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Problem 1

a. $CPUtime = IC \times CPI \times Clock\ Cycle\ time$ = Execution time. IC means Instruction Counts

Compiler A's $CPUtime_A = 1.0 \times 10^9 \times CPI_A \times 1.0 \times 10^{-9} = 1.1$

Compiler B's $CPUtime_B = 1.2 \times 10^9 \times CPI_B \times 1.0 \times 10^{-9} = 1.5$

$$\therefore CPI_A = \frac{1.1}{1.0 \times 10^9 \times 1.0 \times 10^{-9}} = 1.1$$

$$CPI_B = \frac{1.5}{1.2 \times 10^9 \times 1.0 \times 10^{-9}} = 1.25$$

$\therefore$ answer

$CPI_A = 1.1$

$CPI_B = 1.25$

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b. $CPU\ time = \frac{IC \times CPI}{Clock\ Rate}$

Since both excution times are Same.

$\underbrace{CPU\ time_1}_{\text{a Processor that is runnig Compiler A's Code}} = \underbrace{CPU\ time_2}_{\text{a Processor that is running Compiler B's code}}$

$$\Rightarrow \frac{1.0 \times 10^9 \times 1.1}{clock\ Rate_1} = \frac{1.2 \times 10^9 \times 1.25}{clock\ Rate_2}$$

$$\Rightarrow Clock Rate_1 = \frac{1.0 \times 10^9 \times 1.1}{1.2 \times 10^9 \times 1.25} ClockRate_2 \approx 0.73\ ClockRate_2$$

$\therefore$ So a Processor which is running Compiler A's code is 27% slower than a Processor which is runnig Compiler B's code.

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c. $CPU\ time_{new} = 6.0 \times 10^8 \times 1.1 \times \underbrace{1 \times 10^{-9}}_{\text{ins (original Processor's clock cycle time in a)}}$

$$\frac{Performance_{new}}{Performance_A} = \frac{CPU\ time_A}{CPU\ time_{new}} = \frac{1.0 \times 10^9 \times 1.1 \times 1 \times 10^{-9}}{6.0 \times 10^8 \times 1.1 \times 1 \times 10^{-9}} \approx 1.67$$

$$\frac{Performance_{new}}{Performance_B} = \frac{CPU\ time_B}{CPU\ time_{new}} = \frac{1.2 \times 10^9 \times 1.25 \times 1 \times 10^{-9}}{6.0 \times 10^8 \times 1.1 \times 1 \times 10^{-9}} \approx 2.27$$

$\therefore$ A new compiler's code is 1.67 faster than A's code and 2.27 faster than B's Code

Speed Up : 1.67 (relative to A's code)

2.27 (relative to B's Code)

Problem 2

1.9.1 CPUtime $= \frac{\text{Clock cycles}}{\text{Clock Rate}} =$ Execution time. IC means instruction counts.

Case1 single processor

$$\text{Clock Cycles}_1 = \sum_{i=1}^{3} IC_i \times CPI_i$$

Number of Processors

$$= 2.56\times10^9\times1 + 1.28\times10^9\times12 + 256000000\times5$$

$$= 2.56\times10^9\times1 + 1.28\times10^9\times12 + 2.56\times10^8\times5$$

$$= 1.92\times10^{10}$$

$$\text{execution time}_1 = \frac{1.92\times10^{10}}{2\times10^9} = 9.6S \text{ (single processor)}$$

Case 2 $P>1$

$$\text{Clock Cycles}_P = \frac{2.56\times10^9}{0.7\times P}\times1 + \frac{1.28\times10^9}{0.7\times P}\times12 + 2.56\times10^8\times5$$

$$= \frac{2.56\times10^9 + 1.28\times10^9\times12}{0.7\times P} + 2.56\times10^8\times5$$

$$= \frac{2.56\times10^{10}}{P} + 1.28\times10^9$$

$$\text{execution time}_P = \frac{\frac{2.56\times10^{10}}{P} + 1.28\times10^9}{2\times10^9}$$

answer

execution time$_1$ = 9.6S
execution time$_2$ = 7.04S
execution time$_4$ = 3.84S
execution time$_8$ = 2.24S

$\rightarrow$ $\boxed{\text{Speed up}}$ (relative to single Processor)
2 Processors : 1.36
4 Processors : 2.5
8 Processors : 4.29

1.9.2 Case1 Single Processor

$$\text{Clock Cycles}_1 = 2.56\times10^9\times2 + 1.28\times10^9\times12 + 2.56\times10^8\times5$$

$$= 2.176\times10^{10}$$

$$\text{execution time}_1 = \frac{2.176\times10^{10}}{2\times10^9} = 10.88S$$

Case2 $P>1$

$$\text{clock Cycles}_P = \frac{2.56\times10^9}{0.7\times P}\times2 + \frac{1.28\times10^9}{0.7\times P}\times12 + 2.56\times10^8\times5$$

$$= \frac{2.93\times10^{10}}{P} + 1.28\times10^9$$

$$\text{execution time}_P = \frac{\frac{2.93\times10^{10}}{P} + 1.28\times10^9}{2\times10^9} = \frac{14.65}{P} + 0.64$$

answer

execution time$_1$ = 10.88 S
execution time$_2$ = 7.965 S
execution time$_4$ = 4.3025 S
execution time$_8$ = 2.477 S

$\rightarrow$ CPI doubled in arithmatic instruction make execution time slower than CPI not doubled execution time in all case. (1, 2, 4, 8 Processors)

1.9.3

By 1.9.1

$execution time_4 = 3.84s$

$$execution\ time_{new\ (1\ Processor)} = execution\ time_4$$

$$execution\ time_{new} = \frac{2.56\times10^9\times1 + 1.28\times10^9\times CPI_{2new} + 2.56\times10^8\times5}{2.0\times10^9}$$

$$= 1.92 + 0.64\,CPI_{2new} = 3.84$$

$$\Rightarrow CPI_{2new} = \frac{3.84-1.92}{0.64} = 3$$

$\therefore CPI_{2new} = 3$

Problem 3

1.11.1 $execution\ time = CPU\ time = IC\times CPI\times clock\ Cycle time$

$$execution\ time = 750 = 2.389\times10^{12}\times CPI\times 0.333\times10^{-9}$$

$$\therefore CPI = \frac{750}{2.389\times10^{12}\times0.333\times10^{-9}}$$

$$\approx 0.94$$

1.11.2 $SPEC\ ratio = \frac{Reference\ time}{Execution time} = \frac{9650}{750} = 12.87$

1.11.4

$$CPU\ time_{new} = \underbrace{2.389\times10^{12}\times1.1}_{Instruction\ Count new}\times\underbrace{0.94\times1.05}_{CPI_{new}}\times0.333\times10^{-9}$$

$$\approx 863.71s$$

$\Rightarrow \frac{863.71}{750}\approx1.15$ increased 15% CPU time

1.11.6

$$CPU\ time_{new} = \frac{2.389\times10^{12}\times0.85\times CPI_{new}}{4.0\times10^9} = 700$$

$$\therefore CPI_{new} = \frac{700\times4.0\times10^9}{2.389\times10^{12}\times0.85}\approx1.38$$

1.11.7 $\frac{4GHz}{3GHz}\approx1.333$ and $\frac{1.38}{0.94}\approx1.468$

Clock Rate increased 1.333 times and CPI increased 1.468.
because we reduced the instructions 15%, too, not only clock Rate.

1.11.8 $\frac{CPU\ time_{new}}{CPU\ time_{old}} = \frac{700}{750}\approx0.933$

CPU time reduced 6.7%

Problem4

2.3

sub $s5, $3, $4 → Store i-j in s5
sll $s5, $s5, 2 → Store (i-j)×4 in s5
add $s5, $s6, $s5 → s5 has A[i-j]'s address
lw $t0, 0($s5) → t0 has A[i-j]'s value
sw $t0, 32($s7) → Store A[i-j]'s value in 32($s7) {B[8]}

2.10

A[1] = Ai
f = 2*Ai

2.14

op = 000000 → RType
rs = 10000 → $16 → $s0
rt = 10000 → $16 → $s0
rd = 10000 → $16 → $s0
shamt = 00000
funct = 100000 → add

R-Type Instruction
add $s0, $s0, $s0

2.17

op = 100011 → lw, I-Type Instruction
rs = 00001 → $at
rt = 00010 → $v0
immediate = 0000000000000100

∴ I-Type Instruction
lw $v0, 4($at)
1000 1100 0010 0010 0000 0000 0000 0100