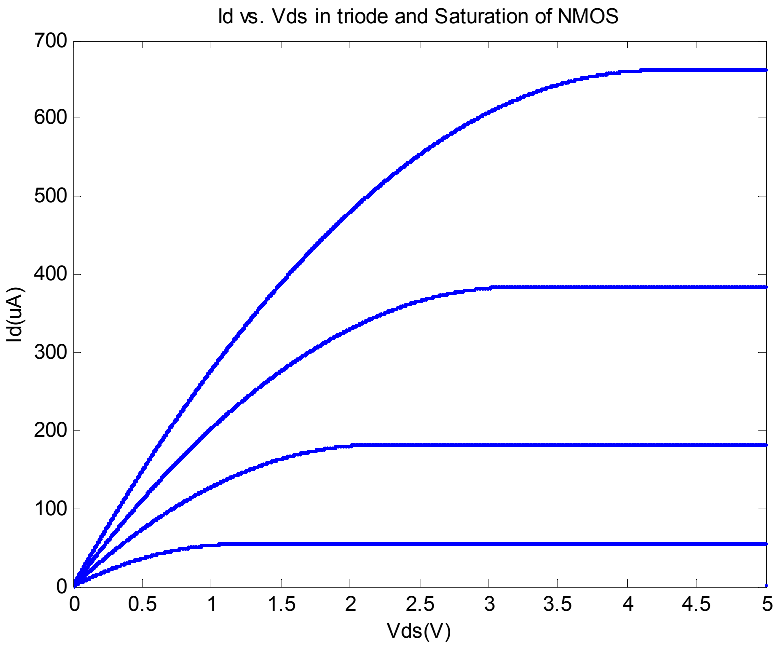
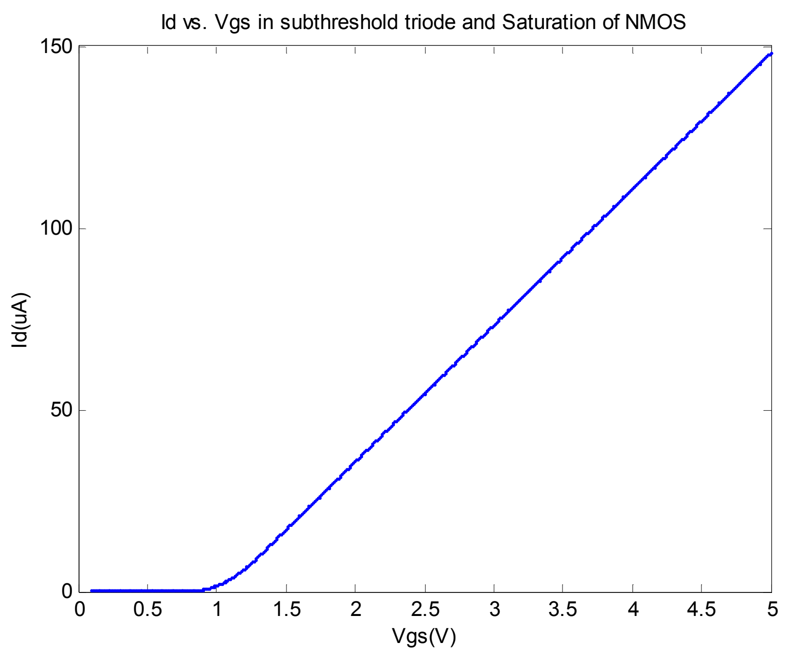
Problem1

```
clear all
L=2;
W=3;
VTO=0.8;
KPn=50;

Vthn=VTO;
Vds=0.5;
for Vgs=0.1:0.01:5;
    if (Vgs-Vthn)>0
        if (Vds<=(Vgs-Vthn))
            Id=KPn*(W/L)*((Vgs-Vthn)*Vds-Vds*Vds/2);
        else
            Id=KPn/2*(W/L)*(Vgs-Vthn)^2;
        end
    else
        Id0=KPn*0.0259*0.0259*exp(1.8);
        Id=Id0*(W/L)*exp((Vgs-Vthn)/0.0259);
    end
    semilogy(Vgs,Id);
    hold on
end
xlabel('Vgs(V)');
ylabel('log Id(uA)');
title('log Id vs. Vgs in subthreshold triode and Saturation of NMOS')
```



Problem 2:

```
clear all
L=2;
W=3;
VTO=0.8;
KPn=50;

Vthn=VTO;
Vds=0.5;
for Vgs=0.1:0.01:5;
    if (Vgs-Vthn)>0
        if (Vds<=(Vgs-Vthn))
            Id=KPn*(W/L)*((Vgs-Vthn)*Vds-Vds*Vds/2);
        else
            Id=KPn/2*(W/L)*(Vgs-Vthn)^2;
        end
    else
        Id0=KPn*0.0259*0.0259*exp(1.8);
        Id=Id0*(W/L)*exp((Vgs-Vthn)/0.0259);
    end
    plot(Vgs,Id);
    hold on
end
xlabel('Vgs(V)');
ylabel('Id(uA)');
title('Id vs. Vgs in subthreshold triode and Saturation of NMOS')
```



Problem 6.5

The drive current of a short-channel MOSFET is given by Eq. (6.41)

$I_{drive} = v_{sat} \times C'_{ox} \times (V_{GS} - V_{THN} - V_{DS,sat})$,

$C'_{ox} = \varepsilon_{ox} / TOX = (8.85 \times 3.97\ aF/\mu m) / (75\times10^{-10}\ m) = 4.685 fF/\mu m^2$

$I_{drive} = 10^7 cm/s \times 4.685 fF/\mu m^2 \times (2.5 - .5 - 1.5)V = \underline{234.25\mu A/\mu m}$

For the long channel MOSFET in chapter five, we assume that electron mobility μ does not vary with V_{DS}. For short-channel MOSFETs, $V_{DS,sat}$ is not directly dependent on the V_{GS} and V_{TH}, but it is used to change the drift velocity. From figure 6.8 and Eq. (6.39), the $V_{DS,sat}$ is dependent directly on the critical electrical field which causes the drift velocity to v_{sat}. Therefore, $V_{DS,sat}$ is not equal to $V_{GS} - V_{THN}$ for short-channel MOSFETs.

Problem 6.7

From eq. (6.21), the output resistance is given by $r_o = 1/(\lambda \bullet I_D)$. Using level 1 MOSFET SPICE model, in saturation region, $I_D = MUZ \bullet C_{ox} \bullet W \bullet (V_{GS} - V_{THN})^2 / 2L$

Therefore,

$r_o = 2L/[\lambda \bullet MUZ \bullet C_{ox} \bullet W \bullet (V_{GS} - V_{THN})^2]$

Set $K = 2/[MUZ \bullet C_{ox} \bullet W \bullet (V_{GS} - V_{THN})^2]$,

$r_o = L/(\lambda \bullet K)$

For 10μm/2μm MOSFET, the effective resistance of NMOS is Rn= 12kΩ × 2/10 = 2.4kΩ, and for the PMOS, Rp = 36kΩ × 0.2 = 7.2kΩ. The capacitance between drain to ground is same for both NMOS and PMOS and equal to C_{ox} + 150fF = 166fF. From eq. (10.8) and (10.9), for NMOS,

t_{PHL}=2.4kΩ×166fF ≈ <u>398ps</u>, t_{HL}=2×2.4kΩ×166fF ≈ <u>797ps</u>

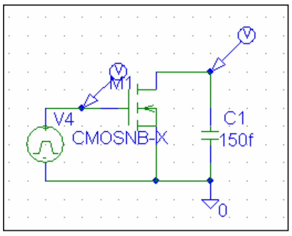
for PMOS,

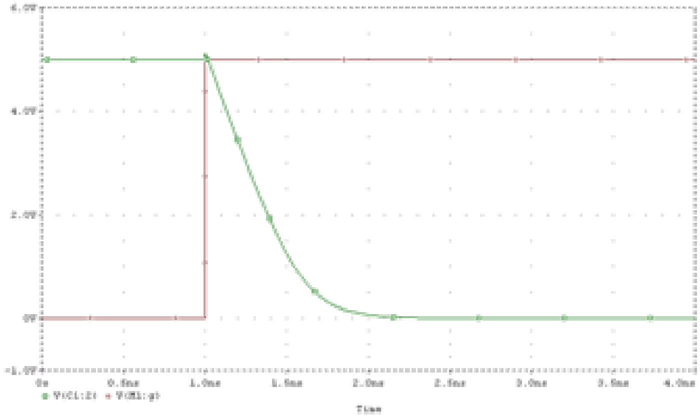
t_{PLH}=7.2kΩ×166fF ≈ <u>1.2ns</u>, t_{LH}=2×7.2kΩ×166fF ≈ <u>2.4ns</u>

Simulation:

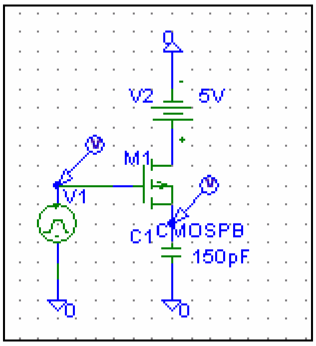
Trick: need to set the IC value for the Capacitor.

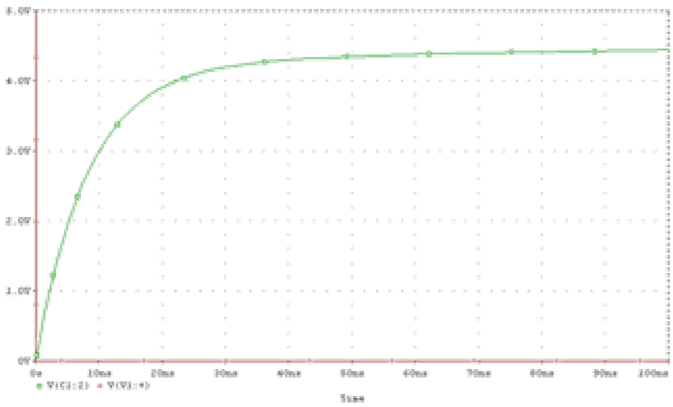
NMOS





PMOS





Problem 10.7

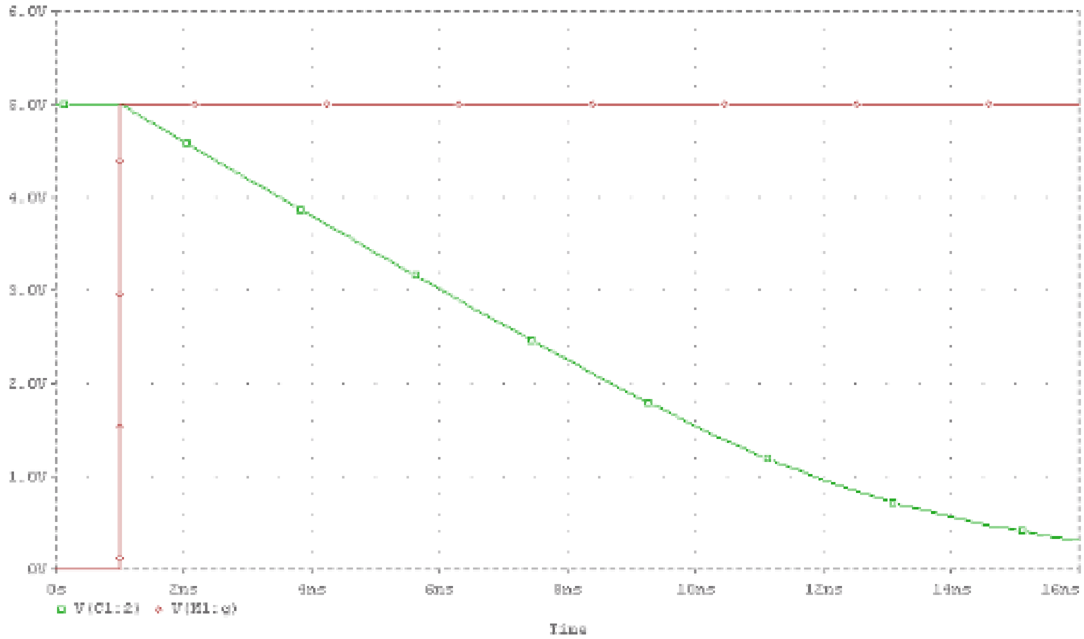
For 3μm/2μm MOSFET, the effective resistance of NMOS is Rn= 12kΩ × 2/3 = 8kΩ, and for the PMOS, Rp = 24kΩ. The capacitance between drain to ground is same for both NMOS and PMOS and equal to C_{ox} + 1pF ≈ 1pF. From eq. (10.8) and (10.9), for NMOS,

$$t_{PHL}=8k\Omega\times 1pF = \underline{8ns}, \quad t_{HL}=2\times 8k\Omega\times 1pF = \underline{16ns}$$

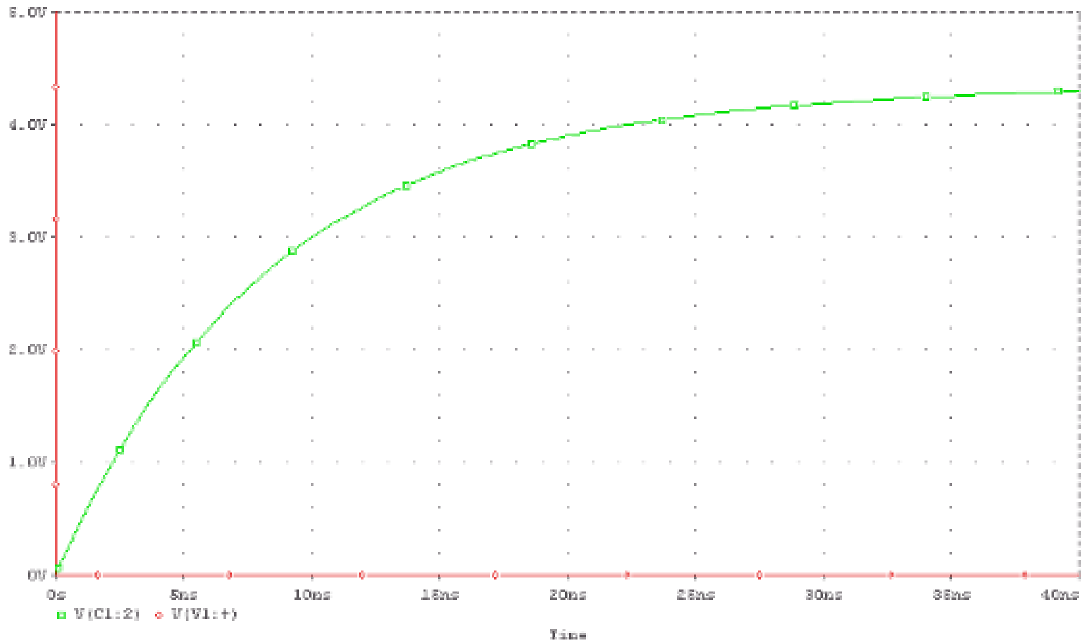
for PMOS,

$$t_{PLH}=24k\Omega\times 1pF = \underline{24ns}, \quad t_{LH}=2\times 24k\Omega\times 1pF = \underline{48ns}$$

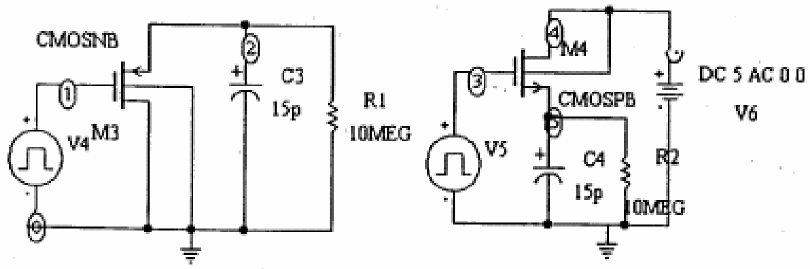
NMOS:


6.0V
5.0V
4.0V
3.0V
2.0V
1.0V
0V
0s
2ns
4ns
6ns
8ns
10ns
12ns
14ns
16ns
V(C1:2)
V(M1:g)
Time

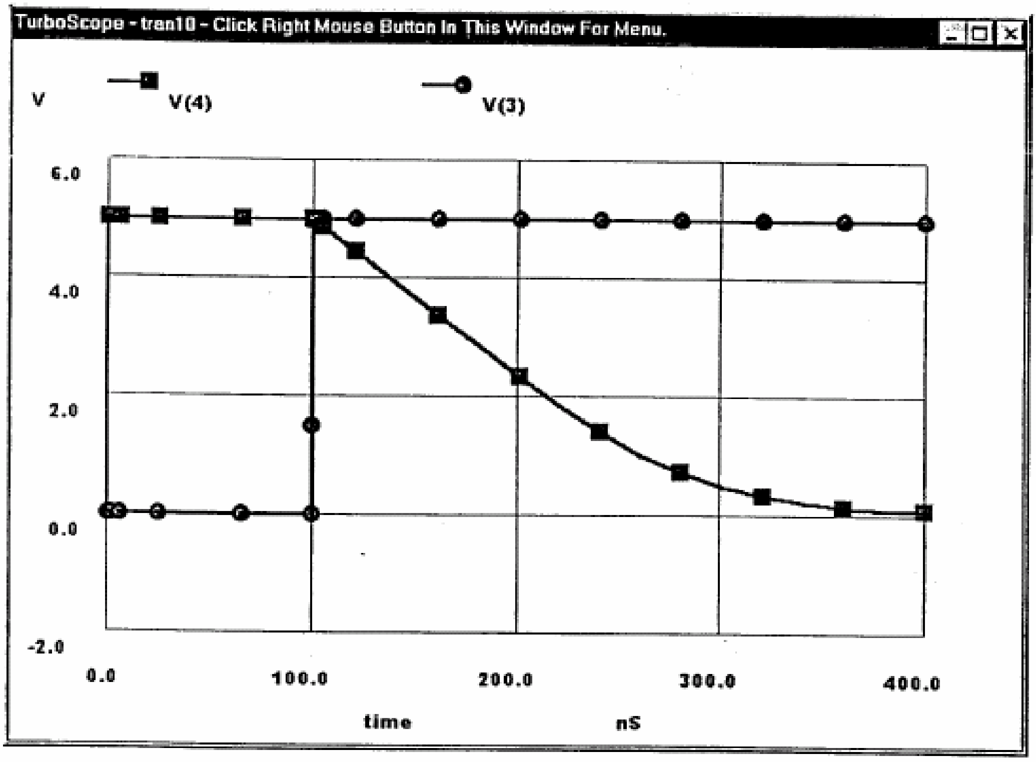
PMOS:

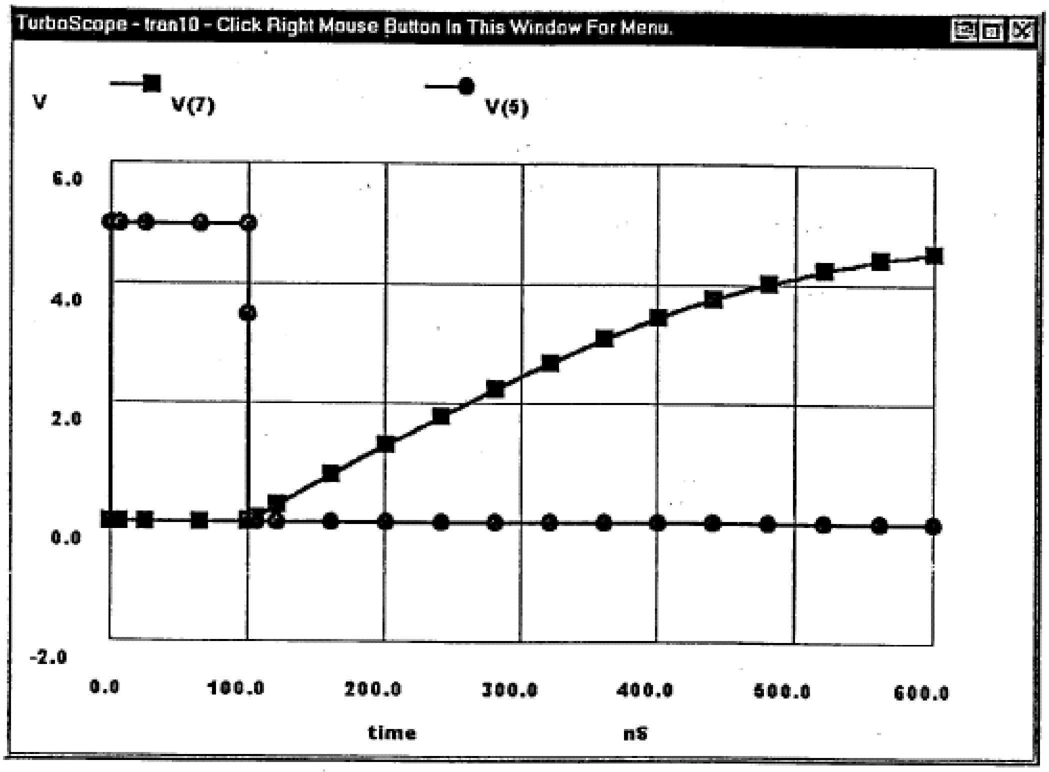

5.0V
4.0V
3.0V
2.0V
1.0V
0V
0s
5ns
10ns
15ns
20ns
25ns
30ns
35ns
40ns
V(C1:2)
V(V1:+)
Time

Problem 10.8



For nmos, $t_{PHL} \approx 8k\Omega \times 15pF = 120ns$; for pmos, $t_{PLH} \approx 360ns$




TurboScope - tran10 - Click Right Mouse Button In This Window For Menu.
V
V(7)
V(5)
6.0
4.0
2.0
0.0
-2.0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
time
nS