1)

a) Performance via Pipelining

b) Performance via Parallelism

c) Performance via Prediction

d) Make the common case faster

e) Use Abstraction to Simplify design

f) Hierarchy of Memories

2) 1

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

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

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

$1 GHz = 10^9 Hz.$

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

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

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

2 Cputime = 10 sec

instructions = Ips * cup time

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

Clock cycles = cputime * 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 $$\text{Execution Time} = \frac{\text{instructions} \ast \text{cpi}}{\text{Clockrate}}$$

finding new clock rate:

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

<u>Example</u>

$$\frac{\text{instructions}_{new} \ast \text{cpi}_{new}}{\text{Clockrate}_{new}} = 0.7 \ast \frac{\text{Instructions}_{old} \ast \text{cpi}_{old}}{\text{Clockrate}_{old}}$$

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

$$\frac{\text{cpi}_{new}}{\text{Clockrate}_{new}} = 0.7 \ast \frac{\text{cpi}_{old}}{\text{clockrate}_{old}}$$

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

$$\frac{1.2}{\text{Clockrate}_{new}} = \frac{0.7}{\text{clockrate}_{old}} \Rightarrow \text{clockrate}_{new} = \frac{1.2}{0.7} \ast \text{clockrate}_{old}$$

$$= 1.71 \ast \text{clockrate}_{old}$$

The clockrate must have increased by 71%.

3) Total time = 250 s

70 seconds = fp (floating point)
85 seconds = L/S (Load / store)
40 seconds = Branch = 195 seconds

The remaining 55 seconds must be consumed by INT

a) $T_{fp} = 70 \times 0.8 = 56$ seconds
$T_{new} = 56 + 85 + 55 + 40 = 236$ seconds
It will be reduced by 5.6%.

b) $T_{new} = 250 \times 0.8 = 200$ seconds
$T_{fp} + T_{L/S} + T_{Branch} = 165$ seconds
$T_{int} = 35$ seconds
The Reduction time is INT = 58.8%.

c) $T_{new} = 250 \times 0.8 = 200$ seconds
$T_{fp} + T_{INT} + T_{L/S} = 210$ seconds

It's not possible to achieve this reduction through reducing solely branch instructions.

4) Amdahl's Law Formula

$$\text{overall speed} = \frac{\text{old execution time}}{\text{new execution time}}$$

$$= \frac{1}{\left((1 - \text{Fraction}_{\text{enhanced}}) + \frac{\text{Fraction}_{\text{enhanced}}}{\text{Speedup}_{\text{enhanced}}}\right)}$$

Overall Speedup $= 2$

$\text{Speedup}_{\text{enhanced}} = 6$

$\text{Fraction}_{\text{enhanced}}$ = fraction of the time spent on the instructions that can be run on the CUs in order to achieve an overall speedup.

$$2 = \frac{1}{(1-x) + \frac{x}{6}}$$ (x is the fraction enhanced)

$\Rightarrow 2 - 2x + \frac{x}{3} = 1$

$\Rightarrow 1 = 2x - \frac{x}{3}$

$\Rightarrow 3 = 5x$

$\Rightarrow x = \frac{3}{5}$

The % of time spent $= \frac{3}{5} \times 100 = 60\%$.