UNM Physics 262, Problem Set 4, Fall 2006

Instructor: Dr. Landahl
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Do all of the exercises and problems listed below. Hand in your problem set in the rolling cart hand-in box, either before class or after class, or in the box in the Physics and Astronomy main office by 5 p.m. **Please put your box number on your assignment, which is 952 plus your CPS number**, as well as the course number (Physics 262). Show all your work, write clearly, indicate directions for all vectors, and be sure to include the units! Credit will be awarded for clear explanations as much, if not more so, than numerical answers. Avoid the temptation to simply write down an equation and move symbols around or plug in numbers. Explain what you are doing, draw pictures, and check your results using common sense, limits, and/or dimensional analysis.

Shorter "Exercises"

4.1. CSI: Albuquerque. As a crime scene investigator, you are sent a strand-like sample that you are told is either a human hair ($\sim 25\ \mu$m dia.), a dog hair ($\sim 30\ \mu$m dia.) or a piece of fine carpeting ($\sim 40\ \mu$m dia.). Remembering the physics you learned about thin wedges, you decide to place the sample (of diameter d) at one end between two square glass ($n = 1.52$) microscope slides of side length $L = 20$ cm and shine your trusty crime scene monochromatic sodium lamp of wavelength $\lambda = 590$ nm perpendicularly down on the slides. (The setup is similar to Fig. 35.11 in your textbook.) What you see is $m = 100$ bright fringes going across the slides. (a) This measurement puts an upper and lower bound on d as a function of L, m, and λ. Express these upper and lower bounds in terms of these variables. (*Hint*: The final fringe seen might not be right at the end, but you do not see fringe $m + 1 = 20$ at all.) (b) What do you report that the sample most likely is?

4.2. A prison for Superman. Evil supergenius Lex Luthor has finally managed to capture Superman in a prison designed by LuthorCorp. Lex cannot help but boast to Superman about the prison's diabolical design. He tells Superman, "The walls are made of two successive layers of kryptonite, with an air gap in between them. If you get too close to them, your powers will disappear and you will become so weak that you can't smash them. If you move far away from the walls where your powers are restored, you can't use your X-ray vision to see through them to discover where I've hidden the wall controls. I've designed it so that one of the walls is the minimum thickness to block X-ray transmission by destructive interference. And even if you do manage to find the controls, the other wall is the minimum thickness to block your infrared heat vision from penetrating the walls and melting the controls." An underling then enters the room and whispers something in Lex's ear. Lex dismisses him and continues, "I have to leave now, but don't worry, you won't miss me for long. I'm getting rid of you once and for all Superman, with the slow death that you deserve. Your prison will fill with water over the next hour until there is no air left and you will drown. Such a sad way to go, but it will give you time to reflect on how inferior you are to me." With that, Lex leaves. (*a*) Using your expert knowledge of kryptonite ($n = 1.37$), X-rays ($\lambda = 0.15$ nm), and infrared light ($\lambda = 800$ nm), what are the thicknesses of the walls? (*b*) Not too long after Lex leaves, Superman escapes. How did he do it? Does the fact that he escaped tell you anything about the order of the kryptonite walls?

4.3. Gesundheit! On a particularly bad day for allergies for Mr. Young, the man who played a key role in deciphering hieroglyphics and the inventor of the eponymous double-slit experiment, Mr. Young is tinkering with his double slit apparatus when he accidentally sneezes on the double slits. Young notices that the intensity pattern, which is being illuminated by light of wavelength $\lambda = 550$ nm, has now shifted towards the left slit. The central point of the viewing screen is now occupied by what had been the fifth bright side fringe ($m = 5$) before the sneeze. Approximating the index of refraction of the "film" on the slits as that of water ($n = 1.33$), (*a*) how much thicker is the "film" on one slit relative to the other? (*b*) Which slit has more "film" on it?

Longer "Problem"

4.4. Young's apprentice. After studying for years with the sneezy Mr. Young, his apprentice decides to branch off and try a radical new idea—a *three* slit experiment. Consider a setup like that of Fig. 35.5 in your textbook, with light of wavelength λ, but with the second sheet having *three* slits, each a distance d apart. (*a*) Let E be the electric field amplitude of the wave reaching the screen from each of the three individual slits, and let ϕ be the phase difference between the waves from adjacent slits arriving at some point P on the final screen. Draw a phasor diagram for the *total* wave at P and show that the amplitude of this total wave is $E_P = E(1 + 2\cos\phi)$. (*Hint*: The three phasors of length E and the total phasor of length E_P form a trapezoid.) (*b*) Calculate the intensity measured on the final screen as a function of d, λ, and θ (the angle between the straight-ahead direction and a line extending from the center slit to point P.) Graph the intensity as a function of ϕ. (*c*) Show that the intensity function calculated in part (*b*) has the following properties: *i*) The intensity at the principal maximum is nine times greater than the intensity from a single slit. *ii*) The locations of the principal maxima are given by $d\sin\theta = m\lambda$, where $m = 0, \pm1, \pm2, \ldots$, corresponding to values of ϕ that are integral multiples of 2π, just as in the two-slit pattern. *iii*) There are $(3-1) = 2$ minima between each pair of principal maxima. *iv*) The minima are located at $d\sin\theta = \pm\lambda/3, \pm2\lambda/3, \pm4\lambda/3, \pm5\lambda/3, \ldots$, corresponding to values of ϕ that are integral multiples of $2\pi/3$ but not integral multiples of 2π. *v*) Between each pair of principal maxima there is a *secondary* maximum at which the intensity is only 1/9 the value at the principal maximum. (*d*) Draw the phasor diagram for the following cases: *i*) $\phi = 2\pi/3$; *ii*) $\phi = \pi$; *iii*) $\phi = 4\pi/3$; *iv*) $\phi = 2\pi$. State which of these cases are intensity maxima, which are minima, and which are neither.