Problem 1 (15 points) Consider three different processors P1, P2, and P3 executing the same instruction set. P1 has a 3.2 GHz clock rate and a CPI of 1.5. P2 has a 2.0 GHz clock rate and a CPI of 1.0. P3 has a 4.0 GHz clock rate and has a CPI of 2.3.

a. Calculate the performance of each processor expressed in instructions per second.

b. If each of these processors executes a program in 10 seconds, calculate the number of cycles and the number of instructions.

c. We are trying to reduce the execution time of P2 by 30%, but this leads to an increase of 20% in the CPI. What should the clock rate be to obtain this reduction in execution time?

Problem 1.

a.

Clock Rate / CPI = Instructions / second

P1 -> (3.2*10^9)/1.5 = 2.133*10^9 instructions per second

P2 -> (2*10^9)/1 = 2*10^9 instructions per second

P3 -> (4.0*10^9)/2.3 = 1.74*10^9 instructions per second

b.

10s = Instructions * CPI / CR

P1 -> (10*(3.2*10^9))/1.5 = 2.13*10^10 = Instructions
Clock Cycles = 2.13*10^10 * 1.5 = 3.195 * 10^10 Clock Cycles

P2 -> (10*(2*10^9))/1 = 2 * 10^10 = Instructions
Clock Cycles = (2*10^10)* 1 = 2 * 10^10 Clock Cycles

P3 -> (10*(4.0*10^9))/2.3 = 1.74*10^10 = Instructions
Clock Cycles = 1.74*10^10 * 2.3 = 4.002 * 10^10 Clock Cycles

c.

P2 -> .7 * Time = Instructions * (1.2 * CPI) / (x *Clock Rate)
.7 * 10s = (2 * 10^10) * (1.2 * 1.0) / (x * Clock Rate)
7s = 24000000000 /(x * Clock Rate)
x = 24000000000 / (7 * (2*10^9)) = 1.7

The Clock Rate must be increased by 70% to obtain this reduction

Problem 2 (15 points) Consider two different implementations of the same instruction set architecture. The instructions can be divided into four classes according to their CPI (classes A, B, C, and D). P1 with a clock rate of 2.5 GHz and CPIs of 1, 2, 3, and 3 for the corresponding classes, and P2 with a clock rate of 3 GHz and CPIs of 2, 2, 2, and 2. Given a program with a dynamic instruction count of 1.0E6 instructions divided into classes as follows: 30% class A, 20% class B, 30% class C, and 20% class D, which is faster: P1 or P2?

a. What is the total CPI for each implementation?
b. Calculate the clock cycles required in both cases.

Problem 2.

a.

P1 -> 3*1 + 2*2 + 3*3 + 2*3 = 22
CPI = 22/10 = 2.2

P2 -> 3*2 + 2*2 + 3*2 + 2*2 = 20
CPI = 20/10 = 2

b.

P1 -> Clock Cycles = 1.0* 10^6 * 2.2 = 2200000

P2 -> Clock Cycles = 1.0* 10^6 * 2 = 2000000

P1 time = 1 * 10^6 *2.2 / (2.5* 10^9) = 0.00088

P2 time = 1 * 10^6 *2 / (3* 10^9) = 0.00066 P2 is Faster

Problem 3 (20 points) Compilers can have a profound impact on the performance of an application. Assume that for a program, compiler A results in a dynamic instruction count of 1.0E9 and has an execution time of 1.2 s, while compiler B results in a dynamic instruction count of 1.2E9 and an execution time of 1.5 s.

a. Find the average CPI for each program given that the processor has a clock cycle time of 1 ns.

b. 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 As code versus the clock of the processor running compiler Bs code?

c. A new compiler is developed that uses only 6.0E8 instructions and has an average CPI of 1.1. What is the speedup of using this new compiler versus using compiler A or B on the original processor?

Problem 3.

Compiler A - 1.0E9 instructions 1.2 s
Compiler B - 1.2E9 instructions 1.5 s

a.

processor clock cycle time 1ns

Compiler A -> 1.2s = 1.0E9 * CPI * 1ns
1.2s /(1.0E9 *(1E-9s)) = CPI
1.2 CPI

Compiler B -> 1.5s = 1.2E9 * CPI * 1ns
1.5s /(1.2E9 *(1E-9s)) = CPI
1.25 CPI

b.

Compiler A -> I * 1.2 * 1000ps = 1200

Compiler B -> I * 1.25 * 1000ps = 1250

1250/1200 = 1.042 "3b. (-5) CPI for B is wrong, the ratio is wrong.

A's clock is running 4.2% faster than B's (faster by 1.042)

c.

Compiler C -> Time = 6.0E8 * 1.1 * 1ns
Time = 0.66 seconds

1.2/.66 = 1.82 ——> C is faster than A by 1.82 (82% faster)
1.5/.66 = 2.27 ——> C is faster than B by 2.27 (127% faster)

Problem 4 (20 points) Assume a 15 cm diameter wafer costs \$12, contains 84 dies, and has 0.022 defects/cm^2. Assume a 20 cm diameter wafer costs \$15, contains 100 dies, and has 0.031 defects/cm^2.

a. Calculate the yield for both wafers.

b. Calculate the cost per die for both wafers.

c. If the number of dies per wafer is increased by 10% and the defects per area unit increases by 15%, find the die area and yield.

Problem 4.

15cm wafer — 12\$ — 84 dies — 0.022 defects/cm^2
20cm wafer — 15\$ — 100 dies — 0.031 defects/cm^2

a.

Wafer 1 -> wafer area = 3.14*(15/2)^2 = 176.63 cm^2
die area = 176.63 / 84 = 2.103
Yield = 1/ (1+(0.022 defects/cm^2 * (2.103/2)))^2 = 0.955

Wafer 2 -> wafer area = 3.14*(20/2)^2 = 314 cm^2
die area = 314/ 100 = 3.14
Yield = 1/ (1+(0.031 defects/cm^2 * (3.14 /2)))^2 = 0.909

b.

Wafer 1 -> Cost per die = 12/(84*0.955) = 0.15

Wafer 2 -> Cost per die = 15/(100*0.909) = 0.165

c.

Wafer 1 ->
die area = 176.63 / (1.1*84) = 1.912
Yield = 1/ (1+((1.15*0.022) * (1.912/2)))^2 = 0.953

Wafer 2 ->
die area = 314/ (1.1*100) = 2.855
Yield = 1/ (1+((1.15*0.031) * (2.855 /2)))^2 = 0.905

Problem 5 (30 points) Assume a program requires the execution of 50E06 floating point (FP) instructions, 100E06 integer (INT) instructions, 80E06 load/store (L/S) instructions, and 16E06 branch (B) instructions. The CPI for each type of instruction is 1, 1, 4, and 2, respectively. Assume that the processor has a 2 GHz clock rate.

a. How much faster can we execute the program if the CPI of INT and FP instructions is reduced by 40% and the CPI of L/S and Branch is reduced by 30%?

b, By how much must we improve the CPI of FP instructions if we want the program to run 20% faster? (That is to take 80% of the original time.)

c. By how much must we improve the CPI of L/S instructions if we want the program to run 30% faster?

Problem 5.

time = (50E06 *1 + 100E06 *1 + 80E06 *4 +16E06*2) / (2*10^9) = 0.251

a.

time = (50E06 *(1*0.6) + (100E06)*(1 * .6) + 80E06 *(4 * .7) +16E06*(2 * .7)) / (2*10^9) = 0.1682

0.251 / 0.1682 = 1.49 1.49 times faster

b.

(0.8 * 0.251) = ((50E06) *1x + 100E06 *1 + 80E06 *4 +16E06*2) / (2*10^9)
0.2008 * (2*10^9) = 1x * 50E06 + 452000000
-50400000 = x = -1.008

Doesn't work?? $\boxed{\text{5b. (-3) Should clarify if it is possible."}}$

c.

(0.7 * 0.251) = (50E06 *1 + 100E06 *1 + 80E06 *(4x) +16E06*2) / (2*10^9)
0.1757* (2*10^9) = 4x * 80E06 + 182000000
169400000 = 4x 80E06
2.1175 = 4x
x = 0.529 ————-> We must improve the CPI of L/s by 47.1%