MINOR WRITTEN PRELIM EXAM

Fall 2012

September 19, 2012
8:30 a.m. to 12:00 p.m.

Please answer all questions.

Start each answer on a new page.

In the upper right hand corner of each sheet you hand in, put your name and the problem number. Staple together all sheets for a given problem.

Insert your answers and this exam into the manila envelope supplied. The exam questions will be returned to you along with your answers after they have been graded.

The following are some helpful items:

$h = 6.625 \times 10^{-34}\ \mathrm{J \cdot s} = 4.134 \times 10^{-15}\ \mathrm{eV \cdot s}$

$e = 1.6 \times 10^{-19}\ \mathrm{C}$

$c = 3.0 \times 10^{8}\ \mathrm{m/s}$

$k_B = 1.38 \times 10^{-23}\ \mathrm{J/K}$

$\sigma = 5.67 \times 10^{-8}\ \mathrm{W/K^4 \cdot m^2}$

$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F/m}$

$\mu_0 = 1.26 \times 10^{-6}\ \mathrm{H/m}$

$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$

$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$

$2\cos A \cos B = \cos(A - B) + \cos(A + B)$

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

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

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

$\sin 2A = 2\sin A \cos A$

$\cos 2A = 2\cos^2 A - 1$

$\cos 2A = 1 - 2\sin^2 A$

$\sinh x = \frac{1}{2}\left(e^{x} - e^{-x}\right)$

$\cosh x = \frac{1}{2}\left(e^{x} + e^{-x}\right)$

$\nabla(\phi + \psi) = \nabla\phi + \nabla\psi$

$\nabla\phi\psi = \phi\nabla\psi + \psi\nabla\phi$

$\nabla \cdot (\mathbf{F} + \mathbf{G}) = \nabla \cdot \mathbf{F} + \nabla \cdot \mathbf{G}$

$\nabla \times (\mathbf{F} + \mathbf{G}) = \nabla \times \mathbf{F} + \nabla \times \mathbf{G}$

$\nabla(\mathbf{F} \cdot \mathbf{G}) = (\mathbf{F} \cdot \nabla)\mathbf{G} + (\mathbf{G} \cdot \nabla)\mathbf{F} + \mathbf{F} \times (\nabla \times \mathbf{G}) + \mathbf{G} \times (\nabla \times \mathbf{F})$

$\nabla \cdot (\phi\mathbf{F}) = \phi(\nabla \cdot \mathbf{F}) + \mathbf{F} \cdot \nabla\phi$

$\nabla \cdot (\mathbf{F} \times \mathbf{G}) = \mathbf{G} \cdot \nabla \times \mathbf{F} - \mathbf{F} \cdot \nabla \times \mathbf{G}$

$\nabla \cdot (\nabla \times \mathbf{F}) = 0$

$\nabla \times (\phi\mathbf{F}) = \phi(\nabla \times \mathbf{F}) + \nabla\phi \times \mathbf{F}$

$\nabla \times (\mathbf{F} \times \mathbf{G}) = \mathbf{F}(\nabla \cdot \mathbf{G}) - \mathbf{G}(\nabla \cdot \mathbf{F}) + (\mathbf{G} \cdot \nabla)\mathbf{F} - (\mathbf{F} \cdot \nabla)\mathbf{G}$

$\nabla \times (\nabla \times \mathbf{F}) = \nabla(\nabla \cdot \mathbf{F}) - \nabla^2\mathbf{F}$

$\nabla \times \nabla\phi = 0$

$\oint_{\mathrm{S}} (\mathbf{F} \cdot \mathbf{n})\, da = \int_{\mathrm{V}} (\nabla \cdot \mathbf{F})\, d^3x$

$\oint_{\mathrm{C}} \mathbf{F} \cdot d\ell = \int_{\mathrm{S}} (\nabla \times \mathbf{F}) \cdot \mathbf{n}\, da$

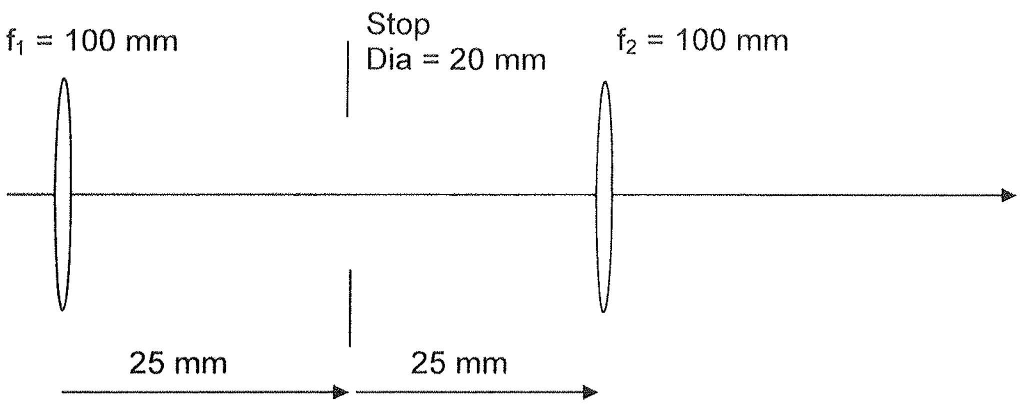
$\oint_{\mathrm{S}} \phi\mathbf{n}\, da = \int_{\mathrm{V}} \nabla\phi\, d^3x$

$\oint_{\mathrm{S}} \mathbf{F}(\mathbf{G} \cdot \mathbf{n})\, da = \int_{\mathrm{V}} [\mathbf{F}(\nabla \cdot \mathbf{G}) + (\mathbf{G} \cdot \nabla)\mathbf{F}]\, d^3x$

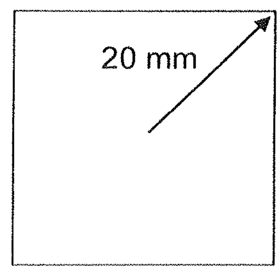
$\oint_{\mathrm{S}} (\mathbf{n} \times \mathbf{F})\, da = \int_{\mathrm{V}} (\nabla \times \mathbf{F})\, d^3x$

Fall 2012 Written Comprehensive Exam
Opti 502

An optical system comprised of two thin lenses in air places the system stop between the two elements. The object is at infinity.



This lens is used with a sensor that has a corner-to-corner dimension of 40 mm. What are the required element diameters for this system to be unvignetted over this field of view?



A raytrace sheet is attached on the next page and may be used for the solution.

Surface	0	1	2	3	4	5	6
f							
$-\phi$							
t							
y							
u							
y							
u							
y							
u							
y							
u							
y							
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Fall 2012 Written Comprehensive Exam
OPTI 506

You are putting together a lab experiment where the students will measure the radiometric properties of various sources. You need to pick the equipment to include in the lab and the goal is to maximize the signal coming from the detector. If two different configurations produce the same signal, cost should be the deciding factor. You may choose from the following parts:

Detector	Active area	Cost	Responsivity (A/W)
A	0.5mm diameter	$35	0.42
B	1mm by 1mm square	$41	0.28
Lens focal length (mm)	**type**	**cost**	**diameter (mm)**
50	uncoated thin lens	$22	12.7
100	uncoated thin lens	$17	12.7
200	uncoated thin lens	$12	12.7

To prevent stray light, a black paper tube 12.7 mm in diameter will be placed over the detector with a minimum length of 50 mm. If you wish to make it longer, the extra paper is free, but you may not make it shorter.

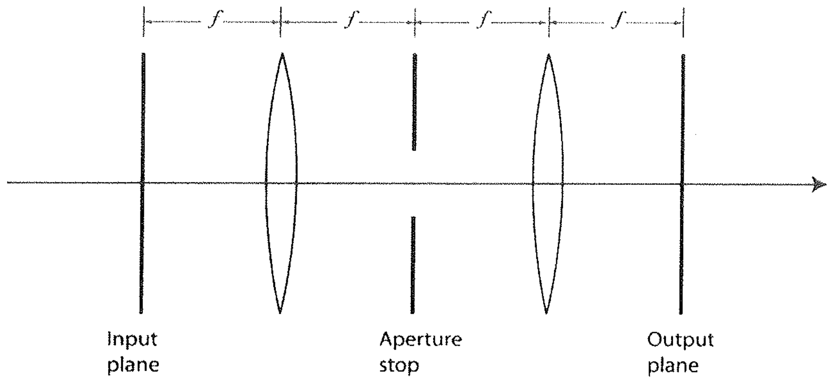
A) The first source is a television that is 700 by 400 mm that is located 1,000 mm from the system that you are putting together (i.e. the closest thing to the television is 1,000 mm from it). Sketch the system that you would use. Make sure that your sketch has enough detail so that someone would know what components to order and how to position them. What would the total cost of your system be?

B) For the system that you sketched in part A, what would the signal from the detector be if the television is a Lambertian source with a radiance of 0.33 W/m^2sr.

C) Since you might not be able to get the television, the backup plan is to measure a light emitting diode (LED). The distance from the LED to the nearest element of your system is still 1,000 mm. Because you don't have any measured data on the LED, you can only assume that it is an isotropic point source. If you only have to measure the signal from the LED, sketch the system that you would use. Make sure that your sketch has enough detail so that someone would know what components to order and how to position them. What would the total cost of your system be?

D) For the LED measurement system you sketched in part C, what would the signal from the detector be if the LED has an intensity of 3mW/sr?

Fall 2012 Written Comprehensive Exam
Opti 536



This question relates to the so-called 4f imaging system depicted above. The horizontal axis is the z axis and the lenses and the aperture stop are circular and centered on this axis. The lenses are ideal and have the same focal length f and same diameter D_{lens} . The diameter of the aperture stop is D_{ap} .

The parts are equally weighted. If you must make additional assumptions to answer any of the parts, be sure to state them explicitly. For the requested sketches, label the axes carefully.

(a) Demonstrate by a simple ray trace that an object placed in the input plane will be imaged to the output plane.

(b) What is the magnification between input plane and output plane?

(c) Suppose that the object in the input plane is a transparency with amplitude transmittance $t_{obj}(\boldsymbol{r})$, where $\boldsymbol{r}$ is a two-dimensional vector with components (x, y). You may assume that the size of the transparency is small compared to the diameter of the lenses. Suppose that this transparency is illuminated with a monochromatic plane wave traveling in the z direction. Write an expression for the complex electric field just to the right of the transparency.

(d) Is the system as described so far coherent or incoherent? Is it linear and shift-invariant (LSIV)? Why or why not?

(e) Give an integral expression for the relation between object and image and sketch the point-spread function. (No derivation is needed, but explain all symbols used)

(f) Now consider what happens if a rapidly rotating ground glass is placed between the illuminating plane wave and the object transparency. You may assume that the ground glass is thin so both it and the transparency are in the input plane. With this setup, is the system coherent or incoherent? Is the system LSIV now? Why or why not?

(g) Give an integral expression for the relation between object and image with the rotating ground glass in place. Again, explain all symbols used.

(h) Sketch the point-spread function of the system with the ground glass in place.

(i) Sketch the transfer function of the system with the ground glass in place.

(j) What is the highest spatial frequency transmitted by the system, with and without the ground glass?

Fall 2012 Written Comprehensive Exam
OPTI 566

A photodiode having a dynamic resistance (R_oA_d) of 2500 ohms-cm^2 at zero bias voltage is operated at liquid nitrogen temperature (T_d) of 77 K. It is subjected to a background photon irradiance (E_p) of 10^{14} photons / sec-cm^2 from a 300 K background temperature, the detector area (A_d) is a square 50 microns on a side with a quantum efficiency of 75 %., with a electrical noise equivalent bandwidth (Δf) of 1 Hz..

a) What is the Johnson noise current of this detector?
b) Is this detector under these conditions Blip or Johnson nose limited?
c) What is the total noise current expected in this configuration?
d) What conditions must E_p, A_d, R_o, and T_d satisfy in order for the detector to be BLIP? Hint: derive an expression for background irradiance (E_p) as a function of R_o, A_d, T_d and η