This is a  $2\frac{1}{2}$  hour in class closed book exam. All questions are straightforward and you should have no trouble doing them. Please show all work and write legibly. Thank you.

- 1. Is it decidable for regular sets  $R_1$  and  $R_2$  whether  $R_1 \subseteq R_2$ ? Justify your answer.
- 2. Write a context-free grammar for the compliment of  $\{ww \mid w \in (a+b)^*\}$ .
- 3. Let  $L \subseteq (a+b)^*$  be a context-free language. In each string interchange the order of a and b in each occurrence of ab. Is the resulting language context free? Give a proof of your answer.

Examples

$$aabb \rightarrow abab$$
 $ababab \rightarrow bababa$ 
 $bababa \rightarrow bbabaa$ 

- 4. If one can list the elements of a set in order, then must the set be recursive? Prove your answer.
- 5. Is the class of Turing machines that accept the empty set recursive, r.e. or not r.e.? Justify your answer.