CS M151B - Homework 1

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Section 1B

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Problem 1.5

a

To calculate the instructions per second we can follow the equation $IPS = \frac{CPU}{CPI}$ where CPU is the processor speed.

$$IPS_{P1} = \frac{3 \cdot 10^9}{1.5} = 2 \cdot 10^9 \rightarrow 2MIPS$$
$$IPS_{P2} = \frac{2.5 \cdot 10^9}{1} = 2.5 \cdot 10^9 \rightarrow 2.5MIPS$$
$$IPS_{P3} = \frac{4 \cdot 10^9}{2.2} = 1.82 \cdot 10^9 \rightarrow 1.82MIPS$$

Thus we see that based on instructions per second, **P2** is the fastest.

b

To find the number of cycles that run in a given period of time we use the equation $num\, cycles = CPU \cdot time$ and to find the number of instructions we use $num\, instructions = \frac{num\, cycles}{CPI}$. This gives us the following results

Processor	**Number of cycles**	**Number of instructions**
P1	$3 \cdot 10^9 \cdot 10 = 30 \cdot 10^9$	$\frac{30 \cdot 10^9}{1.5} = 20 \cdot 10^9$
P2	$2.5 \cdot 10^9 \cdot 10 = 25 \cdot 10^9$	$\frac{25 \cdot 10^9}{1} = 25 \cdot 10^9$
P3	$4 \cdot 10^9 \cdot 10 = 40 \cdot 10^9$	$\frac{40 \cdot 10^9}{2.2} = 18.18 \cdot 10^9$

c

To find the new clock rate required we have to consider the following equation: $ET = \frac{IC \cdot CPI}{Rate} \rightarrow Rate = \frac{IC \cdot CPI}{ET}$. We know that the new execution time ET is 30% lower than in part b which suggests that the new desired execution time is 7 seconds. To compensate for this we have a 20% increase in the CPI meaning that it is now 1.2 times more. To calculate the Instruction count IC we simply use the results from the third column of our table in part b. This then gives us the following results for the new clock rates:

$$New\, CPU_{P1} = \frac{20 \cdot 10^9 \cdot (1.2 \cdot 1.5)}{7} = 5.14GHz$$

$$New\, CPU_{P2} = \frac{25 \cdot 10^9 \cdot (1.2 \cdot 1)}{7} = 4.28GHz$$

$$New\, CPU_{P3} = \frac{18.18 \cdot 10^9 \cdot (1.2 \cdot 2.2)}{7} = 6.86GHz$$

Problem 1.6

We start by breaking the problem statement down into the following table

	CPI_{P1} (2.5GHz)	CPI_{P2} (3GHz)	occurrence
Class A	1	2	10
Class B	2	2	20
Class C	3	2	50
Class D	3	2	20

a

To find out which implementation is faster we first calculate the execution time for each processor as per the equation $ET = \frac{IC \cdot CPI}{Rate}$.

$$ET_{P1} = \frac{(0.1 \cdot 1 \cdot 10^6 \cdot 1) + (0.2 \cdot 1 \cdot 10^6 \cdot 2) + (0.5 \cdot 1 \cdot 10^6 \cdot 3) + (0.2 \cdot 1 \cdot 10^6 \cdot 3)}{2.5 \cdot 10^9} = 10.4 \cdot 10^{-4} s$$

$$ET_{P2} = \frac{(0.1 \cdot 1 \cdot 10^6 \cdot 2) + (0.2 \cdot 1 \cdot 10^6 \cdot 2) + (0.5 \cdot 1 \cdot 10^6 \cdot 2) + (0.2 \cdot 1 \cdot 10^6 \cdot 2)}{3 \cdot 10^9} = 6.66 \cdot 10^{-4} s$$

From the given execution times, we can find the global CPI by manipulating the execution time equation to get $Avg\,CPI = \frac{ET \cdot Rate}{IC}$ thus giving us the following global CPI's:

$$CPI_{P1} = \frac{10.4 \cdot 10^{-4} \cdot 2.5 \cdot 10^9}{1 \cdot 10^6} = 2.6$$

$$CPI_{P2} = \frac{6.66 \cdot 10^{-4} \cdot 3 \cdot 10^9}{1 \cdot 10^6} = 2.0$$

b

To find the clock cycles required we just multiply the average CPI with the Instruction count so we get the following:

$$Cycles_{P1} = 1 \cdot 10^6 \cdot 2.6 = 2.6 \cdot 10^6$$

$$Cycles_{P2} = 1 \cdot 10^6 \cdot 2.0 = 2.0 \cdot 10^6$$

Thus we can conclude that **P2** is faster.

Problem 1.7

a

To find the average CPI we use the equation $Avg\,CPI = \frac{ET \cdot Rate}{IC}$. Clock cycle time being 1ns means we have a 1GHz processor. Thus we have the following CPI's:

$$CPI_A = \frac{1.1 \cdot 1 \cdot 10^9}{1 \cdot 10^9} = 1.1$$

$$CPI_B = \frac{1.5 \cdot 1 \cdot 10^9}{1.2 \cdot 10^9} = 1.25$$

b

To find the speedup we have to look at the ratio between the two rates, $Rate = \frac{IC \cdot CPI}{ET}$. Because we assume the same execution time, we only care about the relative effects of the instruction count and the CPI:

$$\frac{Rate_B}{Rate_A} = \frac{1.2 \cdot 10^9}{1 \cdot 10^9} \cdot \frac{1.25}{1.1} = 1.36$$

Thus the speedup factor is **1.36** times, such that Compiler B is faster.

c

$$\frac{T_A}{T_{new}} = \frac{1 \cdot 10^9}{6 \cdot 10^8} \cdot \frac{1.1}{1.1} = 1.67$$
$$\frac{T_B}{T_{new}} = \frac{1.2 \cdot 10^9}{6 \cdot 10^8} \cdot \frac{1.25}{1.1} = 2.27$$

Problem 1.13

1

The new time spent executing FP instructions is $0.8 \cdot 70 = 56s$. This is a drop by 14 seconds overall which means that the total time is reduced by $\frac{14 \cdot 100}{250} = 5.6\%$.

2

Total time reduction by 20% results in a total time of $0.8 \cdot 250 = 200s$. Because we can assume that the ratio of all instructions with relation to the total time remains the same, we can conclude that reducing the entire time by 20% results in a drop equally distributed by all instructions. Thus INT time is also reduced by 20%. We can assume that the old INT operations took the time that wasn't covered by the given instructions that is $250 - (70 + 85 + 40) = 55s$. Therefore INT drops by $0.2 \cdot 55 = 11s$.

3

Reducing total time by 20% means that we have a drop by $0.2 \cdot 250 = 50s$. However we notice that the branch instructions only take up 40 seconds, so even with a 100% drop in branch instructions we won't get a 20% drop overall. This follows Amdahl's law, and thus means **no** we can't achieve a 20% drop overall by only reducing branch instruction times.