October 29, 2008

University of Saskatchewan
Department of Electrical Engineering

EE372 Electronic Materials and Devices
Midterm Examination
Professor Robert E. Johanson

PART B
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Welcome to the EE372 ... e examination has two parts. Part A consists of questions that test knowledge of basic concepts, and part B requires more involved calculations. Part A is closed book and closed notes. When you finish part A, hand it in (raise your hand) and then proceed to part B. Part B is open book; you may refer to your textbook (Kasap, any edition) but not to any other material such as notes or other books. You may also use a calculator for both parts. The examination lasts **1:30** hour.

Each problem is weighted equally but subparts may be differently weighted. Show your work if the question involves more than a simple answer; credit will be given only if the steps leading to the answer are **clearly** shown. Partial credit will be given for partially correct answers but only if correct intermediate steps are shown. Write your answers on these pages.

For part B, answer all 3 questions.

1. 4
2. 8
3. 10

total 22/30

PHYSICAL CONSTANTS

$c = 2.9979\times10^{8}$ m s^{-1}
$e = 1.6021\times10^{-19}$ C
$m_e = 9.1091\times10^{-31}$ kg
$h = 6.62608\times10^{-34}$ J s
$k = 1.3807\times10^{-23}$ J K^{-1}
$\varepsilon_o = 8.8542\times10^{-12}$ F m^{-1}

1. Photo-electric Effect

a) A multi-alkali metal is used as the photocathode material in a photo-emissive electron tube. The longest wavelength radiation that gives photo-emitted electrons is 440 nm. If ultra-violet radiation of wavelength 220 nm is incident on to this photocathode, what is the maximum kinetic energy (in eV) of the photo-emitted electrons? What is the work function of the metal? What voltage applied to the collecting electrode would extinguish the photocurrent?

b) The 220 nm light has an intensity of 10 mW/cm². The photocathode is a disk with an area of 1 cm². The emitted electrons are collected by applying a positive bias of 50 V to the anode. What is the photocurrent assuming that the quantum efficiency of the photocathode is 0.3.

Note: Quantum efficiency is the ratio of emitted electrons to absorbed photons.

$\lambda_{max} = 440nm = \lambda_0$

$\lambda_{incident} = 220nm = \lambda$

find max K.E in eV, Φ, Vstop

$K.E = \frac{hc}{e\lambda} - \frac{hc}{e\lambda_0} = 5.635645eV - 2.817823$

$K.E_{max} = 2.82eV$ ✓

$\Phi = \frac{hc}{e\lambda_0} = 2.82eV$ ✓

Vstop ⇒ when $I_{current} = 0$ ✗

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b) $I_{220} = 10mW/cm^2$ $A_{PC} = 1cm^2$ $V_{Bias} = 50V$ $\eta = 0.3 = \frac{emitted}{absorbed}$

$I = \frac{\Delta N_{ph}}{A \Delta t} h\nu$ (Flux)

$Flux = \frac{(10mW/cm^2)\, 1cm^2}{h\nu}$

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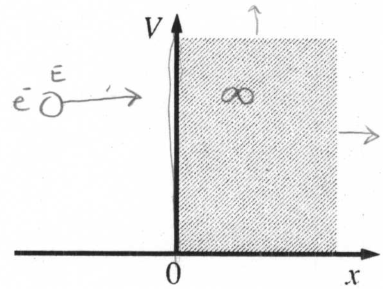
1. Schrödinger's Equation

An infinite step potential has $V = 0$ for $x < 0$ and $V = \infty$ for $x > 0$ as illustrated below. An electron is incident from the left onto the step with energy E.

a) Write down the solution to Schrödinger's Equation in the two regions $x < 0$ and $x > 0$.

b) Write down the boundary condition on the wavefunction at $x = 0$.

c) What does the boundary condition imply about the constants in your solution?



$$\frac{\partial^2 \psi}{\partial x^2} + \frac{2m_e}{\hbar^2}(E-V)\psi = 0$$

a) $\psi(x) = Ae^{jkx} + Be^{-jkx}$ $\quad k = \sqrt{\frac{2m(E-V_0)}{\hbar}}$ $\quad E > V_0$

$V_0 = 0$ for $x < 0$

when $x < 0$

$\psi(x) = Ae^{jkx} + Be^{-jkx}$ ✓ $k = \sqrt{\frac{2m(E-V_0)}{\hbar}}$

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when $x > 0$

$\psi(x) = 0$ ✓

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b) boundry conditions at $x = 0$

$\psi(0) = A + B \rightarrow \psi(x) = \begin{cases} 0, & x > 0 \\ Ae^{jkx} + Be^{-jkx}, & x < 0 \\ A+B & x = 0 \end{cases}$

you don't actuall state the B.C. $\psi(0) = 0$

c) $B = -A$ ✓

3. Atoms

a) An excited hydrogen atom has its electron in the 4d state. Indicate with an energy level diagram all possible allowed transitions that can occur while the electron returns to the ground state. Calculate all wavelengths of light that will be emitted during these transitions.

b) Magnesium has the electronic configuration $[Ne]3s^2$. The first ionization energy (the energy to remove an electron) of magnesium is 7.65 eV. What is the effective nuclear charge (Z_{eff}) acting on the 3s electron?

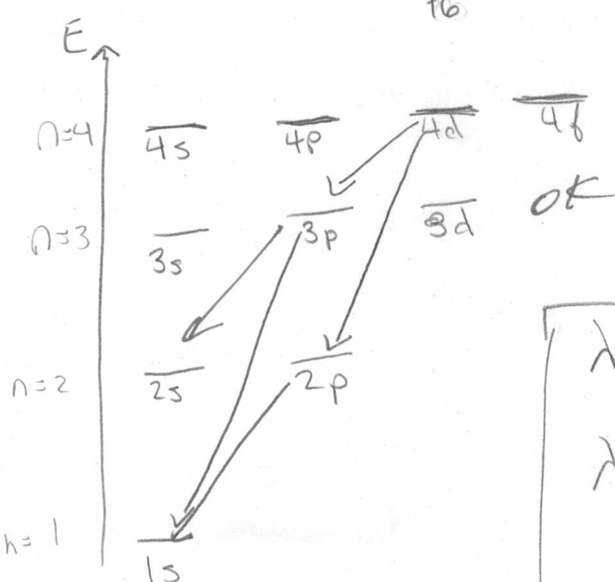
$-\frac{13.6}{9} + \frac{13.6}{16} -$

a) H atom in 4d state

n = 5
l = 4

$\Delta E = \left(-\frac{13.6}{n^2}\right) - \left(-\frac{13.6}{}\right) eV$

$E = (13.6 eV) \frac{1}{16} = 0.850 eV$



4d - 3p → $\Delta E_{43} = 0.6611 eV$ 0.66

4d - 2p → $\Delta E = +2.55 eV$

3p - 1s → $\Delta E = -0.6611 eV + (-12.088)$

2p - 1s → $\Delta E = -2.55 eV + (-10.2 eV)$

$\lambda_{4-3} = \frac{hc}{\Delta E_{43}} = 1.875 \mu m$ ✓

$\lambda_{4-2} = \frac{hc}{\Delta E_{42}} = 486.21 nm$ ✓

$\lambda_{31} = \frac{hc}{\Delta E_{31}} = 109.57 nm$ ✓

$\lambda_{21} = \frac{hc}{\Delta E_{21}} = 121.5 nm$ ✓

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b) find Z_{eff} n = 3

$7.65 eV = \frac{Z_{eff}^2 (13.6 eV)}{9} \Rightarrow Z_{eff} = 2.25$ ✓