PHYS 201 WINTER 2010

HOMEWORK 4

**Write down all steps towards the solution to obtain maximum credit.
Don't forget to specify units!**

1. Half-Baked

A more precise way to say that an oven is "red-hot" would be "the peak spectral emittance of this oven has a wavelength in the range $630 \leq \lambda \leq 740$ nanometers." **At what temperatures is an oven red-hot?** Look up Wien's displacement law, treat the oven as an approximate blackbody, and give your answer in $^\circ C$.

2. Sunglasses At Night

Engineers for the secretive PrimaTech company are designing anti-reflective coatings for sunglasses to be worn by Secret Service agents. The sunglasses are made of polycarbonate and the coating is made of MgF_2. The indices of refraction for these materials are $n = 1.585$ and $n = 1.374$, respectively. (Use $n \approx 1.000$ for air.)

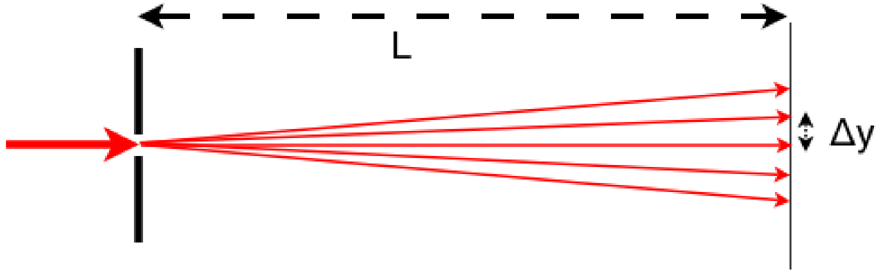
2.1. **Does light traveling through air undergo a phase shift when it reflects off of MgF_2? What about when light traveling through MgF_2 reflects off of polycarbonate?** Explain your answers.

2.2. **How thick (in nanometers) should the coating be in order to block green reflections with wavelength $\lambda = 525$ nm?** Hints: Look up "thin-film interference." The engineers' goal is to ensure that light reflected off the MgF_2 interferes destructively with light reflected off the polycarbonate.

3. The Bends

When light of wavelength λ passes through a slit of size a, it produces an interference pattern called a *Fraunhofer pattern*. The Fraunhofer pattern is a complicated function, but there is a simple formula for the locations of its minima: $a(\sin\theta_{min}) = m\lambda$, where m can be any integer. At the angles θ_{min}, light interferes destructively and dark fringes appear.

3.1.



A red laser pointer ($\lambda = 680$ nm) is aimed at a slit of width a. The light strikes a wall $L = 5.00$ meters away and produces dark fringes at distances $\Delta y = \pm 4.20$ mm, ± 8.40 mm, ± 12.6 mm, etc. from the center. **Find a in microns.** (Hint: Use any of the small-angle formulas $\sin\theta \approx \theta, \cos\theta \approx 1$, and $\tan\theta \approx \theta$.)

3.2. A diffraction grating is a series of equally-spaced slits each a distance d from their neighbor. When light strikes a diffraction grating at an angle normal to the grating, it can appear to "bend" by producing bright spots at certain angles θ_{max} given by the formula $d(\sin\theta_{max}) = m\lambda$ where m can be any integer.

The rows of data in a compact disc are about 1.5 μm apart from each other. Together with the reflective coating on a CD, they act like a diffraction grating in front of a mirror. When a laser is aimed at a CD, the light reflects and produces bright spots at angles of $\pm 26.4°$ and $\pm 62.5°$. **What is λ for this laser?**

4. Bonus Problem

Einstein's explanation of the photoelectric effect claims that energy from light is exchanged in discrete packets called "quanta" or "photons." Each photon has energy $E = hf$, where f is light frequency and h is a number called Planck's constant.

According to quantum mechanics, a photon can ionize a hydrogen atom (that is, separate it into a proton and an electron) if its energy is at least 13.6 electron volts. **What is the minimum frequency of light needed to ionize a hydrogen atom? Can visible light ionize a hydrogen atom?**