

4.4

1. (1) T_{pipe} 为最长延时 $\therefore T_{\text{pipe}} = 2\text{ns} + 0.1\text{ns} = 2.1\text{ns}$
流水化后时钟周期为 2.1ns

$$(2) S = \frac{T_{\text{pipe}}}{T_{\text{cycle}}} \times \frac{\text{CPI}_{\text{pipe}}}{\text{CPI}_{\text{cycle}}} \approx \frac{2.1\text{ns}}{1\text{ns}} = \frac{3}{10}$$

加速比 $S = \frac{3}{10}$

(3) 设有 k 个流水级, 则 k 足够大,

可近似为均匀分割, $\therefore T_{\text{pipe}} = \frac{T_{\text{cycle}}}{k} + 0.1\text{ns}$

$$S \approx \frac{T_{\text{cycle}}}{T_{\text{pipe}}} = \frac{1}{\frac{1}{k} + \frac{0.1}{T_{\text{cycle}}}}$$

$$\lim_{k \rightarrow \infty} S = \frac{0.1\text{ns}}{0.7\text{ns}} = \frac{1}{7}$$

4.11

02.	I1	I2	I3	I4	I5	I6
I1	—					
I2	无	—				
I3	RAW	RAW	—			
I4	无	WAW	WAR	—		
I5	RAW	RAW	RAW	RAW	—	
I6	无	无	无	无	WAR	—

4. (1) 加速比 $S = \frac{T_A}{T_B} = \frac{CPI_A \times T_{CA}}{CPI_B \times T_{CB}}$

$T_{CA} = 1ns$ $T_{CB} = 0.6ns$

$CPI_A = 5 + 1 \times \frac{5}{5} = 6$

$CPI_B = 12 + \frac{12}{8} \times 3 = 16.5$

$\therefore S = \frac{6 \times 1}{16.5 \times 0.6} \approx 0.61$

(2) ~~CPI~~ A: $CPI = 5 + 1 \times \frac{5}{5} + 1.5 \times 20\% \times 5\% \times 2 = 6.1$

B: $CPI = 12 + \frac{12}{8} \times 3 + \frac{12}{8} \times 20\% \times 5\% \times 5 = 17.1$

6. (1) 可能出现 RAW、WAW、WAR 类型的数据冲突

RAW 体现在 $ld\ a1, 0(a2)$ 与 $sd\ a1, a1, 1$ 等间

WAW 体现在 $addi\ a1, a1, 1$ 与 $sd\ a1, 0(a2)$ 等间

WAR 体现在 $sd\ a1, 0(a2)$ 与 $addi\ a2, a2, 4$ 等间

(2) 解:

	1	2	3	4	5	6	7	8	9	10	11	12	13
$ld\ a1, 0(a2)$	IF	ID	EX	MEM	WB								
$addi\ a1, a1, 1$		IF	ID	S	S	EX	MEM	WB					
$sd\ a1, 0(a2)$			IF	ID	S	S	S	S	EX	MEM	WB		
$addi\ a2, a2, 4$				IF	ID	EX	MEM	WB					
$sub\ a4, a3, a2$					IF	ID	S	S	EX	MEM	WB		
$bnez\ a4, loop$						IF	ID	S	S	S	S	EX	MEM

需要 13 个周期

7. (1)	1	2	3	4	5	6	7	8	9
ld a1, 0(a2)	IF	ID	EX	MEM	WB				
addi a1, a1, 1		IF	ID	S	EX	MEM	WB		
sd a1, 0(a2)			IF	ID	EX	MEM	WB		
addi a2, a2, 4				IF	ID	EX	MEM	WB	
sub a4, a3, a2					IF	ID	EX	MEM	WB
bnez a4, loop						IF	ID	EX	MEM

共 9 个周期

(2)	1	2	3	4	5	6	7
ld a1, 0(a2)	IF	ID	EX	MEM	WB		
addi a1, a1, 1	IF	ID	S	EX	S	EX	MEM WB
sd a1, 0(a2)	IF	ID	EX		S	S	MEM
addi a2, a2, 4	IF	ID	EX		MEM	WB	
sub a4, a3, a2	IF	ID	S		EX	MEM	WB
bnez a4, Loop	IF	ID	S		S	EX	MEM

(在IF级有预测跳转位置的分支)

8. (1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ld a1, 0(a2)	IF1	IF2	ID1	ID2	EX1	EX2	MEM1	M2	WB1	WB2				
addi a1, a1, 1		IF1	IF2	ID1	ID2	S	S	S	EX1	EX2	WB1	WB2		
sd a1, 0(a2)			IF1	IF2	ID1	ID2	EX1	EX2	S	S	S	S	WB1	WB2
addi a2, a2, 4				IF1	IF2	ID1	ID2	EX1	EX2	M1	M2	WB1	WB2	
sub a4, a3, a2					IF1	IF2	ID1	ID2	S	EX1	EX2	M1	M2	WB1
bnez a4, loop						IF1	IF2	ID1	ID2	S	S	EX1	EX2	M1

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(接上表)

WB2

共 15 个周期

M2

(2) ① 题 6: $CPI = \frac{13}{6} \approx 2.167$

② 题 7: $CPI_1 = \frac{9}{6} = 1.5$

$CPI_2 = \frac{7}{6} \approx 1.167$

③ 题 8: $CPI = \frac{15}{6} = 2.5$

19. (1) add addi ld sd bne jal jalr
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(2)	1	2	3	4	5	6	7	8	9
lw a4, 0(a3)	IF	ID	EX	MEM	WB				
addw a1, a4, a1		IF	ID1	ID2	S	EX	MEM	WB	
addiw a2, a2, 1			IF	ID	EX	MEM	WB		
addiw a3, a3, 4				IF	ID	EX	MEM	WB	
bnez a2, Loop					IF	ID	S	EX	MEM

需9个周期

(3)	1	2	3	4	5	6	7	8
lw	IF	ID	EX	MEM	WB			
addw		IF	ID	EX	MEM	WB		
addiw			IF	ID	EX	MEM	WB	
addiw				IF	ID	EX	MEM	WB
bnez					IF	ID	EX	MEM

需8个周期