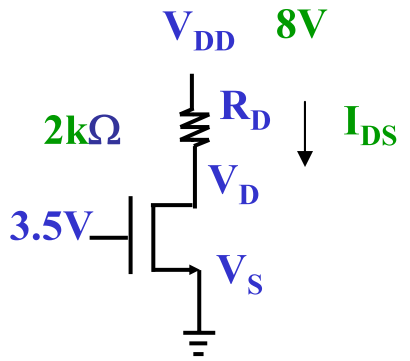
2

Given $V_T = 1V$
$K = 0.25mA/V^2$



Find V_{DS} and I_{DS} for $V_G = 3.5V$

If MOS is in saturation mode

$$\therefore I_{DS} = K\,(V_{GS} - V_T)^2 = 0.25\mathbf{m}(3.5-1)^2 = 1.5625\mathbf{mA}$$

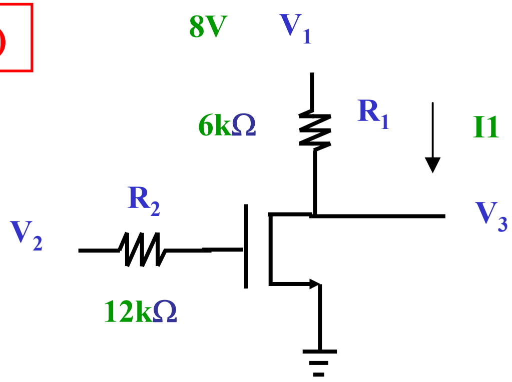
$$\therefore V_{DS} = V_{DD} - I_{DS}R_D$$
$$= 8V - 1.5625\mathbf{mA} * 2k\Omega \cong 4.875V$$

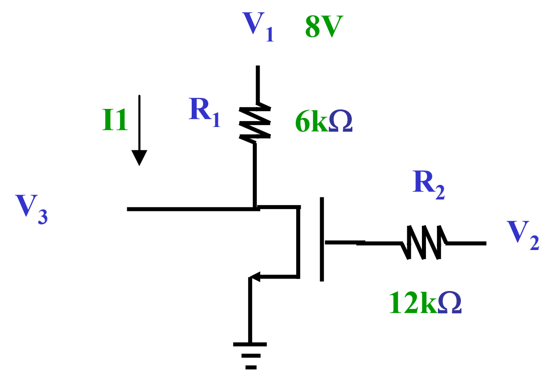
NMOS in saturation is confirmed since

1. $V_{GS} = 3.5V > V_T$
2. $V_{DS} = 4.875V > V_{GS} - V_T$

4 **(18)**

Given
$V_T = 1V$
$K = 0.25mA/V^2$





---

a **If $V_2 = 0.5V$**

$V_{GS} < V_T$ $\quad$ $0.5 < 1$ $\quad$ **NMOS cut off**

$$\therefore I_1 = 0 \qquad \therefore V_3 = 8V$$

---

b **If $V_2 = 3V$** **Assume NMOS is in saturation**

$$\therefore I_1 = K\,(V_{GS} - V_T)^2 = 0.25m(3-1)^2 = 1mA$$

$$\therefore V_3 = 8 - I_1R_1 = 8 - 1m(6k) = 2V$$

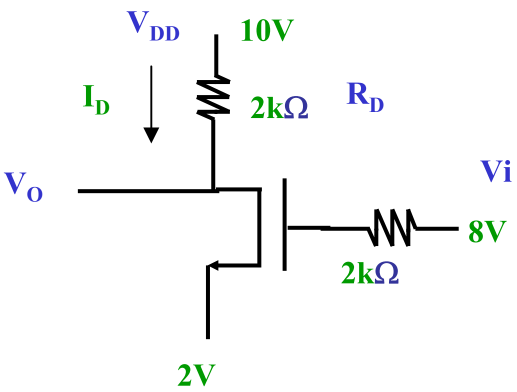
NMOS in saturation is confirmed since
1. $3 > 1$
2. $2 = 3 - 1$

NMOS is saturated since
1. $V_{GS} > V_T$
2. $V_{DS} = V_{GS} - V_T$

4. (a) If $V_2 = 0.5V$, find I_1 and V_3. (b) If $V_2 = 2V$, find I_1 and V_3. State clearly the reasons for your answer.
Given $V_T = 1V$, $K = 0.25mA/V^2$.
Given that
at triode region, $\quad I_{DS} = 2K[(V_{GS} - V_T)V_{DS} - V_{DS}^2 / 2]$

at saturation region, $\quad I_{DS} = K[(V_{GS} - V_T)^2]$ $\quad$ (19).

5 (26)



Given
$V_T = 1V$
$K = 0.5mA/V^2$

$$\therefore I_D = \frac{V_{DD} - V_{DS}}{R_D} = \frac{10 - V_{DS}}{2k}$$

$$= 2K[(V_{GS} - V_T)V_{DS} - \frac{V_{DS}^2}{2}] = 1m[(8-2-1)V_{DS} - \frac{V_{DS}^2}{2})]$$

$$\therefore \frac{10 - V_{DS}}{2k} = 1m[5V_{DS} - \frac{V_{DS}^2}{2}]$$

$$\therefore 10 - V_{DS} = 2[5V_{DS} - \frac{V_{DS}^2}{2}]$$

$$\therefore V_{DS}^2 - 11V_{DS} + 10 = 0$$

$$\therefore V_{DS} = 10V \quad \text{or} \quad 1V$$

hence $\underline{Vo = 3 + 1 = 4V}$

$Vo = 13\ V = V_{DD}$ is impossible since MOS is not cut off $(V_{DGS} > V_T)$

NMOS is in triode since
1. $V_{GS} > V_T$
2. $V_{DS} < V_{GS} - V_T$

NMOS is triode since
1. $6 > 1$
2. $1 < 6 - 1$

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

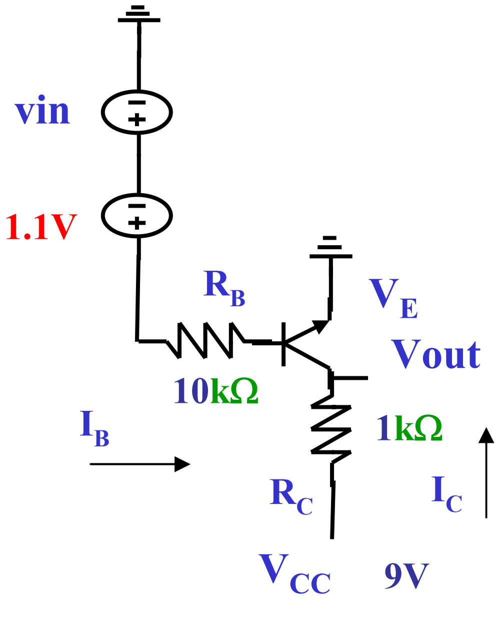
$$= 1m[(6-1)1 - \frac{1}{2})] = 4.5mA$$

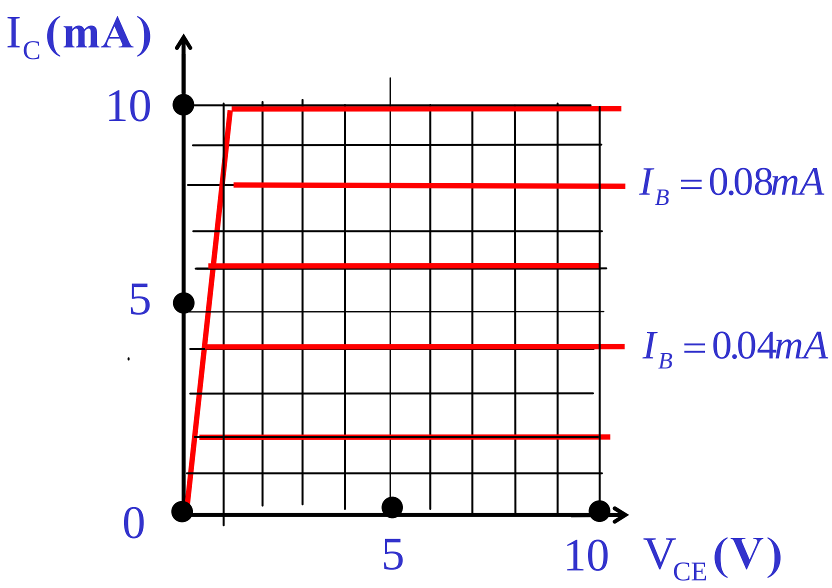
5. In the circuit, find V_O. State clearly the reasons for your answer.
Given $V_T = 1V$, $K = 0.5mA/V^2$.
Given that
at triode region, $I_{DS} = 2K[(V_{GS}-V_T)V_{DS} - V_{DS}^2/2]$

at saturation region, $I_{DS} = K[(V_{GS}-V_T)^2]$ (26).

8

8. A BJT with the following I_C-V_{CE} characteristics is used in the following circuit. (a) Sketch the load line $V_{CE} = V_{CC} - I_C R_C$ and the Q point on the graph.
(b) If vin = 0.1 cos ωt V, sketch the base current I_B , the collector current I_C and the output voltage Vout. Show clearly the DC value, the maximum and minimum value in your sketch. Estimate also the current gain dI_C / dI_B and voltage gain dVout / dVin.
(c) Sketch the small signal (AC) equivalent circuit of the amplifier and find the voltage gain Av (= Vout/Vin). For the BJT, given $r\pi = 0\Omega$, $V_{BE(ON)} = 0.7V$. (49)

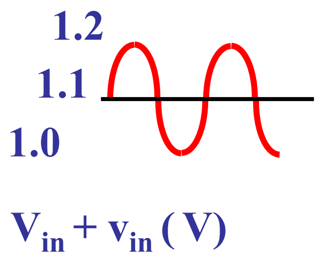


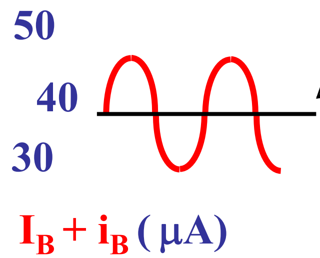


b **Find I_C from graph**

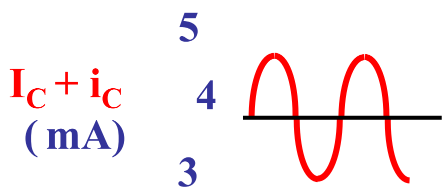
a **Find I_B from equation**

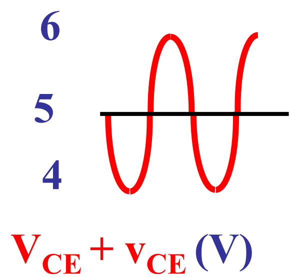
$$\therefore I_B = \frac{V_{in} - V_{BE}}{R_B} = \frac{1.1V - 0.7V}{10k\Omega} = 0.04mA$$



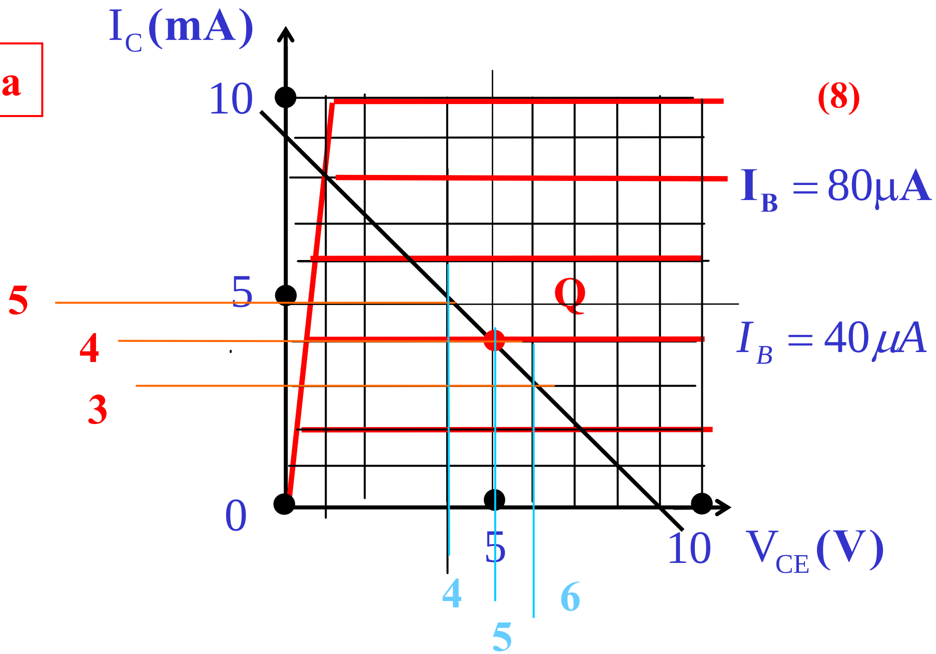


c **Find V_{CE} from graph**





a



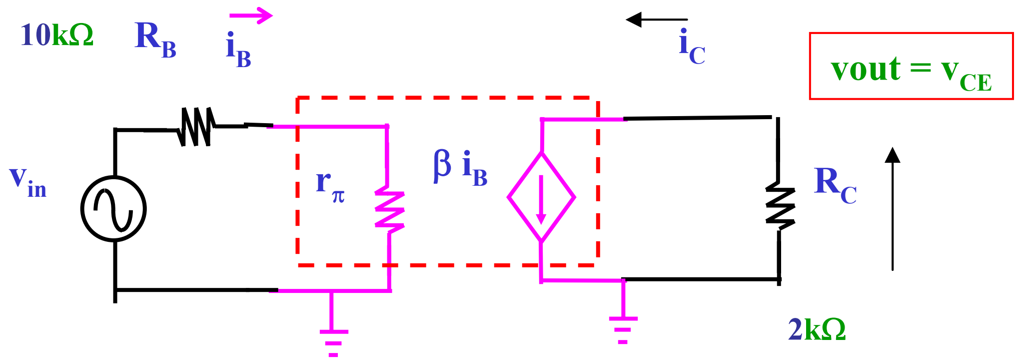
(8)

Estimate current and voltage gain

$$\therefore A_I = \beta_F = \frac{\Delta I_C}{\Delta I_B} \approx \frac{5m - 3m}{50\mu - 30\mu} = \frac{2mA}{20\mu A} = 100$$

$$\therefore A_V = \frac{\Delta V_{out}}{\Delta V_{in}} = \frac{6V - 4V}{1.0V - 1.2V} = \frac{2V}{-0.2V} = -10$$

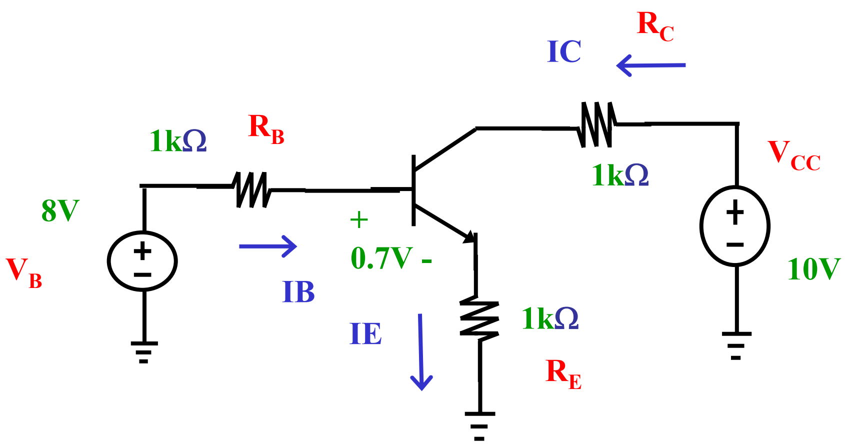
c



$$\therefore Av = \frac{v_{OUT}}{v_{in}} = \frac{-\beta\, i_B R_C}{i_B(R_B + r_\pi)} = \frac{-\beta R_C}{R_B + r_\pi} = \frac{-(100)(1k)}{10k} \cong -10$$

9

9. Given the BJT circuit.
Given that IB is about 1.57mA. Show that the BJT is in saturation.
Hence show that the forced beta is about 2.7.
For the BJT, given $V_{BE} = 0.7V$, $\beta = 100$, $V_{CESAT} = 0.1V$. (30)

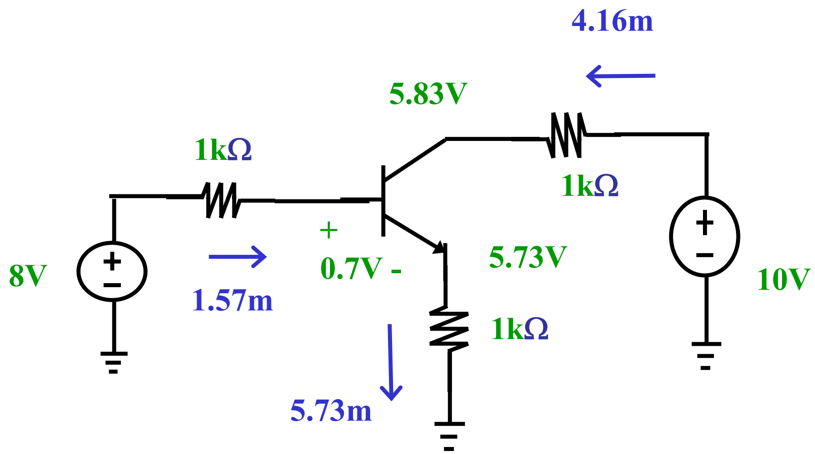


$$\therefore\ I_C = \beta I_B = 100 * 1.57mA = 157mA$$

$$>> I_C \text{ when } V_{CE} = 0V = \frac{10V}{2k\Omega} = 5mA$$

$\therefore$ BJT is in saturation

$$\therefore \frac{I_C}{I_B} = \beta^*$$



$$\therefore \frac{I_C}{I_B} = \beta^* = \frac{4.16m}{1.57m} \cong 2.65$$

or

$$\therefore\ I_B = \frac{V_B - V_{BE}}{R_B + (1+\beta^*)R_E} = \frac{V_{CC} - V_{CESAT}}{\beta^* R_C + (1+\beta^*)R_E}$$

$$\therefore\ I_B = \frac{8-0.7}{1k + (1+\beta^*)1k} = \frac{10-0.1}{1k(1+2\beta^*)}$$

$$\therefore 7.3(1+2\beta^*) = 9.9(2+\beta^*)$$

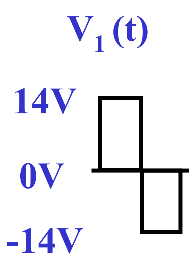
$$\therefore 14.6\beta^* + 7.3 = 9.9\beta^* + 19.8$$

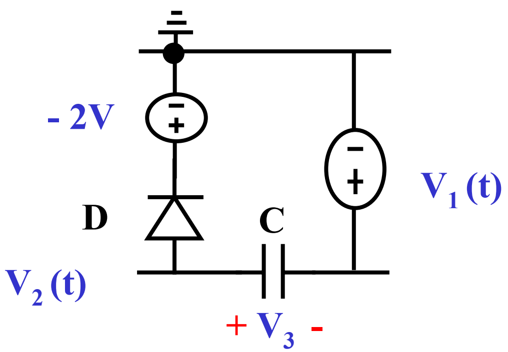
$$\therefore \beta^* = \frac{19.8-7.3}{14.6-9.9} \cong 2.66$$

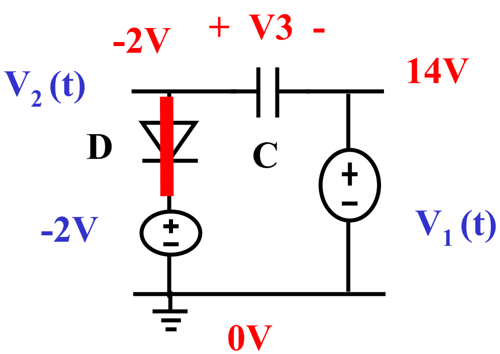
(15)

11

11. (a) In the ideal diode circuit, find V3 and sketch V2(t). (15)

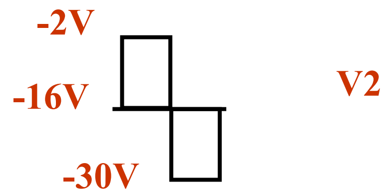






Hence V3 = - 16V

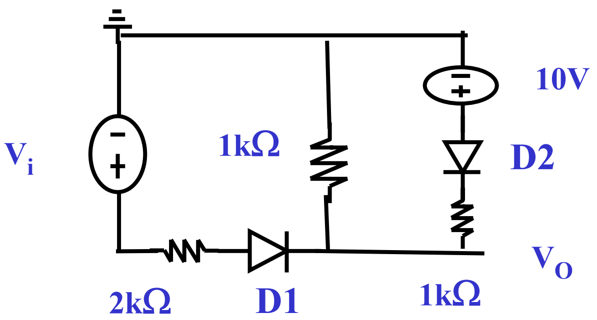
Hence V2 = V1 + V3 = V1 - 16V

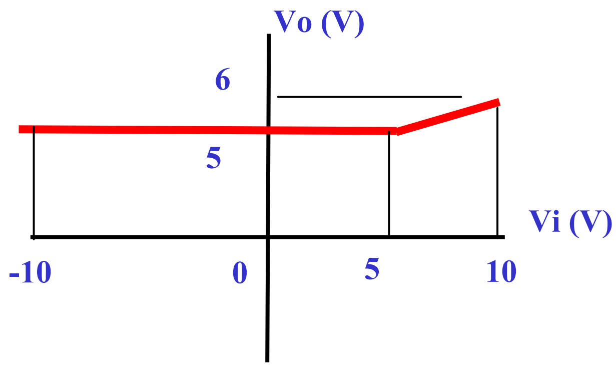


(20)

11

(b) In the ideal diode circuit, plot Vo versus Vi for
-10V ≤Vi ≤ 10V.
Show clearly all voltages in your sketch. (20)





(6)

Vi < 5V, D1 OFF and D2 ON

$\therefore Vo = 5V$

Vi > 5V, D1 and D2 ON,

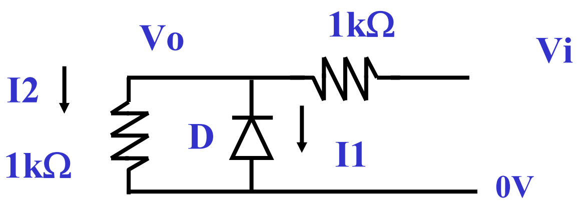
$$\therefore \frac{Vi - Vo}{2k} + \frac{10 - Vo}{1k} = \frac{Vo}{1k}$$

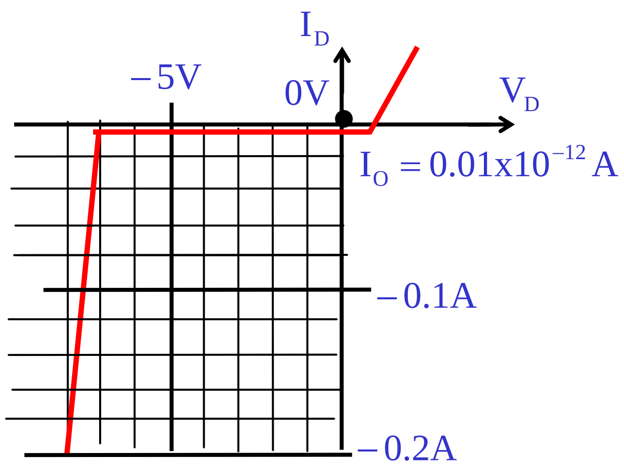
$$\therefore Vi - Vo + 20 - 2Vo = 2Vo$$

$$\therefore Vo = \frac{Vi + 20}{5}$$

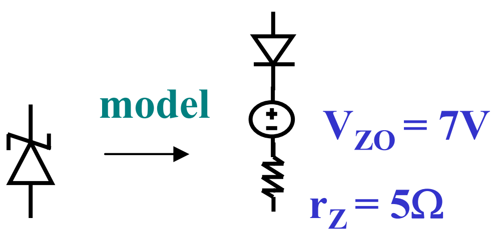
12

12. In the diode circuit, the diode has the reverse characteristics as shown. The diode equation is
I = Io exp [(V/25mV) – 1].
(a) Sketch the circuit model of the diode at breakdown.
(b) Find I1 if Vi = – 1V.
(c) Find I1 if Vi = 2V.
(d) Find I2 if Vi = 16V. (35)





a



b

$$\mathbf{Vi = -1V,\ \therefore Vo = -0.5V}$$

$$\therefore I_1 = -I_O\,(e^{\frac{0.5V}{25mV}} - 1)$$

$$= -0.01x10^{-12}\,A\,(e^{\frac{500m}{25m}} - 1) = -4.85x10^{-6}\,A$$

c

$$\therefore I_1 = I_O = 0.01x10^{-12}\,A$$

d

$$Vi = 16V,\ \therefore Vo = 8V,\ D\ \text{breakdown}$$

$$\frac{16 - Vo}{1k} = \frac{Vo - 7}{5} + \frac{Vo}{1k}$$

$$16 - Vo = 200(Vo - 7) + Vo$$

$$Vo = \frac{1400 + 16}{202} \cong 7.01V$$

$$\therefore I2 = \frac{Vo}{R_L} \cong \frac{7.01}{1k} = 7.01mA$$