Quiz 4
ECEn 370

Name: ______ Key ____________________________

1. Like your camcorder, sensitive astronomical telescopes use CCD (charge coupled device) solid state integrated circuit imaging arrays to collect light and form images. Each pixel in the image plane consists of a single CMOS transistor with a floating isolated gate that is exposed to light. A photon striking the gate displaces an electron and causes a slight voltage change. When sufficient photons strike, the voltage is changed enough to be sensed by the transistor. For the most sensitive, cryogenically cooled systems, it is possible to detect even a single photon per pixel and thus form a grainy "photon limited" image. For a given image source, the arrival of photons is a random process, with each arrival being an independent random event. The image structure detail is observable because the *average rate* of photon arrival, λ, for bright regions is higher than for dark regions. Thus you form an image as an estimate of the spatial change in photon arrival rate, $\lambda(x,y)$.

   a) What probability law would be an accurate model for photon arrivals at a single CCD pixel? (give the name)

   The POISSON distribution

   b) Assume your CCD array is sensitive enough to detect 3 or more photons which fall on a single pixel during a single frame exposure. For less than three, that pixel sees complete blackness. Assume that a given pixel observes a dim source with a photon arrival rate of λ = 80 photons per second. Assume a 1/60 second exposure time (standard 480p video frame rate).
   What is the probability that this pixel will not see complete black?

P[a detection] = 1 - P[no detection]
$= 1 - (P[k=0; \lambda\tau] + P[k=1; \lambda\tau] + + P[k=2; \lambda\tau])$

$$= 1 - \left(\frac{(80/60)^0}{0!} e^{-(80/60)} + \frac{(80/60)^1}{1!} e^{-(80/60)} + \frac{(80/60)^2}{2!} e^{-(80/60)} \right)$$

$$= 1 - (1 + \tfrac{4}{3} + \tfrac{16}{2\cdot 9}) e^{-4/3} = 0.151$$