Final Examination

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 (AL4 9am enter 444, AL1 10am enter 111,
      AL2 1pm enter 222, AL3 2pm enter 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. NO CALCULATORS ARE PERMITTED ON THE EXAM!
   Using a calculator will be treated as cheating.
B. One two-sided sheet of notes is permitted on the exam.
C. 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.
D. All problems are equally weighted.
E. 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. Recall the definition of capacitance: \( C = \frac{Q}{V} \). Now, consider a capacitor with a constant charge of \( Q \). What happens to the \textbf{voltage}, which starts out as \( V \), across the capacitor, if its capacitance is doubled (e.g. by moving the capacitor plates closer together)?
   a. becomes \( \frac{V}{4} \)
   b. becomes \( \frac{V}{2} \)
   c. stays as \( V \)
   d. becomes \( 2V \)
   e. becomes \( 4V \)

2. A motor performs mechanical work at the rate of \( 6 \, W \). If the motor converts electrical to mechanical energy with a 66.7\% (2/3) efficiency, what is the current that it draws from a 12 \( V \) battery?
   a. \( \frac{3}{2} \, A \)
   b. \( \frac{3}{4} \, A \)
   c. \( \frac{1}{2} \, A \)
   d. \( \frac{1}{3} \, A \)
   e. \( \frac{1}{6} \, A \)

3. Apply KVL to find the values of \( V_1 \) and \( V_2 \) in the diagram below.
   a. \( V_1 = 7 \, V, \, V_2 = 14 \, V \)
   b. \( V_1 = 7 \, V, \, V_2 = 5 \, V \)
   c. \( V_1 = 3 \, V, \, V_2 = 14 \, V \)
   d. \( V_1 = 3 \, V, \, V_2 = 5 \, V \)
   e. \( V_1 = 3 \, V, \, V_2 = 4 \, V \)

4. What is the value of \( V_{out} \), the voltage across the 700 \( \Omega \) resistor, in the circuit below?
   a. 0.18 \( V \)
   b. 0.42 \( V \)
   c. 0.60 \( V \)
   d. 0.98 \( V \)
   e. 1.40 \( V \)
5. What is the value of the resistance, \( R \), if the voltage across it is 2 V?
   a. 4 kΩ
   b. 6 kΩ
   c. 8 kΩ
   d. 16 kΩ
   e. 24 kΩ

6. All lightbulbs below are identical and can be modeled as resistors. Of the labeled lightbulbs, which one is dissipating the least power?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5

7. What is \( R_{AB} \)?
   a. 0.67 kΩ
   b. 2.1 kΩ
   c. 2.4 kΩ
   d. 3.0 kΩ
   e. 3.6 kΩ
8. What is the smallest non-zero resistance one can make with one 200 Ω, one 300 Ω, and one 600 Ω resistor?
   a. 50 Ω
   b. 75 Ω
   c. 100 Ω
   d. 150 Ω
   e. 200 Ω

9. What is the power supplied by the current source?
   a. 25 mW
   b. 50 mW
   c. 75 mW
   d. 100 mW
   e. 125 mW

10. What is the labeled node voltage, $V_1$?
    a. 3 V
    b. 4 V
    c. 5 V
    d. 6 V
    e. 7 V
11. What is the power dissipated (absorbed) by the 60 Ω resistor?
   a. 1/6 W
   b. 2/15 W
   c. 1/10 W
   d. 1/15 W
   e. 1/30 W

![Circuit Diagram 1]

12. What is the resistance, $R$, which makes the labeled current zero, i.e. $I_1 = 0$?
   a. 100 Ω
   b. 150 Ω
   c. 600 Ω
   d. 750 Ω
   e. 2 kΩ

![Circuit Diagram 2]

13. What is the correct I-V expression (where $I$ is in amps and $V$ is in volts), for the circuit below?
   a. $I = -\frac{V}{240} + 1$
   b. $I = -\frac{V}{240} + 2$
   c. $I = -\frac{V}{120} + 1$
   d. $I = -\frac{V}{120} + 2$
   e. $I = -\frac{V}{80} + 1$

![Circuit Diagram 3]
14. In comparison with a higher-valued resistor a **lower-valued resistor’s IV characteristic** line would have a
   a. larger magnitude voltage-axis intercept
   b. smaller magnitude current-axis intercept
   c. smaller magnitude voltage-axis and larger magnitude current-axis intercepts
   d. larger magnitude slope
   e. smaller magnitude slope

15. Consider a circuit, C, with two terminals shown connected to three loads below. If its open-circuit voltage is 12 V, short circuit current is 3 A, what is the **power** dissipated (absorbed) by a 2 A load connected to the circuit?

   ![Circuit Diagram](image1)

   a. 36 W
   b. 24 W
   c. 16 W
   d. 8 W
   e. 6 W

16. What is the Norton equivalent of the circuit below?

   ![Circuit Diagram](image2)

   a. $I_N = 1.5 \text{ A}, R_N = 9 \Omega$
   b. $I_N = 1.5 \text{ A}, R_N = 6 \Omega$
   c. $I_N = 1.5 \text{ A}, R_N = 2 \Omega$
   d. $I_N = 0.5 \text{ A}, R_N = 6 \Omega$
   e. $I_N = 0.5 \text{ A}, R_N = 2 \Omega$
17. Two identical linear circuits, each with a Norton equivalent given by $I_N = 3 \, \text{A}$, $R_N = 3 \, \Omega$, are combined in parallel to form a new circuit. The new circuit’s Thevenin equivalent is given by

- a. $V_T = 18 \, \text{V}, R_T = 3 \, \Omega$
- b. $V_T = 18 \, \text{V}, R_T = 1.5 \, \Omega$
- c. $V_T = 9 \, \text{V}, R_T = 3 \, \Omega$
- d. $V_T = 9 \, \text{V}, R_T = 1.5 \, \Omega$
- e. $V_T = 4.5 \, \text{V}, R_T = 3 \, \Omega$

18. What is a good estimate of a lightbulb’s resistance, if the lightbulb absorbs 50W of average power when the AC voltage across it is given by the following equation? (If you need, $1.4^2 \approx 2$)

$v(t) = 140 \cos(120\pi t)$

- a. 100 $\Omega$
- b. 140 $\Omega$
- c. 200 $\Omega$
- d. 250 $\Omega$
- e. 400 $\Omega$

19. Assuming an offset ideal model, what is the resistance, $R$, needed to set the current to 25 mA through the blue LED which has the turn on voltage $V_{on} = 3 \, \text{V}$?

- a. 180 $\Omega$
- b. 120 $\Omega$
- c. 90 $\Omega$
- d. 60 $\Omega$
- e. 30 $\Omega$
20. What is the current, \( I \), supplied by the voltage source, if \( V_{ON} = 0.7 \, \text{V} \), assuming offset ideal diode model?

a. 0 mA
b. 8.0 mA
c. 11.5 mA
d. 16 mA
e. 23 mA

21. Assuming an ideal offset model with \( V_{ON} = 0.7 \, \text{V} \) for each diode, what is the minimum voltage \( V_2 \) for which \( D_1 \) 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

22. Suppose that the input signal is given by \( V_{in} = 2 \cos(120\pi t) \, \text{V} \) and we would like to set the minimum value of \( V_{out} \) to \(-1 \, \text{V}\). Assuming the offset ideal model for the diode with \( V_{ON} = 0.7 \, \text{V} \), what should be the value chosen for \( V_s \)?

a. \( V_s = -1.7 \, \text{V} \)
b. \( V_s = -1.3 \, \text{V} \)
c. \( V_s = -1 \, \text{V} \)
d. \( V_s = -0.3 \, \text{V} \)
e. \( V_s = 0.3 \, \text{V} \)
23. What is $I_C$ if $V_B = 2.2\ V$, $R_B = 500\ \Omega$, and $R_C = 15\ \Omega$?
   a. 0 mA
   b. 100 mA
   c. 200 mA
   d. 300 mA
   e. 400 mA

24. What is $V_B$ if $V_O = 4.2\ V$, $R_B = 500\ \Omega$, and $R_C = 10\ \Omega$?
   a. 0.3 V
   b. 1.0 V
   c. 1.7 V
   d. 2.7 V
   e. 3.7 V

25. For which of the following $V_B$ values is the transistor absorbing (dissipating) the most power if $R_B = 500\ \Omega$, and $R_C = 10\ \Omega$?
   a. 0.7 V
   b. 1.2 V
   c. 1.7 V
   d. 2.2 V
   e. 2.7 V
26. Consider the BJT below biased with $V_{CC} = 6.2 \, V$, $R_C = 200 \, \Omega$. Under what condition on $R_B$ will the transistor avoid saturation, if the input voltage is given by $V_i(t) = 1.2 + 0.4 \cos(2000\pi t)$?

a. $R_B > 3 \, k\Omega$
b. $R_B < 3 \, k\Omega$
c. $R_B > 5.3 \, k\Omega$
d. $R_B < 5.3 \, k\Omega$
e. Any $R_B$ will avoid saturation

27. If the BJT circuit below is biased with $V_{CC} = 12 \, V$, $R_C = 300 \, \Omega$, $R_B = 1.5 \, k\Omega$, what is the active-region slope of the transfer characteristics given by $G = \frac{V_{o2} - V_{o1}}{V_{i2} - V_{i1}}$?

a. -20
b. -17
c. -15
d. -12
e. -10
28. Consider the graph and the nMOS circuit below.
If \( I_1 = 5 \, mA \), \( V_{TH} = 2 \, V \) and \( V_{GS} = V_{DD} = 5 \, V \), what is the value of \( R_D \) which would result in \( V_{DS} = 2 \, V \)?

![Graph and nMOS circuit diagram]

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

29. Which of the following output columns correctly represents the output of the logic gate circuit below for inputs \( A \) and \( B \)?

![Logic gate circuit diagram]

<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>
30. For which set of inputs below is the output undefined?

a. A = 0, B = 0, C = 0
b. A = 0, B = 0, C = 1
c. A = 0, B = 1, C = 0
d. A = 1, B = 0, C = 0
e. A = 0, B = 1, C = 1

31. Jill’s integrated CMOS circuit consumes 2 W when powered with V_{DD} of 8 V and running with the switching rate of 200 MHz and 10% activity factor. Jill can **double the switching rate** to 400 MHz **AND double activity factor** to 20% while consuming a **quarter of the power** (0.5 W) if V_{DD} is changed to

a. 12 V
b. 6 V
c. 3 V
d. 2 V
e. 1 V

32. If thermal noise with RMS voltage of 0.05 V is added to a sinusoidal signal with the peak voltage of 1 V, the **ratio of signal power to noise power** is

a. 5
b. 20
c. 100
d. 200
e. 400
33. What is the minimum sampling rate for a digital voice mail system if all the frequencies below 4 kHz should be preserved (and correctly reproduced)?
   a. 2 kHz
   b. 4 kHz
   c. 8 kHz
   d. 20 kHz
   e. 40 kHz

34. If a signal is not sampled with sufficiently high frequency, the reconstructed signal will exhibit **aliasing** – a phenomenon when after reconstruction
   a. high frequency components disappear.
   b. low frequency components disappear.
   c. high frequency components appear at lower frequencies.
   d. low frequency components appear at higher frequencies.
   e. all frequencies are shifted by Nyquist rate.

35. What is the minimum number of bits per sample needed to digitize a signal in 0 to 4 V range if the quantization error (half of level spacing) should be less than 0.1 V?
   a. 4
   b. 5
   c. 6
   d. 7
   e. 8
36. What is the size of the compressed file if the uncompressed file size was 1200 kB and the percent saving due to compression was 40%?
   a. 30 kB  
   b. 480 kB  
   c. 720 kB  
   d. 1680 kB  
   e. 2000 kB

37. If a single-channel audio signal is sampled at the rate of 40 kHz and quantized to 256 levels, what is the data compression rate (DCR) needed to compress the data rate to 32 kbps (kilobits per second)?
   a. 5  
   b. 10  
   c. 40  
   d. 160  
   e. 320

38. About how many 8-megapixel (8×10^6 pixels/image) images can be stored on a 4 GB (~4×10^9 Bytes) SD card, if 48 bits (3×16, 16 per color) are recorded for every pixel and the images are compressed with a 12-fold compression ratio (DCR = 12)?
   Hint: 1 Byte = 8 bits  
   a. 16,000  
   b. 4,000  
   c. 1,000  
   d. 500  
   e. 125
39. Five types of birds are observed at a bird feeder with the frequencies given below. If a Huffman code is created to encode the visiting birds, which bird does not appear in the following message describing a stream of visitors?

Pigeons 45%  Sparrows 25%  Crows 18%  Robins 8%  Finches 4%

Message: 00101011011011001100

Hint: in the Huffman tree, the more likely branches were marked with 1.

a. pigeon  
b. sparrow  
c. crow  
d. robin  
e. finch

40. The six sandwich choices on the menu are ordered with the estimated probabilities given in the table below. What is the best estimate of entropy \( H = \sum p_i \log_2 \frac{1}{p_i} \) of a sandwich order?

(Hints: \( \log_2 3 \approx 1.6 \), \( \log_2 \frac{a}{b} = \log_2 a - \log_2 b \))

<table>
<thead>
<tr>
<th>Sandwich</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability</td>
<td>3/4</td>
<td>1/8</td>
<td>1/32</td>
<td>1/32</td>
<td>1/32</td>
<td>1/32</td>
</tr>
</tbody>
</table>

a. 0.8 bits  
b. 1.3 bits  
c. 1.8 bits  
d. 2.3 bits  
e. 2.8 bits

41. Which assertion below is always correct if there are 15 possible symbols, which occur with entropy, \( H \), and are Huffman coded with an average code length, \( L \)?

a. \( H \leq L \leq 4 \)  
b. \( L \leq H \leq 4 \)  
c. \( 3 \leq H \leq L \)  
d. \( H \leq L \leq 3 \)  
e. \( L \leq H \leq 3 \)
42. Which of the following light sources emits the largest photon flux (photons/sec)?

<table>
<thead>
<tr>
<th>Source #</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength(nm)</td>
<td>230</td>
<td>433</td>
<td>620</td>
<td>1550</td>
<td>4300</td>
</tr>
<tr>
<td>Power (mW)</td>
<td>20</td>
<td>0.5</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

a. 1  
b. 2  
c. 3  
d. 4  
e. 5

43. A table of lasers and their wavelengths is attached below. Which of them are absorbed by Si if its bandgap energy is 1.1 eV? Hint: E(eV) = 1240/wavelength(nm)

<table>
<thead>
<tr>
<th>Laser</th>
<th>Wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Er:Glass</td>
<td>1540 nm</td>
</tr>
<tr>
<td>InGaAs</td>
<td>980 nm</td>
</tr>
<tr>
<td>HeNe</td>
<td>633 nm</td>
</tr>
</tbody>
</table>

a. None of them  
b. Only Er:Glass  
c. Only HeNe  
d. HeNe and InGaAs  
e. All of them

44. If four identical photodiodes, with $V_{OC} = 1\ V$ and $I_{SC} = 0.1\ mA$ given for a certain illumination, are connected in series, what is the $V_{OC}$ and $I_{SC}$ for the resulting combination (under the same illumination)?

a. $V_{OC} = 1\ V$ and $I_{SC} = 0.1\ mA$  
b. $V_{OC} = 2\ V$ and $I_{SC} = 0.2\ mA$  
c. $V_{OC} = 4\ V$ and $I_{SC} = 0.4\ mA$  
d. $V_{OC} = 4\ V$ and $I_{SC} = 0.1\ mA$  
e. $V_{OC} = 1\ V$ and $I_{SC} = 0.4\ mA$

45. A solar cell array has $V_{OC} = 12\ V$ and $I_{SC} = 20\ A$ for a certain illumination. What is the fill factor if the maximum power provided under this illumination is 200 W?

a. $1/2$  
b. $2/3$  
c. $5/6$  
d. $1$  
e. $3/2$
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PLEASE TURN IN THIS SCRATCH PAPER WITH THE EXAM