HPC Midterm Exam - Fall 2012

Name: ____ (Please print)

Put the answers on these sheets. Use additional sheets when necessary. You can collect 100 points for this exam and a bonus for an additional 10 points.

1. What does *NUMA* stand for, i.e. a property of a parallel machine architecture? (7 points)

2. What is *false sharing* and what causes it? (7 points)

3. What is *profile-guided optimization*? (7 points)

4. What is a *data speculation* compiler optimization? Give an example. (7 points)

5. Give an example of a *loop interchange* transformation. (7 points)

6. Profiling is either sampling-based or event-based. What are the advantages of event-based hardware counter profiling compared to sampling-based profiling? (7 points)

7. Shared memory programming under the assumption of *relaxed memory consistency* requires threads to execute a *flush*. Most OpenMP constructs include a flush operation. What is a flush? (7 points)

8. Give a 4x4 *two-stage interconnect network* of switches. (7 points)

9. OpenMP loop scheduling can be static or dynamic/guided. Give an example of a static and a dynamic OpenMP loop schedule (show OpenMP directive and a scheduling diagram). (10 points)

10. Consider the following loop.

```
int i, k, n;
double a[], b[], c[], h;
...
for (i = 0; i < n; i++)
{ a[i] = a[i] + b[k] * c[k] / h;
  k = k+2;
}
```

For $n \to \infty$, what is the FP:M ratio of this loop (show calculation)? (8 points)

11. Consider the following code

```
S1:   a = 1
S2:   b = a+1
S3:   a = 2*b
```

Determine the RAW (=flow) and WAR (=anti) dependences between these statements. (8 points)

12. Consider the following loop

```
      DO I = 1,N
S1:    C(I) = 0
S2:    A(I) = A(I) + B(I-1)
S3:    B(I) = A(I) + C(I)
      ENDDO
```

Draw the dependence graph for statements S1 to S3. Then apply loop fission. (10 points)

13. Amdahl's law determines the speedup $S_P = P/(1 + (P - 1)f)$ of a parallel application. Suppose the sequential fraction f is 20%. What is the speedup for $P = 16$? (8 points)

14. **[BONUS 10 points]** Consider a perfectly parallelizable program with computation time $t_{\text{comp}} = 100/P$. Suppose the communication time of this program linearly increases with increasing number of processors $t_{\text{comm}} = 0.01 \cdot P$ seconds.

    (a) Determine all $P \geq 1$ such that $t_{\text{comp}} \geq t_{\text{comm}}$, that is, the range of P for which the computation time dominates the communication time. (5 points)

    (b) Assuming that the sequential program runs in the same time as t_{comp} for $P = 1$, that is $t_s = 100/P = 100/1$ seconds, what is the speedup S_P and parallel efficiency E_P when $t_{\text{comp}} = t_{\text{comm}}$? (5 points)