1. (6 points)
For the series $RC$ circuit in Fig. 1, (a) (2 points) find the transfer function between
the source voltage and the output voltage; (b) (2 points) determine an equation for
the cutoff frequency in the series $RC$ circuit; and (c) (2 points) choose values for $R$
that will yield a low-pass filter with a cutoff frequency 30 KHz, where $C = 0.1 \mu F$.

![Figure 1](image1.png)

2. (10 points)
The operational amplifier in the noninverting amplifier circuit of Fig. 2 has an input
resistance of $560K\Omega$, an output resistance of $8K\Omega$, and an open-loop gain of
50,000. Assume that the op amp is operating in its linear region.

(a) (3 points) Calculate the voltage gain ($v_o / v_i$).

(b) (3 points) Find the inverting and noninverting input voltages $v_i$ and $v_p$ (in
millivolts) if $v_i = 1.0V$.

(c) (2 points) Calculate the difference $(v_p - v_i)$ in microvolts when $v_i = 1.0V$.

(d) (2 points) Find the current drain in picoamperes on the signal source $v_i$ when $v_i = 1.0V$.

![Figure 2](image2.png)
3. (10 points)
  (a) (5 points) Sketch the output voltage for Fig. 3 for $V_i(t) = 30V - 3(t - 10V)$ and $0 \leq t \leq 10ms$, assuming that the diode is ideal and represented by $V_r = 0.6V$ and $R_f = 20\Omega$.

(b) (5 points) Sketch the voltage transfer characteristics ($v_o$ versus $v_i$) for Fig. 3, assuming that the diode is ideal and represented by $V_r = 0.5V$ and $R_f = 40\Omega$.

![Figure 3](image)

4. (8 points)
   Fig. 4 is operating at room temperature; for the passband, find the gain of (a) (4 points) $v_o/v_i$ and (b) (4 points) $i_o/i_i$.

![Figure 4](image)
5. (10 points)

Figures 5a-5c shows circuits of heterojunction bipolar transistor (HBT) in the DC and AC analyses, where \( V_{IN} \) is the DC bias voltage, \( V_{\text{in}} = V_m (\cos(\omega_1 t) + \cos(\omega_2 t)) \) is the two-tone input signal. \( \omega_1 = 2\pi f_1 \) and \( \omega_2 = 2\pi f_2 \) are two different frequencies, and \( V_m \) is the amplitude of tones.

(a) (2 points) Please write down the nodal equation for the DC analysis, shown in Fig. 5a.

(b) (6 points) Please also write down all nodal equations with the Gummel-Poon large signal equivalent circuit model, shown in Fig. 5c, of HBT for AC analysis of Fig. 5b.

(c) (2 points) Why do we perform the DC analysis before the AC analysis in general?
6. (10 points)

For the current source operating at room temperature shown in Fig. 6,

(a) (5 points) please show that \[
\frac{I_2}{I_1} = \frac{R_1}{R_2} \left(1 - \frac{V_T \ln \left(\frac{I_1}{I_2}\right)}{R_1}ight)
\]
by neglecting base currents,

where \(V_T\) is the thermal voltage.

(b) (3 points) If \(0.1 < \frac{I_1}{I_2} < 10\) and \(I_1 R_1 = 10V\), what error is made if it is assumed

that \(\frac{I_2}{I_1} = \frac{R_1}{R_2}\)?

(c) (2 points) How is the answer to (b) affected if \(I_1 R_1\) is increased and other factors
are fixed?

![Figure 6.](image-url)
7. (8 points)
As shown in Fig. 7,

(a) (4 points) Please find the transfer function \( H(\omega) = \frac{V_o}{V_i} \) for the corresponding circuit and calculate its poles and zeroes.

(b) (2 points) Calculate \( H(\omega) = \frac{V_o}{V_i} \) when \( R_1 = R_2 = R_3 = 1M\Omega \),
\( C_1 = C_2 = C_3 = 0.01\mu F \), \( R_4 = 0.5K\Omega \) and \( L_1 = L_2 = L_3 = 250mH \).

(c) (2 points) Determine the upper and lower ranges of \( H(\omega) = \frac{V_o}{V_i} \) when
\( 0.1\mu H \leq L_1 = L_2 = L_3 \leq 1000mH \), \( 0.1K\Omega \leq R_1 \leq 10K\Omega \), and
\( 10K\Omega \leq R_1 = R_2 = R_L \leq 10M\Omega \), where all capacitances are the same with the setting of problem (b).

Figure 7.
8. (12 Points)

(a) (5 points) Assume that the op amps are ideal, please derive \( Y_i = \frac{I_i}{V_i} \).

(b) (4 points) If \( Y_4 = sC_4 \) and all other components are resistive, then prove that \( Y_i \) is inductive.

(c) (3 points) Assuming that any resistance can lie between \( 0.01 \Omega \) and \( 10 \Omega \)
and \( 1 \text{pF} \leq C \leq 500 \text{pF} \), what is the range of inductance values possible?

\[ \text{Figure 8.} \]

9. (26 points)

Please answer the following problems briefly.

(a) (2 points) What is the distinction between intrinsic and extrinsic semiconductor?

(b) (2 points) What is the difference among the amorphous, poly, and single crystal silicon?

(c) (2 points) What are the cut-in voltage and built-in potential?

(d) (2 points) Explain how BJT and MOSFET can be used as a switch.

(e) (2 points) Define SSI, MSI, LSI, VLSI, ULSI, and SOC.

(f) (2 points) How are the PAL and PLA related to a ROM?

(g) (2 points) What is the difference among flash memory, MRAM, and \( \text{E}^2\text{PROM} \)?

(h) (2 points) Give the truth table for each FLIP-FLOP type: SR, JK, D, and T.

(i) (3 points) What is the distinction between the CCD and CMOS?

(j) (3 points) What is the distinction between LTPS TFT and a-Si TFT?

(k) (4 points) For a n-MOS capacitor with an ultrathin oxide (e.g., 1 nm) under strong inversion condition, please plot the classical and quantum mechanical electron densities from the interface of Si/SiO\(_2\) to substrate.