NOTES:

Some of the problems can have multiple correct answers. One example is shown below.

SOLUTIONS:

Problem 1:

The average thickness of a 12 inch (300 mm) wafer is 750-800 μm With a 150 μm saw

With n cuts (n+1) wafers are obtained

$(n+1)(775\ \mu m) + n(150\ \mu m) = 2\ m\ \rightarrow n = 2161$

Numbers of wafer = 2161 + 1 = 2162

Answer can range from 2105 to 2222 depending on thickness value

Problem 2:

From the last page we find,

Poly1 sheet resistance = $7.7\frac{\Omega}{\blacksquare}$

poly1-Insulator-M1 capacitance = $64\frac{aF}{\mu m^2}$

$\omega_{3dB} = \frac{1}{RC} = 2\pi f \rightarrow R = \frac{1}{2\pi f * c} = 19.89 * 10^6 \Omega$

a. The minimum area of a poly1 resistor is

$A_{Resistor} = \frac{19.89 * 10^6}{7.7} * 0.2^2 \mu m^2 = 103.32 * 10^3\ \mu m^2$

The minimum area of a Poly-M1 capacitor is

$A_{Capacitor} = \frac{8pF}{64\frac{aF}{\mu m\hat{}2}} = 125 * 10^3\ \mu m^2$

Total Area $A = A_{Res} + A_{Cap} = 103.32 * 10^3 + 125 * 10^3 = 228.32 * 10^3\ \mu m^2$

b) We will start with the minimized size resistor has a sheet of x ■ and the capacitor has an area of $y\ \mu m^2$.

Total area $A = (0.2 * 0.2) * x + y = 0.04x + y$

$$\frac{1}{RC} = \omega_{3dB} = 2\pi f \rightarrow RC = \frac{1}{2\pi f} = 0.0001592\ Hz$$

$$(x * 7.7)(64 * 10^{-18} * y) = 0.0001592 \rightarrow y = \frac{3.23 * 10^{11}}{x}$$

$$A = 0.04x + \left(\frac{3.23 * 10^{11}}{x}\right) \rightarrow A_{min}\ when\ 0.04x = \frac{3.23 * 10^{11}}{x}$$

$$x = 2.84 * 10^{6} \rightarrow y = \frac{7.952 * 10^{12}}{7.0495 * 10^{6}} = 0.114 * 10^{6}\ \mu m\text{^}2$$

$R = 2.84 * 10^{6} * 7.7 = 55.2 * 10^{6} =$ 21.87 $M\Omega$

$C = 0.114 * 10^{6} * 64 * 10^{-18} = 7.28 * 10^{-12} =$ 7.28 pF

Problem 3:

a. Length = $1\mu m$, width = $2\mu m$
b. Positive photoresist overexposed decreases the size, under-etching increases the size
   Length = $1 - 0.1 + 0.1 =$ 1.0 μm
   Width is unchanged.
c. Overexposing negative photoresist increases the size, under-etching negative photoresist increases size
   Length = $1 + 0.1 + 0.1 =$ 1.2 μm

Problem 4:

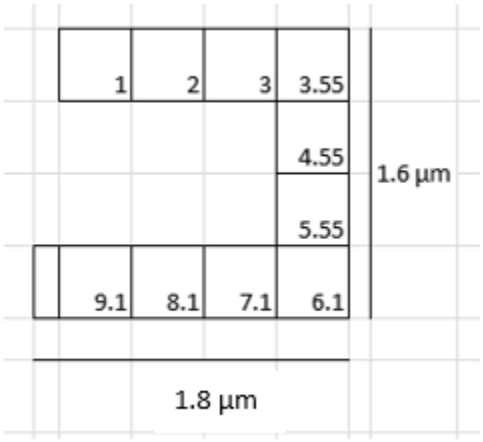
Approximately 53% of the oxide grows above the wafer, and 47% grows into the wafer.
The increased wafer height $W_{height} = 0.53 * 5000 =$ 2650Å

Problem 5:

Sheet Resistance of poly is 317.1 Ω/■ => $\frac{3000}{317.1} = 9.46$

Use 0.4 µm by 0.4 µm squares with the last square being 0.2 µm by 0.4 µm (counts as 1/2 of square).

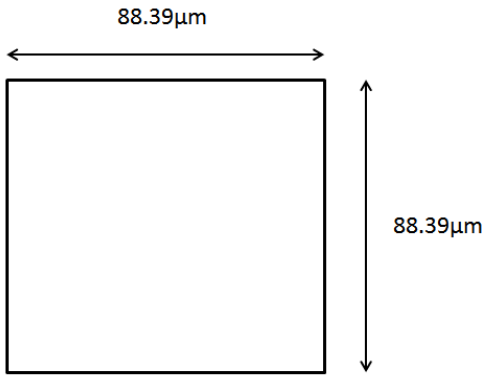
$8 + 0.5 + (2 * 0.55) = 9.6■ = 3044.2\Omega$



Problem 6:

Using poly and Metal1 => 64 aF/µm^2

$$A_C = \frac{0.5 * 10^{-12}\ F}{64 * 10^{-18}\ F/\mu m^2} = 7812.5\ \mu m^2 => \sqrt{A_C} = 88.39 \mu m$$



Problem 7:

$$R(320) = 4534 * \left(1 + (320 - 250) * \left(\frac{1200}{10^6}\right)\right) = 4914\ \Omega$$

Problem 8:

Number of ■ = 100

Sheet resistance of Poly = 7.7 Ω/■

Resistance = 100 * 7.7 = 770 Ω

Area = 100 µm^2

Poly-Substrate = 103 aF/µm^2

M1-Poly = 64 aF/µm^2

$$C_{Poly-Substrate} = 100\ \mu m^2 * 103 \frac{aF}{\mu m^2} = 10.3\ fF$$

$$C_{M1-Poly} = 100\ \mu m^2 * 64 \frac{aF}{\mu m^2} = 6.4\ fF$$

Problem 9 :

Half adder code:

```
Ln#
 1  `timescale 1ns / 1ps
 2
 3  module Halfadder (iA, iB, oSum, oCarry);
 4    input iA,iB; //defining inputs
 5    output oSum, oCarry; //defining outputs
 6
 7    assign oSum = iA^iB; //sum is equal to A xor B
 8    assign oCarry = iA & iB; //carry is equal to A and B
 9
10  endmodule
```

Test Bench:

/home/falegria/ee330/Half_adder_tb.v - Default

```
Ln#
 1  `timescale 1ns / 1ps
 2  module half_adder_tb ();
 3    reg A,B;
 4    wire Sum, Carry;
 5    Halfadder uut (.iA(A), .iB(B), .oSum(Sum), .oCarry(Carry)); //unit under
 6
 7  initial
 8  begin //begin setting bits (basically recreating the truth table)
 9
10
11      A = 1'b0;
12      B = 1'b0;
13    end
14    initial
15    begin
16      #10//timestamp to wait 35ns
17
18      A = 1'b0;
19      B = 1'b1;
20
21      #10 //timestamp to wait 35ns
22
23      A = 1'b1;
24      B = 1'b0;
25
26      #10 //timestamp to wait 35ns
27
28      A = 1'b1;
29      B = 1'b1;
30
31     #10 ;//timestamp to wait 35ns
32    end
33  endmodule
```

Ignore timestamp comments

Waveform: