Student ID:_______________________**Student Name:** ____________________________

EHB222E INTRODUCTION TO ELECTRONICS (12006, 12084, 12085, 15189)

Midterm Exam 1 ✎ 1 November 2022 🕔 17.30-19.30

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1. When a silicon diode having a doping concentration of $N_A = 1.5x10^{14}$ /cm^3 on p-side and $N_D = 4.5x10^{17}$ /cm^3 on the n-side,

(L_n = 10 µm, L_p = 5 µm, μ_n = 1500 cm^2/Vs, μ_p = 500 cm^2/Vs. n_i = 1.5 10^{10} 1/cm^3, q = 1.602 10^{-19} C, V_T = 25 mV, ε_r = 12, ε_o = 8.85 10^{-12} F/m)

   a. Find the barrier voltage and saturation current for a junction area of 0,25 mm^2 (6 points)
   b. Calculate the specific conductivities of n- and p-type doped silicon (6 points)
   c. Determine the depletion zone width in unbiased state, when the junction is reverse biased at 3,5 V and when it is forward biased at 0,35 V (8 points)

2. Measurement on the circuit of figure produce labelled voltage as indicated in Fig.1. Find the value of I_B, I_E, I_C and β for transistor. ($|V_{BE}|$=0.7 V) (20 points)

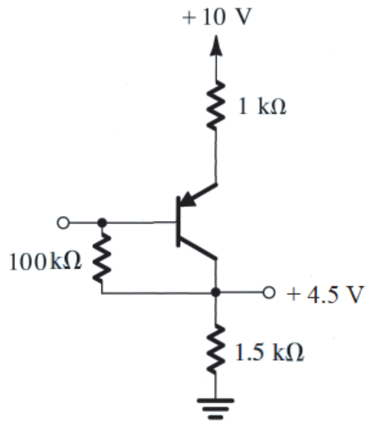


Fig.1

3. Build the truth table of the logic gate shown below in Fig.2. LOGIC 0 = 0 V, LOGIC 1 = 6 V. What GATE is this circuit? Write down your analysis and why you decided this is a ___________ gate? (10 points)

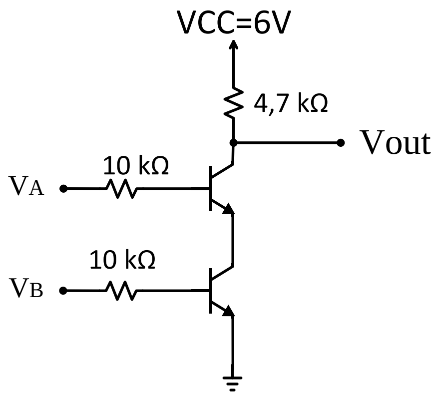


Fig.2

GOOD LUCK EVERYONE

4. For the circuit shown below in Fig.3, transistor parameters are: I_s=0,1 pA (saturation current), $ß_F$= 250, V_T=26mV

   a) Express the voltage V_{CE} in terms of V_{CC}, R_C, R_B, I_0 and $ß_F$, when the transistor is operating in the active region. (10 points)
   b) In which regime does the transistor work when the current I_0 is 2mA? Why? (10 points)
   c) Design a current mirror that will provide 2mA biasing current (I_0). (10 points)

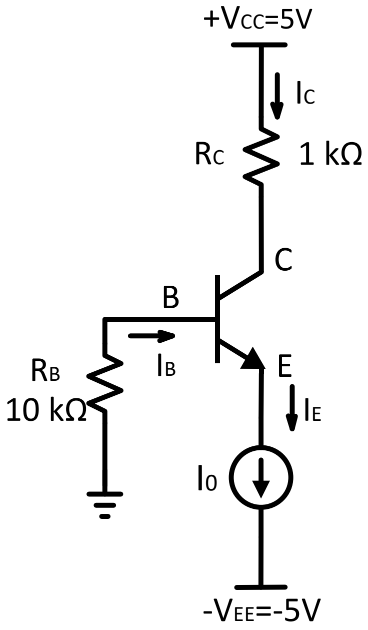


Fig.3

5. Find an expression for V_{out}(t) and skech it for 2 periods shown circuit below in Fig.4. Assume that diode D is ideal (20 points)

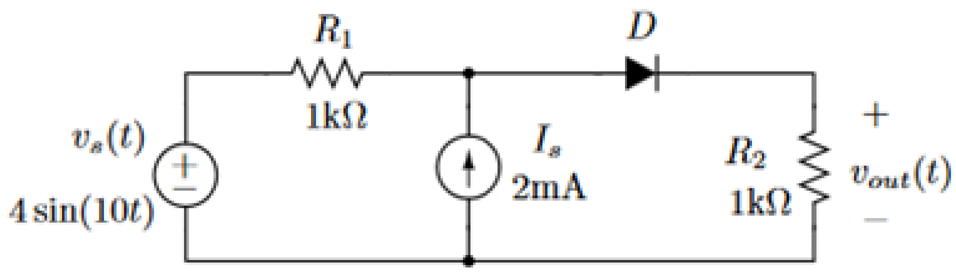


Fig.4

Solutions:

1. Using Einstein Equation , i.e., $D_{p/n} = V_T \cdot \mu_{p/n}$, we find D_p = 12,5 cm^2/s and D_n = 37,5 cm^2/s.

a. $V_B = V_T \cdot \ln\left(\frac{N_A \cdot N_D}{n_i^2}\right)$ =661 mV; $I_o = A \cdot q \cdot n_i^2 \cdot \left[\frac{D_p}{L_p N_D} + \frac{D_n}{L_n N_A}\right]$ = 22,5 pA

b. $\sigma_p = q \cdot \left(\frac{n_i^2}{N_A}\mu_n + N_A\mu_p\right) \cong qN_A\mu_p$= 0,012 /(Ω cm)

$\sigma_n = q \cdot \left(N_D\mu_n + \frac{n_i^2}{N_D}\mu_p\right) \cong qN_D\mu_n$ = 108 /(Ω cm)

c. unbiased $w_{dep} = \sqrt{\frac{2 \cdot \varepsilon_o \cdot \varepsilon_r \cdot V_B}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)}$ =2,417 μm

with reverse bias at 3,5 V, $w_{dep} = \sqrt{\frac{2 \cdot \varepsilon_o \cdot \varepsilon_r \cdot (V_B + V_{bias})}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)}$ = 6,06 μm

with forward bias at 0,35 V, $w_{dep} = \sqrt{\frac{2 \cdot \varepsilon_o \cdot \varepsilon_r \cdot (V_B - V_{bias})}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)}$ = 1,657 μm

2. $I_E = I_C + I_B = \frac{4.5V}{1.5K} = 3\text{ mA}$

V_E = 10V - 3mA x 1K = 7V

V_B = 7V - 0.7V = 6.3V

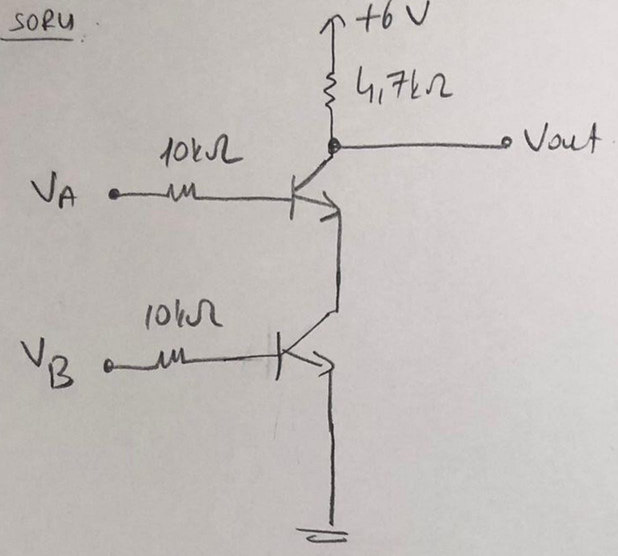
$I_B = \frac{6.3V - 4.5V}{100K} = 0.018\text{mA}$

I_C = 3mA - 0.018mA = 2.98mA

$\beta = \frac{2.98mA}{0.018mA} = 166$

3.

SORU: (1)



V_A / V_B	logic 0	logic 1
logic 0	1	1
logic 1	1	0

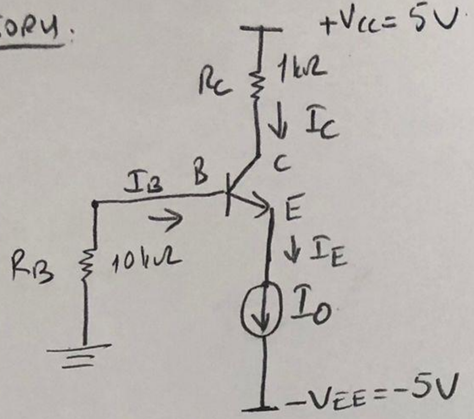
if V_A and V_B are zero voltage, transistor is in cut-off regime and $V_{out} = 6V$ = logic 1.

if V_A is logic 1 and V_B is logic 0, one of the transistor operates, the other is in cut-off regime. Transistors are serial connected. Therefore there is no current through the transistors V_{out} = logic 1

The same thing happend when V_A is logic 0 and V_B is logic 1. If V_A and V_B are logic 1 there is curent and V_{out} = logic 0

4.

SORU: 2



$I_S = 91pA$

$\beta_F = 250$

$V_T = 26mV$

a) $I_E = I_0 = I_C + I_B = I_B(1+\beta_F) = I_C \dfrac{(1+\beta_F)}{\beta_F}$

$V_{CC} = R_C I_C + V_{CE} + V_E$

$0 = R_B I_B + V_{BE} + V_E \Rightarrow V_E = -R_B I_B - V_{BE} = -R_B \dfrac{I_0}{(1+\beta_F)} - V_{BE}$

$$V_{CC} = R_C \cdot \frac{\beta_F}{(1+\beta_F)} I_0 + V_{CE} - R_B \frac{I_0}{(1+\beta_F)} - V_{BE}$$

$$V_{CE} = V_{CC} + R_B \frac{I_0}{(1+\beta_F)} + V_{BE} - R_C I_0 \cdot \frac{\beta_F}{(1+\beta_F)} \qquad (1)$$

$\underbrace{I_C = I_S e^{V_{BE}/V_T}}_{\text{Diode equation}} \Rightarrow V_{BE} = V_T \ln \dfrac{I_C}{I_S} = V_{BE} = V_T \ln \dfrac{I_0 \beta_F}{(1+\beta_F) \cdot I_S}$

Subtituting this equatin into (1)

$$\boxed{V_{CE} = V_{CC} + R_B \frac{I_0}{(1+\beta_F)} + V_T \ln \frac{I_0 \beta_F}{(1+\beta_F) I_S} - R_C I_0 \frac{\beta_F}{(1+\beta_F)}}$$

3

b)

$V_C \cong V_{CC} - R_C I_C = 3V$

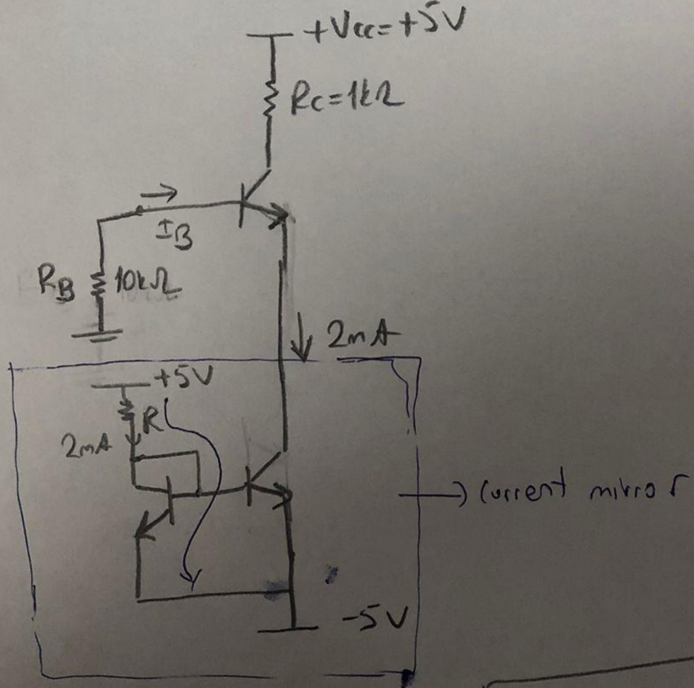
$V_{BE} \cong 26\cdot10^{-3} \ln \frac{2\cdot10^{-3}}{10^{-13}} \cong 617mV$

$I_B \cong \frac{2\cdot10^{-3}}{250} = 8\mu A$, $R_B \times I_B = 10^{4} \cdot 8\times10^{-6} = 80mV$

$V_E = -R_B I_B - V_{BE} \cong -0,7V$

$\underline{V_{CE} = 3 + 0,7 = 3,7 > V_{BE}}$ ⇒ Transistor operates in active region.

c)

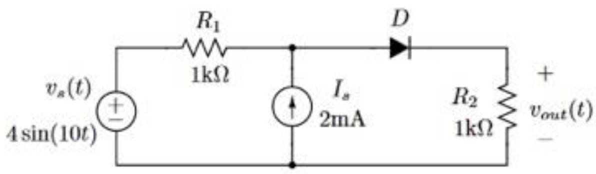


$5V = 2mA \times R + V_{BE} - 5V \Rightarrow \boxed{R = \frac{10V - 0,617}{2mA} \cong 4,7k\Omega}$

5.

Q-1)

Find an expression for $v_{out}(t)$ and sketch it for 2 periods. Assume that **diode D is ideal.**



When Vsine=-2V and Vx=0V all of the 2mA goes to the source Vout hits zero there on.

hence Vout=0 for Va(t)<-2V

for Va>-2V:

Due to current source:

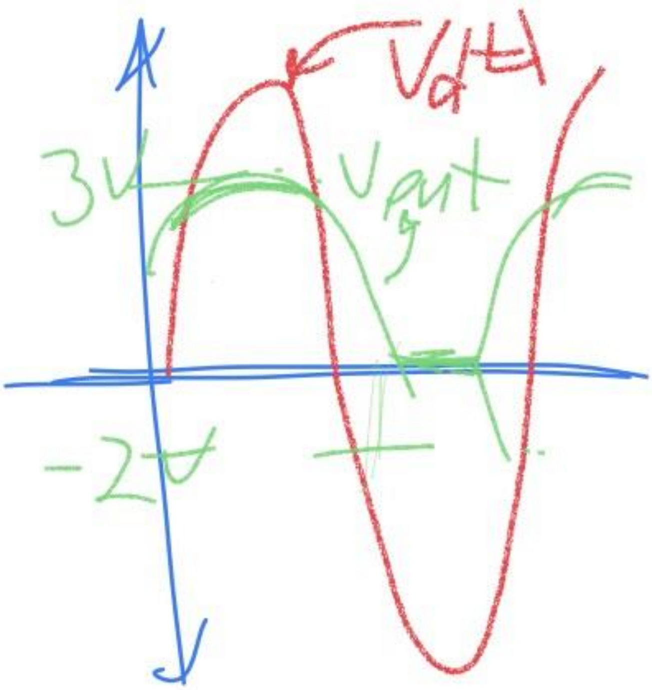
VoutCS=(2mA/2)x1k=1V

Due to Sine Voltage source:

VoutCS=Va/2

hence total Vout(t)=

2sin(10t)+1 V



Q-2)