# Physics 160
# Principles of Modern Physics
(Spring 2008)
# Midterm Examination #1

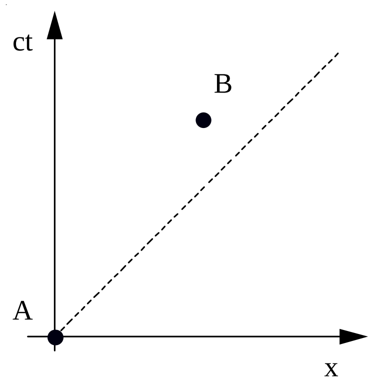
Name: Honor Code:

## I. Multiple Choice (20 points)
Circle all that apply. In some cases there may be multiple correct answers.

1. (2 pts.) By what factor is the 5th Bohr orbit for the electron in the hydrogen atom larger than the 2nd Bohr orbit?

(a) 1.50
(b) 2.00
(c) 2.25
(d) 2.50
(e) 6.25
(f) 21.0
(g) 25.0

2. (2 pts.) The spacetime diagram below shows two events. Event A occurs at x=0, t=0 and event B occurs at the location and time shown in some inertial reference frame. Which of the following statements is/are true regarding the spacetime separation of these two events.




(a) A and B are timelike separated
(b) A and B are spacelike separated
(c) A and B are lightlike separated
(d) A and B are simultaneous in some inertial reference frame
(e) A could have caused B
(f) A and B occur at the same place in some inertial reference frame.

3. (2 pts.) A monochromatic (single color) light is directed onto a surface, and significant electron emission is observed. What can you conclude based on your understanding of the photoelectric effect?

(a) The photons have less energy than the work function for the material.
(b) The photons have more energy than the work function for the material.
(c) The wavelength of the light is shorter than the critical wavelength.
(d) The wavelength of the light is longer than the critical wavelength.

4. (2 pts.) What previously arbitrary assumption did deBroglie's matter wave hypothesis provide a justification for?

(a) The speed of light is the same for all observers in inertial reference frames.
(b) Light energy comes in quantized bundles called photons.
(c) Changing electric fields produce magnetic fields.
(d) The atom has a nucleus.
(e) The angular momentum of the electron in the hydrogen atom is quantized.

5. (2 points) The proper time interval between two events is the time interval measured in a frame where

(a) The events are simultaneous.
(b) The events occur at the same location.
(c) The events are ticks on a clock.
(d) The events are very polite.

6. (2 points) Two energetic particles collide in the center of mass frame (total momentum of the particles is zero). In the inelastic collision can two new particles emerge with rest masses greater than the rest masses of the initial colliding particles?

(a) No, the final rest masses must total the same as the initial rest masses.
(b) Yes, anything can happen in modern physics.
(c) Yes, as long as the additional rest mass energy is less than the total kinetic energy of the initial colliding particles.
(d) No, you can't conserve momentum in such a collision.

7. (2 points) The wavelength of a beam of electrons accelerated by several hundred volts is comparable to…

(a) The wavelength of microwave photons
(b) The wavelength of visible photons
(c) The wavelength of UV photons
(d) The wavelength of X-ray photons

8. (2 points) The wave that describes a particle like an electron is best characterized as

(a) an electromagnetic wave
(b) an acoustic (or sound) wave
(c) a density wave
(d) a probability wave

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10. (2 points) When Millikan turned off the electric field, the oil droplet came to a terminal velocity because

(a) the viscous drag force balanced the gravitational force
(b) the viscous drag force balanced the electric force
(c) the gravitational force balanced the electric force
(d) the droplet opened its parachute

## I. Short Answer Section (26 points)

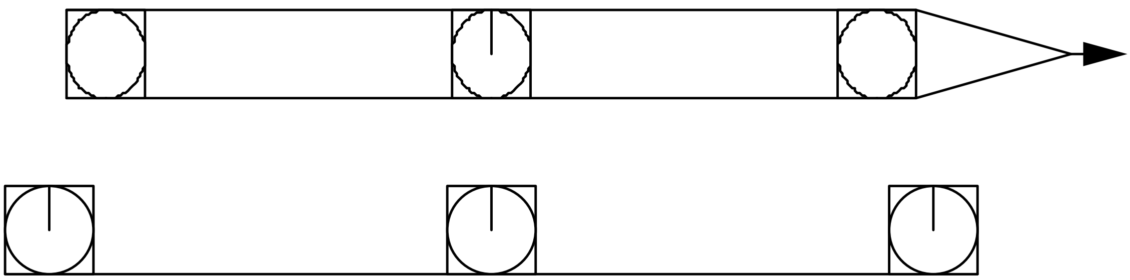
11. (5 pts.) Match up the experiment on the left with the main result of that experiment on the right.

| | |
|---|---|
| Rutherford's scattering experiment | measured e/m for electron, inferred that electron was part of an atom |
| Compton's scattering experiment | charge comes in quantized units, measured the fundamental charge |
| Thomson's cathode ray experiments | atoms have small, massive nuclei |
| Millikan's oil-drop experiment | light behaves like a particle when colliding (or scattering) off electrons |

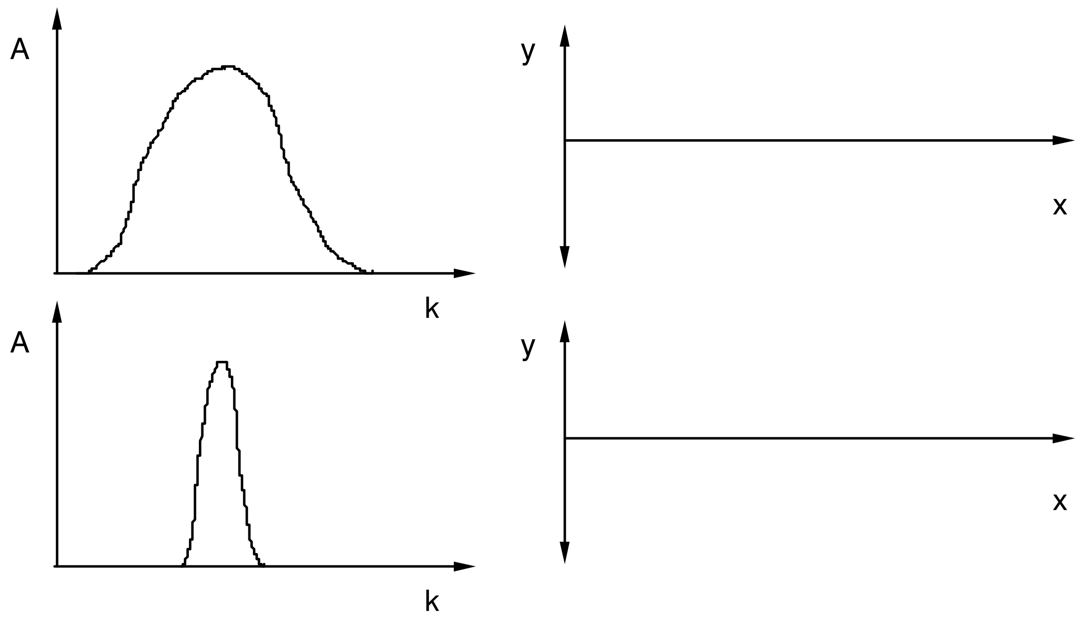
12. (6 points) A blackbody initially at 1000 K radiates 1000 W. Later, the radiated power is 5000 W. What is the new temperature?

13. (5 points) Sketch the energy level diagram for the Bohr model of the hydrogen atom. Indicate on the diagram the transitions that correspond to the visible Balmer series of emission lines.

14. (5 pts.) Ole has a set of synchronized clocks that all read 12:00 at the instant Sven flies past in his rocket. Sven has his own set of synchronized clocks. Indicate (qualitatively) the times that Ole observes on the front and back clocks on Ole's rocket at the instant shown.



15. (5 pts.) Qualitatively sketch the spatial appearance of the wave packets corresponding to the two amplitude distributions shown below. The amplitude distribution is related to the spatial structure of the wave through $y(x,t) = \int A(k)\cos(\omega t - kx)dk$



# II. Exercises (54 points).

16. (18 points) The electron (rest mass energy = 0.511 MeV) has a positively charged anti-matter twin particle called the positron with the same mass as the electron. When a particle and its anti-matter twin are close to each other, they annihilate.

(a) Energy must be conserved. After annihilation, the electron and positron no longer exist, but some number of photons are present. If the positron and electron have no kinetic energy prior to annihilation, what must be the total energy of the photons after annihilation?

(b) Argue that there must be at least two photons after annihilation (Hint: think about conservation laws).

(c) If there are two photons after annihilation, what is the wavelength of each photon?

(d) If one of the photons scatters off a free electron through an angle of 90°, what is the wavelength and energy of the photon after scattering?

17. (18 pts.) The lifetime of a pion at rest is $2.8 \times 10^{-8}$ s. In Professor Stoneking's lab, the pion is created at a speed of 0.95c.

(a) What lifetime does Professor Stoneking measure for this particle?

(b) How far does it travel before decaying in Professor Stoneking's lab?

(c) Professor Pickett is observing the same pion decay from her rocket that is moving in the opposite direction of the pion at a speed of 0.8c. With what speed does Professor Pickett observe the pion to move?

(d) What lifetime does Professor Pickett measure for this particle?

(e) Show that the you can obtain the time interval (between birth and death for the pion) measured by Professor Pickett by using the Lorentz transformation of the space and time coordinates of the two events as measured by Professor Stoneking.

(f) Are the two events in this problem space-like separated, time-like separated, or light-like separated? Explain.

18. (18 pts.) Photoelectric Effect: When light of wavelength 500 nm is incident on a metallic surface, the stopping potential is measured to be 0.45 V.

(a) What is the work function for the metal?

(b) What is the longest wavelength for which one gets photoelectric emission with this metal?

(c) If the intensity of the light is doubled, what is the stopping potential?

(d) If the wavelength is changed to 400 nm, what is the stopping potential?