1) \textbf{7.25}

\textbf{7.25} (a) \[ I_D = \frac{1}{2} k_n V_{GS} - V_t^2 \]
\[ = \frac{1}{2} \times 5(0.6 - 0.4)^2 = 0.1 \text{ mA} \]
\[ V_{DS} = V_{DD} - I_D R_D = 1.8 - 0.1 \times 10 = 0.8 \text{ V} \]
(b) \[ g_m = k_n V_{OV} = 5 \times 0.2 = 1 \text{ mA/V} \]
(c) \[ A_v = -g_m R_D = -1 \times 10 = -10 \text{ V/V} \]
(d) \[ \lambda = 0.1 \text{ V}^{-1}, \quad V_A = \frac{1}{\lambda} = 10 \text{ V} \]
\[ r_o = \frac{V_A}{I_D} = \frac{10}{0.1} = 100 \text{ k}\Omega \]
\[ A_v = -g_m (R_D \parallel r_o) \]
\[ = -1(10 \parallel 100) = -9.1 \text{ V/V} \]

2) \textbf{7.29}

\textbf{7.29} Given \[ \mu_n C_{ox} = 250 \mu\text{A/V}^2, \]
\[ V_t = 0.5 \text{ V}, \]
\[ L = 0.5 \mu\text{m} \]
For \[ g_m = 2 \text{ mA/V}^2 \] and \[ I_D = 0.25 \text{ mA}, \]
\[ g_m = \sqrt{2 \mu_n C_{ox} \frac{W}{L} I_D} \Rightarrow \frac{W}{L} = 32 \]
\[ \therefore W = 16 \mu\text{m} \]
\[ V_{OV} = \frac{2I_D}{g_m} = 0.25 \text{ V} \]
\[ \therefore V_{GS} = V_{OV} + V_t = 0.75 \text{ V} \]
$V_i = 0.5 \text{ V}$
$V_A = 50 \text{ V}$

Given $V_{DS} = V_{GS} = 1 \text{ V}$. Also, $I_D = 0.5 \text{ mA}$.

$V_{OV} = 0.5 \text{ V}$, $g_m = \frac{2I_D}{V_{OV}} = 2 \text{ mA/V}$

$r_o = \frac{V_A}{I_D} = 100 \text{ k}\Omega$

$\frac{v_o}{v_i} = -g_m \left( R_G \parallel R_L \parallel r_o \right) = -18.2 \text{ V/V}$

For $I_D = 1 \text{ mA}$:

$V_{OV}$ increases by $\sqrt{\frac{1}{0.5}} = \sqrt{2}$ to

$\sqrt{2} \times 0.5 = 0.707 \text{ V}$.

$V_{GS} = V_{DS} = 1.207 \text{ V}$

$g_m = 2.83 \text{ mA/V}$, $r_o = 50 \text{ k}\Omega$ and

$\frac{v_o}{v_i} = -23.6 \text{ V/V}$
7.33 (a) Open-circuit the capacitors to obtain the bias circuit shown in Fig. 1, which indicates the given values.

![Figure 1](image)

From the voltage divider, we have

$$V_G = 15 \frac{5}{10 + 5} = 5 \text{ V}$$

From the circuit, we obtain

$$V_G = V_{GS} + 0.5 \times 7$$

$$= 1.5 + 3.5 = 5 \text{ V}$$

which is consistent with the value provided by the voltage divider.

Since the drain voltage (+7 V) is higher than the gate voltage (+5 V), the transistor is operating in saturation.

From the circuit

$$V_D = V_{DD} - I_D R_D = 15 - 0.5 \times 16 = +7 \text{ V}, \text{ as assumed}$$

Finally,

$$V_{GS} = 1.5 \text{ V}, \text{ thus } V_{OV} = 1.5 - V_t = 1.5 - 1 = 0.5 \text{ V}$$

$$I_D = \frac{1}{2} k_n V_{OV}^2 = \frac{1}{2} \times 4 \times 0.5^2 = 0.5 \text{ mA}$$

which is equal to the given value. Thus the bias calculations are all consistent.

(b) $$g_m = \frac{2I_D}{V_{OV}} = \frac{2 \times 0.5}{0.5} = 2 \text{ mA/V}$$

$$r_o = \frac{V_A}{I_D} = \frac{100}{0.5} = 200 \text{ k}\Omega$$

(c) See Fig. 2 below.

(d) $$R_{in} = 10 \text{ M}\Omega \parallel 5 \text{ M}\Omega = 3.33 \text{ M}\Omega$$

$$\frac{v_{ot}}{v_{st}} = \frac{R_{in}}{R_{in} + R_{st}} = \frac{3.33}{3.33 + 0.2}$$

$$= 0.94 \text{ V/V}$$

$$\frac{v_o}{v_{gs}} = -g_m(200 \parallel 16 \parallel 16)$$

$$= -2 \times 7.69 = -15.38 \text{ V/V}$$

$$\frac{v_o}{v_{st}} = \frac{v_{ot}}{v_{st}} \times \frac{v_o}{v_{gs}} = -0.94 \times 15.38$$

$$= -14.5 \text{ V/V}$$
Figure 2

\[ R_{\text{seg}} = 200 \, \text{k}\Omega \]

\[ v_{\text{seg}} \]

\[ R_{\text{ia}} \]

\[ 10 \, \text{M}\Omega \]  \[ 5 \, \text{M}\Omega \]

\[ v_{\text{gs}} \]

\[ g_m v_{\text{rf}} \]

\[ 200 \, \text{k}\Omega \]  \[ 16 \, \text{k}\Omega \]  \[ 16 \, \text{k}\Omega \]

\[ v_o \]