Solutions of the practice final

- 1. solution -> drawback
- (a) increase cache size drawback -> increase cache access time
- (b) Loop unrolling with compiler -> increase code size
- (c) Hierarchical CLA -> More hardware
- (d) reduce register field -> more register spilling
- (e) pipeline -> more hardware
- 2. a. 22 cycle: 4 (to fill pipeline) + 7 (#instruction) + 8 (stall by data hazard) + 3 (control hazard)
- b. 18 cycles: 4 + 7 + 4(stall by data hazard) + 3 (control hazard)
- 3. Miss, Miss, Miss, Miss, Hit, Miss, Hit, Miss
 Compulsory, Compulsory, Compulsory, Conflict, Conflict
- 4. a. Physical Memory size / page size = $2^30 / 2^15 = 2^15$
- b. page table size = #entry * the size of an entry = $2^17 \times 2B = 2^18$ Bytes #entry = 2^17 (size of VPN)
 - the size of an entry = the size of PPN + 1 (the extra bit) = 30-15+1 = 15+1 (bit) = 2 Bytes
- c. #entry in TLB / total #page table = $64 * 8 / 2^17 = 2^9 / 2^17 = 1 / 2^8 = 1 / 2^6$
- d. TLB has 64 sets, so 6 bit needed for the index. The 15 right most bits are used for page offset.

 So, the six bits are: bit 20 ~ bit 15

Nop	LW \$to			
Nop	Nop			
ADDI	Lw \$+1			
BNE_	Nop			
[400	NOP			
N/a P	5W			
NOP	NOR			

NOP	IN \$+0,0(\$50)
Nop	LW \$18,4 (\$50)
NOP	LW \$+1
ADDI 8	LW \$+9_
ADD \$+1	Nop
BNE	5w \$+1
POD \$ 49	NOP
NOP	5 w \$+9

6. (a) the prediction of 1K-entry predictor

PC	Branch	1K index	State		Dundistion
	outcome	TK Index	Current	Next	Prediction
128	Т	128	00	01	NT
640	NT	640	00	00	NT
1152	NT	128	01	00	NT
128	Т	128	00	01	NT
640	Т	640	00	01	NT
1152	NT	128	01	00	NT
128	Т	128	00	01	NT
640	NT	640	01	00	NT
1152	NT	128	01	00	NT
128	Т	128	00	01	NT
640	Т	640	00	01	NT
1152	NT	128	01	00	NT

(b) the prediction of 512-entry predictor

PC	Branch	512	State		Dradiation	
PC	outcome	index	Current	Next	Prediction	
128	Т	128	00	01	NT	
640	NT	128	01	00	NT	
1152	NT	128	00	00	NT	
128	Т	128	00	01	NT	
640	Т	128	01	11	NT	
1152	NT	128	11	10	Т	
128	Т	128	10	11	Т	
640	NT	128	11	10	Т	
1152	NT	128	10	00	Т	
128	Т	128	00	01	NT	
640	Т	128	01	11	NT	
1152	NT	128	11	10	Т	

(c) the prediction of 768-entry predictor

DC	Branch	768	State		Dradiation	
PC	outcome	index	Current	Next	Prediction	
128	Т	128	00	01	NT	
640	NT	640	00	00	NT	
1152	NT	384	00	00	NT	
128	Т	128	01	11	NT	
640	Т	640	00	01	NT	
1152	NT	384	00	00	NT	
128	Т	128	11	11	Т	
640	NT	640	01	00	NT	
1152	NT	384	00	00	NT	
128	Т	128	11	11	Т	
640	Т	640	00	01	NT	
1152	NT	384	00	00	NT	

Answer

PC	Branch	Prediction				Correct?	
PC	outcome	1K entry	512 entry	768 entry	Final	Correct?	
128	T	NT	NT	NT	NT	N	
640	NT	NT	NT	NT	NT	Υ	
1152	NT	NT	NT	NT	NT	Υ	
128	T	NT	NT	NT	NT	N	
640	T	NT	NT	NT	NT	Ν	
1152	NT	NT	T	NT	NT	Υ	
128	Т	NT	Т	Т	Т	Υ	
640	NT	NT	Т	NT	NT	Υ	
1152	NT	NT	Т	NT	NT	Υ	
128	Т	NT	NT	Т	NT	Ν	
640	Т	NT	NT	NT	NT	N	
1152	NT	NT	Т	NT	NT	Υ	

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7.
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a. TCPI = BCPI + MCPI = 3.725

BCPI = Peak CPI(=1) + Data Hazard CPI (DHCPI) + Control Hazard CPI (CHCPI) = 1+ 0.075 + 0.1

DHCPI = 0.3 x 0.25 x 1 = 0.075

CHCPI = 0.15 x 1/3 x 2 = 0.1

So, BCPI = 1 + DHCPI + CHCPI = 1.175

MCPI = I\$CPI + D\$CPI = 1.5 + 1.05 = 2.55

I\$CPI = 0.1 x (10 + 0.05 x 100) = 1.5

b. Wrong, lw -> lw dependency will stall cause a stall since the result of EX (ALU) is used as input address of Data memory.

c. Right, it removes all stall by data hazard. (But, control hazard still exists.)

 DCPI = (0.1 + 0.25) \times 0.2 \times (10 + 0.05 \times 100) = 1.05$

d. data hazard: the distance is 1 cycle-> 3 stalls, 2 cycle -> 2 stalls, 3 cycle -> 1 stall control hazard: bench penalty is 4 cycle

BCPI = Peak CPI + DHCPI + CHCPI =
$$1 + 0.375 + 0.2 = 1.575$$

DHCPI = $0.25 \times (\mathbf{0.3 \times 3 + 0.2 \times 2 + 0.2 \times 1}) = 0.25 \times (0.9 + 0.4 + 0.2) = 0.375$
CHCPI = $0.15 \times 1/3 \times 4 = \mathbf{0.2}$

MCPI => cycle time is half -> miss penalty in cycle is doubled

Since memory access "time" is not changed, halved cycle time takes twice number of cycles to reach the same access time.

MCPI = I\$CPI + D\$CPI =
$$3 + 2.1 = 5.1$$

I\$CPI = $0.1 \times (20 + 0.05 \times 200) = 3$
D\$CPI = $(0.1 + 0.25) \times 0.2 \times (20 + 0.05 \times 200) = 2.1$
TCPI = $1.575 + 5.1 = 6.675$

e. ET = IC x CPI x CT =
$$10^6$$
 x 6.675 x 100 ps
= 10^6 x 6.675 x 1 x 10^-12 sec = 6.675 x 10^-4 sec
cf. the ET of baseline (5 stage) = 10^6 x 3.725 x 200 ps = 7.45 x 10^-4 sec