Knowledge Graphs 2022/23: Mock Exam

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Task 1: a–b

RDF Literals I

Let the prefix `xsd` be defined as `http://www.w3.org/2001/XMLSchema#`. Which of the following three RDF literals describe the same value?

1. `"2"^^xsd:integer`
2. `"2"^^xsd:float`
3. `"2.0"^^xsd:decimal`

1. `"2021-03-16T09:20:00"^^xsd:dateTime`
2. `"2021-03-16T09:20:00+01:00"^^xsd:dateTime`
3. `"2021-03-16T08:20:00Z"^^xsd:dateTime`

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Solution

- `"2"^^xsd:integer` describes the same value as `"2.0"^^xsd:decimal`, since `xsd:integer` is a derived type of `xsd:decimal`

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Solution

- `"2"^^xsd:integer` describes the same value as `"2.0"^^xsd:decimal`, since `xsd:integer` is a derived type of `xsd:decimal`
- `"2021-03-16T09:20:00+01:00"^^xsd:dateTime` and `"2021-03-16T08:20:00Z"^^xsd:dateTime` describe the same value in different time zones

Task 1: c

RDF Literals II

Define the term “RDF graph”. You may use the terms “IRI”, “blank node”, “literal”, and “Unicode” in your definition.

Task 1: c

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Define the term “RDF graph”. You may use the terms “IRI”, “blank node”, “literal”, and “Unicode” in your definition.

Solution

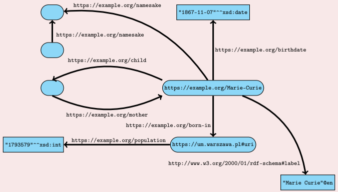
A **triple** is a 3-tuple of **subject**, **predicate**, and **object**, where

- subject is an IRI or a blank node,
- predicate is an IRI, and
- object is an IRI, a blank node, or a literal.

An **RDF graph** is a set of triples.

Task 2

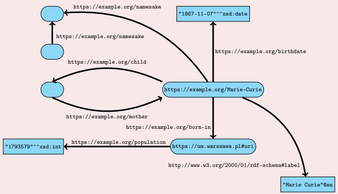
Turtle Serialisation



Use the Turtle format to encode this RDF graph, using the base IRI `https://example.org/` and the prefixes `xsd` (for `http://www.w3.org/2001/XMLSchema#`) and `rdfs` (for `http://www.w3.org/2000/01/rdf-schema#`). Take advantage of syntactic abbreviations wherever possible.

Task 2

Turtle Serialisation



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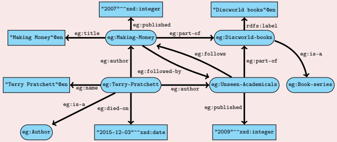
Solution

```
<Marie—Curie> <birthdate> "1867—11—07"^^xsd:date ;
              rdfs:label "Marie Curie"@en ;
              <born—in> <https://um.warszawa.pl#uri> ;
              <child> [ <mother> <Marie—Curie> ] ;
              <namesake> _:1 .
_:2 <namesake> _:1 .
<https://um.warszawa.pl#uri> <population> 1793579 .
```

Task 3: a

SPARQL Querying I

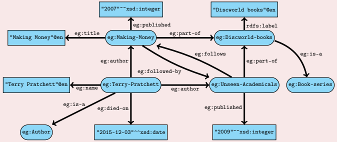


Consider an RDF graph describing authors and book series, using a schema as described by the image to the left (i.e., the image shows just a tiny portion of the whole graph, which contains information on many more book series, authors, and books).

Write a SPARQL query that finds all books belonging to the Discworld series.

Task 3: a

SPARQL Querying I



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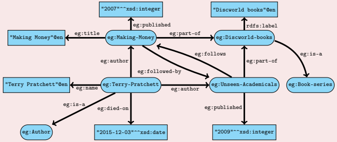
Write a SPARQL query that finds all books belonging to the Discworld series.

Solution

```
SELECT ?book WHERE {
  ?book eg:part—of eg:Discworld—books .
}
```

Task 3: b

SPARQL Querying II



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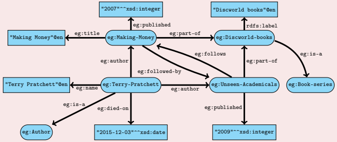
Write a SPARQL query that finds all authors of book series, ordered by the maximal number of books they contributed to any series. Note that multiple authors may contribute books to a series, and that authors may contribute books to multiple series.

Task 3: b

SPARQL Querying II



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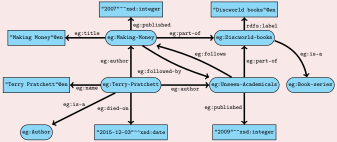
Write a SPARQL query that finds all authors of book series, ordered by the maximal number of books they contributed to any series. Note that multiple authors may contribute books to a series, and that authors may contribute books to multiple series.

Solution

```
SELECT ?author (MAX(?contributions) AS ?books) WHERE {
  { SELECT ?author ?series (COUNT(?book) AS ?contributions) WHERE {
      ?series eg:is—a eg:Book—series .
      ?author eg:author ?book .
      ?book eg:part—of ?series .
  } GROUP BY ?author ?series }
} GROUP BY ?author
ORDER BY DESC(?books)
```

Task 3: c

SPARQL Querying III

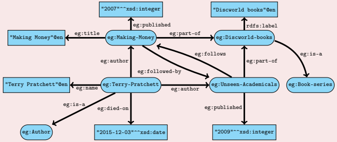


Consider an RDF graph describing authors and book series, using a schema as described by the image to the left (i.e., the image shows just a tiny portion of the whole graph, which contains information on many more book series, authors, and books).

Write a SPARQL query that finds all book series consisting only of books whose authors have died. Note that multiple authors may contribute books to a series.

Task 3: c

SPARQL Querying III



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Solution

```
SELECT ?series WHERE {
  ?series eg:is-a eg:Book-series .
  FILTER NOT EXISTS {
    ?book eg:part-of ?series ; ^eg:author ?author .
    FILTER NOT EXISTS { ?author eg:died-on [] . }
  }
}
```

Task 4: a

RDF Leanness I

Give a formal definition of a **lean RDF graph**. Briefly describe the intuitive significance of this notion.

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RDF Leanness I

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Solution

An **instance** $\sigma(G)$ of an RDF graph G is obtained by replacing some blank nodes by arbitrary RDF terms. An RDF graph G is lean if it does not have an instance $\sigma(G)$ with $\sigma(G) \subsetneq G$. Intuitively, lean graphs do not have internal redundancy.

Task 4: b

RDF Leanness II

Which of the following RDF graphs is not lean?

1.
```
eg:s   eg:p   eg:o .
_:1    eg:p   _:1  .
```

2.
```
eg:s   eg:p   _:2  .
_:1    eg:p   eg:o .
```

3.
```
eg:s   eg:p   eg:s .
_:1    eg:p   [ eg:p   [] ] .
```

4.
```
eg:s   eg:p   eg:o .
_:1    eg:p   [ eg:p   [] ] .
```

Task 4: b

RDF Leanness II

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_:1    eg:p   eg:o .
```

3.
```
eg:s   eg:p   eg:s .
_:1    eg:p   [ eg:p   [] ] .
```

4.
```
eg:s   eg:p   eg:o .
_:1    eg:p   [ eg:p   [] ] .
```

Solution

Graph 3 is not lean: the instance mapping all blank nodes to `eg:s` maps to the only triple `eg:s eg:p eg:s`, which is a proper subset of the graph.

Task 5: a

Cypher Querying

Consider a property graph that uses the `HAS_CHILD` relationship type to model parent–child relationships. Write a Cypher query that finds persons and their great-grandparents.

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Cypher Querying

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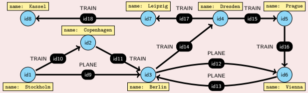
Solution

```
MATCH (person)<-[:HAS_CHILD*3]-(greatGrandparent)
RETURN person, greatGrandparent
```

Task 5: b

Cypher Query Evaluation

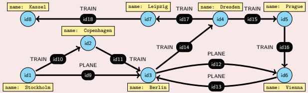


Which answers does the following Cypher query produce on this graph?

```
MATCH p = (s {name: "Stockholm"})-[:TRAIN*]-(a)-[:PLANE*1..]->(b)-[:TRAIN*0..]-(d {name: "Vienna"})
RETURN [ n IN nodes(p) | n.name ]
UNION ALL MATCH p = (s {name: "Stockholm"})-[:TRAIN*]-(d {name: "Vienna"})
RETURN [ n IN nodes(p) | n.name ]
```

Task 5: b

Cypher Query Evaluation



Which answers does the following Cypher query produce on this graph?

```
MATCH p = (s {name: "Stockholm"})—[:TRAIN∗]—(a)—[:PLANE∗1..]—>(b)—[:TRAIN∗0..]—(d {name: "Vienna"})
RETURN [ n IN nodes(p) | n.name ]
UNION ALL MATCH p = (s {name: "Stockholm"})—[:TRAIN∗]—(d {name: "Vienna"})
RETURN [ n IN nodes(p) | n.name ]
```

Solution

- ["Stockholm", "Copenhagen", "Berlin", "Vienna"]
- ["Stockholm", "Copenhagen", "Berlin", "Dresden", "Prague", "Vienna", "Berlin", "Vienna"]
- ["Stockholm", "Copenhagen", "Berlin", "Vienna", "Berlin", "Dresden", "Prague", "Vienna"]
- ["Stockholm", "Copenhagen", "Berlin", "Dresden", "Prague", "Vienna"]

Task 6: a

Datalog Querying

Consider a schema consisting of two unary predicates `first` and `last`, and of a binary predicate `next`. Let D be a database of that schema, encoding a linear order of the form $1 < 2 < 3 < \cdots < n-1 < n$ using facts

$$\texttt{first}(1) \qquad \texttt{next}(1,2) \qquad \texttt{next}(2,3) \qquad \cdots \qquad \texttt{next}(n-1,n) \qquad \texttt{last}(n)$$

Write a Datalog program P such that $\langle P, \texttt{Result}\rangle$ derives `Result` over D iff the linear order encoded by D has even length. If D is not of the form described above, the behaviour of P is unspecified.

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Write a Datalog program P such that $\langle P, \texttt{Result}\rangle$ derives Result over D iff the linear order encoded by D has even length. If D is not of the form described above, the behaviour of P is unspecified.

Solution

```
odd(?X)  :- first (?X) .
odd(?Y)  :- next(?X, ?Y), even(?X) .
even(?Y) :- next(?X, ?Y), odd(?X) .
Result   :- even(?X), last (?X) .
```

Task 6: b

Stratified Datalog

Give a stratification of the following Datalog program P.

```
mother(?x, ?y)         :- triple(?x, wdt:P25, ?y) .
father(?x, ?y)         :- triple(?x, wdt:P22, ?y) .
notSameMother(?x, ?y) :- mother(?x, ?z), ~mother(?y, ?z) .
sameFather(?x, ?y)     :- father(?x, ?z), father(?y, ?z) .
notSameFather(?x, ?y) :- ~sameFather(?x, ?y) .
halfSiblings(?x, ?y)   :- sameMother(?x, ?y), notSameFather(?x, ?y) .
halfSiblings(?x, ?y)   :- sameFather(?x, ?y), notSameMother(?x, ?y) .
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Task 6: b

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halfSiblings(?x, ?y)  :- sameMother(?x, ?y), notSameFather(?x, ?y) .
halfSiblings(?x, ?y)  :- sameFather(?x, ?y), notSameMother(?x, ?y) .
```

Solution

Using three strata, a possible stratification maps predicates as follows:

1. `triple`, `mother`, `father`, `sameFather`
2. `notSameMother`, `notSameFather`
3. `sameMother`, `halfSiblings`

Task 7

Complexity of Problems

1. **given** a SPARQL query q, **decide** whether q has a match on the empty RDF graph
2. **given** a database instance $\mathcal{I}$, **decide** whether a fixed Datalog query $\langle P, \texttt{Result}\rangle$ derives $\texttt{Result}$ on $\mathcal{I}$
3. **given** a simple graph G, **decide** whether G has a 3-colouring
4. **given** a database instance $\mathcal{I}$ and a Datalog query $\langle P, \texttt{Result}\rangle$, **decide** whether $\langle P, \texttt{Result}\rangle$ derives $\texttt{Result}$ on $\mathcal{I}$

Sort the problems by their computational complexity, from the easiest to the hardest. That is, every problem should provably be at most as hard as all the problems following it.

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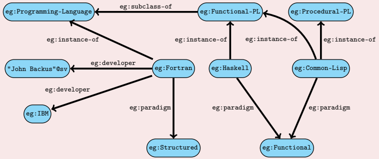
Question 15

ShEx Evaluation




```
eg:programming-language {
  (eg:instance-of @<#programming_language> |
   eg:instance-of @<#subclass_of_programming_language>)+;
  eg:developer IRI*;
  eg:paradigm @<#programming_paradigm>*;
  eg:publication-date LITERAL*;
} <#subclass_of_programming_language> {
  (eg:subclass-of @<#programming_language> ; eg:subclass-of IRI *) |
  (eg:subclass-of @<#subclass_of_programming_language>; eg:subclass-of IRI *)
} <#programming_language> [ eg:Programming-Language ]
<#programming_paradigm> [ eg:Functional eg:Structured ]
```

Validate the RDF graph according to this schema, i.e., apply the `eg:programming-language` shape to the nodes `eg:Fortran`, `eg:Common-Lisp`, and `eg:Haskell`. Which of the nodes is valid and which is invalid for the schema? Explain your answer in each case.

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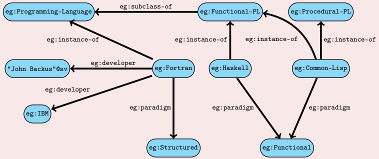


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Solution

- `eg:Fortran` is invalid, `"John Backus"@sv` is not an IRI

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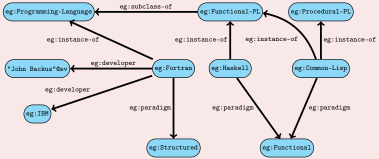
ShEx Evaluation

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Solution

- `eg:Common-Lisp` is invalid, `eg:Procedural-Programming-Language` is not a `eg:subclass-of` of `eg:Programming-Language`

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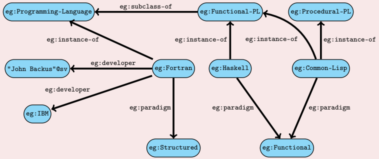
ShEx Evaluation

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Solution

- `eg:Haskell` is valid: both `eg:paradigm` and `eg:instance-of` comply with the schema