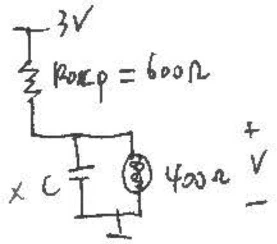
(1) When $V_{in}=0$, M_1 "ON", M_2 "OFF" the equivalent circuit:

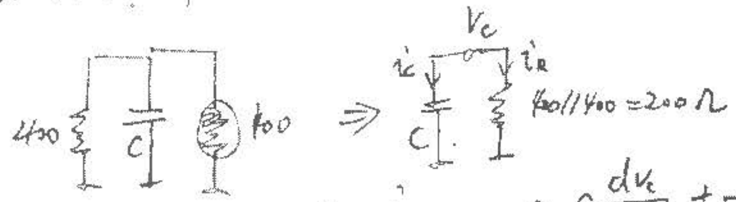


At steady state. $V = \dfrac{400}{400+600} \times 3V = 1.2V > 1V$

So the lamp is $\underline{\underline{ON}}$

(2)

when $t>0$, pmos $\Rightarrow$ OFF, NMOS ON. the circuit is:



$-i_c - i_R = 0 \Rightarrow i_c + i_R = 0 \Rightarrow C\dfrac{dV_c}{dt} + \dfrac{V_c}{200} = 0$

$\dfrac{dV_c}{dt} + \dfrac{1}{200 \times C} V_c = 0 \Rightarrow \dfrac{dV_c}{dt} + \dfrac{1}{1} V_c = 0$

$V_c = k \cdot e^{-t}$ $\quad k = 1.2$ (since $V_c(0^-) = V_c(0^+) = 1.2V$).

$V_c(\delta t) = 1.2 \cdot e^{-\delta t} = 1V$

$\underline{\delta t = \ln 1.2 = 0.18(s)}$

(3) $E = E(0^+) - E(\delta t)$

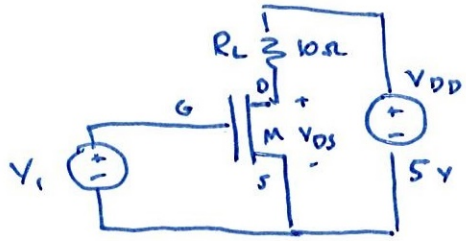
$= \frac{1}{2} C V_c^2(0^+) - \frac{1}{2} C \cdot V_c^2(\delta t)$

$= \frac{1}{2} C \cdot \left(V_c^2(0^+) - V_c^2(\delta t) \right)$

$= \frac{1}{2} C \times (1.2^2 - 1) = \frac{1}{2} \times 0.005 \times 0.44 = 1.1\ mJ = 1.1 \times 10^{-3} (J)$

Problem #2

a.) if $K = \frac{2.5\,mA}{V^2}$, $V_T = 1\,V$, what is V_{DS}?



$\Rightarrow$ if $V_1 = 0\,V$, $V_{GS} = 0 < V_T$ ... M is OFF

$V_{DS} = 5$ volts. (no current through R_L).

$\Rightarrow$ if $V_1 = 5\,V$, $V_{GS} = 5 > V_T$ ... M is ON

if M is SATURATED $i_D = \frac{1.25\,mA}{V^2}(5-1)^2$

$= 20\,mA$

$\Rightarrow V_{DS} = 5 - 0.2$

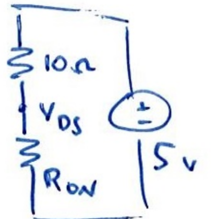
$= 4.8\,V$

$V_{DS} \overset{?}{>} V_{GS} - V_T$ YES

it is SATURATED

$\boxed{V_{DS} = 4.8\,V}$

$\Rightarrow$ if M is in TRIODE MODE



$R_{ON} = \frac{1}{K(V_{GS} - V_T)} = 100\,\Omega$

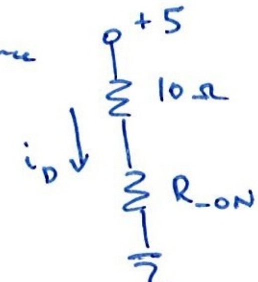
$V_{DS} = 5\,\frac{100}{110} = 4.5\,V$

$V_{DS} > V_{GS} - V_T$ ...

NOT IN TRIODE

b.) The most efficient operating regime of the MOSFET will be in the Triode Mode....

Hence



$P_{TOTAL} = i_D V_{DD}$ $\quad P_M = i_D V_{DS}$

want $\frac{P_M}{P_{TOT}} < 0.05 \Rightarrow \frac{i_D V_{DS}}{i_D V_{DD}} < 0.05 \Rightarrow V_{DS} < 0.25\,V$

$V_{DS} = 5\,\frac{R_{ON}}{10 + R_{ON}} < 0.25\,V \Rightarrow \frac{R_{ON}}{10 + R_{ON}} < 0.05$

$\Rightarrow 0.5 > R_{ON}(1 - 0.05) \Rightarrow \frac{0.5}{0.95} > R_{ON} \Rightarrow 0.53 > R_{ON}$

$0.53 > \frac{1}{K(V_{GS} - V_T)} \Rightarrow K > \frac{1}{4(0.53)} \Rightarrow \boxed{K > 0.475\ A/V^2}$

Problem 3:

(1) when $V_I = 1$ $\quad V^+ = V^- = 1$

$V_{GS} = V_4 - V_I = 1.5 - 1 = 0.5 < V_T$. $M_1 \Rightarrow$ Cut off.

So: $i_1 - i_2 = 0$. or: $\frac{V_o - 1}{2k} - \frac{1}{1k} = 0$

$\Rightarrow V_o = 3(V)$

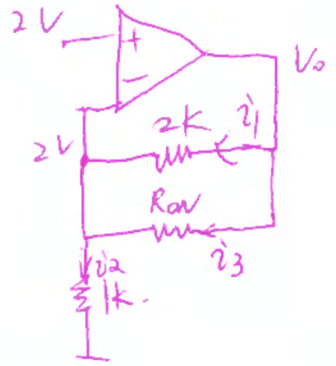
(2) when $V_I = 2V$, $\quad V^+ = V^- = 2V$

$V_{GS} = V_4 - V_I = 5 - 2 = 3(V)$. $M_1 \Rightarrow$ "ON"

Assume M_1 in "Triode" mode.

$$R_{on} = \frac{1}{k(V_{GS} - V_T)} = \frac{1}{2\times10^{-3}\times(3-1)} = \frac{1}{4\times10^{-3}} = 0.25\,k\Omega$$

So: the equivalent circuit:



$i_1 + i_3 - i_2 = 0$

$$\frac{V_o - 2}{2k} + \frac{V_o - 2}{0.25k} - \frac{2}{1k} = 0$$

$V_o - 2 + 8(V_o - 2) - 4 = 0$

$9V_o - 22 = 0 \quad \Rightarrow V_o = 2.44\ (V)$

check: $V_{DS} = V_o - V^- = 2.44 - 2V = 0.44 < V_{GS} - V_T = 2V$ ✓

"Triode" Assumption correct.

$\boxed{V_o = 2.44\ V}$