Instructions:

Deadline for submitting files on Moodle:	Tomorrow (14th), 10 PM
Deadline for late submission of files on Moodle:	Saturday, (16th), 8 PM

Please follow the general instructions given below

- There are two exercises in this lab.
- The name for submission of Exercise 1 should be YOURROLLNUMBER_IE_507_Lab10Ex1.pdf
- The name for submission of Exercise 2 should be YOURROLLNUMBER_IE_507_Lab10Ex2.pdf
- Please post your doubts in MS Teams or Moodle so that TAs can clarify.

We will practice some formulations of discrete optimization problems and their solution through some heuristics.

Some of these problems may be possible to model as Mixed Integer Linear programmes, but in some practical situations, that may not be needed (or possible to do). Often, simple, good quality heuristics are also available and we will try to see a few examples.

Exercise 1: Berlin Tram Map colouring problem. [10 marks] See the pdf file in moodle representing the tram network in the city of Berlin. The tram routes in the city are M1, M2, M4, M5, M6, M8, M10, 12, M13, 16, M17, 18, 21, 27, 37, 50, 60, 61, 62, 63, 67, 68. You can observe that when tram routes intersect at any point in the tram network, they have different colours. This makes is possible to easily track the route of a tram through the network (please try out what would be the difficulty if all routes were depicted with the same colour). The question is how to do this with the minimum number of colours (so that they are all nice and distinct). Think of ways of doing this on your own.
The raw data is on moodle, in the form of the pdf map and the route intersection info (in csv and xlsx format).

1. [**R**] Provide a specific solution for the Berlin tram routes. You need to specify the number of colours used and which colours are used for which routes.
2. [**R**] Explain your procedure in your own words (you may be asked about this in a short oral exam!), written in the form of a flow chart which can be implemented for larger problems.
3. Develop an online version of your procedure where route information is provided to you one at a time (i.e. you don't know the entire route information at the beginning).
4. [**R**] If we have n routes and there is a route that intersects the other $n-1$ routes, then we need n colours to represent the map. True or false? If true, provide a proof, if false, provide a counterexample.

Exercise 2: Bin Packing. [10 Marks] Items $(1, ...n)$ with weights $w_1, w_2, ..., w_n$ have to be put into bins of capacity B. Items cannot be cut into pieces! We would like to do it with as few bins as possible.

You have studied the First Fit Decreasing algorithm for this. Briefly, it is this. Arrange the items in decreasing order of weight. Starting with the first item, put each item in the first bin that can accommodate it (you need to make this precise).

1. [**R**] Write a procedure to execute the First Fit Decreasing algorithm. You will be asked to implement this on a moderate sized example (approx 20 items) in a test of 15-20 minutes time to be done at any time between 12.30-2.00 p.m. on Thursday, 14 October on SAFE app. Instructions will be put on moodle on Thursday by 11 a.m. You have to keep your algorithm/procedure ready.

2. [**R**] Construct a small example where the FFD algorithm is NOT optimal.

Your evaluation will be mainly on the result you report on the SAFE app.