Answer any 7 of the 9 questions. All parts of a given problem are worth the same number of points unless noted in the problem. The number of points earned on this exam will be added to your total points for determination of the final course grade. Notice that you may earn 5 bonus points above the advertised 100 points for this exam. Do your work on these pages. Use the backs of the pages for extra space if necessary.

The exam is closed book. Calculators are allowed. A straight edge is desirable.
Question 1

An experiment produces the periodic signal \( A \). Two cycles of this signal are shown in Figure 1. The signal is to be studied using a simple analog oscilloscope such as used in the CEM 838 lab.
Question 1

a.) (4 points) Figure 2 is a display of the signal of Figure 1 that has been achieved on the oscilloscope. What are the trigger conditions used to achieve this display?

*Trigger Level = 5 volts*
*Trigger Slope = positive*
b.) (4 points) Figure 3 is a display of the signal of Figure 1 that has been achieved on the oscilloscope. What are the trigger conditions used to achieve this display?

*Trigger Level = 6 volts*
*Trigger Slope = negative*

![Figure 3](image)

c.) (4 points) Figure 4 is a display of the signal of Figure 1 that has been achieved on the oscilloscope. What are the trigger conditions used to achieve this display?

*Trigger Level = 2 volts*
*Trigger Slope = positive*

d.) (3 points) Figure 4 is not a desirable display. Why?

*Ambiguous triggers*
Question 2

The circuit in Figure 5 has the values: $V_2 = 8.0$ volts, $R_1 = 8 \, \text{k}\Omega$, $R_2 = 4 \, \text{k}\Omega$, $R_3 = 8 \, \text{k}\Omega$, $R_4 = 8 \, \text{k}\Omega$. What is the value of $V_1$ and $V_3$? Show your work.

NOTE: $V_2$ is specified, not $V_1$ or $V_3$

\[
V_2 = V_1 \frac{R_2 + R_3 \parallel R_4}{R_1 + R_2 + R_3 \parallel R_4}
\]

\[
8 = V_1 \frac{4 + 4}{8 + 4 + 4} = V_1 \frac{8}{16}
\]

\[
V_1 = 2 \cdot V_2 = 2 \cdot 8 = 16 \text{ volts}
\]

\[
V_3 = V_2 \frac{R_1 \parallel R_4}{R_1 + R_2 + R_3 \parallel R_4}
\]

\[
V_3 = 8 \cdot \frac{4}{8 + 4 + 4} = 8 \cdot \frac{4}{16} = 2 \text{ volts}
\]
Question 3

The circuit in Figure 6 has the input $V_1$, which is a 60 Hz sign wave with a peak-to-peak amplitude of 160 volts. Assume that $n_s = 5$ and $n_p = 50$.

(5 points) Sketch $V_2$ of Figure 6 as a function of time. Be sure to indicate the peak-to-peak value of $V_2$. 

![Figure 6](image-url)
Figure 7

(5 points) Figure 7 is a circuit related to that of Figure 6. Sketch $V_3$ as a function of time for the circuit shown in Figure 7. Be sure to include labeled tick marks that provide quantitative vertical values of your sketch.

(5 points) If $V_1$ were to decrease in the circuit displayed in Figure 6, what would the response be of the portion of the circuit labeled $\text{Element}_4$?

*The Controller would decrease the value of $R_{\text{PASS}}$ to bring $V_L$ back to the desired value.*
a) (10 points) Sketch the behavior of the signal $V_{\text{out}}$ in the circuit shown in Figure 8 in response to the signal shown in Figure 9 being input to the circuit. Be sure to include labeled tick marks for the vertical axis.

![RC Response to Step Function](image1)

b) (5 points) What is the effect of the values of $R$ and $C$ on the output of the circuit?

*As $R \times C$ increases, the charging is slower. As $R \times C$ decreases, the charging is faster.*
Question 5

A real voltage source exists that can be modeled as an ideal source, \( V_S = 8 \) volts in series with a resistance \( R_S = 2 \text{ M}\Omega \). The measurement of the voltage of the source is to be made with a real voltage meter that can be modeled as an ideal voltage meter that displays the value of \( e_M \) presented across the two inputs of the meter and has an input resistance, \( R_M = 6 \text{ M}\Omega \) between the two inputs.

Answer the following questions. Show your work.

a) (3 points) Sketch the schematic diagram of this measurement. Label any voltages and currents with appropriate symbols.

b) (3 points) What will be the voltage reported by the voltmeter?

\[
e_M = V_M = V_S \frac{R_M}{R_M + R_S}
\]

\[
e_M = V_M = 8 \frac{6}{6+2} = 6 \text{ volts}
\]

c) (3 points) What is the value of the current flowing in or out of the voltage source?

\[
i_S = i_M = \frac{V_S}{R_M + R_S} = \frac{8}{6 \times 10^6 + 2 \times 10^6} = 1 \times 10^{-6} \text{ amps}
\]
Question 5

d) (6 points) Is this a good measurement? If not, what could be done to improve the measurement? Explain your reasoning.

No, this is not a good measurement because a non-zero current is being drawn from the source. Another way of stating this is that the voltage drop across $R_S$ (which is an error voltage) is not zero. The answer: get a better VDM or put a voltage follower between the two devices.
Diodes can be used as input transducers that convert the intensity of light impinging on the diode junction into a current. Diodes can also be used as output transducers that convert a current into light.

a) (7 points) Sketch the characteristic curve of a diode. Label the axes and the three regions of operation.

b) (8 points) Discuss how these two significantly different examples of transducers can be achieved with a diode. You do not have to include any additional circuitry; just discuss the role of the diode and any constraints that will be applied to achieve the desired behaviors.

To use a diode as an input transducer to measure light, hold \( V_d \) constant in the reverse bias region. The value of \( i_d \), although small, is then a function of the light intensity impinging on the diode junction.

To use a diode as an output transducer to generate light, operate with \( V_d \) in the forward bias region. The diode will emit light the intensity of which will be a function of the amount of current (and hence the value of \( V_d \)) passing through the junction.

In both cases, the diode will be designed for that particular function.
Question 7

If $R_1 = 8 \, \text{K}\Omega$, $R_2 = 4 \, \text{K}\Omega$, $R_f = 8 \, \text{K}\Omega$, $e_1 = +6$ volts, and Signal A of Figure 11 is connected to $e_3$, answer the following questions for the circuit shown in Figure 10. Assume that $i_+ = i_- = 0$ for both operational amplifiers, and that both operational amplifiers are operational.
Question 7

a) (5 points) Sketch the amplitude versus time plot for the signal $e_2$. Try to be quantitative. Annotate your axes with labeled tickmarks.

b) (10 points) Sketch the amplitude versus time plot for the signal $e_{out}$. Annotate your axes with labeled tickmarks.
Question 8

A two input OR gate is to be used to gate the logic signal, $A$, shown in Figure 12. The gate control signal, $B$, is to be constructed so that the gate will be closed except for the intervals $t = 2$ to $t = 9$ and $t = 12$ to $t = 20$. The output of the gate is to be called $M$.

a.) (3 points) Draw the symbol for the OR gate. Label the symbol with the names of the signals $A$, $B$, and $M$.

```
+---+---+---+
|   | A |   |
+---+---+---+
    ^   
    |    
    +---+
     B  

M = A + B
```

b.) (4 points) Give the table of states for the OR gate.

<table>
<thead>
<tr>
<th>$B$</th>
<th>$A$</th>
<th>$M$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

c.) (4 points) On the first blank plot provided below, sketch the gate control signal, $B$, which you would have to supply to achieve the desired gating.

d.) (4 points) On the second blank plot provided below, sketch the gate output, $M$, that would result.
Question 9

Signal A and Signal B are to be studied using the circuit shown in Figure 13.

Figure 14 - Signal Timings
a.) (2 points) Where would you connect Signal A to the circuit in Figure 13?

\[ e_{gi} \]

b.) (2 points) Where would you connect Signal B to the circuit in Figure 13?

\[ e_{\text{start}} \text{ and } e_{\text{stop}} \]

c.) (3 points) In the space provided in Figure 14, sketch the time course for \( e_{ge} \) that would result.

d.) (3 points) In the space provided in Figure 14, sketch the time course for \( e_{go} \) that would result.

e.) (5 points) Given only the information stated in this problem and the observations in the previous parts of this problem, what can you say about Signal A and Signal B?

\[ p_A / p_B = 6 \text{ or } f_B / f_A = 6 \]

The error in this measurement is 1 part in 6.