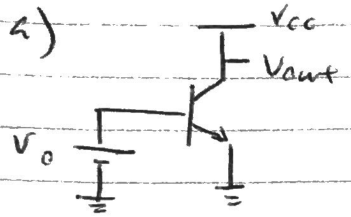
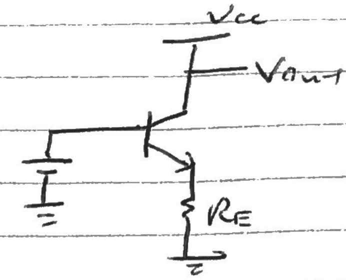
ECE342 Quiz I. 9/30/20.

a)



b)



i) <u>which one is a better current source?</u>

In general a good current source should not be too sensitive to fluctuations in voltage, temperature, etc.

large signal model:

$$I_C = I_S \exp\left(\frac{V_{BE}}{V_T}\right)\left(1 + \underbrace{\frac{V_{CE}}{V_A}}\right)$$

non-ideal: changes in V_{CE} cause I_C to change. (early effect)

For (a), $V_{BE} = V_0$

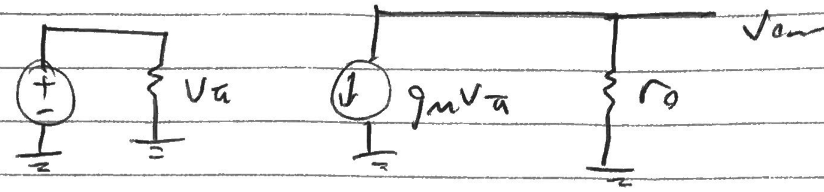
For (b), $V_{BE} = V_0 - I_E R_E$

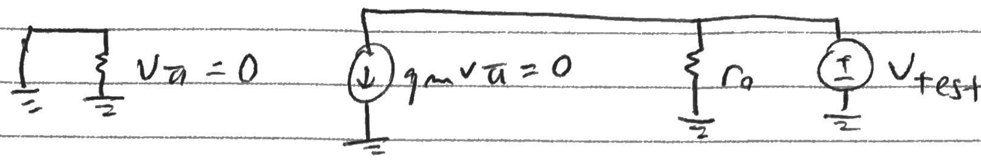
Due to the early effect, when V_{CE} increases, I_C also increases. However, for (b), V_{BE} also ~~changes~~ decreases if $I_E \approx I_C$ increases, which helps to lower I_C and thus mitigates the early effect non ideality. Thus (b) acts as a better current source because it is more resistant to changes in V_{CE}.

(Here, the assumption is made that $V_A \neq \infty$. (i.e., has a nontrivial effect on the circuit). If $V_A = \infty$, then the early effect would be gone and the two circuits would behave similarly as a current source).

(ii) Find output impedances of the circuits.

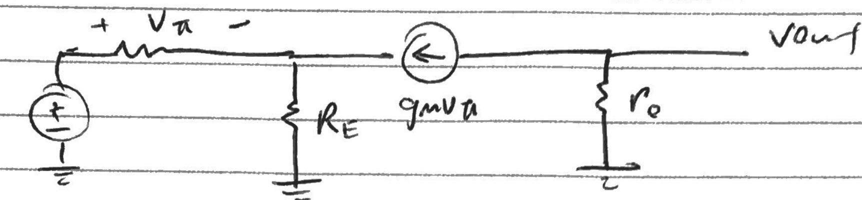
SSM (a):

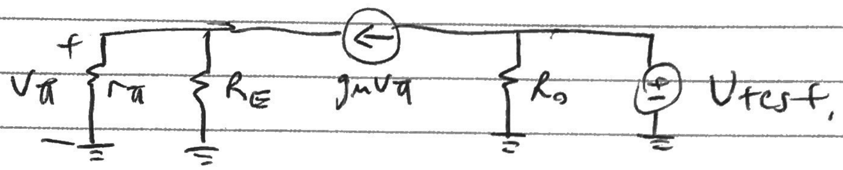




Clearly output impedance $= r_o$.

SSM (b).





Do KCL on left node: $\frac{V_\pi}{R_\pi} + \frac{V_\pi}{R_E} = g_m V_\pi$

assuming $V_\pi \neq 0$: $\cancel{\frac{1}{V_\pi}}\left(\frac{\cancel{V_\pi}}{R_\pi} + \frac{\cancel{V_\pi}}{R_E}\right) = \cancel{\frac{1}{V_\pi}}\left(g_m \cancel{V_\pi}\right)$

$$\frac{1}{R_\pi} + \frac{1}{R_E} = g_m.$$

This equation makes no sense, so $V_\pi = 0$.

Thus $g_m V_\pi = 0$, so no current flows through the VCCS so output impedance $= r_o$ again.

The output impedances are the same, so it doesn't really support ~~[illegible]~~ the claim in part (i). It just shows that both circuits are affected by the early effect (r_o is related to V_A). This is because the resulting change in V_{BE} (that helps to mitigate the early effect) is not a small-signal property.