Chapter 4, Current Sources
1. Current Mirror. Inequality of the reference current and the output current caused by area ratio of the transistors, finite $\beta$, and finite Early voltage. Base compensation current mirror for finite $\beta_3$

$$I_{out} = I_{ref} \frac{A_2 (1 + V_{CE2}/V_A) \frac{1}{A_1 (1 + V_{CE1}/V_A) 1 + 2/\beta_3}}{1 + 2/\beta_3}$$

Multiple output current sources.
2. Resistor ratioed current mirror.

$$I_2 = I_{ref} \frac{R_1}{R_2} \left[ 1 - \frac{V_T}{I_{ref} R_1} \ln \frac{I_2}{I_{ref}} \right]$$

3. Widlar current source for low output current.
4. Wilson current source for accurate current values and high output impedance.
5. Others: Cascode, Wilson, supply independent current sources.
6. Active loads. Differential amplifier with active loads. Output resistance when the load are a pair of PNP transistors.

$$R_{out} = \frac{1}{V_T g_m} \cdot \frac{V_{AN} V_{AP}}{V_{AN} + V_{AP}}$$

7. Low impedance voltage source (i.e. emitter follower).
8. D.C. level shift circuits using the $V_{be}$ multiplier.
9. Temperature independent voltage references.

$$S_T = \frac{1}{I_{out}} \frac{\partial I_{out}}{\partial T}$$

10. How to calculate the offset voltages or currents.
11. Differential amplifier with active load. $G_m \approx g_m$.

Chapter 5 - Output Stages
1. Class A, B, and C amplifiers.
2. Various complementary class B output stages. Small signal analysis. Gain (with saturation regions), output resistance.
3. Maximum and minimum output voltages. Maximum load power: $\hat{V}_{om}$, $\hat{I}_{om}$ maximum peak voltage or current before clipping occurs.

$$P_{L_{max}} = \frac{\hat{V}_{om} \hat{I}_{om}}{2} = \frac{\hat{V}_{om}^2}{2R_L}$$

$$I_{supply} = \frac{\hat{V}_{om}}{\pi R_L}$$ How obtained

$$P_{supply} = 2V_{CC} I_{supply} = \frac{2V_{CC} \hat{V}_{om}}{\pi R_L}$$

Efficiency $= \eta = \frac{P_{L_{max}}}{P_{supply}}$
4. Instantaneous device dissipation (neglecting power loss in base): \( P_c = V_{ce} I_c \)
5. The maximum device dissipation (by differentiation) is \( P_{cmax} = V_{CC}^2 / (4R_L) \).

Chapter 6.1.1 - 6.1.6, 6.8 - Operational Amplifiers
1. Ideal operational amplifier - \( Z_{in} = \infty, Z_{out} = 0, A = \infty \).
2. Deviations from ideality of Op Amp (eg. \( U_{os}, V_{os} \), etc.
3. Techniques of dc analysis used in the NE5234 amplifier. It is not the purpose of the exam to memorize each detailed calculation for the NE5234.
   Note that the file “advele6.x” is for the \( \mu \)A741 and is not that helpful for this chapter.