Name______________________

PH206 Final Spring 2000

Some constants are shown on the *<u>next page.</u>*

Write your solutions on these pages, and turn in the entire exam. If you need extra paper, just ask.

For problems: to receive full credit for correct answers, you must show your work!

Report numerical answers to three (3) significant figures.

Score Summary (to be filled in by instructor)

Mult Choice	Short Answer	Problems
1.________	11.________	16.________
2.________	12.________	17.________
3.________	13.________	18.________
4.________	14.________	19.________
5.________	15.________	20.________
6.________		21.________
7.________		22.________
8.________		23.________
9.________		24.________
10.________		25.________

Totals ________ + ________ + ________ = ________

Score = ________

Some Constants

$\pi = 3.14159$
$\sigma = 5.6696 \times 10^{-8}$ W/m^2·K^4
$k_B = 1.38 \times 10^{-23}$ J/K
R = 8.315 J/mol·K
$A_V = 6.02 \times 10^{23}$ molecules/mol
1 cal = 4.184 J
1 atm = 101 kPa
monatomic ideal gas: $\gamma = C_p/C_V = 1.6667$
$I_0 = 1.00 \times 10^{-12}$ W/m^2
velocity of sound in air (room temp, 1 atm) = 343 m/s.
0 ºC = 273.15 K

$c = 2.99793 \times 10^8$ m/s (Speed of light)
$e = 1.602 \times 10^{-19}$ C (Magnitude of charge of electron)
$m_e = 0.91095 \times 10^{-30}$ kg (electron rest mass)
$m_ec^2 = 0.511$ MeV
$m_p = 1.6726 \times 10^{-27}$ kg (proton rest mass)
$m_pc^2 = 938.3$ MeV
1 eV = 1.602×10^{-19} J
$h = 6.6262 \times 10^{-34}$ J·s (Planck's constant)
$\hbar = h/2\pi = 1.0546 \times 10^{-34}$ J·s
hc = 1240 eV·nm
$\hbar c$ = 197.3 eV·nm
$a_0 = 0.5292 \times 10^{-10}$ m (Bohr radius)
$R_H = 13.606$ eV/hc $= 1.0974 \times 10^7$ m^{-1} (Rydberg constant)

Some Trig Identities

$\cos(A\pm B)=\cos A\cos B \mp \sin A\sin B$
$\sin(A\pm B)=\sin A\cos B \pm \cos A\sin B$
$\sin A \pm \sin B = 2 \sin \tfrac{1}{2}(A\pm B) \cos\tfrac{1}{2}(A\mp B)$
$\cos A \pm \cos B = 2 \cos\tfrac{1}{2}(A+B) \sin\tfrac{1}{2}[\pm(A-B)]$

Some Integrals

$$\int \sin x\, dx = -\cos x \qquad \int \cos x\, dx = \sin x$$

$$\int \sin^2 x\, dx = \frac{x}{2} - \frac{\sin 2x}{4} \qquad \int \cos^2 x\, dx = \frac{x}{2} + \frac{\sin 2x}{4}$$

$$\int \sin x \cos x\, dx = \frac{\sin^2 x}{2}$$

Multiple Choice:
(Circle your choice)

1. A piece of copper of mass m_1 is heated from room temperature, T_1, to a higher temperature, T_2 . If the same amount of heat were added to a second piece of copper, which is also initially at room temperature but of mass m_2 , then the final temperature of the second piece of copper would be

a. $(m_2 / m_1) T_2$ b. $(m_1 / m_2) T_2$ c. $(m_2 / m_1)(T_2 - T_1) + T_1$

d. $(m_1 / m_2)(T_2 - T_1) + T_1$ e. T_2 f. None of the above

2. A brick which is way out in outer space is initially at 27 ºC . The brick is then heated to 327 ºC . The ratio of the brick's rate of thermal energy loss by radiation at the higher temperature to the rate of thermal energy loss by radiation at the lower temperature is very close to

a. 2 b. 4 c. 12 d. 16 e. 147 f. 21,500

3. A volume of 1 m^3 of helium gas is initially at 10 K and is then heated to 300 K. If the initial and final pressure are both 1 atm, then the final volume of the gas is

a. 1 m^3 b. 1/30 m^3 c. 30 m^3 d. 1/900 m^3 e. 900 m^3
f. cannot be determined from given data.

4. An object is placed on the axis of a converging lens, a distance, x, from the lens. If x is *less* than the focal length of the lens, then

a. no image will be formed.
b. a real image will be formed on the other side of the lens.
c. a real image will be formed on the same side of the lens.
d. a virtual image will be formed on the other side of the lens.
e. a virtual image will be formed on the same side of the lens.

5. Which of the following is always true for a quantity of a monatomic (ideal) gas undergoing any adiabatic process. (P = pressure, V = volume, and T = temperature of gas)

a. P = constant b. V = constant c. T = constant d. PV = constant
d. P/T = constant e. V/T = constant f. PV/T = constant g. none of these

6. A wave on a string has an amplitude of 2.00 cm, a wavelength of 30.0 cm and a wave speed of 10.0 m/s. The wave number for this wave is

a. 3.00 cm b. 3.33 m^{-1} c. 20.9 m^{-1} d. 33.3 Hz e. 4.78×10^{-3} s

7. Unpolarized light is sent through a single polarizing sheet which has its axis horizontal. How much intensity gets through the sheet? (Assume a perfect polarizer, with no additional losses).

a. 0% b. 29.3% c. 50% d. 70.7% e. 100%

8. A rocket is headed straight for the Earth with a speed of 0.8 c . The rocket emits a pulse of monochromatic light just before it veers to avoid hitting the Earth. An astronaut on the rocket and an observer on the Earth are both making accurate observations (i.e. measurements). For which of the following quantities will the two observers get the same results (within their small experimental error)?

(Circle ALL that apply)

a. The length of the rocket.
b. The relative speed of the rocket and the Earth.
c. The speed of the light pulse.
d. The proper length of the rocket.
e. The rocket's kinetic energy.
f. The frequency of the light emitted.

9. In a photoelectric experiment, light with different wavelengths is incident on a metal surface. Assuming that for all of the wavelengths used photoelectrons *are* ejected from the metal. Which statement is true?

a. The number of photoelectrons emitted per second is independent of the intensity of the light for all the different wavelengths.
b. The number of photoelectrons emitted per second is equal to a constant times the frequency of the light.
c. The maximum kinetic energy of the photoelectrons emitted is equal to a constant times the frequency of the light.
d. The maximum kinetic energy of the photoelectrons is proportional to the intensity of light.
e. none of the above.

10. In the laboratory, it is often most convenient for us to think of gamma rays as particles while microwaves are usually thought of as waves. Both are forms of light, which we know has both particle-like and wave-like properties. Which principle or theory below can best be used to explain why we observe gamma rays to behave more like particles and microwaves more like waves? (A typical gamma ray has $\lambda \leq 0.01$ nm, while microwaves have $\lambda \approx 1$ cm).

a. Uncertainty Principle b. Special Relativity c. Conservation of Energy
d. Correspondence Principle e. Schrödinger's Equation f. Peter Principle

Short Answer

Provide a short answer (1 or 2 sentences and/or appropriately labeled diagram) for each.

11. A ideal gas undergoes an irreversible cyclic process during which it does some work, W. After it has completed one full cycle, the temperature and entropy of the gas are unchanged (since both only depend on initial and final states and not the path taken). How can this be consistent with the result of the second law of thermodynamics, which says that for irreversible processes, the total entropy of an isolated system always increases?

12. Steam engines were commonly used before internal combustion engines and gasoline were readily available. Consider a steam engine used outdoors. Would the engine be more efficient on a cool day or on a hot day? Why?

13. A single wave pulse on a string is traveling towards -x with a speed v. At t = 0 the pulse is described by a displacement, y, given by

$$y = 1.75 \sin[3 \tan^{-1}(e^{-2x}) + 4]$$

where x and y are in meters. Write the function y(x,t) which describes this wave for any time, t.

14. There has been recent interest in the mass of an elementary particle called a neutrino. One theory is that the rest mass of the neutrino is zero, just like a photon. Several competing theories suggest the neutrino has a very small but non-zero rest mass. Show that any massless particle which has a kinetic energy, $K \neq 0$, cannot be traveling slower than the speed of light. (Hint: assume a mass, m, and speed v, then look at $m \rightarrow 0$.)

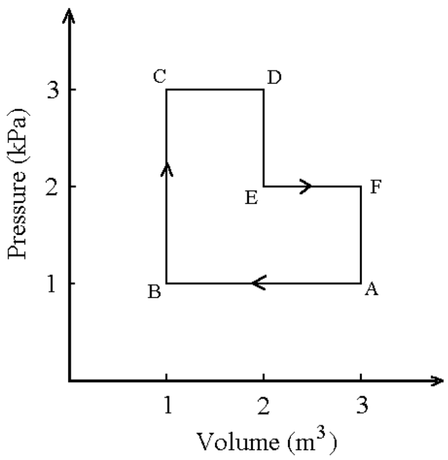
15. If you hold two small flashlights near each other and shine the light from both at the same spot on a distant wall, you do not see a diffraction pattern. Why?

Problems

(SHOW YOUR WORK, you will not get credit unless we can see how you got your answer.)

16. A monatomic (ideal) gas initially with volume $V_i = 5.00 \times 10^{-3}$ m^3 and at a temperature of 315 K and a pressure of 99.0 kPa undergoes an adiabatic expansion until its final volume is 7.75×10^{-3} m^3. What is the final temperature of the gas?

17. A gas is taken through the cyclic process shown, starting from point A. How much net heat was added to the system during one complete cycle?



18. An object 2.50 cm high is placed 45.0 cm to the left of a converging lens with a focal length of 25 cm. A diverging lens with a focal length of -25.0 cm is placed 51.25 cm to the right of the converging lens. Determine the location of the final image.

19. If 350 g of liquid nitrogen, initially at its boiling point of 77 K, all boils and becomes gas at 77K, how much has the entropy of the nitrogen changed? The latent heat of vaporization of nitrogen is 2.01×10^5 J/kg and its latent heat of fusion is 2.55×10^4 J/kg.

20. A source of sound emits uniformly in all directions. An observer 4.00 m from the source measures a sound level of 50.0 dB. What is the average power level, in Watts, of the source?

21. In an early particle accelerator, the electrons were accelerated (starting from rest) through a potential difference of 500.0 kV (500,000 V) before they hit a target. What is the speed of the electrons just before they strike the target? (Put your value in units of “c”).

22. What are the momentum and energy of a photon of light with a wavelength of 523 nm?

23. What is the speed of an electron with a de Broglie wavelength of 0.200 nm?
(Hint: it is much less than the speed of light).

24. An electron which is part of a certain atom undergoes a transition from an energy level, E_a = -3.45 eV to a level with an energy E_b = -6.78 eV. What is the wavelength of the light emitted ?

25. The (time-independent) wave function of an electron is given by

$$\psi(x) = \sqrt{\frac{2}{L}}\,\sin\left(\frac{3\pi x}{L}\right)$$

for $0 < x < L$, and is zero everywhere else. What is the probability that the electron will be found between $x_1 = L/2$ and $x_2 = 2L/3$?

END