EECS170A Fall 2011 **Midterm 2**

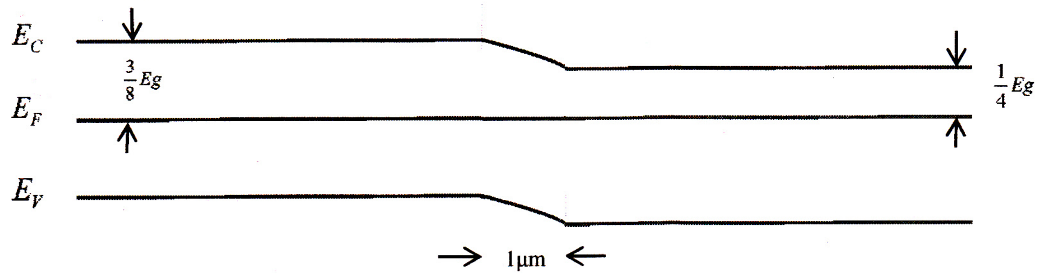
11/14/2011 4:00pm to 4:50pm

Professor Peter Burke

Name: Solution w GC

ID no.:

PROBLEM ONE: (30 points)



a) Sketch and find n(x) and p(x) on both sides.

b) Sketch $J_{ndiff}(x)$, $J_{ndrift}(x)$, $J_{pdiff}(x)$, $J_{pdrift}(x)$

c) Sketch E-field $\mathcal{E}(x)$

d) Find $N_D(x)$ on both sides assuming $N_A(x) = 0$.

a) $n(x)_L = N_c e^{-(E_c - E_F)/kT}$

$= 3.2\times10^{19} \cdot e^{-0.42/0.0259}$

$= 2.9\times10^{12}$ cm^{-3} on left

$p(x)_L = N_V e^{-(E_F - E_V)/kT}$

$= 1.9\times10^{19} e^{-(0.7)/0.0259}$

$= 3.476\times10^{7}$ cm^{-3} on left

2pts for p(x) calculation

2pts for n(x) calculation

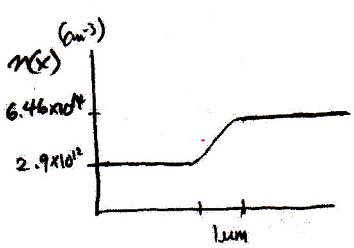
$n(x)_R = 3.2\times10^{19} \cdot e^{-0.28/0.0259}$

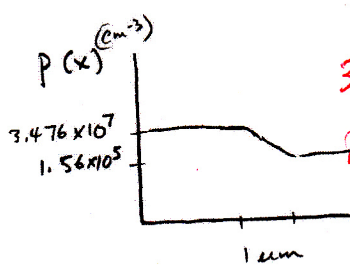
$= 6.46\times10^{14}$ cm^{-3} on right

$p(x)_R = 1.9\times10^{19} e^{-.84/0.0259}$

$= 1.56\times10^{5}$ cm^{-3} on right

3pts for n(x) sketch with Values

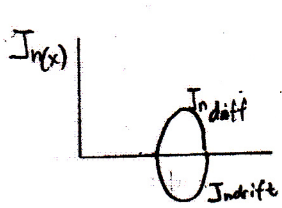




3pts for p(x) sketch with values

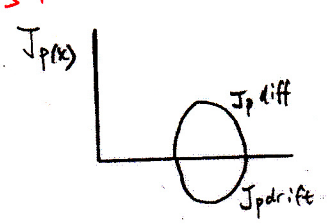
5pts for Jn

b)



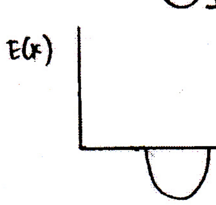
J total = 0

5pts for Jp



J total = 0

c)



6 pts for $\mathcal{E}(x)$

d) $N_D(x)$ left $= n(x)$ left $= 2.9\times10^{12}$ cm^{-3}

$N_D(x)$ right $= n(x)$ right $= 6.46\times10^{14}$ cm^{-3}

4 pts for d):

2pt for left side.

2pt for right side.

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PROBLEM TWO(25 points):

a) For a Given Silicon pn diode at room temperature, $N_A = 10^{17}\ cm^{-3}$ and $N_D = 10^{17}\ cm^{-3}$. Find Vbi.

$$Vbi = \frac{kT}{q}\ln\left(\frac{Na * Nd}{ni^2}\right)$$

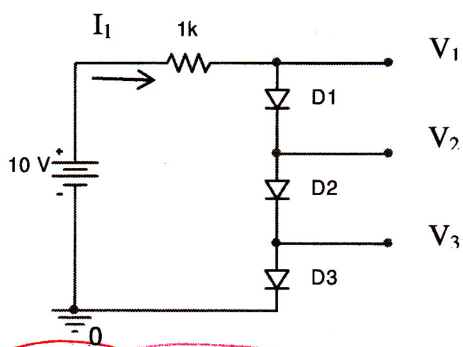
$$Vbi = 0.0259\ln\left(\frac{10^{34}}{10^{20}}\right)$$

3pts for correct setup

$$Vbi = 0.835V$$

2 pts for answer

b) For the circuit below, find the approximate current I_1, V_1, V_2, and V_3.



For 0.6V assumption: ← 2 pts for Diode turn on voltage assumption.

$$KVL: 10 = I_1R + 3Vd$$

$$I_1 = \frac{10 - 3Vd}{R} = \frac{10 - 3(0.6)}{1000} = 8.2mA$$ ← 2 pts for I_1

$$V_1 = 10 - I_1R = 10 - (8.2)(1000) = 1.8V$$ ← 2 pts for V_1

$$V_2 = 1.8V - 0.6V = 1.2V$$ ← 2 pts for V_2

$$V_3 = 1.2V - 0.6V = 0.6V$$ ← 2 pts for V_3

For 0.7V assumption:

$$KVL: 10 = I_1R + 3Vd$$

$$I_1 = \frac{10 - 3Vd}{R} = \frac{10 - 3(0.7)}{1000} = 7.9mA$$

$$V_1 = 10 - I_1R = 10 - (7.9)(1000) = 2.1V$$

$$V_2 = 2.1V - 0.7V = 1.4V$$

$$V_3 = 1.4V - 0.7V = 0.7V$$

Same as above

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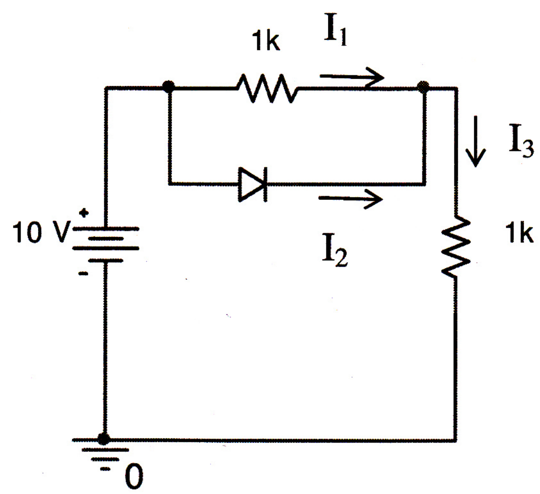
c) For the circuit below, find the approximate current for I_1, I_2, I_3.



For 0.6V assumption: ← 1pts for Diode turn on Voltage assumption

Set node between the two resistors to be Vx.

$$Vx = 10 - 0.6 = 9.4V$$ ← 3 pts for I_3

$$I_3 = Vx / 1000 = 9.4mA$$

$$I_1 = \frac{10 - Vx}{1000} = 0.6mA$$ ← 3pts for I_1

$$I_2 = I_3 - I_1 = 9.4 - 0.6 = 8.8mA$$ ← 3pts for I_2

For 0.7V assumption:

Set node between the two resistors to be Vx.

$$Vx = 10 - 0.7 = 9.3V$$

$$I_3 = Vx / 1000 = 9.3mA$$

$$I_1 = \frac{10 - Vx}{1000} = 0.7mA$$

$$I_2 = I_3 - I_1 = 9.3 - 0.7 = 8.6mA$$

} Same as Above.

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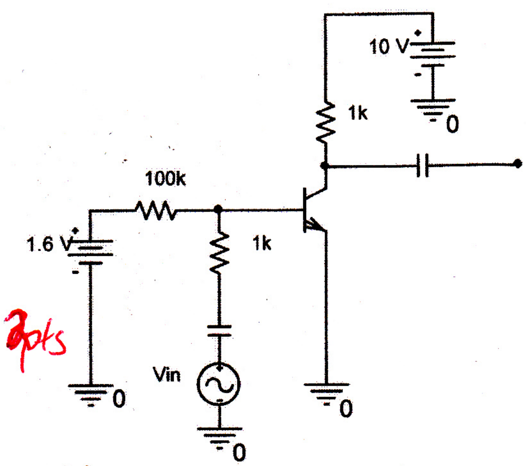
PROBLEM THREE(45 points):

For the amplifier circuit below at room temperature, β = 100 and the turn-on voltage for V_{BE} is 0.7V.

a) 22.5 pts — a) Find the AC voltage gain.

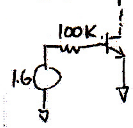
b) 22.5 pts — b) If the 100KΩ resistor becomes 50KΩ, find the AC voltage gain.

a) Find the AC voltage gain.
b) If the 100KΩ resistor becomes 50KΩ, find the AC voltage gain.



a).
i_B: 2 pts
i_C: 2 pts
V_C: 2 pts
Forward Active mode verification: 1 pt
Hybrid-π Model Correct drawing: 3 pts
g_m: 3 pts
r_π: 3 pts

a) DC op point: Assume F.A



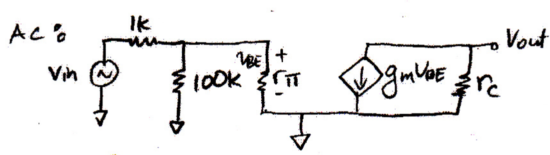
KVL: $1.6 = 100k\, i_B + 0.7$

$i_B = \frac{0.9mA}{100k} = 9\mu A$

$i_C = \beta i_B = 0.9mA$

$V_C = 10 - i_C \cdot R_C = 10 - (0.9)(1000) = 9.1V$ ← F.A ✓

AC:



$g_m = \frac{I_C}{V_T} = \frac{0.9mA}{0.0259} = 0.03475\ S$

$r_\pi = \frac{\beta}{g_m} = \frac{100}{0.03475} = 2877.7\Omega$

$v_{BE} = v_{in}\left(\frac{r_\pi // 100K}{r_\pi // 100K + 1K}\right)$

KCL: $\frac{V_{out}}{1K} = -g_m V_{BE}$ → $\frac{V_{out}}{V_{in}} = \left(\frac{r_\pi // 100K}{r_\pi // 100K + 1K}\right)(-g_m R_C) = \boxed{-25.6}$

Correct $\frac{V_{out}}{V_{in}}$ expression: 5 pts

Correct Final answer: 2.5 pts.

b) Same as (a)

b) DC op point: Assume F.A

$1.6 = 50k\, i_B + 0.7$

$i_B = 18\mu A$

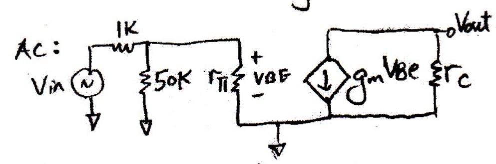
$i_C = 100 i_B = 1.8mA$ F.A ✓

$V_C = 10 - i_C \cdot R_C = 8.2V$

$g_m = \frac{I_C}{V_T} = \frac{1.8mA}{0.0259} = 0.695\ S$

$r_\pi = \frac{\beta}{g_m} = 143.9\Omega$

AC:



$V_{BE} = V_{in}\left(\frac{r_\pi // 50K}{r_\pi // 50K + 1K}\right)$

$\frac{V_{out}}{1K} = -g_m V_{BE}$

$\frac{V_{out}}{V_{in}} = \left(\frac{r_\pi // 50K}{r_\pi // 50K + 1K}\right)(-g_m R_C) = \boxed{-40.5}$