**CS1104: Computer Organisation Part I**
**Tutorial #5: Performance**
**Answers**

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1. Two programs *P1* and *P2* are run on two machines *M1* and *M2* and the following measurements were made:

| Program | Time on *M1* | Time on *M2* |
|---|---|---|
| *P1* | 10 seconds | 5 seconds |
| *P2* | 3 seconds | 4 seconds |

   a. The following additional measurements on *P1* were also made:

| Program | Instructions executed on *M1* | Instructions executed on *M2* |
|---|---|---|
| *P1* | $200 \times 10^6$ | $160 \times 10^6$ |

Moreover, the clock rates of machines *M1* and *M2* are 200MHz and 300MHz respectively. Find the clock cycles per instruction (CPI) for program *P1* on each of the two machines. Round your answers to 3 decimal places.

***Answer**:*

Since we know the number of instructions executed and the time it took to execute the instructions, we can easily calculate the number of instructions per second.

The instruction execution rate (instructions per second) for *M1* is $(200 \times 10^6) / 10 = \mathbf{20 \times 10^6}$, and for *M2*, it is $(160 \times 10^6) / 5 = \mathbf{32 \times 10^6}$.

Since

Cycles per instruction (CPI) = Cycles per second / Instructions per second

$CPI_{M1}$ = $200 \times 10^6$ cycles per second / $20 \times 10^6$ instructions per second
= **10.000** cycles per instruction.

$CPI_{M2}$ = $300 \times 10^6$ cycles per second / $32 \times 10^6$ instructions per second
= **9.375** cycles per instruction.

b. Assuming the CPI for program *P2* on each machine is the same as the CPI for program *P1* computed above, find the instruction count (number of instructions) for program *P2* running on each machine.

***Answer****:*

We are given the number of cycles per second and the number of seconds, so we can calculate the number of required cycles for each machine. If we divide this by the CPI we'll get the number of instructions.

For *M1*:

#Instructions for *P2* = 3 seconds $\times$ 200 $\times$ $10^6$ cycles / second
= 600 $\times$ $10^6$ cycles / 10 cycles per instruction
= **$60 \times 10^6$** instructions

For *M2*:

#Instructions for *P2* = 4 seconds $\times$ 300 $\times$ $10^6$ cycles / second
= 1200 $\times$ $10^6$ cycles / 9.375 cycles per instruction
= **$128 \times 10^6$** instructions

c. Machine *M1* costs $10,000 and machine *M2* costs $15,000. Now the requirement is that program *P1* must be executed 200 times each hour and any remaining time is to be used for running program *P2*. The performance of the machine is measured by the throughout for *P2*.

Which machine has better performance, by how much, and which one is more cost-effective? Round your answers to 3 decimal places.

***Answer****:*

We are given the number of cycles per second and the number of seconds, so we can calculate the number of required cycles for each machine. If we divide this by the CPI we'll get the number of instructions.

On *M1*:

Number of times *P2* can execute per hour = (3600 sec/hr – 200 $\times$ 10)/3
= 1600/3 = **533.333**

On *M2*:

Number of times *P2* can execute per hour = (3600 sec/hr – 200 $\times$ 5)/3
= 2600/3 = **650**

Hence, with the given notion of "performance", *M2* is better by 650/533.333 = **1.219 times**.

Cost-effectiveness can be defined to be performance/dollar. Hence, cost-effectiveness of *M1* = 533.333/10000 = **0.053**; while cost-effectiveness of *M2* = 650/15000 = **0.043**. Therefore, *M1* is more cost-effective (gives more performance per dollar).

2. There are four classes of instructions ($A$, $B$, $C$ and $D$) in a certain instruction set. Consider two different implementations, *M1* and *M2*, of the same instruction set.

   *M1* has a clock rate of 500MHz. The average number of cycles for each instruction class on *M1* is as follows:

| Class | CPI for this class |
|---|---|
| *A* | 1 |
| *B* | 2 |
| *C* | 3 |
| *D* | 4 |

   *M2* has a clock rate of 750MHz. The average number of cycles for each instruction class on *M2* is as follows:

| Class | CPI for this class |
|---|---|
| *A* | 2 |
| *B* | 2 |
| *C* | 4 |
| *D* | 4 |

   Assume that peak performance is defined as the fastest rate that a machine can execute an instruction sequence chosen to maximize that rate. What are the peak performances of *M1* and *M2* expressed as instructions per second?

**Answer:**

Peak performance(*M1*) = #inst / Execution time
= #inst / ( $CPI_A$ × #inst / Clock_rate(*M1*))
= Clock_rate(*M1*) / $CPI_A$
= $500 \times 10^6 / 1$ = $\mathbf{500 \times 10^6}$ instructions per second

Peak performance(*M2*) = #inst / Execution time
= #inst / ( $CPI_A$ × #inst / Clock_rate(*M2*))
= Clock_rate(*M2*) / $CPI_A$
= $750 \times 10^6 / 2$ = $\mathbf{375 \times 10^6}$ instructions per second

3. If the number of instructions executed in a certain program is divided equally among the classes of instructions in question 2, how much faster is *M2* than *M1*?

**Answer:**

$\text{CPI}(M1) = (1 \times 0.25) + (2 \times 0.25) + (3 \times 0.25) + (4 \times 0.25) =$ **2.5**

$\text{CPI}(M2) = (2 \times 0.25) + (2 \times 0.25) + (4 \times 0.25) + (4 \times 0.25) =$ **3**

$$\frac{\text{Performance}(M2)}{\text{Performance}(M1)} = \frac{2.5 / 500\text{ MHz}}{3 / 750\text{ MHz}} = \mathbf{1.25}$$

So *M2* is **1.25** times faster than *M1*.