1. [12 pts.]

```
jack = ref "Jack"
queen = ref "Ace"
king = ref "King"
ace = ref "Queen"
```

2. [18 pts.]

   a. $\left\{ a^m b^m c^n d^n \;\middle|\; m, n \geq 0 \right\} \cup \left\{ a^n b^m c^m d^n \;\middle|\; m, n \geq 0 \right\}$

   b. Some example strings are the empty string, *abcd* or *aabbccdd* (any string where $m = n$).

   c. Here is an answer assuming the answer to part (b) was *abcd*. **Note**: this problem asked for a **derivation**. Ambiguity can be demonstrate by showing two parse trees for the same string in a grammar, but that is **not** what this question asks for. (It is partly testing knowledge of derivations.)

$$\underline{\mathrm{S}} \implies \underline{\mathrm{T}}\mathrm{U} \implies a\underline{\mathrm{T}}b\mathrm{U} \implies ab\underline{\mathrm{U}} \implies abc\underline{\mathrm{U}}d \implies abcd$$

$$\underline{\mathrm{S}} \implies \underline{\mathrm{V}} \implies a\underline{\mathrm{V}}d \implies a\underline{\mathrm{W}}d \implies ab\underline{\mathrm{W}}cd \implies abcd$$

3. [10 pts.] Two different answers exist because the grammar is ambiguous, so either of these would be correct: