

## 1 1.6

class A = 10,  
class B = class D = 20,  
class C = 50,  
IC =  $10^6$

	Clock Rate	CPI Class A	CPI Class B	CPI Class C	CPI Class D
P1	2.5GHZ	1	2	3	3
P2	3GHZ	1	2	3	2

### 1.0.1 a

$CPI(P1) = (CPU * \text{clock rate}) / IC$ .

$$CPU(P1) = \sum [(IC * CPI) / \text{clockrate}]$$

$$= [[10^6 * ((0.1 * 1) + (0.2 * 2) + (0.5 * 3) + (0.2 * 3))] / [2.5 * 10^9]] = (2.6) / 2.5 * 10^3 = 1.04 \text{ms},$$

$$\Rightarrow CPI(P1) = (1.04 * 2.5 * 10^9) / (10^6 * 10^3) = 2.6 * 10^6 / 10^6 = 2.6.$$

$CPI(P2) = (CPU * \text{clock rate}) / IC$ .

$$CPU(P2) = \sum [(IC * CPI) / \text{clockrate}]$$

$$= [[10^6 * ((0.1 * 2) + (0.2 * 2) + (0.5 * 2) + (0.2 * 2))] / [3 * 10^9]] = (2) / 3 * 10^3$$

$$= 0.67 \text{ms} \Rightarrow CPI(P2) = (0.67 * 3 * 10^9) / (10^6 * 10^3) = 2.01$$

### 1.0.2 b

$\text{Clock Cycle}(P1) = CPI * IC = 2.6 * 10^6$ .

$\text{Clock Cycle}(P2) = CPI * IC = 2.01 * 10^6$ .

## 2 1.7

Execution Time (A) = 1.1s IC(A) =  $10^9$

Execution Time (B) = 1.51s IC(B) =  $1.2 * 10^9$

Clock Time =  $1 / 10^9 \text{s}$ .

### 2.0.1 a

$CPI = (\text{Execution Time}) / (IC * \text{Clock Time})$

$$\Rightarrow CPI(A) = (1.1 * 10^9) / (1 * 10^9) = 1.1$$

$$\Rightarrow CPI(B) = (1.5 * 10^9) / (1.2 * 10^9) = 1.25$$

### 2.0.2 b

$\text{ExecutionTime}(A) = IC \times CPI \times \text{ClockCycleTime}(A)$   
 $= 1 \times 10^9 \times 1.1 \times \text{ClockCycleTime}(A)$   
 $\text{ExecutionTime}(B) = IC \times CPI \times \text{ClockCycleTime}(B)$   
 $= 1.2 \times 10^9 \times 1.25 \times \text{ClockCycleTime}(B)$   
 $\text{ExecutionTime}(B) = \text{ExecutionTime}(A)$   
 $1 \times 10^9 \times 1.1 \times \text{ClockCycleTime}(A) = 1.2 \times 10^9 \times 1.25 \times \text{ClockCycleTime}(B)$   
 $\text{ClockCycleTime}(A) = (1.5/1.1) \times (\text{ClockCycleTime}(B))$   
 $\text{ClockCycleTime}(A) = 1.36 \times (\text{ClockCycleTime}(B))$

### 2.0.3 c

$\text{newIC} = 6 \times 10^8$   
 $\text{newCPI} = 1.1 \text{ CPU}$   
 $\text{newExecutionTime} = IC \times CPI \times \text{Clock cycle time} = (6 \times 10^8 \times 1.1) / 109 = 0.66 \text{ secs}$

For A:  $\text{newExecutionTime}(A) = 1.1 \text{ secs.}$   
 $\text{Speed} = \text{ExecutionTime}(A) / \text{newExecutionTime}$   
 $\text{speed} = 1.67.$

For B:  $\text{newExecutionTime}(B) = 1.5 \text{ secs.}$   
 $\text{Speed} = \text{ExecutionTime}(B) / \text{newExecutionTime}$   
 $\text{speed} = 2.27.$

## 3 1.9

$CPI(\text{Arithmetic}) = 1.$   
 $CPI(\text{Load/store}) = 12.$   
 $CPI(\text{Branch}) = 5.$   
 $IC(\text{Arithmetic}) = 2.56 \times 10^9$   
 $IC(\text{Load/store}) = 1.28 \times 10^9$   
 $IC(\text{Branch}) = 256 \times 10^9$   
 $\text{Clock Rate} = 2 \text{ GHz}$

### 3.1 a

$\text{ExecutionTime} = \text{ClockCycles} / \text{ClockRate}$   
 $\text{Clock Cycles} = CPI(\text{Arithmetic}) \times IC(\text{Arithmetic}) + CPI(\text{Load/store}) \times IC(\text{Load/store}) + CPI(\text{Branch}) \times IC(\text{Branch}).$

### 3.1.1 1

ExecutionTime(1):

$$\text{ClockCycles}(1) = 2.56 * 10^9 + 1.28 * 10^9 * 12 + 256 * 10^6 * 5 = 19.2 * 10^9 \text{ cycles}$$

$$\text{ExecutionTime}(1) = \text{ClockCycle} / \text{ClockRate} = 19.2 * 10^9 \text{ cycles} / 2 * 10^9 \text{ cycle/sec} = 9.6 \text{ secs}$$

### 3.1.2 2

ExecutionTime(2):

$$\begin{aligned} \text{ClockCycles}(2) &= \text{CPI}(\text{Arithmetic}) * \text{IC}(\text{Arithmetic}) / 0.7 * p + \text{CPI}(\text{Load/Store}) * \text{IC}(\text{Load/Store}) / 0.7 * p + \text{CPI}(\text{Branch}) * \text{IC}(\text{Branch}) \\ &= (2.56 * 10^9) / (0.7 * 2) + (1.28 * 10^9 * 12) / (0.7 * 2) + (256 * 10^6 * 5) \\ &= 14.08 * 10^9 \text{ cycles} \end{aligned}$$

$$\text{ExecutionTime}(2) = \text{Clock Cycle} / \text{Clock Rate} = 14.08 * 10^9 \text{ cycles} / 2 * 10^9 \text{ cycles/sec} = 7.04 \text{ secs}$$

### 3.1.3 4

ExecutionTime(4):

$$\begin{aligned} \text{ClockCycles}(4) &= \text{CPI}(\text{Arithmetic}) * \text{IC}(\text{Arithmetic}) / 0.7 * p + \text{CPI}(\text{Load/Store}) * \text{IC}(\text{Load/Store}) / 0.7 * p + \text{CPI}(\text{Branch}) * \text{IC}(\text{Branch}) \\ &= (2.56 * 10^9) / (0.7 * 4) + (1.28 * 10^9 * 12) / (0.7 * 4) + (256 * 10^6 * 5) \\ &= 7.68 * 10^9 \text{ cycles} \end{aligned}$$

$$\text{ExecutionTime}(4) = \text{Clock Cycle} / \text{Clock Rate} = 7.68 * 10^9 \text{ cycles} / 2 * 10^9 \text{ cycles/sec} = 3.84 \text{ secs}$$

### 3.1.4 8

ExecutionTime(8):

$$\begin{aligned} \text{ClockCycles}(8) &= \text{CPI}(\text{Arithmetic}) * \text{IC}(\text{Arithmetic}) / 0.7 * p + \text{CPI}(\text{Load/Store}) * \text{IC}(\text{Load/Store}) / 0.7 * p + \text{CPI}(\text{Branch}) * \text{IC}(\text{Branch}) \\ &= (2.56 * 10^9) / (0.7 * 8) + (1.28 * 10^9 * 12) / (0.7 * 8) + (256 * 10^6 * 5) \\ &= 4.48 * 10^9 \text{ cycles} \end{aligned}$$

$$\text{ExecutionTime}(8) = \text{Clock Cycle} / \text{Clock Rate} = 4.48 * 10^9 \text{ cycles} / 2 * 10^9 \text{ cycles/sec} = 2.24 \text{ secs}$$

### 3.2 b

ExecutionTime of 1, 2, 4, and 8:

$$\begin{aligned}\text{TotalExecutionTime} &= \text{ExecutionTime}(1) + \text{ExecutionTime}(2) + \text{ExecutionTime}(4) \\ &+ \text{ExecutionTime}(8) \\ &= 9.60\text{secs} + 7.4\text{secs} + 3.84\text{secs} + 2.24\text{secs} + 22.72\text{secs} = 22.72\text{secs}.\end{aligned}$$

### 3.3 c

#### 3.3.1 2

$$\begin{aligned}\text{SpeedUp}(2) &= \text{ExecutionTime}(2) / \text{ExecutionTime}(\text{single processor}) \\ &= 7.04\text{secs} / 9.60\text{secs} = 0.73.\end{aligned}$$

#### 3.3.2 4

$$\begin{aligned}\text{SpeedUp}(4) &= \text{ExecutionTime}(4) / \text{ExecutionTime}(\text{single processor}) \\ &= 3.84\text{secs} / 9.60\text{secs} = 0.40.\end{aligned}$$

#### 3.3.3 8

$$\begin{aligned}\text{SpeedUp}(8) &= \text{ExecutionTime}(8) / \text{ExecutionTime}(\text{single processor}) \\ &= 2.24\text{secs} / 9.60\text{secs} = 0.23.\end{aligned}$$