April 14, 2005

PHY 114 – Fourth Hour Exam – alternate version

Note: This exam has 5 problems each worth 20 points. For some problems, you may wish to draw on this exam paper, but most of your work – algebraic setup, mathematical manipulations, and your answers – should be recorded in the blue book. Please show your intermediate steps so that partial credit can be awarded if appropriate. When your work is completed, please turn in: (1) the exam booklet, (2) your equation sheet, and (3) this exam paper. It is assumed that all work will be done under the guidelines of the honor code.

Useful constants and mathematical identities

Coulomb Constant: $k_e \equiv \frac{1}{4\pi\epsilon_0}$: 8.98755×10^9 N $\cdot$ m^2/C^2

Permittivity constant: ϵ_0: 8.854×10^{-12} C^2/N $\cdot$ m^2

Permeability constant: μ_0: $4\ \pi \times 10^{-7}$ T $\cdot$ m/A

Elementary charge e: 1.602177×10^{-19} C

Mass of electron m_e: 9.10939×10^{-31} kg

Mass of proton m_p: 1.6726×10^{-27} kg

Area of a circle of radius r: πr^2

Circumference of a circle of radius r : $2\pi r$

Area of a sphere of radius r: $4\pi r^2$

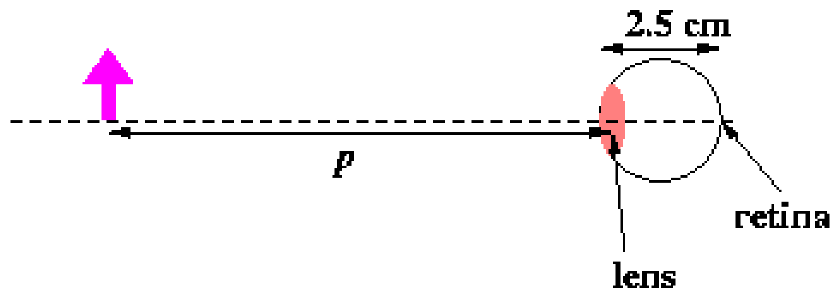
Speed of light in vacuum c: 3×10^8 m/s

$$\sin A + \sin B = 2 \sin\left(\tfrac{1}{2}(A+B)\right) \cos\left(\tfrac{1}{2}(A-B)\right)$$

$$\sin A - \sin B = 2 \cos\left(\tfrac{1}{2}(A+B)\right) \sin\left(\tfrac{1}{2}(A-B)\right)$$

$$\cos A + \cos B = 2 \cos\left(\tfrac{1}{2}(A+B)\right) \cos\left(\tfrac{1}{2}(A-B)\right)$$

$$\cos A - \cos B = -2 \sin\left(\tfrac{1}{2}(A+B)\right) \sin\left(\tfrac{1}{2}(A-B)\right)$$

1. 

The figure above shows an idealized diagram of a human eye with a variable focus lens located 2.5 cm in front of the retina. The following questions concern the relationships between the object distance p, the focal length of the lens f, and the image distance i, assumed to be on the retina. To receive full credit for this problem, draw at least one appropriate ray diagram and answer questions (a), (b), and *either (c)* or (d).

(a) What is the effective focal length of the eye lens for seeing an object 80 cm in front of the eye?

(b) What is the effective focal length of the eye lens for seeing an object 8 cm in front of the eye?

(c) Suppose that the maximum focal length of your eye is 2.3 cm. Using as much quantitative detail as you can, explain how an eyeglass lens placed 1 cm from the eye lens can bring the object at a distance of 80 cm into focus on your retina.

(d) Suppose that the minimum focal length of your eye is 2.0 cm. Using as much quantitative detail as you can, explain how an eyeglass lens placed 1 cm from the eye lens can bring the object at a distance of 8 cm into focus on your retina.

2. An electromagetic wave is propagating along the $x-$axis and its electric field can be described as the sum of two contributions:

$$\mathbf{E}(x,t) = \{5\cos(0.0003x - 90000t) + 5\cos(0.0003x - 90000t + 1.2)\}\,\hat{\mathbf{y}}. \tag{1}$$

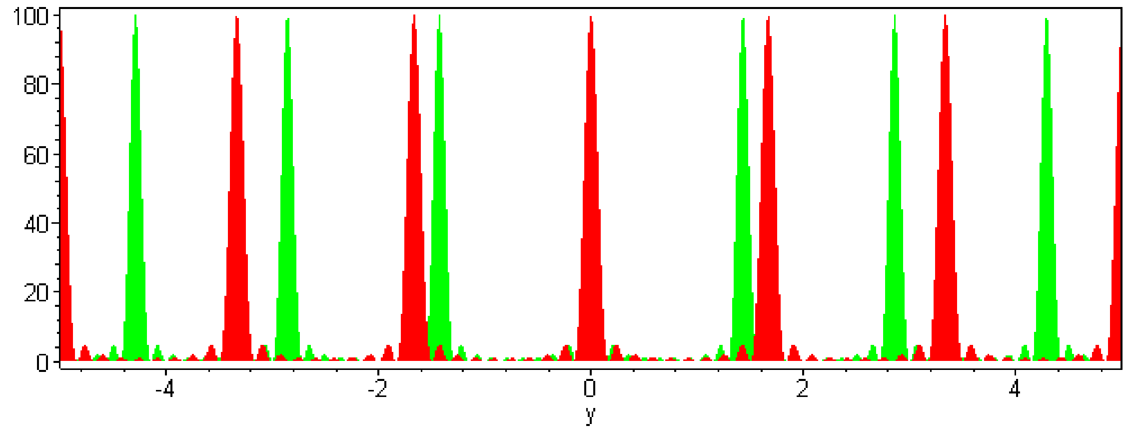
In this expression, the electric field is expressed in units of N/C, the phase is expressed in radians, x is in meters, and t is in seconds.

(a) What is the maximum amplitude of the composite electric field?

(b) What is the maximum amplitude of the composite magnetic field?

(c) What is the maximum intensity of the the electromagnetic wave?

3.



The figure above shows a plot of the intensity pattern produced on a screen at the front of the lecture hall when a source at the back of the hall passes through a diffracting device. The distance from device at the back of the lecture hall to the screen at the front (to the point marked 0 in the plot) is 15 m. The horizonal axis of the plot represents the the horizontal diffraction pattern where the distance y is measured in meters. The plot shows the diffraction pattern of two colors of light with peak intensity positions in units of meters. The distance between slits in the diffracting device is 6 $\times 10^{-6}$ m.

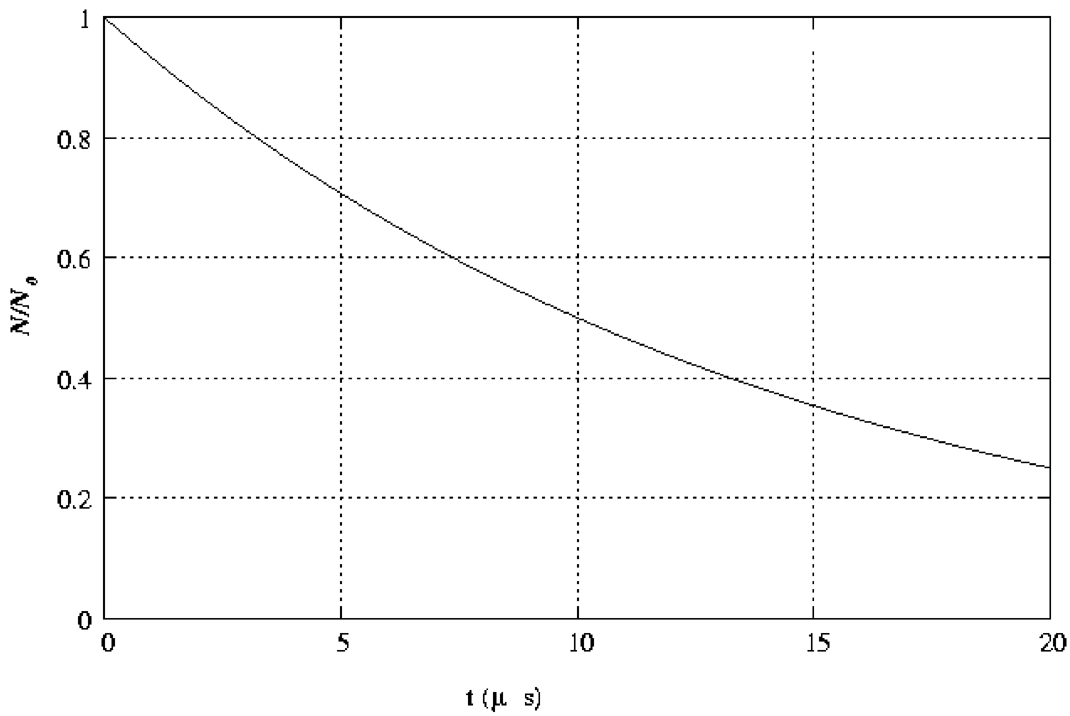
(a) From the form of the intensity pattern, what can you say about the diffracting device?

(b) From the data in the plot, estimate the wavelengths of the light in the source.

4. An astronomer on Earth observes a spectral signal from a distant star. The signal is found to have a wavelength of $\lambda_{\text{obs}} = 450nm$, however, this particular spectral feature would have a wavelength of $\lambda_{\text{rest}} = 600nm$ if the source were at rest.

(a) Is the star moving toward or away from the Earth?

(b) What is the velocity of the star relative to the Earth?



5.

Suppose you have discovered a new unstable particle "A". If you capture N_0 "A" particles in a container (assuming their velocities are essentially zero), the fractional number of undecayed particles present in your container is represented in the plot above, as a function of time (in μs).

(a) How long does it take for $\frac{1}{2}$ of the "A" particles to decay in your container?

(b) Now suppose that these same kind of "A" particles are also found in cosmic rays. To measure them, you set up detectors at the top and bottom of a mountain of height $h = 4000$ m.

  i. Suppose that you find that the average time interval that an "A" particle takes to travel from the top of the mountain to the bottom is $\Delta t_{\text{Earth frame}} = 16.6666\ \mu s$. What is the average velocity of these cosmic "A" particles?

  ii. Using the graph and ignoring the theory of relativity, what fraction of the cosmic "A" particles would you expect to survive the trip from the top of the mountain to the bottom?

  iii. Your experiment finds that $\frac{1}{2}$ particles survive the trip. Using the theory of special relativity in as much quantitative detail that you can, explain the experimental result. (For this purpose you can assume that cosmic particle are moving at essentially constant velocity.)

********************End of Exam**********************