EE42/100 Midterm 2

NO CALCULATORS, CELL PHONES, or other electronics allowed. Show your work, and put final answers in the boxes provided. Use proper units in all answers.

1. [5] Express the following power ratios in dB

<table>
<thead>
<tr>
<th>P/Pref</th>
<th>P/Pref [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td>50</td>
<td>17</td>
</tr>
<tr>
<td>2\times10^{-10}</td>
<td>-97</td>
</tr>
<tr>
<td>1/4</td>
<td>-6</td>
</tr>
<tr>
<td>2.5\times10^8</td>
<td>74</td>
</tr>
</tbody>
</table>

1 pt, no partial credit
No units necessary (dB means dB...)
No credit for answers that include log of anything.

2. [5] Express the following voltage ratios in dB

<table>
<thead>
<tr>
<th>V/Vref</th>
<th>V/Vref [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>\sqrt{2}</td>
<td>3</td>
</tr>
<tr>
<td>1/2</td>
<td>-6</td>
</tr>
<tr>
<td>0.04</td>
<td>-28</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2\times10^{-3}</td>
<td>-24</td>
</tr>
</tbody>
</table>

\[2 \times 10^{-3} \Rightarrow 2.6 \approx 2.20\]

3. [8] You measure an AC voltage across a 1kΩ resistor. The digital voltmeter that you use measures in RMS (like all voltmeters), and reports that the voltage is 1 V. **Use units**

a. What is the zero-to-peak voltage?

\[V_{pp} = \sqrt{2} \times 1V = 1.4 \, \text{V}\]

b. What is the peak-to-peak voltage

\[V_{pp} = 2.8 \, \text{V}\]

c. What is the max power dissipated in the resistor?

\[P_{\text{max}} = \frac{(1.4)^2}{1\Omega} = \frac{2.8}{1}\]

\[P_{\text{max}} = 2 \, \text{mW}\]

d. What is the average power dissipated in the resistor?

\[P_{\text{avg}} = 1 \, \text{mW}\]

-1 (missing unit)
-2 (all missing units)

-1 (right formula, wrong unit)
4. [10] For the circuit below, calculate the steady state values for the current in the two inductors, the voltage across the capacitor, the energy stored in \( L_1 \), and the energy stored in \( C_2 \).

\[
\frac{1}{2} L_1 i_1^2 = \frac{1}{2} (10 \text{ H}) (2 \text{ A})^2 = 20 \\
\frac{1}{2} C_2 v_c^2 = \frac{1}{2} (5 \text{ F}) (4 \text{ V})^2 = 40
\]

5. [10] Two capacitors, each 2\( \mu \text{F} \), are charged in parallel from a single AA battery with a voltage of 1.5V, and then discharged in series into a 1k\( \Omega \) load. The battery has a source resistance of 1\( \Omega \).

a. What is the equivalent capacitance seen by the battery during charging?

\[ C_{\text{charge}} = 4 \mu \text{F} \]

\[ \tau_{\text{charge}} = 4 \mu \text{s} \]

b. What is the time constant during charging?

c. What is the equivalent capacitance of the series combination driving the load?

\[ C_{\text{series}} = 1 \mu \text{F} \]

\[ \tau_{\text{discharge}} = 1 \text{ mS} \]

d. What is the time constant during discharging?

e. How long does it take for the output voltage to droop 5% after the \( \phi_2 \) switches are closed?

\[ t_{\text{5\%}} = 50 \mu \text{s} \]

Also accepted: \(-0.001\text{ln}(0.95)\)
6. [10] In the RC circuit below assume \( V_{in} \) is a voltage step from 0 to 10V at \( t=0 \). If \( R=1 \) and \( C=1 \text{nF} \), sketch the response of the circuit on the three different time scales provided.

\[
\frac{1}{\tau} = R \cdot C = 10^{-9} \text{s}
\]

\[
H(s) = \frac{1}{1 + \frac{s}{\omega_p}} \quad \omega_p = 10^9 \text{ rad/s}
\]

\[+2\]

\[+4 \text{ total}\]

\[10 \text{ ns} \quad \downarrow 1 \text{s} \quad \downarrow 1 \text{ ps}\]

7. [8] The RC circuit above is driven by an input signal \( v_{in}(t) = \sin(100t) + \cos(10^5 t) \). What is \( v_{out}(t) \) in steady state?

\[
v_{out}(t) = \sin(100t) + \frac{1}{\sqrt{2}} \cos(10^5 t - 45^\circ)
\]

2 pts each, 2 pts total max

8. [8] Sketch a Bode plot of the transfer function of the RC circuit above. Label each axis!

-1 wrong pole freq

1 pt off for missing any of these (-3 max)
9. [18 total] You want to build an AM radio with an LC tank at a resonant frequency of $10^{6}$ rad/sec. Your inductor is 100uH and has a series resistance of 20Ω.
   
a. [2] How big should your capacitor be?

   $$C = \frac{1}{2\pi f R} = \frac{1}{2\pi \times 10^{6} \times 20} = 100 \text{pF}$$

   $$C = 100 \text{pF}$$

b. [6] Sketch the magnitude of the inductor impedance (including series resistor) and capacitor impedance on the axes below. Label each axis!

c. [2] Assuming an ideal capacitor, what will the Q of your LC tank be?

   $$Q = \frac{\frac{L}{R}}{\omega C} = \frac{10^{7} \times 10^{-4}}{10^{6}} = 50$$

   $$Q = 50$$

d. [2] What is the magnitude of the tank impedance at 1 rad/sec?

   $$Z(1) = 20$$

   $$Z(10^{6}) = 100$$

e. [2] What is the magnitude of the tank impedance at $10^{6}$ rad/sec?

   $$Z(10^{6}) = 50$$

f. [2] What is the magnitude of the tank impedance at the resonant frequency?

   $$Z(\omega_0) = 50 \Omega$$

g. [2] What is the magnitude of the tank impedance at $10^{9}$ rad/sec?

   $$Z(10^{9}) = 10$$

- 1 total if either or both are missing
- 2 pts each for Resistive/Inductive, capacitive parts (1 pt shape, 1 pt correct value)
Rubric:

- Off by OOM but wrote formula (Wrong no work -2).
  - 1 pt. each for crosses
  - 1 pt. each for shape
  - Only swiggle ½ credit
  - ½ additional if resistor and
    reduction not added correctly

- 1 pt. for formula for Q (Wrong answer)
  - No simplification

- 1 pt. for answer

- 1 pt. for answer
  - Did not multiply by Q
120 A was 100 A

read off correct from their graph: no punishment.

propogated wrong L value. ok. no punishment.

inverted Q (-1)

just expression left but evaluates ok except enter (1)

symbolic expression (-2)

C is right

graph is wrong (-2)

answer is wrong, but take from graph

cal Q instead of multiply by Q.