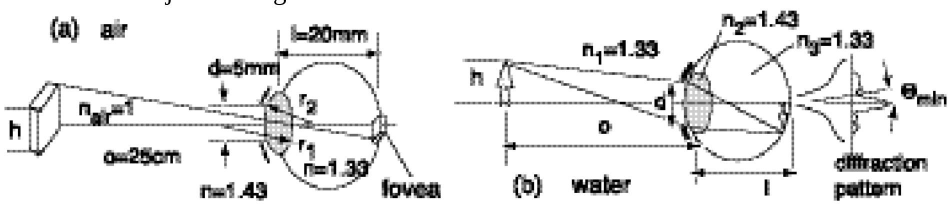
## Assignment #5 Optics due March 17 2005

**P 5-1) Focusing of the human eye, and resolution**

A person reads a book, height h=20cm, Figure 8.33**a**, holding it at a distance of *o*=25cm. (a) Determine the image height and the focal length of the lens in this position, and the radius of curvature of the lens. Assume: (i) the lens is in air, (ii) its index of refraction is *n*=1.43, (iv) negect the focussing contribution of the cornea (iii) the radii of curvature are equal $r_1=r_2=r$, and (iv) the eye accommodates to always produce a sharp image on the retina. (b) Make a similar calculation for an object of height h under water




(b) The person looks through the window and sees a white square 20 cm x20 cm at a distance 150 m away. As the eyes focus onto this distant object, do the muscles holding the lenses have to pull or relax? (c) Calculate the new radius of curvature of the lens after it has accommodated to bring the object into focus. (d) What is the angle subtended by the white square, and what is the height and the area of the image on the retina? There are 400x400=160,000 cones per square mm in the fovea area of the eye, so that a cone has a cross section of 2.5µm diameter. Sketch the image of the square on the retina using a scale where 1µm on the retina equals 1mm on your sketch. Indicate the size of the cones on this sketch. (e) How many cones does the image cover? (f) If the iris has a diameter of d=5mm, what is the diameter $\Delta$ of the center spot of the diffraction pattern on the retina? Draw the center diffraction spot into your sketch of the image of the square. (g) Assume the white square is illuminated by bright sunlight. If 60% of this light is reflected towards the observer, how many photons/s (photon flux) get into her eye and make up the image? (f) How many photons (number) would get into the eye during one "blink" (? t=1/4s)?

**5-2 Steven's eye**

Steven had a cataract in his left eye at birth. The doctors decided to remove his lens and give him prescription glasses, matched over the years to the growing eye. Part of the refracting power of the eye is due to the cornea with a radius of curvature r. At the age of 5, Steven's eyeball has a diameter of 20 mm and the front radius of curvature of 6.8 mm.

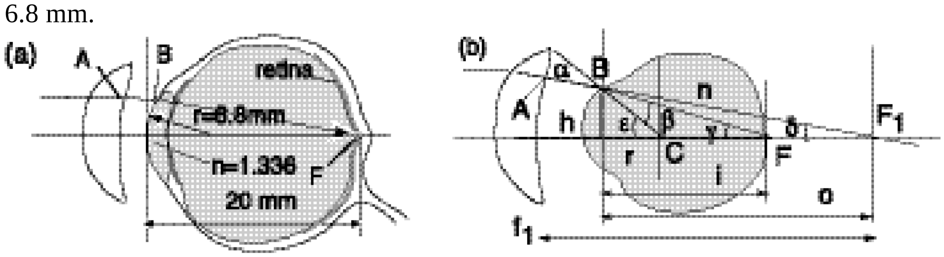



**Fig. 5-2** (a) Steven's eye with the natural lens removed and an artificial lens (glasses) added. The iris is still functioning. (b) Steven's eye showing ray tracing construction. Consider rays that are so close to the optical axis that the angles are so small that $\sin\alpha \approx \alpha$. $\sin\beta \approx \beta$, $\sin\gamma \approx \gamma$. Further the added lens is so close to the eye that the distance o is approximately equal to the focal length $f_1$ of the lens, In the absence of the eye the ray emerging from the lens A would intersect the optical axis at $F_1$, With both the lens and the cornea, the ray emerging from the lens at A, is refracted at B, and intersects the optical axis at F, the fovea focal point. $\alpha$ is the incident angle at point B, and $\beta$ is the refracted angle inside the eye.

For Steven to see clearly, his prescription glasses must have a focal point at $F_1$, so that when combined with the refraction at the cornea, the final focal length is at F. Calculate the focal length of the lens required to produce sharp images of far distant points on Steven's retina. To do this, follow a construction ray that starts at a far away point, runs parallel to the optical axis, runs through the lens and hits the cornea at h=0.5 mm, and then travels to the wanted image point F. (Snell's law for small angles; $n_2/n_1=\sin\varnothing_1/\sin\varnothing_2 \approx \varnothing_1/\varnothing_2$). Calculate the angle $\alpha$. Notice that $\varepsilon=\beta+\gamma$, why?. Does it matter if you chose a different construction ray, say one that hits B at h= 0.8mm?

**5-3 Facette eyes**

How many ommatidia would an insect eye (radius r= 1.3mm, lens aperture d=20µm) require in order to see light coming from one hemispere