Unit 3
The Relational Model
And From ER Diagram To Relational Database

Sets, Relations, and Tables

◆ In this unit, we learn the semantics of specifying a relational database, later we will learn the syntax of SQL for doing this

◆ The basic "datatype", or "variable" of a relational database is a **relation**

◆ In this unit, such a variable will be a **set**

◆ Later, we will extend this, and such a variable will be a **multiset**

◆ In SQL, such a variable is called a **table**

◆ We may use the term table for a relation in this unit too

◆ Good review of basic concepts and terminology is available at http://en.wikipedia.org/wiki/Relational_databases

Sets

◆ We will not use axiomatic set theory

◆ A ***set*** is a "bag" of elements, some/all of which could be sets themselves and a binary relationship "is element of" denoted by $\in$, such as $2 \in \{2, 5, 3, 7\}$, $\{2,8\} \in \{2, \{2, 8\}, 5, 3, 7\}$,

◆ You cannot specify

- How many times an element appears in a set (if you could, this would be a ***multiset***)

- In which position an element appears (if you could, this would be a ***sequence***)

◆ Therefore, as sets: $\{2, 5, 3, 7\} = \{2, 7, 5, 3, 5, 3, 3\}$

◆ Note: in many places you will read: "an element can appear in a set only once"

This is not quite right. And it is important not to assume this, as we will see in a later unit

Sets

◆ Two sets *A* and *B* are equal iff (if and only if) they have the same elements

◆ In other words, for every *x*: *x* is an element of *A* iff (if and only if) *x* is an element of *B*

◆ In still different way: *A* and *B* are equal iff for every possible *x*, the questions "is *x* in *A*" *and* "is *x* in *B*" give the same answer

  • Note there is no discussion or even a way of saying how many times *x* appears in a set, really either none or at least once

◆ "More mathematically,"

  $A = B$ means $\forall\, x \,\{\, x \in A \Leftrightarrow x \in B \,\}$

◆ Therefore, as sets: {2, 5, 3, 7} = {2, 7, 5, 3, 5, 3, 3}

◆ This reiterates what we have said previously

Relation

◆ Consider a table, with a fixed number of columns where elements of each column are drawn from some specific domain

◆ The columns are labeled and the labels are distinct

◆ We will consider such a table to be **a set of rows** (another word for "row": **tuple**)

◆ An example of a table S of two columns A and B

S	A	B
	a	2
	a	2
	b	3
	c	4
	d	3

◆ A **relation** is such a table

◆ We will also write S(A,B) for table S with columns A and B

Relational Schema

◆ What we saw was an ***instance*** (current value for a relation with the defined columns and domains)

◆ To specify this relation in general (not the specific instance) we need to talk about a ***relational schema***

◆ A relational schema defines a set of relations

◆ In databases everything is finite, so a relational schema defines a finite set of finite relations

Relational Schema

◆ Here is an informal, but complete, description what is a relational schema of one relation

◆ We want to define a structure for some table

1. We give it a name (we had S)

2. We chose the number of columns (we had 2) and give them distinct names (we had A and B)

3. We decide on the domains of elements in the columns (we had letters for A and integers for B)

4. We decide on constraints, if any, on the permitted values (for example, we can assume as it was true for our example that any two rows that are equal on A must be equal on B)

Relational Schema

◆ Let's verify

- *A:* all lower case letters in English
- *B:* all positive integers less than 100
- *S(A,B)* satisfies the condition that any two tuples that are equal on *A* must also be equal on B

◆ Our example was an instance of this relational schema

S	A	B
	a	2
	a	2
	b	3
	c	4
	d	3

Relations

◆ Since relations are **sets** of tuples, *the following two relations are equal* (are really one relation written in two different ways)

(This is a different example, not an instance of the previous relational schema)

S	A	B
a		2
a		56
b		2

S	A	B
a		56
a		2
b		2
a		56
a		2
a		56

Relations

◆ Since *the positions* in the tuple (1st, 2nd, etc.) are labeled with the column headings, *the following two relations are equal* (are really one relation written in two different ways)

S	A	B
	a	2
	a	56
	b	2

S	B	A
	56	a
	2	a
	2	b
	56	a
	2	a
	56	a

Relations

◆ To specify relations, it is enough to do what we have done above

◆ As long as we understand what are the domains for the columns, the following are formally fully specified relations

- Relational (schema) P(Name, SSN, DOB, Grade) with some (not specified, but we should have done it) domains for attributes
- Relational (schema) Q(Grade, Salary) with some (not specified, but we should have done it) domains for attributes

P	Name	SSN	DOB	Grade
	A	121	2367	2
	B	101	3498	4
	C	106	2987	2

Q	Grade	Salary
	1	90
	2	80
	3	70
	4	70

Relations

◆ But we will do more. We will specify, as suitable for the schema:

- *Primary keys*
- *Keys* (beyond primary)
- *Foreign keys* and what they reference (we will see soon what this means)
- Additional constraints

◆ Some of the constraints involve more than one relation

◆ The above are most important structurally

◆ Later, when we talk about SQL DDL, we will specify additional properties

Keys (and Superkeys)

◆ Consider relation (schema) Person(FN, LN, Grade, YOB)
◆ Instance:

Person	FN	LN	Grade	YOB
	John	Smith	8	1976
	Lakshmi	Smith	9	1981
	John	Smith	8	1976
	John	Yao	9	1992

◆ We are told that any two tuples that are equal on both FN and LN are (completely) equal

  • We have some tuples appearing multiple times: this is just for clarifying that this is permitted in the definition, we do not discuss here why we would have the same tuple more than one time (we will talk about this later)

◆ This is a property of *every possible instance* of Person in our application—we are told that

◆ Then (FN, LN) is a *superkey* of Person, and in fact a *key*, because neither FN nor LN by themselves are sufficient (we are told that too)

Keys (and Superkeys)

◆ Consider relation (schema) Q(Grade, Salary)

◆ Example:

Pay	Grade	Salary
	8	128
	9	139
	7	147

◆ We are told that for any instance of Pay, any two tuples that are equal on Grade are (completely) equal

- Of course, if each Grade appears in only one tuple, this is automatically true

◆ Then, similarly to before, Grade is a key

◆ What about Salary, is this a key also?

◆ No, because we **are not told (that is, we are not guaranteed)** that any two tuples that are equal on Salary are equal on Grade in every instance of Pay

Keys (and Superkeys)

- A set of columns in a relation is a **superkey** if and only any two tuples that are equal on the elements of these columns are (completely equal)

- *A relation always has at least one superkey*

- The set of all the attributes is a superkey

- Because any two tuples that are equal on all attributes are completely equal

- A minimal superkey, is a **key**

- A relation always has at least one key (start with any superkey and remove unnecessary columns)

- There may be more than one key

- Exactly one key is chosen as **primary key**

- Other keys are just keys

- Sometimes they are called **candidate keys** (as they are candidates for the primary key, though not chosen)

Keys (and Superkeys)

◆ We will underline the attributes of the chosen primary key

◆ Returning to Unit 2 and example of City:
   City(Longitude,Latitude,Country,State,Name,Size)

◆ We can have

- City(<u>Longitude</u>,<u>Latitude</u>,Country,State,Name,Size)
- This implies that Longitude,Latitude form a primary key
- We also have a candidate key: Country,State,Name

◆ We can have

- City(Longitude,Latitude,<u>Country</u>,<u>State</u>,<u>Name</u>,Size)
- This implies that Country,State,Name form a primary key
- We also have a candidate key: Longitude,Latitude

Relational Databases

◆ A ***relational database*** is "basically" a set of relations

◆ It is an instance of a relational schema

◆ This is what is formally correct, but it is misleading in practice

◆ As we will see later, a relational database is

- A set of relations
- A set of binary, many-to-one mappings between them (partial functions)

◆ We will know later what this means exactly, but I did not want to leave you with not quite a useful definition

17

From ER Diagrams To Relational Database

◆ We are now ready to convert ER diagrams into relational databases

◆ *Generally, but not always*

- *An entity set is converted into a table*
- *A relationship is converted into a table*

◆ We will first go through a simple example

◆ Then, we will go through our large example, studied previously

◆ Then, we look at some additional points of interest

◆ Finally, we summarize the process, so we are sure we understand it

18

Small ER Diagram
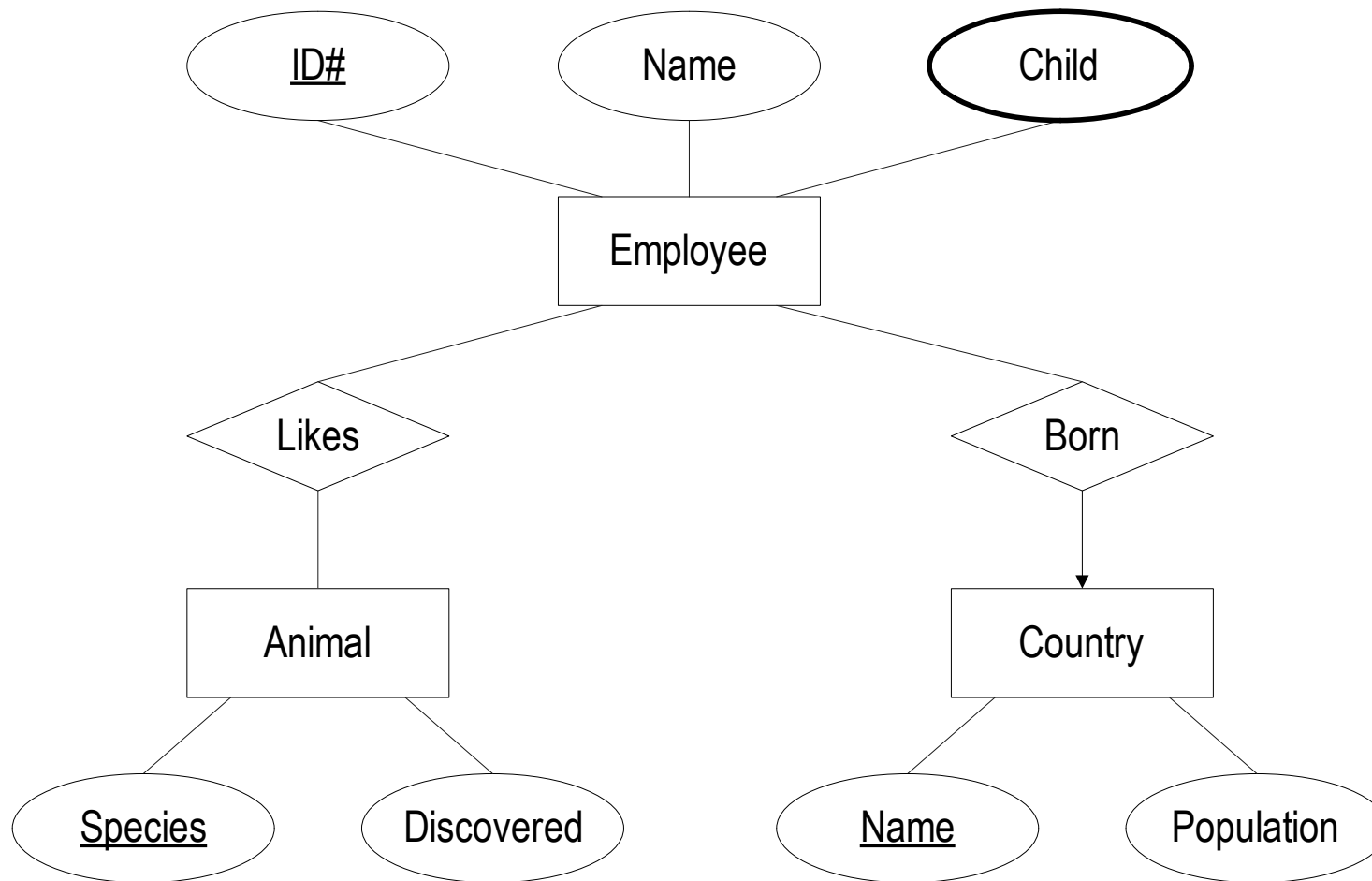
More About The Example

◆ The given ER diagram is clear, other than

- Discovered, which is the continent in which a particular species was first discovered

◆ Each child is a "dependent" of only one employee in our database

- If both parents are employees, the child is "assigned" to one of them

◆ We are given additional information about the application

- ***Values of attributes in a primary key must not be missing*** (this is a general rule, not only for this example)
- Other than attributes in a primary key, other attributes, unless stated otherwise, may be missing
- The value of Name is known (not missing) for every Employee

◆ To build up our intuition, let's look at some specific instance of our application

Small Example

- ◆ 5 Employees:
  - 1 is Alice has Erica and Frank, born in US, likes Horse and Cat
  - 2 is Bob has Bob and Frank, born in US, likes Cat
  - 4 is Carol
  - 5 is David, born in IN
  - 6 is Bob, has Frank, born in CN, likes Yak

- ◆ 4 Countries
  - US
  - IN has 1408
  - CN has 1412
  - RU

- ◆ 4 Animals
  - Horse in Asia
  - Wolf in Asia
  - Cat in Africa
  - Yak in Asia
  - Zebra in Africa

Country

◆ There are four countries, listing for them: Cname, Population (the latter only when known):

- US

- IN, 1408

- CN, 1412

- RU

◆ We create a table for Country "in the most obvious way," by ***creating a column for each attribute*** (underlining the attributes of the primary key) and this works:

Country	Cname	Population
	US	
	IN	1408
	CN	1412
	RU	

◆ Note that some "slots" are NULL, indicated by emptiness

Animal

◆ There are five animals, listing for them: Species, Discovered (note, that even though not required, Discovered happens to be known for every Species):

- Horse, Asia
- Wolf, Asia
- Cat, Africa
- Yak, Asia
- Zebra, Africa

◆ We create a table for Animal as before, and this works:

Animal	Species	Discovered
	Horse	Asia
	Wolf	Asia
	Cat	Africa
	Yak	Asia
	Zebra	Africa

Employee

◆ There are five employees, listing for them: ID#, Name, (name of) Child (note there may be any number of Child values for an Employee, zero or more):

- 1, Alice, Erica, Frank
- 2, Bob, Bob, Frank
- 4, Carol
- 5, David
- 6, Bob, Frank

◆ We create a table for Employee in the most obvious way, and this *does not* work:

Employee	ID#	Name	Child	Child
	1	Alice	Erica	Frank
	2	Bob	Bob	Frank
	4	Carol		
	5	David		
	6	Bob	Frank	

Employee

◆ Child is a multivalued attribute so, the number of columns labeled "Child" is, in principle, unbounded

◆ A table ***must have*** a fixed number of columns

- It must be an instance in/of a relational schema

◆ If we are ready to store up to 8 children for an employee and create a table with 8 columns for children, perhaps tomorrow we get an employee with 9 children, who will not "fit"

◆ We ***replace our attempted single table*** for Employee ***by two tables***

- One for all the attributes of Employee other than the multivalued one (Child)
- One for pairs of the form (primary key of Employee, Child)

◆ Note that both tables have a fixed number of columns, no matter how many children an employee has

Employee And Child

◆ Replace (incorrect)

Employee	ID#	Name	Child	Child
	1	Alice	Erica	Frank
	2	Bob	Bob	Frank
	4	Carol		
	5	David		
	6	Bob	Frank	

By (correct)

Employee	ID#	Name
	1	Alice
	2	Bob
	4	Carol
	5	David
	6	Bob

Child	ID#	Child
	1	Erica
	1	Frank
	2	Bob
	2	Frank
	6	Frank

Employee And Child With Better Column Names

◆ Replace (incorrect)

Employee	ID#	Name	Child	Child
	1	Alice	Erica	Frank
	2	Bob	Bob	Frank
	4	Carol		
	5	David		
	6	Bob	Frank	

By (correct)

Employee	ID#	Name
	1	Alice
	2	Bob
	4	Carol
	5	David
	6	Bob

Child	Parent	Child
	1	Erica
	1	Frank
	2	Bob
	2	Frank
	6	Frank

Employee And Child

◆ The primary key of the table Employee is ID#

◆ The primary key of the table Child is the pair: ID#,Child

◆ One attribute is not sufficient to get a primary key for Child

◆ It is clear from the example *how to handle any number of multivalued attributes* an entity has

  • *Create a "main" table with all the attributes other than multivalued ones*

    Its *primary key* is the original primary key of the entity set

  • *Create a table for each multivalued attribute consisting a primary key for the main table and that multivalued attribute*

    Its *primary key* is the primary key of the entity combined with

    the multivalued attribute

Foreign Key

◆ Let us return to our example

◆ Note that any value of ID# that appears in Child must also appear in Employee
  - Because a child must be a dependent of an existing employee

◆ This is an instance of a *foreign key*

◆ ID# in Child is a *foreign key referencing* Employee
  - This means that ID# appearing in Child must appear in some row "under" columns (here only one) of primary key in Employee
  - Note that ID# is not a key of Child (but is part of a key), *so a foreign key in a table does not have to be a key of that table*

Employee	ID#	Name
	1	Alice
	2	Bob
	4	Carol
	5	David
	6	Bob

Child	ID#	Child
	1	Erica
	1	Frank
	2	Bob
	2	Frank
	6	Frank

Foreign Key ≡ A Binary Many-To-One Relationship Between Tables (Partial Function)

Employee	ID#	Name		Child	ID#	Child
	1	Alice			1	Erica
	2	Bob			1	Frank
	4	Carol			2	Bob
	5	David			2	Frank
	6	Bob			6	Frank

◆ Note:

- Every row of Child has a single value of a primary key of Employee, so every row of Child "maps" to a single row of Employee

- Every row of Employee has zero or more rows of Child mapped into it

    In other words, no constraint

Foreign Key ≡ A Binary Many-To-One Relationship Between Tables

Employee	ID#	Name
	1	Alice
	2	Bob
	4	Carol
	5	David
	6	Bob

Child	Parent	Child
	1	Erica
	1	Frank
	2	Bob
	2	Frank
	6	Frank

◆ Another option

◆ Note names do not have to be the same for the mapping to take place

◆ But you need to specify which column is foreign key referring to what

- Here: Parent in Child is foreign key referencing Employee

Born

◆ Born needs to specify which employees were born in which countries (for whom this information is known)

◆ We can list what is the current state

- Employee identified by 1 was born in country identified by US
- Employee identified by 2 was born in country identified by IN
- Employee identified by 5 was born in country identified by IN
- Employee identified by 6 was born in country identified by CN

Born

◆ Born needs to specify who was born where

◆ We have tables for
- Employee
- Country

◆ We know that **each employee was born in at most one country** (actually was born in exactly one country but we may not know what it is)

◆ We have a **binary many-to-one relationship** between Employee and Country

Employee	ID#	Name
	1	Alice
	2	Bob
	4	Carol
	5	David
	6	Bob

Country	Cname	Population
	US	
	IN	1408
	CN	1412
	RU	

Implementation For Born

◆ Augment Employee so instead of

Employee	ID#	Name
	1	Alice
	2	Bob
	4	Carol
	5	David
	6	Bob

Country	Cname	Population
	US	
	IN	1408
	CN	1412
	RU	

we have

Employee	ID#	Name	Cname
	1	Alice	US
	2	Bob	IN
	4	Carol	
	5	David	IN
	6	Bob	CN

Country	Cname	Population
	US	
	IN	1408
	CN	1412
	RU	

Implementation For Born

◆ Augment Employee so instead of
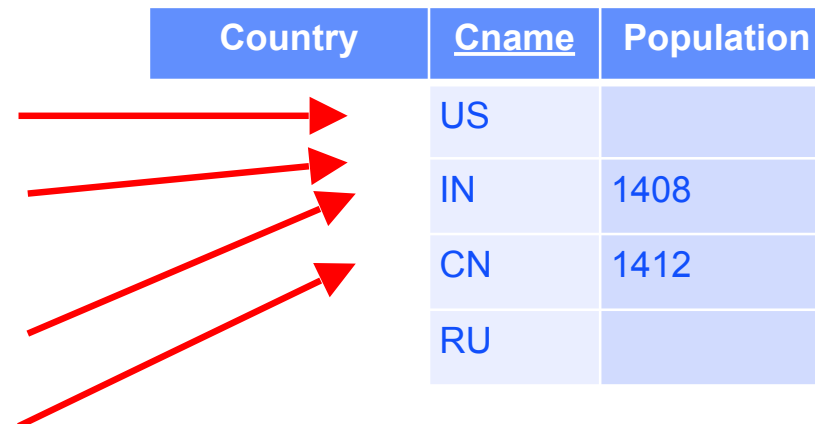
Employee	ID#	Name
	1	Alice
	2	Bob
	4	Carol
	5	David
	6	Bob

Country	Cname	Population
	US	
	IN	1408
	CN	1412
	RU	

we have two tables and a binary many-to-one mapping

Employee	ID#	Name	Cname
	1	Alice	US
	2	Bob	IN
	4	Carol	
	5	David	IN
	6	Bob	CN
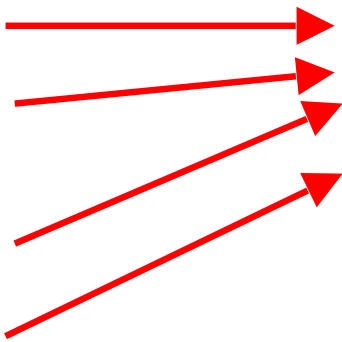
Country	Cname	Population
	US	
	IN	1408
	CN	1412
	RU	

Foreign Key Constraint Implementing Born

◆ We have again a foreign key constraint

◆ Any value of Cname in Employee must also appear in Country as a primary key in some row

◆ Cname in Employee is a foreign key referencing Country

◆ Note that Cname in Employee is not even a part of its primary key

Employee	ID#	Name	Cname
	1	Alice	US
	2	Bob	IN
	4	Carol	
	5	David	IN
	6	Bob	CN

Country	Cname	Population
	US	
	IN	1408
	CN	1412
	RU	

Foreign Key Constraint Implementing Born

◆ Perhaps better (and frequently done in practice) use a different name for foreign keys

◆ Any value of CBirth in Employee must also appear in Country as a primary key in some row

◆ CBirth in Employee is a foreign key referencing Country

◆ We will not talk about such, possibly convenient, renaming

Employee	ID#	Name	CBirth
	1	Alice	US
	2	Bob	IN
	4	Carol	
	5	David	IN
	6	Bob	CN

Country	Cname	Population
	US	
	IN	1408
	CN	1412
	RU	
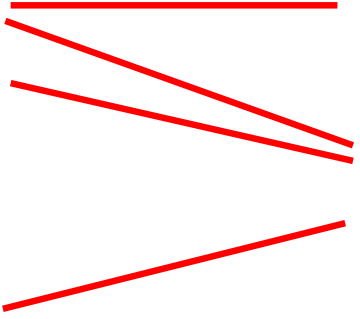
Likes

◆ Likes needs to specify which employees like which animals

◆ We can list what is the current state:

- Employee identified by 1 likes animal identified by Horse
- Employee identified by 1 likes animal identified by Cat
- Employee identified by 2 likes animal identified by Cat
- Employee identified by 6 likes animal identified by Yak

Likes

◆ We can describe Likes by drawing lines between the two tables

◆ We need to "store" this set of red lines

◆ ***Likes is a many-to-many relationship***

  • ***It is not a many-to-one relationship and therefore it is not a partial function***
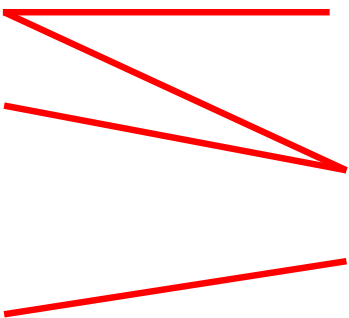
Employee	ID#	Name		Animal	Species	Discovered
	1	Alice			Horse	Asia
	2	Bob			Wolf	Asia
	4	Carol			Cat	Africa
	5	David			Yak	Asia
	6	Bob			Zebra	Africa

Likes (impossible implementation)

◆ Cannot store with Employee (there is no limit on the number of animals an employee likes)

Employee	ID#	Name
	1	Alice
	2	Bob
	4	Carol
	5	David
	6	Bob

Animal	Species	Discovered
	Horse	Asia
	Wolf	Asia
	Cat	Africa
	Yak	Asia
	Zebra	Africa
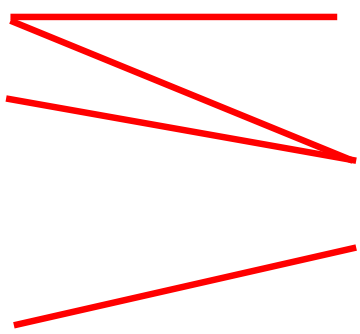
Employee	ID#	Name	Species	Species
	1	Alice	Horse	Cat
	2	Bob	Cat	
	4	Carol		
	5	David		
	6	Bob	Yak	

Likes (impossible implementation)

◆ Cannot store with Animal (there is no limit on the number of employees who like an animal)

Employee	ID#	Name
	1	Alice
	2	Bob
	4	Carol
	5	David
	6	Bob

Animal	Species	Discovered
	Horse	Asia
	Wolf	Asia
	Cat	Africa
	Yak	Asia
	Zebra	Africa

Animal	Species	Discovered	ID#	ID#
	Horse	Asia	1	
	Wolf	Asia		
	Cat	Africa	1	2
	Yak	Asia	6	
	Zebra	Africa		

Likes

◆ Each red line is an **edge** defined by its vertices

◆ We create a table storing the red lines; that is, its vertices

◆ We can do this using the **primary keys** of the entities

　We do not need other attributes such as Name or Discovered

◆ The table for Likes contains tuples:
- 1 likes Horse
- 1 likes Cat
- 2 likes Cat
- 6 likes Yak

Likes	ID#	Species
	1	Horse
	1	Cat
	2	Cat
	6	Yak

Likes

◆ Note that *there are foreign key constraints*
  - ID# appearing in Likes is a foreign key referencing Employee
  - Species appearing in Likes is a foreign key referencing Animal

◆ And two many-to-one mappings are induced

◆ Note: *a binary many-to-many relationship was replaced by a new table and two many-to one relationships*

Employee	ID#	Name	Likes	ID#	Species	Animal	Species	Discovered
	1	Alice		1	Horse		Horse	Asia
	2	Bob		1	Cat		Wolf	Asia
	4	Carol		2	Cat		Cat	Africa
	5	David		6	Yak		Yak	Asia
	6	Bob					Zebra	Africa

Specifying A Relational Implementation

◆ Many tools for ***producing relational schema***

◆ ***Focus on tables and the implicit many-to-one binary relationships induced by foreign key constraints***

◆ ***Table***

- Typically a rectangle with three vertical subrectangles: name, list of attributes in the primary key, list of attributes not in the primary key

- Required attributes are in bold

- Attributes in the primary key and foreign keys are labeled as such

◆ ***Relationship***

- ***A many-to-one binary*** (or perhaps one-to-one, which is a special case) relationship induced by a ***foreign key constraint*** is usually explicitly drawn by means of a segment with an arrow head

  We will see alternative notations later

Relational Implementation For The Example

Country	CName	Population
	US	
	IN	1408
	CN	1412
	RU	

Child	ID#	Child
	1	Erica
	1	Frank
	2	Bob
	2	Frank
	6	Frank

Employee	ID#	Name	CName
	1	Alice	US
	2	Bob	IN
	4	Carol	
	5	David	IN
	6	Bob	CN

Animal	Species	Discovered
	Horse	Asia
	Wolf	Asia
	Cat	Africa
	Yak	Asia
	Zebra	Africa

Likes	ID#	Species
	1	Horse
	1	Cat
	2	Cat
	6	Yak

Country

PK	CName
	Population

Child

PK,FK1 PK	ID# Child

Employee

PK	ID#
FK1	Name CName

Animal

PK	Species
	Discovered

Likes

PK,FK1 PK,FK2	ID# Species

Cardinality Constraints

◆ The statement that a relationship is many-to-one as opposed to a "standard" many-to-many relationship is really a cardinality constraint

◆ We will look at a relationship Likes between Person and Country and four cases of cardinality constraints on how many Countries a Person may like

- No constraint
- At least one
- At most one
- Exactly one

◆ For the first two, Likes is many-to-many

◆ For the last two, Likes is many-to-one

◆ Intuitively, Likes is many to one if for every Person, when you see which Countries this Person Likes, you get 0 or 1

◆ If you always get 1, this is a total function, otherwise this is a partial function

Specifying These Constraints
(Revisited From Unit 2)
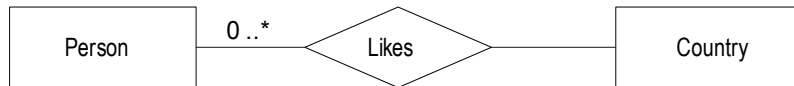
Person —— 0 ..* —— Likes —— Country   Every Person likes 0 or more Countries

Person —— 1 ..* —— Likes —— Country   Every Person likes 1 or more Countries
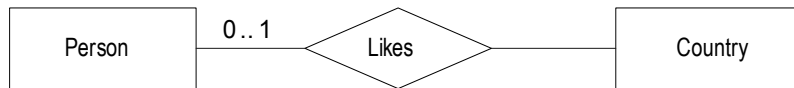
Person —— 0 .. 1 —— Likes —— Country   Every Person likes 0 or 1 Countries
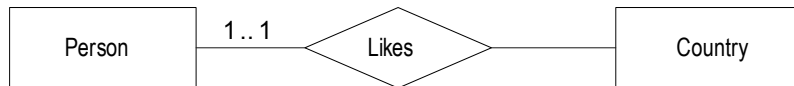
Person —— 1 .. 1 —— Likes —— Country   Every Person likes 1 Country

Arrow Notation Cannot Distinguish Some Cases

| Person | 0 ..* | Likes | Country |

| Person | Likes | Country |

| Person | 1 ..* | Likes | Country |

| Person | Likes | Country |

| Person | 0 .. 1 | Likes | Country |

| Person | Likes | → Country |

| Person | 1 .. 1 | Likes | Country |

| Person | Likes | → Country |
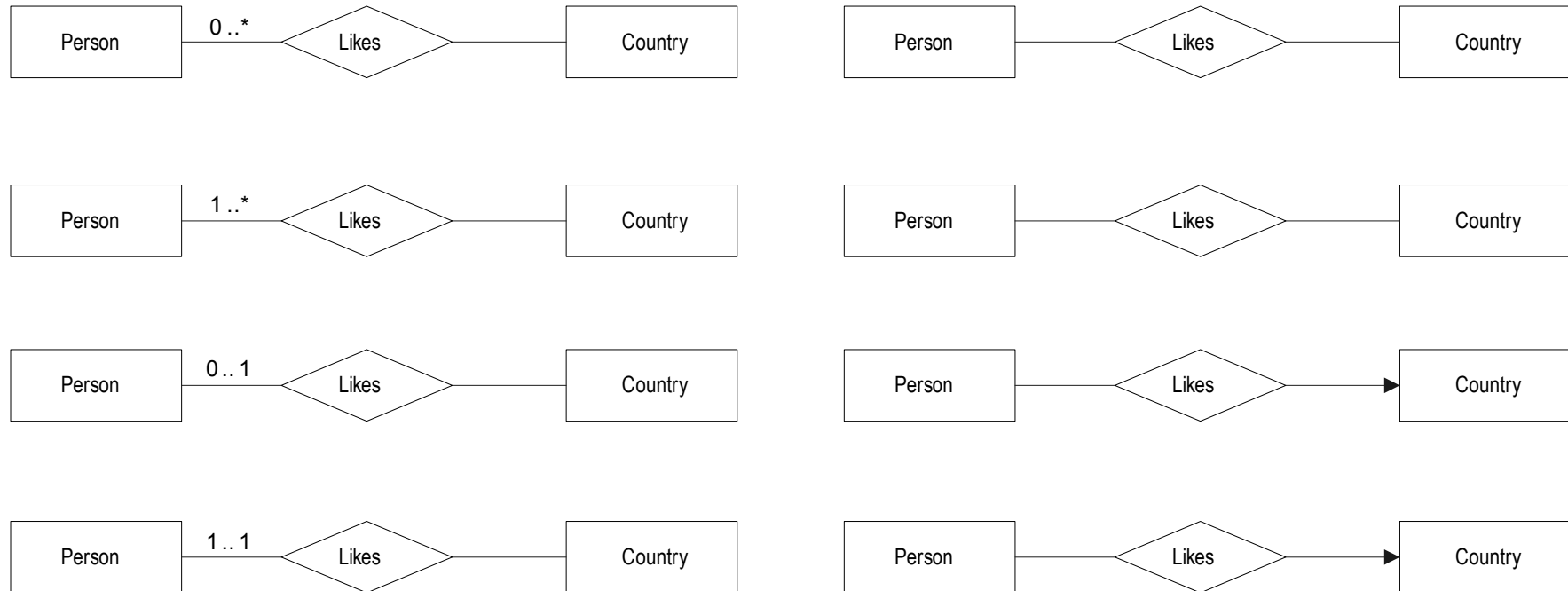
Crow's Feet: Improved Arrow Notation

◆ *Note: different sides of the relationship are labeled in the two notations!*

| Person | 0 ..* | Likes | Country | | Person | Likes | Country |

| Person | 1 ..* | Likes | Country | | Person | Likes | Country |

| Person | 0 .. 1 | Likes | Country | | Person | Likes | Country |

| Person | 1 .. 1 | Likes | Country | | Person | Likes | Country |
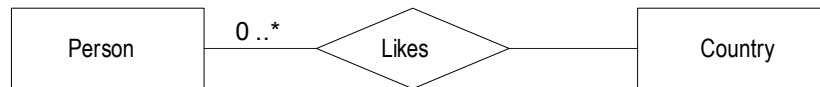
Crow's Feet

- ◆ In general, cardinalities of both sides of the relationship may need to be specified

- ◆ We did only one, because it is sufficient to understand the notation

- ◆ We now return to the relational implementation of our example

- ◆ Many tools use Crow's Feet notation

Relational Implementation For The Example

Country	CName	Population
	US	
	IN	1408
	CN	1412
	RU	

Child	ID#	Child
	1	Erica
	1	Frank
	2	Bob
	2	Frank
	6	Frank

Employee	ID#	Name	CName
	1	Alice	US
	2	Bob	IN
	4	Carol	
	5	David	IN
	6	Bob	CN

Animal	Species	Discovered
	Horse	Asia
	Wolf	Asia
	Cat	Africa
	Yak	Asia
	Zebra	Africa

Likes	ID#	Species
	1	Horse
	1	Cat
	2	Cat
	6	Yak

Country
PK	CName
	Population

Child
PK,FK1 PK	ID# Child

Employee
PK	ID#
FK1	Name CName

Animal
PK	Species
	Discovered

Likes
PK,FK1 PK,FK2	ID# Species

51

End Of Lines In Crow's Feet Notation

◆ 0..1
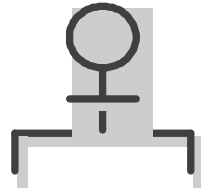
◆ 0..*
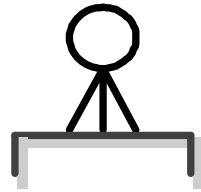
◆ 1..1
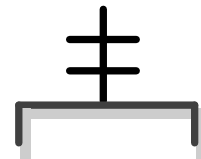
◆ 1..*
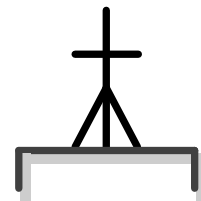
Intuition For The Notation: One-Level Tree

One Side

A

1 3 6 8 9
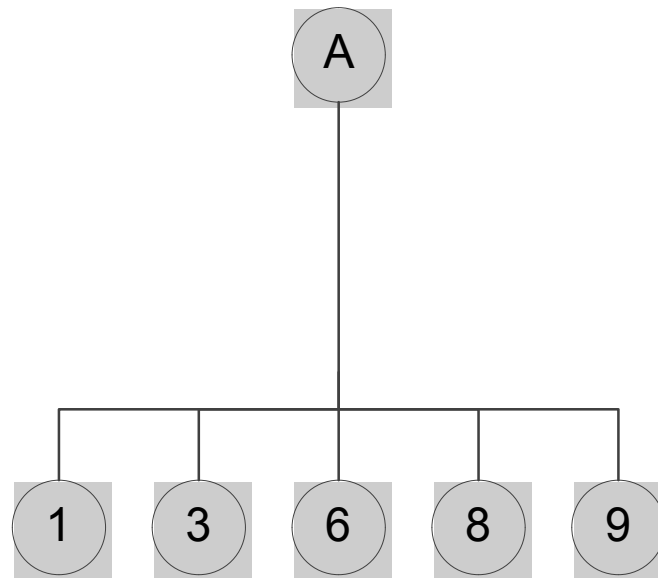
Many Side

Pattern Of Lines

◆ The line between Animal and Likes is ***solid*** because the primary key of the "many side", Likes, includes the primary key of the "one side", Animal, so it "cannot exist" without it

◆ The line between Employee and Likes is ***solid*** because the primary key of the "many side", Likes, includes the primary key of the "one side", Employee, so it "cannot exist" without it

◆ The line between Employee and Child is ***solid*** because the primary key of the "many side", Child, includes the primary key of the "one side", Employee, so it "cannot exist" without it

◆ The line between Country and Employee is ***dashed*** because the primary key of the "many side", Employee, does not include the primary key of the "one side", Country, so it "can exist" without it

Pattern Of Lines

◆ ***This is not a question of the ends of lines "forcing" the pattern of lines***

◆ In the next slide, we see a slight modification of our example in which all lines have the same pair of endings

◆ We required that for each Employee the Country of Birth is known

◆ Nevertheless, as Cname is not part of the primary key of Country, the line is dashed

◆ For technical reasons, the tables have slightly different names, but this has nothing to do with our point

Example

◆ Assume: Every employee has exactly one Country (that is
we know the country of birth)
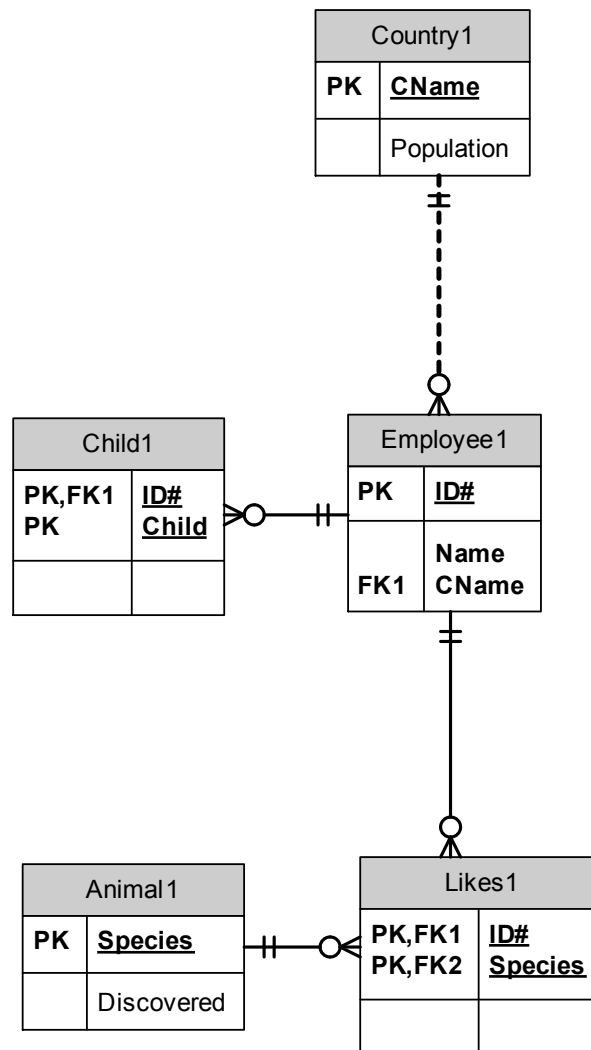
Alternative Implementation For Born

◆ We **need** an "in-between" table for Likes because it is **many-to-many**

◆ We **do not need** an "in-between" table for Born because it is **many-to-one**

◆ But we can implement Born using such an "in-between" table

Employee	ID#	Name
	1	Alice
	2	Bob
	4	Carol
	5	David
	6	Bob

Born	ID#	Cname
	1	US
	2	IN
	5	IN
	6	CN

Country	CName	Population
	US	
	IN	1150
	CN	1330
	RU	

Alternative Implementation For The Example

Country	Cname	Population
US		
IN	1408	
CN	1412	
RU		

Born	ID#	CName
1		US
2		IN
5		IN
6		CN

Child	ID#	Child
1		Erica
1		Frank
2		Bob
2		Frank
6		Frank

Employee	ID#	Name
1		Alice
2		Bob
4		Carol
5		David
6		Bob

Animal	Species	Discovered
Horse	Asia	
Wolf	Asia	
Cat	Africa	
Yak	Asia	
Zebra	Africa	

Likes	ID#	Species
1		Horse
1		Cat
2		Cat
6		Yak

Country
PK	CName
	Population

Born
PK,FK1	ID#
FK2	CName

Child
PK,FK1 PK	ID# Child

Employee
PK	ID#
	Name

Animal
PK	Species
	Discovered

Likes
PK,FK1 PK,FK2	ID# Species

Alternative Implementation For The Example

Country	Cname	Population
	US	
	IN	1408
	CN	1412
	RU	

Born	ID#	CName
	1	US
	2	IN
	5	IN
	6	CN

Child	ID#	Child
	1	Erica
	1	Frank
	2	Bob
	2	Frank
	6	Frank

Employee	ID#	Name
	1	Alice
	2	Bob
	4	Carol
	5	David
	6	Bob

Animal	Species	Discovered
	Horse	Asia
	Wolf	Asia
	Cat	Africa
	Yak	Asia
	Zebra	Africa

Likes	ID#	Species
	1	Horse
	1	Cat
	2	Cat
	6	Yak

Country
PK	CName
	Population

Born
PK,FK1	ID#
FK2	CName

Child
PK,FK1 PK	ID# Child

Employee
PK	ID#
	Name

Animal
PK	Species
	Discovered

Likes
PK,FK1 PK,FK2	ID# Species

Which Implementation To Use For Born?

◆ We cannot give a general rule

◆ The first implementation may introduce NULLs (empty values), which we do not like

◆ The second implementation uses one more table which has overhead and for every person with a known birth country their key is stored twice

◆ *For the purpose of the class we will always use the first version, to have better exercises*

◆ *So do this for all the homeworks and tests, when relevant*

To Remember!

◆ Structurally, a relational database consists of

1. A *set of tables with identifiers (primary keys)*

2. A *set of many-to-one binary relationships* between them, induced by foreign key constraints

   In other words; *a set of functions (in general partial), each from a table into a table*

◆ When designing a relational database, you *should* specify both (or you will produce a bad specification)

- Technically, tables are enough, but this a very bad practice as you do not specify the relationships between tables

From ER Diagram To Relational Database

◆ We now convert our big ER diagram into a relational database

◆ We specify
  - Attributes that must not be NULL
  - Primary keys
  - Keys (beyond primary)
  - Foreign keys and what they reference
  - Cardinality constraints
  - Some additional "stubs"

◆ We both give a narrative description, similar to actual SQL DDL (so we are learning about actual relational databases) and relational diagrams

◆ We should specify domains also, but we would not learn anything from this here, so we do not do it

◆ *We go bottom up, in the same order as the one we used in constructing the ER diagram*

Our ER Diagram

We Will Produce

Automobile

PK	Model
PK	Year
	Weight

Likes

PK,FK2	ID#
PK,FK1	Model
PK,FK1	Year

Person

PK	ID#
	SS#
	FN
	LN
	DOB

Child

PK,FK1	ID#
PK	ChildName

Car

PK	VIN
FK2	ID#
	Color
FK1	Model
FK1	Year
	Date

Book

PK	Author
PK	Title

Required

PK,FK1	ID#
PK,FK2	C#
PK,FK3	Author
PK,FK3	Title

Student

PK,FK1	ID#

Professor

PK,FK1	ID#
	Salary

Taught

PK,FK2	ID#
PK,FK1	C#
PK,FK1	Year
PK,FK1	Semester
PK,FK1	Sec#
FK3	Monitor

Prereq

PK,FK2	First
PK,FK1	Second

Horse

PK	Name

Took

PK,FK1	ID#
PK,FK2	C#
PK,FK2	Year
PK,FK2	Semester
PK,FK2	Sec#
	Grade

Section

PK,FK1	C#
PK	Year
PK	Semester
PK	Sec#
	MaxSize

Course

PK	C#
	Title
	Description

64

Horse

◆ Define Table Horse (
Name NOT NULL,
Primary Key (Name));

◆ This represents the simplest possible relational database
- One table with one attribute

Horse

Horse	
PK	<u>**Name**</u>

Person

◆ Person has some interesting attributes

◆ Multivalued attribute: we will create another table

◆ Derived attribute: we do not create a column for it, it will be computed as needed

◆ Composite attribute: we "flatten" it

Person

- Define Table Person (
  ID# NOT NULL,
  SS# NOT NULL,
  FN,
  LN NOT NULL,
  DOB NOT NULL,
  Primary Key (ID#),
  Candidate Key (SS#),
  Age (computed by procedure …));

- In SQL DDL, the keyword UNIQUE is used instead of Candidate Key, but "Candidate Key" is better for reminding us what this could be

- Age would likely not be stored but defined in some view

Person

Person	
PK	**ID#**
	SS# FN **LN** **DOB**

Horse	
PK	**Name**

Child

◆ Define Table Child (
ID# NOT NULL,
ChildName NOT NULL,
Primary Key (ID#,ChildName),
Foreign Key (ID#) References Person);

◆ This lists all pairs (ID# of person, a child's name)
- We have chosen a more descriptive attribute name than the one in the ER diagram for children's names

◆ Note
- A person may have several children, each with a different name
- Two different persons may have children with the same name

◆ Because of this, no single attribute can serve as primary key of Child

Person And Child

◆ Note that some attributes are not bold, such as FN here

◆ This means that FN could be NULL (in this context, meaning empty)

◆ Note the induced many-to-one relationship

◆ We need to make sure we understand what the line ends indicate

- A person may have 0 or more children (unbounded)

- A child has exactly 1 person to whom it is attached

◆ We need to pay attention to such matters, though we are generally not going to be listing them here

But you should look at all lines and understand the ends and the patterns (solid or dashed)

Person And Child

Person	
PK	**ID#**
	SS#
	FN
	LN
	DOB

Child	
PK,FK1 **PK**	**ID#** **ChildName**
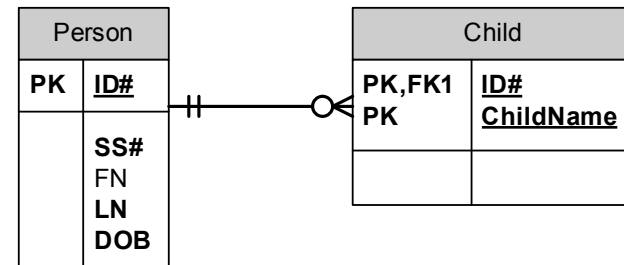
Horse	
PK	**Name**

Automobile

◆ Define Table Automobile (
   Model NOT NULL,
   Year NOT NULL,
   Weight NOT NULL,
   Primary Key (Model,Year));

Automobile

Automobile	
PK	**Model**
PK	**Year**
	Weight

Person	
PK	**ID#**
	SS#
	FN
	LN
	DOB

Child	
PK,FK1	**ID#**
PK	**ChildName**
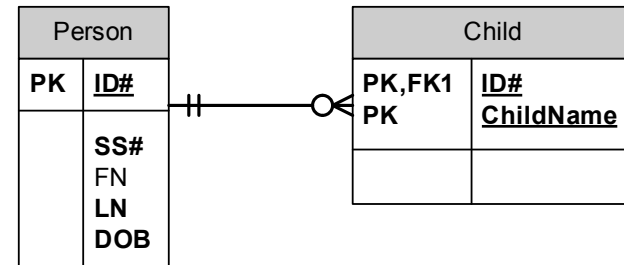
Horse	
PK	**Name**

Likes

◆ Define Table Likes (
ID# NOT NULL,
Model NOT NULL,
Year NOT NULL,
Primary Key (ID#,Model,Year),
Foreign Key (ID#) References Person,
Foreign Key (Model,Year) References Automobile);

◆ *Note: this is bad*, replacing one line by two lines
- Foreign Key (Model) References Automobile
- Foreign Key (Year) References Automobile

◆ There are induced binary many-to-one relationships between
- Likes and Person
- Likes and Automobile

Likes

Automobile	
PK	**Model**
PK	**Year**
	Weight

Likes	
PK,FK2	**ID#**
PK,FK1	**Model**
PK,FK1	**Year**

Person	
PK	**ID#**
	SS#
	FN
	LN
	DOB

Child	
PK,FK1	**ID#**
PK	**ChildName**
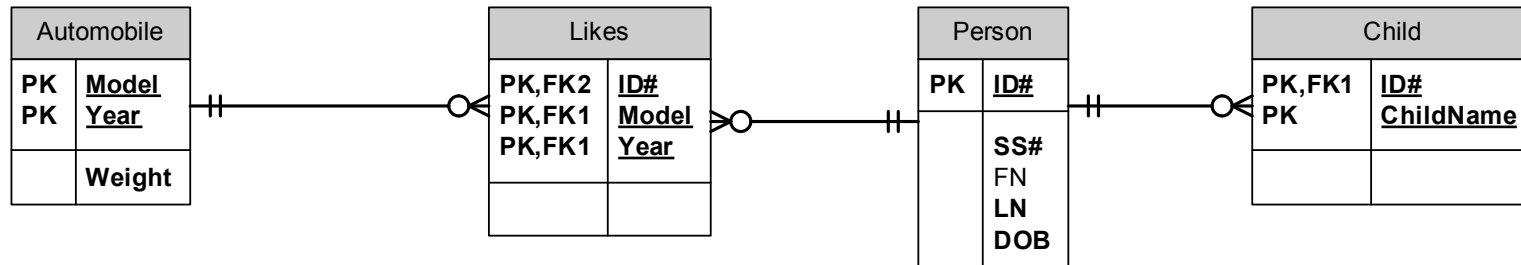
Horse	
PK	**Name**

Car

◆ Define Table Car (
   VIN NOT NULL,
   Color,
   Primary Key (VIN));

Car

Automobile	
PK	**Model**
PK	**Year**
	Weight

Likes	
PK,FK2	**ID#**
PK,FK1	**Model**
PK,FK1	**Year**

Person	
PK	**ID#**
	SS#
	FN
	LN
	DOB

Child	
PK,FK1	**ID#**
PK	**ChildName**
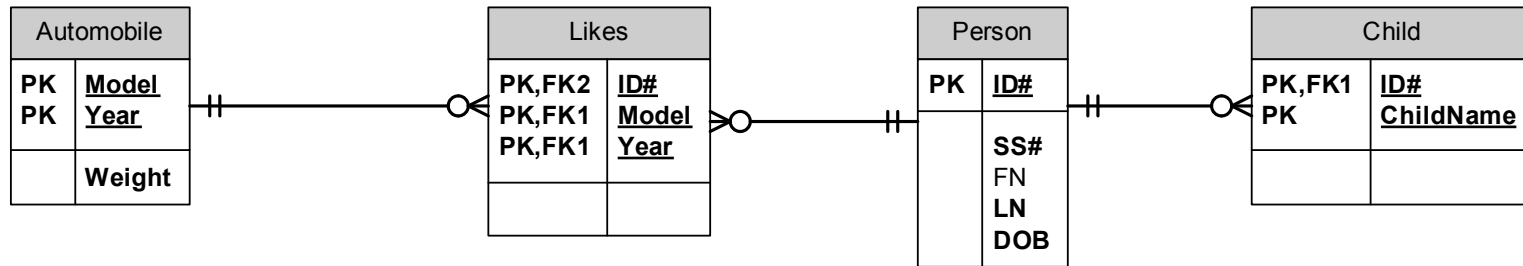
Car	
PK	**VIN**
	Color

Horse	
PK	**Name**

Type

◆ There is no need for a table for Type as Type is a binary many-to-one relationship

◆ It is essentially "stored" in the "many" side, that is in Car

Car

- Define Table Car (
  VIN NOT NULL,
  Color,
  Model NOT NULL,
  Year NOT NULL,
  Primary Key (VIN),
  Foreign Key (Model,Year) References Automobile);

Type

Automobile	
PK	**Model**
PK	**Year**
	Weight

Likes	
PK,FK2	**ID#**
PK,FK1	**Model**
PK,FK1	**Year**

Person	
PK	**ID#**
	SS#
	FN
	LN
	DOB

Child	
PK,FK1	**ID#**
PK	**ChildName**

Car	
PK	**VIN**
	Color
FK1	**Model**
FK1	**Year**

Horse	
PK	**Name**

81

Has
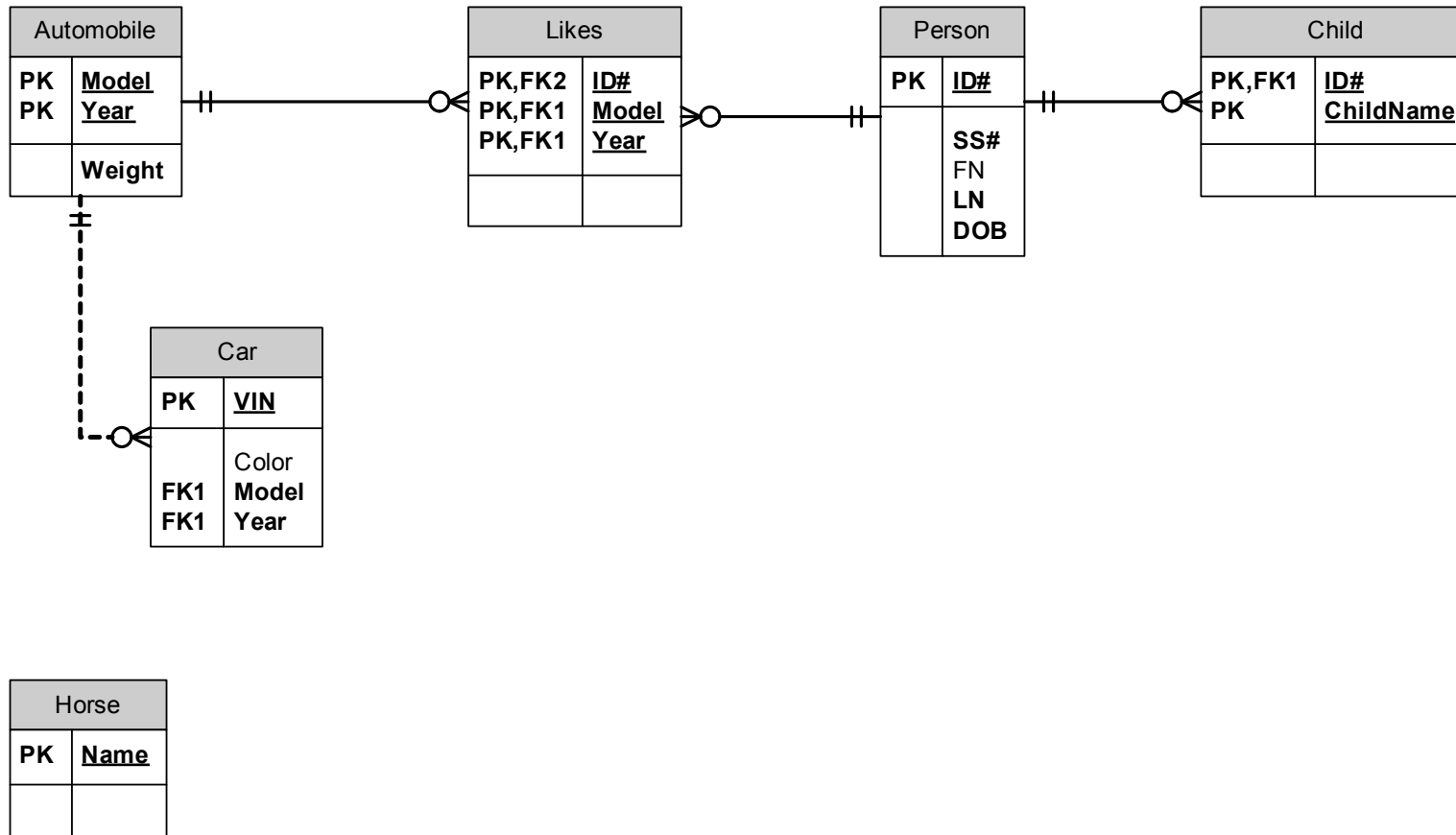
- As Has is a binary many-to-one relationship, the attribute of this relationship, Date, is stored in the "many" side, Car

- There is no need for a table for Has as Has is a binary many-to-one relationship

- It is essentially "stored" in the "many" side, that is in Car

- We can only specify that a Person has at least 1 Car with the notation we currently use

- The CHECK condition is specified using appropriate SQL constraint syntax

   This can actually be done in some tools also

Car

- Define Table Car (
  VIN NOT NULL,
  Color,
  Model NOT NULL,
  Year NOT NULL,
  ID#,
  Primary Key (VIN),
  Foreign Key (Model,Year) References Automobile
  Foreign Key (ID#) References Person);

Has

Automobile

PK	Model
PK	Year
	Weight

Likes

PK,FK2	ID#
PK,FK1	Model
PK,FK1	Year

Person

PK	ID#
	SS#
	FN
	LN
	DOB

Child

PK,FK1	ID#
PK	ChildName

Car

PK	VIN
FK2	ID#
	Color
FK1	Model
FK1	Year
	Date

Horse

PK	Name
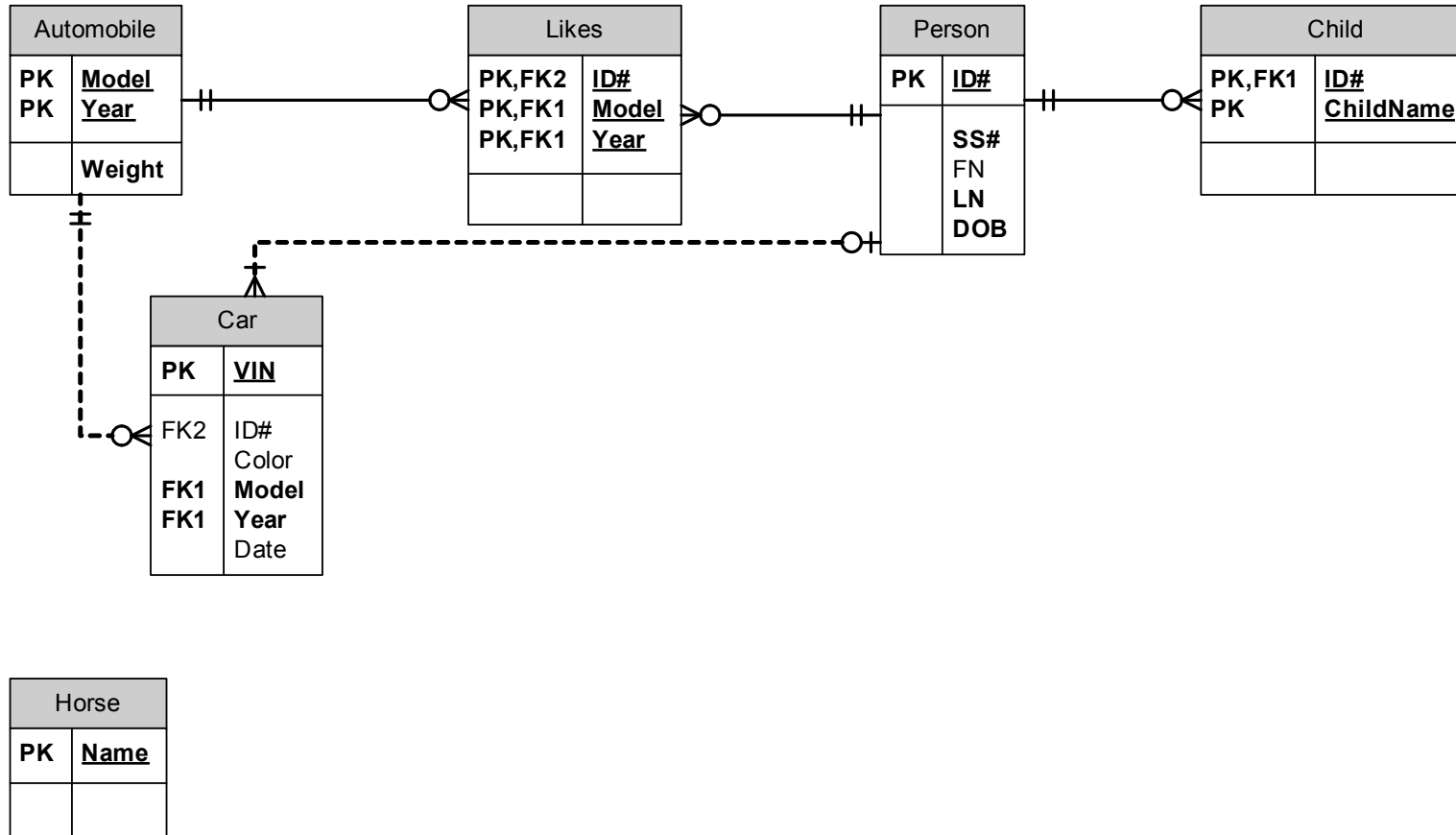
ISA

- We do not define a table for ISA
- This/these relationship/s is/are "embedded" in Student and Professor

Student

◆ Define Table Student (
   ID# NOT NULL,
   Primary Key (ID#),
   Foreign Key (ID#) References Person,
    GPA (computed by procedure …));

◆ Note, how ISA, the class/subclass (set/subset) relations, is modeled

Student And ISA

Automobile

PK	Model
PK	Year
	Weight

Likes

PK,FK2	ID#
PK,FK1	Model
PK,FK1	Year

Person

PK	ID#
	SS#
	FN
	LN
	DOB

Child

PK,FK1	ID#
PK	ChildName

Car

PK	VIN
FK2	ID#
	Color
FK1	Model
FK1	Year
	Date

Student

PK,FK1	ID#

Horse

PK	Name
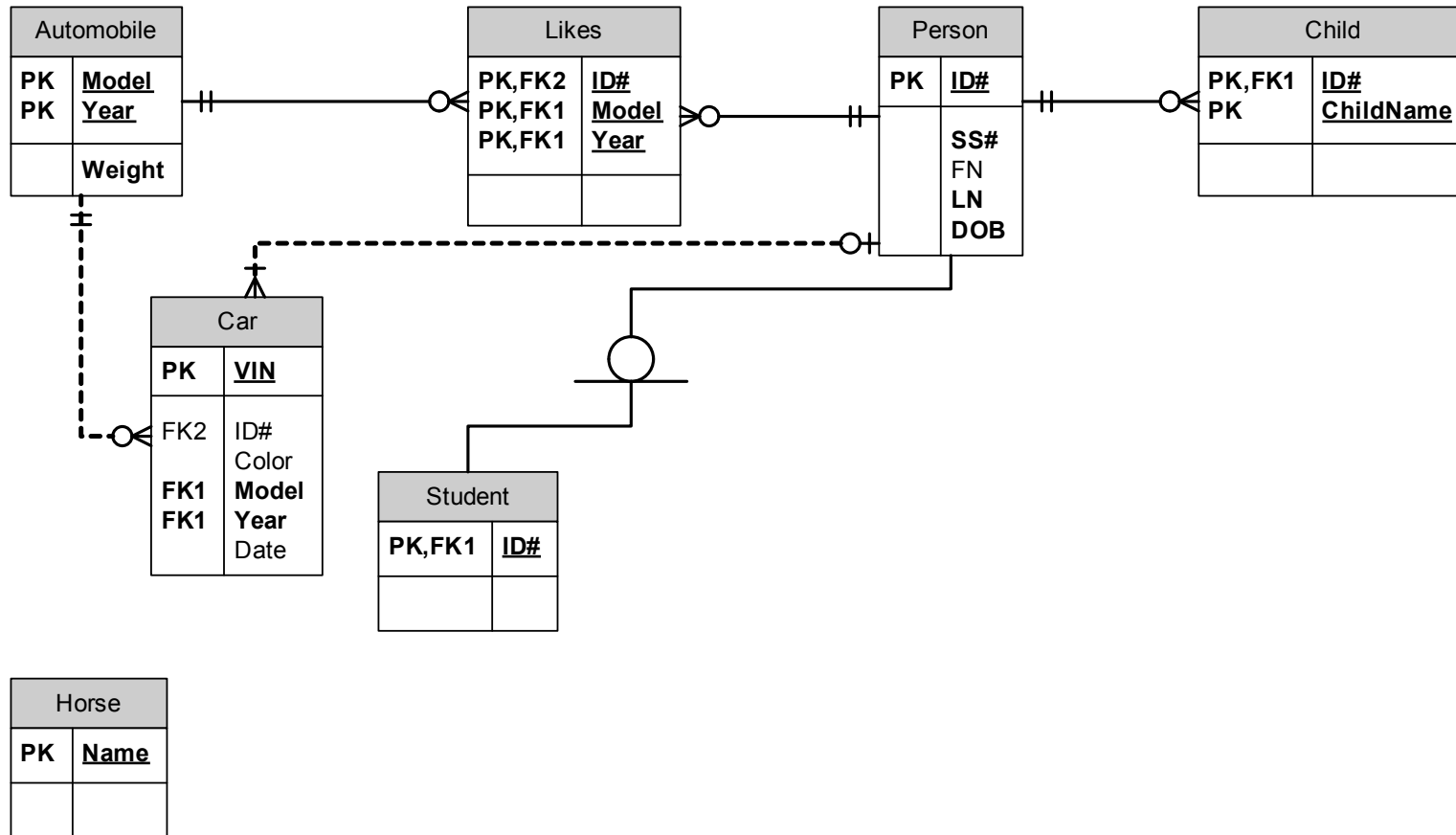
Professor

- Define Table Professor (
  ID# NOT NULL,
  Salary NOT NULL,
  Primary Key (ID#),
  Foreign Key (ID#) References Person);

Professor And ISA

Automobile

PK	Model
PK	Year
	Weight

Likes

PK,FK2	ID#
PK,FK1	Model
PK,FK1	Year

Person

PK	ID#
	SS#
	FN
	LN
	DOB

Child

PK,FK1	ID#
PK	ChildName

Car

PK	VIN
FK2	ID#
	Color
FK1	Model
FK1	Year
	Date

Student

PK,FK1	ID#

Professor

PK,FK1	ID#
	Salary

Horse

PK	Name
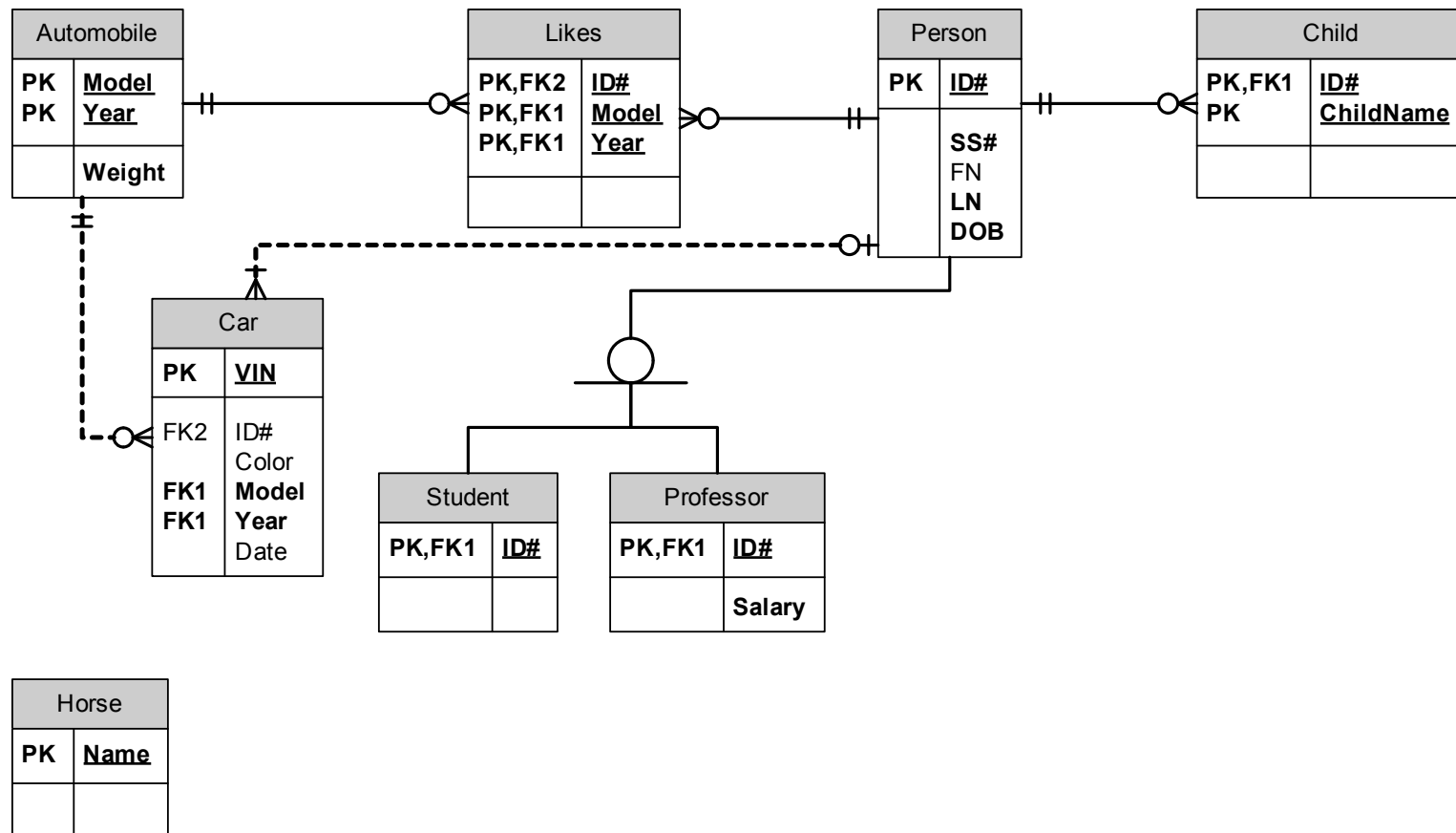
Course

◆ Define Table Course (
C# NOT NULL,
Title NOT NULL,
Description,
Primary Key (C#));

Course

Automobile

PK	Model
PK	Year
	Weight

Likes

PK,FK2	ID#
PK,FK1	Model
PK,FK1	Year

Person

PK	ID#
	SS#
	FN
	LN
	DOB

Child

PK,FK1	ID#
PK	ChildName

Car

PK	VIN
FK2	ID#
	Color
FK1	Model
FK1	Year
	Date

Student

PK,FK1	ID#

Professor

PK,FK1	ID#
	Salary

Horse

PK	Name

Course

PK	C#
	Title
	Description
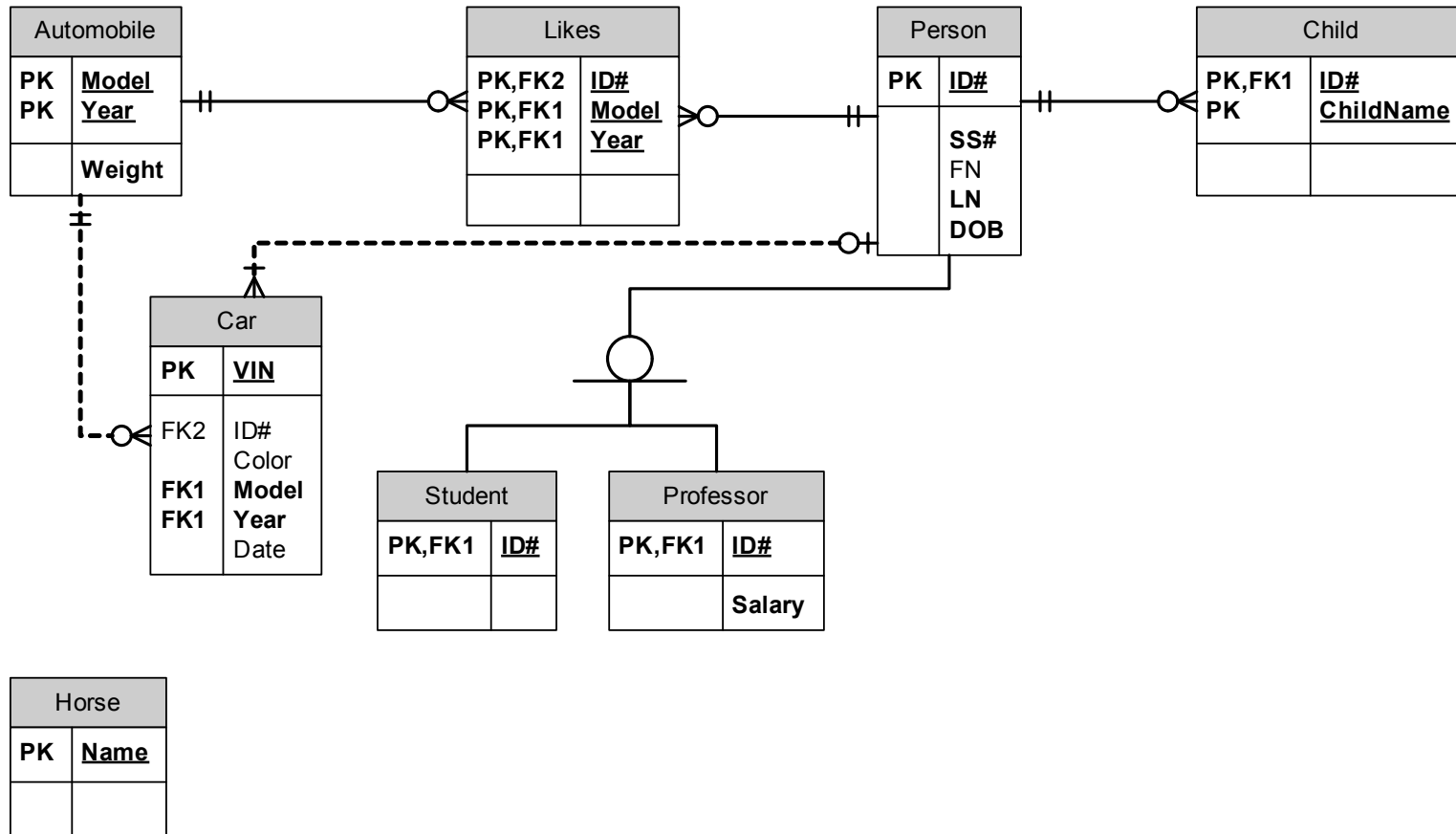
Prerequsite

◆ Define Table Prereq (
   First NOT NULL,
   Second NOT NULL,
   Primary Key (First,Second),
   Foreign Key (First) References Course,
   Foreign Key (Second) References Course);

Prereq

◆ This is our first example of a table modeling a recursive relationship, between an entity set and itself

◆ We decide to name the table Prereq, as this is shorter than Prerequisite

◆ Note that it is perfectly clear and acceptable to refer here to C# by new names: First and Second
  - Similarly, to using ChildName in the Child table

◆ We should add some constraint to indicate that this (directed graph) should be acyclic (but as annotations)
  - Maybe other conditions, based on numbering conventions specifying course levels

Prereq
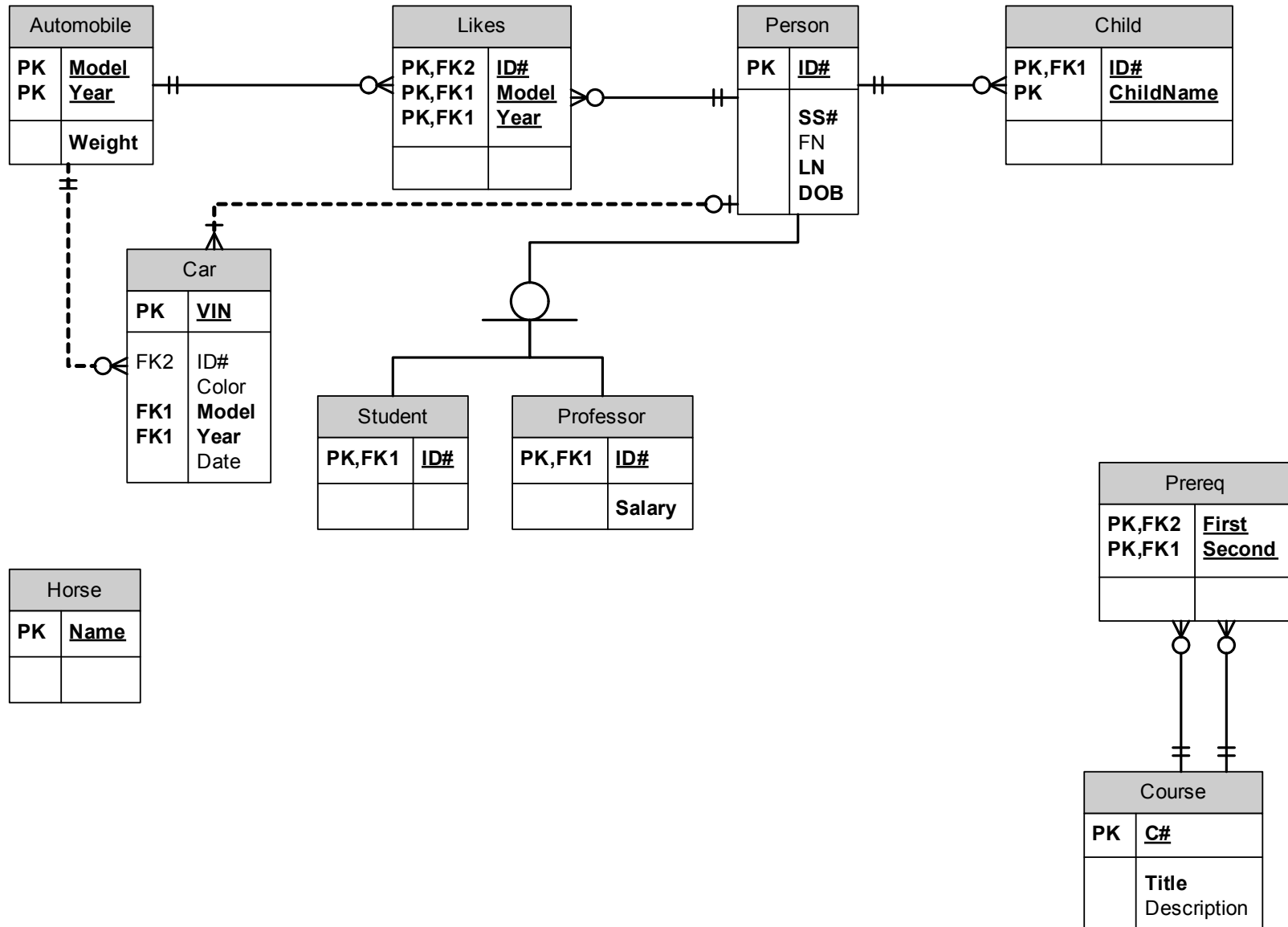
Book

◆ Define Table Book (
   Author NOT NULL,
   Title NOT NULL,
   Primary Key (Author,Title));

Book

Automobile

PK	Model
PK	Year
	Weight

Likes

PK,FK2	ID#
PK,FK1	Model
PK,FK1	Year

Person

PK	ID#
	SS#
	FN
	LN
	DOB

Child

PK,FK1	ID#
PK	ChildName

Car

PK	VIN
FK2	ID#
	Color
FK1	Model
FK1	Year
	Date

Book

PK	Author
PK	Title

Student

PK,FK1	ID#

Professor

PK,FK1	ID#
	Salary

Prereq

PK,FK2	First
PK,FK1	Second

Horse

PK	Name

Course

PK	C#
	Title
	Description
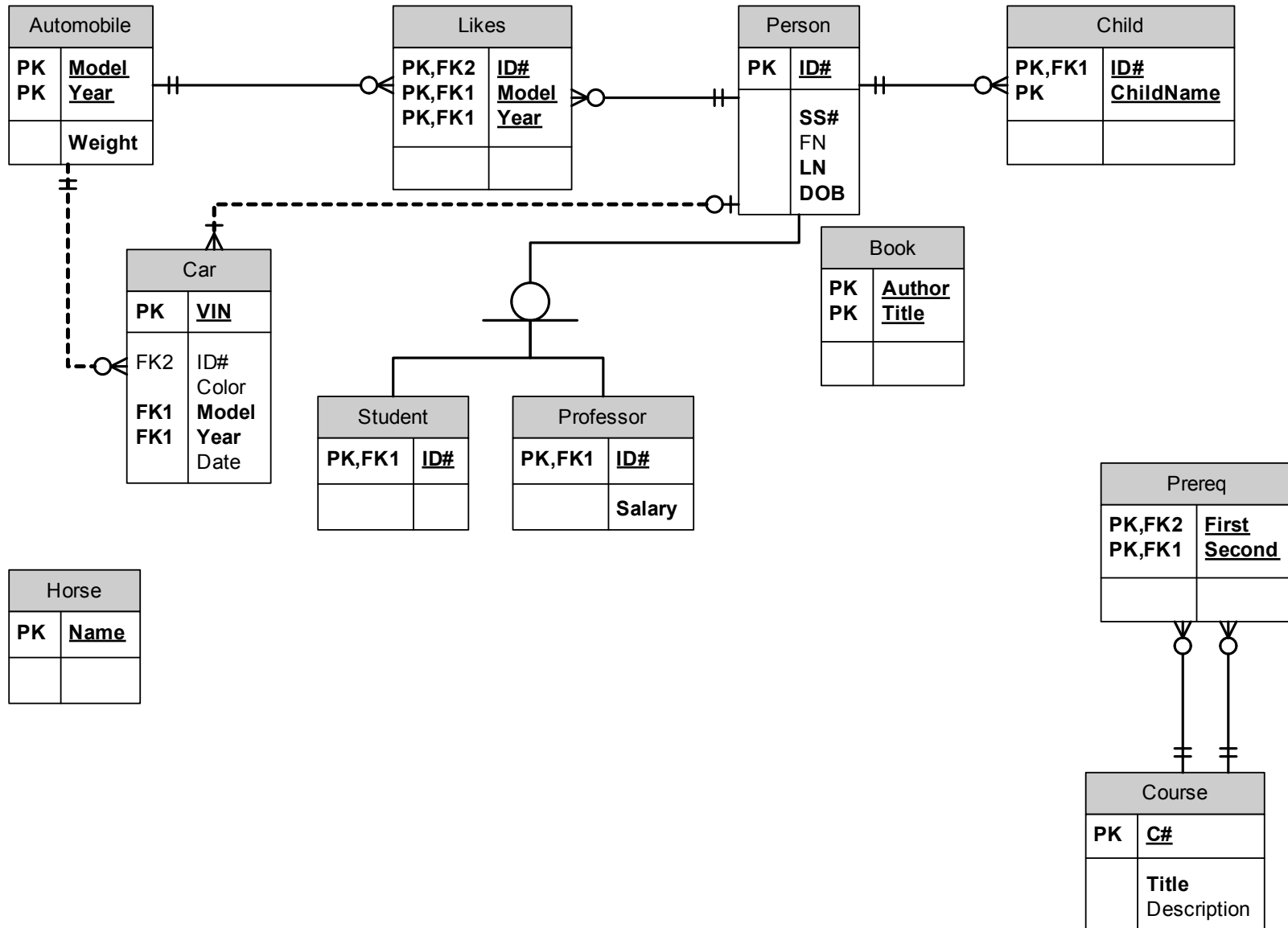
Required

◆ Define Table Required (
ID# NOT NULL,
C# NOT NULL,
Author NOT NULL,
Title NOT NULL,
Primary Key (ID#,C#,Author,Title),
Foreign Key (ID#) References Professor,
Foreign Key (C#) References Course,
Foreign Key (Author,Title) References Book);

◆ Why is it **bad** to have

Foreign Key (ID#) References Person,

instead of

Foreign Key (ID#) References Professor?

Because only a Professor can Require a Book

Required

- This is our first example of a table modeling a relationship that is not binary

- Relationship Required was ternary: it involved three entity sets

- There is nothing unusual about handling it

- We still have as foreign keys the primary keys of the "participating" entities

Required

Automobile

PK	Model
PK	Year
	Weight

Likes

PK,FK2	ID#
PK,FK1	Model
PK,FK1	Year

Person

PK	ID#
	SS#
	FN
	LN
	DOB

Child

PK,FK1	ID#
PK	ChildName

Car

PK	VIN
FK2	ID#
	Color
FK1	Model
FK1	Year
	Date

Student

PK,FK1	ID#

Professor

PK,FK1	ID#
	Salary

Book

PK	Author
PK	Title

Required

PK,FK1	ID#
PK,FK2	C#
PK,FK3	Author
PK,FK3	Title

Prereq

PK,FK2	First
PK,FK1	Second

Course

PK	C#
	Title
	Description

Horse

PK	Name
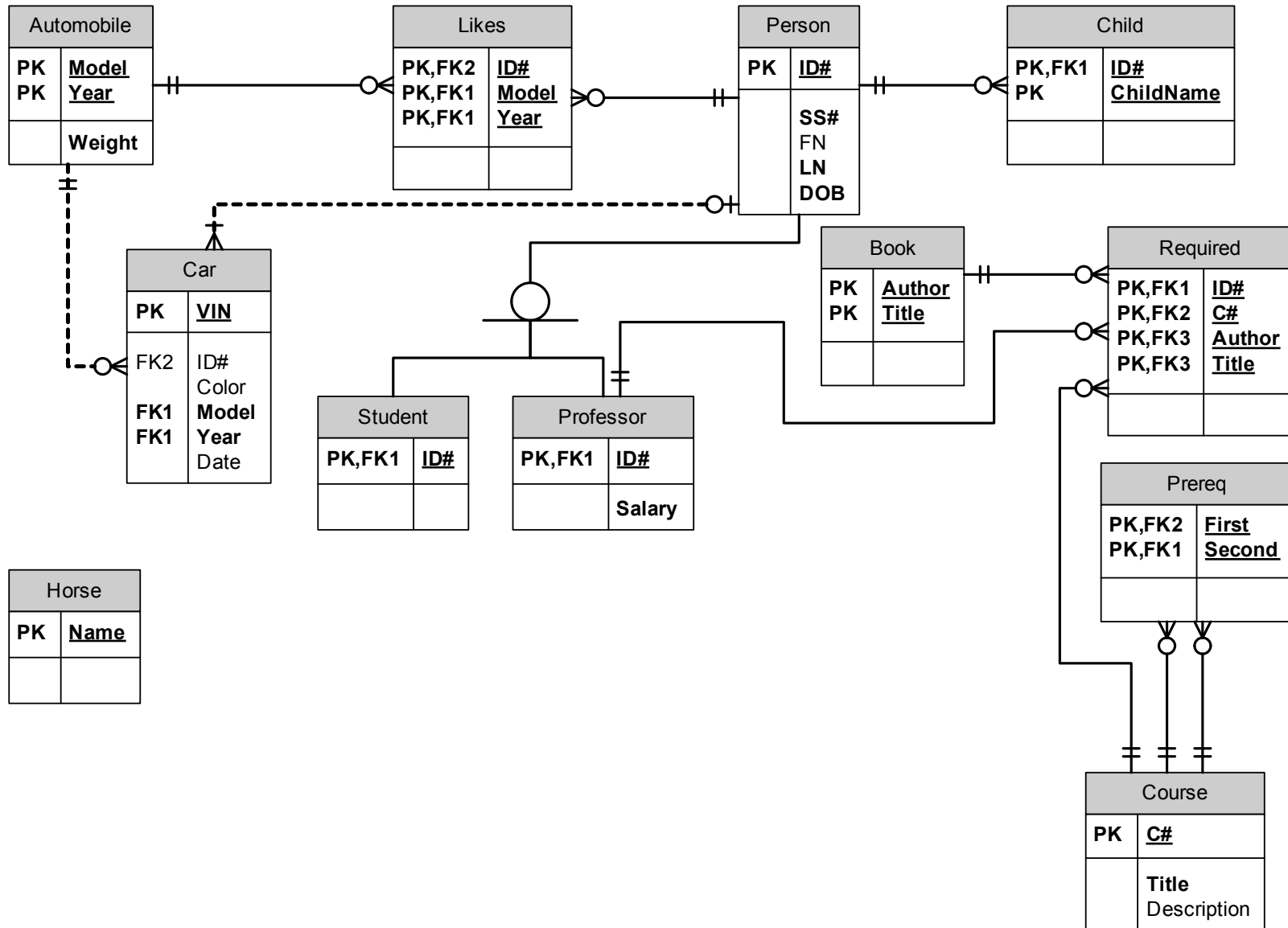
Section

◆ Define Table Section (
C# NOT NULL,
Year NOT NULL,
Semester NOT NULL,
Sec# NOT NULL,
MaxSize,
Primary Key (C#,Year,Semester,Sec#),
Foreign Key (C#) References Course);

◆ Note on the end of the edge between Course and Section,
the Section end, on the drawing how the requirement of
having at least one Section is modeled

Section

◆ Section is our first example of a weak entity

Offered

◆ We do not define a table for Offered

◆ Relationship Offered is implicit in the foreign key constraint

Section + Offered
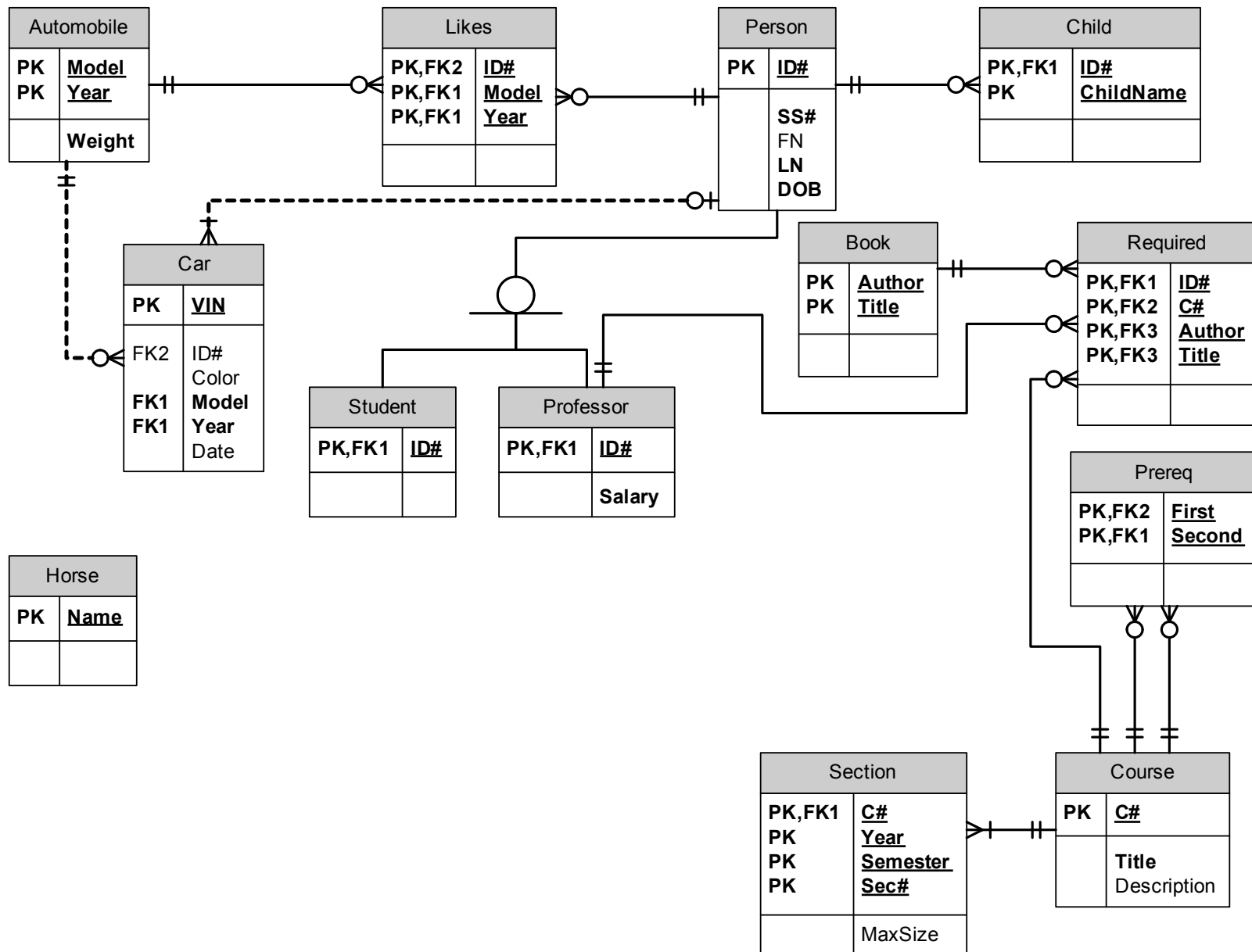
Took

◆ Define Table Took (
ID# NOT NULL,
C# NOT NULL,
Year NOT NULL,
Semester NOT NULL,
Sec# NOT NULL,
Grade,
Primary Key (ID#,C#,Year,Semester,Sec#),
Foreign Key (ID#) References Student,
Foreign Key (C#,Year,Semester, Sec#) References
                                      Section);

◆ Note on the end of the edge between Section and Took, the Took end, on the drawing how the requirement of having between 3 and 50 students in a section is not fully modeled

◆ We can only show 1 or more using current notation

104

Took

◆ Because Took is a many-to-many relationship we store its attribute, Grade, in its table

◆ We cannot store Grade in any of the two

  • Section
  • Student

Took

Automobile

PK	Model
PK	Year
	Weight

Likes

PK,FK2	ID#
PK,FK1	Model
PK,FK1	Year

Person

PK	ID#
	SS#
	FN
	LN
	DOB

Child

PK,FK1	ID#
PK	ChildName

Car

PK	VIN
FK2	ID#
	Color
FK1	Model
FK1	Year
	Date

Book

PK	Author
PK	Title

Required

PK,FK1	ID#
PK,FK2	C#
PK,FK3	Author
PK,FK3	Title

Student

PK,FK1	ID#

Professor

PK,FK1	ID#
	Salary

Taught

PK,FK2	ID#
PK,FK1	C#
PK,FK1	Year
PK,FK1	Semester
PK,FK1	Sec#

Prereq

PK,FK2	First
PK,FK1	Second

Horse

PK	Name

Took

PK,FK1	ID#
PK,FK2	C#
PK,FK2	Year
PK,FK2	Semester
PK,FK2	Sec#
	Grade

Section

PK,FK1	C#
PK	Year
PK	Semester
PK	Sec#
	MaxSize

Course

PK	C#
	Title
	Description

Taught

- Define Table Taught (
  ID# NOT NULL,
  C# NOT NULL,
  Year NOT NULL,
  Semester NOT NULL,
  Sec# NOT NULL,
  Primary Key (ID#,C#,Year,Semester,Sec#),
  Foreign Key (ID#) References Professor,
  Foreign Key (C#,Year,Semester,Sec#) References
                      Section);
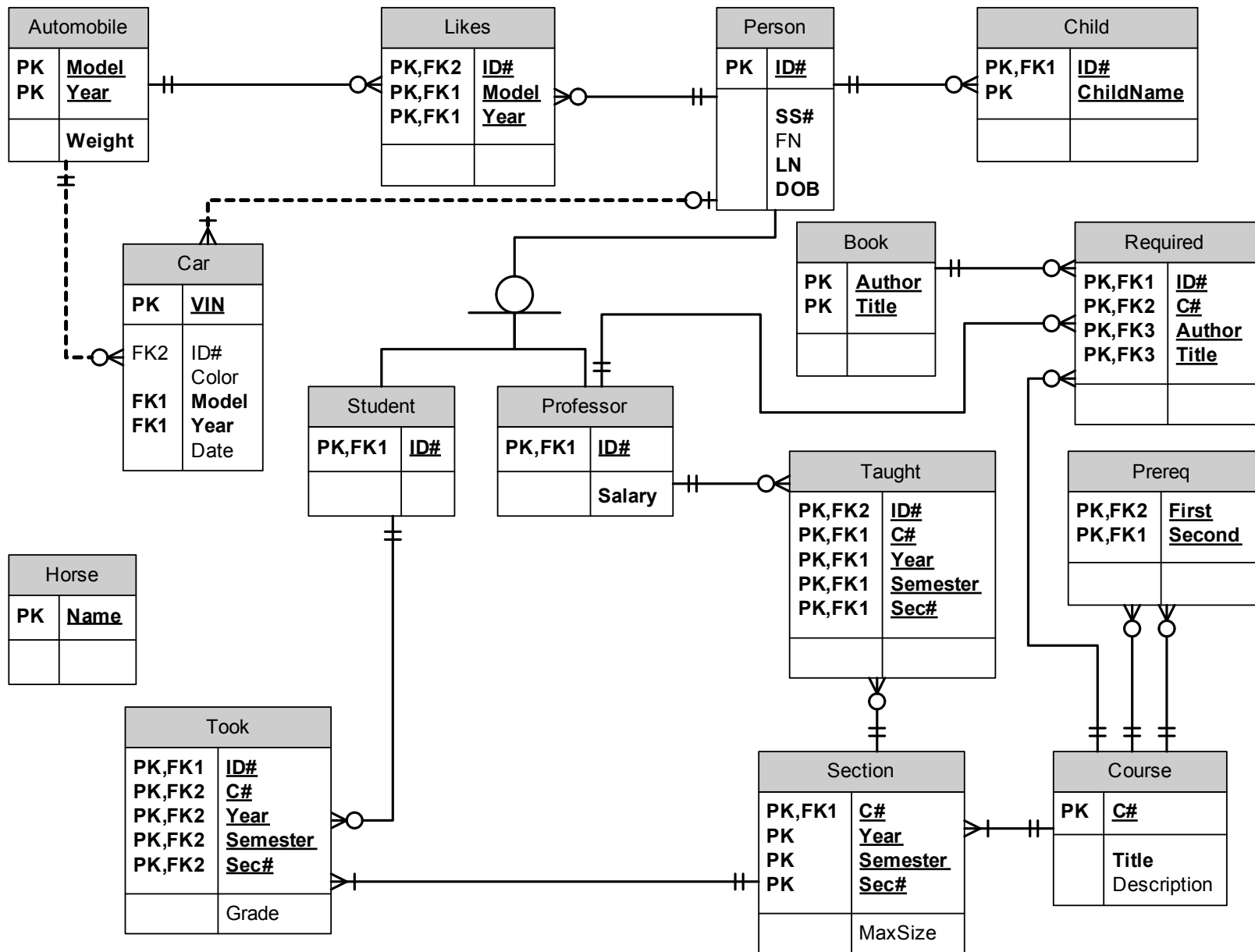
Taught

Automobile

PK	Model
PK	Year
	Weight

Likes

PK,FK2	ID#
PK,FK1	Model
PK,FK1	Year

Person

PK	ID#
	SS#
	FN
	LN
	DOB

Child

PK,FK1	ID#
PK	ChildName

Car

PK	VIN
FK2	ID#
	Color
FK1	Model
FK1	Year
	Date

Book

PK	Author
PK	Title

Required

PK,FK1	ID#
PK,FK2	C#
PK,FK3	Author
PK,FK3	Title

Student

PK,FK1	ID#

Professor

PK,FK1	ID#
	Salary

Taught

PK,FK2	ID#
PK,FK1	C#
PK,FK1	Year
PK,FK1	Semester
PK,FK1	Sec#

Prereq

PK,FK2	First
PK,FK1	Second

Horse

PK	Name

Took

PK,FK1	ID#
PK,FK2	C#
PK,FK2	Year
PK,FK2	Semester
PK,FK2	Sec#
	Grade

Section

PK,FK1	C#
PK	Year
PK	Semester
PK	Sec#
	MaxSize

Course

PK	C#
	Title
	Description

108

Monitors

◆ This is our first example in which a table, Taught, that "came from" a relationship is treated as if it came from an entity and participates in a relationship with other tables

◆ Nothing special needs to be done to "convert" a table that models a relationship, to be also treated as a table modeling an entity

◆ In this case, Monitors is a binary many-to-one relationship, so we do not need to create a table for it, and it can be stored in the "many" side, Taught
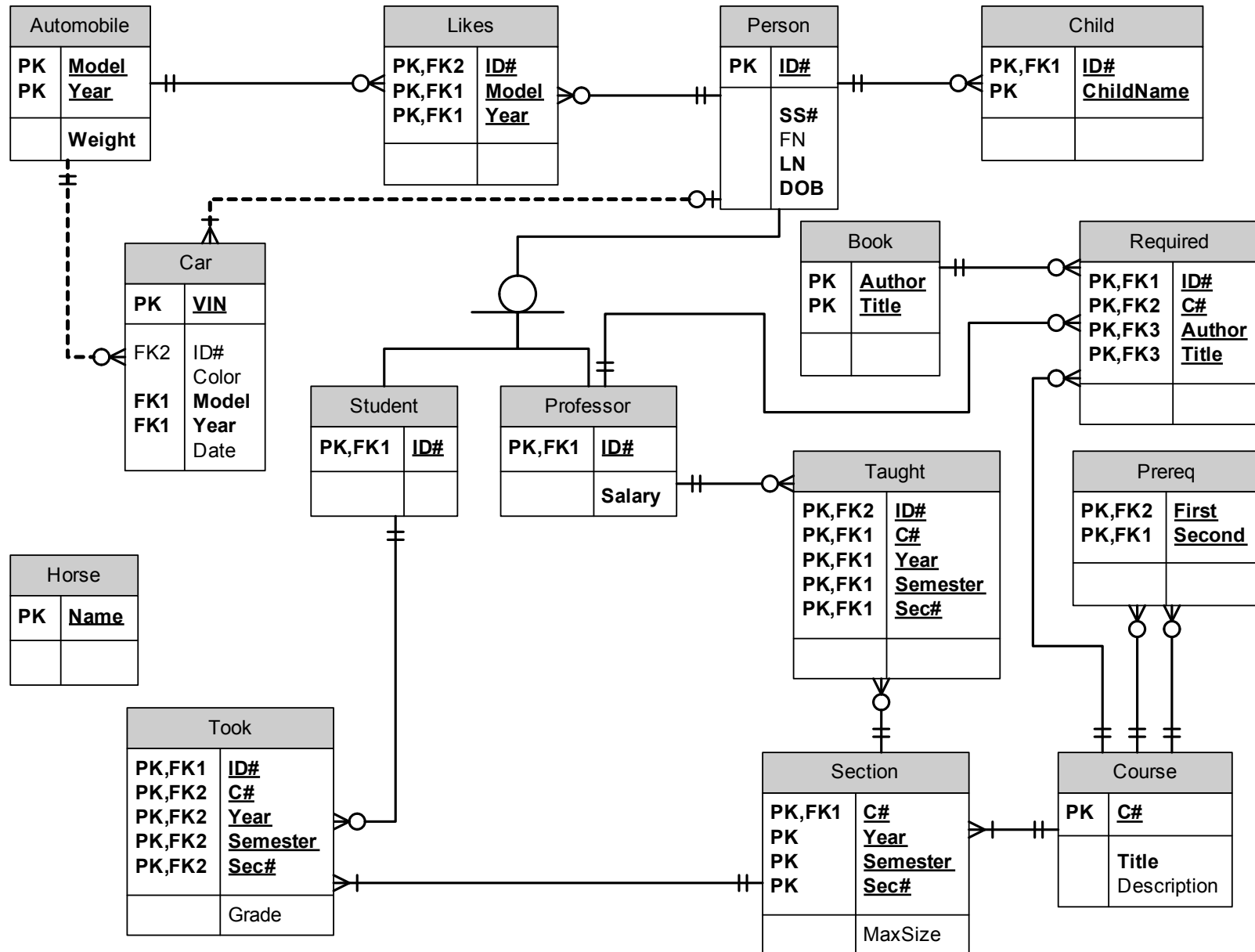
Taught

- Define Table Taught (
  ID# NOT NULL,
  C# NOT NULL,
  Year NOT NULL,
  Semester NOT NULL,
  Sec# NOT NULL,
  Monitor,
  Primary Key (ID#,C#,Year,Semester,Sec#),
  Foreign Key (ID#), References Professor,
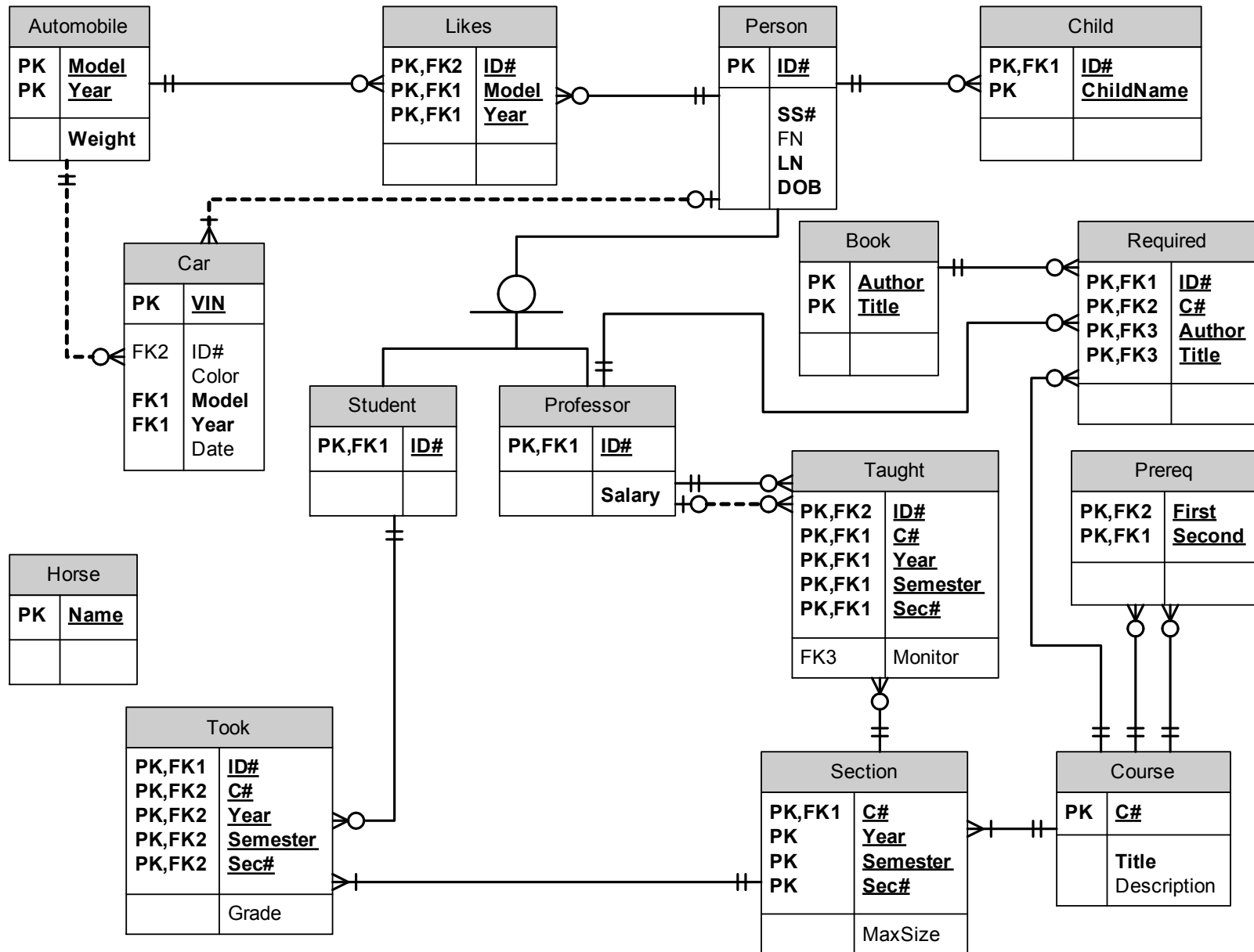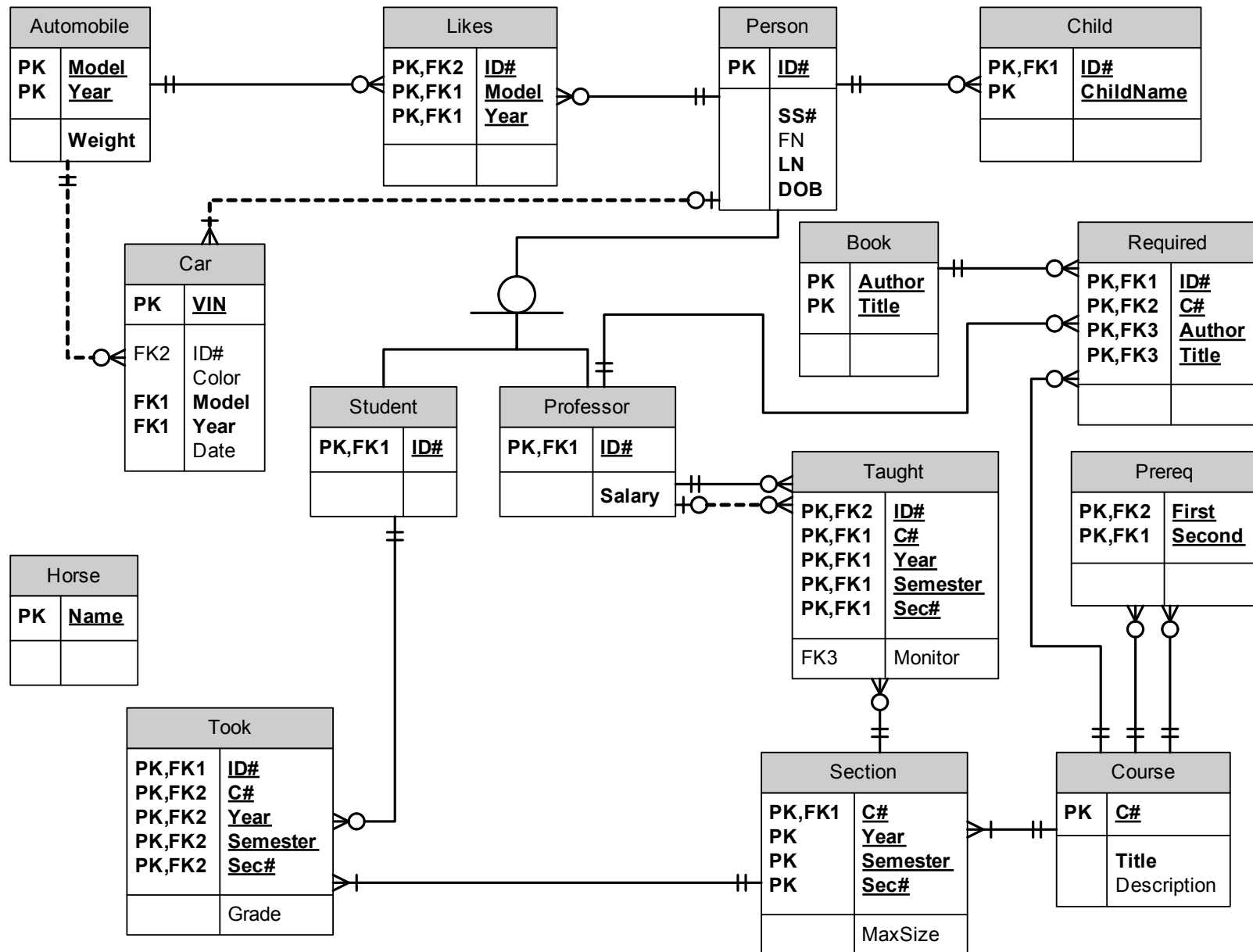 Foreign Key (C#,Year,Semester,Sec#) References
  Section,
  Foreign Key (Monitor) References Professor);

110

Monitors

We Are Done

Automobile

PK	Model
PK	Year
	Weight

Likes

PK,FK2	ID#
PK,FK1	Model
PK,FK1	Year

Person

PK	ID#
	SS#
	FN
	LN
	DOB

Child

PK,FK1	ID#
PK	ChildName

Car

PK	VIN
FK2	ID#
	Color
FK1	Model
FK1	Year
	Date

Book

PK	Author
PK	Title

Required

PK,FK1	ID#
PK,FK2	C#
PK,FK3	Author
PK,FK3	Title

Student

PK,FK1	ID#

Professor

PK,FK1	ID#
	Salary

Taught

PK,FK2	ID#
PK,FK1	C#
PK,FK1	Year
PK,FK1	Semester
PK,FK1	Sec#
FK3	Monitor

Prereq

PK,FK2	First
PK,FK1	Second

Horse

PK	Name

Took

PK,FK1	ID#
PK,FK2	C#
PK,FK2	Year
PK,FK2	Semester
PK,FK2	Sec#
	Grade

Section

PK,FK1	C#
PK	Year
PK	Semester
PK	Sec#
	MaxSize

Course

PK	C#
	Title
	Description

Arrow Notation

Automobile

PK	Model
PK	Year
	Weight

Likes

PK,FK2	ID#
PK,FK1	Model
PK,FK1	Year

Person

PK	ID#
	SS#
	FN
	LN
	DOB

Child

PK,FK1	ID#
PK	ChildName

Car

PK	VIN
FK2	ID#
	Color
FK1	Model
FK1	Year
	Date

Book

PK	Author
PK	Title

Required

PK,FK1	ID#
PK,FK2	C#
PK,FK3	Author
PK,FK3	Title

Student

PK,FK1	ID#

Professor

PK,FK1	ID#
	Salary

Taught

PK,FK2	ID#
PK,FK1	C#
PK,FK1	Year
PK,FK1	Semester
PK,FK1	Sec#
FK3	Monitor

Prereq

PK,FK2	First
PK,FK1	Second

Horse

PK	Name

Took

PK,FK1	ID#
PK,FK2	C#
PK,FK2	Year
PK,FK2	Semester
PK,FK2	Sec#
	Grade

Section

PK,FK1	C#
PK	Year
PK	Semester
PK	Sec#
	MaxSize

Course

PK	C#
	Title
	Description

113

Arrows And Cardinality Notation

Automobile

PK	Model
PK	Year
	Weight

Likes

PK,FK2	ID#
PK,FK1	Model
PK,FK1	Year

Person

PK	ID#
	SS#
	FN
	LN
	DOB

Child

PK,FK1	ID#
PK	ChildName

Car

PK	VIN
FK2	ID#
	Color
FK1	Model
FK1	Year
	Date

Book

PK	Author
PK	Title

Required

PK,FK1	ID#
PK,FK2	C#
PK,FK3	Author
PK,FK3	Title

Student

PK,FK1	ID#

Professor

PK,FK1	ID#
	Salary

Taught

PK,FK2	ID#
PK,FK1	C#
PK,FK1	Year
PK,FK1	Semester
PK,FK1	Sec#
FK3	Monitor

Prereq

PK,FK2	First
PK,FK1	Second

Horse

PK	Name

Took

PK,FK1	ID#
PK,FK2	C#
PK,FK2	Year
PK,FK2	Semester
PK,FK2	Sec#
	Grade

Section

PK,FK1	C#
PK	Year
PK	Semester
PK	Sec#
	MaxSize

Course

PK	C#
	Title
	Description

3..50

1..*

2

Additional Points

◆ We did not write out on the diagram various constraints that must be known, such as

  - At least preliminary domains, e.g., number, string, etc.
  - What is the maximum permitted section size

◆ ***This must be done for proper documentation of the application's requirements***

◆ We will discuss some additional, important, points

  - Elaboration on recursive relationships
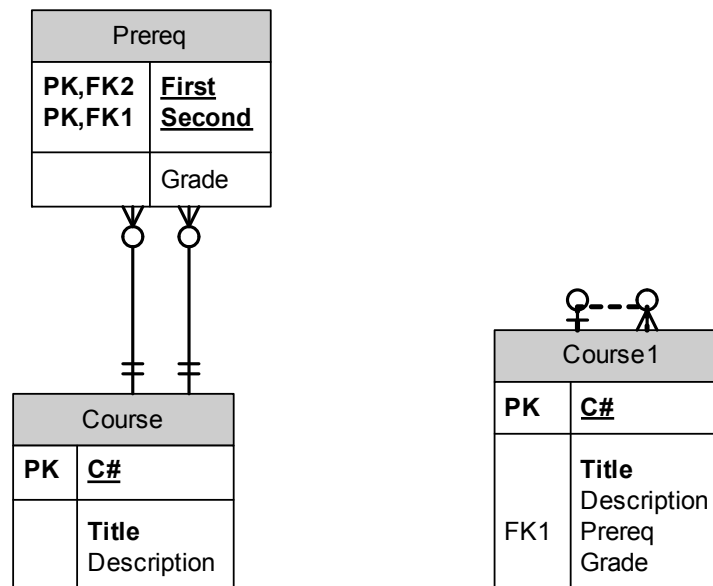 - Referential Integrity
  - Temporal databases

Recursive Relationships: Example

◆ Assume now that a prerequisite course, "First" course, must be taken with at least some Grade to count as a prerequisite

◆ This to make an example a little "richer"

◆ Two cases:

- A course may have any number of prerequisites

  Prereq is many-to-many

- A course may have at most one prerequisite

  Prereq is many to one (Second is the many side, a single First could be a prerequisite for many Second courses)
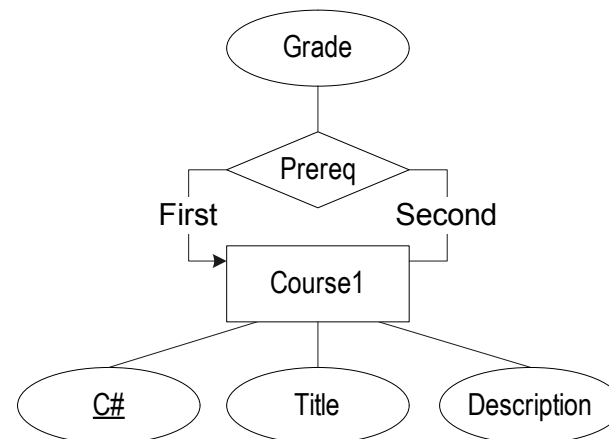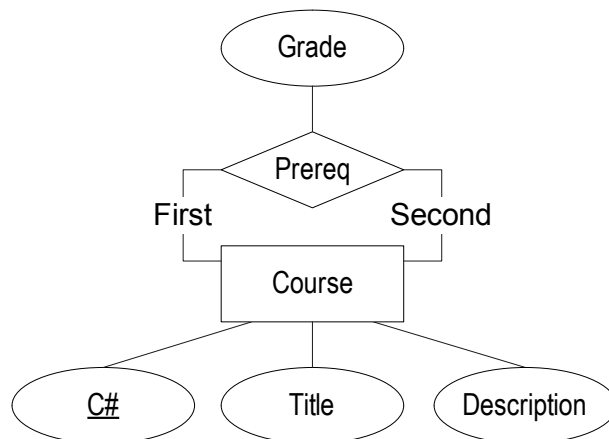
Recursive Relationships: Example

◆ Nothing special, we handle the second case of Prereq by storing it in the "many" side of the relationship

◆ So there are two additional attributes in Course1

- • The prerequisite course, if any
- • The required grade, if any

Referential Integrity: Example

Professor	ID#	Salary
5	1	
7	2	

Taught	ID#	C#	Year	Semester	Sec#	Monitor
5	G22.2433	2009	Spring	001	7	

◆ Assume that we have some professors in table Professor, with rows: 5,1 and 7,2

◆ There is a row in Taught 5,G22.2433,2009,Spring,001,7

◆ This means that 5 teaches a specific section and 7 monitors this assignment

Referential Integrity: Example

Professor	ID#	Salary
5	1	
7	2	

Taught	ID#	C#	Year	Semester	Sec#	Monitors
5	G22.2433	2009	Spring	001	7	

◆ A user accesses the database and *attempts to delete row* (or all rows like this, recall that duplicates are permitted) 5,1 *from Professor*

◆ What should happen, as there is a row in Taught referencing this row in Professor?

◆ A user accesses the database and attempts to delete row 7,2 from Professor?

◆ What should happen, as there is a row in Taught referencing this row in Professor?

Referential Integrity: Example

◆ Part of specification of foreign key in Taught

◆ An action on Professor can be denied, or can trigger an action on Taught

◆ For example

- ON DELETE NO ACTION

  This means that the "needed" row in Professor cannot be deleted

  Of course, it is possible to delete the row from Taught and then from the Professor (if no other row in in any table in the database "needs" the row in Professor)

- ON DELETE CASCADE

  This means that if a row is deleted from Professor, all the rows in Taught referring to it are deleted too

- ON DELETE SET NULL

  This means, that the value referring to no-longer-existing professor is replaced by NULL

  In our example, this is not possible for ID# as it is a part of the primary key of Taught, but is possible for Monitor

Referential Integrity: Another Example

◆ Part of specification of foreign key in Professor

◆ An action on Person can be denied, or can trigger an action on Professor

◆ For example
  - ON UPDATE CASCADE

    This means that if the value of ID# in Person is changed, this value of ID# also propagates to Professor

◆ Could (and probably should) add to Taught and Required:
  - ON UPDATE CASCADE

    In appropriate attributes, so that the change of ID# in Professor also propagates to them

    In Taught in both ID# and Monitor

    In Required in ID#

◆ Excellent mechanism for centralized maintenance

Temporal Databases

◆ Of course, we may want to maintain historical data

◆ So, in practice one may have some indication that the professor no longer works, but still keep historical information about the past

◆ But we do not assume this for our example

Summary: Strong Entity

- Example: **Person**

- Create a table for the entity without multivalued and derived attributes, flattening composite attributes

  The primary key of this table will consist of the attributes serving as primary key of the entity

  Example table: Person

- If there is a derived attribute, describe how it is computed, but do not store it

- If there is a multivalued attribute, create a table for it consisting of it and attributes of the primary key of the entity; do not put it in the table for the entity

  Example table: Child

  The primary key of this table will consist of all its attributes

Summary: Strong Entity

◆ There could be an attribute that is composite with some components being multivalued and some derived

◆ And similar complexities

◆ Example, without drawing the appropriate entity using the ER model (this is getting too hairy)

- A person has many children (multivalued)
- Each child has both FirstName and MiddleName
- The child has DOB
- The child has Age

◆ Then the table for child will look like

Child	ID#	FirstName	MiddleName	DOB
	5432	Krishna	Satya	2006-11-05

Summary: ISA And A Subclass

◆ Example: **ISA** and **Professor**

◆ Do not produce anything for ISA

◆ The class "above" ISA (here Person) has already been implemented as a table

◆ Create a table with all the attributes of the subclass (as for strong entity above) augmented with the primary key of the table "above" ISA, and no other attributes from it

The primary key is the same as the primary key of the table "above" ISA

Example table: Professor

Summary: Weak Entity And Defining Relationship

◆ Example: ***Offered*** and ***Section***

◆ Do not produce anything for the defining relationship, here Offered

◆ Imagine that the weak entity is augmented by the primary key of the "stronger" table through which it is defined (the table for it has been created already)

   Treat the augmented weak entity the same way as a strong entity

   The primary key is the primary key of the "stronger" table augmented by the attributes in the discriminant of the weak entity (a discriminant may consist of more than one attribute)

   Example table: Section and Offered

Summary: A Relationship That Is Not Binary Many-To-One

◆ Example **Took**

The tables for the participating entities have already been created

Create a table consisting of the primary keys of the participating tables and the attributes of the relationship itself

Of course, treat attributes of the relationship that are derived, multivalued, or composite, appropriately, not storing them, producing additional tables, flattening them

The primary key consists of all the attributes of the primary keys of the participating tables

Example table: Took

Summary: A Relationship That Is Binary Many-To-One

◆ Example: **Has**

Do not create a table for this relationship

Put the attributes of the primary key of the "one" side and the attributes of the relationship itself into the table of the "many" side

Of course, treat attributes of the relation that are derived, multivalued, or composite, appropriately, not storing them, producing additional tables, flattening them, as the case may be

You may decide to treat such a relationship the way you treat a relationship that is not binary many to one (but not in our class)

If the relationship is one-to-one, choose which side to treat as if it were "many"

Example table: Has

Summary: Treating A Relationship As An Entity

◆ Example: **Taught** (before it was modified by removing Approved)

We have a table for that was created when we treated it as a relationship

We do not need to do anything else to this table

Example table: Taught

Key Ideas

- ◆ Sets
- ◆ Relations and tables
- ◆ Relational schema
- ◆ Primary keys
- ◆ Implementing an ER diagram as a relational schema (relational database)
- ◆ General implementation of strong entities
- ◆ Handling attributes of different types
- ◆ General implementation of relationships
- ◆ Possible special implementation of binary many-to-one relationships
- ◆ Implementation of ISA
- ◆ Implementation of weak entities

Key Ideas

◆ Foreign keys

◆ Primary key / foreign key constraints inducing many-to-one relationships between tables

◆ Concept of referential integrity

◆ Crow's feet notation: ends of lines

◆ Crow's feet notation: pattern of lines