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 $20$ $\mu$A, what is the collector current? Using this bias point, what is the Early Voltage, $V_A$, the zero bias current gain or forward beta $\beta_0$ and the zero bias saturation current $I_{SO}$?

$$I_c = 0.5 \times 7.3 = 3.65 \text{ mA}$$

$$\beta_0 = \frac{I_c}{1 + \frac{v_{CE}}{V_A}}$$

$$V_A = 180.32 \text{ V}$$

$$I_{SO} = \frac{I_c e^{\frac{v_{BE}}{V_T}}}{1 + \frac{v_{CE}}{V_A}} = 29.67 \text{ mA}$$

<table>
<thead>
<tr>
<th>$I_C$</th>
<th>$V_A$</th>
<th>$\beta_0$</th>
<th>$I_{SO}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.65 mA</td>
<td>180</td>
<td>17.3</td>
<td>29.67 mA</td>
</tr>
</tbody>
</table>
2 Shown below is a single stage common emitter amplifier with a unipolar power supply using a NPN BJT as the active device. It is specified that $V^+ = 15$ V, $C_1 = C_2 = C_E = 386 \mu$F, $R_C = 6.8 \, \text{k}\Omega$, $R_{E1} = 3.9 \, \text{k}\Omega$, $R_{E2} = 12 \, \Omega$, $R_{B1} = 75 \, \text{k}\Omega$, $R_{B2} = 150 \, \text{k}\Omega$, and $R_L = 10 \, \text{k}\Omega$. For the calculations assume that the base-to-emitter dc voltage drop is 0.65 V, $\beta = 173$, and the Early voltage is infinity. Assume that the thermal voltage is 25.9 mV. Determine the bias and the small signal midband voltage gain.

\[ \alpha' = \frac{R}{\beta + 1} = 0.997 \]

\[ R_{BB} = R_{B1} \parallel R_{B2} = 50 \, \text{k}\Omega \]

\[ V_{BB} = V^+ \frac{R_{E1}}{R_{B1} + R_{B2}} = 5 \, \text{V} \]

\[ I_B = \frac{V_{BB} - V_{BB}}{R_{BB} + (\beta + 1) R_{E1}} = 5.97 \, \mu\text{A} \]

\[ I_E = I_C = \beta I_B = 1.033 \, \text{mA} \]

\[ V_C = V^+ - I_C R_C = 7.976 \, \text{V} \]

\[ V_E = I_E R_{E1} = 7.051 \, \text{V} \]

\[ V_B = V_E + V_{BE} = 4.701 \, \text{V} \]

\[ A_v = -\alpha' \frac{R_{E2} \parallel R_C}{I_E + R_{E1} \parallel R_{C2}} = -109.077 \]

<table>
<thead>
<tr>
<th>$V_C$</th>
<th>$V_B$</th>
<th>$V_E$</th>
<th>$I_C$</th>
<th>$I_B$</th>
<th>$I_E$</th>
<th>$A_v$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4.7</td>
<td>7.05</td>
<td>$1.03 , \text{mA}$</td>
<td>$5.97 , \mu\text{A}$</td>
<td>$1.04 , \text{mA}$</td>
<td>-109</td>
</tr>
</tbody>
</table>

2 3 each
3. Shown below in a BJT common emitter amplifier using NPN BJTs. Assume that the dc voltage drop from base to emitter for each transistor is 0.65 V, the Early voltage is infinity, and $\beta = \infty$. The power supply voltage are $V^+ = 15$ V and $V^- = -15$ V. The component values are: $R_E = 330 \, \Omega$, $R_{E2} = 12 \, k\Omega$, $R_{C} = 6.2 \, k\Omega$, $R_L = 10 \, k\Omega$, $R_1 = 75 \, k\Omega$, $R_B = 100 \, k\Omega$, and $R_{E3} = 13 \, k\Omega$. Each of the capacitors is 1,000 F. Determine the collector, base, and emitter voltages of each transistor with respect to ground. Determine the small-signal midband voltage gain. Assume that the thermal voltage is 25.9 mV.

![Circuit Diagram]

\[
\beta = \infty \rightarrow I_{B1} = I_{B2} = I_{B3} = 0
\]

\[
V_{B1} = -I_N R_B = 0
\]

\[
V_{E1} = V_{B1} - V_{BE} = -0.65 V
\]

\[
I_1 = \frac{V^+ - V^- - 2V_{BE}}{R_1 + R_{E3}} = \frac{15 - ( -15 ) - 2 \times 0.65}{75 + 13} = 0.3261 mA
\]

\[
B = \infty \rightarrow I_{B1} = I_{B2} = I_{B3} = 0
\]

\[
I_{C1} = I_{E1} = I_{C2} = I_{E2} \quad I_{E2} = \frac{R_{E3} I_1 + V_{BE}}{R_{E2}} = 0.4075 mA
\]

\[
V_{C1} = V^+ - I_1 R_C = 12.474 V
\]

\[
V_{C2} = V_{E1} - I_{E1} R_E = -0.7841 V
\]

\[
V_{E3} = V^+ - I_1 R_1 = -9.67 V = V_{B2} \quad V_{E2} = V_{B2} - V_{BE} = -10.11 = V_{B3}
\]

\[
V_{E3} = V_{B3} - V_{BE} = -10.76 \quad I_{E1} = \frac{V_T}{I_{E1}} = 27.432 \Omega
\]

\[
A_v = -\frac{R_{C1} R_L}{r_e + R_E} = -10.783
\]

<table>
<thead>
<tr>
<th>$V_{C1}$</th>
<th>$V_{B1}$</th>
<th>$V_{E1}$</th>
<th>$V_{C2}$</th>
<th>$V_{B2}$</th>
<th>$V_{E2}$</th>
<th>$V_{C3}$</th>
<th>$V_{B3}$</th>
<th>$V_{E3}$</th>
<th>$A_v$</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5</td>
<td>0</td>
<td>-0.65</td>
<td>-0.787</td>
<td>-9.67</td>
<td>-10.1</td>
<td>-9.67</td>
<td>-10.1</td>
<td>-10.3</td>
<td>-10.8</td>
</tr>
</tbody>
</table>