1. Diffraction is a useful tool in crystallography, and it can be done with photons (i.e., X-ray photons), electrons, and neutrons. For all cases, the wavelengths of the particle waves must all be of the order of an angstrom, but then the energies and velocities are all quite different.

(a) Assuming that the wavelength is $2\AA = 10^{-10}\text{m}$ in every case, make a table showing the velocity (the dimensionless ratio $v/c$ is most convenient and most instructive), and the energy (in MeV) for each of the three particles. You may assume from the start that the electrons and the neutrons are nonrelativistic.

(b) Through what angle $\chi$ will the particles diffract if the crystal planes are separated by $3.5\AA$? Be careful about the definition of the angle $\chi$ in the diagram below and the definition referred to in the crystal diffraction formula.

2. A particle of mass $m$ moves in a central potential $V(r) = Fr$, which means that there is a restoring force directed inward toward the origin, $\mathbf{F} = F(-\hat{r})$, with magnitude independent of $r$. (Such a force acts on a frictionless hockey puck when it is attached to an object of mass $M$ by a massless string through a frictionless hole in the ice, as shown.) Find the quantized energy levels of circular orbits for this particle by applying the DeBröglie wave ideas as one does for the H atom.
3. This problem considers an electron orbiting around a proton. Part (a) looks at purely classical relations, part (b) looks at the quantum case, and part (c) makes a connection between the two. This connection is valid for large quantum numbers ($n >> 1$), and is known as Bohr's correspondence principle. In general, this principle states that a quantum system must behave consistently with classical physics when excited to high energy levels.

(a) Show that classical circular orbits of an electron in an H atom obey the Kepler Law relating period and cross sectional area, $\tau \sim A^{3/4}$, and find the proportionality constant. Also find the frequency $f$ as a function of $E$ and show that $f \sim |E|^{3/2}$.

(b) Find the frequency of the photon emitted in the transition from the $(n+1)$st to the $n$th energy level. For large $n$, show that this frequency is proportional to $n^{-3}$ to a good approximation. Find the coefficient.

(c) Using part (a), find the frequency of the classical orbit that has the energy of the $n$th quantum level, and show that this frequency is equal to that of the emitted photon found in part (b). (It doesn't matter whether you take the $n$th or $(n+1)$st level, to within the accuracy of part b.)