

- (1) For each one of the relational schemas obtained in a step (1) find all functional dependencies valid in each schema.

```
STUDENT(snumber,full-name,degree,school)
snumber → full-name,degree,school
degree → school
```

```
UNIVERSITY-LIBRARY(university-name,campus-name,university-address,campus-address)
university-name,campus-name → campus-address
university-name → university-address
university-address → university-name
campus-address → campus-name
campus-address → university-name
```

```
BORROWS-FROM(snumber,university-name,campus-name,borrow-date-time,call-number,ISBN,title,price)
snumber,university-name,campus-name,borrow-date-time → call-number,ISBN,title,price
call-number → ISBN
ISBN → title, price
```

- (3) For each one of the relational schemas obtained from a step (1) and functional dependencies obtained from a step (2) find the minimal keys.

```
STUDENT(snumber, full-name, degree, school)
If snumber → full-name, degree, school then
minimal key = (snumber)
```

```
UNIVERSITY-LIBRARY(university-name,campus-name,university-address,campus-address)
If university-name → university-address then
university-name,campus-name → university-address
```

```
If university-name,campus-name → university-address and
university-name,campus-name → campus-address then
university-name,campus-name → university-address,campus-address
```

```
If university-name,campus-name → university-address,campus-address then
minimal key 1 = (university-name,campus-name)
```

```
If university-address → university-name then
university-address,campus-name → university-name,campus-name
```

```
If university-address,campus-name → university-name,campus-name and
university-name,campus-name → campus-address then
university-address,campus-name → campus-address
```

```
If university-address,campus-name → university-name,campus-name and
university-address,campus-name → campus-address then
university-address,campus-name → university-name,campus-name,campus-address
```

```
If university-address,campus-name → university-name,campus-name,campus-address then
university-address,campus-name → university-name,campus-address
```

If university-address, campus-name $\rightarrow$ university-name, campus-address then
minimal key 2 = (university-address, campus-name)

If campus-address $\rightarrow$ university-name and university-name $\rightarrow$ university address then
campus-address $\rightarrow$ university address

If campus-address $\rightarrow$ university-name and
campus-address $\rightarrow$ university address and
campus-address $\rightarrow$ campus-name
then
minimal key 3 = (campus-address)

BORROWSFROM(snumber, university-name, campus-name, borrow-date-time, call-number, ISBN, title, price)

If snumber, university-name, campus-name, borrow-date-time $\rightarrow$ call-number, ISBN, title, price then
minimal key = (snumber, university-name, campus-name, borrow-date-time)

- (4) Apply the definitions of normal forms, functional dependencies and minimal keys to find the highest normal form valid for each one of the relational schemas obtained from a step (1).

STUDENT(snumber, full-name, degree, school)
snumber $\rightarrow$ full-name, degree, school
degree $\rightarrow$ school
minimal key = (snumber)

If minimal key = (snumber) then degree $\rightarrow$ school violates 3NF because degree is not a superkey and school is not a member of minimal key.
2NF is valid because no nonprime attribute depends on a subset of a minimal key.

UNIVERSITY-LIBRARY(university-name, campus-name, university-address, campus-address)
university-name, campus-name $\rightarrow$ campus-address
university-name $\rightarrow$ university-address
university-address $\rightarrow$ university-name
campus-address $\rightarrow$ campus-name
campus-address $\rightarrow$ university-name
minimal key 1 = (university-name, campus-name)
minimal key 2 = (university-address, campus-name)
minimal key 3 = (campus-address)

The minimal keys cover entire schema. No nonprime attributes, yet left-hand side of
university-name $\rightarrow$ university-address
is not a superkey $\Rightarrow$ 3NF and not BCNF

BORROWS-FROM(snumber, university-name, campus-name, borrow-date-time, call-number, ISBN, title, price)
snumber, university-name, campus-name, borrow-date-time $\rightarrow$ call-number, ISBN, title, price
call-number $\rightarrow$ ISBN
ISBN $\rightarrow$ title, price
minimal key = (snumber, university-name, campus-name, borrow-date-time)
2NF and not 3NF due to transitive functional dependencies.

(5) If a relational schema is not in BCNF then decompose it into the relational schemas in BCNF.

STUDENT'(snumber, full-name, degree)
DEGREES(degree, school)

UNIVERSITY-LIBRARY'(university-name, campus-name, campus-address)
UNIVERSITY(university-name, university-address)

BORROWS-FROM(snumber, university-name, campus-name, borrow-date-time, call-number)
BOOKCOPY(call-number, ISBN)
BOOK(ISBN, title, price)
