Physics 101 Test - Tuesday, January 15, 1963 - 9 a.m.

Attempt not more than six questions.

1. Give two examples each of systematic and random errors. How is the mean deviation defined, and what is meant by the standard deviation of the mean?

   An oblong envelope is measured by a myopic man holding a ruler against each edge. For the first edge the readings of one end are 1", 1.1", 1.2" and of the other end 8.1", 7.5", 8.3". The ruler is not moved during this operation. Measurements of the other side made similarly are 2.1", 2.3", 2.5" and 2.6", 2.5", 2.7". Find the mean value and the standard deviation of the mean, for the area of the envelope.

2. Describe how the latent heat of vaporization of a liquid together with its surface tension may be used to determine molecular dimensions.

   The most accurate method for determining interatomic spacing in crystals involves diffraction of x-rays. The diffraction of x-rays incident on a ruled reflection grating of 40,000 lines per inch at an angle of 30' 10", near to grazing incidence yields a first maximum at the corresponding angle of reflection. The same x-ray source, gives a Bragg reflection maximum at an angle of 27° for a particular crystal. What is the interatomic spacing corresponding to this reflection?

3. Describe the experiments of Nicholls and Hull to measure the pressure of light. A flat satellite of area 1 sq. m and mass 1 kg, is perfectly reflecting on one side and perfectly absorbing on the other. It revolves close to the surface of the earth, radius 6.4×10^6 m. It is adjusted so that the absorbing side lies toward the sun when the satellite is moving toward the sun, and away from the sun when the satellite moves away from the sun, on an equatorial orbit. The solar constant at the earth is 2 cal/min/cm^2 and 1 cal = 4.2×10^7 erg. How much will the satellite move away from the earth each day, assuming it keeps a circular orbit? $T = 90$ min

4. Derive a simple expression for the refractive index of a solid in a region of anomalous dispersion.

   The refractive indices of a glass are 1.4946 at 21,720 Å, 1.5170 at 5,893 Å and 1.5318 at 4,047 Å, What is the characteristic frequency for the anomalous dispersion in the glass, and if the mass of the electron is 9×10^{-28} gm, and its charge is 4.8×10^{-10} c.g.s. units, how many oscillation electrons/cc are there?

5. ✓ Establish Stefans law, and Wien's law, using a thermodynamic argument. Rayleigh and Jeans calculated the frequency spectra of black body radiation, but found it tended to infinity in the so-called ultra violet catastrophe. Explain the modification necessary to make the Rayleigh Jeans law behave as the experiments. ✓

   The earth receives 2 cal/cm^2 from the sun. What temperature is the sun if Stefan's constant is 5.6×10^{-5} ergs/sec/cm^2/°K^4 and the angular diameter of the sun seen from the earth is 0.53°?

$E = \sigma T^4$ $\quad u(\nu) = B\nu^3 g\left(\frac{\nu}{T}\right)$

$\lambda_m T = \text{const}$

$1 A^\circ = 10^{-10} m = 10^{-8} cm$

6. Derive the wavelength shift in the Compton effect, using a simple argument. The hydrogen nucleus is 1,840 times the mass of the electron. Find the ratio of the change in wavelength of a light ray 6,000 Å scattered from an electron, to a gamma ray of energy 10 Mev scatterëd from a proton. $h = 6.6 \times 10^{-27}$ erg sec
$1 \text{ ev} = 1.6 \times 10^{-12}$ erg

7. Describe the "ether drag" experiment performed by Fizeau and later by Michelson and Morley, using a moving medium of water. If the water moves at 10 m/sec (i.e., 22.5 mph), the path length in the water is 6 m, refractive index of water = 4/3, what fringe shift would be observed. What is the modern explanation of the ether drag?

8. Use a quantum argument to derive the gravitational red shift for a wavelength λ emitted from a star of mass M and radius R. What velocity of recession would give the same wavelength change as a Doppler shift?

9. Using the De Broglie hypothesis, derive a relation showing the dependence of group velocity of a wave representing a particle and the particle itself.

How were the matter waves verified?

For a 10 kev electron, what is the first Bragg reflection angle for a crystal plane separation of 2×10^{-8} cm.

10. What is the uncertainty principle?

Light of wavelength 1,000 Å falls on a shutter in a screen, which is opened for 10^{-5} seconds. Show how the uncertainty principle places limits on the position and momentum of the light after passing the aperture.

11. Derive Schrödinger's time independent equation and show how this will affect the transmission of particles through a barrier.

If the potential energy V of the particle is less than its total energy, what sort of solution is obtained? What sort of solution follows if V is less than E?