UNIVERSITY OF CALIFORNIA AT BERKELEY

Physics 7C – (Stahler)

Spring 2020

FIRST MIDTERM

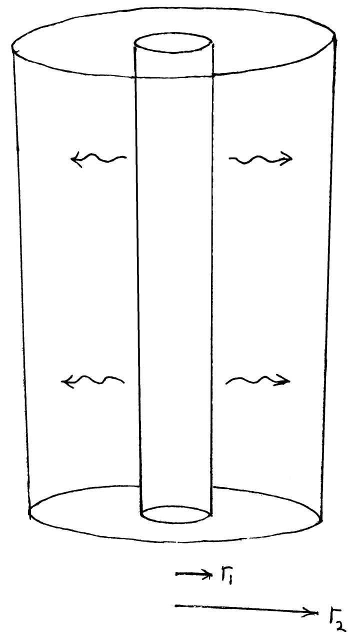
Please do all your work in this printed exam – not in a blue or green book. Feel free to use the final, blank side of paper for scratch work. Below, write your name, SID, discussion section number, and GSI's name.

You must attempt all four problems. If you become stuck on one, go on to another and return to the first one later. Be sure to show all your reasoning clearly, i.e., do not simply write down equations. **Remember to circle your final answer!**

Name:____________________ **SID:**____________________

Discussion Section #:__________ **GSI:**____________________

Problem 1 (20 points)



A glowing rod of height H and radius r_1 emits infrared radiation at the rate $\dot{E}$. Surrounding this cylinder, and coaxial with it, is a thin, cylindrical shell. This shell also has height H, and radius $r_2 > r_1$. Although the shell looks transparent in the sketch, its inner surface is actually coated with black paint, so that it absorbs all the radiation from the central rod. The shell is kept cool, and thus does not emit its own radiation into the cavity between it and the rod.

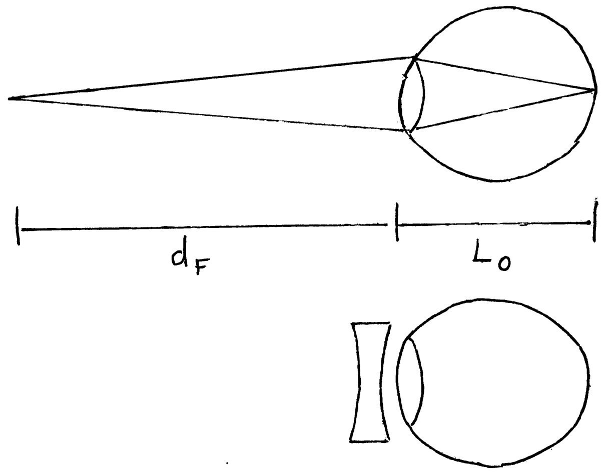
(a) Find E_1, the amplitude of the electric field at radius r_1. Feel free to use, in addition to r_1 and H, the constants μ_0, ϵ_0, and/or c in your expression.

(b) Find E_2, the amplitude of the electric field at radius r_2. Express E_2 in terms of E_1, r_1, and r_2.

(c) Find u_2, the energy density of the electromagnetic field inside the cavity, at radius r_2. Express your answer in terms of $\dot{E}$, r_2, H, and the above constants, as needed.

(d) Find $P_{\mathrm{rad}}(r_2)$, the radiation pressure acting on the outer shell. Express your answer in terms of u_2.

Problem 2 (30 points)



For a near-sighted person, there exists a "far point," located a certain distance d_F in front of the eyeball, which has a length L_0. Light from an object at d_F comes to a focus at the retina in the back of the eye. While closer objects are viewed clearly, the light from more distant ones comes to a focus in front of the retina. Thus, these distant objects look blurry.

To correct this condition, a divergent, glass lens is placed just in front of the eye. When light is emitted from an object at infinity, the glass lens by itself creates a virtual image at d_F. Objects at a finite distance create a virtual image inside d_F, and are thus viewed clearly by the eye.

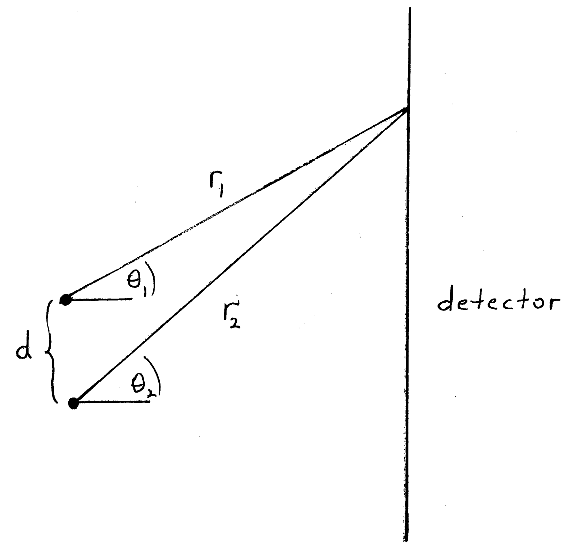
(a) Find f_e, the focal length of the eye's own lens, when it views (without glasses) an object located at d_F.

(b) Find f_g, the focal length of the corrective glass lens.

(c) An object is placed a distance $2\,d_F$ in front of the near-sighted person, who is wearing glasses. Suppose the eyeball lens still had the focal length f_e. What is the location of the final image?

(d) What must be f_1, the eyeball's *actual* focal length, so that this object is viewed clearly? Indicate whether f_1 is greater or less than f_e.

Problem 3 (25 points)



Two linear antennas 1 and 2, shown here edge-on, emit radio waves of the same frequency ($\omega = 2\pi f$), but with different phases, ϕ_1 and ϕ_2. The antennas are separated by a distance d, and their waves are sent to a flat detector, also shown edge-on. When the distance from the top antenna to the detector is r_1 and the angle with respect to the horizontal θ_1, the corresponding distance and angle for the bottom antenna are r_2 and θ_2, respectively. At this point on the detector, the incoming electric fields are

$$\begin{aligned} E_1(r_1) &= A(\bar{r}) \cos(\omega t + \phi_1 - k r_1), \\ E_2(r_2) &= A(\bar{r}) \cos(\omega t + \phi_2 - k r_2), \end{aligned}$$

where $\bar{r} \equiv (r_1 + r_2)/2$. Assume $\bar{r} >> d$, so that you may denote by θ both θ_1 and the nearly identical θ_2.

When answering the following questions, these trig identities may be useful:

$\cos^2(A) + \sin^2(A) = 1$

$\cos^2(A) = \dfrac{1 + \cos(2A)}{2}$

$\cos A + \cos B = 2 \cos[(A+B)/2] \cos[(A-B)/2]$

$\sin A + \sin B = 2 \sin[(A+B)/2] \cos[(A-B)/2]$

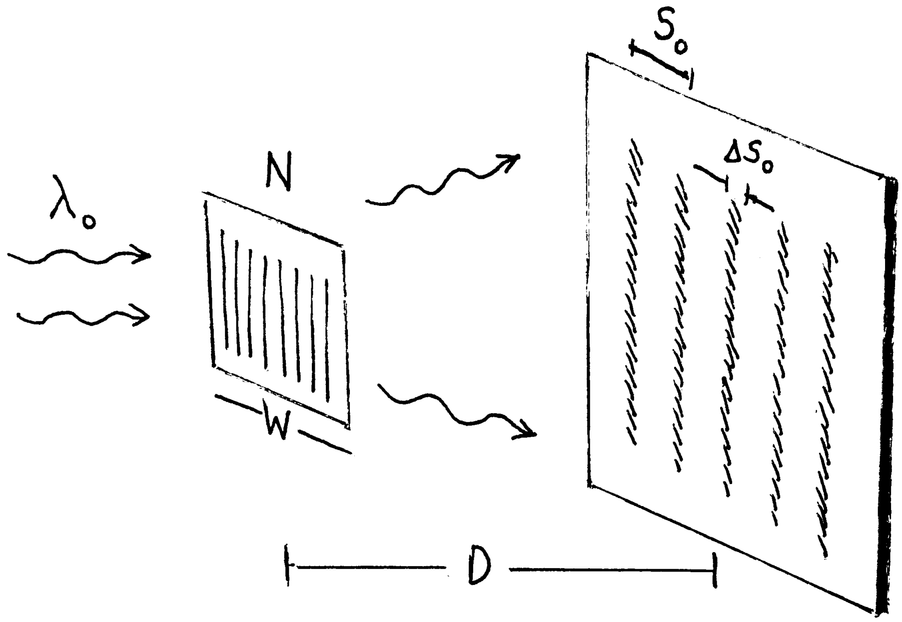
(a) Find $E_{\text{tot}}(\bar{r}, \theta, t)$, the total electric field received at the detector as a function of time.

(b) Find $<[E_{\text{tot}}(\bar{r}, \theta)]^2>$, where $< \ >$ denotes a time average over many wave periods.

(c) Sketch $<[E_{\rm tot}(\bar{r},\theta)]^2>$ as a function of $\sin\theta$ for both $\phi_1 = \phi_2$ and $\phi_1 = \phi_2 + \pi$.

(d) Finally, assume that the two antennas radiate *incoherently*. That is, suppose that the phase difference $\phi_1 - \phi_2$ itself fluctuates in time. Again sketch $<[E_{\rm tot}(\bar{r},\theta)]^2>$ as a function of $\sin\theta$, under the assumption that the averaging is done over a much longer time span than that of the fluctuations.

Problem 4 (25 points)



A translucent slab of width W has N parallel grooves cut into it. Light of wavelength λ_0 shines on the slab, passing easily through the grooves, but not the space between them. At a distance D from the slab is a screen, which shows a series of vertical stripes – a bright central one, and successively dimmer ones to either side.

(a) What is S_0, the distance on the screen between adjacent stripes?

(b) What is ΔS_0, the width of each individual stripe?

A second source of light, of wavelength $\lambda_0 + \Delta\lambda$, is now added to the first. This source produces its own set of vertical stripes on the screen.

(c) What is the *minimum* value of $\Delta\lambda$ such that the new stripes next to the central one are distinguishable from the analogous, "nearest neighbor" stripes created by the first light source?

(d) What is the minimum $\Delta\lambda$ such that the stripes *two away* from the central one are distinguishable from the "next-to-nearest neighbor" stripes due to the first source?