Week 4 Practice Assignment

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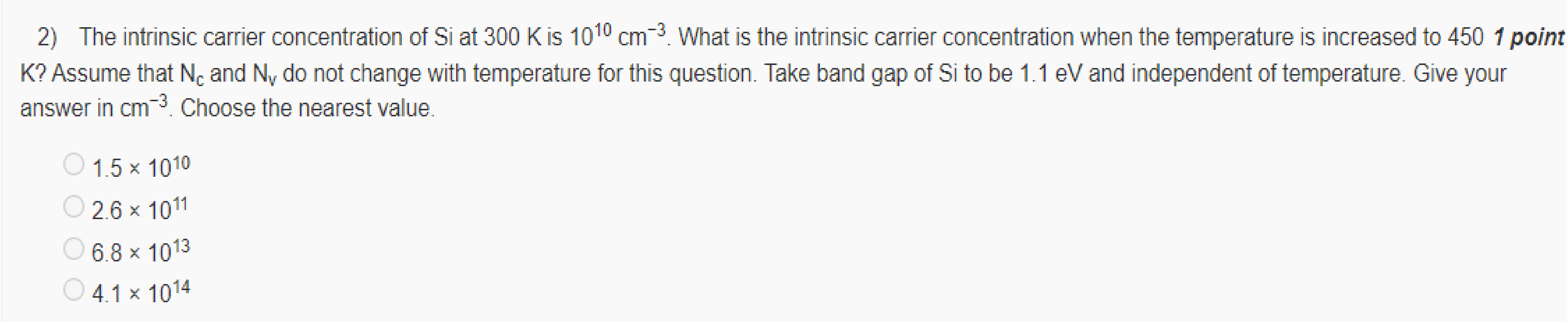
NOC22 MM11

Fundamentals of Electronic Materials and Devices

February 20, 2022

Doubts clarification



2) The intrinsic carrier concentration of Si at 300 K is 10^{10} cm^{-3}. What is the intrinsic carrier concentration when the temperature is increased to 450 K? Assume that N_c and N_v do not change with temperature for this question. Take band gap of Si to be 1.1 eV and independent of temperature. Give your answer in cm^{-3}. Choose the nearest value. ***1 point***

- ○ 1.5×10^{10}
- ○ 2.6×10^{11}
- ○ 6.8×10^{13}
- ○ 4.1×10^{14}

Week-2 "Graded Assignment 2"

$$n_i = \sqrt{N_C N_V}\, e^{-\frac{E_g}{2kT}}$$

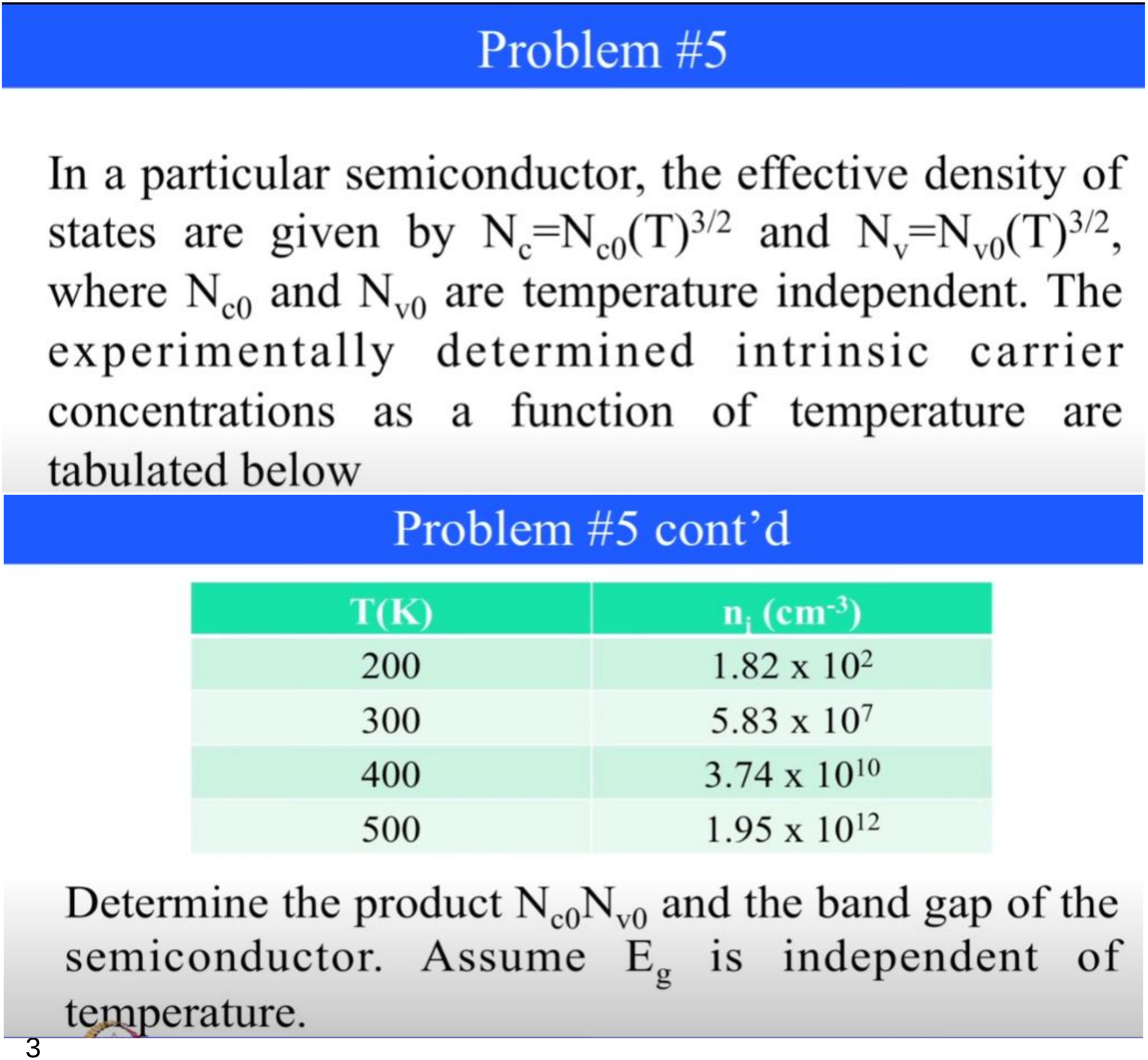
$$\frac{n_{i1}}{n_{i2}} = e^{-\frac{E_g}{2k}\left(\frac{1}{T_1}-\frac{1}{T_2}\right)}$$

$$\frac{n_{i1}}{n_{i2}} = e^{-\frac{E_g}{2k}\left(\frac{1}{450}-\frac{1}{300}\right)}$$

$$\frac{n_{i1}}{n_{i2}} = 1190.4$$

$$\boldsymbol{n_{i1} = 1.2 \times 10^{13}\ cm^{-3}}$$

Doubts clarification



Problem #5

In a particular semiconductor, the effective density of states are given by $N_c=N_{c0}(T)^{3/2}$ and $N_v=N_{v0}(T)^{3/2}$, where N_{c0} and N_{v0} are temperature independent. The experimentally determined intrinsic carrier concentrations as a function of temperature are tabulated below

Problem #5 cont'd

T(K)	n_i (cm^{-3})
200	1.82×10^{2}
300	5.83×10^{7}
400	3.74×10^{10}
500	1.95×10^{12}

Determine the product $N_{c0}N_{v0}$ and the band gap of the semiconductor. Assume E_g is independent of temperature.

Week-3 "Worked assignment on intrinsic semiconductors"- Week-3

Doubts clarification

$$n_{i(T)} = \left(T^{\frac{3}{2}}\right) e^{-\frac{E_g}{2kT}} \sqrt{N_{C_0} N_{V_0}}$$

$$n_{i(T)} = \left(T^{\frac{3}{2}}\right) e^{-\frac{E_g}{2kT}} \sqrt{N_{C_0} N_{V_0}}$$

$$5.83 \times 10^7 = (300)^{\frac{3}{2}}\, e^{-\frac{1.25 \times 1.6 \times 10^{-19}}{2k \times (300)}} \sqrt{N_{C_0} N_{V_0}}$$

For T = 300 K

$$\boldsymbol{N_{C_0} N_{V_0} = 1.18 \times 10^{29}\ cm^{-6} K^{-3}}$$

$$3.74 \times 10^{10} = (400)^{\frac{3}{2}}\, e^{-\frac{1.25 \times 1.6 \times 10^{-19}}{2k \times (400)}} \sqrt{N_{C_0} N_{V_0}}$$

For T = 400 K

$$\boldsymbol{N_{C_0} N_{V_0} = 1.18 \times 10^{29}\ cm^{-6} K^{-3}}$$

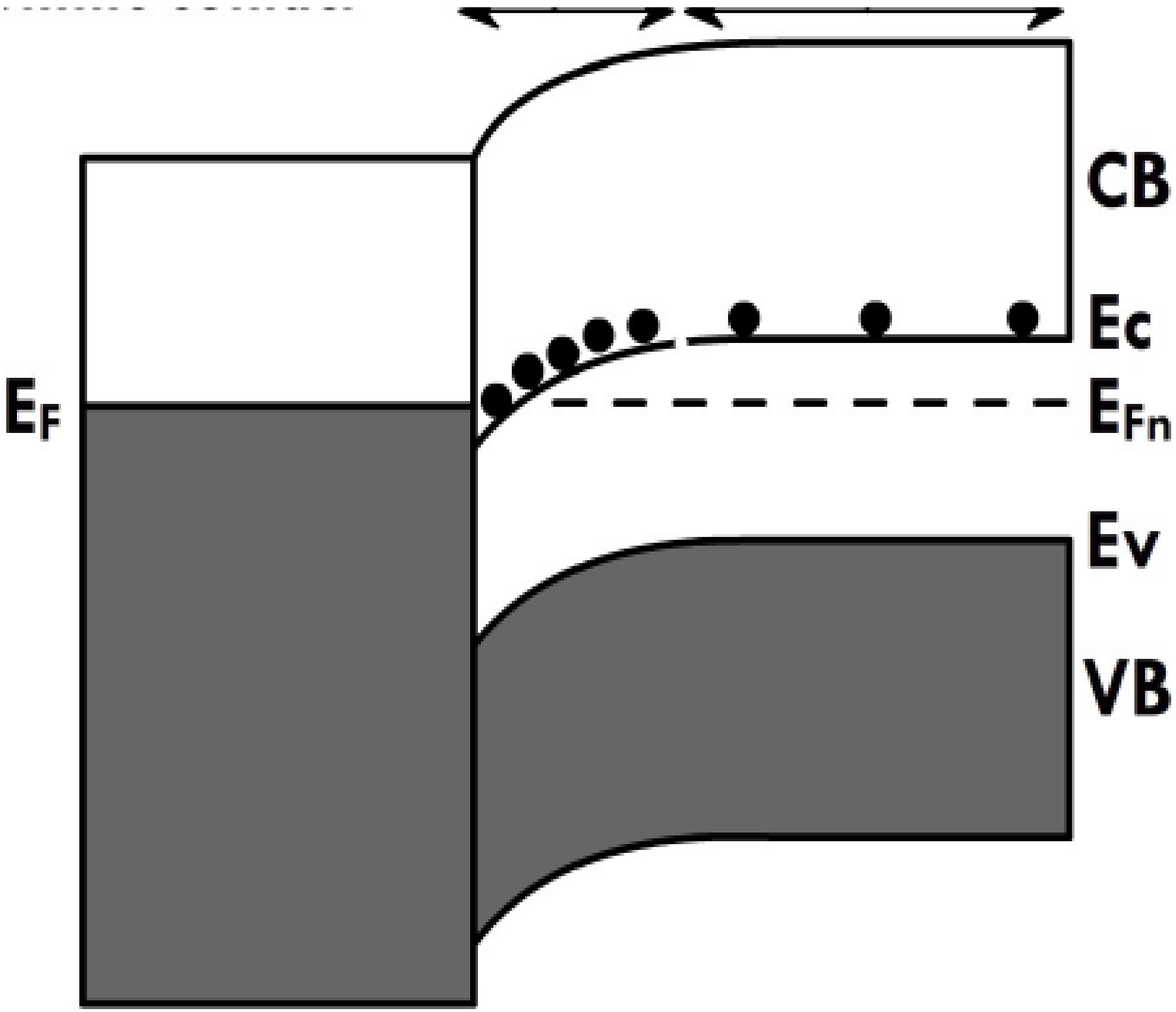
Week 4 Practice Assignment

Poll Q1. Identify the junction (assume equilibrium):

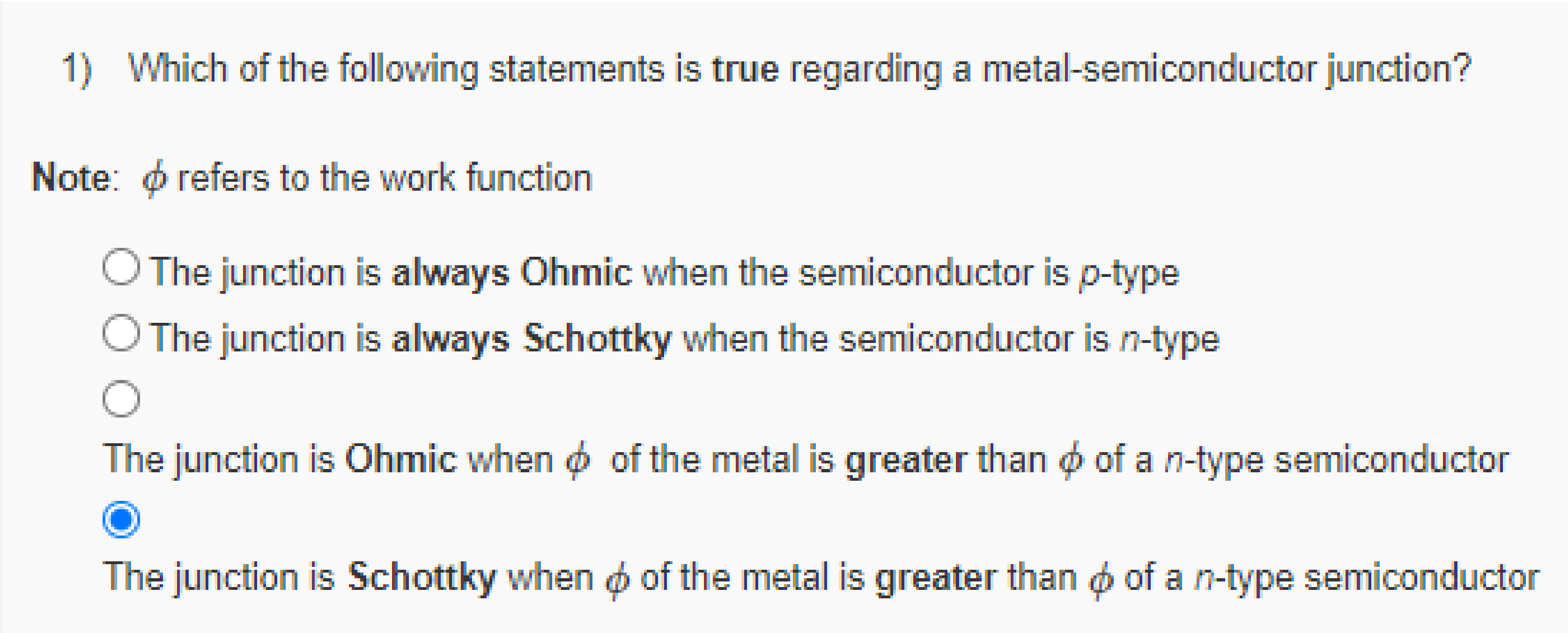
A. Metal-metal
B. Schottky
C. Ohmic

Poll Q2. Under biasing, this junction behaves as a:

A. Rectifier (conduction under forward bias only)
B. Resistor (conduction under forward & reverse bias)
C. None



Week 4 Practice Assignment



1) Which of the following statements is **true** regarding a metal-semiconductor junction?

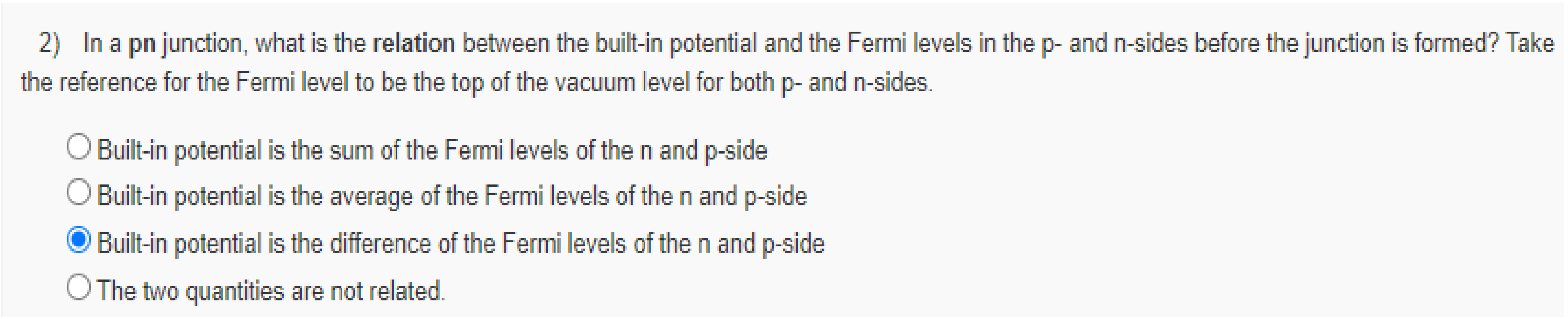
Note: ϕ refers to the work function

- ○ The junction is **always Ohmic** when the semiconductor is *p*-type
- ○ The junction is **always Schottky** when the semiconductor is *n*-type
- ○ The junction is **Ohmic** when ϕ of the metal is **greater** than ϕ of a *n*-type semiconductor
- ● The junction is **Schottky** when ϕ of the metal is **greater** than ϕ of a *n*-type semiconductor

Schottky Junction: $\phi_m > \phi_{semi}$

For n-type semiconductor

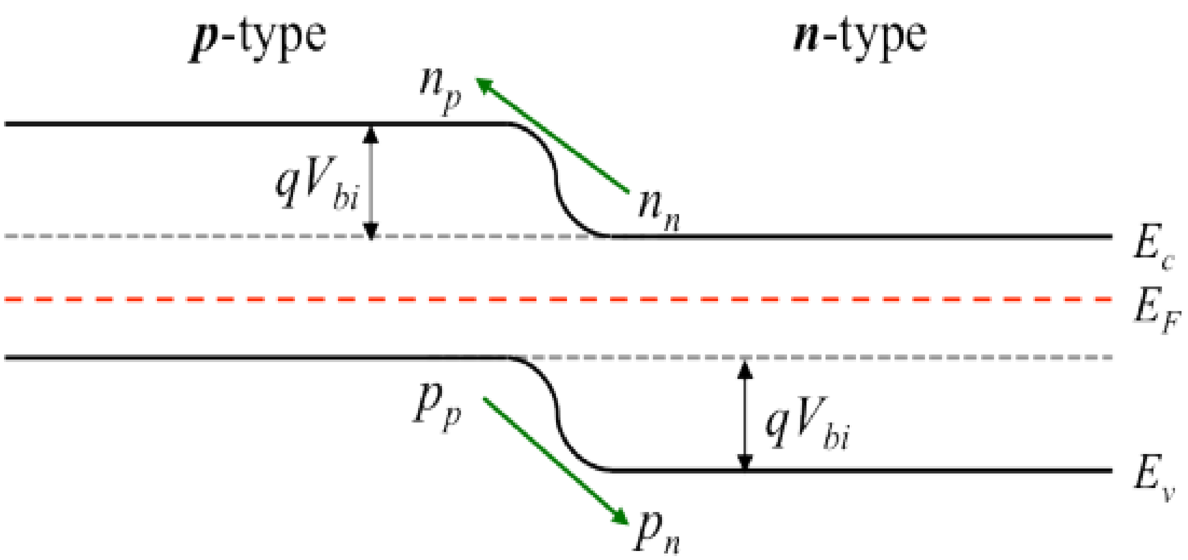
Week 4 Practice Assignment



2) In a **pn** junction, what is the **relation** between the built-in potential and the Fermi levels in the p- and n-sides before the junction is formed? Take the reference for the Fermi level to be the top of the vacuum level for both p- and n-sides.

- ○ Built-in potential is the sum of the Fermi levels of the n and p-side
- ○ Built-in potential is the average of the Fermi levels of the n and p-side
- ● Built-in potential is the difference of the Fermi levels of the n and p-side
- ○ The two quantities are not related.

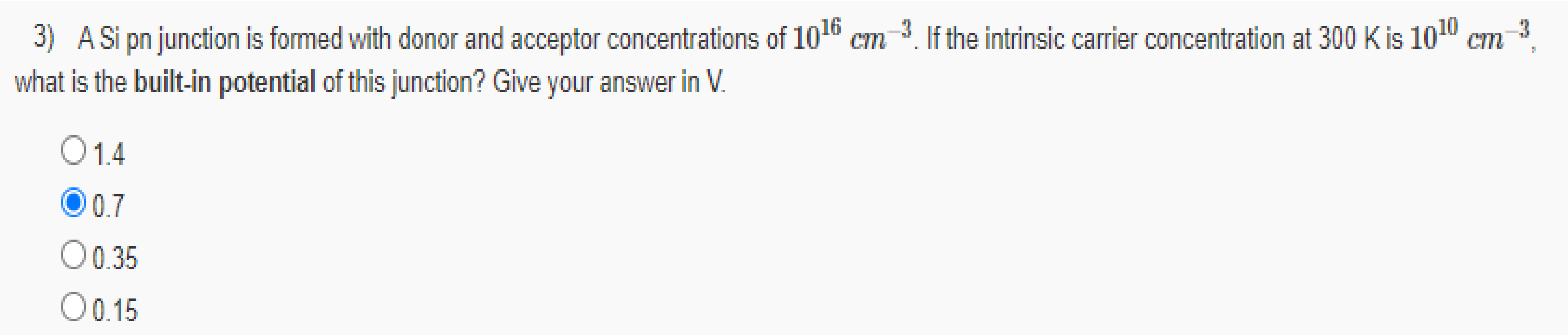
What is the built-in voltage V_{bi}?



$$\boxed{eV_0 = E_{Fn} - E_{Fp}}$$

Built-in voltage is simply the difference of the Fermi levels in p- and n-type semiconductors before they were joined.

Week 4 Practice Assignment



3) A Si pn junction is formed with donor and acceptor concentrations of $10^{16}\ cm^{-3}$. If the intrinsic carrier concentration at 300 K is $10^{10}\ cm^{-3}$, what is the **built-in potential** of this junction? Give your answer in V.

○ 1.4

● 0.7

○ 0.35

○ 0.15

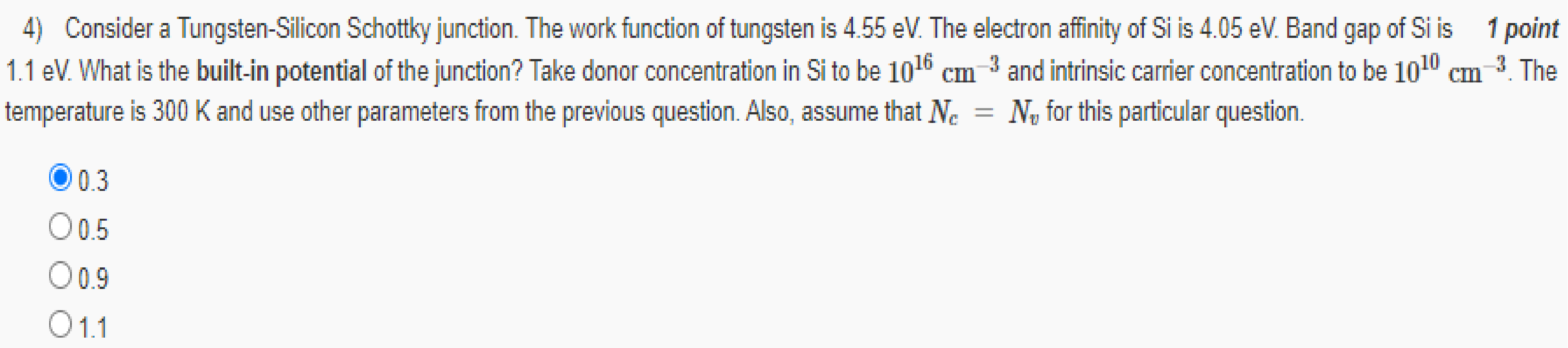
Given: $N_D = N_A = 10^{16}\ cm^{-3},\ n_i = 10^{10}\ cm^{-3}$

$$\boxed{V_0 = \frac{kT}{e} ln\left(\frac{N_A N_D}{{n_i}^2}\right)}$$

$$V_0 = 0.026 \times ln\left(\frac{10^{16} \times 10^{16}}{10^{20}}\right)$$

$$\mathbf{V_0 = 0.71\ V}$$

Week 4 Practice Assignment



4) Consider a Tungsten-Silicon Schottky junction. The work function of tungsten is 4.55 eV. The electron affinity of Si is 4.05 eV. Band gap of Si is 1.1 eV. What is the **built-in potential** of the junction? Take donor concentration in Si to be 10^{16} cm^{-3} and intrinsic carrier concentration to be 10^{10} cm^{-3}. The temperature is 300 K and use other parameters from the previous question. Also, assume that $N_c = N_v$ for this particular question.

1 point

- ● 0.3
- ○ 0.5
- ○ 0.9
- ○ 1.1

Given: $\phi_m = 4.55\ eV, \chi = 4.05\ eV,\ E_g = 1.1\ eV,\ N_D = 10^{16}\ cm^{-3},\ n_i = 10^{10}\ cm^{-3}$

$$\boxed{eV_0 = \phi_m - \phi_{semi}} \qquad \boxed{\phi_{semi} = \chi + \left(E_C - E_{F_n}\right)}$$

$$\phi_{semi} = \chi + \left[E_g - \left\{E_{F_i} + kT\ln\left(\frac{n}{n_i}\right)\right\}\right]$$

$$\phi_{semi} = \chi + \left[E_g - \left\{\frac{E_g}{2} + kT\ln\left(\frac{N_D}{n_i}\right)\right\}\right]$$

Week 4 Practice Assignment

$$\phi_{semi} = 4.05 + \left[1.1 - \left\{\frac{1.1}{2} + kTln\left(\frac{10^{16}}{10^{10}}\right)\right\}\right]$$

$$\phi_{semi} = 4.05 + \left[0.55 - \left\{kTln\left(\frac{10^{16}}{10^{10}}\right)\right\}\right]$$

$$\phi_{semi} = 4.05 + 0.19$$

$$\phi_{semi} = 4.24\ eV$$

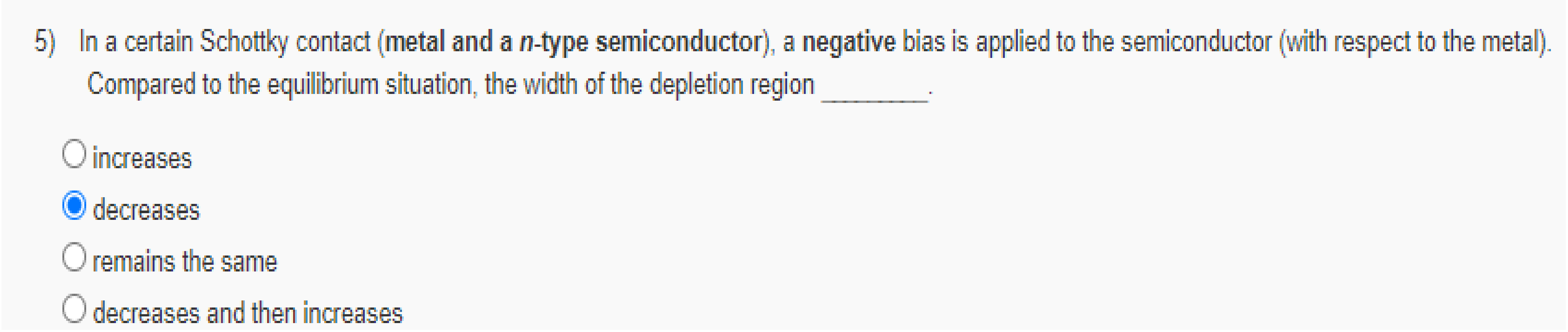
$$eV_0 = \phi_m - \phi_{semi}$$

$$eV_0 = 4.55 - 4.24$$

$$eV_0 = 0.31\ eV$$

$$\boldsymbol{V_0 = 0.31\ V}$$

Week 4 Practice Assignment



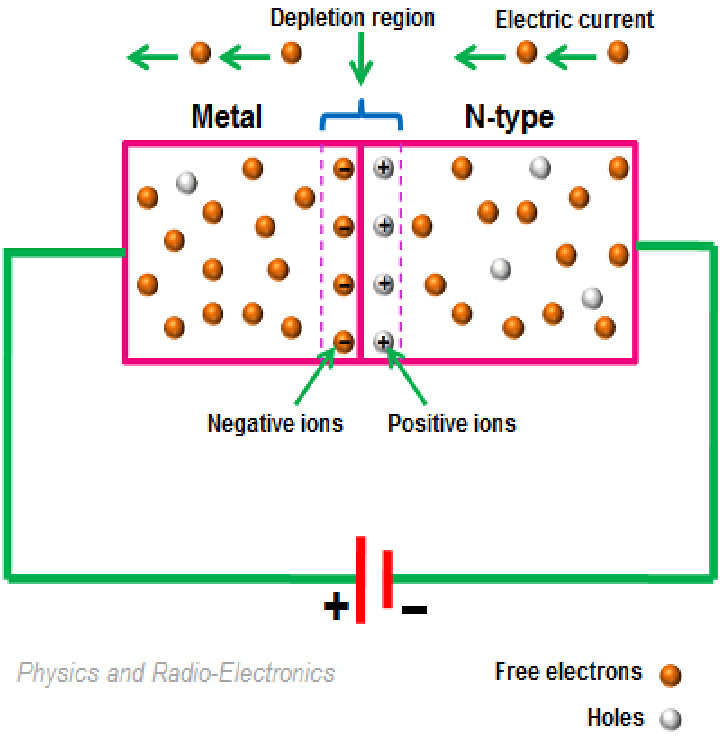
5) In a certain Schottky contact (**metal and a *n*-type semiconductor**), a **negative** bias is applied to the semiconductor (with respect to the metal). Compared to the equilibrium situation, the width of the depletion region ________.

○ increases

● decreases

○ remains the same

○ decreases and then increases



Forward biased schottky diode

If the applied voltage is continuously increased, the depletion region becomes very thin and finally disappears