Trigonometric Identities
\[
\cos(-\theta) = \cos(\theta) \quad \sin(-\theta) = -\sin(\theta) \quad \sin(\theta) = \cos \left( \theta - \frac{\pi}{2} \right)
\]

Cosines and Sines of common angles

<table>
<thead>
<tr>
<th>( \theta ) (radians)</th>
<th>( \theta ) (degrees)</th>
<th>( \cos \theta )</th>
<th>( \sin \theta )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>( \pi/6 )</td>
<td>30°</td>
<td>( \sqrt{3}/2 )</td>
<td>( 1/2 )</td>
</tr>
<tr>
<td>( \pi/4 )</td>
<td>45°</td>
<td>( \sqrt{2}/2 )</td>
<td>( \sqrt{2}/2 )</td>
</tr>
<tr>
<td>( \pi/3 )</td>
<td>60°</td>
<td>( 1/2 )</td>
<td>( \sqrt{3}/2 )</td>
</tr>
<tr>
<td>( \pi/2 )</td>
<td>90°</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Euler’s Formula
\[
e^{j\theta} = \cos \theta + j \sin \theta \quad e^{-j\theta} = \cos \theta - j \sin \theta
\]

Complex Numbers
- rectangular form: \( z = a + j b \)  \( a \) is the real part of \( z \), \( b \) is the imaginary part of \( z \)
- polar form: \( z = A e^{j\theta} \)  \( A \) is the magnitude of \( z \), \( \theta \) is the angle of \( z \)
- rectangular to polar: \( z = a + j b \rightarrow \sqrt{a^2 + b^2} e^{j \tan^{-1}(b/a)} = A e^{j\theta} \)
- polar to rectangular: \( z = A e^{j\theta} \rightarrow A \cos \theta + j A \sin \theta = a + j b \)
- complex conjugate: \( z = a + j b \rightarrow z^* = a - j b \)
- complex conjugate: \( z = A e^{j\theta} \rightarrow z^* = A e^{-j\theta} \)

Complex Number Properties
\[
j = \sqrt{-1} = e^{j\pi/2} = e^{-j3\pi/2} \\
j^2 = -1 = e^{j\pi} = e^{-j\pi} \\
j^3 = -j = e^{j3\pi/2} = e^{-j\pi/2} \\
j^4 = 1 = e^{j0} = e^{j2\pi} = e^{-j2\pi}
\]

Impedances
\( R \rightarrow Z_R = R, \quad L \rightarrow Z_L = j\omega L, \quad C \rightarrow Z_C = 1/(j\omega C) = -j/(\omega C) \)

Series: \( R_1 + R_2 \) or \( Z_1 + Z_2 \), Parallel: \( R_1||R_2 = \frac{R_1 R_2}{R_1 + R_2} \) or \( Z_1||Z_2 = \frac{Z_1 Z_2}{Z_1 + Z_2} \)

Ohm’s Law, Voltage Division, Current Division
Ohm’s Law — Assuming passive sign convention: \( V = IR \) or \( V = IZ \)

Voltage Division — For \( R_1 \) and \( R_2 \) in series with \( V_s \): \( V_1 = \frac{R_1}{R_1 + R_2} V_s, \quad V_2 = \frac{R_2}{R_1 + R_2} V_s \)

Current Division — For \( R_1 \) and \( R_2 \) in parallel with \( I_s \): \( I_1 = \frac{R_2}{R_1 + R_2} I_s, \quad I_2 = \frac{R_1}{R_1 + R_2} I_s \)

Voltage Division — For \( Z_1 \) and \( Z_2 \) in series with \( V_s \): \( \tilde{V}_1 = \frac{Z_1}{Z_1 + Z_2} \tilde{V}_s, \quad \tilde{V}_2 = \frac{Z_2}{Z_1 + Z_2} \tilde{V}_s \)

Current Division — For \( Z_1 \) and \( Z_2 \) in parallel with \( I_s \): \( \tilde{I}_1 = \frac{Z_2}{Z_1 + Z_2} \tilde{I}_s, \quad \tilde{I}_2 = \frac{Z_1}{Z_1 + Z_2} \tilde{I}_s \)
Opamp 1 (5 points)
Consider the following circuit where the opamp is ideal. Recall that for an ideal opamp, $V_+ = V_-$, $I_+ = 0\, \text{A}$ and $I_- = 0\, \text{A}$. 

**Hint:** Start by determining $V_-$ then use KVL, KCL and Ohm’s Law.

![Circuit Diagram]

(a) Find the current $I_{R1}$.

(b) Find the current $I_{R2}$.

(c) Find the output voltage $V_{out}$.

(d) Find the power dissipation $P_{diss, R1}$ in resistor $R_1$.

(e) Find the power dissipation $P_{diss, R2}$ in resistor $R_2$.

Opamp 2 (5 points)
Consider the following circuit where the opamp is ideal. Recall that for an ideal opamp, $V_+ = V_-$, $I_+ = 0\, \text{A}$ and $I_- = 0\, \text{A}$. 

**Hint:** Start by determining $V_-$ then use KVL, KCL and Ohm’s Law.

![Circuit Diagram]

(a) Find the current $I_{R1}$.

(b) Find the current $I_{R2}$.

(c) Find the output voltage $V_{out}$.

(d) Find the power dissipation $P_{diss, R1}$ in resistor $R_1$.

(e) Find the power dissipation $P_{diss, R2}$ in resistor $R_2$. 
Truth Tables and Logic Functions (6 points)
Consider the following logic circuit with inputs $x$ and $y$ and output $z$.
(a) (4 points) Determine the truth table for the circuit.
(b) (2 points) Write $z$ as a logical function of $x$ and $y$.

Logic Function Implementation (4 points)
Given the logical function $w = [xyz + (xy)' + (x'z)']'$, synthesize a logic circuit with inputs $x, y, z$ and output $w$. **Hint:** start working with the innermost parentheses first.
Equivalent Resistance Calculation (6 points, 3 points each)
Find the equivalent resistance $R_{eq}$ for each of the circuits shown below.

Logic Function Implementation (4 points)
Given the logical function $w = \left[ x'y'z' + x(yz)' + (x'y)'z \right]'$, synthesize a logic circuit with inputs $x$, $y$, $z$ and output $w$. *Hint:* start working with the innermost parentheses first and be careful with how you implement $x(yz)'$ and $(x'y)'z$. 
Complex Impedance Calculation (5 points)
Suppose you are given a 50 Ω resistor and a 0.2 H inductor operating at ω = 1000 rad/s.

(a) Find the impedance $Z_R$ of the resistor.

(b) Find the impedance $Z_L$ of the inductor.

(c) Find the parallel combination $Z_p$ of the resistor and inductor.

(d) Simplify and express $Z_p$ in polar form as $A\angle\theta$.

(e) Simplify and express $Z_p$ in rectangular form as $a + jb$.

LED Current Limit Calculation (5 points)
In the circuit shown below, the resistor $R_s$ is used to limit the current through the LED. When the LED is on (conducting), its voltage is $V_{LED} = 2V$.

(a) Determine the value of $R_s$ so that the LED current $I_{LED} = 2mA$ when it is on.

(b) Find the power dissipation $P_{diss,Rs}$ in resistor $R_s$ when the LED is on.

(c) Find the power dissipation $P_{diss,LED}$ in the LED when it is on.

(d) Determine the power supplied by the voltage source when the LED is on.
Extra Workspace