KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS
2016/2017 ACADEMIC YEAR

THIRD YEAR SECOND SEMESTER
SPECIAL/SUPPLEMENTARY EXAMINATIONS

FOR THE DEGREE OF BACHELOR OF SCIENCE IN PHYSICS ANDBACHELOR OF EDUCATION (SCIENCE)

COURSE CODE: SPH313

COURSE TITLE: QUANTUM MECHANICS I

DURATION: 2 HOURS

DATE: 20TH SEPETEMBER 2017 TIME: 11:30AM – 1:30PM

INSTRUCTIONS TO CANDIDATES

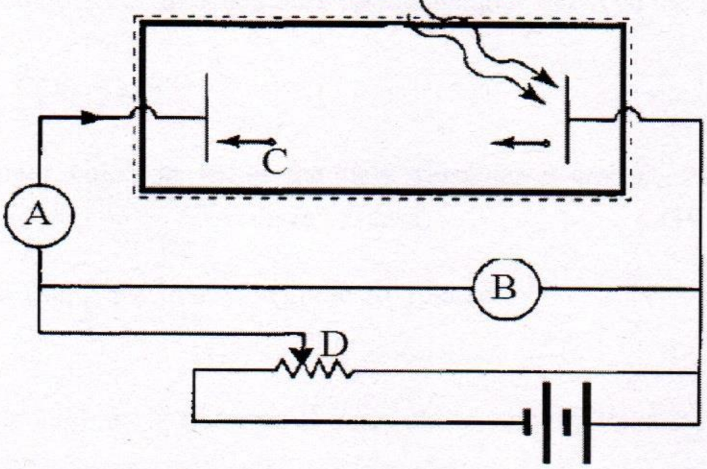
- Answer **QUESTION ONE** (Compulsory) and any other **TWO** (2) Questions.
- Question **ONE** carries **30 MARKS** and the remaining carry **20 MARKS** each.
- Symbols used bear usual meaning.
- Plancks constant $h = 6.625 \times 10^{-34} Js$
- Indicate **answered questions** on the front cover.
- Start every question on a new page and make sure question's number is written on each page.

This paper consists of **3** printed pages. Please Turn Over

KIBU observes ZERO tolerance to examination cheating

QUESTION ONE (30 MARKS)

(a) The figure below shows a set of apparatus used to perform the photoelectric effect experiment



(i). At what point will A record zero if the switch is on **(1 mark)**

(ii). Explain, from the figure, what will happen if the quantity of incident photons is kept constant while D is varied **(3 marks)**

(iii). Explain what will happen to A if D is kept constant while the number of incident photons is varied. **(2 marks)**

(b) Based on blackbody radiation, explain the failure of classical mechanics **(4 marks)**

(c) Derive an equation showing an increase in the photon's wavelength as a function of the scattering angle; when a photon collides with a particle at rest? **(9 marks)**

(d) Prove that a Hermitian operator is real **(3 marks)**

(e) Derive an equation showing Bohr radius consequently show also the accompanying velocity **(8 marks)**

QUESTION TWO (20 MARKS)

a) Given the Planck's radiation formula shown below

$$E_\lambda d\lambda = \frac{8\pi hc}{\lambda^5}\frac{1}{(e^{hc/\lambda kT}-1)}d\lambda$$

Deduce from it

(i). Rayleigh – Jeans law **(4 marks)**

(ii). Wien law **(4 marks)**

b) When two ultra violet beams of wavelengths $\lambda_1 = 280nm$ and $\lambda_2 = 490nm$ fall on a lead surface they produce photoelectrons with maximum energies 8.57eV and 6.67eV, respectively

i). Estimate the numerical value of the Planck's constant **(4 marks)**

ii). Calculate the work function of lead **(3 marks)**

iii). Calculate the cut off frequency of lead **(2 marks)**

c) Calculate the De Broglie's wavelength for a mass of 2g moving at a speed of 1m/s **(3 marks)**

QUESTION THREE (20 MARKS)

a) Consider the Hamiltonian for a one – dimensional system of two particles of masses m_1 and m_2 subjected to a potential that depends only on the distance between the particles $x_1 - x_2$.

$$H = \frac{p_1^2}{2m_1} + \frac{p_2^2}{2m_2} + V(x_1 - x_2)$$

Write the schrodinger equation using the new variables x and X, where $x = x_1 - x_2$ (Relative distance), $X = \frac{m_1x_1+m_2x_2}{m_1+m_2}$ (centre of mass) **(10 marks)**

b) The wavelength and frequency in a waveguide are related by

$$\lambda = \frac{c}{\sqrt{v^2 - v_0^2}}$$

Express the group velocity V_g in terms of c and phase velocity $V_P = v\lambda$**(10 marks)**

QUESTION FOUR (20 MARKS)

a) Find $[p_x, x]$ **(5 marks)**

b) Consider the wave function $\Psi(r,t) = \left[Ae^{-ipx/\hbar} + Be^{ipx/\hbar}\right]e^{-ip^2t/2m\hbar}$. Find the probability current corresponding to this wave function **(10 marks)**

c) What is the smallest possible uncertainty in the position of an electron moving with velocity $10^6 m/s$ **(5 marks)**

QUESTION FIVE (20 MARKS)

a) What is the energy of a photon of visible light of wavelength $\lambda = 6 \times 10^{-7} m$ **(2 marks)**

b) Consider a particle trapped in a well with potential given by:

$$V(x) = \begin{cases} 0 & 0 \leq x \leq a \\ \infty otherwise \end{cases}$$

Show that $\Psi(x,t) = A\sin(kx)\exp -\left(\frac{iEt}{\hbar}\right)$ solves the Schrödinger equation provided that $E = \frac{\hbar^2k^2}{2m}$ **(10 marks)**

c) Suppose $\Psi(x,t) = A(x - x^3)e^{-iEt/\hbar}$. Find $V(x)$such that the Schrödingerequation is satisfied. **(8 marks)**