Homework 1 Solutions

1) Given 15 wafers of radius 20cm and a die with side 14mm and a defect density of 0.35 per cm^2, calculate the total number of defective chips. (Assuming the wafer yield is 100% and α=4)

$$Dies_{per\ wafer} = \frac{Wafer\ Area}{Die\ area} - \frac{Wafer\ circumference}{Diagonal\ of\ the\ die}$$

$$Dies_{per\ wafer} = \frac{\pi*20^2}{1.4^2} - \frac{2*\pi*20}{\sqrt{2}*1.4} = 578$$

$$Die\ yield = wafer\ yield \times \left(1 + \frac{Defect\ density\ \times Die\ area}{\alpha}\right)^{-\alpha}$$

$$Die\ yield = 1 \times \left(1 + \frac{0.35\ \times 1.4^2}{4}\right)^{-4} = 0.53$$

$$Number\ of\ defective\ chips$$
$$= no.of\ wafers\ \times dies_{per\ wafer} \times (1 - die\ yield)$$

$$= 15\ \text{x}\ 578\ \text{x}\ 0.47 = 4075$$

2) You find yourself in a game show presented with 2 machines. You are supposed to pick the fastest one to win an awesome prize! You are given the following information about the two machines A and B (running different compilers)

Machine A has a clock rate of 2 GHz with the following measurements.

Instruction Class	CPI for the class	Instruction Count (in billions)
A	4	9 = .15
B	1	15 = .25
C	5	12 = .20
D	2	24 = .40

Machine B has a clock rate of 2.5 GHz with the following measurements.

Instruction Class	CPI for the class	Instruction Count (in billions)
A	1	16 = .20
B	3	24 = .30
C	1	12 = .15
D	5	28 = .35

To make sure you don't parrot the answers given from the audience, the host asks you the following questions.

a. What is the average CPI of machine A and B?
Avg CPI for A $= 4 \times 0.15 + 1 \times 0.25 + 5 \times 0.20 + 2 \times 0.40 = 2.65$
Avg CPI for B $= 1 \times 0.20 + 3 \times 0.30 + 1 \times 0.15 + 5 \times 0.35 = 3.0$

b. On which machine is the program faster with respect to
   i. Execution time
      A = 2.65 * 60 = 159 billion clock cycles
      B = 3 * 80 = 240 billion clock cycles
      Exec time of A = 159/2 = 79.5 s
      Exec time of B = 240/2.5 = 96 s

ii. MIPS rating
  $A = (60 * 10^9) / (79.5 * 10^6) = 755$
  $B = (80 * 10^9) / (96 * 10^6) = 833$

3) 30% of a benchmark program's execution time is from multiply operations. Uber cool hardware speeds up these operations 12 times! Suppose the program took 20 seconds to execute without the enhanced hardware, what will be the overall speedup achieved? During its enhanced operation, what is the new execution time, and what is the percentage of time multiply operations take?   (20 points)

$$speedup = \frac{1}{(1 - 0.3) + \frac{0.3}{12}}$$
$$= 1 / (0.725) = 1.38$$

New execution time = old execution time / speed up = 14.5 s

Multiply operations take 0.5 seconds now and account for only 3% of the time taken in the enhanced mode.

4) When making changes to optimize part of a processor, it is often the case that speeding up one type of instruction comes at the cost of slowing down something else. For example, if we put in a complicated fast floating-point unit, that takes space, and something might have to be moved farther away from the middle to accommodate it, adding an extra cycle in delay to reach that unit. The basic Amdahl's law equation does not take this trade-off into account.

Let's assume for some benchmark program, 15% of the original execution time is taken up by floating point operations, 25% by data accesses and 30% by I/O operations..

You have 3 teams of engineers who come up with cool hardware to enhance each of the operations! But unfortunately, they inadvertently end up affecting other operations as well. Your job is to choose the hardware with the highest overall speedup and reward that team with a bag of goodies!

- Team A comes up with an improvement on the floating point hardware. It speeds up floating point operations 12 times but slows down data accesses by 1.25 times and I/O operations by 1.1 times.

$$speedup = \frac{1}{(1-0.7) + \frac{0.15}{12} + (0.25*1.25) + (0.3*1.1)}$$
$$= 1 / (.955) = 1.04$$

- Team B comes up with an improvement on the data access hardware. It speeds up data accesses by 2.5 times. It slows down the I/O operations by 1.5 times but speeds up floating point operations by 2 times!

$$speedup = \frac{1}{(1-0.7) + \frac{0.15}{2} + \frac{0.25}{2.5} + (0.3*1.5)}$$
$$= 1 / (0.925) = 1.08$$

- Team C comes up with an improvement for I/O operations which speeds it up by 6 times but slows down data accesses by 2.5 times and leaves the floating point operations unchanged.

$$speedup = \frac{1}{(1-0.55) + (0.25*2.5) + \frac{0.3}{6}}$$
$$= 1 / (1.125) = 0.89$$

Team B wins!!!!