Review Questions

3.1. Discuss the role of a high-level data model in the database design process.

3.2. List the various cases where use of a NULL value would be appropriate.

3.3. Define the following terms: *entity, attribute, attribute value, relationship instance, composite attribute, multivalued attribute, derived attribute, complex attribute, key attribute,* and *value set* (*domain*).

3.4. What is an entity type? What is an entity set? Explain the differences among an entity, an entity type, and an entity set.

3.5. Explain the difference between an attribute and a value set.

3.6. What is a relationship type? Explain the differences among a relationship instance, a relationship type, and a relationship set.

3.7. What is a participation role? When is it necessary to use role names in the description of relationship types?

3.8. Describe the two alternatives for specifying structural constraints on relationship types. What are the advantages and disadvantages of each?

3.9. Under what conditions can an attribute of a binary relationship type be migrated to become an attribute of one of the participating entity types?

3.10. When we think of relationships as attributes, what are the value sets of these attributes? What class of data models is based on this concept?

3.11. What is meant by a recursive relationship type? Give some examples of recursive relationship types.

3.12. When is the concept of a weak entity used in data modeling? Define the terms *owner entity type, weak entity type, identifying relationship type,* and *partial key*.

3.13. Can an identifying relationship of a weak entity type be of a degree greater than two? Give examples to illustrate your answer.

3.14. Discuss the conventions for displaying an ER schema as an ER diagram.

3.15. Discuss the naming conventions used for ER schema diagrams.

Exercises

3.16. Which combinations of attributes have to be unique for each individual SECTION entity in the UNIVERSITY database shown in Figure 3.20 to enforce each of the following miniworld constraints:

a. During a particular semester and year, only one section can use a particular classroom at a particular DaysTime value.

b. During a particular semester and year, an instructor can teach only one section at a particular DaysTime value.

c. During a particular semester and year, the section numbers for sections offered for the same course must all be different.

Can you think of any other similar constraints?

3.17. Composite and multivalued attributes can be nested to any number of levels. Suppose we want to design an attribute for a STUDENT entity type to keep track of previous college education. Such an attribute will have one entry for each college previously attended, and each such entry will be composed of college name, start and end dates, degree entries (degrees awarded at that college, if any), and transcript entries (courses completed at that college, if any). Each degree entry contains the degree name and the month and year the degree was awarded, and each transcript entry contains a course name, semester, year, and grade. Design an attribute to hold this information. Use the conventions in Figure 3.5.

3.18. Show an alternative design for the attribute described in Exercise 3.17 that uses only entity types (including weak entity types, if needed) and relationship types.

3.19. Consider the ER diagram in Figure 3.21, which shows a simplified schema for an airline reservations system. Extract from the ER diagram the requirements and constraints that produced this schema. Try to be as precise as possible in your requirements and constraints specification.

3.20. In Chapters 1 and 2, we discussed the database environment and database users. We can consider many entity types to describe such an environment, such as DBMS, stored database, DBA, and catalog/data dictionary. Try to specify all the entity types that can fully describe a database system and its environment; then specify the relationship types among them, and draw an ER diagram to describe such a general database environment.

3.21. Design an ER schema for keeping track of information about votes taken in the U.S. House of Representatives during the current two-year congressional session. The database needs to keep track of each U.S. STATE's Name (e.g., 'Texas', 'New York', 'California') and include the Region of the state (whose domain is {'Northeast', 'Midwest', 'Southeast', 'Southwest', 'West'}). Each CONGRESS_PERSON in the House of Representatives is described by his or her Name, plus the District represented, the Start_date when the congressperson was first elected, and the political Party to which he or she belongs (whose domain is {'Republican', 'Democrat', 'Independent', 'Other'}). The database keeps track of each BILL (i.e., proposed law), including the Bill_name, the Date_of_vote on the bill, whether the bill Passed_or_failed (whose domain is {'Yes', 'No'}), and the Sponsor (the congressperson(s) who sponsored—that is, proposed—the bill). The database also keeps track of how each congressperson voted on each bill (domain

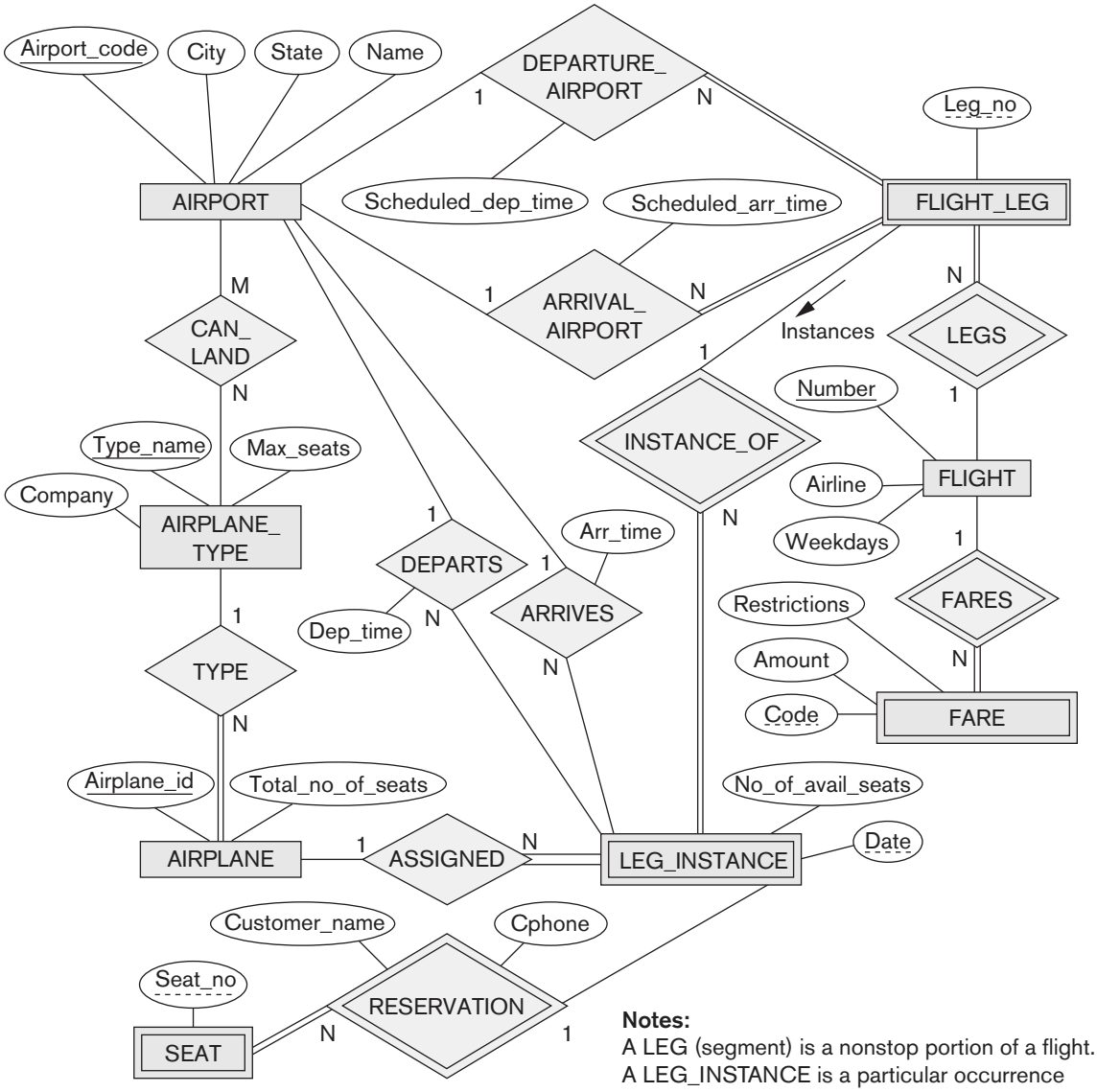


Figure 3.21
An ER diagram for an AIRLINE database schema.

of Vote attribute is {'Yes', 'No', 'Abstain', 'Absent'}). Draw an ER schema diagram for this application. State clearly any assumptions you make.

3.22. A database is being constructed to keep track of the teams and games of a sports league. A team has a number of players, not all of whom participate in each game. It is desired to keep track of the players participating in each game for each team, the positions they played in that game, and the result of

the game. Design an ER schema diagram for this application, stating any assumptions you make. Choose your favorite sport (e.g., soccer, baseball, football).

3.23. Consider the ER diagram shown in Figure 3.22 for part of a BANK database. Each bank can have multiple branches, and each branch can have multiple accounts and loans.

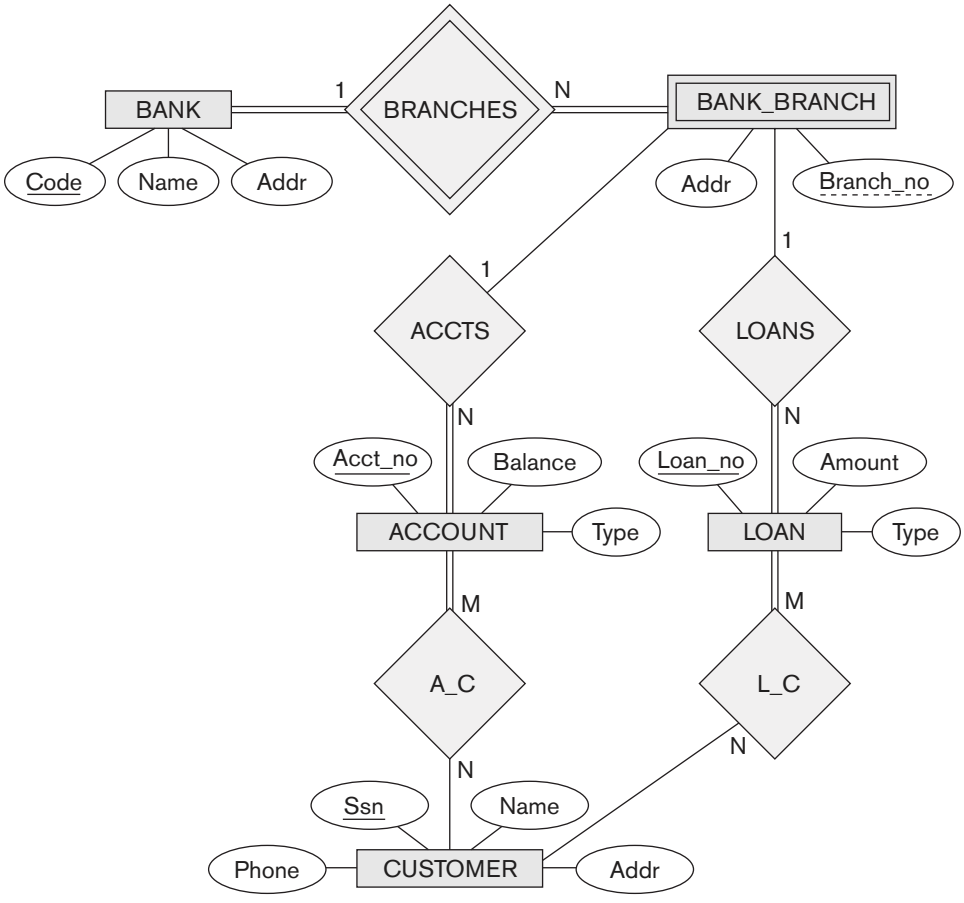
a. List the strong (nonweak) entity types in the ER diagram.

b. Is there a weak entity type? If so, give its name, partial key, and identifying relationship.

c. What constraints do the partial key and the identifying relationship of the weak entity type specify in this diagram?

d. List the names of all relationship types, and specify the (min, max) constraint on each participation of an entity type in a relationship type. Justify your choices.

Figure 3.22
An ER diagram for a BANK database schema.



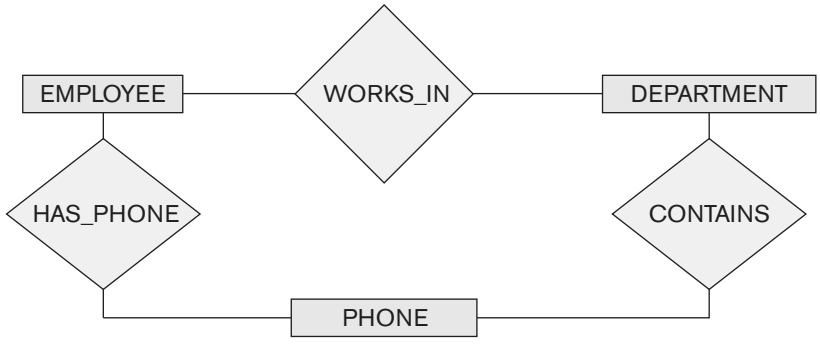


Figure 3.23
Part of an ER diagram for a COMPANY database.

e. List concisely the user requirements that led to this ER schema design.

f. Suppose that every customer must have at least one account but is restricted to at most two loans at a time, and that a bank branch cannot have more than 1,000 loans. How does this show up on the (min, max) constraints?

3.24. Consider the ER diagram in Figure 3.23. Assume that an employee may work in up to two departments or may not be assigned to any department. Assume that each department must have one and may have up to three phone numbers. Supply (min, max) constraints on this diagram. *State clearly any additional assumptions you make.* Under what conditions would the relationship HAS_PHONE be redundant in this example?

3.25. Consider the ER diagram in Figure 3.24. Assume that a course may or may not use a textbook, but that a text by definition is a book that is used in some course. A course may not use more than five books. Instructors teach from two to four courses. Supply (min, max) constraints on this diagram. *State clearly any additional assumptions you make.* If we add the relationship ADOPTS, to indicate the textbook(s) that an instructor uses for a course, should it be a binary relationship between INSTRUCTOR and TEXT, or a ternary relationship among all three entity types? What (min, max) constraints would you put on the relationship? Why?

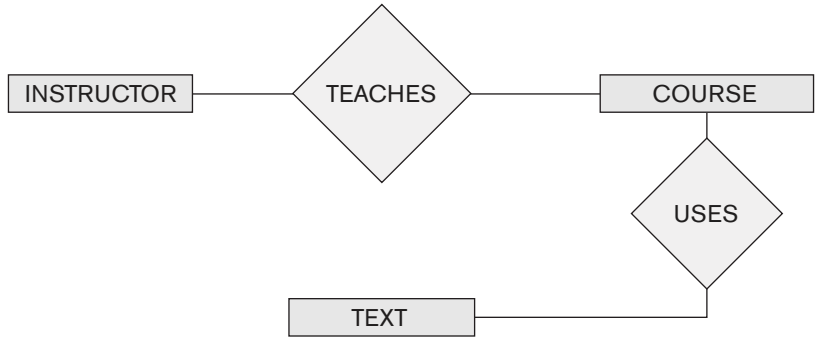


Figure 3.24
Part of an ER diagram for a COURSES database.

3.26. Consider an entity type SECTION in a UNIVERSITY database, which describes the section offerings of courses. The attributes of SECTION are Section_number, Semester, Year, Course_number, Instructor, Room_no (where section is taught), Building (where section is taught), Weekdays (domain is the possible combinations of weekdays in which a section can be offered {'MWF', 'MW', 'TT', and so on}), and Hours (domain is all possible time periods during which sections are offered {'9–9:50 A.M.', '10–10:50 A.M.', . . . , '3:30–4:50 P.M.', '5:30–6:20 P.M.', and so on}). Assume that Section_number is unique for each course within a particular semester/year combination (that is, if a course is offered multiple times during a particular semester, its section offerings are numbered 1, 2, 3, and so on). There are several composite keys for section, and some attributes are components of more than one key. Identify three composite keys, and show how they can be represented in an ER schema diagram.

3.27. Cardinality ratios often dictate the detailed design of a database. The cardinality ratio depends on the real-world meaning of the entity types involved and is defined by the specific application. For the following binary relationships, suggest cardinality ratios based on the common-sense meaning of the entity types. Clearly state any assumptions you make.

	Entity 1	Cardinality Ratio	Entity 2
1.	STUDENT	_____	SOCIAL_SECURITY_CARD
2.	STUDENT	_____	TEACHER
3.	CLASSROOM	_____	WALL
4.	COUNTRY	_____	CURRENT_PRESIDENT
5.	COURSE	_____	TEXTBOOK
6.	ITEM (that can be found in an order)	_____	ORDER
7.	STUDENT	_____	CLASS
8.	CLASS	_____	INSTRUCTOR
9.	INSTRUCTOR	_____	OFFICE
10.	EBAY_AUCTION_ITEM	_____	EBAY_BID

3.28. Consider the ER schema for the MOVIES database in Figure 3.25.

Assume that MOVIES is a populated database. ACTOR is used as a generic term and includes actresses. Given the constraints shown in the ER schema, respond to the following statements with *True, False*, or *Maybe*. Assign a response of *Maybe* to statements that, although not explicitly shown to be *True*, cannot be proven *False* based on the schema as shown. Justify each answer.

a. There are no actors in this database that have been in no movies.

b. There are some actors who have acted in more than ten movies.

c. Some actors have done a lead role in multiple movies.

d. A movie can have only a maximum of two lead actors.

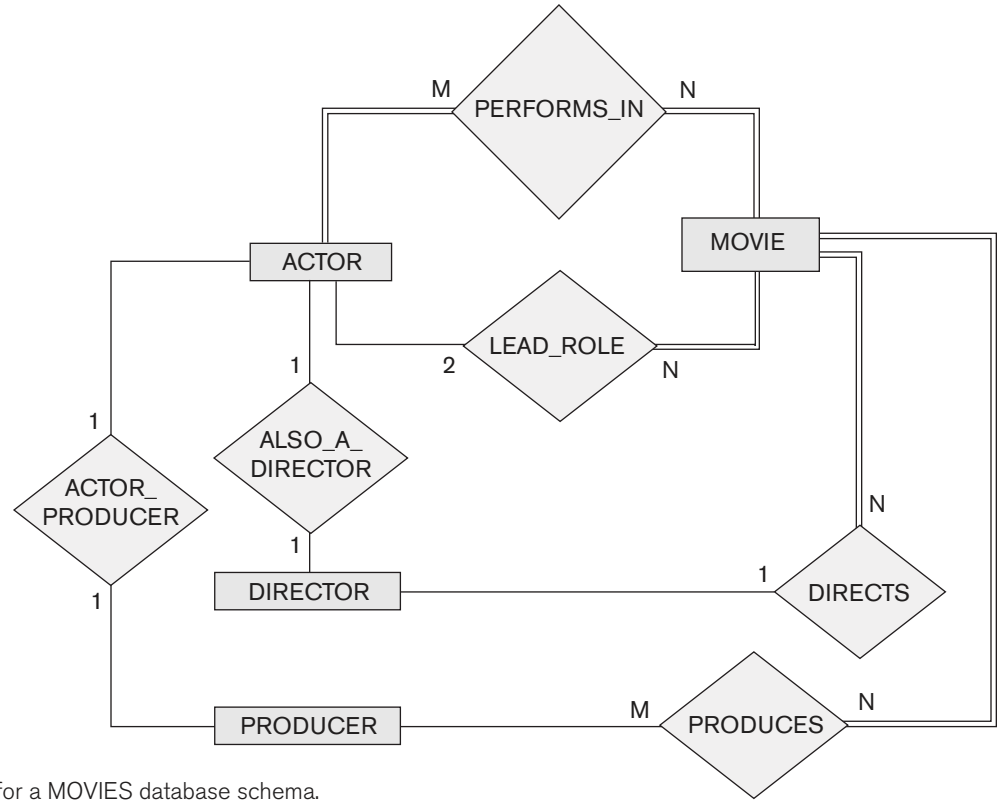


Figure 3.25
An ER diagram for a MOVIES database schema.

e. Every director has been an actor in some movie.
f. No producer has ever been an actor.
g. A producer cannot be an actor in some other movie.
h. There are movies with more than a dozen actors.
i. Some producers have been a director as well.
j. Most movies have one director and one producer.
k. Some movies have one director but several producers.
l. There are some actors who have done a lead role, directed a movie, and produced a movie.
m. No movie has a director who also acted in that movie.

3.29. Given the ER schema for the MOVIES database in Figure 3.25, draw an instance diagram using three movies that have been released recently. Draw instances of each entity type: MOVIES, ACTORS, PRODUCERS, DIRECTORS involved; make up instances of the relationships as they exist in reality for those movies.

3.30. Illustrate the UML diagram for Exercise 3.16. Your UML design should observe the following requirements:

a. A student should have the ability to compute his/her GPA and add or drop majors and minors.

b. Each department should be able to add or delete courses and hire or terminate faculty.

c. Each instructor should be able to assign or change a student's grade for a course.

Note: Some of these functions may be spread over multiple classes.

Laboratory Exercises

3.31. Consider the UNIVERSITY database described in Exercise 3.16. Build the ER schema for this database using a data modeling tool such as ERwin or Rational Rose.

3.32. Consider a MAIL_ORDER database in which employees take orders for parts from customers. The data requirements are summarized as follows:

- The mail order company has employees, each identified by a unique employee number, first and last name, and Zip Code.
- Each customer of the company is identified by a unique customer number, first and last name, and Zip Code.
- Each part sold by the company is identified by a unique part number, a part name, price, and quantity in stock.
- Each order placed by a customer is taken by an employee and is given a unique order number. Each order contains specified quantities of one or more parts. Each order has a date of receipt as well as an expected ship date. The actual ship date is also recorded.

Design an entity–relationship diagram for the mail order database and build the design using a data modeling tool such as ERwin or Rational Rose.

3.33. Consider a MOVIE database in which data is recorded about the movie industry. The data requirements are summarized as follows:

- Each movie is identified by title and year of release. Each movie has a length in minutes. Each has a production company, and each is classified under one or more genres (such as horror, action, drama, and so forth). Each movie has one or more directors and one or more actors appear in it. Each movie also has a plot outline. Finally, each movie has zero or more quotable quotes, each of which is spoken by a particular actor appearing in the movie.
- Actors are identified by name and date of birth and appear in one or more movies. Each actor has a role in the movie.

4.9. How does a category differ from a regular shared subclass? What is a category used for? Illustrate your answer with examples.

4.10. For each of the following UML terms (see Sections 3.8 and 4.6), discuss the corresponding term in the EER model, if any: *object*, *class*, *association*, *aggregation*, *generalization*, *multiplicity*, *attributes*, *discriminator*, *link*, *link attribute*, *reflexive association*, and *qualified association*.

4.11. Discuss the main differences between the notation for EER schema diagrams and UML class diagrams by comparing how common concepts are represented in each.

4.12. List the various data abstraction concepts and the corresponding modeling concepts in the EER model.

4.13. What aggregation feature is missing from the EER model? How can the EER model be further enhanced to support it?

4.14. What are the main similarities and differences between conceptual database modeling techniques and knowledge representation techniques?

4.15. Discuss the similarities and differences between an ontology and a database schema.

Exercises

4.16. Design an EER schema for a database application that you are interested in. Specify all constraints that should hold on the database. Make sure that the schema has at least five entity types, four relationship types, a weak entity type, a superclass/subclass relationship, a category, and an n-ary ($n > 2$) relationship type.

4.17. Consider the BANK ER schema in Figure 3.21, and suppose that it is necessary to keep track of different types of ACCOUNTS (SAVINGS_ACCTS, CHECKING_ACCTS, …) and LOANS (CAR_LOANS, HOME_LOANS, …). Suppose that it is also desirable to keep track of each ACCOUNT's TRANSACTIONS (deposits, withdrawals, checks, …) and each LOAN's PAYMENTS; both of these include the amount, date, and time. Modify the BANK schema, using ER and EER concepts of specialization and generalization. State any assumptions you make about the additional requirements.

4.18. The following narrative describes a simplified version of the organization of Olympic facilities planned for the summer Olympics. Draw an EER diagram that shows the entity types, attributes, relationships, and specializations for this application. State any assumptions you make. The Olympic facilities are divided into sports complexes. Sports complexes are divided into *one-sport* and *multisport* types. Multisport complexes have areas of the complex designated for each sport with a location indicator (e.g., center, NE corner, and so

on). A complex has a location, chief organizing individual, total occupied area, and so on. Each complex holds a series of events (e.g., the track stadium may hold many different races). For each event there is a planned date, duration, number of participants, number of officials, and so on. A roster of all officials will be maintained together with the list of events each official will be involved in. Different equipment is needed for the events (e.g., goal posts, poles, parallel bars) as well as for maintenance. The two types of facilities (one-sport and multisport) will have different types of information. For each type, the number of facilities needed is kept, together with an approximate budget.

4.19. Identify all the important concepts represented in the library database case study described below. In particular, identify the abstractions of classification (entity types and relationship types), aggregation, identification, and specialization/generalization. Specify (min, max) cardinality constraints whenever possible. List details that will affect the eventual design but that have no bearing on the conceptual design. List the semantic constraints separately. Draw an EER diagram of the library database.

Case Study: The Georgia Tech Library (GTL) has approximately 16,000 members, 100,000 titles, and 250,000 volumes (an average of 2.5 copies per book). About 10% of the volumes are out on loan at any one time. The librarians ensure that the books that members want to borrow are available when the members want to borrow them. Also, the librarians must know how many copies of each book are in the library or out on loan at any given time. A catalog of books is available online that lists books by author, title, and subject area. For each title in the library, a book description is kept in the catalog; the description ranges from one sentence to several pages. The reference librarians want to be able to access this description when members request information about a book. Library staff includes chief librarian, departmental associate librarians, reference librarians, check-out staff, and library assistants.

Books can be checked out for 21 days. Members are allowed to have only five books out at a time. Members usually return books within three to four weeks. Most members know that they have one week of grace before a notice is sent to them, so they try to return books before the grace period ends. About 5% of the members have to be sent reminders to return books. Most overdue books are returned within a month of the due date. Approximately 5% of the overdue books are either kept or never returned. The most active members of the library are defined as those who borrow books at least ten times during the year. The top 1% of membership does 15% of the borrowing, and the top 10% of the membership does 40% of the borrowing. About 20% of the members are totally inactive in that they are members who never borrow.

To become a member of the library, applicants fill out a form including their SSN, campus and home mailing addresses, and phone numbers. The librari-

ans issue a numbered, machine-readable card with the member's photo on it. This card is good for four years. A month before a card expires, a notice is sent to a member for renewal. Professors at the institute are considered automatic members. When a new faculty member joins the institute, his or her information is pulled from the employee records and a library card is mailed to his or her campus address. Professors are allowed to check out books for three-month intervals and have a two-week grace period. Renewal notices to professors are sent to their campus address.

The library does not lend some books, such as reference books, rare books, and maps. The librarians must differentiate between books that can be lent and those that cannot be lent. In addition, the librarians have a list of some books they are interested in acquiring but cannot obtain, such as rare or out-of-print books and books that were lost or destroyed but have not been replaced. The librarians must have a system that keeps track of books that cannot be lent as well as books that they are interested in acquiring. Some books may have the same title; therefore, the title cannot be used as a means of identification. Every book is identified by its International Standard Book Number (ISBN), a unique international code assigned to all books. Two books with the same title can have different ISBNs if they are in different languages or have different bindings (hardcover or softcover). Editions of the same book have different ISBNs.

The proposed database system must be designed to keep track of the members, the books, the catalog, and the borrowing activity.

4.20. Design a database to keep track of information for an art museum. Assume that the following requirements were collected:

- The museum has a collection of ART_OBJECTS. Each ART_OBJECT has a unique Id_no, an Artist (if known), a Year (when it was created, if known), a Title, and a Description. The art objects are categorized in several ways, as discussed below.
- ART_OBJECTS are categorized based on their type. There are three main types—PAINTING, SCULPTURE, and STATUE—plus another type called OTHER to accommodate objects that do not fall into one of the three main types.
- A PAINTING has a Paint_type (oil, watercolor, etc.), material on which it is Drawn_on (paper, canvas, wood, etc.), and Style (modern, abstract, etc.).
- A SCULPTURE or a statue has a Material from which it was created (wood, stone, etc.), Height, Weight, and Style.
- An art object in the OTHER category has a Type (print, photo, etc.) and Style.
- ART_OBJECTs are categorized as either PERMANENT_COLLECTION (objects that are owned by the museum) and BORROWED. Information captured about objects in the PERMANENT_COLLECTION includes Date_acquired, Status (on display, on loan, or stored), and Cost. Information

captured about BORROWED objects includes the Collection from which it was borrowed, Date_borrowed, and Date_returned.

- Information describing the country or culture of Origin (Italian, Egyptian, American, Indian, and so forth) and Epoch (Renaissance, Modern, Ancient, and so forth) is captured for each ART_OBJECT.
- The museum keeps track of ARTIST information, if known: Name, DateBorn (if known), Date_died (if not living), Country_of_origin, Epoch, Main_style, and Description. The Name is assumed to be unique.
- Different EXHIBITIONS occur, each having a Name, Start_date, and End_date. EXHIBITIONS are related to all the art objects that were on display during the exhibition.
- Information is kept on other COLLECTIONS with which the museum interacts; this information includes Name (unique), Type (museum, personal, etc.), Description, Address, Phone, and current Contact_person.

Draw an EER schema diagram for this application. Discuss any assumptions you make, and then justify your EER design choices.

4.21. Figure 4.12 shows an example of an EER diagram for a small-private-airport database; the database is used to keep track of airplanes, their owners, airport employees, and pilots. From the requirements for this database, the following information was collected: Each AIRPLANE has a registration number [Reg#], is of a particular plane type [OF_TYPE], and is stored in a particular hangar [STORED_IN]. Each PLANE_TYPE has a model number [Model], a capacity [Capacity], and a weight [Weight]. Each HANGAR has a number [Number], a capacity [Capacity], and a location [Location]. The database also keeps track of the OWNERs of each plane [OWNS] and the EMPLOYEEs who have maintained the plane [MAINTAIN]. Each relationship instance in OWNS relates an AIRPLANE to an OWNER and includes the purchase date [Pdate]. Each relationship instance in MAINTAIN relates an EMPLOYEE to a service record [SERVICE]. Each plane undergoes service many times; hence, it is related by [PLANE_SERVICE] to a number of SERVICE records. A SERVICE record includes as attributes the date of maintenance [Date], the number of hours spent on the work [Hours], and the type of work done [Work_code]. We use a weak entity type [SERVICE] to represent airplane service, because the airplane registration number is used to identify a service record. An OWNER is either a person or a corporation. Hence, we use a union type (category) [OWNER] that is a subset of the union of corporation [CORPORATION] and person [PERSON] entity types. Both pilots [PILOT] and employees [EMPLOYEE] are subclasses of PERSON. Each PILOT has specific attributes license number [Lic_num] and restrictions [Restr]; each EMPLOYEE has specific attributes salary [Salary] and shift worked [Shift]. All PERSON entities in the database have data kept on their Social Security number [Ssn], name [Name], address [Address], and telephone number [Phone]. For CORPORATION entities, the data kept includes name [Name], address [Address], and telephone number [Phone]. The database also keeps track of the types of

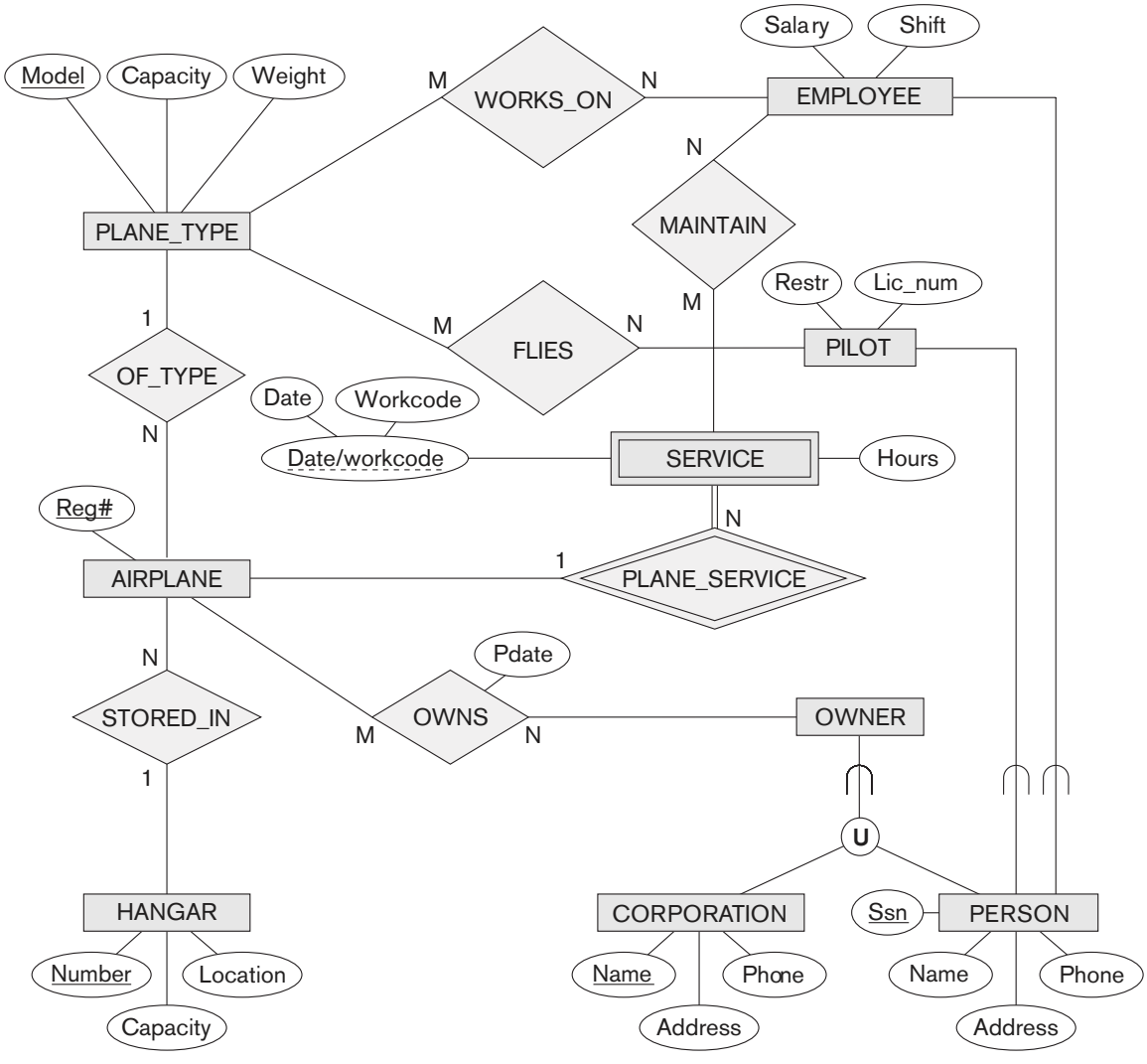


Figure 4.12
EER schema for a SMALL_AIRPORT database.

planes each pilot is authorized to fly [FLIES] and the types of planes each employee can do maintenance work on [WORKS_ON]. Show how the SMALL_AIRPORT EER schema in Figure 4.12 may be represented in UML notation. (*Note*: We have not discussed how to represent categories (union types) in UML, so you do not have to map the categories in this and the following question.)

4.22. Show how the UNIVERSITY EER schema in Figure 4.9 may be represented in UML notation.

4.23. Consider the entity sets and attributes shown in the following table. Place a checkmark in one column in each row to indicate the relationship between the far left and far right columns.

a. The left side has a relationship with the right side.

b. The right side is an attribute of the left side.

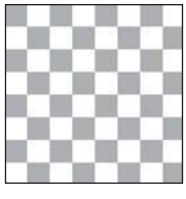
c. The left side is a specialization of the right side.

d. The left side is a generalization of the right side.

	Entity Set	(a) Has a Relationship with	(b) Has an Attribute that is	(c) Is a Specialization of	(d) Is a Generalization of	Entity Set or Attribute
1.	MOTHER					PERSON
2.	DAUGHTER					MOTHER
3.	STUDENT					PERSON
4.	STUDENT					Student_id
5.	SCHOOL					STUDENT
6.	SCHOOL					CLASS_ROOM
7.	ANIMAL					HORSE
8.	HORSE					Breed
9.	HORSE					Age
10.	EMPLOYEE					SSN
11.	FURNITURE					CHAIR
12.	CHAIR					Weight
13.	HUMAN					WOMAN
14.	SOLDIER					PERSON
15.	ENEMY_COMBATANT					PERSON

4.24. Draw a UML diagram for storing a played game of chess in a database. You may look at http://www.chessgames.com for an application similar to what you are designing. State clearly any assumptions you make in your UML diagram. A sample of assumptions you can make about the scope is as follows:

1. The game of chess is played between two players.
2. The game is played on an 8 × 8 board like the one shown below:



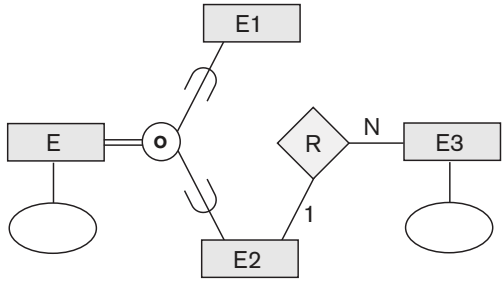
3. The players are assigned a color of black or white at the start of the game.
4. Each player starts with the following pieces (traditionally called chessmen):
   a. king
   b. queen
   c. 2 rooks
   d. 2 bishops
   e. 2 knights
   f. 8 pawns
5. Every piece has its own initial position.
6. Every piece has its own set of legal moves based on the state of the game. You do not need to worry about which moves are or are not legal except for the following issues:
   a. A piece may move to an empty square or capture an opposing piece.
   b. If a piece is captured, it is removed from the board.
   c. If a pawn moves to the last row, it is "promoted" by converting it to another piece (queen, rook, bishop, or knight).

   Note: Some of these functions may be spread over multiple classes.

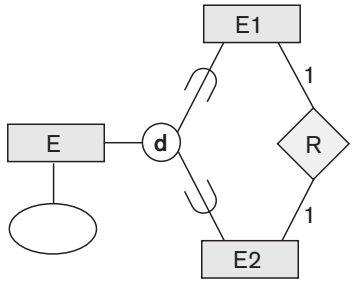
4.25. Draw an EER diagram for a game of chess as described in Exercise 4. 24. Focus on persistent storage aspects of the system. For example, the system would need to retrieve all the moves of every game played in sequential order.

4.26. Which of the following EER diagrams is/are incorrect and why? State clearly any assumptions you make.

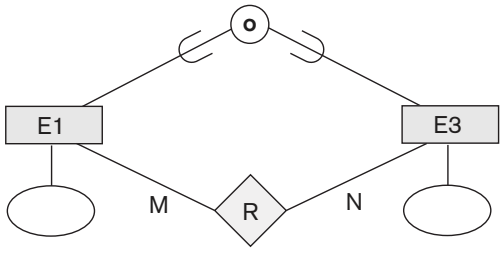
a.



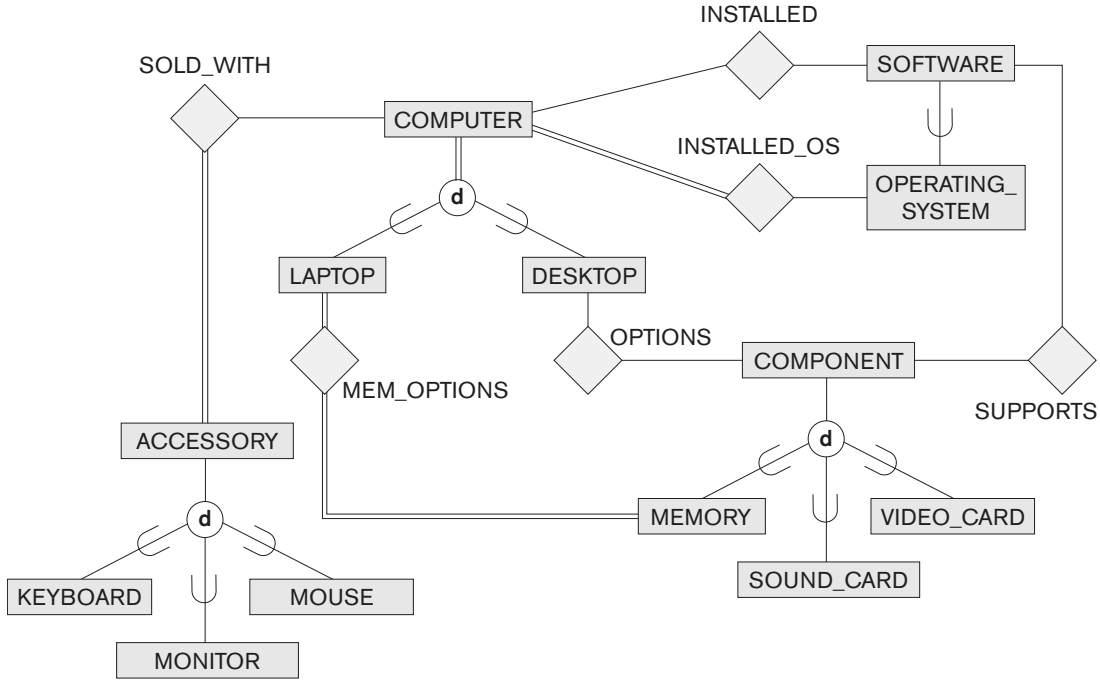
b.



c.



4.27. Consider the following EER diagram that describes the computer systems at a company. Provide your own attributes and key for each entity type. Supply max cardinality constraints justifying your choice. Write a complete narrative description of what this EER diagram represents.



Laboratory Exercises

4.28. Consider a GRADE_BOOK database in which instructors within an academic department record points earned by individual students in their classes. The data requirements are summarized as follows:

- Each student is identified by a unique identifier, first and last name, and an e-mail address.
- Each instructor teaches certain courses each term. Each course is identified by a course number, a section number, and the term in which it is taught. For