

Name _____

PH2400

Exam II

Spring 2001

Some Constants:

$$\pi = 3.14159$$

$$h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s}$$

$$hc = 1240 \text{ eV}\cdot\text{nm}$$

$$c = 3.00 \times 10^8 \text{ m/s}$$

$$R_H = 1.0974 \times 10^7 \text{ m}^{-1} = 13.606 \text{ eV}/hc$$

$$1 \text{ eV} = 1.6022 \times 10^{-19} \text{ J}$$

A Table of integrals is attached
at the end of this exam.

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 11 to 15: 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. _____

6. _____

11. _____

2. _____

7. _____

12. _____

3. _____

8. _____

13. _____

4. _____

9. _____

14. _____

5. _____

10. _____

15. _____

Totals _____ + _____ + _____ = _____

Multiple Choice:

(Circle your choice(s))

1. Consider two observers, O_1 and O_2 , in two different inertial reference frames. As they pass, O_1 and O_2 each turn on a light. Which of the following values will be the same for both observers? (*Circle ALL that apply*).
 - a. The speed of the other observer.
 - b. The wavelength of the light emitted by O_1 .
 - c. The speed of the light emitted by O_1 .
 - d. The speed of the light emitted by the other observer.
 - e. The time it takes O_1 's clock to tick off 1 second after they pass.
2. A policeman parked on the side of the road observes a car go passed which is traveling North at $0.800 c$.^{*} The policeman gets in his car and drives (slowly) north and discovers that the car collided with a tree 5.00 km north of the policeman's original position. How much time elapsed on the car's clock between the time the car passed the policeman and the collision?
 - a. $20.8 \mu\text{s}$
 - b. $12.5 \mu\text{s}$
 - c. $34.7 \mu\text{s}$
 - d. $7.49 \mu\text{s}$
 - e. $57.8 \mu\text{s}$
3. In a photoelectric effect measurement using a metal with work function ϕ and light of wavelength λ and intensity I , a stopping potential of V is measured. The intensity of the light is then doubled. Which of the following will now occur?
 - a. The stopping potential will now be $2V$.
 - b. The stopping potential will now be $V/2$.
 - c. The stopping potential will be unchanged.
 - d. None of the above.
4. 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
5. Which of the following has the longest deBroglie wavelength?
 - a. An electron traveling at 1 m/s.
 - b. An electron traveling at 100 m/s.
 - c. A baseball traveling at 1 m/s.
 - d. A baseball traveling at 100 m/s.
 - e. They are all the same.

^{*} Professional driver on closed course – do not try this at home.

Short Answer

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

6. 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*?

7. We have looked at the results of quantum mechanics for several simple bound systems including the hydrogen atom, the "particle in a box," and the harmonic oscillator. Qualitatively, what is the same and what is different about the solutions to these three problems?

8. What is the "ultraviolet catastrophe?"

9. What is wrong with the following statement?

“Absolute zero is the temperature where all motion is frozen out.”

10. Explain the following statement (what does it mean? what is implied about the regions A and B and the boundary between them?, etc...)

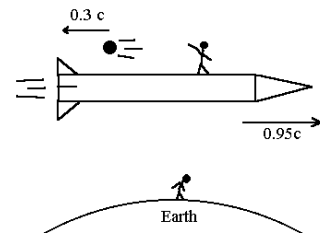
“An electron is observed to rapidly tunnel from region A to a region B.”

Problems

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

11. 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 $(493.7 \text{ MeV})/c^2$ and its charge is equal to the charge of an electron. When at rest, the decay occurs with an average lifetime of $1.237 \times 10^{-8} \text{ s}$. If the K^- is not at rest, but has a kinetic energy of 800.0 MeV , what average lifetime will be measured?

12. A passenger on a rocket throws a baseball backwards with a speed of $0.300 c$ (as measured by the passenger). If an observer on Earth sees the rocket go by with a speed of $0.950 c$, what speed does the Earth observer measure for the baseball?



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

$$\begin{aligned} \psi(x) &= A(b^4 - x^4) & -b < x < b \\ \psi(x) &= 0 & \text{otherwise} \end{aligned}$$

In terms of what is given, what is the value of $\int |A|^2 dx$?

14. The normalized wavefunction for a “particle in a box” is given by

$$\psi(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{5\pi}{L}x\right) \quad 0 < x < L$$
$$\psi(x) = 0 \quad \text{otherwise}$$

What is the probability of finding the particle between $x = L/5$ and $x = L/2$?

15. As an order of magnitude, the size of the nucleus of an atom is about $1 \text{ fm} = 10^{-15} \text{ m}$. If one were to study the structure of the nucleus of an atom using α -particles one would like to have the wavelength of the α -particles smaller than the size of the nucleus. What kinetic energy is required for an α -particle to have a wavelength of 0.300 fm ? (For an α -particle, $M_{\alpha}c^2 = 3760 \text{ MeV} = 3.76 \text{ GeV}$. Hint: do NOT assume $v \ll c$ for the alpha particle).

bonus: what is the speed of the alpha particles?

END