Homework 1

Q1 P_1

Clock Rate = 3.5 GHz

A : 1.5, 15%

B : 2.5, 20%

C : 3.2, 45%

D : 4.0, 20%

IC : 1 E 8

P_2

Clock Rate = 4 GHz

A = 1.7, 15%

B = 2.7, 20%

C = 3.2, 45%

D = 3.8, 20%

IC = 1E8

(a) CPU Time_A = Instruction count × CPI × clock cycle time

$= \text{Instruction count} \times \text{CPI} \times \frac{1}{\text{Clock Rate}}$

$= \frac{1E8 \times CPI}{3.5 E9}$

$CPI = \Sigma \, Freq_i \times CPI_i$

$= \frac{1E8 \times 2.965}{3.5 E9}$

$= (1.5 \times 0.15) + (2.5 \times 0.2) + (3.2 \times 0.45) + (4.0 \times 0.2)$

$= \frac{2.965 E8}{3.5 E9}$

$= (0.225) + (0.5) + (1.44) + (0.8)$

$\text{CPU Time}_A = 0.0847$

$= 2.965$

$\text{CPU Tim}_B = \frac{\text{Instruction Count} \times CPI}{\text{Clock Rate}}$

$(1.7 \times 0.15) + (2.7 \times 0.2) + (3.2 \times 0.45) + (3.8 \times 0.2)$

$= \frac{1E8 \times 2.995}{4 \text{ GHz}}$

$= (0.255) + (0.54) + (1.44) + (0.76)$

$= \frac{2.995 E8}{4 E9}$

$= 2.995$

$= 0.0748$

$\boxed{\text{CPU}_B \text{ works faster}}$

$\text{CPU Time}_A < \text{CPU Time}_B$

$0.0847 < 0.0748$

(B) $\boxed{\begin{array}{l} CPI_A = 2.965 \\ CPI_B = 2.995 \end{array}}$

(c) Clock Cycles = Instruction Count × Cyces per Instruction
=

$$\text{CPU Time} = \frac{\text{CPU clock cycles}}{\text{clock Rate}}$$

$$\text{CPU Time}_A = \frac{\text{clock cycles}_A}{\text{clock Rate}_A}$$

$$\text{CPU Time}_B = \frac{\text{clock cycles}_B}{\text{clock Rate}_B}$$

$\text{clock cycles}_A = \text{CPU Time}_A \times \text{clock Rate}_A$
$= 0.0847 \times 3.5\ \text{GHz}$
$= 296450000$
$= 2.9645\ E8$

$\text{clock cycles}_B = \text{CPU Time}_B \times \text{clock Rate}_B$
$= 0.074 \times 4\ \text{GHz}$
≈ 299200000
$\approx 2.992\ E8$

$$\boxed{\begin{array}{l} \text{clock cycles}_A = 2.9645\ E8 \\ \text{clock cycles}_B = 2.992\ E8 \end{array}}$$

Q2) dynamic Ic_A = 2.8 E8
execution time_A = 3.5

dynamic Ic_B = 3.5 E8
execution time_B = 5.8

~~clock~~ cycle

(a) clock cycle time = 2.8 ns
clock rate = 357142857
= 3.57 E8

CPU Time = Instruction count × CPI × clock cycle times
CPU time = Execution time

$$CPI_A = \frac{\text{Execution time}}{\text{Instruction count} \times \text{clock cycle time}}$$

$$CPI_A = \frac{3.5}{(2.8\ E8)(2.8\ E{-9})} = \frac{3.5}{7.84\ E{-1}} = 4.46$$

$$CPI_B = \frac{\text{Execution time}}{\text{Instruction count} \times \text{clock cyle time}}$$

$$= \frac{5.8}{(3.5\ E8)(2.8\ E{-9})} = \frac{5.8}{9.8\ E{-1}} = 5.91$$

$$\boxed{\begin{array}{l} CPI_A = 4.46 \\ CPI_B = 5.918 \end{array}}$$

(b) CPU time $_A$ = CPU time $_B$ Clock Rate $_A$?

$CPI_A = 4.46$ $CPI_B = 5.918$ clock Rate $_B$?

$IC_A = 2.8E8$ $IC_B = 3.5E8$

$$\frac{IC_A \times CPI_A}{\text{clock Rate}_A} = \text{cpu time } A \qquad \text{cpu time } B = \frac{IC_B \times CPI_B}{\text{Clock Rate}_B}$$

$$\frac{IC_A \times CPI_A}{\text{clock Rate}_A} = \frac{IC_B \times CPI_B}{\text{clock Rate}_B} \qquad \frac{\text{Clock Rate}_B}{\text{Clock Rate}_A} = \frac{IC_B \times CPI_B}{IC_A \times CPI_A}$$

$$\frac{\text{clock Rate } B}{\text{clock Rate } A} = \frac{(3.5E8)(5.918)}{(2.8E8)(4.46)} = \frac{20.713}{12.448} = 1.664$$

$$\boxed{\text{clock Rate A is 1.664 times faster than B}}$$

(c) $IC_C = 7.8E9$ Execution time = Instruction Count $\times$ CPI $\times$ cycle time

$CPI_C = 2.3$

clock cycle time = 2.8 ns

$$\text{Exec time}_C = IC_C \times CPI_C \times \text{clock cycle time}$$
$$= 7.8E9 \times 2.3 \times 2.8E-9$$
$$= 50.232$$

$$\frac{\text{Exec time}_C}{\text{Exec time}_A} = \frac{50.232}{3.5} = 14.252$$

$$\frac{\text{Exec time}_C}{\text{Exec time}_B} = \frac{50.232}{5.8} = 8.661$$

$$\boxed{\begin{array}{l}\text{compiler A is faster by 14.252 times} \\ \text{compiler B is faster by 8.661 times}\end{array}}$$

(Q4) Clock Rate $_{P1}$ = 8 GHz
CPI_{P1} = 1.2
IC_{P1} = 8.5 E9

Clock Rate $_{P2}$ = 5.2 GHz
CPI_{P2} = 0.8
IC_{P2} = 6.0 E9

(a) $$\text{CPU Time}_{P1} = \frac{IC_{P1} \times CPI_{P1}}{\text{clock Rate}_{P1}} = \frac{8.5E9 \times 1.2}{8 E9} = 1.275$$

$$\text{CPU Time}_{P2} = \frac{IC_{P2} \times CPI_{P2}}{\text{clock Rate}_{P2}} = \frac{6.0 E9 \times (0.8)}{5.2 E9} = 0.923$$

$$\frac{\text{CPU Time}_{P1}}{\text{CPU Time}_{P2}} = \frac{1.275}{0.923} = 1.381$$

$\boxed{P_2 \text{ is faster than } P_1 \text{ by } 1.381 \text{ times}}$

(b) IC_{P1} : 1.8 E9
CPI_{P1} : 1.2
clock Rate $_{P1}$ = 8 GHz

IC_{P2} : ?
CPI_{P2} : 0.8
clock Rate $_{P2}$: 5.2 GHz

$$\text{CPU Time}_{P1} = \frac{IC_{P1} \times CPI_{P1}}{\text{clock Rate}_{P1}} = \frac{(1.8E9)(1.2)}{8 E9} = \frac{2.16 E9}{8 E9} = 0.27$$

$$\text{CPU Time}_{P2} = \frac{IC_{P2} \times CPI_{P2}}{\text{clock Rate}_{P2}}$$

$$0.27 = \frac{IC_{P2} \times 0.8}{5.2 GHz}$$

$$IC_{P2} = \frac{0.27 (5.2GHz)}{0.8} = 1.856 E9$$

P_2 runs more instructions than P_1 by 0.056 E9

(c) $$MIPS_{P1} = \frac{8.5 E9}{1.27 (1E6)} = \frac{8.5 E3}{1.27} = 6.692 E3 \text{ MIPS}$$

$$MIPS_{P2} = \frac{6.0 E9}{0.923 (1E6)} = \frac{6.0 E3}{0.923} = 6.5 E3 \text{ MIPS}$$

$\boxed{P_1 \text{ is faster when using mips } 6.6923 E3 > 6.5E3}$

4 (d) $FPI_{c_{P_1}} = (8.5\ E9)(0.3)$

$= 2.55\ E9$

$FPI_{c_{P_2}} = (6\ E9)(0.3)$

$= 1.8\ E9$

$MFlops_{P_1} = \dfrac{2.55\ E9}{1.27\ E6}$

$= \cancel{5E}\ 2.007\ E3$

$MFLOPS_{P_2} = \dfrac{1.8\ E9}{0.923\ E6}$

$= 1.95\ E3$

$$\boxed{\begin{array}{ll} MFlops_{P_1} > MFLOPS_{P_2} & \text{thus in MFLOPS } P_1 \\ 2.007\ E3 > 1.95\ E3 & \text{is faster than } P_2 \end{array}}$$

~~thus~~

(3)

(a)

$\text{clock Rate}_{i7} = 3.6\ GHz$

$\text{voltage}_{i7} = 1.394$

$\text{static}_{i7} = 60\ W$

$\text{dynamic}_{i7} = 95\ W$

$\text{clock Rate}_{i9} = 4.2\ GHz$

$\text{voltage}_{i9} = 0.8\ v$

$\text{static}_{i9} = 50\ W$

$\text{dynamic}_{i9} = 70\ W$

$\text{dynamic} = (0.5) \times CL \times \text{Voltage}^2 \times \text{clock Rate}$

$C_L = \dfrac{\text{dynamic} \times (2)}{\text{voltage}^2 \times \text{clock Rate}}$

$CL_{i7} = \dfrac{2\ \text{dynamic}_{i7}}{\text{Voltage}_{i7}^2 \times \text{clock Rate}_{i7}}$

$= \dfrac{2(95)}{(1.394)^2 \times (3.6E9)}$

$= 2.715\ E-8$

$CL_{i9} = \dfrac{2\ \text{dynamic}_{i9}}{\text{Voltage}^2_{i9} \times \text{clock Rate}_{i9}}$

$CL_{i9} = \dfrac{2(70)}{(0.8)^2 \times (4.2\ E9)}$

$CL_{i9} = 5.208\ E-8$

$$\boxed{\begin{array}{l} CL_{i7} = 2.715\ E-8 \\ CL_{i9} = 5.208\ E-8 \end{array}}$$

3 (b) static $i7$ = 60 static $i9$ = 50
dynamic $i7$ = 95 dynamic $i9$ = 70
total $i7$ = 155 total $i9$ = 120

$$\boxed{\frac{\text{static } i7}{\text{total } i7} = 38.7\% \quad \frac{\text{static } i7}{\text{dynamic } i7} = 0.631 \quad \frac{\text{static } i9}{\text{dynamic } i9} = 0.714 \quad \frac{\text{static } i9}{\text{total } i9} = 41.\overline{6}\%}$$

$$\frac{60}{155} = 0.387 \quad \frac{60}{95} = 0.631 \quad \frac{50}{70} \; 0.714 \quad \frac{50}{120} =$$

(c) static power = Voltage × leak current

$\text{total}_{new} = \text{total}_{old} (0.8)$

$\text{total}_{new\ i7} = 155 (0.8)$
$= 124$

$\text{total}_{new\ i9} = 120 (0.8)$
$= 96$

$\text{static}_{i7} = (0.387)\ \text{totalnew}_{i7}$
$= (0.387)(124)$
$= 47.988$

$\text{static}_{i9} = (0.41\overline{6})(\text{total new } i9)$
$= (0.41\overline{6})(96)$
$= 39.999$

$\text{voltage}_{new} = \frac{\text{static}_{new}}{\text{leak current}}$

$\text{leak}_{i7} = \frac{60}{1.394}$
$= \cancel{43.04}\ 43.04$

$\text{leak } i9 = \frac{50}{0.8}$
$= 62.5$

$\text{Voltage}_{new\ i7} = \frac{47.988}{\cancel{43.04}\ 43.04}$
$= \cancel{1.1}\ 1.114\text{v}$

$\text{Voltage}_{new\ i9} = \frac{40}{62.5}$
$= 0.64\ \text{v}$

~~a Vold~~ $V_{old} - V_{new} = ?$

$V_{old\ i7} - V_{new\ i7} = 1.394 - 1.114$
$= 0.28\ \text{v}$

$V_{old\ i9} - \cancel{V_{old}}\ V_{new\ i9} = 0.8 - 0.64$
$= 0.16\text{v}$

$$\boxed{\begin{array}{l}\text{reduce } i7 \text{ voltage by } 0.28\text{v} \\ \text{reduce } i9 \text{ voltage by } 0.16\text{v}\end{array}}$$

(5)

(a) $\text{exec time}_{p1} = 300$

$\text{exec time}_{p2} = \frac{300}{2} + 6$

$= 156$

$\text{exec time}_{p4} = \frac{300}{4} + 6$

$= 81$

$\text{exec time}_{p8} = \frac{300}{8} + 6$

$= 43.5$

$\text{exec time}_{p16} = \frac{300}{16} + 6$

$= 24.75$

$\text{exec time}_{p32} = \frac{300}{32} + 6$

$= 15.375$

$\text{exec time}_{p64} = \frac{300}{64} + 6$

$= 10.6875$

$\text{exec time}_{p128} = \frac{300}{128} + 6$

$= 8.343$

$\text{exec time}_{256} = \frac{300}{256} + 6$

$= 7.172$

(b)

p	S	R	S/R
n = 1	300	300	1
2	156	150	1.04
4	81	75	1.08
8	43.5	37.5	1.16
16	24.75	18.75	1.32
32	15.375	9.375	1.64
64	10.687	4.687	2.28
128	8.343	2.343	3.56
256	7.172	1.172	7.12

S will eventually converge to 6 while R will eventually converge to 0 this is as the number of processors or p increases.

Q6

(a) ~~yield =~~ $\frac{1}{(1 + \cancel{(\text{Defects per area} \times \text{Die area}/2)})^2}$

$\text{Die area}_{35} = \cancel{\text{tea}} =$

$\text{yield}_{35} =$

~~(1+(0.045 x~~

Q6 $\text{yield} = \dfrac{1}{(1+(\text{Defects per area} \times \text{Die area}/2))^2}$

$\text{Die area} = \dfrac{\text{wafer area}}{\text{Dies per wafer}}$

$\text{Die area}_{35} = \dfrac{\pi(35/2)^2}{100} = 9.621$

$\text{Die area}_{40} = \dfrac{\pi(20)^2}{120} = 10.472$

$\text{yield}_{35} = \dfrac{1}{(1+(0.045 \times 9.621/2))^2} = 0.675$

$\text{yield}_{40} = \dfrac{1}{(1+(0.062 \times 10.472/2))^2} = 0.5699$

$$\boxed{\begin{aligned}\text{Yield}_{35} &= 0.675\\ \text{Yield}_{40} &= 0.5699\end{aligned}}$$

(b) $\text{cost per die} = \dfrac{\text{cost per waifer}}{\text{Dies per wafer} \times \text{yield}}$

$\text{cost per die}_{35} = \dfrac{15}{100 \times 0.675} = 0.222$

$\text{cost per die}_{40} = \dfrac{20}{120 \times 0.5699} = 0.292$

$\text{cost per die}_{35} = 0.222$

$\text{Cost per die}_{40} = 0.292$

(c) $\text{Die area new}_{35} = \dfrac{\pi(35/2)^2}{100 \times 1.2} = 8.017$

$\text{Die area new}_{40} = \dfrac{\pi(20)^2}{120 \times 1.2} = 8.726$

$$\boxed{\begin{aligned}\text{Die area new}_{35} &= 8.017\\ \text{Die area new}_{40} &= 8.726\end{aligned}}$$

$\text{yield new}_{35} = \dfrac{1}{(1+(0.045 \times 1.3 \times 8.017/2))^2} = 0.656$

$\text{yield new}_{40} = \dfrac{1}{(1+(0.062 \times 1.3 \times 8.726/2))^2} = 0.547$

$$\boxed{\begin{aligned}\text{yield new}_{35} &= 0.656\\ \text{yield new}_{40} &= 0.547\end{aligned}}$$

* note $\frac{400\ mm^2}{2} = \frac{4\ cm^2}{2}$

use 4/2 in actual calculations

Q6 d) ~~yield new~~

$$\text{yield}_{old} = \frac{1}{(1+(0.065 \times 400/2))^2} = 0.7831$$

$$\text{yield}_{new} = \frac{1}{(1+(0.052 \times 400/2))^2} = 0.820$$

$$\boxed{\begin{array}{l}\text{yield old} = 0.7831 \\ \text{yield new} = 0.820\end{array}}$$

Q7

a) $$\frac{\text{Dynamic new}}{\text{Dynamic old}} = \frac{0.85\ \text{Dynamic old}}{\text{Dynamic old}} = 0.85$$

$$\frac{\text{Dynamic new}}{\text{Dynamic old}} = \frac{A \times CL_{new} \times \text{Voltage}_{new} \times \text{freq}_{\cancel{new}}}{A \times CL_{old} \times \text{Voltage}_{old} \times \text{freq}_{old}} = 0.85$$

$$\frac{CL_{new} \times 1.2 \times 3.2E9}{CL_{old} \times 0.9 \times 2.5E9} = 0.85 \qquad \frac{CL_{new}}{CL_{old}} = 0.85 \times \frac{3.84}{2.25} = 1.45$$

$\boxed{CL_{new} \text{ is } 1.45 \text{ times larger than } CL_{old} \text{ or } 145\% \text{ larger than } CL_{old}}$

b) $$\frac{\cancel{\text{Dynamic new}}}{\text{Dynamic old}} = \frac{A \times CL \times \text{Voltage}_{new} \times \text{freq}_{new}}{A \times CL \times \text{Voltage}_{old} \times \text{freq}_{old}} = \frac{0.9 \times 2.5E9}{1.2 \times 3.2E9} = 0.5859$$

$$1 - 0.5859 = 0.414$$

$\boxed{\text{dynamic power has been reduced } 41.4\%}$

c) $$\frac{\text{static old}}{\text{dynamic old}} = 1 \qquad \frac{\text{static new}}{\text{dynamic new}} = 1.3$$