Note that alternate solutions have been provided in lower case Roman numerals.

Relational Schema:

Book(b_id, title, author, category, year, location)
    /*location refers to Library.name*/

Student(s_id, name, major, gender)

Borrow(s_id, b_id, date)
    /*s_id refers to Student.s_id and b_id refers to Book.b_id */

Library(name, address)

The schema above is a segment of a library database. It contains some basic information about books in different libraries and the students who borrow them. For each book, the database stores its unique ID, the book title, the author, the category it belongs to (e.g., Computer Science, Medicine), the year of publication, and the name of the library where the book is located. The student table records the student’s unique ID, the name and some other information. Similarly, the database keeps record of the borrowing transactions, and library address.

There are a few important things that you should know about this schema. (1) You should consider Book.year as integers. (2) You should consider Borrow.date strings which could be compared in the order of time. For example, ‘01/01/2013’ > ‘01/02/2013’, ‘02/01/2013’ > ‘01/01/2013’ and ‘01/01/2014’ > ‘01/01/2013’ (3) Except for the two attributes mentioned above, all other attributes are strings. (4) Book.location refers to Library.name instead of Library.address.
(a) Output the names of the students in ‘Computer Science’.
\[ \pi_{\text{name}}(\sigma_{\text{major}='\text{Computer Science}'}(\text{Student})) \]

(b) Output the names of students who have borrowed at least one book within this year. (This year begins at ‘01/01/2013’.)

i) \[ \pi_{\text{name}}(\sigma_{\text{date}>'01/01/2013'}(\text{Student} \bowtie \text{Borrow})) \]

ii) \[ \pi_{\text{name}}(\text{Student} \bowtie (\delta_{\text{date}>'01/01/2013'}(\text{Borrow}))) \]

(c) Output the titles of all books located in the library at ‘100 Washington Street’.

i) \[ \pi_{\text{title}}(\sigma_{\text{Book.location}='\text{Library.name AND address='100 Washington Street'}}(\text{Book} \times \text{Library})) \]

ii) \[ \pi_{\text{title}}(\sigma_{\text{Book.location}='\text{Library.name'}}(\text{Book} \times (\sigma_{\text{address='100 Washington Street'}}(\text{Library})))) \]

(d) Output the majors of students who have borrowed ‘Database System’.

i) \[ \pi_{\text{major}}(\sigma_{\text{Book.title='Database System'}}(\text{Student} \bowtie \text{Borrow} \bowtie \text{Book})) \]

ii) \[ \pi_{\text{major}}(\text{Student} \bowtie \text{borrow} \bowtie (\sigma_{\text{Book. title='Database System'}}(\text{Book}))) \]

(e) Output the names and majors of the students who have borrowed at least 1 book from ‘Main Library’ this year. (‘Main Library’ is the name of the library.)

i) \[ \pi_{\text{Student.name, major}}(\sigma_{\text{date}>'01/01/2013'}(\text{Student} \bowtie \text{Borrow} \bowtie (\sigma_{\text{Library.name='Main Library'}}(\text{Book} \bowtie_0 \text{Library})))) \]

\[ \theta: \text{Book.location }= \text{ Library.name} \]

Correction on i) (don’t need to join with Library as Book has location)
\[ \pi_{\text{Student.name, major}}(\sigma_{\text{date}>'01/01/2013'}(\text{Student} \bowtie \text{Borrow} \bowtie (\sigma_{\text{location='Main Library'}}(\text{Book})))) \]
ii) $\Pi_{\text{Student.name, major}} ((\text{Student} \bowtie (\sigma_{\text{date}='01/01/2013'} (\text{Borrow}))) \bowtie (\sigma_{\text{Library.name}='Main Library'} (\text{Book} \bowtie_0 \text{Library})))$

$\theta$: Book.location = Library.name

**Correction on ii) (don’t need to join with Library as Book has location)**

$\Pi_{\text{Student.name, major}} (\text{Student} \bowtie (\sigma_{\text{date}='01/01/2013'} (\text{Borrow}))) \bowtie (\sigma_{\text{location}='Main Library'} (\text{Book})))$

(f) Output the majors in which none of the students have borrowed any book in the category ‘Computer Science’

i) $\Pi_{\text{major}} (\text{Student}) - \Pi_{\text{major}} (\sigma_{\text{category}='Computer Science'} (\text{Student} \bowtie \text{Borrow} \bowtie \text{Book}))$

ii) $\Pi_{\text{major}} (\text{Student}) - \Pi_{\text{major}} (\text{Student} \bowtie (\sigma_{\text{category}='Computer Science'} (\text{Borrow}))) \bowtie \text{Book}$

(g) Output the names of libraries that have not been visited by all students. (This means that for library X to be listed in the output, there should be at least one student who has borrowed zero books from X.)

$\Pi_{\text{name}} (\text{library}) - ((\Pi_{\text{s.id,location}} (\text{Borrow} \bowtie \text{Book})) + \Pi_{\text{s.id}} (\text{Student}))$