**Engin 112 – Fall 2022**
**Homework 7: Optical Sensors**
**Due: 5:00 pm Tuesday, November 8**

1.) Focal length and f-stop.
   a) If the focal length, $f$, of a camera is 50 mm, calculate the distance to the point of focus in a camera for objects that are 1 km, 100 m, 10 m, 1 m and 10 cm away from the lens.
   b) If an aperture has a focal length of 50 mm, calculate the diameter of the aperture for f-stop values of N = 2, 4, 8, 16 and 22.
   c) What is the fraction for the number of photons that enter an aperture for a camera set with an fstop of N=4 ($f/4$) versus N=1.4 ($f/1.4$). In other words, you should be calculating the fraction: $photons_{N=4}/photons_{N=1.4}$

2.) Angle of view and Field of View
   a) If the height of the focal plane (the plane where the image is collected) is 3 cm, calculate the Angle of View (AOV), if the focal length is 400 mm, 100 mm, 50 mm, and 30 mm. Specify values of AOV in both radians and degrees.
   b) Using the same values as part 2a above, calculate the Field of View (FOV) for objects that are 10 meters away. Use the longer formula that uses a tangent computation.

3.) For this next problem, you will use your cell phone camera, or a digital camera to calculate AOV and FOV. To begin, you need to identify a wall in your room, house or dormitory where it is easy to judge distance both horizontally and vertically. There should be things along the wall that you can identify in the picture to measure horizontal distance. Similarly, use objects like posters, or the junction between the wall and the floor, to measure vertical distance. Measure a distance of 3 meters or 3 yards from the wall and take a picture of the wall with your camera such that the wider dimension of the photo is aligned with the horizontal direction of the wall.
   a) Include a copy of the picture in your homework and specify the Field of View (FOV) for both the horizontal and vertical dimensions (units should be in meters or yards).
   b) Use your measured distance from the wall and values of FOV from above, to calculate the Angle of view for your camera.
   c) Use the AOV calculated from above to calculate the size of the imaging area of your digital camera or cell phone. If you used a cell phone, assume that the focal point is 0.5 mm. If you used a digital camera, use the advertised focal point of the lens, or choose a value of 50 mm.

4.) For a digital camera
   a) If the camera has 6270 x 4480 pixels, how many Megapixels is the equivalent to (specify only up to the first decimal place).
   b) If the number of pixels calculated above is the total available, and the camera uses a Bayer color filter, how many of the pixels are related to the intensity of green light? blue light? red light?

5.) Thermal Noise

a) Using notes from the lecture for a CCD camera, if the temperature of the CCD is 40 degrees Fahrenheit, how many electrons from *thermal noise* (i.e. the dark current) will show up in one pixel over one second of time? If the temperature of the CCD is 0 degrees Fahrenheit, how many electrons from thermal noise will show up in one pixel over this same time period?

b) After solving part c of this problem, you will see that there is a great advantage to cooling down the electronics of a CCD camera. However, even expensive professional cameras don't normally do this. Why not?

6.) If the energy per unit wavelength in white light is constant,

a) how many photons are there for 1 Watt of power collected over one second for light with a wavelength of 700 nm (red light)?

b) How many photons are there for 1 Watt of power collected over one second for light with a wavelength of 450 nm (blue light)?

c) How many photons are there for 1 Watt of power collected over one second for light with a wavelength of 300 nm (ultraviolet light)