CS 347, Spring 1998
Homework Assignment 4

Assigned: April 23
Due: Thurs., April 30, 3:00PM

Policy

You must work alone on this assignment. These problems are similar to ones that have appeared on 15-347 exams in the past. It is in your best interest to be able to independently solve problems of this form.

Any clarifications and revisions to the assignment will be posted on Web page `assigns.html` in the class WWW directory.

You should hand in a hard copy document for this assignment. One option is to simply write your answers on the assignment handout. If you submit a separate document, formatted text is preferred to hand written.

The following series of problems concern the components of the memory hierarchy and the way virtual addresses are translated into physical addresses.

- The memory is byte addressable.
- Virtual addresses are 14 bits wide.
- Physical addresses are 12 bits wide.
- The page size is 64 bytes.
- The TLB is 4-way set associative with 16 total entries.
- The cache is direct mapped, with a 4 byte line size and 16 total lines.

In the following tables, all numbers are given in hexadecimal. The contents of the TLB are as follows.

TLB												
Set Index	Tag	PPN	Valid	Tag	PPN	Valid	Tag	PPN	Valid	Tag	PPN	Valid
0	03	21	0	09	0D	1	00	13	0	07	02	1
1	03	2D	1	02	13	0	04	21	0	0A	11	1
2	02	00	0	08	1F	0	06	2F	0	03	11	1
3	07	29	0	03	0D	1	0A	34	1	02	1B	0

The page table for the first 16 pages and the cache are as follows:

Page Table					
VPN	PPN	Valid	VPN	PPN	Valid
00	28	1	08	13	1
01	2B	0	09	17	1
02	33	1	0A	09	0
03	02	1	0B	1A	0
04	2A	0	0C	27	0
05	16	1	0D	2D	1
06	04	0	0E	11	1
07	26	0	0F	0D	1

Cache						
Index	Tag	Valid	Byte 0	Byte 1	Byte 2	Byte 3
0	19	1	99	11	23	11
1	15	0	55	59	0B	41
2	1B	1	00	02	04	08
3	36	0	84	06	B2	9C
4	32	1	43	6D	8F	09
5	0D	1	36	72	F0	1D
6	31	0	A2	37	68	10
7	16	1	11	C2	DF	03
8	24	1	3A	00	51	89
9	2D	0	46	92	88	FE
A	24	1	93	15	DA	3B
B	0B	0	71	49	10	05
C	12	0	82	03	02	12
D	16	1	04	96	34	15
E	13	1	83	77	1B	D3
F	14	0	20	07	12	19

For the following problems, you are to show how the memory system translates a virtual address into a physical address and accesses the cache. For the given virtual address, indicate the TLB entry accessed, the physical address, and the cache byte value returned. Indicate whether the TLB misses, whether a page fault occurs, and whether a cache miss occurs. Carry each translation as far as possible, i.e. until there is insufficient data to complete the translation. Mark '–' through entries that cannot be correctly determined.

Problem 1:

A. The box below shows the format of a virtual address. Indicate (by labeling the diagram) the fields that would be used to determine the following:

VPO	The virtual page offset
VPN	The virtual page number
TLBI	The TLB index
TLBT	The TLB tag

13	12	11	10	9	8	7	6	5	4	3	2	1	0

B. The box below shows the format of a physical address. Indicate (by labeling the diagram) the fields that would be used to determine the following:

PPO	The physical page offset
PPN	The physical page number
CO	The byte offset within the cache line
CI	The cache index
CT	The cache tag

11	10	9	8	7	6	5	4	3	2	1	0

Problem 2:

Virtual address: `027C`

A. Virtual address format

13	12	11	10	9	8	7	6	5	4	3	2	1	0

B. Address translation

Parameter	Value
VPN	
TLB Index	
TLB Tag	
TLB Hit? (Y/N)	
Page Fault? (Y/N)	
PPN	

C. Physical address format

11	10	9	8	7	6	5	4	3	2	1	0

D. Physical memory reference

Parameter	Value
Byte offset	
Cache Index	
Cache Tag	
Cache Hit? (Y/N)	
Cache Byte returned	

Problem 3:

Virtual address: `03D4`

A. Virtual address format

13	12	11	10	9	8	7	6	5	4	3	2	1	0

B. Address translation

Parameter	Value
VPN	
TLB Index	
TLB Tag	
TLB Hit? (Y/N)	
Page Fault? (Y/N)	
PPN	

C. Physical address format

11	10	9	8	7	6	5	4	3	2	1	0

D. Physical memory reference

Parameter	Value
Byte offset	
Cache Index	
Cache Tag	
Cache Hit? (Y/N)	
Cache Byte returned	

Problem 4:

You have recently purchased a system which is identical to the one shown on page 32 of the April 14th lecture notes on multimedia (i.e. with a Pentium processor and a PCI bus). You primarily use your system to playback compressed MPEG-2 video which is stored on disk. Your system currently does this by using the Pentium to decompress the image into memory, and then using a DMA engine to transfer the raw image across the PCI bus to the frame buffer.

Unfortunately, you notice that the video image on your screen is often jittery, and you suspect that the problem is insufficient bandwidth on your PCI bus. You have allocated $500 to fixing this problem, and you can use this money to do one of two things: either upgrade to a faster processor with MMX support, or else purchase a new graphics card which not only contains the frame buffer but also contains hardware to directly decompress an MPEG-2 video stream. Which approach is more likely to fix your jittery video problem, and why?

The following problems involve evaluating the proposed standards for digital video disk (DVD) based video.

Problem 5:

For working with "broadcast" quality video, the accepted standard is to digitize at 720×480 pixels per frame at a rate of 30 frames per second. Each pixel has a color depth of 24 bits. In addition, we would like "CD" quality sound, consisting of two stereo channels, sampled at 44,100 samples per second, with 2 bytes per sample.

Future DVDs will have two sides, with a storage capacity of 4.38 GB per side. A standard CDROM only uses 1 side and is limited to 747 MB.

A. If we were to store the video plus audio tracks uncompressed, what bandwidth would be required during playback?

B. What speed CDROM (measured relative to an audio CD player) would this correspond to?

C. How many minutes of uncompressed video + audio could be stored on a single CDROM? On a DVD?

Problem 6:

The new MPEG-2 video compression standard is designed to allow broadcast quality videos to be played from low cost media such as CDROMs and DVDs. They claim that images can be compressed to such a degree that they require a bandwidth of just 440 KB/second for the video portion of the playback. In addition, audio would be played in the "CD-quality" format described above without any compression.

A. What compression ratio does this video bandwidth represent over the raw broadcast quality video?

B. What would be the bandwidth required for playback of both audio and video?

C. What speed CDROM or DVD drive would be required for playback?

D. How many minutes of compressed video + audio could be stored on a standard CDROM? On a DVD?

E.