Instructions: Complete each of the following Problems

(1) **Elements of Radiometry and Radiant Energy Exchange**. For this problem the following may be useful: $\sigma_{SB} = 5.67031 \times 10^{-8} \dfrac{\mathrm{W}}{\mathrm{m}^2\ \mathrm{K}^4}$

(a) Define the following radiometric terms and give their units based upon energy–Q, measured in watts.

(i) Flux–φ

(ii) Exitance–M

(iii) Irradiance–E

(iv) Intensity–I

(v) Radiance–L

(vi) Blackbody Radiator

(b) Consider a 1 meter diameter sphere (#1) and a 10 cm diameter sphere (#2) whose center to center separation is 2 meters. Each is a blackbody radiator. Prove that if each sphere is at the same temperature, T = 1000°K, that the flux radiated from sphere #1 onto #2 is same as from #2 to #1.

(c) For the two isolated spheres above, consider the case where sphere #1 maintains a constant temperature (by some magical means) of $T_1 = 1000$°K. Initially sphere #2 is at a temperture of $T_2 = 500$°K. Describe what happens to sphere #2. You can assume that you know its heat capacity *C* (units equal °K J^{-1} gm^{-1}) and density.

(2) **Optical Coherence.** Many optical devices and effects require Optical Coherence (Require what?).

(a) Give clear definitions of

(i) Spatial Coherence (sometimes called transverse)

(ii) Temporal Coherence (sometimes called longitudinal)

(b) Sketch the experiments commonly associated with the measurement of spatial and temporal coherence. Describe the experiential data normally obtained and how that data is analyzed to determine the coherence for each case.

(c) For sunlight on the earth's surface, which is "larger", spatial or temporal coherence (*i.e.* converting temporal coherence to an equivalent distance). What does this have to do with the rainbow pattern observed from oil films on water puddles?

(3) **The Focusing of Light.** Light can be "focused" by using either refraction or diffraction. As a reminder, the Fresnel approximation for propagation of a scalar optical field is

$$E(x,y;z_2) = A_{21}\iint_A E(\xi,\eta;z_1)e^{i\frac{\pi}{\lambda z_{12}}\left[(x-\xi)^2+(y-\eta)^2\right]}d\xi\, d\eta$$

$$= A_{21}e^{i\frac{\pi}{\lambda z_{12}}(x^2+y^2)}\iint_A E(\xi,\eta;z_1)e^{i\frac{\pi}{\lambda z_{12}}(\xi^2+\eta^2)}e^{-i\frac{2\pi}{\lambda z_{12}}(x\xi+y\eta)}d\xi\, d\eta$$

where $A_{21} = \dfrac{e^{ikz_{21}}}{i\lambda z_{21}}$

Consider a plane wave incident upon either a refractive or diffractive focusing optic.

(a) Explain how each element works.

(b) Choose two such optical elements with equal focal lengths and circular aperture. Write down their transmission function. Assume a plane wave incident upon each. Find the transmitted fields and propagate to the focal plane. Discuss the result.

(c) Describe an application for each element for the concentration of sun or laser light.

(4) **Laser Cavity.** An argon-ion laser has a cavity length of 75 cm and a central wavelength of 514.5 nm. The output coupling mirror is planar and transmits 5% and reflects 95%. The other mirror is concave and 100% reflective.

(a) Define what is meant by a transverse mode and a longitudinal mode.

(b) Find the longitudinal mode spacing.

(c) How much must the cavity length be changed so that the frequency of a particular longitudinal mode changes by one-half the mode spacing.

(d) What is the cavity lifetime of this laser?

(e) The laser operates in the fundamental Gaussian mode of a single longitudinal mode. Its beam waist at the output mirror is 1 mm. Find the radius of curvature of the 100% reflector and the beam size on this mirror. (Great BIG Hint: The method of y-ybar makes this part of the problem a hunk-of-cake.)

(5) **Optical Design and y-$\bar{y}$ diagram.** Below is the y-$\bar{y}$ data for a two lens photographic lens. The object is at infinity and the half cone angle of the field of view is 11.31°. (Note the tangent of this should give you a nice number on your calculator, which you may round to two significant figures.)

Element	y	$\bar{y}$
Lens 1	4cm	-2cm
Lens 2	2cm	2cm
Image	0cm	3cm

(a) Carefully draw to scale the y-$\bar{y}$ diagram.

Find the following quantities (and make it clear how you calculated them):

(b) The optical invariant of the system.
(c) The diameter of the aperture stop.
(d) The separation between lens 1, lens 2 and the aperture stop.
(e) The focal length of the first lens.
(f) The effective focal length of the system.
(g) The sizes of the entrance and exit pupils.