Answer ALL SIX questions from Section A and THREE questions from Section B.

The numbers in square brackets at the right-hand margin indicate the provisional allocation of marks per sub-section of a question.

SECTION A

[Part marks]

1. Compton investigated the scattering of X-rays passing through a thin metal film. What feature of his results was inconsistent with the classical theory of electromagnetic radiation? [2]

   Outline, without using mathematics, how the Compton Effect can be explained. [4]

2. Define the commutator of two operators $\hat{P}$ and $\hat{Q}$. [2]

   What does it mean if $\hat{P}$ and $\hat{Q}$ are *compatible* operators? What does this imply about their commutator? [2]

   Suppose that $\hat{P}$ and $\hat{Q}$ are not compatible. For a given system, $\hat{P}$ is first measured yielding the value p, then $\hat{Q}$ is measured yielding the value q. If $\hat{P}$ is then measured again, what can be said about the possible results of the measurement, and why? [2]

3. A particle of mass m moves in a one-dimensional square well potential

$$V(x) = \begin{cases} 0 & (-a \leq x \leq a) \\ V_0 & (\text{otherwise}) \end{cases}$$

   For the case of an infinitely deep well, $V_0 = \infty$, sketch the form of the wavefunction of the two lowest energy states. Does the energy difference between these states increase or decrease as the width of the well, $2a$, decreases? Give reasons for your answer. [4]

   How does the number of bound states change as the depth of the well decreases (i.e. V_0 decreases)? Sketch carefully the wavefunction of the lowest energy state for a well that is both shallow and broad (i.e. small V_0 and large a). [4]

4. What is meant by the concept of "tunnelling" in quantum mechanics? [3]

   Briefly explain why tunnelling plays an important role in both nuclear fusion and alpha decay. [3]