In this assignment, we will explore solar array outputs a little further, and we will calculate the optimal band gap of a semiconductor for a photovoltaic cell here on earth.

Please note: You may attach Excel spreadsheets, Matlab code, Mathematica, etc. However, if you use external software, please write out the formulas or methodology you used to calculate your answer. Your logic flow/thought process should be described clearly.

**Question #1: PV on Roofs vs. PV on Cars**
(a) Calculate the space required in Illinois to meet the time-averaged power requirements of a typical home. Assume a 15% efficient PV system, and that the energy burn rate of an average home is around 2kW.
(b) How do these values change, if peak demand must be met (i.e. there is no energy storage battery available)? You can assume that peak energy is roughly double the average load, so 4kW.
(c) Repeat parts (a) and (b) for an electric car. To estimate the electricity consumption for a car, we’ll assume the fuel efficiency and peak power of a Tesla roadster (vroom!!!).
(d) Given your answers to (a), (b), and (c), where do you think PV will be deployed – on cars or on rooftops?

You will want to make use of the following information about the Tesla roadster: engine is rated at 215 kW (according to the official website). According to Wikipedia, its efficiency is 21.7 kWh per 100 miles. The average car drives around 12,000 miles a year (source: epa.gov), which means the average person drives around 33 miles a day and would consume 7.1 kWh per day in their car if they drove the Tesla roadster.

**Question #2: Integrated Spectral Irradiance for AM1.5.**
Calculate numerically the integrated spectral irradiance in W/m² for the AM1.5 solar spectra. (Note that we already know what the answers should be (see your class notes!), but we will make use of this calculation in problem 3 and 4)

The spectra can be downloaded from: [http://rredc.nrel.gov/solar/spectra/am1.5/](http://rredc.nrel.gov/solar/spectra/am1.5/)
Use the “Direct+Circumsolar” column.

Hint: Watch your units here, and make sure to note that the data you download (Intensity vs. wavelength) is not necessarily provided on uniform intervals. You may need to go back to your calculus books to recall the trapezoidal rule or Simpson’s rule.
Question #3: Solar photon spectrum.
Using the same “Direct+Circumsolar” data, make your own plot of the photon spectral flux vs. wavelength. You will need to convert from Intensity (W m\(^{-2}\) nm\(^{-1}\)) instead to (#photons m\(^{-2}\) s\(^{-1}\) nm\(^{-1}\)).

Question #4: Reflection and Absorption Losses.
For many of these problems, you may need to look up the index of refraction or absorption coefficient for silicon and silicon nitride (SiNx). Your class discussion slides, or on http://www.pveducation.org/PVCDROM is a good place to look. You can assume that the absorption for a thin SiNx layer is negligible.

(a) For 550 nm light (peak of the solar spectrum), what percentage of light is reflected off the front surface of a polished silicon wafer?
(b) If SiNx is used as an anti-reflection coating (ARC), what thickness should be used to optimize for 550 nm light?
(c) If we assume only one pass of light through the silicon, estimate the thickness required to absorb 90% of incident, non-reflected photons at 1070 nm.
(d) Say we texture the back surface, and introduce total internal reflection at the front surface. It turns out that there is a fundamental upper limit to how much the effective path length of light can be extended. This limit arises from pure statistical mechanics considerations, and is known as the Yablonovitch limit. It states that the effective path length of the light can only be increased by a factor of \(4n^2\), where \(n\) is the refractive index. How does the thickness needed in part (c) change, assuming we achieve this limit?

Note: If you are curious about the Yablonovitch limit, for more details see E. Yablonovitch and G.D. Cody, IEEE Trans. Electron Dev. 29, 3000 (1982). The following websites may be useful:
http://optoelectronics.eecs.berkeley.edu/ey1982josa727.pdf
http://www.eecs.berkeley.edu/Faculty/Homepages/yablonovitch.html