3. (22 marks) Consider the following relations which will hold information similar to that in the previous (XML) question:

```
Recipients(FromUser, FromDomain, ToUser, ToDomain, MsgID)  primary key is all
                                                           attributes
Messages(MsgID, Subj, Message, DateTime)  primary key: {MsgID}
```

Suppose the following fragments have been created (we will store the first and third fragments on a machine called gaul, and the second and fourth on another machine in a distributed database):

RatGaul = $\sigma_{ToDomain = "gaul"}$ (Recipients)

RnotGaul = $\sigma_{ToDomain \neq "gaul"}$ (Recipients)

MessagesAtGaul = Messages $\ltimes$ RatGaul

MessagesNotGaul = Messages $\ltimes$ RnotGaul

(a) (2 marks) What kind of fragmentation is represented by the two relations RatGaul and RnotGaul?

(b) (2 marks) Suppose I have the SQL query:

```
Select FromUser, FromDomain
From Recipients
Where ToUser = "Ann" and ToDomain = "gaul"
```

Translate this query to relational algebra.

(c) (3 marks) Show the query tree corresponding to your algebra query just above.

(d) (5 marks) Replace any relations in your tree with the fragments defined above, expressed as qualified relations of the form

`[F:R]`

where F contains any predicates you know to be true about the fragment. After doing this, perform any further optimizations possible on your algebra tree.

(e) (10 marks) Now consider the following query:

```
Select FromUser, FromDomain, Subj
From Recipients R, Messages M
Where ToUser = "Ann" and ToDomain = "gaul" and R.MsgID = M.MsgID
```

Follow the same steps as above: (i) translate the query to relational algebra, (ii) draw the algebra tree and optimize the centralized query, (iii) substitute the qualified fragments for the relations and optimize that some more. Put your answer on the next page.