CACHE MEMORY

- CPU MEMORY GAP (google)

CPU will look for DATA FIRST OF ALL IN THE LEVEL 1 CACHE.

IF THE DATA IS FOUND THERE THEN WE HAVE A CACHE HIT OTHERWISE ⇒ CACHE MISS.

IF WE HAVE A CACHE MISS, THEN WE HAVE TO GO OFF TO ONE OF THE LOWER LEVELS IN THE HIERARCHY.

CACHE (BLOCKS / CACHE LINES)	0	1	2	3	4	5	6	7

LOGICAL MAIN MEMORY (BLOCKS)								
	0	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	29	30	31

L1 CACHE	64 KB
MAIN MEMORY (RAM)	16 GB

Q. HOW MUCH BIGGER IS THE RAM VS THE CACHE IN THE ABOVE EXAMPLE

$1\ GB = 2^{30}$ BYTES

$16\ GB = 2^{30} \times 16 = 17,179,869,184$

$1\ KB = 2^{10}$ BYTES

$64\ KB = 2^{10} \times 64 = 65536$

$17,179,869,184 \div 65536 = 262144$

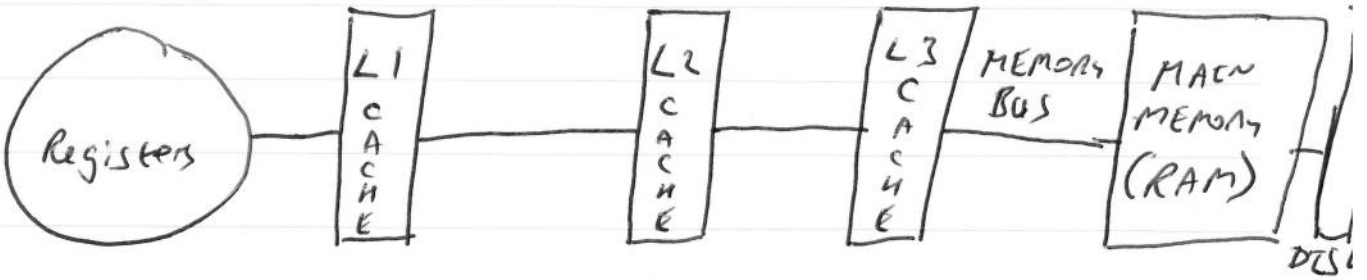
ANSWER: 262144

~~TIMES~~ ~~AS MUCH~~

THE RAM IS 262,144 TIMES THE SIZE OF THE LEVEL 1 CACHE IN THE EXAMPLE

{"SPEED VS SIZE" 5.Memory.pdf}

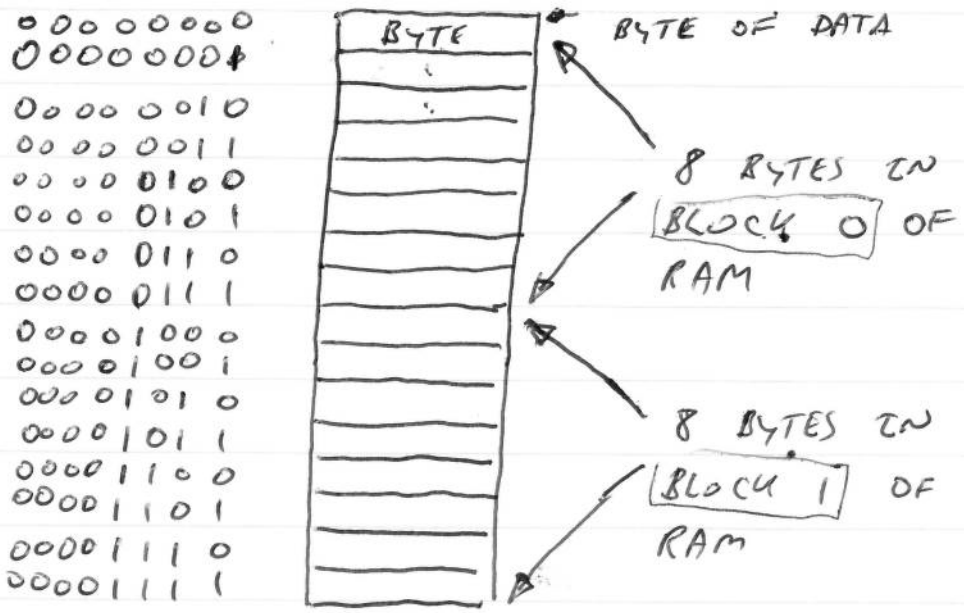
CPU



SIZE	1000 BYTES	64KB	256KB	2-4MB	4-16GB
	300 ps	1 ns	3-10ns	10-20ns	500-100ns

MAIN MEMORY

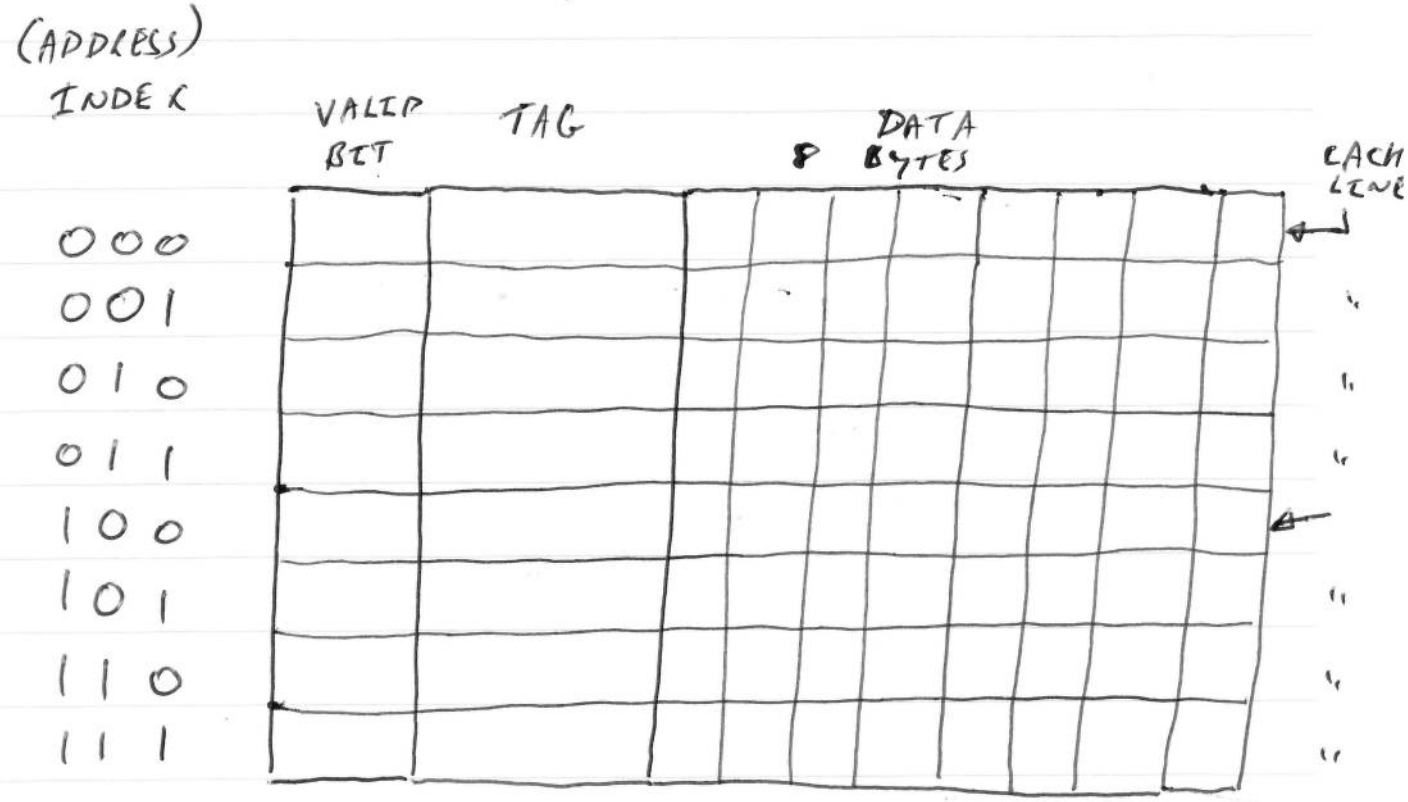
Suppose BLOCK SIZE IS 8 BYTES



DIRECT MAPPED CACHE

CACHE : 8 BLOCKS (0..7)
MAIN MEMORY : 32 BLOCKS (0..31)
IN OUR EXAMPLE EACH BLOCK HAS 8 BYTES OF DATA.

CACHE (logical view)



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CONSIDER ADDRESS 97 IN RAM : WHICH BLOCK IN RAM IS ADDRESS 97 IN ?

ADDRESS 97 : BLOCK 12 IN RAM

Why is it 12 ?

BLOCKS		BYTES
BLOCK	0 IN RAM	0 .. 7
"	1	8 .. 15
"	2	16 .. 23
"	3	24 .. 31
"	4	32 .. 39
"	5	40 .. 47
"	6	48 .. 55
"	7	56 .. 63
"	8	64 .. 71
"	9	72 .. 79
"	10	80 .. 87
"	11	88 .. 95
"	12	96 .. 103

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MACHINE WORKS WITH BINARY.

EXPRESS 97 (ADDRESS / BYTE) IN BINARY.

1100001

RAM

32 BLOCKS OF 8 BYTES

32 × 8 = 256 BYTES

Q. TO PROVIDE 256 DIFFERENT ADDRESSES:
HOW LONG DOES THE ADDRESS BUS NEED TO BE?

A. 8 BITS.

$$2^8 = 256$$

$2^2 = 4$ ADDRESSES

E.G. 2 BIT ADDRESS BUS

0	00
1	01
2	10
3	11

$2^3 = 8$ ADDRESSES

3 BIT ADDRESS BUS

0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

$2^8 = 256$

0	0000 0000
1	0000 0001
2	0000 0010
3	0000 0011
⋮	
255	1111 1111

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97: 1100001

97: 01100001 ← EIGHT BIT ADDRESS BUS (FOR EXAMPLE)

ADDRESS GENERATED: 01100001

ROWS: 4

CACHE LINES: 8

BYTES PER BLOCK: 8

ROWS:	RAM							
0	0	1	2	3	4	5	6	7
1	8	9	10	11	12	13	14	15
2	16	17	18	19	20	21	22	23
3	24	25	26	27	28	29	30	31

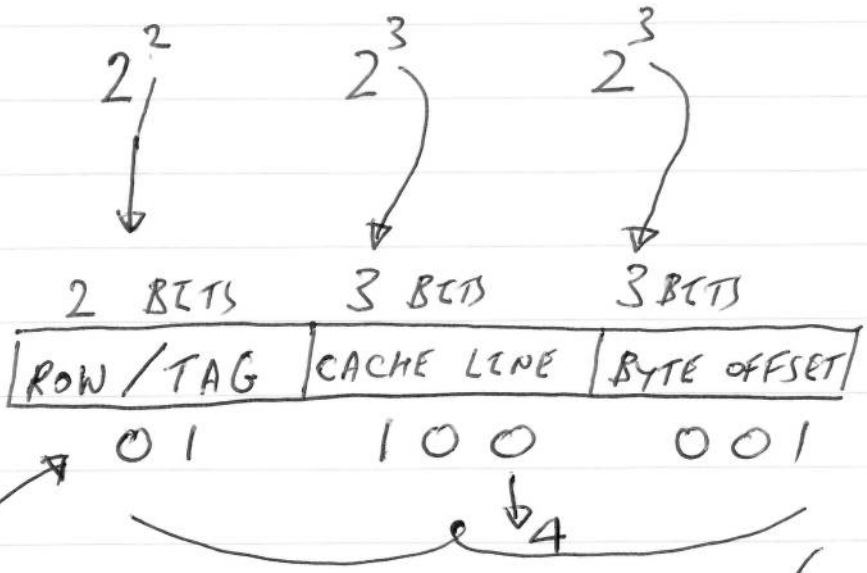
CACHE

0	1	2	3	4	5	6	7

ROWS: 4 $2^? = 4$ $2^{(2)} = 4$

CACHE LINES: 8 $2^? = 8$ $2^{(3)} = 8$

BYTES PER BLOCK (CACHE LINE): 8 $2^? = 8$ $2^{(3)} = 8$



ADDRESS 97 EXPRESSED IN BINARY

MEMORY ADDRESS (FOR BYTE 97)

97 IS IN BLOCK 12 IN RAM.

BINARY	BLOCK NO. IN CACHE
100 →	4

Q What addresses are "in" block 12 in RAM, assuming that each block takes up 8 BYTES.

OTHER ASSUMPTIONS :→

CACHE	8 BLOCKS
MAIN MEMORY	32 BLOCKS

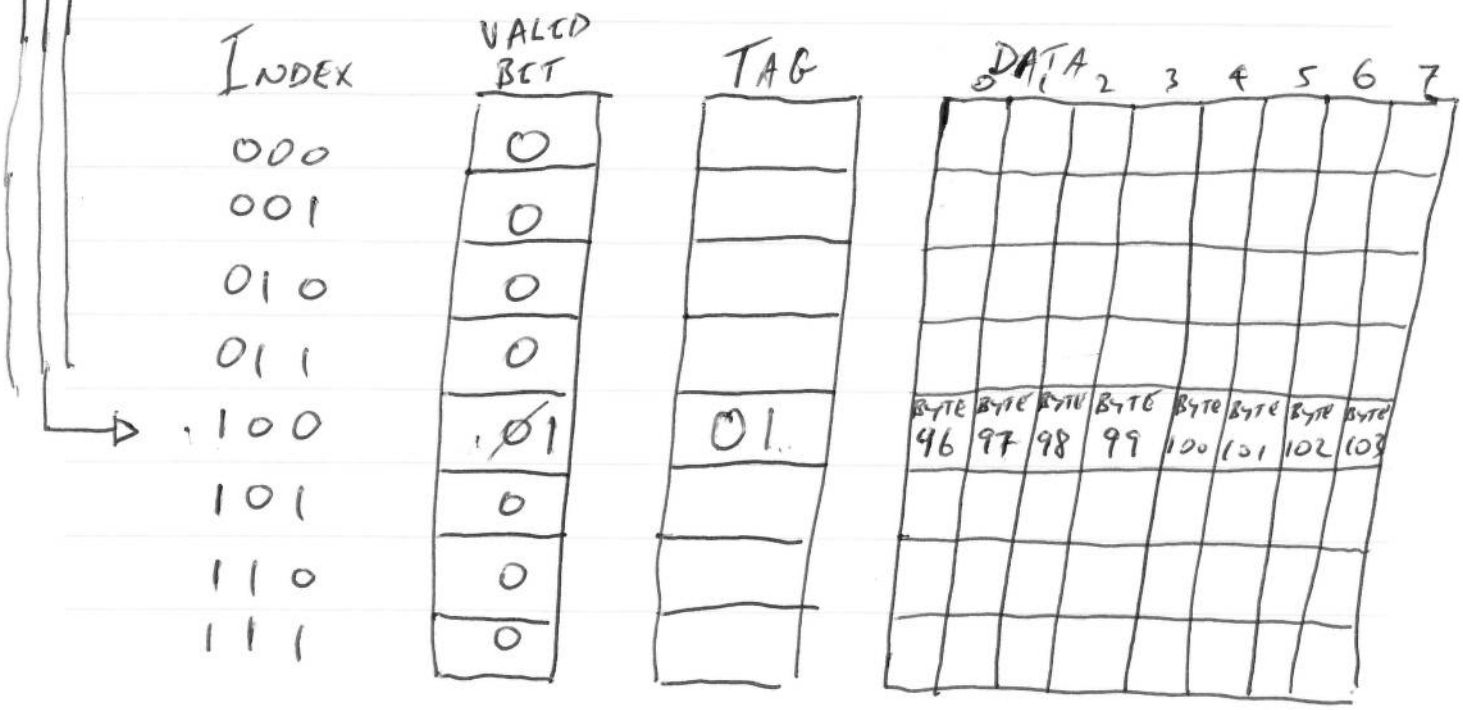
A. ANS. ADDRESSES 96 97 98 99 100 101 102 10

CPU GENERATES THE FOLLOWING ADDRESS

97 : 01 | 100 | 001

TAG / ROW | INDEX / CACHELINE | BYTE OFFSET

WHERE IN THE CACHE WILL BLOCK 12 go?



(CACHE MISS)

3 THINGS DONE (FIRSTLY FIND LINE 100 IN CACH

(A) SET VALID BIT TO 1

(B) SET TAG TO 01

(C) COPY DATA FROM BYTES 96 TO 103 IN RAM, INTO CACHE

WAS THIS A HIT OR A MISS ?

A. MISS. IT TAKES TIME TO COPY DATA FROM ONE LEVEL OF THE MEMORY HIERARCHY INTO ANOTHER. (IN THIS CASE FROM BLOCK 12 IN RAM INTO BLOCK 4 IN CACHE)

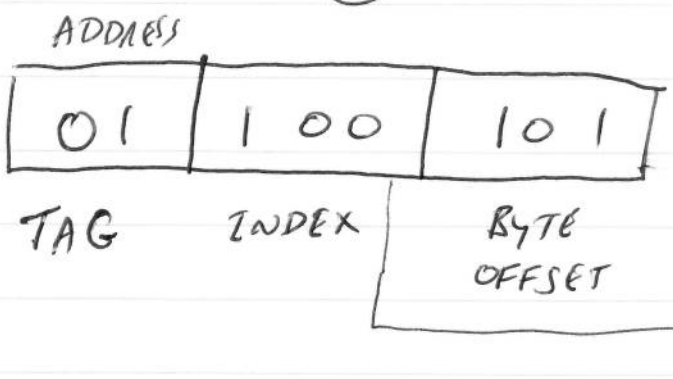
(CACHE HIT)

CPU GENERATES A REQUEST FOR BYTE 101

8 BIT BINARY ADDRESS

101 ⟶ 01100101

(11)



CACHE CAN GO OFF TO CACHE LINE 100 (IN CACH

IT WILL COMPARE TAG FROM ADDRESS: 01
WCT THE TAG IN CACHE LINE 100
IF THEY MATCH AND THE VALID BIT IS
1 ⇒ CACHE HIT

THU 10 MAR 2016

(i)

		000	001	010	011	100	101	110	111
		0	1	2	3	4	5	6	7
	TAG/ROW								
0	00	0	1	2	3	4	5	6	7
1	01	8	9	10	11	12	13	14	15
2	10	16	17	18	19	20	21	22	23
3	11	24	25	26	27	28	29	30	31

EACH OF THE ABOVE IS A BLOCK.

WE ASSUMED 8 BYTES PER BLOCK.

HOW MANY BYTES IN THE RAM ABOVE?

32 BLOCKS x 8 BYTES = 256

TAKE ADDRESS 77.

Which block is it in?

$8 \overline{)77}$

$9 \text{ R } 5$

77 CONVERTED TO BINARY

01001101

TAG	INDEX	BYTE OFFSET
01	001	101

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Consider Block 9.
What is the addresses of the other bytes in block 9 ?

BYTES/BLOCK $8 \overline{)77}$

$9 \; R \; 5$

TAG | INDEX | BYTE OFF. | REMAINDER OF 5

	TAG	INDEX	BYTE OFF.
BLOCK 9	0 1	0 0 1	1 0 1

OTHER ADDRESSES IN BLOCK 9

72	0 1	0 0 1	0 0 0
73	0 1	0 0 1	0 0 1
74	0 1	0 0 1	0 1 0
75	0 1	0 0 1	0 1 1
76	0 1	0 0 1	1 0 0
77	0 1	0 0 1	1 0 1
78	0 1	0 0 1	1 1 0
79	0 1	0 0 1	1 1 1

ADDRESS 6

$8 \overline{)77}$

BLOCK 9 R 5

$9 \times 8 = 72$

72 IS 1ST ADDRESS IN BLOCK 9

EXERCISE

TAKE ADDRESS 180
What block is it in ?

What ~~is~~ are the addresses of the other bytes in the block ?
(EXPRESSED IN BOTH BINARY AND DECIMAL)

What block is it in ?

$8 \overline{)180}$
22 R 4

Block 22 ~~INDEX~~ ~~4~~ BYTE OFFSET: 4

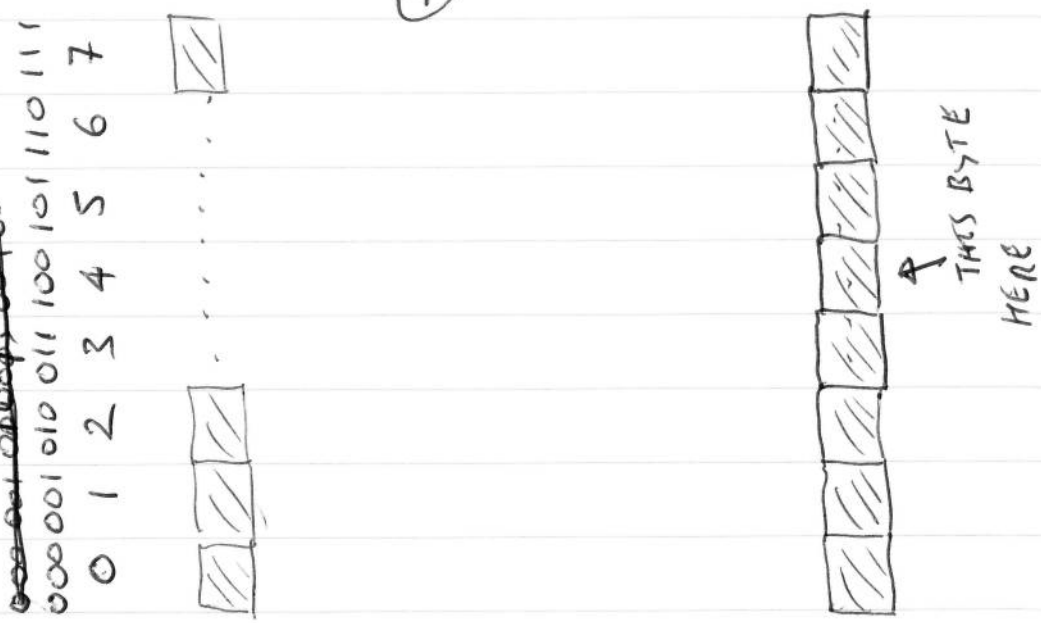
TAG , INDEX , BYTE OFFSET
180 = 10 11 0 100

176	10 11 0 000
177	10 11 0 001
178	10 11 0 010
179	10 11 0 011
180	10 11 0 100
181	10 11 0 101
182	10 11 0 110
183	10 11 0 111

ADDRESS
$8 \overline{)180}$
BLOCK: 22 R 4

$22 \times 8 = 176$
176 IS 1ST ADDRESS IN BLOCK 22

(4)



	000	001	010	011	100	101	110	111
	0	1	2	3	4	5	6	7
TAG/ROW								
0	00	0	1	2	3	4	5	6	7
1	01	8	9	10	11	12	13	14	15
2	10	16	17	18	19	20	21	22	23
3	11	24	25	26	27	28	29	30	31

BLOCK 22 ABOVE