UNIVERSITY OF
MARYLAND

Department of Physics
Physics 270 Fall 2008

Dr. Wallace, MWF 12:00, Room 1410 Physics

Sections: 0301 (W 1:00); 0302 (W 2:00); 0303 (Th 10:00)

Midterm Exam. III Friday December 5, 2008

Name (please print):

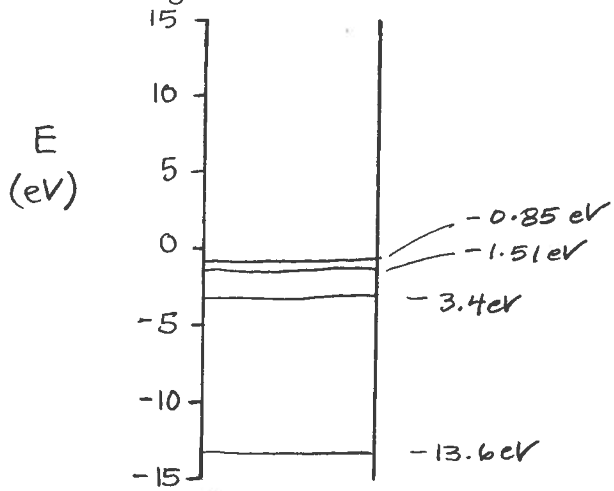
Circle section number above. Exams will be returned in sections.

Pledge: I pledge on my honor that I have not given or received any unauthorized assistance on this examination.

Signature:

Useful constants: $h = 6.63 \times 10^{-34}$ J s, $c = 3 \times 10^{8}$ m/s $1 \text{ eV} = 1.6 \times 10^{-19}$ J.

1.) a.) (15 pts.) Show the 4 lowest energies of the electron in a hydrogen atom as horizontal lines on the energy-level diagram below and give the numerical values of the 4 energies in electron volts.



b.) (15 pts.) If a hydrogen atom emits a photon of wavelength 656 nm, what is its energy before the photon is emitted?

$$E_{photon} = \frac{hc}{\lambda} = \frac{1243 \text{ eV nm}}{656 \text{ nm}} = 1.89 \text{ eV}$$

Emission: $E_i = E_{photon} + E_f = 1.89 \text{ eV} + E_f$

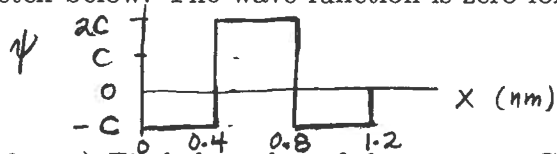
$$\Rightarrow \boxed{E_i = -1.51 \text{ eV}} \;\&\; E_f = -3.40 \text{ eV}$$

2.) (20 pts.) If an electron is confined to a length of 5×10^{-11}m, estimate the kinetic energy that it has in electron-volt units.

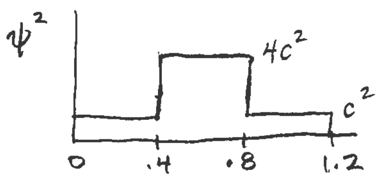
$$\Delta p \, \Delta x \geq \hbar \quad \text{so} \quad p \sim \frac{\hbar}{\Delta x} \sim \frac{1.05 \times 10^{-34} \text{ J s}}{5 \times 10^{-10} \text{ m}} = 2.1 \times 10^{-24} \text{ kg m/s}$$

$$E = \frac{p^2}{2m} \sim \frac{(2.1 \times 10^{-24} \text{ kg m/s})^2}{2\,(9.1 \times 10^{-31} \text{ kg}) \times 1.6 \times 10^{-19} \frac{\text{J}}{\text{eV}}} = 15.1 \text{ eV}$$

3.) A particle is in the interval $0 \leq x \leq 1.2$ nm of the x-axis. Its wave function is as shown in the sketch below. The wave function is zero for x < 0 and for x > 1.2 nm.



a.) (10 pts.) Find the value of the constant C.



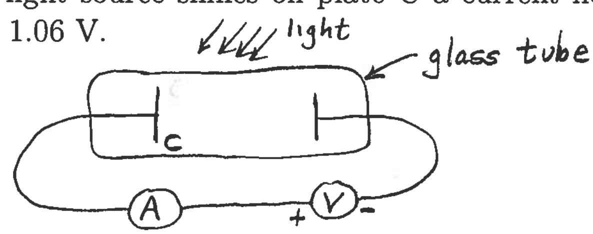
$$\int_0^{1.2} dx\, P(x) = C^2[0.4] + 4C^2[0.4] + C^2[0.4] = 2.4C^2 = 1$$

so $C = \frac{1}{\sqrt{2.4\,nm}}$

b.) (10 pts.) Find the probability that the particle is located in the range $0.6 \text{ nm} \leq x \leq 0.72$ nm.

$$P[0.6, 0.72] = 4C^2(0.72 - 0.6) = 4\frac{1}{2.4}(0.12) = \underline{0.20}$$

4.) A wire, an ammeter A and a variable voltage source V are connected to a glass tube that has all the air removed. When V=0 and a light source of wavelength 400 nm shines on plate C, a current is detected in the circuit. When V is raised to 2.0V, the current stops. The first light source is replaced by a second light source that has wavelength 600 nm. When V=0 and the second light source shines on plate C a current flows, but that current stops when V is raised to 1.06 V.



a.) (20 pts.) Use the data given above to determine the value of Planck's constant in units of Js. Note that the data are not very accurate so the value obtained will be approximate.

$$hf = eV - E_0 \Rightarrow h\Delta f = e\Delta V \Rightarrow h = \frac{e\Delta V}{\Delta f}$$

$\Delta V = 2.0 - 1.06 = 0.94\,V$

$\Delta f = \frac{c}{400nm} - \frac{c}{600nm} = 2.5 \times 10^{14}\,Hz$

$$h = \frac{(1.6 \times 10^{-19})(0.94)\,J}{2.5 \times 10^{14}\,Hz} = 6.016 \times 10^{-34}\,Js$$

b.) (5 pts.) What aspect of your analysis treats light as particle-like?

$E_{photon} = hf$ assigns energy

The use of energy conservation is particle-like

c). (5 pts.) What aspect of your analysis treats light as wave-like?

Frequency and wavelength are wave-like properties.