Exam #1’s Solutions

1. (1) Empower the client (offload to the client), or asynchronous communication
   (2) Data/service partition
   (3) Data/service replication

2. Given events a and b, a \[\not\rightarrow\] b, and b \[\not\rightarrow\] a

3. Catch causality, \( C(e1) < C(e2) \rightarrow e1 \rightarrow e2 \)

4. A vector clock maintains logical clocks of all involved processes. When a process \( Pi \) sends a message, it increases its logical clock in the vector by 1 and attach the updated logical clock to the message; Upon receiving a message from \( Pk \) with a vector clock \( VC(k) \), for each component in \( Pi \)’s vector clock \( VC(i) \), take the greater value in \( VC(k) \) and \( VC(i) \). Optionally, \( Pi \) can increase its logical clock by 1.

   Given \( VC(a) < VC(b) \) where a and b are events, we conclude \( a \rightarrow b \)

5. Solution
   \[
   \begin{align*}
   P1 & \rightarrow P3: (1, 0, 0) \\
   P2 & \rightarrow P3: (0, 1, 0) \\
   P3 & \rightarrow P2: (1, 0, 2) \\
   P1 & \rightarrow P2: (2, 0, 0) \\
   P2 & \rightarrow P1: (2, 4, 2)
   \end{align*}
   \]

6. \[
   \begin{align*}
   T2 - T1 & = 0:42:55.600 \\
   T3 - T4 & = 0:42:55.460 \\
   \Theta & = [(T2 - T1) + (T3 - T4)] / 2 = 0:42:55.530 \\
   \Theta > 0, \text{ so we need to move the client’s clock forward by } & 42 \text{ min } 55 \text{ second and } 530 \text{ msec} \\
   \text{the client’s clock has to be set at time } & 6:22:15.250 + 00:42:55.530 = 07:05:10.780
   \end{align*}
   \]