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

**Exercise 1.** The age of employees must be greater than 18.

**Exercise 2.** The supervisor of an employee must be older than the employee.

**Exercise 3.** The salary of an employee cannot be greater than the salary of his/her supervisor.

**Exercise 4.** The manager of a department must be an employee of that department.

**Exercise 5.** The location of a project must be one of the locations of its department.

**Exercise 6.** The hire date of employees must be greater than their birth date.

**Exercise 7.** A supervisor must be hired at least 1 year before every employee s/he supervises.

**Exercise 8.** The attribute Department.NbrEmployees is a derived attribute from Employee.DNo.

**Exercise 9.** An employee works at most in 4 projects.

**Exercise 10.** An employee works at least 30h/week and at most 50 h/week on all its projects.

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

**Exercise 12.** Only department managers can work less than 5 hours on a project.

**Exercise 13.** Employees that are not supervisors must work at least 10 hours on every project they work.

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

**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.

**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) 
)
## Initial data in the tables

### 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>3232 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>38000</td>
<td>333445555</td>
<td>5</td>
<td>01-01-1985</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>987987887</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>5</td>
<td>1</td>
<td>01-01-1980</td>
</tr>
</tbody>
</table>

### Department

<table>
<thead>
<tr>
<th>DName</th>
<th>DNumber</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>DNumber</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>Ahmer</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>DNumber</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>10.0</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('Constraint Violation: The age of an employee
               must be greater than 18', 1, 1)
    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( 'Constraint Violation: 
               The age of an employee must be less than 
               the age of his/her supervisor', 1, 1)
    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('Constraint Violation:
The salary of an employee cannot be greater than
the salary of his/her supervisor', 1, 1)
   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('Constraint Violation:
    A supervisor must be hired at least 1 year before
    every employee s/he supervises', 1, 1)
  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 DNumber in ( select distinct I.DNo
    from Inserted I )
  or DNumber in ( select distinct D.DNo
    from Deleted D )
end
```

Incremental version

```sql
create trigger derived_Department_NbrEmployees_Employee
on Employee
after insert, update, delete
as
begin
  update Department D
  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('Constraint Violation: 
The attribute Department.NbrEmployees is a derived 
attribute from Employee.DNo', 1, 1)
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('Constraint Violation: An employee works at 
    most in 4 projects', 1, 1)
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('Constraint Violation: An employee works at 
    least 30 h/week and at most 50 h/week on all its projects', 1, 1)
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 worksonLess10h
on WorksOn
after insert, update
as
if exists ( select *
    from WorksOn
    where Hours < 10
    group by PNo
    having count(*) > 2 )
begin
    raiserror('Constraint Violation: A project can have at most 2 employees working on the project less than 10 hours', 1, 1)
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 worksonLess5h_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('Constraint Violation: Only department managers can work less than 5 hours on a project', 1, 1)
rollback end

create trigger worksonLess5h_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('Constraint Violation: Only department managers can work less than 5 hours on a project', 1, 1)
rollback end
```
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('Constraint Violation: Employees that are not supervisors
            must work at least 10 hours on every project they work', 1, 1)
        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('Constraint Violation: Employees that are not supervisors
            must work at least 10 hours on every project they work', 1, 1)
        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 loose 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('Constraint Violation: A manager must work at least 5 hours on all projects controlled by his/her department', 1, 1)
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('Constraint Violation: A manager must work at least 5 hours on all projects controlled by his/her department', 1, 1)
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('Constraint Violation: A manager must work at least 5 hours on all projects controlled by his/her department', 1, 1)
rollback
end
```
"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

```sql
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 -- while previous operation affected some rows
begin
  if exists ( select *
from #Supervision
where SSN = SuperSSN )
begin
    raiserror('Constraint Violation: The supervision relationship is cyclic', 1, 1)
    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
```