1. Problem 3.8. Note: $x = 0$ refers to the (second) interface where $V_2$ changes from $-2eV$ to $3eV$.

2. Consider electron incidence onto a metal/vacuum interface (from metal to vacuum). The height of the potential barrier is $5eV$. Suppose the electron energy is $10eV$ and $3eV$, respectively, calculate (for both cases)
   (1) $k_1$ and $k_2$.
   (2) The electron reflection/transmission coefficients and the current reflection/transmission coefficients.

3. If the location of the metal and vacuum is switched (electron incidence from vacuum to metal), repeat Problem 2. Hint: please note the sign of $V_2$.

4. Suppose we shoot UV light of certain wavelength onto two quantum dot (QD) solutions (same material, but different size). One solution appears red color (with light emission wavelength of $630$ nm) and another solution appears blue color (with light emission wavelength of $480$ nm). Suppose energy levels $E_1$ and $E_{11}$ are most preferable for the electrons.
   (1) Calculate the energy gap (difference) between $E_1$ and $E_{11}$ for the above two QD solutions.
   (2) Determine the average size of the nanoparticles of the above two QD solutions.
   (3) What is the minimum photon energy of the incident UV light to “light up” both the QD solutions? What can you say about the wavelength requirement of the incident UV light?
   (4) If the size of QD particles are increased to $50 \mu m$, what is the difference between $E_{11}$ and $E_1$? What is the wavelength of the emission? Is it still visible ($400$ nm-$700$ nm)?

Hint:
(1) QDs can be considered as 3D quantum wells for the electrons confined inside when $E<V_2$. The energy of the electrons is thus discrete and turn into individual levels, which can be estimated by $E_n = \frac{h^2n^2}{8mL^2}$, where $n$ is the energy level number and $L$ is the average size of the QD (nanoparticle). The electrons cannot take any energy values between $E_{n-1}$ and $E_n$.
(2) When absorbing energy from photons, thermal heating, or electrical current, the energy of the electrons can be increased to a preferable higher discrete value determined by the equation of $E_n$. In this case, we can say the electrons are
“excited” to a higher energy level. The total absorbed energy is equal to the
difference between the original and targeted levels. To do so, the total supplied
energy must be equal to or greater than the difference.
(3) Naturally, the electrons on high energy levels tend to lose their energy to “relax”
to a lower energy level. The total lost energy is equal to the difference between
the original and targeted levels. Under certain conditions, this energy can be
completely converted into that of a photon with energy equal to $\frac{hc}{\lambda}$.

5. Suppose we use a scanning tunneling microscope (STM) to conduct surface
measurements on copper surface. At the measurement temperature, the electron
energy is 4.45eV lower than the potential barrier imposed by the vacuum gap. When
the probe tip is scanning on a flat and smooth surface, the tunneling current is
maintained at $I_0$. However, when the probe tip scans across a surface feature, the
tunneling current becomes 0.1$I_0$.
(1) Is this a concave or convex feature?
(2) Calculate $k_2$.
(3) What is the depth ($d$) or height ($h$) of this feature?

Hint: Suppose when the probe is on the flat surface, the gap is $d_1$. When the probe is
scanning on the surface feature, the gap becomes $d_2$. The difference between $d_1$ and
$d_2$ gives $h$ or $d$. 

![STM probe tip diagram]