Exercise 1.

1) Data structure for transition systems.

Typically, state names are numbers as are action names, too. But when generating a transition system, for example from a Lotos specification, we need to keep track of real action and state names. There may be a huge number of states, but usually there are only a modest number of actions. So we need

- linked structure for transition system,
- symbol table for actions,
- hash table for state names.

i) The linked structure is simple (adjacency list)

\[
\begin{array}{c}
\text{state action } \rightarrow \cdots \rightarrow \\
0 & \rightarrow \\
1 & \rightarrow \\
2 & \rightarrow \\
3 & \rightarrow \\
\vdots &
\end{array}
\]

Sometimes it is necessary to know the father of a node, too. If this is the case, we need an extra link from a node.
The symbol table for actions shows real names and the corresponding numbers. One could use either number or name when searching in the table. Hence, use both a trie and an ordinary array.

The hash table should be based on bit hashing (see lectures).

2. \[ T = \text{transition system} \]
\[ a = \text{action} \]
\[ s = \text{state} \]

\[ \text{Cycle} (T, s, a) \]

mark \( s \) red;
for each \( t \in \text{Adj}[s] \) (with \( a \))
do if color[\( t \)] = white
then Cycle \((T, t, a)\)
else if color[\( t \)] = red {
print "cycle found";
break;
}
color[\( s \)] = black;
R cannot know that this do is a duplicate and acknowledges it.

If the order cannot change, old do cannot come after d7. In this case duplicates are handled in the same way as resendings caused by too fast timeouts. So in this case AB works correctly.

Let us use signals, although other solutions are possible, too.

Also lost data packets must cause timeouts.
So the timer does not timeout too early. On the other hand, one can always ask, if signals are an appropriate way to model time settings. At least the global state graph shows that everything proceeds as if the timers were set properly.
6. a) The receiver can always separate different messages from each other. The same is true for acknowledgements. Thus, Stenning's protocol seems to tolerate more channel errors than the A13 protocol. Mathematical proof is also possible, but it demands more work.

b) It is possible to write transition systems for Stenning's protocol in the case of 10, or even 100 messages. If the protocol works in the case of 100 messages, there are good reasons to believe that it works in the case of 1000 messages or more.

It is possible to extend transition system formalism in many ways: variables in actions, states, operations with variables, etc. In this way, one can specify large systems with reasonable size expressions.