\documentclass[10pt]{article}

% math fonts

\usepackage{amsmath,amsfonts,amsthm,amssymb}

% to insert graphics

\usepackage{graphicx}

% to change margins of the pages

\usepackage[margin=0.9in]{geometry}

% Makes equations flush left

\usepackage{fleqn}

% This generates a page header with your name in it.

\usepackage{fancyhdr}

\pagestyle{fancy}

\fancyhf{}

\lhead{Comp Org Fall 2018}

\rhead{HW02 solution by Sriyuth Sagi}

\rfoot{Page \thepage}

% This package makes it easy to have boxes around large text.

\usepackage{framed}

\begin{document}

{\bf Exercise 1.6:} \\

\\

Finding which is faster:\\\\

Execution time for P1:\\\\

$ ET\_{P1} = \dfrac{(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}$\\

\hspace{0.65cm} $= 1.04 \cdot 10^{-3}$ $seconds$\\\\

Execution time for P1:\\\\

$ ET\_{P2} = \dfrac{(1 \cdot 10^5)(2) + (2 \cdot 10^5)(2) + (5 \cdot 10^5)(2) + (2 \cdot 10^5)(2)}{3 \cdot 10^9}$\\

\hspace{0.65cm} $= 6.657 \cdot 10^{-4}$ $seconds$\\\\

P2 is a faster implementation\\\\\\

a) Find the global CPI for each:\\\\

$ CPI\_{P1} = \dfrac{(2.5 \cdot 10^9)(1.04 \cdot 10^{-3})}{10^6} = 2.6$\\\\

$ CPI\_{P2} = \dfrac{(3 \cdot 10^9)(6.657 \cdot 10^{-4})}{10^6} = 1.9971$\\\\\\

b) Find the clock cycles for each:\\\\

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

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

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{\bf Exercise 1.9:} \\

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

\\

1 processor:\\\\

$ ET\_{1} = \dfrac{(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} = \dfrac{(\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$ $seconds$\\\\

$speedup\_2 = \dfrac{9.6s}{7.04s} = 1.36$\\\\

4 processor:\\\\

$ ET\_{4} = \dfrac{(\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$ $seconds$\\\\

$speedup\_4 = \dfrac{9.6s}{3.84s} = 2.5$\\\\

8 processor:\\\\

$ ET\_{8} = \dfrac{(\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$ $seconds$\\\\

$speedup\_2 = \dfrac{9.6s}{2.24s} = 4.28$\\\\\\

{\bf Exercise 1.9.2:} Find total execution times with the CPIs for the arithmetic instructions doubled.\\

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1 processor:\\\\

$ ET\_{1} = \dfrac{(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} = \dfrac{(\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} = \dfrac{(\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} = \dfrac{(\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$ $seconds$\\\\

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

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CPU execution time for 4 processors = 3.86 seconds\\\\

$ 3.86 = \dfrac{(\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}$\\\\

$x = 3.03$\\\\

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

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

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{\bf Exercise 1.12:} \\

{\bf Exercise 1.12.1:} Check if the fallacy is true for P1 and P2.\\

Execution time for P1:\\\\

$ ET\_{P1} = \dfrac{(5 \cdot 10^9)(0.9)}{4 \cdot 10^9} = 1.125s$\\

Execution time for P1:\\\\

$ ET\_{P2} = \dfrac{(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.\\\\

{\bf 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} = \dfrac{(1 \cdot 10^9)(0.9)}{4 \cdot 10^9} = 0.225s$\\

Number of instructions for P2:\\\\

$ Instructions\_{P2} = \dfrac{(0.225)(3 \cdot 10^9)}{0.75} = 9 \cdot 10^8$ $instructions$\\

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{\bf Exercise 1.14:} \\

{\bf 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 = \dfrac{(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 = \dfrac{(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} = \dfrac{0.256s}{2}$\\\\

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

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

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

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.\\\\\\

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

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Same original execution time = 0.256s\\

Twice as fast is 0.128\\

Required CPI:\\\\

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

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

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

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

$x = 0.8$

$\dfrac{4}{0.8} = 5$\\\\

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

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{\bf 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:\\\\

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

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

The program is 1.5 times faster.

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