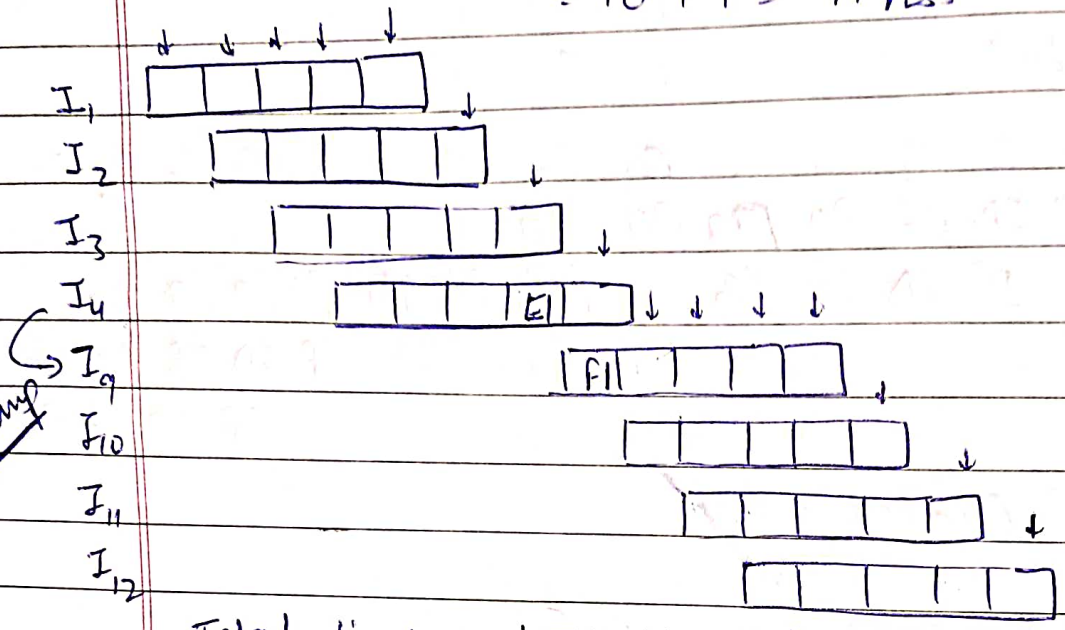
①

Clock cycle time = slowest stage + buffer
= 10 + 1 = 11 ns.



Total time = 15 × 11 = 165 ns.

②

$S_1 = 5$ ns $S_3 = 11$ ns Buffer = 1 ns.
$S_2 = 6$ ns $S_4 = 8$ ns

Clock cycle time = 11 + 1 = 12 ns

T_{seq} (normal execution) = 5 + 6 + 11 + 8
= 30 ns

For N ins. $T_{seq} = 30N$
" " " $T_p = (4 + N - 1) \times 12$
$(\because (k + (N-1)))$

$\therefore$ speedup = $\frac{T_{seq}}{T_p}$

$= \frac{30N}{[4 + (N-1)]12} = \frac{30N}{[N+3]\cdot 12}$

Assume $N >>> 3$

$\approx \frac{30N}{12N} = 2.5$

IF ID OF PO WO

(3) ADD 1 1 1 1 1

SUB 1 1 1 1 1

MUL 1 1 1 3 1

DIV 1 1 1 6 1

C_1 C_2 C_3 C_4 C_5 C_6 C_7 C_8 C_9 C_{10} C_{11} C_{12} C_{13} C_{14} C_{15}

I_0 IF ID OF PO PO PO WO

IF ID OF PO PO PO PO PO PO WO

IF ID OF PO WO

IF ID OF PO WO

Cycles = 15

C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}
S1	S1	S2	S3	S4																		
		S1	S2	S2	S2	S3	S3	S4	S4													
			S1	S1		S2		S3		S4	S4	S4										
					S1		S2	S2	S3	S3			S4	S4								
						S1	S1		S2	S	S3				S4							
								S1		S2	S2	S2	S3	S3	S	S4	S4					
									S1	S1			S2		S3			S4	S4	S4		
											S1			S2	S2	S3	S3				S4	S4

∴ Cycles needed = 23

(5)

	1	2	3	4	5	6	7	8
I_0	If	ID	EX	WB				
I_1		If	ID	EX	EX	EX	WB	
						If	ID	EX	WB

8 clock cycles.

(6)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	If	OF	PO	PO	PO	WB							
2		If		OF	PO	PO	PO	PO	PO	WB			
3			If				OF	PO	WB				
4				If				OF	PO	WB			

Cycles = 13