

ID # _____

NAME _____

EE-255 EXAM 3 April 7, 1998

Instructor (circle one) Ogborn Lundstrom

This exam consists of 20 multiple choice questions. Record all answers on this page, but you must turn in the entire exam. There will be no partial credit, but you must show your work.

Assume that $V_T = 0.026$ V (where V_T is the thermal voltage).

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

17) a b c d e

18) a b c d e

19) a b c d e

20) a b c d e

- 1) A bipolar transistor has a mid-frequency hybrid-pi equivalent circuit model with $g_m = 50$ mA/V and $r_P = 3\text{K}\Omega$. What is h_{FE} ?
- (a) 3 (b) 50 (c) 53 (d) 150 (e) 2500
-

- 2) A MOSFET, described by $I_D = 2(V_{GS}-I)^2$, is biased so that $I_D = 2$ mA. What is g_m ?
- (a) 1 mA/V (b) 2 mA/V (c) 3 mA/V (d) 4 mA/V (e) 5 mA/V
-

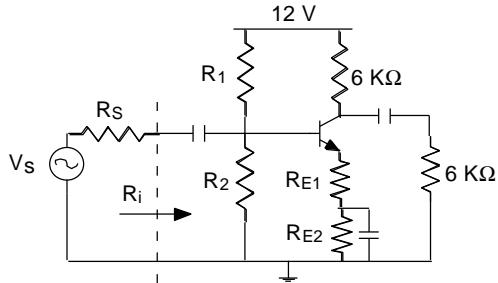
- 3) The small signal output resistance, r_o , for the MOSFET described in problem 2 is
- (a) 0 Ω (b) 1 $\text{K}\Omega$ (c) 10 $\text{K}\Omega$ (d) 100 $\text{K}\Omega$ (e) ∞
-

- 4) A clever Purdue graduate student invents a new type of MOSFET which is described by $I_D = 2(V_{GS}-I)^3$. If she puts this new transistor in a circuit that biases it with $V_{GS} = 3$ V, what is g_m ?

- (a) 4 mA/V (b) 6 mA/V (c) 8 mA/V (d) 12 mA/V (e) 24 mA/V

5) What is the input impedance of the amplifier shown below? (Assume that the capacitors are large.) HINT: Apply the Resistance Reflection Rule.

- (a) $R_i = R_1 \parallel R_2 \parallel (r_p + R_{E1})$ (b) $R_i = R_1 \parallel R_2 \parallel (r_p + R_{E1} + R_{E2})$
 (c) $R_i = R_1 \parallel R_2 \parallel [r_p + (b+1)R_{E1}]$ (d) $R_i = R_1 \parallel R_2 \parallel \frac{r_p}{(b+1)}$
 (e) $R_i = r_p + (b+1)R_{E1} \parallel R_{E2}$

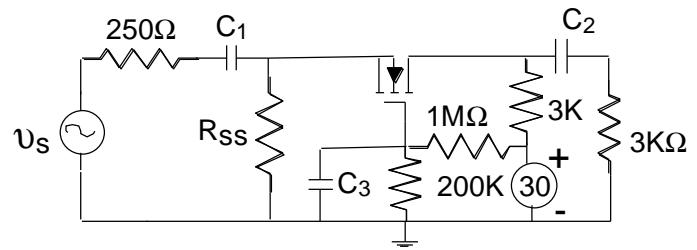


6) A common collector amplifier is biased at $I_C = 2.5$ mA and has a low series resistance source attached to it. About what is its output impedance? (Assume that $b = 150$.)

- (a) 10 Ω (b) 20 Ω (c) 50 Ω (d) 100 Ω (e) not enough information

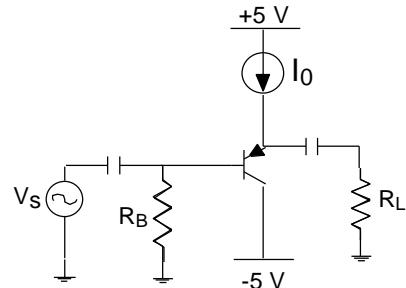
7) If an input resistance of about 250 Ω is required for the circuit below, what value of I_D should be selected? (Assume $I_D = 2(V_{GS} - 2)^2$ mA)

- (a) 0.5 mA (b) 1.0 mA (c) 1.5 mA (d) 2.0 mA (e) 2.5 mA

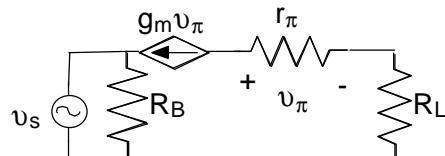


- 8) A single stage amplifier is desired with an input resistance less than $1000\ \Omega$ and a voltage gain magnitude of at least 100. The mid-frequency gain must be positive. What configuration should you recommend?
- (a) CE (b) CS (c) CD (d) CB (e) CG

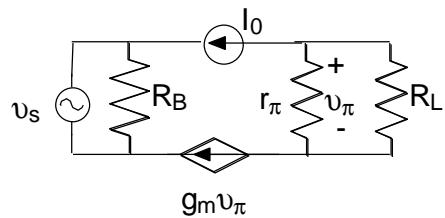
- 9) Select the proper small-signal equivalent circuit for the circuit shown below



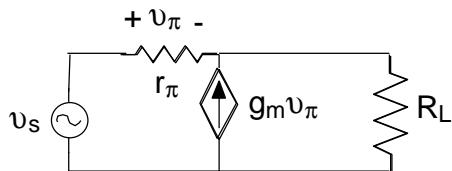
(A)



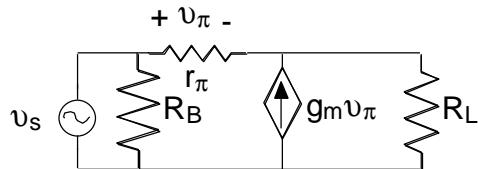
(B)



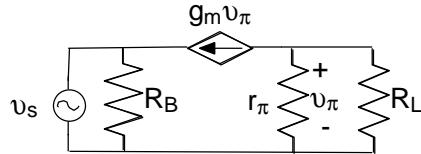
(C)



(D)

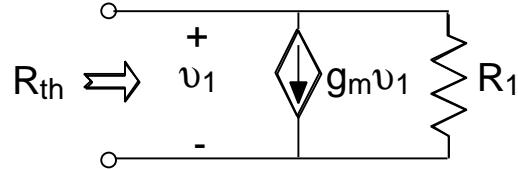


(E)



- 10) Determine the Thevinin equivalent resistance for the circuit shown. (**Hint:** squirt I_x into the terminals and determine the V_x that results.)

- (a) $R_{th} = R_i$ (b) $R_{th} = 1/g_m$ (c) $R_{th} = R_i + 1/g_m$
 (d) $R_{th} = R_i \parallel \frac{1}{g_m}$ (e) $R_{th} = \infty$



- 11) A bipolar transistor has $V_{BE} = 700$ mV, $\beta = 100$, and $I_C = 1$ mA. The best estimate for I_S is:

- (a) 2×10^{-3} A (b) 2×10^{-6} A (c) 2×10^{-9} A (d) 2×10^{-12} A (e) 2×10^{-15} A

12) A small signal equivalent circuit for the transistor in Problem 11 would include $g_m = :$

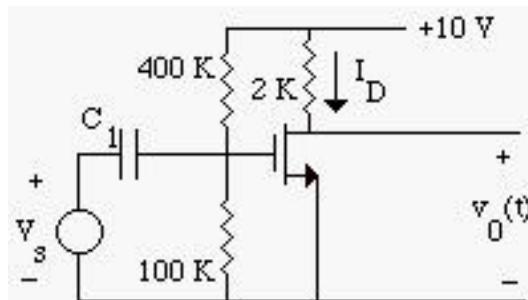
- (a) 0.010 mho (b) 0.038 mho (c) 0.143 mho (d) 0.070 mho (e) 0.700 mho

13) A single stage NMOS amplifier has a device $g_m = 1500 \text{ mmho}$. If g_m is to be doubled, then I_D must be increased by a factor of:

- (a) 0.25 (b) 0.5 (c) 2.0 (d) 4.0 (e) 16.0

14) For the transistor at the right, $I_D = (V_{GS} - 1)^2$. The value of I_D is:

- (a) 2 mA (b) 1 mA (c) 0.25 mA (d) 0.125 mA (e) 0.025 mA

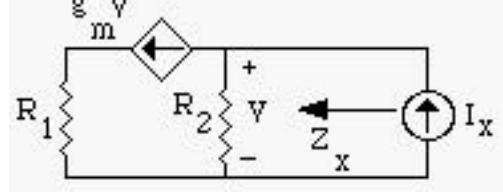


15) In problem 14, assume C_1 is large. If $V_S(t) = 0.1 \sin(1000t)$, then $v_o(t) = :$

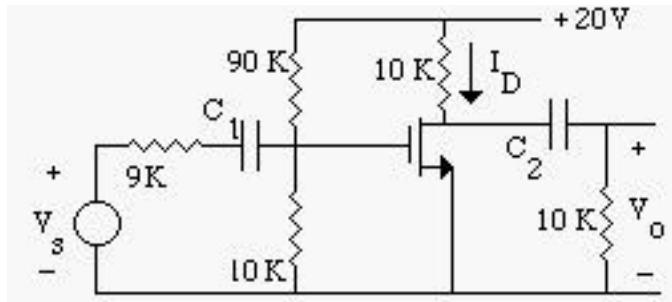
- (a) $1 - 0.2 \sin(1000t)$ V; (b) $8 + 0.4 \sin(1000t)$ V; (c) $2 + 0.2 \cos(1000t)$ V;
 (d) $9.5 - 0.1 \sin(1000t)$ V; (e) $8 - 0.4 \sin(1000t)$ V
-

- 16) The bipolar transistor in a single stage amplifier is operating with $I_C = 2$ mA and is modeled in Spice by the the following parameters: $VAF = 100$, $BF = 100$, $BR = 2$, $IS = 10^{-15}$. The transistor has an output resistance, $r_O =$
- (a) 0 ohms; (b) $10 \text{ K}\Omega$; (c) $50 \text{ K}\Omega$; (d) $100 \text{ K}\Omega$; (e) infinity.
-

- 17) The impedance Z_x is:
- (a) R_2 ; (b) $R_1 + R_2$; (c) $\frac{1}{g_m}$; (d) $\frac{1}{g_m} \parallel R_2$; (e) $\frac{1}{g_m} + R_1$



- 18) For the circuit at the right, $I_D = 1$ mA, r_O is infinite ($\lambda = 0$), $g_m = 0.001$ mho. The mid frequency small signal gain for V_O/V_S is
- (a) -2.5; (b) -5; (c) -10; (d) +10 (e) -20



19) -- Using a load line approach, what is the maximum amplitude for the ac output voltage $v_o(t)$ in Problem 18?

- (a) 20 V; (b) 10 V; (c) 5 V; (d) 2.5 V; (e) 1 V

20) -- The dc power absorbed by the transistor in Problem 18 (in milliwatts) is :

- (a) 50; (b) 40; (c) 30; (d) 20; (e) 10

EE-255 Formula Sheet: Exam 3

Data:

$$At \ 25 \ ^\circ C \ (R.T.) \quad V_T = kT/q = 0.026 \text{ volts}$$

$$k = 1.3806 \times 10^{-23} \text{ J / K} = 8.618 \times 10^{-5} \text{ eV / K} \quad q = 1.6022 \times 10^{-19} \text{ C} \quad 0^\circ C = 273.16 \text{ K}$$

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

Diodes:

$$I_D = I_S (e^{V_D/nV_T} - 1) \quad V_D = V_g + I_D r_f \quad C_j = C_{j0} (1 + V_R/V_{bi})^{-1/2}$$

$$r_d = \left. \frac{d\mathbf{u}_D}{di_D} \right|_Q = \frac{V_T}{I_{DQ}} \quad (\text{forward bias}) \quad v_D = V_D + v_d$$

Rectifiers:

$$V_r = V_M \left(\frac{T_p}{RC} \right) \quad R = R_s \left(\frac{L}{W} \right)$$

Monolithic Resistors:
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:

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

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

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

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

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

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

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

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

MOSFETs:

$$r_o = \frac{1}{I I_D} = \frac{V_A}{I_D} \quad V_{Th} = V_{Th0} + g \left[\sqrt{2f_f + V_{SB}} - \sqrt{2f_f} \right]$$

Bipolar Transistors:

$$I_C = bI_B \cong I_S e^{\frac{V_{BE}}{V_T}} \left(1 + \frac{V_{CE}}{V_A} \right) \quad (\text{active}) \quad \mathbf{b} = \frac{\mathbf{a}}{1 - \mathbf{a}} \quad \mathbf{a} = \frac{\mathbf{b}}{1 + \mathbf{b}}$$

$$I_C = \frac{b[V_{Th} - V_{BE}(\text{on})]}{R_{Th} + (b+1)R_E}$$

Thermal Effects:

$$T_{dev}-T_{amb}=\pmb{q}\,P_D$$

$$P_D=I_BV_{BE}+I_CV_{CE}\hspace{1in}P_D=I_DV_{DS}$$

Bipolar Amplifiers:

$$g_m = \frac{I_C}{V_T} \quad g_m r_p = b \quad r_o = \frac{V_A}{I_C}$$

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

CE with emitter degeneration:

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

CB: $A_{vi} = +g_m(R_C \parallel R_L)$ $R_{is} = R_E \parallel \frac{r_p}{b+1}$ $R_o = R_C$

CC: $A_{vi} = \frac{(1+b)(r_o \parallel R_E \parallel R_L)}{r_p + (1+b)(r_o \parallel R_E \parallel R_L)}$
 $R_{is} = (R_1 \parallel R_2) \parallel [r_p + (b+1)r_o \parallel R_E \parallel R_L]$ $R_o = r_o \parallel R_E \parallel \left[\frac{r_p + (R_1 \parallel R_2) \parallel R_S}{b+1} \right]$

FET Amplifiers:

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

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

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

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