1. Shown below are the output and transfer characteristic for a NPN BJT. The thermal voltage is $V_T = 25.9$ mV. When the collector to emitter voltage is 10 V and the base current is $40 \mu A$, what is the collector current? Using this bias point, what is the Early Voltage, the zero bias current gain $\beta_0$ and the zero bias saturation current $I_{SO}$?

\[ V_T = 25.9 \text{ mV} \]
\[ \beta_0 = \frac{I_C}{I_B} \]
\[ I_{SO} = \frac{I_C}{1 + \frac{V_C-E}{V_T}} \]

\[ V_B = 149.1 \text{ V} \]
\[ I_C = 7.5 \times 1 = 7.5 \text{ mA} \]

\[ I_{SO} = \frac{1}{1 + \frac{149}{25.9}} = 2.78 \times 10^{-14} = 27.8 \text{ fA} \]

\[ V_{BE} = 0.68 \text{ V} \]
\[ \text{at } I_C = 7.5 \text{ mA} \]

<table>
<thead>
<tr>
<th>$I_C$</th>
<th>$V_A$</th>
<th>$\beta_0$</th>
<th>$I_{SO}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5 mA</td>
<td>149</td>
<td>176</td>
<td>27.8 fA</td>
</tr>
</tbody>
</table>
2 Shown below is a single stage common emitter amplifier with a bipolar power supply using a NPN BJT as the active device. It is specified that $V^+ = 15 \text{ V}$, $V^- = -15 \text{ V}$, $C_1 = C_2 = C_E = 300 \mu\text{F}$, $R_C = 5.1 \text{ k}\Omega$, $R_B = 73 \text{ k}\Omega$, and $R_L = 4.3 \text{ k}\Omega$. Design the circuit so that it clips symmetrically and the magnitude of the small-signal midband voltage gain is 7.3. For the design calculations assume that the base-to-emitter dc voltage drop is 0.65 V, $\beta = \infty$, $V_{CE(sat)} = 0 \text{ V}$ and the Early voltage is infinity for each transistor. Assume that the thermal voltage is 25.9 mV. Determine the values of the resistors $R_T$ and $R_E$ to satisfy the design criteria. What is the small signal mid band input and output impedances?

\[\beta = \infty\]
\[\alpha = \frac{\beta}{\beta + 1} = 1\]
\[A_v = -7.3\]

\[R_E = \frac{R_C \cdot R_L}{V_T} = 319.586 \Omega\]

\[I_C = \frac{V^+ + V_{BE} - V_{CE(sat)}}{R_C + R_E + R_C \cdot R_L} = 2.019 \text{ mA}\]

\[I_T = I_E = I_C\]

\[R_T = \frac{V^- - V_{BE}}{I_T} = 7.109 \text{ k} \Omega\]

<table>
<thead>
<tr>
<th>$R_T$</th>
<th>$R_E$</th>
<th>$z_i$</th>
<th>$z_o$</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.11 kΩ</td>
<td>320</td>
<td>73 kΩ</td>
<td>5.1 kΩ</td>
</tr>
</tbody>
</table>

\[S = 5\]
3. Shown below in a BJT common base amplifier using NPN BJTs. Assume that the dc voltage drop from base to emitter for each is 0.65 V, the Early voltage is infinity, and $\beta = \infty$. The power supply voltages are $V^+ = 15$ V and $V^- = -15$ V. The load resistor is $R_L = 4.3 \, \text{k}\Omega$. Each of the capacitors is 100 $\mu\text{F}$ and $R_B = 100 \, \text{k}\Omega$. Design the circuit so that it clips symmetrically and has a small signal midband gain of 7.3, and an output impedance of 6.8 $\Omega$.

$$z = R_C = 6.8 \, \Omega$$

$$\beta = \infty \Rightarrow q = 1$$

$$I_{B1} = \frac{I_{C1}}{\beta} = 0$$

$$V_{B1} = -I_{B1} R_B = 0$$

Assume $r_e << R_e$

$$R_{CE} = \frac{R_c \| R_L}{A_v} = 360.85 \, \text{k}\Omega$$

$$I_{C1} = I_{C1} = \frac{V^+ + V_{BE}}{R_c + R_E + R_c \| R_L} = 1.578 \, \text{mA}$$

$$V_{C1} = V^+ - I_{C1} R_c = 4.17 \, \text{V}$$

$$I_T = I_{E1} = I_{C1} \Rightarrow R_T = \frac{-V^- - V_{BE}}{I_{E1}} = 8.48 \, \text{k}\Omega$$

<table>
<thead>
<tr>
<th>$R_C$</th>
<th>$R_E$</th>
<th>$R_T$</th>
<th>$V_{B1}$</th>
<th>$V_{C1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.8 $\Omega$</td>
<td>361</td>
<td>8.98 $\Omega$</td>
<td>0</td>
<td>4.17</td>
</tr>
</tbody>
</table>