ECE-255
Final Exam

May/01/2012

Name: ______________________________
(Please print clearly)

Student ID: ________________

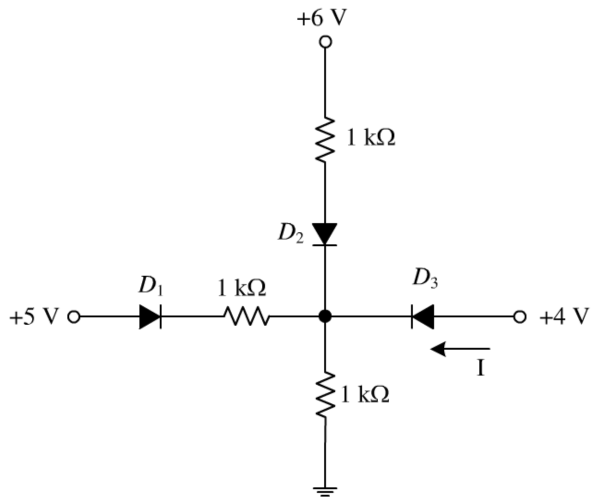
INSTRUCTIONS

- This is a closed book, closed notes exam. Calculators are allowed.
- Carefully mark your multiple choice answers on the scantron form. Work on multiple choice problems and marked answers in the test booklet will not be graded. Nothing is to be on the seat beside you.
- When the exam ends, all writing is to stop. This is not negotiable. No writing while turning in the exam/scantron or risk an F in the exam.
- All students are expected to abide by the customary ethical standards of the university, i.e., your answers must reflect only your own knowledge and reasoning ability. As a reminder, at the very minimum, cheating will result in a zero on the exam and possibly an F in the course.
- Communicating with any of your classmates, in any language, by any means, for any reason, at any time between the official start of the exam and the official end of the exam is grounds for immediate ejection from the exam site and loss of all credit for this exercise.

1. A silicon sample at room temperature has an intrinsic carrier concentration of $n_i = 10^{10}$ cm^{-3}. It is doped with $N_A = 1\times10^{18}$ boron atoms/cm^3 and $N_D = 6\times10^{12}$ arsenic atoms/cm^3. The electron mobility is measured as $\mu_n = 1000$ cm^2/V·s. What are the electron and hole concentration in this material and electron current density when an external field of E=100 V/cm is applied?
(q=1.6x10^{-19} C)

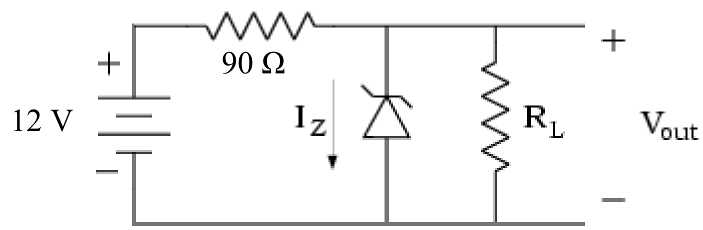
(1) p =1x10^{18} /cm^3; n =6x10^{12} /cm^3; j_n =9.6x10^{-2}A/cm^2
(2) p =1x10^{10} /cm^3; n =6x10^{12} /cm^3; j_n =1.6x10^{-4}A/cm^2
(3) p =6x10^{12} /cm^3; n =1x10^{18} /cm^3; j_n =1.6x10^{4}A/cm^2
(4) p =1x10^{18} /cm^3; n =100 /cm^3; j_n =1.6x10^{-12}A/cm^2
(5) p =1x10^{18} /cm^3; n =100 /cm^3; j_n =1.6x10^{4}A/cm^2
(6) None of the above

2. For the diode circuit below, determine the current, I (indicated in the graph), using the constant voltage model with Von =0.7V.



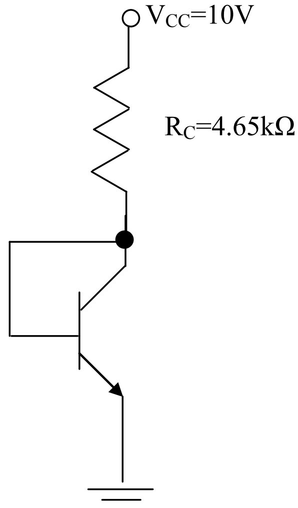
(1) I =0A
(2) I =0.3mA
(3) I =2.7mA
(4) I =3.3mA
(5) I =3.7mA
(6) None of the above

3. In the circuit below, the Zener diode has a breakdown voltage $V_{Z0} = 8.0$ V and a measurement has shown that $V_Z = 8.2$ V when $I_Z = 20$ mA. What is the value of V_{out} when R_L is infinitely large?



(1) $V_{out} = 0$ V
(2) $V_{out} = 8.2$ V
(3) $V_{out} = 8.8$ V
(4) $V_{out} = 8.4$ V
(5) $V_{out} = 8.0$ V
(6) None of the above

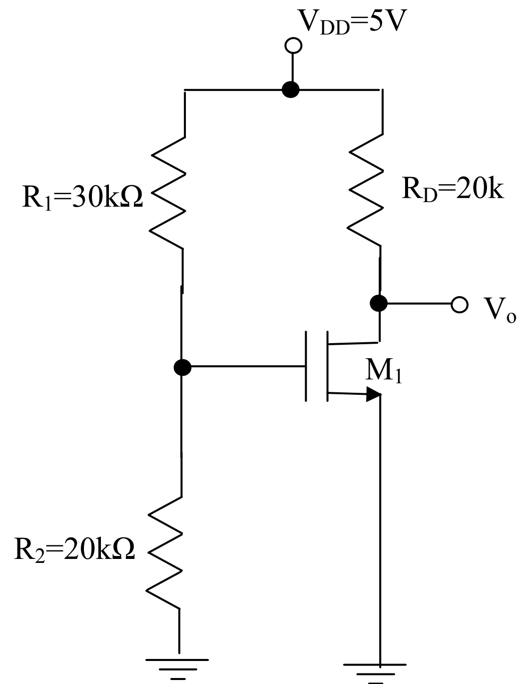
4. Determine the collector current, Ic, for the following BJT circuit.
β_F=99, V_{BE}(on)=0.7V.



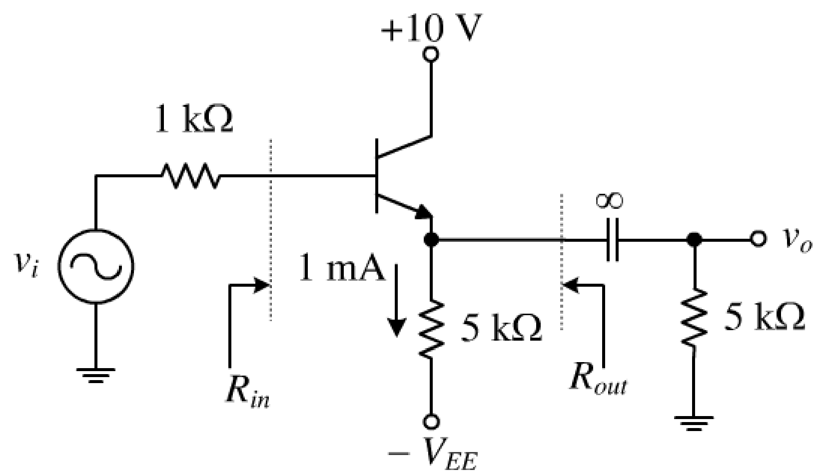
(1) Ic =2mA
(2) Ic =1.98mA
(3) Ic =2.15mA
(4) Ic =0.02mA
(5) Ic =1.435mA
(6) None of the above

5. For the MOS circuit shown below, what is the output voltage, V_o?
$\lambda=0$, $V_{TN}=1V$, $K_N=0.3\ mA/V^2$

(1) $V_o = 2V$
(2) $V_o = 2.5V$
(3) $V_o = 3V$
(4) $V_o = 3.5V$
(5) $V_o = 4V$
(6) None of the above

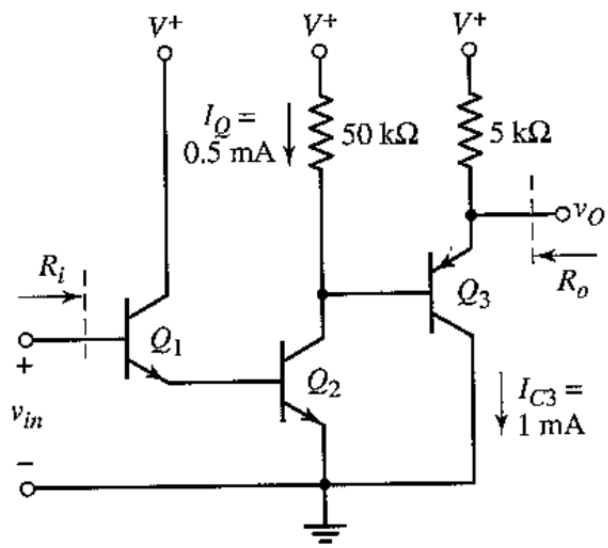


6. Determine the voltage gain, input resistance and output resistance (both are indicated in the graph) of the amplifier circuit shown below.
$\beta_o = 80$, $V_A = \infty$, $V_T = 25mV$.



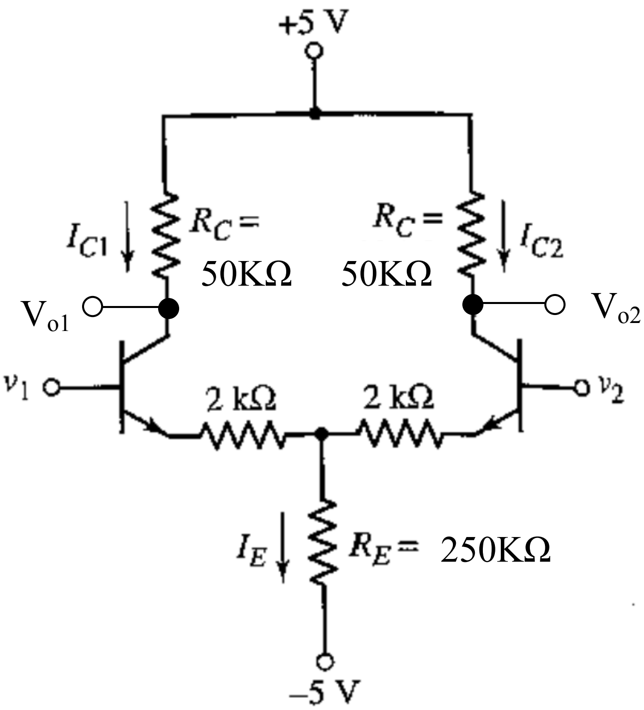
(1) $A_v \approx 1$; $R_{in} = 204.5k\Omega$; $R_{out} \approx 37\Omega$
(2) $A_v \approx 100$; $R_{in} = 20k\Omega$; $R_{out} \approx 37\Omega$
(3) $A_v \approx -100$; $R_{in} = 2k\Omega$; $R_{out} \approx 2.5k\Omega$
(4) $A_v \approx 1$; $R_{in} = 400k\Omega$; $R_{out} \approx 25\Omega$
(5) $A_v \approx 100$; $R_{in} = 1k\Omega$; $R_{out} \approx 5k\Omega$
(6) None of the above

7. Determine the input resistance, R_i, for the amplifier circuit below (currents for Q_2 and Q_3 are indicated in the figure, and it needs to be calculated for Q_1). Assume β_0=100, V_A=∞, V_{BE} (on)=0.7V, V_T=25mV for all BJTs, and V+=5V.



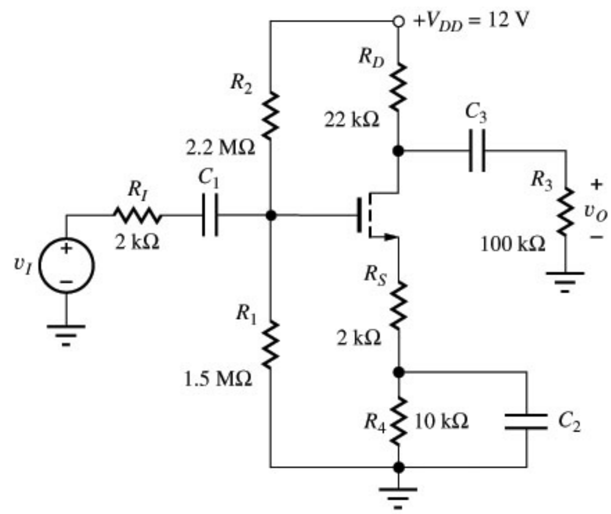
(1) ≈ 500kΩ
(2) ≈ 5kΩ
(3) ≈ 250kΩ
(4) ≈ 1.5MkΩ
(5) ≈ 1MΩ
(6) None of the above

8. What are the common-mode gain ($|Av_c|$) and differential mode gain ($|Av_d|$) for the circuit shown below? Assuming β_0>>1.



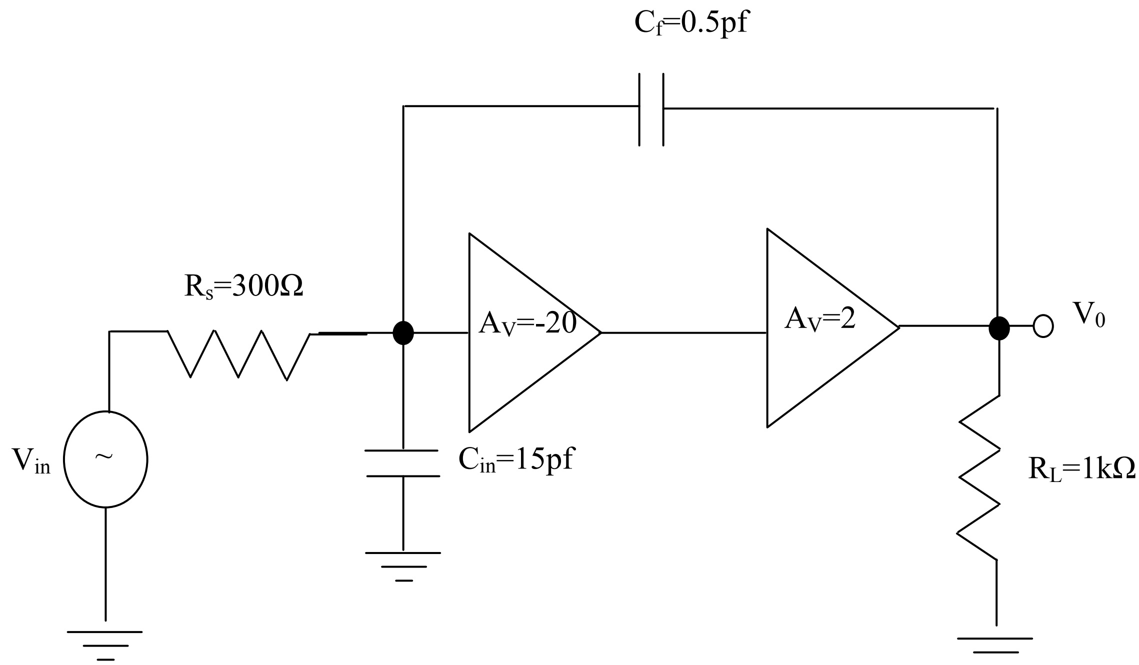
(1) $|Av_c| \approx 0.1$; $|Av_d| \approx 10$
(2) $|Av_c| \approx 0.1$; $|Av_d| \approx 33$
(3) $|Av_c| \approx 0.2$; $|Av_d| \approx 50$
(4) $|Av_c| \approx 0.1$; $|Av_d| \approx 25$
(5) $|Av_c| \approx 25$; $|Av_d| \approx 0.1$
(6) None of the above

9. Choose the value of C_1 so that it can be neglected at frequencies larger than the low cutoff frequency, $f_L = 10KHz$. We use $C_1 \geq 10\frac{1}{\omega_L R_{1S}}$ as the design rule.



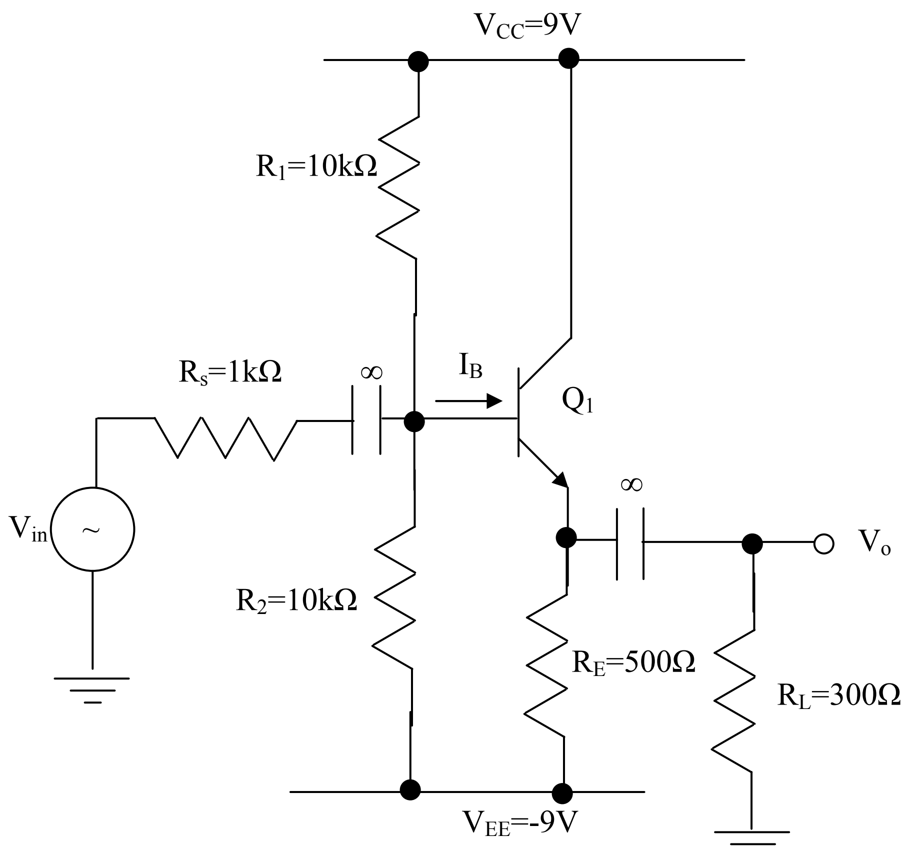
(1) $C_1 > 79$ nF
(2) $C_1 > 72.3$ pF
(3) $C_1 > 106$ pF
(4) $C_1 > 0.0178$ nF
(5) $C_1 > 0.178$ nF
(6) None of the above

10. For the amplifier circuit shown below, calculate upper- cutoff frequency, f_H.



(1) ~94MHz
(2) ~15MHz
(3) ~35MHz
(4) ~50MHz
(5) ~10MHz
6) Non of the above

11. For the amplifier circuit shown below I_B=?
Assume β=180, V_A=∞, and V_{BE}(on)=0.7V



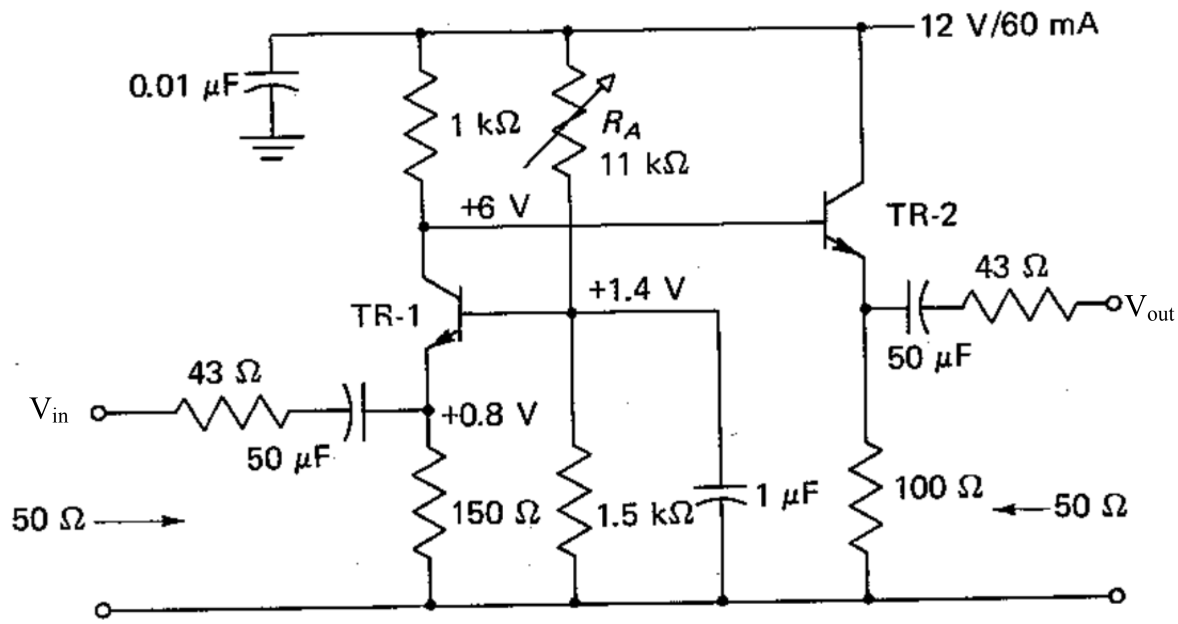
(1) ~87μA
(2) ~182μA
(3) ~7.3μA
(4) ~1.4mA
(5) 100μA
(6) None of the above

12. Mid-band gain (A_{mid}), lower cutoff frequency (ω_L), and higher cutoff frequency (ω_H) for the amplifier transfer function given below are

$$A_v(s) = \frac{4\times10^8 s^2}{(s+1)(s+2)(s+1000)(s+2000)}$$

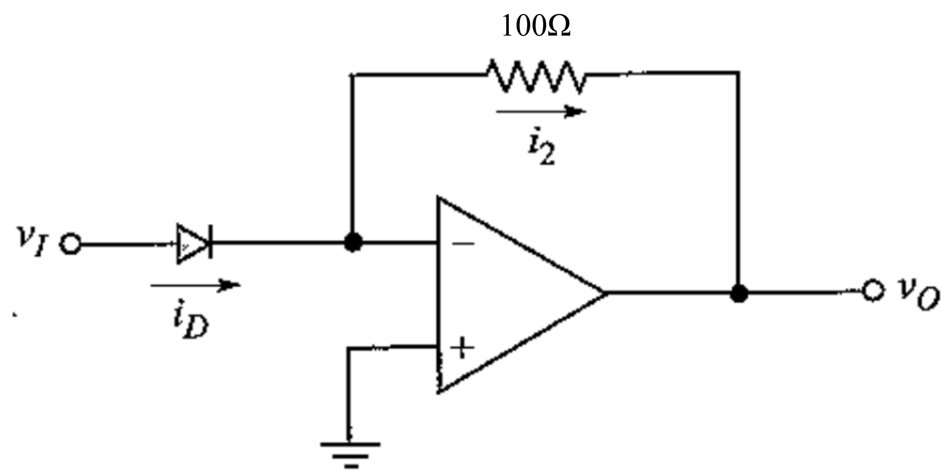
(1) A_{mid}=4x10^8, ω_L=2 rad/s, ω_H=1000 rad/s
(2) A_{mid}=200, ω_L=1 rad/s, ω_H=816.5 rad/s
(3) A_{mid}=400, ω_L=2.24 rad/s, ω_H=1000 rad/s
(4) A_{mid}=200, ω_L=2.24 rad/s, ω_H=2000 rad/s
(5) A_{mid}=200, ω_L=2.24rad/s, ω_H=894 rad/s
(6) None of the above

13. What is the configuration of the multi-stage amplifier shown below?



(1) CB-CC
(2) CE-CC
(3) CB-CB
(4) CC-CC
(5) CB-CE
(6) None of the above

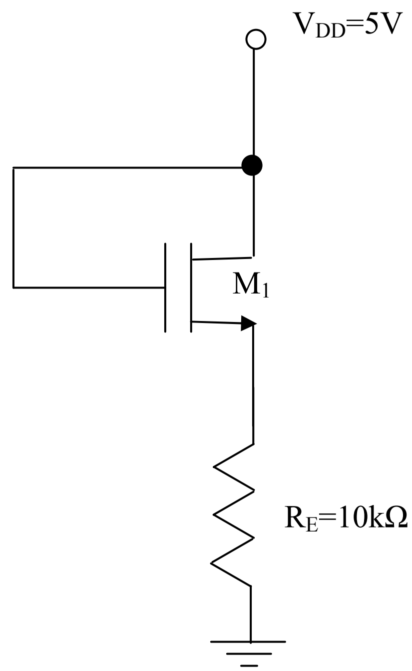
14. What is V_o? if V_i=0.725V and $I_s=10^{-14}$A (Assume V_T=25mV)



(1) 0V
(2) -0.725V
(3) -3.9V
(4) -0.1V
(5) -2.5V
(6) None of the above

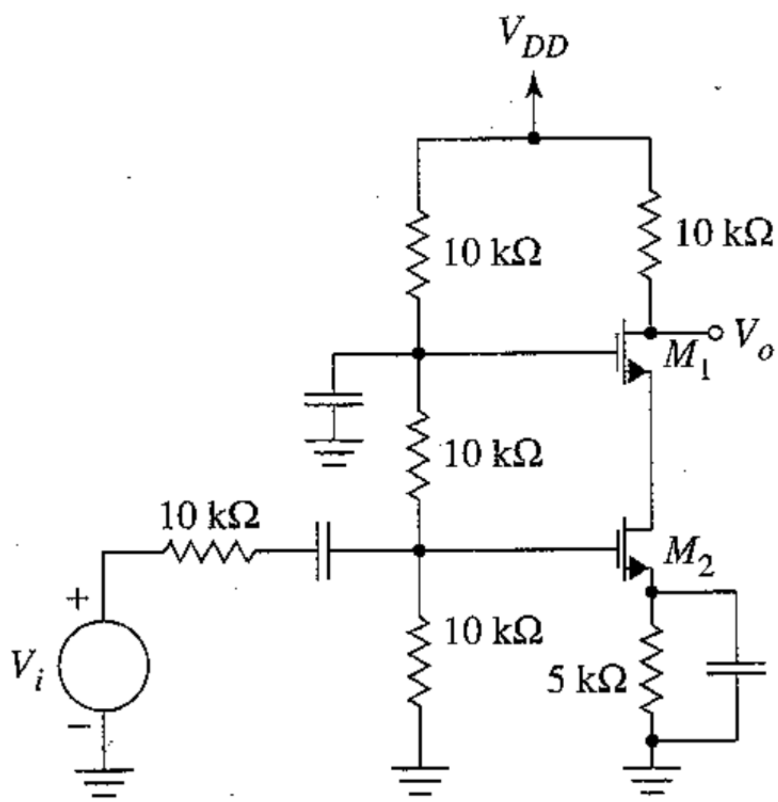
15. For the MOS circuit shown below, I_D=?

V_{TN}=1V, K_N=0.1 mA/V^2



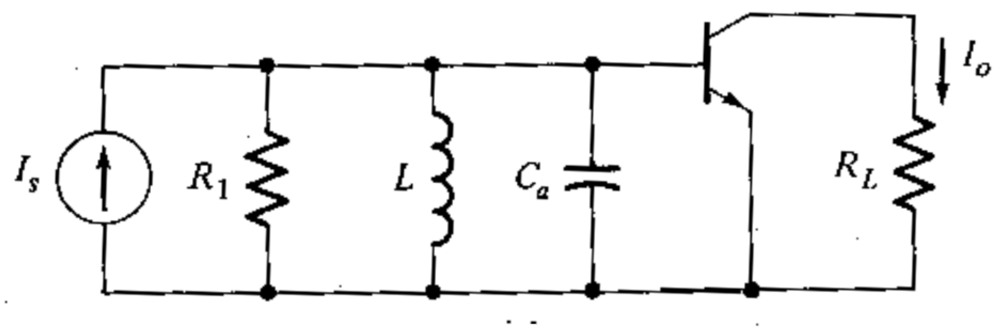
(1) 0.1mA
(2) 0.4mA
(3) 0.5mA
(4) 0.2mA
(5) 1mA
(6) None of the above

16. Figure below shows a cascode MOSFET, what is the mid-band gain ($A_v=V_o/V_i$)? Assume g_m=2mA/V and λ=0 for both transistors

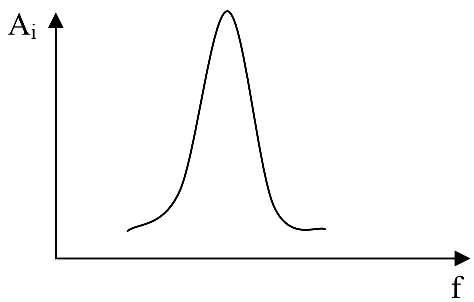


(1) -20
(2) -400
(3) -2
(4) -100
(5) -6.67
(6) None of the above

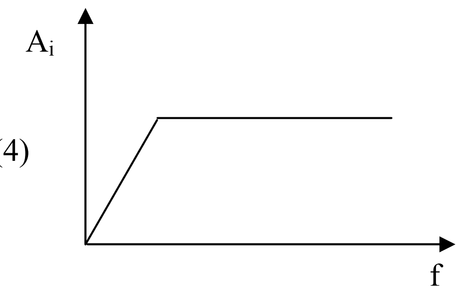
17. Which one of the current gain (A_i) frequency response curves belong to the amplifier shown below?



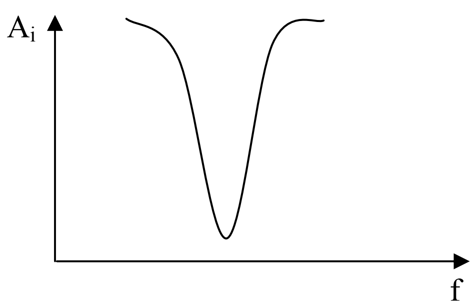
(1)



(4)

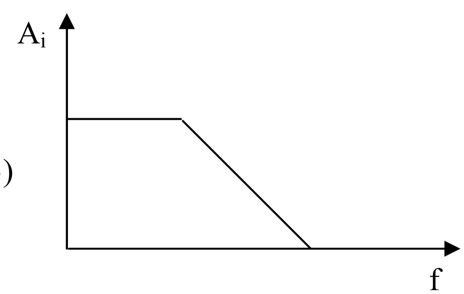


(2)



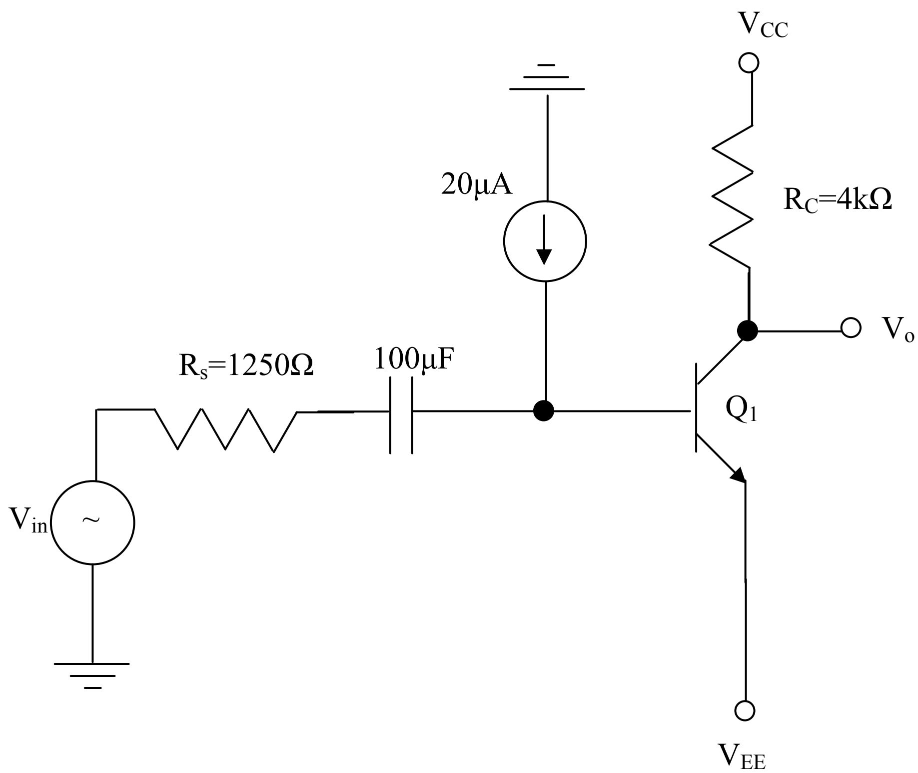
(5) Circuit cannot provide any current gain

(3)



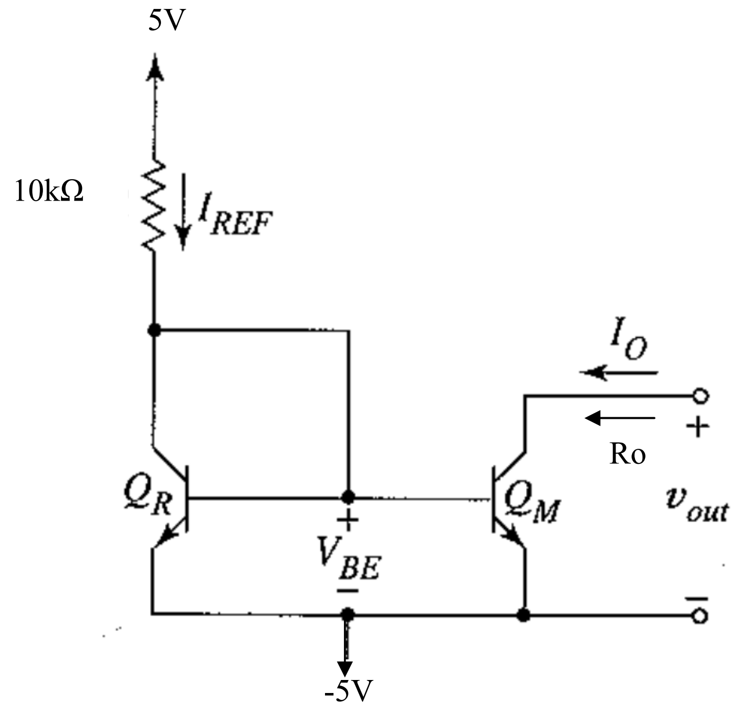
(6) None of the above

18. For the amplifier circuit shown below estimated value of f_L is? For BJT assume β=150, V_A=75V, V_{BE}(on)=0.7, V_T=25 mV.



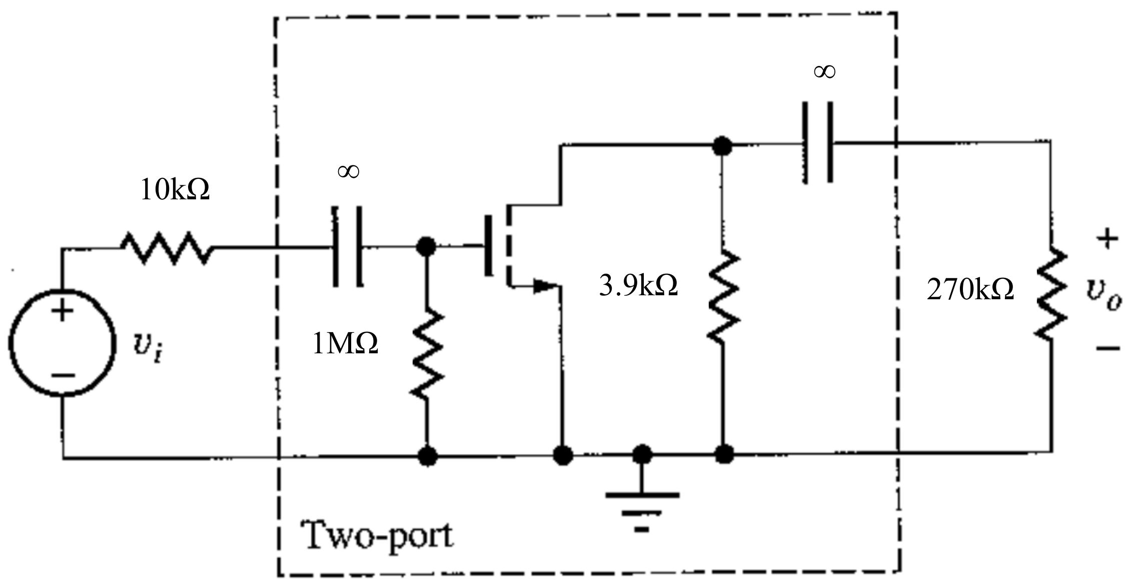
(1) ~1kHz
(2) ~10Hz
(3) ~ 0.64Hz
(4) 0Hz
(5) ~2.5Hz
(6) None of the above

19. What is the value of output impedance (Ro) for the current mirror shown below? Assume $\beta=\infty$, $V_{BE}(ON)=0.7V$, $V_A=75V$. Two transistors are identical



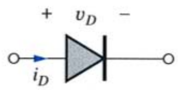
(1) 40 kΩ
(2) ∞
(3) 174 kΩ
(4) 81 kΩ
(5) 500 kΩ
(6) None of the above

20. What is the voltage gain (v_0/v_i) for the amplifier below? Assume the MOSFET Q points are (2mA, 7.5V), K_n=1mA/V^2, and λ=0



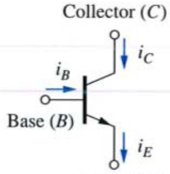
(1) -7.8
(2) -7.61
(3) -540
(4) -25
(5) gain is zero since we ignored the channel length modulation
(6) None of the above

DIODE EQUATIONS



$$i_D = I_S\left[\exp\left(\frac{v_D}{nV_T}\right) - 1\right] \qquad V_T = \frac{kT}{q} \qquad C_j = \frac{C_{jo}A}{\sqrt{1 - \dfrac{v_D}{\phi_j}}} \qquad C_D = \frac{I_D}{V_T}\tau_T$$

(FORWARD) ACTIVE REGION EQUATIONS— *npn* TRANSISTOR ($v_{BE} > 0$ AND $v_{CE} \geq v_{BE}$)



$$i_C = I_S \exp\left(\frac{v_{BE}}{V_T}\right)\left(1 + \frac{v_{CE}}{V_A}\right) \qquad i_C = \beta_F i_B \qquad i_E = (\beta_F + 1)i_B \qquad \beta_F = \beta_{FO}\left(1 + \frac{v_{CE}}{V_A}\right)$$

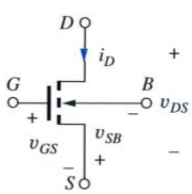
BJT SMALL-SIGNAL MODEL PARAMETER RELATIONSHIPS ($\beta_o \cong \beta_F$)

$$g_m = \frac{I_C}{V_T} \cong 40I_C \qquad \beta_o = g_m r_\pi \qquad r_o = \frac{V_A + V_{CE}}{I_C} \cong \frac{V_A}{I_C} \qquad \mu_f = g_m r_o \qquad C_\pi = g_m \tau_F \qquad \omega_T = \frac{g_m}{C_\pi + C_\mu}$$

LARGE SIGNAL MODEL EQUATIONS—NMOS TRANSISTOR

Triode (Linear) Region ($v_{GS} > V_{TN}$ and $v_{DS} \leq v_{GS} - V_{TN}$)

$$i_D = K_n\left(v_{GS} - V_{TN} - \frac{v_{DS}}{2}\right)v_{DS} \qquad i_G = 0 \qquad i_S = i_D \qquad K_n = K_n'\frac{W}{L}$$



Active (Saturation) Region ($v_{GS} > V_{TN}$ and $v_{DS} \geq v_{GS} - V_{TN}$)

$$i_D = \frac{K_n}{2}(v_{GS} - V_{TN})^2(1 + \lambda v_{DS}) \qquad i_G = 0 \qquad i_S = i_D \qquad K_n = K_n'\frac{W}{L}$$

$$V_{TN} = V_{TO} + \gamma\left(\sqrt{v_{SB} + 2\phi_f} - \sqrt{2\phi_f}\right)$$

FET SMALL-SIGNAL MODEL PARAMETER RELATIONSHIPS

$$g_m = \frac{2I_D}{V_{GS} - V_{TN}} \cong \sqrt{2K_n I_D} \qquad r_o = \frac{1 + \lambda V_{DS}}{\lambda I_D} \cong \frac{1}{\lambda I_D} \qquad \mu_f = g_m r_o \qquad \omega_T = \frac{g_m}{C_{GS} + C_{GD}}$$

Low frequency pole location for a transfer function with n poles and zeros

$$\omega_L \cong \sqrt{\sum_n \omega_{Pn}^{\ 2} - 2\sum_n \omega_{Zn}^{\ 2}}$$

High frequency pole location for a transfer function with n poles and zeros

$$\omega_H \cong \frac{1}{\sqrt{\sum_n \frac{1}{\omega_{Pn}^{\ 2}} - 2\sum_n \frac{1}{\omega_{Zn}^{\ 2}}}}$$

Approximate equation for finding ω_L using short-circuit time constant method

$$\omega_L \cong \sum_{i=1}^{n} \frac{1}{R_{iS} C_i}$$

Approximate equation for finding ω_H using open-circuit time constant method

$$\omega_H \cong \frac{1}{\sum_{i=1}^{m} R_{io} C_i}$$