

# COMM1822

Term 2 2022

## Introduction to Databases for Business Analytics

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### Week 5 Normalisation

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We recognise Aboriginal and Torres Strait Islander people's ongoing leadership and contributions, including to business, education and industry.

UNSW Business School. (2022, May 7). *Acknowledgement of Country* [online video]. Retrieved from <https://vimeo.com/369229957/d995d8087f>

# Agenda

- ❑ Review normalisation and its role in the database design process
- ❑ Identify and describe each of the normal forms: 1NF, 2NF, 3NF, and BCNF.
- ❑ Explain how normal forms are derived from lower normal forms to higher normal forms (and denormalisation)
- ❑ Apply normalisation rules to evaluate and correct table structures
- ❑ Identify situations that require denormalisation to generate information efficiently

# Review (Normal Forms)

Normal Form	Characteristic
First normal form (1NF)	PK identified and no repeating groups
Second normal form (2NF)	1NF and no partial dependencies
Third normal form (3NF)	dependencies
Boyce-Codd NF (BCNF)	candidate key

- ❑ *Create a valid primary key and resolve multi-value*
  - **First Normal Form (1NF)**
- ❑ *Draw partial functional dependency diagrams and resolve them.*
  - **Second Normal Form (2NF)**
- ❑ *Draw transitive functional dependency diagrams and resolve them.*
  - **Third Normal Form (3NF)**
- ❑ *Resolve cases where non-key attributes determine primary key attributes. (Special case of 3NF)*
  - **Boyce-Codd Normal Form (BCNF)**

# Review (Functional Dependencies)

## ❑ Functional Dependencies

- Inclusion (or reflexive) rule
- Augmentation rule
- Transitivity rule, ...

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## ❑ Partial dependency: functional determinant is only part of the primary key

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- Assumption: one candidate key
- Straight forward
- Easy to identify

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## ❑ Transitive dependency: attribute is dependent on another attribute that is not part of the primary key

- More difficult to identify among a set of data
- Occur only when a functional dependence exists among nonprime attributes

# Inference Rules for Functional Dependencies (FDs) - Armstrong's Axioms Primary Rules

**$A \rightarrow B$ :** Attribute B “functionally depends” on an attribute A; or  
Attribute A determines attribute B; or  
“If I know the value of A, then I know the value of B”.

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- 1) **Inclusion (Reflexive) rule:** if  $Y \subseteq X$ , then  $X \rightarrow Y$  (notation of subset)  
“If  $zID \subseteq \{zID, LastName\}$ , then  $\{zID, LastName\}$  determines  $zID$ ”  
If  $zID$  is a part of the attribute set  $\{zID, LastName\}$ , then  $\{zID, LastName\}$  determines  $zID$ ”)
- 2) **Augmentation rule:** if  $X \rightarrow Y$ , then  $\{W, X\} \rightarrow \{W, Y\}$   
“If  $zID \rightarrow LastName$ , then  $\{zID, FirstName\} \rightarrow \{LastName, FirstName\}$ ”
- 3) **Transitivity rule:** if  $X \rightarrow Y$  and  $Y \rightarrow Z$ , then  $X \rightarrow Z$   
“If  $zID \rightarrow MobileNumber$  and  $MobileNumber \rightarrow LastName$ , then  $zID \rightarrow LastName$ ”.



# Union

If  $X \rightarrow Y$  and  $X \rightarrow Z$ , then  $X \rightarrow \{Y, Z\}$ .

Proof:

$X \rightarrow Y \dots (1)$  (Given)

$\{X, Z\} \rightarrow \{Y, Z\} \dots (2)$  (Augmentation of (1) & Z)

$X \rightarrow Z \dots (3)$  (Given)

$X \rightarrow \{X, Z\} \dots (4)$  (Augmentation of (3))

$X \rightarrow \{Y, Z\} \dots (5)$  (Transitivity of (4) and (2))

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## Armstrong's Axioms Primary Rules

- Inclusion (Reflexive) rule: If  $Y \subseteq X$ , then  $X \rightarrow Y$ .
- Augmentation rule: If  $X \rightarrow Y$ , then  $\{W, X\} \rightarrow \{W, Y\}$ .
- Transitivity rule: If  $X \rightarrow Y$  and  $Y \rightarrow Z$ , then  $X \rightarrow Z$ .

# Pseudo-Transitivity

If  $X \rightarrow Y$  and  $\{Y, Z\} \rightarrow W$ , then  $\{X, Z\} \rightarrow W$ .

Proof:

$X \rightarrow Y \dots (1)$  (Given)

$\{X, Z\} \rightarrow \{Y, Z\} \dots (2)$  (Augmentation of (1) with  $Z$ )

$\{Y, Z\} \rightarrow W \dots (3)$  (Given)

$\{X, Z\} \rightarrow W \dots (4)$  (Transitivity of (2) and (3))

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## Armstrong's Axioms Primary Rules

- Inclusion (Reflexive) rule: If  $Y \subseteq X$ , then  $X \rightarrow Y$ .
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- Transitivity rule: If  $X \rightarrow Y$  and  $Y \rightarrow Z$ , then  $X \rightarrow Z$ .

# Review – Denormalisation

## ❑ Structural point of view of normal forms

- Higher normal forms are better than lower normal forms

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## ❑ Denormalisation: practical form

- Results in increased performance and redundancy

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# Demonstration of Normalisation (Exercises)

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Source: weightwatchers.com

# Demonstration (Exercise 0)

We are supposed to create **1NF, 2NF and 3NF** as well as to create an **ER diagram** from this table. To do this, we need to draw **functional, partial and transitive dependency diagrams**.

Attribute	Value
Emp#	1003
Emp. Na	
Educatio	
Dep. Co	
Dep. Name	Information Systems
Dep. Mgmt	Mr. Black
Job Class	SL-4
Title	Senior Lecturer
Dependents	Marge (wife), Bart (son), Lisa (daughter)
DOB	1/1/1960
Hire Date	10/4/1990
Training	Level-1, Level-2
Base Salary	\$85,000

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# Handling Multi-Valued Attributes

Problem 1: the table has several **multi-valued attributes** and some attributes are not atomic...

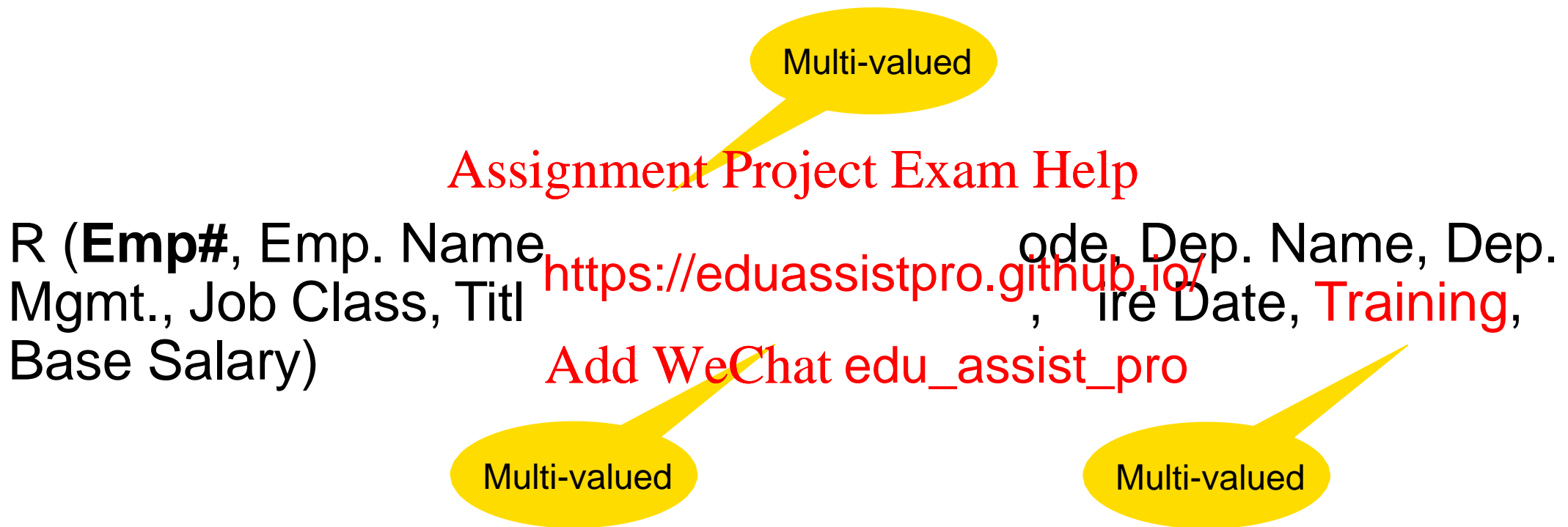
Attribute	Value
Emp#	1003
Emp. Name	Simpson
Educat	
Dep. C	
Dep. Name	Information Systems
Dep. Mgmt	Mr. Black
Job Class	SL-4
Title	Senior Lecturer
Dependents	<b>Marge (wife), Bart (son), Lisa (daughter)</b>
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# Handling Multi-Valued Attributes



**Dependency diagrams cannot handle multi-valued attributes.**

# Handling Multi-Valued Attributes

We **split the multivalued attributes apart**, using our ER/conceptual modelling knowledge.  
We **replace with appropriate single-value attributes**.

- **Delete** Education → **Add** Education ID (Edu#), Education Description, Graduate Date
- **Delete** Dependents → **Add** Dependent Name
- **Delete** Training → **Add** Training Description, Certification Date

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❑ For the case of Job Class, we also associate with **Add WeChat edu\_assist\_pro**, we can change to:

- **Delete** Job Class → **Add** Job ID (Job#), Title, Base Salary

R (**Emp#**, Employee Name, DOB, Hire Date, **Edu#**, Education Desc., Graduate Date, **Dept. Code**, Dept. Name, Dept. Mgmt., **Job#**, Title, Base Salary, **Depd#**, Dependent Name, **Train#**, Training Desc. Certification Date)



# Bottom-Up Approach

**Start with existing data structure/tables** > then try to derive the 3NF from there.

Identify the candidate keys – from there you can identify the PKs

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(Hint: this is what we do here)

- ☐ You can see Emp# and Educ# could be candidate keys. Other Employee attributes associate with Emp#.
- ☐ Likewise, a few attributes are associated with Educ#.

# Normalisation: Weak Entity

There seems there is a “**weak entity**” in the table.

Attribute	Value
Emp#	1003
Emp. Name	Simpson
Education	BE, MSc, PhD
Dep. Code	SISTM
Dep. Name	Information Systems
Dep. Mgmt	Mr. Black
Job Class	SL-4
Title	Senior Lecturer
Dependents	<b>Marge (wife), Bart (son), Lisa (daughter)</b>
DOB	1/1/1960
Hire Date	10/4/1990
Training	Level-1, Level-2
Base Salary	\$85,000

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# 1NF

## Original R:

R (Emp#, Emp. Name, Education, Dep. Code, Dep. Name, Dep. Mgmt., Job Class, Title, Dependents, DOB, Hire Date,

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## Modified R:

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After all the changes, now the updated R is 1NF because: **no multivalued attributes + valid primary key.**

R (Emp#, Emp. Name, DOB, Hire Date, Edu#, Education Desc., Graduate Date, Dept#, Dept Name, Dept Mgmt., Job#, Title, Base Salary, Depd#, Depd. Name, Train#, Training Desc., Certification Date)

# From 1NF to 2NF Via Dependency Diagrams

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# Using Dependency Diagrams

- 1) Emp# + Dep.# + Job# + Edu# + Train# + Depd# > primary key functional dependency > **OK/no action**
- 2) Dep.# is the key for Dep.Name and Dep.Mgmt (partial func. dependency) > **new relation Department required**
- 3) Job# is the key for Title, Base S. (partial func. dependency) > **new relation Job required**
- 4) Edu# is the key for Educ.Desc. > **relation Education required**
- 5) Emp# AND Edu# are the keys for Grad.Date (partial func. dependency) > **new relation Emp.-Edu. required (Composite/Bridge entity)**
- 6) Train# is the key for Train. Desc. (partial func. dependency) > **new relation Training required**
- 7) Emp# AND Train# are the keys for Cert.Date (partial func. dependency) > **new relation Emp.-Train. required (Composite/Bridge entity)**
- 8) Emp# AND Depd# are the key for Depn.Name (partial func. dependency) > **new relation Dependent required (weak entity)**

# 2NF / 3NF

1. Employee (Emp#, Emp. Name, DOB, Hire Date, Dept. Code, Job#)
2. Department (Dept.#, Dept Name, Dept Mgmt)
3. Job (Job #, Title, Base Salary)
4. Education (Edu#, Edu. De
5. Emp.-Edu. (Emp#, Edu#,
6. Training (Train#, Train. Desc.)
7. Emp.-Train. (Emp#, Train#, Cert. Date)
8. Dependent (Emp#, Depd#, Dependent Name)

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No transitive dependencies → 3NF

# ER Diagram

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# Normalisation Exercises

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Source: weightwatchers.com



# Exercise 1

Consider the following **relational schema** R (A, B, C, D, E, F, G, H) and the following **functional dependencies**:

- A, B  $\rightarrow$  C, D, E, F, G, H
- A  $\rightarrow$  C, D, G, H
- B  $\rightarrow$  E
- G  $\rightarrow$  H

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- ☐ Create functional dependency, partial dependency, transitive dependency diagrams.
- ☐ Normalise to 1NF, 2NF and 3NF.
- ☐ Draw the ER diagram from the 3NF (Optional)

# Exercise 2

For the following relations:

- ☐ Indicate the normal form (1NF, 2NF or 3NF) for that relation.
- ☐ Decompose into the 3NF (if not already in 3NF)
- ☐ Note: Functional dependencies implied by the primary keys (PKs) – are shown.

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- 1) CLASS (Course\_No, Section\_No)
- 2) CLASS (Course\_No, Section\_No, Room)
- 3) CLASS (Course\_No, Section\_No, Room, Capacity),  
with FD: Room → Capacity
- 4) CLASS (Course\_No, Section\_No, Course\_Name, Room, Capacity),  
with FDs: Course\_No → Course\_Name; Room → Capacity

# Exercise 3

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A librarian has created the above table in an effort to create a “database”. However, there are several issues with the design.

1. Argue what potential problems there are with the table design.
2. Identify the PK(s) and draw the dependencies diagrams.
3. Normalise the relational model the 3NF.
4. Draw the ER diagram based on the 3NF.

# Solution to Exercise 3

1. Potential problems with the table are:

- Not in 1NF, hence cannot be used in relational DBMS.
- PK not completely defined, could let to identical tuples.
- Order of rows matters (cannot be sorted in different order).
- Has redundant data.
- Invites inconsistencies/anomali

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# Solution to Exercise 3

2. PK(s) and dependencies diagrams

1NF

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Functional  
dependency  
diagram

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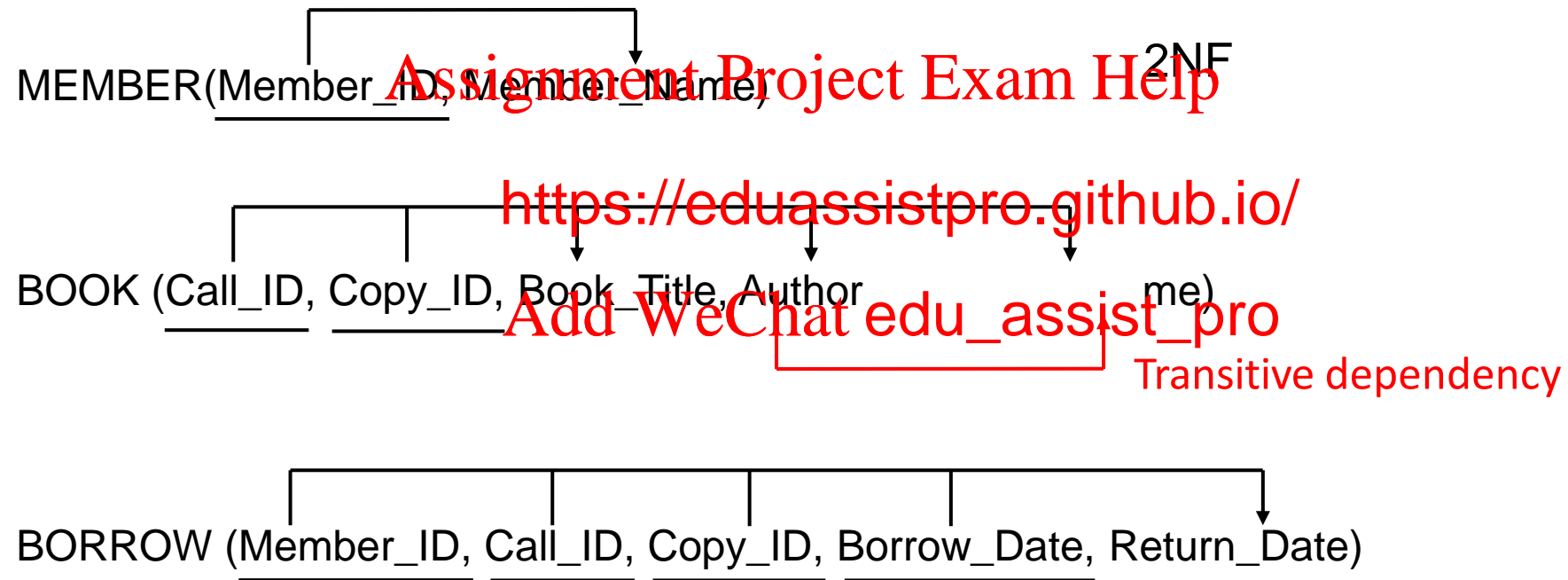
Partial  
dependency



Transitive  
dependency

# Solution to Exercise 3

3. Normalise it to the 3NF (Step 1)



Note: Borrow Date should be modelled as part of PK to handle multiple borrowing for the same book by the same member.

# Solution to Exercise 3

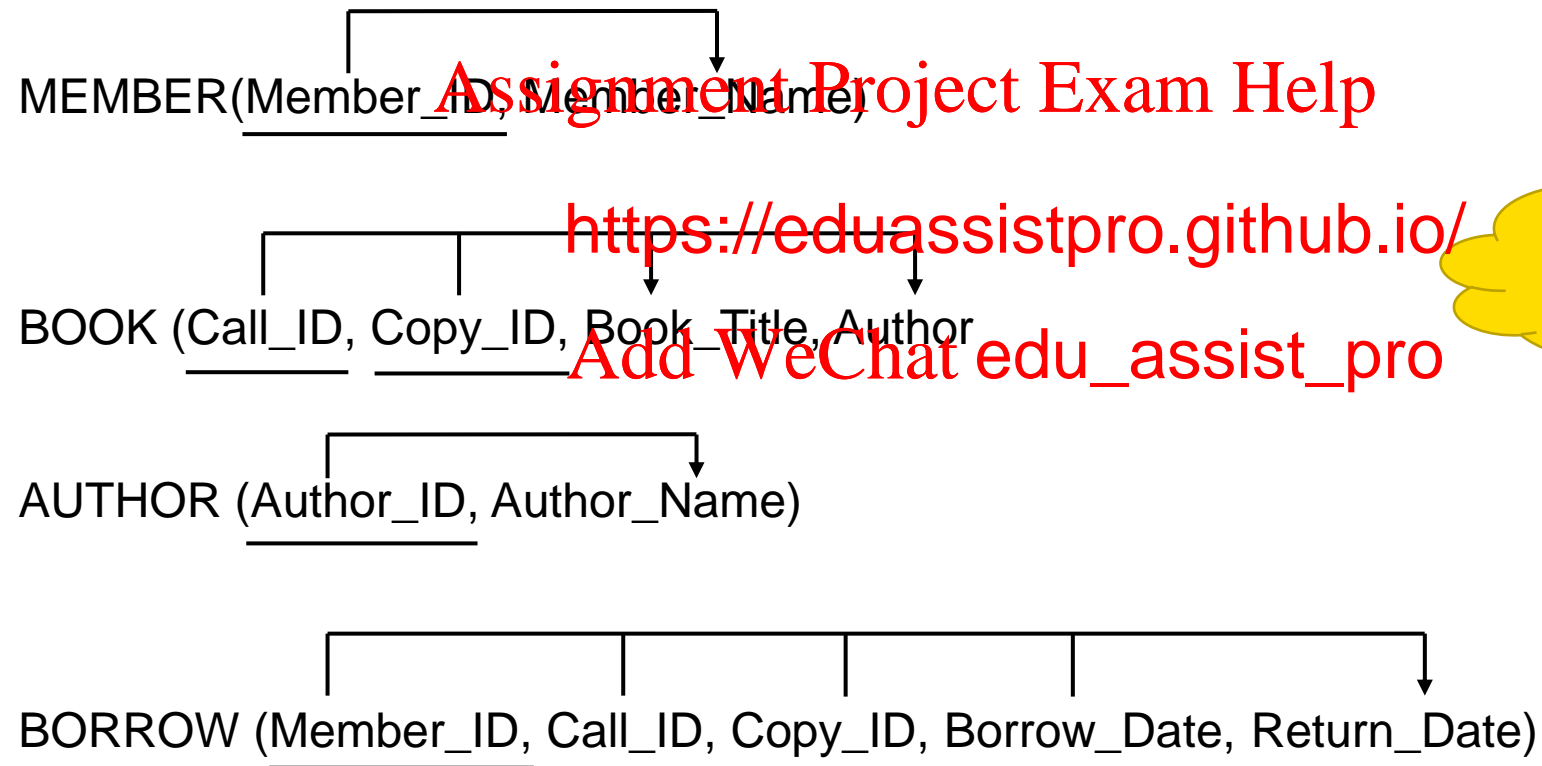
3. Normalise it to the 3NF (Step 2)

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MEMBER(Member\_ID, Member\_Name)  
BOOK (Call\_ID, Copy\_ID)  
AUTHOR (Author\_ID, Author\_Name)  
BORROW (Member\_ID, Call\_ID, Copy\_ID, Borrow\_Date, Return\_Date)

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# Solution to Exercise 3

3. Normalise it to the 3NF, and show the dependency diagram for each table



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Required in your  
Assessment



# Solution to Exercise 3

4. Draw the ERM (based on the 3NF):

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Assessment

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# Exercise 4

Joe is the manager of a **dinner club** would like to create a database to email event invitations to the club's members, to plan the meals, to keep track of who attends the dinners etc. He explains the following business rules:

- Each dinner is joined by many members and each member may attend many dinners.
- A member receives many invitations and each invitation is emailed to many members.
- A dinner is based on a single entrée, but an entrée basis for many dinners. For example, a dinner entrée, mushroom risotto and panna cotta. Or, of a fish entrée, wagyu beef and tiramisu. The same goes for the other dishes...

Because the manager is not a database expert, his first attempts at a “database” have resulted in the following, not very functional structure (on the right). Can you help Joe?

1. Draw functional, partial and transitive dependency diagrams.
2. Create the 1NF, the 2NF and the 3NF.
3. Draw the ER diagram from the 3NF.

Attribute Name	Sample Value
MEMBER_NUM	214
MEMBER_NAME	Alice B. Van der Voort
MEMBER_ADDR	325 Meadow Park
MEMBER_CITY	Murkywaters
MEMBER_ZIPCODE	12345
ENTREE_NUM	8
ENTREE_DATE	1/8/12
PT_DATE	9/8/12
DATE	23/8/12
ATTEND	Y
DINNER_CODE	5
DINNER_DESCRIPTION	Sea Delight
ENTREE_CODE	3
ENTREE_DESCRIPTION	Stuffed Crab
DESSERT_CODE	8
DESSERT_DESCRIPTION	Chocolate Mousse

# Questions

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Source: petcare.com.au