PHYS 340: TOPICS for EXAM 2015

The style of the exam is as in previous years – you will have to answer 3 short questions and 2 long questions, drawn from a set of 5-6 short questions in part A, and 4 long questions in part B.

In the questions I tend to mix up themes a little bit. You can get some idea of the style of the questions by looking at previous exams – but note that the material to be examined changes every time I give this course. One obvious difference from previous years is that I will be giving almost no quantitative questions, and I will not be looking much at foundational questions in quantum mechanics (which previously played a role in the last part of the course).

The themes to be examined are as follows:

SPECIFIC TOPICS

Atomic ideas – from Demokritus to quantum mechanical. Details of Demokritus theory
Platonic arguments, for Forms, and timeless unchanging entities we do not experience directly.
Aristotle on elements, causes, cosmology; Aristotelian dynamics.
Greek astronomy – particularly Ptolemaic theory. Describing the apparent motions of the celestial bodies.
The developments of Kepler, Copernicus, Brahe in astronomical ideas

The ‘experimental philosophy’ of Bacon and dynamics in the form of laws of motion.
Galileo’s work – dynamics, and dynamical theories; telescopic observations, experiments on dynamics.
Newtonian revolution - dynamics in the form of universal laws of motion. The universal law of gravitation. How these are used in practise.
Light – the theories of Huyghens and Newton (aether waves vs particles), their strengths and weaknesses, and their predictions. Details on refraction and reflection.
The experiment of Young, and what it demonstrated.
How light is described in EM theory; and why EM waves are inevitable.
The EM Field (the “A-field”). How it interacts with electric charge, which distorts A-field to produce E and B fields. Experiments which show this. Electromagnetic induction, showing how varying E in time produces B, and vice-versa – why this leads to EM waves. Experiments on induction.

Curved space – what it means, how one establishes that a geometry is flat or curved “from inside” the geometry – the example of the internal geometry of a 2-dimensional surface (which we can look at from the vantage of our 3-d geometry).

Curved spacetime and General Relativity: How the spacetime field couples to mass/energy, which can lead to strong distortions around very massive bodies. How spacetime curvature itself possesses energy, so that one can get black holes. Definition of a black hole – event horizon. How black holes form in Nature – collapse of massive stars. Tests of general relativity (GR) – bending of light, red shift, gravitational lensing, binary pulsar and gravitational waves, etc. How GR leads to prediction of the Big Bang. Evidence for the Big Bang (Hubble, microwave background, etc).

Quantum Mechanics: The idea of superposition of states; how a quantum state of a particle travels as a ‘probability wave (wave-particle duality). How when a wave is confined we get certain discrete states with definite wavelengths and energies. Transition of electrons between different energy levels in an atom, with emission and absorption of photons. The different possible states of an electron around a nucleus, their energy levels, what they look like. Quantum tunneling of quantum states through an energy barrier.

Applications of Quantum mechanics:

Nuclear physics and stars – the structure of a nucleus, with neutrons and protons, the strong attractive force between all nucleons, and the repulsive Coulomb force between protons only. Nuclear fission and fusion, how tunneling allows fission for heavy nuclei and fusion for light nuclei if the light nuclei are moving very fast. Fusion in the centres of stars, the cycle of fusion of increasingly heavy nuclei until Fe is reached and fusion stops – leading to white dwarfs for light stars and supernovae and either neutron stars or black holes for heavy stars.

Chemical bonds and biology – how chemical bonds result from electrons tunneling between atoms and the 'spreading out' of the electronic wave-functions. Catalysis, in which a 3rd party lowers the energy barrier to this tunneling. Autocatalysis, in which a molecule catalyzes its own creation. How this allows evolution of very complex systems in conjunction with external energy.

Some astrophysics – formation of stars and planets, life cycles of stars. The beginning of the universe, Big Bang and microwave background, Supermassive black holes in galaxies. Quantum black holes.

GENERAL QUESTIONS

The idea of building blocks for matter, etc, from ancient Greek ideas (elements, atoms, Platonic forms, etc.), via Newtonian particles, to fields, quantum mechanics, and wave-particle duality, and to the building blocks of modern physics.

Dynamics – the dichotomy between change and fundamental constituents or forms that are unchanging, how to describe dynamics in different theories (Ptolemaic, Newtonian, fields, etc.).

How to investigate Nature – by observation, theoretical ideas, experiment. The relationship between observations, experiments, and the "Real world". The way in which theory and experiment/observation work together. The disturbance of objects by experiments/observations of them. The limitations to human senses, and how physics is able to get past this.

Measurement and definition of physical quantities, relationship of these to entities in the real world – and whether or not these entities actually exist. Measurement of time & distance. How existence of fields is established.

The idea of a "Field" – which itself may not be directly detectable, and which only interacts with certain "charges" (electric charge for EM fields, and mass/energy for the spacetime field), so that these charges distort the Fields (these distortions are also, confusingly, called fields). The distortions then act back on the charges via forces and cause them to move. Mediation of forces between 'charges' via "Fields".