1. The US energy consumption is about $3 \times 10^{13}$ kW-h/year. If one were to generate 10% of the energy by solar cells, what percentage of US area needs to be covered by solar cells? The power density of solar radiation on earth surface is about 1.4 kW/m$^2$. For simplicity, assume the wavelength of sunlight to be 500 nm. The efficiency of solar cells is about 25% (i.e., the electrical energy output is about 25% of incident light energy).

2. The separation of the quasi-Fermi levels ($E_{fc} - E_{fv}$) is a measure of the semiconductor’s deviation from equilibrium. In the following, you will be asked to express $E_{fc}$ and $E_{fv}$ in terms of the concentration of the injected electron-hole pairs $\Delta n (=\Delta p)$. For simplicity, assume $T=0$ K and $\Delta n >> n_0$.
   a. Using $n = \int_{E_C}^{E_F} \rho_e(E) \cdot f(E) dE = n_0 + \Delta n \approx \Delta n$, show that
   $$E_{fc} = E_C + (3\pi^2)^{2/3} \frac{\hbar^2}{2m_e} (\Delta n)^{2/3}.$$  
   b. Under similar assumptions, show that
   $$E_{fv} = E_V + (3\pi^2)^{2/3} \frac{\hbar^2}{2m_v} (\Delta n)^{2/3}.$$  
   c. From (a) and (b), show that
   $$E_{fc} - E_{fv} = E_g + (3\pi^2)^{2/3} \frac{\hbar^2}{2m_e} (\Delta n)^{2/3}.$$  
   Explain the physical meaning of $(E_{fc} - E_{fv})$.
   d. For GaAs, $m_e = 0.067 m_0$ and $m_v = 0.45 m_0$ and $E_g = E_C - E_V = 1.42$ eV, plot $E_{fc}$ and $E_{fv}$ versus $\Delta n$ in the following semi-log plot ($E_{fc}$ and $E_{fv}$ in linear scale, $\Delta n$ in log scale). Which quasi-Fermi level moves faster with increase of $\Delta n$?