Answer Question 1 and two further questions

1. Answer the following five parts

   a. Describe the concept of transactions by discussing what atomicity, consistency, isolation and durability mean.

   [8 marks]

   b. What is two-phase locking and how does it achieve which of the above transaction properties?

   [5 marks]

   c. Explain the circumstances in which you would use hierarchical locking and the lock modes that are required for this concurrency control scheme. For which situations are each of these lock modes intended?

   [6 marks]

   d. Assume you have to build the concurrency control manager of a database management system. The database consists of many database tables, each of which is composed of a set of records. Each record of the table has several attributes. You choose to use hierarchical locking. Explain what the manager needs to do for:

      i. changing an attribute value;

      [1 marks]

      ii. reading an attribute value;

      [1 marks]

      iii. modifying a record;

      [1 marks]

      iv. reading all attributes of a record;

      [1 marks]

      v. updating a complete column;

      [1 marks]

vi. reading a complete column;

[1 marks]

vii. inserting a table;

[1 marks]

viii. reading the complete database;

[1 marks]

[Subtotal 8 marks]

e. Two-phase locking may lead to deadlocks. This causes many complications in the design of database management systems. Absence of deadlocks can be established using reachability analysis on LTSs. Why can this method not be used to implement deadlock-free database concurrency control?

[7 marks]

[Total 34 marks]

2. Answer the following three parts.

   a. Draw an equivalent LTS for the following FSP process definitions:

      i. `A=(a -> b -> (c -> A | d -> A)).`

      [2 marks]

      ii. `A=(a -> B), B=(b->B | a->A).`

      [3 marks]

      iii. `A=(a->b->A). C=(c->b->C). ||AC=(A||C).`

      [3 marks]

      iv. `A=(a->b->A). C=(c->d->C). ||AC=(A||C)/{b/c}.`

      [3 marks]

      [Subtotal 11 marks]

   b. You have been asked to assist in the re-engineering of the control software for the Northern Line of London Underground. There is a particular difficulty because of the intersection of the Bank/Charing Cross and the Edgware/High Barnet branches between Camden and Euston. In particular, there are trains coming from both Edgware and High Barnet that need to be dispatched onto the Bank and Charing Cross branches. For southbound trains, there is thus a piece of track that needs to be protected by signalling equipment in such a way that trains can be dispatched without crashing into each other.

      Complete the following FSP model to describe the signalling equipment, taking into account that trains can concurrently arrive from the Edgware and from the High Barnet branches and must not crash into each other.

```
Signal = (green -> red -> Signal).
Train = (request -> ... -> Train).
||Branch = ...
Controller = ...
||Camden = (edgware:Branch || highbarnet:Branch || Controller).
```

      [13 marks]

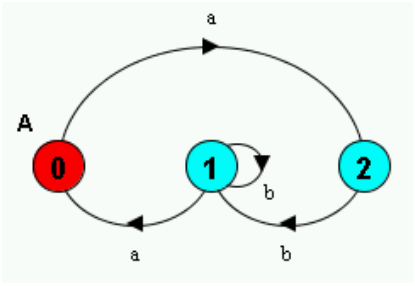
c. For the model of Question 2.b specify a safety property so that you can use a model checker to prove that there is never more than one train crossing the southbound track intersection between Camden and Euston.

[9 marks]

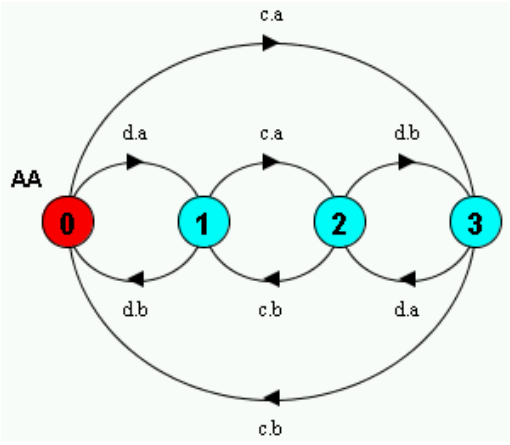
[Total 33 marks]

3. Answer the following three parts

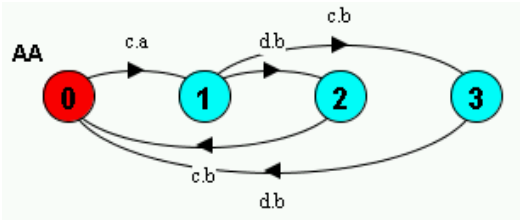
   a. Consider the following Labelled Transition Systems and give equivalent FSP process algebras

i. 

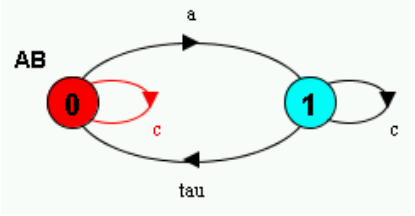
[2 marks]

ii. 

[3 marks]

iii. 

[3 marks]

iv. 

[3 marks]

[Subtotal 11 marks]

b. Consider the McDonald's Restaurant on the corner of Warren St and Tottenham Court Rd. At lunchtime, the restaurant has four waiters (lucy, bob, alice and jill), who take orders (mostly from UCL students). As we are in England, a student who arrives at McDonald's enters an arrival queue. She waits until one of the waiters becomes available. The waiter then takes her order, serves her and finally the student pays her bill. Model how students queue and how their orders are processed concurrently in FSP.

[13 marks]

c. Specify the liveness property that "hungry students eventually get their lunch".

[9 marks]

[Total 33 marks]

4. Answer the following three parts.

   a. For each of the following FSP processes, define the alphabet of:

      i. `Server = (receive -> process -> send-> Server ).`
      [2 marks]

      ii. `Client = (send -> wait -> receive -> Client)\{wait}.`
      [2 marks]

      iii. `{a,b}::Server`
      [3 marks]

      iv. `||CS=(a:Client||b:Client||{a,b}::Server}/{a.send/a.invoke,`
      `b.send/b.invoke,`
      `a.receive/a.return,`
      `b.receive/b.return}.`
      [4 marks]

      [Subtotal 11 marks]

b. Consider the following FSP Process of a cross country railroad that has only a single track, which connects villages N and S via M.

```
const MaxTrains=4
range Trains=0..MaxTrains
NM=NM[0][0],
NM[nb:Trains][mb:Trains]=
  (when (nb==0 && mb<MaxTrains) go_nm->NM[nb][mb+1]
  |when (mb==0 && nb<MaxTrains) go_n->NM[nb+1][mb]
  |when (mb>0) arr_at_m_from_n->NM[nb][mb-1]
  |when (nb>0) arr_at_n->NM[nb-1][mb]
  |when (nb>0&&mb>0) unsafe->ERROR).
SM=SM[0][0],
SM[mb:Trains][sb:Trains]=
  (when (mb==0 && sb<MaxTrains) go_s->SM[mb][sb+1]
  |when (sb==0 && mb<MaxTrains) go_sm->SM[mb+1][sb]
  |when (sb>0) arr_at_s->SM[mb][sb-1]
  |when (mb>0) arr_at_m_from_s->SM[mb-1][sb]
  |when (mb>0&&sb>0) unsafe->ERROR).
N=(go_nm->N |arr_at_n->N).
S=(go_sm->S |arr_at_s->S).
M=M[0][0],
M[nb:Trains][sb:Trains]=
  (when (sb<MaxTrains) arr_at_m_from_n -> M[nb][sb+1]
  |when (nb<MaxTrains) arr_at_m_from_s -> M[nb+1][sb]
  |when (sb>0) go_s -> M[nb][sb-1]
  |when (nb>0) go_n -> M[nb-1][sb]).

||COUNTRYRR=(NM||SM||N||S||M).
```

Design the signalling control software in a UML class diagram, detailing associations, operations and attributes. Use stereotype `<<Monitor>>` to identify those classes in your design that are monitors.

[13 marks]

c. Show the implementation of the operations of the class that controls access to station M.

[9 marks]

[Total 33 marks]

5. Answer the following three parts.

   a. In no more than 50 words each define the following concepts:

      i. Semaphore

      [2 marks]

      ii. Monitor

      [2 marks]

      iii. Deadlock

      [2 marks]

      iv. Livelock

      [2 marks]

      v. Condition Synchronization

      [2 marks]

      vi. Safety Property

      [2 marks]

      vii. Liveness Property

      [2 marks]

      [Subtotal 14 marks]

   b. An ftp server provides two principal operations, `put` and `get`. In order to use these operations, clients have to `open` a connection first and they `close` the connection when they no longer want to use the server. The ftp server can have several concurrent sessions with different clients. To protect ftp servers from becoming too overloaded, the number of concurrent sessions in practice has an upper boundary, which we can assume to be 4 for this exercise. Use FSP to model the behaviour of the ftp server to show how it serves a number of concurrent clients.

      [11 marks]

   c. When trying to access popular ftp servers you might have experienced that it is not possible to get through. Specify the liveness property that every client will eventually be able to connect to the ftp server of Question 5.b in FSP.

      [8 marks]

      [Total 33 marks]

END OF PAPER