Physics 221 – Test 1 – Fall 2009

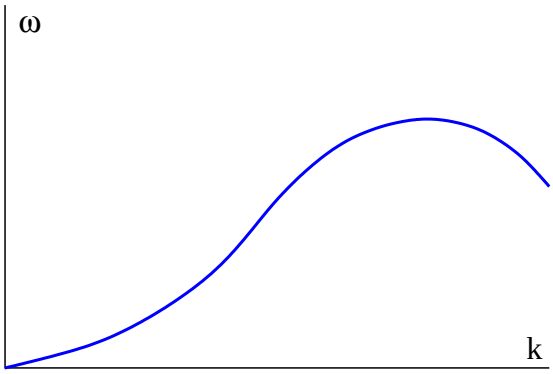
One-page reminder sheet allowed. *Show all work – no credit given if work not shown!* Redraw needed figures on your test paper.

1. A glass lens with index of refraction $n_g = 1.5$ has a thin transparent coating of thickness d with index of refraction $n_c = 1.3$. Compute the minimum d that results in destructive interference between reflections from the front and back surfaces of the coating, and thus minimizes the overall reflection from the lens. The light is normally incident on the lens surface and has a wavelength 5×10^{-7} m.

2. Given the dispersion relation for a wave shown below, graphically indicate the following:

   (a) The wavenumber for which the group velocity equals the phase speed.

   (b) The central wavenumber for which the resulting wave packets are stationary.



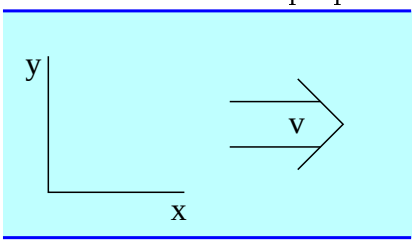
3. A river flows in the x direction with speed v, as shown below. The dispersion relation for shallow water waves on the river relative to the earth is

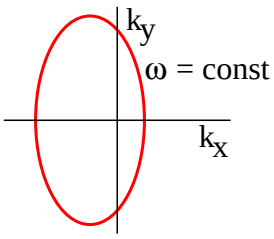
$$\omega = k_x v + c(k_x^2 + k_y^2)^{1/2}$$

   where c is the (constant) phase speed of waves relative to the moving water. One contour for a particular constant value of ω is shown below.

   (a) Find the phase speeds of waves in the earth frame in terms of v and c with the wave vector pointing (i) upstream, (ii) downstream, and (iii) perpendicular to the stream.

   (b) Indicate graphically in the diagram below the central wave vector for a wave packet with all wave components having frequency ω and with lines of constructive interference oriented perpendicular to the streamflow.





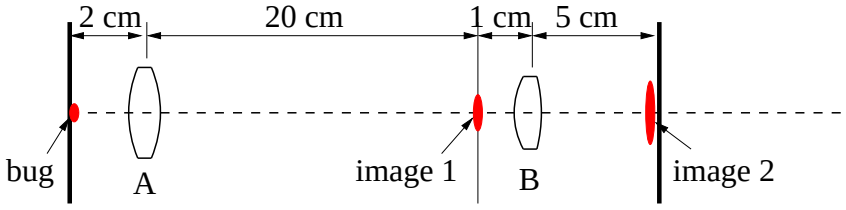
4. The effective diameter of the Very Long Baseline Array radio telescope is about 8600 km (10 antennas from the Virgin Islands to Hawaii). If it receives radio waves with a wavelength of 4 cm, compare its diffraction-limited angular resolution to that of the Hubble Space Telescope receiving light with wavelength 5×10^{-7} m. The main mirror of the Space Telescope is 2.4 m in diameter.

5. A tiny bug 0.2 mm in diameter is photographed by a microscope camera as shown below.

   (a) Compute how big the bug is in image 1 between the lenses.

   (b) Compute how big the bug is in image 2 on the camera film.

   (c) Compute the focal lengths of lenses A and B.



6. The density and hence the index of refraction of air decreases with height.

   (a) Using Fermat's principle or Snell's law, sketch qualitatively the path of light from the sun to an observer on the earth's surface when the sun is near setting. Hint: Remember that the earth is a sphere!

   (b) Does the sun appear to set earlier or later than would be observed if there were no atmosphere? Explain.