Exercise 1.6:

Finding which is faster:

Execution time for P1:

$$ET_{P1} = \frac{(1 \cdot 10^5)(1) + (2 \cdot 10^5)(2) + (5 \cdot 10^5)(3) + (2 \cdot 10^5)(3)}{2.5 \cdot 10^9}$$
$$= 1.04 \cdot 10^{-3} \ seconds$$

Execution time for P1:

$$ET_{P2} = \frac{(1 \cdot 10^5)(2) + (2 \cdot 10^5)(2) + (5 \cdot 10^5)(2) + (2 \cdot 10^5)(2)}{3 \cdot 10^9}$$
$$= 6.657 \cdot 10^{-4} \ seconds$$

P2 is a faster implementation

a) Find the global CPI for each:

$$CPI_{P1} = \frac{(2.5 \cdot 10^9)(1.04 \cdot 10^{-3})}{10^6} = 2.6$$
$$CPI_{P2} = \frac{(3 \cdot 10^9)(6.657 \cdot 10^{-4})}{10^6} = 1.9971$$

b) Find the clock cycles for each:

$$clock\ cycles_{P1} = (1 \cdot 10^5)(1) + (2 \cdot 10^5)(2) + (5 \cdot 10^5)(3) + (2 \cdot 10^5)(3) = 2.6 \cdot 10^6 \ cycles$$

$$clock\ cycles_{P2} = (1 \cdot 10^5)(2) + (2 \cdot 10^5)(2) + (5 \cdot 10^5)(2) + (2 \cdot 10^5)(2) = 2 \cdot 10^6 \ cycles$$

Exercise 1.9:

Exercise 1.9.1: Find total execution times and speedup for 1, 2, 4 and 8 processors.

1 processor:

$$ET_1 = \frac{(2.56 \cdot 10^9)(1) + (1.28 \cdot 10^9)(12) + (2.56 \cdot 10^8)(5)}{2 \cdot 10^9} = 9.6\ seconds$$

2 processor:

$$ET_2 = \frac{(\frac{2.56}{0.7 \cdot 2} \cdot 10^9)(1) + (\frac{1.28}{0.7 \cdot 2} \cdot 10^9)(12) + (2.56 \cdot 10^8)(5)}{2 \cdot 10^9} = 7.02\ seconds$$

$$speedup_2 = \frac{9.6s}{7.04s} = 1.36$$

4 processor:

$$ET_4 = \frac{(\frac{2.56}{0.7 \cdot 4} \cdot 10^9)(1) + (\frac{1.28}{0.7 \cdot 4} \cdot 10^9)(12) + (2.56 \cdot 10^8)(5)}{2 \cdot 10^9} = 3.86\ seconds$$

$$speedup_4 = \frac{9.6s}{3.84s} = 2.5$$

8 processor:

$$ET_8 = \frac{(\frac{2.56}{0.7 \cdot 8} \cdot 10^9)(1) + (\frac{1.28}{0.7 \cdot 8} \cdot 10^9)(12) + (2.56 \cdot 10^8)(5)}{2 \cdot 10^9} = 2.25\ seconds$$

$$speedup_2 = \frac{9.6s}{2.24s} = 4.28$$

Exercise 1.9.2: Find total execution times with the CPIs for the arithmetic instructions doubled.

1 processor:

$$ET_1 = \frac{(2.56 \cdot 10^9)(2) + (1.28 \cdot 10^9)(12) + (2.56 \cdot 10^8)(5)}{2 \cdot 10^9} = 10.88\ seconds$$

2 processor:

$$ET_2 = \frac{(\frac{2.56}{0.7 \cdot 2} \cdot 10^9)(2) + (\frac{1.28}{0.7 \cdot 2} \cdot 10^9)(12) + (2.56 \cdot 10^8)(5)}{2 \cdot 10^9} = 7.95\ seconds$$

4 processor:

$$ET_4 = \frac{(\frac{2.56}{0.7 \cdot 4} \cdot 10^9)(2) + (\frac{1.28}{0.7 \cdot 4} \cdot 10^9)(12) + (2.56 \cdot 10^8)(5)}{2 \cdot 10^9} = 4.29\ seconds$$

8 processor:

$$ET_8 = \frac{(\frac{2.56}{0.7 \cdot 8} \cdot 10^9)(2) + (\frac{1.28}{0.7 \cdot 8} \cdot 10^9)(12) + (2.56 \cdot 10^8)(5)}{2 \cdot 10^9} = 2.47\ seconds$$

Exercise 1.9.3: What should the CPI of load/store be reduced to for a single processor to match 4 processors

CPU execution time for 4 processors = 3.86 seconds

$$3.86 = \frac{(\frac{2.56}{0.7 \cdot 4} \cdot 10^9)(1) + (\frac{1.28}{0.7 \cdot 4} \cdot 10^9)(x) + (2.56 \cdot 10^8)(5)}{2 \cdot 10^9}$$

$x = 3.03$

$$\frac{3.03}{12} = 0.25$$

The value should be reduced to 3.03 or 25% of the original.

Exercise 1.12:

Exercise 1.12.1: Check if the fallacy is true for P1 and P2.

Execution time for P1:

$$ET_{P1} = \frac{(5 \cdot 10^9)(0.9)}{4 \cdot 10^9} = 1.125s$$

Execution time for P1:

$$ET_{P2} = \frac{(1 \cdot 10^9)(0.75)}{3 \cdot 10^9} = 0.25s$$

P1 has a higher clock rate but has a larger execution time which means that its performance is lower which proves the fallacy is not true for P1 and P2.

Exercise 1.12.2: Determine the number of instructions that P2 can execute in the same time that P1 needs to execute $1 \cdot 10^9$ instructions.

Execution time for P1:

$$ET_{P1} = \frac{(1 \cdot 10^9)(0.9)}{4 \cdot 10^9} = 0.225s$$

Number of instructions for P2:

$$Instructions_{P2} = \frac{(0.225)(3 \cdot 10^9)}{0.75} = 9 \cdot 10^8 \; instructions$$

Exercise 1.14:

Exercise 1.14.1: How much must CPI of FP instructions be improved for the program to run twice as quickly.

Original execution time:

$$ET_1 = \frac{(5 \cdot 10^7)(1) + (1.1 \cdot 10^8)(1) + (8 \cdot 10^7)(4) + (1.6 \cdot 10^7)(2)}{2 \cdot 10^9} = 0.256s$$

Required CPI:

$$ET_2 = \frac{(5 \cdot 10^7)(x) + (1.1 \cdot 10^8)(1) + (8 \cdot 10^7)(4) + (1.6 \cdot 10^7)(2)}{2 \cdot 10^9} = \frac{0.256s}{2}$$

$$\frac{(5 \cdot 10^7)(x)}{2 \cdot 10^9} + \frac{(1.1 \cdot 10^8)(1) + (8 \cdot 10^7)(4) + (1.6 \cdot 10^7)(2)}{2 \cdot 10^9} = 0.128$$

$$\frac{(5 \cdot 10^7)(x)}{2 \cdot 10^9} = 0.128 - \frac{(1.1 \cdot 10^8)(1) + (8 \cdot 10^7)(4) + (1.6 \cdot 10^7)(2)}{2 \cdot 10^9}$$

$$\frac{(5 \cdot 10^7)(x)}{2 \cdot 10^9} = 0.128 - 0.231 = -0.103s$$

The required CPI with this instruction alone would be a negative number which is impossible so the CPI of FP alone cannot be improved to double the program speed.

Exercise 1.14.2: How much must CPI of L/S instructions be improved for the program to run twice as quickly.

Same original execution time = 0.256s
Twice as fast is 0.128

Required CPI:

$$\frac{(5 \cdot 10^7)(1) + (1.1 \cdot 10^8)(1) + (8 \cdot 10^7)(x) + (1.6 \cdot 10^7)(2)}{2 \cdot 10^9} = 0.128$$

$$\frac{(8 \cdot 10^7)(x)}{2 \cdot 10^9} + \frac{(1.1 \cdot 10^8)(1) + (5 \cdot 10^7)(1) + (1.6 \cdot 10^7)(2)}{2 \cdot 10^9} = 0.128$$

$$\frac{(8 \cdot 10^7)(x)}{2 \cdot 10^9} = 0.128 - \frac{(1.1 \cdot 10^8)(1) + (5 \cdot 10^7)(1) + (1.6 \cdot 10^7)(2)}{2 \cdot 10^9}$$

$$\frac{(8 \cdot 10^7)(x)}{2 \cdot 10^9} = 0.128 - 0.096 = 0.032s$$

$$x = 0.8 \ \frac{4}{0.8} = 5$$

The new CPI would have to be 0.8 which would be an improvement by a factor of 5

Exercise 1.14.3: How much faster would the program be if the CPI of INT and FP instructions are reduced by 40% and the CPI of L/S and Branch is reduced by 30%.

$CPI_{INT} = 0.6$
$CPI_{FP} = 0.6$
$CPI_{L/S} = 2.8$
$CPI_{Branch} = 1.4$

Find the new execution time:

$$ET = \frac{(5 \cdot 10^7)(0.6) + (1.1 \cdot 10^8)(0.6) + (8 \cdot 10^7)(2.8) + (1.6 \cdot 10^7)(1.4)}{2 \cdot 10^9} = 0.1712$$

$$speedup = \frac{0.256s}{0.1712s} = 1.5$$

The program is 1.5 times faster