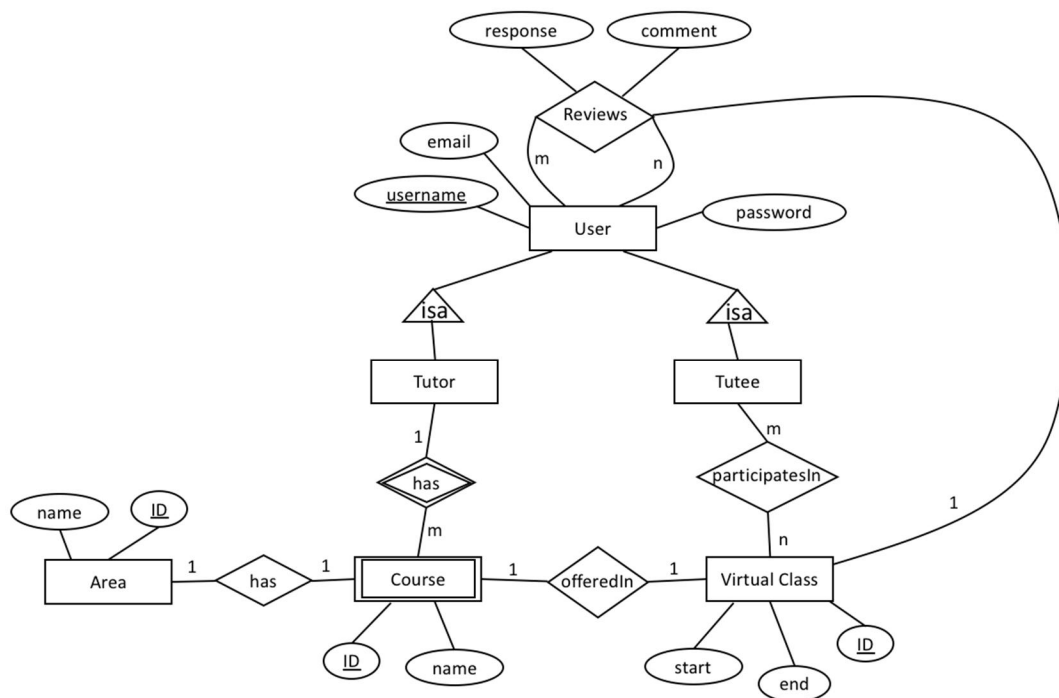


## Question 2 [40 points]

For the following ER design questions, identify the primary key of each entity set (if the primary key is not specified by requirement, use your best knowledge to add a key or use existing attributes). For each relationship, state the cardinalities (1:1, 1:m, m:n) between the entities participating in a relationship.

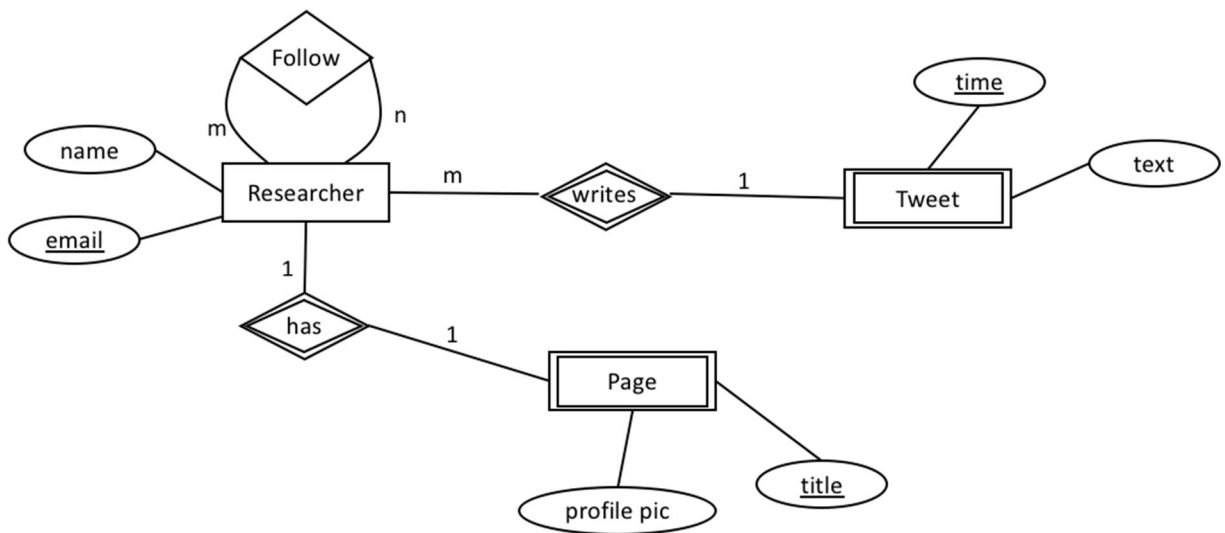
(a) [15 points] Design an ER diagram for the following Online Tutoring System.

- There are two types of users: Tutors and tutees.
- One individual can be both a tutor and a tutee.
- Every user is identified by a user name. A user also has email and a password.
- Each course has an ID and a name. However, the ID alone is not sufficient to distinguish a course from the others, and it must be associated with its tutor.
- Courses are categorized into different areas. Each area has a unique ID and a name.
- Courses are offered in virtual classes.
- Virtual classes have a start date and an end date.
- A tutee might participate in multiple virtual classes.
- Users can write reviews for other individuals only if they have been related through any virtual class.
- A review includes a score, a comment from the reviewer, and a response from the other individual.



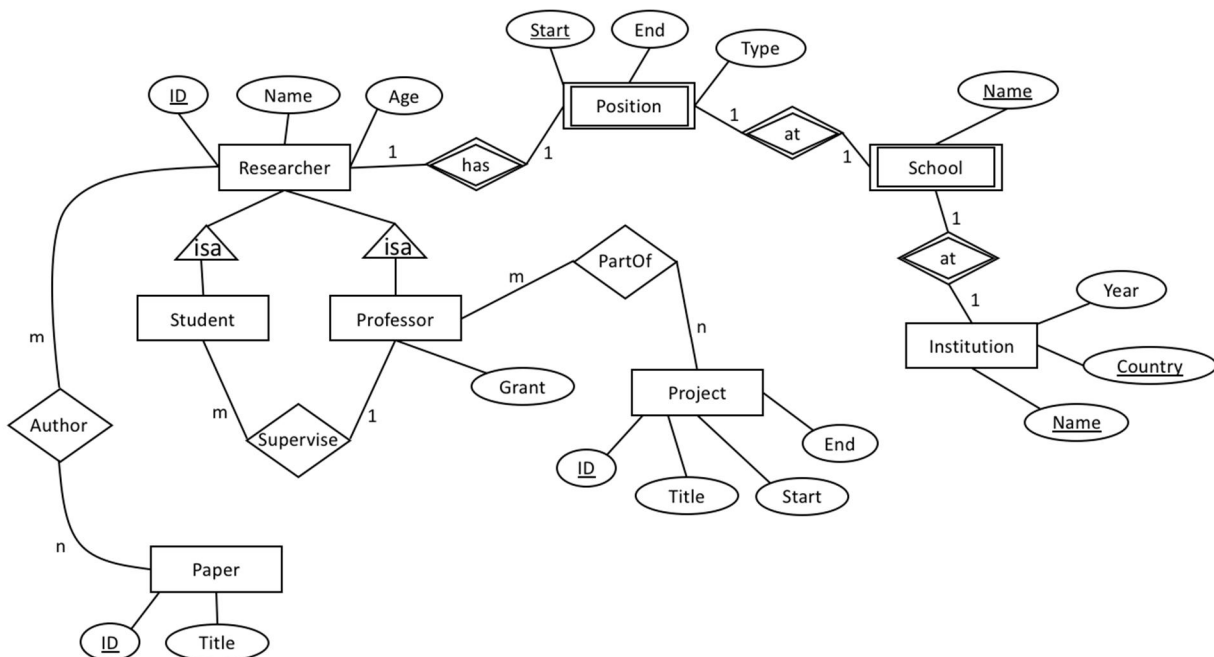
(b) [10 points] You are designing a simplified Twitter social network service, for which you should address the following requirements:

- Users have unique email addresses and you also record their names.
- A user can follow other users.
- Every user has a page, which has a title and (an address to) a profile picture.
- A user writes tweets.
- Each tweet has a text and time.



(c) [15 points] One of the main functionalities of academia is research. Draw an ER diagram which covers information on researchers, institutions, and collaborations among researchers, and includes the following requirements.

- For each researcher, we store his/her name, age, and current position.
- A researcher can either be employed as a professor or a student.
- Every student is supervised by exactly one professor.
- Each institution has a name, country, and start year.
- Each institution has names of its schools. A school belongs to exactly one institution.
- Researchers author papers. The titles of papers should be also stored.
- For each professor, we maintain information on what projects (title, start and end dates) he or she is involved in. We also store the total amount of grant money he or she was the main recipient.



### Question 3 [35 points]

In an online multiplayer game, players register with a username and create characters to fight with others in an island. For this purpose, they choose a hero and a name for their character. Characters can be used in islands as long as they are not eliminated.

Heroes(hero, type, race, numItems, size)

Characters(name, hero, username, created)

Islands(name, date)

Outcomes(character, island, result)

- The relation Heroes stores unique names (hero), the type ('strength', 'agility', and 'intelligence'), the race ('Human', 'Orc', 'NightElf', and 'Undead'), number of items the hero can carry, and size of the hero (ranging from 1 to 10).
- The relation Character records the character's name, a hero, and the time it was created.
- The relation Islands maintains the name and date of an island created for a game.
- The relation Outcomes gives the result ('won', 'survived', and 'eliminated') for each character in each island.

Write Relational Algebra expressions for the following queries.

(a) [5 points] Find the name and lifetimes of characters that were eliminated in islands.

-  $R1 \leftarrow \sigma_{result='eliminated'}(Outcomes) \bowtie_{Outcomes.island=Islands.name} Islands$   
 $\pi_{Characters.name, date-created}(Characters \bowtie_{Character.name=Outcomes.character} R1)$

(b) [5 points] Find players' usernames who chose heroes from all types.

-  $\sigma_{username}((Characters \bowtie Heroes) \div \pi_{type}(Heroes))$

(c) [6 points] Find the year in which the last 'Undead' hero was chosen for a character.

-  $R1 \leftarrow Character \bowtie \sigma_{race='Undead'}(Heroes)$   
 $R2 \leftarrow \rho_{R2}(R1)$   
 $\pi_{created}(Characters) - \pi_{R1.created}(R1 \bowtie_{R1.created < R2.created} R2)$

(d) [6 points] Find players' usernames who have not lost any character.

-  $R1 \leftarrow$   
 $\pi_{username}(\sigma_{result='eliminated'}(Outcomes \bowtie_{Outcomes.character=Character.name} Characters))$   
 $\pi_{username}(Characters) - R1$

(e) [6 points] Find the largest size of heroes for each race.

-  $R1 \leftarrow \pi_{race,size}(Heroes)$   
 $R2 \leftarrow \rho R2(R1)$   
 $\pi_{race,size}(Heroes) - (R1 \bowtie_{R1.race=R2.race \wedge R1.size < R2.size} R2)$

(f) [7 points] Find distinct pair of usernames who have at least one hero in common.

-  $R1 \leftarrow \rho R1(Characters)$   
 $R2 \leftarrow \rho R2(Characters)$   
 $R3 \leftarrow \rho R3_{u1,u2}(\pi_{R1.username,R2.username}(R1 \bowtie_{R1.hero=R2.hero \wedge R1.username \neq R2.username} R2))$   
 $R4 \leftarrow \rho R4(R3)$   
 $R5 \leftarrow \rho R5_{u1,u2}(\pi_{R3.u1,R3.u2}(R3 \bowtie_{R3.u1=R4.u2 \wedge R3.u2=R4.u1} R4))$   
 $R3 - R5$