EE 115A

Midterm Exam

Fall 2015
Group I

Your Name:

Name of Person to

Name of Person to Your Right: No body

Time Limit: 1 Hour and 50 Minutes

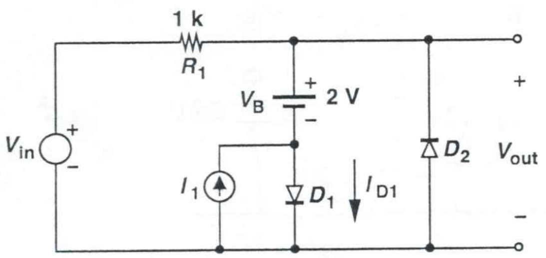
1. ~~9.5/10~~ 10/10
2. 10.5/15
3. 0/10
4. 2/15

Total: 22.5/50

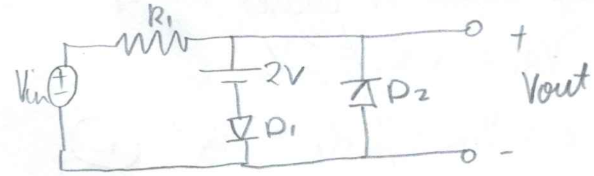
1. Assuming a constant-voltage diode model with $V_{D,on} = 0.8$ V,

(a) plot V_{out} and I_{D1} as a function of V_{in} if $I_1 = 0$. Show the details of your calculations. (5/5)

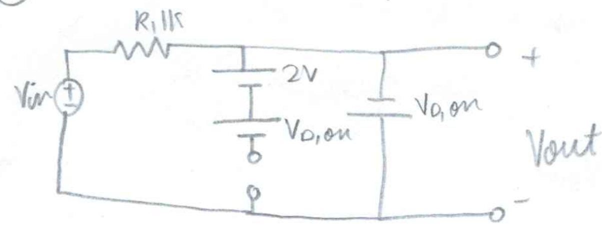
(b) plot V_{out} and I_{D1} as a function of V_{in} if I_1 is constant and equal to 1 mA. Show the details of your calculations. (4.5/5)



a)



① $V_{in} \to -\infty$ D_1 off D_2 on

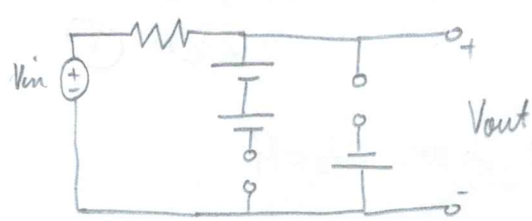


$V_{out} = -V_{D,on}$

$V_{in} < -V_{D,on}$ ✓ (1)

$I_{D_1} = 0$ ✓

② $V_{in} \uparrow$ D_2 off D_1 off

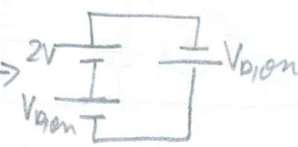


$V_{out} = V_{in}$ ✓ (1)

$-V_{D,on} < V_{in} < 2V + V_{D,on}$ $I_{D_1} = 0$ ✓

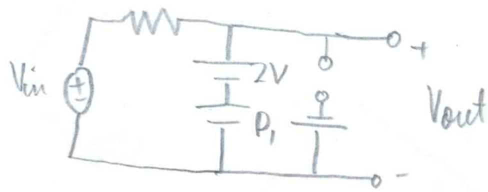
④ D_1 on D_2 on

not possible →



✓ (1)

③ $V_{in} \uparrow$ D_1 on, D_2 off

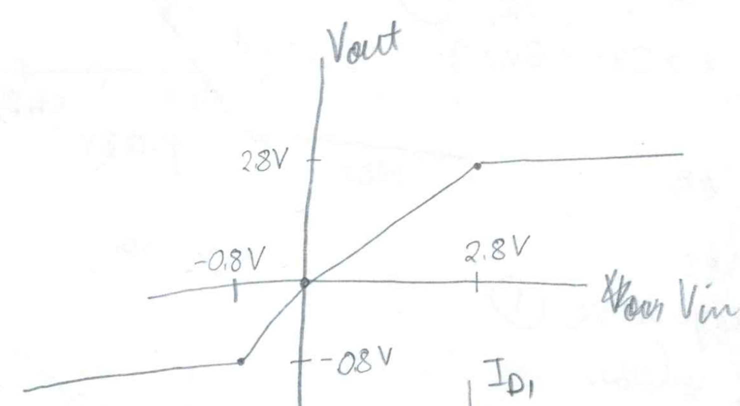


$V_{out} = V_{D,on} + 2V$ ✓

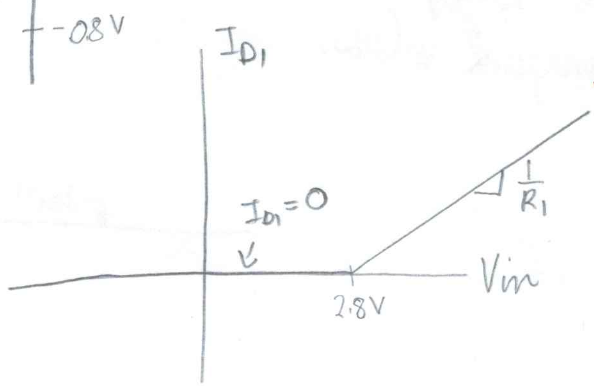
$V_{in} > V_{D,on} + 2V$

$I_{D1} = \frac{V_{in} - 2V - V_{D,on}}{R_1}$ ✓ (1)

$I_{D1} = \frac{V_{in}}{R_1} - \frac{2.8}{1000}$



(1) ✓



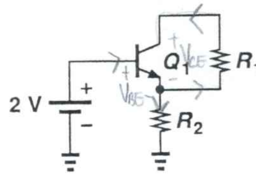
✓

(b) over →

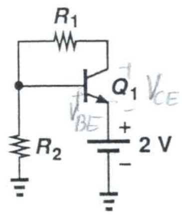
10.5 / 15

2. Determine the region of operation of Q_1 in each of the circuits shown below. Assume $I_S = 2 \times 10^{-16}$ A, $\beta = 100$, $V_A = \infty$. You need only show whether the transistor is in the forward active region, saturated, at the edge of saturation, or off ($I_C = 0$). Indicate which region and and explain why.

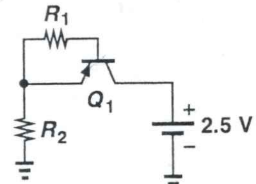
+n
+p
−n



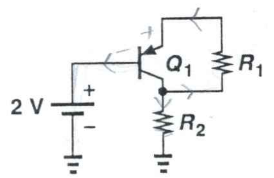
(a)



(b)

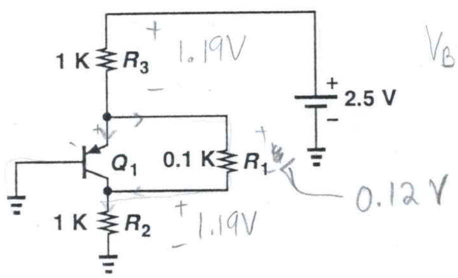


(c)



(d)

$V_B = 0$



(e)

a) $V_B = 2V$
$V_{BE} \approx .75V$
$V_C \approx 1.25V$

$V_B > V_C$ npn

saturation because collector and emitter are forward biased. (3)

b) $V_E = 2V$

off current cannot flow from emitter to colletor. (2.5)

justify E-B bias

c) off current cannot flow from 2.5 to ground. transistor is PNP (2.5)

d) $V_B = 2V$

off no supply voltage source (2.5)

e) off

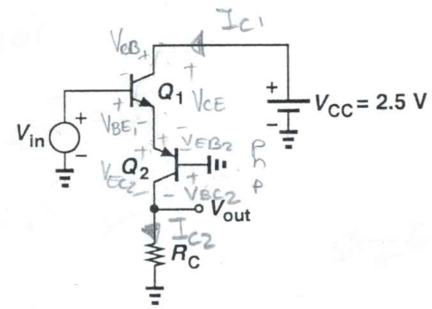
collector base voltage is reversed biased
base emitter voltage is reversed biased
$I_C = 0$ (0)

3. Consider the circuit shown below, where $I_{S1} = 3I_{S2} = 5 \times 10^{-16}$ A, $\beta_{npn} = 2\beta_{pnp} = 100$, and $V_A = \infty$. You can assume the collector and emitter currents are equal. $I_C = I_E$

(a) We wish to forward-bias the collector-base junction of Q_2 by no more than 200 mV. Determine the maximum allowable value of V_{in}.

(b) Suppose $V_{in} = 1.5$ V. What is the maximum value of R_C that forward-biases the collector-base junction of Q_2 by no more than 200 mV?

0/10



$V_{C1} = 2.5V$
$V_{B1} = V_{in}$
$V_{E1} =$
$V_{E2} =$
$V_{B2} = 0$
$V_{C2} =$
$I_{C1} = I_{C2}$
$V_{CE1} =$

a) $V_{CC} = V_{CE1} + V_{EB2}$ $\qquad V_{in} = 2V_{EB}$
$V_{CC} = V_{CB1} + V_{in}$
$V_{CC} = V_{CE1} + V_{EC2} + I_{C2}R_C$

$I_{C1} = I_{S1}\exp\left(\frac{V_{EB}}{V_T}\right)$ $\qquad V_{EB} = V_T \ln\left(\frac{I_{C1}}{I_{S2}}\right)$

$V_{CC} = V_{CE1} + V_T \ln\left(\frac{I_{C1}}{I_{S2}}\right)$

$I_{C2}R_C = -V_{BC2}$ $\qquad V_{CE1} = V_{CC} - V_T \ln\left(\frac{I_{C1}}{I_{S2}}\right)$

$V_{CC} = 2\left(V_{CC} - V_T \ln\left(\frac{I_{C1}}{I_{S2}}\right)\right) + I_C R_C$ ✗

$V_{CC} = -I_C R_C + 2V_T \ln\left(\frac{I_{C1}}{I_{S2}}\right)$

~~$I_C = 1mA$~~

~~$2.5 + I_C R_C =$~~

$2V_{in} + V_{CB2} = I_C R_C$

$V_{CB} = I_{S2}\exp\left(\frac{V_{in}/2}{V_T}\right)R_C - 2V_{in}$

(200mA) $> I_{S2}\exp\left(\frac{V_{in}/2}{V_T}\right)R_C - 2V_{in}$

$-I_C R_C = V_{BC} < 200mV$

$V_{CC} - 2V_T \ln\left(\frac{I_{C1}}{I_{S2}}\right) = V_{BC} < 200mV$

$2.5 - 2V_T \ln\left(\frac{I_{C1}}{I_{S2}}\right) < 200mV$

$2V_T \ln\left(\frac{I_{C1}}{I_{S2}}\right) > 2.3$

$\ln\left(\frac{I_{C1}}{I_{S2}}\right) > 44$

$I_{C1} > 2142$ A

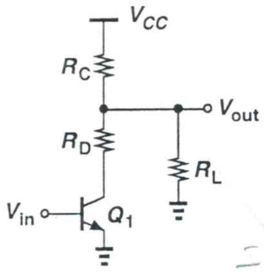
$V_{EB} = 1.14V$

$V_{in} = 2.29V$ ← maximum ✗

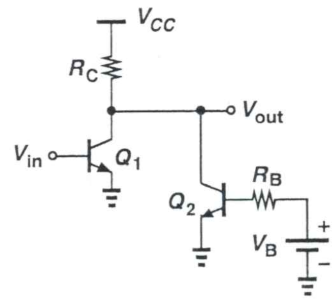
(b) over →

2

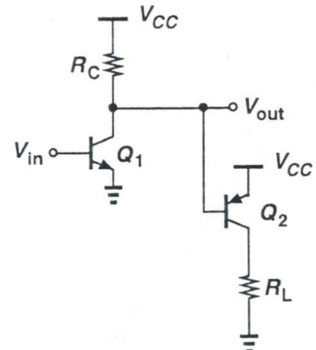
4. Compute the voltage gain of the circuits shown below, assuming that all transistors are biased in the forward active region and $V_A < \infty$ and $\beta \gg 1$.



(a)

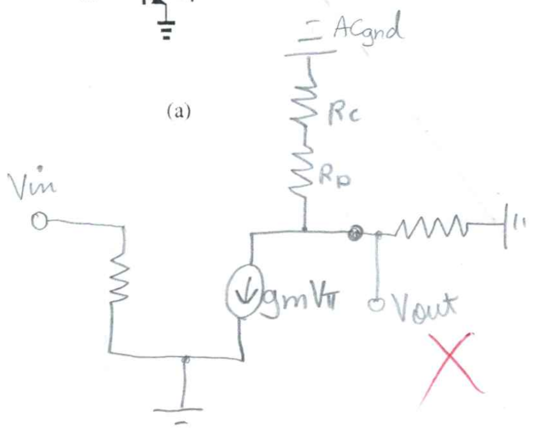


(b)



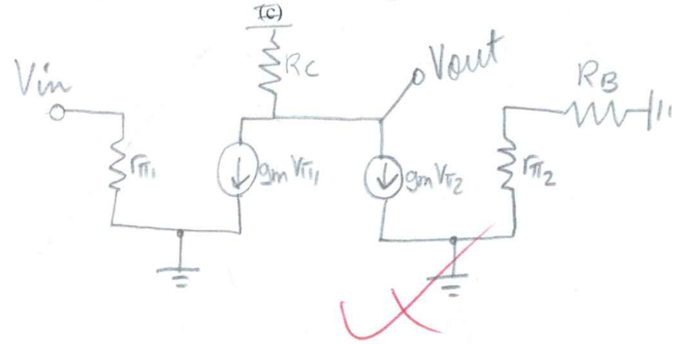
(c)

a)



$$A_V = -g_m \times (R_C + R_D)$$

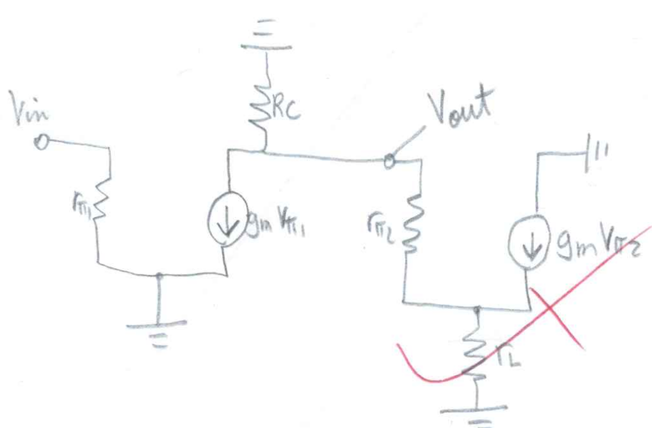
b)



$$A_V = \frac{R_C \| (R_B + r_{\pi 2})}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}}$$

1

c)



$$A_V = \frac{R_C}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}}$$

1