1. (10 points) (Bushnell and Agrawal) Problem 6.4

The following figure shows the SCOAP testability and controllability values for the combinational circuit.

![Circuit of Figure 6.22 with combinational SCOAP measures.](image-url)
2. (15 points) (Bushnell and Agrawal) Problem 6.8

The steps of calculation for SCOAP testability measures are shown in the three figures that follow. Combinational measures are shown as \((CC_0, CC_1)CO\) and sequential measures as \([SC_0, SC_1]SO\).
3. (10 points) (Bushnell and Agrawal) Problem 8.4

The required test has two steps:

(a) *Fault activation.* Assuming the present state to be unknown, we set the next state to 1. For \( C_n = X \), backward justification of \( C_{n+1} = 1 \) in Figure 8.3 (see page 215 of the book) gives us \( A_n = 1 \) and \( B_n = 1 \).

(b) *Path sensitization.* For the next vector, the above next state becomes the present state and the fault \( C_n \) s-a-0 is sensitized. We sensitize a path from \( C_n \) to \( S_n \) by setting \( A_n = 1 \) and \( B_n = 1 \).

Thus, the test sequence is \( (A_n, B_n) = (1,1), (1,1) \).
4. (15 points) (Bushnell and Agrawal) Problem 8.6

The following figure illustrates the time-frame expansion procedure of generating a vector, $A = 0$, $B = 1$, which starting from the unknown state detects the fault $A\ \text{s-a-1}$ as $1/X$. After the application of the input vector, the flip-flop is clocked before the output can be observed. Even if we add more vectors to the test sequence, the faulty circuit output will not become deterministic. This is because the faulty circuit is not initializable. The fault is only potentially detectable.

Note: Some test generators will find the potential detection test of the above type. Others will consider the fault untestable (conservative approach.) Most fault simulators will find the fault potentially detectable. Interestingly, the two test simulation scenarios in the figure show that the fault is definitely detectable, though the detection requires multiple observations. If we assume the initial state to be 1 then the fault is detected as 1/0 after the application of the first clock. However, this output will be 1 (same as the correct output) if the initial state was 0. In this case, repeating the same vector and clocking once again will produce a 1/0 output. A conventional fault simulator will not report such detection because it does not enumerate the possible initial state scenarios. For such multiple observation tests see reference [525] of the book.
5. (15 points) (Bushnell and Agrawal) Problem 8.12

The pseudo-combinational circuit and a combinational test, $A = 0$, $B = 1$, for the fault $D \text{s-a-0}$ are shown in the following figure. Simulation of the sequential circuit with input $A = 0$, $B = 1$, repeated four times shows that the fault will be detected as 1/0 appearing as the fourth output. We assume that the initial states of all three flip-flops are X.

![Pseudo-combinational circuit](image)

6. (15 points) The finite state machine $M7$ in Table 1 has a single input, a single output, and 5 states.

(a) Is this a strongly connected machine?

(b) Find a shortest synchronizing sequence for this machine. (To make grading easier, please designate the left branches of your tree correspond to Input = 0 for all trees in parts (b), (c), and (d).)

(c) Find a minimum length distinguishing sequence. Tabulate the output responses, initial and final states of applying your distinguishing sequence to the machine in each of the 5 starting states.

(d) Find a minimum length homing sequence which is different from the distinguishing sequence found in part (c).
Table 1: State Machine $M_7$ for Problem 6.

<table>
<thead>
<tr>
<th>Input</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A/1</td>
<td>C/1</td>
</tr>
<tr>
<td>B</td>
<td>E/0</td>
<td>E/1</td>
</tr>
<tr>
<td>C</td>
<td>C/1</td>
<td>D/0</td>
</tr>
<tr>
<td>D</td>
<td>D/1</td>
<td>B/0</td>
</tr>
<tr>
<td>E</td>
<td>E/0</td>
<td>A/1</td>
</tr>
</tbody>
</table>

a.) It is strongly connected.

b.) You can draw a synchronizing tree and obtain an 
SS = 0111 1011 1101 1110 and final state will be E.

c.) A distinguishing tree is given below and two distinguishing sequences are 
DS = 101 or 111

<table>
<thead>
<tr>
<th>DS = 101</th>
<th>STATE OUTPUT</th>
<th>FINAL STATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>110</td>
<td>D</td>
</tr>
<tr>
<td>B</td>
<td>101</td>
<td>A</td>
</tr>
<tr>
<td>C</td>
<td>010</td>
<td>B</td>
</tr>
<tr>
<td>D</td>
<td>001</td>
<td>A</td>
</tr>
<tr>
<td>E</td>
<td>111</td>
<td>C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DS = 111</th>
<th>STATE OUTPUT</th>
<th>FINAL STATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>100</td>
<td>B</td>
</tr>
<tr>
<td>B</td>
<td>111</td>
<td>C</td>
</tr>
<tr>
<td>C</td>
<td>001</td>
<td>E</td>
</tr>
<tr>
<td>D</td>
<td>011</td>
<td>A</td>
</tr>
<tr>
<td>E</td>
<td>110</td>
<td>D</td>
</tr>
</tbody>
</table>
d.) The homing tree is given in the figure below and a Homing sequence = 010

7. (20 points) The finite state machine in Fig.1 has a single input, a single output, and 5 states.

(a) Convert the state machine into a state transition table like the one given in Problem 6.

(b) Find a shortest synchronizing sequence for this machine.

(c) Find a minimum length distinguishing sequence. Tabulate the output responses, initial and final states of applying your distinguishing sequence to the machine in each of the 5 starting states.

(d) Design a checking sequence for this machine such that the total length of the sequence is small. Note that you can achieve this by choosing appropriate transfers while designing the checking sequence. You may use SS to denote the synchronizing sequence you found in part (a) and DS to denote distinguishing sequence you found in part (b). Likewise, you may use \( T_{ij} \) to denote transfer sequence from state \( i \) to state \( j \). However, you have to clearly indicate what the sequences are in
terms of inputs, and the states after the application of the sequences. In addition, also indicate the expected outputs whenever the outputs are to be observed.

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{state-diagram.png}
\caption{State Diagram Figure for Problem 7.}
\end{figure}

(a) The state machine is given in the tabular form as follows:

\begin{table}[h]
\centering
\caption{State Machine for Problem 5.}
\begin{tabular}{|c|c|c|}
\hline
   & Input & \\
\hline
0 & 1 & \\
\hline
A & A/1 & B/0 \\
B & E/0 & C/1 \\
C & C/1 & D/0 \\
D & B/0 & A/1 \\
E & A/1 & C/0 \\
\hline
\end{tabular}
\end{table}
b) The shortest SS for the given State Machine is: 000101.

c) There are two shortest length Distinguishing Sequences: 10100 and 10101. The initial and final states can be tabulated as follows:

<table>
<thead>
<tr>
<th>Initial</th>
<th>Output</th>
<th>Final</th>
<th>Initial</th>
<th>Output</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>00011</td>
<td>C</td>
<td>A</td>
<td>00010</td>
<td>D</td>
</tr>
<tr>
<td>B</td>
<td>11000</td>
<td>E</td>
<td>B</td>
<td>11001</td>
<td>C</td>
</tr>
<tr>
<td>C</td>
<td>00111</td>
<td>C</td>
<td>C</td>
<td>00110</td>
<td>D</td>
</tr>
<tr>
<td>D</td>
<td>11001</td>
<td>A</td>
<td>D</td>
<td>11000</td>
<td>C</td>
</tr>
<tr>
<td>E</td>
<td>01000</td>
<td>E</td>
<td>E</td>
<td>01001</td>
<td>C</td>
</tr>
</tbody>
</table>

d) A sample test plan can be given as follows.

Phase I: SS DS1 DS1 DS1 DS1 DS0
A A->B B->C C->D D->E E->A

Phase II: Many different solutions possible. One possible solution
TSA DS0 TSC DS0 TSD DS0 TSB DS0 TSA DS1 TSB DS0 TSC DS1 TSA DS0
A C C C D A B E A D B E C D A C
<TSB> TSE DS1 <TSB> TSC DS0
B E C B C C

The entries in brackets note an inefficiency.