1 Exam rules

1. You are allowed to use any materials that have been distributed through the course website.
2. You are not allowed to discuss these problems with anyone you know.
3. You are allowed to ask clarifying questions only through the discussion board.
4. The solutions you submit should be entirely your own.
5. You are not allowed to share the content of this exam on any website or online group.
6. When writing your code, please make sure that you include sufficient comments so that your thinking is clear to the instructor who will grade your exam. Partial credit will be given for incomplete code.
7. Include a text file with the output of your code.
8. Your code should compile and execute on the Statistics cluster.
9. Points will be deducted for memory leaks, MPI sessions that are not properly defined, random number generators that are not properly initialized and used.
10. Points will be deducted for fragments of code that are unusual (e.g., they are not consistent with any example code provided on the course website, contain mistakes or are very unlikely to have been written independently by students working independently)and appear in multiple submissions from different students.

2 Final Project Problem

Write a C/C++ program that uses MPI to simulate a game of volleyball. The game involves a referee and two teams of six players on a court separated by a net, with the goal of scoring points by hitting the ball over the net and forcing the opposing team to make a fault. In your MPI session, the referee will be the process with identifier 0. The first team (Team A) will be the processes with identifiers $1, \ldots, 6$ and the second team (Team B) will be the processes with identifiers $7, \ldots, 12$. The ball will be a message sent by a player to another player or by the referee to a team player.

These are the key rules of the game of baseball.

- **Team Size**: Six players on each team, with three in the front row and three in the back row. The placement of players in the same in the court is not relevant for implementing this simulation.
- **Number of Hits**: Each team can touch the ball a maximum of three times before sending it over the net.
- **Double Hits**: A player cannot hit the ball twice in a row.
- **Ball in Play**: A ball is "in" if it lands within the court's boundary lines.
- **Ball Out of Play**: A ball is "out" if it hits the antennae, the floor outside the court, the net or cables outside the antennae, the referee stand, or the ceiling.
- **Scoring**: Points are awarded for every rally, with the winning team also gaining the serve.
- **Match Length**: A match is typically a best-of-five-set contest, with the first four sets played to 25 points and the fifth to 15.
- **Winning a Set**: A team must win a set by at least two points.

Implement the simulation of a full game of volleyball (best out of five sets) as follows.

Start of the game. The referee picks Team A or Team B with equal probability 0.5. The referee sends the ball to one of the six players of the team they picked with equal probability $\frac{1}{6}$. In your code, this action means that the process with identifier 0 sends a message to one of the other processes with probability $\frac{1}{12}$. This message indicates that the picked player has the ball.

One play consists of the following actions.

1. The play starts with the player who has the ball. This player serves the ball with the following outcomes: (a) the ball goes out of bounds with probability $\frac{1}{4}$. In this case, the opposing team gets the ball and also receives a point. The player serving the ball sends a message to the referee notifying them that the ball was out of bounds. The referee records a point for the opposing team and sends the

ball to a player of that team. This player is picked at random by the referee with probability $\frac{1}{6}$; (b) the ball lands within the court's boundary lines with probability $\frac{1}{2}$. In this case, the team of the player who served the ball receives a point. The player serving the ball sends a message to the referee notifying them that their team just scored a point. The player serving the ball continues to serve in a new play; (c) the ball is intercepted by one of the players of the opposing team while the ball is in play with probability $\frac{1}{2}$. In this case, the team who has the ball continues to play it. In your implementation, the player who serves the ball sends the ball to one of the opposing team's players with probability $\frac{1}{6}$. This action says that the player who receives the ball needs to continue playing.

2. The player who currently has the ball can pass the ball successfully to another member of their team with probability $\frac{1}{2}$. In this case, this player sends the ball to another player on the same team; this player is selected at random with probability $\frac{1}{5}$. The player who currently has the ball can fail to pass the ball with probability $\frac{1}{4}$. In this case, the opposing team scores a point and gets the ball. In your implementation, the player who has the ball sends a message to the referee notifying them about the outcome of the play. Finally, with probability $\frac{1}{4}$, the player who has the ball manages to score a point for their team. In this case, their team gets a point (the referee needs to be notified about that) and the player gets to serve in the next play.

3. If the player who currently has the ball is the third player who touched the ball consecutively in the same play, they cannot pass the ball to another team member. In this case the only possible outcomes can be that their team successfully scores a point with probability $\frac{1}{2}$ or the opposing team scores a point and gets the ball with probability $\frac{1}{2}$.

4. Every time a new point is scored by a team, the referee needs to print in a log file the current score: the number of sets and the number of points scored by each team in each set. The referee also decides which play will get the ball was sent to them. The referee decides when the game ends. In this case, the referee needs to notify all the players that the game ended.

5. When deciding to award a new set to a team, the referee needs to make sure that the difference between the current scores of the two teams is at least two points and that the match length rule (see above) is followed.

6. Every time an action is taken by a team player, a message needs to be printed in a log file specifying the identifier of the process taking the action and the nature of the action.

Your submission needs to include the source code and the log file with an example execution of your code.