5. 20 pts) When a photon of frequency $\nu$ bounces off of a mirror, the mirror recoils, so the light frequency is reduced to $\nu'$. Find the mass of the mirror.

1. 20 pts) A 15 eV electron collides with a H atom in the $n = 1$ state, leaving it in the $n = 3$ excited state. a) What is the energy of the electron after the collision, assuming the H atom is infinitely massive? b) What are the wavelengths of the photons subsequently emitted by the excited H atom?

5)(15 pts) Describe with sketches two experiments that demonstrate the quantum nature of light.

6)(15pts) When light of wavelength 400 nm lands on a certain metal, a .25 V potential is required to stop the emitted electrons. What potential will stop the electrons emitted when 200 nm light is used?

2) (20 pts) Muonium consists of an electron bound to a positive muon (mass 106 MeV/c$^2$). Draw an energy-level diagram for muonium according to the Bohr model. Calculate the energies of the three lowest energy levels and the wavelengths of the spectral lines which arise from these levels.

1) (15 pts) Describe (with words and diagram) and discuss the significance of one of these experiments: Rutherford Scattering, Franck-Hertz, Moseley’s X-Ray spectra, Davisson-Germer.

3)(15 pts) Calculate the DeBroglie wavelength of a) an electron with 2 MeV kinetic energy, and b) a Rb atom (mass 85 u) moving 10 cm/s. c) What is the DeBroglie frequency of a neutron (mass 940 MeV/c$^2$) at rest? (Since frequency is the experimental quantity which can be measured with the greatest precision, the DeBroglie frequency has been recently proposed as the definition of mass.)

6)(15pts) Calculate the frequency of the longest wavelength K series X-ray for uranium, $Z = 92$. You may ignore the reduced mass correction.
1. 20 pts) How many photons are there, on the average, in a mode of the electromagnetic field at a temperature of 300K and a wavelength of 10 μm? What is the mean energy in the mode? (Note: $k_B T = 1/40$ eV at 300 K.)

2. 20 pts) We showed how the famous Bohr formula works for hydrogenlike atoms and, with corrections, for X-Ray spectra involving inner electron shells. It also works well for the energy levels of the outermost electron of any atom very near the ionization limit. Calculate the frequency of light emitted by a Rb atom in moving from the $n = 51$ level to the $n = 50$ level.

3. 20 pts) A particle of mass $m$ moves in a potential $V(r) = -qr$. a) Find the radii $r_n$ of the quantized orbits in a Bohr theory for this potential. b) Find the quantized energy levels.