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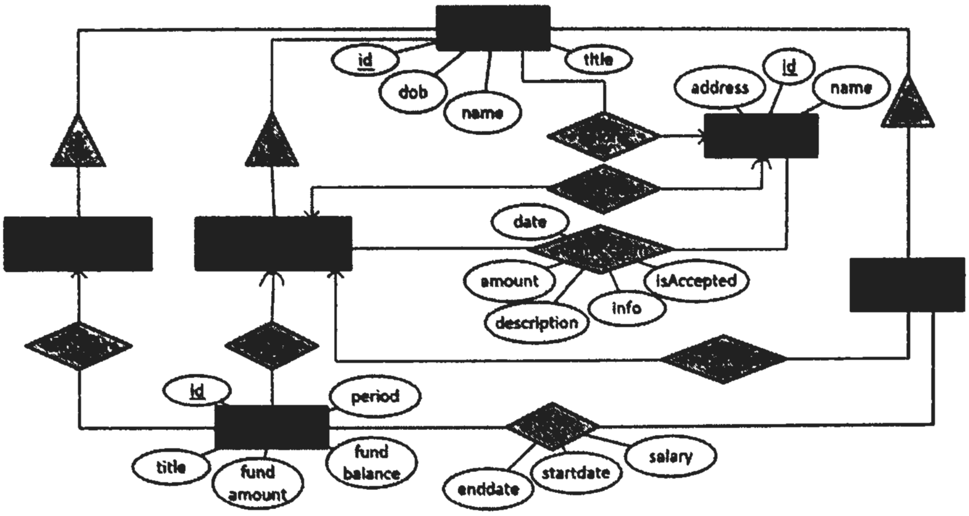
1. (a)

(i)



(ii) Employee (id, dob, name, title)
School (id, name, address)
Emp_belongTo_School (emp_id, school_id)
AdministrationStaff (emp_id)
AcademicStaff (emp_id)
ResearchStaff (emp_id)
ChairOfSchool (academic_staff_id, school_id)
SubmittedClaim (academic_staff_id, school_id, date, amount, description, info, isAccepted)
Supervised (academic_staff_id, research_staff_id)
Project (id, period, title, fund_amount, fund_balance)
MonitorProject (admin_staff_id, project_id)
LeadProject (academic_staff_id, project_id)
WorkForProject (research_staff_id, project_id, startdate, enddate, salary)

(b)

(i) $R1 \coloneqq Customers \bowtie Accounts \bowtie Account\_Owners$
$R2 \coloneqq \Pi_{\text{name}}\left(\gamma_{\text{name, MAX(balance)}\rightarrow\text{maxbalance}}R1\right)$

(ii) $R1 \coloneqq Customers \bowtie Accounts \bowtie Account\_Owners$
$R2 \coloneqq \delta(\Pi_{\text{name}}R1)$
$R3 \coloneqq \delta\left(\Pi_{\text{name}}(\sigma_{\text{balance}>0}R1)\right)$
$R4 \coloneqq R3 - R2$

(iii) $R1 :=$

$Accounts \bowtie_{\text{Accounts.number=Acc.num AND Accounts.balance>Acc.bal}} \rho_{Acc(num,bal)}(Accounts)$

$R2 := \Pi_{\text{balance}} \sigma_{\text{order<100}} (\gamma_{\text{balance, COUNT(bal)}\rightarrow\text{order}} R1)$

$R3 := \Pi_{\text{number}} (R2 \bowtie Accounts)$

2. (a)

C and E do not appear on the RHS of the FDs; thus, they must be included in the keys

$\{CE\}^+ = \{BCDE\}$, $\{ACE\}^+ = \{ABCDEF\}$, $\{BCE\}^+ = \{BCDE\}$,
$\{CDE\}^+ = \{BCDE\}$, $\{CEF\}^+ = \{ABCDEF\}$, $\{BCDE\}^+ = \{BCDE\}$

So, keys of R: ACE, CEF

FD $C \rightarrow D$ violates BCNF definition. $\{C\}^+ = \{BCD\}$

Decomposition of R: $R1(B, C, D)$; $R2(A, C, E, F)$

Keys of R1: C. R1 is in BCNF

Keys of R2: ACE, CEF. There is a hidden FD $AC \rightarrow F$.

FD $AC \rightarrow F$ violates BCNF definition. $\{AC\}^+ = \{ACF\}$

Decomposition of R2: $R3(A, C, F)$; $R4(A, C, E)$

Keys of R3: AC, E. R3 is in BCNF.

Keys of R4: ACE, R4 is in BCNF.

Conclusion: the decomposition of R is $R1(B, C, D)$; $R3(A, C, F)$; $R4(A, C, E)$.

Not all the FDs are reserved; e.g FD $AD \rightarrow F$ is not reserved.

(b)

FD $C \rightarrow D$ violates 3NF definition.

Let $S = \{C \rightarrow D, DF \rightarrow A, AD \rightarrow F, CD \rightarrow B, BCF \rightarrow A\}$.

We will determine the minimal basis of S.

After the first step, S remains the same.

After step 2, S becomes $\{C \rightarrow D, DF \rightarrow A, AD \rightarrow F, CD \rightarrow B\}$.

After step 3, $S = \{C \rightarrow D, DF \rightarrow A, AD \rightarrow F, C \rightarrow B\}$

Hence we ended up with the set $S = \{C \rightarrow BD, DF \rightarrow A, AD \rightarrow F\}$, which gives the 3NF decomposition of R as $R1(B, C, D)$; $R2(A, D, F)$; $R3(A, C, E)$.

3. (a)

```
SELECT temperature, heartRate
FROM Tests, Patients
WHERE Tests.pid = Patients.pid AND Patients.year < 1971
```

(b)

```
CREATE ASSERTION Q3b CHECK (
NOT EXISTS (
  SELECT *
  FROM Wards INNER JOIN PatientInWard ON Wards.number = PatientInWard.wardNumber
  GROUP BY number
  HAVING COUNT(pid) > numBeds ) );
```

(c)

```
CREATE VIEW FreeBeds AS
SELECT number AS ward, COUNT(pid) – numBeds AS numBeds
FROM Wards INNER JOIN PatientInWard ON Wards.number = PatientInWard.wardNumber
GROUP BY number
```

(d)

```
CREATE TRIGGER Q3d
BEFORE INSERT ON PatientInWard
REFERENCING NEW ROW AS n
FOR EACH ROW
WHEN NOT EXISTS ( SELECT * FROM FreeBeds
                  WHERE ward = n.wardNumber AND numBeds > 0 )
INSERT INTO PatientInWard VALUES (n.pid, SELECT MIN(numBeds) FROM FreeBeds);
```

4. (a)

(i)

```
SELECT empid, name, salary
FROM Employees
ORDER BY name;
```

(ii)

```
CREATE PROCEDURE Merge (
        IN city1 CHAR(32),
        IN dept1 CHAR(32),
        IN city2 CHAR(32),
        IN dept2 CHAR(32),
        DECLARE dept1Size INTEGER,
        DECLARE dept2Size INTEGER,
        DECLARE dept1Head CHAR(32)
)
BEGIN
        UPDATE Employees SET dept = dept2, city = city2
                WHERE dept = dept1 AND city = city1;
        SET dept1Size = ( SELECT COUNT(*) FROM Employees WHERE dept = dept1 );
        SET dept2Size = ( SELECT COUNT(*) FROM Employees WHERE dept = dept2 );
        SET dept1Head = ( SELECT departmentHead
                          FROM Departments WHERE dname = dept1 );
        IF dept1Size > dept2Size THEN
                UPDATE Departments SET departmentHead = dept1Head;
        DELETE FROM Departments WHERE dname = dept1;
END;
```

(b)

(i) 1. The DTD states <!ELEMENT A (B)> but there are multiple sections of B under A.
2. The DTD states that attribute b2 of B is required but it is absent in the second section of B

(ii) <!ELEMENT A (B)> needs to be changed to <!ELEMENT A (B+)>
<!ATTLIST B b1 CDATA #REQUIRED b2 CDATA #REQUIRED> needs to be changed to
<!ATTLIST B b1 CDATA #REQUIRED b2 CDATA #IMPLIED>

(c)

(i) There is no visible result, as the target B has no text to show (actually none of the B has any text)

(ii) Third
Fourth