Modern Physics F3241

An overview of what we will cover in each lecture

Lily Asquith

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Lecture 0 Module Info Monday 30 Sep

"Reality is merely an illusion, albeit a very persistent one." – Albert Einstein

Lectures (22) :	MON 3PM & FRI 3PM (JMS BLT)
Classes (10) :	MON 6PM (JMS BLT)
Workshops (10) :	TUE 6PM (PEV1-2A12)
Assessment :	Two assignments (10% each) in weeks 8 and 11
	Unseen exam (80%)
Web :	canvas
Attendance :	get an account polleverywhere sign register: ilovephysics
Books :	Tipler & Llewellyn

Watch:Voyage into the world of atoms: You Tube

Read: The pdf of this document has hyperlinks in blue and is available on github

Key formulae:

Newton's 2^{nd} law:	$F = \frac{mv^2}{r}$
Electric force:	$F = q\ \mathcal{E}$
Magnetic force:	$F = qv\mathcal{B}$
Faraday's constant:	$F = N_A\ e$
Charge	$e \approx 1.60 \times 10^{-19}$ C

Watch:

Thomson's cathode ray experiment

Millikan's oil drop experiment

Read: Chapter 3.1 of Tipler & Llewellyn

Electricity is made up of particles, and they are tiny compared to 'atoms'.

Key formulae:

Wein's displacement law:	$\lambda_m T \approx 2.90 \times 10^{-3} m \cdot K$
Stefan-Boltzmann law:	$P = \sigma T^4 W \cdot m^{-2}$
Rayleigh-Jeans equation:	$U(\lambda) = \frac{8\pi}{\lambda^4} k_B T$

Watch: Blackbodies

Read:

Chapter 3.2 pages 119-121

This is a nice explanation of colour

Everything emits radiation.

The intensity and λ of blackbody radiation depends only on its temperature.

Classical theory predicts short wavelength radiation should be emitted in vast quantities, which is not observed.

Key formulae:

Quantisation of energy:	$E_n = nhf = nh\frac{c}{\lambda} J$
Planck's radiation law:	$U(\lambda) = \frac{8\pi hc}{\lambda^5} \frac{1}{e^{hc/\lambda kT} - 1}$
Planck's constant:	$h \approx 6.63 \times 10^{-34} J \cdot s$

Watch: Planck's contributions

Read: Chapter 3.2 Planck's law

UV catastrophe goes away if energies of 'oscillators' can only take particular values: quanta.

We never realised this before because the values are so very close together.

Lecture 4 The Photoelectric effect Monday 14 Oct

Key formulae:

Photoelectric effect:	$eV_0 = hf = KE_{max} + \Phi$

Watch:

Hertz's radio

Read:Chapter 3.3 The Photoelectric effect

- *At the electron scale, EM radiation* ***does not behave as a wave should****.*
- *The intensity of the EM radiation is ineffectual in releasing electrons if λ is not of a certain value*
- *Different materials have different maximum KE thresholds for emitted electrons.*

Lecture 5 The Compton Effect Friday 18 Oct

Key formulae:

Bragg condition:	$2d \sin\theta = m\lambda$
Compton effect:	$\Delta\lambda = \frac{h}{mc}(1 - \cos\theta)$

Watch:

Discovery of x-rays

Read: Chapter 3.4 X-rays and the Compton effect

- *Some EM radiation can pass right through solids.*
- *Wavelength so tiny that crystals must be used for diffraction grating*
- *Scattering x-rays from crystals changes their wavelength.*

Key formulae:

Balmer's empirical formula:	$\lambda_n = 364.6 \frac{n^2}{n^2-4}$ nm
Rydberg-Ritz formula:	$\frac{1}{\lambda_{mn}} = R\left(\frac{1}{m^2} - \frac{1}{n^2}\right)$ for $n > m$

Watch:

Sodium absorption lines

Read: Chapter 4.1 Atomic spectra

There are gaps in the EM spectrum at different wavelengths when burning metals.

There are bright lines in the sun's EM spectrum at particular wavelengths.

There is a formula that describes the patterns of dark/bright lines

Lecture 7 Rutherford Friday 25 Oct

Key formulae:

Coulomb potential:	$V = -\frac{kZe^2}{r}$
Centripetal force:	$F = \frac{kZe^2}{r^2} = \frac{mv^2}{r}$
Total energy:	$E = \frac{1}{2}mv^2 + \left(-\frac{kZe^2}{r}\right) \sim -\frac{1}{r}$

Watch:

Discovery of the nucleus: You Tube
The T ('skin'tillation) : You Tube
Read: Chapter 4.2 150-153

- *Firing α particles at a gold foil occasionally results in massive deflections.*
- *The positive charge in an atom is concentrated at its centre: a nucleus.*
- *The nucleus is much smaller than the atom, and is different for different atoms.*

Lecture 8 Bohr Monday 28 Oct

Key formulae:

Planck's theory:	$hf = E_i - E_f$
Angular momentum:	$L = mvr = n\hbar$ for $n = 1, 2, 3, \ldots$
Radii of stationary orbits:	$r_n = \frac{n^2\hbar^2}{mkZe^2} = \frac{n^2 a_0}{Z}$
Bohr radius:	$a_0 = \frac{\hbar^2}{mke^2} = 0.529\AA$
Allowed energies:	$E_n = -\frac{Z^2 E_0}{n^2}$ for $n = 1, 2, 3, \ldots$
Binding energy of H:	$E_0 = \frac{mk^2e^2}{2\hbar^2} = 13.6$ eV

Watch:

Atomic energy levels: You Tube

Read: Chapter 4.3 159-163

- *Bohr modelled the nuclear atom as a little solar system.*
- *Electrons don't fall into nucleus if they are in certain stable orbits*
- *EM radiation results from electrons moving between stable orbits.*

Lecture 9 De Broglie Friday 1 Nov

Key formulae:

De Broglie relations:	$f = \frac{E}{h}$ and $\lambda = \frac{h}{p}$
Wave equation:	$\frac{d^2 y}{dx^2} = \frac{1}{v^2}\frac{d^2 y}{dt^2}$
Phase (wave) velocity:	$v_\phi = f\lambda = \frac{\omega}{k}$
Group (packet) (particle) velocity:	$v_g = \frac{d\omega}{dk} = v_\phi + k\frac{dv_\phi}{dk}$

Watch:

The double slit experiment: You Tube

Read: Chapter 5.1

- *The wave-particle nature of photons could be applied to all particles.*
- *Electrons and even molecules are observed to behave like waves*

Key formulae:

Probability:	$P(x)dx = \|\Psi\|^2 dx$
Uncertainty principle:	$\Delta E \Delta t \geq \frac{\hbar}{2}$ and $\Delta x \Delta p \geq \frac{\hbar}{2}$
Particle in a box :	$\bar{E} \geq \frac{\hbar^2}{2mL^2}$

Read: Chapter 5.5

Watch:

Animation of wavefunction: YouTube

Decoherence and entanglement: YouTube

Quantum Mechanics is an embarrassment: YouTube

Lecture 11 The Nucleus and radioactivity Friday 8 Nov

Key formulae:

Mass number:	A = Z+N
Mean radius:	$R = (1.07 \pm 0.02)A^{1/3}$fm; ($\sim$1–10 fm)
Binding energy:	$B_{nuclear} = (ZM_H + Nm_n - M_A)c^2$
Nuclear force range:	$R = c\Delta t = c\hbar/\Delta E = \hbar/m_\pi c$; ($<$ 3fm)
Decay rate:	$R = -\frac{dN}{dt} = \lambda N_0 e^{-\lambda t} = R_0 e^{-\lambda t}$
Half life:	$t_{1/2} = \frac{\ln 2}{\lambda} = 0.693\tau$
Radioactivity:	$\alpha(^4He)$; $\beta(e^{-/+})$; γ

Read:

Is the whole the sum of its parts?

Chapter 11.3

Watch:

Discovery of radioactivity:

Lecture 12 Fission & Fusion Monday 11 Nov

Read: Chapter 11.8
Watch:

Fusion: YouTube

Fission: YouTube

Lecture 13 Elementary Particles Friday 15 Nov

- ✍ What are nucleons made of?
- ✍ What holds a nucleon together?
- ✍ Can particles have negative energy?
- ✍ Why do most elementary particles not form matter?
- ✍ How can quarks interact with leptons?
- ✍ How can we explain nuclear instability in terms of elementary particles?

- ✍ What are we looking for with the ATLAS experiment at CERN?
- ✍ What are we looking for with the NOvA experiment at Fermilab?
- ✍ What are we looking for with the SNO+ experiment at SNOlab?
- ✍ What are we doing to look for Dark Matter?

Lecture 15 Wrap Up Friday 22 Nov

- ✍ A review of the important things we have covered
- ✍ How this course links to your future studies

Lectures 16 – 22 : Special Relativity with Stephen Wilkins

Check canvas!