$T_{4.21}$ (1) $\dfrac{250 \times (1+0.4)n}{300 \times (1+0.05)n} = 1.11$

(2) 带旁路

$300 \times (1+y) \cdot n < 250 \times 1.4n$

得 $y < 16.7\%$

(3) $300 \times (1+y)n < 250 \times (1+x)n$

得 $y < \dfrac{5x-1}{6}$

(4) 不能,

$300 \times (1+0.075)n > 300 \times (1+0.05)n$

(5) $\dfrac{5x-1}{6} > 0$

得 $x > 0.2$

$T_{4.25}$ (1)

```
IF  ID  EX  ME  WB
    IF  ID  EX  ME   WB
        IF  ID  stall  EX  ME!  WB
            IF  stall  ID  EX  ME!  WB
                stall  IF  ID  EX  ME!  WB! (loop)
                    IF  ID  EX  ME  WB
                        IF  ID  stall  EX  ME!  WB
                            IF  stall  ID  EX  ME!  WB!
```

(2) 做无用功: 含 stall 及没有起作用的周期

T 4.31

(1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
li x12,0	IF	ID	EX	ME	WB																							
jal ENT		IF	ID	••	EX	ME	WB																					
bne x12,x13,Top				IF	``	ID	EX	ME	WB																			
slli x5,x12,3				IF	``	ID	``	EX	ME	WB																		
add x6,x10,x5					IF	``	ID	EX	ME	WB																		
ld x7,0(x6)					IF	``	ID	``	``	EX	ME	WB																
ld x29,08(x6)						IF	``	``	ID	EX	ME	WB																
sub x30,x7,x29						IF	``	``	ID	``	EX	ME	WB															
add x31,x11,x5								IF	``	ID	EX	ME	WB															
sd x30,0(x31)								IF	``	ID	``	EX	ME	WB														
addi x12,x12,2										IF	``	ID	EX	ME	WB													
bne x12,x13,Top										IF	``	ID	``	EX	ME	WB												
slli x5,x12,3												IF	``	ID	EX	ME	WB											
add x6,x10,x5												IF	``	ID	``	EX	ME	WB										
ld x7,0(x6)													IF	``	ID	``	EX	ME	WB									
ld x29 08(x6)													IF	``	ID	``	``	EX	ME	WB								
sub x30,x7,x29															IF	``	ID	``	EX	ME	WB							
add x31,x11,x5															IF	``	ID	``	``	EX	ME	WB						
sd x30,0(x31)																	IF	``	``	ID	EX	ME	WB					
addi x12,x12,2																	IF	``	``	ID	``	EX	ME	WB				
bne x12,x13,Top																			IF	``	ID	EX	ME	WB				
slli x5,x12,3																			IF	``	ID	``	EX	ME	WB			

(2) 加速比: (26−6)/2 = 10

(3)

```
      beqz x13, DONE
      li x12,0
      jal ENT
TOP:
      slli x5,x12,3
      add x6,x10,x5
      ld x7,0(x6)
      ld x29,8(x6)
      addi x12,x12,2
      sub x30,x7,x29
      add x31,x11,x5
      sd x30,0(x31)
ENT:
      bne x12,x13,TOP
DONE:
```

(4)

```
      beqz x13, DONE
      li x12,0
TOP:
      slli x5,x12,3
      add x6,x10,x5
      ld x7,0(x6)
      add x31,x11,x5
      ld x29,8(x6)
      addi x12,x12,2
      sub x30,x7,x29
      sd x30,0(x31)
      bne x12,x13,TOP
DONE:
```

(5)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
beqz x13, DONE	IF	ID	EX	ME	WB																		
li x12, 0	IF	ID	··	EX	ME	WB																	
slli x5, x12, 3		IF	··	ID	EX	ME	WB																
add x6, x10, x5		IF	··	ID	··	EX	ME	WB															
ld x7, 0(x6)			IF	··	ID	EX	ME	WB															
add x31, x11, x5			IF	··	ID	EX	ME	WB															
ld x29, 8(x6)				IF	ID	EX	ME	WB															
addi x12, x12, 2				IF	ID	EX	ME	WB															
sub x30, x7, x29					IF	··	··	ID	EX	ME	WB												
sd x30, 0(x31)					IF	··	··	ID	··	EX	ME	WB											
bne x12, x13, TOP								IF	··	ID	EX	ME	WB										
slli x5, x12, 3								IF	··	ID	··	EX	ME	WB									
add x6, x10, x5										IF	··	ID	EX	ME	WB								
ld x7, 0(x6)										IF	··	ID	EX	ME	WB								
add x31, x11, x5												IF	ID	EX	ME	WB							
ld x29, 8(x6)												IF	ID	··	EX	ME	WB						
addi x12, x12, 2													IF	ID	EX	ME	WB						
sub x30, x7, x29													IF	ID	··	EX	ME	WB					
sd x30, 0(x31)														IF	··	··	ID	EX	ME	WB			
bne x12, x13, TOP														IF	··	··	ID	EX	ME	WB			
slli x5, x12, 3																	IF	ID	EX	ME	WB		
add x6, x10, x5																	IF	ID	···	EX	ME	WB	✓

(6) 加速比: 为 1.2

(7) beqz x13, DONE
     li x12, 0
     TOP:
         slli x5, x12, 3
         add x6, x10, x5
         add x31, x11, x5
         ld x7, 0(x6)
         ld x29, 8(x6)
         ld x5, 16(x6)
         ld x15, 24(x6)
     addi x12, x12, 4
     sub x30, x7, x29
     sub x14, x5, x15
     sd x30, 0(x31)
     sd x14, 16(x31)
     bne x12, x13, TOP
     DONE:

(8) beqz x13, DONE
     li x12, 0
     addi x6, x10, 0
     TOP:
         ld x7, 0(x6)
         add x31, x11, x5
         ld x29, 8(x6)
         addi x12, x12, 4
         ld x16, 16(x6)
         sub x30, x7, x29
         sd x30, 0(x31)
         sub x14, x16, x15
         sd x14, 16(x31)
         add x6, x10, x5
         bne x12, x13, TOP
     DONE:

(9) 加速比为 1.73

(10) 与 4.31.8 相比：无阻塞/结构冒险

T 4.32   (1) 消耗均为: 140 + 2×70 + 60 = 340 pJ
         (2) 取指令
                14 + 2×70 + 60 + 140 = 480 pJ
         (3) 70/48 = 14.6%

         (4) 还有 jal 跳转

         (5) 使 ID 的延迟增加

         (6)