UNM Physics 262, Problem Set 5, Fall 2006

Instructor: Dr. Landahl
Issued: September 20, 2006
Due: September 27, 2006

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.

5.1. James Bond adventure. (Every part of this question relates to resolving power, discussed in section 36.7 of your text.) During an undercover mission in Kinshasa, James Bond intercepts a DVD from a S.P.E.C.T.R.E. agent suspected of working for the insidious Dr. Yes. He sends it to the techs at MI6 who discover that unlike an ordinary DVD, the pit spacing is half as wide as ordinary pits on a DVD. (See Problem 35.33 in the text to see what "pits" are on CDs and DVDs.) To read the secret information on the DVD, they replace the usual laser of wavelength 640 nm with one of a different wavelength. (*a*) *What wavelength did they use?*

The DVD describes a secret lair Dr. Yes is operating off the coast of Fiji. Bond's boss M orders satellite imagery of the location. The images reveal over 100 armed guards posted outside the complex. Assuming the spy satellite has a 2.5 m diameter aperture that is diffraction-limited and uses visible light of wavelength 550 nm to see the guards who are each approximately 0.5 m wide, (*b*) *what is the highest the satellite can be above the earth?* Due to blurring caused by atmospheric distortion, the best resolution that can be obtained by any spy satellite without the use of advanced adaptive optics is 0.3 arcseconds. (There are 60 arcminutes in a degree and 60 arcseconds in an arcminute.) (*c*) *Does this spy satellite need to use adaptive optics?*

Bond is sent to Fiji to investigate. He sets up a rendezvous at midnight off of an abandoned dirt road with Dr. Yes's mistress, Imogene DeMirror, who will be arriving by motorcycle. As Bond waits for the meeting, he sees the light from an approaching vehicle off in the distance. He can't tell if it is a single headlight or a pair of headlights. Approximating the spacing between headlights on a standard vehicle as 1.5 m that emit light at wavelength 550 nm, and the diameter of each of Bond's pupils as 5 mm, (*d*) *how close must the vehicle get before Bond can tell if it has one headlight or two?*

The light was from DeMirror's motorcycle, and after a romantic dinner and night of seduction, Bond learns from her that Dr. Yes receives supply shipments every night at 3 a.m. from a supply boat that leaves port from Fiji. The shipments are monitored closely by

Yes' radar, which uses a wavelength of 3.2 cm and a circular antenna dish of diameter 2.3 m. Bond plans to follow the shipment in by following it with his own small boat until he is a mile away, at which point he will scuttle the boat and swim in. (*e*) *How close must he be to the supply ship when he is ready to scuttle his boat if he is to remain undetected by the radar dish?*

Bond swims to the complex and notices that most of the guards are protecting the front entrance, but only two are guarding the back service entrance. Bond prepares to take out the two guards at the back with his silenced pistol, but he knows it has a limited range. Q told him that he should wait until he "sees the whites of their eyes" with his night-vision goggles before firing. If each of the guard's eyes are separated by 6.5 cm, Bond's pupils are 5 mm in diameter, and the night goggles use infrared light of wavelength 800 nm, (*f*) *how close does Bond have to get before he fires?*

Bond sneaks his way into the complex and discovers its dark secret. Dr. Yes plans on destroying the Moon with a giant laser! After the usual storyline of being captured by Dr. Yes, executing a cunning escape, destroying the Moon laser, blowing the entire complex up, and being rescued by CIA agents, Bond files his final report to M about the incident. In it, he states that Yes' plan was to bore a hole in the moon using a laser fitted with advanced adaptive optics. By boring a hole smaller than the 0.3 arcseconds perceivable by conventional ground-based telescopes, Yes was hoping to avert any notice by the authorities until it was too late. (*g*) *What was the diameter of the hole on the surface of the moon that Dr. Yes planned to bore?* (Use the astronomical data in the back cover of the textbook for the relevant information about the moon.)

5.2. Sound diffraction. (Every part of this question refers to single-slit diffraction, covered in sections 36.2 and 36.3 in your text.) Diffraction is a phenomenon that occurs for all waves, not just light waves. The wavelength of sound waves is comparable to everyday objects, so the phenomenon can be seen in everyday life.

You are talking with someone in private but you don't close the door all the way. Sound travels at 330 m/s and a typical voice frequency is 1250 Hz. (*a*) *What is the widest the door can be opened so that only a single central maximum of sound intensity exists?* You open the door fully, leaving it 1.0 m wide. (*b*) *At which angles relative to the centerline perpendicular to the doorway will someone outside the room hear no sound?* In both parts, assume the listener outside the room is far away from the door and ignore any reflections.

At a Lobo football game, you notice that the loudspeaker is taller than it is wide. (*c*) *Why isn't it square, or wider than it is tall?* (*Hint*: Think of the profile the audience presents to the loudspeaker.) The width of the speaker is chosen so that it is the widest possible that won't generate any diffraction intensity minima. (*d*) *Using the speed of sound and voice frequency from part (a), what is this width?* You are sitting 10 m directly in front of the loudspeaker and you hear an intensity of $I_0 = 1$ W/m^2. (*e*) *What intensity does your friend hear, who is sitting* 5.0 *m to your left?* (Use the speaker width found in part (*d*).) Considering the width of a human mouth (measure your own, if need be), (*f*) *are there intensity minima angles from you where someone can't hear you speaking? If so, at what angles are they?*