Name_____

PH2400 Final Exam Spring 2001

Some Constants:

$\pi = 3.14159$
$h = 6.626 \times 10^{-34}$ J·s
$hc = 1240$ eV·nm
$c = 3.00 \times 10^{8}$ m/s
$R_H = 1.0974 \times 10^{7}\ m^{-1} = 13.606$ eV/hc
1 eV = 1.6022×10^{-19} J
1 amu = 931.48432 MeV/c^2 = 1.66054×10^{-27} kg

$I_0 = 1.00 \times 10^{-12}$ W/m^2 = 0 dB
velocity of sound in air (room temp, 1 atm) = 343 m/s.

$d^2\psi/dt^2 = -2m(E-U)/\hbar^2\ \psi$

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

For problems 14 to 20: 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._____	9._____	14._____
2._____	10._____	15._____
3._____	11._____	16._____
4._____	12._____	17._____
5._____	13._____	18._____
6._____		19._____
7._____		20._____
8._____		

Totals _____ + _____ + _____ = _____

Multiple Choice:

(Circle your choice(s))

1. A point source emits sound with an intensity of 75 dB when measured 1.0 m away from the source. If the power is turned up so that the intensity 1.0 m away is increased by a factor of 10, the intensity 2.0 m away from the source will now be closest to

a. 69 dB b. 79 dB c. 85 dB d. 91 dB e. 188 dB

2. A saxophonist plays a note with a constant frequency of 256.0 Hz [*]. A second player then joins in, attempting to play the same note. When the second player joins in, beats are heard which have a frequency of 3.0 Hz. Which one of the following could be the frequency of the tone produced by the second player?

a. 250 Hz b. 256 Hz c. 259 Hz d. 515 Hz
e. none of the above.

3. An electron in a hydrogen atom is in the state with $n = 3$. What is the shortest wavelength possible for a photon emitted by this atom?

a. 0 b. 91.2 nm c. 103 nm d. 137 nm e. 821 nm

4. In a photoelectric effect measurement using a metal with work function $\phi = 3$ eV and light of wavelength λ and intensity I, a stopping potential of $V = 1.70$ V is measured. If the wavelength of the light is reduced to $\lambda/2$ while the intensity remains constant, then

a. The stopping potential will now be $V/2 = 0.85$ V.
b. The stopping potential will now be $2V = 3.40$ V.
c. No electrons will be emitted.
d. None of the above.

5. A transition between vibrational states for a typical diatomic molecule corresponds to a vibrational energy change closest to

a. 13.6 eV b. 0.511×10^6 eV c. 0.3 eV d. 0.005 eV e. 0

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[*] This, by the way, is not a note of our usual musical scale and so this player should not quit his/her day job. In our usual scale, middle C is 262 Hz. There is a "scientific scale" which is sometimes cited, where middle C is set equal to 256 Hz = 2^8 Hz, but just try to convince musicians to use that!

6. The ground state electronic configuration of a certain neutral atom is given as $1s^2 2s^2 2p^6 3s^2 3p^5$. The atomic number, Z, for this atom is

a. 0 b. 1 c. 3 d. 11 e. 17 f. 32

7. At $t = 0$, a scientist measures the activity of 7.00 g of a radioactive isotope to be 4.00 Ci. After 1 hour, the scientist measures the activity from the same sample to be 1.00 Ci. What is the half-life of this isotope?

a. 0.719 hr b. 1.39 hr c. 30.0 min d. 1.00 hr e. 2.00 hr

8. What of the following is true?

a. The electron is composed of a quark and an antiquark.
b. A proton is composed of a quark and an antiquark.
c. In the quark model, the neutron is the antiparticle for the proton.
d. All mesons have a nonzero value for strangeness.
e. The only particles in the Standard Model are quarks, leptons, and field particles.

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

9. 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

$$y(x,0) = 1.37 \sin(7.3x)\, e^{-x^2/90}$$

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

10. An observer on Earth observes a rocket passing by at a speed v and which is moving along the x-axis towards +x. In the observer's reference frame, the rocket emits two flashes of light, the first at t_1 when the rocket is at x_1 and the second at t_2 when the rocket is at x_2. In terms of what is given, what is the space-time interval between the flashes *measured by a passenger on the rocket*?

11. Why does the electrical resistance of a semiconductor decrease with an increase in temperature?

12. What is the “Fermi Energy” and what would be a typical value?

13. The reaction

$$p + p \rightarrow p + \pi^{+}$$

is forbidden. Why?

Problems

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

14. A transverse wave on a string is described by the displacement

$$y(x,t) = 0.33\sin(1.7x - 32t + 17)$$

where x and y are in meters and t is in seconds. For this wave, complete the following: (Show your work below!)

Amplitude = _____ m Wavelength = _____ m

Wave speed = _____ m/s Frequency = _____ Hz

Wave is traveling toward _____

15. A laser beam (λ = 740 nm) is incident on two narrow slits which are 0.150 mm apart. How far apart are adjacent intensity minima on a screen 2.00 m away?

. A particular charged particle known as a K^{--} (a Kaon) decays into a muon (μ^{--}) and a neutrino (ν). The mass of this Kaon is (493.7 MeV)/c^2 and its charge is equal to the charge of an electron. When at rest, the decay occurs with an average lifetime of 1.237×10^{-8} s. If the K^- is not at rest, but has a kinetic energy of 900.0 MeV, what average lifetime will be measured?

17. The wavefunction for a particle of mass, *m*, (in a one-dimensional problem) is given by

$$\psi(x) = A(b^4 - x^4) \qquad -b < x < b$$
$$\psi(x) = 0 \qquad \text{otherwise}$$

If this wavefunction is a solution to Schrödinger's time-independent equation, with energy

$$E = \frac{-6\hbar^2}{mb^2}$$

what is the potential energy, *U*(x)? (Hint: you do not need to know the value of *A*, so don't waste time trying to find it.)

18. Consider an electron in a magnetic field of B = 7.50 Teslas = 7.50 T. The energy levels are given by $E = \mu_z B$. The possible values for z-component of the electron's spin magnetic moment are determined by $\mu_z = \pm \frac{e\hbar}{2m_e} = \pm(5.79 \times 10^{-5} eV / T)$. What is(are) the wavelength(s) of photons which will be absorbed?

19. Right in the middle of the periodic table is Technetium, Tc, which is anomalous since it is the lightest element (by far) which has no stable isotope. Technetium can be produced artificially as a by-product of the fission of ^{235}U. The Tc produced decays to Ruthenium with a half-life of 2.12×10^5 years via beta decay

$$^{99}_{43}\mathrm{Tc} \rightarrow {}^{99}_{44}\mathrm{Ru} + e^- + \overline{\nu}_e$$

Assuming the Tc atom is at rest when the decay occurs, what is the maximum kinetic energy which will be observed for the electron?

Data from Appendix A.3 of text:
Tc Z=43 A=99 Mass = 98.906254
Ru Z=44 A=99 Mass = 98.905939

20. A very small crystal of a metal is constructed which is a cube 2.30 nm on a side corresponding to a cube 4 atoms on a side for a total of $4^3 = 64$ atoms. Assume each atom contributes one free electron to the conduction band, that the electron-electron interaction can be ignored, and that the crystal is electrically neutral and in its ground (lowest energy) state. Of all the 64 electrons in the conduction band, what is the smallest kinetic energy you should expect to find?

Bonus: sketch the appropriate energy levels (roughly to scale) for the 64 electrons above showing how many electrons are in each level. (Use the back of the page or an extra sheet, as necessary).