

## Homework 11 – Due Wednesday, April 23, 2008 before the lecture

Please refer to the general information handout for the full homework policy and options.

**Page limit** You can submit **at most** 1 page per problem, even if the problem has multiple parts. If you submit a longer solution for some problem, only the first page will be graded. This homework contains 3 problems, worth 10 points each.

**Reminder** Collaboration is permitted, but you must write the solutions *by yourself without assistance*, and be ready to explain them orally to the instructor if asked. You must also identify your collaborators. Getting solutions from outside sources such as the Web or students not enrolled in the class is strictly forbidden.

**Exercises** Please practice on exercises and solved problems in chapter 9.

### Problems

1. **(True, False or Open)**

For each of the following statements, answer **True**, **False** or **Open Question** according to our current state of knowledge of complexity theory, as described in class. **Give a brief justification of your answer.** No points will be given for a correct answer with incorrect justification.

- (a)  $P \subseteq (NP \cap \text{co-NP})$
- (b)  $CLIQUE$  is  $\text{co-NP}$ -hard.
- (c)  $TQBF$  is  $NP$ -hard.
- (d)  $TQBF$  is  $NP$ -complete.
- (e)  $TQBF$  is  $EXPSPACE$ -complete.
- (f)  $SAT \leq_P \overline{SAT}$
- (g)  $SAT \leq_m \overline{SAT}$
- (h)  $TBQF \leq_L PATH$
- (i)  $HAMPATH \leq_P PATH$
- (j)  $P^{SAT} \subseteq (NP \cup \text{co-NP})$

2.  $ATMEXP = \{ \langle M, w, t \rangle \mid \text{TM } M \text{ accepts input } w \text{ within } 2^t \text{ steps, where } t \text{ is a binary integer} \}$ . Show that  $ATMEXP \notin EXPTIME$ .

3. **(Two Oracles for TQBF)** Book, 9.22