CSci370 Computer Architecture: Homework 1 Solutions

Due date: On or before Thursday, February 13, 2020 in class
Absolutely no copying others' works **Name:** ____________________

- The purpose of homeworks is for students to practice for the exams without others' help, so the penalty of mistakes will be minor.
- Without practicing for the exams properly, students would not be able to do well on the exams.

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1. The following table shows manufacturing data of a processor:

Wafer Diameter	Dies per Wafer	Defects per Unit Area	Cost per Wafer
40 cm	80	0.04 defects/cm^2	30

a. (15%) Find the yield.
Ans>

Wafer area
$= 3.14159 \times 20.0^2\ \text{cm}^2$
$= 1256.636\ \text{cm}^2$

Die area
$= 1256.636\ \text{cm}^2 / 80$
$= 15.71\ \text{cm}^2$

Yield
$= 1 / (1 + \text{Defects per area} \times \text{Die area} / 2)^2$
$= 1 / [1 + (0.04\ \text{defects/cm}^2) \times (15.71\ \text{cm}^2) / 2]^2$
$= 0.58$

b. (10%) Find the cost per die.
Ans>

Cost per die
$= \text{Cost per wafer} / (\text{Dies per wafer} \times \text{Yield})$
$= 30 / (80 \times 0.58)$
$= 0.65$

c. (15%) If the number of dies per wafer is increased by 20% and the defects per area unit increase by 30%, find the die area and yield.
Ans>

Wafer area
$= 3.14159 \times 20.0^2\ \text{cm}^2$
$= 1256.636\ \text{cm}^2$

Die area
$= 1256.636\ \text{cm}^2 / (80 \times 1.2)$
$= 13.09\ \text{cm}^2$

Yield
$= 1 / (1 + \text{Defects per area} \times \text{Die area} / 2)^2$
$= 1 / [1 + (0.040 \times 1.30\ \text{defects/cm}^2) \times (13.09\ \text{cm}^2) / 2]^2$
$= 0.56$

2. Compilers can have a profound impact on the performance of an application. Consider the following two compilers for a program:

Compiler A		Compiler B	
Instruction count	Execution time	Instruction count	Execution time
1.2×10^9	4.5 s	1.8×10^9	6.0 s

a. (20%) Find the average CPI for each program given that the processor has a clock cycle time of 3 ns (or 3×10^{-9} s).
Ans>

CPI_A
$= \text{CPU time}_A / (\text{Instruction count}_A \times \text{Clock cycle time}_A)$
$= 4.5\ \text{s} / (1.2\times10^9\ \text{instructions} \times 3\times10^{-9}\ \text{s/cycle})$
$= 1.25$ cycles/instruction

CPI_B
$= \text{CPU time}_B / (\text{Instruction count}_B \times \text{Clock cycle time}_B)$
$= 6.0\ \text{s} / (1.8\times10^9\ \text{instructions} \times 3\times10^{-9}\ \text{s/cycle})$
$= 1.11$ cycles/instruction

b. (20%) Assume the compiled programs run on two different processors. If the execution times on the two processors are the same, how much faster is the clock of the processor running compiler A's code versus the clock of the processor running compiler B's code?
Ans>

$\text{Clock rate}_A / \text{Clock rate}_B$ (or $\text{Clock cycle time}_B / \text{Clock cycle time}_A$)
$= [(\text{CPI}_A \times \text{Instruction count}_A) / \text{CPU time}] / [(\text{CPI}_B \times \text{Instruction count}_B) / \text{CPU time}]$
$= (1.25\ \text{cycles/instruction} \times 1.2\times10^9\ \text{instructions}) /$
$(1.11\ \text{cycles/instruction} \times 1.8\times10^9\ \text{instructions})$
$= 0.75$

Therefore, the processor A is 0.75 times faster than the processor B.

c. (20%) A new compiler is developed that uses 5.0×10^8 instructions and has an average CPI of 1.5. What is the speedup of using this new compiler versus using Compiler A on the original processor?
†Hint: The speedup here is equal to T_A/T_n where
- T_A: the execution time by using the A compiler and
- T_n: the execution time by using the new compiler.

Ans>

T_A/T_n
$= (\text{Instruction count}_A \times \text{CPI}_A \times \text{Clock cycle time}_A) /$
$(\text{Instruction count}_n \times \text{CPI}_n \times \text{Clock cycle time}_n)$
$= (1.2\times10^9\ \text{instructions} \times 1.25\ \text{cycles/instruction} \times 3\times10^{-9}\ \text{s/cycle}) /$
$(5.0\times10^8\ \text{instructions} \times 1.50\ \text{cycles/instruction} \times 3\times10^{-9}\ \text{s/cycle})$
$= 2.0$