**1. Formulating queries in Relational Algebra, RA SQL and TRC**

**1. Find each triple (c, p, s) where c is the cname of a company, p is the pid of a person who earns the lowest salary at that company and knows at least someone who has Operating Systems skill, and s is the salary of p.  
(a) Formulate this query in Relational Algebra in standard notation. (4.5 points)  
ANSWER:**   
πcname, pid, salary((Company ▷◁ worksFor) ⨝ worksFor) ⨝ Knows ⨝ (πpid, skill(personSkill) ⨝ σskill=Operating Systems(personSkill)))

**(c) Formulate this query in Tuple Relational Calculus. (4.5 points)  
ANSWER:**   
{(c, p, s) | Company(c) ∧ worksFor(w) ∧ w.cname = c.cname ∧ pid = w.pid ∧ s = w.salary ∧Knows(k) ∧ k.pid1 = w.pid ∧ ∃(p2)(personSkill(ps) ∧ ps.pid = k.pid2 ∧ ps.skill = 'Operating Systems')}  
  
**2. Find the name, salary and city of each person who (a) lives in a city where no one has the Networks skill and (b) earns the highest salary in his/her company.**

**(a) • Formulate this query in Relational Algebra in standard notation. (4.5 points)  
ANSWER:**   
πpname, salary, city(Person ▷◁ worksFor ⨝ worksFor) - πpname, salary, city(πcity(personLocation ⨝ πpid, skill(personSkill) ⨝ σskill=Networks(personSkill)))

**(c) • Formulate this query in Tuple Relational Calculus. (4.5 points)ANSWER:**   
{(pname, salary, city) | Person(p) ∧ worksFor(w) ∧ p.pid = w.pid ∧ w.salary = (πmaxSalary(σw.cname = w.cname(MaxSalaries))) ∧ ∃(c)(companyLocation(cl) ∧ cl.cname = w.cname ∧ cl.city = city) ∧ city ∉ (πcity(σps.skill = 'Networks'(personSkill)) ∩ πcity(personLocation))}  
  
**3. Find each pair (c1, c2) of cnames of different companies such that no employee of c1 and no employee of c2 live in Chicago.**

**(a) • Formulate this query in Relational Algebra in standard notation. (4.5 points)  
ANSWER:**   
πc1.cname, c2.cname(πw1.cname(σcity≠'Chicago'(worksFor ⨝ πpid, city(personLocation)))) ⨝ πw2.cname(σcity≠'Chicago'(worksFor ⨝ πpid, city(personLocation))))

**(c) • Formulate this query in Tuple Relational Calculus. (4.5 points)ANSWER:**  
{(c1, c2) | worksFor(w1) ∧ worksFor(w2) ∧ w1.cname < w2.cname ∧ ∀(p1)(personLocation(pl1) ∧ pl1.pid = w1.pid → pl1.city ≠ 'Chicago') ∧ ∀(p2)(personLocation(pl2) ∧

pl2.pid = w2.pid → pl2.city ≠ 'Chicago')}

**4. Formulate these query in Relational Algebra in standard notation:**

**(a) • Find the pid, pname of each person who lives in MountainView, works for a company which is headquartered in MountainView , and has a salary less than or equal to 60000 (4 points)**

**ANSWER:**4a) πpid, pname(σcity=MountainView(Person) ⨝ worksFor ⨝ companyLocation ⨝ σheadquarter=MountainView(Company) ⨝ σsalary≤60000(worksFor)))

**(b) • Find the pid, pname, and city of a person who knows at least one person who knows another person who earns more than 65000. Let us consider 3 people p1,p2, and p3. p1 knows p2 and p2 knows p3. p3 earns more than 65000. The query returns the pid, pname, and city of p1. (4 points)**  
**ANSWER:**πpid, pname, city(πpid, pname, city(Person) ⨝ Knows ⨝ πpid2, pname2, city2(Knows ⨝ πpid3, salary(worksFor ⨝ σsalary>65000(worksFor)))))  
  
**5. Formulate these query in Tuple Relational Calculus:**

**(a) • Find the pid, pname, cname, and salary of a person who lives in Bloomington, earns at least 40000, and works for a company headquartered in Seattle. (4 points)  
ANSWER:**{p.pid, p.pname, w.cname, w.salary | Person(p) ∧ worksFor(w) ∧ companyLocation(cL) ∧ p.pid = w.pid ∧ w.cname = cL.cname ∧p.city = 'Bloomington' ∧ w.salary ≥ 40000 ∧ cL.headquarter = 'Seattle'}

**(b) • Find the name of all skills of persons who don’t live in Bloomington but their managers live in Bloomington. (4 points)  
ANSWER:**   
{sk.skill | Person(p1) ∧ Person(p2) ∧ hasManager(hm) ∧ personSkill(ps) ∧ ps.pid = p1.pid ∧ ps.skill = sk.skill ∧ p1.city ≠ 'Bloomington' ∧ p2.pid = hm.mid ∧ p2.city = 'Bloomington'}  
  
  
**2. Formulating constraints using Relational Algebra**

**6. Each manager knows all of his/her employees. (3 points)ANSWER:**πeid(M) ⊆ πmid1(K1) ⨝ πmid2(K2) ⨝ ... ⨝ πmidn(Kn)  
  
**7. No person who works at Amazon knows at-most 2 people. (3 points)  
ANSWER:**πpid(P) ⊆ πpid1(K1) ⨝ πpid2(K2)  
  
**8. • Some person who works for a company headquartered at Cupertino has a salary less than person with no skills. (3 points) (Assumption: Only 1 person with no skills)**  
**ANSWER:**πpid1(W1) ⊆ πpid2(W2) ⨝ πpid3(σskill=∅(P3))

**3. Formulating constraints in the Tuple Relational Calculus**

**9. Each Manager manages at least two people. (3 Points)**  
**ANSWER:**∀m (Manager(m) → ∃e1 ∃e2 (hasManager(hm1) ∧ hm1.mid = m.mid ∧ hm1.eid = e1.eid ∧ ∃hm2 (hasManager(hm2) ∧ hm2.mid = m.mid ∧ hm2.eid = e2.eid ∧ e1.eid ≠ e2.eid)))  
  
**10. Some person has a salary that is strictly lower than the salary of each of his or her managers. (3 Points)ANSWER:**  
∃p ∃m1 ∃m2 (Person(p) ∧ hasManager(hm1) ∧ hm1.eid = p.pid ∧ worksFor(w1) ∧ w1.pid = p.pid ∧ hasManager(hm2) ∧ hm2.mid = hm1.mid ∧ worksFor(w2) ∧ w2.pid = hm2.eid ∧ w1.salary < w2.salary)  
  
**11. Each employee and his or her managers work for the same company. (3 Points)ANSWER:**  
∀e ∃m (Employee(e) ∧ hasManager(hm) ∧ hm.eid = e.eid ∧ worksFor(w1) ∧ w1.pid = e.eid ∧ worksFor(w2) ∧ w2.pid = hm.mid ∧ w1.cname = w2.cname)