Optics for Energy

Fall 2013

Mid-Term

Please show all steps.

1. Your goldfish Wanda happens to be situated at the center of her spherical waterworld. At the same time, your friend Olive happens to have her gaze aligned with Wanda's. If Olive is located a distance s from the edge of the sphere, the sphere radius is R, and the refractive index of water is n, then answer the following questions about Olive and Wanda's mutual perception of each other.
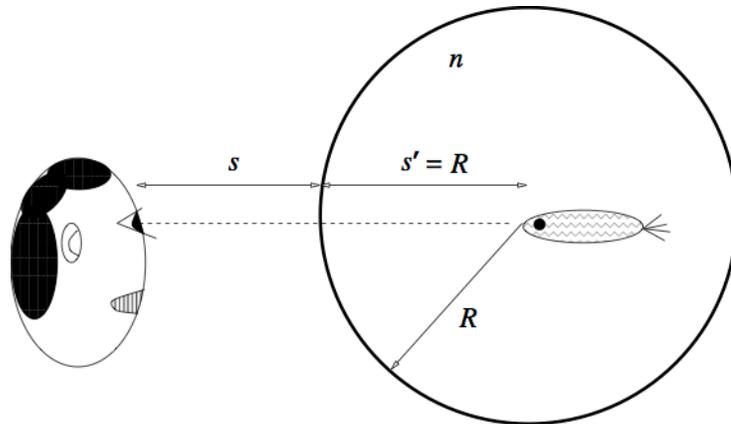

Figure 1

   a) [5 points] How does Wanda look like to Olive? That is, where is Wanda's image formed, what is the magnification, and is the image real or virtual?

   b) [5 points] How does Olive look like to Wanda? That is, where is Olive's image formed, what is the magnification, and is the image real or virtual?

2. [5 points] A light source consists of monochromatic light with wavelength of 600 nm with a spectral irradiance of 1 x 10^{17} photons/cm^2/sec. What is the power density of this light source? Is the light source visible to the human eye?

3. Telephoto lenses for cameras are often built in the form of a Galilean telescope. Assume that the front lens has +50mm focal length and the second lens has -25mm focal length. The distance between both, to provide focusing on the film plane, is 30mm. Determine: (a) [5 points] the equivalent focal length of the system, and (b) [5 points] the actual physical length of the system.
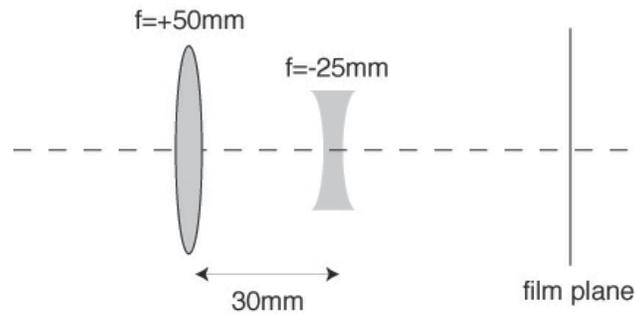
Figure 2

4. [10 points] Spherical aberration from a planar glass plate. A beam is perfectly focused in free space so that all the rays converge towards the axis at distance d from a reference plane (see left figure below). We insert a plate of thickness t and refractive index n in the path of the beam, just beyond the reference plane (see right figure below). Compute the primary (Seidel) longitudinal spherical aberration introduced by the plate. Ignore reflections from the plate surfaces. Hint: calculate the distance from the plate where the rays intersect the axis as a function of the ray incidence angle ϕ and height h on the reference plane; expand to Taylor series in the small number (h/d), making sure that powers up to $(h/d)^2$ survive in the final result.
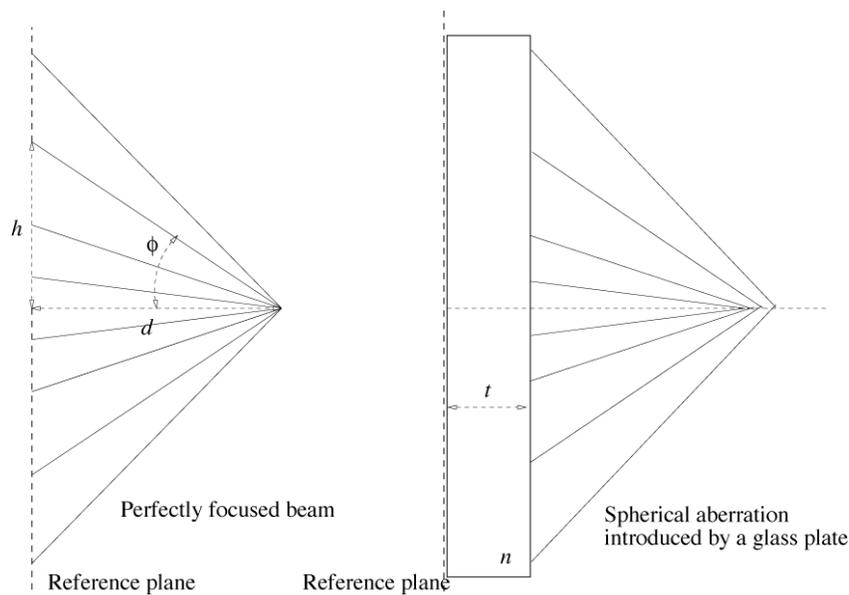

Figure 3

5. [5 points] Assuming that the sun has a black-body spectrum with the temperature at

6000K, what is the power density reaching the atmosphere of the Earth? At what wavelength is the peak in the spectrum?

6. [5 points] Diffuse radiation has a higher fraction of high energy radiation than direct radiation. Explain why this is so.