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	<b>COURSE:</b> FORMAL METHOD	<b>CODE:</b> BCS2213	
	<b>TOPIC:</b> Chapter 1-4	<b>SEM:</b> I 2025/2026	
	<b>ASSESSMENT:</b> Assignment	<b>DUE:</b> WEEK 9	

**MATRIC NUM:** CB22102

**IC NUM:** 021127-03-0972



**Faculty of Computing**  
Fakulti Komputeran

# BCS2213 FORMAL METHOD


## SEMESTER I 2025/2026


### ASSIGNMENT

**STUDENT DETAIL:**

**SECTION : 01B**

**LECTURER : DR. NURUL IZZATIE HUSNA BINTI  
MUHAMAD FAUZI**

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## Introduction

This report's goal is to use Z notation to describe a study room booking system. User registration, group participation, room availability, booking creation, revision, cancellation, and system data maintenance are all managed by this system. Making ensuring the system is reliable, error-free, and compliant with all specified limitations is the aim.

## Requirements

### 1. User Registration

- Users must register with a unique ID and role (student or librarian).
- Students will be able to form groups to book study rooms.

### 2. Room List and Schedule

- The system keeps a list of available rooms including room ID, capacity and availability.
- Only valid rooms can be booked.

### 3. Study Room Booking


- A group leader can book a room for their group.
- Booking requires a valid room, date, start time, end time and group size.
- Once booked, the room cannot be double booked.

### 4. Booking Cancellation

- Users are allowed to cancel their booking before the booking start time.
- When cancelled, the room becomes available again.

### 5. Data Maintenance

- Only valid booking schedules are stored.
- Outdated or invalid data is removed to keep the system clean.

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## Specification using Z notation

### 1. State Schema

```


- [ UserID, RoomID, BookingID, Date]
Time ==  $\mathbb{N}$ 
Role ::= student | librarian
Status ::= active | cancelled
L

State Schema
r StudyRoomSystem
users: (UserID  $\leftrightarrow$  Role)
loggedIn:  $\mathbb{P}$  UserID
rooms:  $\mathbb{P}$  RoomID
bookingRoom: BookingID  $\leftrightarrow$  RoomID
bookingDate: BookingID  $\leftrightarrow$  Date
startTime: BookingID  $\leftrightarrow$  Time
endTime: BookingID  $\leftrightarrow$  Time
groupLeader: BookingID  $\leftrightarrow$  UserID
groupMembers: BookingID  $\leftrightarrow$   $\mathbb{P}$  UserID
groupSize: BookingID  $\leftrightarrow$   $\mathbb{N}$ 
bookingStatus: BookingID  $\leftrightarrow$  Status
|
 $\forall b : \text{dom groupSize} \bullet \text{groupSize } b = \#(\text{groupMembers } b)$ 

 $\forall b : \text{dom startTime} \cap \text{dom endTime} \bullet$ 
     $1 \leq (\text{endTime } b - \text{startTime } b) \leq 4$ 

 $\forall b : \text{dom bookingStatus} \bullet$ 
     $\text{bookingStatus } b = \text{active} \Rightarrow \text{groupLeader } b \in \text{groupMembers } b$ 
L


```

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<b>Z Specification</b>	<b>Explanation</b>
StudyRoomSystem	Name of state schema for the whole system.
users: (UserID $\leftrightarrow$ Role)	Partial function that maps each user ID to one role.
loggedIn: $\mathbb{P}$ UserID	Set of users currently logged into the system.
rooms: $\mathbb{P}$ RoomID	Set of all study rooms that can be booked.
bookingRoom: BookingID $\leftrightarrow$ RoomID	Each booking ID is linked to exactly one room.
bookingDate: BookingID $\leftrightarrow$ Date	Each booking ID is linked to its booking date.
startTime: BookingID $\leftrightarrow$ Time	Each booking has a start time.
endTime: BookingID $\leftrightarrow$ Time	Each booking has an end time.
groupLeader: BookingID $\leftrightarrow$ UserID	Each booking has one group leader.
groupMembers: BookingID $\leftrightarrow$ $\mathbb{P}$ UserID	Each booking has a set of group members.
groupSize: BookingID $\leftrightarrow$ $\mathbb{N}$	Each booking stores the number of group members.
bookingStatus: BookingID $\leftrightarrow$ Status	Shows whether each booking is active or cancelled.
$\forall b : \text{dom groupSize} \bullet \text{groupSize } b = \#(\text{groupMembers } b)$	For every booking, stored group size must equal the actual number of group members.

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$\forall b : \text{dom } \text{startTime} \cap \text{dom } \text{endTime} \bullet$ $1 \leq (\text{endTime } b - \text{startTime } b) \leq 4$	Every booking must between 1 and 4 hours long.
$\forall b : \text{dom } \text{bookingStatus} \bullet$ $\text{bookingStatus } b = \text{active} \Rightarrow$ $\text{groupLeader } b \in \text{groupMembers } b$	If a booking is active, its leader must be one its members.


## 2. Initial Schema

```

InitStudyRoomSystem
├ InitStudyRoomSystem
│ StudyRoomSystem
│
│ users = ∅
│ loggedIn = ∅
│ rooms = ∅
│ bookingRoom = ∅
│ bookingDate = ∅
│ startTime = ∅
│ endTime = ∅
│ groupLeader = ∅
│ groupMembers = ∅
│ groupSize = ∅
│ bookingStatus = ∅
└

```


Z Specification	Explanation
InitStudyRoomSystem	Name of the initialization schema.
StudyRoomSystem	Includes all the variables from the state schema.

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users = $\emptyset$	Starts with no registered users.
loggedIn = $\emptyset$	No one is logged in when the system begins.
rooms = $\emptyset$	No room are defined yet.
bookingRoom = $\emptyset$	No bookings exists.
bookingDate = $\emptyset$	No booking dates stored.
startTime = $\emptyset$	No start times recorded.
endTime = $\emptyset$	No end times recorded.
groupLeader = $\emptyset$	No leaders assigned yet.
groupMembers = $\emptyset$	No members for any booking.
groupSize = $\emptyset$	No group sizes stored.
bookingStatus = $\emptyset$	No active or cancelled bookings.

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### 3. Operation Schemas

#### ➤ Registration

<div> <div>Registration</div> <div> <div>ΔStudyRoomSystem</div> <div>uid?: UserID</div> <div>role?: Role</div> <div> </div> <div>uid? ∉ dom users</div> <div>users' = users ⊕ { uid? ↦ role? }</div> <div>loggedIn = loggedIn</div> <div>rooms' = rooms</div> <div>bookingRoom' = bookingRoom</div> <div>bookingDate = bookingDate</div> <div>startTime' = startTime</div> <div>endTime' = endTime</div> <div>groupLeader' = groupLeader</div> <div>groupMembers' = groupMembers</div> <div>groupSize' = groupSize</div> <div>bookingStatus' = bookingStatus</div> </div> </div>
--

Z Specification	Explanation
Registration	Name of schema.
ΔStudyRoomSystem	The state will change after this operation.
uid?: UserID	Input new user's ID.
role?: Role	Input the user's role.
uid? ∉ dom users	The user ID must not exist in the system.
users' = users ⊕ { uid? ↦ role? }	Add new user

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loggedIn'= loggedIn	Remain unchanged.
rooms'= rooms	Remain unchanged.
bookingRoom' = bookingRoom	Remain unchanged.
bookingDate'= bookingDate	Remain unchanged.
startTime' = startTime	Remain unchanged.
endTime'= endTime	Remain unchanged.
groupLeader' = groupLeader	Remain unchanged.
groupMembers' = groupMembers	Remain unchanged.
groupSize' = groupSize	Remain unchanged.
bookingStatus'= bookingStatus	Remain unchanged.


➤ Login

```

Login
ΔStudyRoomSystem
uid?: UserID
|
uid? ∈ dom users
loggedIn' = loggedIn ∪ {uid?}
users'= users
rooms'= rooms
bookingRoom' = bookingRoom
bookingDate' = bookingDate
startTime'= startTime
endTime'= endTime
groupLeader= groupLeader
groupMembers'= groupMembers
groupSize'= groupSize
bookingStatus' = bookingStatus

```




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<b>Z specification</b>	<b>Explanation</b>
Login	Name of schema
$\Delta \text{StudyRoomSystem}$	Operation changes the system state.
uid?: UserID	Input user ID attempting to log in.
uid? $\in$ dom users	User must already be registered.
$\text{loggedIn}' = \text{loggedIn} \cup \{\text{uid?}\}$	Add the user to the logged in set.
$\text{users}' = \text{users}$	Remain unchanged.
$\text{rooms}' = \text{rooms}$	Remain unchanged.
$\text{bookingRoom}' = \text{bookingRoom}$	Remain unchanged.
$\text{bookingDate}' = \text{bookingDate}$	Remain unchanged.
$\text{startTime}' = \text{startTime}$	Remain unchanged.
$\text{endTime}' = \text{endTime}$	Remain unchanged.
$\text{groupLeader}' = \text{groupLeader}$	Remain unchanged.
$\text{groupMembers}' = \text{groupMembers}$	Remain unchanged.
$\text{groupSize}' = \text{groupSize}$	Remain unchanged.
$\text{bookingStatus}' = \text{bookingStatus}$	Remain unchanged.

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➤ Logout


```

r Logout
ΔStudyRoomSystem
uid? : UserID

uid? ∈ loggedIn
loggedIn' = loggedIn \ {uid?}
users' = users
rooms' = rooms
bookingRoom' = bookingRoom
bookingDate' = bookingDate
startTime' = startTime
endTime' = endTime
groupLeader' = groupLeader
groupMembers' = groupMembers
groupSize' = groupSize
bookingStatus' = bookingStatus

```


Z specification	Explanation
Logout	Name of schema
ΔStudyRoomSystem	Operation changes the system state.
uid? : UserID	Input user logging out.
uid? ∈ loggedIn	User must already be logged in.
loggedIn' = loggedIn \ {uid?}	Remove the user from logged in list.
users' = users	No changes to registered users.
rooms' = rooms	Remain unchanged.

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bookingRoom' = bookingRoom	Remain unchanged.
bookingDate' = bookingDate	Remain unchanged.
startTime' = startTime	Remain unchanged.
endTime' = endTime	Remain unchanged.
groupLeader' = groupLeader	Remain unchanged.
groupMembers' = groupMembers	Remain unchanged.
groupSize' = groupSize	Remain unchanged.
bookingStatus' = bookingStatus	Remain unchanged.

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➤ Create Booking

```

CreateBooking
ΔStudyRoomSystem
bid?: BookingID
rid?: RoomID
date?: Date
start?: Time
end?: Time
leader?: UserID
members?: P UserID

bid? ∈ dom bookingRoom
leader? ∈ loggedIn
leader? ∈ members?
3 ≤ #(members?) ≤ 10
1 ≤ (end? - start?) ≤ 4
rid? ∈ rooms

∀ b : dom bookingRoom •
    bookingStatus b = active ∧ bookingRoom b = rid? ∧ bookingDate b = date? ⇒
        ¬ (start? < endTime b ∧ end? > startTime b)

∀ m : members? •
    ∀ b : dom groupMembers • bookingStatus b = active ∧ m ∈ groupMembers b ⇒
        ¬ (date? = bookingDate b ∧ start? < endTime b ∧ end? > startTime b)

bookingRoom' = bookingRoom ∪ {bid? ↦ rid?}
bookingDate' = bookingDate ∪ {bid? ↦ date?}
startTime' = startTime ∪ {bid? ↦ start?}
endTime' = endTime ∪ {bid? ↦ end?}
groupLeader' = groupLeader ∪ {bid? ↦ leader?}
groupMembers' = groupMembers ∪ {bid? ↦ members?}
groupSize' = groupSize ∪ {bid? ↦ #(members?)}


```

**bookingStatus' = bookingStatus ∪ {bid? ↦ active}**

**users' = users**

**loggedIn' = loggedIn**


**rooms' = rooms**

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Z specification	Explanation
CreateBooking	Name of schema
$\Delta$ StudyRoomSystem	Operation changes the system state.
bid?: BookingID	Input new booking ID.
rid?: RoomID	Input room ID
date?: Date	Input date.
start?: Time	Input start time.
end?: Time	Input end time.
leader?: UserID	Group leader making the booking.
members?: P UserID	Set of group members.
$\text{bid?} \notin \text{dom bookingRoom}$	Booking ID must be unique.
$\text{leader?} \in \text{loggedIn}$	Leader must be logged in.
$\text{leader?} \in \text{members?}$	Leader must be part of the group.
$3 \leq \#(\text{members?}) \leq 10$	Group size must be between 3 and 10.
$1 \leq (\text{end?} - \text{start?}) \leq 4$	Booking duration time must be 1 to 4 hours.
$\text{rid?} \in \text{rooms}$	Room must exist.
$\forall b : \text{dom bookingRoom} \bullet$ $\text{bookingStatus } b = \text{active}$ $\wedge \text{bookingRoom } b = \text{rid?} \wedge \text{bookingDate } b = \text{date?} \Rightarrow$ $\neg (\text{start?} < \text{endTime } b \wedge \text{end?} > \text{startTime } b)$	Prevents the same room from being booked at overlapping times on the same date.
$\forall m : \text{members?} \bullet$ $\forall b : \text{dom groupMembers} \bullet$	Ensures no group member already has another active booking that overlaps the

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$\text{bookingStatus } b = \text{active} \wedge m \in \text{groupMembers } b \Rightarrow$ $\neg (\text{date?} = \text{bookingDate } b \wedge \text{start?} < \text{endTime } b \wedge \text{end?} > \text{startTime } b)$	requested time.
$\text{bookingRoom}' = \text{bookingRoom} \cup \{\text{bid?} \mapsto \text{rid?}\}$	Add room assignment to booking.
$\text{bookingDate}' = \text{bookingDate} \cup \{\text{bid?} \mapsto \text{date?}\}$	Add date.
$\text{startTime}' = \text{startTime} \cup \{\text{bid?} \mapsto \text{start?}\}$	Add start time.
$\text{endTime}' = \text{endTime} \cup \{\text{bid?} \mapsto \text{end?}\}$	Add end time.
$\text{groupLeader}' = \text{groupLeader} \cup \{\text{bid?} \mapsto \text{leader?}\}$	Add leader info.
$\text{groupMembers}' = \text{groupMembers} \cup \{\text{bid?} \mapsto \text{members?}\}$	Add group members
$\text{groupSize}' = \text{groupSize} \cup \{\text{bid?} \mapsto \#(\text{members?})\}$	Add group size.
$\text{bookingStatus}' = \text{bookingStatus} \cup \{\text{bid?} \mapsto \text{active}\}$	Mark as active booking.
$\text{users}' = \text{users}$	Remain unchanged.
$\text{loggedIn}' = \text{loggedIn}$	Remain unchanged.
$\text{rooms}' = \text{rooms}$	Remain unchanged.

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- Modify Booking

<pre> r ModifyBooking   ΔStudyRoomSystem   bid?: BookingID   leader?: UserID   newRoom?: RoomID   newDate?: Date   newStart?: Time   newEnd?: Time   newMembers?: P UserID     bid? ∈ dom groupLeader   leader? = groupLeader bid?   leader? ∈ loggedIn    3 ≤ #(newMembers?) ≤ 10   1 ≤ (newEnd? - newStart?) ≤ 4    bookingRoom' = bookingRoom ⊕ {bid? ↦ newRoom?}   bookingDate' = bookingDate ⊕ {bid? ↦ newDate?}   startTime' = startTime ⊕ {bid? ↦ newStart?}   endTime' = endTime ⊕ {bid? ↦ newEnd?}   groupMembers' = groupMembers ⊕ {bid? ↦ newMembers?}   groupSize' = groupSize ⊕ {bid? ↦ #(newMembers?)}    users' = users   loggedIn' = loggedIn   rooms' = rooms   bookingStatus' = bookingStatus   groupLeader' = groupLeader L </pre>
---

Z specification	Explanation
ModifyBooking	Name of schema
ΔStudyRoomSystem	Operation changes the system state.


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bid?: BookingID	Booking being modified
leader?: UserID	User attempting modification.
newRoom?: RoomID	New room to update in the booking.
newDate?: Date	New date chosen for the booking.
newStart?: Time	New start time for the booking.
newEnd?: Time	New end time for the booking.
newMembers?: P UserID	New group members list for the booking.
bid? $\in$ dom groupLeader	Booking must exist
leader? = groupLeader bid?	Only the leader can modify
leader? $\in$ loggedIn	Leader must be logged in
$3 \leq \#(\text{newMembers?}) \leq 10$	New group size must be valid
$1 \leq (\text{newEnd?} - \text{newStart?}) \leq 4$	New duration must be valid
$\text{bookingRoom}' = \text{bookingRoom} \oplus \{\text{bid?} \mapsto \text{newRoom?}\}$	Update room using overriding
$\text{bookingDate}' = \text{bookingDate} \oplus \{\text{bid?} \mapsto \text{newDate?}\}$	Update date
$\text{startTime}' = \text{startTime} \oplus \{\text{bid?} \mapsto \text{newStart?}\}$	Update start time
$\text{endTime}' = \text{endTime} \oplus \{\text{bid?} \mapsto \text{newEnd?}\}$	Update end time
$\text{groupMembers}' = \text{groupMembers} \oplus \{\text{bid?} \mapsto \text{newMembers?}\}$	Update member list
$\text{groupSize}' = \text{groupSize} \oplus \{\text{bid?} \mapsto \#(\text{newMembers?})\}$	Update group size
users' = users	Remain unchanged.



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loggedIn' = loggedIn	Remain unchanged.
rooms' = rooms	Remain unchanged.
bookingStatus' = bookingStatus	Remain unchanged.
groupLeader' = groupLeader	Remain unchanged.

- Cancel Booking

```


CancelBooking
ΔStudyRoomSystem
bid?: BookingID
uid?: UserID
|
bid? ∈ dom bookingStatus
bookingStatus bid? = active
uid? = groupLeader bid?
uid? ∈ loggedIn

bookingStatus' = bookingStatus ⊕ {bid? ↦ cancelled}

users' = users
loggedIn' = loggedIn
rooms' = rooms
bookingRoom' = bookingRoom
bookingDate' = bookingDate
startTime' = startTime
endTime' = endTime
groupLeader' = groupLeader
groupMembers' = groupMembers
groupSize' = groupSize

```


Z specification	Explanation
CancelBooking	Name of schema

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	<b>COURSE:</b> FORMAL METHOD	<b>CODE:</b> BCS2213	
	<b>TOPIC:</b> Chapter 1-4	<b>SEM:</b> I 2025/2026	
	<b>ASSESSMENT:</b> Assignment	<b>DUE:</b> WEEK 9	

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$\Delta \text{StudyRoomSystem}$	Operation changes the system state.
$\text{bid?} : \text{BookingID}$	Booking being cancelled.
$\text{uid?} : \text{UserID}$	User requesting cancellation
$\text{bid?} \in \text{dom bookingStatus}$	Booking must exist
$\text{bookingStatus bid?} = \text{active}$	Only active bookings can be cancelled
$\text{uid?} = \text{groupLeader bid?}$	Only leader can cancel
$\text{uid?} \in \text{loggedIn}$	Leader must be logged in
$\text{bookingStatus}' = \text{bookingStatus} \oplus \{\text{bid?} \mapsto \text{cancelled}\}$	Change booking status to cancelled
$\text{users}' = \text{users}$	Remain unchanged.
$\text{loggedIn}' = \text{loggedIn}$	Remain unchanged.
$\text{rooms}' = \text{rooms}$	Remain unchanged.
$\text{bookingRoom}' = \text{bookingRoom}$	Remain unchanged.
$\text{bookingDate}' = \text{bookingDate}$	Remain unchanged.
$\text{startTime}' = \text{startTime}$	Remain unchanged.
$\text{endTime}' = \text{endTime}$	Remain unchanged.
$\text{groupLeader}' = \text{groupLeader}$	Remain unchanged.
$\text{groupMembers}' = \text{groupMembers}$	Remain unchanged.
$\text{groupSize}' = \text{groupSize}$	Remain unchanged.

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- View Booking


```

r ViewBooking
  ∃ StudyRoomSystem
  uid?: UserID
  b!: P BookingID
  |
  uid? ∈ loggedIn

b! = { b : dom bookingRoom | groupLeader b = uid? ∨ uid? ∈ groupMembers b }

```

Z specification	Explanation
ViewBooking	Name of schema
$\exists$ StudyRoomSystem	No operation state will change.
uid?: UserID	User who wants to view bookings.
b!: P BookingID	Output set of booking ID
uid? ∈ loggedIn	User must be logged in to view bookings
$b! = \{ b : \text{dom bookingRoom} \mid \text{groupLeader } b = \text{uid?} \vee \text{uid?} \in \text{groupMembers } b \}$	Returns booking where user is leader or member.

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➤ View All Booking

```

r ViewAllBookings
ΞStudyRoomSystem
uid?: UserID
all!: P BookingID
|
uid? ∈ loggedIn
users uid? = librarian
all! = dom bookingRoom
L

```

<b>Z specification</b>	<b>Explanation</b>
ViewAllBookings	Name of schema
ΞStudyRoomSystem	No operation state will change.
uid?: UserID	User requesting full list
all!: P BookingID	Output variable that will store the set of all booking ID.
uid? ∈ loggedIn	User must be logged in
users uid? = librarian	Only librarians can access full list
all! = dom bookingRoom	Output all booking ID in the system.