Name:_____

Problem 1 (30 points):

Part a (5 points): What is the wobble between the sub-normal binade and the smallest normal binade? Recall that the wobble between two binades is the ratio of the ULP of the two binades.

1

Part b (5 points): What is the maximum possible IPC of a machine that has a 100% accurate branch predictor, 100% cache hit ratio, and the ability to fetch up to 4 instructions/cycle, execute up to 8 instructions/cycle, and retire up to 6 instructions/cycle?

Flynn's Bottleneck

4

Part c (5 points): In Memory-Mapped I/O, software can communicate with the I/O devices using regular load/store instructions.

Part d (5 points): On an I/O bus where devices have different priorities, the piece of logic that decides who is going to use the I/O bus next is called Priority Arbitration Unit. The inputs to this logic includes the SACK and Bus Request signals from the devices and the outputs are the Bus Grant signals to the devices.

Name:_____

Problem 1 continued

Part e (5 points): Consider two microarchitectures for the LC-3b. One is an OoO processor which runs at a frequency of 1.5GHz, achieves an IPC of 1.33, and consumes 2W of power. The alternate is an InOrder processor which runs at a frequency of 2.5GHz, achieves and IPC of 0.8, and consumes 1.6W of power. Which one would you recommend for use in a smartphone? Which microarchitecture will you recommend to a friend for a desktop? Explain your choice for each one in less than 15 words.

(1.33)(1.5) ≈2 (2.5)(0.8) = 2

Smartphone:

In Order processor because the performance of both processors is the same and InOrder uses less power

Desktop:

InOrder processor because the performance of both processors is the same and InOrder uses less power

Part f (5 points): An aggie has designed a new branch predictor she calls FTBN (Forward-taken, Backward not-taken). As the name implies, it predicts all forward branches to be taken and all backward branches to be not taken. What will be the branch prediction accuracy of FTBN when executing the following code?

```
; The code counts the number of zeros in an array
; Assume: R1 = 4; R2 = Address of first ARRAY element; R3 = 0
LOOP        LDR R4, R2, R1
            BRnp  END   Taken 4 times, Not Taken 1 time
            ADD R3, R3, #1
END         ADD R1, R1, #-1
            BRzp LOOP  Taken 4 times, Not Taken 1 time
            HALT
ARRAY       .fill 0xfeed
            .fill 0xbeef
            .fill 0xcafe
            .fill 0xceed
            .fill 0x0
```

Branch Preditor Accuracy: 50%

Name:_____

Problem 2 (10 points):

Consider an 8-bit, radix-2, IEEE-like floating point specification. We know the highest representable value is $\frac{15}{8} \times 2^9$. Calculate the excess, number of exponent bits, and number of fraction bits. Show your work.

$\frac{15}{8} \times 2^9 = 1.111 \times 2^9$

3 fraction bits

8 - 3 - 1 = 4 exponent bits

9 ⇒ 1110

8 ⇒ 1101

⋮

0 ⇒ 0101

⋮

-4 ⇒ 0000

Bias : 5

Number of fraction bits: 3

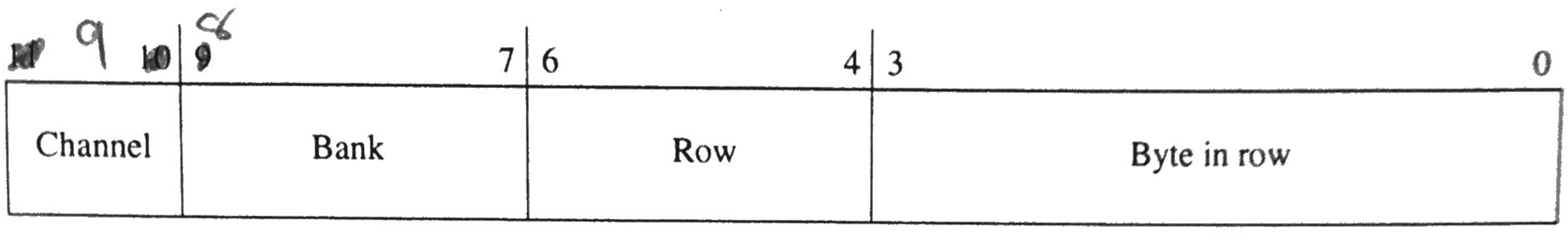
Number of exponent bits: 4

Excess: 5

Name:_____

Problem 3 (25 points):

In this problem, you will work with a byte addressable memory with a 16 bit memory bus. The memory address is split as follows:



Part a (1 point): What is the total size of physical memory?

2^{10} Bytes

Part b (2 points): What is the total number of ranks needed for this memory?

2 Ranks

Part c (2 points): What is the total number of byte addressable chips needed for this memory?

4 Chips

Part d (20 points): Assume an optimal memory scheduler, which schedules requests to complete them in minimum possible time, is presented with the physical addresses shown on the next page.

Notes:

1. The memory bus is 16 bits and so are the accesses.
2. An older request must be scheduled first unless there is a performance gain otherwise.
3. On a row buffer hit, an access takes 1 cycle. On a row buffer miss, an access takes 3 cycles.
4. For all banks in memory, assume Row 0 is currently open.
5. Assume all banks are free at cycle 0.
6. A particular address can be sent to memory in a particular cycle if (1) the corresponding bank is free (notice how B is sent in cycle 0), or (2) the data from the previous request to that bank is being transferred concurrently (Notice D is sent in cycle 1).
7. Address0 and Data0 represent the lines to Channel0, and Address1 and Data1 are the lines to Channel1.

Name:_____

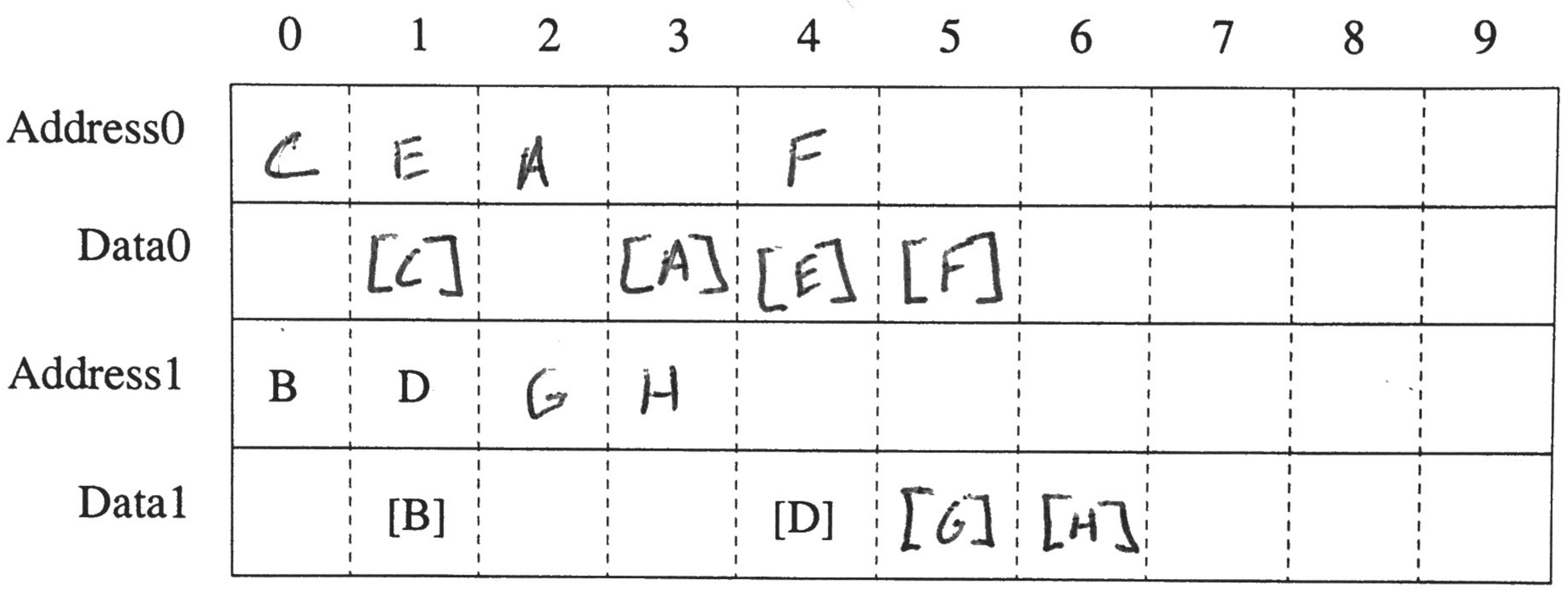
Problem 3 continued

Your job: Complete the timing diagram representing the cycles during which addresses are sent and the corresponding data is received. We have filled requests B and D as examples. You may not need to fill in all the cycles shown.

Oldest ⟶

A	0 01 000 1100	E	0 00 001 1110
B	1 00 000 1010	F	0 00 001 0000
C	0 00 000 0100	G	1 11 111 1110
D	1 00 001 0000	H	1 10 110 0000

⟵ Newest



Name:_____

Problem 4 (25 points):

Consider an out-of-order processor with seven registers (R0-R6) with the following properties:

1. There is one multiplier and one adder. Both units are pipelined. These units take an unknown number of cycles to execute instructions.
2. There is a common Reservation Station (RS) shared between the multiply and the add unit.
3. The Allocate Reorder Buffer, Allocate RS and Update RAT takes place in the Decode stage. Thus, the pipeline looks like F-D-E1-E2-...-WB.
4. Only one instruction can be fetched, decoded, and retired in one cycle.
5. Instructions enter the reservation stations in program order. I.e. I1 is allocated in slot A, I2 is allocated in slot B and so on.
6. An instruction's reservation station entry is freed as soon as it begins execution.
7. The calculated value is broadcast to the Reservation station, Register Allocation Table and Reorder Buffer at the end of the last stage of execution (data will be available at the beginning of the next cycle).
8. There is in-order retirement, but the Reorder Buffer is not shown.

Part a (18 points): Identify the five instructions, I1-I5, to complete the partially filled table. Figure 1 (on next page) shows the Architectural Register File before I1 is fetched (i.e. at the beginning of cycle 0) and after I5 retires (i.e. at the end of cycle 14). Figure 2 shows a snapshot of the Reservation Station and the functional units at the end of cycle 6.

	Opcode	DR	SR1	SR2
I1	add	R0	R1	R2.
I2	add	R6	R0	R0
I3	mul	R4	R6	R2
I4	mul	R1.	R2	R3.
I5	add	R5	R5	R1

Part b (7 points): Circle the number of cycles for the respective functional units.

ADD : 2 (3) 4

MUL : 2 3 (4)

PROBLEM IS CONTINUED ON THE NEXT PAGE!