chapter 2 - Problems

2.1) The higher the beam's acceleration potential, the deeper the maximum ion concentration into the silicon wafer. The higher the beam current or the time of exposure, the larger the amount of dosage.

2.2) Well implantation, Field implantation, Field oxide growth, Polysilicon deposition & patterning, Junction implantation, Metal deposition & patterning.

2.3) Single threshold-voltage-adjust normally leads to an n-well doping level which is higher than optimum. This will increase the junction capacitance and the body effect of the transistors in the well.

2.4) It prohibits the silicon under the field oxide from inversion when a conductor running over the field oxide has a large voltage. The field implants are not critical for the wells, as the heavier doping of the well guarantees that the silicon will never invert under

2.4) (cont.)   the *field oxide* in this region.

2.5)   Dry process is slower than the wet process. However, it results in denser, higher quality SiO_2 that is less porous.

2.6)   Polysilicon has a much higher melting point compared to metals, and that will allow annealing at higher temperature before metal deposition.
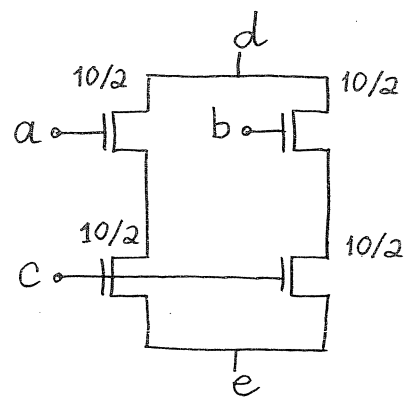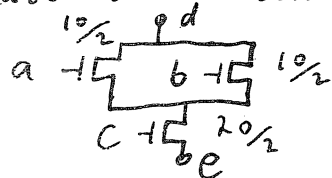
2.7)   Annealing temperatures are normally higher than the metal melting point.

2.8)   0λ since their is no restriction on overlaying metal and polysilicon. However, many processes do not allow parallel metal and polysilicon lines to overlap each other due to metal breakage because of "hill" effects.

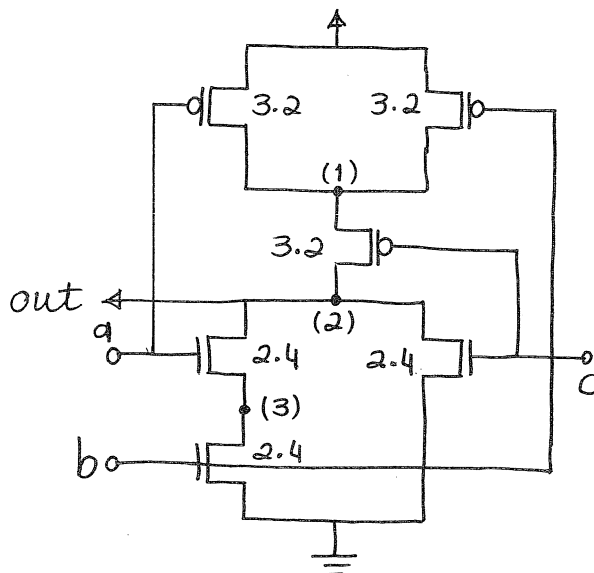2.9)   The circuit cannot be simplified. (sizes are in μm).

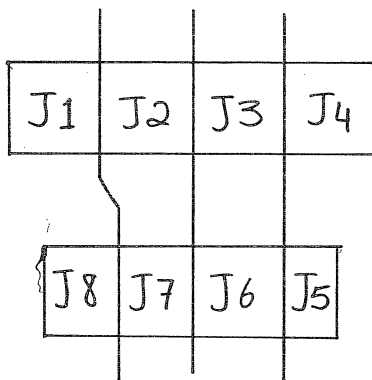unless it is a digital circuit in which case

2.10) All the transistors have the same length equal to $0.8\,\mu m$. The width are shown on the schematic. (all sizes are in μm.)
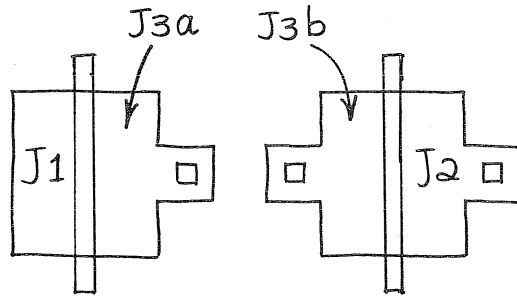

Junction	Node	Area (μm^2)	Peri. (μm)
J1	1	7.68	8
J2	V_{DD}	—	—
J3	1	7.68	4.8
J4	2	7.68	8
J5	2	5.76	7.2
J6	GND	—	—
J7	3	1.92	1.6
J8	2	5.76	7.2

2.11) J1 & J2 remain unchanged.

J3 is now splitted to J3a & J3b.
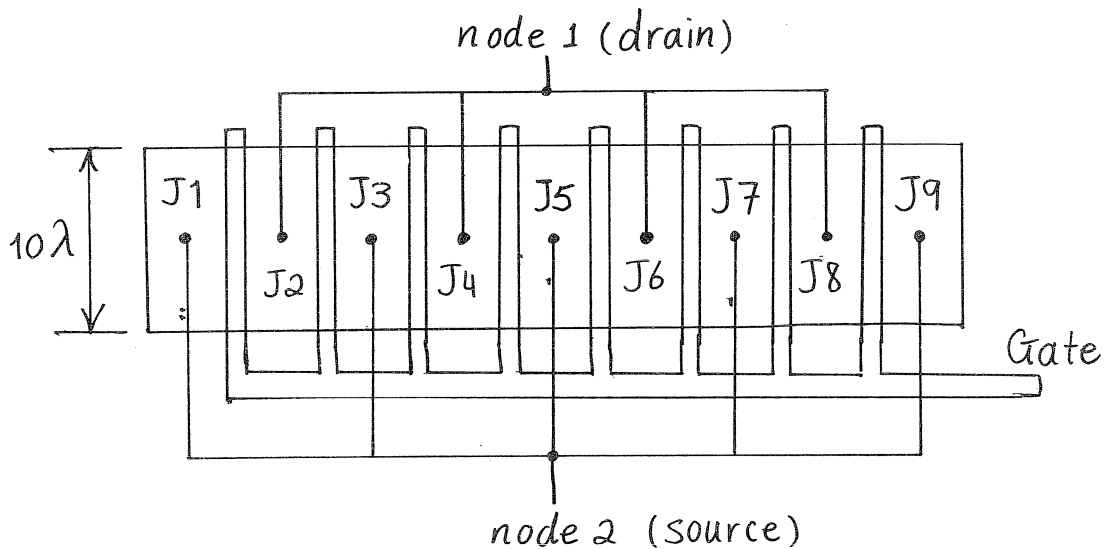

$$A_{3a} = A_{3b} = A_{J2} = 8 \,(\mu m)^2$$

$$P_{3a} = P_{3b} = P_{J2} = 10 \,\mu m$$

The area is increased by a factor of ≈ 3, the peri. is increased by a factor of 10.

2.12)

(layout not to scale)

For the drain:

$$A_{J2} = A_{J4} = A_{J6} = A_{J8} = 6\lambda \times 10\lambda = 60\,\lambda^2 = \underline{15\,(\mu m)^2}$$

$$P_{J2} = P_{J4} = P_{J6} = P_{J8} = 6\lambda + 6\lambda = 12\lambda = \underline{6\,\mu m}$$

(cont.)

2.12) (cont.)

$$\therefore\ C_{db} = 4(A_{J2}C_j + P_{J2}C_{jsw}) = \underline{0.019\ pF}$$

For the source:

$$A_{J1} = A_{J9} = 5\lambda \times 10\lambda = 50\ \lambda^2 = \underline{12.5\ (\mu m)^2}$$

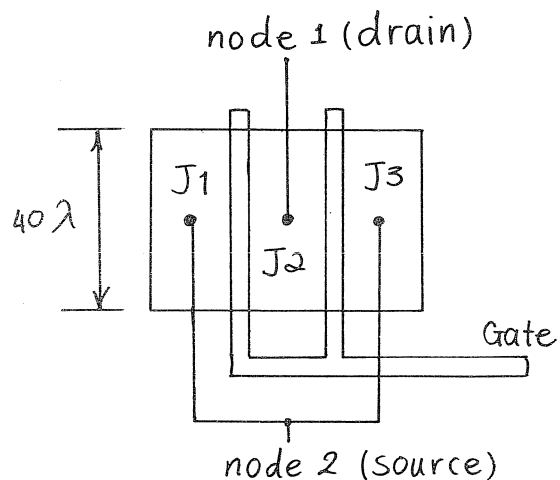$$A_{J3} = A_{J5} = A_{J7} = A_{J2} = \underline{15\ (\mu m)^2}$$

$$P_{J1} = P_{J9} = 5\lambda + 5\lambda + 10\lambda = 20\lambda = \underline{10\ \mu m}$$

$$P_{J3} = P_{J5} = P_{J7} = P_{J2} = \underline{6\ \mu m}$$

$$\therefore\ C_{sb} = (A_{J1} + A_{J3} + \cdots + A_{J9} + WL)C_j +$$
$$(P_{J1} + P_{J3} + \cdots + P_{J9})C_{jsw} = \underline{0.034\ pF}$$

Compared to the results of Example 2.2, the changes in capacitances are insignificant.

2.13)   (layout not to scale)

node 1 (drain)

For the drain:

$$A_{J2} = 6\lambda \times 40\lambda = \underline{60\ (\mu m)^2}$$

$$P_{J2} = 6\lambda + 6\lambda = \underline{6\ \mu m}$$

$$\therefore\ C_{db} = A_{J2}C_j + P_{J2}C_{jsw} = \underline{0.016\ pF}$$

(cont.)

2.13) (Cont.)

For the source:

$$A_{J1} = A_{J3} = 5\lambda \times 40\lambda = \underline{50\ (\mu m)^2}$$
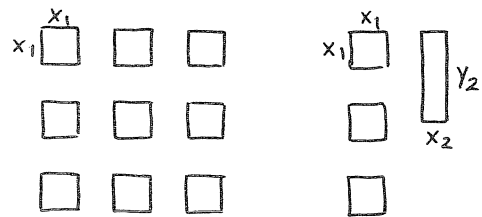
$$P_{J1} = P_{J3} = 5\lambda + 5\lambda + 40\lambda = \underline{25\ \mu m}$$

$$\therefore\ C_{sb} = (A_{J1} + A_{J3} + WL)C_j + (P_{J1} + P_{J3})C_{jsw} = \underline{0.044\ pF}$$

2.14) $K = 1.523$

Using (2.26):

$$\frac{Y_2}{X_1} = 2.415\ ,\quad \frac{X_2}{X_1} = 0.631$$

$$\therefore\ \underline{Y_2 = 2.415\,X_1}\quad \&\quad \underline{X_2 = 0.631\,X_1}$$

2.15) It is desired to have coeff matching of $\frac{9}{4.523} = 1.9898$

Using $X_1 = 5\mu m$ & the results of problem (2.14):

$$Y_2 = 12.075\ \mu m \xrightarrow{rounding} 12.1\mu m$$

$$X_2 = 3.155\ \mu m \xrightarrow{rounding} 3.2\mu m$$

actual coeff matching $= \dfrac{(9 \times 25)}{(3 \times 25) + (12.1 \times 3.2)} = \underline{1.9785}$

% matching accuracy error $= \dfrac{1.9785 - 1.9898}{1.9898} \times 100\% = \underline{-0.6\%}$

(cont.)

2.15) (Cont.)

If capacitor sizes are doubled to 18 & 9.046

then $k = 1.046$ leading to

$y_2 = 1.2654\, x_1$ & $x_2 = 0.82665\, x_1$

With $x_1 = 5\,\mu m$ $\Rightarrow$ $y_2 = 6.33\,\mu m$ & $x_2 = 4.13\,\mu m$

Rounding results in $y_2' = 6.3\,\mu m$ + $x_2 = 4.1\,\mu m$

actual coeff matching $= \dfrac{(18 \times 25)}{(8 \times 25) + (6.3 \times 4.1)} = 1.9927$

% matching accuracy error $= \dfrac{1.9927 - 1.9898}{1.9898} \times 100\% = +0.15\%$

a 4 times improvement!!

2.16) $\dfrac{1000\,\mu}{2\,\mu} \times 7\,\Omega = \underline{3.5\,k\Omega}$

2.17) The length of the dashed line is 13 units of $2\,\mu m/unit$, which is equal to $26\,\mu m$.

$1000\,\mu m = 38 \times 26\,\mu m + 12\,\mu m$

∴ there will be $\underline{38}$ bends, each contributing 0.11 square more than their mid-length.
Therefore, the total resistance will be :

$3.5\,k\Omega + (38 \times 0.11 \times 7\,\Omega) = \underline{3.529\,k\Omega}$

the serpentine's height $= 12 \times 2\,\mu m = \underline{24\,\mu m}$

" " width $= 38 \times 4\,\mu m = \underline{152\,\mu m}$