PHYSICS 252: TEST 3 11/13/15 Dr. Varriano NAME:_____

Do all 8 problems. The point value for each problem is indicated next to the problem number. Show all of your work in the space provided to receive partial credit. You may use additional sheets of paper if necessary. Be sure to turn in the additional sheets with your name written on each sheet. Put your final answer to each question on the line provided unless instructed otherwise.

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1. [12 pts]
A sphere is emitting most of its thermal radiation at 4 μm. It is suspended inside a box. The inside walls of the box are at 20°C. Both the box and the sphere can be approximated as blackbodies.

(a) What is the sphere's temperature right now in degrees Celsius? [T(°C) = T(K) -273.15]

451.8 °C

(b) The sphere is emitting a total power of 4 Watts now. Find its diameter. (The surface area of a sphere is 4π times the square of its radius.)

9 mm

(c) Are the following statements true or false? (Circle either the T for true or the F for false.)

(T) F 1. Right now, the sphere absorbs less power from the box walls than it emits.
T (F) 2. Right now, the walls emit most of their thermal radiation at a wavelength shorter than 4 μm.
(T) F 3. The energy of an atom on the surface of the sphere is quantized.
(T) F 4. It would be best to model the radiation emitted from the sphere as a stream of photons instead of as a wave.

2.[16 pts]
(a) A certain photomultiplier tube employs an antimony- cesium photocathode with a work function of 1.65 eV. What is the longest wavelength of light that this PMT can detect?

753 nm

(b) Discuss how the photon model of light explains why there is a longest wavelength of light that can be detected by a photocathode.

(c) This PMT has a gain of 3^9. When 1.5 nW of light with a wavelength of 400 nm hits the PMT, a current of 3 μA is produced at the anode. Find the quantum efficiency of the photocathode.

31.6%

3. [16 pts]
A Hydrogen atom makes a transition from the $n = 2$ state to the $n = 4$ state.

(a) Is a photon emitted or absorbed in the transition? absorbed

(b) What is the wavelength of the photon in (a)?

487 nm

(c) What type of photon is the photon in (a)? (Circle the one correct choice.) *infrared* (*visible*) *ultraviolet*

(d) What is the diameter of the atom in the $n = 4$ state according to Bohr's model?

17 Å = 1.7 nm

(e) The atom is now in the $n = 4$ state. Are the following statements true or false? (Circle either the T or the F.)

T (F) 1. This atom could have an orbital quantum number of ℓ=4.
(T) F 2. This atom could have a magnetic orbital quantum number of m_ℓ =3.
(T) F 3. This atom could now emit a visible photon.
(T) F 4. This atom could now emit an infrared photon.

4.[14 pts]
A free electron and a photon are moving through vacuum. They both have a wavelength of 5 Å. Find the speeds and energies of both particles. (The electron is free so it only has kinetic energy.)

	Speed	Energy
Electron	1.5×10^6 m/s	6 eV
Photon	$c = 3 \times 10^8$ m/s	2486 eV

5.[6 pts]
(a) In his model of the Hydrogen atom, Bohr postulated that the orbital angular momentum is quantized. Write down the quantization condition for L. That is, what are the allowed values of L according to Bohr?

$$L = n\hbar \text{ where } n = 1,2,3,\ldots$$

(b) In the better quantum mechanics model of the atom where the Schrodinger Equation is used, again the orbital angular momentum is quantized. But the quantization condition is slightly different than Bohr's. Write down the better condition.

$$L = \sqrt{l(l+1)}\,\hbar \text{ where } l = 0,1,\ldots n\text{-}1$$

(c) Circle the allowed size(s) of L for the first excited state of Hydrogen for the two models. There may be more than one allowed value for a model.

Bohr's Model	0	$\hbar$	$\sqrt{2}\hbar$	(2$\hbar$)	$\sqrt{6}\hbar$	3$\hbar$
Quantum Mechanics Model	(0)	$\hbar$	($\sqrt{2}\hbar$)	2$\hbar$	$\sqrt{6}\hbar$	3$\hbar$

6. [14 pts]
A He-Ne red laser (λ=633 nm) is emitting 7.5 milliwatts of power. A green laser pointer (λ=532 nm) is emitting less power.

(a) Which kind of photon carries **more** energy, the red photon or the green photon? green

(b) Find the ratio of a green photon's energy to a red photon's energy.

1.19

(c) The emitted photon rate of the red laser is triple the emitted photon rate of the green laser. Find the power emitted by the green laser.

2.92 mW

7. [10 pts]
(a) Which one phrase best describes "Compton scattering"? (Circle the number before the best choice.)

1. the ejection and scattering of electrons from a metal that has been hit with light
2. the scattering of visible light off of air molecules in the atmosphere
3. the scattering of x-ray light off of electrons

(b) Which model of light is used to explain the results of Compton scattering? (Circle one choice.) *wave model* *photon model*

(c) In a Compton scattering experiment, θ=0 describes the incident direction of the light. At what angle will the scattered light have the longest wavelength?

180°

(d) How much longer is the wavelength of the scattered light in (c) than the wavelength of the incident light?

Longer by $2h/mc$ or 0.00486 nm

(e) Briefly explain why the Compton scattered light always has a longer wavelength than the incident light.

Review the Quantum Physics Study Questions.

8.[12 pts]
(a) What is the role of the excitation source in a laser? Give an example of one kind excitation source that is commonly used.

Review the Quantum Physics Study Questions.

(b) Which kind of emission is utilized in a laser? (Circle the correct choice.) *spontaneous* *stimulated*

(c) Explain what is meant by a "metastable state" in a laser and its role in laser operation.

(d) What is the role of the mirrors in laser operation?