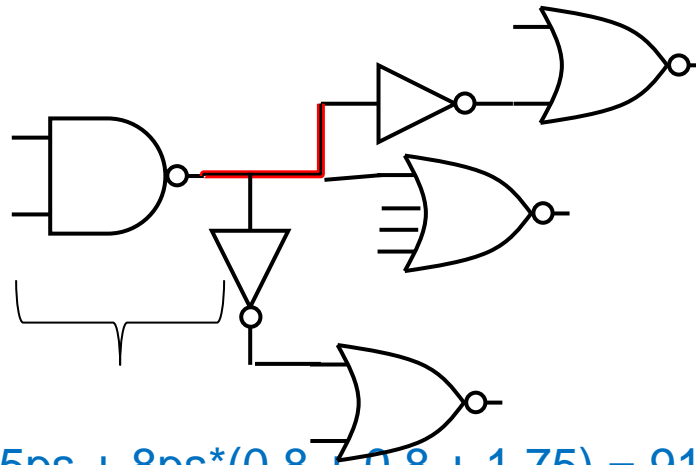1 – Given the gate information below, calculate the t_{pd} for the 2 input nand gate

** we are assuming interconnect capacitance is negligible   30pts

Gate	INV	2-NAND	2-NOR	4-NAND	4-NOR
Input load factor	0.8	1.0	1.0	1.75	1.75
Fixed delay factor	50ps	65ps	65ps	80ps	80ps
Variable delay factor	5ps	8ps	8ps	12ps	12ps

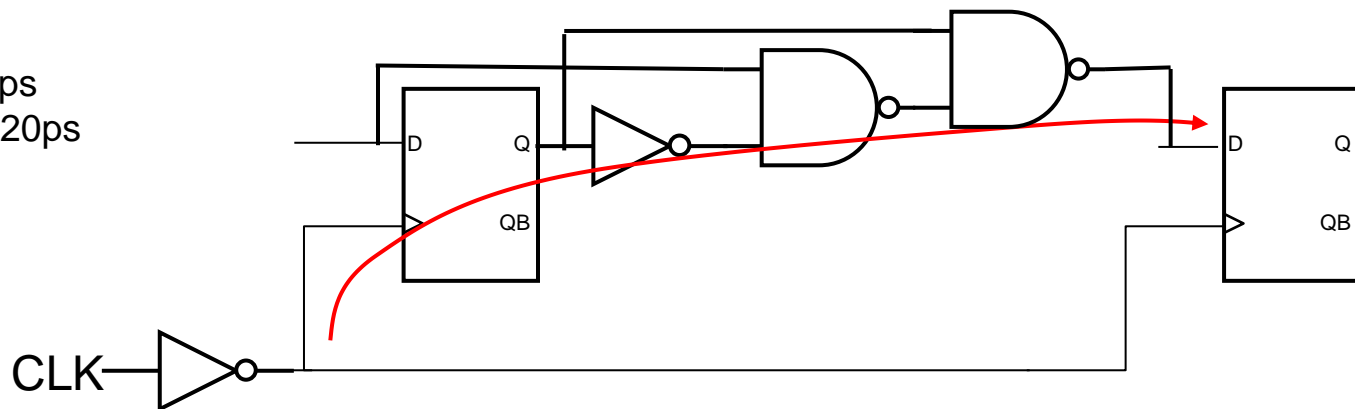$$t_{pd} = t_{fixed} + t_{variable\_factor} * \text{Load Equivalents}$$

$$t_{pd} = 65ps + 8ps*(0.8 + 0.8 + 1.75) = 91.8ps^{**}$$

2 – Calculate the fastest possible clock frequency   30pts

t_{PD} INV = 15ps
t_{PD} NAND = 20ps
t_{CQ} = 25ps
t_{setup} = 5ps
t_{hold} = 2ps

CLK

critical path = t_{CQ} + T_{inv} + T_{nand} + T_{nand} + T_{SU}
        = 25ps + 15ps + 20ps + 20ps + 5ps = 85ps

→ F max = 1/85ps = 0.0117THz = 11.7GHz

3 – You are designing a new system that can operate at 1.2V, 2.4V or 3.3V with one-time programmable clock frequencies of 50% max, 75% max and 100% max. The system has 2 operating tasks. Task 1 requires 10M clk cycles and must execute every 100ms. Task 2 requires 25M clk cycles and must execute every second. The system has the following characteristics.

VDD	Max Clk freq	I_{Idle}	I_{Active}
1.2V	120MHz	10uA	1pA/clk
2.4V	180MHz	20uA	3pA/clk
3.3V	240MHz	40uA	6pA/clk

Determine the optimal operating conditions with respect to total power   40pts

VDD	Max CLK	I idle	I active	Prog CLK	Required	idle time	Idle cur	active cur	total cur	power
1.2	120.0E+6	100.0E-6	1.0E-12	120.0E+6	125.0E+6	-4.2%	-4.2E-6	125.0E-6	120.8E-6	145.0E-6
1.2	120.0E+6	100.0E-6	1.0E-12	90.0E+6	125.0E+6	-38.9%	-38.9E-6	125.0E-6	86.1E-6	103.3E-6
1.2	120.0E+6	100.0E-6	1.0E-12	60.0E+6	125.0E+6	-108.3%	-108.3E-6	125.0E-6	16.7E-6	20.0E-6
2.4	180.0E+6	200.0E-6	3.0E-12	180.0E+6	125.0E+6	30.6%	61.1E-6	375.0E-6	436.1E-6	1.0E-3
2.4	180.0E+6	200.0E-6	3.0E-12	135.0E+6	125.0E+6	7.4%	14.8E-6	375.0E-6	389.8E-6	935.6E-6
2.4	180.0E+6	200.0E-6	3.0E-12	90.0E+6	125.0E+6	-38.9%	-77.8E-6	375.0E-6	297.2E-6	713.3E-6
3.3	240.0E+6	400.0E-6	6.0E-12	240.0E+6	125.0E+6	47.9%	191.7E-6	750.0E-6	941.7E-6	3.1E-3
3.3	240.0E+6	400.0E-6	6.0E-12	180.0E+6	125.0E+6	30.6%	122.2E-6	750.0E-6	872.2E-6	2.9E-3
3.3	240.0E+6	400.0E-6	6.0E-12	120.0E+6	125.0E+6	-4.2%	-16.7E-6	750.0E-6	733.3E-6	2.4E-3