**B27MW syllabus (2016/17) – Semester 2, Second Half**

**Dr. Paul Dalgarno**

**Weeks 6-10 (Sboros taught Weeks 1-5)**

Chapter sections refer to the recommended textbook Sears and Zemansky’s University Physics, with Modern Physics Technology Update, Hugh Young and Roger Freedman, **Thirteenth edition**, Pearson

**Week 6** – **Wave-Particle Duality (Chapter 38, page 1389 and Chapter 39 Page 1416)**

This week covers part of chapter 38 from University Physics, introducing the idea of photons, light as a particle and discussing the wider impact of wave-particle duality and uncertainty. This is crucially important and its vital students are comfortable with the photoelectric effect, E=hf and the implications of wave-particle duality.

Learning Objectives:

* Describe and quantify photoelectric effect
* Know and use E=hf
* Describe Compton Experiment
* Know relationship for photon momentum
* Describe photon pair production
* Describe and use de Broglie relationship
* Describe operation of Electron Microscope

**Lecture 1**

Chapter 38.1 – 38.2: Photoelectric Effect and Photon Production

* Reminder of wave nature of light (Young, Faraday, Maxwell)
* Description of the photoelectric effect experiment and results
* Threshold Frequency and Stopping Potential
* Einstein’s Photon Explanation
* X-Rays Production

**Lecture 2**

Chapter 38.3: Compton Scattering and Pair Production

* Description of Compton Scattering experiment
* Photon momentum
* Derivation of Compton scattering relationship
* Gamma ray and photon pair production

**Lecture 3**

Chapter 39.1: Electron Waves and Electron Microscope

* de Broglie’s proposal and relationship
* Diffraction and the wave nature of electrons
* Wave-particle Duality
* Application: Diffraction limit and the Electron Microscope

**Week 7** – **The Atomic Model (remainder of Chapter 38 and 39)**

This week covers spectral emission, the remainder of chapter 39 on atomic models, energy levels, the Bohr model for the atom and applications such as Laser and fluorescent molecules.

Learning Objectives:

* Describe Black Body Radiation
* Be able to explain Planks radiation law when given equation
* Explain Rutherfords experiment and model of the atom
* Explain absorption and emission of atomic spectra and failure of classical model
* Explain Bohr model of the atom
* Derive discrete angular momentum of Bohr Orbits
* Know and use Bohr Radius of atom
* Explain and quantify Hydrogen energy levels
* Conceptually explain how laser and fluorescence molecules work

**Lecture 1**

Chapter 39.2 – 39.3, 39.5: Atomic Spectra and Black Bodies

* Continuous spectra and Blackbody Radiation
* Planck Radiation Law (description only)
* Atomic spectra, absorption and emission
* Lyman, Bascher and Paschen series Observation
* Rydberg relationship (with constant R)

**Lecture 2**

Chapter 39.3: Rutherfords Atom and the Bohr Model of the Atom

* Rutherford experiment and model of the atom
* Failure of classical physics to atomic model
* Bohr model and quantised energy levels
* Derivation of discrete momentum (L=nh/2π)
* Derivation of Bohr radius

**Lecture 3**

Chapter 39.3 and 39.4: Examples – Hydrogen, Laser and Fluorescent Molecules

* Application of Bohr model to atomic spectra
* Hydrogen energy levels
* Laser as an example of energy levels in action (conceptual)
* Fluorescent Molecules as example of energy levels (conceptual, not in book)

**Week 8 – Quantum Physics (Chapter 38 section 4, Chapter 39 section 6, Chapter 40 in parts)**

This begins with a discussion of uncertainty, from end of chapters 38 and 39. It then covers the very basics of quantum and particle physics from chapters 40 and 41 (all conceptual). There is a high level of technical detail in the textbook not to be covered. Its important students are comfortable with uncertainty principle, and I discussing the basic idea of matter being described by a wavefunction. Flexibility is provided here for lecturers to discuss impact and interest of quantum physics, or to provide more examples on wave-particle duality, atomic models, and uncertainty if preferred.

Learning Objectives:

* Know and use expression for position and momentum uncertainty principle
* Know and use expression for energy and time uncertainty principle
* Describe qualitatively the meaning of a quantum wavefunction applied to matter
* Describe qualitatively a wavepacket
* Know and use energy levels for waves on string (eq 5) and that of free particle (equation 8)
* Derive expression for energy levels of particle in a box (eq 31) and draw diagram

**Lecture 1**

Chapter 38.4 and 39.6: Uncertainty

* Electron diffraction and probability
* Derivation of uncertainty relationship (eq 16, ch 38)
* Uncertainty relationships for position and momentum, energy and time
* Examples and consequence of uncertainty
* Uncertainty and fluorescence lifetime (not in book, conceptual example)

**Lecture 2 – Quantum Physics**

Chapter 40.1, 40.2 and 40.4 : Quantum Mechanics

(This lecture conceptually covers just the basic concepts with little mathematical detail)

* The concept of the wavefunction and probability distribution
* Application to a particle (idea behind the Schrodinger Wavefunction)
* Energy of wave on strong (eg 5) and particle (eq 8)
* Energy and diagram of particle in a box and larger meaning (atomic orbits etc)
* Principle of quantum mechanical tunnelling
* Everyday examples of quantum tunnelling and quantum physics

**Lecture 3 – Quantum Physics Impact**

Chapter 41: Atomic Structure and Particle physics and Chapter 44: Nuclear Physics

(This lecture slot is “free” and offers non-examinable material. In Edinburgh, it will be used to cover the wider implication of quantum physics with some examples. Chapter 41 and 43 are used only as a rough guide to content.)

* Discuss quantum mechanical properties or particles (Mass, charge and spin)
* Quantum applications: MRI, entanglement, computing etc
* Philosophy and impact of quantum physics

**Week 9 – Molecules and Condensed Matter**

This week covers concepts in chapter 42 (Molecules and Condensed Matter). It is almost entirely conceptual with learning objectives based around device operation and description more than mathematical application. Lecturers are free to include additional numerical examples if comfortable.

Learning Objectives:

* Described types of molecular bonds
* Describe, and draw schematic for energy levels in molecules
* Describe energy bands of Insulator, Metal and Semiconductor
* Explain principle of semiconductor
* Explain operation, with diagram, of p-n junction, LED and Transistor

**Lecture 1 – Molecules and Matter**

Chapter 42.1-42.3: Molecular Bonds, Spectra and Solids

* Types of molecular bonds (Ionic, Covalent, van Der Walls and Hydrogen)
* Rotational Energy Levels in Molecules
* Vibrational Energy in Molecules
* Structure of Solids - crystallography

**Lecture 2 – Energy Bands and Semiconductors**

Chapter 42.4, 42.6: Energy Bands and Semiconductors

(Conceptual, and focus on semiconductor applications. Do not include chapter 42.5 on Mathematics of density of states, although conceptual discussion can be included)

* Concept of Energy Bands in Solids
* Insulator vs Metal vs Semiconductor
* Principles of Semiconductor
* Carriers, Holes and Impurities

**Lecture 3 – Semiconductor Devices**

Chapter 42.7: Semiconductor Devices

(Solar Panels and OLEDS are not in the book, but can be included if lecturer wishes to)

* The p-n Junction
* The LED
* The Transistor
* Solar Panels
* Organic Semiconductors (OLEDS and beyond)

**Week 10 – Forces of Nature**

This week covers concepts in chapter 43 (Nuclear Physics) and 44 (Particle Physics) focussing on the four fundamental forces and radioactivity. Some material has been influenced by the old Fields and Forces handbook and it may be useful to refer to that for reference (but do not teach from it)

Learning Objectives:

* Know the four fundamental forces and rank in order of range or magnitude
* Describe strong force and role in atomic stability
* Describe weak force and role in atomic stability
* Know and use atomic notation
* Describe alpha, beta and gamma radiation
* Know and use expression for radioactive decay
* Know and use expression for radioactive half life

**Lecture 1**

Chapter 44.3: The fundamental forces of Nature. *(chapter 12 old B27FF handbook)*

* Revisit atomic model and discuss electrostatic forces and what holds atom together
* Introduction to the four fundamental forces (ch 44.3)
* Strong force as nucleus stabilizing factor
* Weak force and radiative decay
* *Bonus: gravity waves*

**Lecture 2**

Chapter 43.1, 43.3: Introduction to radiation

* The atomic nucleus
* Atomic Number Notation
* Nuclear stability
* Alpha, Beta and Gamma decay (with examples)

**Lecture 3 – Activities, Half-Life, Fission, and Applications**

Chapter 43.4 – 43.8: Radioactive half-life and applications of radioactivity and fusion/fission

* Derivation and form of radioactive decay rate (equation 17)
* Definition of half life, typical examples
* Radioactive dating
* Health and radiative healthcare
* Nuclear reactions, fission and fusion.