1. a. $t_{pd} = 100$ ps $t_{ccg} = 50$ ps $t_c \geq t_{pcg} + 3t_{pd} + t_{setup}$

$t_{cd} = 55$ps $t_{pcg} = 70$ps $= 70 + 300 + 60 = 430$

$t_{setup} = 60$ps

$t_{hold} = 20$ps

max frequency $= \frac{1}{430\text{ps}} = 2.33$ GHz

b. $T_c = \frac{1}{2\text{GHz}} = 500$ps $T_c \geq t_{pcg} + 3t_{pd} + t_{setup} + t_{skew}$

$500 \geq 70 + 300 + 60 + t_{skew}$

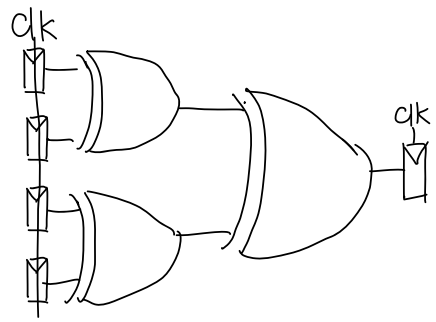
$t_{skew} \leq 70$ps it can tolerate 70 ps

c. $t_{skew} \leq t_{ccg} + t_{cd} - t_{hold}$

$= 50 + 55 - 20 = 85$ps

it can tolerate 85 ps

d.



$t_c \geq t_{pcg} + 2t_{pd} + t_{setup}$

$= 70 + 200 + 60 = 330$ps

max frequency $= \frac{1}{330\text{ps}} = 3.03$ GHz

$t_{ccg} + t_{cd} \geq t_{hold} + t_{skew}$

$t_{skew} \leq t_{ccg} + t_{cd} - t_{hold}$

$t_{skew} \leq 50\text{ps} + 110\text{ps} - 20\text{ps} = 140$

it can tolerate 140 ps

2. a. $T_c = \frac{1}{1\text{GHz}} = 1$ns $T = 100$ps

$T_0 = 110$ ps $t_{setup} = 70$ps

$N = 0.5$

$MTBF = \frac{1}{P(\text{failure/sec})} = 50 \text{ years} = 1.6 \times 10^9$

$P(\text{failure/sec}) = 6.25 \times 10^{-10}$

$P(\text{failuer}) = \frac{P(\text{failure/second})}{N} = \frac{6.25 \times 10^{-10}}{0.5} = 12.5 \times 10^{-10}$

b. waiting time for one clock cycle

$P(\text{failure/sec}) = 0.5 \times \frac{110 \text{ ps}}{1000 \text{ ps}} \cdot e^{-\frac{930}{100}} = 5.03 \times 10^{-6}$

waiting time for two clock cycle

$P(\text{failure/sec}) = 0.5 \times \frac{110 \text{ ps}}{1000 \text{ ps}} (e^{-\frac{930}{100}})^2 = 4.6 \times 10^{-10}$

you need to wait 2 clock cycle before reading the sampled input

3a. $e^{-\frac{t}{20}} = 0.01$

$-\frac{t}{20} = \ln 0.99$

$t = 92 \text{ seconds}$

b. $t = 180 \text{ seconds}$

$e^{-\frac{180}{20}} = 1.23 \times 10^{-2}$

probability $= 0.0123\%$

4. Ben is wrong

if there is a normal transition on D. D_2 will also have transition and enter the forbidden zone. Then it will be reset to zero.

also since the reset is async, if reset at the clock edge, it will cause second FF goes into metastability