Solution 1.3

1.3.1 P2 has the highest performance.

Instr/sec = f/CPI

a.	performance of P1 (instructions/sec) = $3 \times 10^9/1.5 = 2 \times 10^9$ performance of P2 (instructions/sec) = $2.5 \times 10^9/1.0 = 2.5 \times 10^9$ performance of P3 (instructions/sec) = $4 \times 10^9/2.2 = 1.8 \times 10^9$
b.	performance of P1 (instructions/sec) = $2 \times 10^9/1.2 = 1.66 \times 10^9$ performance of P2 (instructions/sec) = $3 \times 10^9/0.8 = 3.75 \times 10^9$ performance of P3 (instructions/sec) = $4 \times 10^9/2 = 2 \times 10^9$

1.3.2 No. cycles = time × clock rate

time = (No. Instr × CPI)/clock rate, then No. instructions = No. cycles/CPI

a.	cycles(P1) = $10 \times 3 \times 10^9 = 30 \times 10^9$ s cycles(P2) = $10 \times 2.5 \times 10^9 = 25 \times 10^9$ s cycles(P3) = $10 \times 4 \times 10^9 = 40 \times 10^9$ s No. instructions(P1) = $30 \times 10^9/1.5 = 20 \times 10^9$ No. instructions(P2) = $25 \times 10^9/1 = 25 \times 10^9$ No. instructions(P3) = $40 \times 10^9/2.2 = 18.18 \times 10^9$
b.	cycles(P1) = $10 \times 2 \times 10^9 = 20 \times 10^9$ s cycles(P2) = $10 \times 3 \times 10^9 = 30 \times 10^9$ s cycles(P3) = $10 \times 4 \times 10^9 = 40 \times 10^9$ s No. instructions(P1) = $20 \times 10^9/1.2 = 16.66 \times 10^9$ No. instructions(P2) = $30 \times 10^9/0.8 = 37.5 \times 10^9$ No. instructions(P3) = $40 \times 10^9/2 = 20 \times 10^9$

1.3.3 $time_{new} = time_{old} \times 0.7 = 7$ s

AQ 3

a.	$CPI_{new} = CPI_{old} \times 1.2$, then CPI(P1) = 1.8, CPI(P2) = 1.2, CPI(P3) = 2.6 f = No. Instr × CPI/time, then f(P1) = $20 \times 10^9 \times 1.8 / 7 = 5.14$ GHz f(P2) = $25 \times 10^9 \times 1.2 / 7 = 4.28$ GHz f(P1) = $18.18 \times 10^9 \times 2.6 / 7 = 6.75$ GHz
b.	$CPI_{new} = CPI_{old} \times 1.2$, then CPI(P1) = 1.44, CPI(P2) = 0.96, CPI(P3) = 2.4 f = No. Instr × CPI/time, then f(P1) = $16.66 \times 10^9 \times 1.44/7 = 3.42$ GHz f(P2) = $37.5 \times 10^9 \times 0.96/7 = 5.14$ GHz f(P1) = $20 \times 10^9 \times 2.4/7 = 6.85$ GHz

1.3.4 IPC = 1/CPI = No. instr/(time × clock rate)

a.	IPC(P1) = 0.95 IPC(P2) = 1.2 IPC(P3) = 2.5
b.	IPC(P1) = 2 IPC(P2) = 1.25 IPC(P3) = 0.89

1.3.5

a.	$Time_{new}/Time_{old} = 7/10 = 0.7$. So $f_{new} = f_{old}/0.7 = 2.5$ GHz/0.7 = 3.57 GHz.
b.	$Time_{new}/Time_{old} = 5/8 = 0.625$. So $f_{new} = f_{old}/0.625 = 4.8$ GHz.

1.3.6

a.	$Time_{new}/Time_{old} = 9/10 = 0.9$. Then $Instructions_{new} = Instructions_{old} \times 0.9 = 30 \times 10^9 \times 0.9 = 27 \times 10^9$.
b.	$Time_{new}/Time_{old} = 7/8 = 0.875$. Then $Instructions_{new} = Instructions_{old} \times 0.875 = 26.25 \times 10^9$.

Solution 1.4

1.4.1

Class A: 10^5 instr.
Class B: 2×10^5 instr.
Class C: 5×10^5 instr.
Class D: 2×10^5 instr.

Time = No. instr × CPI/clock rate

a.	Total time P1 = $(10^5 + 2 \times 10^5 \times 2 + 5 \times 10^5 \times 3 + 2 \times 10^5 \times 3)/(2.5 \times 10^9) = 10.4 \times 10^{-4}$ s Total time P2 = $(10^5 \times 2 + 2 \times 10^5 \times 2 + 5 \times 10^5 \times 2 + 2 \times 10^5 \times 2)/(3 \times 10^9) = 6.66 \times 10^{-4}$ s
b.	Total time P1 = $(10^5 \times 2 + 2 \times 10^5 \times 1.5 + 5 \times 10^5 \times 2 + 2 \times 10^5)/(2.5 \times 10^9) = 6.8 \times 10^{-4}$ s Total time P2 = $(10^5 + 2 \times 10^5 \times 2 + 5 \times 10^5 + 2 \times 10^5)/(3 \times 10^9) = 4 \times 10^{-4}$ s

1.4.2 CPI = time × clock rate/No. instr

a.	CPI (P1) = $10.4 \times 10^{-4} \times 2.5 \times 10^9/10^6 = 2.6$ CPI (P2) = $6.66 \times 10^{-4} \times 3 \times 10^9/10^6 = 2.0$
b.	CPI (P1) = $6.8 \times 10^{-4} \times 2.5 \times 10^9/10^6 = 1.7$ CPI (P2) = $4 \times 10^{-4} \times 3 \times 10^9/10^6 = 1.2$

1.4.3

a.	clock cycles (P1) = $10^5 \times 1 + 2 \times 10^5 \times 2 + 5 \times 10^5 \times 3 + 2 \times 10^5 \times 3 = 26 \times 10^5$ clock cycles (P2) = $10^5 \times 2 + 2 \times 10^5 \times 2 + 5 \times 10^5 \times 2 + 2 \times 10^5 \times 2 = 20 \times 10^5$
b.	clock cycles (P1) = 17×10^5 clock cycles (P2) = 12×10^5

1.4.4

a.	$(650 \times 1 + 100 \times 5 + 600 \times 5 + 50 \times 2) \times 0.5 \times 10^{-9} = 2{,}125$ ns
b.	$(750 \times 1 + 250 \times 5 + 500 \times 5 + 500 \times 2) \times 0.5 \times 10^{-9} = 2{,}750$ ns

1.4.5 CPI = time × clock rate/No. instr

a.	CPI = $2{,}125 \times 10^{-9} \times 2 \times 10^9/1{,}400 = 3.03$
b.	CPI = $2{,}750 \times 10^{-9} \times 2 \times 10^9/2{,}000 = 2.75$

1.4.6

a.	Time = $(650 \times 1 + 100 \times 5 + 300 \times 5 + 50 \times 2) \times 0.5 \times 10^{-9}$ = 1,375 ns Speedup = 2,125 ns/1,375 ns = 1.54 CPI = $1{,}375 \times 10^{-9} \times 2 \times 10^{9}/1{,}100$ = 2.5
b.	Time = $(750 \times 1 + 250 \times 5 + 250 \times 5 + 500 \times 2) \times 0.5 \times 10^{-9}$ = 2,125 ns Speedup = 2,750 ns/2,125 ns = 1.29 CPI = $2{,}125 \times 10^{-9} \times 2 \times 10^{9}/1{,}750$ = 2.43

Solution 1.7

1.7.1

Geometric mean clock rate ratio = $(1.28 \times 1.56 \times 2.64 \times 3.03 \times 10.00 \times 1.80 \times 0.74)^{1/7} = 2.15$

Geometric mean power ratio = $(1.24 \times 1.20 \times 2.06 \times 2.88 \times 2.59 \times 1.37 \times 0.92)^{1/7} = 1.62$

1.7.2

Largest clock rate ratio = 2000 MHz/200 MHz = 10 (Pentium Pro to Pentium 4 Willamette)

Largest power ratio = 29.1 W/10.1 W = 2.88 (Pentium to Pentium Pro)

1.7.3

Clock rate: $2.667 \times 10^9 / 12.5 \times 10^6 = 213.36$
Power: 95 W/3.3 W = 28.78

1.7.4 $C = P/V^2 \times \text{clock rate}$

80286: $C = 0.0105 \times 10^{-6}$
80386: $C = 0.01025 \times 10^{-6}$
80486: $C = 0.00784 \times 10^{-6}$
Pentium: $C = 0.00612 \times 10^{-6}$
Pentium Pro: $C = 0.0133 \times 10^{-6}$
Pentium 4 Willamette: $C = 0.0122 \times 10^{-6}$
Pentium 4 Prescott: $C = 0.00183 \times 10^{-6}$
Core 2: $C = 0.0294 \times 10^{-6}$

1.7.5 3.3/1.75 = 1.78 (Pentium Pro to Pentium 4 Willamette)
1.88

1.7.6

Pentium to Pentium Pro: 3.3/5 = 0.66
Pentium Pro to Pentium 4 Willamette: 1.75/3.3 = 0.53
Pentium 4 Willamette to Pentium 4 Prescott: 1.25/1.75 = 0.71
Pentium 4 Prescott to Core 2: 1.1/1.25 = 0.88
Geometric mean = 0.68

Solution 1.12

1.12.1 CPI = clock rate × CPU time/instr count

clock rate = 1/cycle time = 3 GHz

a.	CPI(bzip2) = $3 \times 10^9 \times 750/(2{,}389 \times 10^9) = 0.94$
b.	CPI(go) = $3 \times 10^9 \times 700/(1{,}658 \times 10^9) = 1.26$

1.12.2 SPECratio = ref. time/execution time

a.	SPECratio(bzip2) = 9,650/750 = 12.86
b.	SPECratio(go) = 10,490/700 = 14.98

1.12.3

$(12.86 \times 14.98)^{1/2} = 13.88$

1.12.4 CPU time = No. instr × CPI/clock rate

If CPI and clock rate do not change, the CPU time increase is equal to the increase in the of number of instructions, that is, 10%.

1.12.5 CPU time(before) = No. instr × CPI/clock rate

CPU time(after) = 1.1 × No. instr × 1.05 × CPI/clock rate

CPU times(after)/CPU time(before) = 1.1 × 1.05 = 1.155 Thus, CPU time is increased by 15.5%.

1.12.6 SPECratio = reference time/CPU time

SPECratio(after)/SPECratio(before) = CPU time(before)/CPU time(after) = 1/1.1555 = 0.86. Thus, the SPECratio is decreased by 14%.