This exam contains 4 questions with a total of 20 points in 4 pages.
The exam is open book/notes.
If you have to make assumptions to continue solving a problem, state your assumptions clearly.

1. a) [2 points] State two advantages of multicore processors.
   - Can reach higher performance without the high clock frequency (at its power consumption implication), assuming we have parallel programs.
   - Can exploit different type of parallelism (given compiler and programmer support): task-level parallelism, data-level parallelism, … .

b) [2 points] State two advantages of single core processors.
   - Easier to program
   - Historically, with increasing clock frequency, can result in higher performance with no effort from the programmer.

c) [2 points] State two disadvantages of multicore processors.
   - Hard to program.
   - With increase in number of cores, there is contention on shared resources (e.g. shared cache, interconnect, memory controller, … ).

d) [2 points] State two disadvantages of single core processors.
   - Does not scale anymore in terms of performance.
   - Does no exploit other type of parallelism, such as task level parallelism.
2. [2 points] We have seen that a multicore processor is MIMD in Flynn’s classification. Can a single core processor be anything else but SISD? If yes, give examples. If not, why not?

Yes, a superscalar processor and simultaneous multithreading architectures (i.e. processor with hyperthreading technology) can be considered MIMD.

3. [3 points] Describe 3 different scenarios where an MPI program can have a deadlock.

- A send call without the corresponding receive
- Collective calls not called by all processes of the communicator
- Deadlock due to out-of-order sends and receives
4. Suppose that MPI_COMM_WORLD consists of the three processes 0, 1, and 2, and suppose the following code is executed (my_rank contains the rank of the executing process):

```c
int x, y, z;
switch(my_rank) {
    case 0:
        x=0; y=1; z=2;
        MPI_Bcast(&x, 1, MPI_INT, 0, MPI_COMM_WORLD);
        MPI_Send(&y, 1, MPI_INT, 2, 43, MPI_COMM_WORLD);
        MPI_Bcast(&z, 1, MPI_INT, 1, MPI_COMM_WORLD);
        break;
    case 1:
        x=3; y=8; z=5;
        MPI_Bcast(&x, 1, MPI_INT, 0, MPI_COMM_WORLD);
        MPI_Bcast(&y, 1, MPI_INT, 1, MPI_COMM_WORLD);
        break;
    case 2:
        x=6; y=7; z=8;
        MPI_Bcast(&z, 1, MPI_INT, 0, MPI_COMM_WORLD);
        MPI_Recv(&x, 1, MPI_INT, 0, 43, MPI_COMM_WORLD, &status);
        MPI_Bcast(&y, 1, MPI_INT, 1, MPI_COMM_WORLD);
        break;
}
```

a. [4 points] What will be the values of x, y, and z for each of the 3 processes after executing the above code?

<table>
<thead>
<tr>
<th></th>
<th>P0</th>
<th>P1</th>
<th>P2</th>
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<tbody>
<tr>
<td>X</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Y</td>
<td>1</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Z</td>
<td>8</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

b. [2 points] Is there a possibility that the communication among the 3 processes be executed out of order? If yes, explain the reason. If not, why not?

**No, because collective communication are blocking, and MPI_recv() is blocking.**
c. [1 point] What will happen if we execute the above code with: mpiexec –n 4 (and MPI_COMM_WORLD will then contain 4 processes)?

The program will hang because the collective communication calls must be done by all the processes.