Sample Problem 1

Assume the following memory setup:

- Virtual addresses are 20 bits wide
- Physical addresses are 15 bits wide
- The page size if 1KB (2^{10} bytes)
- The TLB is 2-way set associative, with 8 total entries
- The cache is 4-way set associative, with 4-byte blocks, and 16 total lines

Determine the breakdown of the virtual address into the following fields (i.e., which bit ranges correspond to each):

- Virtual Page Number (VPN): _____
- Virtual Page Offset (VPO): _____
- TLB index (TLBI): _____
- TLB tag (TLBT): _____

Next, determine the breakdown of the physical address into the following fields:

- Physical Page Number (PPN): _____
- Physical Page Offset (PPO): _____
- Cache offset: _____
- Cache index: _____
- Cache tag: _____

Finally, for each of the following virtual addresses, determine the corresponding physical address and byte of data returned. Also indicate whether a TLB hit occurs. Base your answers on the TLB, cache, and partial page table on the next page:

- Virtual address **0x67F06**

  TLB Hit? Y / N Physical address:_____ Data byte:_____

- Virtual address **0x037B8**

  TLB Hit? Y / N Physical address:_____ Data byte:_____

TLB			
Index	Tag	Valid	PPN
0	94	0	00
	61	1	09
1	64	0	07
	9A	1	16
2	8F	1	02
	13	1	1D
3	67	1	10
	44	0	06

Page Table					
VPN	PPN	Valid	VPN	PPN	Valid
00	18	0	0A	0D	0
01	14	1	0B	0A	0
02	16	1	0C	00	0
03	13	1	0D	0E	1
04	0B	1	0E	08	1
05	1E	1	0F	1F	0
06	07	0	10	03	0
07	12	1	11	1B	1
08	11	0	12	19	1
09	02	1	13	0F	0

Cache						
Index	Tag	Valid	Byte 0	Byte 1	Byte 2	Byte 3
0	2B1	1	32	72	CF	E8
	793	0	8E	05	19	4D
	7E2	1	5F	8E	C2	EC
	666	1	30	F2	F9	8F
1	10B	1	EE	7D	B4	F1
	430	1	4F	31	E7	A3
	7BE	0	E3	EF	85	AF
	332	1	E5	86	CA	F2
2	288	0	A1	63	64	67
	3BB	1	CA	6D	BA	C4
	4EF	1	95	BB	EB	1C
	637	1	F9	AA	BC	DA
3	754	1	09	DC	CD	13
	291	0	B0	51	7B	4F
	170	0	A7	5C	84	3C
	3E2	0	AE	E1	A3	D0

Sample Problem 2

Assume the following setup of virtual memory and cache:

- Memory is byte addressable
- Virtual addresses are 14 bits wide
- Physical addresses are 10 bits wide
- The page size is 32 bytes (2^5 bytes)
- The TLB is direct-mapped, with 8 total entries
- The cache is 2-way set associative, with 1-byte blocks, and 8 total lines

Determine the breakdown of the virtual address into the following fields (i.e., which bit ranges correspond to each):

- Virtual Page Number (VPN): _____
- Virtual Page Offset (VPO): _____
- TLB index (TLBI): _____
- TLB tag (TLBT): _____

Next, determine the breakdown of the physical address into the following fields:

- Physical Page Number (PPN): _____
- Physical Page Offset (PPO): _____
- Cache offset: _____
- Cache index: _____
- Cache tag: _____

Finally, for each of the following virtual addresses, determine the corresponding physical address and byte of data returned. Also indicate whether a TLB hit occurs. Base your answers on the TLB, cache, and partial page table on the next page:

- Virtual address **0x1BA3**

  TLB Hit? Y / N Physical address:_____ Data byte:_____

- Virtual address **0x0194**

  TLB Hit? Y / N Physical address:_____ Data byte:_____

TLB			
Index	Tag	Valid	PPN
0	34	1	0C
1	03	1	1B
2	00	1	0F
3	3A	1	1D
4	1D	0	09
5	1B	1	03
6	2A	1	14
7	13	0	19

Page Table					
VPN	PPN	Valid	VPN	PPN	Valid
00	09	1	0A	17	1
01	04	1	0B	01	1
02	0E	1	0C	16	1
03	18	0	0D	00	0
04	0D	0	0E	0C	0
05	15	0	0F	08	1
06	12	0	10	1A	0
07	0B	1	11	1F	0
08	1E	1	12	11	0
09	10	0	13	13	1

Cache			
Index	Tag	Valid	Byte 0
0	96	0	D0
	B5	1	92
1	F2	1	93
	35	0	05
2	FF	0	5A
	F3	1	2E
3	98	1	EF
	18	1	CB

Sample Problem 3

Assume the following setup of virtual memory and cache:

- Memory is byte addressable
- Virtual addresses are 32 bits wide
- Physical addresses are 30 bits wide
- The page size is 4KB (2^{12} bytes)
- The TLB is 4-way set associative, with 16 total entries
- The cache is 2-way set associative, with 8-byte blocks, and 16 total lines

Determine the breakdown of the virtual address into the following fields (i.e., which bit ranges correspond to each):

- Virtual Page Number (VPN): _____
- Virtual Page Offset (VPO): _____
- TLB index (TLBI): _____
- TLB tag (TLBT): _____

Next, determine the breakdown of the physical address into the following fields:

- Physical Page Number (PPN): _____
- Physical Page Offset (PPO): _____
- Cache offset: _____
- Cache index: _____
- Cache tag: _____

Finally, for each of the following virtual addresses, determine the corresponding physical address and byte of data returned. Also indicate whether a TLB hit occurs. Base your answers on the TLB, cache, and partial page table on the next page:

- Virtual address **0x0868161E**

  TLB Hit? Y / N Physical address:_____ Data byte:_____

- Virtual address **0x00001B70**

  TLB Hit? Y / N Physical address:_____ Data byte:_____

TLB			
Index	Tag	Valid	PPN
0	12F5C	0	05118
	1E019	1	23275
	13647	0	062F2
	01CFD	1	0DF82
1	10321	1	01F8A
	2304D	0	1B11C
	021A0	1	23818
	0D9AA	0	0C6B3
2	36EFA	0	271C4
	20D6D	1	19A89
	07E08	1	05B61
	39A4E	0	23D81
3	1B532	1	28695
	1D1EA	0	1A7FB
	1B0C0	0	06A32
	24AAE	1	154F7

Page Table					
VPN	PPN	Valid	VPN	PPN	Valid
00	1EA62	1	0A	28672	1
01	3E44B	1	0B	2F31D	0
02	18EF8	0	0C	36C50	1
03	37466	0	0D	2A8BB	0
04	2EEA3	0	0E	388FF	0
05	25F79	1	0F	2E23F	0
06	38723	1	10	327F0	1
07	15F25	0	11	0E9E9	1
08	11A67	0	12	326F1	1
09	33F92	1	13	23CFD	1

Cache										
Index	Tag	Valid	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0	3BFD59	0	C3	FC	D9	5F	9A	81	69	AC
	602386	0	69	98	BC	1A	F2	5E	7D	00
1	98E617	1	E5	04	ED	3E	F6	E5	0F	16
	5044DC	0	D4	52	7C	D8	7E	89	4E	07
2	138C39	1	2F	D9	89	BE	0E	D6	36	E2
	FB8FA8	0	D0	54	12	97	74	CA	35	C1
3	8E0618	1	25	21	0F	90	1F	34	A0	1F
	9DE9A0	0	B9	AB	54	8E	D5	24	39	DC
4	8D91EA	0	1F	30	9E	34	C6	4E	9F	55
	1FFEE1	1	4B	93	F8	7B	98	B2	9F	D7
5	55A54C	0	3D	2C	C3	85	A7	AB	D6	B8
	1561B2	0	46	5D	A3	2B	8E	1B	81	76
6	F912ED	1	00	3E	FB	A5	50	8A	1A	31
	80E19E	0	3F	BC	32	06	D1	ED	15	9E
7	E77927	1	F1	E2	36	8D	B1	0C	68	49
	FA452B	1	A7	F1	0F	EE	EC	85	AC	7D