#1. A function generator (symbol \( \square \)) has an output impedance \( Z = 500 \Omega \). Design (no need to build) a low-pass RC filter appropriate to use with this signal generator, with a knee frequency of 1KHz (1000 Hz)

• Draw it below, specifying the component value right next to each component symbol. Show the function generator's symbol where it connects, and show the connection point for \( V_{\text{OUT}} \). **Use resistors and capacitors only, no opamps.**

• If the function generator produces a 1KHz sine wave with an RMS amplitude of 1.414 volts, what is the RMS amplitude of the waveform at \( V_{\text{OUT}} \)? \( \approx 7 \) volts

• What is the frequency of the waveform observed at \( V_{\text{OUT}} \)? \( \approx 7000 \) Hz

• If the function generator produces a 7KHz sine wave with an RMS amplitude of 1.414 volts, what is the RMS amplitude of the waveform at \( V_{\text{OUT}} \)? \( \approx 18 \) volts

• What is the frequency of the waveform observed at \( V_{\text{OUT}} \)? \( \approx 7000 \) Hz

![Image of RC filter diagram]

#2. Shown below is a regulator that attempts to drive a bright red LED at a current proportional to a voltage \( V_{\text{IN}} \). The voltage \( V_{\text{IN}} \) is specified by a potentiometer, in the range \( \pm 5 \) V. You may assume that the forward voltage of the LED is 1.6V whenever it is lit. The maximum current that the opamp is capable of is 20mA. The opamp's output voltage range is \( \pm 4 \) V.

• What is the current though the LED when \( V_{\text{IN}} = 500 \) mV? \( \approx 0.5 \) mA

• What is the maximum current that the circuit will ever put through the LED, for any \( V_{\text{IN}} \)? \( \approx 2 \) mA

• What is the voltage across the LED when that maximum current is in fact passing through it? \( \approx 1.6 \) volts

• For what range of voltages \( V_{\text{IN}} \) is the LED's current proportional to \( V_{\text{IN}} \)? \( \approx 0 \) volts to \( \approx 2 \) volts

![Image of regulator circuit diagram]

#3. In the circuit below, you may assume that \( I_{\text{CE}} = 100 \) and that \( V_{\text{BE}} = 0.6 \) V whenever there is a nonzero base current.

• Complete the table, finding \( V_{R2} \) (the voltage across \( R2 \)) and \( V_{\text{CE}} \) (the voltage across the transistor), in volts, for each combination of \( V_{\text{IN}} \), \( R1 \), and \( R2 \) shown.

<table>
<thead>
<tr>
<th>( V_{\text{IN}} )</th>
<th>( R1 )</th>
<th>( R2 )</th>
<th>( V_{R2} )</th>
<th>( V_{\text{CE}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 mV</td>
<td>10KΩ</td>
<td>66Ω</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>2V</td>
<td>10KΩ</td>
<td>66Ω</td>
<td>1 * 4</td>
<td></td>
</tr>
<tr>
<td>2V</td>
<td>1KΩ</td>
<td>66Ω</td>
<td>5</td>
<td>0 *</td>
</tr>
</tbody>
</table>

One more question on the other side →
#4. **Design and build** an opamp circuit that takes a **20Hz sine wave** from the function generator as its input, and provides an output that is the time derivative of the input.

• Display the input on Channel A of your scope and the output on Channel B of your scope.

Since the input is a sine wave such as $\sin(20 \cdot 2\pi \cdot t)$, the output should turn out to be $k \cdot \cos(20 \cdot 2\pi \cdot t)$, where $k$ is some negative number. You may find that the derivative is noisy, that's OK, but it should be visible on your scope that the derivative is 90 degrees out of phase with the input, and is indeed a sinusoidal wave too.

• Draw your circuit below, specifying each component value right next to each component symbol. Show where the scope channels A and B connect. Show where the function generator connects.

• When your circuit works, raise your hand to show your scope traces and receive a sticker.