1) Write your official:
   Last Name (use capital letters): ________________________________
   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 444, AL2 10am - 111, AL3 1pm - 222, AL4 2pm - 333)
   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
You have TEST FORM:

A

Please enter this in the lower right corner of the orange bubble sheet in the location marked TEST FORM.
1. If a 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 25 mA (assuming the offset ideal model)?
   a. 20 $\Omega$
   b. 25 $\Omega$
   c. 30 $\Omega$
   d. 35 $\Omega$
   e. 40 $\Omega$

2. If a light-emitting diode (LED) has the turn on voltage $V_{ON} = 2 \, V$, what fraction of the power supplied by the 3 V source is consumed by the resistor?
   a. 1/9
   b. 1/3
   c. 4/9
   d. 2/3
   e. Depends on $R$

3. Assuming an offset ideal model, what is the current, $I$, through each of the two identical diodes if their turn on voltage is $V_{ON} = 0.7 \, V$?
   a. 10 mA
   b. 20 mA
   c. 35 mA
   d. 40 mA
   e. 55 mA
4. Assuming an ideal offset model with $V_{ON} = 0.7\ V$ for each diode, what is the minimum voltage $V_2$ for which D1 has no current flowing through it?

- a. 1.8 $V$
- b. 2.5 $V$
- c. 3.2 $V$
- d. 3.6 $V$
- e. 4.3 $V$

5. 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 $V_{in} = 3\cos(120\pi t)$ $V$?

- a. minimum -3 $V$, maximum 2.2 $V$
- b. minimum -3 $V$, maximum 1.5 $V$
- c. minimum -3 $V$, maximum 0.8 $V$
- d. minimum 0.8 $V$, maximum 3 $V$
- e. minimum 2.2 $V$, maximum 3 $V$
6. 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 $V_{in} = 2 \cos(120\pi t) \, V$?

   a. minimum -2 V, maximum 2 V
   b. minimum -2 V, maximum 0.7 V
   c. minimum -0.7 V, maximum 2 V
   d. minimum -0.7 V, maximum 0.7 V
   e. minimum 0 V, maximum 0 V

7. 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. 6
   b. 5
   c. 4
   d. 3
   e. none
8. The diode in the model circuit below correctly represents the model of a

a. base-emitter junction of a BJT  
   ![Diode Circuit]
   \[ \beta I_B \]
   \[ V_{out} \]
   \[ I_B \]
   \[ \beta = 100 \]
   \[ V_{CE,sat} = 0.2 \text{ V} \]
   \[ V_{BE,\text{on}} = 0.7 \text{ V} \]

b. collector-emitter junction of a BJT

c. gate-body junction of an nMOS

d. gate-source junction of an nMOS

e. drain-source junction of an nMOS

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

a. 0 mA  
b. 0.04 mA  
c. 0.07 mA  
d. 0.11 mA  
e. 0.18 mA

10. If we bias the transistor below with \( R_B = 20 \text{ k}\Omega \) and \( R_C = 400 \text{ \Omega} \) what is the output voltage, \( V_{CE} \), when the input voltage, \( V_{IN} = 1.7 \text{ V} \)?

a. 6.2 V  
b. 5.2 V  
c. 4.2 V  
d. 2.8 V  
e. 0.2 V
11. If we bias the transistor below with $R_B = 10 \, \text{k}\Omega$ and $R_C = 500 \, \Omega$ what is the minimum input voltage, $V_{IN}$, for which output voltage reaches saturation, i.e. $V_{CE} = 0.2 \, V$?

- a. 0.7 V
- b. 1.2 V
- c. 1.9 V
- d. 3.1 V
- e. 6.2 V

![Transistor Circuit Diagram]

$V_{CE, sat} = 0.2 \, V$
$V_{BB, on} = 0.7 \, V$

12. Cathy has just connected the circuit below, but cannot read the resistor code and does not know what value she used for either resistor. She measures $V_{CE}$ to be 6.2 V. What will $V_{CE}$ become if he adds a resistor identical to $R_C$ in parallel to $R_C$ (thereby reducing $R_C$ by a factor of two)? Note: You don’t need $V_{IN}$ to solve this.

- a. 0.2 V
- b. 3.1 V
- c. 4.2 V
- d. 5.5 V
- e. 7.2 V

![Cathy's Circuit Diagram]

$V_{CE} = 6.2 \, V$
$V_{CE, sat} = 0.2 \, V$
$V_{BB, on} = 0.7 \, V$
13. If we double the base current to $2 \text{mA}$, the power dissipated by the transistor approximately

a. goes up by a factor of 4  
b. goes up by a factor of 2  
c. remains the same  
d. goes down by a factor of 2  
e. goes down by a factor of 4

14. Given the BJT IV characteristic with the load line provided, and assuming $V_{BE, on} = 0.7V$, what is the output voltage, $V_o$, when $V_i = 1.3 \text{V}$, in the circuit below?

   HINT: $R_B = 40 \text{k}\Omega$, while $V_{CC}$ and $R_C$ can be found from the load line.

   ![BJT IV characteristic and circuit diagram](image)

   a. 0.5 V  
b. 1 V  
c. 2 V  
d. 3 V  
e. 4 V
15. Given the BJT below biased with $V_{CC} = 5.2 \, V$, $R_C = 200 \, \Omega$, $R_B = 4 \, k\Omega$, what is/are the regime(s) of operation of the BJT if the input voltage is given by $V_i(t) = 1.5 + 1.1 \cos(200\pi t)$?

   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

16. If the BJT below is biased with $V_{CC} = 12 \, V$ and $R_C = 200 \, \Omega$, what should be the value of $R_B$ in order to set the magnitude of amplifier “gain” to ten, i.e. $G = \frac{V_{o2} - V_{o1}}{V_{i2} - V_{i1}} = -10$?

   a. 500 $\Omega$
   b. 1 k$\Omega$
   c. 1.5 k$\Omega$
   d. 2 k$\Omega$
   e. 5 k$\Omega$
17. The **drain-source** junction of an nMOS with a grounded source, operating in the **ohmic** region, is sometimes modeled as a
   a. voltage source
   b. current source
   c. resistor
   d. diode
   e. capacitor

18. Consider the graph and the nMOS circuit below. If $I_1 = 5 \, mA$, $V_{TH} = 2 \, V$ and $V_{GS} = V_{DD} = 6 \, V$, what is the value of $R_D$ which would result in $V_{DS} = 4 \, V$?

   a. 25 $\Omega$
   b. 50 $\Omega$
   c. 75 $\Omega$
   d. 100 $\Omega$
   e. 125 $\Omega$
19. Which of the following output columns correctly represents the output of the logic gate circuit below for inputs $A$ and $B$?

a. $Z_1$

b. $Z_2$

c. $Z_3$

d. $Z_4$

e. $Z_5$

![Logic Gate Circuit]

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Output Choices</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A$</td>
<td>$B$</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

20. For which set of inputs below is this MOS logic circuit’s output $Z$ simultaneously connects to both $V_{DD}$ and ground?

a. $A = 0$, $B = 0$, $C = 0$

b. $A = 0$, $B = 0$, $C = 1$

c. $A = 1$, $B = 0$, $C = 0$

d. $A = 0$, $B = 1$, $C = 1$

e. $A = 1$, $B = 1$, $C = 1$

![MOS Logic Circuit]
21. Jack’s integrated CMOS circuit consumes 2 W when powered with $V_{DD}$ of 6 V and running with the switching rate of 200 MHz and 10% activity factor. Jack can **double the switching rate** to 400 MHz **AND double activity factor** to 20% while consuming the **same power** if $V_{DD}$ is

(Hint: 1 MHz = 1,000,000 Hz, but you don’t need it)

a. 12 V  
b. 6 V  
c. 3 V  
d. 2 V  
e. 1.5 V

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 40?

a. 140 mV  
b. 200 mV  
c. 280 mV  
d. 400 mV  
e. 640 mV

23. What is the frequency NOT present in the signal given by the equation below, where $t$ is in seconds?

$$v(t) = \cos(220\pi t) + 2\cos(440\pi t) - \sin(740\pi t) + 3\cos(880\pi t)$$

a. 110 Hz  
b. 220 Hz  
c. 370 Hz  
d. 440 Hz  
e. 740 Hz
24. If a sampling period is 0.25 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)

\[ v(t) = 2\cos(\pi t) - \sin(2\pi t) \]

\[
\begin{array}{|c|c|c|c|c|c|c|c|}
\hline
x & 0 & \pi/4 & \pi/2 & 3\pi/4 & \pi & 5\pi/4 & 3\pi/2 & 7\pi/4 & 2\pi \\
\hline
\sin(x) & 0 & 0.7 & 1 & 0.7 & 0 & -0.7 & -1 & -0.7 & 0 \\
\hline
cos(x) & 1 & 0.7 & 0 & -0.7 & -1 & -0.7 & 0 & 0.7 & 1 \\
\hline
\end{array}
\]

a. -2.4  
b. -1.7  
c. -0.4  
d. 0.7  
e. 1.4

25. What is the sampling period if 500 samples are taken each second?

a. 4 ms  
b. 2 ms  
c. 1 ms  
d. 0.5 ms  
e. 0.2 ms