This is a closed-book exam, except for use of two 8.5 x 11 inch sheet of your notes. Show all your work to receive full or partial credit. Write your answers clearly in the spaces provided.

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1.

a) (5 points)
A silicon sample is uniformly doped with Boron to a concentration of $10^{16}$ atoms/cm$^3$. Determine the resistivity of the sample at room temperature.
Use electron mobility $\mu_n = 1000$ cm$^2$/V-s, hole mobility $\mu_p = 400$ cm$^2$/V-s,
$Q = 1.6 \cdot 10^{-19}$ C and $n_i = 10^{10}$ at room temperature.

b) (5 points)
The same sample is then to be counter doped to a depth of 5 $\mu$m with Arsenic atoms
to create a resistor technology with resistance of 100 $\Omega/\square$.
Determine the required Arsenic doping density.
2.

a) (10 points)

The diode in Figure 2(a) is ideal. The waveform $V_S(t)$ is a balanced square wave with amplitude of 10 V and period 1 mS. Take $L = 50 \mu H$ and $R = 1 \Omega$.

The circuit operates in a periodic steady state. Sketch and carefully dimension one period of the $i_L(t)$ waveform on the axes below. Make reasonable approximations.
b) (10 points)

In the circuit of Figure 2(b), switch $S_1$ is initially closed and switch $S_2$ is initially open and the circuit is in equilibrium. Switch $S_1$ is then opened and switch $S_2$ is closed for a sufficiently long time so that the circuit can be considered to be in equilibrium. How much energy is dissipated in the 1 kΩ resistor during the transient?

**Hint:** Think in terms of net charge and energy flow. Detailed transient analysis is **NOT** needed.
Mosfet M1 in Figure 3 is modeled by

\[ i_D = \frac{1}{2} k' \frac{W}{L} (v_{GS} - V_T)^2 (1 + \lambda v_{DS}) \]

in saturation with parameters listed in Figure 3.

a) (5 points)

Determine the required bias voltage \( V_G \) so that M1 is biased in saturation with \( V_{DS} = 2 \) V. Take \( v_S = 0 \)

\[ \lambda = 0.1 \ V^{-1} \]

\[ V_T = 0.5 \ V \]

\[ k' = 100 \ \mu A/V^2 \]

\[ \frac{W}{L} = 2 \]
b) (10 points)
Draw the small signal model for this circuit. Compute the parameters of this small signal model.

c) (5 points)

\[ A_v = \frac{v_o}{v_s} \]

Determine the small signal gain \( A_v \).