**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, embeded 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)** $2*10^9 / 3072000 \approx 651\,(frames)$
or $2*2^{30} / 3072000 \approx 699\,(frames)$

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

**(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**: $2*10^9 / 1.5 = 1.33*10^9$
**P2**: $1.5*10^9$
**P3**: $3*10^9 / 2.5 = 1.2*10^9$

**(b)**

| | **Number of Cycles** | **Number of Instructions** |
|---|---|---|
| P1 | $20*10^9$ | $1.33*10^9*10 = 13.33*10^9$ |
| P2 | $15*10^9$ | $1.5*10^9*10 = 15*10^9$ |
| P3 | $30*10^9$ | $1.2*10^9*10 = 12*10^9$ |

**(c)**
**Clock Rate:**

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

$$Time' = 10*0.7 = 7\,(s)$$

$$CPI' = CPI*1.2$$

**P1**: $\frac{(1.5*1.2)*13.33*10^9}{7} = 3.42\,GHz$

**P2**: $\frac{(1.0*1.2)*15*10^9}{7} = 2.57\,GHz$

**P3**: $\frac{(2.5*1.2)*12*10^9}{7} = 5.14\,GHz$

**(d)**

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

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

**(e)**

$$Clock\ Rate' = 1.5\,GHz * 10 / 7 = 2.14\,GHz$$

**(f)**

$$Number(Instructions)' = 30*10^9*9/10 = 27*10^9$$

**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 = <u>2.8</u>

(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**

$$MIPS = \frac{Instruction\,Count}{Execution\,Time * 10^6} = \frac{Instruction\,Count}{(Instruction\,Count\ /\ Clock\,Rate) * 10^6} = \frac{Clock\,Rate}{CPI * 10^6}$$

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

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

**(d)**
**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)**

$$Performance(Mcomp)/Performance(Mbase)$$
$$= CPU(Mbase)/CPU(Mcomp) = \frac{IC*CPI/clock\,rate(Mbase)}{IC*CPI/clock\,rate(Mcomp)} = \frac{IC*2.8/clock\,rate}{(IC*0.8925)*2.81/clock\,rate}$$

=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)

$$Performance(Mboth)/Performance(Mbase)$$
$$= CPU(Mbase)/CPU(Mboth) = \frac{IC*CPI/clock\,rate(Mbase)}{IC*CPI/clock\,rate(Mboth)} = \frac{IC*2.8/500}{(IC*0.8925)*2.45/600}$$

=1.54 => 54% faster

**(g)**

$$CPU\ Performace\ improvement\ by\ 6\ months: 1.034^6 = 1.22$$
$$CPU\ Performace\ improvement\ by\ 8\ months: 1.034^8 = 1.31$$
$$CPU\ Performace\ improvement\ by\ 2\ months: 1.034^2 = 1.07$$
$$Performance(Mopt) = 1.37 * 1.07 = 1.46 > 1.31$$
$$Performance(Mcomp) = 1.12 * 1.07 = 1.2 < 1.31$$
$$Performance(Mboth) = 1.54 > 1.31$$

=> Implement Mboth.