Resistor Color Codes

- In the **Basic circuit elements** section under the image of a resistor, the colors should be ordered by number (i.e., from 0–9). Then it would be clear that 2–7 are the ROYGBV colors of a rainbow.

Experiment 1: Introduction to Oscilloscope & Function Generator

- Under **1. Oscilloscope** in the introductory material,
  - In **8) Measure the phase difference** the expression for \( \theta \) uses the **principal arcsine**, and so it is only valid for quadrant I phase angles between 0° and 90°. Often, \( \theta \) will need to be manipulated to place the phase in the proper quadrant.

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>Positive Phase Difference</th>
<th>Negative Phase Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>( \theta )</td>
<td>(-360° + \theta)</td>
</tr>
<tr>
<td>II</td>
<td>(180° - \theta)</td>
<td>(-180° - \theta)</td>
</tr>
<tr>
<td>III</td>
<td>(180° + \theta)</td>
<td>(-180° + \theta)</td>
</tr>
<tr>
<td>IV</td>
<td>(360° - \theta)</td>
<td>(-\theta)</td>
</tr>
</tbody>
</table>

Because the filters in this class are **causal**, phase differences will usually be **negative** indicating that signals have been “delayed.”

- Under **part 6** of the exercises,
  - Because these frequencies are all greater than 1.7 kHz, this circuit provides a phase shift from quadrant III, and so the expression for \( \theta \) should be
  \[
  \theta = \arcsin \left( \frac{\text{distance between two vertical intersections}}{\text{maximum vertical extension of ellipse}} \right) - 180°.
  \]

Experiment 4: Frequency Response of First Order Active Circuits

- In **1. Frequency Response of First Order Active Low Pass Filter** in the intro. material,
  - The **Phase Response** in Figure 2 has a deceiving vertical scale.
    * The highest value on the scale **should** be \(-180°\).
    * The lowest value on the scale **should** be \(-270°\).
  
  Technically, there is nothing wrong with the present scale. However, it may be confusing to associate **positive** phase shift with a **low-pass filter** that is described as adding **lag**. The source of the confusion is the extra \(180°\) shift that accompanies the inverting configuration.

- In **2. Frequency Response of First Order Active High Pass Filter** in the intro. material,
  - Change \( R \) to \( R_1 \) in \( \phi \) expression so that \( \phi(\omega) = -90° - \arctan(R_1 C\omega) \).

- Under **part 2** of the exercises,
  - The **Calculated phase shift** in the last column of the data table should read
  \[
  -180° + \arcsin \left( \frac{\text{intersection}}{V_{opp}} \right).
  \]

  Otherwise, phase shift will be \(-180°\) for low frequencies and \(-90°\) for high frequencies, which is incorrect for a high-pass filter. Figure 4 in the introductory material shows the correct curve.
Experiment 5: Step Response of Second Order Circuits

- Under 2. Frequency Response of Second Order Low Pass Filter in the intro. material,
  - The expression for phase should be

\[ \phi(\omega) = -\arctan(2\sqrt{\frac{2\xi\omega_0\omega}{\omega^2_0 - \omega^2}}) \begin{cases} 
-\arctan\left(\frac{2\xi\omega\omega_0}{\omega^2_0 - \omega^2}\right) & \text{if } \omega < \omega_0, \\
-90^\circ & \text{if } \omega = \omega_0, \\
-180^\circ - \arctan\left(\frac{2\xi\omega_0\omega}{\omega^2_0 - \omega^2}\right) & \text{if } \omega > \omega_0.
\end{cases} \]

That is, \( \phi \) cannot be calculated without specifying the quadrant of the \( H(j\omega) \) phasor. As \( \omega \) increases, \( \phi \) should swing smoothly from \( 0^\circ \) to \( -180^\circ \), as shown in the phase response in Figure 2.

- In the phase response in Figure 2, it should be noted that the steepness of the transition region depends on the damping ratio \( \xi \). That is, as the damping ratio decreases, not only does the magnitude response get a higher peak, but the phase response gets steeper. In fact, for \( \xi = 0 \), the phase response is a negative step that switches from \( 0^\circ \) to \( -180^\circ \) at \( \omega = \omega_0 \).

Experiment 6: Non-Linear Circuit — Diode and Transistor Switch

- Under 2. Transistor Switch in the intro. material,
  - The explanation refers to current \( I_b \) and nodes \( c \) and \( e \), but it does not define these entities.
  * Current \( I_b \) flows through resistor \( R_1 \) into the base of the transistor.
  * Node \( c \) (i.e., transistor collector) is the positive (i.e., “+”) side of output \( V_{out}(t) \).
  * Node \( e \) (i.e., transistor emitter) is the negative (i.e., “−”) side of output \( V_{out}(t) \).
  - In the explanation, “\( V0 \)” should be named \( V_{out} \) to match Figure 3.

Experiment 7: D/A Application

- Under 1. DAC using Summing Amplifier in the intro. material,
  - The expression for output voltage is wrong. The \( R_0 \) and \( R_f \) variables should be swapped:

\[ V_{out} = -I \cdot R_f = -\frac{R_f}{R_0} V_{ref} (8D_3 + 4D_2 + 2D_1 + D_0) \]

- In both of the exercises,
  - The \( V_{ref} \) signal would normally be a constant 5 V DC.
  - However, it is not trivial to generate a third DC voltage in this laboratory.
    * The DC supply provides the 15 V DC and -15 V DC supply rails for the operational amplifier, and so the 5 V DC reference would have to be derived from the 15 V DC rail (e.g., using a voltage divider followed by a unity-gain buffer circuit).
    - For simplicity, let \( V_{ref} \) be a sine wave with 5 V RMS amplitude and 1 kHz frequency.
    * Set digital voltmeter (DVM) to measure AC RMS voltage INSTEAD of DC voltage.
    * Note that all measured voltages will be positive even though we expect them to be negative. This effect is an artifact of using RMS rather than DC.
    * Function generator has 50 Ω output impedance (i.e., Thévenin equivalent resistance is 50 Ω).
      - So for the current-summing DAC, you should measure both \( V_{out} \) and \( V_{ref} \) for each input.
      - As the current-summing DAC requires more current, \( V_{ref} \) will fall because of the voltage dropped across the 50 Ω output impedance.
      - In the R-2R ladder, the current draw is the same for every input, and so the \( V_{ref} \) should also be steady (but not necessarily 5 V RMS) across all inputs.