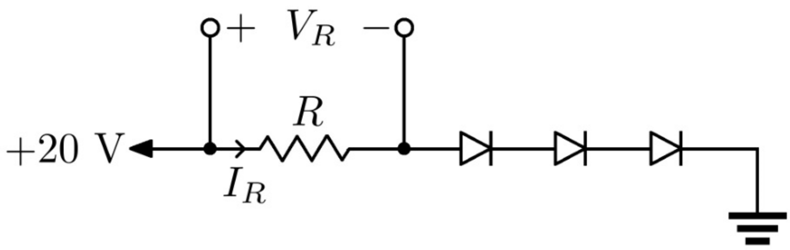
① (from 2022 midterm)

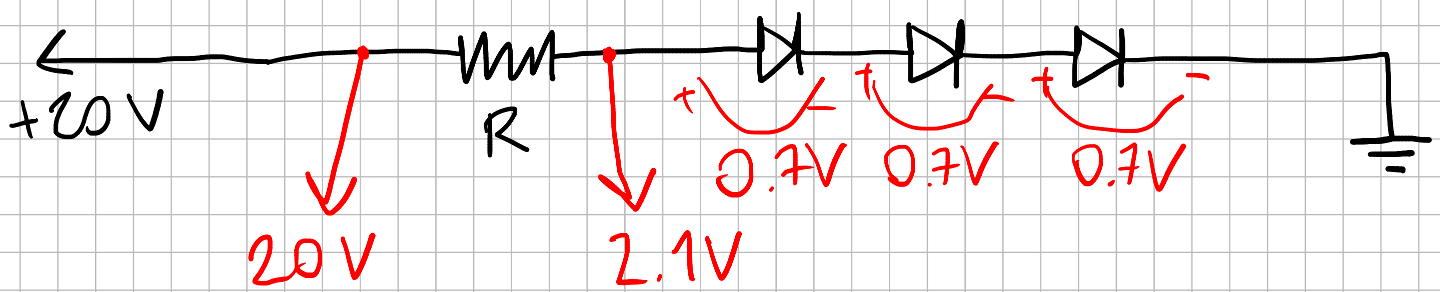
([redacted] points) Consider the circuit shown below, consisting of a resistor (with resistance R) and three diodes. The voltage drop across the resistor is denoted as V_R, while the current through the resistor is denoted as I_R. Use the constant-voltage-drop model for the diodes (with $V_D = 0.7$ V) to answer the following questions.



a) Find the value of V_R.

solution:

Using the constant-voltage-drop model with $V_D = 0.7V$, we observe:



Thus: $V_R = 20V - 2.1V = 17.9V$

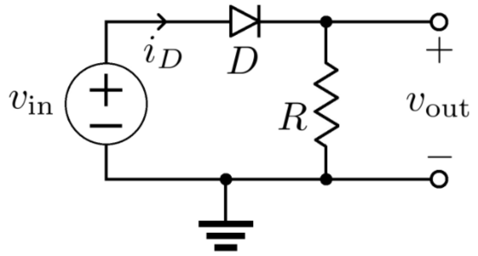
b) Using the value of V_R found in a), find the value of R for which I_R is equal to 2 A.

solution: Writing Ohm's law for the resistor:

$$R = \frac{V_R}{I_R} = \frac{17.9\,V}{2\,A} = 8.95\,\Omega$$

② (from 2022 midterm)

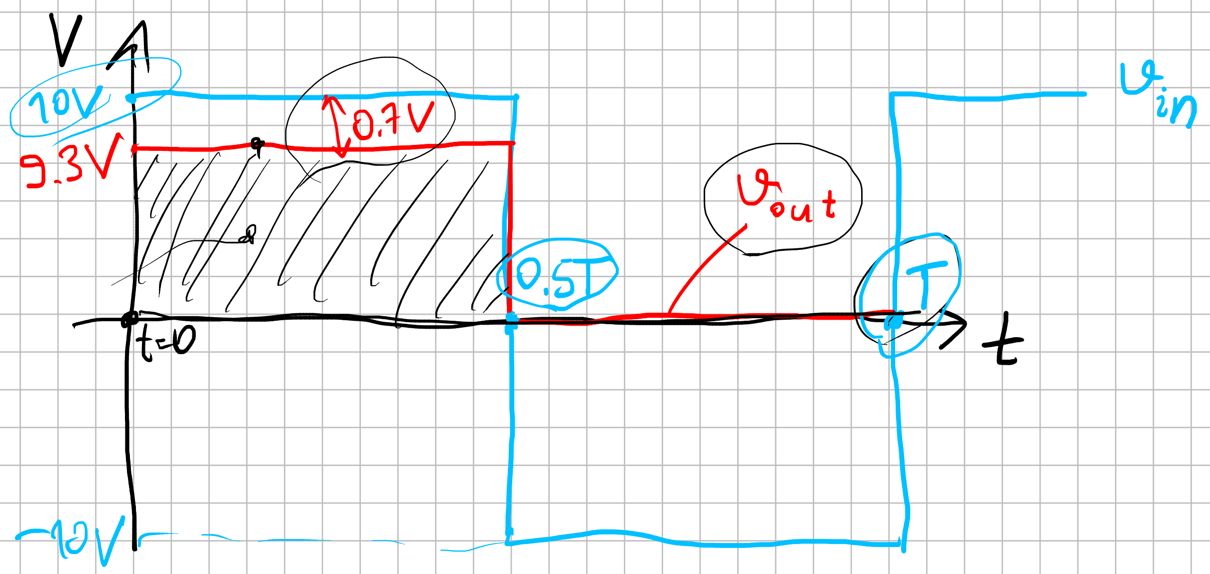
[redacted] points) Consider the circuit shown below, consisting of a resistor (with a resistance of $R = 100$ Ω) and a diode D. The input voltage is denoted as v_{in}, while the diode current is denoted as i_D. The output voltage is the voltage drop across the resistor, and it is denoted as v_{out}.



A symmetrical square wave of 10 V peak amplitude and zero average is applied to the circuit as v_{in}. Use the constant-voltage-drop model for the diode (with $V_D = 0.7$ V) to answer the following questions.

a) Find the resulting average value of v_{out}.

solution:



$$\text{average}(v_{out}) \triangleq \frac{\int_0^T v_{out}\,dt}{T}$$

$$= \frac{9.3\,V \cdot 0.5\cancel{T}}{\cancel{T}} = 4.65\,V$$

b) Find the resulting peak value of i_D.

solution: Writing Ohm's law for the resistor:

$$i_D(t) = \frac{v_{out}(t)}{R}$$

$\Leftrightarrow$

$$\text{peak}(i_D) = \frac{\text{peak}(v_{out})}{R} = \frac{9.3V}{100\Omega} = 93mA$$

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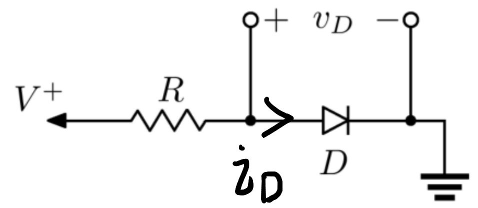
③ (from 2022 midterm)

([redacted]points) Consider the circuit shown below, consisting of a resistor (with resistance $R = 20\ k\Omega$) and a diode. The voltage drop across the diode is denoted as v_D.



The power supply V^+ has a dc value of 20.7 V, and a 60-Hz sinusoid of 2-V peak amplitude superimposed on this dc value. Assume the diode to have a 0.7-V drop at 1-mA current and answer the following questions.

a) Find the dc value of the diode current.

solution: Writing Ohm's law for the resistor:

$$i_D(t) = \frac{V^+(t) - v_D(t)}{R}$$

assume that this is 0.7V

$\Leftrightarrow$

$$dc(i_D) = \frac{dc(V^+) - V_D}{R} = \frac{20.7V - 0.7V}{20k\Omega} = 1mA$$

assumption is correct

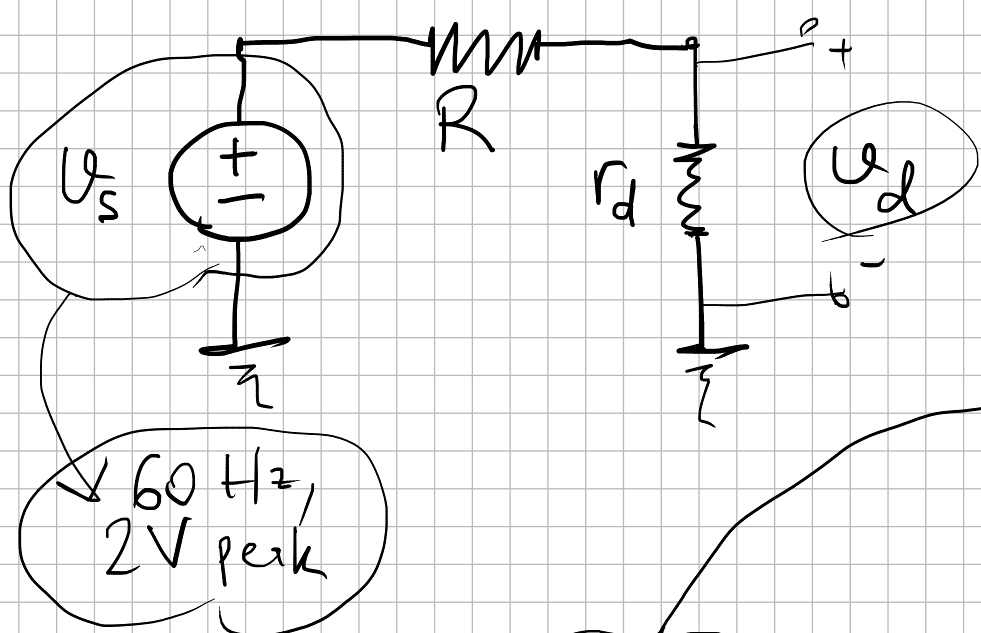
b) Find the peak amplitude of the sine-wave voltage signal appearing across the diode.

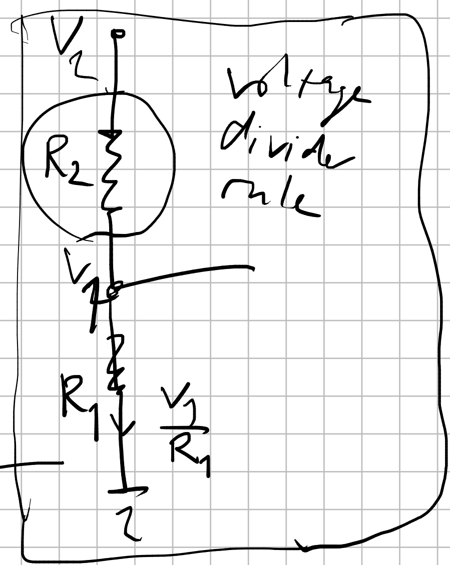
solution:

diode incremental resistance:

(for $I_D = 1mA$) $r_d = \frac{V_T}{I_D} = \frac{25\,mV}{1mA} = 25\,\Omega$

small-signal equivalent circuit:





$$v_d = v_s \cdot \frac{r_d}{R + r_d}$$

$$\text{peak}(v_d) = \text{peak}(v_s) \cdot \frac{r_d}{R + r_d}$$

$$\text{peak}(v_d) = 2V \cdot \frac{25\,\Omega}{20k\Omega + 25\,\Omega} = 2.5\,mV$$

④ (from 2022 midterm)

([redacted] points) Consider a MOSFET (n-channel enhancement-type) with the following parameters: $W/L = 12$, $t_{\text{ox}} = 6$ nm, $\epsilon_{\text{ox}} = 3.45 \times 10^{-11}$ F/m, $\mu_n = 450$ cm^2/Vs, and $V_t = 0.7$ V.

(a) ([redacted] points) Find the value of V_{GS} (voltage between the gate and the source) needed to operate the MOSFET in the saturation region with a dc current of 120 µA.

(b) ([redacted] points) Find the value of V_{OV} (overdrive voltage) required to make the MOSFET operate as a 2000-Ω resistor for very small v_{DS} (voltage between the drain and the source).

solution (a):

$$C_{\text{ox}} = \frac{\epsilon_{\text{ox}}}{t_{\text{ox}}} = \frac{3.45 \times 10^{-11}\ \text{F/m}}{6 \times 10^{-9}\ \text{m}} = 5.75 \times 10^{-3}\ \text{F/m}^2$$

$$k_n' = \mu_n C_{\text{ox}} = \left(450\ \text{cm}^2/\text{Vs}\right) \times \left(5.75 \times 10^{-3}\ \text{F/m}^2\right) = 258.75 \times 10^{-6}\ \text{F/(V s)}$$

For operation in the saturation region:

$$i_D = \frac{1}{2} k_n' \frac{W}{L} V_{OV}^2$$

$$120 \times 10^{-6}\ \text{A} = \frac{1}{2} \times \left(258.75 \times 10^{-6}\ \text{F/(V s)}\right) \times 12 \times V_{OV}^2$$

$$V_{OV} = 0.28\ \text{V}$$

$$V_{GS} = V_t + V_{OV} = 0.7\ \text{V} + 0.28\ \text{V} = 0.98\ \text{V}$$

solution (b):

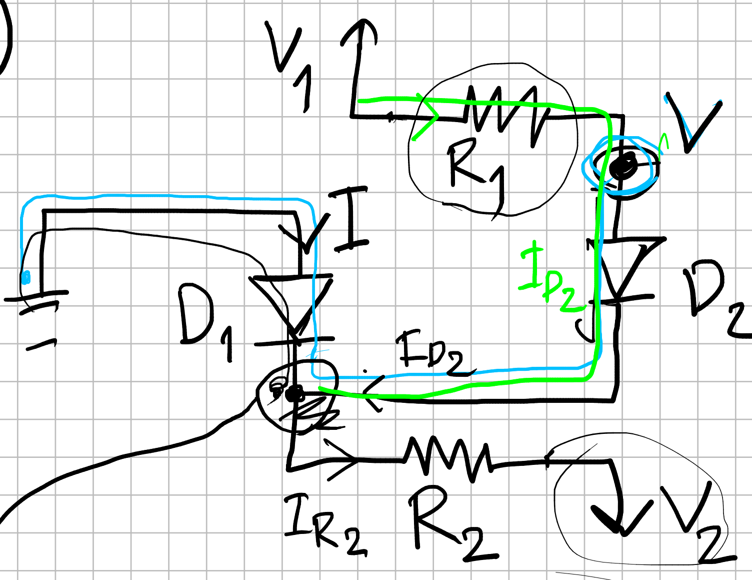
For the MOSFET with v_{DS} very small

$$r_{DS} = \frac{1}{k_n' \frac{W}{L} V_{OV}}$$

$$2000\ \Omega = \frac{1}{\left(258.75 \times 10^{-6}\ \text{F/(V s)}\right) \times 12 \times V_{OV}}$$

$$V_{OV} = 0.16\ \text{V}$$

⑤



D_1, D_2: ideal diode
$R_1 = 5k\Omega$
$R_2 = 10k\Omega$
$V_1 = 10V$
$V_2 = -50V$
given

a) Find V: Sol'n: $V = 0\,V$ (ideal diode <=> voltage drop across the diode is 0V)

b) Find I: → KCL: $I + I_{D_2} = I_{R_2}$

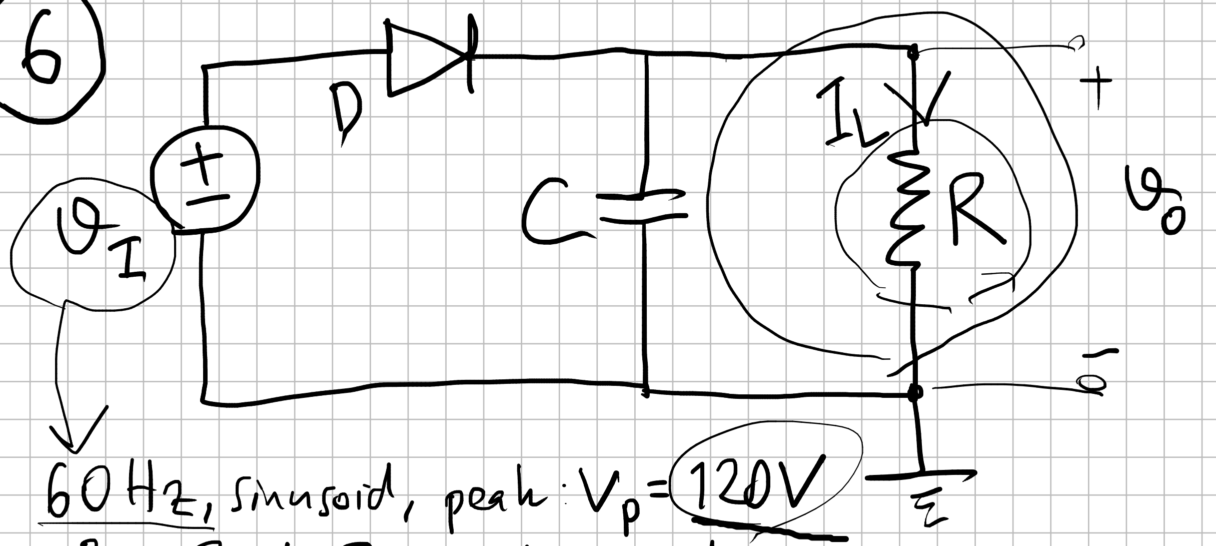
(Ohm's law R_1): $I_{D_2} = \frac{V_1 - 0}{R_1} = \frac{V_1}{R_1}$

(Ohm's law R_2): $I_{R_2} = \frac{0 - V_2}{R_2} = \frac{-V_2}{R_2}$

$$I = I_{R_2} - I_{D_2} = \frac{-V_2}{R_2} - \frac{V_1}{R_1} = \frac{50V}{10k\Omega} - \frac{10V}{5k\Omega}$$

$$= 5mA - 2mA = 3mA$$

(6)



60 Hz, sinusoid, peak: $V_p = 120V$
$R = 20\,k\Omega$, D: diode ideal

a) Ripple voltage is 1V. Find C.

solution:

$$V_r = \frac{V_p}{f\,C\,R} \longrightarrow C = \frac{V_p}{V_r \cdot f \cdot R}$$

$$C = 1 \cdot 10^{-4}\ F$$

b) Find the fraction of the cycle during which diode is conducting.

sol'n: conduction angle

$$\omega \cdot \Delta t = \sqrt{\frac{2 \cdot V_r}{V_p}}$$

$$\omega \cdot \Delta t = 0.1291\ \text{rad}$$

(ω: rad/s, Δt: s)

$$\text{fraction} = \frac{0.1291\ \text{rad}}{2\pi\ \text{rad}} = 2\%$$

c) Find the average value of diode current.

Solution:

$$i_{D_{av}} = I_L \left(1 + \pi \sqrt{2 V_p / V_r}\right)$$

(Ohm's law R): $I_L = \frac{\hat{v}_o}{R} = \frac{V_p}{R} = 6mA$

$i_{D_{av}} = 0.3\,A$