

1. Find the latest object catalogued by the newest volunteer. Report the volunteer's ID number and first name, as well as the object's description, type, and date of cataloguing.

$\text{Volunteer}(\text{SID}) := \prod_{\text{type} = \text{'volunteer'}} \text{Staff}$

$\text{NewestVolunteer}(\text{SID}) := \prod_{\text{V2.SID} \neq \text{V1.SID} \wedge \text{V1.date} < \text{V2.date}} (\text{fv}_1 \text{ Volunteer} \times \text{fv}_2 \text{ Volunteer})$

$\text{NewVolCat}(\text{SID}, \text{CN}, \text{date}) := \prod_{\text{U.SID}, \text{o.CN}, \text{o.date}}$

$(\text{fv} \text{ NewestVolunteer} \bowtie \text{v.SID} = \text{o.Who} \text{ fv Object})$

A  
B

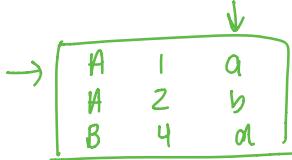
CN X fv<sub>2</sub> date  
a A 1  
b A 2  
c A 3  
d B 4  
e B 5

$\text{NotRecent}(\text{CN}) := \prod_{\text{T2.CN}}$

$(\text{Ti.SID} = \text{T2.SID} \wedge \text{Ti.date} > \text{T2.date})$

$(\text{PTi.NewVolCat} \times \text{PT2.NewVolCat})$

V1	V2	V1 > V2	V1	V2
A	A	1 1	a	a
A	A	1 2	a	b
A	A	1 3	a	c
A	A	2 1	b	a
A	A	2 2	b	b
A	A	2 3	b	c
A	A	3 1	c	a
A	A	3 2	c	b
A	A	3 3	c	c
B	B	4 1	d	d
B	B	4 5	d	e
B	B	5 4	e	d
B	B	5 5	e	e



$\text{Recent}(\text{CN}) := \prod_{\text{CN}} \text{NewVolCat} - \text{NotRecent}$

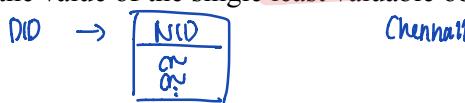
$\text{Answer}(\text{SID}, \text{firstname}, \text{description}, \text{type}, \text{date}) :=$

$\prod_{\text{U.SID}, \text{v.firstname}, \text{o.description}, \text{o.type}, \text{o.date}}$

$(\text{Recent} \bowtie \text{Object} \bowtie \text{o.who} = \text{v.SID} \text{ fv staff})$

2. For each donor who has made a donation in every Chenhall category in the database, report in a single tuple:

- the value of the single most valuable object they have ever donated, and
- the value of the single least valuable object they have ever donated.



# Info of donation

$\text{Donated}(\text{CN}, \text{DID}, \text{Category}, \text{Value}) := \prod_{\text{DID}, \text{category}, \text{CN}, \text{value}}$

$\text{Donation} \bowtie \text{Contains} \bowtie \text{Object} \bowtie \text{type} = \text{secondary Secondary Term}$   
 $\bowtie \text{primary Term}$

# Everyone donated to every category

$\text{ShouldHave}(\text{DID}, \text{Category}) := \text{Chenhall} \times \prod_{\text{DID}} \text{Doker};$

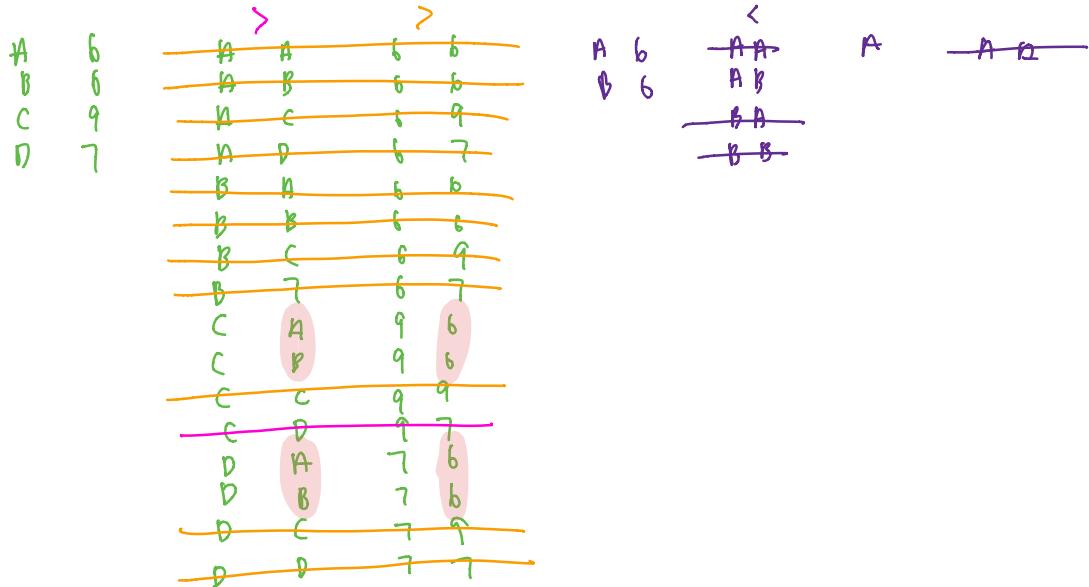
# who did not donate to all

$\text{WasNotAlways}(\text{DID}, \text{cat}) := \text{ShouldHave} - \prod_{\text{DID}, \text{category}} \text{Donated}$

# donated to every categories

$\text{EveryCat(DID)} := \pi_{\text{DID}} \text{Doners} - \text{WasNotAlways}$

$\text{DonatedValue(DID, value)} := \pi_{\text{DID}, \text{value}} (\text{EveryCat} \bowtie \text{Object} \bowtie \text{Contains} \bowtie \text{Donation})$



3. For each donation with three or more objects in it, report the second tallest object in the donation. Report the object's catalogue number, height, and width, as well as the ID of the donation it came from.

$\text{AtLeastThree(NID)} := \pi_{T1.NID \bowtie T2.NID \bowtie T3.NID} (T1.CN = T2.CN = T3.CN \wedge T1.ON \neq T2.ON \neq T3.ON)$   
 $(P_{T1} \text{ Contains}) \times (P_{T2} \text{ Contains}) \times (P_{T3} \text{ Contains})$

$\text{MultipleObject(NID, CN, height)} := \pi_{NID, CN, height} (\text{AtLeastThree} \bowtie \text{Contains} \bowtie \text{Object})$

WithoutFirstTallest (NID, CN, height) :=  $\Pi T1.NID, T1.CN, T1.height$

$$\sigma_{T1.NID = T2.NID \wedge T1.CN \neq T2.CN \wedge T1.height < T2.height} \\ (\ell_{T1} \text{ Multiple Obj}(t) \times (\ell_{T2} \text{ Multiple Obj}))$$

A	6	6	6
B	6	6	6
C	2	6	6
D	3	7	6
	C	A	2
	C	P	2
	C	D	2
	D	A	3
	D	B	7
	D	C	3
	D	D	3

Tallest (NID, CN, height) := Multiple Obj - without First Tallest

WithoutSecondTallest (NID, CN, height) :=  $\Pi T1.NID, T1.CN, T1.height$

$$\sigma_{T1.NID = T2.NID \wedge T1.CN \neq T2.CN \wedge T1.height < T2.height} \\ (\ell_{T1} \text{ WithoutFirstTallest} \times (\ell_{T2} \text{ WithoutFirstTallest}))$$

SecondTallest (NID, CN, height) := WithoutFirstTallest - withoutSecondTallest

Answer (CN, height, width, NID) :=  $\Pi CN, height, width, NID$   
SecondTallest  $\bowtie$  Object

4. Find any donation that was catalogued entirely by one staff person, where the same tag was used for at least 2 objects, but that tag was never used for any object catalogued by the same staff person in any other donation. For each such donation, report the donation ID and donor ID, and the staff member ID of the one person who catalogued it.

① Catalogued by one staff person; staff who catalogued every object for a donation

# more info  
DonObject (NID, CN, who) :=  $\Pi NID, CN, who$  (Object  $\bowtie$  containing)

NID	CN	who
A	0	Jon
A	1	Jon
A	2	Jon
B	3	Jon
B	4	Bob
B	5	Bob

# object need to remove this  
NotSingle (NID, CN, who) :=  $\Pi T1.who, T1.CN, T1.NID$

$$\sigma_{T1.who \neq T2.who \wedge T1.NID = T2.NID} \\ (\ell_{T1} \text{ DonObject}) \times (\ell_{T2} \text{ DonObject})$$

CataloguedOneStaff (NID, CN, who) := DonObject - NotSingle

② OneStaff Tag (NID, CN, phrase) :=  $\Pi NID, CN, phrase, who$   
cataloguedOneStaff  $\bowtie$  Tag

③ SameTwoTags (NID, CN, phrase) :=  $\Pi T1.NID, T1.CN, T1.phrase, T1.who$   
 $\sigma_{T1.NID = T2.NID \wedge T1.CN \neq T2.CN \wedge T1.phrase = T2.phrase}$   
( $\ell_{T1}$  OneStaff Tag)  $\times$  ( $\ell_{T2}$  OneStaff Tag)

NID	CN	phrase	who
A	0	a	Bob
A	1	a	;
A	2	a	
B	3	b	

\* Bob  $\bowtie$  ( $\Pi$  who CataloguedOneStaff)  $\bowtie$  Object  $\bowtie$  Tag

$\bowtie$  contains

B 4 b Jan ~~T1.NID~~, T1.who, T1.phrase  
 $\{ T1.NID \neq T2.NID \wedge T1.who = T2.who \wedge T1.phrase = T2.phrase \}$   
 $(PT1 \text{ SameTwoTags}) \times (PT2 \text{ StaffTag})$

Never used (who, plural) := ( $\exists$  person, who Same Two Tags) - Tag Used

Don Never Used (ND, CN, WHO);

11 NID, Cr, who  
Same TWO Targets  $\Rightarrow$  Never Use!

Answer(NID, DID, SID) :=  $\pi_{NID, CN, who}$  DonNeverUsed  $\bowtie$  Donation

2006

① ② ③  
5. Find all volunteers who have catalogued object(s) from at least two different donations every year up to and including in 2016, but have catalogued nothing since ④. By “every year” we mean every year that appears in the Object relation. For each of these volunteers, report their staff ID and email address.

① `Volunteers (S10) := πS10 σType = 'volunteers' Staff`      `Volunteers = S10.Volunteers`

② AllCat (NID, CN, SID, date) := TNID, CN, who, date. Object  $\downarrow$  contains

TWO DIFF DONATION ( S.D. & N.Y. date ) := ~~PII + PII~~ T1, S.D. II date

Two Diff Donation ( $SID, NID, date$ ) :=  $T1.T1.NID, T1.SID, T1.date$ ,  $date.year \leq 2006$   
 $\uparrow T1.NID \neq T2.NID \wedge T1.SID = T2.SID \wedge T1.date.year = T2.date.year$   
 $(P_{T1} \text{ AllCat}) \times (P_{T2} \text{ AllCat})$

③ All Year (date) := TDate (date.year ≤ 2016 Object

#Shouldhave(SID, date) := All Year X volunteers

WasNotAlways(SID, date) := ShouldHave - TwoDiffDonation

Every Year ( SID) :=  $\text{TT}_{\text{SID}, \text{date}}$  AllCat - was NOT Always

(4) CatAfter2016 (S ID) :=  $\{ \text{t} \in S \mid \text{t.date.year} > 2016 \}$  Objects

$\Rightarrow$  Partial CS(1) := Every year - Cut after 2016

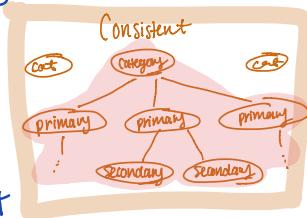
Answer ( \$10\_email ) := TTSID\_email Partial  $\bowtie$  Staff

①  
6. A "consistent donation" is one in which every object is from the same Chenhall category. Find all donations that were consistent, yet more than one person catalogued object(s) from it. For each qualifying donation, include in the result one tuple for each person who catalogued objects from it. Each tuple should contain the donation ID and person's staff member ID.

② Catalogued (NID, CN, SID) :=  $\pi_{NID, CN, \text{who\_type}}$  Object  $\bowtie$  Contains

Multiple Cat (NID, CN) :=  $\pi_{NID, CN}$   
 $\sigma_{T1.NID = T2.NID \wedge T1.SID \neq T2.SID}$   
 $(\ell_{T1} \text{ Catalogued}) \times (\ell_{T2} \text{ Catalogued})$

$\rightarrow$  AllObjects (NID, CN, type) :=  $\pi_{NID, CN, \text{type}}$  Contains  $\bowtie$  Multiple Cat



① Chen  $\rightarrow$  Category  $\rightarrow$  primary  $\rightarrow$  secondary

$\rightarrow$  AllCat (Category, primary, Secondary) := Primary Term  $\bowtie$  Secondary term

ObjectCategory (NID, CN, Category, primary, Secondary) :=  
 $\pi_{NID, CN, \text{Category}, \text{primary}, \text{Secondary}}$   
 $\text{AllCat} \bowtie \text{Secondary} = \text{pre All Objects}$

Multiple Categories (NID) :=  $\pi_{NID}$

$\sigma_{T1.NID = T2.NID \wedge T1.category \neq T2.category}$   
 $(\ell_{T1} \text{ ObjectCategory}) \times (\ell_{T2} \text{ ObjectCategory})$

Consistent (NID, CN) := AllObjects - (AllObjects  $\bowtie$  NID)

Answer (DID, SID) :=  $\pi_{DID, SID}$  Object  $\bowtie$  Consistent  $\bowtie$  Donation

7. The “largest donation” is the one with the most objects in it (there could be ties for largest). Find any donor who made a donation that qualifies as largest. Report the ID of each staff member who has catalogued an object that was part of any donation by any of these donors.

All donated objects ( D10, N10, CN ) :=  $\exists D10, N10, CN \text{ Donation } \bowtie \text{ Contains}$

Cannot be expressed

(3)

U

8. Find staff who have, two or more times, catalogued every object in a donation but gave none of them tags. Report only the SID of these staff members.

① Employees who catalogued every object in a donation

$\text{EmployeeCatalogue} (NID, \cancel{X}, SID) := \prod_{T1} NID, SID \text{ Contains } \cancel{X} \text{ Object}$

$\text{NotEveryObject} (NID, SID) := \prod_{T1} T1, NID, T1, SID$

$$\cap T1, NID = T2, NID \wedge T1, SID \neq T2, SID$$

( $\ell_{T1} \text{ EmployeeCatalogue} \times \ell_{T2} \text{ EmployeeCatalogue}$ )

$\text{EveryObject} (NID, SID) := \prod_{T1} NID, SID \text{ EmployeeCatalogue} - \text{Not EveryObject}$

NID	SID
A	a
A	a
A	b
B	c
C	c

A	B	a	a
A	B	a	a
A	B	a	b
A	B	a	a
A	B	a	b
A	B	b	a
A	B	b	a
A	B	b	b

B	B	c	c
B	C	c	c
B	C	c	c
B	C	c	c

$$\left\{ \begin{array}{l} A \\ A \\ B \\ C \end{array} \right\} - \left\{ \begin{array}{l} A \\ A \\ B \end{array} \right\} = \underline{\underline{BC}}$$

ANSWER

$\text{MoreThanOnce} (NID, SID) := \prod_{T1} \cancel{X} NID, T1, SID$

$$\cap T1, NID \neq T2, NID, T1, SID = T2, SID$$

( $\ell_{T1} \text{ EveryObject} \times \ell_{T2} \text{ EveryObject}$ )

0 6 X

9. Find all pairs of staff members who have catalogued together yet neither of them has catalogued with anyone else. (Two people have “catalogued together” if they have each catalogued object(s) from the same donation.) Put each pair into a tuple that includes their staff IDs and their email addresses. Don’t include pseudo-duplicates, that is, don’t report A, B and also B, A.

$\text{Catalogued}(NID, CN, SID) := \pi_{NID, CN, SID}(\text{Contains Object})$

$\text{Catalogued Together}(NID, SID1, SID2) := \pi_{NID, SID1, SID2}(\text{Catalogued Together})$

1	A	X	A A	X 2	C C
1	B		A B	X 2	C C
1	C		A C	X 2	C E
2	C	+	B A	X 2	C C
2	C	+	B B	X 2	C C
3	B		B C	X 3	B B
3	D		C A	3	B D
3	D		C B	3	D B
X	C	X	C C	X 3	D D

$\cap_{T1.SID \neq T2.SID \wedge T1.NID = T2.NID} (\rho_{T1}(\text{Catalogued})) \times (\rho_{T2}(\text{Catalogued}))$

1	A
1	B
1	C
3	B
3	C

$\text{Catalogued Other}(NID1, NID2, SID) := \pi_{NID1, NID2, SID}(\text{Catalogued Other})$

1	3	A	B	
1	3	A	C	
1		B	B	
1		B	C	
1		C	B	
1		C	C	

$\cap_{T1.NID \neq T2.NID \wedge T1.SID = T2.SID} (\rho_{T1}(\text{Catalogued Other})) \times (\rho_{T2}(\text{Catalogued Other}))$

$\text{Cat Only Toy}(NID, SID) := \text{Cat Toyetor} - \left[ \begin{array}{l} \pi_{NID, SID}(\text{Catalogued Other}) \\ \pi_{NID2, SID}(\text{Catalogued Other}) \end{array} \right]$

$\text{Together}(SID1, SID2) := \pi_{SID1, SID2}(\text{Cat Toyetor}) \cap_{T1.NID = T2.NID \wedge T1.SID < T2.SID} (\rho_{T1}(\text{Cat Toy})) \times (\rho_{T2}(\text{Cat Toy}))$

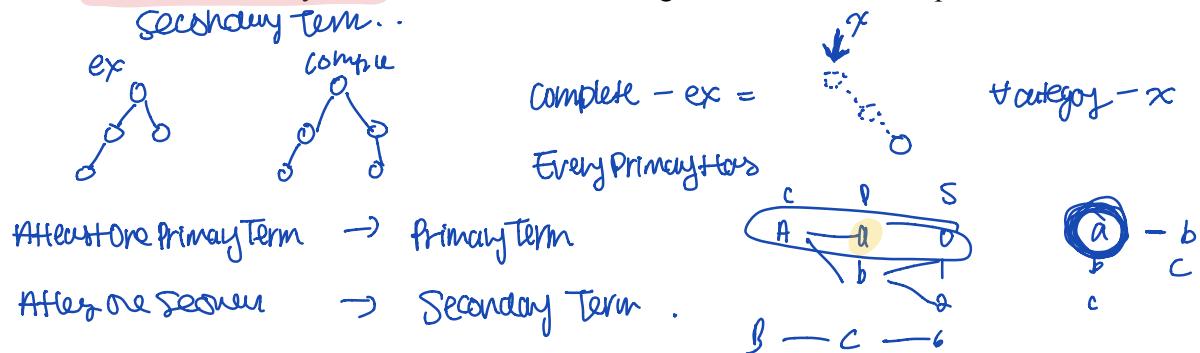
$\text{Answer}(SID1, Email1, SID2, Email2) := \pi_{SID1, SID2, Email1, Email2}(\text{Staff})$

$\text{Staff} \rightarrow SID = T1.SID (\rho_{T1}(\text{Staff}))$

$\text{Staff} \rightarrow SID = T2.SID (\rho_{T2}(\text{Staff}))$

✓      after  
.....  $\rightarrow$   $\text{Cat} \rightarrow \text{Dri} \rightarrow \text{Sel}$

- primary term  $\rightarrow$  such -  
 10. A Chenhall category is "complete" if it has at least one primary term and each of its primary terms has at least one secondary term. Find all Chenhall categories that are not complete.



No Secondary Term (Primary) :=  $\neg$  primary Primary Term -  $\neg$  primary Secondary

Complete Secondary (Primary) :=  $\neg$  primary Primary Term - No Secondary Term

No Complete Primary (Cat) :=  $\neg$  Cat Primary - ( $\neg$  Category Primary Term  $\times$  Complete Secondary)

Complete Chenhall (Cat) :=  $\neg$  Cat Primary - No Complete Primary

Not Complete Chenhall (Cat) := Chenhall - Complete Chenhall

## PART 2

1. No secondary term can be a primary term or a Chenhall category, and no primary term can be a Chenhall category.

$$[(\text{Secondary Term} \wedge \text{secondary} = \text{primary Primary Term}) \vee (\text{Secondary} \wedge \text{secondary} = \text{Category (Chenhall)})] \\ \wedge (\text{Primary Term} \wedge \text{primary} = \text{category Chenhall}) = \emptyset$$

2. A donation can be catalogued only if (a) it has one object, which is worth at least \$100, or (b) it has two or more objects, which are worth at least \$150 in total.

$$\text{Value (NID, CN, value)} := \text{TT}_{\text{NID}, \text{CN}, \text{value}} \text{ contains } \wedge \text{Object} \\ (\text{a}) \qquad \qquad \qquad (\text{b}) \\ \text{TT}_{\text{NID} \text{ Donation}} - (\text{TT}_{\text{NID}} \wedge \text{value} \leq 100 \text{ Value}) - ( \\ \boxed{\text{cannot be expressed}}$$

3. Each object catalogued before 2018 must have exactly three tags.

$$\text{Before2018 (CN, Tag)} := \text{TT}_{\text{CN}, \text{Tag}} \cap_{\text{date.year} < 2018} \text{Object} \wedge \text{Tag}.$$

$$\text{AtLeastThree (CN)} := \text{TT}_{\text{CN}} \cap_{\substack{\text{P1 Before2018} \times \text{P2 Before2018} \times \text{P3 Before2018}}} \text{Object} \wedge \text{Tag} \\ \wedge \text{P1.Tag} \neq \text{P2.Tag} \neq \text{P3.Tag}$$

$$\text{AtLeastFour (CN)} := \text{TT}_{\text{CN}} \cap_{\substack{\text{P1 Before2018} \times \text{P2 Before2018} \times \text{P3 Before2018} \times \text{P4 Before2018}}} \text{Object} \wedge \text{Tag} \\ \wedge \text{P1.Tag} \neq \text{P2.Tag} \neq \text{P3.Tag} \neq \text{P4.Tag}$$

$$\text{ExactThree (CN)} := \text{AtLeastFour} - \text{AtLeastThree}$$

$$\text{TT}_{\text{CN} \text{ Before2018}} - \text{ExactThree} = \emptyset$$

4. There are strict rules for who is allowed to catalogue what:

$$\text{ObjectCategory (CN, SID, Category)} := \text{TT}_{\text{CN}, \text{SID}, \text{Category}} \\ \text{Object} \wedge \text{type} = \text{Secondary Secondary Term} \\ \wedge \text{Primary Term}$$

$$\text{Catalogued (SID, type, Category)} := \text{TT}_{\text{SID}, \text{type}, \text{Category}} \\ \text{ObjectCategory} \wedge \text{Staff}$$

$$\text{TT}_{\text{SID} \wedge \text{type} = \text{'Temp'}} \text{ Catalogued} \vee \text{TT}_{\text{CN} \wedge \text{Category} \neq \text{'Personal artifact'} \wedge \text{Category} \neq \text{'architectural'}} \\ \wedge \text{type} \neq \text{'permanent'} \text{ Catalogued} \\ = \emptyset$$

