1. Consider the 2-loop circuit configuration shown below, with input voltage \( v_i(t) \), output voltage \( v_o(t) \), two resistors, and two one capacitors, so that
\[
z_1(s) = R_1, \quad z_2(s) = 1/sC_1, \quad z_3(s) = R_2, \quad z_4(s) = 1/sC_2.
\]

i. Define loop currents \( I_1(s) \) and \( I_2(s) \), and determine the transfer function, \( H(s) = \frac{V_0(s)}{V_i(s)} \), in terms of \( z_1(s), z_2(s), z_3(s), \) and \( z_4(s) \). Then specialize to the specific components listed above, and express the transfer function in terms of \( R_1, R_2, C_1, C_2 \).

ii. Design the circuit (select the values of \( R_1, R_2, C_1, C_2 \)) to meet the following specifications:
   a. The dc gain is unity (zero dB);
   b. The gain is no smaller than -3 dB for frequencies between 0 and 2 kHz; and
   c. The gain is no larger than -40 dB for frequencies larger than 40 kHz.

iii. Present the design with Bode plots of the filter magnitude and phase response and verify on your plots that the design specifications are satisfied.

iv. Can you design this filter to be a 2\(^{nd}\)-order Butterworth lowpass filter? Explain.

2. Design a second-order Butterworth low-pass filter to satisfy the specifications
   a. The dc gain is unity (zero dB);
   b. The gain is no smaller than -1 dB for frequencies between 0 and 2,000 Hz; and
   c. The gain is no larger than -40 dB for frequencies larger than 40 kHz.

   Determine a circuit realization as a series RLC low-pass filter. Pick reasonable values of \( R, L, \) and \( C \).

3. Digital music is to be acquired using an A/D converter with 36 kHz sampling rate, requiring that the audio signal to be sampled first be (approximately) bandlimited to 18 kHz. Design a lowpass Butterworth filter (that is, determine suitable values of \( N = \) number of poles and \( \omega_c = -3 \) dB cutoff frequency) to satisfy the specifications i) the filter gain is no less than -2 dB for frequencies up to 12 kHz, and ii) the gain is no larger than -40 dB for frequencies larger than 18 kHz.

4. Text, problem 13.53.
5. Text, problem 13.61. Also, solve for \( v_0(t) \) using the transfer function and inverse Laplace transform (and verify that your convolution result is correct).
7. Text, Problem 13.69. Also, use Laplace transforms to solve for \( v_0(t) \).