Hour Examination #2

1) Write your official:
   Last Name (use capital letters): SOLUTIONS
   First Name (use capital letters): ____________________________
   NetID: ____________________________
   UIN: ____________________________

2) Fill in the Orange bubble sheet with all the information requested:
   a. LAST NAME, FIRST INITIAL example: SCHMITZ C
   b. STUDENT NUMBER (UIN) example: 678912345
   c. SECTION (AL1 9am enter 111, AL2 10am - 222, AL3 2pm - 333, AL4 3pm - 444)
   d. NETWORK ID (NetID) example: cdschmit
   e. Also, fill out the hand-written center of the sheet with course, instructor, section and your signature.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD

A. CALCULATORS ARE NOT ALLOWED ON THIS EXAM

B. Write or print clearly in this exam booklet for your own benefit. Circle the correct answer within the exam booklet and then mark it on the orange bubble sheet. You may not argue for points because you marked one answer in the exam and another on the bubble sheet, so be careful when marking your answers.

C. All problems are equally weighted.

D. Your grade will be determined based on the answers submitted on your bubble sheet. Submit both the bubble sheet AND the complete exam booklet.

Students caught cheating on this exam will earn a grade of F for the entire course. Other penalties may include suspension and/or dismissal from the university.

I have read and acknowledge the above statements. Furthermore, I promise not to give or receive help on this or any other exam.

______________________________
Signature

Page 1 of 1
1. What is the node voltage $V_A$ if $V_1=3\ V$ and $V_2=2\ V$?
   a. 1 $V$
   b. 1.5 $V$
   c. 2 $V$
   d. 2.5 $V$
   e. 3 $V$

   
   [Diagram showing voltage relationships]

   $V_1 = 3\ V$
   $V_2 = 2\ V$

   $\frac{3-V_A}{2} + \frac{2-V_A}{2} = \frac{V_A - 0}{2} 
   \Rightarrow 6 - 2V_A + 2 - V_A = V_A 
   \Rightarrow 4V_A = 8$

2. What is the node voltage $V_A$ if $V_2=6\ V$?

   [Diagram showing voltage relationships]

   $\frac{6-(V_A-2)}{2} + \frac{6-V_A}{1} = \frac{V_A - 0 + (V_A - 2) - 0}{2}$

   $8 - V_A + 12 - 2V_A = V_A + 2V_A - 4$

   $2V_A = 6V_A$

3. If the light-emitting diode (LED) has the turn on voltage $V_{ON} = 2\ V$, what is the resistance $R$ needed to set the current through the LED to 40 mA (assuming the offset ideal model)?

   a. 20 $\Omega$
   b. 25 $\Omega$
   c. 30 $\Omega$
   d. 35 $\Omega$
   e. 40 $\Omega$

   $R = \frac{V_A}{I_A} = \frac{1\ V}{0.04\ A} = 25\ \Omega$
4. If the light-emitting diode (LED) has the turn on voltage \( V_{ON} = 2 \, V \), and the resistance in series is \( R=50 \, \Omega \), what is the power consumed by the LED (assuming the offset ideal model)?

- a. 180 mW
- b. 80 mW
- c. 60 mW
- d. 40 mW
- e. 20 mW

\[
I = \frac{1}{50} \frac{V}{\Omega} = 0.02 \, A = 20 \, mA
\]

\[
P_D = (2 \, V)(20 \, mA) = 40 \, mW
\]

5. Assuming an offset ideal model, what is the current, \( I \), through the voltage source if the diodes have the turn on voltage \( V_{ON} = 0.7 \, V \)?

- a. 110 mA
- b. 55 mA
- c. 40 mA
- d. 20 mA
- e. 10 mA

\[
I = \frac{1.1 - 0.7}{0.02} \, mA = 40 \, mA
\]

6. Assuming an ideal offset model with \( V_{ON} = 0.7 \, V \) for each diode, what minimum voltage \( V_D \) drives D2 to the point of turning on?

- a. 0.7 V
- b. 1.2 V
- c. 1.7 V
- d. 2.2 V
- e. 2.9 V

\[
V_D = V_{ON} = 0.7 \, V
\]

KCL: \( \frac{2.2 - (V_A + 0.7)}{50} = \frac{V_A - 0}{100} \)

\[
V_A = 1 \, V
\]

KVL: \( V_2 = 0 + 0.7 + V_A = 1.7 \, V \)
7. What are the minimum and maximum values of $V_{out}$ assuming the offset ideal model for the diodes with $V_{on} = 0.7$ V and the input signal given by $V_{in} = 6 \cos(120\pi t)$ V?

- a. minimum -6 V, maximum 6 V
- b. minimum -6 V, maximum 0.7 V
- c. minimum -6 V, maximum 1.4 V
- d. minimum -0.7 V, maximum 6 V
- e. minimum -1.4 V, maximum 6 V

8. How many of the light-emitting diodes are ON (emitting light) in the diagram below, assuming an offset ideal model with $V_{on} = 2$ V?

- a. 3
- b. 4
- c. 5
- d. 6
- e. 7
9. The circuit below correctly represents the model of
   - a. BJT in active regime
   - b. BJT in saturation regime
   - c. nMOS in cutoff regime
   - d. nMOS in active regime
   - e. nMOS in ohmic regime

![Circuit Diagram]

10. What is the base current, \( I_B \), in the transistor circuit below?

   - a. 0.10 mA
   - b. 0.23 mA
   - c. 0.30 mA
   - d. 10 mA
   - e. 23 mA

\[
I_B = \frac{3 - 0.7}{10k} = 0.23 \text{ mA}
\]

11. If we bias the transistor below with \( R_B = 10 \text{k}\Omega \) and \( R_C = 300 \text{\Omega} \) what is the output voltage, \( V_{CE} \), when the input voltage, \( V_{IN} = 1.7 \text{ V} \)?

   - a. 6.2 V
   - b. 5.1 V
   - c. 3.2 V
   - d. 1.1 V
   - e. 0.2 V

\[
\begin{align*}
I_B &= \frac{1.7 - 0.7}{10} \\
&= 0.1 \text{ mA} \\
\text{Assume ACTIVE} \\
I_C &= \beta I_B = 10 \text{ mA} \\
I_{C_{sat}} &= \frac{6.2 - 0.2}{0.3k} = 20 \text{ mA} \\
\text{So } I_C &= 10 \text{ mA} \Rightarrow V_{CE} = V_{CC} - I_C R_C = 6.2 - 10(0.3 \text{ k}\Omega) \\
&= 6.2 - 3 = 3.2 \text{ V}
\end{align*}
\]
12. If we bias the transistor below with $R_B = 5 \, \text{k}\Omega$ and $R_C = 500 \, \Omega$ what is the minimum input voltage, $V_{IN}$, for which output voltage reaches saturation, i.e. $V_{CE} = 0.2 \, \text{V}$?

\[
I_C = I_C_{sat} = \frac{6.2 - 0.2}{0.5 \, \text{k}\Omega} = 12 \, \text{mA}
\]
\[
I_B = \frac{I_C}{\beta} = \frac{12}{100} = 0.12 \, \text{mA}
\]
\[
V_{IN} = I_B R_B + V_{BE, on} = (0.12 \, \text{mA})(5 \, \text{k}\Omega) + 0.7 \, \text{V} = 0.6 + 0.7 = 1.3 \, \text{V}
\]

13. Bobby has just connected the circuit below, but cannot read the resistor code and does not know what value he used for either resistor. He measures $V_{CE}$ to be 2.2 V. What will $V_{CE}$ become if he adds a resistor identical to $R_B$ in parallel to $R_B$ (thereby reducing $R_B$ by a factor of two)? Note: You don’t need $V_{IN}$ to solve this.

\[
\text{Original } I_C R_C = 8.2 - 2.2 = 6 \, \text{V}
\]
\[
\frac{1}{2} R_B \Rightarrow \frac{1}{2} I_B \text{ since } I_B = \frac{V_{IN} - V_{BE, on}}{R_B}
\]
\[
\Rightarrow 2 \times I_C \text{ since } I_C = \beta I_B \text{ (assuming } \text{ACTIVE)}
\]
\[
\Rightarrow 2 \times I_C \Rightarrow \text{New } I_C R_C = 12 \, \text{V}
\]
\[
\text{New } V_{CE} = V_{CE} - I_C R_C = 8.2 - 12 < V_{CE, sat}, \text{ so } V_{CE} - V_{CE, sat}
\]
14. Assuming our BJT model from class, estimate the power dissipated by the transistor below.

\[ P = V_{BE} I_B + V_{CE} I_C \]

\[ I_B = 3 \, mA \]
\[ V_{BE} = 0.7 \, V \]
\[ V_{CE} = 0.2 \, V \]

\[ I_C = \beta I_B = 100 \times 3 \, mA = 30 \, mA \]

\[ I_{Sat} = \frac{3.2 - 0.2}{0.1 \, k} = 30 \, mA \]

\[ I_C = 30 \, mA \]
\[ V_{CE} = 0.2 \, V \]

\[ P = (0.7)(3) + (0.2)(30) = 2.1 + 6 = 8.1 \, mW \]

15. Given the BJT IV characteristic with the load line provided, what is the base current, \( I_B \), which results in the output node voltage, \( V_o = 2 \, V \) in the circuit below?

- a. 0 \( \mu A \)
- b. 10 \( \mu A \)
- c. 20 \( \mu A \)
- d. 30 \( \mu A \)
- e. 40 \( \mu A \)
16. Given the BJT below biased with $V_{CC} = 6.2 \, \text{V}$, $R_C = 50 \, \Omega$, $R_B = 1 \, \text{k}\Omega$, what is/are the regime(s) of operation of the BJT if the input voltage is given by $V_i(t) = 1.5 + 0.7\cos(200\pi t)$?
   a. Active only
   b. Cut-off (Off) and Active
   c. Cut-off (Off) and Saturation
   d. Active and Saturation
   e. Cut-off (Off), Active, and Saturation

\[ V_i = V_{BE,\text{on}} + \frac{R_B}{\beta R_C} (V_{CC} - V_{CE,\text{sat}}) \]
\[ = 0.7 + \frac{1000}{100 \times 50} (6.2 - 0.2) \]
\[ = 0.7 + \frac{6}{5} = 1.9 \, \text{V} \]

17. The gate-source junction of an nMOS with a grounded source is best modeled by
   a. voltage source
   b. current source
   c. resistor
   d. diode
   e. capacitor

connected to body
18. Consider the graph and the nMOS circuit below. If $I_D = 5 \text{ mA}$, $V_{TH} = 2 \text{ V}$ and $V_{GS} - V_{DD} = 5 \text{ V}$, what is the value of $R_D$ which would result in $V_{DS} = 2 \text{ V}$?

- a. $300 \Omega$
- b. $150 \Omega$
- c. $100 \Omega$
- d. $75 \Omega$
- e. $50 \Omega$

$I_D = 6 \times I_1 = 30 \text{ mA}$

$R_D = \frac{5 - 2}{I_D} = \frac{3 \text{ V}}{30 \text{ mA}} = 0.1 \text{ k}\Omega = 100 \text{ } \Omega$

19. If a computer chip with a switching rate of 1 GHz and $V_{DD}$ of 6 V is dissipating 180 W, what will be the power dissipation if we lower $V_{DD}$ to 4 V and increase the switching rate to 1.5 GHz, while keeping the activity factor the same?

- a. 80 W
- b. 120 W
- c. 180 W
- d. 270 W
- e. 405 W

\[ P = nafCV^2 \]

Decrease $V$ by $\frac{2}{3}$

Increase $f$ by $\frac{3}{2}$

\[ P_{\text{new}} = P_{\text{old}} \left( \frac{2}{3} \right)^2 \cdot \left( \frac{3}{2} \right) \]

\[ = 180 \times \frac{2}{3} \times \frac{2}{3} \times \frac{3}{2} = 120 \text{ W} \]
20. Which of the following output columns correctly represents the output of the logic circuit below for inputs A and B?

- a. $Z_1$
- b. $Z_2$
- c. $Z_3$
- d. $Z_4$
- e. $Z_5$

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Output Choices</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
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<tr>
<td>0</td>
<td>0</td>
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</tbody>
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21. For which set of inputs below is this MOS logic circuit’s output Z undefined?

- a. $A = 0$, $B = 0$, $C = 0$
- b. $A = 1$, $B = 0$, $C = 0$
- c. $A = 0$, $B = 1$, $C = 0$
- d. $A = 1$, $B = 1$, $C = 0$
- e. $A = 1$, $B = 1$, $C = 1$
22. If the average noise power in a 50 Ω resistor is 0.02 mW, what is the RMS signal voltage required to achieve the signal-to-noise power ratio of 10?
   a. 320 mV
   b. 200 mV
   c. 140 mV
   d. 100 mV
   e. 70 mV

   \[ P_{\text{signal}} = 10 \times P_{\text{noise}} = 0.2 \text{ mW} = 0.0002 \text{ W} \]
   \[ \frac{V_{\text{RMS}}^2}{R} = P_{\text{signal}} \Rightarrow V_{\text{RMS}} = 50 \times 0.0002 = 0.01 \]
   \[ V_{\text{RMS}} = \sqrt{0.01} = 0.1 \text{ V} = 100 \text{ mV} \]

23. What is the highest frequency in the signal given by the equation below, where \( t \) is in seconds?
   \[ v(t) = 2 \cos(440\pi t) - \sin(740\pi t) + 3 \cos(880\pi t) \]
   a. 220 Hz
   b. 370 Hz
   c. 440 Hz
   d. 740 Hz
   e. 880 Hz

24. If a sampling period is 0.5 s, what is the sample \( v[3] \) (for \( n = 3 \)) for the signal given below, where \( t \) is in seconds? (Note: trigonometric function reference is given below)
   \[ v(t) = 3 \sin(2\pi t) - \cos(\pi t) \]
   \[ T_s = \frac{3\pi}{4} \]

   \[ \begin{array}{|c|c|c|c|c|}
   \hline
   x & 0 & \pi/2 & \pi & 3\pi/2 & 2\pi \\
   \hline
   \sin(x) & 0 & 1 & 0 & -1 & 0 \\
   \cos(x) & 1 & 0 & -1 & 0 & 1 \\
   \hline
   \end{array} \]
   a. -1
   b. 0
   c. 1
   d. 2
   e. 3

   \[ v[3] = v(3T_s) = v\left(\frac{3\pi}{4}\right) = 3\sin\left(\frac{3\pi}{2}\right) - \cos\left(\frac{3\pi}{2}\right) = 3 \times 0 - 0 = 0 \]

25. What is the sampling period if 2000 samples are taken each second?
   a. 4 ms
   b. 2 ms
   c. 1 ms
   d. 0.5 ms
   e. 0.25 ms