COEN 122: Computer Architecture
Homework #1

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Question #1

Consider three different processors P1, P2, and P3 executing the same instruction set. P1 has a 3 GHz clock rate and CPI of 1.5. P2 has a 2.5 GHz clock rate and a CPI of 1.0. P3 has a 4 GHz clock rate and has a CPI of 2.2.

a. Which processor has the highest performance expressed in instructions per second?

   Processor P2 has the highest performance with $\frac{2.5*10^9}{1} = 2.5 * 10^9$ instructions per second

b. If the processors each execute a program in 10 seconds, find the number of cycles and number of instructions?

Processor	Number of Instructions	Cycles
P1	$20 * 10^9$	$30 * 10^9$
P2	$25 * 10^9$	$25 * 10^9$
P3	$1.81 * 10^9$	$40 * 10^9$

c. We are trying to reduce the execution time by 30%, but this leads to an increase of 20% in the CPI. What clock rate should we have to get this time reduction?

   We should be adjusting the clock rate by a factor of $1.2/0.7 = 1.714$ to get our reduction in CPU time by 30%.

Question #2

Describe the steps that transform a program written in a high-level language such as C into a representation that is directly executed by a computer processor.

Typically, high-level languages such as C, C++, Java need to be compiled. These high level languages are an abstraction, to make programming simpler. The compiler turns the compiled code into assembly language, which is the textual representation of instructions. Then, the assembler of the machine takes the instructions and encodes the instructions and data into bits for the CPU to understand.

Question #3

For the following C statement, write the corresponding LEGv8 assembly code. Assume that the C variables f, ..., j (signed integers) have already been placed in registers X19, X20, ..., X23 respectively. Use a minimal number of LEGv8 assembly instructions.

```
f = (g * h) - (i / j);

MUL     X20, X20, X21
DIV     X22, X22, X23
SUB     X19, X20, X22
```

Question #4

a. Show how the value 0xABCDEF12 would be arranged in memory of a little-endian and a big-endian machine. Assume the data are stored starting at address 0 and that the word size is 4 bytes.

   The value in little-endian would be 0xABCDEF12, and 0x12EFCDAB in big-endian.

b. Translate

   i. 0x078E6 (to decimal)

$$6 + 16 * 14 + 16^2 * 8 + 16^3 * 7 = 30950_{10}$$

   ii. 3.1875 (to binary)

$$3 = 11_2$$
$$0.1875 \rightarrow \mathbf{0}.375 \rightarrow \mathbf{0}.75 \rightarrow \mathbf{1}.5 \rightarrow \mathbf{1}.0$$
$$0.1875 = .0011$$
$$3.1875 = 11.0011_2$$

c. Write the following signed number to decimal

   i. 100001

$$1 * 2^0 + (-)1 * 2^5 = -31$$

   ii. 110111.101101

$$1 + 1 * 2 + 1 * 2^2 + 1 * 2^4 + (-)1 * 2^5 = -9$$
$$1 * 2^{-1} + 1 * 2^{-3} + 1 * 2^{-4} + 1 * 2^{-6} = 0.703125$$
$$-9 + 0.703125 = -8.296875$$

Question #5

Measurement	Computer A	Computer B
Instruction Count	10 Billion	8 Billion
Clock Rate	4 GHz	4 GHz
CPI	1.0	1.1

a. Which computer has the higher MIPS rating?

$$\frac{10 * 10^9 * 1}{4 * 10^9} = 2.5 \text{ CPU time}$$
$$\frac{10 * 10^9}{2.5 * 10^6} = 4000 \text{ MIPS}$$

$$\frac{8 * 10^9 * 1.1}{4 * 10^9} = 2.2 \text{ CPU time}$$
$$\frac{8 * 10^9}{2.2 * 10^6} = 3636 \text{ MIPS}$$

Computer A has the higher MIPS rating with 4000.

b. Which computer is faster?

Computer B has a faster (smaller) CPU time, so Computer B is faster.

Question #6

Assume variable h is associated with register X21 and the base address of the array A is in X22. What is the LEGv8 assembly code for the C assignment statement below?

```
A[12] = h + A[8];

LDUR    X9, [X22, #64]  // X9 << A[8]
ADD     X9, X21, X9     // X9 << h + A[8]
STUR    X9, [X22, #96]  // A[12] << X9
```