Assignment 1

Contents

Question A

```
// TrainA
process TrainA (string name) {
     // limit trains on track to max 8
    <await  (trainsOnTrack < 8)  trainsOnTrack++;>
    // wait for slots 4 and 5 to be free and then move into slot[5]
    <await  ( (slots[4]==”[...]”) && (slot[5]==”[...]”) slots[5] = "[" + trainName + "]";
   // train moves around from section 5 to section 8
    int currentPosition = 5;
    do   {
           // wait until the position ahead is empty and then move into it
           <await (slots[currentPosition+1]==”[...]”)  slots[currentPosition+1]=slots[currentPosition];
                      slots[currentPosition]=”[...]”; >
           currentPosition++;
    } while (currentPosition < 8)

     // wait for the junction to be clear and then grab access to it
    <await (!junctionOccupied)  junctionOccupied = true;>
        // progress through the junction (first time)
        slots[9] = slots[8]; slots[8] = “[…]”;
        slots[0] = slots[9]; slots[9] = “[…]”;
        slots[10] = slots[0]; slots[0] = “[…]”;
        slots[11] = slots[10]; slots[10] = “[…]”;
     // release access to the junction
    <  junctionOccupied = false;>

    // move around B loop from junction to junction
    int currentPosition = 11;
    do   {
           // wait until the position ahead is empty and then move into it
           <await (slots[currentPosition+1]==”[...]”)  slots[currentPosition+1]=slots[currentPosition];
                      slots[currentPosition]=”[...]”; >
           currentPosition++;
    } while (currentPosition < 17)

     // wait for the junction to be clear and then grab access to it
    <await (!junctionOccupied)  junctionOccupied = true;>
        // progress through the junction (second time)
        slots[18] = slots[17]; slots[17] = “[…]”;
        slots[0] = slots[18]; slots[18] = “[…]”;
        slots[1] = slots[0]; slots[0] = “[…]”;
        slots[2] = slots[1]; slots[1] = “[…]”;
     // release access to the junction
    <  junctionOccupied = false;>

    // move around A loop from junction and exit
    int currentPosition = 2;
    do   {
           // wait until the position ahead is empty and then move into it
           <await (slots[currentPosition+1]==”[...]”)  slots[currentPosition+1]=slots[currentPosition];
                      slots[currentPosition]=”[...]”; >
           currentPosition++;
    } while (currentPosition < 5)
   // exit the track
   slots[5] = “[…]”;
   <trainsOnTrack--;> // leaving the track and make space for another train

} // end TrainA
```

```
// TrainB
process TrainB (string name) {
      // limit trains on track to max 8
     <await  (trainsOnTrack < 8)  trainsOnTrack++;>
     // wait for slots 13 and 14 to be free and then move into slot[14]
     <await  ( (slots[13]==”[...]”) && (slot[14]==”[...]”) slots[5] = "[" + trainName + "]";
    // train moves around from section 14 to section 17
     int currentPosition = 14;
     do   {
             // wait until the position ahead is empty and then move into it
             <await (slots[currentPosition+1]==”[...]”)  slots[currentPosition+1]=slots[currentPosition];
                          slots[currentPosition]=”[...]”; >
             currentPosition++;
     } while (currentPosition < 17)

      // wait for the junction to be clear and then grab access to it
     <await (!junctionOccupied)  junctionOccupied = true;>
          // progress through the junction (first time)
          slots[18] = slots[17]; slots[17] = “[…]”;
          slots[0] = slots[18]; slots[18] = “[…]”;
          slots[1] = slots[0]; slots[0] = “[…]”;
          slots[2] = slots[1]; slots[1] = “[…]”;
      // release access to the junction
     <  junctionOccupied = false;>

     // move around A loop from junction to junction
     int currentPosition = 2;
     do   {
             // wait until the position ahead is empty and then move into it
             <await (slots[currentPosition+1]==”[...]”)  slots[currentPosition+1]=slots[currentPosition];
                          slots[currentPosition]=”[...]”; >
             currentPosition++;
     } while (currentPosition < 8)

      // wait for the junction to be clear and then grab access to it
     <await (!junctionOccupied)  junctionOccupied = true;>
          // progress through the junction (second time)
          slots[9] = slots[8]; slots[8] = “[…]”;
          slots[0] = slots[9]; slots[9] = “[…]”;
          slots[10] = slots[0]; slots[0] = “[…]”;
          slots[11] = slots[10]; slots[10] = “[…]”;
      // release access to the junction
     <  junctionOccupied = false;>

     // move around B loop from junction and exit
     int currentPosition = 11;
     do   {
             // wait until the position ahead is empty and then move into it
             <await (slots[currentPosition+1]==”[...]”)  slots[currentPosition+1]=slots[currentPosition];
                          slots[currentPosition]=”[...]”; >
             currentPosition++;
     } while (currentPosition < 14)
    // exit the track
    slots[14] = “[…]”;
    <trainsOnTrack--;> // leaving the track and make space for another train

} // end TrainB
```

Question B

```
sharedTrackLock = new Semaphore(1); //initialize shared track as open
slotsSem[] = new Semaphore(19); //initialize slots semaphores
slots[] = {"[..]", "[..]", "[..]", "[..]", "[..]", "[..]", "[..]", "[..]", "[..]",
       "[..]", "[..]", "[..]", "[..]", "[..]", "[..]", "[..]", "[..]", "[..]", "[..]"}; // Array of slots

// TrainA
process TrainA (string name) {
     // limit trains on track to max 4 A trains
    trainASem = new Semaphore(4);
    aMutexSem = new Semaphore(1); //initialize mutually exclusive semaphore
    aUsingSharedTrack = new AtomicInteger(0);  //set using shared track to false;
    trainASem.P();
    // wait for slots 4 and 5 to be free and then move into slot[5]
    slotSem[4].P();
    slotSem[4].V();
    slotSem[5].P();

   // train moves around from section 5 to section 8
    int currentPosition = 5;
    do   {
           // wait until the position ahead is empty and then move into it
           slotSem[currentPosition + 1].P(); // wait for the slot ahead to be free
          slots[currentPosition + 1] = slots[currentPosition]; // move train forward
          slots[currentPosition] = "[..]"; //clear the slot the train vacated
          theTrainActivity.addMovedTo(currentPosition + 1); //record the train activity
          slotSem[currentPosition].V(); //signal slot you are leaving
          currentPosition++;
    } while (currentPosition < 8)

       aMutexSem.P(); // obtain mutually exclusive access to global variable aUsingSharedTrack
       if (aUsingSharedTrack.incrementAndGet() == 1)// if first A train joining shared track
       {
          sharedTrackLock.P();  // grab lock to shared track
       }
       aMutexSem.V(); // release mutually exclusive access to global variable aUsingSharedTrack

       // move on to shared track
       slotSem[9].P(); //Check 9 free
       slotSem[18].P(); //Check 18 free
       slotSem[18].V(); //Release 18
       slots[9] = slots[8];
       slots[8] = "[..]";
       slotSem[8].V(); //move from slot[8] to slot[9]

       // move along shared track
       slotSem[0].P();
       slots[0] = slots[9];
       slots[9] = "[..]";
       slotSem[9].V(); //move from slot[9] to slot[0]

       // move along shared track
       slotSem[10].P();
       slots[10] = slots[0];
       slots[0] = "[..]";
       slotSem[0].V(); //move from slot[0] to slot[10]

       // Move off shared track
       slotSem[11].P();
       slots[11] = slots[10];
       slots[10] = "[..]";
       slotSem[10].V(); //move from slot[10] to slot[11]

       aMutexSem.P(); // obtain mutually exclusive access to global variable aUsingSharedTracK
       if (aUsingSharedTrack.decrementAndGet() == 0) // if last A train leaving shared track
       {
          sharedTrackLock.V(); // release lock to shared track
       }
       aMutexSem.V(); // release mutually exclusive access to global variable aUsingSharedTrack
    // move around B loop from junction to junction
    int currentPosition = 11;
    do   {
         /* wait until the position ahead is empty and then move into it*/
        slotSem[currentPosition + 1].P(); // wait for the slot ahead to be free
        slots[currentPosition + 1] = slots[currentPosition]; // move train forward
        slots[currentPosition] = "[..]"; //clear the slot the train vacated
        theTrainActivity.addMovedTo(currentPosition + 1); //record the train activity
        slotSem[currentPosition].V(); //signal slot you are leaving
        currentPosition++;
    } while (currentPosition < 17)

     // wait for the junction to be clear and then grab access to it
    aMutexSem.P(); // obtain mutually exclusive access to global variable aUsingSharedTrack
      if (aUsingSharedTrack.incrementAndGet() == 1)// if first A train joining shared track
      {
        sharedTrackLock.P();  // grab lock to shared track
      }
      aMutexSem.V(); // release mutually exclusive access to global variable aUsingSharedTrack

      // move on to shared track
      slotSem[18].P();
      slotSem[9].P();
      slotSem[9].V();
      slots[18] = slots[17];
      slots[17] = "[..]";
      slotSem[17].V(); //move from slot[17] to slot[18]

      // move along shared track
      slotSem[0].P();
      slots[0] = slots[18];
      slots[18] = "[..]";
      slotSem[18].V(); //move from slot[18] to slot[0]

      // move along shared track
      slotSem[1].P();
      slots[1] = slots[0];
      slots[0] = "[..]";
      slotSem[0].V(); //move from slot[0] to slot[1]

      // Move off shared track
      slotSem[2].P();
      slots[2] = slots[1];
      slots[1] = "[..]";
      slotSem[1].V(); //move from slot[1] to slot[2]

      aMutexSem.P(); // obtain mutually exclusive access to global variable aUsingSharedTracK
      if (aUsingSharedTrack.decrementAndGet() == 0) // if last A train leaving shared track
      {
        sharedTrackLock.V(); // release lock to shared track
      }
      aMutexSem.V(); // release mutually exclusive access to global variable aUsingSharedTrack

    // move around A loop from junction and exit
    int currentPosition = 2;
    do   {
         // wait until the position ahead is empty and then move into it
         slotSem[currentPosition + 1].P(); // wait for the slot ahead to be free
        slots[currentPosition + 1] = slots[currentPosition]; // move train forward
        slots[currentPosition] = "[..]"; //clear the slot the train vacated
        theTrainActivity.addMovedTo(currentPosition + 1); //record the train activity
        slotSem[currentPosition].V(); //signal slot you are leaving
        currentPosition++;
    } while (currentPosition < 5)
   // exit the track
   slots[5] = “[…]”;
   slotSem[5].V();// signal slot 5 to be free
   trainASem.V(); // signal space for another A train
} // end TrainA
```

```
// TrainB
process TrainB (string name) {
     // limit trains on track to max 4 B trains
    trainBSem = new Semaphore(4);
    bMutexSem = new Semaphore(1); //initialize mutually exclusive semaphore
    bUsingSharedTrack = new AtomicInteger(0);  //set using shared track to false;
    trainBSem.P();
    // wait for slots 13 and 14 to be free and then move into slot[5]
    slotSem[13].P();
    slotSem[13].V();
    slotSem[14].P();

   // train moves around from section 14 to section 17
    int currentPosition = 14;
    do   {
           // wait until the position ahead is empty and then move into it
           slotSem[currentPosition + 1].P(); // wait for the slot ahead to be free
          slots[currentPosition + 1] = slots[currentPosition]; // move train forward
          slots[currentPosition] = "[..]"; //clear the slot the train vacated
          theTrainBctivity.addMovedTo(currentPosition + 1); //record the train activity
          slotSem[currentPosition].V(); //signal slot you are leaving
          currentPosition++;
    } while (currentPosition < 17)

      bMutexSem.P(); // obtain mutually exclusive access to global variable bUsingSharedTrack
      if (bUsingSharedTrack.incrementAndGet() == 1)// if first A train joining shared track
      {
          sharedTrackLock.P();  // grab lock to shared track
      }
      bMutexSem.V(); // release mutually exclusive access to global variable bUsingSharedTrack


      bMutexSem.P(); // obtain mutually exclusive access to global variable bUsingSharedTracK
      if (bUsingSharedTrack.decrementAndGet() == 0) // if last A train leaving shared track
      {
          sharedTrackLock.V(); // release lock to shared track
      }
      bMutexSem.V(); // release mutually exclusive access to global variable bUsingSharedTrack

      // move on to shared track
      slotSem[18].P();
      slotSem[9].P();
      slotSem[9].V();
      slots[18] = slots[17];
      slots[17] = "[..]";
      slotSem[17].V(); //move from slot[17] to slot[18]

      // move along shared track
      slotSem[0].P();
      slots[0] = slots[18];
      slots[18] = "[..]";
      slotSem[18].V(); //move from slot[18] to slot[0]

      // move along shared track
      slotSem[1].P();
      slots[1] = slots[0];
      slots[0] = "[..]";
      slotSem[0].V(); //move from slot[0] to slot[1]

      // Move off shared track
      slotSem[2].P();
      slots[2] = slots[1];
      slots[1] = "[..]";
      slotSem[1].V(); //move from slot[1] to slot[2]
    // move around A loop from junction to junction
    int currentPosition = 2;
    do  {
         /* wait until the position ahead is empty and then move into it*/
        slotSem[currentPosition + 1].P(); // wait for the slot ahead to be free
        slots[currentPosition + 1] = slots[currentPosition]; // move train forward
        slots[currentPosition] = "[..]"; //clear the slot the train vacated
        theTrainBctivity.addMovedTo(currentPosition + 1); //record the train activity
        slotSem[currentPosition].V(); //signal slot you are leaving
        currentPosition++;
    } while (currentPosition < 8)

     // wait for the junction to be clear and then grab access to it
    bMutexSem.P(); // obtain mutually exclusive access to global variable bUsingSharedTrack
      if (bUsingSharedTrack.incrementAndGet() == 1)// if first A train joining shared track
      {
        sharedTrackLock.P();  // grab lock to shared track
      }
      bMutexSem.V(); // release mutually exclusive access to global variable bUsingSharedTrack

      // move on to shared track
      slotSem[9].P(); //Check 9 free
      slotSem[18].P(); //Check 18 free
      slotSem[18].V(); //Release 18
      slots[9] = slots[8];
      slots[8] = "[..]";
      slotSem[8].V(); //move from slot[8] to slot[9]

      // move along shared track
      slotSem[0].P();
      slots[0] = slots[9];
      slots[9] = "[..]";
      slotSem[9].V(); //move from slot[9] to slot[0]

      // move along shared track
      slotSem[10].P();
      slots[10] = slots[0];
      slots[0] = "[..]";
      slotSem[0].V(); //move from slot[0] to slot[10]

      // Move off shared track
      slotSem[11].P();
      slots[11] = slots[10];
      slots[10] = "[..]";
      slotSem[10].V(); //move from slot[10] to slot[11]

      bMutexSem.P(); // obtain mutually exclusive access to global variable bUsingSharedTracK
      if (bUsingSharedTrack.decrementAndGet() == 0) // if last A train leaving shared track
      {
        sharedTrackLock.V(); // release lock to shared track
      }
      bMutexSem.V(); // release mutually exclusive access to global variable bUsingSharedTrack

    // move around B loop from junction and exit
    int currentPosition = 11;
    do  {
         // wait until the position ahead is empty and then move into it
         slotSem[currentPosition + 1].P(); // wait for the slot ahead to be free
        slots[currentPosition + 1] = slots[currentPosition]; // move train forward
        slots[currentPosition] = "[..]"; //clear the slot the train vacated
        theTrainBctivity.addMovedTo(currentPosition + 1); //record the train activity
        slotSem[currentPosition].V(); //signal slot you are leaving
        currentPosition++;
    } while (currentPosition < 14)
   // exit the track
   slots[14] = “[…]”;
   slotSem[14].V();// signal slot 14 to be free
   bCountSem.V(); // signal space for another A train
} // end TrainB
```

Question C

Trains.java class

```
public class Trains {
// Note. You can assuming that trains approaching the track will
// adhere to normal protocol.

    static final int NUM_OF_A_TRAINS = 10;
    static final int NUM_OF_B_TRAINS = 10;
    static TrainTrack theTrainTrack;

    public static void main(String[] args) {

        // create a train track
        theTrainTrack = new TrainTrack();

        System.out.println("STARTED");

        // create arrays to hold the trains
        TrainA[] trainA = new TrainA[NUM_OF_A_TRAINS];
        TrainB[] trainB = new TrainB[NUM_OF_B_TRAINS];
```

```
// create trains to enter the track
for (int i = 0; i < NUM_OF_A_TRAINS; i++) {
    CDS.idleQuietly((int) (Math.random() * 500));
    trainA[i] = new TrainA("A" + i, theTrainTrack);
}
for (int i = 0; i < NUM_OF_B_TRAINS; i++) {
    CDS.idleQuietly((int) (Math.random() * 500));
    trainB[i] = new TrainB("B" + i, theTrainTrack);
}

// set the train processes running
for (int i = 0; i < NUM_OF_A_TRAINS; i++) {
    trainA[i].start();
} // end for
for (int i = 0; i < NUM_OF_B_TRAINS; i++) {
    trainB[i].start();
} // end for
// trains now travelling
//  wait for all the train threads to finish before printing out final message.
```

```
        for (int i = 0; i < NUM_OF_A_TRAINS; i++) {
            try {
                trainA[i].join();
            } catch (InterruptedException ex) {
            }
        } // end for
        for (int i = 0; i < NUM_OF_B_TRAINS; i++) {
            try {
                trainB[i].join();
            } catch (InterruptedException ex) {
            }
        } // end for

        // Display all the train activity that took place
        theTrainTrack.theTrainActivity.printActivities();

        // Final message
        System.out.println("All trains have successfully travelled 1 circuits of their track loop ");
    } // end main

} // end Trains class
```

TrainTrack.java class

```
import java.util.concurrent.atomic.*;
public class TrainTrack {
    private void Idle(int time) {
        CDS.idleQuietly((int) (Math.random() * time));
    }
    private final String[] slots = {"[..]", "[..]", "[..]", "[..]", "[..]", "[..]", "[..]", "[..]", "[..]",
        "[..]", "[..]", "[..]", "[..]", "[..]", "[..]", "[..]", "[..]", "[..]", "[..]"};
    // declare array to hold the Binary Semaphores for access to track slots (sections)
    private final MageeSemaphore slotSem[] = new MageeSemaphore[19];
    // reference to train activity record
    Activity theTrainActivity;

    // global count of trains on shared track
    AtomicInteger aUsingSharedTrack;
    AtomicInteger bUsingSharedTrack;

     // counting semaphore to limit number of trains on track
    MageeSemaphore aCountSem;
    MageeSemaphore bCountSem;

    // declare  Semaphores for mutually exclusive access to aUsingSharedTrack
    private final MageeSemaphore aMutexSem;
    // declare  Semaphores for mutually exclusive access to bUsingSharedTrack
    private final MageeSemaphore bMutexSem;
    // shared track lock
    MageeSemaphore sharedTrackLock;

    /* Constructor for TrainTrack */
    public TrainTrack() {
        // record the train activity
        theTrainActivity = new Activity(slots);
        // create the array of slotSems and set them all free (empty)
        for (int i = 0; i <= 18; i++) {
            slotSem[i] = new MageeSemaphore(1);
        }
        // create  semaphores for mutually exclusive access to global count
        aMutexSem = new MageeSemaphore(1);
        bMutexSem = new MageeSemaphore(1);
        // create global AtomicInteger count variables
        aUsingSharedTrack = new AtomicInteger(0);
        bUsingSharedTrack = new AtomicInteger(0);
        // create  semaphores for limiting number of trains on track
        aCountSem = new MageeSemaphore(4);
        bCountSem = new MageeSemaphore(4);
        // initially shared track is accessible
        sharedTrackLock = new MageeSemaphore(1);
    }  // constructor
```

```
public void trainA_MoveOnToTrack(String trainName) {
    Idle(100);
    aCountSem.P(); // limit  number of trains on track to avoid deadlock
    // record the train activity
    slotSem[5].P();// wait for slot 5 to be free
    slots[5] = "[" + trainName + "]"; // move train type A on to slot zero
    theTrainActivity.addMovedTo(5); // record the train activity
}// end trainA_movedOnToTrack

public void trainB_MoveOnToTrack(String trainName) {
    // record the train activity
    bCountSem.P();  // limit  number of trains on track to avoid deadlock
    Idle(100);
    slotSem[14].P();// wait for slot 14 to be free
    slots[14] = "[" + trainName + "]"; // move train type B on to slot sixteen
    theTrainActivity.addMovedTo(14); // record the train activity
}// end trainB_movedOnToTrack
```

```
public void trainA_MoveOffTrack(String trainName) {
    Idle(100);
    // record the train activity
    slots[5] = "[..]"; // move train type A off slot zero
    slotSem[5].V();// signal slot 5 to be free
    Idle(100);
    aCountSem.V(); // signal space for another A train
    theTrainActivity.addMovedOff(trainName);
}// end trainA_movedOffTrack

public void trainB_MoveOffTrack(String trainName) {
    Idle(100);
    // record the train activity
    slots[14] = "[..]"; // move train type A off slot zero
    slotSem[14].V();// signal slot 0 to be free
    Idle(100);
    bCountSem.V(); // signal space for another B train
    theTrainActivity.addMovedOff(trainName);
}// end trainB_movedOffTrack
```

```
public void trainA_MoveAroundToSharedTrackPart1(String trainName) {
    Idle(100);
    int currentPosition = 5;
    do {
        /* wait until the position ahead is empty and then move into it*/
        slotSem[currentPosition + 1].P(); // wait for the slot ahead to be free
        slots[currentPosition + 1] = slots[currentPosition]; // move train forward
        slots[currentPosition] = "[..]"; //clear the slot the train vacated
        theTrainActivity.addMovedTo(currentPosition + 1); //record the train activity
        slotSem[currentPosition].V(); //signal slot you are leaving
        currentPosition++;
    } while (currentPosition < 8);
    Idle(100);
} // end trainA_MoveAroundToSharedTrackPart1
```

```
    public void trainA_MoveAlongSharedTrackPart1(String trainName) {
        // wait for the necessary conditions to get access to shared track
        Idle(100);
        aMutexSem.P(); // obtain mutually exclusive access to global variable aUsingSharedTrack
        if (aUsingSharedTrack.incrementAndGet() == 1)// if first A train joining shared track
        {
            sharedTrackLock.P();  // grab lock to shared track
        }
        aMutexSem.V(); // release mutually exclusive access to global variable aUsingSharedTrack
        // move on to shared track
        slotSem[9].P();
        slotSem[18].P();
        slotSem[18].V();
        slots[9] = slots[8];
        slots[8] = "[..]";
        slotSem[8].V(); //move from slot[8] to slot[9]
        theTrainActivity.addMovedTo(9);  //record the train activity

        // move along shared track
        slotSem[0].P();
        slots[0] = slots[9];
        slots[9] = "[..]";
        slotSem[9].V(); //move from slot[9] to slot[0]
        theTrainActivity.addMovedTo(0); // record the train activity
        // Move off shared track
        slotSem[10].P();
        slots[10] = slots[0];
        slots[0] = "[..]";
        slotSem[0].V(); //move from slot[0] to slot[10]
        theTrainActivity.addMovedTo(10); // record the train activity
        Idle(100);
        aMutexSem.P(); // obtain mutually exclusive access to global variable aUsingSharedTracK
        if (aUsingSharedTrack.decrementAndGet() == 0) // if last A train leaving shared track
        {
            sharedTrackLock.V(); // release lock to shared track
        }
        aMutexSem.V(); // release mutually exclusive access to global variable aUsingSharedTrack
        Idle(100);
    }// end   trainA_MoveAlongSharedTrackPart1
```

```
    public void trainA_MoveAroundToSharedTrackPart2(String trainName) {
        Idle(100);
        int currentPosition = 10;
        do {
            /* wait until the position ahead is empty and then move into it*/
            slotSem[currentPosition + 1].P(); // wait for the slot ahead to be free
            slots[currentPosition + 1] = slots[currentPosition]; // move train forward
            slots[currentPosition] = "[..]"; //clear the slot the train vacated
            theTrainActivity.addMovedTo(currentPosition + 1); //record the train activity
            slotSem[currentPosition].V(); //signal slot you are leaving
            currentPosition++;
        } while (currentPosition < 17);
        Idle(100);
    } // end trainA_MoveAroundToSharedTrackPart2
```

```
public void trainA_MoveAlongSharedTrackPart2(String trainName) {
    // wait for the necessary conditions to get access to shared track
    aMutexSem.P(); // obtain mutually exclusive access to global variable aUsingSharedTrack
    if (aUsingSharedTrack.incrementAndGet() == 1)// if first A train joining shared track
    {
        sharedTrackLock.P();  // grab lock to shared track
    }
    aMutexSem.V(); // release mutually exclusive access to global variable aUsingSharedTrack
    // move on to shared track
    slotSem[18].P();
    slotSem[9].P();
    slotSem[9].V();
    slots[18] = slots[17];
    slots[17] = "[..]";
    slotSem[17].V(); //move from slot[17] to slot[18]
    theTrainActivity.addMovedTo(18);  //record the train activity
    Idle(100);

    // move along shared track
    slotSem[0].P();
    slots[0] = slots[18];
    slots[18] = "[..]";
    slotSem[18].V(); //move from slot[18] to slot[0]
    theTrainActivity.addMovedTo(0); // record the train activity
    // Move off shared track
    slotSem[1].P();
    slots[1] = slots[0];
    slots[0] = "[..]";
    slotSem[0].V(); //move from slot[0] to slot[1]
    theTrainActivity.addMovedTo(1); // record the train activity
    Idle(100);
    aMutexSem.P(); // obtain mutually exclusive access to global variable aUsingSharedTracK
    if (aUsingSharedTrack.decrementAndGet() == 0) // if last A train leaving shared track
    {
        sharedTrackLock.V(); // release lock to shared track
    }
    aMutexSem.V(); // release mutually exclusive access to global variable aUsingSharedTrack
    Idle(100);
}// end   trainA_MoveAlongSharedTrackPart1
```

```
public void trainA_MoveAroundToSharedTrackPart3(String trainName) {
    Idle(100);
    int currentPosition = 1;
    do {
        /* wait until the position ahead is empty and then move into it*/
        slotSem[currentPosition + 1].P(); // wait for the slot ahead to be free
        slots[currentPosition + 1] = slots[currentPosition]; // move train forward
        slots[currentPosition] = "[..]"; //clear the slot the train vacated
        theTrainActivity.addMovedTo(currentPosition + 1); //record the train activity
        slotSem[currentPosition].V(); //signal slot you are leaving
        currentPosition++;
    } while (currentPosition < 5);
    Idle(100);
} // end trainA_MoveAroundToSharedTrackPart3
```

```
public void trainB_MoveAroundToSharedTrackPart1(String trainName) {
    Idle(100);
    int currentPosition = 14;
    do {
        /* wait until the position ahead is empty and then move into it*/
        slotSem[currentPosition + 1].P(); // wait for the slot ahead to be free
        slots[currentPosition + 1] = slots[currentPosition]; // move train forward
        slots[currentPosition] = "[..]"; //clear the slot the train vacated
        theTrainActivity.addMovedTo(currentPosition + 1); //record the train activity
        slotSem[currentPosition].V(); //signal slot you are leaving
        currentPosition++;
    } while (currentPosition < 17);
    Idle(100);
} // end trainB_MoveAroundToSharedTrackPart1
```

```
public void trainB_MoveAlongSharedTrackPart1(String trainName) {
    // wait for the necessary conditions to get access to shared track
    bMutexSem.P(); // obtain mutually exclusive access to global variable bUsingSharedTrack
    if (bUsingSharedTrack.incrementAndGet() == 1)// if first A train joining shared track
    {
        sharedTrackLock.P();  // grab lock to shared track
    }
    bMutexSem.V(); // release mutually exclusive access to global variable bUsingSharedTrack
    // move on to shared track
    slotSem[9].P();
    slotSem[9].V();
    slotSem[18].P();
    slots[18] = slots[17];
    slots[17] = "[..]";
    slotSem[17].V(); //move from slot[17] to slot[18]
    theTrainActivity.addMovedTo(18);  //record the train activity
    Idle(100);

    // move along shared track
    slotSem[0].P();
    slots[0] = slots[18];
    slots[18] = "[..]";
    slotSem[18].V(); //move from slot[18] to slot[0]
    theTrainActivity.addMovedTo(0); // record the train activity
    // Move off shared track
    slotSem[1].P();
    slots[1] = slots[0];
    slots[0] = "[..]";
    slotSem[0].V(); //move from slot[0] to slot[1]
    theTrainActivity.addMovedTo(1); // record the train activity
    Idle(100);
    bMutexSem.P(); // obtain mutually exclusive access to global variable aUsingSharedTracK
    if (bUsingSharedTrack.decrementAndGet() == 0) // if last A train leaving shared track
    {
        sharedTrackLock.V(); // release lock to shared track
    }
    bMutexSem.V(); // release mutually exclusive access to global variable bUsingSharedTrack
    Idle(100);
}// end   trainB_MoveAlongSharedTrackPart1
```

```
public void trainB_MoveAroundToSharedTrackPart2(String trainName) {
    Idle(100);
    int currentPosition = 1;
    do {
        /* wait until the position ahead is empty and then move into it*/
        slotSem[currentPosition + 1].P(); // wait for the slot ahead to be free
        slots[currentPosition + 1] = slots[currentPosition]; // move train forward
        slots[currentPosition] = "[..]"; //clear the slot the train vacated
        theTrainActivity.addMovedTo(currentPosition + 1); //record the train activity
        slotSem[currentPosition].V(); //signal slot you are leaving
        currentPosition++;
    } while (currentPosition < 8);
    Idle(100);
} // end trainB_MoveAroundToSharedTrackPart1
```

```
public void trainB_MoveAlongSharedTrackPart2(String trainName) {
    // wait for the necessary conditions to get access to shared track
    bMutexSem.P(); // obtain mutually exclusive access to global variable bUsingSharedTrack
    if (bUsingSharedTrack.incrementAndGet() == 1)// if first A train joining shared track
    {
        sharedTrackLock.P();  // grab lock to shared track
    }
    bMutexSem.V(); // release mutually exclusive access to global variable bUsingSharedTrack
    // move on to shared track
    slotSem[18].P();
    slotSem[18].V();
    slotSem[9].P();
    slots[9] = slots[8];
    slots[8] = "[..]";
    slotSem[8].V(); //move from slot[8] to slot[9]
    theTrainActivity.addMovedTo(9);  //record the train activity
    Idle(100);

    // move along shared track
    slotSem[0].P();
    slots[0] = slots[9];
    slots[9] = "[..]";
    slotSem[9].V(); //move from slot[9] to slot[0]
    theTrainActivity.addMovedTo(0); // record the train activity
    // Move off shared track
    slotSem[10].P();
    slots[10] = slots[0];
    slots[0] = "[..]";
    slotSem[0].V(); //move from slot[0] to slot[10]
    theTrainActivity.addMovedTo(10); // record the train activity
    Idle(100);
    bMutexSem.P(); // obtain mutually exclusive access to global variable bUsingSharedTracK
    if (bUsingSharedTrack.decrementAndGet() == 0) // if last A train leaving shared track
    {
        sharedTrackLock.V(); // release lock to shared track
    }
    bMutexSem.V(); // release mutually exclusive access to global variable bUsingSharedTrack
    Idle(100);
}// end   trainA_MoveAlongSharedTrackPart1
```

```
    public void trainB_MoveAroundToSharedTrackPart3(String trainName) {
        Idle(100);
        int currentPosition = 10;
        do {
            /* wait until the position ahead is empty and then move into it*/
            slotSem[currentPosition + 1].P(); // wait for the slot ahead to be free
            slots[currentPosition + 1] = slots[currentPosition]; // move train forward
            slots[currentPosition] = "[..]"; //clear the slot the train vacated
            theTrainActivity.addMovedTo(currentPosition + 1); //record the train activity
            slotSem[currentPosition].V(); //signal slot you are leaving
            currentPosition++;
        } while (currentPosition < 14);
        Idle(100);
    } // end trainB_MoveAroundToSharedTrackPart3

} // end Train track
```

Activity.java

```java
import java.util.concurrent.CopyOnWriteArrayList;
import java.util.Iterator;

// - Represents the train track activity in a thread-safe CopyOnWriteArrayList<String>
// - called theActivities
// - addMovementTo(<Integer>) adds a train movement (destination) activity to the record
// - addMessage(<String>) adds a message to the record
// - printActivities() display all the activity history of the train movement
// - trackString() takes a snapshot of the traintrack (with trains) for printing
public class Activity {

    private final CopyOnWriteArrayList<String> theActivities;

    private final String[] trainTrack;

    // Constructor for objects of class Activity
    // A reference to the track is passed as a parameter
    public Activity(String[] trainTrack) {
        theActivities = new CopyOnWriteArrayList<>();
        this.trainTrack = trainTrack;
    }
```

```
public void addMovedTo(int section) {
    // add an activity message to the activity history
    String tempString1 = "Train " + trainTrack[section] + " moving/moved to [" + section + "]";
    theActivities.add(tempString1);
    // add the current state of the track to the activity history
    theActivities.add(trackString());
}// end addMovedTo

public void addMovedOff(String trainName) {
    // add an activity message to the activity history
    String tempString1 = "Train " + trainName + " has left the track";
    theActivities.add(tempString1);
    // add the current state of the track to the activity history
    theActivities.add(trackString());
}// end addMovedTo

public void addMessage(String message) {
    // add an activity message to the activity history
    String tempString1 = message;
    theActivities.add(tempString1);
}// end addMessage
```

```
    public void printActivities() {
        // print all the train activity history
        System.out.println("TRAIN TRACK ACTIVITY(Tracks [0..18])");
        Iterator<String> iterator = theActivities.iterator();
        while (iterator.hasNext()) {
            System.out.println(iterator.next());
        }
    }// end printActivities
    // Utility method to represent the track as a string for printing/display
    public String trackString() {
        String trackStateAsString = "           " + trainTrack[5] + "\n"
                + "        " + trainTrack[4] + "  " + trainTrack[6] + "\n"
                + "      " + trainTrack[3] + "      " + trainTrack[7] + "\n"
                + "      " + trainTrack[2] + "      " + trainTrack[8] + "\n"
                + "        " + trainTrack[1] + "  " + trainTrack[9] + "\n"
                + "           " + trainTrack[0] + "\n"
                + "        " + trainTrack[10] + "  " + trainTrack[18] + "\n"
                + "      " + trainTrack[11] + "      " + trainTrack[17] + "\n"
                + "      " + trainTrack[12] + "      " + trainTrack[16] + "\n"
                + "        " + trainTrack[13] + "  " + trainTrack[15] + "\n"
                + "           " + trainTrack[14] + "\n";
        return trackStateAsString;
    }// end trackString
} // end Activity
```

CDS.java

```
public class CDS {


      public static void idle(int millisecs) { // with messages
            Thread mainThread = Thread.currentThread();
            System.out.println(mainThread.getName() + ": About to sleep");
            try {
                  Thread.sleep(millisecs);
            } catch (InterruptedException e) {
            }
            System.out.println(mainThread.getName() + ": Woken up");
      } // end idle

      public static void idleQuietly(int millisecs) { // idle with no messages
            try {
                  Thread.sleep(millisecs);
            } catch (InterruptedException e) {
            }
      } // end idleQuietly

} // end CDS
```

MageeSemaphore.java

```
import java.util.concurrent.*;
//MageeSemaphore.java
//This is an implementation of the traditional (counting) Semaphore with P() and V() operations
class MageeSemaphore
{
   private Semaphore sem;
   public MageeSemaphore (int initialCount)
   {
      sem = new Semaphore(initialCount);
   } // end constructor

   public void P()
   {
      try {
          sem.acquire();
      } catch (InterruptedException ex) {System.out.println("Interrupted when waiting");}
   } // end P()

   public void V()
   {
      sem.release();
   } // end V()
} // end MageeSemaphore
```

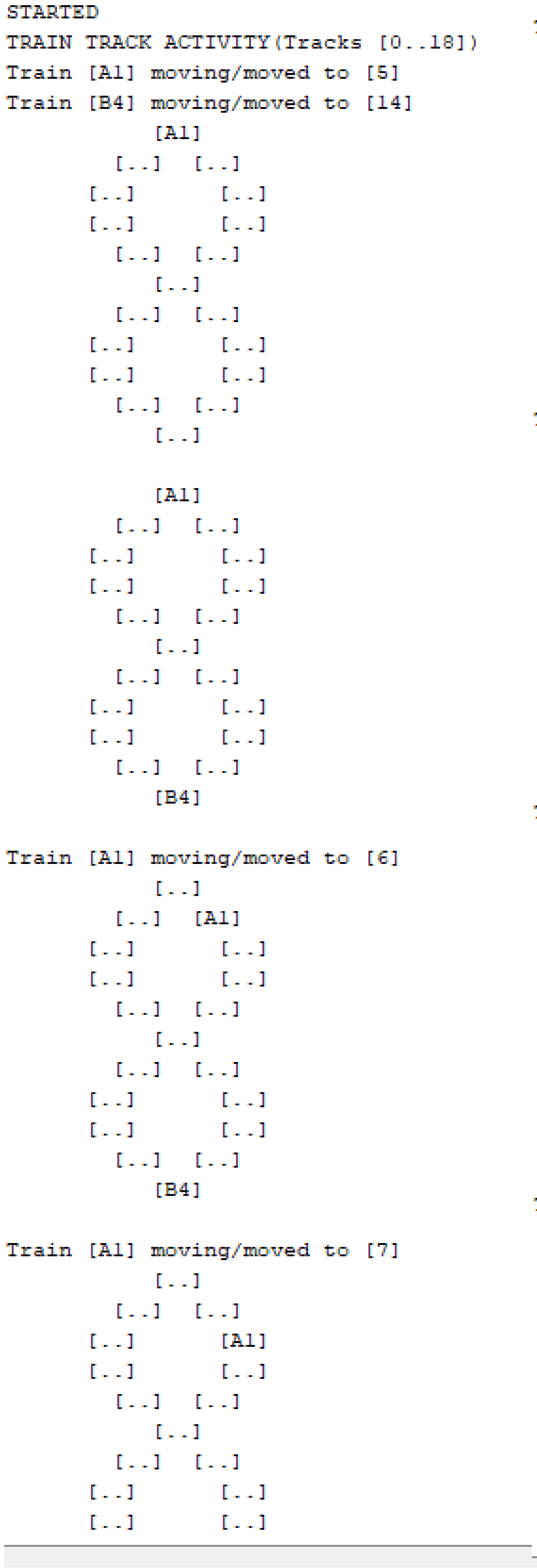
TrainA.java

```java
public class TrainA extends Thread {
    String trainName;
    TrainTrack theTrack;
    //initialise (constructor)
    public TrainA(String trainName, TrainTrack theTrack) {
        this.trainName = trainName;
        this.theTrack = theTrack;
    }
    @Override
    public void run() {   // start train Process
        // wait for clearance before moving on to the track
        theTrack.trainA_MoveOnToTrack(trainName); // move on to track A
        int circuitCount = 0;
        while (circuitCount < 1) { // keep cycling the A track loop
            theTrack.trainA_MoveAroundToSharedTrackPart1(trainName);
            theTrack.trainA_MoveAlongSharedTrackPart1(trainName);
            theTrack.trainA_MoveAroundToSharedTrackPart2(trainName);
            theTrack.trainA_MoveAlongSharedTrackPart2(trainName);
            theTrack.trainA_MoveAroundToSharedTrackPart3(trainName);
            circuitCount++;
        }
        theTrack.trainA_MoveOffTrack(trainName); // move off the track
    } // end run  } // end trainAProcess
```

TrainB.java

```
public class TrainB extends Thread {
    String trainName;
    TrainTrack theTrack;
    //initialise (constructor)
    public TrainB(String trainName, TrainTrack theTrack) {
        this.trainName = trainName;
        this.theTrack = theTrack;
    }
    @Override
    public void run() {   // start train Process
        // wait for clearance before moving on to the track
        theTrack.trainB_MoveOnToTrack(trainName); // move on to track B
        int circuitCount = 0;
        while (circuitCount < 1) { // keep cycling the B track loop
            theTrack.trainB_MoveAroundToSharedTrackPart1(trainName);
            theTrack.trainB_MoveAlongSharedTrackPart1(trainName);
            theTrack.trainB_MoveAroundToSharedTrackPart2(trainName);
            theTrack.trainB_MoveAlongSharedTrackPart2(trainName);
            theTrack.trainB_MoveAroundToSharedTrackPart3(trainName);
            circuitCount++;
        }
        theTrack.trainB_MoveOffTrack(trainName); // move off the track */
    } // end run  } // end trainBProcess
```

Console Output

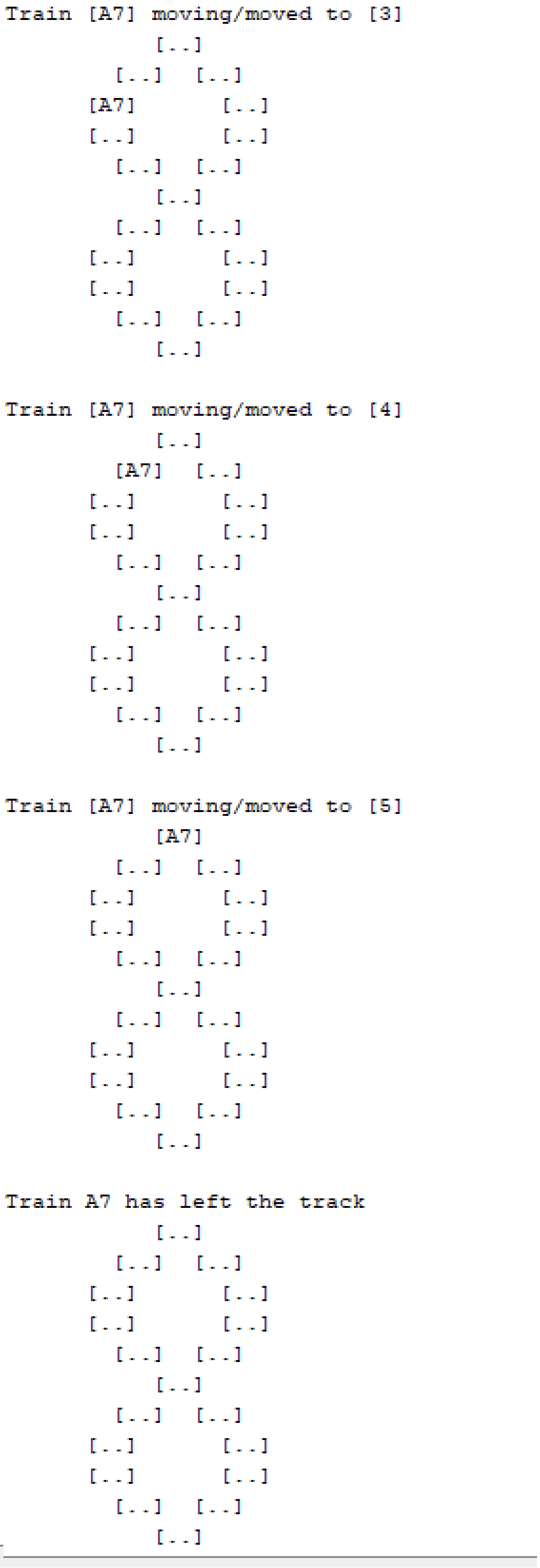


```
STARTED
TRAIN TRACK ACTIVITY(Tracks [0..18])
Train [A1] moving/moved to [5]
Train [B4] moving/moved to [14]
           [A1]
        [..]  [..]
      [..]      [..]
      [..]      [..]
        [..]  [..]
           [..]
        [..]  [..]
      [..]      [..]
      [..]      [..]
        [..]  [..]
           [..]

           [A1]
        [..]  [..]
      [..]      [..]
      [..]      [..]
        [..]  [..]
           [..]
        [..]  [..]
      [..]      [..]
      [..]      [..]
        [..]  [..]
           [B4]

Train [A1] moving/moved to [6]
           [..]
        [..]  [A1]
      [..]      [..]
      [..]      [..]
        [..]  [..]
           [..]
        [..]  [..]
      [..]      [..]
      [..]      [..]
        [..]  [..]
           [B4]

Train [A1] moving/moved to [7]
           [..]
        [..]  [..]
      [..]      [A1]
      [..]      [..]
        [..]  [..]
           [..]
        [..]  [..]
      [..]      [..]
      [..]      [..]
```



```
Train [A7] moving/moved to [3]
           [..]
        [..]  [..]
      [A7]      [..]
      [..]      [..]
        [..]  [..]
           [..]
        [..]  [..]
      [..]      [..]
      [..]      [..]
        [..]  [..]
           [..]

Train [A7] moving/moved to [4]
           [..]
        [A7]  [..]
      [..]      [..]
      [..]      [..]
        [..]  [..]
           [..]
        [..]  [..]
      [..]      [..]
      [..]      [..]
        [..]  [..]
           [..]

Train [A7] moving/moved to [5]
           [A7]
        [..]  [..]
      [..]      [..]
      [..]      [..]
        [..]  [..]
           [..]
        [..]  [..]
      [..]      [..]
      [..]      [..]
        [..]  [..]
           [..]

Train A7 has left the track
           [..]
        [..]  [..]
      [..]      [..]
      [..]      [..]
        [..]  [..]
           [..]
        [..]  [..]
      [..]      [..]
      [..]      [..]
        [..]  [..]
           [..]
```