

ID # \_\_\_\_\_

NAME \_\_\_\_\_

EE-255      EXAM 3      November 8, 2001

Instructor (circle one)      Talavage      Gray

This exam consists of 16 multiple choice questions and one workout problem. Record all answers to the multiple choice questions on this page. **NO CREDIT WILL BE AWARDED FOR A MULTIPLE CHOICE QUESTION IF THE ANSWER IS NOT CIRCLED ON THIS PAGE.** You must turn in the entire exam. Partial credit will only be awarded for the workout problem.

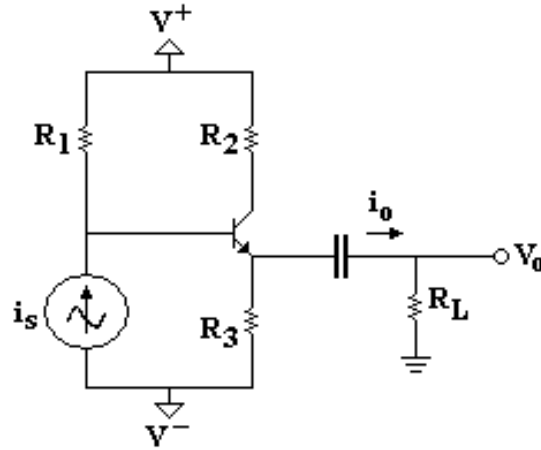
Circle the one best answer for each question. Five points per question.

**Do not open and begin until you are instructed to do so!**

- 1)    a    b    c    d    e
- 2)    a    b    c    d    e
- 3)    a    b    c    d    e
- 4)    a    b    c    d    e
- 5)    a    b    c    d    e
- 6)    a    b    c    d    e
- 7)    a    b    c    d    e
- 8)    a    b    c    d    e
- 9)    a    b    c    d    e
- 10)   a    b    c    d    e
- 11)   a    b    c    d    e
- 12)   a    b    c    d    e
- 13)   a    b    c    d    e
- 14)   a    b    c    d    e
- 15)   a    b    c    d    e
- 16)   a    b    c    d    e

**SHOW ALL WORK FOR PROBLEM #17 ON THESE TWO SHEETS**

- 17) Use the amplifier circuit shown below for all parts of this problem. The transistor has  $|V_{BE(on)}| = 0.6 \text{ V}$ ,  $\beta = 200$ , and an infinite Early voltage.



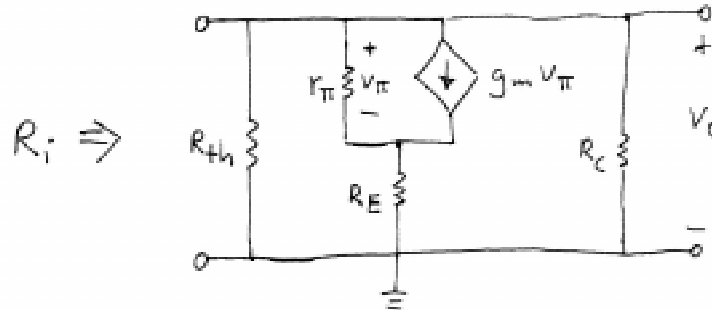
- a) **(6 pts)** Draw the small-signal equivalent circuit.
- b) **(4 pts)** Derive an equation for the input impedance,  $R_{i_s}$ , seen from the current source,  $i_s$ .

c) **(4 pts)** Derive an equation for the output resistance,  $R_o$ , seen from the load resistor,  $R_L$ .

d) **(6 pts)** Derive an equation for the current gain provided by this circuit,  $A_i = \frac{i_o}{i_s}$ .

## MULTIPLE CHOICE QUESTIONS

- 1) In the circuit below,  $R_i = ?$

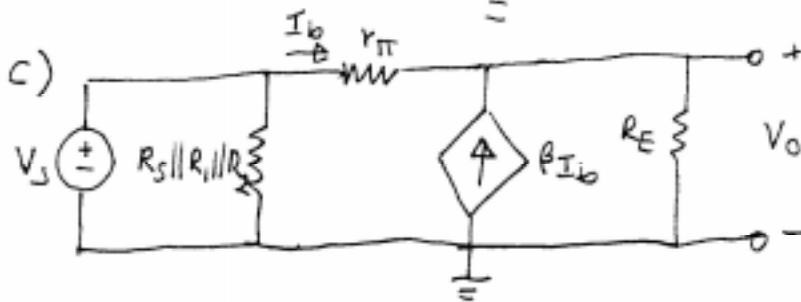
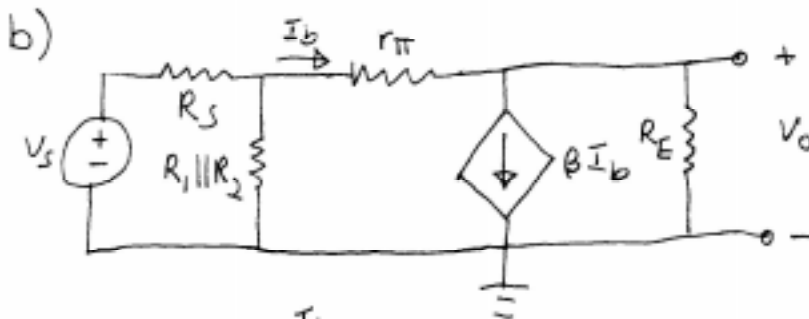
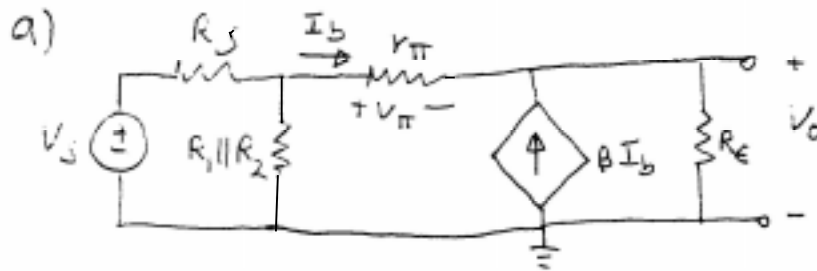
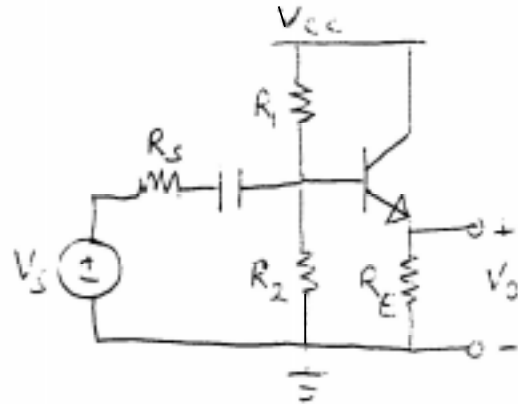


- a)  $R_{th}$   
 b)  $R_{th} \parallel (r_{\pi} + R_E)$   
 c)  $R_{th} \parallel [r_{\pi} + (1 + g_m R_E)]$   
 d)  $R_{th} \parallel [r_{\pi} + (1 + g_m r_{\pi}) R_E]$   
 e) None of the above

- 2) Given a pnp transistor in a bias-stable circuit for which  $I_{CQ} = 3.17 \text{ mA}$ ,  $\beta = 111$ ,  $V_A = 177 \text{ V}$ , and  $V_{th} = 27.3 \text{ mV}$ , what is the quantity  $(1 + g_m r_{\pi}) = ?$

- a) 113  
 b) 177  
 c) 178  
 d) 112  
 e) None of the above

- 3) The transistor in the circuit below has an infinite Early voltage. Which is the correct small-signal model for the circuit?



- d) Both (a) and (c) are correct  
 e) None of the above

- 4) The instantaneous drain current in a MOSFET amplifier is given by

$$i_D = K_n (v_{GS} - V_{TN})^2, \text{ where } v_{GS} = V_{GSQ} + v_{gs}.$$

To minimize undesirable harmonics, or nonlinear distortion, what is required?

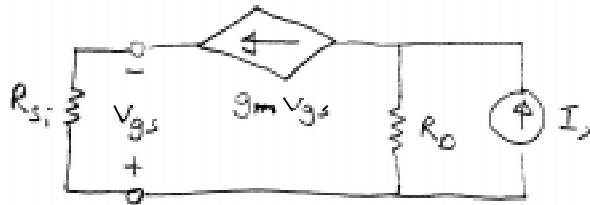
- a)  $v_{gs} \ll V_T$
  - b)  $v_{gs} \ll V_{TN}$
  - c)  $v_{gs} \ll 2(V_{GSQ} - V_{TN})$
  - d)  $v_{gs} = V_{GSQ}$
  - e) None of the above
- 
- 5) A common-drain amplifier has been constructed using an n-channel e-mode MOSFET transistor ( $k = 1 \text{ mA/V}^2$ ,  $|V_{th}| = 1 \text{ V}$ ) biased at  $I_D = 1 \text{ mA}$ . The output resistance of this circuit is  $400 \Omega$ . What is the output resistance of a common-collector amplifier (npn BJT transistor:  $|V_{BE(on)}| = 0.7 \text{ V}$ ,  $\beta = 200$ ,  $V_A = 150 \text{ V}$ ) having the same resistor values and constructed such that  $I_C = 1 \text{ mA}$ ?

- a)  $8 \Omega$
  - b)  $400 \Omega$
  - c)  $500 \Omega$
  - d)  $13 \Omega$
  - e) None of the above
-

6) In a source-follower amplifier, which of the following can be true?

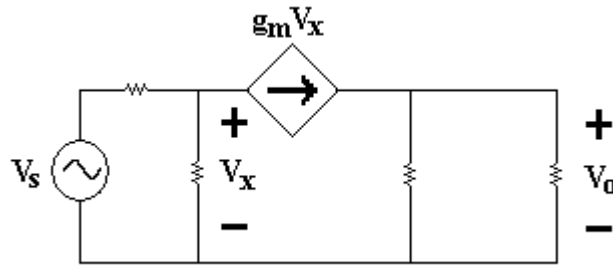
- a)  $R_C = 0$
  - b)  $R_D = 0$
  - c)  $R_S = 0$
  - d) All of the above
  - e) None of the above
- 

7) In the circuit below,  $v_{gs} = ?$



- a)  $v_{gs} = -I_x R_{Si}$
  - b)  $v_{gs} = I_x / g_m$
  - c)  $v_{gs} = 0$
  - d)  $v_{gs} = +I_x R_{Si}$
  - e) None of the above
-

8) The following small-signal circuit represents what type of MOSFET amplifier?



- a) CC
- b) CD
- c) CG
- d) CS
- e) None of the above

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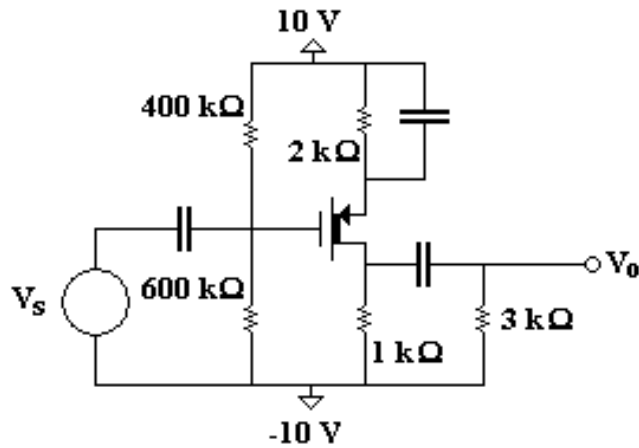
9) A BJT amplifier is found to have an intrinsic voltage gain,  $A_{v_i} = -14.7$ . What type of amplifier is it most likely to be?

- a) CS
- b) CE
- c) CC
- d) CB
- e) None of the above

10) Which amplifier type should be used to achieve a significant gain in power with a minimal change in voltage?

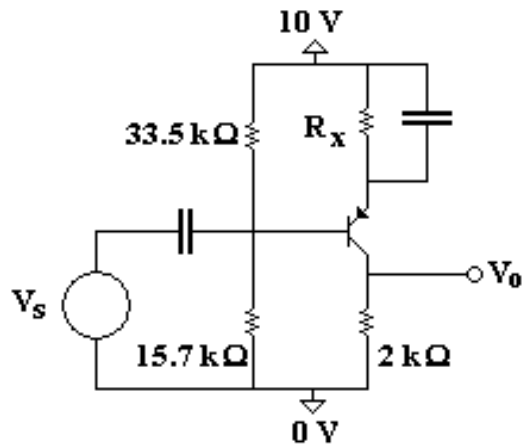
- a) CB
- b) CC
- c) CD
- d) CE
- e) None of the above

11) The transistor in the circuit below has  $k = 1 \text{ mA/V}^2$  and  $|V_{th}| = 2 \text{ V}$ . Compute the source voltage gain,  $A_{v_s}$ , in the circuit below:



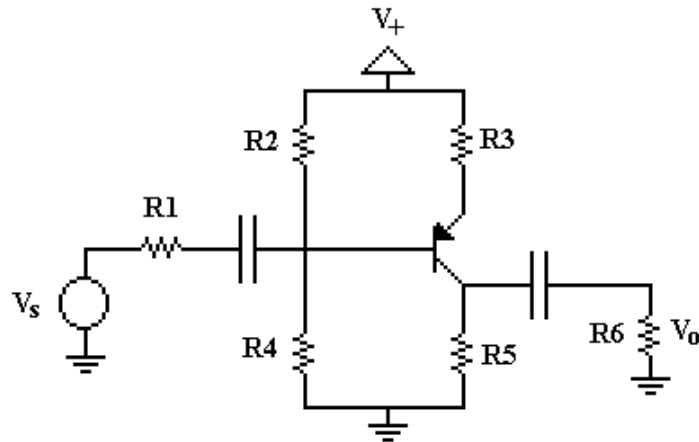
- a) -8.00
- b) -4.00
- c) -2.25
- d) -3.00
- e) None of the above

12) The circuit below is a \_\_\_\_\_ amplifier.



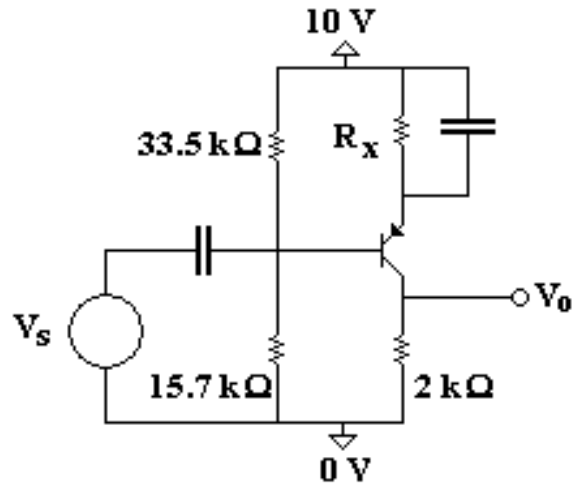
- a) CB
- b) CS w/source degeneration
- c) CC w/collector degeneration
- d) CC
- e) None of the above

13) Given:  $R_1 = 20 \Omega$ ,  $R_2 = 70 \text{ k}\Omega$ ,  $R_3 = 1 \text{ k}\Omega$ ,  $R_4 = 75 \text{ k}\Omega$ ,  $R_5 = 5 \text{ k}\Omega$ ,  $R_6 = 5 \text{ k}\Omega$ .  
 For a particular  $V_+$ , a collector current of  $I_C = 300 \mu\text{A}$  and a diffusion resistance of  $r_\pi = 1.3 \text{ k}\Omega$  are observed. What is the magnitude of the intrinsic voltage gain,  $|A_{v_i}|$ ?



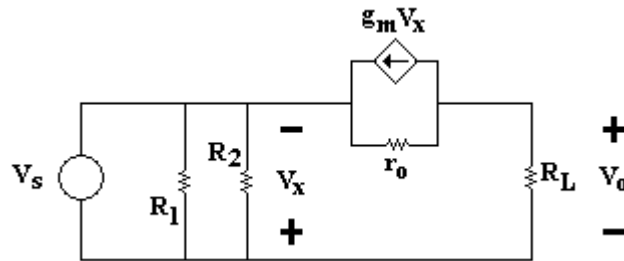
- a) 2.17
- b) 2.31
- c) 2.50
- d) 2.88
- e) None of the above

- 14) What is the minimum value for  $R_X$  such that the following circuit will be (a) bias stable, and (b) exhibit an input impedance of at least  $1.8 \text{ k}\Omega$  when  $\beta = 50$  and  $|V_{BE(on)}| = 0.7 \text{ V}$ .



- a)  $9.7 \text{ k}\Omega$
- b)  $6.3 \text{ k}\Omega$
- c)  $3.9 \text{ k}\Omega$
- d)  $2.1 \text{ k}\Omega$
- e) None of the above

- 15) Compute  $R_o$ , the output resistance seen from the load,  $R_L$ , for the small-signal equivalent circuit below.



- a) 0  
 b)  $R_1 \parallel R_2$   
 c)  $R_1 \parallel R_2 + r_o$   
 d)  $r_o$   
 e) None of the above

- 16) Derive an equation for the magnitude of the source voltage gain,  $|A_{v_s}|$ , for the circuit in **Problem 15**.

- a)  $g_m \left( \frac{R_L \parallel r_o}{R_1 \parallel R_2 + R_L} \right)$   
 b)  $g_m (R_L \parallel r_o)$   
 c)  $g_m R_L$   
 d)  $\left( \frac{g_m r_o - 1}{r_o - R_L} \right) R_L$   
 e) None of the above

## EE-255 Formula Sheet: Exam #3

### Data:

$$\begin{aligned} \text{At } 25^\circ \text{C (R.T.) } \quad V_T = kT/q = 0.026 \text{ V} \quad k = 1.3806 \times 10^{-23} \text{ J / K} \\ q = 1.6022 \times 10^{-19} \text{ C} \quad 0^\circ \text{C} = 273.16 \text{ K} \end{aligned}$$

### Formulas:

$$e^x = 1 + x + x^2 / 2 + \dots$$

### Diodes:

$$I_D = I_0 (e^{V_D / nV_T} - 1) \quad V_D = V_0 + I_D R_0 \quad C_j = \frac{C_{j0}}{(1 - V_D / V_{bi})^N} \quad nV_T = \frac{V_{D2} - V_{D1}}{\ln(I_{D2} / I_{D1})}$$

$$r_d = \left. \frac{dv_D}{di_D} \right|_Q = \frac{nV_T}{I_D + I_0} \quad v_D = V_D + v_d$$

### Rectifiers:

$$V_r = V_M \left( \frac{I_p}{RC} \right)$$

### Monolithic Resistors:

$$R = R_s \left( \frac{L}{W} \right)$$

### n-channel MOSFETs:

$$I_D = k_n [2(V_{GS} - V_{Th})V_{DS} - V_{DS}^2] \quad (\text{ohmic/triode})$$

$$I_D = k_n [V_{GS} - V_{Th}]^2 \quad (\text{saturation})$$

$$V_{GS} > V_{Th} \quad (\text{NOT cut-off})$$

$$V_{DS} > V_{GS} - V_{Th} \quad (\text{saturation})$$

### p-channel MOSFETs:

$$I_D = k_p [2(V_{GS} - V_{Th})V_{DS} - V_{DS}^2] \quad (\text{ohmic/triode})$$

$$I_D = k_p [V_{GS} - V_{Th}]^2 \quad (\text{saturation})$$

$$V_{GS} < V_{Th} \quad (\text{NOT cut-off})$$

$$V_{DS} < V_{GS} - V_{Th} \quad (\text{saturation})$$

$$I_D = k_p [2(V_{SG} + V_{Th})V_{SD} - V_{SD}^2] \quad (\text{ohmic/triode})$$

$$I_D = k_p [V_{SG} + V_{Th}]^2 \quad (\text{saturation})$$

$$V_{SG} > -V_{Th} \quad (\text{NOT cut-off})$$

$$V_{SD} > V_{SG} + V_{Th} \quad (\text{saturation})$$

### Thermal Effects:

$$T_{dev} - T_{amb} = \theta P_D$$

$$P_D = I_B V_{BE} + I_C V_{CE}$$

$$P_D = I_D V_{DS}$$

### Bipolar Transistors:

$$I_C = \beta I_B \cong I_S e^{\frac{V_{BE}}{V_T}} \left( 1 + \frac{V_{CE}}{V_A} \right) \quad (\text{active})$$

$$\beta = \frac{\alpha}{1 - \alpha} \quad \alpha = \frac{\beta}{1 + \beta}$$

**Bipolar Transistor Amplifiers (mid-frequency):**

$$\text{CE: } A_{vi} = -g_m(R_C \parallel r_o \parallel R_L) \quad R_{is} = r_\pi \parallel (R_1 \parallel R_2) \quad R_o = R_C \parallel r_o$$

**CE with emitter degeneration:**

$$A_{vi} = \frac{-\beta(R_C \parallel R_L)}{r_\pi + (1 + \beta)R_E} \quad R_{is} = (R_1 \parallel R_2) \parallel [r_\pi + (\beta + 1)R_E] \quad R_o = R_C$$

$$\text{CB: } A_{vi} = +g_m(R_C \parallel R_L) \quad R_{is} = R_E \parallel \frac{r_\pi}{\beta + 1} \quad R_o = R_C$$

$$\text{CC: } A_{vi} = \frac{(1 + \beta)(r_o \parallel R_E \parallel R_L)}{r_\pi + (1 + \beta)(r_o \parallel R_E \parallel R_L)}$$

$$R_{is} = (R_1 \parallel R_2) \parallel [r_\pi + (\beta + 1)r_o \parallel R_E \parallel R_L] \quad R_o = r_o \parallel R_E \parallel \left[ \frac{r_\pi + (R_1 \parallel R_2) \parallel R_S}{\beta + 1} \right]$$

**FET Models:**

$$g_m = 2\sqrt{k_n I_D} = 2k_n(V_{GS} - V_T) \quad r_o = (\lambda I_D)^{-1}$$

**FET Amplifiers (mid-frequency):**

$$\text{CS: } A_{vi} = -g_m(R_D \parallel r_o \parallel R_L) \quad R_{is} = (R_1 \parallel R_2) \quad R_o = R_D \parallel r_o$$

$$\text{CG: } A_{vi} = +g_m(R_D \parallel R_L) \quad R_{is} = R_{SS} \parallel \frac{1}{g_m} \quad R_o = R_D$$

$$\text{CD: } A_{vi} = \frac{g_m(R_{SS} \parallel R_L)}{1 + g_m(R_{SS} \parallel R_L)} \quad R_{is} = (R_1 \parallel R_2) \quad R_o = R_{SS} \parallel \frac{1}{g_m}$$