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1.3 We have

	Processor	Clock rate	CPI
a	P_1	3 GHz	1.5
	P_2	2.5 GHz	1.0
	P_3	4 GHz	2.2
B	P_1	2 GHz	1.2
	P_2	3 GHz	0.8
	P_3	4 GHz	2.0

1.3.1 Which processor has the highest performance expressed in instructions per second

instructions per second is the units from

$$\text{CPU execution} = \frac{\text{number of instruction} \times \text{CPI}}{\text{clock rate}}$$

$$aP_1 = \frac{n \text{ instrc} \times 1.5}{3} = n \text{ instru} \times 0.5$$

$$aP_2 = \frac{n \text{ instrc} \times 1.0}{2.5} = n \text{ instru} \times 0.4$$

$$aP_3 = \frac{n \text{ instru} \times 2.2}{4} = n \text{ instru} \times 0.55$$

answ: in instruction a processor P_2 has the highest performance

$$bP_1 = \frac{n \text{ instru} \times 1.2}{2} = n \text{ instru} \times 0.6$$

$$bP_2 = \frac{n \text{ instru} \times 0.8}{3} = n \text{ instru} \times 0.27$$

$$bP_3 = \frac{n \text{ instru} \times 2.0}{4} = n \text{ instru} \times 0.5$$

answ: in instruction b processor P_2 has the highest performance

1.3.2 If the processors each execute a program in 10 seconds, find the number of cycles and the number of instruction

from CPU execute time = number of instruction × CPI × Clock cycle

number of instruction

$$\text{number of instruction} = \frac{\text{CPU execute time} \times \text{clock rate}}{\text{CPI}}$$

number of cycles

$$\text{number of cycles} = \frac{\text{CPU execute time}}{\text{number of instruction} \times \text{CPI}}$$

N = Number

a

P1 $N\text{instruction} = \frac{10 \times 3 \times 10^9}{1.5} = 20 \times 10^9$

$N\text{cycle} = \frac{10}{20 \times 10^9 \times 1.5} = 3 \times 10^{-9}$

P2 $N\text{instruction} = \frac{10 \times 2.5 \times 10^9}{1.0} = 25 \times 10^9$

$N\text{cycle} = \frac{10}{25 \times 10^9 \times 1} = 2.5 \times 10^{-9}$

P3 $N\text{instruction} = \frac{10 \times 4 \times 10^9}{2.2} = 1.82 \times 10^{10}$

$N\text{cycle} = \frac{10}{1.82 \times 10^{10} \times 2.2} = 2.5 \times 10^{-9}$

b

P1 $N\text{instruction} = \frac{10 \times 2.5 \times 10^9}{1.2} = 20.83 \times 10^9$

$N\text{cycle} = \frac{10}{20.83 \times 10^9 \times 1.2} = 0.4 \times 10^{-9}$

P2 $N\text{instruction} = \frac{10 \times 3 \times 10^9}{0.8} = 37.5 \times 10^9$

$N\text{cycle} = \frac{10}{37.5 \times 10^9 \times 0.8} = 3.33 \times 10^{-9}$

P3 $N\text{instruction} = \frac{10 \times 4 \times 10^9}{2.0} = 20 \times 10^9$

$N\text{cycle} = \frac{10}{20 \times 10^9 \times 2.0} = 0.25 \times 10^{-9}$

1.3.3 We are trying to reduce the time by 30% but this leads to an increase of 20% in CPI. What clock rate should we have to get this time reduction?

From formula CPU execution = (Number of Instruction × CPI) / clock rate

but from problem We will get CPU execution × 0.7 = (Number of Instruction × CPI × 1.2) / clock

So $\text{Clock rate} = \frac{1.2}{.7} = 1.71$ ✗

a (clock rate × 1.71)

P1 = 3 × 1.71 = 5.13 GHz

P2 = 2.5 × 1.71 = 4.275 GHz

P3 = 4 × 1.71 = 6.84 GHz

b (clock rate × 1.71)

P1 = 2 × 1.71 = 3.42 GHz

P2 = 3 × 1.71 = 5.13 GHz

P3 = 4 × 1.71 = 6.84 GHz

FOR problems below, use the information in the following table.

	Processor	Clock rate	No. Instructions	Time
a.	P_1	3 GHz	20×10^9	7 s
	P_2	2.5 GHz	30×10^9	10 s
	P_3	4 GHz	90×10^9	9 s
b	P_1	2 GHz	20×10^9	5 s
	P_2	3 GHz	30×10^9	8 s
	P_3	4 GHz	25×10^9	7 s

1.3.4 Find the IPC (instruction per cycle) for each processor

$$\text{CPU execution} = \frac{\text{No. Instr} \times \text{CPI}}{\text{Clock rate}}, \quad \text{IPC} = \frac{1}{\text{CPI}}$$

$$\text{CPI} = \frac{\text{CPU execution} \times \text{Clock rate}}{\text{No. Instruction}}$$

$$\text{IPC} = \frac{\text{No. Instruction}}{\text{CPU execution} \times \text{Clock rate}}$$

a

$P1 = \frac{20}{7 \times 3} = 0.95$

$P2 = \frac{30}{10 \times 2.5} = 1.2$

$P3 = \frac{90}{9 \times 4} = 2.5$

b

$P1 = \frac{20}{5 \times 2} = 2$

$P2 = \frac{30}{8 \times 3} = 1.25$

$P3 = \frac{25}{7 \times 4} = 0.9$

1.3.5 Find the clock rate for P2 that reduces it execution time to that of P1

CPU execute time = (No. instru × CPI) / Clock rate

But you want to find new Clock rate of P 2 so it will be

$$\frac{\text{CPU execute P2}}{\text{CPU execute P1}} = \frac{(\text{No. instr P}_2 \times \text{CPI P2}) / \text{clock rate P2}}{(\text{No. instr P}_1 \times \text{CPI P1}) / \text{Clock rate P1}}$$

to get clock rate

$$\frac{\text{Clock rate P1}}{\text{Clock rate P2}} = \frac{\text{CPU time P2} \times \text{No. instr P2} \times \text{CPI P2}}{\text{CPU time P1} \times \text{No. instr P2} \times \text{CPI P2}}$$

We will get

$$\text{Clock rate P1} = \frac{\text{CPU time P2}}{\text{CPU time P1}} \times \text{Clock rate P2}$$

a $\text{Clock rate P1} = \frac{10}{7} \times 2.5 = 3.57$

b $\text{clock rate P1} = \frac{8}{5} \times 3 = 4.8$

1.3.6 Find the number of instructions for P2 that reduces in execution time to that P

CPU execute = (No. instru × CPI) / Clock rate

Compare

$$\frac{\text{CPU execute P2}}{\text{CPU execute P3}} = \frac{(\text{No. Instr P}_2 \times (\text{CPI P2})) / \text{Clock Rate P2}}{(\text{No. Instr P}_3 \times (\text{CPI P3})) / \text{Clock Rate P3}}$$

We find P3 but use P2

$$\frac{\text{No. Instru P3}}{\text{No. Instru P2}} = \frac{(\text{CPU exe P3}) \times \text{CPI P2} / \text{Clock Rate P2}}{(\text{CPU exe P2})\ \ \text{CPI P2} / \text{Clock Rate P2}}$$

We will get

$$\text{No. Instr P3} = \frac{\text{CPU exe P3}}{\text{CPU exe P2}} \times \text{No. Instr P2}$$

a $\text{No. Instr P3} = \frac{9}{10} \times 30 \times 10^9 = 27 \times 10^9$

b $\text{No. Instru P3} = \frac{7}{8} \times 30 \times 10^9 = 26.25 \times 10^9$

1.4.0 Consider two different implementations of the same instruction set architecture. There are 4 classes of instruction, A, B, C, D. Clock rate and CPI are given in following table

		Clock rate	CPI A	CPI B	CPI C	CPI D
a	P1	2.5 GHz	1	2	3	3
	P2	3 GHz	2	2	2	2
b	P1	2.5 GHz	2	1.5	2	1
	P2	3 GHz	1	2	1	1

1.4.1 Given a program with 10^6 instructions divided into class A × 1.1, B × 1.2, C × 1.5, D × 1.2

CPU execution time $= \frac{\sum (\text{number of instruction} \times CPI)}{\text{clock rate}} \times$ ___

if it is the same instruction but implement it so it will be

Class A 10% of $10^6 = 1 \times 10^5$

Class B 20% of $10^6 = 2 \times 10^5$

Class C 50% of $10^6 = 5 \times 10^5$

Class D 20% of $10^6 = 2 \times 10^5$

a $$P1 = \frac{((1 \times 10^5) + (2 \times 2 \times 10^5) + (3 \times 5 \times 10^5) + (3 \times 2 \times 10^5))}{2.5 \times 10^9} = 10.4 \times 10^{-4} \text{ s}$$

$$P2 = \frac{((2 \times 10^5) + (2 \times 2 \times 10^5) + (2 \times 5 \times 10^5) + (2 \times 2 \times 10^5))}{3 \times 10^9} = 6.66 \times 10^{-4} \text{ s}$$

Ans in set a P2 is faster than P1

b $$P1 = \frac{((2 \times 10^5) + (1.5 \times 2 \times 10^5) + (2 \times 2 \times 10^5) + (1 \times 2 \times 10^5))}{2.5 \times 10^9} = 4.4 \times 10^{-4} \text{ s}$$

$$P2 = \frac{((1 \times 10^5) + (2 \times 2 \times 10^5) + (1 \times 5 \times 10^5) + (1 \times 2 \times 10^5))}{3 \times 10^9} = 4 \times 10^{-4} \text{ s}$$

Ans in set b P2 is faster than P1

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1.4.2 what is the global CPI for each implementation

$$\text{CPU execution} = \frac{\text{No. Instruction} \times \text{CPI}}{\text{Clock rate}}$$

$$\text{CPI} = \frac{\text{CPU execution} \times \text{Clock rate}}{\text{No. Instruction}}$$

from previous problem we know CPU execution P1 is 10.4 and P2 is 6.66

a $$P1 = \frac{10.4 \times 10^{-4} \times 2.5 \times 10^{9}}{10^{6}} = 2.6$$

$$P2 = \frac{6.66 \times 10^{-4} \times 3 \times 10^{9}}{10^{6}} = 2.0$$

from previous problem we know CPU excution P1 is 4.4 and P2 is 4.0

b $$P1 = \frac{4.4 \times 10^{-4} \times 2.5 \times 10^{9}}{10^{6}} = 1.1$$

$$P2 = \frac{4 \times 10^{-4} \times 3 \times 10^{9}}{10^{6}} = 1.2$$

1.4.3 Find the clock cycles required in both case

from CPU execution = No. instru × CPI × clock cycle

so $$\text{clock cycles} = \frac{\text{CPU execution}}{\text{No. instru} \times \text{CPI}}$$

from previous we know CPU exe P1 is 10.4 and CPI P1 is 2.6, P2 is 2.0 CPI 1.2

a $$P1 \text{ clock cycle} = \frac{10.4 \times 10^{-4}}{10^{6} \times 2.6} = 4 \times 10^{2}$$

$$P2 \text{ clock cycle} = \frac{6.66 \times 10^{-4}}{10^{6} \times 2.0} = 3.33 \times 10^{2}$$

from previous we know CPU exe P1 is 4.4 CPI P1 is 1.1 CPU exe P2 is 4.0 CPI 1.2

b $$P1 \text{ clock cycle} = \frac{4.4 \times 10^{-4}}{10^{6} \times 1.1} = 4 \times 10^{2}$$

~~P2~~

$$P2 \text{ clock cycle} = \frac{4.0 \times 10^{-4}}{10^{6} \times 1.1} = 3.6 \times 10^{2}$$

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The following table shows the number of instructions for a program

	arith	store	load	Branch	Total
a	650	100	600	50	1400
b	750	250	500	500	2000

1.4.4 Assuming that arith instrc take 1 cycle and store 5 cycles branches 2 cycle what is the execution time in 2 GHz processor from

CPU execution = $\frac{\text{CPU clock cycle}}{\text{clock rate}}$

a $= \frac{(650 \times 1) + (5 \times 100) + (5 \times 600) + (2 \times 50)}{2 \times 10^9} = 2{,}125 \times 10^{-9}$

b $= \frac{(750 \times 1) + (5 \times 250) + (5 \times 500) + (2 \times 500)}{2 \times 10^9} = 2{,}750 \times 10^{-9}$

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1.4.2 Find the CPI for the program

CPI = CPU clock cycle / No of instruc

a CPI = 4250 / 1400 = 3.04
b CPI = 5500 / 2000 = 2.75

1.46 If number of load instructions can be reduced by one half find speeded up and CPI

a new Instruction : 650 + 100 + (600/2) + 50 = 1100
new Clock cycle : (650 × 1) + (5 × 100) + (5 × 300) + (2 × 50) = 2750

$$CPI = \frac{2750}{1100} = 2.5$$

$$\text{CPU execution} = \frac{1100 \times 2.5}{2 \times 10^{-9}} = 1,375 \times 10^{-9}$$

$$\text{Speed up} = \frac{\text{CPU exe old}}{\text{CPU exe new}} = \frac{2125 \times 10^{-9}}{1375 \times 10^{-9}} = 1.5$$

b new Instruction = 750 + 250 + (500/2) + 500 = 1750
new clock cycle = (750 × 1) + (250 × 5) + (250 × 5) + (500 × 2) = 4250

$$CPI = \frac{4250}{1750} = 2.4$$

$$\text{CPU execution} = \frac{1750 \times 2.4}{2 \times 10^{-9}} = 2,100 \times 10^{-9}$$

$$\text{Speed up} = \frac{\text{CPU exe old}}{\text{CPU exe new}} = \frac{2,750 \times 10^{-9}}{2,100 \times 10^{-9}} = 1.3$$