1 Binary Problems

1.1 **Choose the best answer.** Given the following 8-bit integer binary variables:

`X1` = 0001 0010

`X2` = 0010 1010

What is the value in X3 after the following command:

```
ADD X3, X2, X1
```

A. Overflow error or carry flag

B. 0001 1110

C. 0011 1100

D. 0000 1111

1.2 **Choose the best answer.** Given the following 8-bit integer binary variables:

`X1` = 0101 0100

`X2` = 1110 1100

What is the value in X3 after the following command:

```
ADD X3, X2, X1
```

A. 0001 0100

B. 1001 1000

C. 0100 0000

D. Overflow error or carry flag

1.3 **Choose the best answer.** How is the integer 64_{10} represented in memory?

A. 01000000

B. 10000000

C. 00111111

D. 00100000

1.4 **Choose the best answer.** How is the integer 69_{10} represented in memory?

A. 01011100

B. 10000000

C. 01000101

D. 01001001

1.5 **Choose the best answer.** How is the integer 63_{10} represented in memory?

A. 00111110

B. 01111110

C. 00111111

D. 00011111

1.6 **Choose the best answer.** How is the integer -5_{10} represented in memory?

A. 11110110

B. 11111101

C. 11111110

D. 11111011

Solution: Assume that the *two's complement* method is being used. Other methods for Representing negative binary numbers exist, but they have ambiguous representations for zero. Hence *two's complement* is used in computing.

Two's complement method:
To represent both positive and negative numbers, the most significant bit (MSB) is always the *sign bit*. If the MSB is 0, there are no changes, e.g., $5 = 00000101$. The MSB is 1 for negative numbers. If it can be calculated directly as follows: The leftmost 1 represents $-2^3 = -8$ (the four bits are 3, 2, 1, 0)

Now everything else is positive:

$$\begin{aligned} 3^{\text{rd}} \text{ bit} &= 0 \cdot 2^2 &= 0 \\ 2^{\text{nd}} \text{ bit} &= 1 \cdot 2^1 &= 2 \\ 1^{\text{st}} \text{ bit} &= 1 \cdot 2^0 &= 1 \end{aligned}$$

So $1011 = (-8) + (0) + (2) + (1) = -5$

Alternatively, you can find the one's complement of $5 = 00000101$ (I need more than 4 bits for this): 11110101 (just flip everything) and add 00000001 to get the two's complement:

$$\begin{array}{r} {\scriptstyle 1} \\ 1001\,1111 \\ -\,0101\,0101 \\ \hline 0100\,1010 \end{array}$$

I cover this problem here around the 8:50 mark. (BTW, in this video, toward the end, I get confused around the 1-hour mark and say that 2.12 should be 5 -4 is the correct answer. It was late.)

1.7 **Choose the best answer.** What does extending to 16 bits yield given -11_{10} in 8-bit 2's complement 11110101? (Sorry about the poor wording, but this is how it appears on the assessments!)

A. 1111 1111 1111 0110

B. 1111 1111 1111 1011

C. 1111 1111 1110 1010

D. 1111 1111 1111 0101

1.8 **Choose the best answer.**What does extending to 16 bits yield given 98_{10} in 8-bit 2's complement 01100010? (Sorry about the poor wording, but this is how it appears on the assessments!)

A. 0000 0000 0011 0001

B. 0000 0000 1100 0100

C. 0000 0000 0110 0010

D. 0000 0000 0110 0011

2 Pipelining Problems

2.9 **Choose the best answer.** An instruction set has 8 steps and each step takes one clock cycle. What is the number of cycles needed to complete the instruction sets using a pipelined process to complete 100 instruction sets?

A. 800

B. 8.0

C. 1.08

D. 1.07

E. 107

F. 7.99

2.10 **Choose the best answer.** An instruction set has 9 steps and each step takes one clock cycle. What is the average number of cycles needed to complete each instruction set using a pipelined process to complete 30 instruction sets?

A. 8.967

B. 270

C. 1.267

D. 1.3

E. 38

F. 9.0

2.11 **Choose the best answer.** An instruction set has 14 steps each taking 5 clock cycles to complete. What is the number of cycles needed to complete 30 instruction sets using a pipelined process?

A. 2100

B. 7.333

C. 70.0

D. 220

E. 7.167

F. 215

2.12 **Choose the best answer.** An instruction set has 5 steps each taking 4 clock cycles to complete. Approximately what is the average number of cycles needed to complete each instruction set using a pipelined process to complete 2.15×10^{50} instruction sets?

A. 20

B. 0

C. 1.25

D. 4

E. 4×10^{50}

Solution: For a pipelined process, we find the total number of cycles for n instruction sets as follows:

$$\text{total time} = [\text{time for } 1^{\text{st}} \text{ set}] + (n-1)(\text{time for slowest step}) \tag{1}$$

To find the average time, we simply divide this by the number of instruction sets, n:

$$\text{average} = \frac{[\text{time for } 1^{\text{st}} \text{ set}] + (n-1)(\text{time for slowest step})}{n} \tag{2}$$

Here, time = cycles and our slowest step takes 4 cycles (they are all the same):

$$\text{average} = \frac{[4 \cdot 5] + (n-1)(4)}{n} \tag{3}$$

$$= \frac{[4 \cdot 5] + (2.15 \cdot 10^{50} - 1)(4)}{2.15 \cdot 10^{50}} \tag{4}$$

$$\approx 4 \tag{5}$$

For these types of problems, there's no need to plug in $n = 2.15 \times 10^{50}$. Note as n gets large, the average tends toward the time of the slowest step.

n	average
10	5.6
100	4.16
1000	4.016
10000	4.0016
$\vdots$	$\vdots$
10^{∞}	4

Recall from calculus,

$$\lim_{n\to\infty} \text{average} = \lim_{n\to\infty} \frac{[4 \cdot 5] + (n-1)(4)}{n} \tag{6}$$

$$= \lim_{n\to\infty} \frac{[4 \cdot 5]}{n}^{0} + \lim_{n\to\infty} 4\frac{n}{n} + \lim_{n\to\infty} \frac{-4}{n}^{0} \tag{7}$$

$$= 4 \tag{8}$$

2.13 **Choose the best answer.** An instruction set has 5 steps each taking 4 clock cycles to complete. If 150 sets of instructions are processed, what is the performance improvement using a pipelined instead of a non-pipelined process?

A. 20

B. 4.87

C. 0.205

D. 0.795

E. 30.8

F. 616

2.14 **Choose the best answer.** An instruction set has 8 steps each taking 2 clock cycles to complete. If n sets of instructions are processed, what is the theoretical performance improvement using a pipelined instead of a non-pipelined process as $n \to \infty$ (or for n is very large)?

A. 8

B. ∞

C. 4.0

D. 16

E. 2

2.15 **Choose the best answer.** How many minutes does it take to wash, dry, and fold four loads of laundry using a pipelining approach, given the following information?

One washer takes 10 minutes.

One dryer takes 30 minutes.

One folder takes 60 minutes.

A. 280

B. 160

C. 400

D. 340

E. 220

2.16 **Choose the best answer.** How many minutes does it take to wash, dry, and fold four loads of laundry using a pipelining approach, given the following information?

One washer takes 40 minutes.

One dryer takes 25 minutes.

One folder takes 50 minutes.

A. 215

B. 460

C. 165

D. 265

E. 315

2.17 **Choose the best answer.** A processor will execute an instruction set, S1, S2, and S3, five times using a pipeline approach.

S1 takes 3 clock cycles to complete.

S2 takes 8 clock cycles to complete.

S3 takes 8 clock cycles to complete.

How many clock cycles will this take the processor to complete?

A. 35

B. 51

C. 43

D. 95

E. 59

3 CPU Time Problems

3.18 **Choose ALL that apply.** How can the CPU performance of a program be improved?

A. Increasing the length of the clock cycle

B. Increasing the clock rate.

C. Decreasing the response time for disk access.

D. Decreasing the number or clock cycles

E. Increasing the clock cycles per instruction.

F. Increasing the instruction count.

G. Increasing the throughput of the processor.

3.19 **Choose the best answer.** A program with 5000e9 instructions runs alone on a CPU. The CPU clock rate is 3e9 cycles per second, i.e., 3 GHz. The average cycles per instruction is 3. How many seconds is the CPU performance for the task?

A. 0.002

B. 0.0

C. 5000.0

D. 50000.0

E. 0.0002

F. 45000

3.20 **Choose the best answer.** A program with 4000e9 instructions runs alone on a CPU. The CPU clock cycle time is 700e−12. The average cycles per instruction is 4. How many seconds is the CPU performance for the task?

A. 0.0

B. 11200.0

C. 1120.0

D. 22.857

E. 11200000

F. 0.0

3.21 **Choose the best answer.** A program runs alone on a CPU. The CPU clock rate is rate is 4e9 cycles per second, i.e., 4 GHz. It takes 12e11 clock cycles to complete the program. How many seconds is the CPU performance for the task?

A. 4.8

B. 48

C. 300.0

D. 480

E. 30.0

F. 3000.0

3.22 **Choose the best answer.** A program requires 3000e11 instructions to execute on a processor running at 10e9 cycles per second, i.e., 10 GHz. Suppose that 45% of the instructions execute in one cycle, 40% in 2 cycles, and 15% in 4 cycles. How many seconds is the CPU performance for the task?

A. 5550.0

B. 55500.0

C. 5550000.0

D. 555000.0

E. 120000.0

3.23 **Choose the best answer.** A program requires 7e9 instructions to execute on a processor running at 4 GHz with an average cycles per instruction of 5, resulting in an execution time of 8.75 seconds. Which adjustment improves overall performance approximately by 25%?

A. A rate of 3 GHz and 7 cycles per instruction.

B. A rate of 6 GHz and 6 cycles per instruction.

C. A rate of 5 GHz and 2 cycles per instruction.

D. A rate of 2 GHz and one cycle per instruction.

3.24 **Choose the best answer.** A program with 4000e11 instructions runs alone on a CPU. The CPU clock rate is 4e9 cycles per second, i.e., 4 GHz. The average cycles per instruction is 6. Suppose that the clock rate is increased to 8 GHz and the cycles per instruction is reduced to 4. Approximately, what is the overall performance improvement?

A. 600000.0

B. 200.0%

C. 5.0%

D. 50.0%

E. 20.0%

F. 60000.0

3.25 **Choose the best answer.** A program requires 1e9 instructions to execute on a processor running at 3 GHz. Suppose that 30% of the instructions execute in 2 cycles, 30% in 3 cycles, and 40% in 4 cycles resulting in an execution time of 1.03333 seconds.
Which adjustment improves overall performance approximately by 41%?

A. 100% executes at 2 cycles

B. 20% executes at 2 cycles and 80% at 3 cycles

C. 80% executes at 2 cycles and 20% at 3 cycles

D. 100% executes at 3 cycles

Answer Key

1: C
2: D
3: A
4: C
5: C
6: D
7: D
8: C
9: E
10: C
11: F
12: D
13: B
14: A
15: A
16: D
17: B
18: B, C, D, G
19: C
20: B
21: C
22: B
23: B
24: B
25: C