Phys 340: PRACTISE REVISION QUESTIONS: No (1)

Many of the following questions are the kind that might appear in an exam as short questions, or as part of a longer question. The exam will in fact be a mixture of short (15 minute) and long (45 minute) questions. There will be a choice- you will have to answer a few out of a selection of questions.

This is the first set of practise questions. You should attempt them and be ready to ask questions about them, either in a tutorial or in the last few classes of the course.

(1) **Length, Mass, and Time Scales** (These will help you get a feeling for some of the magnitudes in physics).

(a) Name something that is of the following size (ie., typical length, width, etc.):

(i) 1 μm ($= 10^{-6}$ m).
(ii) 10^6 km.
(iii) 1 m
(iv) 10 light years (NB: 1 light year = 10 trillion km = 10^{13} km = 10^{16} m).
(v) 1 nanometre = 10^{-9} m.
(vi) 1 Angstrom = 10^{-10} m = 1/10 nanometre.
(vii) 1 Fermi = 10^{-15} m.
(viii) 10^5 light years = 100,000 light years
(ix) 10^9 km.
(x) 10^4 km.
(xi) 50 million light years = 5×10^7 light years.
(xii) 2 million light years = 2×10^6 light years
(xiii) 2.5 billion light years = 2.5×10^9 light years.
(xiv) 14 billion light years = 1.4×10^10 light years.

(b) Give estimates for the **mass** of the following objects (giving your justification or argument for the answer if you think it is necessary):

(i) A jumbo jet (mostly empty space inside)
(ii) the water in the university swimming pool
(iii) a microbe, of size 10 μm.
(iv) A hydrogen atom
(v) the moon (diameter $\sim$ 3,000 km).
(vi) The Milky Way galaxy (which contains $\sim 10^{11}$ stars, of mass similar to the sun).

(c) You set off from Vancouver in a car which travels at 100 km/hr without ever stopping, day or night. Estimate how long it will it take for you to travel the following distances (you may have to estimate some of the distances, in which case give your estimates):

(i) 10 kms.
(ii) To Toronto
(iii) Once around the earth
(iv) to the moon
(v) to the sun
(vi) to Pluto
(vii) to the nearest star (Proxima Centauri, 4.3 light years away)
(viii) to the centre of our galaxy, 25,000 light years away.

(2) **Atoms, Old and New**

(i) Explain briefly the essential features of the atomic picture of matter proposed by Democritus. What were the defining features of the atoms, and what led him to these? And how was the structure of solids supposed to be explained?

(ii) Explain now the modern picture of a hydrogen atom. You should discuss the constituents of the atom, and how they relate to each other, and what determines the atomic structure. It is not necessary to explain quantum mechanics but you should say in what way it is responsible for the structure of the electronic energy levels.

Democritus did not explain the nature of light, in his picture (although he probably thought it was another particle, which could scatter off the atoms). Explain how light interacts with atoms in the quantum theory. Assuming that the Rydberg constant R which determines the electronic energy levels of Hydrogen is $R = 13.6\ eV$, give the energy of 2 different spectral lines for a Hydrogen atom.

(3) **Forms, Old and New**

(i) Explain briefly Plato's argument that physical geometrical objects as well as other physical objects are not the most primitive objects of which the world is made- which instead were "forms". What in his view were these more primitive forms, and what is the relationship between them and the original physical objects?

(ii) Newton's laws describe the motion of point particles, or collections of them. These laws prescribe relationships between the accelerations and masses of the particles, and the forc4es acting on them. Explain what these relations are (ie., what are the relevant laws).

Can the quantities "mass" and "force" in your opinion be described as Platonic forms? If so, in what way?

(iii) How, according to Descartes, will a simple body move, when not impeded by another body? How, on this basis, does Descartes explain gravitation and the motions of the planets?

(iv) In quantum mechanics, the wave-function $\psi(\mathbf{r}, t)$ is a mathematical function describing the amplitude of a wave. In what way is this be used to describe the motion of a particle?

(4) **The Astronomical Revolution**

(i) Until Galileo turned his telescope to the heavens, the known universe consisted of the earth, plus the sun, moon, and 5 planets revolving around the earth- and finally the fixed stars. Describe briefly the astronomical discoveries made by Galileo, which in his hands completely disrupted this picture.

(ii) The wave and particle theories of light each had points in their favour at the time of Newton. Give one argument in favour of each theory, which could have been used at that that time. In what way were these arguments relevant to the reflecting and refracting telescopes then being used?

(iii) The known universe has grown enormously in the last century, and so has our understanding of it. One example is the physics of stars. Explain briefly:

How we now know what is the composition of the stars? And how does quantum mechanics play a role in the process that powers stars during their long lives?

(5) **Geometry, Motion, and Physics**

(i) Euclidean geometry, as formulated by Euclid, is a purely mathematical description of relations between objects which we may call points, lines, and angles. Given that it is purely mathematical, why is it possible for it to be tested empirically, ie., in the physical rather than mathematical world? Give 2 tests that one could perform.

(ii) One of the most striking predictions of general relativity is the existence of black holes. What is the observational evidence for such objects? How is it that they are believed to form in the first place?

(iii) Explain the difference between gravitational mass and inertial mass- and how they were considered to be the same thing in Newton's law of gravitation. Describe Einstein's thought experiment, in which he argues that they are exactly the same.

(6) **Scientific Method**

(i) Francis Bacon emphasized the great importance in Science of respecting the facts of Nature- the idea of "Immaculate Perception". However the scientific method was not for him a mere gathering of facts. What else was crucial for him? Explain what he meant by the "Experimental Philosophy"?

(ii) Huyghens argued that no conclusion based on experiments could be considered a proof. Nevertheless he argued that some experiments could be more convincing than others for a theory. Explain in what context you think that experiments can make a theory very probably correct, and why.

(iii) In considering how experiments could establish the physical existence or 'physical reality' of some quantity, Einstein gave a criterion for deciding whether some quantity corresponded to an 'element of physical reality'. Explain his criterion. does Einstein's idea contradict the argument of Huyghens?

(7) **Some Quantum Facts and Ideas**

(i) We can estimate the typical velocity of an electron in a Hydrogen atom, using the uncertainty principle. Assume that in the Hydrogen atom the electron is confined in a region of size $\Delta r \sim 10^{-10}$ m around the nucleus. From this estimate the uncertainty in momentum of the electron. Assuming that the typical momentum is the same as this uncertainty, now give the typical velocity of the electron. You can use the following rough numbers: an electron mass is approximately 10^{-30} kg, and Planck's constant is $h \sim 7 \times 10^{-34}$ J secs. Note that no calculator should be necessary to do this problem.

(ii) After Bohr developed his quantum model for the atom in 1912- the so-called 'old quantum theory'- it was only a matter of time before the correct quantum theory was found in 1925. Experiment played little role in this period. However a number of crucial experimental facts were important in the development of the old quantum theory of Planck, Einstein, and Bohr. Give 3 examples of these.