Summary of Course

Reading material for Weeks 1 and 2: Krane section 3.3 and Bransden-Joachain 1.1

• Week 1: Lecture 1, 2: The electromagnetic thermal emission of bodies. Black body - perfect absorber. explain Kirchoff's - good emitter is good absorber. Define the spectral intensity I(λ, T). Definition of black body. Stefan's Law, Wien's displacement Law, Planck spectral distribution formula. Derivation of Wien's law from Planck. CMB radiation and examples.

Lecture 3: Derive Stefan-Boltzmann Law from Planck's spectral distribution. Recap of classic harmonic oscillator and beats.

• Week 2: Lecture 1, 2: Black Body Radiation - Recap of Week 1. Recap of mechanical waves. Emittance in frequency space. Relation between emittance and energy density per unit wavelength range. Counting standing waves.. Average energy kT per mode as the outcome of integrating over energies. Rayleigh-Jeans derivation.

Lecture 3: Recap of probability and probability distribution functions, expectation value and variance of a distribution function. The quantum modification: integral to sum. Derivation of Planck's formula.

Reading for Week 3 - Krane Section 3.1,3.2 ; Bransden-Joachain Section 1.2 ;

•Week 3: Lecture 1, 2: Electromagnetic waves, Equations for E, B fields for EM-waves, Poynting vector, Average intensity, Plane wave-fronts. Photo-electric effect. work function. Stopping potential. The equations:

$$hf - \phi = K_{max}$$

$$K_{max} = eV_s$$

$$\phi = hf_c$$

Critical frequency needed for photo-electric effect - explained by quantum physics but not classical physics.

•Lecture 3: The Millikan experiment; Energy of photons. Review of relativistic kinematics: momentum, kinetic energy, total energy, conservation of energy and momentum in collisions

Reading for Week 4 - Krane Section 3.4-3.6 and 3.1 ; Feynman Lectures Volume 3 - Chapter 1,2.

•Week 4: Lecture 1, 2: Summary of relativistic kinematics. Compton scattering, derivation of wavelength shift formula. Other photon processes: bremsstrahlung

•<u>Lecture 3</u>: Young's double slit experiment. Review of complex notation for oscillations. Revisiting Interference. The equations

$$
\begin{aligned}
\omega^2 &= c^2(k_x^2 + k_y^2 + k_z^2) \\
\vec{p} &= \hbar\vec{k} \\
E &= \hbar\omega = hf
\end{aligned}
$$

for photons. Superposition property of the solutions to Maxwell's equations.

Reading for Week 5 - Krane Section 3.1 (X-ray diffraction and Bragg's Law) + Chapter 4. Bransden and Joachian Section 1.6

•<u>Week 5: Lecture 1, 2</u>: Double slit interference, single slit diffraction, diffraction gratings, Crystals as diffraction gratings, Bragg's Law, Wave properties of particles, De Broglie's hypothesis.

•<u>Lecture 3</u>: Davisson-Germer experiment, neutrons and protons diffraction, Electron microscope.

Reading for Week 6/7 - Chapter 4 of Krane. Chapter 2 (and Appendix) of Bransden and Joachain

•<u>Week 6: Lecture 1, 2</u>: Electron 2-slit experiment and interference. Photon interfence : superpose $E^{(1)}$, $E^{(2)}$ solutions to linear Maxwell's equations and $I \propto E^2$. Electron interfence: Superpose $\Psi^{1)}(x, t)$, $\Psi^{(2)}(x, t)$ - solutions to linear equations of QM (mention Schrodinger to be studied later). Ψ complex, and $\Psi^*\Psi$ as probability density. The wavefunction for a free particle of definite wavenumber. Hence first sign of Heisenberg Uncertainty. The Gaussian wave-packet as superposition of plane waves.

•<u>Week 6: Lecture 3</u>: Start studying Gaussian wave-packets to describe localised objects. Calculate $< x >$, $< x^2 >$, Δx. Explain calculations of $< p >$, $< p^2 >$. The Gaussian in k-space (or momentum space). Hence $\Delta x \Delta p$ =hbar/2 for Gaussian wave-packets. And $\Delta x \Delta p \geq$ hbar/2 for general wavepackets. Hesienberg-Uncertainty principle - A fundamental limitation on accuracy of simultaneous measurements of x, p.

<u>Week 7 : Reading week.</u>

Reading for Week 8 - Chapter 4 of Krane. Chapter 2 (and Appendix) of Bransden and Joachain

•Week 8: Lecture 1, 2: Summary of previous lectures; Heisenberg Uncertainty Principle in 3 dimensions. Application of HUP to single slit experiment. Diffraction limit of microscopes. Heisenberg's thought experiment - The Heisenberg microscope. HUP and double slit experiment - Complementarity. HUP in terms of wavelengths $\Delta x \Delta\lambda$.
•Week 8: Lecture 3: Energy-time uncertainty. Group Velocity of de Broglie Waves - Relativistic and non-Relativistic.

Reading for Week 9 - Chapter 5 of Krane + Parts of Chapter 3 and 5 of Bransden and Joachain.

Week 9: Lecture 1, 2: Postulates of quantum physics (Reading - Bransden and Joachain - Chapter 5). Wavefunctions, Superposition, Observables and their corresponding operators. The time-dependent Schrodinger's equation for a non-relativistic particle in presence of potential energy function $\Psi(x, t)$.

Week 9: Lecture 3: Separation of variables - Ansatz $\Psi(x,t) = \psi(x)f(t)$. Time- independent Schrodinger equation. Energy eigenstates. Time evolution of energy eigenstates. Free Particle in an infinite potential well. Derivation of energy level formula. (See Krane section 5.4).

Reading for Week 10 - Krane Chapter 5, Parts of Chapter 3 and 5 of Bransden and Joachain.

Week 10: Lecture 1, 2: Start with the infinite potential well hamiltonian eigenfunctions. Normalisation. Calculating the probability of the particle being in a specified region of the box. Orthogonality. Calculation of average energy. Time evolution of energy eigenstates. Time evolution of superpositions.
Week 10: Lecture 3: Summary of the previous lecture, Calculating the energy of an eigenfunction of the Hamiltonian by applying the Hamiltonian, e.g. finding E_n from $\psi_n(x)$. Outline calculation of uncertainties Δx and Δp in eigenstate $\psi_n(x)$

Reading for Week 11 - Krane Sec. 5.5 ; Br and Jo Chapter 4 - see pictures of probability distribu- tions and classical limit ; Dr Russo notes (under the heading "textbooks" in QMPLUS) - see oxygen molecule - for discussion of quantum mechanics of molecule vibrations also see sec 1.3 and 9.4 of Krane.

Week 11: Lecture 1, 2: Review of the classical mechanics of simple harmonic oscillator. Schrodinger's equation. Energy spectrum. Ground state wavefunction - start with ansatz

Ae^{-ax^2} and determine a in terms of k,m, and the ground state energy. Excited states from ladder operator. Normalization condition. Uncertainties DxDp.

Week 11: Lecture 3: Summary, Parity of wavefunctions, Offset potentials, Use of normalizability condition in deriving physical wavefunctions.

Reading for Week 12 - See Krane section 6.5 for the derivation, as well as the successes and failures of the Bohr model. Rotational and Vibrational modes of molecules ; Specific heat capacities. See Krane section 1.3, section 9.4 and 9.5.

Week 12: Lecture 1,2: The Ehrenfest theorem (no proof given). The Bohr model of the atom, Rotational and Vibrational modes of molecules; Specific heat capacities. Discussion of last year exam paper.