Problem.1 In the circuit shown in Fig.1, Find I_{D1} and I_{D2}. Assuming V_{Don} = 0.7 V.

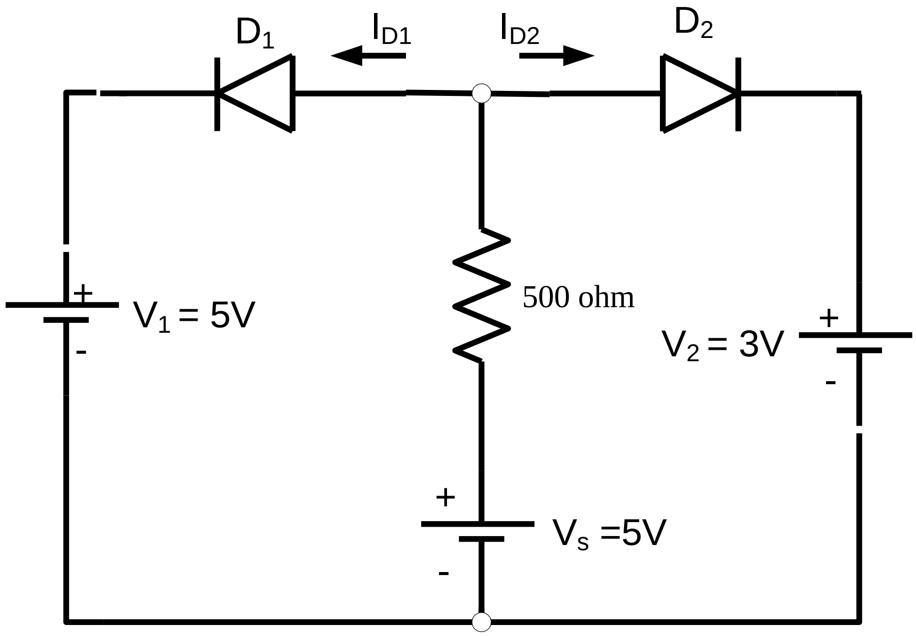


Fig.1

Solution: From the above Figure:

D_1 is off → $\mathbf{I_{D1} = 0\ mA}$

D_2 is On , and the current flowing through the D_2 is given by :

$$\rightarrow I_{D2} = \frac{5 - V_{D2} - 3}{0.5K\Omega} = \frac{5 - 0.7 - 3}{0.5} = \frac{1.3}{0.5} = 2.6mA$$

Problem.2: The diode in the circuit of Fig.2 (a) has the terminal characteristic of Fig.2(b). Find i_D and v_D **analytically**, given $v_s = 0.1\cos\omega t$ V and V_B= 2 V.

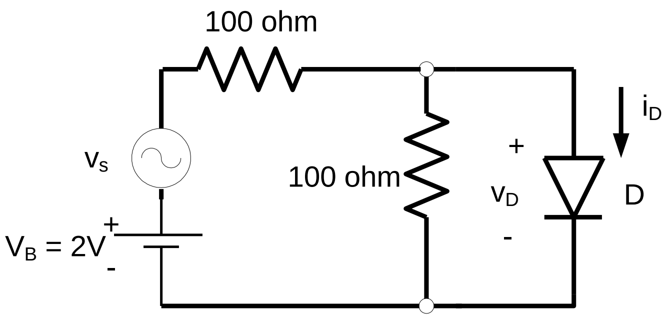


Fig.2 (a)

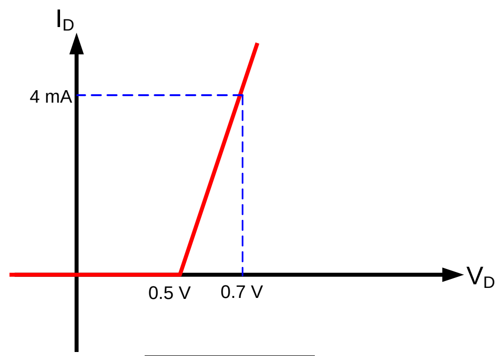


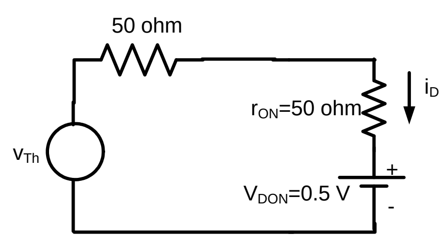
Fig.2 (b)

Solution:

The Thevenin equivalent circuit for the network to the left of the Diode D has :

$$R_{th} = 100\Omega // 100\Omega = 50\Omega$$

$$V_{th} = (2 + 0.1\cos\omega t) * \frac{100}{100+100} = 1 + 0.05\cos\omega t$$



The diode can be modeled as shown with

$V_{DON} = 0.5V$ And $r_{ON} = \frac{0.7-0.5}{4mA} = 0.05K\Omega = 50\Omega$

Therefore:

$$i_D = \frac{V_{th} - V_{D,oN}}{0.05K\Omega + 0.05K\Omega} = (5 + 0.5\cos\omega t)mA$$

And

$$v_D = V_{DON} + i_D r_{ON} = 0.5 + (5 + 0.5\cos\omega t)mA * 0.05K\Omega = (0.75 + 0.025\cos\omega t)\ V$$

Problem 3: Design the circuit in Fig.4 to obtain a current of 80 µA. Find the value required for R and find the DC voltage V_D**.** Let the NMOS transistor have V_T =0.6V, $\mu_n C_{ox} = 200\,\mu A/V^2$**,** L = 0.8 µm and W = 4 µm

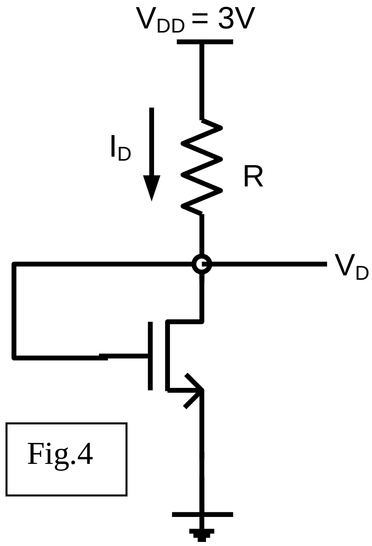
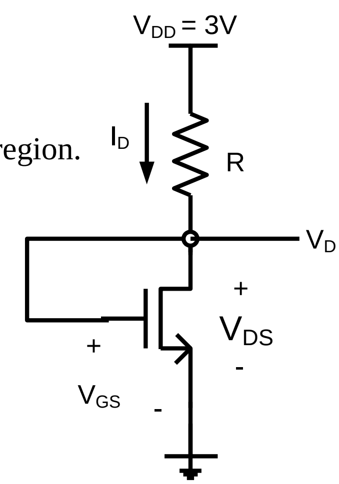


Fig.4

Solution:



From the circuit,
$V_{DS} = V_{GS}$ → $V_{DS} > V_{DS,sat} = V_{GS} - V_T$,
Therefore, the NMOS transistor is operating in the saturation region.

$$I_D = \frac{K}{2}(V_{GS} - V_T)^2$$

$$80*10^{-3} = \frac{200*10^{-3}*(\frac{4}{0.8})}{2}(V_{GS} - 0.6)^2 \rightarrow V_{GS} = 1\text{ V}$$

From the circuit $V_D = V_{GS} = V_{DS} = 1V$

From the output loop:

$3 = I_D R + V_{DS}$

$3 = 80*10^{-3}*R + 1 \rightarrow R = 25\ K\Omega$

Problem 4: Consider the circuit of Fig.4 which is designed in **Problem 4 (to which you should refer before solving this problem)**. Let the voltage V_D be applied to the gate of another transistor M2 as shown in Fig.5. Assume that M2 is identical to M1. Find the drain current and mode of operation of M2.

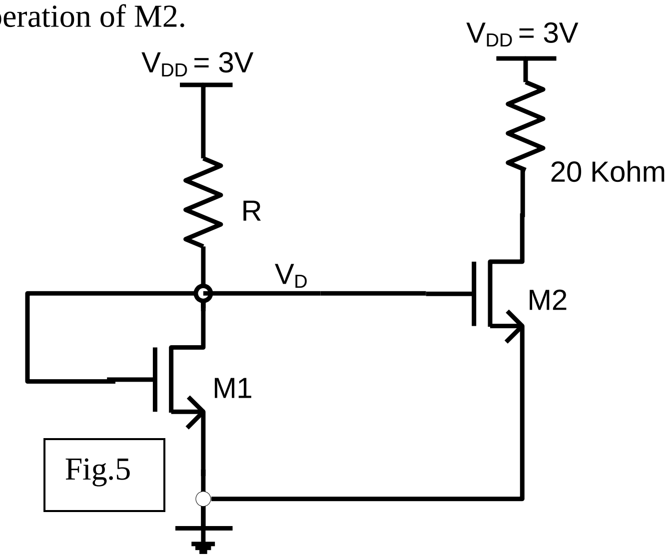


Fig.5

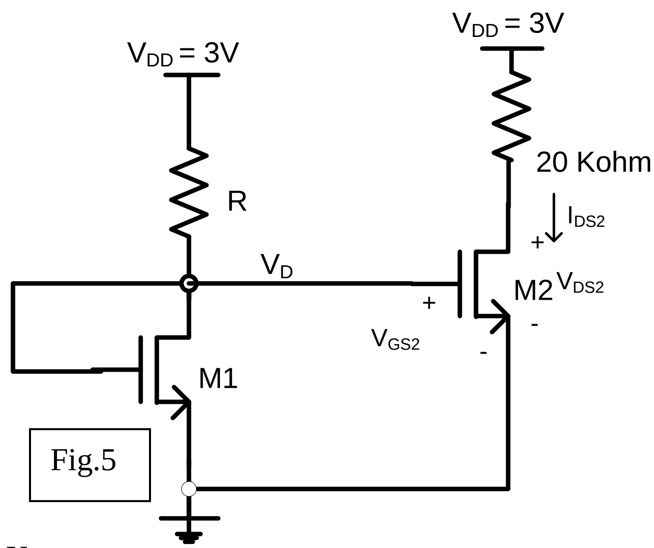


Fig.5

From the shown Figure:

$V_{GS2} = V_D = 1$ V

And assuming M2 is sat

Therefore:

$$I_{DS2} = \frac{K_2}{2}(V_{GS2} - V_T)^2$$

But M2 and M1 are matched, therefore $K_2 = K_1$

$$I_{DS2} = \frac{200*10^{-3}*(\frac{4}{0.8})}{2}(1-0.6)^2 = 0.08mA = 80\mu A$$

From the o/p loop of M2:

$$V_{DS2} = V_{DD} - I_{DS2} * 20 = 3 - 0.08 * 20 = 1.4V$$

Since $V_{DS2,sat} = V_{GS2} - V_T$ = 1-0.6 =0.4 V

Therefore $V_{DS2} > V_{DS2,sat}$ → **M2 is sat.**

Problem 5: Consider the common source amplifier shown in Fig.6. Determine the small signal voltage gain, input resistance and the output resistance Assuming that the transistor has V_T = 1.5 V, K=0.25 mA/V^2 ,$V_A = \frac{1}{\lambda} = 50V$ and assuming the coupling capacitors to be sufficiently large so as can be neglected.

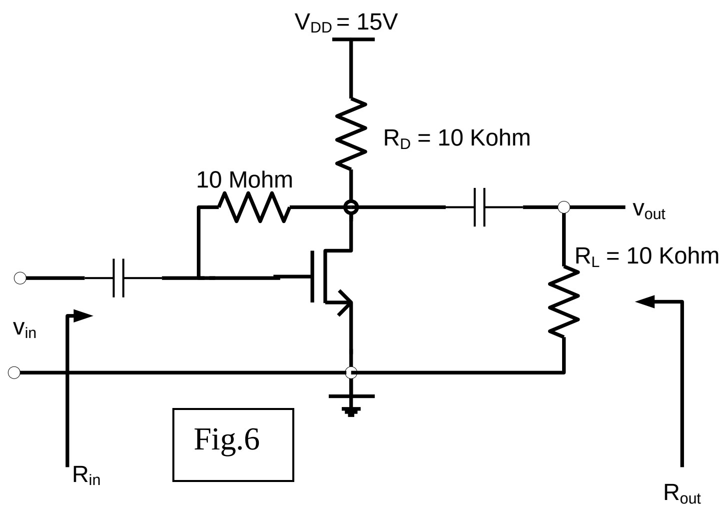
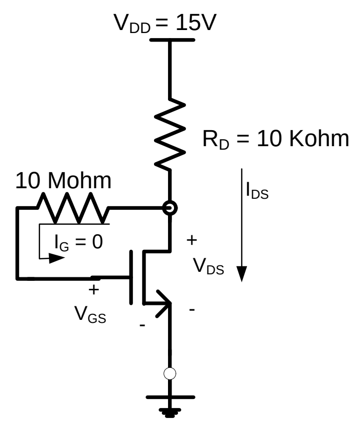


Fig.6

First DC analysis:



From the shown equivalent circuit in DC,

$V_{DS} = V_{GS}$ → The MOS transistor is saturated

And $I_{DS} = \frac{K}{2}(V_{GS} - V_T)^2 = \frac{0.25}{2}(V_{DS} - 1.5)^2$ (1)

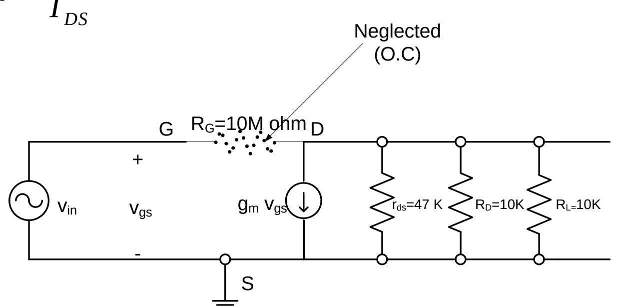
From the output loop:

$15 = I_{DS} * 10 + V_{DS}$ (2)

From eqns. (1) and (2) $V_{DS} = 4.4V$ and I_{DS} = 1.06 mA

→ $g_m = \sqrt{2KI_{DS}} = 0.725 mA/V$ and $r_{ds} = \frac{V_A}{I_{DS}} = 47\,K\Omega$

Second AC analysis:



$$A_v = \frac{v_{out}}{v_{in}} = -g_m(47 // 10 // 10) = -3.3$$

$$R_{in} = \frac{v_{in}}{i_{in} = 0} = \infty$$

$$Rout = 47 // 10 // 10 = 4.5K$$

Problem 6: In the circuit of Fig.7, V_{CC} = 12 V, V_S = 2 V, R_C = 4KΩ and R_S = 100KΩ. The transistor is characterized by β = 50 and $V_{CE,Sat}$ =0.2 V. Find the value of R_B that **just results in saturation** (at the edge between active and sat) if

(a) The capacitor is present

(b) The capacitor is replaced with a short circuit.

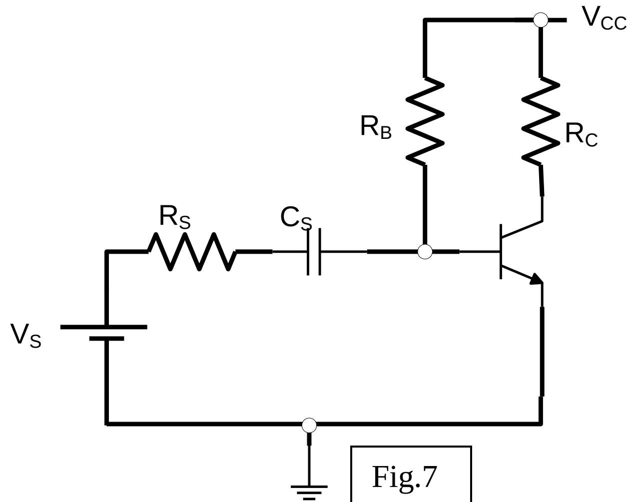
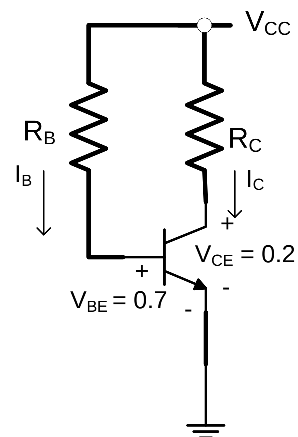


Fig.7

Solution:

(a) if the capacitor present, the equivalent circuit is as shown:



and $I_C = \dfrac{V_{CC} - V_{CE,sat}}{R_C} = \dfrac{12 - 0.2}{4} = 2.95mA$

Since the transistor is operating at the edge between the active and sat

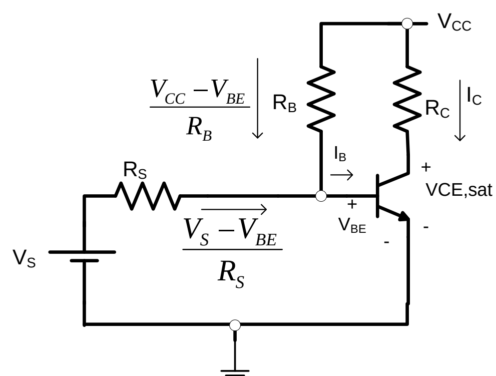
$$I_B = \frac{I_C}{\beta} = \frac{2.95}{50} = \frac{V_{CC} - V_{BE}}{R_B} = \frac{12 - 0.7}{R_B}$$

→ R_B = 191.5 KΩ

(b) If the capacitor is replaced by SC:

Similarly, from the equivalent circuit

$$I_B = \frac{I_C}{\beta} = \frac{2.95}{50} = \frac{12 - 0.7}{R_B} + \frac{2 - 0.7}{R_S = 100}$$



→ R_B= 245.65 KΩ