Name: ______________________

EE451 Problem Set 1
(Due 8/27/07)

These problems are based on Anderson, Chapter 1. Please complete the problems in pencil on engineering paper and attach them by staple to this cover sheet.

Review Questions: 1, 4, 5, 6, 7, 12

Problems1.4, 1.8 parts a and b only, 1.14, 1.15, 1.19, 1.20, 1.21

Review

1 1 eV = 1.602×10^{-19} J it is energy gained by an electron accelerated through a potential difference of 1 Volt

4 each atom in the solid contributes energy states. These states can not be exactly the same - so they instead form a band of closely spaced states

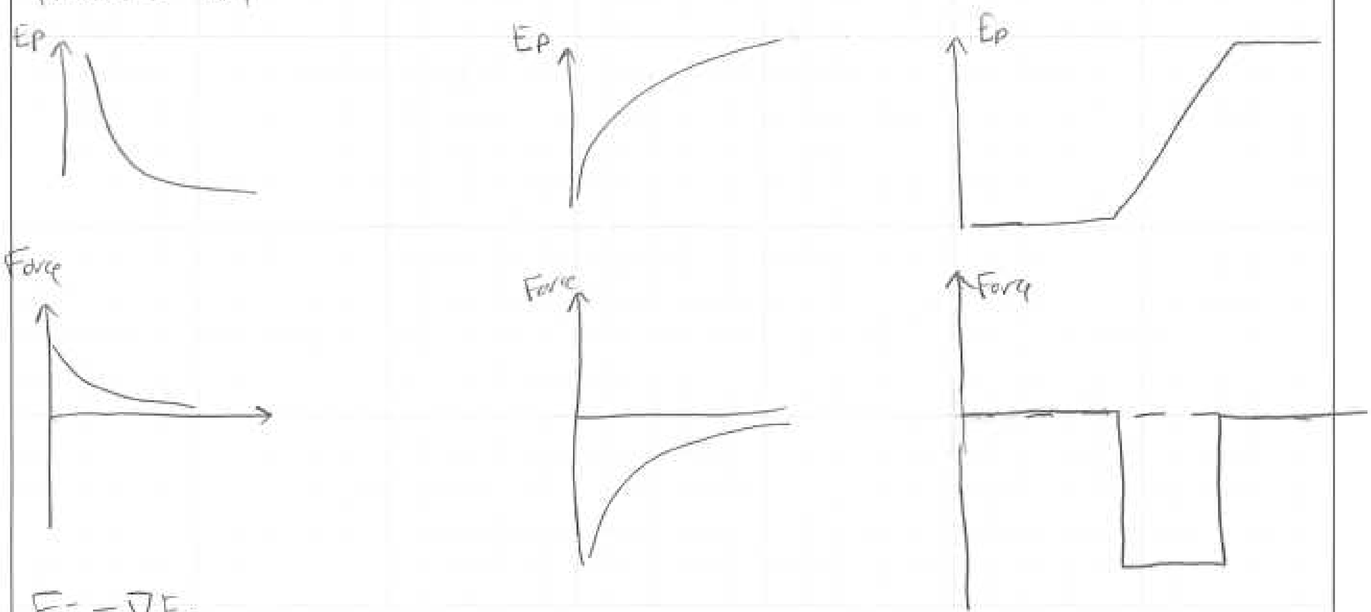
5 Band gap of insulator is greater than band gap of semiconductor

6 Metals do not have full valence shells + do not covalently bond - the valence electrons are free to move - There is no energy gap.

7 Thermal energy [phonons] increases with temp. This causes more electrons to be pushed into conduction band increasing conductivity

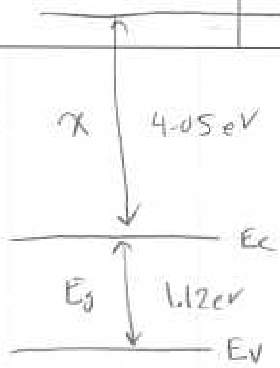
12 When a photon transfers its energy to an electron, the electron's energy increases by an amount equal to photon energy. The photon is annihilated - it ceases to exist.

Problems 1.4

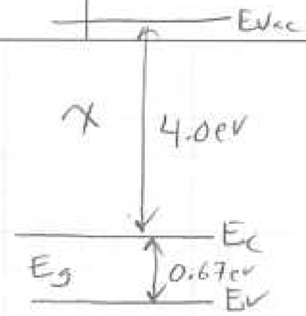


$F = -\nabla E_p$

P1.8 Si



Ge



P1.11 10^6 electrons/cm^3 in the conduction band

a) There must be an equal number [density] of holes in the valence band - That is where the electrons had to come from

b) Constant recombination of electron-hole pairs is offset by equal constant generation of electron-hole pairs

P1.14 wavelength

a) e^- with 1eV of KE $\quad E_K = \frac{1}{2}mv^2 = \frac{(mv)^2}{2m} = \frac{p^2}{2m}$

$$p = \sqrt{2mE_K} = \sqrt{(2)(9.109\times10^{-31}\,kg)(1eV)(1.602\times10^{-19}\,\tfrac{J}{eV})}$$

units $\left[kg\, kg\, \frac{m^2}{s^2}\right]^{1/2} = kg\,\frac{m}{s}$

$$= 5.40\times10^{-25}\ \frac{kg\,m}{s}$$

$$\lambda = \frac{h}{p} = \frac{6.626\times10^{-34}\ J\cdot s}{5.40\times10^{-25}\ \frac{kg\,m}{s}} = 1.23\times10^{-9}\ m$$

$= 1.23\ nm$

b) e^- $E_K = 10\,keV$ $\quad p \propto \sqrt{E_K}$ so $p = \sqrt{10{,}000}\ 5.40\times10^{-25}\ \frac{kg\,m}{s}$ ↑ from above

$$\lambda = \frac{h}{p} = \frac{1.23\,nm}{\sqrt{10000}} \quad 0.0123\ nm$$

c) $$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{6.626\times10^{-34}\ J\cdot s}{(1\times10^{-9}\,kg)(1\times10^{-3}\,\frac{m}{s})} = 6.626\times10^{-22}\ m$$

me mass = 200 lb = 90.9 kg

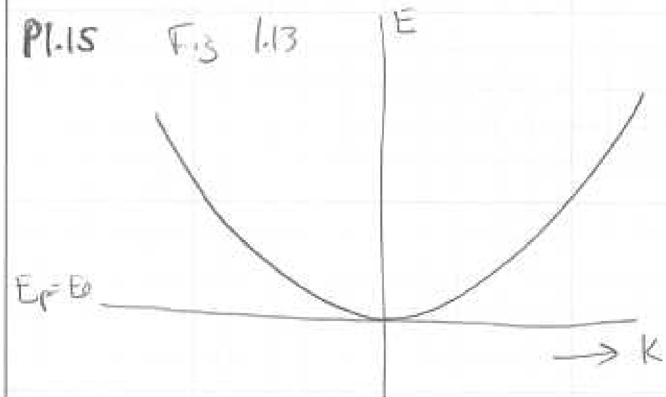
$$v = \left(4\,\frac{\text{miles}}{\text{hr}}\right)\left(\frac{5280\text{ ft}}{\text{mile}}\right)\left(\frac{0.3048\text{ m}}{\text{ft}}\right)\left(\frac{1\text{ hr}}{3600\text{ s}}\right) = 1.79\ \frac{m}{s}$$

$$\lambda = \frac{h}{p} = \frac{6.626\times10^{-34}\ J\cdot s}{(90.9\text{ kg})(1.79\ \frac{m}{s})} = 4.07\times10^{-36}\ m$$

b The size of atoms is on the order of angstroms $\text{Å} = 10^{-10}\ m$

Wavelengths of large bodies is much smaller than atomic size.

P1.15 Fig 1.13



at bottom of parabola $K = \phi$

Thus $\lambda = \frac{2\pi}{K} \to \infty$

Wavelength is infinite

$E_K = \frac{p^2}{2m}$ $\quad p = \frac{h}{\lambda} = \phi$

So KE is ϕ

P1.19 a) $E_2 \to E_1$ $\quad \Delta E = E_2 - E_1 = (E_{vac} - 3.4\,eV) - (E_{vac} - 13.6\,eV)$
$= 10.2\,eV$

$$\Delta E = h\nu = \frac{hc}{\lambda} \qquad \lambda = \frac{hc}{\Delta E} = \frac{(6.626\times10^{-34}\ J\cdot s)(3\times10^{8}\ \frac{m}{s})}{(10.2\ eV \times 1.602\times10^{-19}\ \frac{J}{eV})}$$

$= 122\ nm$

b) $E_4 \to E_3$ $\quad \Delta E = (E_{vac} - 0.85\,eV) - (E_{vac} - 1.51\,eV) = 0.66\,eV$

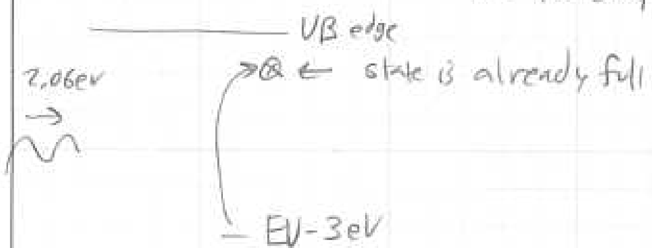
$$\lambda = \frac{hc}{\Delta E} = 1.9\,\mu m$$

P1.20 a) Since $E_2 \rightarrow E_1$ emits light with $\lambda = 122$, the same wavelength light will be absorbed by hydrogen

b) Light with $\lambda = 430\,nm$ has $E = \frac{hc}{\lambda} = 2.88\,eV$

will not be absorbed by Hydrogen since this energy does not correspond with any transition between states

P1.21 a) an electron deep in conduction band [greater than 2.06eV below] can not absorb a photon with E=2.06eV. This is because the valence band is nearly completely full - There would be no empty state for the electron to move into



b) a photon is unlikely to be absorbed by an electron in the conduction band because the conduction band is very nearly empty -