Homework 11:

Remember: In addition to this problem, you also have a "Mastering Physics" assignment Due April 25 Due at the **beginning** of lecture, Friday, April 25 Write up of the solution to this problem in a coherent fashion.

This problem explores the idea of photons and how it relates to the energy, momentum and pressure of light.

Suppose that we have monochromatic light of frequency f. Classically the wave has an electric field with an amplitude of E_0. From earlier in the semester, recall that average energy density of such a wave is given by $u = \frac{1}{2}\varepsilon_0 E_0^2$ and the intensity (the average power per time) is given by $I = \frac{1}{2}c\varepsilon_0 E_0^2$. From a quantum mechanical view the light is made of photons with energy *hf* and momentum of *hf/c*. We can try to envision the classical wave as a collection of photon.

a. As a first step use your knowledge of the energy density to show that density of photons (number of photons per volume) is given by $n = \dfrac{\varepsilon_0 E_0^2}{2hf}$.

b. Now assume that the light hits a black surface(oriented perpendicular to the direction of the light's propagation) and is completely absorbed.

   i. Show that the number of photons per unit time per unit area hitting the surface is $\frac{1}{2}\varepsilon_0 c E_0^2 /(hf)$.

   ii. Use the result in i. to compute the intensity--- the average power per time---and demonstrate that exactly reproduces the classical result.

c. Consider again the black surface in described in party b.

   i. Us the result in b.i. to show that the momentum absorbed per unit area per unit time is $\frac{1}{2}\varepsilon_0 E_0^2$.

   ii. Explain on simple physical grounds why the momentum absorbed per unit area per unit time is the pressure put on the material by the light. Thus we have shown that with absorption the radiation pressure is given by $P_{abs} = \frac{1}{2}\varepsilon_0 E_0^2$

d. Suppose the light hits a reflecting surface. What is the radiation pressure? Explain your logic.