Physics 5B
Final Examination
March 22, 2007
STAPLE YOUR QUESTION PAPER TO YOUR ANSWERS

Use $g = 10m/s^2$, density of water $= 1000kg/m^3$.

1. (60 points)
   a) A plane flies horizontally at 1.25 times the speed of sound. The sonic boom reaches a person on the ground exactly 100 seconds after the plane has passed directly overhead. What is the altitude of the plane?
   (The speed of sound in air is 330 m/s.)

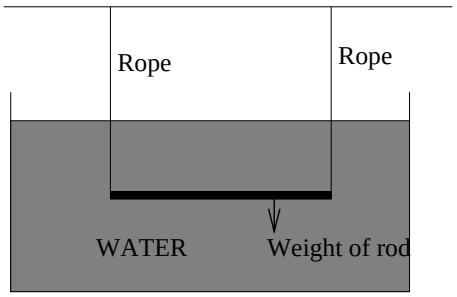
   b) A violin string that is 25cm long and weighs 0.9g has a fundamental frequency of 200 Hz.
   i) What is the speed of waves in the string?
   ii) What is the tension in the string?

   c) A wave pulse on a string is described by the function $y(x,t) = A^3/[A^2 + (x - vt)^2]$ with A = 1 cm and v= 10 m/s.
   i) At what times will the displacement at $x = 2$ cm be half its maximum value?
   ii)What is the velocity of the string at $x = 2$ cm at these times?

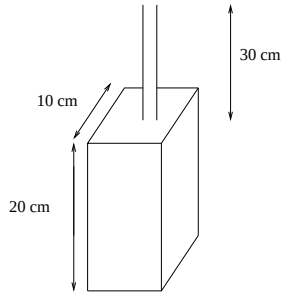
   d) A diffraction grating is 2 cm wide and has 6000 rulings. At what angle will the $m = 1$ intensity maximum (i.e. the first intensity maximum away from the center) occur for light of wavelength 500 nm?
   (Approximate $\sin\theta \approx \theta$.)

   e) Unpolarized light of intensity I_0 passes through a sequence of three polarizers. The axes of the first and last polarizers are perpendicular to each other. The axis of the second polarizer is at an angle θ to the first. What is the intensity of light that emerges from the last polarizer?

2. (30 points)
a) A metal rod of length 80 cm and mass 1.6 kg has a uniform cross sectional area of 5.0 cm^2. Due to a nonuniform density, the center of mass is 20 cm from one end of the rod. The rod is suspended in a horizontal position in water by ropes attached to both ends. When the rod is fully submerged, what is the tension in each of the ropes?



b) A container of square cross section 10 cm X 10 cm has height of 20 cm. The container is full of water. The top of the container is sealed, with a small hole through which a vertical tube is inserted. The tube extends 30 cm above the top of the container, and has a cross sectional area of 5 cm^2. The tube is filled with water, and its top is open to the atmosphere. What is the net outward force exerted on any of the four vertical sidewalls of the container?

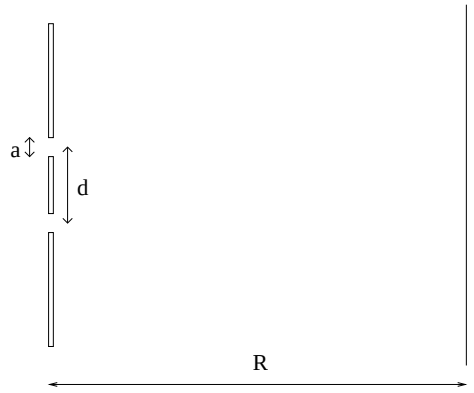


3. (30 points)
a) When a bright light source is placed 30 cm in front of a thin lens, there is an erect image 7.5 cm from the lens. There is also a faint inverted image 6 cm in front of the lens due to reflection from the front surface of the lens. When the lens is turned around, this weaker, inverted image is 10 cm in front of the lens. What is the index of refraction of the lens?
b) An object is 15 cm to the left of a converging lens of focal length 10 cm. A second lens of focal length -5 cm is placed 5 cm to the right of the first lens. Where is the final image formed, and is it upright or inverted?

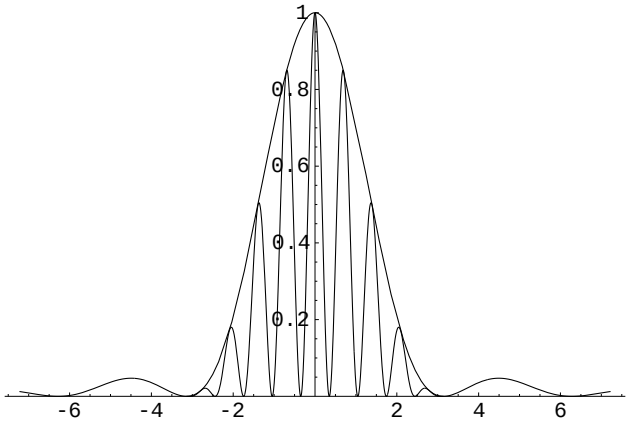
4. (30 points) A screen has two long parallel slits in it. Each slit has width a, and the separation between the centers of the slits is d. Light of wavelength λ is incident normally on the screen from a source very far away. The diffraction pattern on another screen, at a distance R from the slits, is observed. The intensity pattern for such a configuration is

$$I_0 \cos^2 \frac{\phi}{2} \left[\frac{\sin(\beta/2)}{\beta/2} \right]^2$$

where $\phi = (2\pi d/\lambda) \sin\theta$ and $\beta = (2\pi a/\lambda) \sin\theta$.

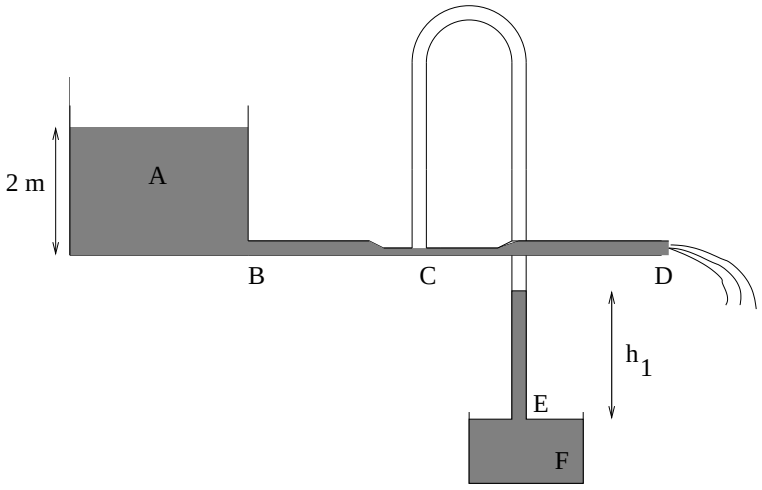


a) Exactly 9 bright fringes are contained in the central maximum of the diffraction envelope. That is to say, the edges of the central diffraction maximum are the centers of dark interference fringes, with 9 bright fringes enclosed. What relationship can you infer between a, d, R, and λ?



b) How many bright fringes lie between the first and second minima of the diffraction envelope?

5. (30 points)
Water flows from the tank A through the pipe BCD, out into the open as shown. The height of the water in the tank A is 2 meters. The cross sectional area of the pipe is small compared to the height of the water in A. The radius of the pipe at D is $3^{1/4}$ times that at C. Tank F also contains water.
a) If tanks A and F are open to the atmosphere, to what height h_1 does water rise in the pipe at E?



b) The pipe BCD is now sealed off at D. Water rises at C, and falls at E. We wait till all the water stops flowing. Assume that the gas trapped inside the curved tube CE is incompressible. The tube is of uniform cross section. What is the height of water at C and E, h_2 and h_3 respectively?