Problem 1: Rubric: Each section has 10 points:

a.

We define performance as execution time, so first find the execution time:

$$Exe.Time = \frac{Instruction\ Count \times CPI}{Clock\ rate}$$

P1

$$Exe.Time = \frac{5 \times 10^9 \times 0.9}{4 \times 10^9} = 1.125$$

P2

$$Exe.Time = \frac{1 \times 10^9 \times 0.75}{3 \times 10^9} = 0.25$$

P1 has higher clock rate but it is slower than P2. So, Clock rate is not a good measurement for the performance

b.

How long does it take P1 to execute 1.0E9 instructions:

Exe. Time =
$$\frac{1 \times 10^9 \times 0.9}{4 \times 10^9} = 0.225$$

How many instructions P2 can run in the same time (0.225):

Instruction Count =
$$\frac{Exe.Time \times Clock \ rate}{CPI}$$
Instruction Count =
$$\frac{0.225 \times 3 \times 10^{9}}{0.75} = 0.9 \times 10^{9} = 0.9E9$$

In the same amount of time P2 execute fewer instructions than P1, So it is not correct that the larger number of instructions need a larger CPU time

c.

P1
$$MIPS = \frac{Instruction\ Count}{Execution\ Time \times 10^6}$$
 P1
$$MIPS = \frac{5 \times 10^9}{1.125 \times 10^6} = 4.4 \times 10^3 = 4.4E3$$
 P2
$$MIPS = \frac{1 \times 10^9}{0.25 \times 10^6} = 4 \times 10^3 = 4E3$$

P1 has higher MIPS but P2 is faster so MIPS is not a good measurement for the performance

d.

No.FP operations = Percent of FP instructions \times Instruction Count

P1

No. FP operations =
$$\frac{40}{100} \times 5 \times 10^9 = 2E9$$

$$MFLOPS = \frac{2 \times 10^9}{1.125 \times 10^6} = 1.8 \times 10^3 = 1.8E3$$

P2

No.FP operations =
$$\frac{40}{100} \times 1 \times 10^9 = 0.4E9$$

$$MFLOPS = \frac{0.4 \times 10^9}{0.25 \times 10^6} = 1.6 \times 10^3 = 1.6E3$$

Although P1 has higher MFLOPS but P2 is faster. So MFLOPS is not a good measurement for the performance

Note:

As mentioned before MFLOPS shows how many (millions) instructions a processor can execute per second. So, it is dependent on the processor and on the program. If the program we are using for measurement has no floating-point instruction, then the MFLOPS will be zero no matter how fast the CPU is.

$$MFLOPS = No.FP \ operations/(execution \ time \times 1E6)$$

In this formula the execution time is the execution time of the program not only the execution time of the floating-point instructions in the program

Problem 2: Rubric: Each part has 10 points:

(a) Calculate T_2 , T_4 , T_8 , which are the times to execute program P on a two-, four-, eight-processor system, respectively.

Assume the time taken to execute on a single processor system is T.

$$T_2 = 0.4T + (0.6/2)T = 0.7T$$

$$T_4 = 0.4T + (0.6/4)T = 0.55T$$

$$T_8 = 0.4T + (0.6/8)T = 0.475T$$

(b) Calculate T_{∞} on an system with an infinite number of processors. Calculate the speedup of the program on this system, where *speedup* is defined as $\frac{T}{T_{\infty}}$. What does this correspond to?

$$T_{\infty} = 0.4T + (0.6/\infty)T = 0.4T$$

$$Speedup = (T/T_{\infty}) = T/0.4T = 2.5$$

This corresponds to the speedup if "only" the serial portion had been executed.

Problem 3: Rubric: 15 points:

a) suppose the percentage of vectorization is x. Based on Amdahl's law, we have:

Speedup_{overall} =
$$\frac{1}{\left(1 - \text{Fraction}_{\text{enhanced}}\right) + \frac{\text{Fraction}_{\text{enhanced}}}{\text{Speedup}_{\text{enhanced}}}}$$

$$2 = \frac{1}{(1 - X) + \frac{X}{20}}$$

b) The maximum speed up can be achieved if the percentage of vectorization is 100%.

$$\begin{aligned} \text{MaxSpeedup}_{\text{overall}} &= \frac{1}{\left(1 - \text{Fraction}_{\text{enhanced}}\right) + \frac{\text{Fraction}_{\text{enhanced}}}{\text{Speedup}_{\text{enhanced}}}} \\ &= \frac{1}{\left(1 - 100\%\right) + \frac{100\%}{20}} \\ &= 20 \end{aligned}$$

If only one-half of the maximum speedup is needed with the percentage of vectorization as X, using Amdahl's Law

$$Speedup_{overall} = \frac{1}{\left(1 - Fraction_{enhanced}\right) + \frac{Fraction_{enhanced}}{Speedup_{enhanced}}}$$

$$\frac{20}{2} = \frac{1}{(1-X) + \frac{X}{20}}$$

$$X \approx 94.74\%$$

c) Based on Amdahl's Law, the speedup that the hardware group could achieve is

Speedup_{overall} =
$$\frac{1}{(1 - \text{Fraction}_{\text{enhanced}}) + \frac{\text{Fraction}_{\text{enhanced}}}{\text{Speedup}_{\text{enhanced}}}}$$
$$= \frac{1}{(1 - 70\%) + \frac{70\%}{2 \times 20}}$$
$$\approx 3.1496$$

For the compiler crew, they have to increase the original percentage of vecorization to X for achieving the same speedup as what the hardware group does. X can be found by using Amdahl's Law again as

Speedup_{overall} =
$$\frac{1}{(1 - \text{Fraction}_{\text{enhanced}}) + \frac{\text{Fraction}_{\text{enhanced}}}{\text{Speedup}_{\text{enhanced}}}}$$

$$3.1496 = \frac{1}{(1 - X) + \frac{X}{20}}$$

 $X \approx 71.84\%$

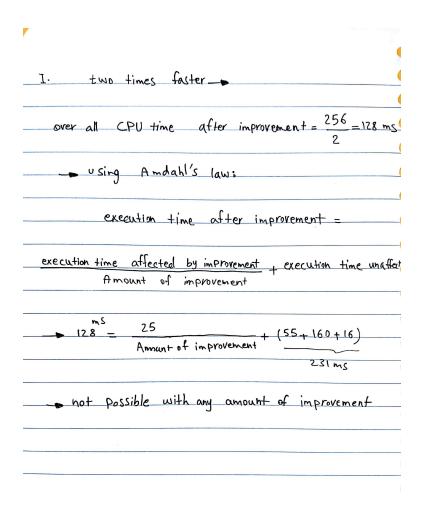
So, the increase of the percentage of vectorization is 1.84%. Comparing to a significant additional engineering investment required by the hardware group, adding a small amount of the percentage of vectorization costs less. It is defiantly worth investing the compiler crew!

Problem 4: Rubric: each CPU time has 1.5 point

Instruction ount CPI
FP Soxlo ⁶
INT 110x106
L/S 80 x16 4
branch 16x10 ⁶ 2
Instruction count x CPI
<u> </u>
$\frac{\text{CPU fine}}{\text{(FP)}} = \frac{50 \times 10^6 \times 1}{2 \times 10^9} = 25 \text{ ms}$
$\frac{\text{CPU time}}{(INT)} = \frac{110 \times 10^6 \times 1}{2 \times 10^9} = 55 \text{ ms}$
$\frac{\text{CPU time}}{(L/S)} = \frac{80 \times 10^6 \times 4}{2 \times 10^9} = 160 \text{ ms}$
$\frac{\text{CPU time}}{\text{(branch)}} = \frac{16 \times 10^6 \times 2}{2 \times 10^9} = 16 \text{ m/s}$
Over all CPU time before improvement = 25+55+160+16 =

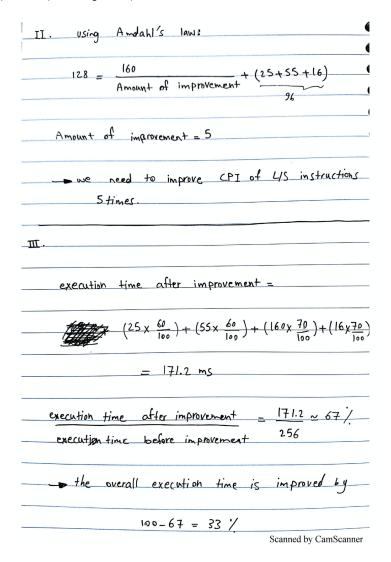
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a. (3 points):



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(Each part (b and c) has 3 points):



Problem 5: Rubric: calculating capacitive load for each processor has 5 points:

$$dynamic\ power = capacitive\ load\ \times voltage^2 \times Frequency$$

$$\Rightarrow capacitive\ load = \frac{dynamic\ power}{voltage^2 \times Frequency}$$

$$Processor\ A: \quad capacitive\ load = \frac{90}{1.25^2 \times 3.6 \times 10^9} = 16\ nF$$

$$Processor\ B: \quad capacitive\ load = \frac{40}{0.9^2 \times 3.4 \times 10^9} = 14.52\ nF$$