4/13 假设所有指令为执行阶段时间只有一个周期

2. ① 在严格顺序执行流水线中：

$I_5 - I_3$: RAW

$I_5 - I_4$: RAW

$I_3 - I_2$: RAW

② 可以乱序：

$I_1 - I_3$: WAW

$I_1 - I_5$: RAW

$I_2 - I_4$: WAR

$I_2 - I_3$: RAW

$I_2 - I_5$: RAW

$I_2 - I_4$: WAW

$I_3 - I_4$: WAR

$I_3 - I_5$: RAW

$I_4 - I_5$: RAW

$I_5 - I_6$: RAW

$D_1 = \{s_1\}$, $R_1 = \{a_1\}$

$D_2 = \{a_0, a_2\}$, $R_2 = \{a_2\}$

$D_3 = \{a_2\}$, $R_3 = \{a_1\}$

$D_4 = \{s_2\}$, $R_4 = \{a_2\}$

$D_5 = \{a_1, a_2\}$, $R_5 = \{a_3\}$

$D_6 = \{s_3, a_3$

4/1). $S = \frac{t_A}{t_B} = \frac{T_{A\,cycle} \cdot N_{A\,cycle}}{T_{B\,cycle} \cdot N_{B\,cycle}}$

$= \frac{T_{A\,cycle} \cdot CPI_A \cdot N_{IA}}{T_{B\,cycle} \cdot CPI_B \cdot N_{IB}}$

$(N_{IA} = N_{IB}) \quad = \frac{Ins \cdot \frac{N + 1.4 + \frac{N}{2}}{N}}{0.6Ns \cdot \frac{N + 1.1 + \frac{3N}{8}}{N}} \quad (N \to +\infty)$

$= \frac{1.5}{1}$

2). $CPI_A = \frac{0.8N \times \frac{0.8N + \psi + \frac{0.8N}{2}}{0.8N} + 0.2N \times \frac{0.2 \times (0.2N + \psi + \frac{0.2N}{2}) + 0.2 \times (2 + 0.2N + \psi + \frac{0.2N}{2})}{0.2N}}{N}$

$= \frac{3.1}{N} + 1.2$ (N为指令总数)

$CPI_B = \frac{3.5}{N} + \frac{11}{8}$

6.1). $D_1 = \{a_2\}$, $R_1 = \{a_1\}$

$D_2 = \{a_1\}$, $R_2 = \{a_1\}$

$D_3 = \{a_2, a_1\}$

$D_4 = \{a_2\}$, $R_4 = \{a_2\}$

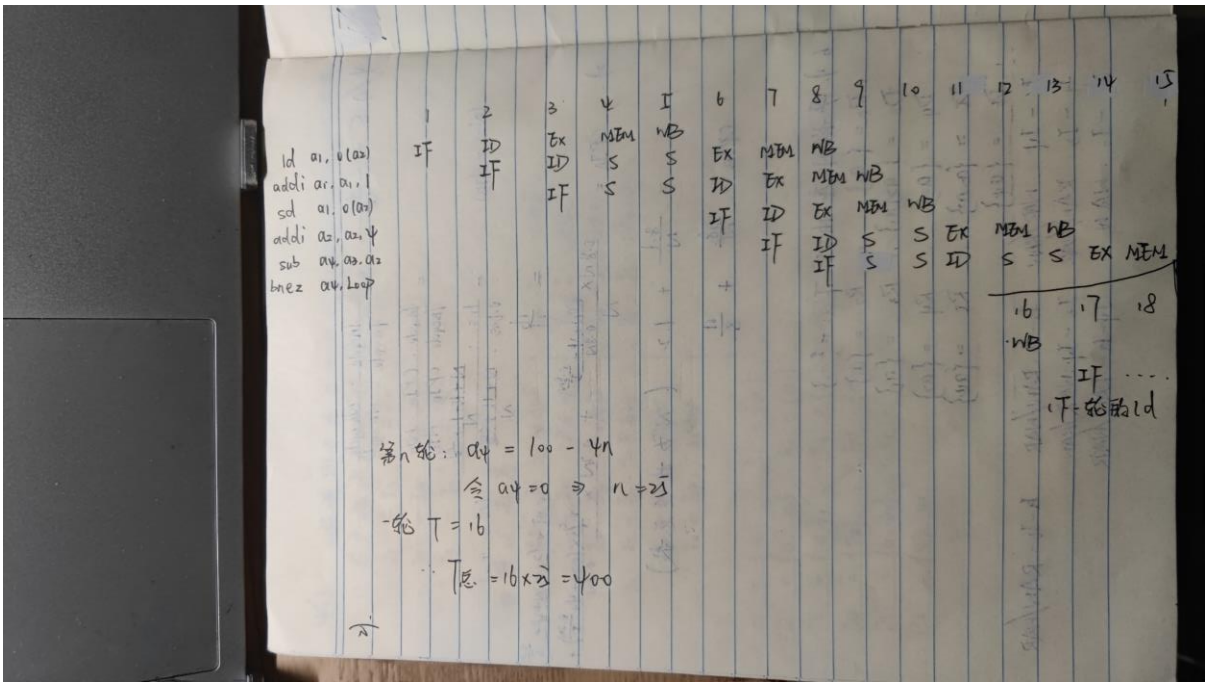
$D_5 = \{a_2, a_3\}$, $R_5 = \{a_4\}$

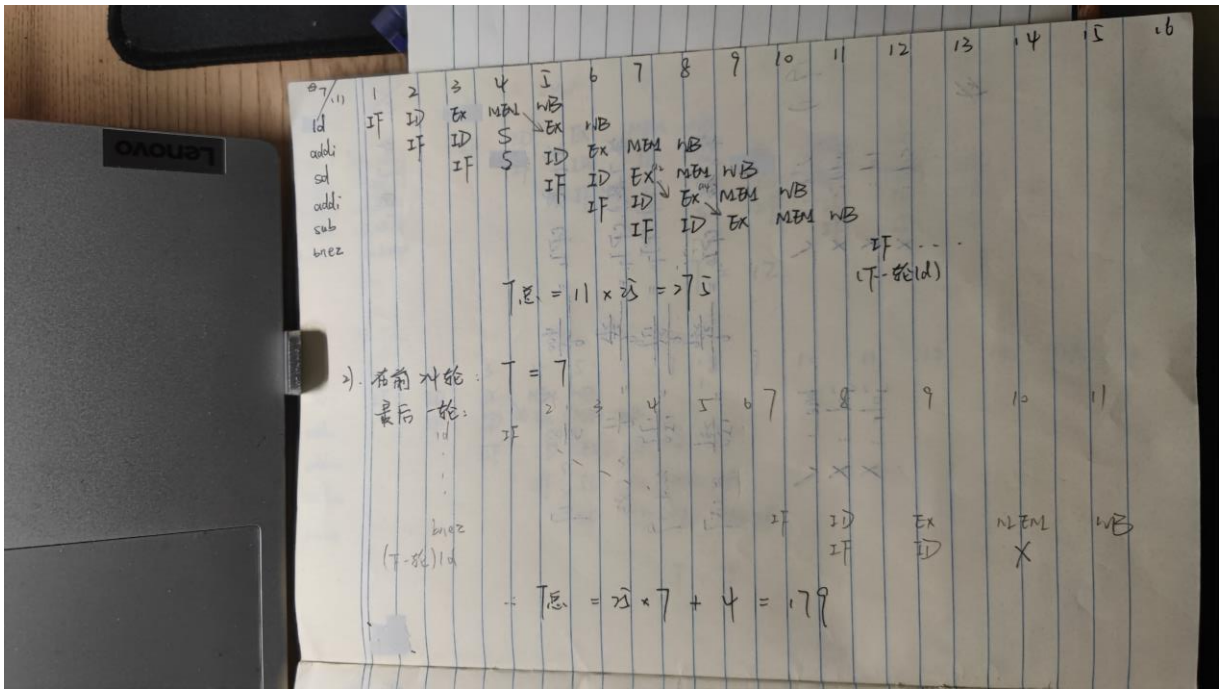
$D_6 = \{a_4\}$

$I_1 - I_4$: WAR/RAW $I_2 - I_3$: RAW/WAR $I_5 - I_6$: RAW/WAR

$I_1 - I_3$: RAW/WAR $I_3 - I_4$: WAR/RAW

$I_1 - I_2$: WAW $I_4 - I_5$: RAW/WAR


ld a1, 0(a2)
addi a2, a2, 1
sd a1, 0(a2)
addi a3, a3, -1
sub a4, a3, a2
bnez a4, Loop
IF ID EX MEM WB
第n轮: a4 = 100 - 4n
令 a4 = 0 ⇒ n = 25
一轮 T = 16
T总 = 16 × 25 = 400


ld
addi
sd
addi
sub
bnez
IF ID EX MEM WB
T总 = 11 × 25 = 275
2). 若前N轮: T = 7
最后一轮:
T总 = 25 × 7 + 4 = 179

8.1. 如下图：

2). 第6题 $CPI_6 = \frac{400}{\frac{300}{6}} = \frac{8}{3} \approx 2.67$

第7题1). $CPI_{71} = \frac{\frac{275}{6}}{\frac{150}{6}} = \frac{11}{6} \approx 1.83$

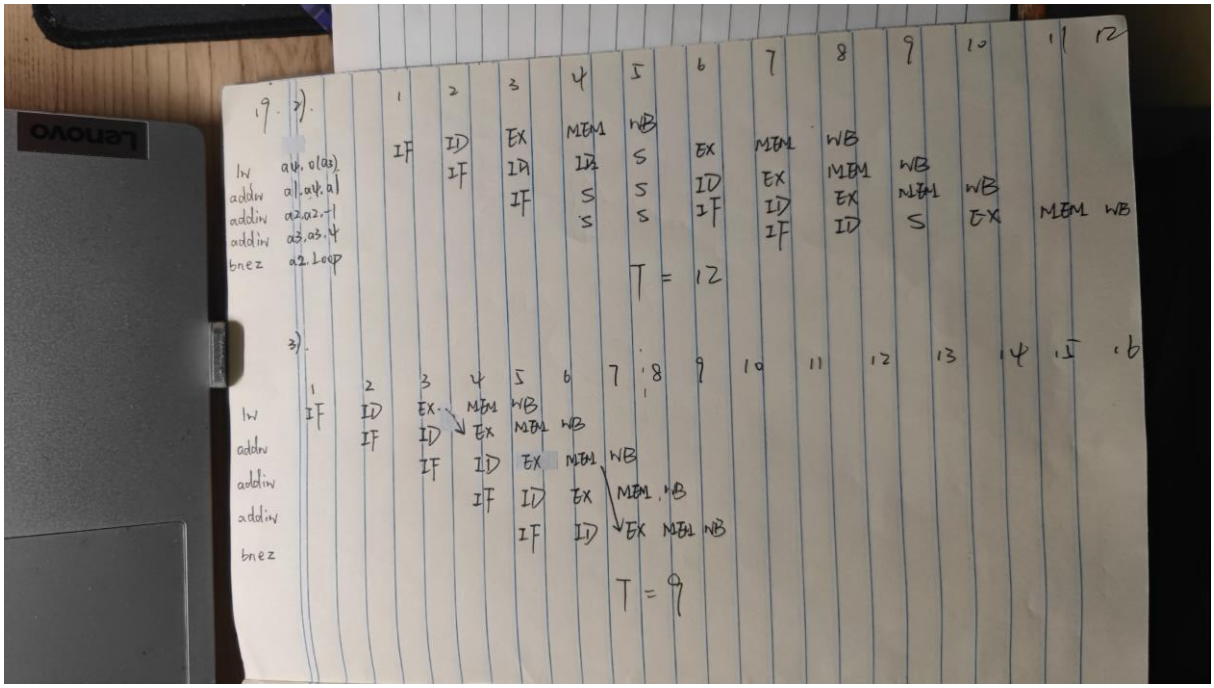
2). $CPI_{72} = \frac{\frac{179}{6}}{\frac{150}{6}} = \frac{179}{150} \approx 1.19$

第8题：$CPI_8 = \frac{\frac{236}{6}}{\frac{150}{6}} = \frac{236}{150} \approx 1.57$

19.1).

add：	✓	bne：	✓
addi：	X	jal：	X
ld：	X	jalr：	X
sd：	X		

✓


2).
lw a4, 0(a3)
addiw a1, a4, a1
addiw a2, a2, -1
addiw a3, a3, 4
bnez a2, Loop
IF ID EX MEM WB
IF ID EX MEM WB
IF ID EX MEM WB
IF ID EX MEM WB
T = 12
3).
lw
addw
addiw
addiw
bnez
T = 9