Consider the following database schema:
In SQL Server, enforce the following constraints using a set of \texttt{CHECK} constraints, referential integrity constraints, or triggers.

\textbf{Exercise 1.} The age of employees must be greater than 18.

\textbf{Exercise 2.} The supervisor of an employee must be older than the employee.

\textbf{Exercise 3.} The salary of an employee cannot be greater than the salary of his/her supervisor.

\textbf{Exercise 4.} The manager of a department must be an employee of that department.

\textbf{Exercise 5.} The location of a project must be one of the locations of its department.

\textbf{Exercise 6.} The hire date of employees must be greater than their birth date.

\textbf{Exercise 7.} A supervisor must be hired at least 1 year before every employee s/he supervises.

\textbf{Exercise 8.} The attribute Department.NbrEmployees is a derived attribute from Employee.DNo.

\textbf{Exercise 9.} An employee works at most in 4 projects.

\textbf{Exercise 10.} An employee works at least 30h/week and at most 50 h/week on all its projects.

\textbf{Exercise 11.} Among all employees working on a project, at most 2 can work for less than 10 hours.

\textbf{Exercise 12.} Only department managers can work less than 5 hours on a project.

\textbf{Exercise 13.} Employees that are not supervisors must work at least 10 hours on every project they work.

\textbf{Exercise 14.} The manager of a department must work at least 5 hours on all projects controlled by the department.

\textbf{Exercise 15.} The attribute Employee.SuperSSN is a derived attribute computed as follows. Department managers are supervised by the manager of Department 1 (Headquarters). Employees that are not managers are supervised by the manager of their department. Finally, the manager of Department 1 has a null value in attribute SuperSSN.

\textbf{Exercise 16.} The supervision relationship defined by Employee.SuperSSN must not be cyclic. (It is supposed that attribute Employee.SuperSSN is not derived as stated above.)
Details of the database for the exercises

Table creation script

create table Employee (  
FName varchar(15) not null,  
MInit char(1),  
LName varchar(15) not null,  
SSN char(9) not null,  
BDate smalldatetime null,  
Address varchar(30),  
Sex char(1),  
Salary decimal(18,2),  
SuperSSN char(9),  
DNo int not null,  
HireDate smalldatetime null,  
constraint PK_Employee primary key (SSN),  
constraint FK_Employee_Employee foreign key (SuperSSN) references Employee (SSN),  
)
create table Department (  
DName varchar(15) not null,  
DNumber int not null,  
MgrSSN char(9) not null,  
MgrStartDate smalldatetime,  
nbrEmployees int,  
constraint PK_Department primary key (DNumber),  
constraint FK_Department_Employee foreign key (MgrSSN) references Employee (SSN)  
on delete cascade on update cascade  
)
alter table Employee  
add constraint FK_Employee_Department foreign key (DNo) references Department (DNumber)
create table Project (  
PName varchar(15) not null,  
PNumber int not null,  
PLocation varchar(15),  
DNumber int not null,  
constraint PK_Project primary key (PNumber),  
constraint FK_Project_Department foreign key (DNumber) references Department (DNumber)  
)
create table DeptLocations (  
DNumber int not null,  
DLocation varchar(15) not null,  
constraint PK_Dept_Locations primary key (DNumber,DLocation),  
constraint FK_Dept_Locations_Department foreign key (DNumber) references Department (DNumber)  
)
create table Dependent (  
ESSN char(9) not null,  
DependentName varchar(15) not null,  
Sex char(1),  
BDate smalldatetime null,  
Relationship varchar(8),  
constraint PK_Dependent primary key (ESSN,DependentName),  
constraint FK_Dependent_Employee foreign key (ESSN) references Employee (SSN)  
)
create table WorksOn (  
ESSN char(9) not null,  
PNo int not null,  
hours decimal(18,1) not null,  
constraint PK_WorksOn primary key (ESSN,PNo),  
constraint FK_WorksOn_Employee foreign key (ESSN) references Employee (SSN),  
constraint FK_WorksOn_Project foreign key (PNo) references Project (PNumber)  
)
### Employee

<table>
<thead>
<tr>
<th>FName</th>
<th>Minit</th>
<th>LName</th>
<th>SSN</th>
<th>BDate</th>
<th>Address</th>
<th>Sex</th>
<th>Salary</th>
<th>SuperSSN</th>
<th>DNo</th>
<th>HireDate</th>
</tr>
</thead>
<tbody>
<tr>
<td>John</td>
<td>B</td>
<td>Smith</td>
<td>123456789</td>
<td>09-05-1955</td>
<td>731 Fondren, Houston, TX</td>
<td>M</td>
<td>30000</td>
<td>333445555</td>
<td>5</td>
<td>01-01-1985</td>
</tr>
<tr>
<td>Franklin</td>
<td>T</td>
<td>Wong</td>
<td>333445555</td>
<td>08-12-1945</td>
<td>638 Voss, Houston, TX</td>
<td>M</td>
<td>40000</td>
<td>888665555</td>
<td>5</td>
<td>01-01-1982</td>
</tr>
<tr>
<td>Alicia</td>
<td>J</td>
<td>Zelaya</td>
<td>999887777</td>
<td>19-07-1958</td>
<td>323 Castle, Spring, TX</td>
<td>F</td>
<td>25000</td>
<td>987654321</td>
<td>4</td>
<td>01-01-1985</td>
</tr>
<tr>
<td>Jennifer</td>
<td>S</td>
<td>Wallace</td>
<td>987654321</td>
<td>20-06-1931</td>
<td>291 Berry, Bellaire, TX</td>
<td>F</td>
<td>43000</td>
<td>888665555</td>
<td>4</td>
<td>01-01-1982</td>
</tr>
<tr>
<td>Ramesh</td>
<td>K</td>
<td>Narayan</td>
<td>666884444</td>
<td>15-09-1952</td>
<td>975 Fire Oak, Humble, TX</td>
<td>M</td>
<td>55000</td>
<td>888665555</td>
<td>4</td>
<td>01-01-1982</td>
</tr>
<tr>
<td>Joyce</td>
<td>A</td>
<td>English</td>
<td>453453453</td>
<td>31-07-1962</td>
<td>5631 Rice, Houston, TX</td>
<td>F</td>
<td>25000</td>
<td>333445555</td>
<td>5</td>
<td>01-01-1985</td>
</tr>
<tr>
<td>Ahmad</td>
<td>V</td>
<td>Jabbar</td>
<td>987987987</td>
<td>29-03-1959</td>
<td>980 Dallas, Houston, TX</td>
<td>M</td>
<td>25000</td>
<td>987654321</td>
<td>4</td>
<td>01-01-1985</td>
</tr>
<tr>
<td>James</td>
<td>A</td>
<td>Borg</td>
<td>888665555</td>
<td>10-11-1927</td>
<td>450 Stone, Houston, TX</td>
<td>M</td>
<td>55000</td>
<td>888665555</td>
<td>1</td>
<td>01-01-1980</td>
</tr>
</tbody>
</table>

### Department

<table>
<thead>
<tr>
<th>DName</th>
<th>DNbr</th>
<th>MgrSSN</th>
<th>MgrStartDate</th>
<th>nbrEmployees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>5</td>
<td>333445555</td>
<td>22-05-1978</td>
<td>4</td>
</tr>
<tr>
<td>Administration</td>
<td>4</td>
<td>987654321</td>
<td>01-01-1985</td>
<td>3</td>
</tr>
<tr>
<td>Headquarters</td>
<td>1</td>
<td>888665555</td>
<td>19-06-1971</td>
<td>1</td>
</tr>
</tbody>
</table>

### Project

<table>
<thead>
<tr>
<th>PName</th>
<th>PNumber</th>
<th>PLocation</th>
<th>DNbr</th>
</tr>
</thead>
<tbody>
<tr>
<td>ProductX</td>
<td>1</td>
<td>Bellaire</td>
<td>5</td>
</tr>
<tr>
<td>ProductY</td>
<td>2</td>
<td>Sugarland</td>
<td>5</td>
</tr>
<tr>
<td>ProductZ</td>
<td>3</td>
<td>Houston</td>
<td>5</td>
</tr>
<tr>
<td>Computerization</td>
<td>10</td>
<td>Stafford</td>
<td>4</td>
</tr>
<tr>
<td>Reorganization</td>
<td>20</td>
<td>Houston</td>
<td>1</td>
</tr>
<tr>
<td>Newbenefits</td>
<td>30</td>
<td>Stafford</td>
<td>4</td>
</tr>
</tbody>
</table>

### Dependent

<table>
<thead>
<tr>
<th>ESSN</th>
<th>DependentName</th>
<th>Sex</th>
<th>BDate</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>333445555</td>
<td>Alice</td>
<td>F</td>
<td>05-04-1976</td>
<td>Daughter</td>
</tr>
<tr>
<td>333445555</td>
<td>Theodore</td>
<td>M</td>
<td>25-10-1973</td>
<td>Son</td>
</tr>
<tr>
<td>333445555</td>
<td>Joy</td>
<td>F</td>
<td>03-05-1948</td>
<td>Spouse</td>
</tr>
<tr>
<td>987654321</td>
<td>Ahner</td>
<td>M</td>
<td>29-02-1932</td>
<td>Spouse</td>
</tr>
<tr>
<td>123456789</td>
<td>Michael</td>
<td>M</td>
<td>01-01-1978</td>
<td>Son</td>
</tr>
<tr>
<td>123456789</td>
<td>Alice</td>
<td>F</td>
<td>31-12-1978</td>
<td>Daughter</td>
</tr>
<tr>
<td>123456789</td>
<td>Elizabeth</td>
<td>F</td>
<td>05-05-1957</td>
<td>Spouse</td>
</tr>
</tbody>
</table>

### DeptLocations

<table>
<thead>
<tr>
<th>DNbr</th>
<th>DLocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Houston</td>
</tr>
<tr>
<td>4</td>
<td>Stafford</td>
</tr>
<tr>
<td>5</td>
<td>Bellaire</td>
</tr>
<tr>
<td>5</td>
<td>Sugarland</td>
</tr>
<tr>
<td>5</td>
<td>Houston</td>
</tr>
</tbody>
</table>

### WorksOn

<table>
<thead>
<tr>
<th>ESSN</th>
<th>PNo</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>123456789</td>
<td>1</td>
<td>32.5</td>
</tr>
<tr>
<td>123456789</td>
<td>2</td>
<td>7.5</td>
</tr>
<tr>
<td>333445555</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>333445555</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>333445555</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>453453453</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>453453453</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>666884444</td>
<td>3</td>
<td>40</td>
</tr>
<tr>
<td>888665555</td>
<td>20</td>
<td>30.0</td>
</tr>
<tr>
<td>987654321</td>
<td>10</td>
<td>5.0</td>
</tr>
<tr>
<td>987654321</td>
<td>20</td>
<td>15.0</td>
</tr>
<tr>
<td>987654321</td>
<td>30</td>
<td>20.0</td>
</tr>
<tr>
<td>987987987</td>
<td>10</td>
<td>35.0</td>
</tr>
<tr>
<td>987987987</td>
<td>30</td>
<td>5.0</td>
</tr>
<tr>
<td>999887777</td>
<td>10</td>
<td>1.0</td>
</tr>
<tr>
<td>999887777</td>
<td>30</td>
<td>30.0</td>
</tr>
</tbody>
</table>
Solution to Exercise 1

“*The age of employees must be greater than 18.*"

Using a CHECK constraint

```sql
alter table Employee
add constraint employee_Age18
check ( dateadd(year,18,BDate) <= getdate() )
```

Using a trigger

```sql
create trigger age18
on Employee
after insert, update
as
if exists ( select * 
    from Inserted
    where dateadd(year,18,BDate) > getdate() )
begin
    raiserror 13001 'Constraint Violation: The age of an employee must be greater than 18'
    rollback
end
```

Solution to Exercise 2

“*The supervisor of an employee must be older than the employee*"

Using a trigger

```sql
create trigger supervisorAge
on Employee
after insert, update
as
if exists ( select * 
    from Inserted I,
    Employee E
    where ( I.SuperSSN = E.SSN and I.BDate < E.BDate )
    or ( E.SuperSSN = I.SSN and E.BDate < I.BDate ) )
begin
    raiserror 13002 'Constraint Violation:
The age of an employee must be less than the age of his/her supervisor'
    rollback
end
```
Solution to Exercise 3

“The salary of an employee cannot be greater than the salary of his/her supervisor.”

Using a trigger

```sql
CREATE TRIGGER supervisorSalary
ON Employee
AFTER INSERT, UPDATE
AS
IF EXISTS (
    SELECT *
    FROM Inserted I,
    Employee E
    WHERE ( I.SuperSSN = E.SSN AND I.Salary > E.Salary )
    OR ( E.SuperSSN = I.SSN AND E.Salary > I.Salary )
)
BEGIN
    RAISERROR 13003 'Constraint Violation: The salary of an employee cannot be greater than the salary of his/her supervisor'
    ROLLBACK
END
```

Solution to Exercise 4

“The manager of a department must be an employee of that department.”

Using UNIQUE and foreign key constraints

```sql
ALTER TABLE Employee
ADD CONSTRAINT UN_Employee_SSN_DNo
UNIQUE (SSN, DNO)

ALTER TABLE Department
ADD CONSTRAINT FK_Employee_SSN_DNo
FOREIGN KEY (MgrSSN, DNumber)
REFERENCES Employee (SSN, DNo)
```

Solution to Exercise 5

“The location of a project must be one of the locations of its department.”

Using a foreign key constraint

```sql
ALTER TABLE Project
ADD CONSTRAINT FK_Project_DeptLocations
FOREIGN KEY (DNumber, PLocation)
REFERENCES DeptLocations (DNumber, DLocation)
```

Solution to Exercise 6

“The hire date of employees must be greater than their birth date.”

Using a CHECK key constraint

```sql
ALTER TABLE Employee
ADD CONSTRAINT HireDate_BDate
CHECK (HireDate > BDate)
```
Solution to Exercise 7

“A supervisor must be hired at least 1 year before every employee s/he supervises.”

Using a trigger

```sql
create trigger hireSuperv
on Employee
after insert, update
as
if exists ( select * 
            from Inserted I, 
            Employee E 
            where ( I.SuperSSN = E.SSN and datediff(year, E.HireDate, I.HireDate) < 1 ) 
            or ( E.SuperSSN = I.SSN and datediff(year, I.HireDate, E.HireDate) < 1 ) ) 
begin
    raiserror 13007 'Constraint Violation: 
    A supervisor must be hired at least 1 year before 
    every employee s/he supervises'
    rollback
end
```

Solution to Exercise 8

“The attribute Department.NbrEmployees is a derived attribute from Employee.DNo”

Using value deriving triggers

```sql
create trigger DeptNbrEmp_Employee_InsUpdDel_Derive 
on Employee 
after insert, update, delete 
as 
begin 
    update Department D 
    set NbrEmployees = ( 
        select count(*) 
        from Employee E 
        where E.DNo = D.DNumber ) 
    where D.DNumber in ( 
        select distinct I.DNo 
        from Inserted I ) 
    or D.DNumber in ( 
        select distinct D.DNo 
        from Deleted D ) 
end 

Incremental version

create trigger derived_Department_NbrEmployees_Employee 
on Employee 
after insert, update, delete 
as 
begin 
    update Department 
    set NbrEmployees = NbrEmployees + 
    ( select count(*) from Inserted I where DNumber=I.DNo ) 
        - ( select count(*) from Deleted D where DNumber=D.DNo ) 
    where DNumber in ( select DNo from Inserted ) 
    or DNumber in ( select DNo from Deleted ) 
end 

create trigger derived_Department_NbrEmployees_Department
```
on Department
after insert, update
as
if exists ( select *
    from Inserted
    where NbrEmployees <> ( select count(*)
        from Employee E
        where E.DNo = DNumber ) )
begin
    raiserror 13008 'Constraint Violation:
The attribute Department.NbrEmployees is a derived
attribute from Employee.DNo'
rollback
end

Solution to Exercise 9

"An employee works at most in 4 projects"
Using a trigger

create trigger empNbrProj
on WorksOn
after insert, update
as
if exists ( select *
    from WorksOn W
    group by W.ESSN
    having count(*) > 4 )
begin
    raiserror 13009 'Constraint Violation: An employee works at
most in 4 projects'
rollback
end

Solution to Exercise 10

"An employee works at least 30h/week and at most 50 h/week on all its projects"
Using a trigger

create trigger workson_30_50
on WorksOn
after insert, update, delete
as
if exists ( select *
    from WorksOn
    group by ESSN
    having ( sum(Hours) < 30 )
    or ( sum(Hours) > 50 ) )
begin
    raiserror 13010 'Constraint Violation: An employee works at
least 30 h/week and at most 50 h/week on all its projects'
rollback
end
Solution to Exercise 11

"A project can have at most 2 employees working on the project less than 10 hours"

Using a trigger

```sql
create trigger worksLess10h
on WorksOn
after insert, update
as
if exists ( select *
    from WorksOn
    where Hours < 10
    group by PNo
    having count(*) > 2 )
begin
    raiserror 13011 'Constraint Violation: A project can have at most 2 employees working on the project less than 10 hours'
rollback end
```

Solution to Exercise 12

"Only department managers can work less than 5 hours on a project"

Using a set of triggers

```sql
create trigger worksLess5h_WorksOn
on WorksOn
after insert, update
as
if exists ( select *
    from Inserted
    where Hours < 5
    and ESSN not in ( select MgrSSN
        from Department
        where MgrSSN is not null ) )
begin
    raiserror 13012 'Constraint Violation: Only department managers can work less than 5 hours on a project'
rollback end

create trigger worksLess5h_Department
on Department
after update, delete
as
if exists ( select *
    from Deleted
    where MgrSSN not in ( select MgrSSN
        from Department )
    and MgrSSN in ( select ESSN
        from WorksOn
        where Hours < 5 ) )
begin
    raiserror 13012 'Constraint Violation: Only department managers can work less than 5 hours on a project'
rollback end
```

after insert, update if exists ( select * begin raiserror 13012 'Constraint Violation: Only department managers can work less than 5 hours on a project' rollback
Solution to Exercise 13

“Employees that are not supervisors must work at least 10 hours on every project they work”

Using a set of triggers

```sql
create trigger workson10h_WorksOn
on WorksOn
after insert, update
as
if exists ( select *
   from Inserted
   where Hours < 10
   and ESSN not in ( select SuperSSN
                        from Employee
                        where SuperSSN is not null ) )
begin
  raiserror 13013 'Constraint Violation: Employees that are not supervisors must work at least 10 hours on every project they work'
  rollback
end

create trigger workson10h_Employee
on Employee
after update, delete
as
if exists ( select *
   from Deleted
   where SuperSSN not in ( select SuperSSN
                             from Employee
                             where SuperSSN is not null )
   and SuperSSN in ( select ESSN
                      from WorksOn
                      where Hours < 10 ) )
begin
  raiserror 13013 'Constraint Violation: Employees that are not supervisors must work at least 10 hours on every project they work'
  rollback
end
```

Note about the second trigger. The logic behind that trigger is the following: A supervisor is a supervisor as long as there is at least one employee he supervises... When an employee is updated (changes the supervisor) or is deleted, there is a chance for a supervisor to lose his status and to become a “regular” employee again. When this happens, that former supervisor has to work at least 10 hours on every project.

Therefore, the query in the above trigger looks for an employee who had a supervisor (since it was a SuperSSN entry for at least one employee in the Deleted table), that is not supervisor anymore (since it is not in the set of current supervisors) and belongs to the set of employees that work less than 10 hours on a project.
Solution to Exercise 14

“The manager of a department must work at least 5 hours on all projects controlled by the department.”

Using a set of triggers

```sql
create trigger mgrProj_Department
on Department
after insert, update
as
if exists ( select *
    from ( Inserted I join Project P on I.DNumber = P.DNumber )
    left outer join WorksOn on MgrSSN = ESSN and PNumber = PNo
    where Hours is null
    or Hours < 5 )
begin
    raiserror 13014 'Constraint Violation: A manager must work at least 5 hours on all projects controlled by his/her department'
    rollback
end

create trigger mgrProj_Project
on Project
after insert, update
as
if exists ( select *
    from ( Project P join Department D on D.DNumber = P.DNumber )
    left outer join WorksOn on MgrSSN = ESSN and PNumber = PNo
    where P.PNumber in ( select PNumber
        from Inserted )
    and ( Hours is null
    or Hours < 5 ) )
begin
    raiserror 13014 'Constraint Violation: A manager must work at least 5 hours on all projects controlled by his/her department'
    rollback
end

create trigger mgrProj_WorksOn
on WorksOn
after update, delete
as
if exists ( select *
    from ( Department D join Project P on D.DNumber = P.DNumber )
    left outer join WorksOn on MgrSSN = ESSN and PNumber = PNo
    where D.MgrSSN in ( select ESSN
        from Deleted )
    and ( Hours is null
    or Hours < 5 ) )
begin
    raiserror 13014 'Constraint Violation: A manager must work at least 5 hours on all projects controlled by his/her department'
    rollback
end
```
Solution to Exercise 15

“The attribute Employee. SuperSSN is a derived attribute computed as follows. Department managers are supervised by the manager of Department 1 (Headquarters). Employees that are not managers are supervised by the manager of their department. Finally, the manager of Department 1 has a NULL value in attribute SuperSSN.”

Using a set of triggers

create trigger derived_Employee_SuperSSN_Department
on Department
after insert, update
as
if update(MgrSSN)
begin
update Employee
set SuperSSN = ( 
    select case when SSN != D.MgrSSN
        then D.MgrSSN
        when SSN = D.MgrSSN and DNo != 1
            then ( select MgrSSN 
                        from Department
                        where DNumber = 1 )
        else null
    end
from Department D
where DNo = D.DNumber )
-- if the department manager changes all employees of the department
-- must be updated
where ( DNo in ( 
    select DNumber 
    from Inserted ) )
-- if the manager of department 1 changes, all department managers
-- must be updated
or ( 1 in ( 
    select DNumber 
    from Inserted )
and SSN in ( 
    select MgrSSN 
    from Department ) )
end

create trigger derived_Employee_SuperSSN_Employee
on Employee
after insert, update
as
if update(DNo)
begin
update Employee
set SuperSSN = ( 
    select case when SSN != MgrSSN
        then D.MgrSSN
        when SSN = MgrSSN and I.DNo != 1
            then ( select MgrSSN 
                        from Department
                        where DNumber = 1 )
        else null
    end
from Inserted I, Department D
where SSN = I.SSN
and I.DNo = D.DNumber )
where SSN in ( 
    select SSN
Solution to Exercise 16

“The supervision relationship in Employee.SuperSSN must not be cyclic”

Using a trigger

```sql
create trigger noncyclic_subordinates
    on Employee
    after insert, update
    as
begin
    create table #Supervision (
        SSN char(9),
        SuperSSN char(9)
    )
    primary key (SSN, SuperSSN)
    insert into #Supervision
    select SSN, SuperSSN
    from Employee
    where SuperSSN is not null
while @@rowcount != 0
begin
    if exists ( select *
        from #Supervision
        where SSN = SuperSSN )
    begin
        raiserror 13016 'Constraint Violation: The supervision relationship is cyclic'
        rollback
    end
    insert into #Supervision
    select distinct S1.SSN, S2.SuperSSN
    from #Supervision S1 join #Supervision S2
    on S1.SuperSSN = S2.SSN
    where not exists ( select *
        from #Supervision S
        where S.SSN = S1.SSN
        and S.SuperSSN = S2.SuperSSN )
end
end
```