10 $V_{GS} = V_{DS}$ implies saturation-mode operation. Thus

$$1 = \frac{1}{2} k_n' \frac{W}{L} (5 - V_t)^2$$

$$\Rightarrow k_n' \frac{W}{L} = \frac{2}{(5 - V_t)^2}$$

$$4 = \frac{1}{2} k_n' \frac{W}{L} (9 - V_t)^2$$

$$4 = \frac{1}{2} \frac{2}{(5 - V_t)^2} (9 - V_t)^2$$

$$\frac{9 - V_t}{5 - V_t} = 2$$

$$\Rightarrow V_t = \underline{1\ V}$$

$$k_n' \frac{W}{L} = \frac{2}{(5-1)^2} = \underline{\frac{1}{8}\ mA/V^2}$$

13 In the linear-resistance region,

$$i_D \simeq k_n' \frac{W}{L} (v_{GS} - V_t) v_{DS}$$

Thus, $40 = k_n' \frac{W}{L} (2 - V_t) \times 0.1$

and, $80 = k_n' \frac{W}{L} (3 - V_t) \times 0.1$

Thus, $2 = \frac{3 - V_t}{2 - V_t}$

$\Rightarrow V_t = \underline{1\ V}$

$$k_n' \frac{W}{L} = \frac{40}{(2-1) \times 0.1} = 400\ \mu A/V^2$$

For $k_n' = 40\ \mu A/V^2$,

$$\frac{W}{L} = \underline{10}$$

For $v_{GS} = 2.5$ V and $v_{DS} = 0.15$ V,

$$i_D \simeq 40 \times 10\ (2.5-1) \times 0.15 = \underline{90\ \mu A}$$

For $v_{GS} = 2.5$ V, the drain-end of the channel just reaches pinch-off at

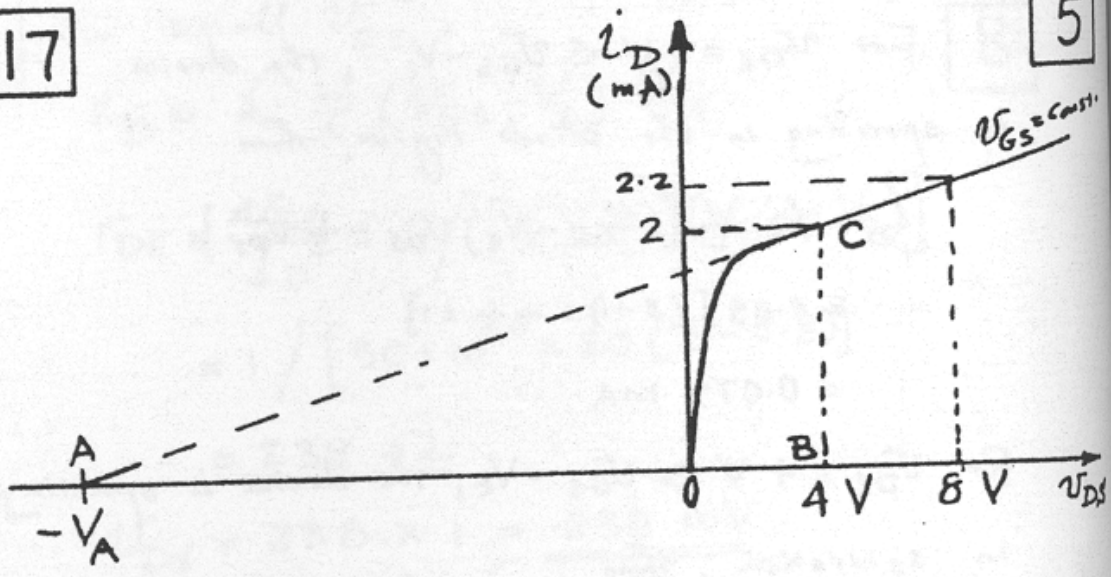
$$v_{DS} = v_{GS} - V_t = 2.5 - 1 = \underline{1.5\ V}$$

The corresponding drain current is

$$i_D = \frac{1}{2} \times 40 \times 10\ (1.5)^2 = \underline{450\ \mu A}$$

17

5



$$r_o = \left.\frac{\Delta v_{DS}}{\Delta i_D}\right|_{v_{GS}\ \text{constant}}$$

$$= \frac{8-4}{2.2-2} = \underline{\underline{20\ k\Omega}}$$

To find the value of V_A, consider the triangle ABC,

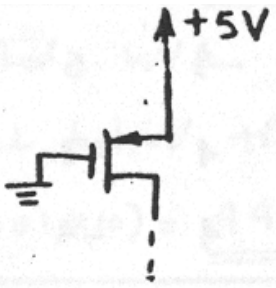
$$(V_A + 4) = 2\,mA \times r_o$$

$$V_A + 4 = 2 \times 20 = 40$$

$$V_A = \underline{\underline{36\ V}}$$

$$\lambda = \frac{1}{V_A} = \frac{1}{36} = \underline{\underline{0.028\ V^{-1}}}$$

23 (a) $v_D = +4\,V \Rightarrow v_{DG} > V_t$, thus the channel is continuous. Alternatively



$v_{DS} = +4 - 5 = -1\,V$

$v_{GS} = -5 \quad V_t = -1.5$

$v_{GS} - V_t = -5 + 1.5 = -3.5$

Thus, $v_{DS} > v_{GS} - V_t$ and the channel must be continuous, i.e. the MOSFET is operating in the triode region, [5]

$$i_D = k_p' \frac{W}{L}\left[(v_{GS} - V_t)v_{DS} - \tfrac{1}{2}v_{DS}^2\right]$$

$$= 80\left[-3.5 \times -1 - \tfrac{1}{2} \times (-1)^2\right]$$

$$= \underline{240\ \mu A}$$

(b) $v_D = +1.5\,V \qquad v_{DS} = 1.5 - 5 = -3.5\,V$

Thus, $v_{DS} = v_{GS} - V_t$ and the transistor is operating at the edge of saturation,

$$i_D = \tfrac{1}{2} k_p' \frac{W}{L}(v_{GS} - V_t)^2\left[1 + \lambda v_{DS}\right]$$

$$= \tfrac{1}{2} \times 80\ (-5 + 1.5)^2\left[1 + (-0.02)(-3.5)\right]$$

$$= \underline{524\ \mu A}$$

(c) $v_D = 0\,V \qquad v_{DS} = -5\,V \qquad v_{DS} < v_{GS} - V_t$

$\Rightarrow$ saturation

$$i_D = \tfrac{1}{2} \times 80\,(-5 + 1.5)^2\left[1 + (-0.02)(-5)\right]$$

$$= \underline{539\ \mu A}$$

(d) Saturation

$$i_D = \tfrac{1}{2} \times 80 \times 3.5^2\left[1 + (-0.02)(-10)\right]$$

$$= \underline{588\ \mu A}$$