 = 1.40$, because at this temperature there are 5 active degrees of freedom. Indicate how many of these 5 active degrees of freedom are of each of the types below:

Q11. translational: _____

rotational: _____

vibrational: _____

Q12. Define in words the efficiency of a heat engine (not necessarily a Carnot engine).

Q13. (TRUE OR FALSE) If a gas is taken quasi-statically around any closed path (cycle) in the PV plane, the integral of ratio of heat added to absolute temperature equals

zero: $\oint \frac{\delta Q}{T} = 0$.

Q13. _____

Q14. Identify each of the following variables as intensive (independent of size) OR extensive (proportional to size):

Q14. pressure _____
 entropy _____
 temperature _____
 density _____

Q15. (TRUE OR FALSE) In thermodynamic equilibrium, all macrostates of a system are equally likely.

Q15. _____

Problem 1. (20 points) Show your work. Partial credit will depend on that.

A cyclic heat engine that operates between a highest temperature of 800 K and a lowest temperature of 300 K has a work output of 5.40 megajoules (MJ) per cycle and rejects waste (low-temperature) heat of 7.20 MJ per cycle.

(A) If the power output (work output per unit time) of this heat engine is 400 kilowatts (kW), what is the duration of one cycle?

(B) What is the heat input per cycle?

(C) What is the efficiency of this heat engine?

(D) If a Carnot engine could be used between a hot reservoir of 800 K and a cold reservoir at 300 K, how much work output per cycle could it achieve given the same heat input found in part B?

Problem 2. (20 points) Show your work. Partial credit will depend on that.

Neon gas (which is monatomic) is confined at a pressure $P_o = 1.00 \times 10^4$ pascals and a temperature $T_o = 800$ K. The volume occupied by the gas is $V_o = 1.00 \text{ m}^3$.

(A) Find the number of moles of neon gas.

(B)-(C) This gas undergoes an isobaric compression to volume $V_1 = 0.500V_o$.

(B) What is the gas temperature T_1 at the completion of this isobaric compression?

(C) During the isobaric compression, does the entropy of the neon gas increase, decrease, or remain the same?

_____ Explain your choice. _____

Problem 2 continues on the next page.

Problem 2. (continued)

(D)-(E) Following the isobaric compression described above, the gas is allowed to expand quasi-statically and adiabatically from V_1 to $V_2 = 2.000V_1 = V_0$.

(D) What is the gas temperature T_2 at the completion of the adiabatic expansion?

(E) How much work is done by the gas during the adiabatic expansion?