# Database Systems: Design, Implementation, and Management

*Lesson 4*

# The Entity Relationship Model (ERM)

- ER model forms the basis of an ER diagram
- ERD represents conceptual database as viewed by end user
- ERDs depict database's main components:
  - ◦ Entities
  - ◦ Attributes
  - ◦ Relationships

# Entities

- Refers to entity set and not to single entity occurrence
- Corresponds to table and not to row in relational environment
- In Chen and Crow's Foot models, entity is represented by rectangle with entity's name
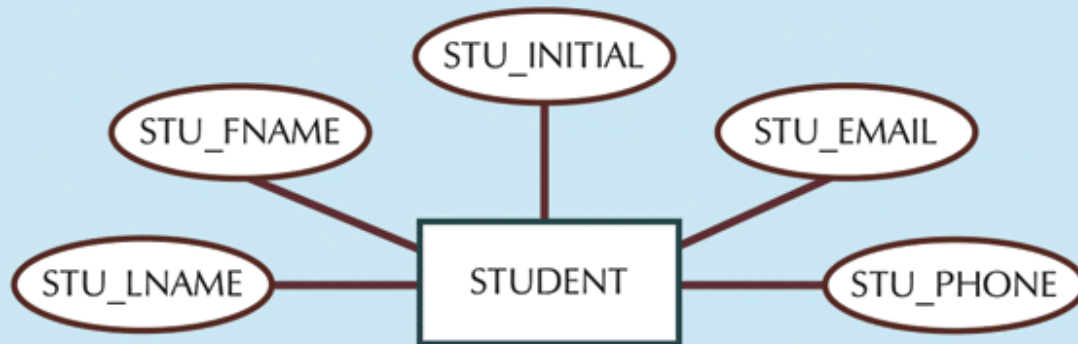- Entity name, a noun, written in capital letters

# Attributes

- Characteristics of entities
- Chen notation: attributes represented by ovals connected to entity rectangle with a line
  ◦ Each oval contains the name of attribute it represents
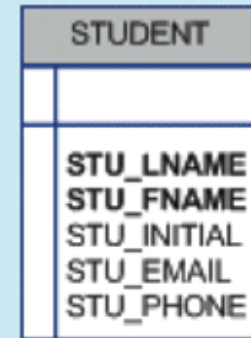- Crow's Foot notation: attributes written in attribute box below entity rectangle

**FIGURE 4.1** The attributes of the STUDENT entity: Chen and Crow's Foot

# Attributes (cont'd.)

- **Required attribute**: must have a value
- **Optional attribute**: may be left empty
- Domain: set of possible values for an attribute
  - Attributes may share a domain
- **Identifiers**: one or more attributes that uniquely identify each entity instance
- **Composite identifier**: primary key composed of more than one attribute

FIGURE
4.2

**The CLASS table (entity) components and contents**

| CLASS_CODE | CRS_CODE | CLASS_SECTION | CLASS_TIME | ROOM_CODE | PROF_NUM |
|---|---|---|---|---|---|
| 10012 | ACCT-211 | 1 | MWF 8:00-8:50 a.m. | BUS311 | 105 |
| 10013 | ACCT-211 | 2 | MWF 9:00-9:50 a.m. | BUS200 | 105 |
| 10014 | ACCT-211 | 3 | TTh 2:30-3:45 p.m. | BUS252 | 342 |
| 10015 | ACCT-212 | 1 | MWF 10:00-10:50 a.m. | BUS311 | 301 |
| 10016 | ACCT-212 | 2 | Th 6:00-8:40 p.m. | BUS252 | 301 |
| 10017 | CIS-220 | 1 | MWF 9:00-9:50 a.m. | KLR209 | 228 |
| 10018 | CIS-220 | 2 | MWF 9:00-9:50 a.m. | KLR211 | 114 |
| 10019 | CIS-220 | 3 | MWF 10:00-10:50 a.m. | KLR209 | 228 |
| 10020 | CIS-420 | 1 | W 6:00-8:40 p.m. | KLR209 | 162 |
| 10021 | QM-261 | 1 | MWF 8:00-8:50 a.m. | KLR200 | 114 |
| 10022 | QM-261 | 2 | TTh 1:00-2:15 p.m. | KLR200 | 114 |
| 10023 | QM-362 | 1 | MWF 11:00-11:50 a.m. | KLR200 | 162 |
| 10024 | QM-362 | 2 | TTh 2:30-3:45 p.m. | KLR200 | 162 |
| 10025 | MATH-243 | 1 | Th 6:00-8:40 p.m. | DRE155 | 325 |

# Attributes (cont'd.)
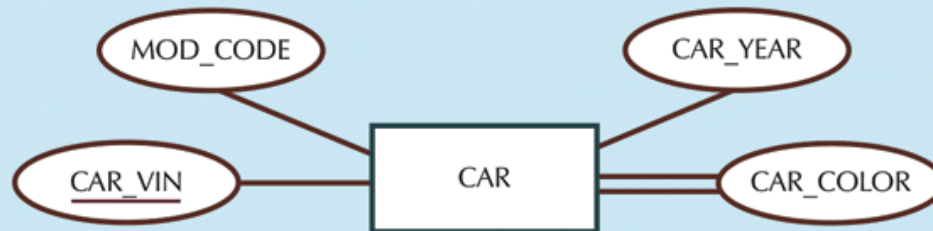
- Composite attribute can be subdivided
- Simple attribute cannot be subdivided
- Single-value attribute can have only a single value
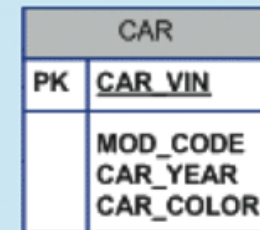- Multivalued attributes can have many values

**FIGURE 4.3** A multivalued attribute in an entity
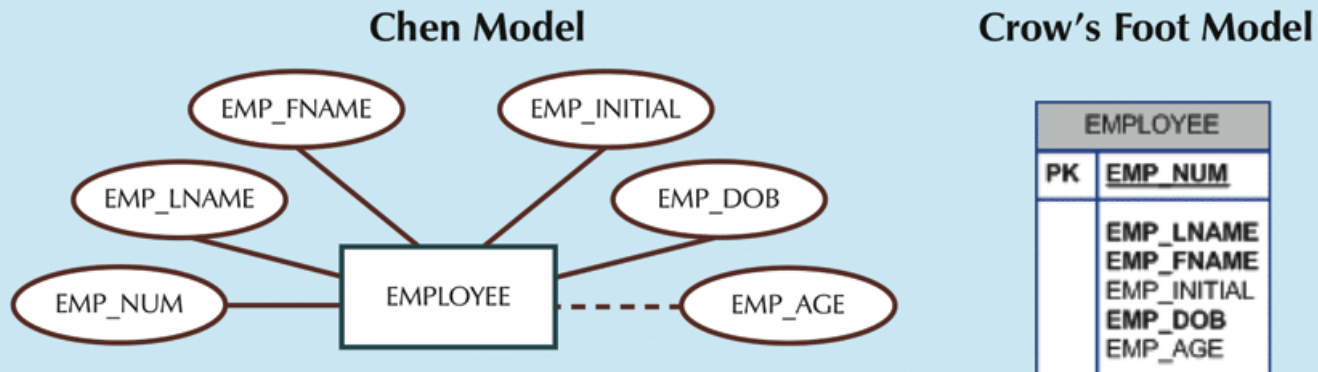
Chen Model

Crow's Foot Model

# Attributes (cont'd.)

- M:N relationships and multivalued attributes should not be implemented
  - Create several new attributes for each of the original multivalued attributes' components
  - Create new entity composed of original multivalued attributes' components
- **Derived attribute**: value may be calculated from other attributes
  - Need not be physically stored within database

**FIGURE 4.6** Depiction of a derived attribute

Chen Model

Crow's Foot Model

| TABLE 4.2 | Advantages and Disadvantages of Storing Derived Attributes | |
|---|---|---|
| | **DERIVED ATTRIBUTE** | |
| | **STORED** | **NOT STORED** |
| **Advantage** | Saves CPU processing cycles<br>Saves data access time<br>Data value is readily available<br>Can be used to keep track of historical data | Saves storage space<br>Computation always yields current value |
| **Disadvantage** | Requires constant maintenance to ensure derived value is current, especially if any values used in the calculation change | Uses CPU processing cycles<br>Increases data access time<br>Adds coding complexity to queries |

# Relationships

- Association between entities
- **Participants** are entities that participate in a relationship
- Relationships between entities always operate in both directions
- Relationship can be classified as 1:M
- Relationship classification is difficult to establish if only one side of the relationship is known
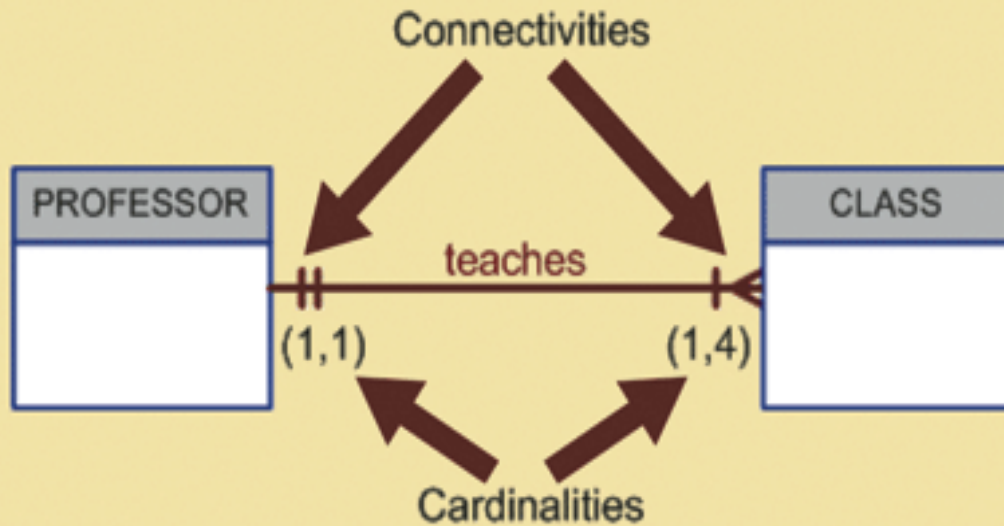
# Connectivity and Cardinality

- **Connectivity**
  - Describes the relationship classification
- **Cardinality**
  - Expresses minimum and maximum number of entity occurrences associated with one occurrence of related entity
- Established by very concise statements known as business rules
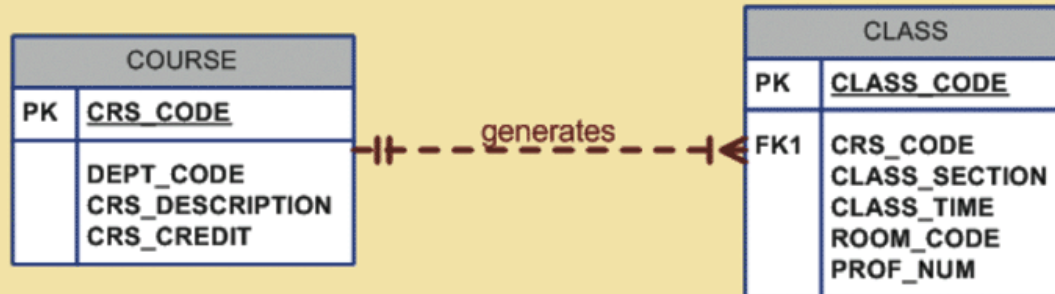
FIGURE 4.7 Connectivity and cardinality in an ERD

# Relationship Strength

- ## Weak (non-identifying) relationships
  - Exists if PK of related entity does not contain PK component of parent entity
- ## Strong (identifying) relationships
  - Exists when PK of related entity contains PK component of parent entity

FIGURE 4.8

# A weak (non-identifying) relationship between COURSE and CLASS



**Table name: COURSE**                                    **Database name: Ch04_TinyCollege**

| CRS_CODE | DEPT_CODE | CRS_DESCRIPTION | CRS_CREDIT |
|----------|-----------|-----------------|------------|
| ACCT-211 | ACCT | Accounting I | 3 |
| ACCT-212 | ACCT | Accounting II | 3 |
| CIS-220 | CIS | Intro. to Microcomputing | 3 |
| CIS-420 | CIS | Database Design and Implementation | 4 |
| MATH-243 | MATH | Mathematics for Managers | 3 |
| QM-261 | CIS | Intro. to Statistics | 3 |
| QM-362 | CIS | Statistical Applications | 4 |

**Table name: CLASS**

| CLASS_CODE | CRS_CODE | CLASS_SECTION | CLASS_TIME | ROOM_CODE | PROF_NUM |
|------------|----------|---------------|------------|-----------|----------|
| 10012 | ACCT-211 | 1 | MWF 8:00-8:50 a.m. | BUS311 | 105 |
| 10013 | ACCT-211 | 2 | MWF 9:00-9:50 a.m. | BUS200 | 105 |
| 10014 | ACCT-211 | 3 | TTh 2:30-3:45 p.m. | BUS252 | 342 |
| 10015 | ACCT-212 | 1 | MWF 10:00-10:50 a.m. | BUS311 | 301 |
| 10016 | ACCT-212 | 2 | Th 6:00-8:40 p.m. | BUS252 | 301 |
| 10017 | CIS-220 | 1 | MWF 9:00-9:50 a.m. | KLR209 | 228 |
| 10018 | CIS-220 | 2 | MWF 9:00-9:50 a.m. | KLR211 | 114 |
| 10019 | CIS-220 | 3 | MWF 10:00-10:50 a.m. | KLR209 | 228 |
| 10020 | CIS-420 | 1 | W 6:00-8:40 p.m. | KLR209 | 162 |
| 10021 | QM-261 | 1 | MWF 8:00-8:50 a.m. | KLR200 | 114 |
| 10022 | QM-261 | 2 | TTh 1:00-2:15 p.m. | KLR200 | 114 |
| 10023 | QM-362 | 1 | MWF 11:00-11:50 a.m. | KLR200 | 162 |
| 10024 | QM-362 | 2 | TTh 2:30-3:45 p.m. | KLR200 | 162 |
| 10025 | MATH-243 | 1 | Th 6:00-8:40 p.m. | DRE155 | 325 |

**FIGURE 4.9**

**A strong (identifying) relationship between COURSE and CLASS**



**Table name: COURSE**

Database name: Ch04_TinyCollege_Alt

| CRS_CODE | DEPT_CODE | CRS_DESCRIPTION | CRS_CREDIT |
|----------|-----------|-----------------|------------|
| ACCT-211 | ACCT | Accounting I | 3 |
| ACCT-212 | ACCT | Accounting II | 3 |
| CIS-220 | CIS | Intro. to Microcomputing | 3 |
| CIS-420 | CIS | Database Design and Implementation | 4 |
| MATH-243 | MATH | Mathematics for Managers | 3 |
| QM-261 | CIS | Intro. to Statistics | 3 |
| QM-362 | CIS | Statistical Applications | 4 |

**Table name: CLASS**

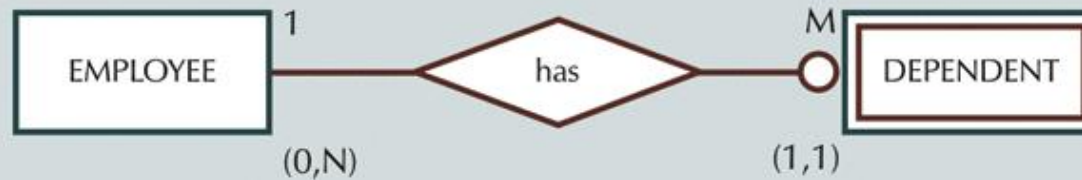| CRS_CODE | CLASS_SECTION | CLASS_TIME | ROOM_CODE | PROF_NUM |
|----------|---------------|------------|-----------|----------|
| ACCT-211 | 1 | MWF 8:00-8:50 a.m. | BUS311 | 105 |
| ACCT-211 | 2 | MWF 9:00-9:50 a.m. | BUS200 | 105 |
| ACCT-211 | 3 | TTh 2:30-3:45 p.m. | BUS252 | 342 |
| ACCT-212 | 1 | MWF 10:00-10:50 a.m. | BUS311 | 301 |
| ACCT-212 | 2 | Th 6:00-8:40 p.m. | BUS252 | 301 |
| CIS-220 | 1 | MWF 9:00-9:50 a.m. | KLR209 | 228 |
| CIS-220 | 2 | MWF 9:00-9:50 a.m. | KLR211 | 114 |
| CIS-220 | 3 | MWF 10:00-10:50 a.m. | KLR209 | 228 |
| CIS-420 | 1 | W 6:00-8:40 p.m. | KLR209 | 162 |
| MATH-243 | 1 | Th 6:00-8:40 p.m. | DRE155 | 325 |
| QM-261 | 1 | MWF 8:00-8:50 a.m. | KLR200 | 114 |
| QM-261 | 2 | TTh 1:00-2:15 p.m. | KLR200 | 114 |
| QM-362 | 1 | MWF 11:00-11:50 a.m. | KLR200 | 162 |
| QM-362 | 2 | TTh 2:30-3:45 p.m. | KLR200 | 162 |

# Weak Entities

- **Weak entity** meets two conditions
  - Existence-dependent
  - Primary key partially or totally derived from parent entity in relationship
- Database designer determines whether an entity is weak based on business rules
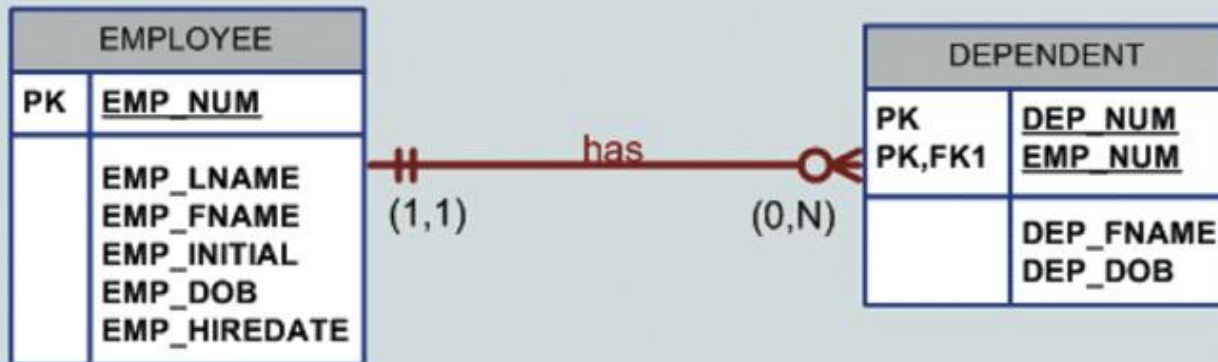
**FIGURE 4.10**  A weak entity in an ERD

## Chen Model



**EMPLOYEE** 1 — has — M — **DEPENDENT**
(0,N)  (1,1)

**EMP_NUM**
EMP_LNAME
EMP_FNAME
EMP_INITIAL
EMP_DOB
EMP_HIREDATE

**EMP_NUM**
**DEP_NUM**
DEP_FNAME
DEP_DOB

## Crow's Foot Model



| EMPLOYEE | |
|---|---|
| PK | **EMP_NUM** |
| | EMP_LNAME |
| | EMP_FNAME |
| | EMP_INITIAL |
| | EMP_DOB |
| | EMP_HIREDATE |

has
(1,1)  (0,N)

| DEPENDENT | |
|---|---|
| PK | **DEP_NUM** |
| PK,FK1 | **EMP_NUM** |
| | DEP_FNAME |
| | DEP_DOB |

19

FIGURE
4.11

## A weak entity in a strong relationship

**Table name: EMPLOYEE**

Database name: Ch04_ShortCo

| EMP_NUM | EMP_LNAME | EMP_FNAME | EMP_INITIAL | EMP_DOB | EMP_HIREDATE |
|---|---|---|---|---|---|
| 1001 | Callifante | Jeanine | J | 12-Mar-64 | 25-May-97 |
| 1002 | Smithson | William | K | 23-Nov-70 | 28-May-97 |
| 1003 | Washington | Herman | H | 15-Aug-68 | 28-May-97 |
| 1004 | Chen | Lydia | B | 23-Mar-74 | 15-Oct-98 |
| 1005 | Johnson | Melanie | | 28-Sep-66 | 20-Dec-98 |
| 1006 | Ortega | Jorge | G | 12-Jul-79 | 05-Jan-02 |
| 1007 | O'Donnell | Peter | D | 10-Jun-71 | 23-Jun-02 |
| 1008 | Brzenski | Barbara | A | 12-Feb-70 | 01-Nov-03 |

**Table name: DEPENDENT**

| EMP_NUM | DEP_NUM | DEP_FNAME | DEP_DOB |
|---|---|---|---|
| 1001 | 1 | Annelise | 05-Dec-97 |
| 1001 | 2 | Jorge | 30-Sep-02 |
| 1003 | 1 | Suzanne | 25-Jan-04 |
| 1006 | 1 | Carlos | 25-May-01 |
| 1008 | 1 | Michael | 19-Feb-95 |
| 1008 | 2 | George | 27-Jun-98 |
| 1008 | 3 | Katherine | 18-Aug-03 |

# Relationship Participation

- ## Optional participation
  - One entity occurrence does not require corresponding entity occurrence in particular relationship
- ## Mandatory participation
  - One entity occurrence requires corresponding entity occurrence in particular relationship

**TABLE 4.3**    **Crow's Foot Symbols**

| CROW'S FOOT SYMBOL | CARDINALITY | COMMENT |
|---|---|---|
| | (0,N) | Zero or many. Many side is optional. |
| | (1,N) | One or many. Many side is mandatory. |
| | (1,1) | One and only one. 1 side is mandatory. |
| | (0,1) | Zero or one. 1 side is optional. |

**FIGURE 4.13** CLASS is optional to COURSE

**FIGURE 4.14** COURSE and CLASS in a mandatory relationship

# Relationship Degree

- Indicates number of entities or participants associated with a relationship
- **Unary relationship**
  - Association is maintained within single entity
- **Binary relationship**
  - Two entities are associated
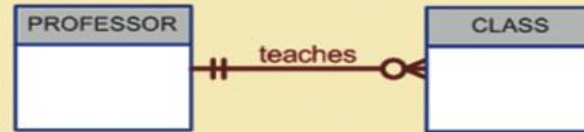- **Ternary relationship**
  - Three entities are associated
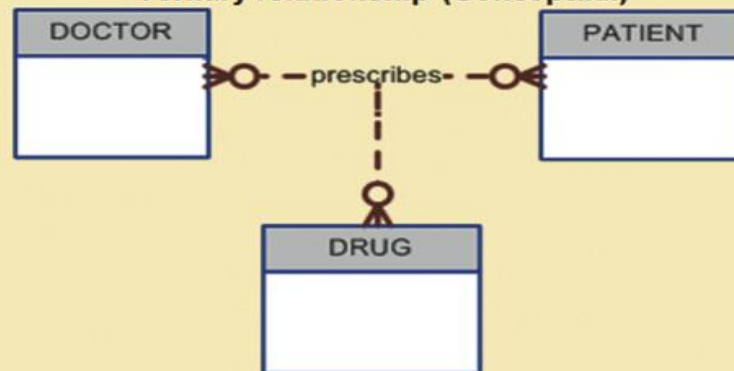
**FIGURE 4.15** Three types of relationship degree

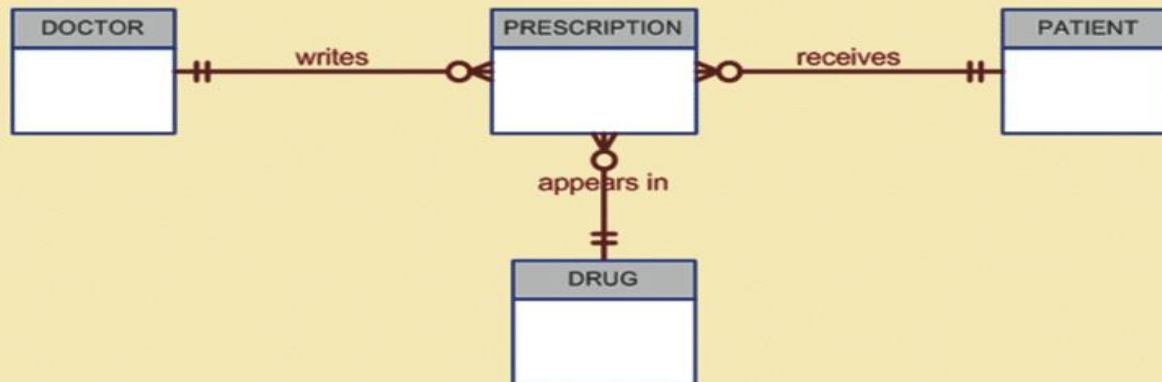**FIGURE 4.16**   The implementation of a ternary relationship

**Database name: Ch04_Clinic**

**Table name: DRUG**

| DRUG_CODE | DRUG_NAME | DRUG_PRICE |
|---|---|---|
| AF15 | Afgapan-15 | 25.00 |
| AF25 | Afgapan-25 | 35.00 |
| DRO | Droalene Chloride | 111.89 |
| DRZ | Druzocholar Cryptolene | 18.99 |
| KO15 | Koliabar Oxyhexalene | 65.75 |
| OLE | Oleander-Drizapan | 123.95 |
| TRYP | Tryptolac Heptadimetric | 79.45 |

**Table name: PATIENT**

| PAT_NUM | PAT_TITLE | PAT_LNAME | PAT_FNAME | PAT_INITIAL | PAT_DOB | PAT_AREACODE | PAT_PHONE |
|---|---|---|---|---|---|---|---|
| 100 | Mr. | Kolmycz | George | D | 15-Jun-1942 | 615 | 324-5456 |
| 101 | Ms. | Lewis | Rhonda | G | 19-Mar-2005 | 615 | 324-4472 |
| 102 | Mr. | Vandam | Rhett | | 14-Nov-1958 | 901 | 675-8993 |
| 103 | Ms. | Jones | Anne | M | 16-Oct-1974 | 615 | 898-3456 |
| 104 | Mr. | Lange | John | P | 08-Nov-1971 | 901 | 504-4430 |
| 105 | Mr. | Williams | Robert | D | 14-Mar-1975 | 615 | 890-3220 |
| 106 | Mrs. | Smith | Jeanine | K | 12-Feb-2003 | 615 | 324-7883 |
| 107 | Mr. | Diante | Jorge | D | 21-Aug-1974 | 615 | 890-4567 |
| 108 | Mr. | Wiesenbach | Paul | R | 14-Feb-1966 | 615 | 897-4358 |
| 109 | Mr. | Smith | George | K | 18-Jun-1961 | 901 | 504-3339 |
| 110 | Mrs. | Genkazi | Leighla | W | 19-May-1970 | 901 | 569-0093 |
| 111 | Mr. | Washington | Rupert | E | 03-Jan-1966 | 615 | 890-4925 |
| 112 | Mr. | Johnson | Edward | E | 14-May-1961 | 615 | 898-4387 |
| 113 | Ms. | Smythe | Melanie | P | 15-Sep-1970 | 615 | 324-9006 |
| 114 | Ms. | Brandon | Marie | G | 02-Nov-1932 | 901 | 882-0845 |
| 115 | Mrs. | Saranda | Hermine | R | 25-Jul-1972 | 615 | 324-5505 |
| 116 | Mr. | Smith | George | A | 08-Nov-1965 | 615 | 890-2984 |

**Table name: DOCTOR**

| DOC_ID | DOC_LNAME | DOC_FNAME | DOC_INITIAL | DOC_SPECIALTY |
|---|---|---|---|---|
| 29827 | Sanchez | Julio | J | Dermatology |
| 32445 | Jorgensen | Annelise | G | Neurology |
| 33456 | Korenski | Anatoly | A | Urology |
| 33989 | LeGrande | George | | Pediatrics |
| 34409 | Washington | Dennis | F | Orthopaedics |
| 36221 | McPherson | Katye | H | Dermatology |
| 36712 | Dreifag | Herman | G | Psychiatry |
| 38995 | Minh | Tran | | Neurology |
| 40004 | Chin | Ming | D | Orthopaedics |
| 40028 | Feinstein | Denise | L | Gynecology |

**Table name: PRESCRIPTION**

| DOC_ID | PAT_NUM | DRUG_CODE | PRES_DOSAGE | PRES_DATE |
|---|---|---|---|---|
| 32445 | 102 | DRZ | 2 tablets every four hours -- 50 tablets total | 12-Nov-09 |
| 32445 | 113 | OLE | 1 teaspoon with each meal -- 250 ml total | 14-Nov-09 |
| 34409 | 101 | KO15 | 1 tablet every six hours -- 30 tablets total | 14-Nov-09 |
| 36221 | 109 | DRO | 2 tablets with every meal -- 60 tablets total | 14-Nov-09 |
| 38995 | 107 | KO15 | 1 tablet every six hours -- 30 tablets total | 14-Nov-09 |

# Recursive Relationships

▸ Relationship can exist between occurrences of the same entity set
  ◦ Naturally found within unary relationship

**FIGURE 4.19** Another unary relationship: "PART contains PART"

Table name: PART_V1                                                  Database name; CH04_PartCo

| PART_CODE | PART_DESCRIPTION | PART_IN_STOCK | PART_UNITS_NEEDED | PART_OF_PART |
|-----------|-----------------|--------------|-------------------|--------------|
| AA21-6 | 2.5 cm. washer, 1.0 mm. rim | 432 | 4 | C-130 |
| AB-121 | Cotter pin, copper | 1034 | 2 | C-130 |
| C-130 | Rotor assembly | 36 | | |
| E129 | 2.5 cm. steel shank | 128 | 1 | C-130 |
| X10 | 10.25 cm. rotor blade | 345 | 4 | C-130 |
| X34AW | 2.5 cm. hex nut | 879 | 2 | C-130 |

**FIGURE 4.22**  Implementation of the 1:M recursive relationship "EMPLOYEE manages EMPLOYEE"

Database name: Ch04_PartCo
Table name: EMPLOYEE_V2

| EMP_CODE | EMP_LNAME | EMP_MANAGER |
|---|---|---|
| 101 | Waddell | 102 |
| 102 | Orincona | |
| 103 | Jones | 102 |
| 104 | Reballoh | 102 |
| 105 | Robertson | 102 |
| 106 | Deltona | 102 |

# Associative (Composite) Entities

- Also known as bridge entities
- Used to implement M:N relationships
- Composed of primary keys of each of the entities to be connected
- May also contain additional attributes that play no role in connective process

# Developing an ER Diagram

- Database design is an iterative process
  - Create detailed narrative of organization's description of operations
  - Identify business rules based on description of operations
  - Identify main entities and relationships from business rules
  - Develop initial ERD
  - Identify attributes and primary keys that adequately describe entities
  - Revise and review ERD
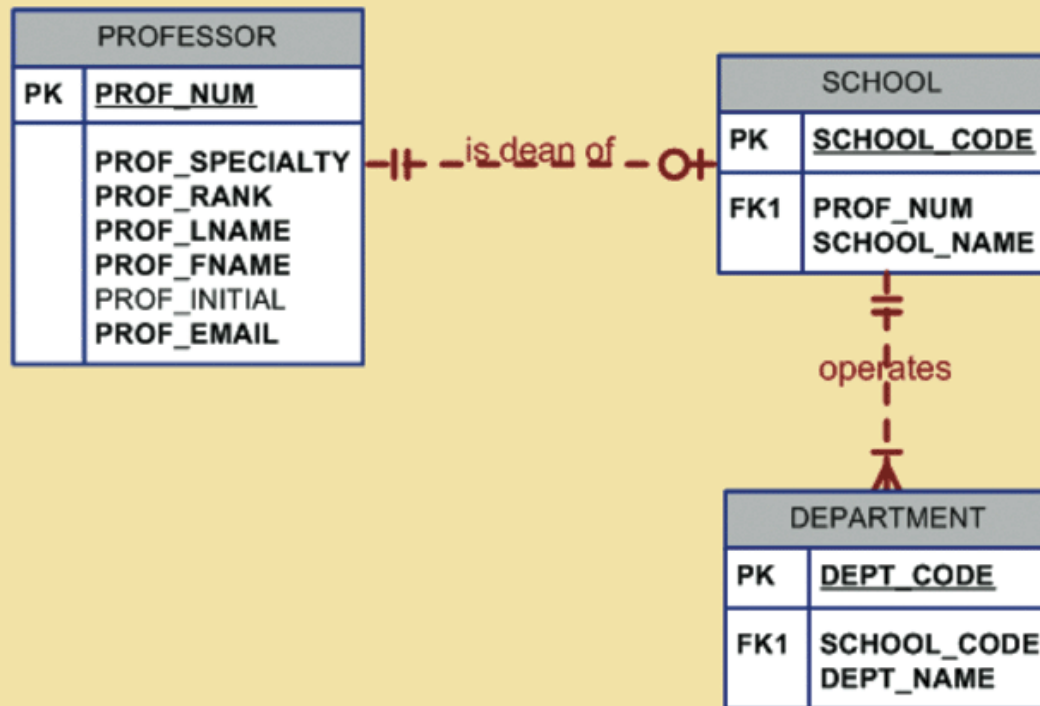
FIGURE 4.26 — The first Tiny College ERD segment

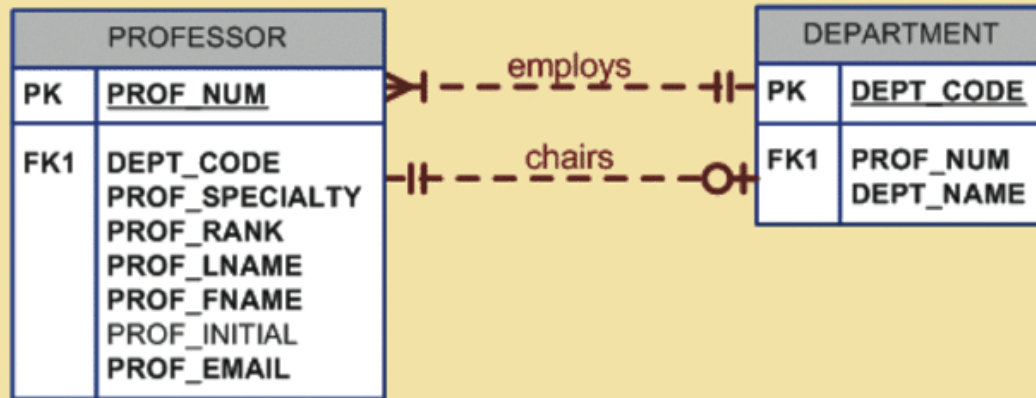**FIGURE 4.27** The second Tiny College ERD segment



**FIGURE 4.28** The third Tiny College ERD segment
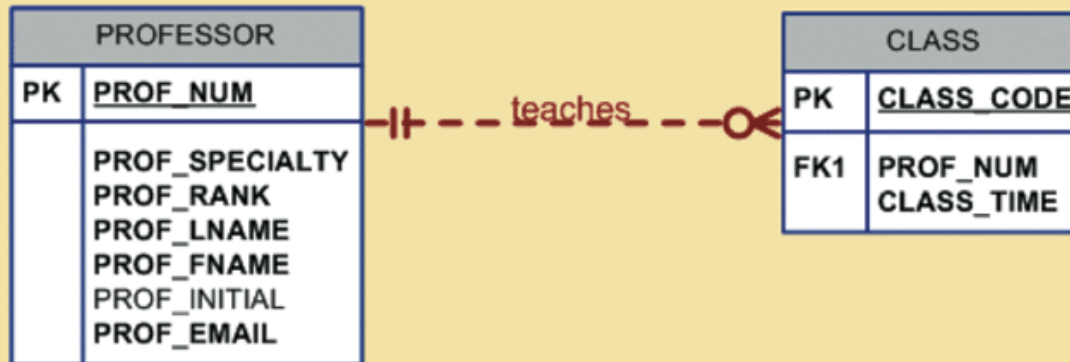
Database Systems, 9th Edition

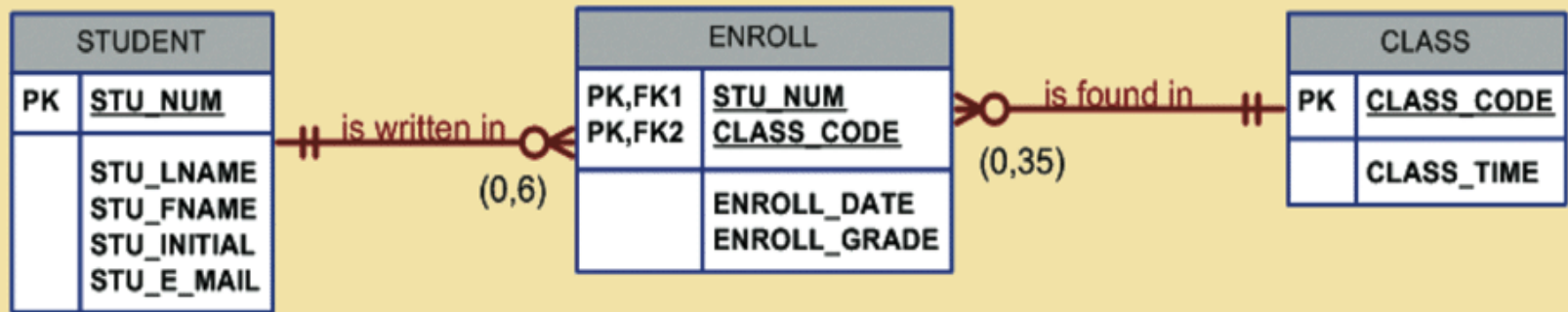**FIGURE 4.29** The fourth Tiny College ERD segment

**FIGURE 4.30** The fifth Tiny College ERD segment
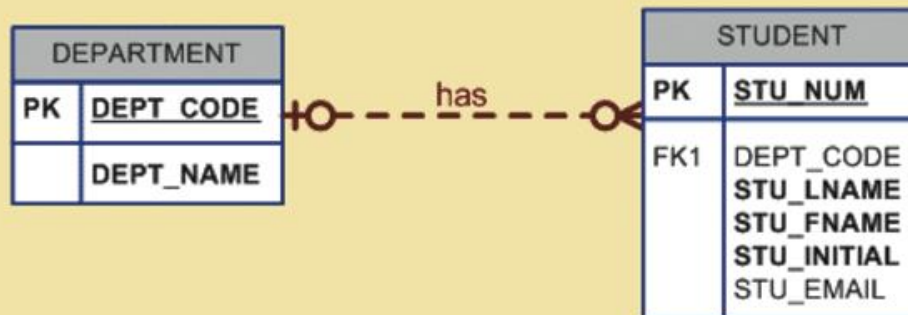
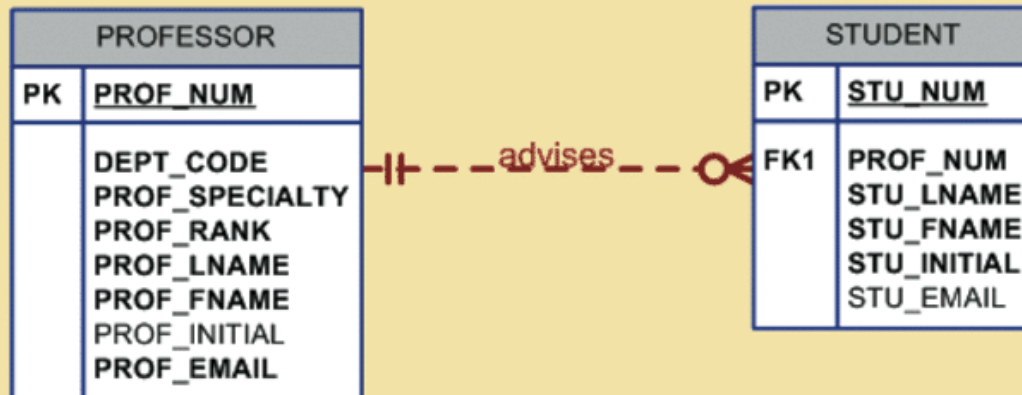**FIGURE 4.31** The sixth Tiny College ERD segment

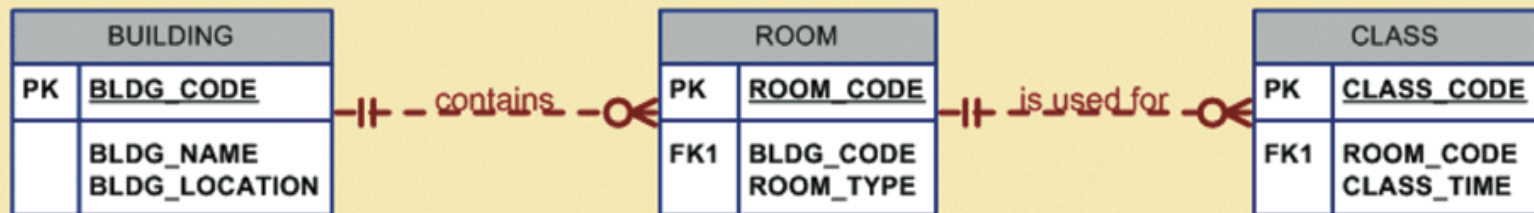**FIGURE 4.32** The seventh Tiny College ERD segment

FIGURE 4.33 The eighth Tiny College ERD segment

**FIGURE 4.34** The ninth Tiny College ERD segment

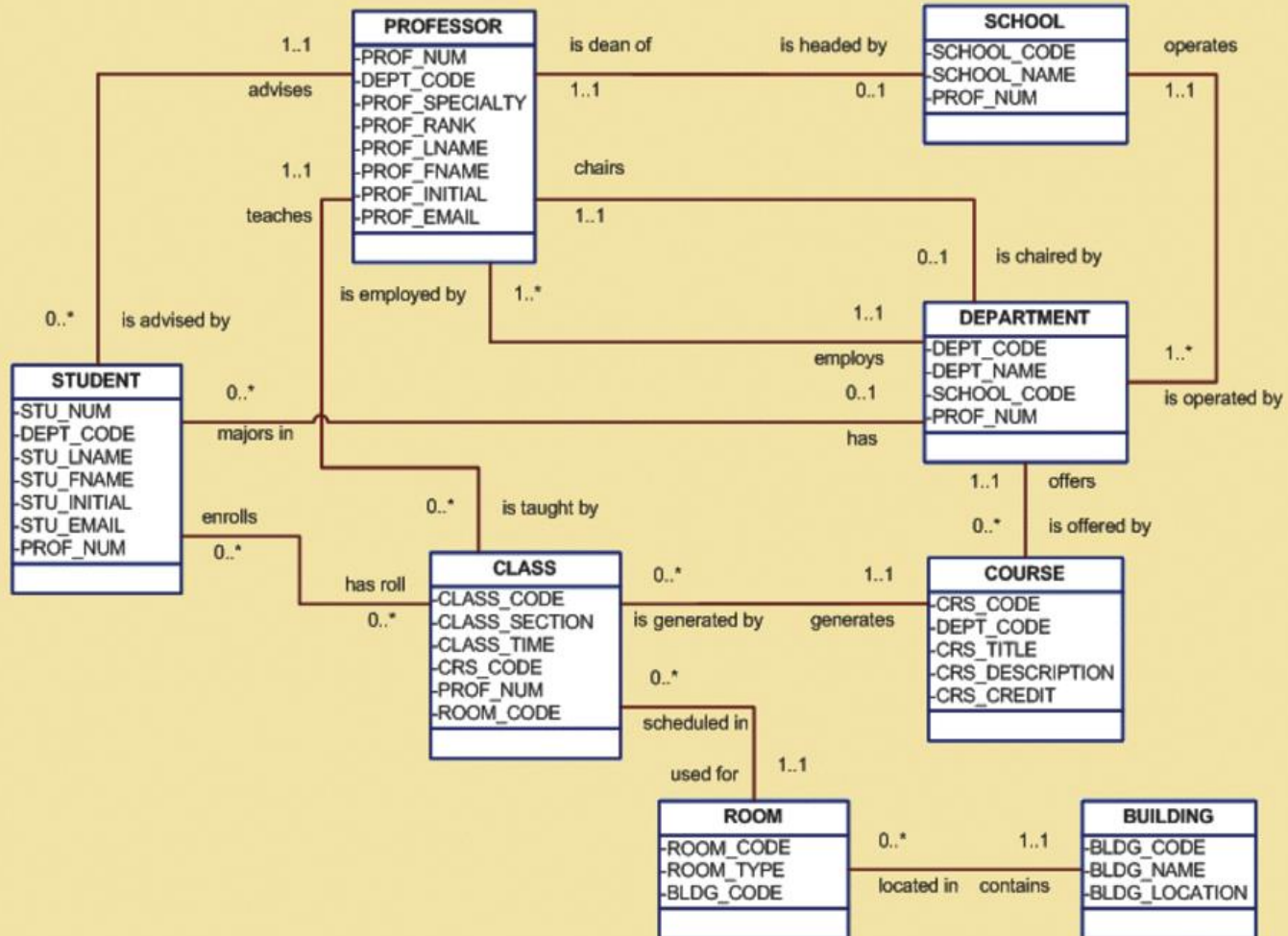| BUILDING | | | ROOM | | | CLASS | |
|---|---|---|---|---|---|---|---|
| PK | BLDG_CODE | | PK | ROOM_CODE | | PK | CLASS_CODE |
| | BLDG_NAME BLDG_LOCATION | | FK1 | BLDG_CODE ROOM_TYPE | | FK1 | ROOM_CODE CLASS_TIME |

contains — is used for

**TABLE 4.4**    **Components of the ERM**

| ENTITY | RELATIONSHIP | CONNECTIVITY | ENTITY |
|---|---|---|---|
| SCHOOL | operates | 1:M | DEPARTMENT |
| DEPARTMENT | has | 1:M | STUDENT |
| DEPARTMENT | employs | 1:M | PROFESSOR |
| DEPARTMENT | offers | 1:M | COURSE |
| COURSE | generates | 1:M | CLASS |
| PROFESSOR | is dean of | 1:1 | SCHOOL |
| PROFESSOR | chairs | 1:1 | DEPARTMENT |
| PROFESSOR | teaches | 1:M | CLASS |
| PROFESSOR | advises | 1:M | STUDENT |
| STUDENT | enrolls in | M:N | CLASS |
| BUILDING | contains | 1:M | ROOM |
| ROOM | is used for | 1:M | CLASS |

Note: ENROLL is the composite entity that implements the M:N relationship "STUDENT enrolls in CLASS."
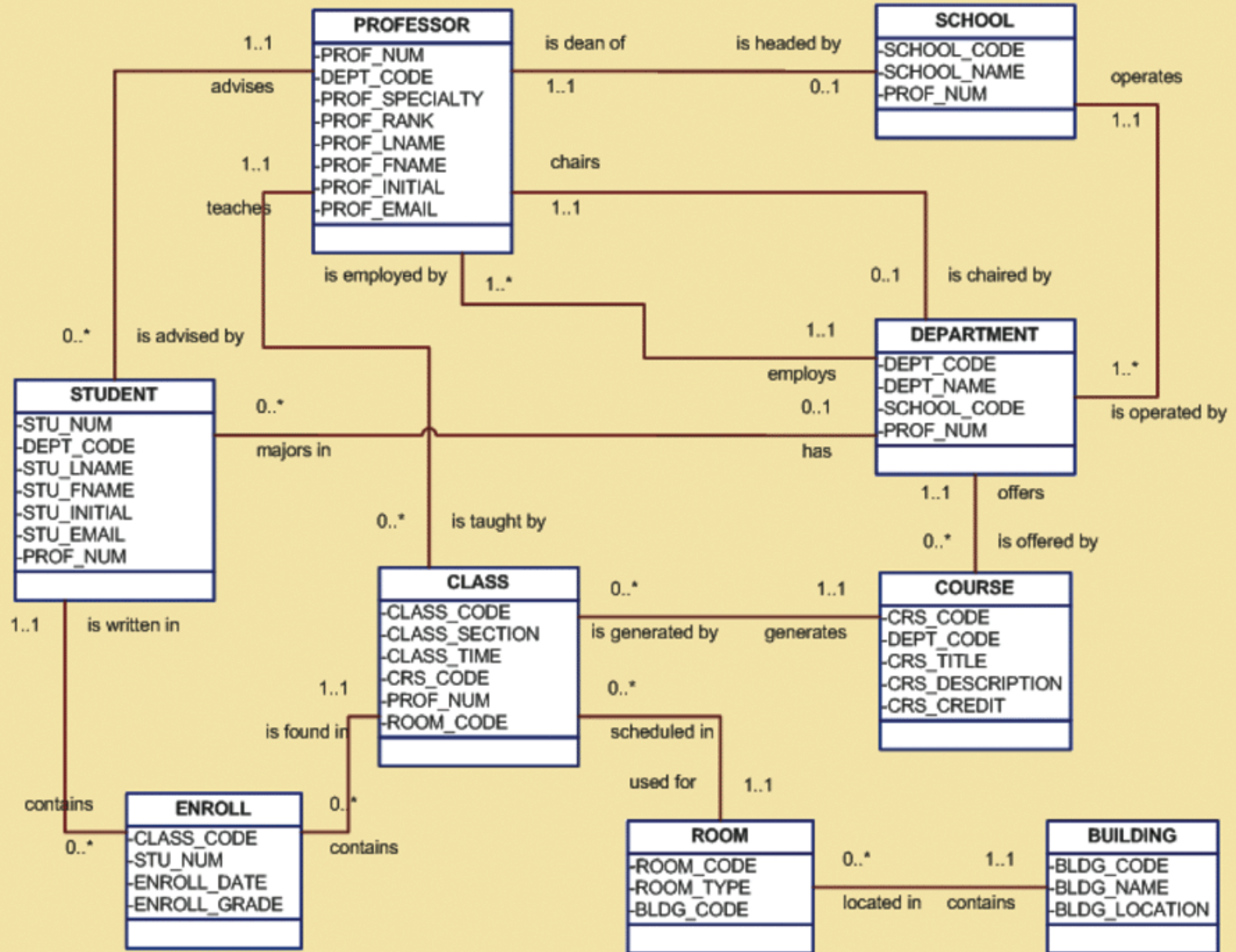
**FIGURE 4.36** The conceptual UML class diagram for Tiny College

**FIGURE 4.37** The implementation-ready UML class diagram for Tiny College

41

# Database Design Challenges: Conflicting Goals

- Database designers must make design compromises
  - Conflicting goals: design standards, processing speed, information requirements
- Important to meet logical requirements and design conventions
- Design is of little value unless it delivers all specified query and reporting requirements
- Some design and implementation problems do not yield "clean" solutions

**FIGURE 4.38** Various implementations of the 1:1 recursive relationship

Database name: Ch04_PartCo

**Table name: EMPLOYEE_V1**

| EMP_NUM | EMP_LNAME | EMP_FNAME | EMP_SPOUSE |
|---|---|---|---|
| 345 | Ramirez | James | 347 |
| 346 | Jones | Anne | 349 |
| 347 | Ramirez | Louise | 345 |
| 348 | Delaney | Robert | |
| 349 | Shapiro | Anton | 346 |

**First implementation**

**Table name: EMPLOYEE**

| EMP_NUM | EMP_LNAME | EMP_FNAME |
|---|---|---|
| 345 | Ramirez | James |
| 346 | Jones | Anne |
| 347 | Ramirez | Louise |
| 348 | Delaney | Robert |
| 349 | Shapiro | Anton |

**Table name: MARRIED_V1**

| EMP_NUM | EMP_SPOUSE |
|---|---|
| 345 | 347 |
| 346 | 349 |
| 347 | 345 |
| 349 | 346 |

**Second implementation**

**Table name: MARRIAGE**

| MAR_NUM | MAR_DATE |
|---|---|
| 1 | 04-Mar-03 |
| 2 | 02-Feb-99 |

**Table name: MARPART**

| MAR_NUM | EMP_NUM |
|---|---|
| 1 | 345 |
| 1 | 347 |
| 2 | 346 |
| 2 | 349 |

**Table name: EMPLOYEE**

| EMP_NUM | EMP_LNAME | EMP_FNAME |
|---|---|---|
| 345 | Ramirez | James |
| 346 | Jones | Anne |
| 347 | Ramirez | Louise |
| 348 | Delaney | Robert |
| 349 | Shapiro | Anton |

The relational diagram for the third implementation

**Third implementation**

43