QMSE01 Quantum Mechanics for Scientists and Engineers

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Syllabus and Textbook references

Section numbers at the beginnings of the lines below (e.g., 1.2 and 1.2.3) refer to the corresponding sections of the online course.

References below to "QMSE" are to sections in the book "Quantum Mechanics for Scientists and Engineers" by David A. B. Miller (Cambridge, 2008), which is the recommended text for this class.

Week 1

1.1 Introduction to quantum mechanics

1.1.1 Introduction to quantum mechanics QMSE 1.1
1.1.2 – 1.1.3 Light QMSE 1.1
1.1.4 – 1.1.5 Matter QMSE 1.1
1.1.6 The usefulness of quantum mechanics QMSE 1.1
1.1.7 Science, philosophy and meaning QMSE 1.2 – 1.3

1.2 Classical mechanics, oscillations and waves

1.2.1 Useful ideas from classical physics QMSE Appendix B
1.2.2 – 1.2.3 Elementary classical mechanics QMSE B.1
1.2.4 – 1.2.5 Oscillations QMSE B.3
1.2.6 – 1.2.7 The classical wave equation QMSE B.4

Week 2

2.1 Wave propagation

2.1.1 – 2.1.2 Plane waves and interference QMSE B.4
2.1.3 – 2.1.4 Diffraction QMSE B.4
2.1.5 – 2.1.6 Diffraction from periodic structures QMSE B.4

2.2 Schrödinger's wave equation

2.2.1 Schrödinger wave equation introduction QMSE Chapter 2 introduction
2.2.2 – 2.2.3 From de Broglie to Schrödinger QMSE 2.1 – 2.2
2.2.4 – 2.2.5 Diffraction by two slits QMSE 2.3 (first part)
2.2.6 – 2.2.7 Interpreting diffraction by two slits QMSE 2.3 (second part)

2.3 Particle in a box

2.3.1 Introduction to the particle in a box
2.3.2 – 2.3.3 Linearity and normalization QMSE 2.4 – 2.5
2.3.4 – 2.3.5 Solving for the particle in a box QMSE 2.6 (first part)
2.3.6 – 2.3.7 Nature of the particle-in-a-box solutions QMSE 2.6 (second part)

Week 3

3.1 Particles and barriers

3.1.1 – 3.1.2 Sets of functions QMSE 2.7 ("Completeness of sets – Fourier series")

3.1.3 – 3.1.4 Orthogonality of functions QMSE 2.7 (“Orthogonality of eigenfunctions” and “Expansion coefficients”)
3.1.5 – 3.1.6 Barriers and boundary conditions QMSE 2.8

3.2 Finite well and harmonic oscillator

3.2.1 Particles in potential wells – introduction
3.2.2 – 3.2.3 The finite potential well QMSE 2.9
3.2.4 – 3.2.5 The harmonic oscillator QMSE 2.10

3.3 The time-dependent Schrödinger equation

3.3.1 Introduction to the time-dependent Schrödinger equation QMSE Chapter 3 introduction
3.3.2 – 3.3.3 Rationalizing the time-dependent Schrödinger equation QMSE 3.1 – 3.2
3.3.4 – 3.3.5 Solutions of the time-dependent Schrödinger equation QMSE 3.3
3.3.6 – 3.3.7 Linear superposition QMSE 3.4 – 3.5

Week 4

4.1 Time evolution of superpositions

4.1.1 Introduction to time evolution of superpositions
4.1.2 – 4.1.3 Superposition for the particle in a box QMSE 3.6 (“Simple linear superposition in an infinite potential well”)
4.1.4 – 4.1.5 Superposition for the harmonic oscillator QMSE 3.6 (“Harmonic oscillator example”)
4.1.6 – 4.1.7 The coherent state QMSE 3.6 (“Coherent state”)

4.2 Wavepackets

4.2.1 Introduction to wavepackets QMSE 3.7 introduction
4.2.2 – 4.2.3 Group velocity QMSE 3.7 (“Group velocity” first part)
4.2.4 – 4.2.5 Group velocity for a free electron QMSE 3.7 (“Group velocity” second part)
4.2.6 – 4.2.7 Electron wavepackets QMSE 3.7 (“Examples of motion of wavepackets”)

4.3 Measurement and expectation values

4.3.1 – 4.3.2 Quantum-mechanical measurement QMSE 3.8
4.3.3 – 4.3.4 Expectation values and operators QMSE 3.9 – 3.10
4.3.5 – 4.3.6 Time evolution and the Hamiltonian QMSE 3.11

Week 5

5.1 Uncertainty principle and particle current

5.1.1 – 5.1.2 Momentum, position, and the uncertainty principle QMSE 3.12 – 3.13
5.1.3 – 5.1.4 Particle current QMSE 3.14

5.2 Functions and Dirac notation

5.2.1 Introduction to functions and Dirac notation QMSE Chapter 4 introduction
5.2.2 Functions as vectors QMSE 4.1 (up to “Dirac bra-ket notation”)
5.2.3 – 5.2.4 Dirac notation QMSE 4.1 (first part of “Dirac bra-ket notation”)
5.2.5 – 5.2.6 Using Dirac notation QMSE 4.1 (remainder of 4.1)

5.3 Vector spaces, operators and matrices

5.3.1 – 5.3.2 Vector space QMSE 4.2
5.3.3 – 5.3.4 Operators QMSE 4.3 – 4.4
5.3.5 – 5.3.6 Linear operators and their algebra QMSE 4.4 – 4.5

Week 6

6.1 Types of linear operators

6.1.1 – 6.1.2 Bilinear expansion of operators QMSE 4.6
6.1.3 – 6.1.4 The identity operator QMSE 4.8
6.1.5 – 6.1.6 Inverse and unitary operators QMSE 4.9 – 4.10 (up to “Changing the representation of vectors”)

6.2 Unitary and Hermitian operators

6.2.1 – 6.2.2 Using unitary operators QMSE 4.10 (starting from “Changing the representation of vectors”)
6.2.3 – 6.2.4 Hermitian operators QMSE 4.11
6.2.5 – 6.2.6 Matrix form of derivative operators QMSE 4.12 – 4.13

6.3 Operators and quantum mechanics

6.3.1 – 6.3.2 Hermitian operators in quantum mechanics QMSE 5.1
6.3.3 – 6.3.4 General form of the uncertainty principle QMSE 5.2 (up to “Position-momentum uncertainty principle”)
6.3.5 – 6.3.6 Specific uncertainty principles QMSE 5.2 (starting from “Position-momentum uncertainty principle”)

Week 7

7.1 Angular momentum

7.1.1 – 7.1.2 Angular momentum operators QMSE Chapter 9 introduction and 9.1 (first part)
7.1.3 – 7.1.4 Angular momentum eigenfunctions QMSE 9.1 (remainder)

7.2 The L squared operator

7.2.1 – 7.2.2 Separating the L squared operator QMSE 9.2
7.2.3 – 7.2.4 Visualizing spherical harmonics QMSE 9.3
7.2.5 – 7.2.6 Notations for spherical harmonics QMSE 9.4

7.3 The hydrogen atom

7.3.1 – 7.3.2 Multiple particle wavefunctions QMSE Chapter 10 introduction and 10.1
7.3.3 – 7.3.4 Solving the hydrogen atom problem QMSE 10.2 – 10.3 (up to “Bohr radius and Rydberg energy”)
7.3.5 – 7.3.6 Informal solutions for the relative motion QMSE 10.3 (“Bohr radius and Rydberg energy”)

Week 8

8.1 The hydrogen atom solutions

8.1.1 – 8.1.2 Separating for the radial equation QMSE 10.4 (up to “Solution of the hydrogen radial wavefunction”).
8.1.3 – 8.1.4 Radial equation solutions QMSE 10.4 starting with “Solution of the hydrogen radial wavefunction”, and 10.5
Note: The section QMSE 10.4 contains the complete mathematical details for solving the radial equation in the hydrogen atom problem. For this course, not all those details are required and they are consequently not all covered in the online lectures, so the additional detail, in particular on power series solutions in section QMSE 10.4, is optional for the student.

8.2 Approximation methods

8.2.1 Approximation methods – introduction QMSE Chapter 6 introduction

8.2.2 – 8.2.3 Potential well with field QMSE 6.1

8.2.4 – 8.2.5 Use of finite matrices QMSE 6.2

8.3 Perturbation theory

8.3.1 Constructing perturbation theory QMSE 6.3 (up to "First order perturbation theory")

8.3.2 – 8.2.3 First and second order theories QMSE 6.3 (starting at "First order perturbation theory" up to "Example of well with field")

8.3.4 – 8.3.5 Applying perturbation theory QMSE 6.3 (starting at "Example of well with field")

Week 9

9.1 Tight binding and variational models

9.1.1 – 9.1.2 Tight binding model QMSE 6.5

9.1.3 – 9.1.4 The variational method QMSE 6.6

9.2 Time-dependent perturbation theory

9.2.1 – 9.2.2 Time-dependent perturbation basics QMSE 7.1

9.2.3 – 9.2.4 Simple oscillating perturbations QMSE 7.2 (first part)

9.2.5 – 9.2.6 Transition probabilities QMSE 7.2 (second part)

9.3 Applying time-dependent perturbation theory

9.3.1 – 9.3.2 Fermi's Golden Rule QMSE 7.2 (third part)

9.3.3 – 9.3.4 Refractive index QMSE 7.3