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Homework

5.3.1 - Cache block size (in words)

5 offset bits → block size of 2^5 bytes = 32 bytes

32 bits per word → 4 bytes per word

32 bytes → $\boxed{\text{8 words per block}}$

5.3.2 - # entries in the cache?

Direct-mapped cache

5 index bits

2^5 entries = $\boxed{\text{32 entries}}$

5.3.4

Tag [31-10]	Index [9-5]	Offset [4-0]		
0	00000	00000	0	Miss/put in
0	00000	00100	4	Hit
0	00000	10000	16	Hit
0	00100	00100	132	Miss/put in
0	00111	01000	232	Miss/put in
0	00101	00000	160	Miss/put in
1	00000	00000	1024	Miss/replace 0 tag
0	00000	11110	30	Miss/replace 1 tag
0	00100	01100	140	Hit
11	00000	11100	3100	Miss/replace 0 tag
0	00101	10100	180	Hit
10	00100	00100	2180	Miss/replace 0 tag

$\boxed{\text{4 blocks replaced}}$

5.3.5

Hit ratio = $\frac{\text{4 hits}}{\text{12 instr}}$ = $\boxed{33.3\%}$

5.5.1

Cache holds 64x1024 bytes.
Cache block size is 32 bytes/block
Block count: $\frac{64 \times 1024}{32} = 2048$ blocks

Byte 0 gets accessed
↳ miss, pull in 32 bytes (bytes 0-31)
This is direct-mapped, so put into block 0

$\underbrace{\text{4 hits, 8 hits, 12 hits, 16 hits, 20 hits, 24 hits, 28 hits}}_{\text{7 hits (one miss for 0)}}$

Block 32 gets accessed (pull into cache)
Trend continues → 7 hits, 1 miss
Miss rate of $\frac{1}{8} = \boxed{12.5\%}$

Miss rate is insensitive to size of the cache and the size of the working set (as long as it has sufficiently large input to see this trend). Miss rate is only affected by the line size. Misses in this case are compulsory. It's the first time we see data for these blocks, so of course we miss and have to pull them into the cache.

5.5.2

Block size: 16 bytes → 1 miss, 3 hits → $\frac{1}{4} = \boxed{25\%}$

64 bytes → 1 miss, 15 hits → $\frac{1}{16} = \boxed{6.25\%}$

128 bytes → 1 miss, 31 hits → $\frac{1}{32} = \boxed{3.125\%}$

The workload is using adjacent data, so spatial locality. It doesn't use the same data, so no temporal locality

5.6.2

Average Memory Access Time (AMAT)

penalty

L1 Hit Time + L1 Miss Rate × Main memory Access time

P1: $0.66\text{ns} + (0.08)(70\text{ns}) = \boxed{6.26\text{ ns}}$

P2: $0.90\text{ns} + (0.06)(70\text{ns}) = \boxed{5.1\text{ns}}$

5.6.4.

AMAT using L2 cache (w/ L1 cache from before)

L1 Hit Time + L1 Miss Rate (L2 Hit Time + L2 Miss Rate × Mem Access)

P1: $0.66\text{ns} + 0.08(5.62\text{ns} + .95 \times 70\text{ns}) = \boxed{6.43\text{ns}}$

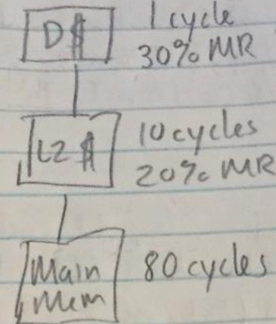
95% miss rate seems very high. Maybe lost a decimal place in textbook. Doesn't really help our penalty. In fact, our AMAT is higher/worse using this L2 cache w/ such a high miss rate.

Practice Exam Problem

5. a) AMAT of processor

HT = Hit Time

MR = Miss Rate



AMAT: D\$ HT + D\$ MR (L2\$ HT + L2\$ MR × MM HT)

$= 1\text{ cycle} + 0.3(10\text{ cycle} + 0.2 \times 80\text{ cycle}) = \boxed{8.8\text{ cycles}}$

If assume same HT and MR for Instruction hierarchy

this just becomes 0.1 → so AMAT: $\frac{8.8\text{ cycles}}{3} = \boxed{2.93\text{ cycles}}$

b) TCPI

$$BCPI = \underset{\text{peak CPI}}{1} + \underset{\text{misprediction rate}}{\overset{\%\text{branch}}{0.3}\,(0.5)\,\overset{\text{penalty}}{(1)}} + \underset{\text{LW→dep \%}}{\overset{\%\text{LW}}{(0.2)}\,(0.6)\,\overset{\text{penalty}}{(1)}} = 1.27$$

$$MCPI = \underset{\text{I\$ \% Access}}{(1)}\,\overset{\text{I\$ MR}}{(0.1)}\,(\underset{\text{L2\$ HT}}{10} + \overset{\text{L2\$ MR}}{0.2}\,(\underset{\text{MM HT}}{80}))$$

$$+ \underset{\%\text{LW, only source D\$ stall}}{(.20)}\,\underset{\text{D\$ MR}}{(0.3)}\,(\underset{\text{L2\$ HT}}{10} + \underset{\text{L2\$ MR}}{0.2}\,(\underset{\text{MM HT}}{80}))$$

$= 2.6 + 1.56 = 4.16$

$TCPI = BCPI + MCPI = \boxed{5.43}$

c) Procedure calls
1,000,000 instructions
30% instructions branches
1/6 branches procedure calls (jal) → all mispredicted
Additional 1/6 branches are returns (jr)

Before had 300,000 branch instructions (1,000,000 × 30%)
50% misprediction → 150,000 predicted correct 150,000 not
After in-line, we remove $\frac{1}{3}$ of branch instructions ($\frac{1}{6}+\frac{1}{6}$)
($\frac{1}{3} \cdot 30\% \times 1{,}000{,}000$) = 100,000 ← remove this many branch instructions (all were mispredicted)
Now have 200,000 branch instructions
↳ 150,000 predicted correct 50,000 not → 75% prediction rate

Calculate ET before inlining
ET = IC × TCPI × CT

$$= 1{,}000{,}000 \text{ instr} \times \frac{5.43 \text{ cycle}}{\text{instr}} \cdot \frac{s}{2\times10^9 \text{ cycles}} = 0.002715 \text{ s}$$

After inlining
ET = IC × TCPI × CT
IC: reduced by 100,000 to 900,000
TCPI: different
CT: this is the same

$$TCPI = \frac{ET}{IC \times CT} = \frac{0.002715 \text{ s}}{\left(900{,}000 \text{ inst} \times \frac{s}{2\times10^9 \text{ cycles}}\right)} = \frac{6.033 \text{ cycles}}{\text{instr}}$$

This is max CPI to reduce ET w/ inlining.

900,000 instructions

200,000 branches 25% MR

200,000 LW

↳ 1/6 of these have dependency (cause hazard)

$$BCPI = 1 + \left(\frac{2}{9}\right)(0.25)(1) + \left(\frac{2}{9}\right)\left(\frac{1}{6}\right)(1) = 1.09$$

peak CPI, %BR, BR MR, penalty, %LW, %dep, penalty

MCPI (1) (need to find) (penalty) +

I\$ Access %, I\$ MR

penalty = L2\$ Access + L2\$MR × Mem Access

= 10 + 0.2 × 80 = 26

$$\left(\frac{2}{9}\right)(0.3)(\text{penalty}) = 26(\text{I\$MR}) + 1.733$$

%LW, D\$MR

TCPI = BCPI + MCPI = 6.033 = 26(I\$MR) + 1.733

6.033 - 1.733 = 4.3 = 26(I\$MR)

$$\text{I\$MR} = \frac{4.3}{26} \approx \boxed{16.5\%}$$