① CPU time = IC × CPI × CCT

② CPU time = $\frac{IC \times CPI}{\text{Clock Rate}}$

IC: Instruction count (instructions)

CPI: Clock cycles per instruction. (clock cycles / instruction)

CCT: Clock cycle time (seconds / clock cycle)

F: Clock Rate (clock cycles / second). ($= \frac{1}{CCT}$).

Q1.5

Q1.5

	clock rate	CPI
P1	3 GHz	1.5
P2	2.5 GHz.	1.0
P3	4.0 GHz	2.2

a. instruction/second? clock cycles/second

clock rate: ~~clock cy~~ ~~seconds / clock cycle~~

CPI: clock cycles / instruction

$\frac{\text{clock rate}}{\text{CPI}}$ ∴ instruction rate/second.

note: $1\ \text{GHz} = 1 \times 10^9\ \text{Hz}$

P1: ~~clock rate~~ performance ∝ $\frac{\text{clock rate}}{\text{CPI}} = \frac{3 \times 10^9\ \text{Hz}}{1.5} = 2 \times 10^9$.

P2: 2.5×10^9

P3: 1.8×10^9

(P2) has the highest performance.

b. exec. time = 10 s

#cycles? #instruction?

~~#ins. #cyc/ins~~

CPU time = IC × CPI × CCT

#cyles . time

① CPU time = $\frac{IC \times CPI}{\text{clock rate}}$.

~~CPU time × clock rate = IC × CPI~~.

#Clock cycles = IC × CPI.

⇒ #clock cycles = CPU time × clock rate

P1: #clock cycles = . 10s × 3×10^9 = 3×10^10.

P2: 2×10^10

P3: 4×10^10.

time of all of clock cycles.
= .

clock cycles
× .
Clock cycle time

② # instruct = . IC

CPU time = . IC × CPI / clock rate

⇔ . # instruction = . CPU time × clock rate / CPI

P1: . # instr. = . 10 × 3×10^9 / 1.5 = 2×10^10

P2: # instr = 2 / .5 ×10^10

P3: # instruct = ~~1.818×10^1~~
1.818 × 10^10.

③

exect. time = . IC × CPI / clock rate old

(1 − 30%) exect. time = . IC . × (1+20%) CPI / clock rate new.

(1−30%) = . clock rate old / clock rate new. . (1+20%).

↳ clock rate new = . (1−30%)/(1+20%) × (1+20%)/(1−30%) × clock rate old

P1: # = . 1.2 / 0.7 / Clock rate new = (1+0.4)/(1+3) = 1.2/0.7 × 3×10^9 = 5.14 GHz.

P2: ~~4GHz~~ clock rate$_{new}$ = 4.2 GHz

P3: Clock rate$_{new}$ = 6.75 GHz.

Q1.8.

	IC	exec. time
A	1.0E9	1.1 s
B	1.2E9	1.5 s.

CCT = 1ns

a. CPI?

note 1 ns = 1×10^{-9} s.

exec. time = IC × CPI × CCT

CPI = $\frac{\text{exec. time}}{IC \times CCT}$ #.

$CPI_A = \frac{1.1}{1.0 \times 10^9 \times 1 \times 10^{-9}} = 1.1$.

CPI_B = ~~~ = 1.25.

b.

exec. time = $\frac{IC_A \times CPI_A}{\text{clock rate}_A}$

exec. time = $\frac{IC_B \times CPI_B}{\text{clock rate}_B}$

~~CPI~~ $\Rightarrow \frac{(\text{clock rate})_A}{(\text{clock rate})_B} = \frac{IC_A \times CPI_A}{IC_B \times CPI_B}$ #.

B can perform more clock cycles in a second. weird

or

$\frac{(\text{clock rate})_B}{(\text{clock rate B})_A} = \frac{IC_B \times CPI_B}{IC_A \times CPI_A}$ #. = $\frac{1.0E9 \times 1.1}{1.2E9 \times 1.25}$

$\frac{1.2 \times 10^9 \times 1.25}{1.0E9 \times 1.1} = 0.137 = 0.75$.

A B is "faster"

c.

	IC	CPI
new	6.0E9	1.1.

"speed up" → performance?.

fact: compiler can't not affect CCT. / clock rate

faster $\frac{\text{performance}_{new}}{\text{performance}_{old}} = \frac{\text{exec. time}_{old}}{\text{exec. time}_{new}}$

$= \frac{IC_{new} \times CPI_{new}}{\text{clock rate}} \Big/ \text{exec time}_{old}$

$= \frac{IC_{new} \times CPI_{new}}{\text{clock rate}} \Big/ \text{exec time}_{A}$

$\frac{\text{performance}_{new}}{\text{performance}_{A}} = \frac{IC_{new} \times CPI_{new}}{\text{clock rate}} \times CCT.$

$= \frac{1.1}{6.0 \times 10^9 \times 1.1 \times 1 \times 10^{-9}}$

$= \frac{1.1}{6.6} =$

$= \frac{IC_{old} \times CPI_{old}}{IC_{new} \times CPI_{new}} = \frac{IC_{old} \cdot CPI_{old}}{IC_{new} \cdot CPI_{new}}$

faster than A $= \frac{1.0 \times 10^9 \times 1.1}{6.0 \times 10^8 \times 1.1} = 1.67.$

faster than B $= \frac{1.2 \times 10^9 \times 1.5}{6.0 \times 10^8 \times 1.1} = 2.27.$

Q 1.12*

ref. time for a benchmark

	IC	exec time	ref. time
Barcelona	2.389×10^{12}	750	9650

1) CPI? clock cycle time (CCT) = 0.333 ns.

exec time = IC × CPI × CCT.

$$\Leftrightarrow CPI = \frac{\text{exec. time}}{IC \times CCT}$$

$$(CPI)_{Barcelona} = \frac{750}{2.389 \times 10^{12} \times 0.333 \times 10^{-9}} = 0.94$$

~~$(CPI)_B =$~~

2). $$\text{SPEC ratio} = \frac{\text{ref. time}}{\text{exec. time}}$$

$$= \frac{9650}{750} = 12.86$$

weird not consistent with website but the Zurich author seem to say (SPEC ratio ↑ Same → performance ↑

3. $$CPU\ time = \frac{IC_{old} \times CPI}{\text{clock rate}}$$

$$CPU_{new}\ time = \frac{1.1 \times IC_{old} \times CPI}{\text{clock rate}}$$

fact. only hardware can affect CCT.

$$\Leftrightarrow \frac{CPU_{new}}{CPU_{old}} = 1.1$$

4). $CPU_{new} = \frac{IC \times (1+5\%)\, CPI}{(1+10\%)\, \text{clock rate}}$

$CPU_{old} = \frac{IC \times CPI}{\text{clock rate}}$

$\Rightarrow \frac{CPU_{new}}{CPU_{old}} = (1+10\%) \times (1+5\%) = 1.155$

$\text{increase} = \frac{CPU_{new} - CPU_{old}}{CPU_{old} \times 100\%} = .155 = 15.5\%$

5.. $\text{SPEC ratio}_{old} = \frac{\text{ref. time}}{\text{exe. time}_{old}}$

$\text{SPEC ratio}_{new} = \frac{\text{ref time}}{\text{exe. time}_{new}}$

$\frac{CPU_{new}}{CPU_{old}} = 1.55$

$\Rightarrow \frac{\text{SPEC ratio}_{new}}{\text{SPEC ratio}_{old}} = \frac{\text{exec time}_{old}}{\text{exe. time}_{new}} = \frac{1}{1.155} = 0.86.$

$\text{decrease} = \frac{\text{SPEC}_{old} - \text{SPEC}_{new}}{\text{SPEC}_{old}} =$

$\frac{\text{SPEC}_{old} - \text{SPEC}_{new}}{\text{SPEC}_{old} \times 100\%} = .1 - 0.86 = .0.14$

$= 14\%.$

6)

~~SPEC ratio~~ = $\frac{\text{ref. time}}{\text{exec. time}}$ =

	IC	exec time
Barcelona old	2.389×10^{12}	750
Barcelona new	$(1-15\%) \times 2.389 \times 10^{12}$	700

$$CPI = \frac{\text{exec. time} \times \text{clock rate}}{IC}$$

$$= \frac{700 \times 4 \times 10^9}{(1-15\%) \times 2.389 \times 10^{12}}$$

$$= 1.38$$

7).

$$\frac{(CPI)_{new}}{(CPI)_{old}} = \frac{1.38}{0.94} = 1.47$$

see → x1) ~~[illegible]~~

OR

$$\frac{(\text{Clock rate})_{new}}{(\text{Clock rate})_{old}} = \frac{4}{3} = 1.33$$

not similar. ~~because~~ why?

$$\frac{\text{CPU time}}{IC} = \frac{CPI}{\text{clock rate}}$$

CPU time: 750 → 700, ~6% ↓; IC ↓ 15%; CPI ↑ 47%; clock rate ↑ 33%

Although the # instruction has been reduced by 15%, the CPU time has been reduce by a lower percentage.

8). reduce = ~~$\frac{CPU_{old} - CPU_{new}}{CPU_{old}} = \frac{750 - 700}{750} =$~~ .

$\frac{CPU_{new}}{CPU_{old}} = \frac{700}{750} = 0.933$

reduce = $\frac{CPU_{old} - CPU_{new}}{CPU_{old}} = (1 - 0.933) =$ 6.7% .

~~6.67%~~ .

9.). $IC = \frac{\text{exect.} \times \text{Clock rate}}{CPI}$ ~~fact: CPI~~

$= \frac{(1-10\%)60 \times 4 \times 10^9}{1.61} = 2.1 \times 10^{12}$

~~2.147~~

10). $\text{CPU time}_{old} = \frac{IC \times CPI}{\text{Clock rate}_{old}}$

$\begin{cases} (-10\%)\text{CPU time}_{old} \\ \text{CPU time}_{new} \end{cases} = \frac{IC \times CPI}{\text{Clock rate}_{new}}$

~~CPU time new~~ =

$\Leftrightarrow$ Clock rate new = $\frac{\text{CPU Time}_{old}}{(\text{CPU time})_{new}} \times (\text{Clock rate})_{old}$

$(1 - 10\%)$ ~~CPU time~~

$= \frac{1}{1-10\%} \times 3 \times 10^9$

$= 3.33 \times 10^9$.

$= 3.33$ GHz.