UTHM
Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	QUANTUM PHYSICS
COURSE CODE	:	BWC 20803
PROGRAMME CODE	:	BWC
EXAMINATION DATE	:	DECEMBER 2019 / JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **FOUR (4)** PAGES

Q1 A particle is trapped in a square well potential as shown in **Figure Q1** with

$$V(x) = \begin{cases} \infty & x < 0 \\ 0 & 0 \le x \le L \\ \infty & x > L \end{cases}$$

The Time Independent Schrödinger Equation is given by

$$\hat{H}\psi(x) = E\psi(x),$$

$$\text{and } \hat{H} = -\frac{\hbar}{2m}\nabla^2 + V(r)$$

where m and E is the mass and kinetic energy of the particle, respectively.

(a) Determine the general form of wave function $\psi(x)$ of the particle in this one-dimensional potential well.

(6 marks)

(b) Consider the boundary conditions and determine the allowed energy levels E_n of the particle.

(8 marks)

(c) Based on the normalization of wave function, conclude the complete form of wave function $\psi(x)$.

(6 marks)

Q2 A particle with energy E is traveling to the right towards a step potential as in **Figure Q2**. The potential in the figure corresponds to

$$V(x) = \begin{cases} 0 & x < 0 \\ V_0 & x > 0 \end{cases}$$

(a) Solve the Schrödinger Equation for the regions $x < 0$ and $x > 0$, in the case of

(i) $E > V_0$

(4 marks)

(ii) $E < V_0$

(4 marks)

(b) Given the wave's probability current density $S(x) = \frac{i\hbar}{2m}\left[\frac{d\psi^*(x)}{dx}\psi(x) - \psi^*(x)\frac{d\psi(x)}{dx}\right]$, calculate the reflection coefficient, R and transmission coefficient, T for the wave in the case of

(i) $E > V_0$

(6 marks)

(ii) $E < V_0$

TERBUKA

(6 marks)

Q3 (a) Justify that any operator commutes with itself.

(3 marks)

(b) Express [A, B] in terms of [B, A].

(3 marks)

(c) Determine the Hermitian adjoint of a commutator $[A, B]^\dagger$ if A and B are Hermitian operators.

(6 marks)

(d) Calculate the eigenvalues and eigenvectors of the following operator.

$$A = \begin{vmatrix} 3 & -1 \\ 4 & -2 \end{vmatrix}$$

(8 marks)

Q4 (a) Deduce the commutator of component angular momentum L_y and L_z, $[L_y, L_z]$.

(6 marks)

(b) If $|\alpha, \beta\rangle$ is an angular momentum eigenvector, determine $L_+ L_z |\alpha, \beta\rangle$ and subsequently evaluate $L_+ |\alpha, \beta\rangle$, given that $L_z |\alpha, \beta\rangle = \hbar\beta |\alpha, \beta\rangle$ and $[L_z, L_\pm] = \pm\hbar L_\pm$.

(8 marks)

(c) For an angular momentum eigenstate $|l, m\rangle$, eigenvalues of L^2 and L_z are given as $L^2 |l, m\rangle = l(l+1)\hbar^2 |l, m\rangle$ and $L_z |l, m\rangle = m\hbar |l, m\rangle$.

(i) Explain the physical meaning of l and m.

(4 marks)

(ii) Determine the allowable value of m.

(2 marks)

Q5 (a) Determine the spin eigenstates of electrons, $s = \frac{1}{2}$.

(4 marks)

(b) Determine the spin eigenstates of photons, $s = 1$.

(6 marks)

(c) The spin operator S^2 works similar to the angular momentum operator L^2. Predict the eigenvalues of S^2.

(4 marks)

(d) The S_+ and S_- operators are defined in analogy to the L_+ and L_- operator. Determine S_+ and S_-.

(6 marks)

-END OF THE QUESTIONS-

FINAL EXAMINATION

SEMESTER / SESSION	: SEM I / 2019/2020	PROGRAMME CODE	: BWC
COURSE	: QUANTUM PHYSICS	COURSE CODE	: BWC 20803

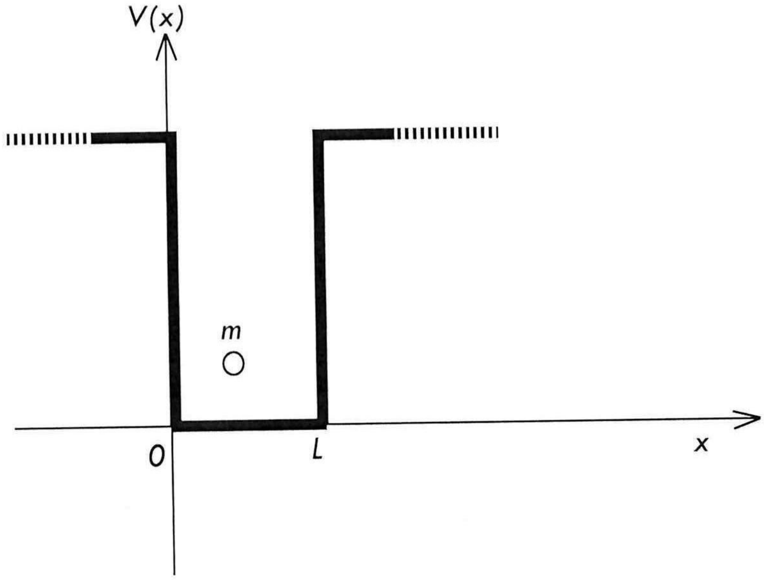

Figure Q1

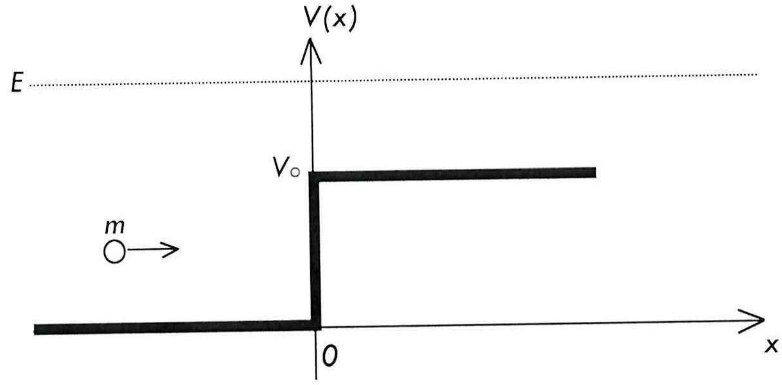

Figure Q2