**Problem 1:   
A program runs in 8 seconds on Computer X, which has a clock rate of 3 GHz. You are helping a designer build Computer Y, which should run the program in 5 seconds. The designer determined that Computer Y will require 1.5 times as many clock cycles as Computer X for this program. What clock rate should Computer Y target?**Computer X Information Given   
execution time = 8 Seconds   
clock rate = 3 GHz = 3×109 cycles/second  
  
Computer Y Information Given  
execution time = 5 secondsStep 1:Formula To Find Clock Cycles   
execution time = clock cycles / clock rate  
  
Calculate The Number of Clock Cycles for Computer X  
clock cycles X = execution time X × clock rate X  
 X = 8 × 3 × 109 cycles/second  
 X = 24 × 109 cycles/second  
**Computer X = 24 × 109 clock cycles**

Step 2:Determine the Number of Clock Cycles for Computer Y  
clock cycles Y = 1.5 × clock cycles X  
 Y = 1.5 × 24 × 109 cycles/second  
 Y = 36 x 109 cycles/second  
**Computer Y = 36 × 109 clock cycles**  
  
Step 3:Calculate the Required Clock Rate for Computer Y  
execution time Y = clock cycles Y / clock rate Y  
 Y = 36 × 109 clock cycles / 5 seconds  
 Y = 7.2 × 109 cycles/second

Conclusion **The clock rate for Computer Y should be 7.2 GHz to meet the performance goal.**

**Problem 2:  
A benchmark contains 200 instructions, divided as follows:**

**• 40 instructions are loads/stores (each takes 3 cycles).**

**• 100 instructions are added (each takes 1 cycle).**

**• 60 instructions are division operations (each takes 20 cycles).**

**What is the CPI (Cycles Per Instruction) for this benchmark?**

Benchmark Information Given  
total instructions = 200  
  
Step 1:  
Calculate the Total Numbers of Cycles  
Sum of the Total Cycles = (Load/Store) + (Add) + (Division)  
 Load/Store Instructions = 40 × 3 cycles = 120 cycles  
 Add Instructions = 100 × 1 cycles = 100 cycles  
 Division Instructions = 60 × 20 cycles = 1200 cycles  
 Sum of the Total Cycles = (120 + 100 + 1200) cycles  
**Total Cycles = 1420 cycles**

Step 2:  
Calculate the CPI  
CPI = total cycles / total instructions  
 CPI = (1420 / 200) cycles per instruction  
**CPI = 7.1 cycles per instruction**

Conclusion  
**The CPI (Cycles Per Instruction) for this benchmark is 7.1.**

**Problem 3: Suppose we have two implementations of the same instruction set architecture.**

**• Computer X has a clock cycle time of 300 ps and a CPI of 2.5 for some program.**

**• Computer Y has a clock cycle time of 600 ps and a CPI of 1.5 for the same program.**

**Which computer is faster for this program, and by how much?**

Computer X Information Given   
clock cycle time = 300 picoseconds  
cycles per instruction = 2.5  
  
Computer Y Information Given  
clock cycle time = 600 picoseconds  
cycles per instruction = 1.5  
  
Formula to Find Execution Time  
execution time = clock per instruction × clock cycle time  
  
Step 1:  
Calculate the Execution Time for Computer X  
execution time X = 2.5 cpi × 300 ps  
**Computer X execution time = 750 ps/instruction**Step 2:  
Calculate the Execution Time for Computer Y  
execution time Y = 1.5 cpi x 600 ps  
**Computer Y execution time = 900 ps/instruction**Step 3:  
Compare the Execution Times  
Computer X: 750 picoseconds per instruction  
Computer Y: 900 picoseconds per instruction  
**Computer X = lower execution time = faster**  
  
Step 4:  
Determine how much Faster Computer X is Compared to Computer Y  
Speedup = execution time X / execution time Y  
 S = 900 ps / 750 ps  
**Speedup = 1.2**Conclusion  
**Computer X is 1.2 times faster than Computer Y, or 20% faster**

**Problem 4: Consider three different processors: Q1, Q2, and Q3, executing the same instruction set.**

**• Q1 has a clock rate of 3.5 GHz and a CPI of 1.8.**

**• Q2 has a clock rate of 2.8 GHz and a CPI of 1.1.**

**• Q3 has a clock rate of 4.2 GHz and a CPI of 2.5.**

**Which processor is the fastest, and by how much compared to the others?**

Processor Information Given  
clock rate Q1= 3.5GHz = 3.5 × 109 cycles/second  
cpi Q1 = 1.8  
clock rate Q2 = 2.8GHz = 2.8 × 109 cycles/second  
cpi Q2 = 1.1  
clock rate Q3 = 4.2GHz = 4.2 × 109 cycles/second  
cpi Q3 = 2.5  
  
Formula to Find Clock Cycle Times  
clock cycle time = 1 / clock rate  
  
Step 1:  
Convert clock rates to clock cycle times  
Q1 = 1 / 3.5 x 109 = 0.286 ns  
Q2 = 1 / 2.8 x 109 = 0.357 ns  
Q3 = 1 / 4.2 x 109 = 0.238 ns

Step 2:  
Calculate the Execution Time for Each Processor  
Execution time Q​1 = 1.8 × 286ps = 514.8ps per instruction  
Execution time Q​2 = 1.1 × 357ps = 392.7ps per instruction  
Execution time Q​3 = 2.5 × 238ps = 595ps per instruction  
  
Step 3:  
Compare the execution times  
Q1: 514.8 ps per instruction  
Q2: 392.7 ps per instruction  
Q3: 595 ps per instruction  
  
Step 4:  
Calculate How Fast Q2 Is  
Speedup = execution time Q1 / execution time Q2  
**Speedup = 514.8 / 392.7 = 1.31**Speedup = execution time Q3 / execution time Q2  
**Speedup = 595 / 392.7 = 1.52**

Conclusion  
**Q2 is the fastest processor. It is 1.31 times faster than Q1 (31% faster) and 1.52 times faster than Q3 (52% faster)**  
**Problem 5:  
Suppose we have two implementations of the same instruction set architecture.**

**• Computer M has a clock cycle time of 400 ps and a CPI of 3.0 for a certain program.**

**• Computer N has a clock cycle time of 200 ps and a CPI of 2.5 for the same program.**

**Which computer is faster for this program, and by how much?**

Formula to Solve Execution Time  
Execution Time = CPI x Clock Cycle Time  
  
Step 1:   
Calculate the Execution Time for Computer M

Clock cycle time of Computer M = 400 ps

CPI of Computer M = 3.0  
**Execution time M ​= 3.0 × 400ps = 1200ps per instruction**  
Step 2:  
Calculate the execution time for Computer N  
Clock cycle time of Computer N = 200 ps

CPI of Computer N = 2.5  
Execution time N​ = 2.5 × 200ps = 500ps per instruction  
  
Step 3:   
Compare the execution times

Computer M: 1200 ps per instruction

Computer N: 500 ps per instruction

Step 4:  
Determine how much faster Computer N is compared to Computer M  
Speedup = execution time M / execution time N

Speedup = 1200ps / 500ps = 2.4  
  
Conclusion:  
**Computer N is 2.4 times faster than Computer M, or 140% faster for this program**

**Problem 6:**

**Consider three different processors A1, A2, and A3 executing the same instruction set.**

**• A1 has a clock rate of 3.5 GHz and a CPI of 1.4.**

**• A2 has a clock rate of 3.0 GHz and a CPI of 1.0.**

**• A3 has a clock rate of 4.0 GHz and a CPI of 1.6.**

**Questions:**

**1. Which processor has the highest performance expressed in instructions per second**Formula to find Instruction per Second  
Ins Per Sec = Clock Rate / CPI  
  
A1: Ins/Sec A1 = 3.5 GHz / 1.4 = ~2.5 × 10 Ins/Sec  
A2: Ins/Sec A2 = 3.0 GHz / 1.0 = 3.0 × 10 Ins/Sec  
A3: Ins/Sec A3 = 4.0 GHz / 1.6 = 2.5 × 10 Ins/Sec  
  
Conclusion:  
**Processor A2 has the highest performance with 3.0 billion instructions per second.**

**2. If each processor executes a program in 15 seconds, find the number of cycles and**

**the number of instructions executed.**

Step 1:Formula to find the Number of Cycles  
Number of cycles = Execution time × Clock rate  
  
A1: # of Cycles A1 = 15 × 3.5 GHz = 52.5 cycles  
A2: # of Cycles A2 = 15 x 3.0 GHz = 45 cycles  
A3: # of Cycles A3 = 15 x 4.0 GHz = 60 cyclesStep 2:  
Formula to find the Number of Instructions  
Number of Instructions = Number of Cycles / CPI  
  
A1: # of Instructions A1 = 52.5 GHz / 1.4 = 37.5 Instructions  
A2: # of Instructions A2 = 45 GHz / 1.0 = 45 Instructions  
A3: # of Instructions A3 = 60 GHz / 1.6 = 37.5 Instructions  
  
Conclusion:  
**A1**: **37.5 billion instructions** and **52.5 billion cycles**.

**A2**: **45 billion instructions** and **45 billion cycles**.

**A3**: **37.5 billion instructions** and **60 billion cycles**.

**3. We are aiming for a 30% reduction in execution time, but this results in a 10%**

**increase in CPI. What clock rate is needed to achieve this time reduction?**Step 1  
Find the Target Execution Time  
New Execution Time = 15 seconds × (1 = 0.30) = 15 x 0.70 = 10.5 seconds  
  
Step 2  
Define the new CPI  
New CPI = Original CPI × (1 + 0.10)  
  
A1: New CPI A1 = 1.4 × 1.10 = 1.54  
A2: New CPI A2 = 1.0 × 1.10 = 1.10  
A3: New CPI A3 = 1.6 × 1.10 = 1.76  
  
Step 3  
Formula to find Execution Time:  
Execution Time = (CPI × Number of Instructions) / Clock Rate  
  
Rearranged Formula to find Clock Rate  
Clock Rate = (CPI × Number of Instructions) / Execution Time  
  
A1: New Clock Rate A1 = (1.54 × 37.5 GHz) / 10.5  
 A1 = 57.75 GHz / 10.5  
 New Clock Rate A1 = ~5.5 GHz  
  
A2: New Clock Rate A2 = (1.10 × 45 GHz) / 10.5  
 A2 = 49.5 GHz / 10.5  
 New Clock Rate A2 = ~4.71 GHz  
  
A3: New Clock Rate A3 = (1.76 × 37.5 GHz) / 10.5  
 New Clock Rate A3 = 66 GHz / 10.5  
 New Clock Rate A3 = ~6.29GHz  
  
Conclusion:  
**A1 needs a clock rate of approximately 5.5 GHz  
A2 needs a clock rate of approximately 4.71 GHz  
A3 needs a clock rate of approximately 6.29 GHz**