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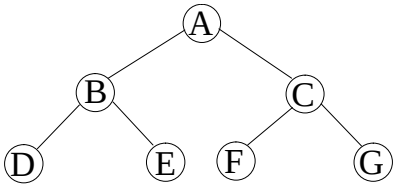
Fall 1998
Test 1

Closed Book Questions - 5 Points Each

1. Indicate the vertex equivalence classes in the following network.



2. How many automorphisms does the network in problem 1 have?
3. What is the bisection width of a 5 x 5 torus?
4. What is the diameter of a 5 x 5 torus?
5. List the processors that are connected to processor 21 in a 5-d hypercube.
6. Describe how semaphores are used in the highly-concurrent queue.
7. Under what two message-passing situations will a sender block in SR?
8. Show how interleaving would be applied to the following loop. Assume that `numThreads` is the number of threads and that `rank` is defined locally for each thread.

```
for (i=0; i<limit; i+=2)
  a[i] = b[i];
```

9. How many necklaces does a 32 node shuffle-exchange network have?
10. What does all-to-all broadcast *achieve* for an application? Do not discuss details of algorithms, lower bounds, etc.

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Test 1

Open Book Questions

1. Comment on the correctness of the following pthreads implementation of a barrier. `numThreads` is the number of threads that must synchronize. Note that 1<<k computes 2^k. 15 points

```
pthread_mutex_t mutex=PTHREAD_MUTEX_INITIALIZER;
int x=0;

int numThreads;

void checkIn(int rank)
{
pthread_mutex_lock(&mutex);
x=x + 1<<rank;
if (x == 1<<numThreads - 1)
     x=0;
else
     while (x != 0)
     {
```

```
                pthread_mutex_unlock(&mutex);
                pthread_mutex_lock(&mutex);
            }
        pthread_mutex_unlock(&mutex);
        }
```

2. Demonstrate static routing for meshes on the following instance. 10 points

	0	1	2
0	2,2	2,1	2,0
1	0,2	1,0	0,0
2	1,2	1,1	0,1

3. Give an efficient pthreads implementation of a concurrent function that corresponds to the following sequential function. Do not give the code to create the threads, i.e. just give the function. Your code must work with an arbitrary number of threads. 15 points

```
void f()
{
int i;

for (i=0; i<n; i++)
  a[i]=i*i;

for (i=1; i<n; i++)
  b[i]=a[i-1] + a[i];
}
```

4. Give a lower bound on the number of rounds for all-to-all communication on linear arrays and an algorithm that achieves this bound. In a round a node may send a message to each of its neighbors. 10 points

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Test 2

Closed Book Questions - 5 Points Each

1. List the arguments used in a call to the function MPI_Recv().
2. Suppose that an MPI program can be executed on ketchup. How would you execute this program such that the even numbered processes run on ketchup and the odd numbered processes run on mustard?
3. How much time does an ordinary prefix sum on n values take on a CREW PRAM with n processors?
4. Explain the notion of concurrent write in the CRCW PRAM.
5. What is lock coupling?
6. In the worst case, how much time does the parallel randomized list ranking method take?
7. When will ξ locks be set in using a concurrent AVL tree?
8. Suppose you are given a PRAM algorithm to be implemented as a parallel application. Which will be more difficult to implement: a shared memory pthreads program or an MPI program? Why?

9. Will the following MPI program execute completely with an arbitrary number of processes? If not, indicate why.

```
#include "mpi.h"
MPI_Status status;

main(int argc, char** argv)
{
int numProcesses,rank;
int a=1,b=2,c=3;

MPI_Init(&argc,&argv);
MPI_Comm_size(MPI_COMM_WORLD,&numProcesses);
MPI_Comm_rank(MPI_COMM_WORLD,&rank);

if (rank%2==0)
  if (numProcesses-1==rank)
    MPI_Bcast(&a,1,MPI_INT,0,MPI_COMM_WORLD);
  else
  {
    MPI_Send(&b,1,MPI_INT,rank+1,1,MPI_COMM_WORLD);
    MPI_Send(&c,1,MPI_INT,rank+1,2,MPI_COMM_WORLD);
    MPI_Bcast(&a,1,MPI_INT,0,MPI_COMM_WORLD);
  }
else
{
  MPI_Bcast(&a,1,MPI_INT,0,MPI_COMM_WORLD);
  MPI_Recv(&b,1,MPI_INT,rank-1,1,MPI_COMM_WORLD,&status);
  MPI_Recv(&c,1,MPI_INT,rank-1,2,MPI_COMM_WORLD,&status);
}

MPI_Finalize();
}
```

10. Comment on the efficiency of the algorithm for searching an ordered array on a CREW PRAM.

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Test 2

Open Book Questions

1. Write a C function `testCycle()` (using MPI commands) to test if a distributed table contains a single cycle and thus could correspond to an Euler tour. As an example, suppose the table contains 20 elements distributed over 4 processes:

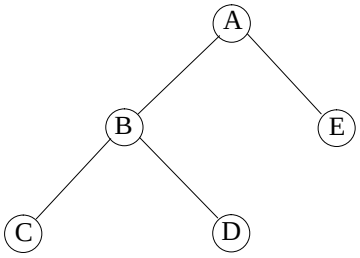
Global Subscript	Rank of Process	Local Subscript	Next Element
0	0	0	5
1	0	1	4
2	0	2	12
3	0	3	9
4	0	4	3
5	1	0	18
6	1	1	17
7	1	2	2
8	1	3	6
9	1	4	8

10	2	0	7
11	2	1	13
12	2	2	19
13	2	3	0
14	2	4	10
15	3	0	11
16	3	1	1
17	3	2	15
18	3	3	14
19	3	4	16

Starting at global subscript 0, if we follow the sequence of ‘‘next elements’’ (5, 18, 14, 10, 7, . . .) we will eventually touch every element once and come back to 0. Your job is to test the integrity of the values in an arbitrary nextElement table. If the table is flawed, you may simply call `MPI_Abort()`. If it is clean, then all processes must be notified so that they return from `testCycle()`.

You may assume that the number of elements is available in the global variable tableSize and that table-Size is divisible by the number of processes. Your function is not required to be fast - linear time is good enough. You may not, however, move the local tables to one process for verification. Other code (main(), generation of the table) is not necessary. It is important to have an appropriate approach - randomly spewed code will be severely penalized. 25 points

2. Give the data structure, Euler tour, preorder traversal, and levels of vertices when vertex A is used as the root of the tree. Order each linked list in ascending order by the head vertices. 25 points



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Test 3

Closed Book Questions - 5 Points Each

1. What is an anti-dependence?
2. Comment on the attainable speed-up for performing the LU method in parallel.
3. Comment on the efficiency of bitonic mergesort for n processors sorting n values.
4. What does ‘‘bitonic’’ mean?
5. Suppose you are generating permutations with 4 elements for the values 0, 1, . . ., 7 in lexicographic order. Which permutation is generated after 4, 1, 2, 3?
6. What is the significance of unranking for parallel enumeration?
7. What is the purpose of the GCD test?
8. How many steps are needed to transpose an N-by-N matrix on an N-by-N mesh?
9. How many steps are need to transpose an 2^N-by-2^N matrix on a 2^{2N}-d hypercube?

10. What is the difference between `doall` and `forall` parallelism?

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Test 3

Open Book Questions

1. How many comparators occur in the bitonic mergesort diagram for 32 items? 10 points
2. Which permutation has rank 100 when working with permutations with 3 elements from the values 0, 1, . . ., 5? 10 points
3. Why is an interleaved allocation of rows desirable for the LU method? 5 points
4. Suppose you are working with a 256-node (8-dimension) hypercube. Each of the 16 processors with an address of form 17i, $0 \leq i < 16$, has a value x_i to be broadcast to processors with addresses of form $16i + j$, $0 \leq j < 16$. Assuming a communication model in which each processor can send or receive no more than one packet in each timestep, give an algorithm to perform these broadcasts simultaneously. Be sure that your algorithm minimizes the number of message rounds. 25 points