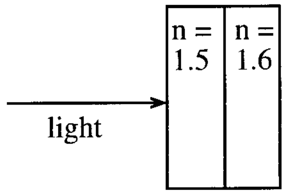
Physics 7c Final Exam -- May 19, 1997
section 1 -- R. Muller
3 index cards of notes allowed. Do all 7 problems. 100 pts max.

$N_0 = 6 \times 10^{23}$	$e = 1.6\times10^{-19}$ coul	1 year $\approx 3 \times 10^7$ sec	$m_e = 9.1 \times 10^{-31}$ kg
$h = 6 \times 10^{-34}$ J sec	$c = 3\times10^8$ m/sec	1 amp = 1 coul/sec	$m_p = 1.7 \times 10^{-27}$ kg

1. Carbon-14 (C-14) has a half-life of 5370 years. Assume you have one gram of C-14. How long does it take (on average) for all the atoms to decay? (10 pts)

2. Suppose that an incident beam of 4.0 eV protons fell on a barrier of height 5 eV and thickness 0.1 nm, and at a rate equivalent to a current of 1.0 ampere. How long would you have to wait, on the average, for one proton to be transmitted? (15 pts)

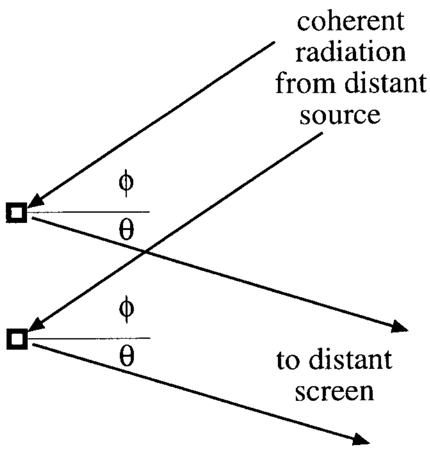
3. Light with wavelength $\lambda = 0.6 \times 10^{-4}$ cm is incident on two glass sheets, as shown. Find the minimum thickness for the first sheet (which has n = 1.5) that will maximize the reflection from the combination. Ignore reflections from the third surface (i.e.from the right side of the n = 1.6 sheet). (15 pts)



4. The index of refraction of still water is 1.33. Assume that the water is moving with respect to the lab frame at the velocity v = 0.8 c. A beam of light is moving through the water in the same direction as the water is moving. What is the velocity of the light (in the lab frame)? (15 pts)

5. A particle of mass m is held to the nucleus with a force F that is independent of distance, i.e. F = g = constant. (The force between quarks has this character.) Assuming that the nucleus is very heavy, find:
(a) the allowed radii for circular orbits (10 pts)
(b) the energy levels for these orbits are proportional to n^p + constant. Find p (5 pts)
(Hint: use reasoning similar to that of Bohr.)

6. Coherent microwave radiation coming from a very distant antenna (at an angle ϕ, as shown), reflects from two identical obstances, as shown in the figure to the right. Each obstacle, of size a, is much smaller than the wavelength of the radiation λ, and much smaller than the obstacle separation d. Find an expression for the angles θ for which there are maxima on the distant screen. (15 pts)



7. Although many people believe that the neutrino has zero mass, they may be wrong. It is possible that the neutrino has a very small mass, which has so far been undetected. In 1987, a large burst of neutrinos was emitted by a supernova located in a nearby dwarf galaxy, 170,000 light-years distant. (A year contains approximately 3×10^7 seconds.) Some of the neutrinos had energies as low as 1 MeV; others had energies as high as 100 MeV. Yet they all arrived at the earth within 10 seconds of each other. If a neutrino had a rest mass, then the velocities would have been different, and they would not have arrived at the same time.
Based on the fact that they all arrived within 10 seconds of each other, and assuming the neutrinos were all emitted at the same instant, we can conclude that the neutrino rest mass must be less than some value M. Find Mc^2 (in units of eV), based on the numbers I have given you. (Hint: note that Mc^2 will be << 1 MeV. The algebra can be simplified by using the right approximation formulas.)
The 1987 supernova event actually gave us the best determination of the neutrino mass (or lack of it) that we have! (15 pts)