Physics 7C **Section 2** Spring 2004
Midterm I, February 22, 2005
Prof. Marco Battaglia

Name:____________________________________ SID:__________________

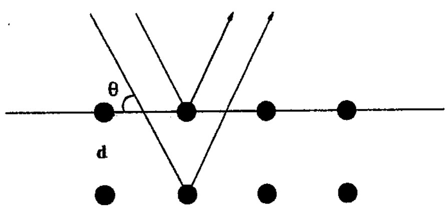
Choose four out of the five proposed problems. The test duration is 120 minutes.

1. Consider an electric field propagating according to the equation $E(\mathbf{x},t) = E_0 sin(kx - \omega t)$, $\mathbf{x} = (x,y,z)$. i) Using Maxwell equations, determine the equation for the propagation of the magnetic field $B(\mathbf{x},t)$. ii) Write the wave equation for $E(\mathbf{x},t)$ and show that the functional form above is a solution of this equation.

2. The Fermat principle of least time states that light propagates from a point A to a point B along the path which minimizes the time necessary to cover the distance. (a) Find the time taken by light to travel from a point A to a point B, located in materials with refractive index n_1 and $n_2 = 2\ n_1$ respectively, through a point C, at the interface between them. (b) Using this principle derive the Snell's Law of refraction and reflection (only consider trajectories which are straight lines within each medium).

3. Estimate the hazard of a laser pointer to the human eye. We model the eye as a lens having a refractive index n=1.5 and a diamater of 7 mm. Light is detected on the fovea (diameter=0.25 cm) and the eye can react to intense light by blinking, within 0.25 s. i) Knowing that the distance between the lens and the fovea is 2.5 cm, determine the radius of curvature of the lens such that the fovea is at the focal length. ii) A laser pointer emits light at λ=677 nm and a divergence such that the spot at 1 m has a diamater of 1 cm. Determine the irradiance (power/spot area) to the retina in a spot corresponding to the fovea area, if the laser beam power is 3 mW. iii) Determine the temperature increase on 0.1 g of tissue (heat constant = 4 J/g/C) due to the energy deposited by the laser on the retina before the eye reacts.

4. Consider the Cherenkov effect in a glass plate (n=1.5) of 1.5 cm thickness. Radiation is emitted along a cone making a half opening angle θ_c to the particle direction, where θ_c depends on the medium refractive index and the particle speed v. i) Using the Huygens principle, show that $\cos\theta_c = c/(vn)$. ii) Determine the minimum speed (in units of c) for a particle traversing the slab to emit Cherenkov radiation. iii) Determine the radius of the ring formed by the radiation emitted by a particle with speed 2.5×10^8 m s^{-1} on a detector surface parallel to the glass plate and located 1 m away. (Consider the case in which the particle direction is normal to the glass plate. Neglect the change in speed of the particle entering the glass plate and assume that the Cherenkov radiation is generated at the midpoint of the plate).



5. The atom spacing d within a crystal can be determined from the interference pattern of reflected radiation. i) Derive the relation that gives the angles corresponding to the maxima in the interference pattern as function of the wavelength λ and of the spacing d. ii) Diamonds have a characteristic spacing d= 0.1075 nm, predict the angle θ, from the crystal plane, corresponding to the first two maxima, when using radiation with λ= 0.154 nm (X rays). iii) Explain if the analysis can also be performed using visible light.