THE UNIVERSITY OF NEW SOUTH WALES

SCHOOL OF PHYSICS

PHYS2110/PHYS2040 QUANTUM PHYSICS

EXAMINATION – APRIL 16 2015

PAPER 1 – MID SESSION

Time allowed = 50 min.

Total number of questions = 3

Total number of marks = 40

Answer ALL questions

The questions are NOT of equal value

Portable battery powered electronic calculators (without alphabetic keyboards) may be used

The paper may be retained by the candidate

Please write your answers in ink but do not use red ink

The following information is supplied as an aid to memory.

Planck's constant $h = 6.626 \times 10^{-34}$ Js

Fundamental charge unit $e = 1.60 \times 10^{-19}$ C

Speed of light (vacuum) $c = 3.0 \times 10^{8}$ m/s

Electron mass = 9.1×10^{-31} kg

Neutron mass = 1.675×10^{-27}kg

Proton mass = 1.672×10^{-27}kg

Boltzmann's constant $k = 1.38 \times 10^{-23}$JK^{-1}

Angstrom (Å) = 1.0×10^{-10} m

Permittivity constant $\varepsilon_o = 8.85 \times 10^{-12}$Fm^{-1}

Gravitational constant $G = 6.67 \times 10^{-11}$Nm^2/kg^2

Photoelectric Effect: $eV_0 = h\upsilon - \phi_0 = \dfrac{hc}{\lambda} - \phi_0$

$\sin 2\theta = 2\sin\theta\cos\theta$ Bragg's law: $\sin 2\theta = 2\sin\theta\cos\theta$ Compton Shift: $\Delta\lambda = \dfrac{h}{mc}(1-\cos\theta)$

Question 1 [15 marks]

(a) Describe in no more than one page including any diagrams, the main features of the photoelectric effect. (3 marks)

(b) Explain how classical theory fails to account for the photoelectric effect and how quantum theory does provide a description. (3 marks)

(c) Light of wavelength $\lambda_1 = 550\,\text{nm}$ is incident on a metal surface causing ejection of electrons for which the stopping potential is $V_{s1} = 0.19\ \text{V}$. Now, radiation of a different wavelength, $\lambda_2 = 190\,\text{nm}$ is incident on the same metal surface. Calculate

(a) the stopping potential for this second wavelength, V_{s2} (3 marks)

(b) the work function of the surface (3 marks), and

(c) the threshold frequency for the surface (3 marks).

Question 2 [15 marks]

(a) To what kinetic energy (in eV) must an electron be accelerated such that its de Broglie wavelength is equal to that of the shortest wavelength X-rays produced in an X-ray tube operating at 30,000 V ? (6 marks)

(b) A particle of mass m has a positional uncertainty equal to its de Broglie wavelength. Calculate the minimum **fractional** uncertainty in its velocity $\Delta v/v$. (9 marks)

Question 3 [10 marks]

Taking a typical atomic diameter to be $\sim 0.1\,\text{nm}$ (approximately two times the Bohr radius), use the Uncertainty principle to estimate the ionisation energy of a single electron in a bound state of this atom.