CSE 4125: Distributed Database Systems
Chapter – 5

Translation of Global Queries to Fragment Queries.

(Part – E)

Topics to be discussed –

- Simplification of Non-distributed Query

Question type:

/* A query is given */

Now, answer the following questions.

i. Draw the *operator tree*. [2]

ii. Perform step-by-step transformations to simplify the operator tree, indicating which rule and criterion is applied at each step. [5]

Non-distributed (Equivalence Transformation for Queries):

- Query $\rightarrow$ Operator Tree.
- Operator Tree $\rightarrow$ Simplified Operator Tree.

We will follow this -

Equivalence Query transformation steps:

1. Generate the equivalent operator tree (T_{global}) for the given query (Q_{global}).
2. Find the common sub-expression (*R*) from T_{global}.
3. Apply rules to remove *R* and obtain simplified tree $T_{removed}$.
4. Apply criteria – 1 and 2 on $T_{removed}$ to obtain final simplified operator tree $T_{transformed}$.
5. Write the query $Q_{transformed}$ from $T_{transformed}$.

So, $Q_{global} \leftrightarrow Q_{transformed}$

Some Rules/Properties

Properties

- $R \; NJN \; R \leftrightarrow R$ → 1
- $R \; UN \; R \leftrightarrow R$ → 2
- $R \; DF \; R \leftrightarrow 0$ → 3
- $R \; NJN \; SL_F \; R \leftrightarrow SL_F \; R$ → 4
- $R \; UN \; SL_F \; R \leftrightarrow R$ → 5
- $R \; DF \; SL_F \; R \leftrightarrow SL_{NOT \; F} \; R$ → 6
- $(SL_{F1} \; R) \; NJN \; (SL_{F2} \; R) \leftrightarrow SL_{F1 \; AND \; F2} \; R$ → 7
- $(SL_{F1} \; R) \; UN \; (SL_{F2} \; R) \leftrightarrow SL_{F1 \; OR \; F2} \; R$ → 8
- $(SL_{F1} \; R) \; DF \; (SL_{F2} \; R) \leftrightarrow SL_{F1 \; AND \; NOT \; F2} \; R$ → 9

They will be used to remove common sub-expressions in the simplification of operator tree.

Example 1

EMP (EMPNUM, DEPTNUM, NAME, SAL, AGE)
DEPT (DEPTNUM, NAME, AREA, MGRNUM)

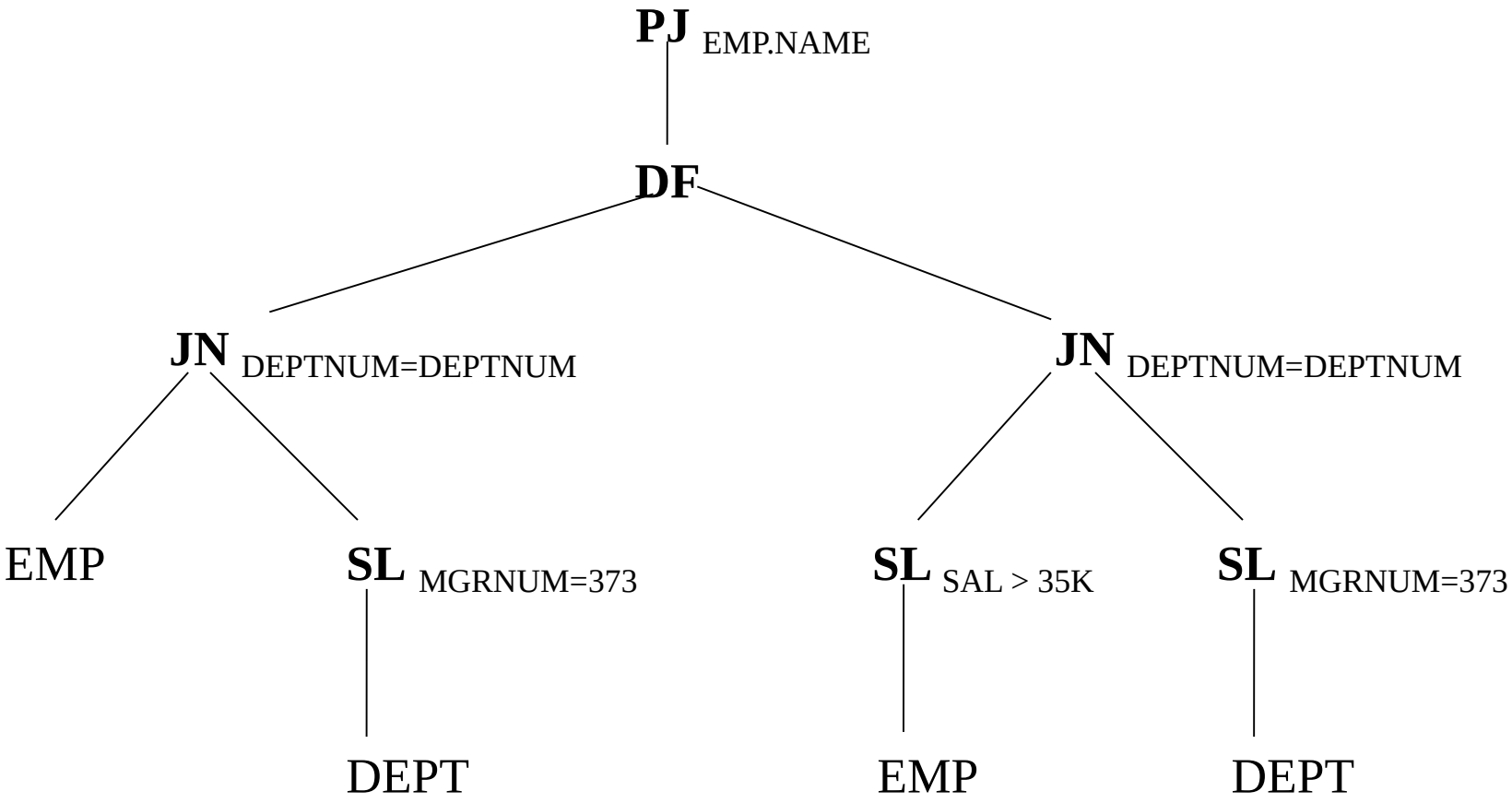
Q: PJ $_{\text{EMP.NAME}}$ ((*EMP* **JN** $_{\text{DEPTNUM=DEPTNUM}}$ **SL** $_{\text{MGRNUM=373}}$ *DEPT*) **DF** (**SL** $_{\text{SAL > 35K}}$ *EMP* **JN** $_{\text{DEPTNUM=DEPTNUM}}$ **SL** $_{\text{MGRNUM=373}}$ *DEPT*))

Now, answer the following questions.

i. Draw the *operator tree*. [2]

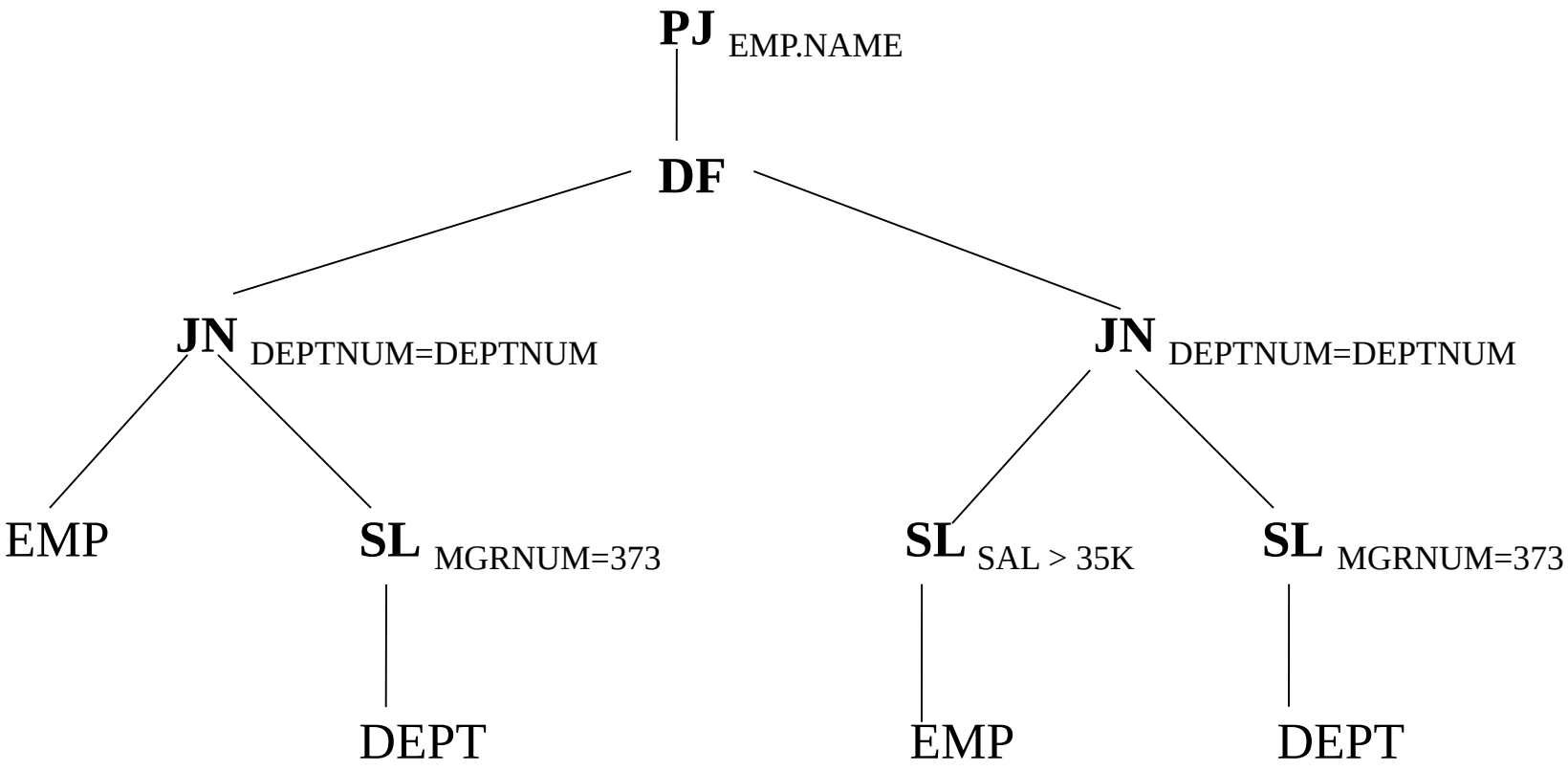
ii. Perform step-by-step transformations to simplify the operator tree, indicating which rule and criterion is applied at each step. [5]

Operator Tree



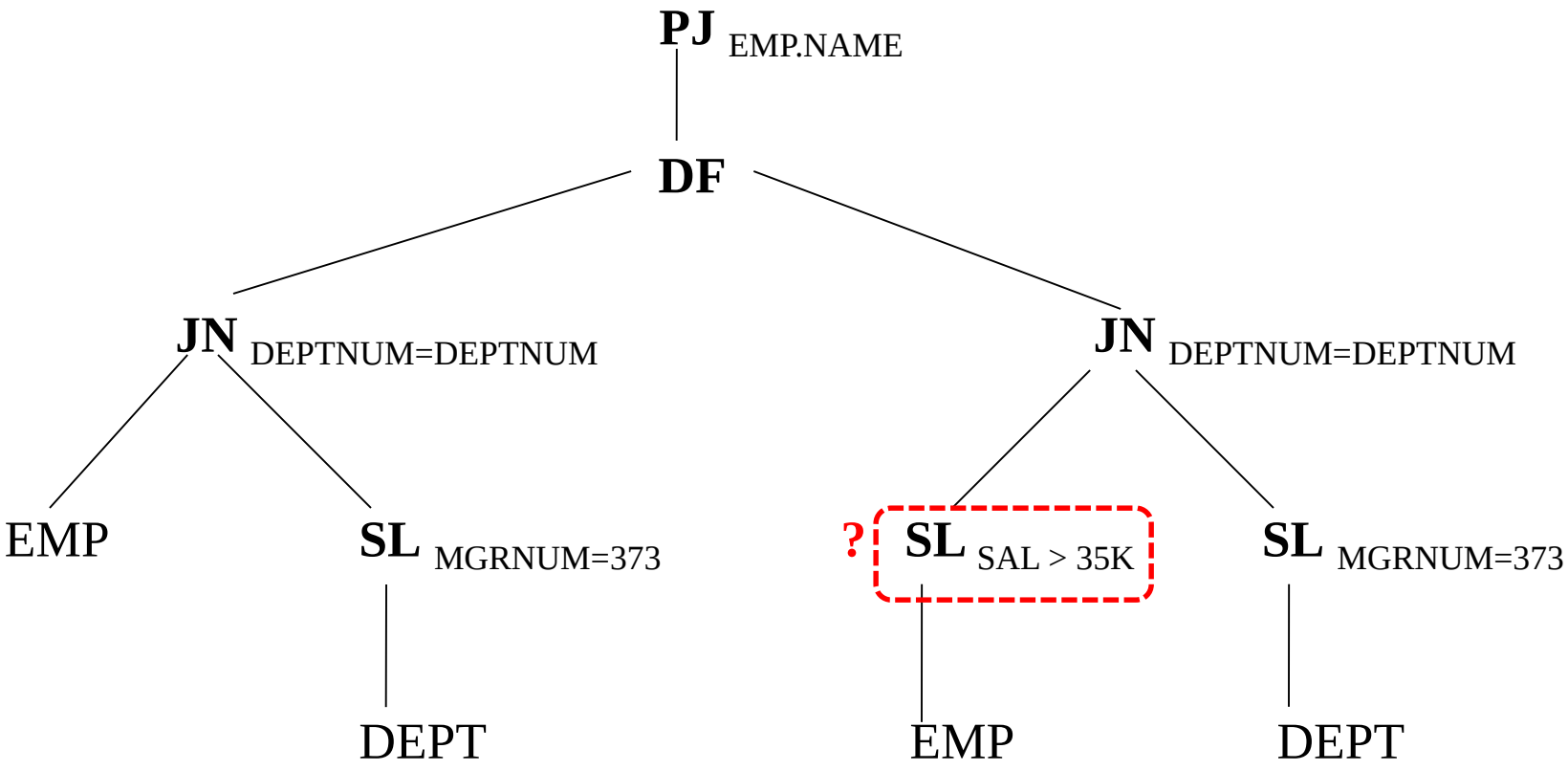
Finding Common Sub-expression

Any common portion?



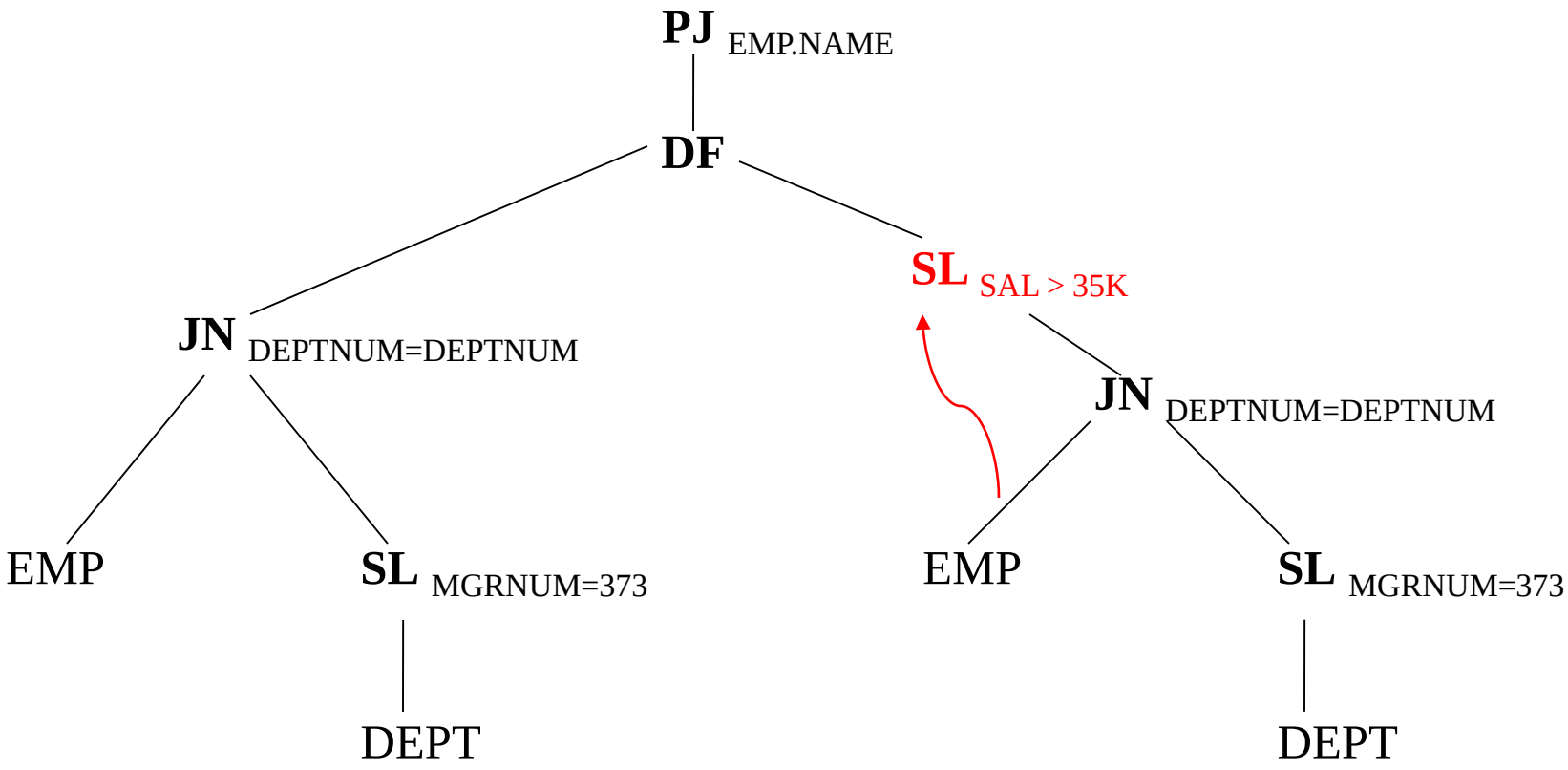
Finding Common Sub-expression

Any common portion?

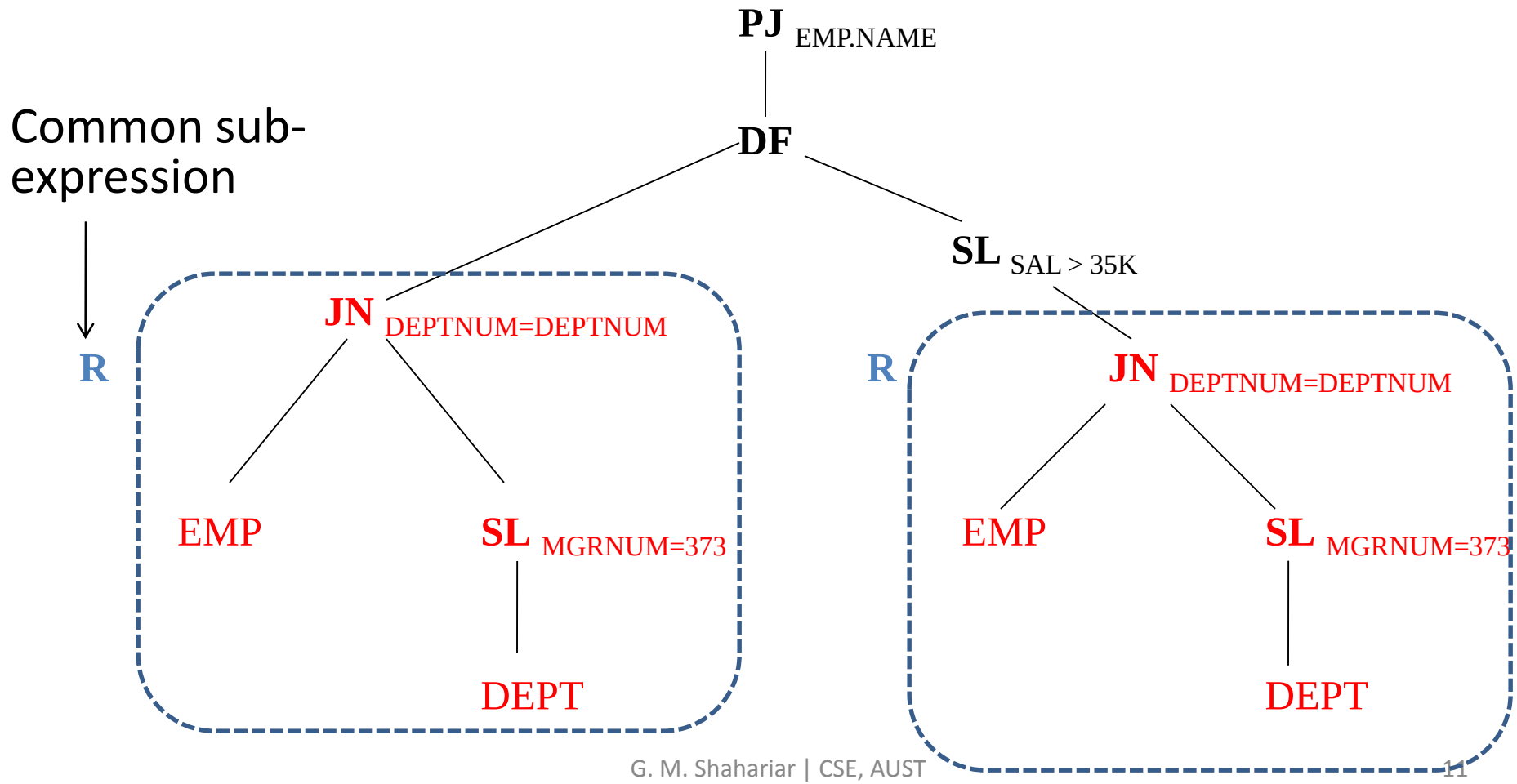


Finding Common Sub-expression

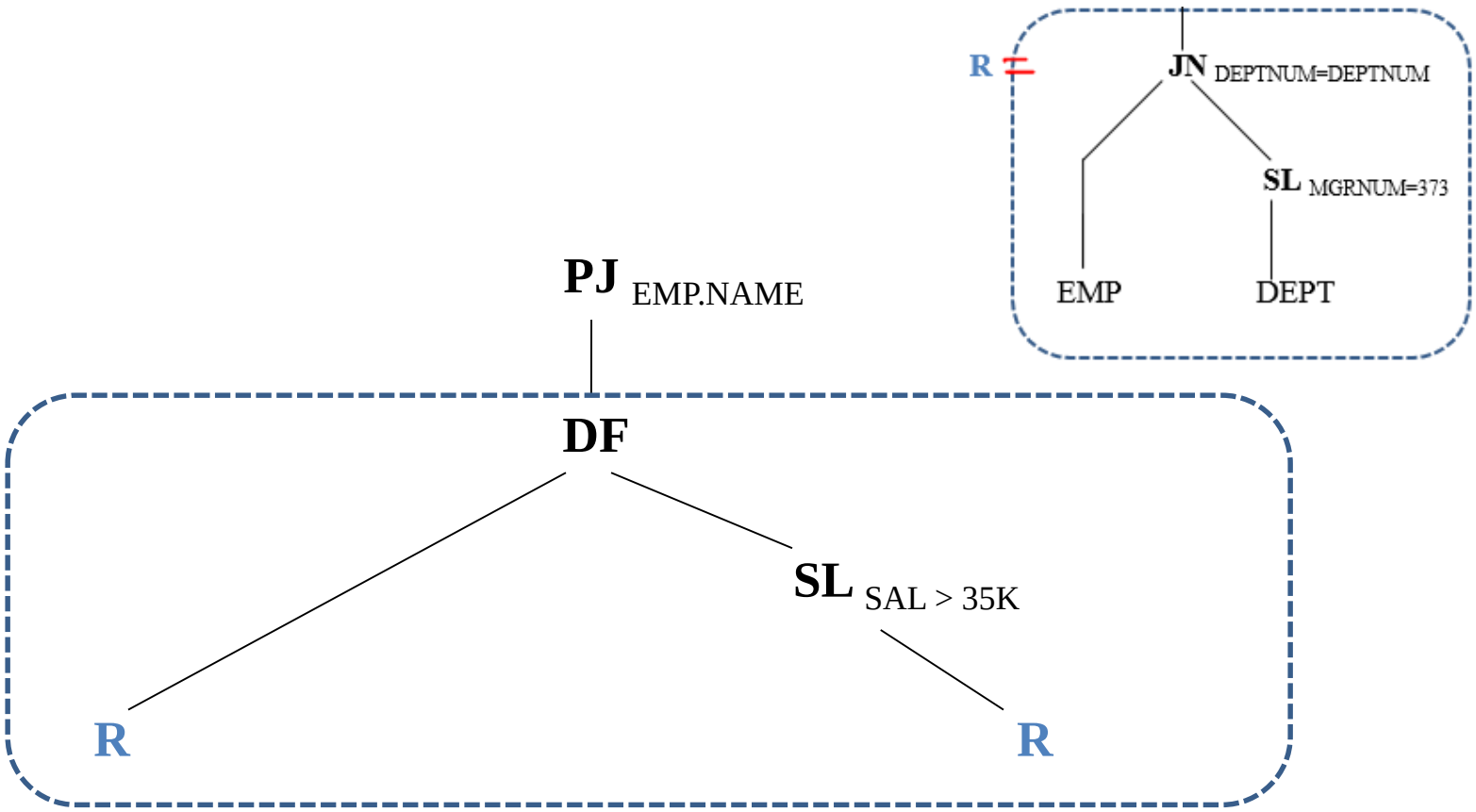
Any common portion? NOW?



Finding Common Sub-expression

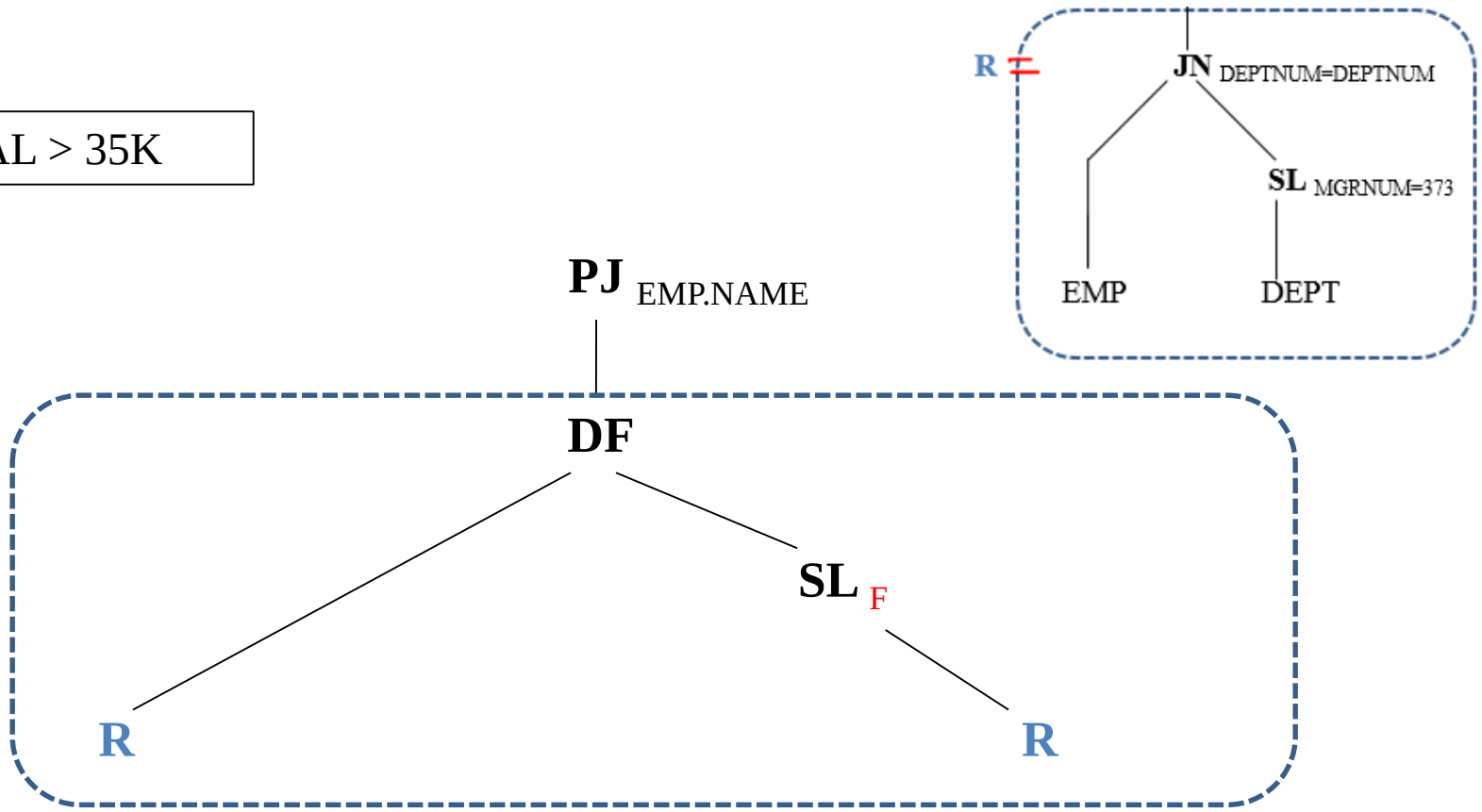


Finding Common Sub-expression



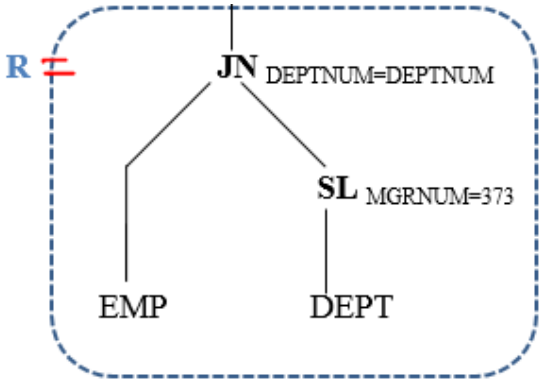
Finding Common Sub-expression

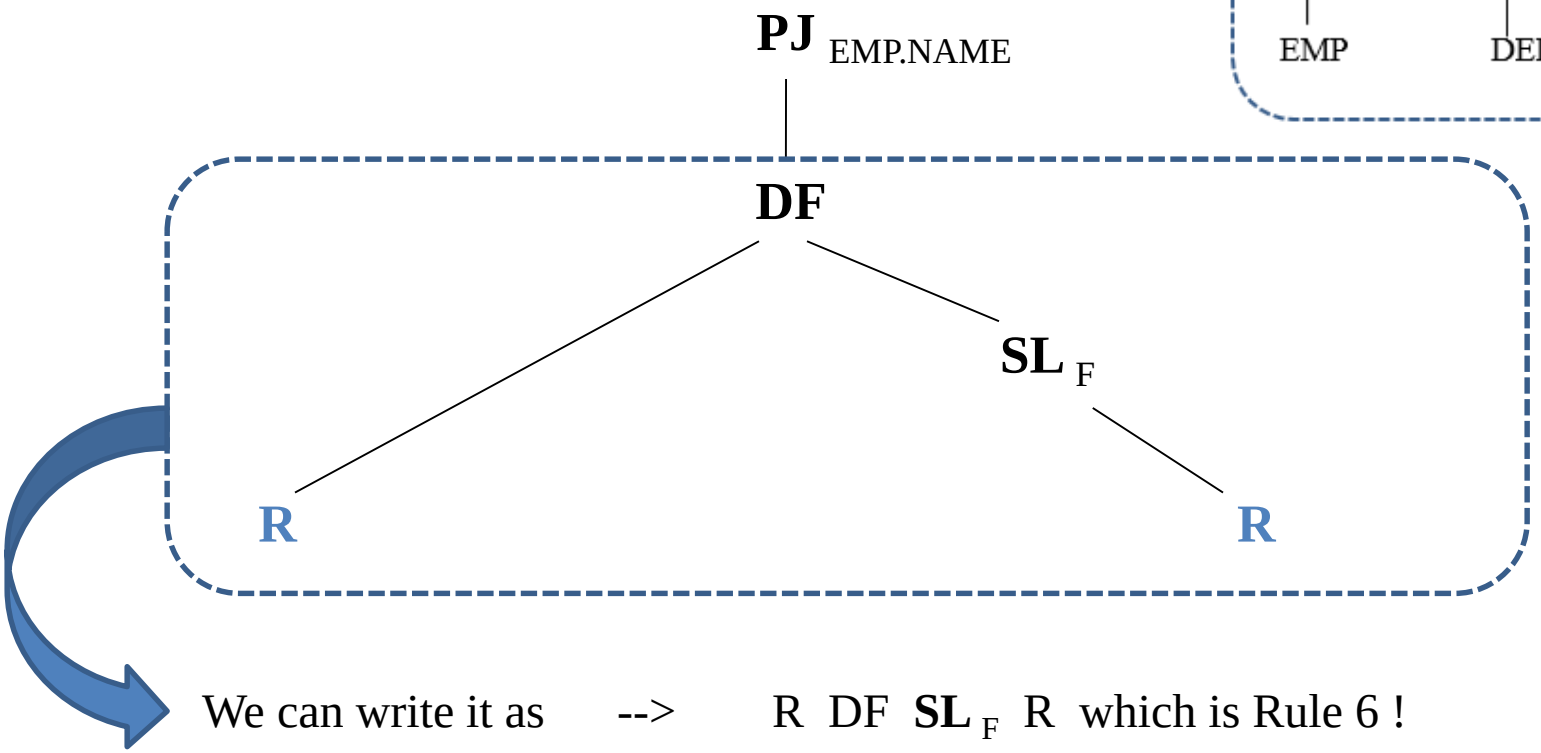
F = SAL > 35K



Finding Common Sub-expression

F = SAL > 35K

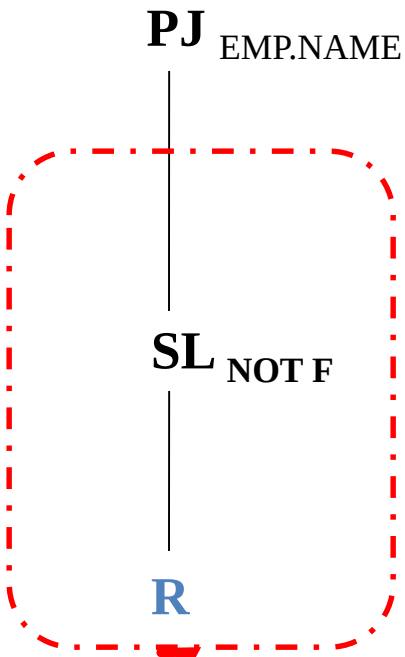


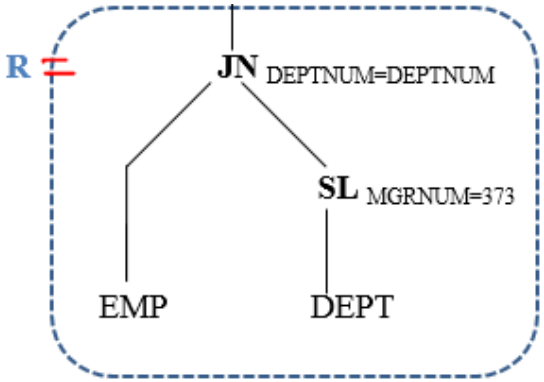


We can write it as --> R DF **SL** $_F$ R which is Rule 6 !

Removing Common Sub-expression

F = SAL > 35K

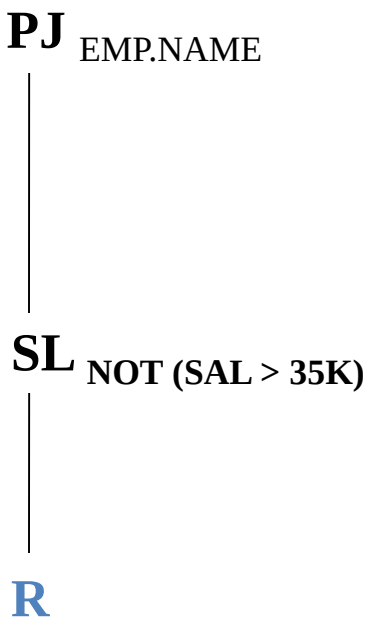


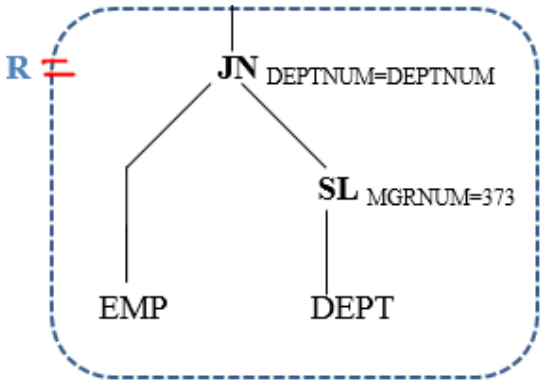


- R DF SL_F R ↔ $SL_{NOT\,F}$ R

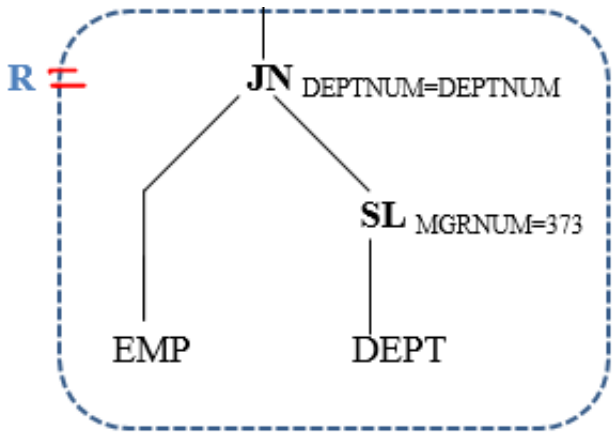
Removing Common Sub-expression

F = SAL > 35K





Removing Common Sub-expression



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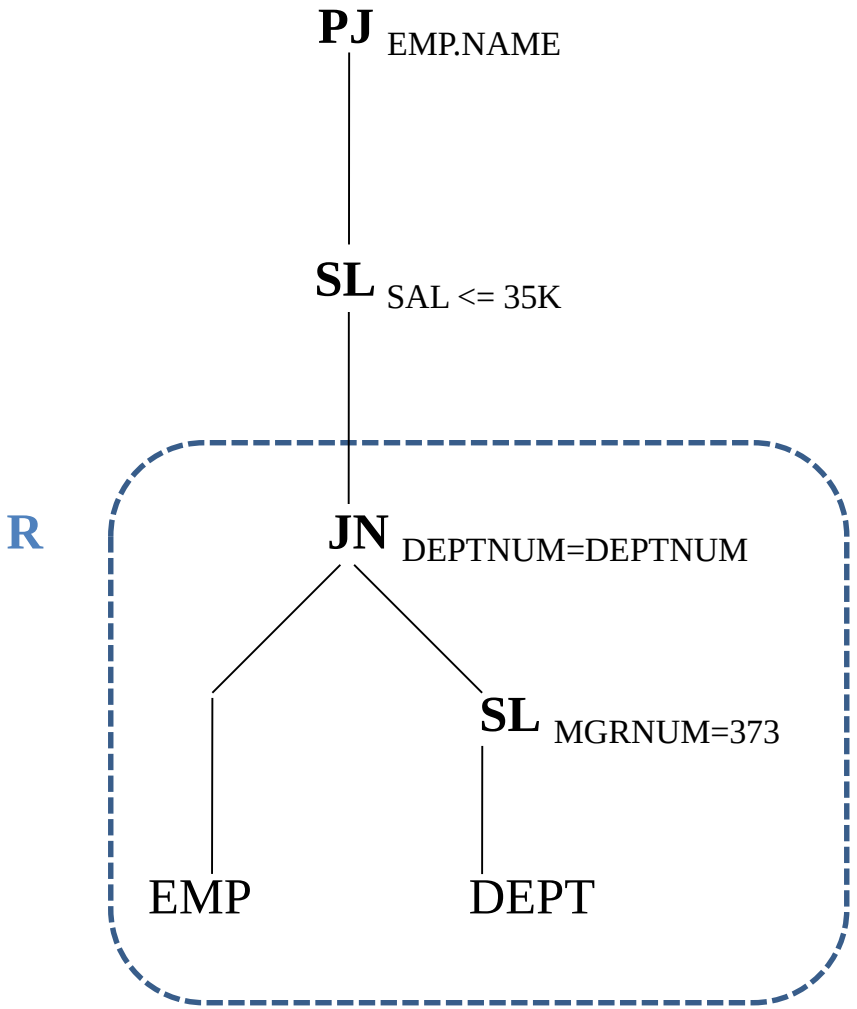
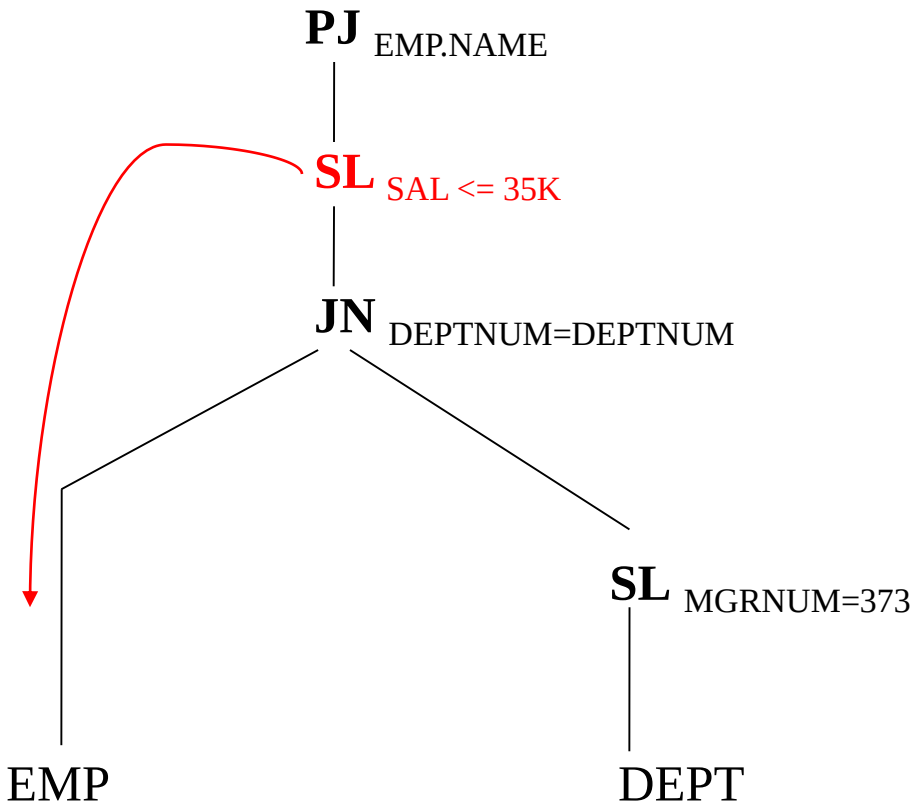


Can you apply Criterion 1 and/or 2 on this tree?

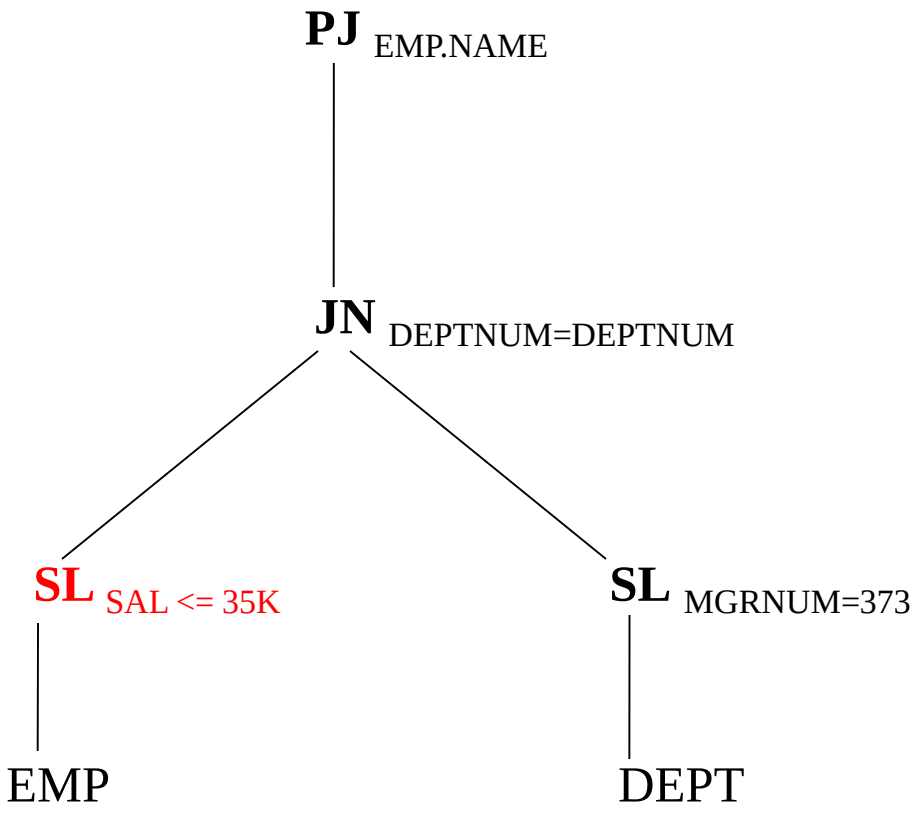
Simplification

Applying criterion – 2



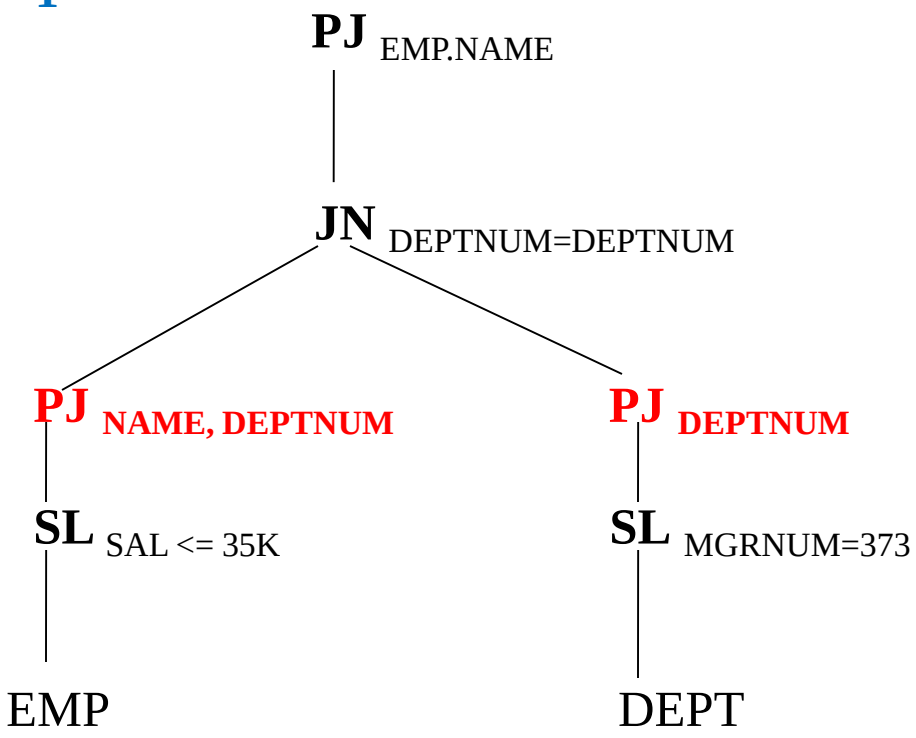
Simplification

After Applying criterion – 2



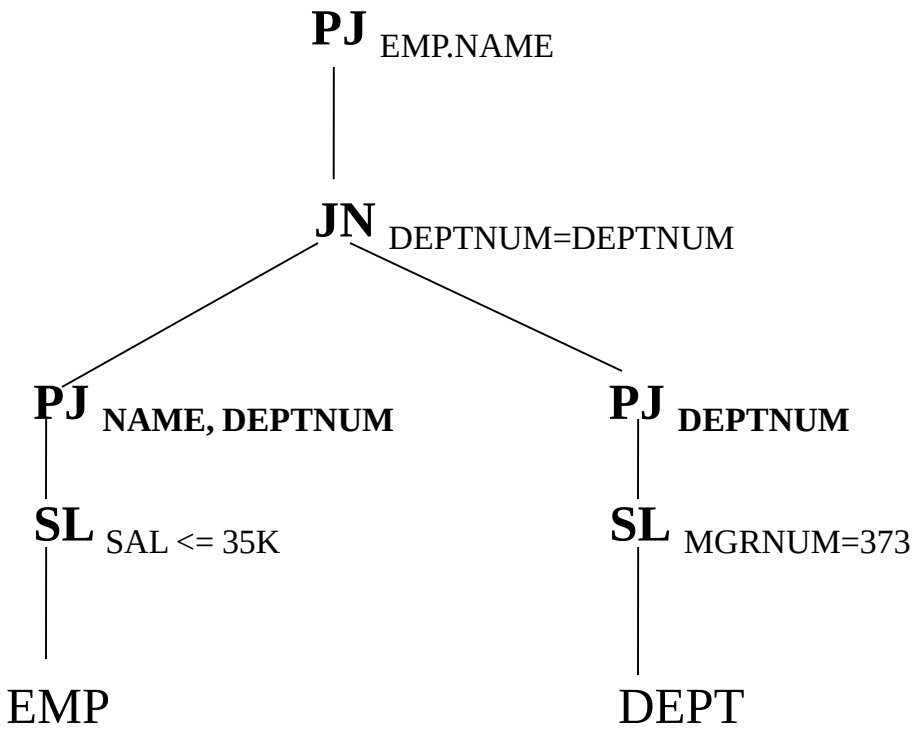
Simplification

After Applying criterion – 1



Transformed Query

Q_T: $PJ_{EMP.NAME}$ (($PJ_{NAME,DEPTNUM}$ $SL_{SAL<=35K}$ *EMP*) $JN_{DEPTNUM=DEPTNUM}$ ($PJ_{DEPTNUM}$ $SL_{MGRNUM=373}$ *DEPT*))



Transformed Query

Output:

$$\mathbf{Q_T:}\ \mathbf{PJ}_{\text{EMP.NAME}}\ ((\mathbf{PJ}_{\text{NAME,DEPTNUM}}\ \mathbf{SL}_{\text{SAL<=35K}}\ \textit{EMP})\ \mathbf{JN}_{\text{DEPTNUM=DEPTNUM}}\ (\mathbf{PJ}_{\text{DEPTNUM}}\ \mathbf{SL}_{\text{MGRNUM=373}}\ \textit{DEPT}))$$

Input:

$$\mathbf{Q:}\ \mathbf{PJ}_{\text{EMP.NAME}}\ ((\textit{EMP}\ \mathbf{JN}_{\text{DEPTNUM=DEPTNUM}}\ \mathbf{SL}_{\text{MGRNUM=373}}\ \textit{DEPT})\ \mathbf{DF}\ (\mathbf{SL}_{\text{SAL > 35K}}\ \textit{EMP}\ \mathbf{JN}_{\text{DEPTNUM=DEPTNUM}}\ \mathbf{SL}_{\text{MGRNUM=373}}\ \textit{DEPT}))$$

$$Q \longleftrightarrow Q_T$$

Example 2.1

EMP (EMPNUM, DEPTNUM, NAME, SAL, AGE)
DEPT (DEPTNUM, NAME, AREA, MGRNUM)

Q: PJ $_{\text{EMP.NAME}}$ **SL** $_{\text{MGRNUM=373}}$ ((*EMP* **JN** $_{\text{DEPTNUM=DEPTNUM}}$ *DEPT*) **DF** (**SL** $_{\text{SAL > 35K}}$ *EMP* **JN** $_{\text{DEPTNUM=DEPTNUM}}$ *DEPT*))

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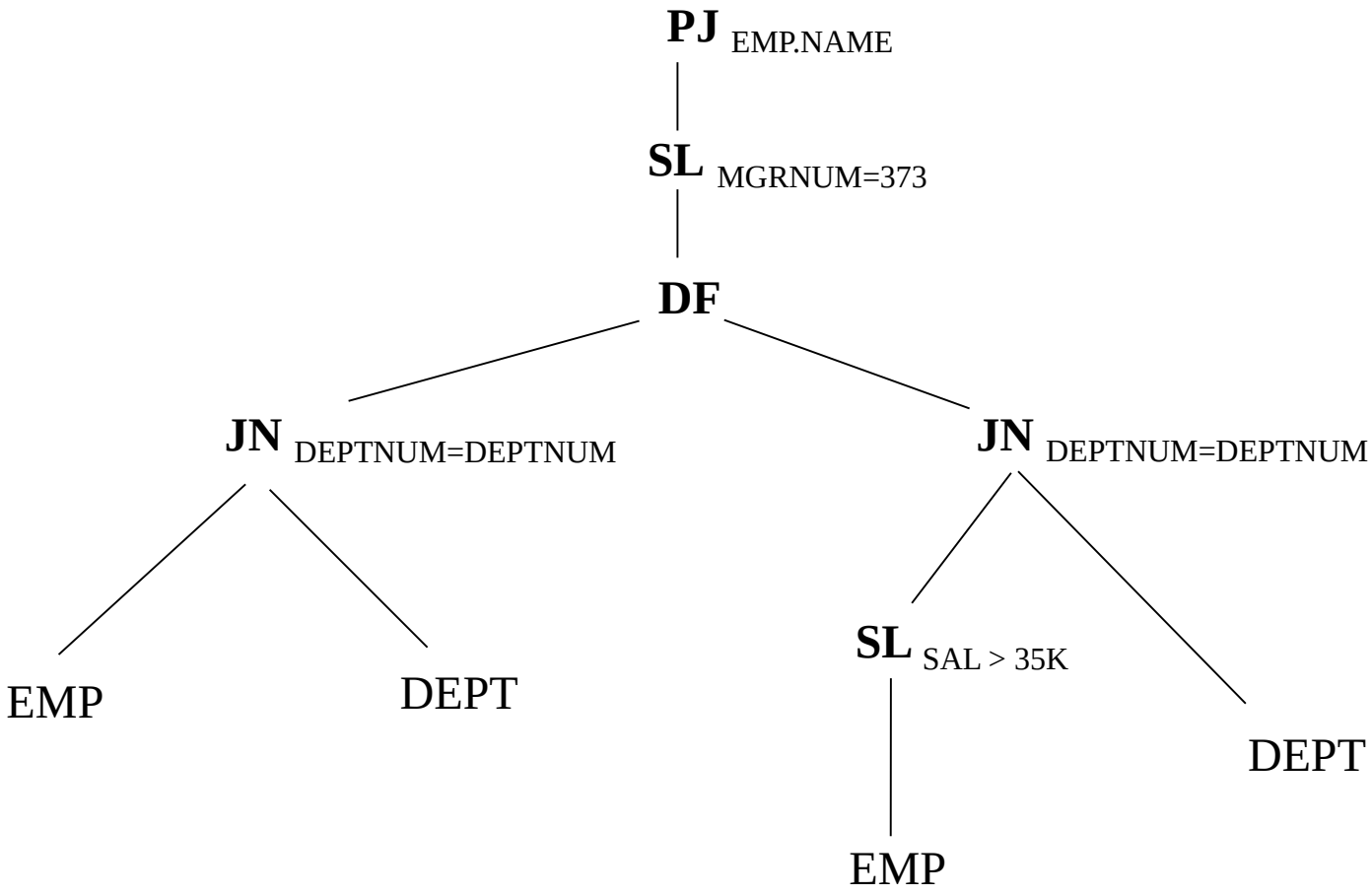
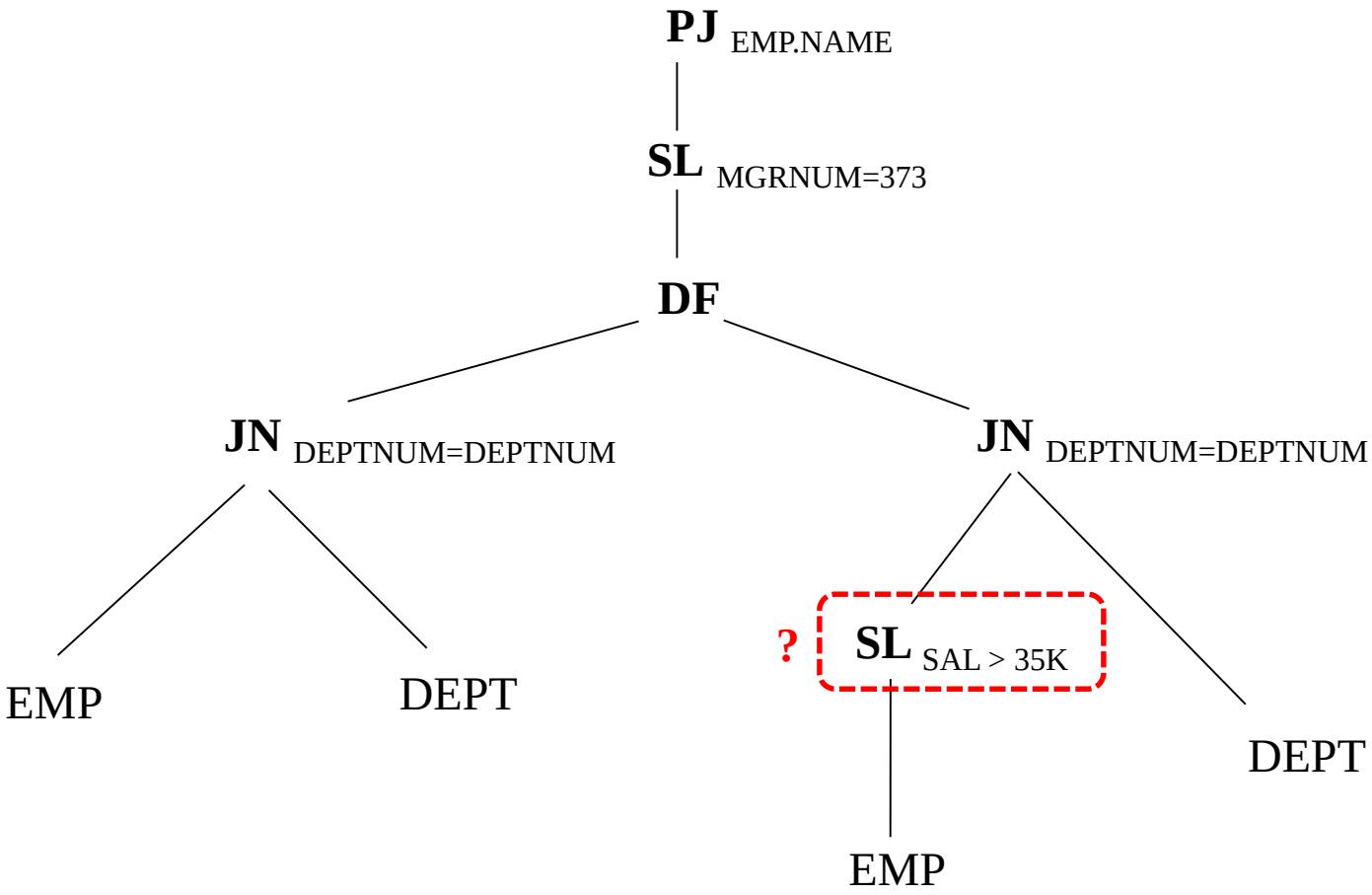


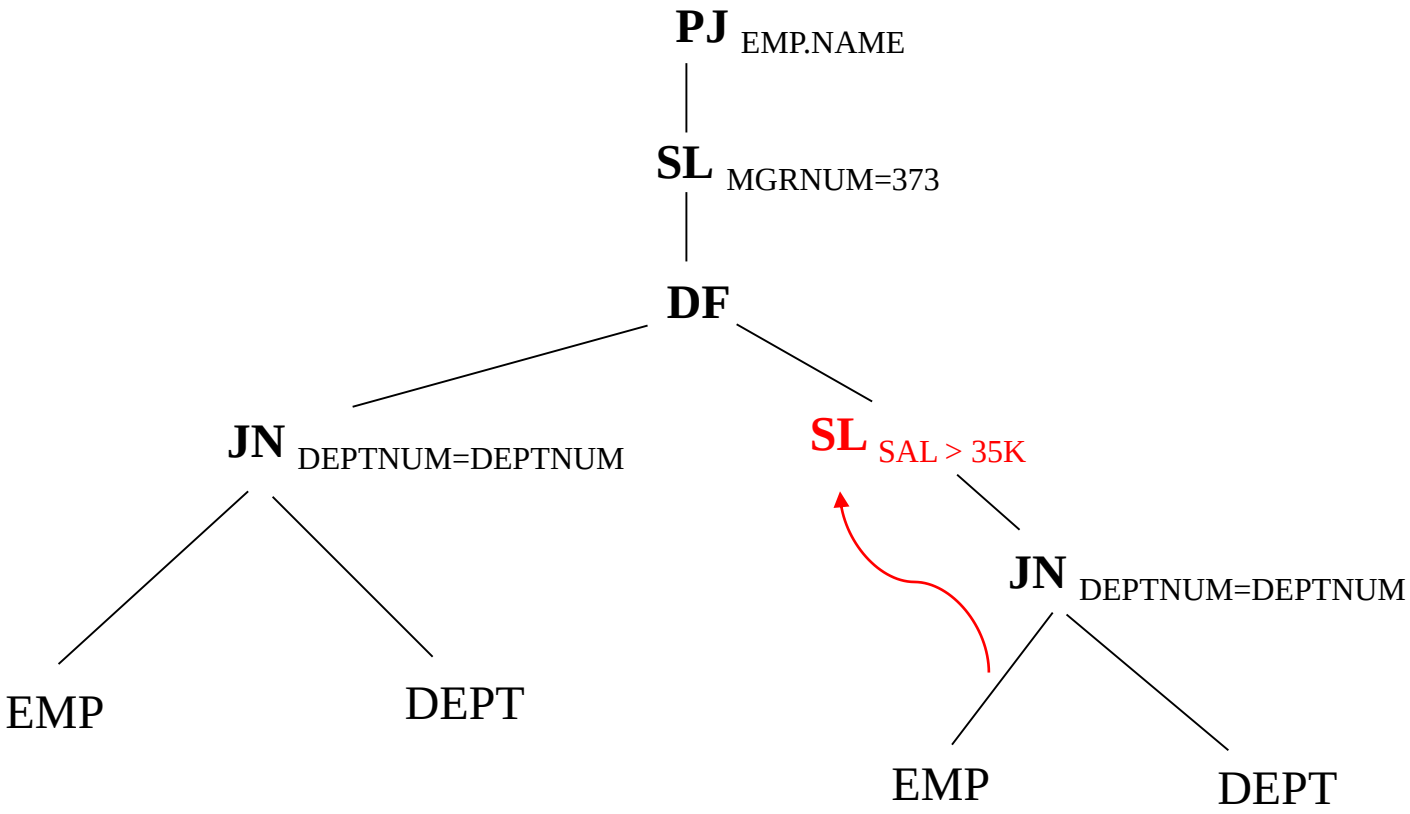
Finding Common Sub-expression

Any common portion?



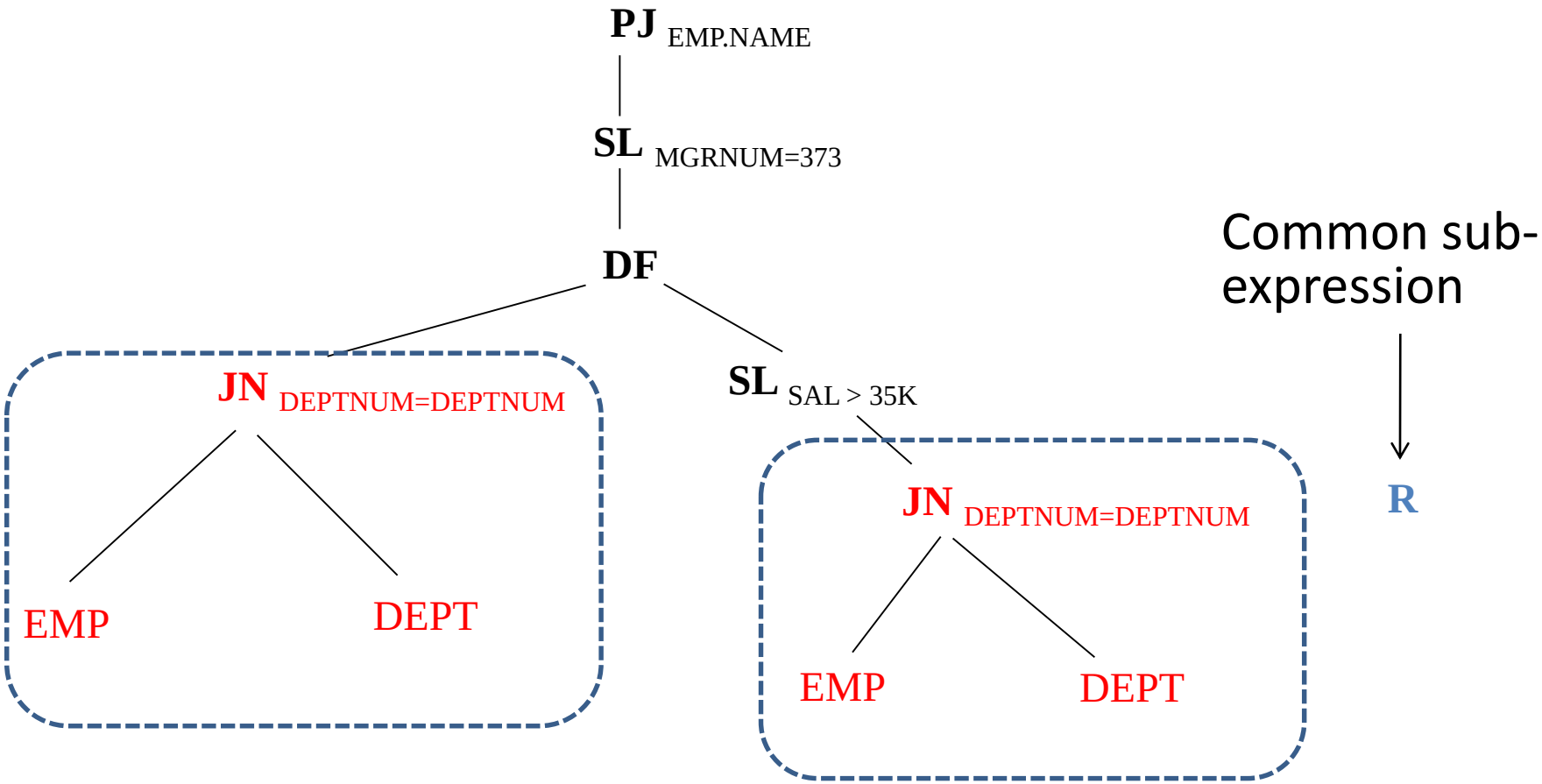
Finding Common Sub-expression

Any common portion? NOW?

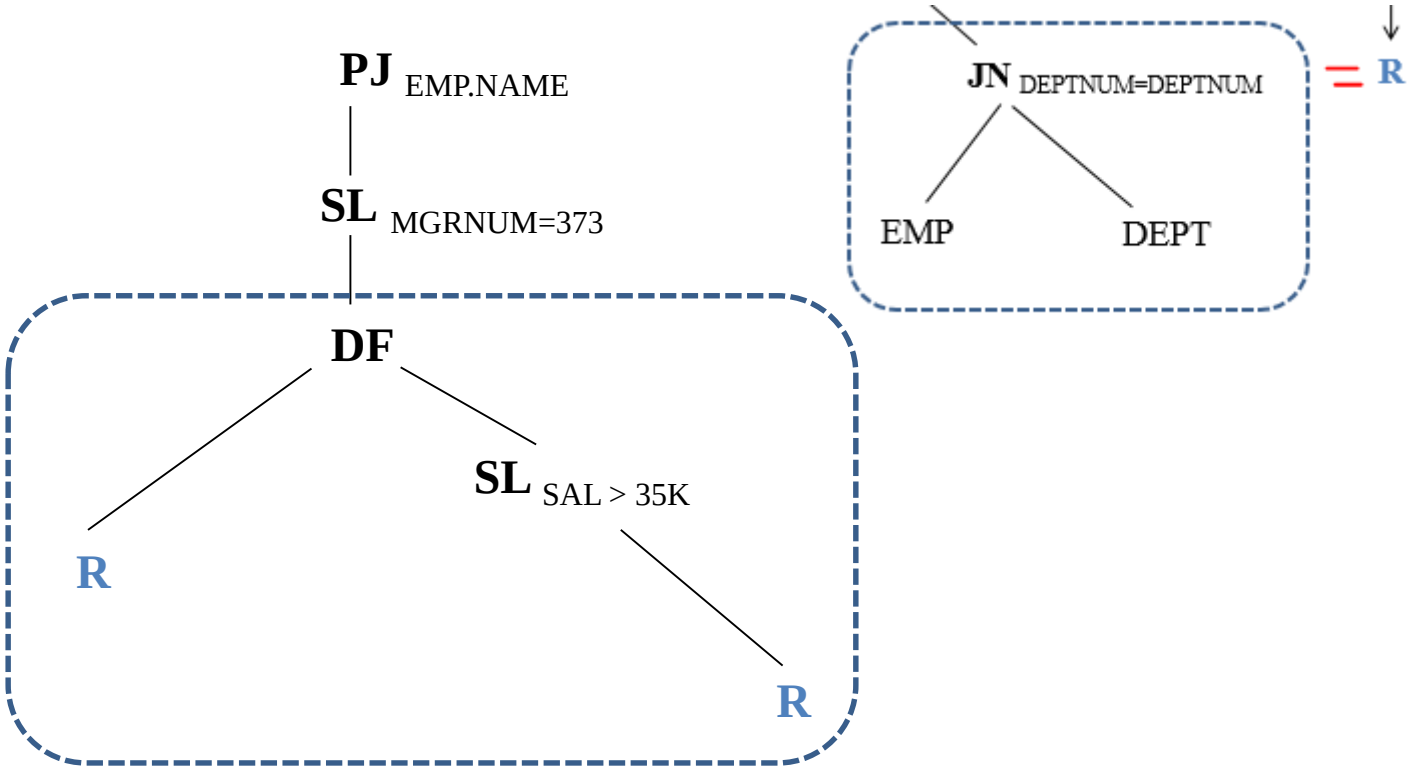


Finding Common Sub-expression

Any common portion? NOW?

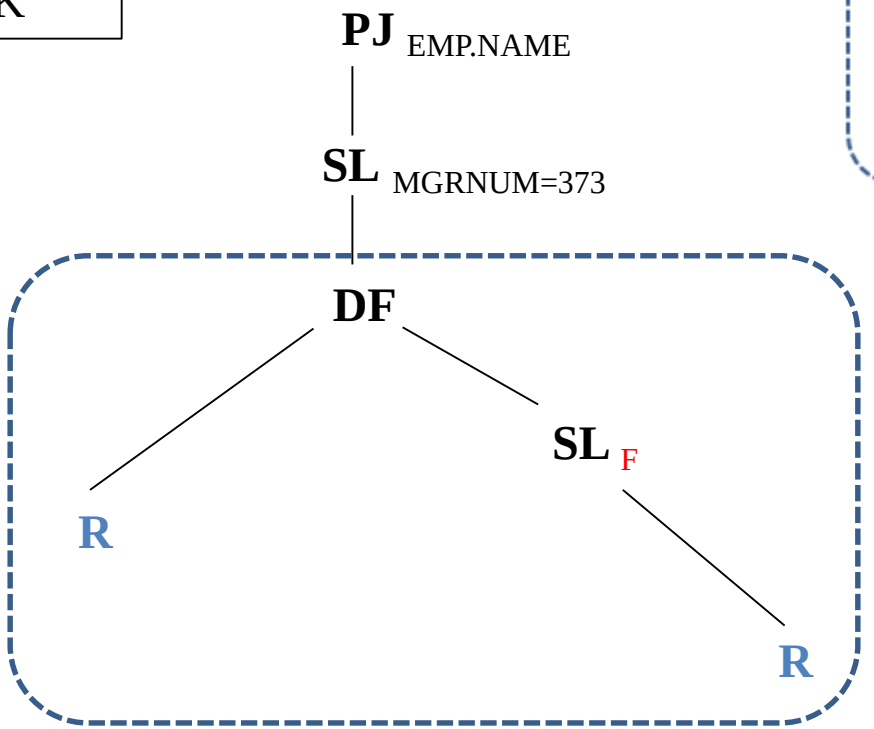


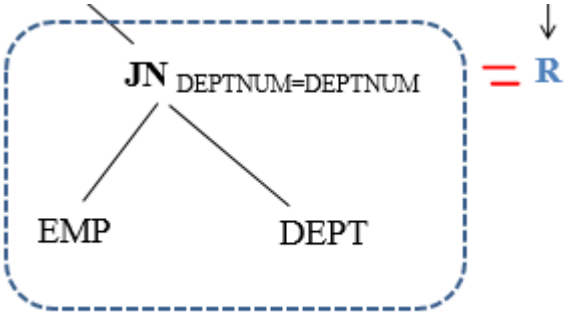
Finding Common Sub-expression



Finding Common Sub-expression

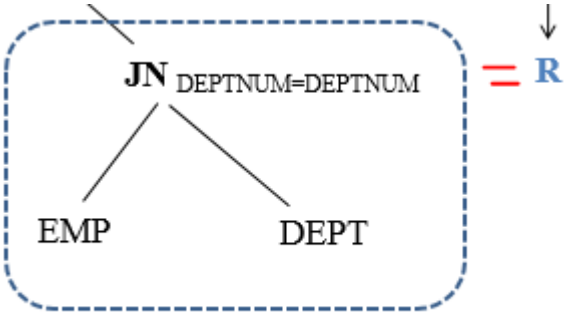
F = SAL > 35K

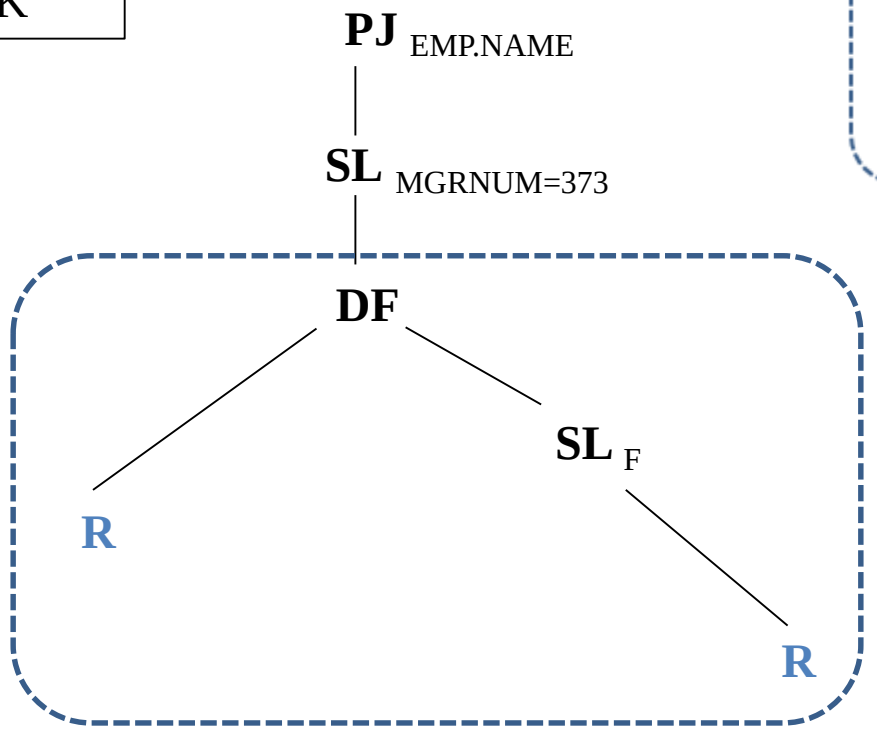




Finding Common Sub-expression

F = SAL > 35K

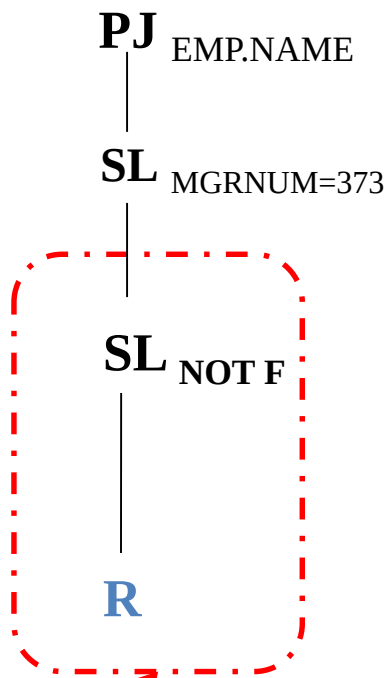


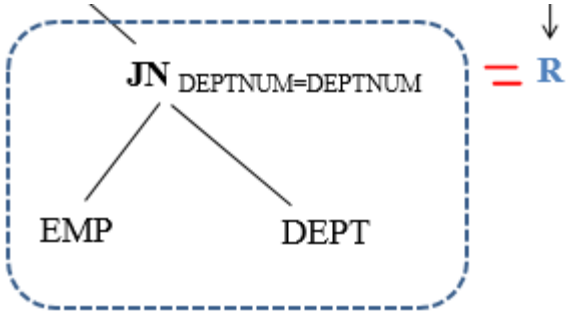


We can write it as --> R DF **SL** F R which is Rule 6 !

Removing Common Sub-expression

F = SAL > 35K

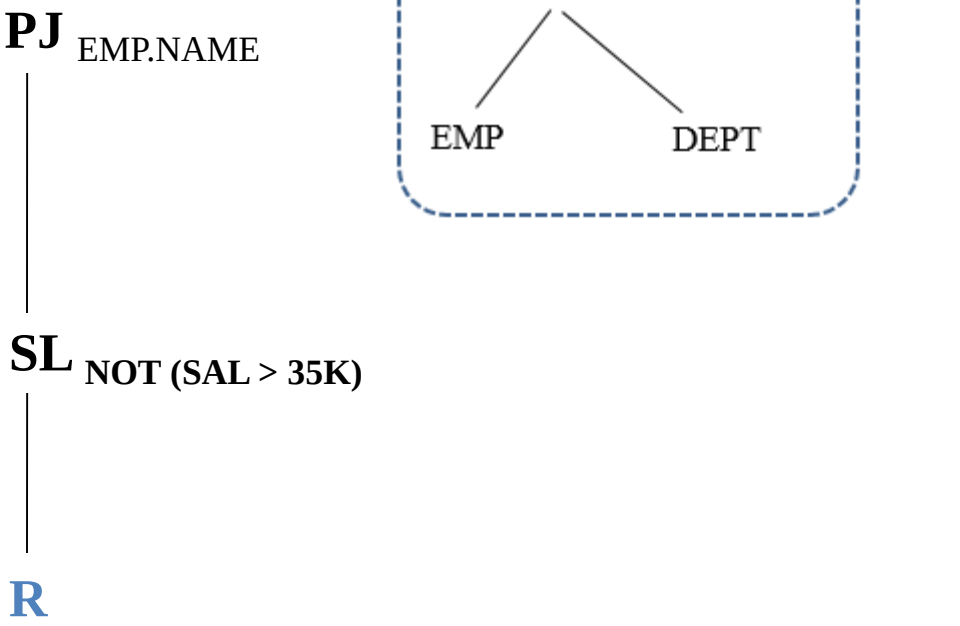




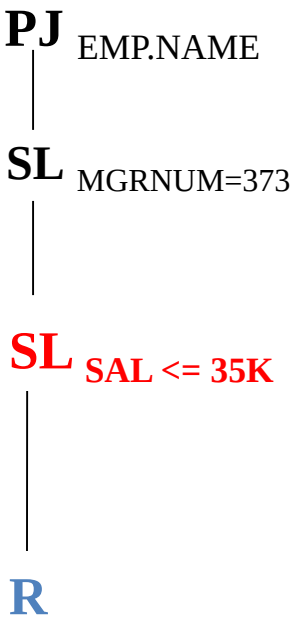
- $R\ DF\ SL_F\ R \leftrightarrow SL_{NOT\ F}\ R$

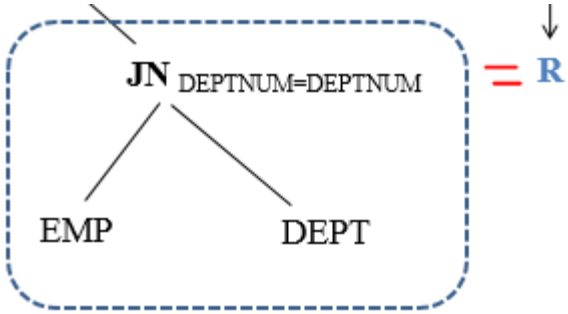
Removing Common Sub-expression

F = SAL > 35K

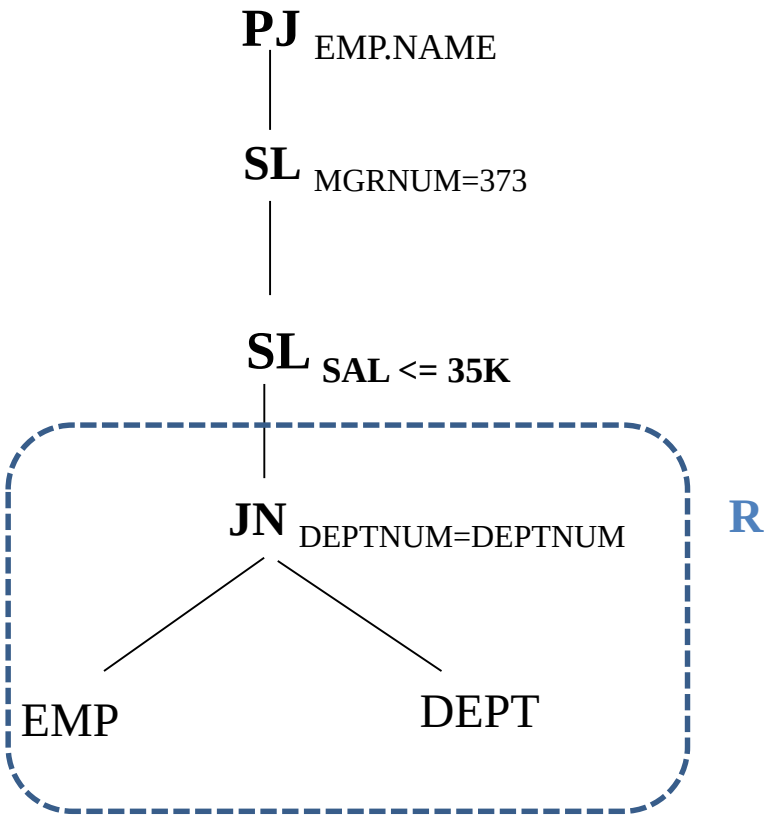


Removing Common Sub-expression





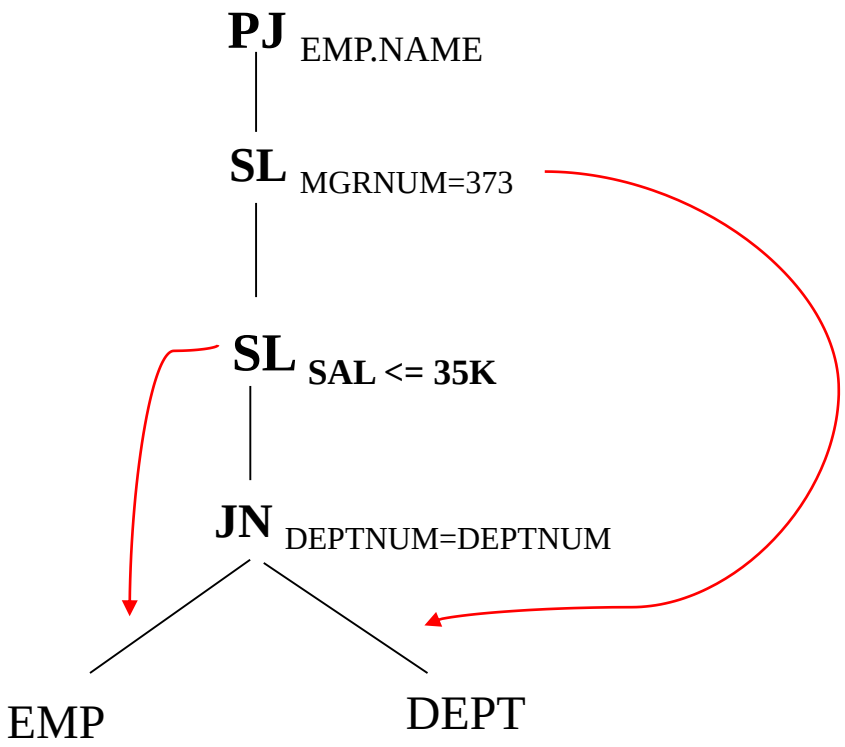
Removing Common Sub-expression



Can you apply Criterion 1 and/or 2 on this tree?

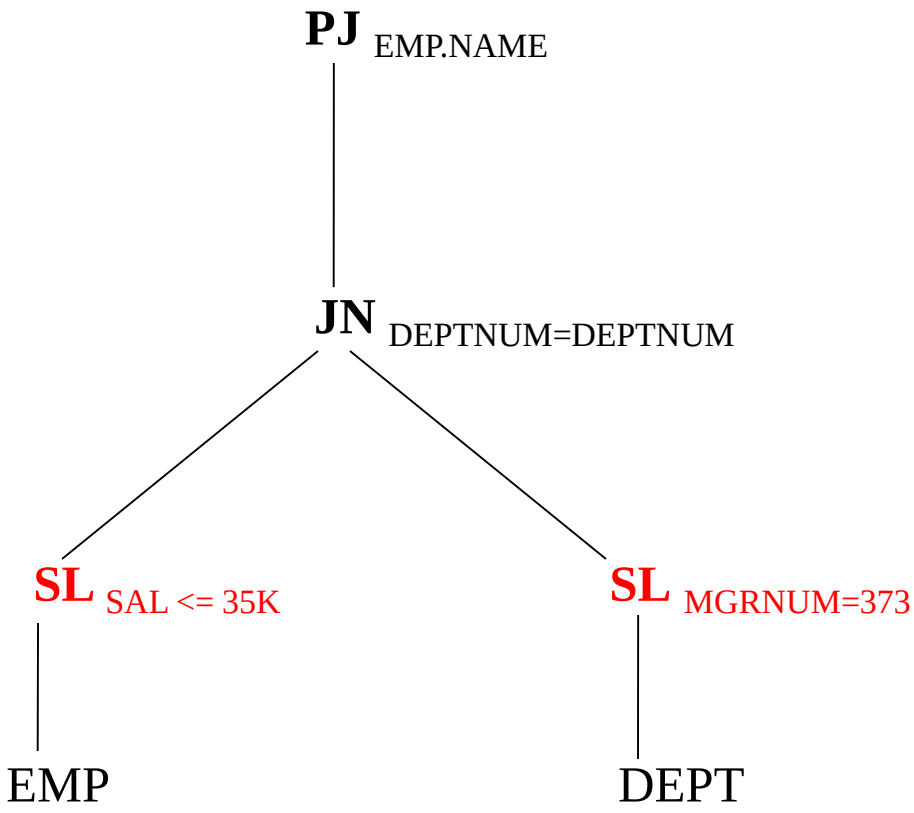
Simplification

Applying Criterion 2 -



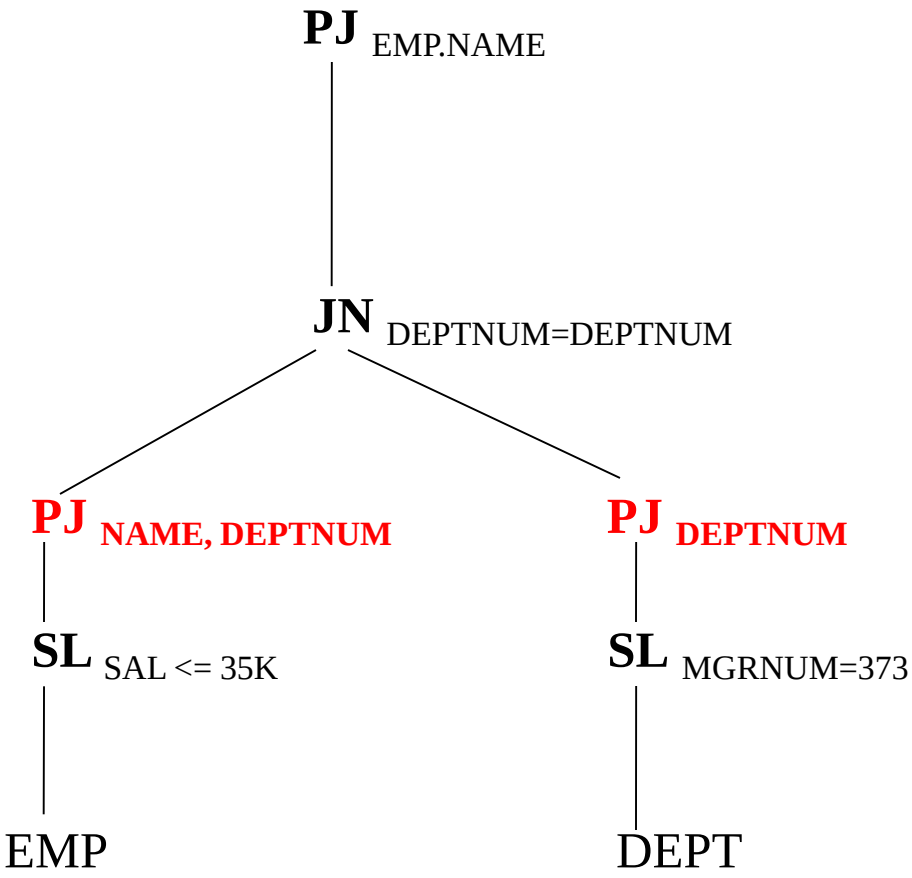
Simplification

After Applying criterion – 2



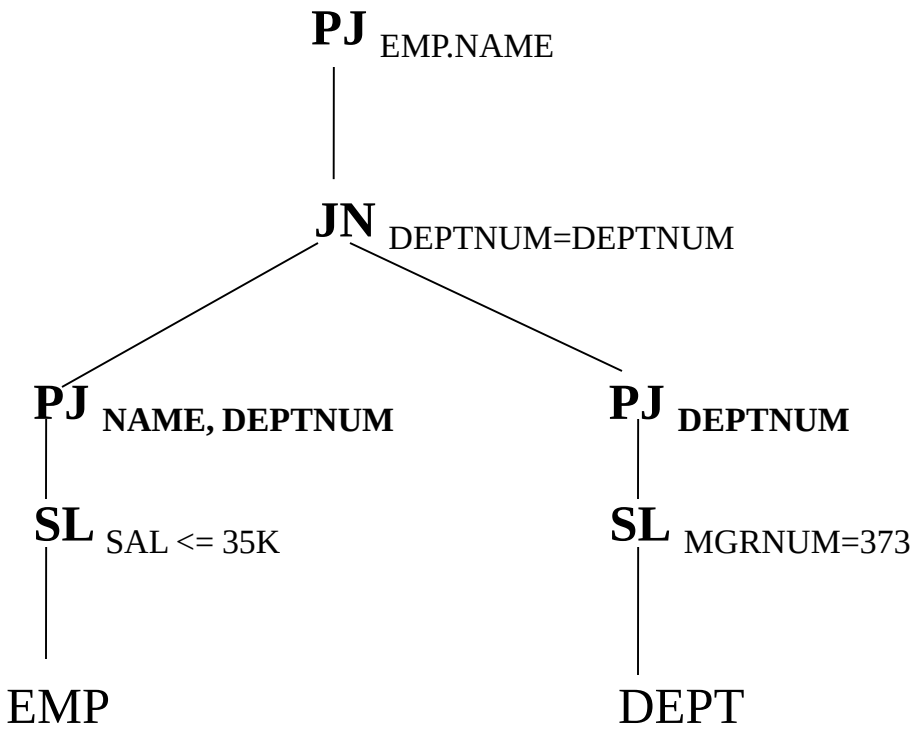
Simplification

After Applying criterion – 1



Transformed Query

$\mathbf{Q_T}$: $\mathbf{PJ}_{\text{EMP.NAME}}$ (($\mathbf{PJ}_{\text{NAME,DEPTNUM}}$ $\mathbf{SL}_{\text{SAL<=35K}}$ *EMP*) $\mathbf{JN}_{\text{DEPTNUM=DEPTNUM}}$ ($\mathbf{PJ}_{\text{DEPTNUM}}$ $\mathbf{SL}_{\text{MGRNUM=373}}$ *DEPT*))



Transformed Query

Output:

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Input:

$$\mathbf{Q:}\ \mathbf{PJ}_{\text{EMP.NAME}}\ \mathbf{SL}_{\text{MGRNUM=373}}\ ((\mathit{EMP}\ \mathbf{JN}_{\text{DEPTNUM=DEPTNUM}}\ \mathit{DEPT})\ \mathbf{DF}\ (\mathbf{SL}_{\text{SAL > 35K}}\ \mathit{EMP}\ \mathbf{JN}_{\text{DEPTNUM=DEPTNUM}}\ \mathit{DEPT}))$$

$$Q \longleftrightarrow Q_T$$

Example 2.2

EMP (EMPNUM, DEPTNUM, NAME, SAL, AGE)
DEPT (DEPTNUM, NAME, AREA, MGRNUM)

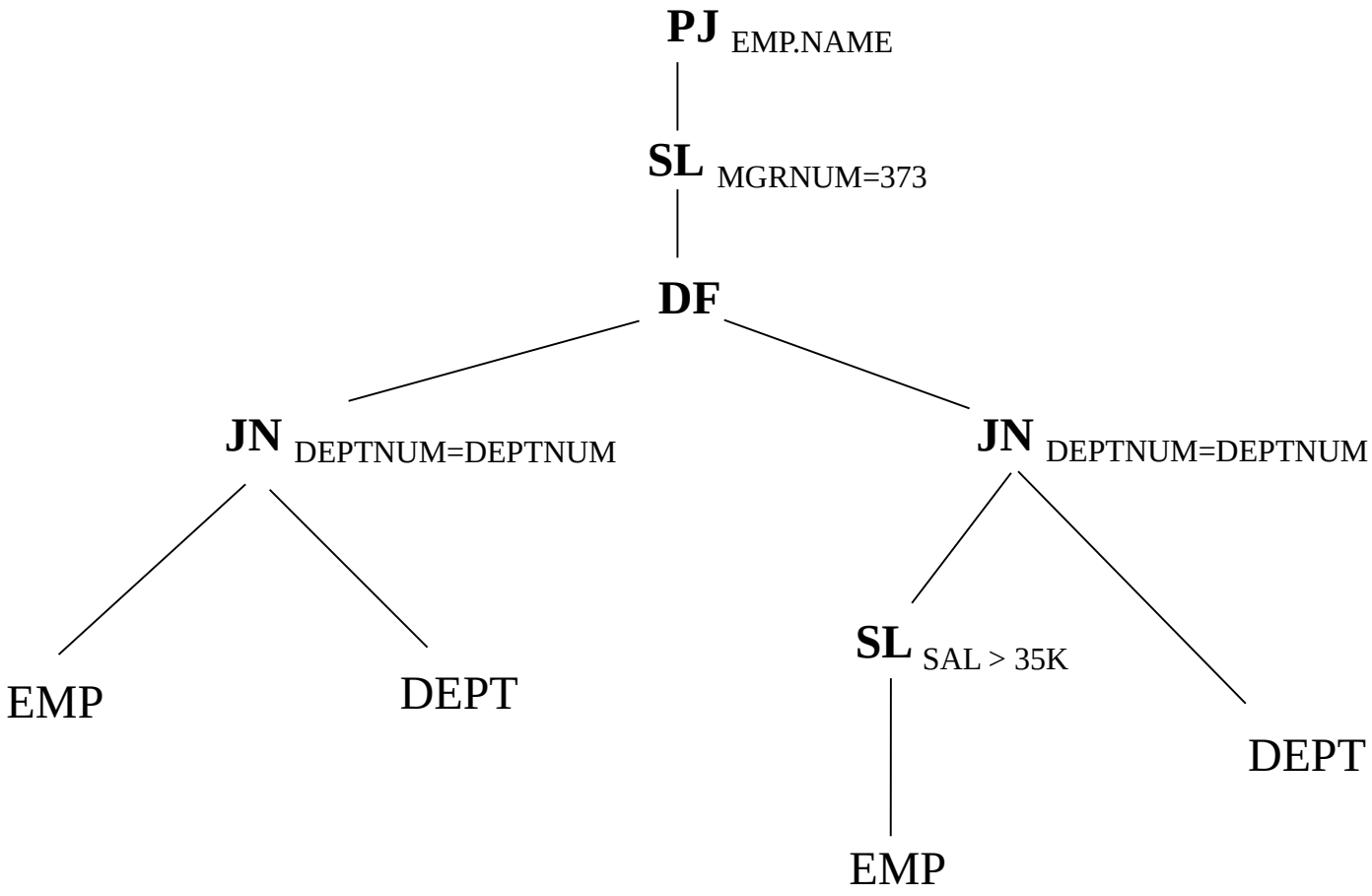
Q: PJ $_{\text{EMP.NAME}}$ **SL** $_{\text{MGRNUM=373}}$ ((*EMP* **JN** $_{\text{DEPTNUM=DEPTNUM}}$ *DEPT*) **DF** (**SL** $_{\text{SAL > 35K}}$ *EMP* **JN** $_{\text{DEPTNUM=DEPTNUM}}$ *DEPT*))

Now, answer the following questions.

i. Draw the *operator tree*. [2]

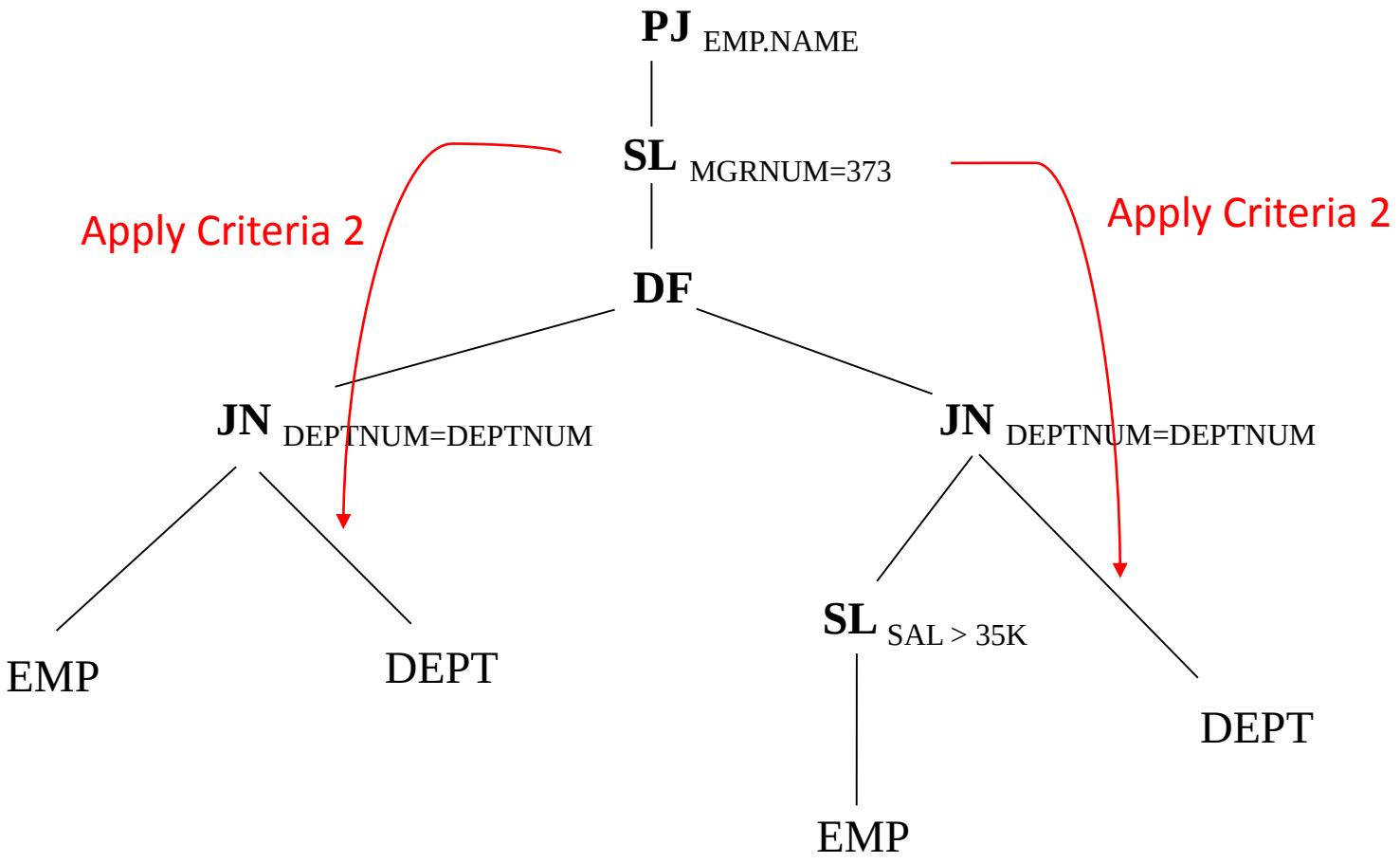
ii. Perform step-by-step transformations to simplify the operator tree, indicating which rule and criterion is applied at each step. [5]

Operator Tree



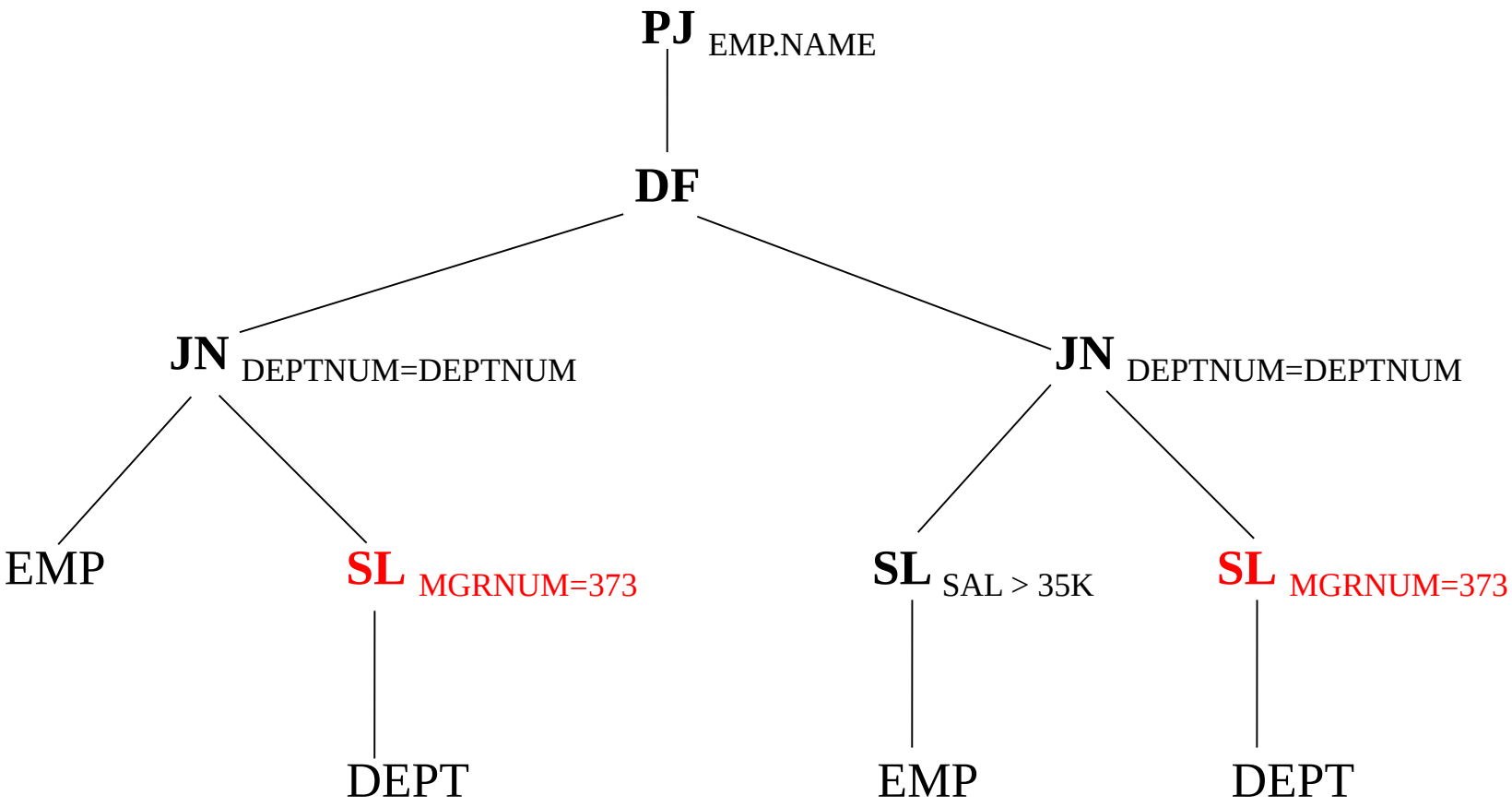
Finding Common Sub-expression

Any common portion?



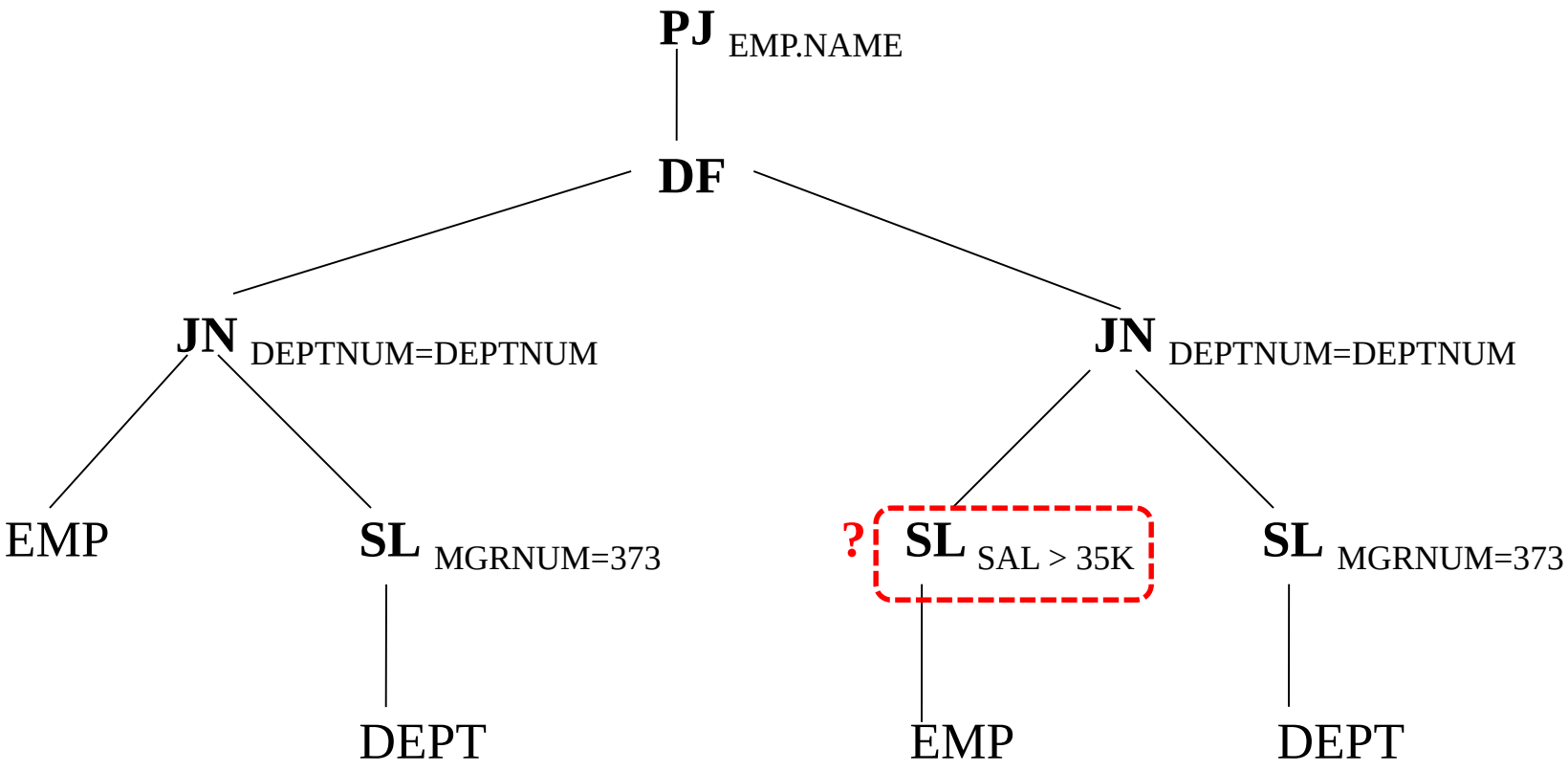
Finding Common Sub-expression

Any common portion?



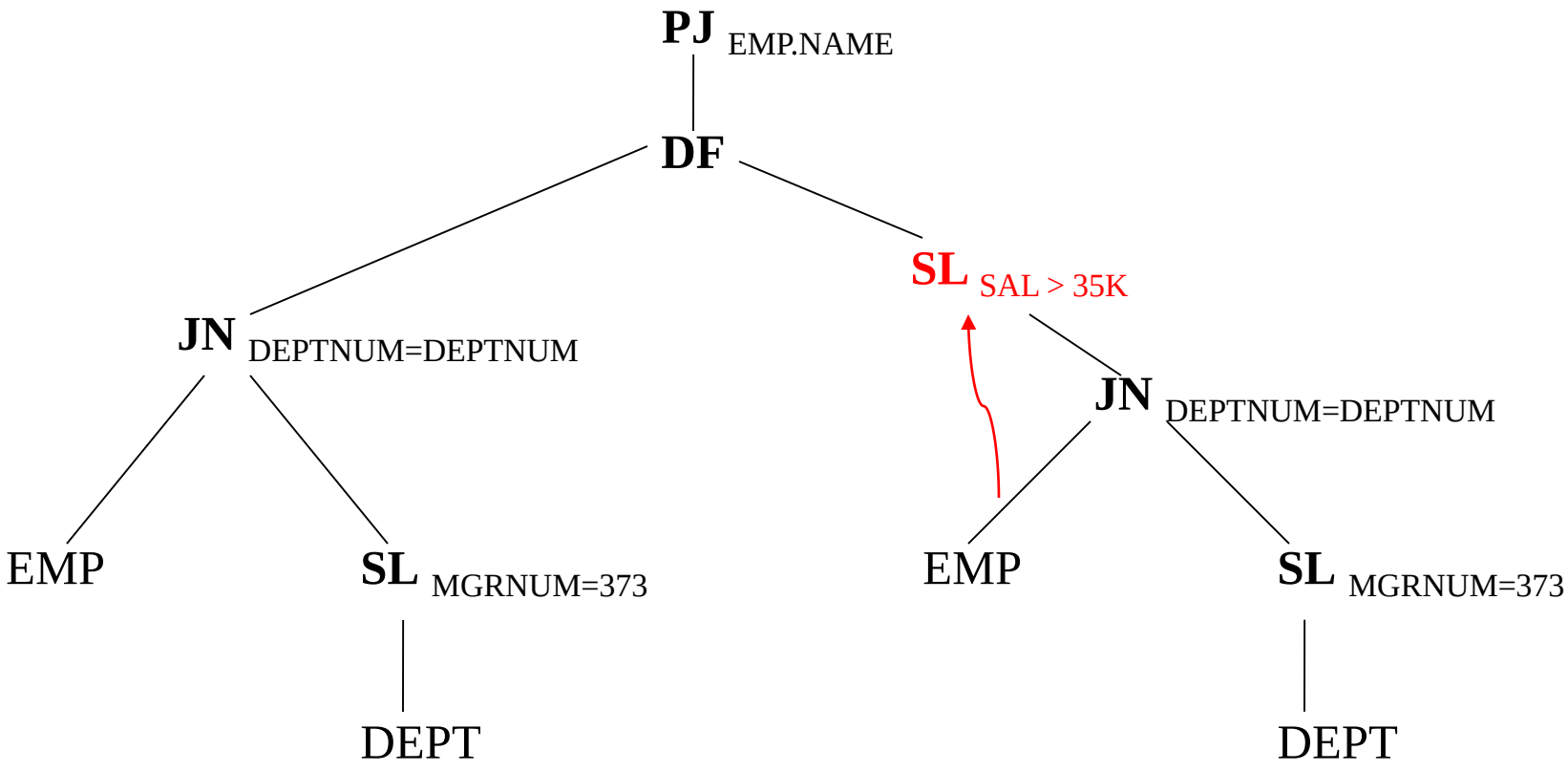
Finding Common Sub-expression

Any common portion?

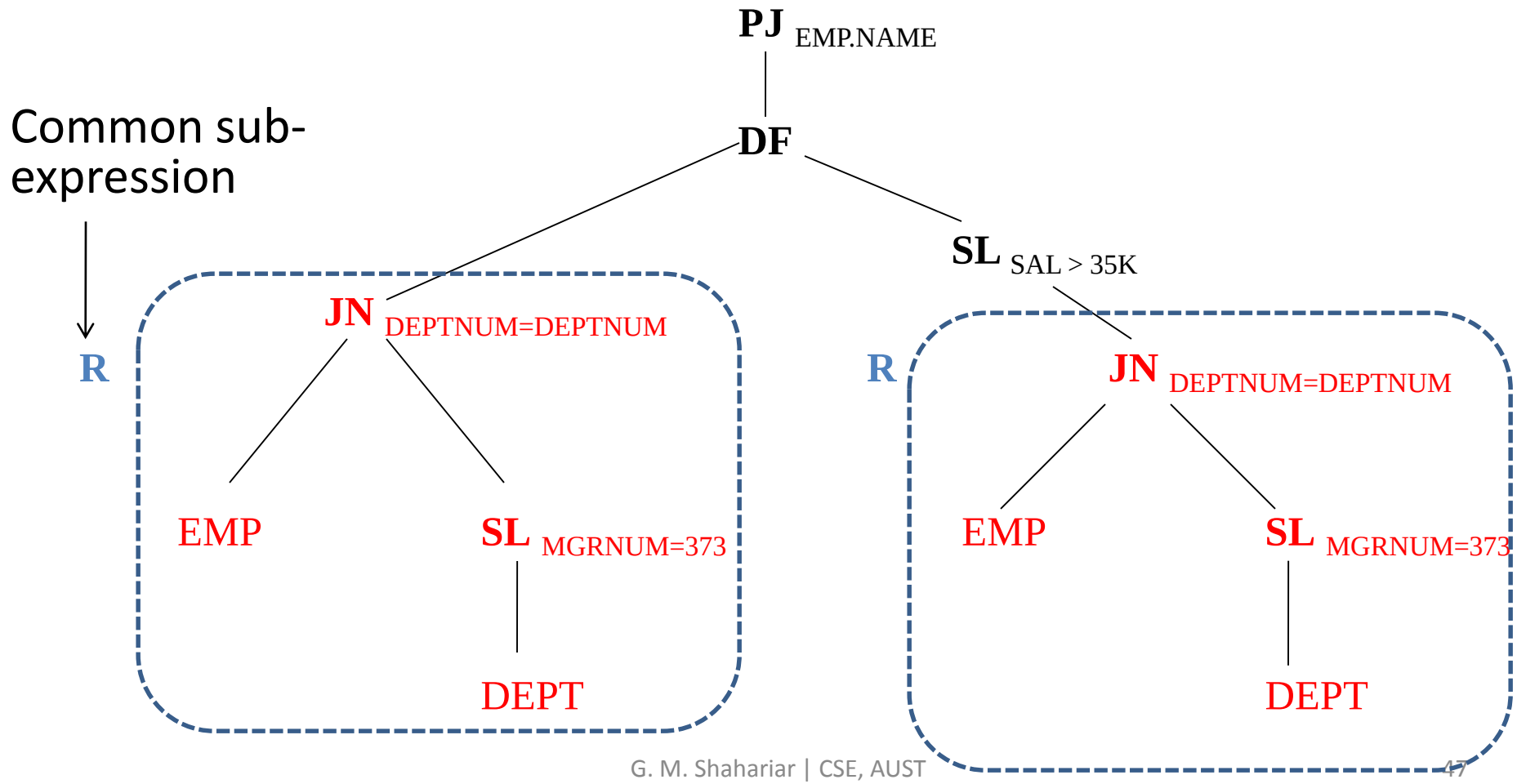


Finding Common Sub-expression

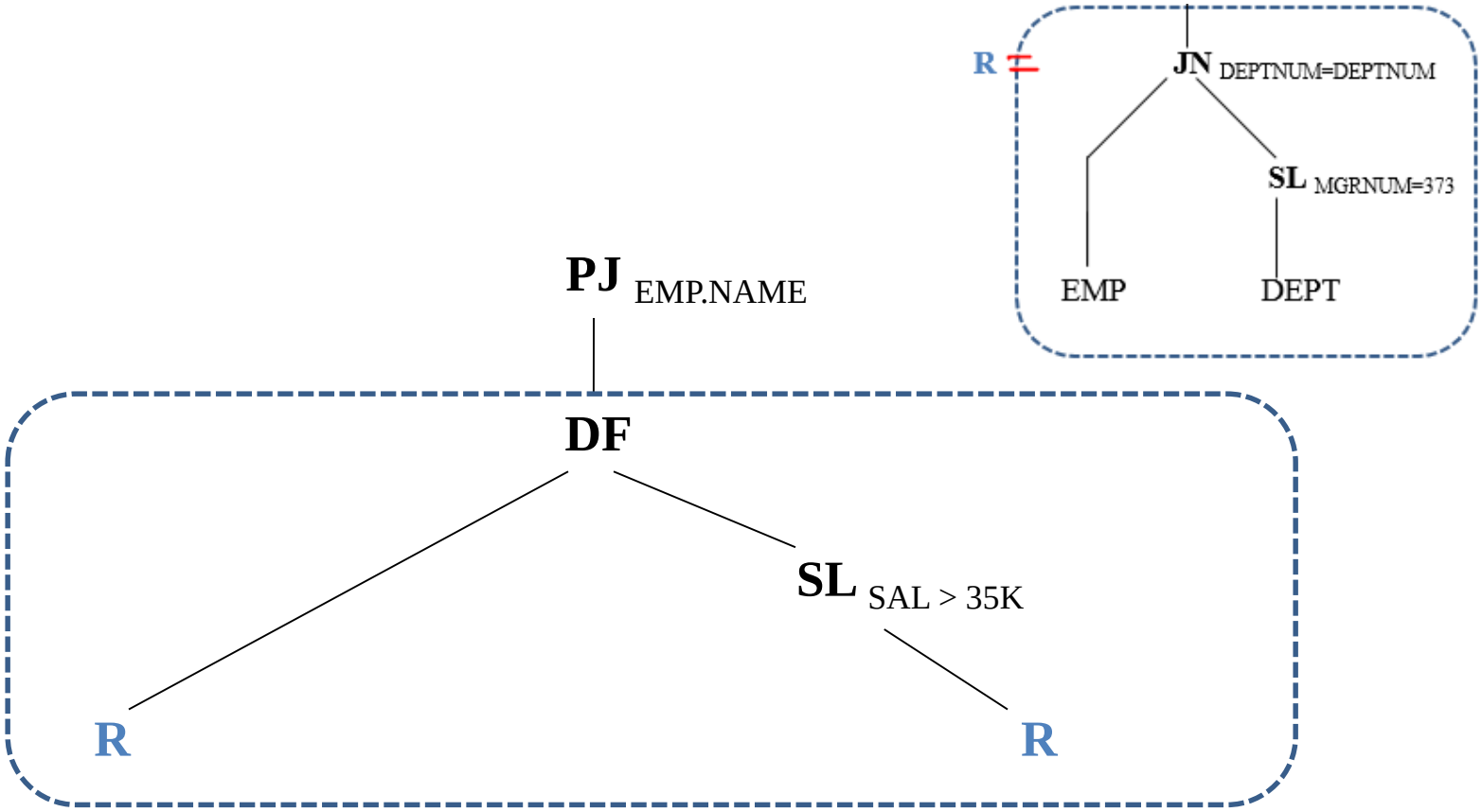
Any common portion? NOW?



Finding Common Sub-expression

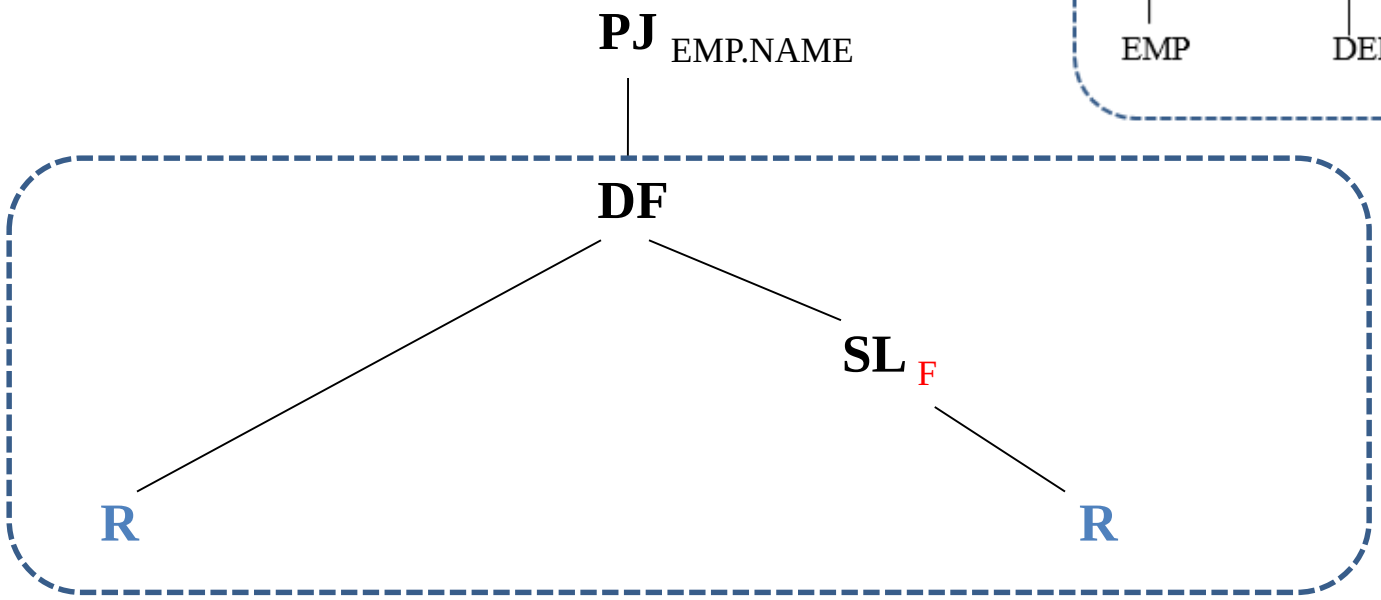


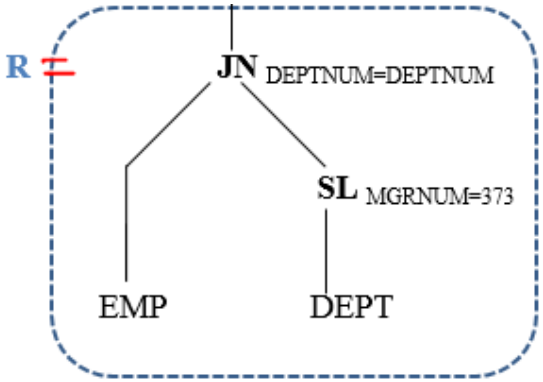
Finding Common Sub-expression



Finding Common Sub-expression

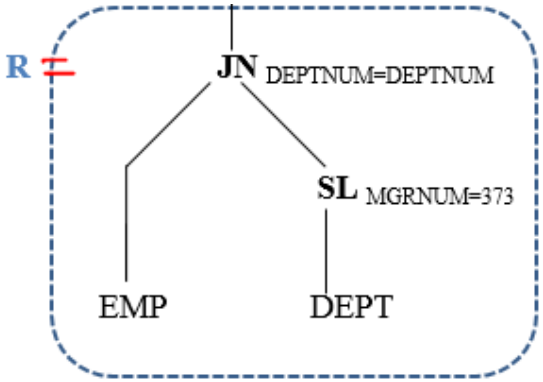
F = SAL > 35K

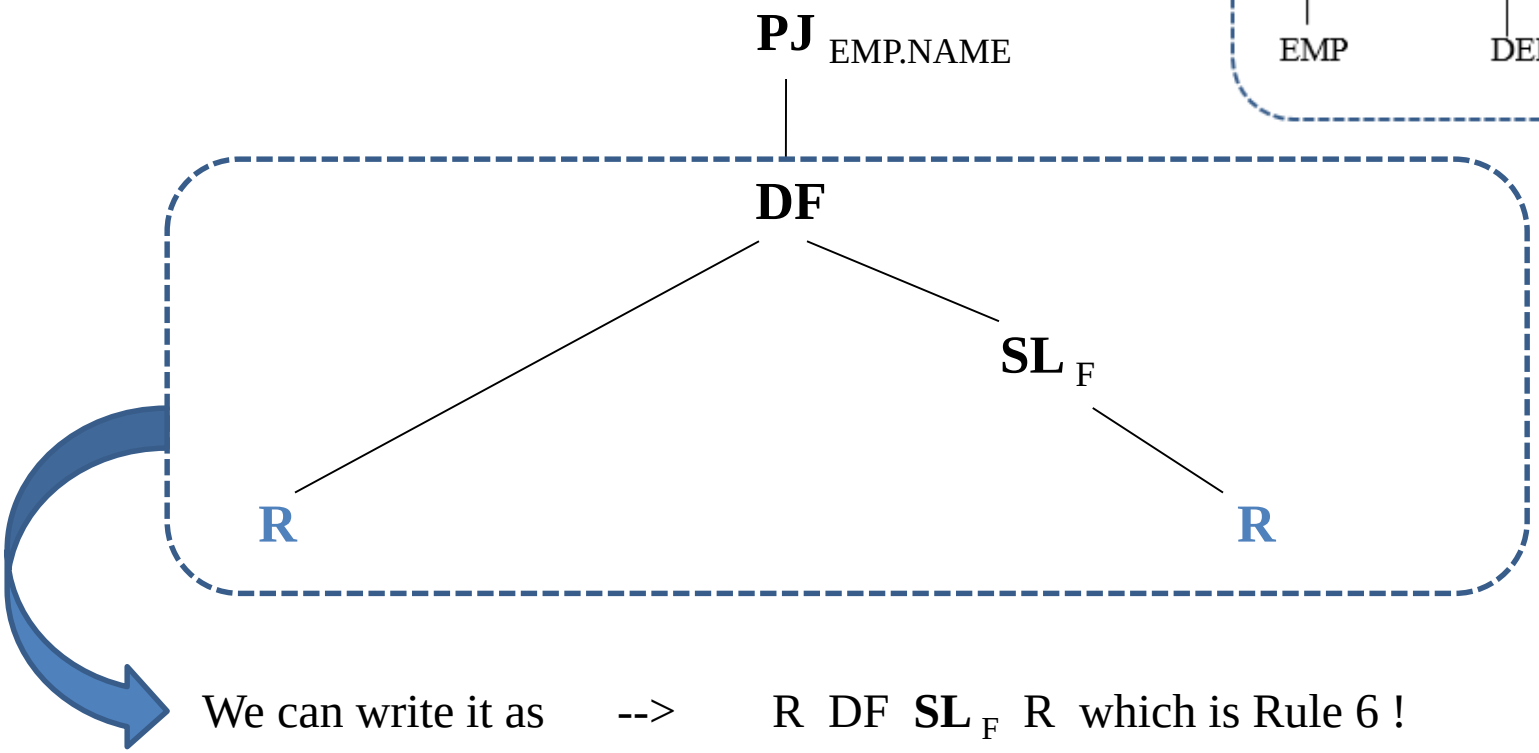




Finding Common Sub-expression

F = SAL > 35K

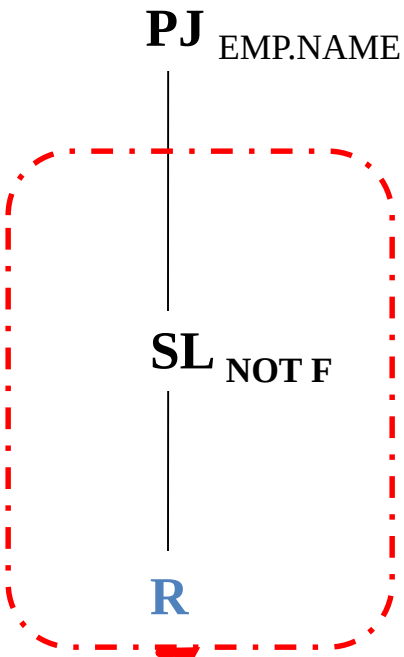


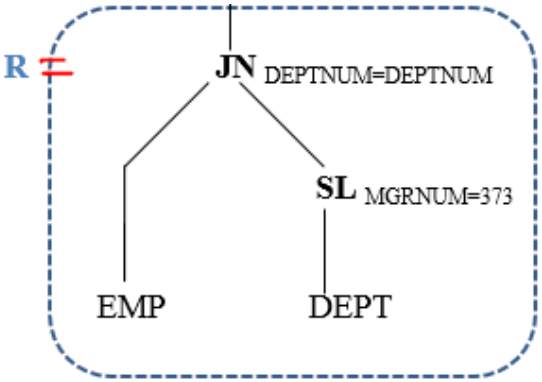


We can write it as --> R DF **SL** $_F$ R which is Rule 6 !

Removing Common Sub-expression

F = SAL > 35K





- $R\ DF\ SL_F\ R \leftrightarrow SL_{NOT\ F}\ R$

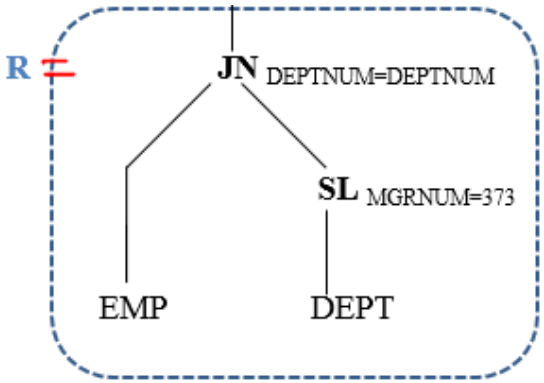
Removing Common Sub-expression

F = SAL > 35K

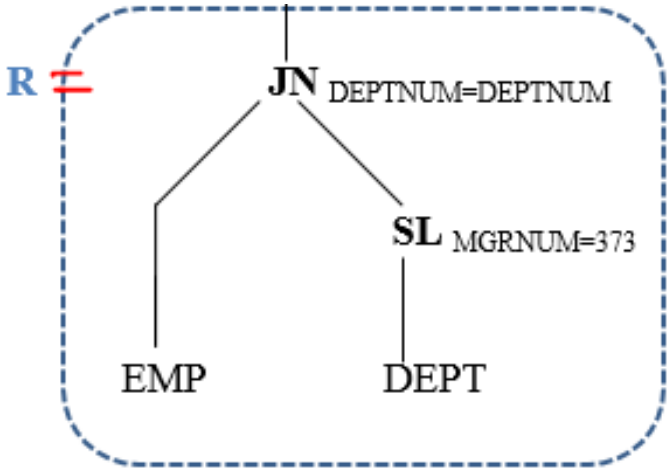
PJ EMP.NAME

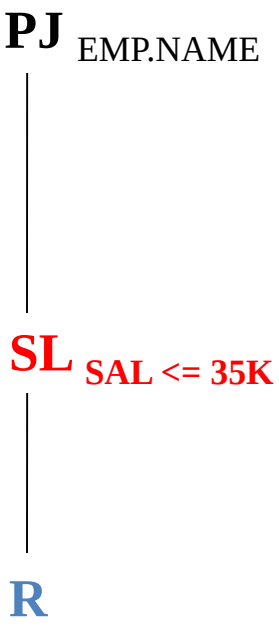
SL **NOT (SAL > 35K)**

R

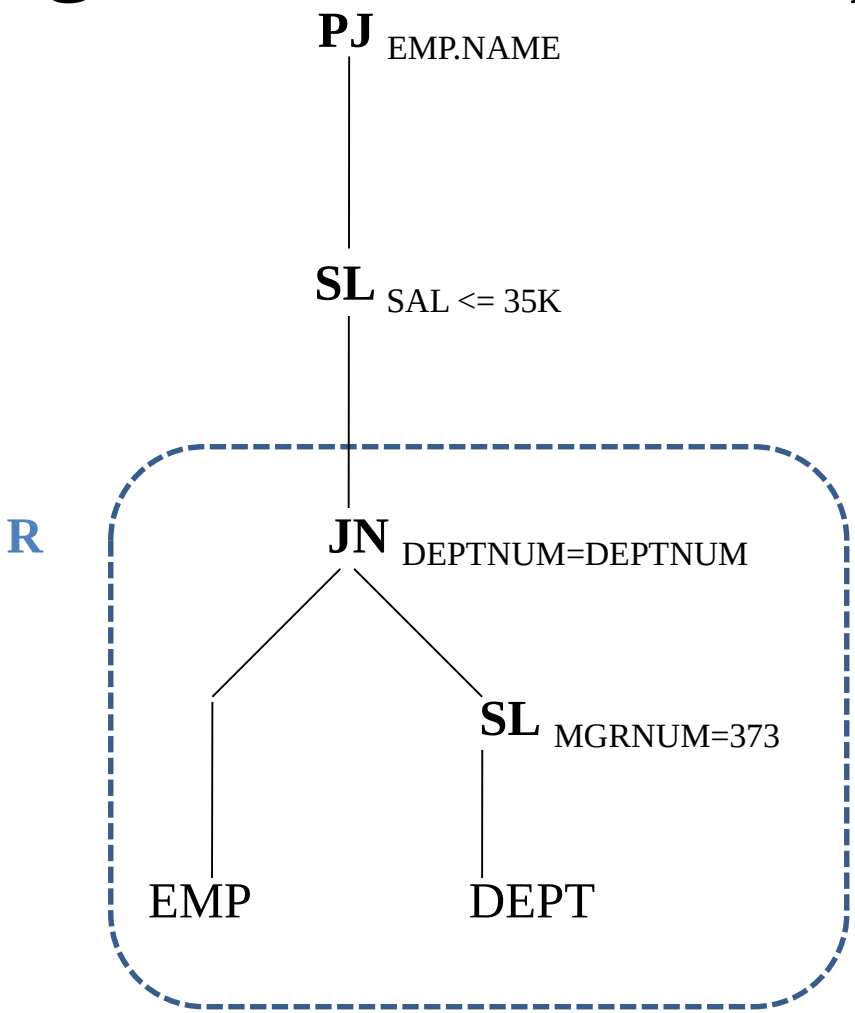


Removing Common Sub-expression





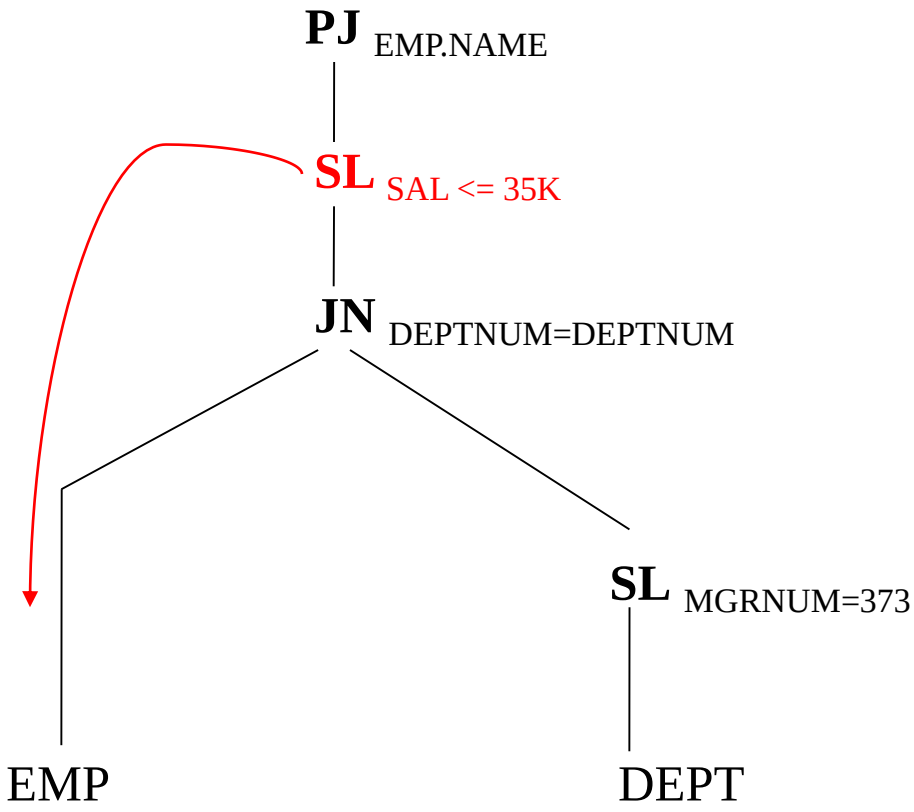
Removing Common Sub-expression



Can you apply Criterion 1 and/or 2 on this tree?

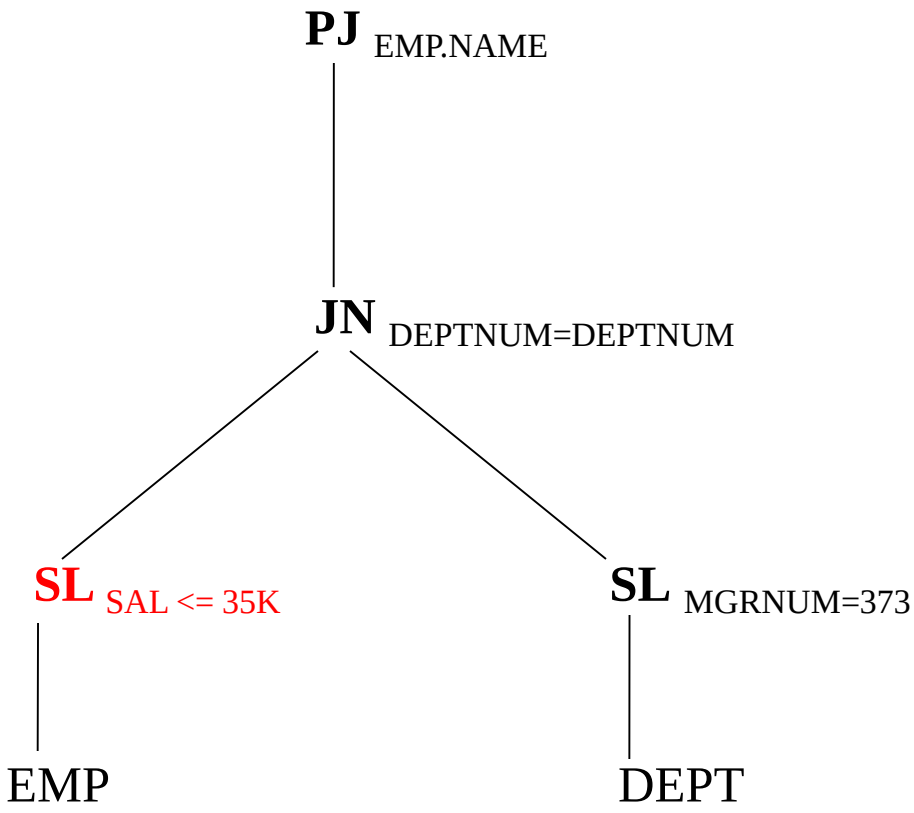
Simplification

Applying criterion – 2



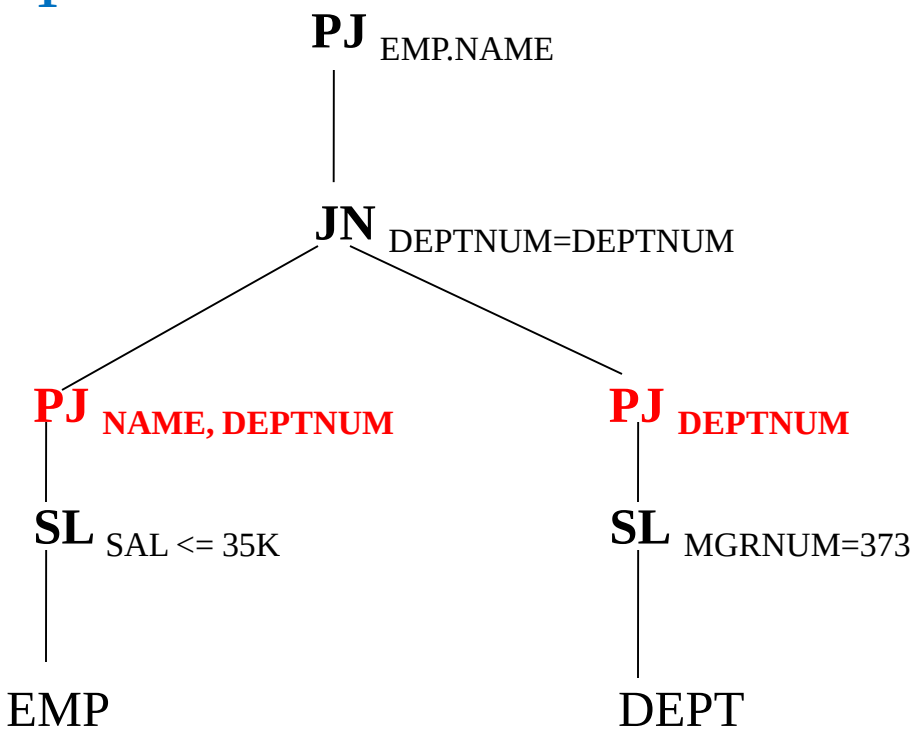
Simplification

After Applying criterion – 2



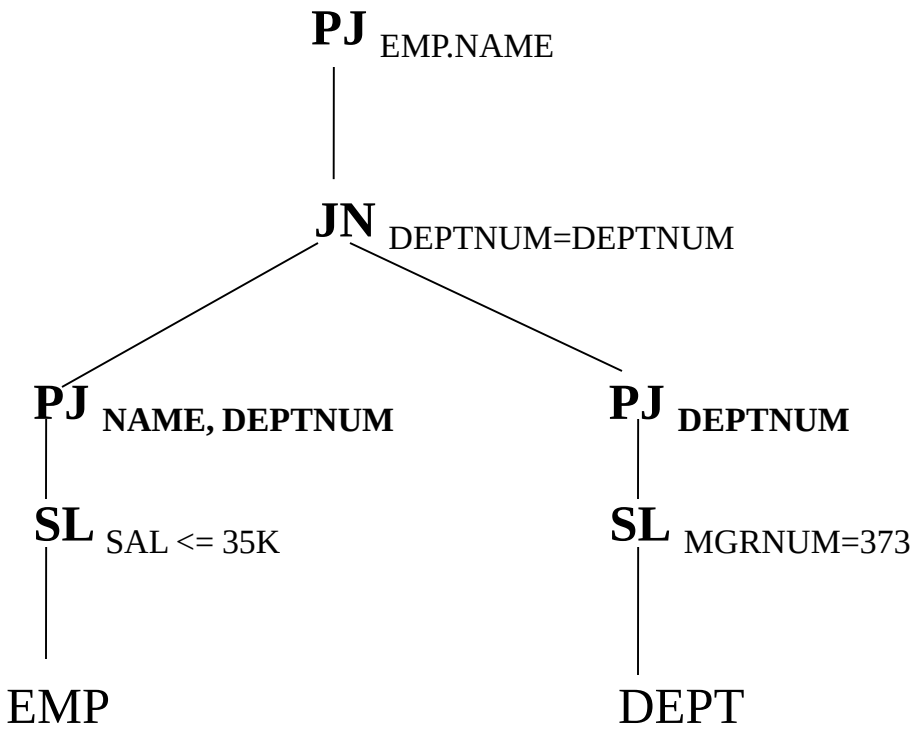
Simplification

After Applying criterion – 1



Transformed Query

$\mathbf{Q_T}$: $\mathbf{PJ}_{\text{EMP.NAME}}$ (($\mathbf{PJ}_{\text{NAME,DEPTNUM}}$ $\mathbf{SL}_{\text{SAL<=35K}}$ *EMP*) $\mathbf{JN}_{\text{DEPTNUM=DEPTNUM}}$ ($\mathbf{PJ}_{\text{DEPTNUM}}$ $\mathbf{SL}_{\text{MGRNUM=373}}$ *DEPT*))



Transformed Query

Output:

$$\mathbf{Q_T:}\ \mathbf{PJ}_{\text{EMP.NAME}}\ ((\mathbf{PJ}_{\text{NAME,DEPTNUM}}\ \mathbf{SL}_{\text{SAL<=35K}}\ \mathit{EMP})\ \mathbf{JN}_{\text{DEPTNUM=DEPTNUM}}\ (\mathbf{PJ}_{\text{DEPTNUM}}\ \mathbf{SL}_{\text{MGRNUM=373}}\ \mathit{DEPT}))$$

Input:

$$\mathbf{Q:}\ \mathbf{PJ}_{\text{EMP.NAME}}\ \mathbf{SL}_{\text{MGRNUM=373}}\ ((\mathit{EMP}\ \mathbf{JN}_{\text{DEPTNUM=DEPTNUM}}\ \mathit{DEPT})\ \mathbf{DF}\ (\mathbf{SL}_{\text{SAL > 35K}}\ \mathit{EMP}\ \mathbf{JN}_{\text{DEPTNUM=DEPTNUM}}\ \mathit{DEPT}))$$

$$Q \longleftrightarrow Q_T$$

Example 3

Practise

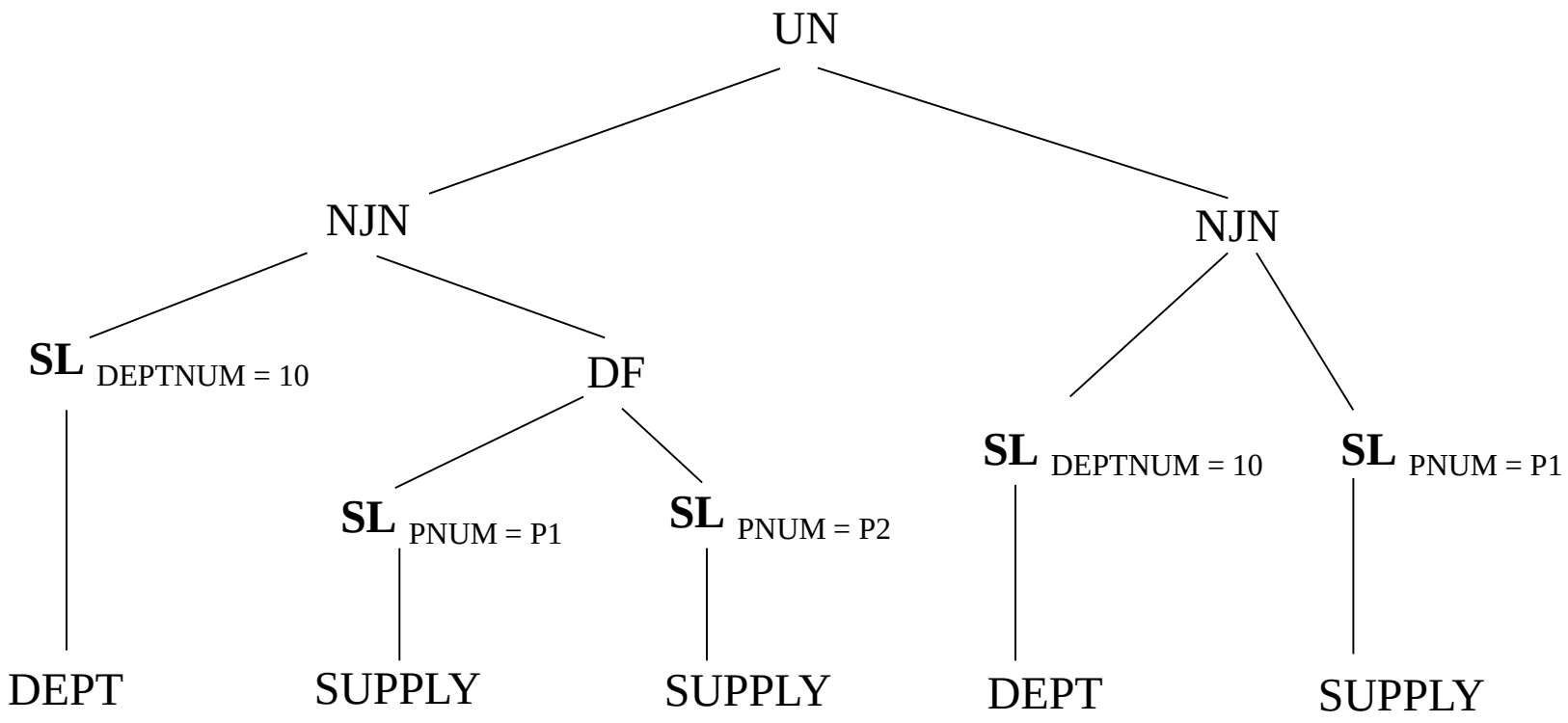
* Draw Operator Tree for the following queries:

① SUPPLY (SNUM, PNUM, DEPTNUM, QUAN)
DEPT (DEPTNUM, NAME, AREA, MGRNUM)

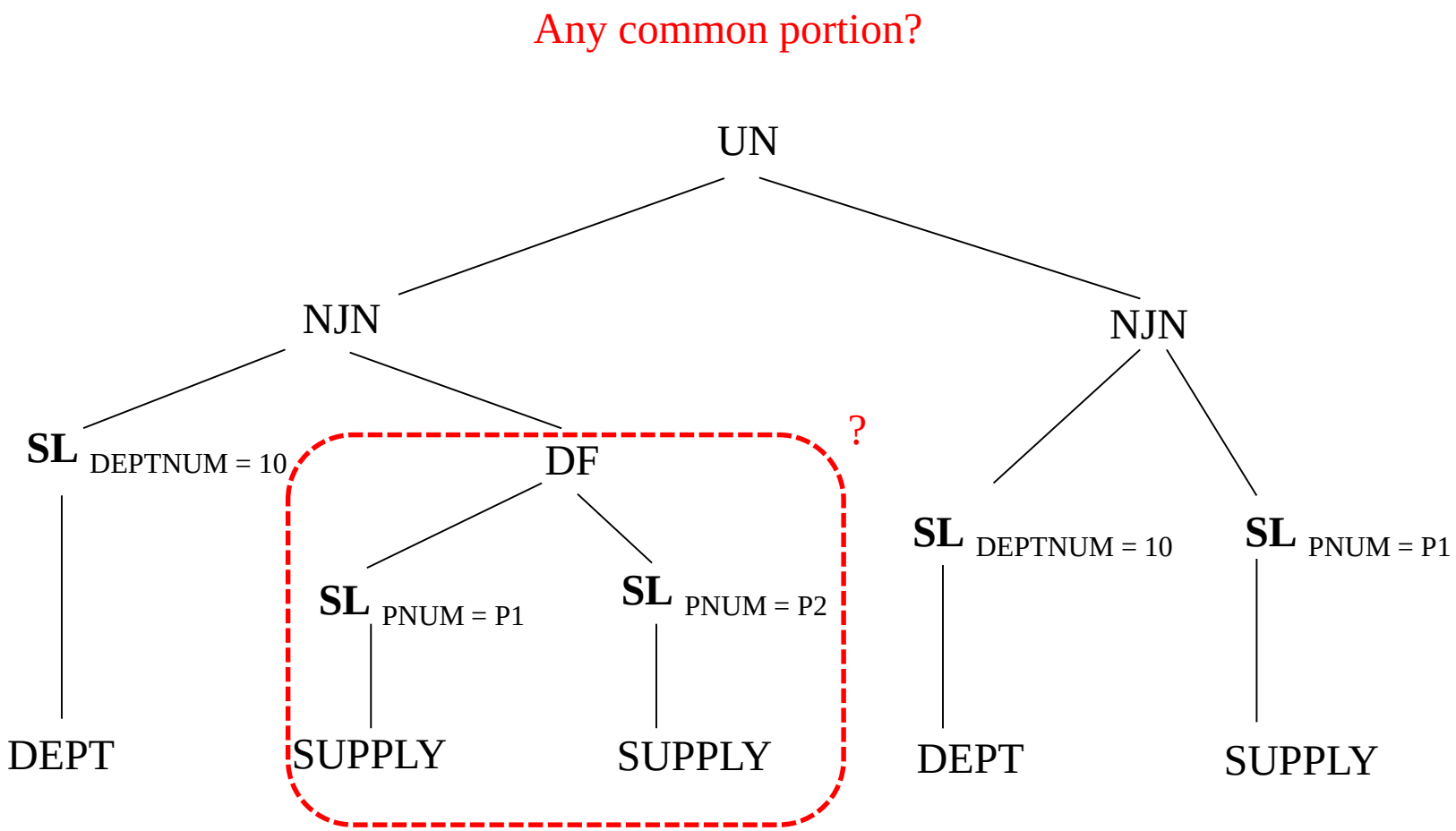
Query:

$(SL_{DEPTNUM=10}$ DEPT NJN $(SL_{PNUM="P1"}$ SUPPLY DF $SL_{PNUM="P_2"}$ SUPPLY)) UN $(SL_{DEPTNUM=10}$ DEPT NJN $SL_{PNUM="P_1"}$ SUPPLY)

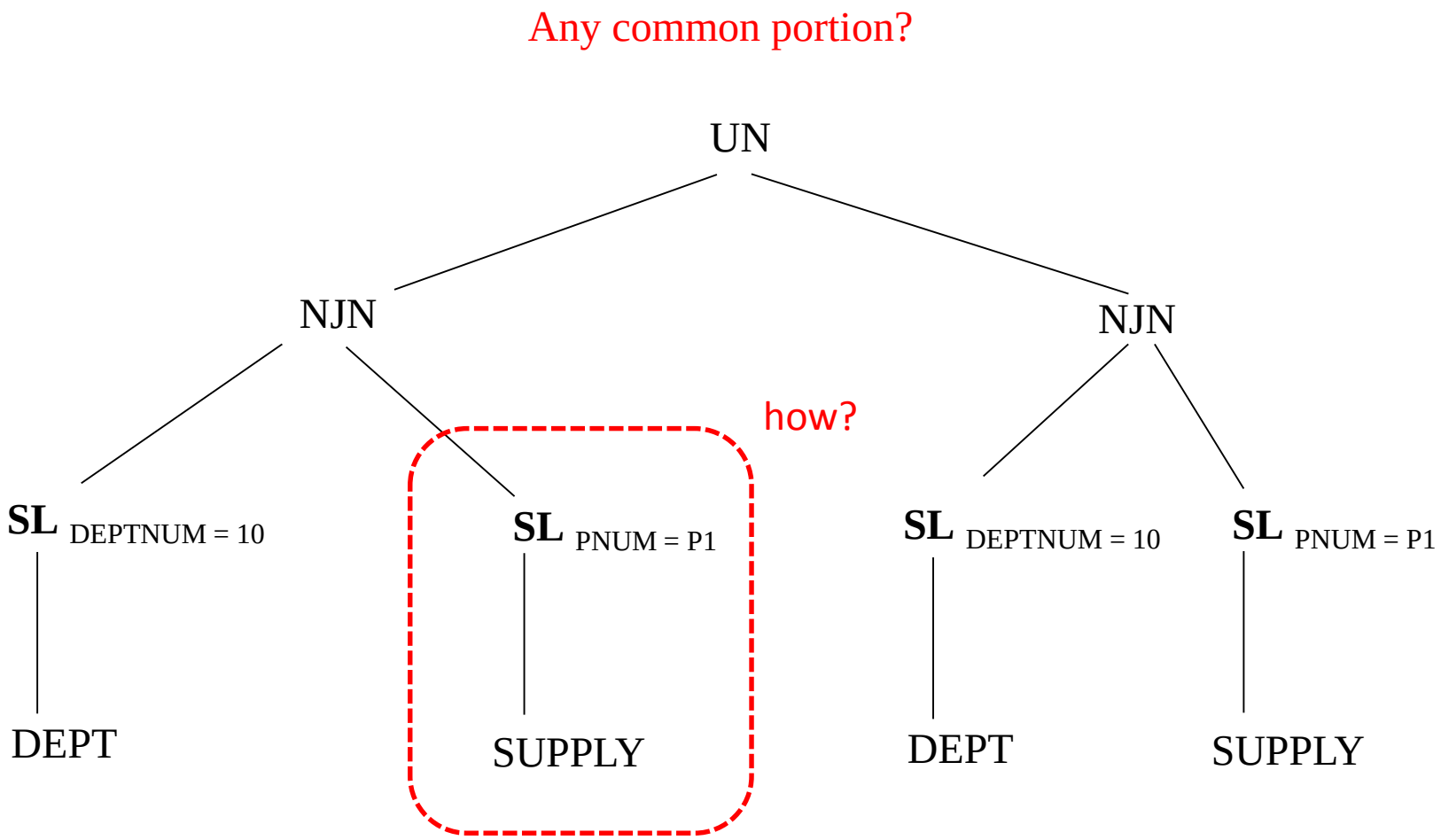
Operator Tree



Finding Common Sub - Expression



Finding Common Sub - Expression



How?

SUPPLY

SNUM	PNUM	DEPTNUM	QUAN
1	P1	1	10
2	P2	2	20
3	P1	1	30
4	P2	1	40
5	P1	2	50
6	P2	1	60

A

SL $_{PNUM = P1}$ SUPPLY

SNUM	PNUM	DEPTNUM	QUAN
1	P1	1	10
3	P1	1	30
5	P1	2	50

B

SL $_{PNUM = P2}$ SUPPLY

SNUM	PNUM	DEPTNUM	QUAN
2	P2	2	20
4	P2	1	40
6	P2	1	60

A DF B = A

SNUM	PNUM	DEPT NUM	QUAN
1	P1	1	10
3	P1	1	30
5	P1	2	50

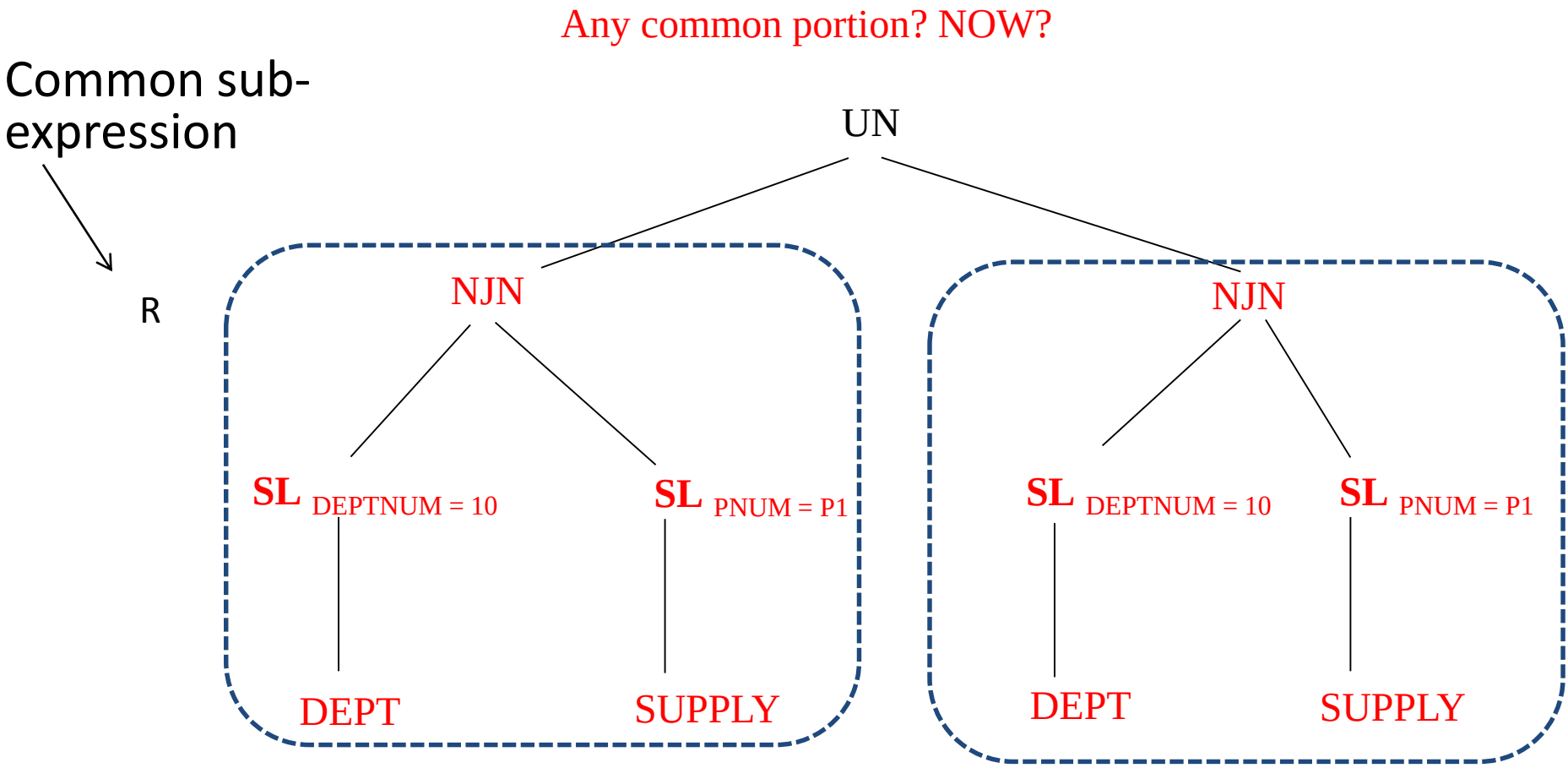
-

SNUM	PNUM	DEPT NUM	QUAN
2	P2	2	20
4	P2	1	40
6	P2	1	60

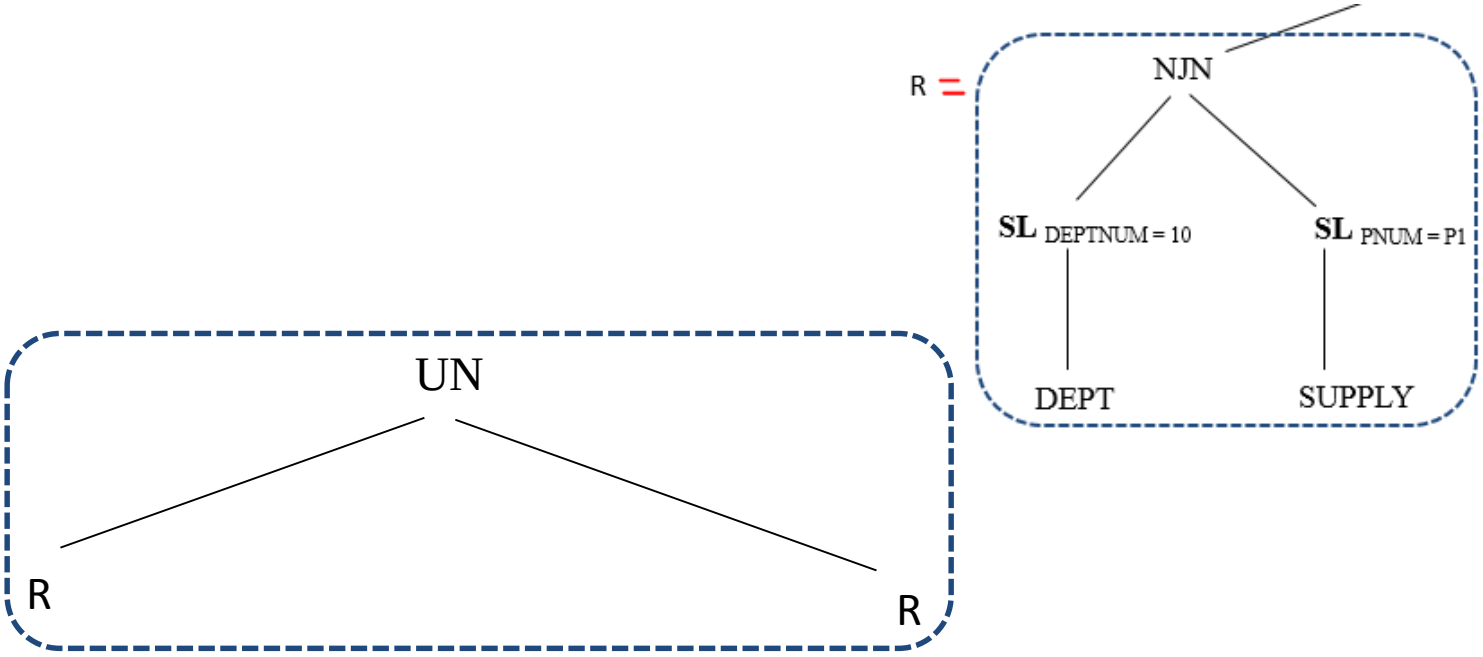
=

SNUM	PNUM	DEPT NUM	QUAN
1	P1	1	10
3	P1	1	30
5	P1	2	50

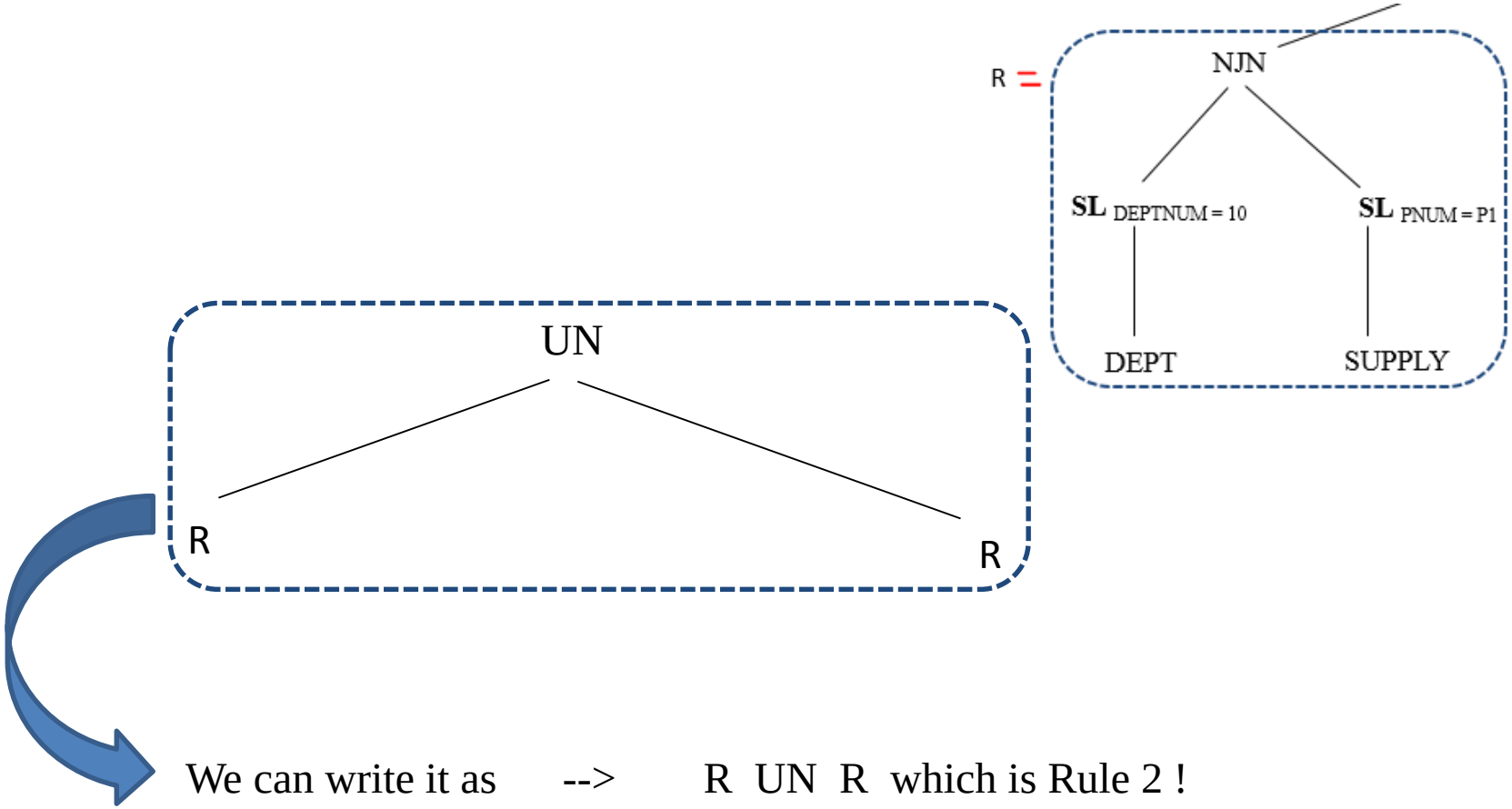
Finding Common Sub - Expression



Finding Common Sub - Expression

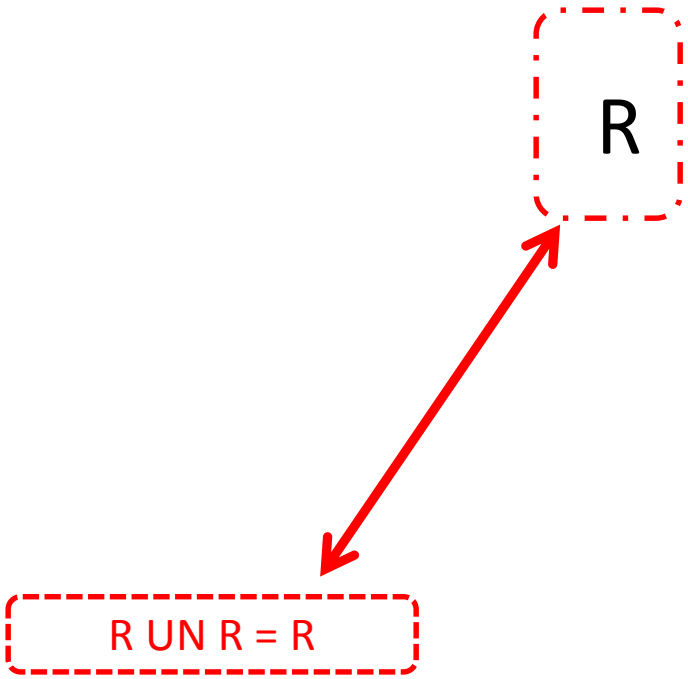


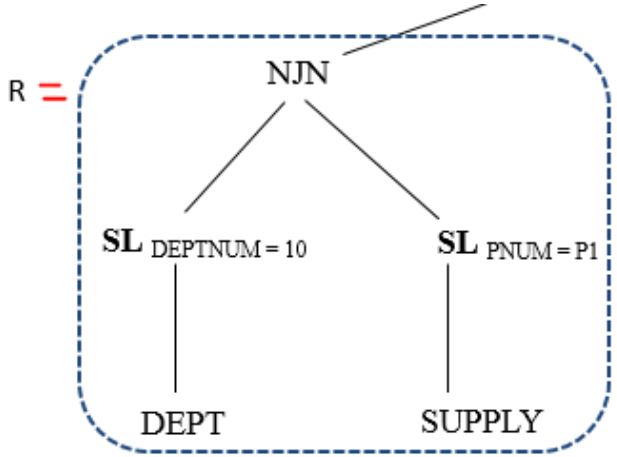
Finding Common Sub - Expression



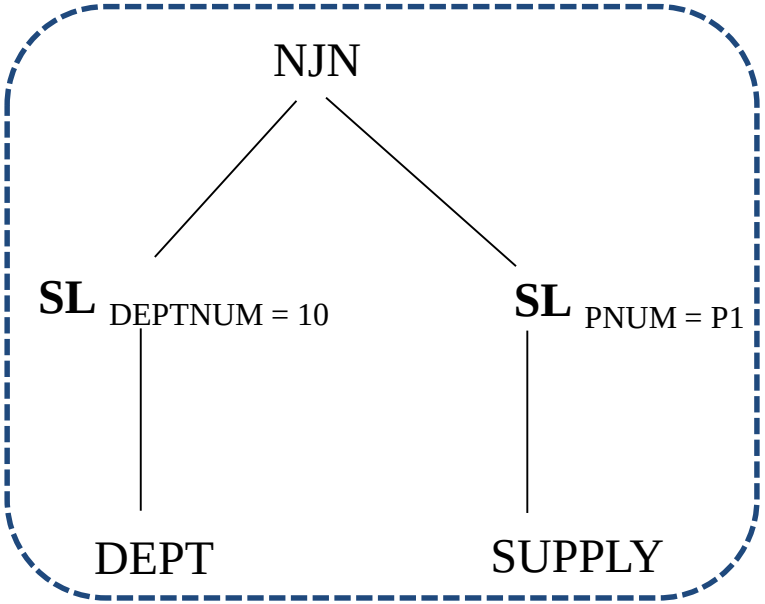
We can write it as --> R UN R which is Rule 2 !

Removing Common Sub - Expression





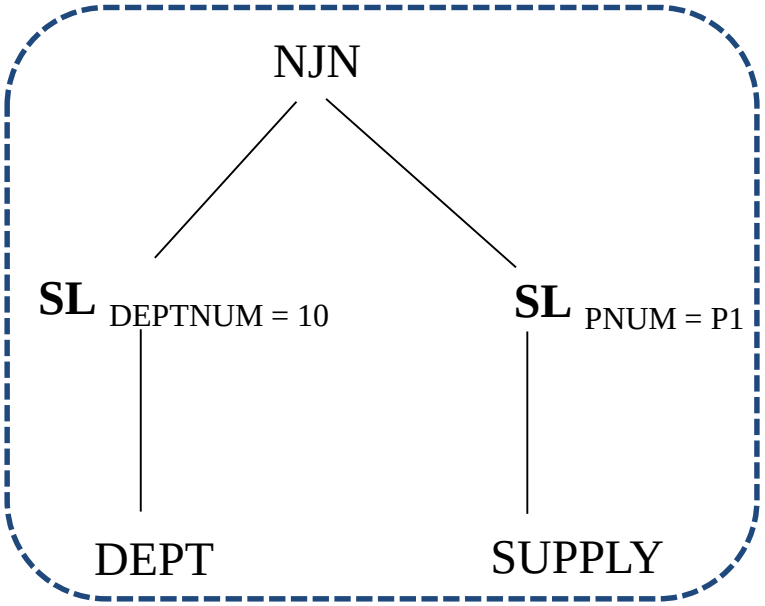
Removing Common Sub - Expression



Do we need to apply criteria 1 and/or 2? No, already simplified.

Transformed Query

Q_T: **SL** $_{\text{DEPTNUM} = 10}$ *DEPT* **NJN** **SL**$_{\text{PNUM} = \text{P1}}$ *SUPPLY*



Transformed Query

Output:

$\mathbf{Q_T:}$ $\mathbf{SL}_{\text{DEPTNUM = 10}}$ *DEPT* **NJN** $\mathbf{SL}_{\text{PNUM = P1}}$ *SUPPLY*

Input:

Q: (SL $_{\text{DEPTNUM = 10}}$ *DEPT* **NJN (SL**$_{\text{PNUM = P1}}$ *SUPPLY* **DF SL**$_{\text{PNUM = P2}}$ *SUPPLY))*

UN (SL $_{\text{DEPTNUM = 10}}$ *DEPT* **NJN SL**$_{\text{PNUM = P1}}$ *SUPPLY)*

$$Q \longleftrightarrow Q_T$$

Last Example

EMP (EMPNUM, DEPTNUM, NAME, SAL, AGE)
DEPT (DEPTNUM, NAME, AREA, MGRNUM)

Consider the following global query:

$$\left((SL_{F1}\ EMP\ \ JN_{A=B}\ \ DEPT)\ \ UN\ \ (SL_{F2}\ EMP\ \ JN_{A=B}\ \ DEPT)\right)\ \ DF\ \ (SL_{F3}\ \ EMP\ \ JN_{A=B}\ \ DEPT)$$

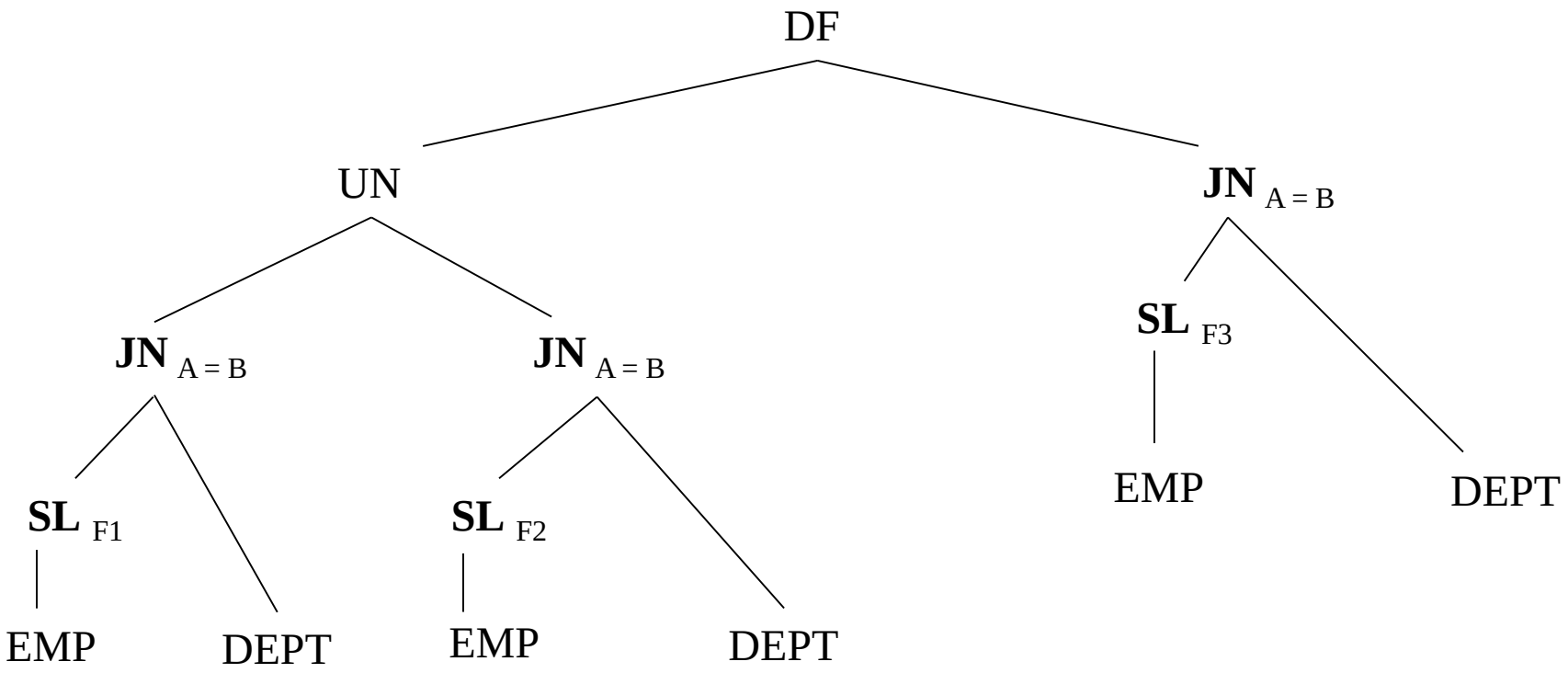
Here,
F1, F2, F3 can represent any condition. In this example consider none of them are same.
Imagine, A = B = DEPTNUM

Now, answer the following questions.

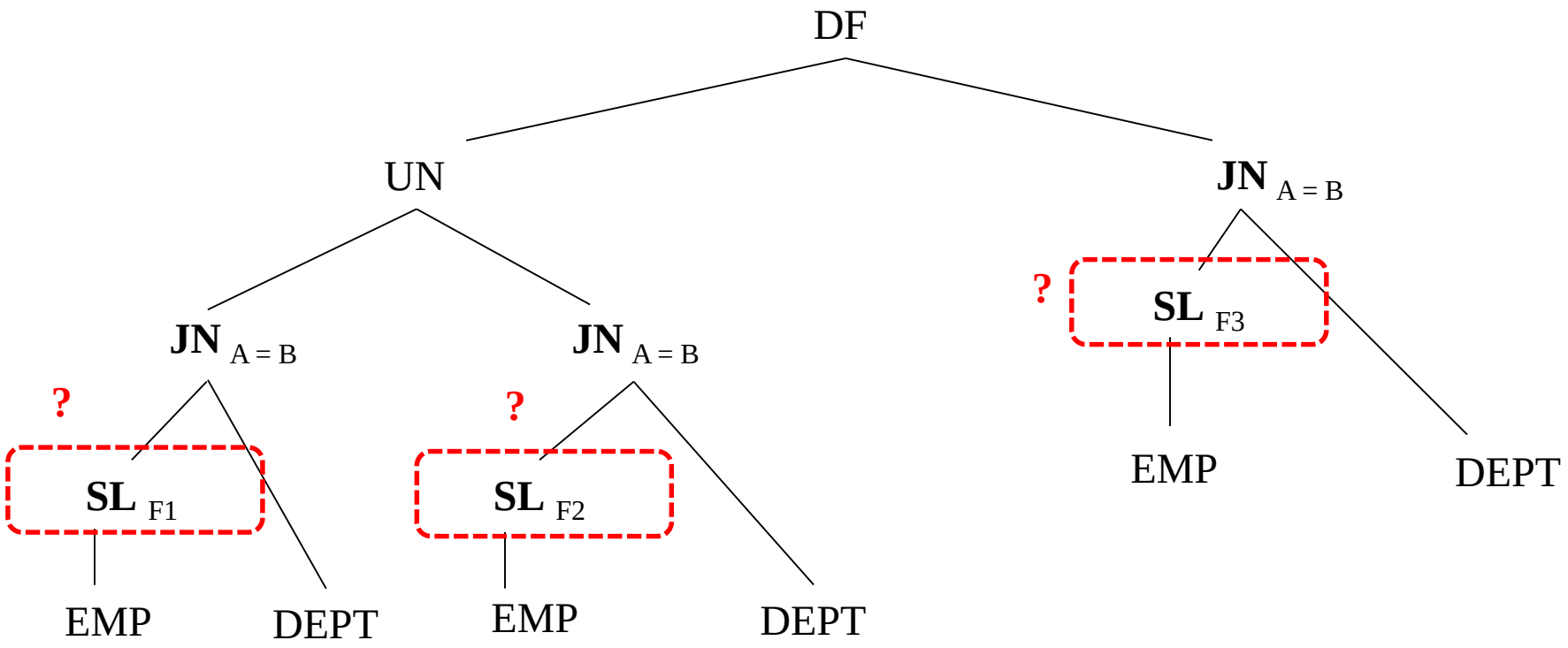
i. Draw the *operator tree*. [2]

ii. Perform step-by-step transformations to simplify the operator tree, indicating which rule and criterion is applied at each step. [5]

Operator Tree

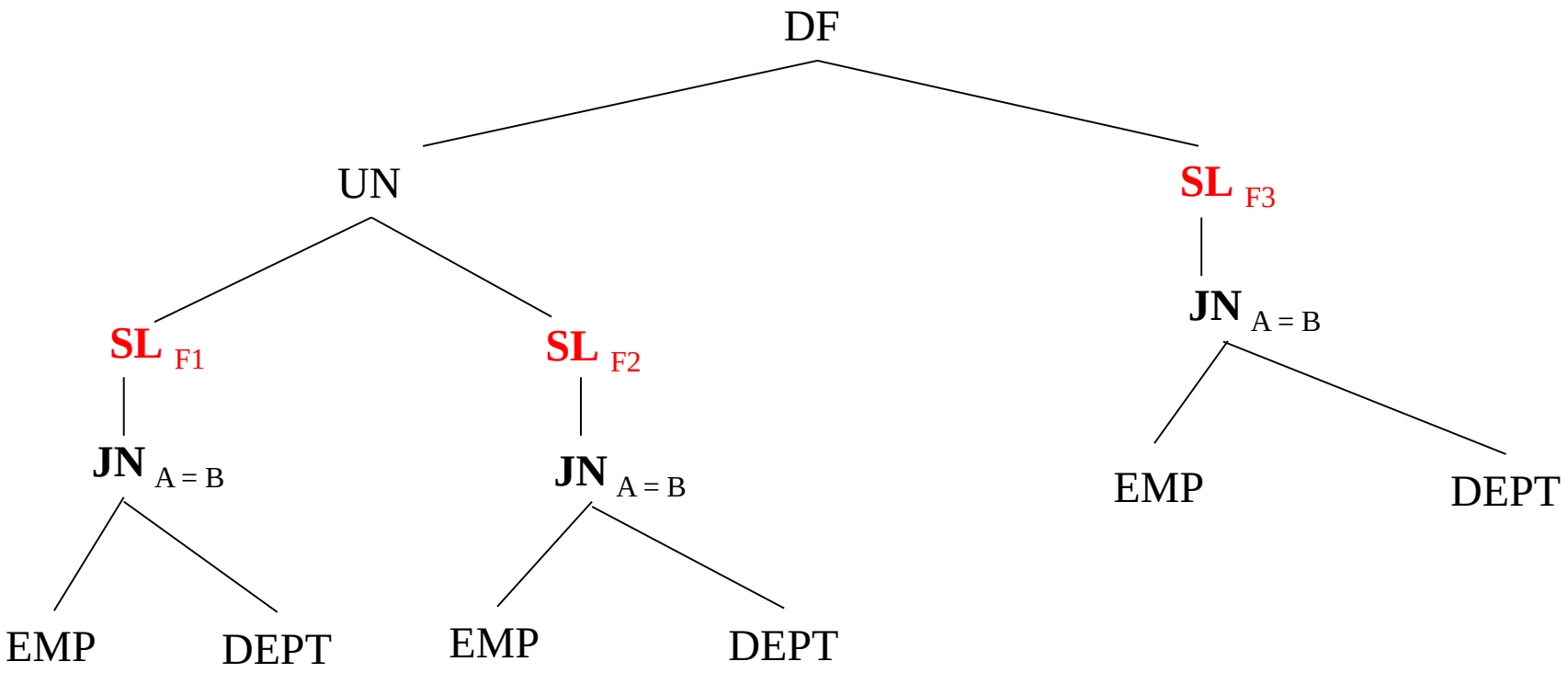


Finding Common Sub-Expression

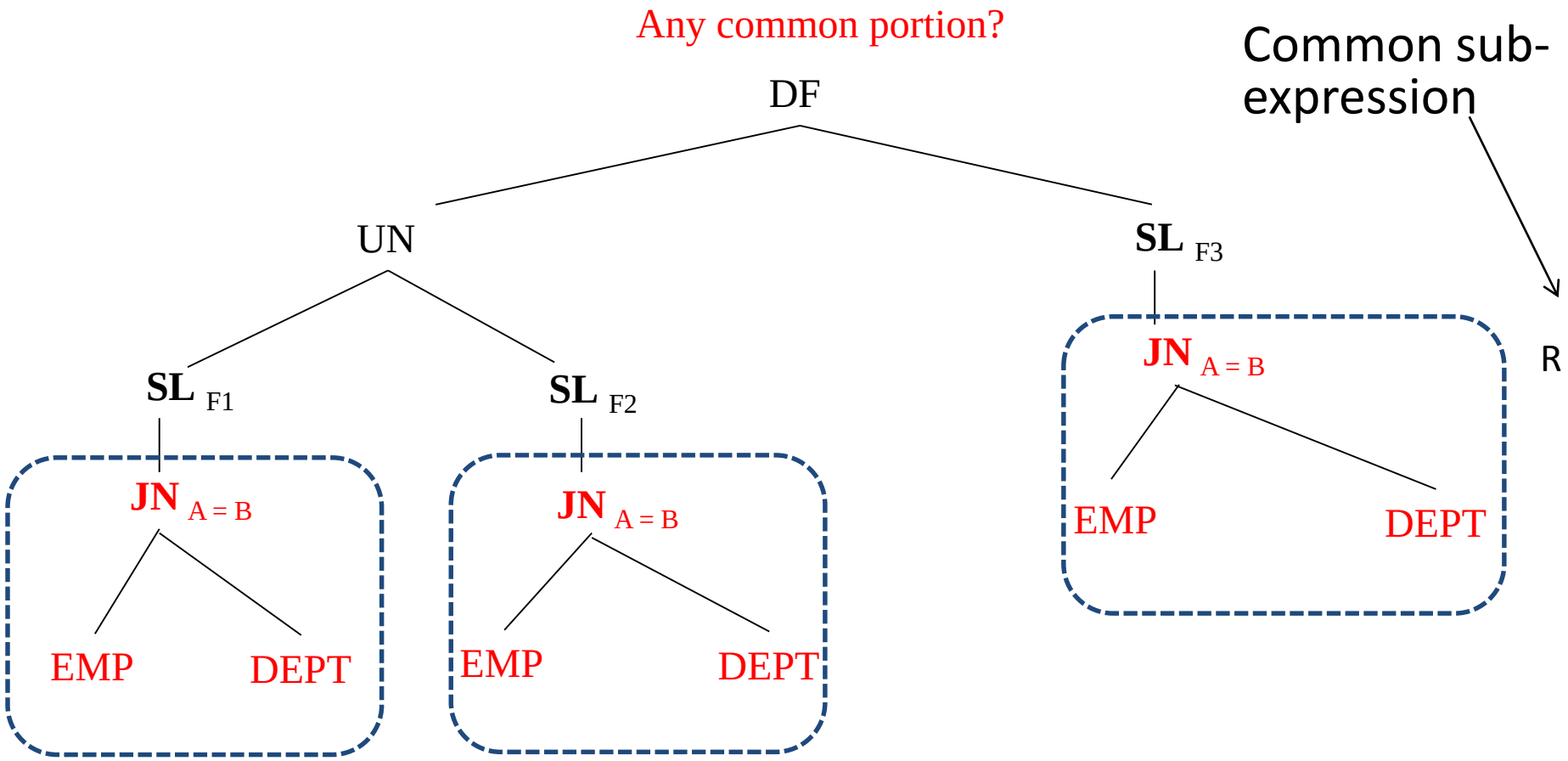


Finding Common Sub-expression

Any common portion?

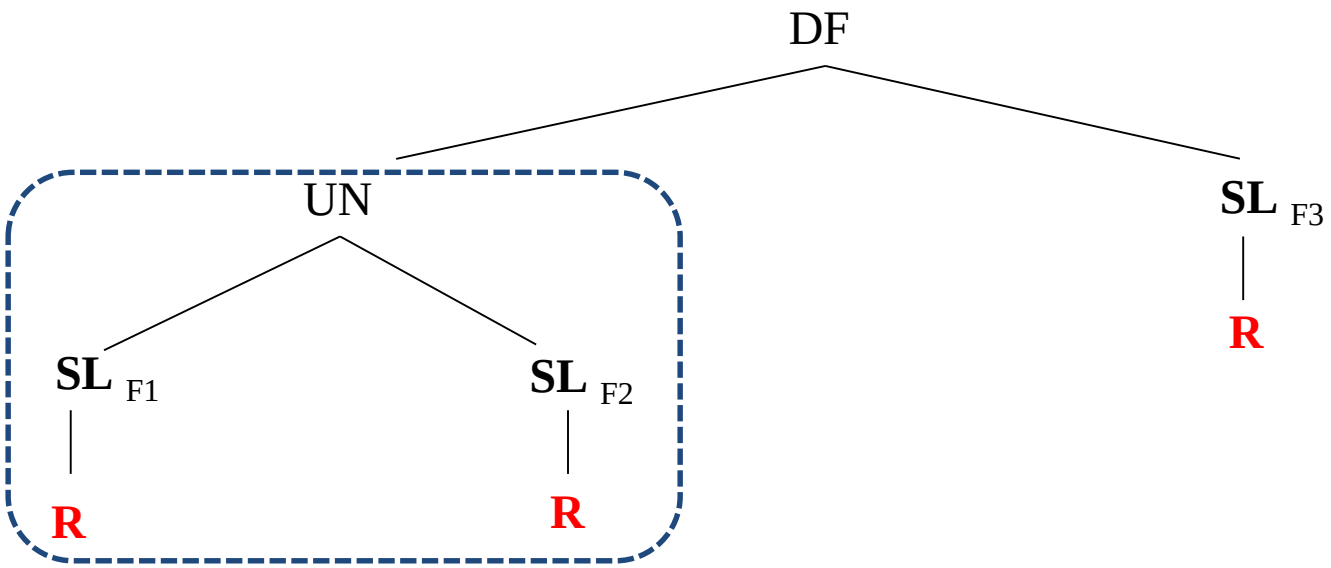


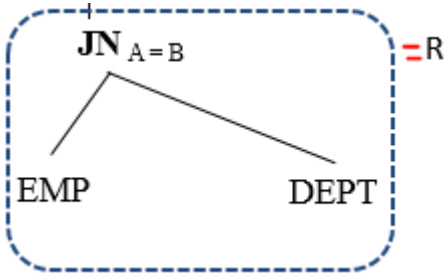
Finding Common Sub-expression



Finding Common Sub-expression

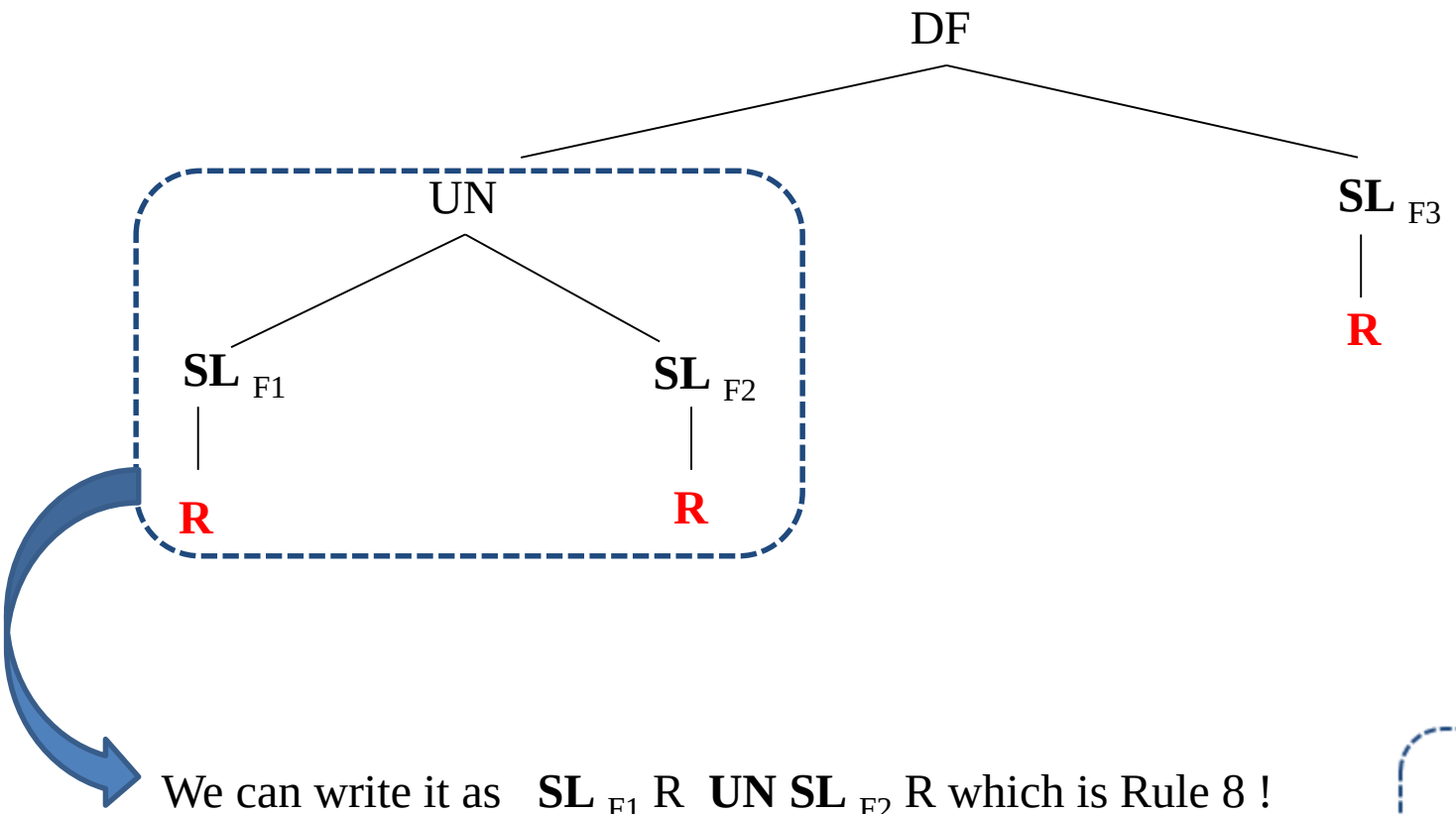
Any common portion?



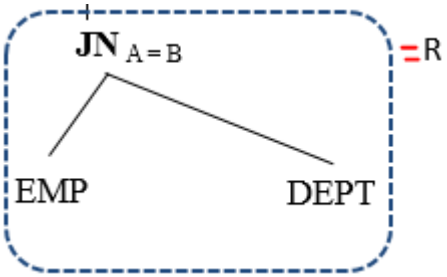


Finding Common Sub-expression

Any common portion?

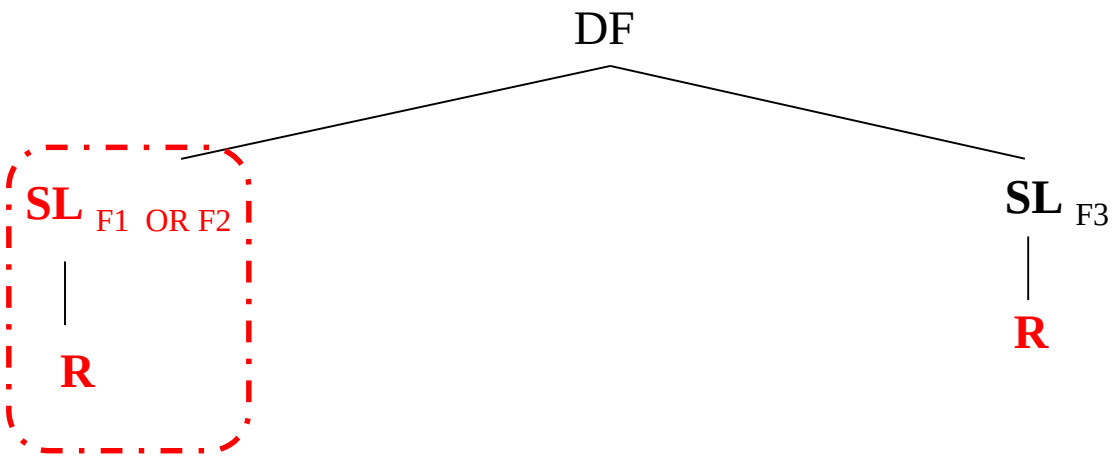


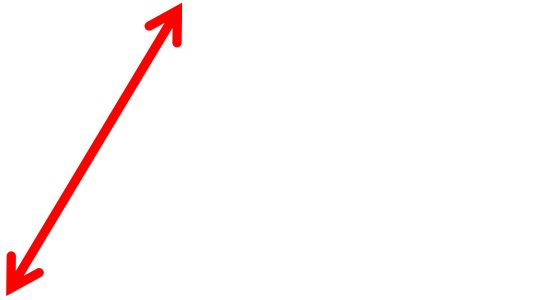
We can write it as **SL** $_{F1}$ R **UN SL** $_{F2}$ R which is Rule 8 !



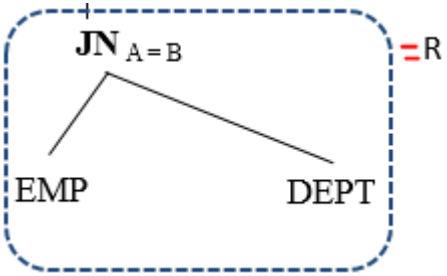
Removing Common Sub-expression

Any common portion?



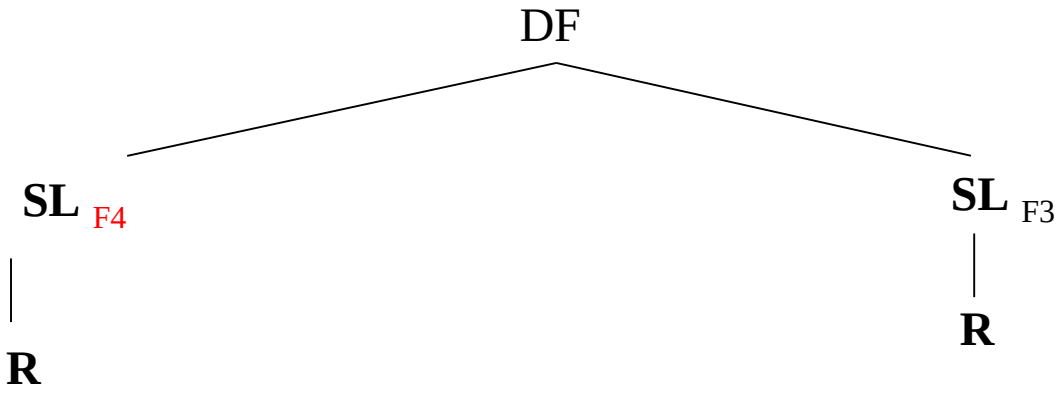


$$\sigma_{F1}(R) \cup \sigma_{F2}(R) = \sigma_{F1 \text{ OR } F2}(R)$$

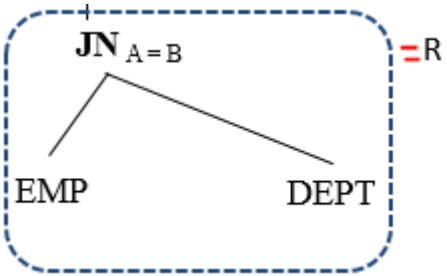


Finding Common Sub-expression

Any common portion?

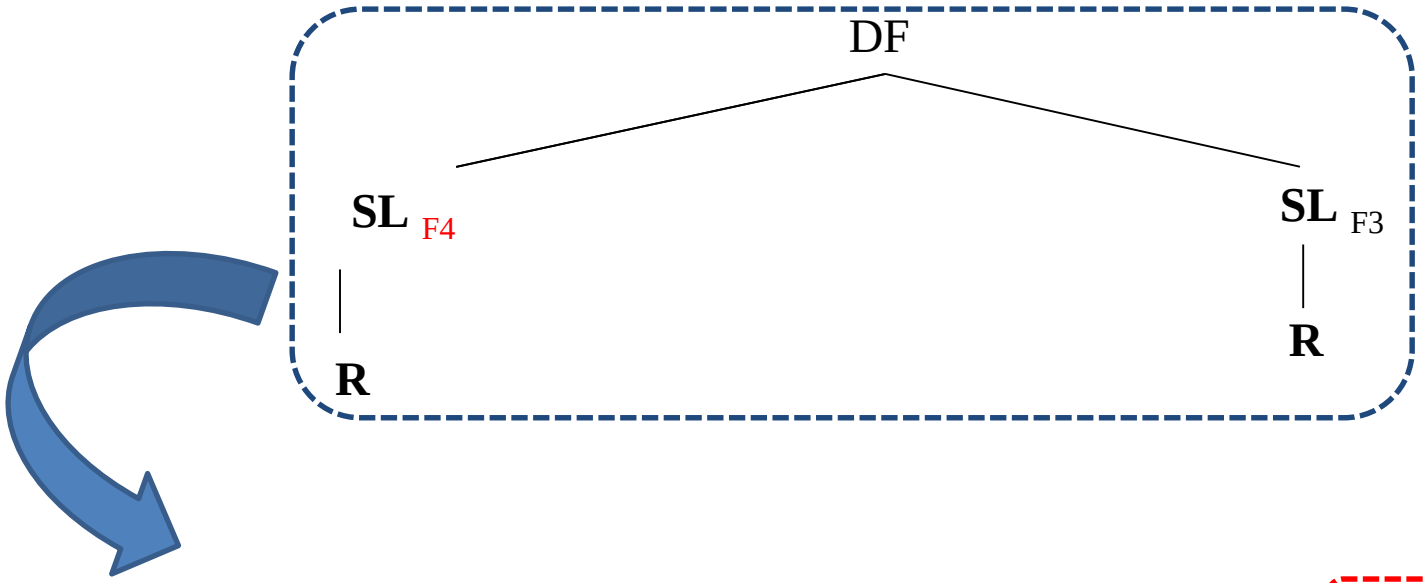


Let, F4 = F1 OR F2



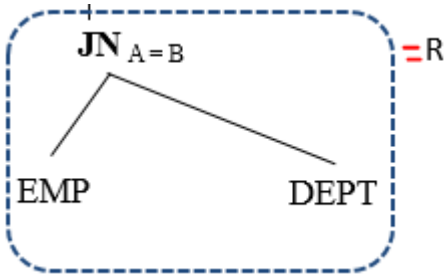
Finding Common Sub-expression

Any common portion?



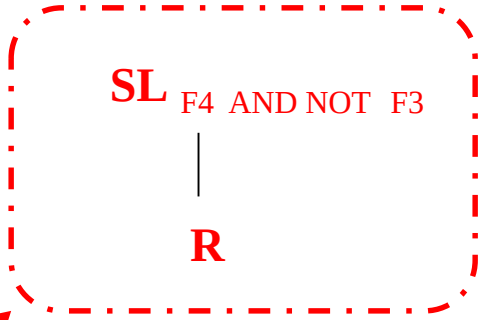
We can write it as **SL** $_{F4}$ R **DF SL** $_{F3}$ R which is Rule 9 !

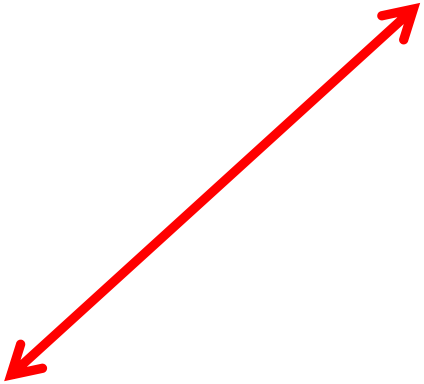
Let, F4 = F1 OR F2



Removing Common Sub-expression

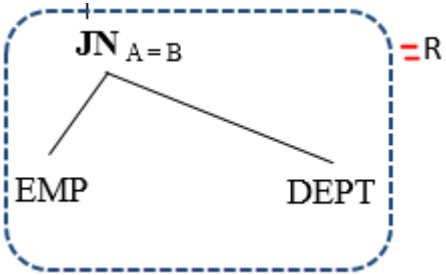
Any common portion?





SL $_{F4}$ R **DF SL** $_{F3}$ R = **SL** $_{F4\ AND\ NOT\ F3}$ R

Let, F4 = F1 OR F2

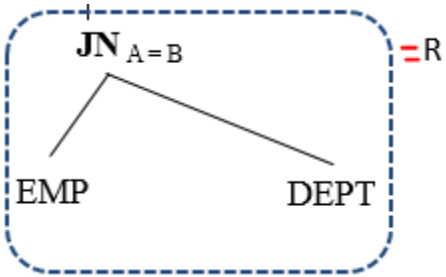


Removing Common Sub-expression

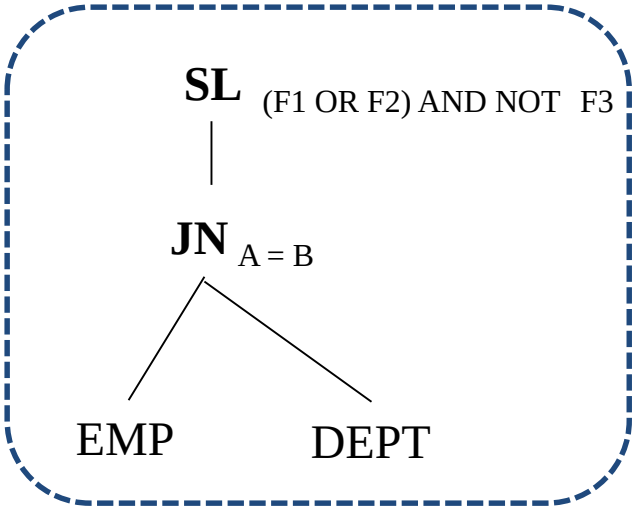
SL (F1 OR F2) AND NOT F3

|

R



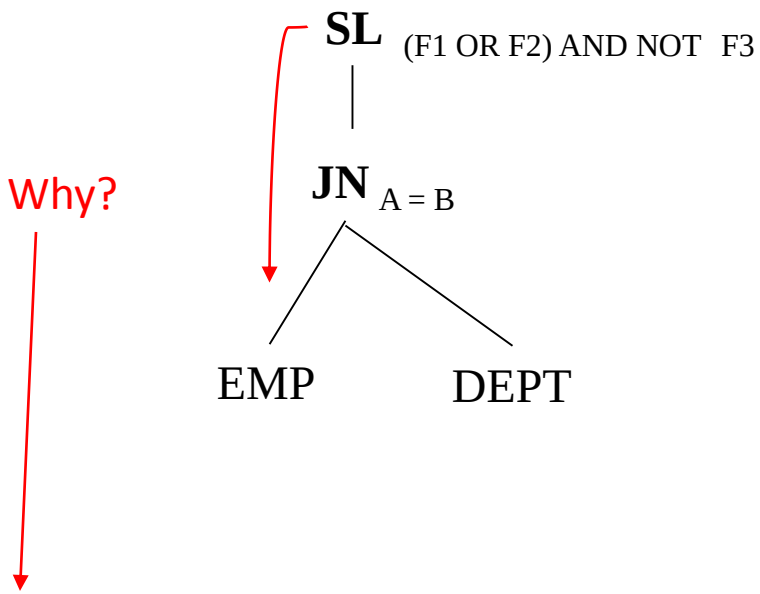
Removing Common Sub-expression



Can we apply Criterion 1 and/or 2?

Simplification

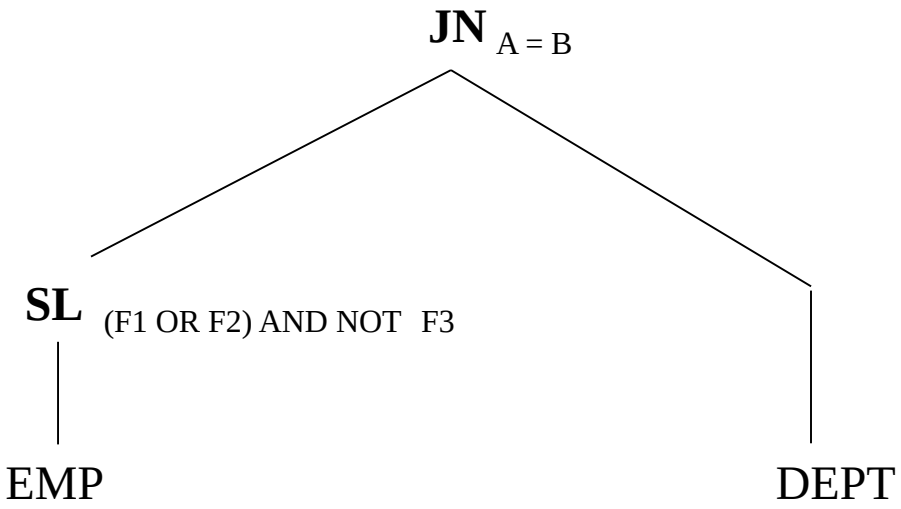
Applying Criterion 2 -



Because in the original query, all $\mathbf{SL}_{F1}$, $\mathbf{SL}_{F2}$, $\mathbf{SL}_{F3}$ were applied on EMP relation.

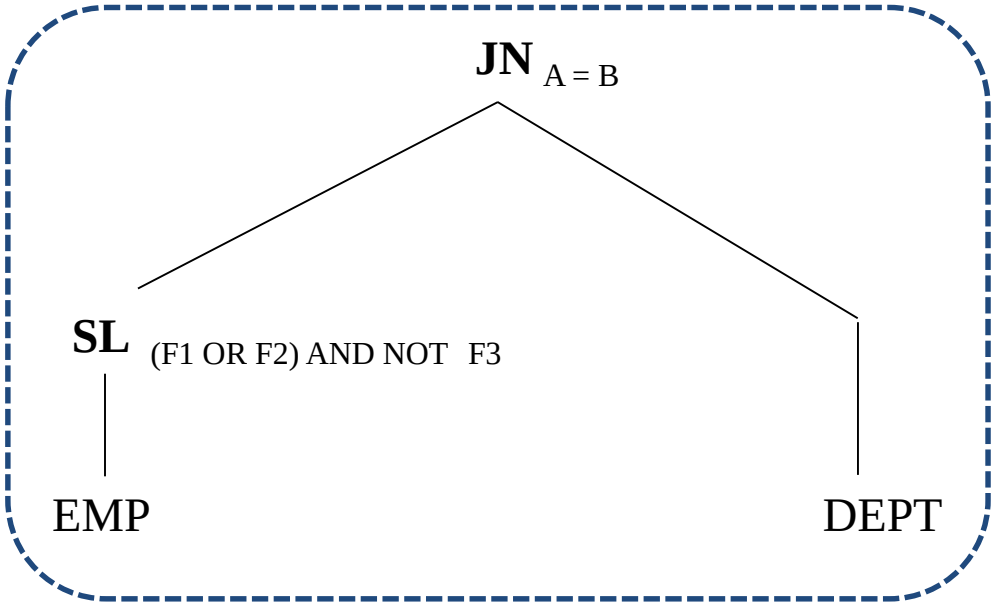
Simplification

After Applying Criterion 2 -



Transformed Query

Q_T: **SL** (F1 OR F2) AND NOT F3 *EMP* **JN** A = B *DEPT*



Transformed Query

Output:

$\mathbf{Q_T}$: **SL** $_{\text{(F1 OR F2) AND NOT F3}}$ *EMP* **JN** $_{\text{A = B}}$ *DEPT*

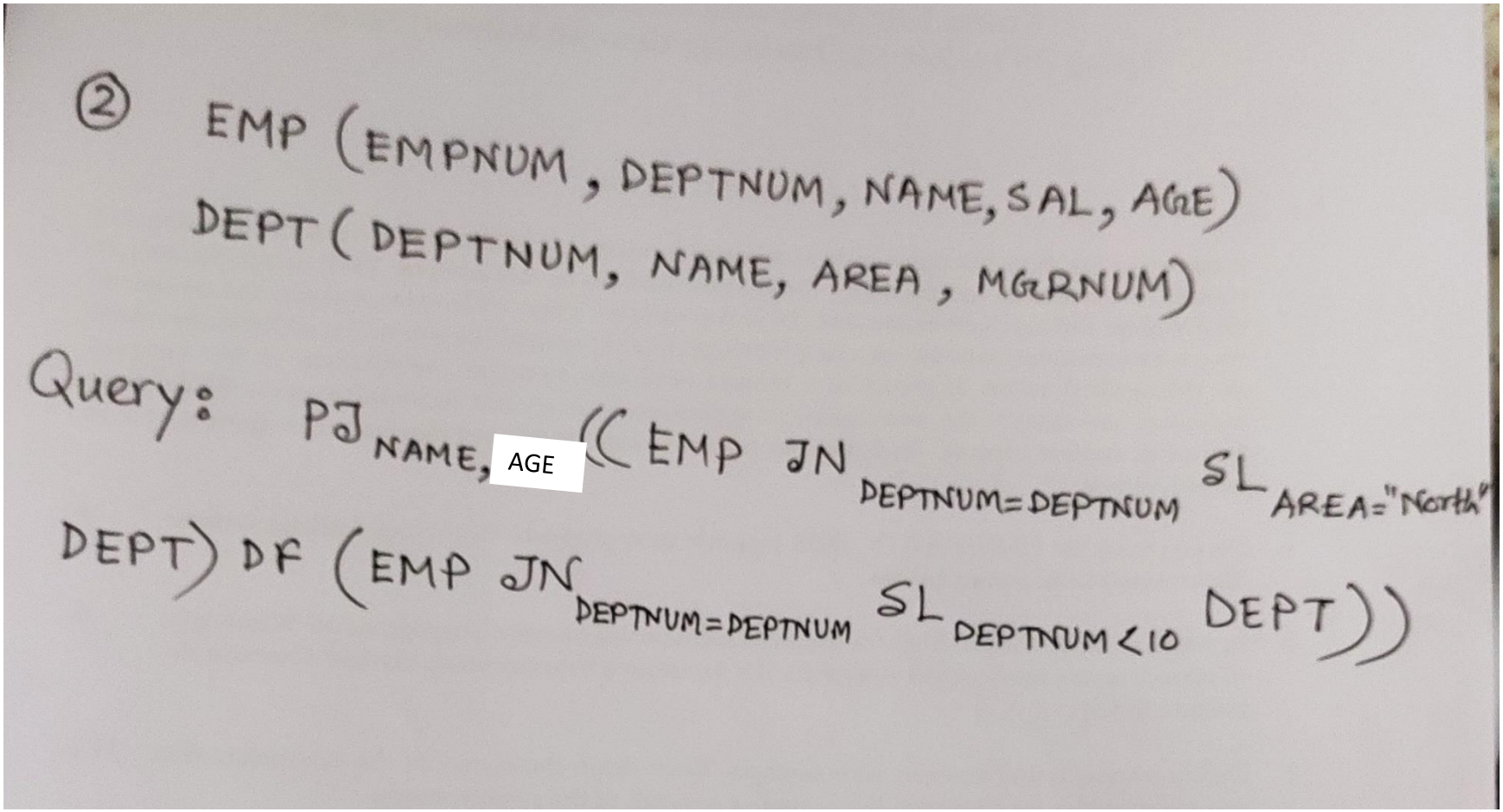
Input:

Q:

$$\left((SL_{F1}\ EMP\ JN_{A=B}\ DEPT)\ UN\ (SL_{F2}\ EMP\ JN_{A=B}\ DEPT)\right)\ DF\ (SL_{F3}\ EMP\ JN_{A=B}\ DEPT)$$

$$Q \longleftrightarrow Q_T$$

Exercise 1


② EMP (EMPNUM, DEPTNUM, NAME, SAL, AGE)
DEPT (DEPTNUM, NAME, AREA, MGRNUM)
Query: PJ NAME, AGE ((EMP JN DEPTNUM=DEPTNUM SL AREA="North" DEPT) DF (EMP JN DEPTNUM=DEPTNUM SL DEPTNUM<10 DEPT))

Exercise 2

4. Consider the following global relational schemata.

EMP (ID, NAME, SAL, AGE, MGRNUM, DEPTNUM)
DEPT (ID, AREA, DEPTNUM, MGRNUM)

Corresponding fragmentation schemata:

$$EMP_1 = SL_{SAL \leq 25K}\, EMP$$
$$EMP_2 = SL_{SAL > 25K}\, EMP$$
$$DEPT_1 = SL_{AREA = "North"}\, DEPT$$
$$DEPT_2 = SL_{AREA = "South"}\, DEPT$$

Also consider the following global query.

$$PJ_{NAME,\ AREA}(((SL_{SAL > 25K}\, EMP\ \ JN_{ID=ID}\ SL_{AREA = "North"}\, DEPT)\ DF\ (SL_{SAL \leq 25K} EMP\ JN_{ID=ID}\ SL_{AREA = "North"}\ \ DEPT))\ NJN\ (SL_{AREA = "North"}\ (EMP\ JN_{ID=ID}\ DEPT)))$$

Exercise 3

EMP (EMPNUM, DEPTNUM, NAME, SAL, AGE)
DEPT (DEPTNUM, NAME, AREA, MGRNUM)

Consider the following global query:

$$\left((SL_{F1}\ EMP\ \ JN_{A=B}\ \ DEPT)\ \ DF\ \ (SL_{F2}\ EMP\ \ JN_{A=B}\ \ DEPT)\right)\ \ NJN$$
$$\left((EMP\ \ JN_{A=B}\ \ DEPT)\ \ UN\ \ (SL_{F3}\ EMP\ \ JN_{A=B}\ \ DEPT)\right)$$

Here,
F1, F2, F3 can represent any condition. In this example consider none of them are same.
Imagine, A = B = DEPTNUM

Exercise 4

EMP (EMPNUM, DEPTNUM, NAME, SAL, AGE)
DEPT (DEPTNUM, NAME, AREA, MGRNUM)

Consider the following global query:

$$\left((SL_{F1}\ EMP\ \ JN_{A=B}\ \ DEPT)\ \ UN\ \ (SL_{F2}\ EMP\ \ JN_{A=B}\ \ DEPT)\right)\ \ NJN$$

$$\left((EMP\ \ JN_{A=B}\ \ DEPT)\ \ DF\ \ (SL_{F3}\ EMP\ \ JN_{A=B}\ \ DEPT)\right)$$

Here,
F1, F2, F3 can represent any condition. In this example consider none of them are same.
Imagine, A = B = DEPTNUM

Exercise 5

Consider the following global query and answer the questions from (i) to (iii).

$$(((SL_{F1}\ R\ JN_{A=B}\ S)\ DF\ (SL_{F2}\ R\ JN_{A=B}\ S))\ NJN\ (R\ JN_{A=B}\ S))$$
$$UN\ (SL_{F1\ AND\ NOT\ F2}\ R\ JN_{A=B}\ S)$$

i) Draw the operator tree. [2]

ii) Perform step-by-step transformations to simplify the operator tree, indicating which rule and criterion is applied at each step. [5]

iii) Write the query from the obtained simplified tree. [2]

Here,
F1, F2, F3 can represent any condition. In this example consider none of them are same.
Imagine, A and B represents the same attribute of two different relation R and S.

Exercise 6

EMP (EMPNUM, DEPTNUM, NAME, SAL, AGE)
DEPT (DEPTNUM, NAME, AREA, MGRNUM)

(a) Consider the following global query and answer the questions (i) and (ii).

$$\Big(\big((SL_{SAL>25K}\ \textbf{EMP}\ JN_{ID=ID}\ \textbf{DEPT})\ DF\ (SL_{AGE\leq 25}\ \textbf{EMP}\ \ JN_{ID=ID}\ \textbf{DEPT})\big)\ NJN\ (\textbf{EMP}\ JN_{ID=ID}\ \textbf{DEPT})\Big)$$
$$DF\ (SL_{SAL>25K\ \ AND\ \ AGE>25}\ \textbf{EMP}\ JN_{ID=ID}\ \textbf{DEPT}\ )$$

i. Draw the operator tree. [2]

ii. Perform step-by-step transformations to simplify the operator tree, indicating which rule and criterion is applied at each step. [6]