2) ①

$$\text{Cpu time} = \frac{\text{cpi} \times \text{instructions}}{\text{Clock rate}}$$

$$\frac{\text{Instructions}}{\text{Cpu time}} = \frac{\text{Clock rate}}{\text{cpi}}$$

$$\text{instructions per sec} = \frac{\text{instructions}}{\text{Cpu time}} \Rightarrow \text{Sec Ips} = \frac{\text{Clock rate}}{\text{cpi}}$$

$1\,GHz = 10^9\,Hz$.

$$Ips_1 = \frac{3\,GHz}{1.5} = 2 * 10^9$$

$$Ips_2 = \frac{2.5\,GHz}{1} = 2.5 * 10^9 \quad (\text{Process 2 has highest performance})$$

$$Ips_3 = \frac{4\,GHz}{2.2} = 1.82 * 10^9$$

② $\text{Cputime} = 10\,\text{Sec}$

$\text{Instructions} = Ips * \text{Cup time}$

$\text{Cpu time} = \frac{\text{Clock wise}}{\text{clock rate}}$

$\text{Clock cycles} = \text{cputime} * \text{clock rate}$

$1\,GHz = 10^9\,Hz$

For every processor

$\text{instructions}_1 = Ips_1 * \text{cputime}_1 = 2 * 10^9 * 10$

$= 2 * 10^9$

$\text{clock cycles}_1 = \text{cputime}_1 * \text{clock rate}_1 = 10 * 3\,GHz = 3 * 10^{10}$

$\text{Instructions}_2 = Ips_2 * \text{cputime}_2 = 2 * 10^9 * 10 = 2 * 10^{10}$

$\text{clock cycles}_2 = \text{cputime}_2 * \text{clock rate}_2 = 10 * 2.5\,GHz = 2.5 * 10^{10}$

$\text{Instructions}_3 = Ips_3 * \text{cputime}_3 = 1.82 * 10^9 * 10 = 1.82 * 10^{10}$

$\text{Clock cycles}_3 = \text{cputime}_3 * \text{clock rate}_3 = 4 * 10^{10}$

| Processors | Instructions | Clock cycle |
|---|---|---|
| 1 | $2 * 10^{10}$ | $3 * 10^{10}$ |
| 2 | $2.5 * 10^{10}$ | $2.5 * 10^{10}$ |
| 3 | $1.82 * 10^{10}$ | $4 * 10^{10}$ |

③ $$\text{Execution Time} = \frac{\text{instructions} \times \text{cpi}}{\text{clock rate}}$$

finding new clock rate:

$$\text{Execution time}_{new} = 0.7 \times \text{Execution time}_{old}$$

Example

$$\frac{\text{instructions}_{new} \times \text{cpi}_{new}}{\text{clock rate}_{new}} = 0.7 \times \frac{\text{Instructions}_{old} \times \text{cpi}_{old}}{\text{clock rate}_{old}}$$

$$\text{instructions}_{new} = \text{instructions}_{old}$$

$$\frac{\text{cpi}_{new}}{\text{clock rate}_{new}} = 0.7 \times \frac{\text{cpi}_{old}}{\text{clock rate}_{old}}$$

We have $\text{cpi}_{new} = 1.2 \times \text{cpi}_{old}$

$$\frac{1.2}{\text{clock rate}_{new}} = \frac{0.7}{\text{clock rate}_{old}} \Rightarrow \text{clock rate}_{new} = \frac{1.2}{0.7} \times \text{clock rate}_{old}$$

$$= 1.71 \times \text{clock rate}_{old}$$

The clock rate must have increased by 71%.