Test design: Part II

Software Testing: INF3121 / INF4121
Summary: Week 5

**Specification-based testing** (black-box)
- Equivalence partitioning | Boundary value analysis
- Decision table | State transition | Use case testing

**Structure-based testing** (white-box)
- Statement / Decision testing and coverage

**Experience-based testing**

**Choosing test technique**
Part I: Close-ended questions
Question 1

Which of the following would **structure-based test design techniques** be likely to be applied to?

1. Boundaries between mortgage interest rate bands
2. An invalid transition between two different arrears statuses
3. The business process flow for mortgage approval
4. Control flow of the program to calculate repayment

a. 2, 3 and 4
b. 2 and 4
c. 3 and 4
d. 1, 2 and 3
Question 1: Answer

Which of the following would **structure-based test design techniques** be likely to be **applied** to?

Different types of testing

**Static**
- Informal reviews
- Walkthroughs
- Technical reviews
- Inspection
- Control flow
- Static analysis
- Data flow
- Structure-based
  - Statement
  - Decision
  - Condition
- Multiple condition

**Dynamic**
- Specification-based
  - Equivalence partitioning
  - Boundary value analysis
  - Use case testing
- Experience-based
- Error guessing
- Exploratory testing
- Decision tables
- State transition
Question 1: Answer

Which of the following would **structure-based test design techniques** be likely to be **applied** to?

**Purpose of structure-based techniques**

- **Test coverage measurement**
  - Assess the amount of testing performed by tests
  - Derived from specification-based technique to assess coverage

- **Structural test design**
  - Generate additional test cases
  - Increase test coverage
Question 1: Answer

Which of the following would **structure-based test design techniques** be likely to be **applied** to?

**Characteristics of structure-based techniques**

- **Target:** Testing the **structure** of a system / component
- **White-box testing** → What happens **inside** the box?
- Can occur at **any test level**
  - Tends to be applied to component / integration level testing
  - Higher test levels → Business process testing
- **Control flow models**
  - **Support** structural testing
Question 1: Answer

Which of the following would **structure-based test design techniques** be likely to be **applied** to?

1. Boundaries between mortgage interest rate bands
2. An invalid transition between two different arrears statuses
3. The **business process flow** for mortgage approval
4. **Control flow** of the program to calculate repayment

a. 2, 3 and 4  
b. 2 and 4  
c. **3 and 4**  
d. 1, 2 and 3
Use case testing is useful for which of the following?

1. Designing acceptance tests with users or customers
2. Making sure the mainstream business processes are tested
3. Finding defects in the interaction between components
4. Identifying the maximum and minimum values for every input field
5. Identifying the percentage of statements exercised by a set of tests

a. 1, 2 and 3
b. 2, 4 and 5
c. 1, 2 and 4
d. 3, 4 and 5
Use case testing is useful for which of the following?

Use case testing

- Technique to identify test cases that exercise the whole system
- Transaction by transaction basis from start to finish
- Sequence of steps → Describes interactions between actor and system
  - Achieve a specific task / Produce something of value to the user
- Defined in terms of the actor, not the system
  - Describes process flows through a system → Based on its actual use
  - Can uncover integration defects → Incorrect actions between components
  - Individual testing would not uncover these
Use case testing is useful for which of the following?

1. Designing acceptance tests with users or customers
2. Making sure the mainstream business processes are tested
3. Finding defects in the interaction between components
4. Identifying the maximum and minimum values for every input field
5. Identifying the percentage of statements exercised by a set of tests

a. 1, 2 and 3  
b. 2, 4 and 5  
c. 1, 2 and 4  
d. 3, 4 and 5
Question 3

Which of the following statements about the relationship between statement and decision coverage is correct?

a. 100 % decision coverage is achieved if statement coverage is greater than 90 %
b. 100 % statement coverage is achieved if decision coverage is greater than 90 %
c. 100 % decision coverage always means 100 % statement coverage
d. 100 % statement coverage always means 100 % decision coverage
Which of the following statements about the relationship between statement and decision coverage is correct?

**Statement coverage**

Code example (each line is a statement)

1. READ A
2. READ B
3. IF A > B THEN C = 0
4. ENDIF

To achieve 100% statement coverage:

How many test cases needed?
Question 3: Answer

Which of the following statements about the relationship between statement and decision coverage is correct?

Achieving 100 % Statement coverage

- Just one test case needed
- A must be greater than B
- Runs through all statements

Example test case

\[ A = 12 \]
\[ B = 10 \]
Which of the following statements about the relationship between statement and decision coverage is correct?

Example II: Statement coverage

1. READ A
2. READ B
3. C = A + 2 * B
4. IF C > 50 THEN
5. PRINT LARGE C
6. ENDIF

Diagram:
- **Read A**
- **Read B**
- **C = A + 2 * B**
- **IF C > 50**
  - **Y** → **PRINT LARGE C**
  - **N** → **ENDIF**
Which of the following statements about the relationship between statement and decision coverage is correct?

Example II: Statement coverage

Test 1_1:
A = 2, B = 3

Test 1_2:
A = 0, B = 25

Test 1_3:
A = 47, B = 1

Which statements have we covered?
Question 3: Answer

Which of the following statements about the relationship between statement and decision coverage is correct?

Example II: Statement coverage

Test 1_1:
A = 2, B = 3 // C = 8

Test 1_2:
A = 0, B = 25

Test 1_3:
A = 47, B = 1

Which statements have we covered?
Question 3: Answer

Which of the following statements about the relationship between statement and decision coverage is correct?

Example II: Statement coverage

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A = 2, B = 3

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Question 3: Answer

Which of the following statements about the relationship between statement and decision coverage is correct?

Example II: Statement coverage

Test 1_1:
A = 2, B = 3

Test 1_2:
A = 0, B = 25

Test 1_3:
A = 47, B = 1 // C = 49

Which statements have we covered?
Question 3: Answer

Which of the following statements about the relationship between statement and decision coverage is correct?

Example II: Statement coverage

Have covered 5 out of 6 statements
Statement coverage = 83 %
Need another test to reach 100 %

Test 1_4:
A = 20, B = 25
Question 3: Answer

Which of the following statements about the relationship between statement and decision coverage is correct?

Example II: Statement coverage

Test 1_4:

\[
A = 20, \quad B = 25 \quad // \quad C = 70
\]

Statement coverage = 100 %

In fact, only one test case needed
Question 3: Answer

Which of the following statements about the relationship between statement and decision coverage is correct?

**Decision coverage**

Each decision must have both a true and false outcome.

Code example (each line is a statement)

1. READ A
2. READ B
3. IF A > B THEN C = 0
4. ENDIF

To achieve 100% decision coverage: How many test cases needed?
Question 3: Answer

Which of the following statements about the relationship between statement and decision coverage is correct?

Decision coverage

One test required for 100 % statement coverage

A = 12, B = 10

// All statements are exercised

Decision coverage requires:

Each condition must have True and False

Test case condition

A must be less than or equal to B
Which of the following statements about the relationship between statement and decision coverage is correct?

Decision coverage
Additional test case
A = 2, B = 4
// All decisions have been exercised
Have achieved 100 % decision coverage
Which of the following statements about the relationship between statement and decision coverage is correct?

**Statement and Decision coverage**

Statement coverage = \[
\frac{\text{Number of statements exercised}}{\text{Total number of statements}} \times 100
\]

Decision coverage = \[
\frac{\text{Number of decision outcomes exercised}}{\text{Total number of decision outcomes}} \times 100
\]

Decision coverage is stronger than statement coverage

100 % decision coverage guarantees 100 % statement coverage

Not the other way around!
Which of the following statements about the relationship between statement and decision coverage is correct?

a. 100 % decision coverage is achieved if statement coverage is greater than 90 %

b. 100 % statement coverage is achieved if decision coverage is greater than 90 %

c. 100 % decision coverage always means 100 % statement coverage

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Question 4

Why are error guessing and exploratory testing techniques good to do?

a. They find defects missed by specification-based and structure-based techniques
b. They don’t require any training to be as effective as formal techniques
c. They can be used more effectively when there are good specifications
d. They will ensure that all of the code or system is tested
Why are **error guessing** and **exploratory testing** techniques good to do?

Experience-based techniques
Question 4: Answer

Why are **error guessing** and **exploratory testing** techniques good to do?

**Error-guessing** and **Exploratory testing**

Experience-based techniques

**Error-guessing**

Guess: “Where are the defects more likely to be found?”

*Anticipate defects based on previous experience*

Should always be *used as a complement to more formal test techniques*

*Success depends on skill of the tester → Can be highly effective*
Question 4: Answer

Why are **error guessing** and **exploratory testing** techniques good to do?

- **Exploratory testing**
  - Hands-on approach
  - Concurrent test design / execution / logging / learning
  - Testers involved in minimum planning and maximum test execution
  - Approach is **useful** when
    - Specification is **poor** / or does not exist at all
    - Time is **limited**
  - Can complement more **formal** testing → Ensure most serious defects are found
Question 4: Answer

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b. They don’t require any training to be as effective as formal techniques
c. They can be used more effectively when there are good specifications
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Question 5

How do experience-based techniques differ from specification-based techniques?

a. They depend on the tester’s understanding of the way the system is structured rather than on a documented record of what the system should do
b. They depend on having older testers rather than younger testers
c. They depend on a documented record of what the system should do rather than on an individual’s personal view
d. They depend on an individual’s personal view rather than on a documented record of what the system should do
Question 5: Answer

How do experience-based techniques differ from specification-based techniques?

Experience-based techniques

Tests derived from skill / knowledge / experience / intuition

Both of technical and business people

Different groups yield different perspectives

Often based on similar applications and technologies

Used predominantly to complement more formal test techniques

Specification-based and structure-based techniques

Success / Effectiveness is highly dependent on the testers skill and experience
Question 5: Answer

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**Question 6**

**Pair the following test design techniques with the typical problems they address:**

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Pair the following test design techniques with the typical problems they address:

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If you are flying with an economy ticket, there is a possibility that you may get upgraded to business class, especially if you hold a gold card in the airline’s frequent flyer program.

If you don’t hold a gold card, there is a possibility that you will get “bumped” off the flight if it is full and you check in late.

This is shown in the following figure. Note that each box (i.e. statement) has been numbered.
Question 7

Tests run:

Test 1  
Gold card holder who gets upgraded to business class

Test 2  
Non-gold card holder who stays in economy

Test 3  
A person who is bumped off the flight
Question 7

What is the \textit{statement coverage} of these three \textit{tests}?

a. 60 %
b. 70 %
c. 80 %
d. 90 %
What is the **statement coverage** of these three tests?

Calculating **statement coverage**

\[
\text{Statement coverage} = \frac{\text{Number of statements exercised}}{\text{Total number of statements}} \times 100
\]

After **running all three tests**:

- **Numerator**: How many *statements* have we exercised?
- **Denominator**: How many *statements* exist in *total*?
- **Multiply** by a *hundred* to get *percentage*
Question 7: Answer

What is the statement coverage of these three tests?

Test 1
- Gold card holder
- Upgraded to business class

Coverage
- Total statements: 10
- Statements so far: 4
What is the statement coverage of these three tests?

Test 2
- Non-gold card holder
- Stays in economy

Coverage
- Total statements: 10
- Statements so far: 6
Question 7: Answer

What is the **statement coverage** of these three tests?

**Test 3**
- Any person
- Bumped off the flight

**Coverage**
- Total statements: 10
- Statements so far: 8
What is the **statement coverage** of these three **tests**?

**Calculating statement coverage**

How many **statements** have we **exercised**? 8


How many **statements** exist in total? 10

Have yet to exercise statements


Statement coverage = 80%
What is the **statement coverage** of these three **tests**?

a. 60 %
b. 70 %
c. **80 %**
d. 90 %
Question 8

When choosing which technique to use in a given situation, which factors should be taken into account?

1. Previous experience of types of defects found in this or similar system
2. The existing knowledge of the testers
3. Regulatory standards that apply
4. The type of test executing tool that will be used
5. The documentation available
6. Previous experience in the development language

a. 2, 3, 5, and 6
b. 1, 2, 3 and 5
c. 1, 4 and 5
d. 2, 3 and 5
Question 8: Answer

When *choosing* which *technique* to *use* in a given situation, which *factors* should be taken into *account*?

Which technique is *best*? → *Wrong* question

Each technique is good for *certain instances*, and less adequate for others

“The best testing technique is no single testing technique”

Examples

*Structure-based* → Can only test what is present
  E.g. find malicious code / Trojan horses

*Specification-based* → Can *reveal* if parts of *specification* are *missing* from code

*Experience-based* → Finds *things missing* from both *specification* and *code*
When choosing which technique to use in a given situation, which factors should be taken into account?

Each technique is aimed at particular types of defects

E.g. State-transition testing is unlikely to find boundary defects

Use a variety of testing techniques

Using one technique → Ensures many defects of that particular class are found

However → Ensures many defects of other classes are missed

Using a variety of techniques

Ensures a variety of defects are found

Effective testing
When choosing which technique to use in a given situation, which factors should be taken into account?

**Internal factors** affecting choice of test techniques

- **Models used**
  - If specification contains state transition diagram → State transition testing
- **Testers knowledge and experience**
  - How much do testers know about the system / various techniques?
- ** Likely defects**
  - Each technique is good at finding particular defects
  - Knowledge about likely defects is therefore helpful
When choosing which **technique** to use in a given situation, which **factors** should be taken into **account**?

**Internal factors** affecting choice of test techniques

- **Test objective**
  - What do we **want** from the test **effort**? → Helps us define **approach**

- **Documentation**
  - Exists? Updated? Content → Serves to **guide** the test **effort**

- **Life cycle model**
  - Sequential → **Formal** testing techniques
  - Iterative → **Exploratory** testing approach
When choosing which technique to use in a given situation, which factors should be taken into account?

External factors affecting choice of test techniques

- **Risk**
  
  The greater the risk, the greater the need for more thorough testing

- **Customer / Contractual requirements**
  
  Contracts may specify particular testing techniques to be used

- **Type of system**
  
  Influence techniques used
  
  E.g. Financial application → Benefits from boundary value analysis
Question 8: Answer

When **choosing which technique to use** in a given situation, which **factors** should be taken into **account**?

**External factors affecting choice of test techniques**

- **Regulatory requirements**
  - Some industries have regulatory standards
  - E.g. Aircraft industry $\rightarrow$ Test effort depends on level of SW integrity required
    - Equivalence partitioning / BVA / State transition
    - Combined with statement / decision coverage

- **Time and budget**
  - How much time is available? More time $\rightarrow$ More techniques
When choosing which technique to use in a given situation, which factors should be taken into account?

1. Previous experience of types of defects found in this or similar system
2. The existing knowledge of the testers
3. Regulatory standards that apply
4. The type of test executing tool that will be used
5. The documentation available
6. Previous experience in the development language

a. 2, 3, 5, and 6  
b. 1, 2, 3 and 5  
c. 1, 4 and 5  
d. 2, 3 and 5
Question 9

Given the state diagram below, which test case is the minimum series of valid transitions to cover every state?

- a. SS-S1-S2-S4-S1-S3-ES
- b. SS-S1-S2-S3-S4-ES
- c. SS-S1-S2-S4-S1-S3-S4-S1-S3-ES
- d. SS-S1-S4-S2-S1-S3-ES
Given the state diagram below, which test case is the minimum series of valid transitions to cover every state?

Want the minimum path from SS to ES, visiting each state at least once.

Path:
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Path:
SS-S1-S2-S3-ES
Given the state diagram below, which test case is the minimum series of valid transitions to cover every state?

Want the minimum path from SS to ES, visiting each state at least once

Path: SS-S1
Question 9: Answer

Given the state diagram below, which test case is the minimum series of valid transitions to cover every state?

Want the minimum path from SS to ES, visiting each state at least once

Path:
SS-S1-S2
Given the state diagram below, which test case is the minimum series of valid transitions to cover every state?

Want the minimum path from SS to ES, visiting each state at least once.

Path:
SS-S1-S2-S4
Given the state **diagram** below, which **test case** is the **minimum series of valid transitions** to cover every state?

Want the minimum path from SS to ES, visiting each state at least once

Path:
SS-S1-S2-S4-S1
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Path:
SS-S1-S2-S4-S1-S3
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d. SS-S1-S4-S2-S1-S3-ES
Part II: Exercises and Open-ended questions
Exercise 1: Decision Table Testing

If you hold an “over 60s” rail card, you get a 34% discount on whatever ticket you buy. If you are travelling with a child (under 16) you get a 50% discount on any ticket if you hold a family rail card, otherwise you get a 10% discount. You may only hold one type of rail card.

a. Produce a decision table showing all combinations of fare types and resulting discounts
b. Derive test cases from the decision table
Exercise 1(a): Answer

Produce a decision table showing all combinations of fare types and resulting discounts

Fare types available based on:

“Over 60s” card
Family card
Travelling with a child

Set up the decision table

Three different conditions → Card type
Each with the outcome Y / N → Holds said card type / Does not hold said card type
Eight different rules → Maps out combinations between inputs and outputs
Exercise 1(a): Answer

Produce a **decision table** showing all combinations of fare types and resulting **discounts**

**Decision table** for fare types and discounts

Each rule yields a different effect

<table>
<thead>
<tr>
<th>Causes (Inputs)</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
<th>R7</th>
<th>R8</th>
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<tr>
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<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
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<tr>
<td>Family rail card?</td>
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<td>Child also travelling?</td>
<td>Y</td>
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<td>Discount (%)</td>
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Exercise 1(a): Answer

Produce a decision table showing all combinations of fare types and resulting discounts

**Decision table**

R8: No rail cards and no children travelling

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<tr>
<td>Discount (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10%</td>
<td>0%</td>
</tr>
</tbody>
</table>
Exercise 1(a): Answer

Produce a decision table showing all combinations of fare types and resulting discounts

Decision table

R6: No “Over 60s” card, with family card, but no children travelling

<table>
<thead>
<tr>
<th>Causes (Inputs)</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
<th>R7</th>
<th>R8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 60s rail card?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Family rail card?</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Child also travelling?</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

Effects (Outputs)

<table>
<thead>
<tr>
<th>Discount (%)</th>
<th>0%</th>
<th>10%</th>
<th>0%</th>
</tr>
</thead>
</table>

**Exercise 1(a): Answer**

Produce a decision table showing all combinations of fare types and resulting discounts

**Decision table**

R5: No “Over 60s” card, with family card, and with children travelling

<table>
<thead>
<tr>
<th>Causes (Inputs)</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
<th>R7</th>
<th>R8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 60s rail card?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Family rail card?</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Child also travelling?</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Effects (Outputs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discount (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50%</td>
<td>0%</td>
<td>10%</td>
</tr>
</tbody>
</table>
Exercise 1(a): Answer

Produce a decision table showing all combinations of fare types and resulting discounts

**Decision table**

R4: Holds “Over 60s” card, no family card, and no children travelling

<table>
<thead>
<tr>
<th>Causes (Inputs)</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
<th>R7</th>
<th>R8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 60s rail card?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Family rail card?</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Child also travelling?</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Effects (Outputs)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>34%</td>
<td>50%</td>
<td>0%</td>
<td>10%</td>
<td>0%</td>
</tr>
</tbody>
</table>
Exercise 1(a): Answer

Produce a decision table showing all combinations of fare types and resulting discounts

### Decision table

R3: Holds “Over 60s” card, no family card, but with children travelling

<table>
<thead>
<tr>
<th>Causes (Inputs)</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
<th>R7</th>
<th>R8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 60s rail card?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Family rail card?</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Child also travelling?</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Effects (Outputs)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount (%)</td>
<td>34%</td>
<td>34%</td>
<td>50%</td>
<td>0%</td>
<td>10%</td>
<td>0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Exercise 1(a): Answer

Produce a decision table showing all combinations of fare types and resulting discounts

Decision table

R2: Holds “Over 60s” card, has family card, but no children travelling

<table>
<thead>
<tr>
<th>Causes (Inputs)</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
<th>R7</th>
<th>R8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 60s rail card?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Family rail card?</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Child also travelling?</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Effects (Outputs)</th>
<th>Discount (%)</th>
<th>34%</th>
<th>34%</th>
<th>50%</th>
<th>0%</th>
<th>10%</th>
<th>0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount (%)</td>
<td>X/34%</td>
<td>34%</td>
<td>34%</td>
<td>50%</td>
<td>0%</td>
<td>10%</td>
<td>0%</td>
</tr>
</tbody>
</table>
Exercise 1(a): Answer

Produce a decision table showing all combinations of fare types and resulting discounts

Decision table

R1: Holds “Over 60s” card, has family card, with children travelling

<table>
<thead>
<tr>
<th>Causes (Inputs)</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
<th>R7</th>
<th>R8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 60s rail card?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Family rail card?</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Child also travelling?</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Effects (Outputs)</th>
<th>Discount (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount (%)</td>
<td>X/½/50%</td>
</tr>
<tr>
<td></td>
<td>X/½/34%</td>
</tr>
<tr>
<td></td>
<td>34%</td>
</tr>
<tr>
<td></td>
<td>34%</td>
</tr>
<tr>
<td></td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>0%</td>
</tr>
</tbody>
</table>
Exercise 1(a): Answer

Produce a decision table showing all combinations of fare types and resulting discounts

**Decision table**

<table>
<thead>
<tr>
<th>Causes (Inputs)</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
<th>R7</th>
<th>R8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 60s rail card?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Family rail card?</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Child also travelling?</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

**Effects (Outputs)**

| Discount (%)             | X/?/50% | X/?/34% | 34% | 34% | 50% | 0%  | 10% | 0%  |

Final result → **What is the output for R1 and R2?**
Exercise 1(a): Answer

Produce a decision table showing all combinations of fare types and resulting discounts

What is the output for R1 and R2?

X → Not possible to hold more than one rail card

? → Specification does not tell us what happens for said cases

If someone holds two cards → Not likely to admit that

R1: Claim 50% discount with family rail card and travelling with children

R2: Claim 34% discount with “Over 60s” card and no children

Notation shows we do not know the expected outcome for R1 and R2

Have revealed ambiguities in the specification
Exercise 1(a): Answer

Produce a decision table showing all combinations of fare types and resulting discounts

Further simplifications

R3 and R4 → Same effect (34% discount)
  Third cause (children also travelling?) has no effect on the outcome

R6 and R8 → Same effect (0% discount)
  Having family rail card has no effect when not travelling with a child

Rationalise table
  Combine these with a “not applicable” entry

Fewer columns and fewer test cases
Exercise 1(a): Answer

Produce a **decision table** showing all combinations of fare types and resulting **discounts**

**Rationalised decision table**

R3*: Combined rules 3 and 4 / R6*: Combined rules 6 and 8

<table>
<thead>
<tr>
<th>Causes (Inputs)</th>
<th>R1</th>
<th>R2</th>
<th>R3*</th>
<th>R5</th>
<th>R6*</th>
<th>R7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 60s rail card?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Family rail card?</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>-</td>
<td>N</td>
</tr>
<tr>
<td>Child also travelling?</td>
<td>Y</td>
<td>N</td>
<td>-</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
</tbody>
</table>

**Effects (Outputs)**

<table>
<thead>
<tr>
<th>Discount (%)</th>
<th>50%</th>
<th>34%</th>
<th>34%</th>
<th>50%</th>
<th>0%</th>
<th>10%</th>
</tr>
</thead>
</table>
Exercise 1(b): Answer

Derive test cases from the decision table

Test cases for rail card scenario

<table>
<thead>
<tr>
<th>Test case ID</th>
<th>Input</th>
<th>Expected outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A. Adams, with over 60s rail card and family rail card, travelling with grandson Ben (age 11).</td>
<td>50% discount for both tickets</td>
</tr>
<tr>
<td>2</td>
<td>Mrs. B. Cook, with over 60s rail card and family rail card, travelling alone.</td>
<td>34% discount</td>
</tr>
<tr>
<td>3</td>
<td>Mr. J. Johnson, with over 60s rail card, travelling with his wife.</td>
<td>34% discount (for Johnson only, not the wife)</td>
</tr>
<tr>
<td>4</td>
<td>Mrs. C. Baker, with family rail card, travelling with her daughter Anna.</td>
<td>50% discount for both tickets</td>
</tr>
<tr>
<td>5</td>
<td>Miss A. Lone, no rail card, travelling alone</td>
<td>No discount</td>
</tr>
<tr>
<td>6</td>
<td>Mr. J. Harper, with no rail card, travelling with his niece (age 5)</td>
<td>10% discount for both tickets</td>
</tr>
</tbody>
</table>
Derive **test cases** from the **decision table**

**Additional issues?**

Does **discount** apply **only** to the **traveller**, or to **someone** travelling **with** them?

**Specification does not explicitly** state the answer

**Assumptions made**

- **Family card**: Discounts apply to **all** travelling **members**
- **Over 60s card**: Discount **only** applies to the **individual** passenger
A website shopping basket starts out empty. As purchases are selected, they are added to the shopping basket. Items can also be removed from the shopping basket. When the customer decides to check out, a summary of the items in the basket and the total cost are shown. Customer states if the information is OK. If the contents and the price are OK, then you leave the summary display and go to the payment system. Otherwise, you go back to shopping (so as to remove items if you want).

a. (i) Produce a state diagram showing the different states and transitions. (ii) Define a test, in terms of a sequence of states, to cover all transitions

b. Produce a state table. Give an example test for an invalid transition
Exercise 2(a.i): State Transitions

Produce a state diagram showing different states and transitions
Exercise 2(a.i): Answer

Produce a **state diagram** showing different **states** and transitions

1. Mapping out the different **states**
   - **Empty** (start state)
     - Nothing has been placed into the basket
   - **Shopping** (intermediate)
     - There are items placed in the basket
   - **Summary and cost** (intermediate)
     - Overview of the items and price
   - **Payment** (final state)
Exercise 2(a.i): Answer

Produce a **state diagram** showing different **states** and **transitions**

2. Mapping out the **transitions** between states

- **Add** item → “Empty” to “Shopping” or “Shopping” to “Shopping”
- **Remove** item → “Shopping” to “Shopping”
- **Remove last item** → “Shopping” to “Empty”
- **Check out** → “Shopping” to “Summary and cost”
- **OK** → “Summary and cost” to “Payment”
- **Not OK** → “Summary and cost” to “Shopping”
Exercise 2(a.i): Answer

Produce a **state diagram** showing different **states** and transitions

3. **Model** state diagram

Start with the initial state “S1: Empty”

What can you **do** in this state?

- Add item

Which state do you **reach**?

- “S2: Shopping”
Exercise 2(a.i): Answer

Produce a state diagram showing different states and transitions

3. Model state diagram

For the state “S2: Shopping”

What can you do within this state?
Add item / Remove item

Which state do you reach?
Still in “S2: Shopping”
Exercise 2(a.i): Answer

Produce a **state diagram** showing different **states** and **transitions**

3. **Model** state diagram

State “S2: Shopping”

Interaction with other states?

- Remove last item / Check out

Which states do you reach?

- “S1: Empty” and “S3: Summary and cost”
Exercise 2(a.i): Answer

Produce a state diagram showing different states and transitions

3. Model state diagram

State “S3: Summary and cost”

What can you do in this state?

OK / Not OK

Which states do you reach?

“S2: Shopping” and “S4: Payment”
Exercise 2(a.i): Answer

Produce a state diagram showing different states and transitions

3. Final diagram
Exercise 2(a.ii): State Transitions

Define a test, in terms of a sequence of states, to cover all transitions
Define a **test**, in terms of a **sequence of states**, to cover all transitions

Find a **path** from S1 to S4, covering all transitions

That is pass every **arrow** in the state diagram
Exercise 2(a.ii): Answer

Define a test, in terms of a sequence of states, to cover all transitions.
Exercise 2(a.ii): Answer

Define a test, in terms of a sequence of states, to cover all transitions

<table>
<thead>
<tr>
<th>State</th>
<th>Event (action)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 Empty</td>
<td>Add item</td>
</tr>
<tr>
<td>S2 Shopping</td>
<td></td>
</tr>
<tr>
<td>S3 Summary and cost</td>
<td></td>
</tr>
<tr>
<td>S4 Payment</td>
<td></td>
</tr>
</tbody>
</table>
Exercise 2(a.ii): Answer

Define a **test**, in terms of a **sequence of states**, to cover all transitions
Define a test, in terms of a sequence of states, to cover all transitions.
Exercise 2(a.ii): Answer

Define a **test**, in terms of a **sequence of states**, to cover **all transitions**
Exercise 2(a.ii): Answer

Define a test, in terms of a sequence of states, to cover all transitions
Define a test, in terms of a sequence of states, to cover all transitions.
Exercise 2(a.ii): Answer

Define a **test**, in terms of a **sequence of states**, to cover **all transitions**

---

**Diagram:**

- **S1 Empty**
  - Add item
  - Remove last item

- **S2 Shopping**
  - Add item
  - Remove item
  - Check out

- **S3 Summary and cost**
  - Not OK

- **S4 Payment**
  - OK

**Table:**

<table>
<thead>
<tr>
<th>State</th>
<th>Event (action)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Add item</td>
</tr>
<tr>
<td>S2</td>
<td>Remove (last) item</td>
</tr>
<tr>
<td>S1</td>
<td>Add item</td>
</tr>
<tr>
<td>S2</td>
<td>Add item</td>
</tr>
<tr>
<td>S2</td>
<td>Remove item</td>
</tr>
<tr>
<td>S2</td>
<td>Check out</td>
</tr>
<tr>
<td>S3</td>
<td>Not OK</td>
</tr>
</tbody>
</table>
Define a test, in terms of a sequence of states, to cover all transitions.
Exercise 2(a.ii): Answer

Define a **test**, in terms of a **sequence of states**, to cover all transitions
Exercise 2(a.ii): Answer

Define a test, in terms of a sequence of states, to cover all transitions.

- State S1: Empty
  - Add item
  - Remove last item

- State S2: Shopping
  - Add item
  - Remove item
  - Check out

- State S3: Summary and cost
  - Not OK

- State S4: Payment
  - OK

<table>
<thead>
<tr>
<th>State</th>
<th>Event (action)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Add item</td>
</tr>
<tr>
<td>S2</td>
<td>Remove (last) item</td>
</tr>
<tr>
<td>S1</td>
<td>Add item</td>
</tr>
<tr>
<td>S2</td>
<td>Add item</td>
</tr>
<tr>
<td>S2</td>
<td>Remove item</td>
</tr>
<tr>
<td>S2</td>
<td>Check out</td>
</tr>
<tr>
<td>S3</td>
<td>Not OK</td>
</tr>
<tr>
<td>S2</td>
<td>Check out</td>
</tr>
<tr>
<td>S3</td>
<td>OK</td>
</tr>
<tr>
<td>S4</td>
<td>-</td>
</tr>
</tbody>
</table>
Exercise 2(b): State Transitions

Produce a state table. Give an example test for an invalid transition.
Exercise 2(b): Answer

Produce a **state table**. Give an **example** test for an **invalid transition**

State table

Maps out **states and transitions in tabular form**

<table>
<thead>
<tr>
<th>State (Event)</th>
<th>Add item</th>
<th>Remove item</th>
<th>Remove last item</th>
<th>Check out</th>
<th>OK</th>
<th>Not OK</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1: Empty</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2: Shopping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S3: Summary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S4: Payment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Exercise 2(b): Answer

Produce a **state table**. Give an **example** test for an **invalid transition**

**S1: Empty**

What **states** can we **reach** from S1?

Through which **transitions**?

<table>
<thead>
<tr>
<th>State (Event)</th>
<th>Add item</th>
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<th>Not OK</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1: Empty</td>
<td>S2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>OK</td>
<td>-</td>
</tr>
<tr>
<td>S2: Shopping</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>S3: Summary</td>
<td></td>
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<tr>
<td>S4: Payment</td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>
Exercise 2(b): Answer

Produce a state table. Give an example test for an invalid transition

S2: Shopping

What states can we reach from S2?

Through which transitions?

<table>
<thead>
<tr>
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<th>Add item</th>
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<tr>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>S2: Shopping</td>
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<td>S2</td>
<td>S1</td>
<td>S3</td>
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<td>-</td>
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<tr>
<td>S3: Summary</td>
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<td></td>
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<tr>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>
Exercise 2(b): Answer

Produce a state table. Give an example test for an invalid transition

S3: Summary and cost

What states can we reach from S3?

Through which transitions?

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<thead>
<tr>
<th>State (Event)</th>
<th>Add item</th>
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<td>S2</td>
<td>S1</td>
<td>S3</td>
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</tr>
<tr>
<td>S3: Summary</td>
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<td>S4</td>
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<tr>
<td>S4: Payment</td>
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<td>-</td>
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<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Exercise 2(b): Answer

Produce a state table. Give an example test for an invalid transition

S4: Payment

What states can we reach from S4?

Through which transitions?

<table>
<thead>
<tr>
<th>State (Event)</th>
<th>Add item</th>
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<td>S4</td>
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<td>-</td>
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<td>-</td>
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</tr>
</tbody>
</table>
Exercise 3: Statement and Decision

A vending machine dispenses either hot or cold drinks.

If you choose a hot drink (e.g. tea or coffee), it asks if you want milk (added if required).

Ten it asks if you want sugar (added if required)

Finally, the drink is dispensed.
Exercise 3(a)

Draw a control flow diagram for this example

Hint: Regard the selection of the type of drink as one statement
Exercise 3(a): Answer

Draw a control flow diagram for this example

1. Map out the different controls for the scenario
   - What is being controlled?
     - Hot or cold drink
     - Milk or no milk
     - Sugar or no sugar

2. Represent each control with a diamond shape
   - These controls will lead to decisions
   - E.g. Choosing a “hot” drink, or choosing “no milk”.
Exercise 3(a): Answer

Draw a **control flow diagram** for this example

3. Map out the different *outcomes* (statements) for each control

What are the outcomes?

- **Hot drink** → Select drink *(coffee or tea)*
- **Cold drink** → Select drink *(water or soda)*
- **Milk** → Add milk
- **No milk** → Nothing happens
- **Sugar** → Add sugar
- **No sugar** → Nothing

4. Represent the statements with **rectangles**
Exercise 3(a): Answer

Draw a control flow diagram for this example

5. Map out the different *decisions* (statements) for each control

   What are the outcomes of each *question*?

   Which statements do they lead to?

   ![Control Flow Diagram]

   - **Hot or cold?**
     - Hot / Cold
     - [Select drink (coffee or tea)]
     - [Select drink (water or soda)]

   - **Milk?**
     - Yes / No
     - [Add milk]
     - N/A

   - **Sugar?**
     - Yes / No
     - [Add sugar]
     - N/A

6. Represent the outcomes with arrows in the diagram
Draw a control flow diagram for this example

7. Construct the control flow diagram combining all elements
Exercise 3(b)

Given the following tests, what is the **statement coverage** achieved? What is the **decision coverage** achieved?

**Test 1**: Cold drink  
**Test 2**: Hot drink with milk and sugar
Exercise 3(b): Answer

Statement and decision coverage

Test 1:
Cold drink

Test 2:
Hot drink with milk and sugar

What is the statement coverage?

What is the decision coverage?
Statement and decision coverage

Statement coverage

100% statement coverage
Every statement has been covered
(All boxes have been touched)

What is the decision coverage?

How many decision outcomes exist?
How many decision outcomes exercised?
Statement and decision coverage

What is the decision coverage?

How many decision outcomes exist?
- Hot / Cold / Yes / No / Yes / No
- 6 decision outcomes in total

How many decision outcomes exercised?
- Hot / Cold / Yes / No
- 4 decision outcomes exercised

Decision coverage
- $4 / 6 = 67\%$
Exercise 3(c)

What additional tests would be needed to achieve 100% decision and statement coverage?
What **additional tests** would be **needed** to achieve **100% decision and statement coverage**?

**Additional tests**

**Statement coverage:**
- No further tests

**Decision coverage**
- Must exercise No / No

**Test 3:**
- Hot drink, no milk, no sugar
- **All decisions exercised**