1. (1pt*26; if a=3 and c=5, only one point would be deducted)
   a. 5, supercomputers
   b. 7, petabyte(PB)
   c. 3, servers
   d. 1, virtual worlds
   e. 12, RAM
   f. 13, CPU
   g. 8, datacenters
   h. 10, multi-core processor
   i. 4, low-end servers
   j. 9, embedded computers
   k. 11, VHDL (Very High Speed Integrated Circuit Hardware Description)
   l. 2, desktop computers
   m. 15, compiler
   n. 21, assembler
   o. 25, COBOL
   p. 19, machine language
   q. 17, instruction
   r. 26, FORTRAN
   s. 18, assembly language
   t. 14, operating system
   u. 24, application software
   v. 16, bit
   w. 23, system software
   x. 20, C
   y. 22, high-level language
   z. 6, terabyte (TB)

2. (3pts*4)
   (1) 1280*800*3*8/8 = 3072000 (bytes)

   (2) $2 \times 10^9 / 3072000 \approx 651 \text{ (frames)}$
   or $2 \times 2^{30} / 3072000 \approx 699 \text{ (frames)}$

   (3) 256 Kbytes = 0.256 Mbytes
   $0.256 \over 10^3 / 8 = 0.002048 (s) = 2.048 (ms)$
   or
   1 gigabit network = $2^{30} \text{ bits / s} = 2^{17} \text{ KBs / s}$
   $256 \text{ KB} / (2^{17} \text{ KB / s}) = 2^{-9} (s) = 0.001953125 (s) = 1.93125 (ms)$

   (4) DRAM = 20 (us, microseconds)
   disk = 20 * 100,000 (us) = 2 (s)
   flash memory = 20 * 100,000 / 1,000 (us) = 2 (ms)

3. (5pts*6)
   (a)
Performance (Instruction / sec)
P1: $2 \times 10^9 / 1.5 = 1.33 \times 10^9$
P2: $1.5 \times 10^6$
P3: $3 \times 10^9 / 2.5 = 1.2 \times 10^6$

(b)

<table>
<thead>
<tr>
<th></th>
<th>Number of Cycles</th>
<th>Number of Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>$20 \times 10^9$</td>
<td>$1.33 \times 10^9 \times 10 = 13.33 \times 10^9$</td>
</tr>
<tr>
<td>P2</td>
<td>$15 \times 10^6$</td>
<td>$1.5 \times 10^9 \times 10 = 15 \times 10^9$</td>
</tr>
<tr>
<td>P3</td>
<td>$30 \times 10^9$</td>
<td>$1.2 \times 10^9 \times 10 = 12 \times 10^9$</td>
</tr>
</tbody>
</table>

(c) Clock Rate:

$Clock Rate' = \frac{CPI' \times Number\ of\ Instructions}{time}$

$Time' = 10 \times 0.7 = 7$ (s)

$CPI' = CPI \times 1.2$

$\frac{(15 \times 1.2) \times 13.33 \times 10^9}{7} = 3.42 GHz$

P1: $\frac{(1.0 \times 1.2) \times 15 \times 10^9}{7} = 2.57 GHz$

P2: $\frac{(2.5 \times 1.2) \times 12 \times 10^9}{7} = 5.14 GHz$

(d)

$IPC = \frac{Number\ of\ Instructions}{Time \times Clock\ Rate}$

IPC(Instructions/Cycle):
P1: 1.43
P2: 2
P3: 3.33

(e) $Clock\ Rate' = 1.5GHz \times 10 / 7 = 2.14 GHz$

(f) $Number(Instructions)' = 30 \times 10^9 \times 9/10 = 27 \times 10^9$

4. (2pts for (a) + 5pts*6)
(a) CPI:

$CPI\ of\ Mbase = 2^*(0.40) + 3^*(0.25) + 3^*(0.25) + 5^*(0.10) = 0.8 + 0.75 + 0.75 + 0.50 = 2.8$
(cycles/instruction)

CPI of Mopt = 2*(0.40) + 2*(0.25) + 3*(0.25) + 4*(0.10) = 0.8 + 0.50 + 0.75 + 0.40 = 2.45
(cycles/instruction)

(b)
MIPS: Millions of Instructions Per Second

\[
MIPS = \frac{\text{Instruction Count}}{\text{Execution Time} \times 10^6} = \frac{\text{Instruction Count}}{(\text{Instruction Count} / \text{Clock Rate}) \times 10^6} = \frac{\text{Clock Rate}}{\text{CPI} \times 10^6}
\]

Mbase: 500/2.8 = 178.57
Mopt: 600/2.45 = 244.90

(c)
MIPS(Mopt)/MIPS(Mbase) = 245/179 = 1.37
=> 37% faster

(d)
\[
\text{ratio of instruction} = (0.40)^*0.9 + (0.25)^*0.9 + (0.25)^*0.85 + (0.10)^*0.95 = 0.8925
\]

CPI of Mcomp = (2*(0.40)^*0.9 + 3*(0.25)^*0.9 + 3*(0.25)^*0.85 + 5*(0.10)^*0.95) / 0.8925 = 2.51/
0.8925 = 2.81 (cycles/instruction)

(e)
\[
\text{Performance(Mcomp)} / \text{Performance(Mbase)} = \frac{\text{CPU(Mbase) / CPU(Mcomp)}}{\text{IC * CPI / clock rate(Mbase) \times IC * CPI / clock rate(Mcomp)}} = \frac{\text{IC * 2.8} / \text{clock rate}}{(\text{IC * 0.8925}) \times 2.81 / \text{clock rate}}
\]

=1.12 => 12% faster

(f)
CPI of Mopt = 2*(0.40) + 2*(0.25) + 3*(0.25) + 4*(0.10) = 0.8 + 0.50 + 0.75 + 0.40 = 2.45
(cycles/instruction)

CPI of Mboth = (2*(0.40)^*0.9 + 2*(0.25) * 0.9+ 3*(0.25)*0.85 + 4*(0.10)*0.95) / 0.8925 = 2.45
(cycles/instruction)

\[
\text{Performance(Mboth)} / \text{Performance(Mbase)} = \frac{\text{CPU(Mbase) / CPU(Mboth)}}{\text{IC * CPI / clock rate(Mbase) \times IC * CPI / clock rate(Mboth)}} = \frac{\text{IC * 2.8} / 500}{(\text{IC * 0.8925}) \times 2.45 / 600}
\]

=1.54 => 54% faster

(g)

CPU Performance improvement by 6 months: 1.03^6 = 1.22
CPU Performance improvement by 8 months: 1.03^8 = 1.31
CPU Performance improvement by 2 months: 1.03^2 = 1.07
Performance(Mopt) = 1.37 * 1.07 = 1.46 > 1.31
Performance(Mcomp) = 1.12 * 1.07 = 1.2 < 1.31
Performance(Mboth) = 1.54 > 1.31

=> Implement Mboth.