Week 2 Practice Assignment

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Week 2 Practice Assignment

Poll Q1. Can intrinsic silicon fermi energy (E_{Fi}) ever be exactly at the center of the bandgap ($\frac{E_g}{2}$) ?

A. Never
B. For T= 0 K
C. For $m^*_e = m^*_h$
D. Insufficient data

$$E_{Fi} - E_V = \frac{E_g}{2} - \frac{3kT}{4} ln\left(\frac{m^*_e}{m^*_h}\right)$$

Poll Q2. For intrinsic silicon what would affect conductivity?

A. temperature
B. μ_e and μ_h
C. Both A and B
D. Neither A nor B

$$\sigma = ne\mu_e + pe\mu_h$$

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Week 2 Practice Assignment

1) In an **intrinsic semiconductor**, $N_c > N_v$. Where is the **Fermi level** located at room temperature? Take E_g as the band gap. All choices are given with respect to the top of the valence band (E_v).

- above $E_g/2$
- below $E_g/2$
- at $E_g/2$
- at E_g

$$E_{Fi} = E_V + \frac{E_g}{2} - \frac{kT}{2} ln\left(\frac{N_C}{N_V}\right)$$

$$E_{Fi} = 0 + \frac{E_g}{2} - \frac{kT}{2} ln(A)$$

Since $N_c > N_v$

A > 1

$$E_{Fi} = \frac{E_g}{2} - (B)$$

B > 0

$$E_{Fi} < \frac{E_g}{2}$$

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2) Which of the following materials can be considered **transparent** to visible light?

- ◯ Silica
- ◯ Silicon
- ◯ Cadmium sulphide
- ◯ Gallium arsenide

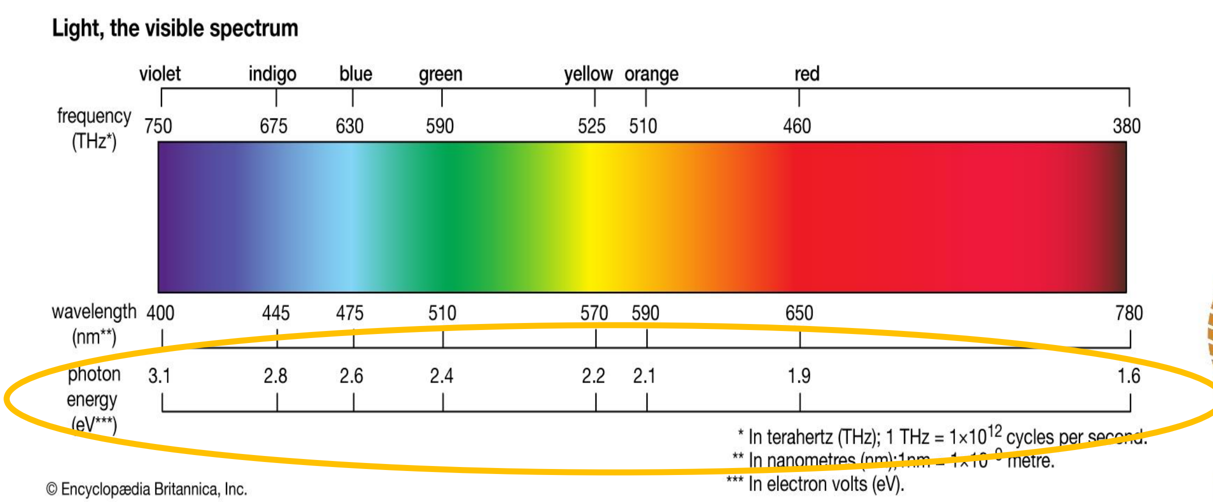
$E_g > E_i$ → Incident light is transmitted through material

Transparent

$E_g < E_i$ → Incident light is absorbed by material

Opaque

Material	Band gap E_g (eV)
SiO_2	9
Si	1.1
CdS_2	2.4
GaAs	1.4



Week 2 Practice Assignment

3) Given that the effective masses of electrons and holes in silicon are 1.10 m_e and 0.55 m_e respectively, find the location of the **intrinsic Fermi level** at 300 K. m_e is the rest mass of an electron and the band gap of silicon is 1.1 eV. Give your answer in eV.

- ○ 0.54 eV above the valence band edge
- ○ 0.54 eV below the conduction band edge
- ○ 0.45 eV above the valence band edge
- ○ 0.45 eV above the conduction band edge

Given: $m_e^* = 1.1m_e$ and $m_h^* = 0.55\ m_e$, $E_g = 1.1$ eV

$$E_{Fi} = E_V + \frac{E_g}{2} - \frac{3kT}{4} ln\left(\frac{m^*{}_e}{m^*{}_h}\right)$$

$$E_{Fi} = 0 + \frac{1.1}{2} - \frac{3kT}{4} ln\left(\frac{1.1m_e}{0.55m_e}\right)$$

$$E_{Fi} = 0 + 0.55 - 0.014$$

$$E_{Fi} = 0.54 \text{ eV}$$

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4) Two semiconductors X and Y have the **same effective density of states** both at the conduction (N_c) and valence band edges (N_v). The intrinsic carrier concentration of X and Y at 300 K are $2 \times 10^{13}\ \mathrm{cm}^{-3}$ and $10^{10}\ \mathrm{cm}^{-3}$ respectively. If the band gap of X is 0.7 eV, find the band gap of Y (in eV). ***1 point***

- 1.4
- 1.1
- 0.9
- 0.7

Given: $N_C x = N_C y$, $N_V x = N_V y$, $n_i x = 2\times10^{13}\ \mathrm{cm}^{-3}$, $n_i y = 10^{13}\ \mathrm{cm}^{-3}$, $E_{gX} = 0.7$ eV

$$n_i = \sqrt{N_V N_C} \times e^{\left(\frac{-E_g}{2kT}\right)}$$

$$n_{iX} = \sqrt{N_{VX} N_{CX}} \times e^{\left(\frac{-E_{gX}}{2kT}\right)} \qquad n_{iY} = \sqrt{N_{VY} N_{CY}} \times e^{\left(\frac{-E_{gY}}{2kT}\right)}$$

$$\frac{n_{iX}}{n_{iY}} = \frac{\sqrt{N_{VX} N_{CX}} \times e^{\left(\frac{-E_{gX}}{2kT}\right)}}{\sqrt{N_{VY} N_{CY}} \times e^{\left(\frac{-E_{gY}}{2kT}\right)}}$$

$$2\times10^{3} = e^{\left(\frac{E_{gY}-E_{gX}}{2kT}\right)}$$

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Week 2 Practice Assignment

4) Two semiconductors X and Y have the **same effective density of states** both at the conduction (N_c) and valence band edges (N_v). The intrinsic carrier concentration of X and Y at 300 K are $2 \times 10^{13}\ \mathrm{cm}^{-3}$ and $10^{10}\ \mathrm{cm}^{-3}$ respectively. If the band gap of X is 0.7 eV, find the band gap of Y (in eV). ***1 point***

- 1.4
- 1.1
- 0.9
- 0.7

$$2 \times 10^3 = e^{\left(\frac{E_{gY} - E_{gX}}{2kT}\right)}$$

$$7.6 = \frac{E_{gY} - 0.7}{2kT}$$

$$7.6 = \frac{E_{gY} - 0.7}{2 \times 0.026}$$

$$0.395 = E_{gY} - 0.7$$

$$E_{gY} = 1.1\ eV$$

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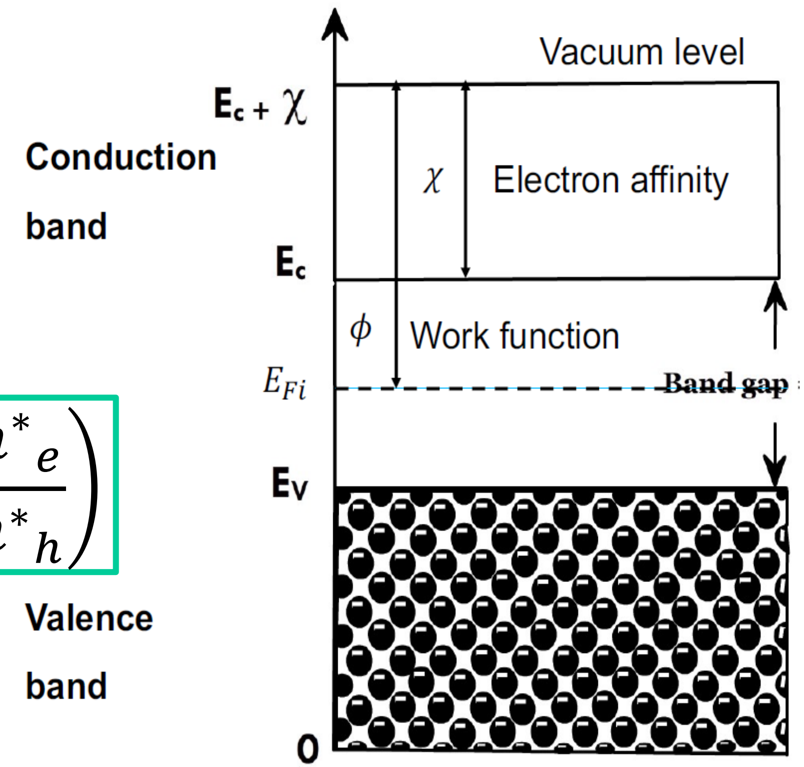
Week 2 Practice Assignment

5) The band gap of intrinsic GaAs is 1.43 eV and its electron affinity is 4.07 eV. Assuming that the effective masses of electrons and holes at the band edges are **equal**, what is the **work function** of the material? Give your answer in eV.

- 2.64
- 5.5
- 4.07
- 4.78



Given: $E_g = 1.43$ eV , $\chi = 4.07$ eV , $m_h^* = m_e^*$

$$\phi = \chi + E_C - E_{Fi}$$

$$E_{Fi} - E_V = \frac{E_g}{2} - \frac{3kT}{4} ln\left(\frac{m^*_e}{m^*_h}\right)$$

$$\phi = \chi + E_C - \left[E_V + \frac{E_g}{2} - \frac{3kT}{4} ln\left(\frac{m^*_e}{m^*_h}\right)\right]$$

0 0

$$\phi = \chi + E_C - \left[0 + \frac{E_g}{2} - 0\right]$$

$$\phi = \chi + E_C - \left[\frac{E_g}{2}\right]$$

$$\phi = \chi + \frac{E_g}{2}$$

$$\phi = 4.78\ eV$$

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