# Chapter 4 - Part I
# Test design

**Software Testing: IN3240 / IN4240**

# Summary:

Test development process

- Analysis / Design / Implementation

Categories of test design techniques

- Static / Dynamic

Specification-based testing (black-box)

- Equivalence partitioning / Boundary value analysis
- Decision table testing
- State transition testing

# Part I: Close-ended questions

# Question 1

In which document described in IEEE 829 would you find instructions for the steps to be taken for a test including set-up, logging, environment and measurement?

a. Test plan
b. Test design specification
c. Test case specification
d. Test procedure specification

# Question 1: Clues

In which document described in IEEE 829 would you find instructions for the steps to be taken for a test including set-up, logging, environment and measurement?

IEEE → Institute of Electrical and Electronics Engineers ("*I triple E*")

IEEE 829

Standard for Software and System Test Documentation

Specifies format of documents used in software / system testing

10 documents in total

# Question 1: Clues

In which document described in IEEE 829 would you find instructions for the steps to be taken for a test including set-up, logging, environment and measurement?

- Master Test Plan (MTP)
- Level Test Plan (LTP)
- Lest Test Design (LTD)
- Level Test Case (LTC)
- Level Test Procedure (LTPr)
- Level Test Log (LTL)
- Anomaly Report (AR)
- Level Interim Test Status Report (LITSR)
- Level Test Report (LTR)
- Master Test Report (MTR)

# Question 1: Clues

In which document described in IEEE 829 would you find instructions for the steps to be taken for a test including set-up, logging, environment and measurement?

Master Test Plan (MTP)

Scope, system overview, organisation

Responsibilities, tools, techniques, methods

Level Test Plan (LTP)

Like MTP but specific for each level of testing

Scope, resources, schedule of the testing activities

# Question 1: Clues

In which document described in IEEE 829 would you find instructions for the steps to be taken for a test including set-up, logging, environment and measurement?

Level Test Design (LTD)

Detailing test cases → Identify features to be tested

Expected results

Level Test Case (LTC)

Objectives

Inputs / Outputs

# Question 1: Clues

In which document described in IEEE 829 would you find instructions for the steps to be taken for a test including set-up, logging, environment and measurement?

- Level Test Procedure (LTPr)
  - Detailed account of how to run each test
  - Description of each step to be taken to execute test cases
    - Set-up: Sequence of necessary actions to prepare for test execution
    - Log: List tools / methods for logging results
    - Environment: Describe environment for test execution
    - Measurement: Describe how test measurements will be made

# Question 1: Answer

In which document described in IEEE 829 would you find instructions for the steps to be taken for a test including set-up, logging, environment and measurement?

a. Test plan
b. Test design specification
c. Test case specification
d. Test procedure specification

# Question 2

With a highly experienced tester with a good business background, which approach to defining test procedures would be effective and most efficient for a project under severe time pressure?

a. A high-level outline of the test conditions and general steps to be taken
b. Every step in the test spelled out in detail
c. A high-level outline of the test conditions with the steps to take discussed in detailed with another experienced tester
d. Detailed documentation of all test cases and careful records of each step taken in testing

# Question 2: Clues

With a highly experienced tester with a good business background, which approach to defining test procedures would be effective and most efficient for a project under severe time pressure?

- Test effort under severe time pressure
  - Not feasible to define test procedures in full detail
  - Experience-based testing
    - Take advantage of the experience of the tester
    - Previous experience → Insights to what could go wrong
- Possible solution
  - High-level outline of test condition + General steps to be taken

# Question 2: Answer

With a highly experienced tester with a good business background, which approach to defining test procedures would be effective and most efficient for a project under severe time pressure?

a. A high-level outline of the test conditions and general steps to be taken
b. Every step in the test spelled out in detail
c. A high-level outline of the test conditions with the steps to take discussed in detailed with another experienced tester
d. Detailed documentation of all test cases and careful records of each step taken in testing

# Question 3

Put the test cases that implement the following test conditions into the best order for the test execution schedule, for a test that is checking modifications of customers on a database.

1) Print modified customer record
2) Change customer address: House number and street name
3) Capture and print the on-screen error message
4) Change customer address: Postal code
5) Confirm existing customer is on the database by opening that record
6) Close the customer record and close the database
7) Try to add a new customer with no details at all

a. 5, 4, 2, 1, 3, 7, 6
b. 4, 2, 5, 1, 6, 7, 3
c. 5, 4, 2, 1, 7, 3, 6
d. 5, 1, 2, 3, 4, 7, 6

# Question 3: Clues

Put the test cases that implement the following test conditions into the best order for the test execution schedule, for a test that is checking modifications of customers on a database.

Activities

1. Print modified customer record
2. Change customer address: House number and street name
3. Capture and print the on-screen error message
4. Change customer address: Postal code
5. Confirm existing customer is in the database by opening that record
6. Close the customer record and close the database
7. Try to add a new customer with no details at all

# Question 3: Clues

Put the test cases that implement the following test conditions into the best order for the test execution schedule, for a test that is checking modifications of customers on a database.

Activities: Simplified

1. Print modified record
2. Change address
3. Capture error message
4. Change address
5. Confirm customer by opening record
6. Close record and close database
7. Try to add new customer with no details

# Question 3: Clues

Put the test cases that implement the following test conditions into the best order for the test execution schedule, for a test that is checking modifications of customers on a database.

Execution schedule for checking modifications

What is the most intuitive order for customer record modification?

Find customer

Modify customer record

Verify modification

Create blank (provoke error)

Verify error

Close record + database

# Question 3: Clues

Put the test cases that implement the following test conditions into the best order for the test execution schedule, for a test that is checking modifications of customers on a database.

Execution schedule for checking modifications

| | |
|---|---|
| Find customer | 5. Confirm existing customer by opening record |
| Modify customer records | 4. Change address: Postal code |
| | 2. Change address: House number + Street |
| Verify modification | 1. Print modified record |
| Create blank (provoke error) | 7. Try to add new customer, no details |
| Verify error | 3. Capture error message |
| Close record + database | 6. Close record + database |

# Question 3: Answer

Put the test cases that implement the following test conditions into the best order for the test execution schedule, for a test that is checking modifications of customers on a database.

1) Print modified customer record
2) Change customer address: House number and street name
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7) Try to add a new customer with no details at all

a. 5, 4, 2, 1, 3, 7, 6
b. 4, 2, 5, 1, 6, 7, 3
c. 5, 4, 2, 1, 7, 3, 6
d. 5, 1, 2, 3, 4, 7, 6

# Question 4

Why are both specification-based and structure-based testing techniques useful?

a. They find different types of defects
b. Using more techniques is always better
c. Both find the same types of defect
d. Because specifications tend to be unstructured

# Question 4: Clues

Why are both specification-based and structure-based testing techniques useful?

Specification-based testing (Black-box testing)

Views software as a black box with inputs and outputs

Testers have *no knowledge* of how the system looks inside

Examines the functionality without looking into the internal structure



# Question 4: Clues

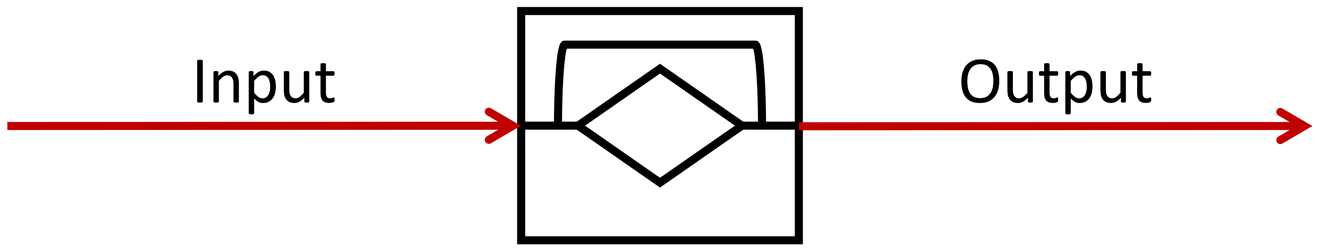
Why are both specification-based and structure-based testing techniques useful?

Structure-based testing (White-box testing)

Testers *require knowledge* of how the software is implemented

Testers ask the question: *How* does the software do it?

Examines the structure by looking into the program logic



# Question 4: Answer

Why are both specification-based and structure-based testing techniques useful?

a. They find different types of defects
b. Using more techniques is always better
c. Both find the same types of defect
d. Because specifications tend to be unstructured

# Question 5

What is a key characteristic of structure-based testing techniques?

a. They are mainly used to assess the structure of a specification
b. They are used both to measure coverage and to design tests to increase coverage
c. They are based on the skills and experience of the tester
d. They use a formal or informal model of the software or component

# Question 5: Clues

What is a key characteristic of structure-based testing techniques?

Overall objectives of testing

Find defects / Gain confidence in the system

Question: How?

Testing as much as possible / feasible

Concern

How to assess the thoroughness of the test effort

How much have we tested? How many aspects of the system have been checked?

# Question 5: Clues

What is a key characteristic of structure-based testing techniques?

Solution

Assess thoroughness of test effort through coverage

Approach: Structure-based techniques

Advantage: We have access to the code!

Examine code / internal structure of the software

Insight into logic / states / system architecture

# Question 5: Answer

What is a key characteristic of structure-based testing techniques?

a. They are mainly used to assess the structure of a specification
b. They are used both to measure coverage and to design tests to increase coverage
c. They are based on the skills and experience of the tester
d. They use a formal or informal model of the software or component

# Question 6

Should pre-conditions and post-conditions be part of a test case?

a. Yes
b. No

# Question 6: Clues

Should pre-conditions and post-conditions be part of a test case?

- Test case (cf. IEEE 829)
  - Inputs
  - Execution conditions (pre- and post-conditions)
  - Expected / Predicted results
- Developed for a particular objective
  - Exercise particular program / functionality
  - Verify compliance with specific requirement(s)

# Question 6: Clues

Should pre-conditions and post-conditions be part of a test case?

The need for test conditions

When can we start a test? / When does a test end?

What conclusions can we derive from a test? / What does the test tell us?

Pre-conditions

Condition(s) that must be in place PRIOR to running the test

Post-conditions

Condition(s) that must be in place AFTER running the test

# Question 6: Answer

Should pre-conditions and post-conditions be part of a test case?

a. Yes
b. No

# Question 7

_____ is the analysis at the edge of each equivalence partition.

We apply this test design technique because at the edges of equivalence partitions, the results are more likely to be incorrect.

# Question 7: Clues

_____ is the analysis at the edge of each equivalence partition.

Equivalence partitioning

Idea: Divide test conditions into groups that can be considered the same

These groups are equivalent

Test only one condition from each partition

Assume all conditions in the same partition will be treated the same

Little point in testing all values in the partition

Simplified assumptions → Not always right

# Question 7: Clues

_____ is the analysis at the edge of each equivalence partition.

Example: Public transport ticket prices

| | |
|---|---|
| Children (under the age of 15): | 20 NOK for a single ticket |
| Students (between 15 and 25): | 25 NOK for a single ticket |
| Adults: | 35 NOK for a single ticket |
| Seniors (over the age of 65): | 20 NOK for a single ticket |

Equivalence partitioning

E.g. We can assume that individuals of age 67, 68, 74, 88 are treated the *same*

Hence, when testing for senior discount → Do not have to test all ages

# Question 7: Clues

_____ is the analysis at the edge of each equivalence partition.

Example: Public transport ticket prices

- Question: What is the right price for persons of age:
  - 15 years / 25 years / 65 years?
- Specifications may be unclear

Boundary value analysis (BVA)

- Testing the boundaries (min. and max. values) / edges of equivalence partitions
- High defect-finding capability

# Question 7: Answer

_____ is the analysis at the edge of each equivalence partition.

BVA – Boundary Value Analysis

# Question 8

Which of the following would be an example of decision-table testing for a financial application applied at system-test level?

a. A table containing rules for combination of inputs to two fields on the screen
b. A table containing rules for interfaces between components
c. A table containing rules for mortgage applications
d. A table containing rules for chess

# Question 8: Clues

Which of the following would be an example of decision-table testing for a financial application applied at system-test level?

Decision-table testing

Cause-Effect table

Different combinations of input result in different actions

Aids in identifying effective test cases

Can reveal ambiguities in the specification

Explores business rules

| Conditions | R1 | R2 | R3 | R4 |
|---|---|---|---|---|
| Student enrolled in course | T | T | F | F |
| Mandatory exercises passed | T | F | T | F |
| **Actions** | | | | |
| Can write exam | T | F | F | F |

# Question 8: Clues

Which of the following would be an example of decision-table testing for a financial application applied at system-test level?

System testing

- Concerned with the behaviour of the entire system
- High-level descriptions of system behaviour
- Often final testing phase on behalf of development

Hence:

- We are interested in testing an overall / main aspect of the system

# Question 8: Answer

Which of the following would be an example of decision-table testing for a financial application applied at system-test level?

a. A table containing rules for combination of inputs to two fields on the screen
b. A table containing rules for interfaces between components
c. A table containing rules for mortgage applications
d. A table containing rules for chess

# Question 9

Which of the following could be a coverage measure for state transition testing?

V. All states have been reached
W. The respond time for each transition is adequate
X. Every transition has been executed
Y. All boundaries have been exercised
Z. Specific sequences of transitions have been exercised

a. X, Y and Z
b. V, X, Y and Z
c. W, X and Y
d. V, X and Z

# Question 9: Clues

Which of the following could be a coverage measure for state transition testing?

Test coverage

- Measure of the amount of testing performed by a set of tests
- Simplified: How much of the code has been tested?
- Aim: Reveal test coverage + Design additional tests to increase coverage

Coverage measure

- How can we measure the coverage of the test effort?
- What approaches / artefacts can be used to determine coverage?

# Question 9: Clues

Which of the following could be a coverage measure for state transition testing?

State-transition testing

- Some aspect of the system can be described in a "finite state machine"
- System can be in a *finite* number of different states
- Transitions from one state to another depend on the *rules* of the machine

State diagram

- Describes the behaviour of the system
- Illustrates the different states a system can be in + Transitions between states

# Question 9: Clues

Which of the following could be a coverage measure for state transition testing?

Example: State diagram for PIN entry in ATM

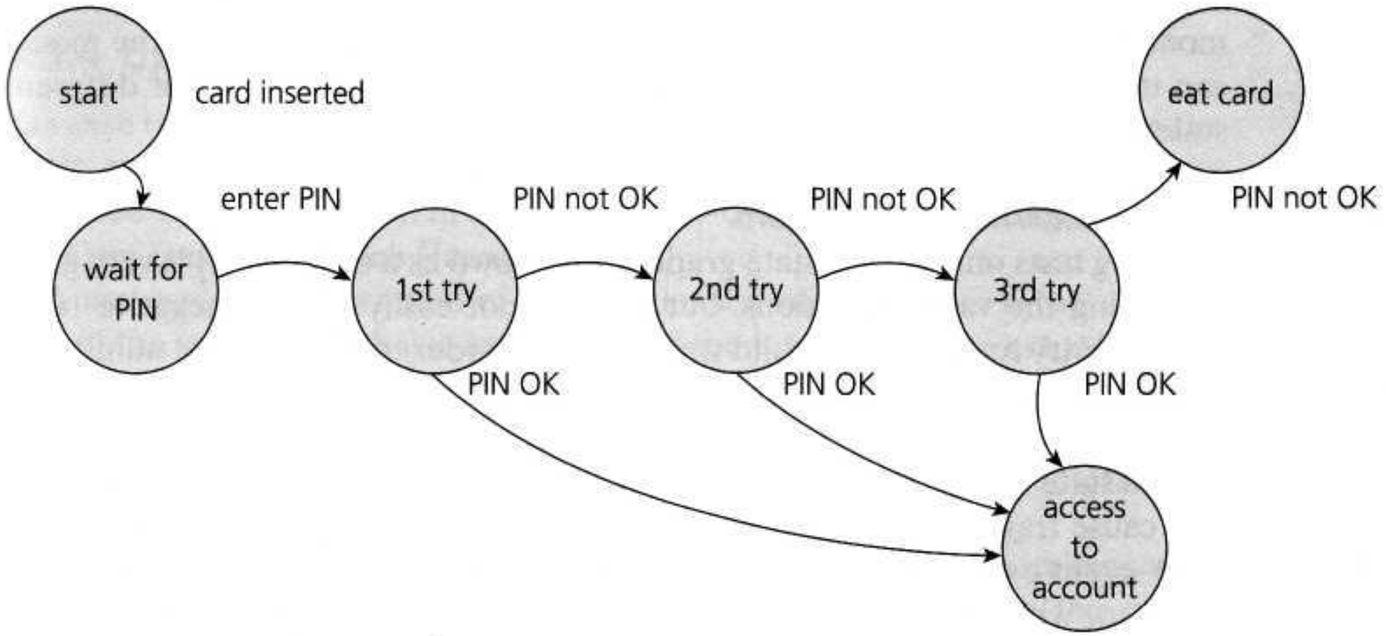



Figure 4.2 in textbook

# Question 9: Clues

Which of the following could be a coverage measure for state transition testing?

Example: State diagram for PIN entry in ATM

States software may be in

Shown in circles

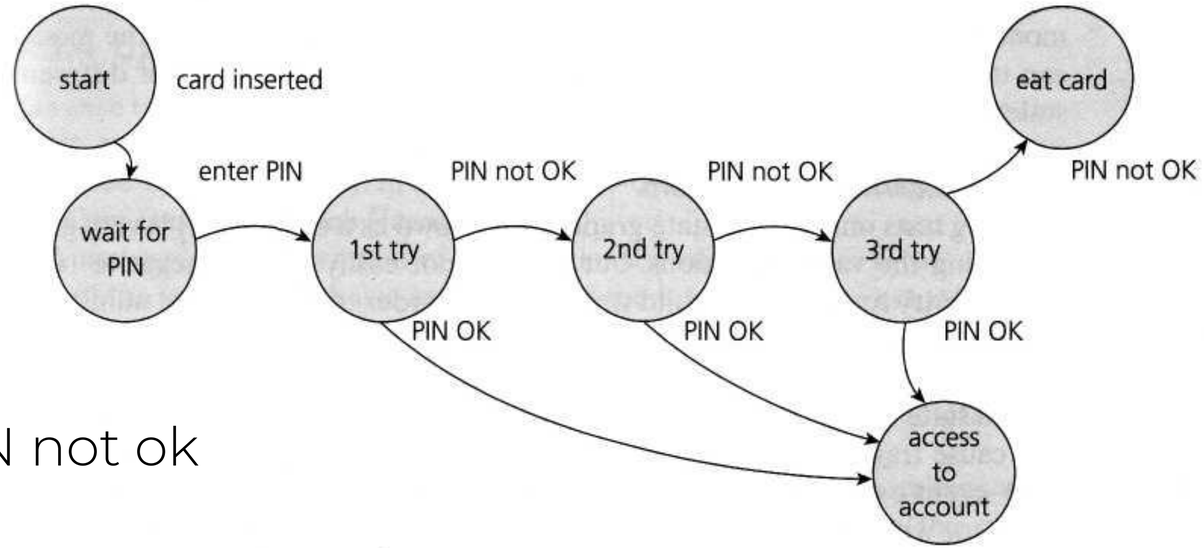
Transitions from one state to another

Arrows pointing to the next transition

Events causing the transitions

Card inserted / Enter PIN / PIN ok / PIN not ok

Actions resulting from transitions



# Question 9: Clues

Which of the following could be a coverage measure for state transition testing?

State transition testing and coverage

When using state transition testing → What can measure coverage?

The number of states reached

Specific sequences of transitions exercised

Every transition has been executed

All of the above tell us about the amount of testing performed through state transition

However: What about testing all boundaries / boundary values?

# Question 9: Clues

Which of the following could be a coverage measure for state transition testing?

- Testing boundary values
  - Indeed a measure of testing coverage
  - Tells us about the percentage of boundaries exercised
- However: *Not* a coverage measure for state transition testing
  - Testing boundary values does not necessarily tell us anything about state transitions
  - Boundary values may only be relevant for certain states
  - Example: We refer back to the ATM state diagram

# Question 9: Clues

Which of the following could be a coverage measure for state transition testing?

Example: State diagram for PIN entry in ATM

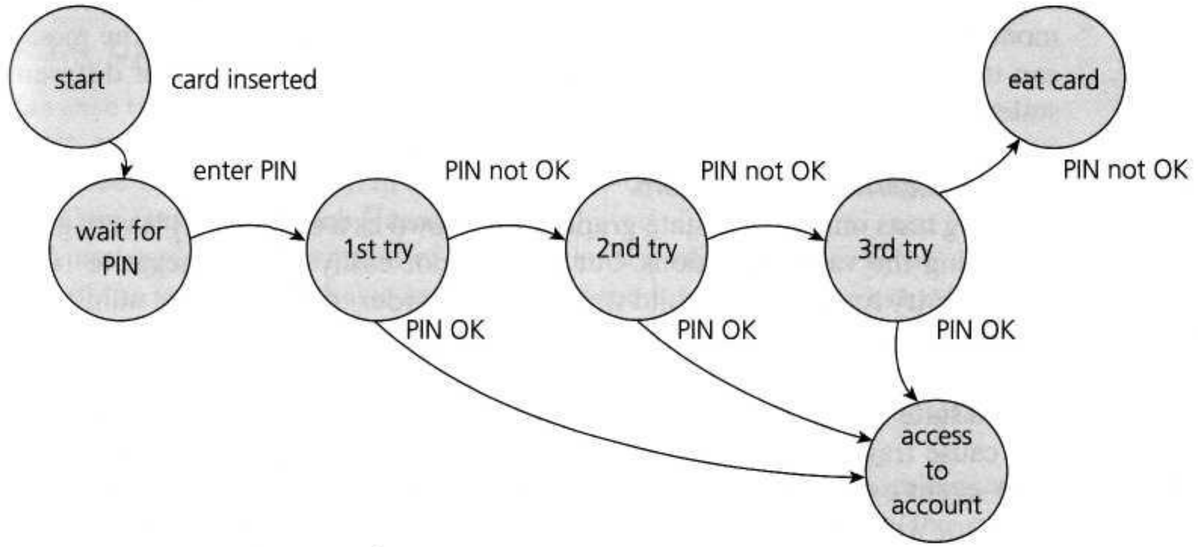
Can test all PIN number boundaries

0000 – 9999

Less than four digits

More than four digits

Not directly linked to state transitions



# Question 9: Answer

Which of the following could be a coverage measure for state transition testing?

V. All states have been reached
W. The respond time for each transition is adequate
X. Every transition has been executed
Y. All boundaries have been exercised
Z. Specific sequences of transitions have been exercised

a. X, Y and Z
b. V, X, Y and Z
c. W, X and Y
d. V, X and Z

# Question 10

Which of the following could be used to assess the coverage achieved for specification-based test techniques?

V. Decision outcomes exercised
W. Partitions exercised
X. Boundaries exercised
Y. State transitions exercised
Z. Statements exercised

a. V, W, Y or Z
b. W, X or Y
c. V, X or Z
d. W, X, Y or Z

# Question 10: Clues

Which of the following could be used to assess the coverage achieved for specification-based test techniques?

Specification-based test techniques

- Views software as a black box
- No knowledge of how the system is internally structured
- Concern: What the system does, not how it does it

Assessing coverage

- Partitions exercised / Boundaries exercised / State transitions exercised

Decisions + Statements exercised → Internal structure

- Structure-based techniques (white box)

# Question 10: Answer

Which of the following could be used to assess the coverage achieved for specification-based test techniques?

V. Decision outcomes exercised
W. Partitions exercised
X. Boundaries exercised
Y. State transitions exercised
Z. Statements exercised

a. V, W, Y or Z
b. W, X or Y
c. V, X or Z
d. W, X, Y or Z

# Part II: Exercises and Open-ended questions

# Exercise I: Equivalence Partitioning

Postal rates for ‘light letters’ are 25 NOK up to 10g, 35 NOK up to 50g, plus an extra 10 NOK for each additional 25g up to 100g. Which test inputs (in grams) would be selected using equivalence partitioning?

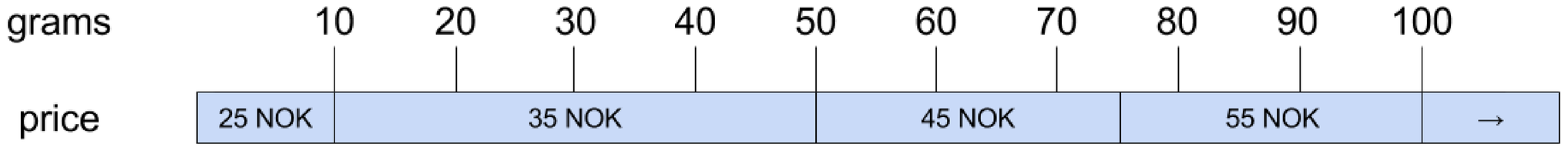
a. 8, 42, 82, 102
b. 4, 15, 65, 92, 159
c. 10, 50, 75, 100
d. 5, 20, 50, 60, 80

# Exercise I: Clues

Which test inputs (in grams) would be selected using equivalence partitioning?

Scenario

How are postal rates calculated?

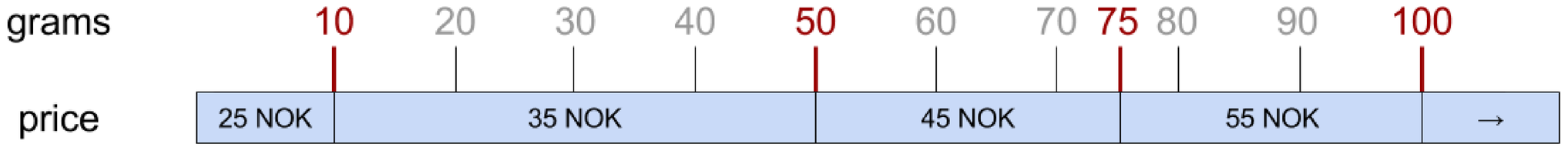


# Exercise I: Clues

Which test inputs (in grams) would be selected using equivalence partitioning?

Questions

What are the key boundaries? / How many values do we need?

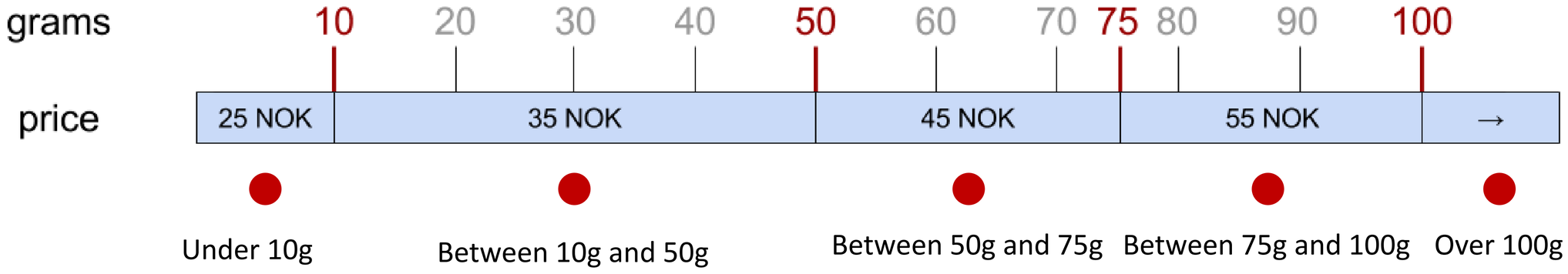


# Exercise I: Clues

Which test inputs (in grams) would be selected using equivalence partitioning?

Answer

We need five test inputs → Each in their own equivalence class

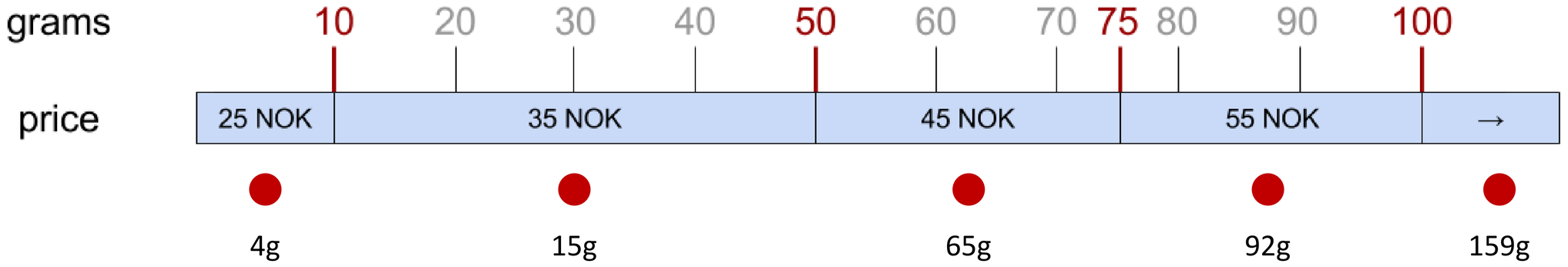


# Exercise I: Clues

Which test inputs (in grams) would be selected using equivalence partitioning?

Answer

We choose five arbitrary values for each equivalence class



# Exercise I: Answer

Postal rates for ‘light letters’ are 25 NOK up to 10g, 35 NOK up to 50g, plus an extra 10 NOK for each additional 25g up to 100g. Which test inputs (in grams) would be selected using equivalence partitioning?

a. 8, 42, 82, 102
b. 4, 15, 65, 92, 159
c. 10, 50, 75, 100
d. 5, 20, 50, 60, 80

# Exercise II

If you take the train before 9:30 AM or in the afternoon after 4:00 PM until 7:30 PM ('rush hour') you must pay full fare. A saver ticket is available for trains between 9:30 AM and 4:00 PM, and after 9:30 PM.

What are the partitions and boundary values to test the train times for this ticket types?

Which are valid partitions and which are invalid partitions?

What are the boundary values? (A table may be useful)

Derive test cases for the partitions and boundaries.

Do you have any questions about this 'requirement'?
Is anything unclear?

# Exercise II: Clues

Approach

Establish the exact boundaries between full fare and saver fare.

We can use a table to map out the information given:

Departure time of train

Corresponding ticket type for the departure time

Saver ticket

Full fare ticket

| Scheduled Departure time | | | | |
|---|---|---|---|---|
| Ticket type | | | | |

# Exercise II: Clues

## Approach

"If you take the train before 9:30 am, or in the afternoon after 4:00 pm until 7:30 pm, you must pay full fare."

| Scheduled Departure time | ≦ 9:29 am | | 4:01 pm - 7:30 pm | |
|---|---|---|---|---|
| Ticket type | FULL | | FULL | |

"A saver ticket is available for trains between 9:30 am and 4:00 pm, and after 7:30 pm."

| Scheduled Departure time | | 9:30 am - 4:00 pm | | ≧ 7:31 pm |
|---|---|---|---|---|
| Ticket type | | SAVER | | SAVER |

# Exercise II: Clues

## Approach

This gives us the following table:

| Scheduled Departure time | ≦ 9:29 am | 9:30 am - 4:00 pm | 4:01 pm - 7:30 pm | ≧ 7:31 pm |
|---|---|---|---|---|
| Ticket type | FULL | SAVER | FULL | SAVER |

We assume that the boundary values are:

9:29 am, 9:30 am

4:00 pm, 4:01 pm

7:30 pm, 7:31 pm

## Benefit of this approach

Our exact interpretation of the specification can reveal ambiguities

# Exercise II: Clues

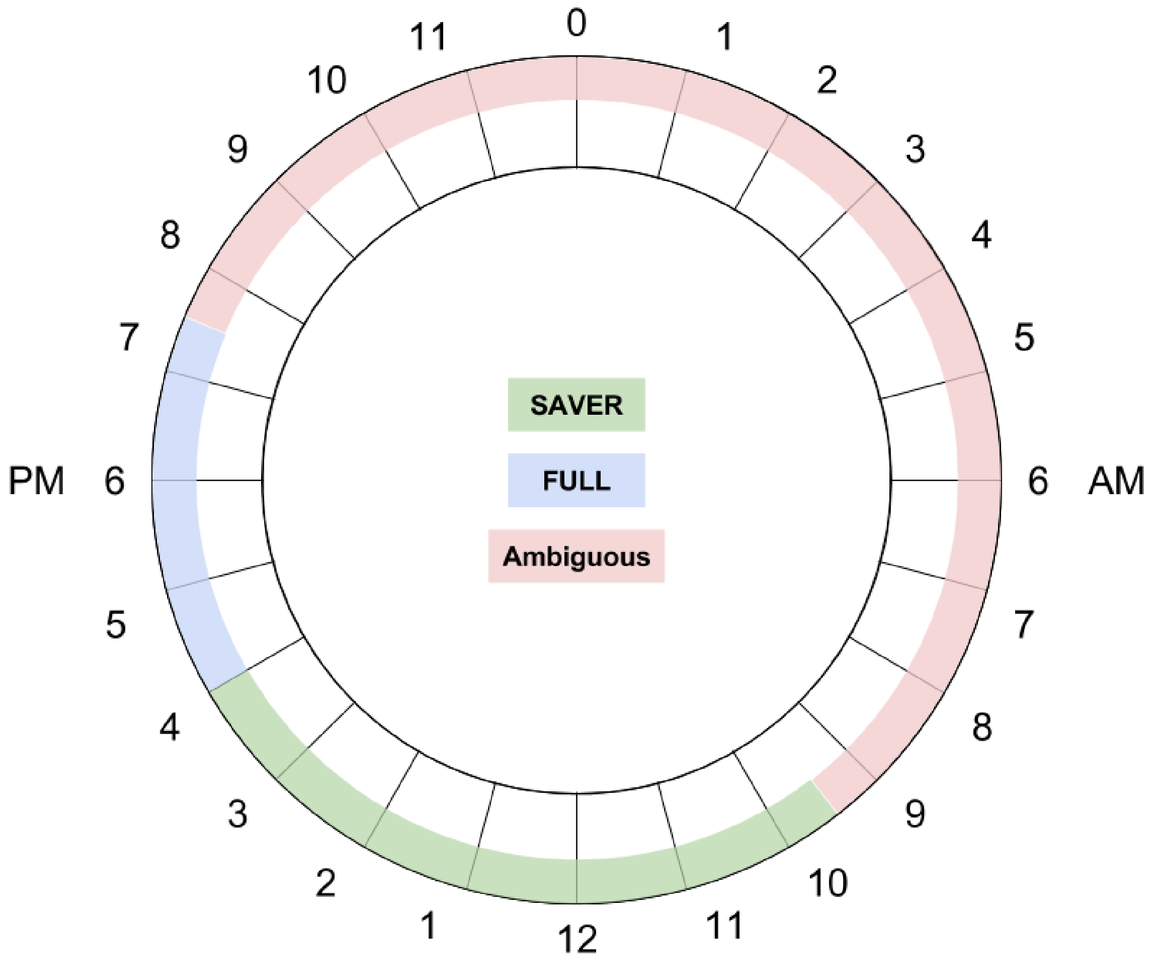
What we have so far:

- Saver: Between 9:30 am and 4:00 pm
- Full: After 4:00 pm and until 7:30 pm

Ambiguities / Considerations

- When does the morning "rush hour" start?
  - At midnight?
  - At 11:30 the previous day?
  - At the time of the first train of the day?

The specification is unclear!



# Exercise II: Clues

Other considerations

- If a train is scheduled to leave at exactly 4:00 pm
  - Is a saver ticket still valid?
- If a train is scheduled to leave before 4:00 pm, but delayed until after 4:00 pm:
  - Is a saver ticket still valid?

We can make assumptions, but we prefer the “correct” specification!

However, let us work with the information we have.

# Exercise II: Clues

Test cases for partitions and boundaries

| Test Case ID | Input | Expected outcome |
|---|---|---|
| 1 | Depart 4:30 am | Pay full fare |
| 2 | Depart 9:29 am | Pay full fare |
| 3 | Depart 9:30 am | Buy saver ticket |
| 4 | Depart 11:37 am | Buy saver ticket |
| 5 | Depart 4:00 pm | Buy saver ticket |
| 6 | Depart 4:01 pm | Pay full fare |
| 7 | Depart 5:55 pm | Pay full fare |
| 8 | Depart 7:30 pm | Pay full fare |
| 9 | Depart 7:31 pm | Buy saver ticket |
| 10 | Depart 10:05 pm | Buy saver ticket |

# Exercise III: Answer

Test cases for partitions and boundaries

Note: All partitions are valid

There may be invalid partitions

At a time no trains are running?

Specification does not mention that!

Equivalence partition values

Test cases: 1, 4, 7, and 10

Boundary values

Test cases: 2, 3, 5, 6, 8, and 9

| Test Case ID | Input | Expected outcome |
|---|---|---|
| 1 | Depart 4:30 am | Pay full fare |
| 2 | Depart 9:29 am | Pay full fare |
| 3 | Depart 9:30 am | Buy saver ticket |
| 4 | Depart 11:37 am | Buy saver ticket |
| 5 | Depart 4:00 pm | Buy saver ticket |
| 6 | Depart 4:01 pm | Pay full fare |
| 7 | Depart 5:55 pm | Pay full fare |
| 8 | Depart 7:30 pm | Pay full fare |
| 9 | Depart 7:31 pm | Buy saver ticket |
| 10 | Depart 10:05 pm | Buy saver ticket |

# Exercise III - Decision tables: Previous exam

An informatics education program (study) at a university college in Norway have the following admission requirements:

- To obtain a study place, the applicant must have a general academic qualification, the mathematic course R1 from upper secondary school, and competition points above the limit of the year.
- If the applicant's competition points are below this limit, he/she is placed on the waiting list, assuming that the two first conditions are fulfilled.
- If the applicant has a general qualification, but not the R1 mathematics course, the applicant is offered a preparatory course in mathematics, assuming that the competition points are above the limit of that year.

# Exercise III - Decision tables: Previous exam

**a)** Draw a decision table, which shows all the possible combinations of conditions for an applicant. The decision table shall include an action part, which shows whether or not the applicant is offered a study place, is placed on a waiting list, or is placed on a preparatory course in mathematics.

## ANSWER:

Conditions:

**GAQ:** General academic qualification
**R1:** Passed the mathematic course R1 from upper secondary school
**CP:** Competition points above this year's limit

Actions:

**SP:** Offer of study place
**WL:** Put on a waiting list
**PR1:** Offer of preparation course in R1.
**R:** Refusal

| | Regel 1 | Regel 2 | Regel 3 | Regel 4 | Regel 5 | Regel 6 | Regel 7 | Regel 8 |
|---|---|---|---|---|---|---|---|---|
| GAQ | true | true | true | true | false | false | false | false |
| R1 | true | true | false | false | true | true | false | false |
| CP | true | false | true | false | true | false | true | false |
| Action | SP | WL | PR1 | R | R | R | R | R |

(It can be discussed whether you can calculate competition points when you do not have general study competence (rules 5 and 7). However, this problem disappears when the table is simplified in the next subtask.)

# Exercise III - Decision tables: Previous exam

**b)** You shall now simplify the decision table and thus reduce the number of rules without losing any of the test cases. Justify the simplification.

**Answer:** We see from the table that when the applicant does not have general study qualifications, the person in question is rejected, regardless of whether the person in question has R1 or not, or whether the person in question has competition points above or below the year's intake limit. Consequently, rules 5, 6, 7 and 8 can be merged, and we get the following table:

| | Regel 1 | Regel 2 | Regel 3 | Regel 4 | Regel 5 |
|---|---|---|---|---|---|
| GAQ | true | true | true | true | false |
| R1 | true | true | false | false | ---- |
| CP | true | false | true | false | ---- |
| Action | SP | WL | PR1 | R | R |

# Exercise III - Decision tables: Previous exam

**c)** Consider the following three different test cases:

1. The applicant has general academic qualification, the mathematics course R1 from upper secondary school, and competition points above the limit of the year.

2. The applicant has general academic qualification, the mathematics course R1 from upper secondary school, and competition points below the limit of the year.

3. The applicant has general academic qualification and competition points above the limit of the year, but not the mathematics course R1 from upper secondary school.

Do we need to have more test cases? If yes, which should they be?

**Answer:**
Our goal is to have test cases that cover all the rules. We see from the table that the 3 test cases above cover rules 1, 2 and 3. We therefore need 2 more tests for rules 4 and 5:

1. The applicant has general academic qualification, but competition points below the limit of the year as well as not having the mathematical course R1 from upper secondary school.

2. The applicant do not have general academic qualification.

## The slides are made by

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Next week:

Test design II