Com S 321 **NAME:** Hosam Abdeltawab

Fall 2017 **Exam 1**

DO NOT OPEN THIS EXAM UNTIL INSTRUCTED TO DO SO

Closed book and closed notes. The use of a calculator is allowed.

You may use extra pages and the backs of pages if needed.

Please stop writing when asked to do so.

Please write your answers neatly and legibly.

Problem	Pts	Pts obtained
1	20	16
2	20	20
3	20	20
4	20	20
5	20	20
TOTAL	100	96

1. (20 points)

(a) (6 points) We wish to compare the performance of two different machines: M1 and M2. The following measurements have been made on these machines:

Program	Time on M1	Time on M2
1	8 secs	4 secs
2	3 secs	5 secs

Which machine is faster for each program and by what percent?

Program 1:

Machine 2 is faster by 100% or twice as fast

3 $\frac{8}{4} = 1 + \frac{N}{100}$, $\boxed{N = 100}$

Program 2:

Machine 1 is faster by $\boxed{66.667\%}$

3 $\frac{5}{3} = 1 + \frac{N}{100}$

$= 1.66667$

(b) (4 points) Consider the two machines and programs in Part (a). The following additional measurements are made:

Program	Instructions executed on M1	Instructions executed on M2
1	$240 * 10^6$	$160 * 10^6$

Find the MIPS rating for each machine when running Program 1.

MIPS rating for M1:

2 $\text{MIPS} = \frac{240 * 10^6}{8 * 10^6} = 30$

MIPS rating for M2:

2 $\text{MIPS} = \frac{160 * 10^6}{4 * 10^6} = 40$

(c) (4 points)

There are 4 classes of instructions on M1 and M2 (let's call them A, B, C, and D). For a certain application program, the average number of cycles for each instruction class on M1 and M2 are given below. Assume the clock rate of M1 to be 500 MHz and the clock rate of M2 to be 750 MHz.

Instr. Class	CPI for M1	CPI for M2
A	2	2
B	4	5
C	1	2
D	3	3

Give the peak MIPS rating on M1 and M2.

Peak MIPS on M1 =

$$P.MIPS = \frac{C.R}{CPI * 10^6} = \frac{500 * 10^6}{1 * 10^6} = 500$$

2

Peak MIPS on M2 =

$$\frac{750 * 10^6}{2 * 10^6} = 375$$

2

(d) (6 points)

Assume that a given application program has the following number of instructions: 650 ALU ops, 600 Loads, 100 Stores, and 50 Branches. Assume that an ALU op takes 1 clock cycle, Stores and Loads take 5 clock cycles each, and Branches take 8 clock cycles and the clock rate is 2 GHz ($2 * 10^9$).

Find the CPI.

$$CPI = \frac{\text{Tot \# of CC}}{\text{Tot \# of Inst.}} = \frac{1+5+8+5}{650+600+100+50} = \frac{19}{1400} = 0.0136$$

0

$$\frac{650*1 + 5*600 + 5*100 + 50*8}{650+600+100+50} = 3.25$$

Find the CPU Execution time (expressed in seconds).

$$CPU.E.T = \frac{I.C * CPI}{C.R} = \frac{1400 * 0.0136}{2 * 10^9} = \frac{19}{2 * 10^9} = 9.5 \times 10^{-9}$$

2

20

2. (20 points) You have a system that contains a special processor for doing floating-point operations. You have determined that 50% of your computations can use the floating-point processor. The floating-point processor is 40% faster than the regular processor (so its speedup is 1 + 40/100 = 1.4).

(a) (4 points) What is the overall speedup achieved by using the floating-point processor?

$$O.S = \frac{1}{(1-0.5)+\frac{0.5}{1.4}} = 1.1667$$

(b) (16 points) In order to improve the overall speedup you are considering two options:

- Option 1: Modifying the compiler so that 60% of the computations can use the floating-point processor. Cost of this option is $48,000.
- Option 2: Modifying the floating-point processor so that it runs 100% faster than the regular processor (so its speedup is 1 + 100/100 = 2). Assume in this case that 40% of the computations can use the floating-point processor. Cost of this option is $55,000.

Which Option (1 or 2) would you recommend and why? Justify your answer quantitatively by comparing the [Cost/Overall Speedup] ratio for each option. Show all your work.

Option 1: $O.S = \frac{1}{(1-0.6)+\frac{0.6}{1.4}} = 1.2069$

$$\frac{Cost}{O.S} = \frac{48,000}{1.2069} = \boxed{39,771.3}$$

Option 2: $O.S = \frac{1}{(1-0.4)+\frac{0.4}{2}} = 1.25$

$$\frac{Cost}{O.S} = \frac{55,000}{1.25} = \boxed{44,000}$$

— I would recommend option 1 Sicne $\frac{Cost}{O.S}$ for option 1 is less than option 2

3. (20 points)

20

You have a computer system that contains a special processor for doing floating-point operations. You have determined that 40% of the computations in your application program can use the floating-point processor. The speedup of the floating-point processor by itself is 20 (not to be confused with the overall speedup).

(a) (5 points) What is the overall speedup achieved by Amdahl's Law when the floating-point processor is used?

$$O.S = \frac{1}{(1-0.4)+\frac{0.4}{20}} = 1.6129$$

(b) (15 points) Suppose now we determine that some more improvements can be made to the application program. Let F_1 denote the 40% fraction described above with a speedup, S_1, of 20. Let F_2 denote another 20% fraction of the application program which can be modified to have a speedup, S_2, of 15. Let F_3 denote a further 10% fraction of the application program which can be modified to have a speedup, S_3, of 10.

Write a formula for overall speedup using a generalized version of Amdahl's Law. Use only the variables F_1, F_2, F_3 and S_1, S_2, S_3 in your formula.

$$O.S = \frac{1}{(1-(F_1+F_2+\dots+F_K))+\frac{F_1}{S_1}+\frac{F_2}{S_2}+\dots+\frac{F_K}{S_K}}$$

Compute the overall speedup when all three improvements are made.

$$O.S = \frac{1}{(1-(0.4+0.2+0.1))+\frac{0.4}{20}+\frac{0.2}{15}+\frac{0.1}{10}}$$

$$= 2.9126$$

4. (20 points) Suppose you have a load/store computer with the following instruction mix:

Operation	Frequency	No. of Clock cycles
ALU ops	40% -16%	1
Loads	20% -16%	3
Stores	15%	3
Branches	25%	~~4~~ 6
New	16%	1

(a) (3 points) Compute the CPI for the above data. Show ALL your work.

$$CPI = (0.4*1) + (0.2*3) + (0.15*3) + (0.25*4)$$
$$= 2.45$$

✓

(b) (5 points) We observe that 40% of the ALU ops are paired with a load, and we propose to replace these ALU ops and their loads with a NEW instruction. The NEW instruction takes 1 clock cycle. With the NEW instruction added, branches take 6 clock cycles. Compute the CPI for the new version. Show ALL your work.

$$CPI_{new} = [(0.4-0.16)(1) + (0.2-0.16)(3) + (0.15)(3) + (0.25)(6) + (0.16)(1)] \div (1-0.16)$$
$$= 2.94048$$

✓

(c) (12 points) If the new clock rate is 30% faster than before, which version is faster and by what percent? Justify your answer quantitatively by showing ALL your work.

$$\frac{CCT_{old}}{CCT_{new}} = 1.3 \quad ; \quad CCT_{old} = 1.3 * CCT_{new}$$

$$CPU.E.T_{old} = IC_{old} * CPI_{old} * CCT_{old}$$

$$= IC_{old} * 2.45 \times 1.3 * CCT_{new}$$

$$\boxed{= 3.185 * IC_{old} * CCT_{new}}$$

$$CPU.E.T_{new} = (1-0.16) * IC_{old} * 2.94048 * CCT_{new}$$

$$\boxed{= 2.47 * IC_{old} * CCT_{new}}$$

$$\frac{3.185}{2.47} = 1 + \frac{N}{100}$$

$$N = 28.947$$

* new is faster by $\boxed{28.947\%}$

5. (20 points)

Consider a program P with the following mix of operations: 10% Floating point multiplies, 15% Floating point adds, 5% Floating point divides, and 70% integer instructions. This program is executed on two machines – one with floating point hardware (MFP) and one with no floating point hardware (MNFP). Both machines have a clock rate of 500 MHz. On the MNFP machine, the floating point instructions are emulated using integer instructions, each integer instruction taking 2 clock cycles. On MFP, the floating point operations require the following number of cycles: $CPI = 2$

Floating point Multiply	8 cycles
Floating point Add	4 cycles
Floating point Divide	25 cycles
Integer instructions	2 cycles

On MNFP, the number of integer instructions required to emulate the floating point operations is as follows:

Floating point Multiply	30 integer instructions
Floating point Add	15 integer instructions
Floating point Divide	50 integer instructions

(a) (6 points) Find the MIPS rating for both MFP and MNFP.

$$CPI_{MFP} = (0.1)(8) + (0.15)(4) + (0.05)(25) + (0.7)(2)$$
$$= \boxed{4.05}$$

$$MIPS_{MFP} = \frac{500 \times 10^6}{4.05 \times 10^6} = \boxed{123.457}$$

6

$$CPI_{MNFP} = 2$$

$$MIPS_{MNFP} = \frac{500 \times 10^6}{2 \times 10^6} = \boxed{250}$$

(b) (8 points) If the MFP machine needs 400 million instructions for a program P, how many integer instructions are needed on the MNFP machine for the same program P?

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0.1 * 400 M = 40 M
0.15 * 400 M = 60 M
0.05 * 400 M = 20 M
0.7 * 400 M = 280 M

40 M * 30 = 1200 M
60 M * 15 = 900 M
20 M * 50 = 1000 M

Inst. MNFP = 1200 M + 900 M + 1000 M + 280 M = $\boxed{3380 M}$ ✓

8

(c) (6 points) What is the execution time in seconds for program P on MFP and MNFP, assuming the instruction count from part (b)?

$$CPU.ET_{MFP} = \frac{I.C}{MIPS \times 10^6} = \frac{400 \times 10^6}{123.457 \times 10^6} = \boxed{3.23999}$$ ✓ Secs

6

$$CPU.ET_{MNFP} = \frac{3380 \times 10^6}{250 \times 10^6} = \boxed{13.52}$$ Secs

20