**Homework for exercise session 1**

**Wednesday Aug 31st , 2022**

Problems with odd numbers will be solved in class

1- Consider a plane electromagnetic wave (in SI units) given by the expression $E_x = 0$, $E_z = 0$, $E_y = 2\cos(2\pi 10^{14}(t - x/c) + \pi/2)$
   a. What is the frequency, wavelength, direction of motion, amplitude, initial phase angle, and polarization of the wave.
   b. Write and expression for the magnetic flux density

f= 10E4 Hz
omega=0.66*pi*10E4 1/s
lambda= 3 micrometer
x direction of motion
E0= 2 V/m
Initial angle = pi/2
Polarization in y direction
B0= E0/c Tesla

2- light bulb puts out 20 Watts of radiant energy (most of it IR). Assume i t to be a point source and calculate the irradiance 1 meter.

Irradiance 5/pi Watt/meter$^2$

3- A 550-nm harmonic EM-wave whose electric field is in the z direction is traveling in the y-direction in vacuum.
a- What is the frequency of the wave?
b- Determine both $\omega$ and k for this wave.
c- If the electric field amplitude is 600 V/m, what is the amplitude of the magnetic field
d- Write an expression for both E(t) and B(t) given that each is zero at x = 0 and t = 0.
   Put in all the appropriate units.

f= 5.45E14 Hz
omega= 3.43E15 1/s
k= 1.14E7 1/meter
Ez=sin(1.14E7*y-3.43E15*t)
Bx=Ez/c

4- What is the momentum of a $10^{19}$ X-ray photon?

P= 2.2E-23 kg.meter/second

5- A 500-nm lightwave in vacuum enters a glass plate of index 1.60 and propagates perpendicularly across it. How many waves span the glass if it's 1.00 cm thick?

Number of wavelengths 3.2E4

6- A plane. harmonic. linearly polarized lightwave has an electric field intensity given by

$$E_y = 2\cos(\pi 10^{15}\left(t - \frac{x}{0.65c}\right))$$

While traveling in a piece of glass. Find

a. The frequency of the light
b. Its wavelength
c. The index of refraction of the glass.

F= 5E14 Hz
Lambda air= 600 nm
Lambda material = 390 nm
n= 1.54

7- A candle that is 6.00 cm tall is standing 10 cm from a thin concave lens whose focal length is -30 cm. Determine the location of the image and describe it in detail.

Si= -7.5 cm, upright image, virtual
Length of the image 4.5 cm

8- Locate the image of an object placed 1.2 m from the vertex of a gypsy's crystal ball, which has a 20-cm diameter (n = 1.5).

Si= 6.95 cm, real image, distance measured from the other side of the sphere.

9- Two positive lenses with focal lengths of 0.30 m and 0.50 m are separated by 0.20 m. A small butterfly rests on the central axis 0.50 m in front of the first lens. Locate the resulting image with respect to the second lens.

Si= 26 cm, on the right side of the second lens, real image

10- A meniscus concave glass (n= 1.5) thin lens has radii of curvature of +20.0 cm and +10.0 cm. If an object is placed 20.0 cm in front of the lens, show that the image distance will be - 13.3 cm.

Si=-13.3 cm

11-The image of a red rose formed by a concave spherical mirror on a screen 100 cm away. If the rose is 25 cm from the mirror, determine its radius of curvature.

R=40 cm

12- Design an eye of a robot using a concave spherical mirror such that the image of the object 1 m tall and 10 m away fills its 1cm square photosensitive detector (which is movable for focusing purposes). Where should this detector be located with respect to the mirror? What should be the focal length of the mirror? Draw a ray diagram

f= 9.9 cm

13- Locate the image of a paper clip 100cm away from a convex spherical mirror having a radius of curvature of 80 cm

Si= -28.57, virtual image

14- We consider a concave spherical mirror with 4 m radius of curvature and 2 m diameter. An object with 1 m height is placed at different positions:

a- The object is placed 10 m from the mirror. Make a drawing of the object and mirror, the object is a vertical arrow perpendicular to the optical axis. Where is the image? Draw the relevant rays.
b- The object is now placed 3 m from the mirror, draw this case. Where is the image?
c- The object is finally placed 1 m from the mirror. Draw this case.
d- What is the size of the image for cases a, b and c?

a- Si= 2.5 meter, real, inverter, scaled down by 0.25
b- Si= 6 meter, real, inverted, scaled up by 2
c- Si= -2, virtual, upright, scaled up by 2

15- You are asked to design a little curved mirror for a dentist to be fixed at the end of a shaft and to be used in the mouth of a patient. The requirements are (1) that the image is erect as seen by the dentist and (2) that when held 1.5 cm from a tooth the mirror produces an image twice life-size

a- Should the mirror be concave or convex?
b- Should the image be real or virtual?
c- What should be the focal length?
d- What should be the radius of curvature?

a- Concave
b- Virtual image
c- f=3cm
d- R= -6 cm

## Supporting information

### Image formation from single refractive spherical surface

$$\frac{n_1}{s_o} + \frac{n_2}{s_i} = \frac{n_2 - n_1}{R}$$

### Thin lens equation

$$\frac{1}{s_o} + \frac{1}{s_i} = (n_l - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$$

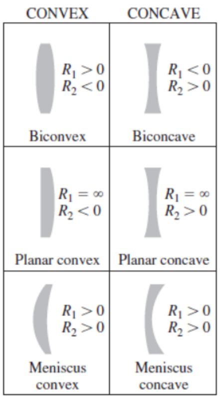
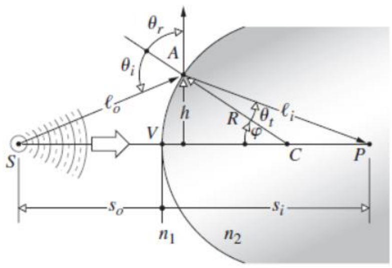



**TABLE 5.1 Sign Convention for Spherical Refracting Surfaces and Thin Lenses* (Light Entering from the Left)**

| | |
|---|---|
| $s_o, f_o$ | + left of $V$ |
| $x_o$ | + left of $F_o$ |
| $s_i, f_i$ | + right of $V$ |
| $x_i$ | + right of $F_i$ |
| $R$ | + if $C$ is right of $V$ |
| $y_o, y_i$ | + above optical axis |

*This table anticipates the imminent introduction of a few quantities not yet spoken of.




### Image magnification

$$M_T \equiv \frac{y_i}{y_o}$$

$$M_T = -\frac{s_i}{s_o}$$

### Spherical mirror equation

$$\frac{1}{s_o} + \frac{1}{s_i} = -\frac{2}{R}$$

**TABLE 5.4 Sign Convention for Spherical Mirrors**

| Quantity | Sign + | Sign − |
|---|---|---|
| $s_o$ | Left of $V$, real object | Right of $V$, virtual object |
| $s_i$ | Left of $V$, real image | Right of $V$, virtual image |
| $f$ | Concave mirror | Convex mirror |
| $R$ | $C$ right of $V$, convex | $C$ left of $V$, concave |
| $y_o$ | Above axis, erect object | Below axis, inverted object |
| $y_i$ | Above axis, erect image | Below axis, inverted image |