MACHAKOS UNIVERSITY

University Examinations 2017/2018

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF EDUCATION SCIENCE

SPH 301: QUANTUM MECHANICS 1

DATE: 18/12/2017 **TIME:2.00-4.00 PM**

Instructions: Answer Question ONE and Any Other TWO questions

Constants

Speed of light, $C = 3.0 \times 10^{8} ms^{-1}$

Planck's constant, $h = 6.625 \times 10^{34} J.s$

Mass of electron, $M_e = 9.1 \times 10^{-31} Kg$

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

Electric charge, $e/q = 1.602 \times 10^{-19} C$

Stephen's constant, $\sigma = 5.67 \times 10^{-8} m^{-2} K^{-4}$

Wien's constant, $b = 2.898 \times 10^{-3} mK$

Permittivity constant, $\varepsilon o = 8.854 \times 10^{-12} Fm^{-1}$

1. (a) Explain and give a model of a black body. Write down the Planck's spectral distribution law for a black body.
Give the name and SI units of each symbol involved. (4 marks)

(b) Show that Planck's spectral distribution law reduces to Wien's distribution formula (3 marks)

(b) Write down Bohr's postulates and indicate the successes of this theory. (7 marks)

(c) Formulate de Broglie duality principle (2 marks)

(d) Give the operators of the following quantities

(i) Coordinate

(ii) Projection of Momentum on to axis

(iii) Total energy

(iv) Projection of Angular momentum on to axis (4 marks)

(d) Deduce and explain the Heisenberg Uncertainty principle . (4 marks)

(e) Indicate the relationship requirements that the wave function must be consistent with. (3 marks)

(f) Explain the Compton Effect and deduce the expression for the wavelength shift in the scattered radiation. (3marks)

2. (a) Write down Raleigh-Jeans spectral distribution and show that is along wave length approximation of the Planck's distribution law. (5marks)

(b) Consider a blue star having a surface temperature of 3000K and a yellow star having a surface temperature of 6000K. Assuming that these stars radiate like black body, calculate for each of them:

(i) The total emissive power (4 marks)

(ii) The wavelength, λ_{max} at which the spectral emittance R (λ, T) peaks (4 marks)

(iii) In which region of the spectrum do the peaks fall? (1 mark)

(c) The sun is assumed to be a spherical black body with radius of 7×10^3m and produce an intensity of solar radiation $1.4\times10^3\ W\,m^{-2}$ at the surface of the earth. If the distance between the sun and the earth is1.5×10^{11} m, calculate:

(i) The surface temperature, T (K), of the sun. (3 marks)

(ii) Using T obtained in No. C (i) above, determine the wavelength λ_{max} at which the spectral emittance R (λ, T) of the sun has its maximum value. (3 marks)

3. (a) Show that if the potential energy is an even function of x (that is, $V(-x) = V(x)$, then when solving time-independent Schrodinger equation, it suffices to consider the even and odd functions ψ for the ones which $\psi(-x) = \psi(x)$ or $\psi(-x) = \psi(x)$ (7 marks)

(b) In the infinite square well, if $\psi(x)$ is even, write down the most general possible forms of the functions $\psi_1(x)$, $\psi_2(x)$ and $\psi_3(x)$ (for $x < -a$; $-a < x < a$ and $x > a$) respectively. (5 marks)

(c) Apply the boundary conditions at a and show that $(ka)\tan ka = ka$ in the infinite square well mentioned above in no (b) above. (3 marks)

(d) Calculate the de Broglie wavelength of:

(i) A mass of 1g moving at a velocity of 1 ms^{-1}. (2 marks)

(ii) A free electron having a kinetic energy of 50 KeV. (3 marks)

4. (a) Deduce the expression of the reflection coefficient R and the transmission coefficient T of a particle on a potential step in the case $E > V_o$ (5 marks)

(b) Consider an electron of energy E incident on a potential step where V_O=10 eV. Calculate the reflection coefficient R and the Transmission T when E = 15eV. (5 marks)

(c) Find eigen functions and energy eigen-values of a particle in infinitely high potential well. (5 marks)

(d) Determine the reflection coefficient R and transmission coefficient T of an electron of energy E = 1eV for a rectangular barrier potential such that V_o = 2eV and a = 1A^o

(5 marks)

5. (a) (i) Write down and explain Einstein's law of photoelectric effect. Explain why classical Physics was unable to explain the photoelectric effect. (6 marks)

(ii) Illustrate using a diagram the experimental set-up for photoelectric effect and explain the characteristic curves of the photoelectric effect. (5 marks)

(b) In a photoelectric experiment in which monochromatic light of wavelength falls on a Potassium metal surface, it is found that the stopping potential is 1.91V for wavelength of 3000A and 0.88V for wavelength of 4000A. From these data, calculate:

(i) The value of Planck's constant. (3 marks)

(ii) The work function, W for Potassium metal. (3 marks)

(iii) The threshold frequency, V_{th} for Potassium metal. (3 marks)