Physics 228 - Second Common Hour Exam
March 26, 2006
Prof. Coleman and Dr. Francis

⟹ Your name sticker with **exam code** ⟹

Your signature ______________________________

Turn off and put away cell phones now!

1. The exam will last from 3:00 PM to 4:20 PM. Use a #2 pencil to make entries on the answer sheet. Enter the following ID information now, before the exam starts.
2. In the section labeled NAME (Last, First, M.I.) enter your last name, then fill in the empty circle for a blank, then enter your first name, another blank, and finally your middle initial.
3. Under STUDENT # enter your 9-digit student ID.
4. Enter 228 under COURSE, and your section number (see label above) under SEC.
5. Under CODE enter the exam code given above.
6. During the exam, you may use pencils, a calculator, and one **handwritten** 8.5 x 11 inch sheet with formulas and notes, without attachments.
7. There are 15 multiple-choice questions on the exam. Mark only one answer on the answer sheet. There is no deduction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess. **At the end of the exam, hand in the answer sheet and the cover page.** Retain this question paper for future reference and study.
8. When you are asked to open the exam, make sure that your copy contains all 15 questions. Raise your hand if this is not the case, and a proctor will help you. Also raise your hand during the exam if you have a question.
9. Please SIGN the cover sheet under your name sticker and have your student ID ready to show to the proctor during the exam.

Some possibly useful information:
c = speed of light = 3.00×10^8 m/s
$q_e = -e$ = charge on an electron = -1.602×10^{-19} Coulombs
$q_p = +e$ = charge on a proton = $+1.602 \times 10^{-19}$ Coulombs
k_B = Boltzmann's constant = 1.38×10^{-23} J/K
m_e = electron mass = 9.11×10^{-31} kg
$m_e c^2$ = electron rest energy = 0.511 MeV
m_p = proton mass = 1.67×10^{-27} kg
1 mHz = 10^{-3} Hz 1 kHz = 10^{+3} Hz
1 MHz = 10^{+6} Hz 1 GHz = 10^{+9} Hz
$m_p c^2$ = proton rest energy = $938.27 MeV$
$m_n c^2$ = neutron rest energy = $939.57 MeV$
Wein's Constant = $2.898 \times 10^{-3} m \cdot K$
σ = Stefan's Constant = $5.670 \times 10^{-8} W/(m^2 K^4)$
$\hbar = \frac{h}{2\pi}$
$h = 6.626 \times 10^{-34}$ J-s
hc = 1240 eV $\cdot$ nm = 1240 MeV $\cdot$ fm
1 nm = 10^{-9} m 1 Å = 10^{-10} m = 0.1 nm

1. Find the speed of a particle whose total energy is twice its rest energy.

   a) 0.925 c
   b) 0.866 c
   c) 0.500 c
   d) 0.250 c
   e) 0.792 c

2. Which of the following statements about the photoelectric effect is FALSE:

   a) The photocurrent increases with increasing light intensity above the cut off frequency.
   b) The cut-off frequency is independent of photon intensity.
   c) The maximum photoelectron kinetic energy increases with decreasing photon wavelength.
   d) The maximum photoelectron kinetic energy increases with increasing light intensity.
   e) The stopping potential increases with increasing photon frequency.

3. An astronaunt travels from the earth to a star 4.8 light years away (as seen by an observer on the earth). Then he returns to the earth. His outbound and return trip are all at the same constant speed of 0.80 c relative to the earth. How much has the astronaut aged during his trip? (Assume that times for acceleration, deceleration and his stay at the distant star are all negligible.)

   a) 16 years
   b) 12 years
   c) 9.6 years
   d) 7.2 years
   e) 5.8 years

4. Two events occur 100 m apart with an intervening time interval of 0.60 μs. The speed of a reference frame in which they occur at the same coordinate is:

   a) 0
   b) 0.25c
   c) 0.56c
   d) 1.1c
   e) 1.8c

5. Planck's blackbody radiation formula

$$I(\lambda, T) = \frac{2\pi hc^2}{\lambda^5 \left(e^{hc/\lambda k_B T} - 1\right)}$$

   differs radically from the Rayleigh-Jeans law, which preceeded it,

   a) for all wavelengths.
   b) for short wavelengths, giving less radiation there and avoiding the ultraviolet catastrophe.
   c) for short wavelengths, giving more radiation there and producing the ultraviolet catastrophe.
   d) for long wavelengths, giving less radiation there and avoiding the infrared catastrophe.
   e) for intermediate wavelengths, giving less visible light from black bodies.

6. The metals lithium, beryllium and mercury have work functions of 2.3 eV, 3.9 eV and 4.5 eV respectively. If light of wavelength 400 nm is incident on each of these metals, which of them exhibit the photoelectric effect?

   a) lithium only
   b) lithium and beryllium only
   c) lithium, beryllium and mercury
   d) mercury only
   e) beryllium and mercury

7. In the He^+ ion, one electron orbits a nucleus which contains two protons. What is the ground state energy for the electron in He^+?

a) -13.6 eV
b) -27.2 e V
c) -40.8 eV
d) -3.4 eV
e) -54.4 eV

8. The wavelength of the matter wave associated with a 10-eV free electron is:

a) $1.9 \text{x} 10^{-7}$ m
b) $1.3 \text{x} 10^{-34}$ m
c) $1.2 \text{x} 10^{-9}$ m
d) $3.9 \text{x} 10^{-10}$ m
e) $1.9 \text{x} 10^{-10}$ m

9. A neutron is confined within a nucleus of diameter 4×10^{-14} m. Assuming that the nuclear potential is a one- dimensional infinite potential well of width 4×10^{-14} m, estimate the ground state energy of the neutron.

a) 130 MeV
b) 2.1×10^{-14} eV
c) 3.7×10^{-44} eV
d) 130 keV
e) 7.7×10^{23} eV

10. An electron is confined in an infinite, one dimensional, square potential well of width 0.200 nm.

$$V = \begin{cases} \infty & \text{for } x < 0 \text{ and } x > 0.200\text{nm} \\ 0 & \text{for } 0 < x < 0.200\text{nm} \end{cases}$$

The electron is in state n = 2. The ratio of the probability that it will be found at the point $x = 0.050$ nm to the probability that it will be found at the point $x = 0.025$ nm is:

a) 0.707
b) 1.414
c) 2.000
d) 0.500
e) 2.828

11. Which of the following (n, ℓ, m_ℓ, m_s) combinations is impossible for an electron in an atom?

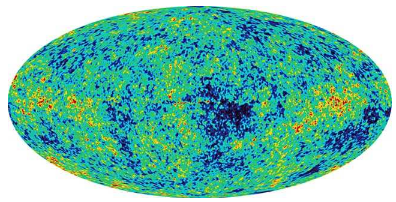
a) 3, 1, 1, $-\frac{1}{2}$
b) 3, 1, -2, $\frac{1}{2}$
c) 3, 2, -2, $-\frac{1}{2}$
d) 6, 2, 0, $\frac{1}{2}$
e) 1, 0, 0, $-\frac{1}{2}$

12. Which of the following statements about relativity is *false*?

a) Kinetic energy at relativistic speeds is greater than the classical value
b) $E = mc^2$ describes the rest energy of a massive particle
c) Blueshifting of light occurs when the emitter is moving towards the receiver
d) Events occuring simultaneously in one frame will always appear to be simultaneous in any frame
e) A Lorentz transformation is essentially a four-dimensional rotation

13. Early in the history of the universe, free electrons joined with free protons, releasing a huge amount of radiation. This radiation, called the cosmic microwave background (CMB), follows the blackbody law and peaks today at a wavelength of 1.06 mm. What is the temperature of the radiation?

a) 0 K
b) 2.73×10^{-3} K
c) 0.366 K
d) 2.73 K
e) 366 K



14. A particle moves in one dimension at a constant potential energy V, so that in a stationary state, its wavefunction satisfies the one dimensional Schrödinger equation

$$-\frac{\hbar^2}{2m}\frac{d^2\psi(x)}{dx^2} + V\psi(x) = E\psi(x)$$

Suppose its wavefunction is given by

$$\psi(x) = A(e^{i\alpha x} + e^{-i\alpha x})$$

What is the energy of the particle?

a) $\frac{\hbar^2\alpha^2}{2m}$.
b) Undefined, because the particle is not in a stationary state.
c) $\frac{\hbar^2\alpha^2}{2m} + V$.
d) $-\frac{\hbar^2\alpha^2}{2m}$.
e) $-\frac{\hbar^2\alpha^2}{2m} + V$.

15. In the Bohr model of the atom, a stationary state is represented by a standing wave that circulates around the orbit of the electron. Consider an electron in the stationary state represented by the figure. What is the energy of the electron in this stationary state?

a) $-13.6/8^2$ eV.
b) $13.6/4^2$ eV.
c) $-13.6/4^2$ eV.
d) $13.6/8^2$ eV.
e) -13.6 eV.