HPC Final Exam - Fall 2012

Name: _____ (Please print)
Put the answers on additional sheets. You can collect 100 points in total for this exam.

1. What does the term *SPMD* stand for? (4 points)

2. Name three *PGAS languages*. (4 points)

3. What is the key property of a *locally blocking send* operation? (4 points)

4. What is the *MPE library* used for in MPI and what basic capabilities does it offer? (4 points)

5. BLAS provides a standard for numerical linear algebra operations. What kind of two data structures are operated on at each the three BLAS levels (answer in the form of "level k: $x - x$ operations" where x is scalar, vector, matrix). (4 points)

6. Explain the workings of `MPI_BSEND`, i.e. show a timeline diagram with the sender and receiver operations over time, assuming the sender starts sending before the receiver listens. (8 points)

7. Explain how a *scatter* collective communication operation can be decomposed in $\log_2(P)$ steps using a branching tree, i.e. starting with processor 0 that holds the P data items. Show the branching tree for $P = 8$ processors annotated with data to scatter. (8 points)

8. UPC supports both strict and relaxed memory consistency models. What is the *relaxed memory consistency model*, why is it useful for high performance computing, and what special precautions besides locking have to be taken when operating on shared data in memory by the tasks? (8 points)

9. Consider the following MPI code that we run on 4 processors (numbered $p = 0$ to 3):

```
float x[4] = {2, 3, 4, 5};
float y = 0, z = 0;
MPI_Scatter(x, 4, MPI_FLOAT, &y, 4, MPI_FLOAT, 0, MPI_COMM_WORLD);
MPI_Scan(&y, &z, 1, MPI_FLOAT, MPI_SUM, MPI_COMM_WORLD);
```

$p =$	0	1	2	3
$y =$				
$z =$				

   Enter the values for `y` and `z` for each of the 4 processors. (8 points)

10. MPI supports *virtual topologies*. What is a virtual topology and why can it help to reduce the message passing overhead of the application over a network? (8 points)

11. How is matrix multiply implemented in a *systolic array*? Show the nodes, links, delays, and actions to compute $C = A \times B$ with $c_{ij} = \sum_k a_{ik} b_{kj}$. (8 points)

12. Explain the *fully distributed work pool* for decentralized dynamic load balancing with task queues. (8 points)

13. Explain the *Barnes Hut algorithm* for a 2D decomposition of space in a quadtree to compute the masses, forces, and displacements of the N bodies (no need to give the equations, show the parallel approach). (8 points)

14. Explain the *divide and conquer strategy* applied to the *convex hull problem*. (8 points)

15. Why are standard pseudo random number generators (RNG) not suitable for parallel sampling methods, i.e. why do we need parallel RNGs for Monte Carlo? (8 points)