Ph.D. Qualifying Exam UCI May 21, 1974

GENERAL PHYSICS

1. Describe in a sentence or two the physical principles behind 4 of the following::
   a. The Mossbauer effect
   b. A hologram
   c. Cerenkov radiation
   d. Synchrotron radiation
   e. Compton scattering
   f. Gravitational redshift
2. What is the laboratory experimental evidence that the rest mass of the neutrino is very small? Approximately what is the upper limit to the neutrino rest mass derived in this fashion?
3. Neutral potassium has a single s electron outside a closed shell. What are the L, S and J values of its ground state? What is the spectroscopic designation for such a term?
   What are the L, S and J values and term designation for the ground state of singly ionized potassium?
4. The uncertainty principle and the existence of the neutron together set an upper limit to the density of matter consisting of electrons and protons (or other nuclei) that can exist. Calculate this limiting density for matter consisting entirely of electrons and protons, making use of the uncertainty principle in the form $\Delta x \, \Delta p = \hbar$ (which tells you the typical energy that an electron must have as a function of density) and the fact that the mass of the neutron is about 1.3 MeV larger than the mass of the proton.

   Useful numbers: $\hbar = 6.626 \times 10^{-27}$ erg sec

   $m_e = 9.11 \times 10^{-28}$ gram

   1 eV = 1.602×10^{-12} ergs = 1.78×10^{-33} grams

5. Calculate the range of the nuclear force, assumed to be carried by virtual mesons, on the basis of the uncertainty principle ($\Delta E \, \Delta t = \hbar$) and the mass of the meson (about 140 MeV/c^2).

   How does this compare with the size of a typical nucleus?

6. A capacitor of capacitance C is in equilibrium with a heat bath at temperature T. Calculate the root mean square noise voltage across the capacitor.

7. A gas consists of atoms of mass M at temperature T and emits radiation at frequency ν. Compute the root mean square value of the Doppler line width. You may assume that the Doppler width is small compared to ν and that the atoms have velocities small compared to c.

8. The average density of matter in the universe is about 10^{-30} g cm^{-3}. Suppose all the matter were converted into black body radiation, which would be added to the present 3° Kelvin black body radiation. Compute the resulting temperature.

$$U(\nu)d\nu = \frac{8\pi h\nu^3}{c^3} \quad \frac{1}{e^{h\nu/kT} - 1}$$

You may find the following integral useful:

$$\int_0^\infty \frac{x^3 dx}{e^x - 1} = \pi^4/15$$

9. Give approximate numerical values <u>including</u> <u>units</u> for the following:

   a. The mass of the proton
   b. The magnetic field at the earth's surface
   c. The age of the universe
   d. The binding energy of the deuteron
   e. The ionization potential of hydrogen in its ground state
   f. The speed of light in a vacuum
   g. The speed of light in a medium with index of refraction 1.5
   h. The distance from the earth to the sun
   i. The diameter of a hydrogen atom in its ground state
   j. The Bohr magneton

10. Two rings rotate with equal and opposite angular velocity about a common center. Suppose Adam rides on one ring and Eve on the other, and that at some moment they pass each other and their clocks agree. At the moment they pass, Eve sees Adams clock running more slowly than her own, so she expects to be ahead the next time they meet. But Adam expects just the reverse.

    What really happens?

    What simple physical principle indicates that this must be so?

11. Associated with each of the standard conservation laws of physics is some type of transformation under which the laws of physics are invariant. What is the conserved quantity associated with the invariance of physical laws to:

    a. Rotations of the coordinate system
    b. Translations of the coordinate system
    c. Lorentz transformations
    d. Gauge invariance

12. State Kepler's three laws of motion. Use one of them to compute the distance of Jupiter from the sun, given that its orbital period is about 12 years.

13. Why does the earth's magnetic field deviate sharply from a dipole pattern?

14. List any two nuclear reactions responsible for producing energy in the sun.

15. A certain ensemble of nuclei has a mean lifetime τ. Sketch a neat curve for the decay rate as a function of time.