# Summary Exam Questions Advanced Quantum Mechanics

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## Lecture 1

- There is expected you can solve the free Schrödinger equation for any initial condition.
- What is the abstract definition of an angular momentum operator? When is an operator a scalar operator? When is an operator a vector operator? When is an operator an angular momentum operator?
  If you sum two angular momenta, is it again an angular momentum? If you take a composite system and you add the angular momentum like $\frac{1}{4}L_1 + \frac{3}{4}L_2$, is that again an angular momentum?
- Suppose you have 20 spin $\frac{1}{2}$ particles. What is the dimension of the Hilbert space of the composite system?
- There will be a question on density matrices $\rho$.
  - Pure v.s. mixed.
  - Calculate $\mathrm{Tr}\left[\rho\hat{A}\right]$ for $2 \times 2$ and $3 \times 3$ matrices.
  - Calculate restrictions. (Partial traces)
  - Suppose component systems with a $\rho$ and you look at an restriction. Is it entangled or not?
  - Calculate von Neumann entropy?
- Lecture 1 exercises 5, 7, 8, 9, 10, 11, 13, 14, 17, 18, 19.

## Lecture 2

- There is expected you can solve the free Schrödinger equation for any initial condition.
- p42: Go from the first eq. to the second eq.
- You can do a similar calculation as on p48 to p49.
- The spin calculation on spin dynamics p52 to p53, e.g. trick to go to rotating frame of reference.
- Lectures 2 exercises 1, 2, 3, 8.

## Lecture 3

- You must know how to apply Rayleigh perturbations.
- There will be a question on variational methods. He referred to question 5 p74 (Exercises lecture 3).

## Lecture 4

- If you apply a magnetic field to a double slit experiment, which effect happens?
  ⟶ Aharonov–Bohm effect
  What are the changes that you get?
- Check energy level calculations (XIII.1).
- Lectures 4 exercises 1, 3, 4, 5.

## Lecture 5

- Solve the free Schrödinger equation or Quantum Harmonic oscillator with Feynman propagator.
- He really likes the Aharonov–Bohm effect, study p 83.

## Lecture 6

- Compute the differential cross section and total cross sections for different types of potential.
  ⟶ do the born approximation
  Start from the Lippmann–Schwinger equation, find the first born approximation and then apply it for a potential. (Lectures 6 exercise 5)
- Quantum effects: Scattering of two identical bosons and scattering of two identical fermions. He said he can give the figure below and you will have to explain what it is and how it is associated with quantum effects.

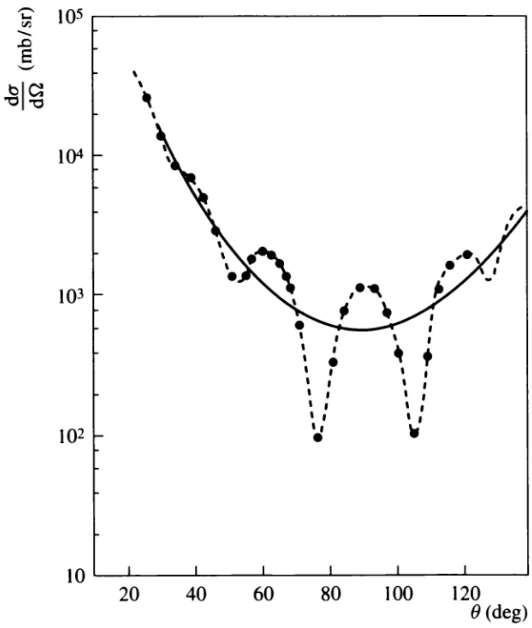


*Figure 13.11* The differential cross-section (in mb/sr, where 1 mb ≡ 1 millibarn = $10^{-31}$ $m^2$), corresponding to the elastic scattering of two $^{12}C$ nuclei having a centre-of-mass energy of 5 MeV. The dashed curve represents the results obtained by using the Mott formula (13.185). The solid curve shows the corresponding 'classical' differential cross-section obtained by omitting the interference term in (13.185). The dots are the experimental data of D. A. Bromley, J. A. Kuehner and E. Almqvist.

Figure 1: Figure 13.11 from Bransden and Joachain p624

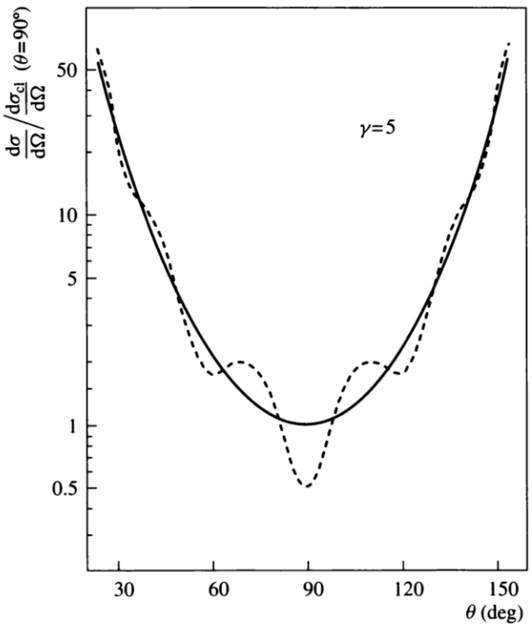


*Figure 13.12* The differential cross-section $d\sigma/d\Omega$ corresponding to the scattering of two spin-$\frac{1}{2}$ fermions interacting through a Coulomb potential, divided by $d\sigma_{cl}(\theta = 90°)/d\Omega$ for the value $\gamma = (Ze)^2/[(4\pi\varepsilon_0)\hbar v] = 5$. The dashed curve represents the results obtained by using the Mott formula (13.195). The solid curve shows the corresponding 'classical' results, obtained by omitting the interference term in (13.195).

Figure 2: Figure 13.11 from Bransden and Joachain p624

## Lecture 7

- Conceptual multiple-choice questions where you defend your answer.

## Lecture 8

## Lecture 9

## Lecture 10

- Reading circuits and applying unitary gates.