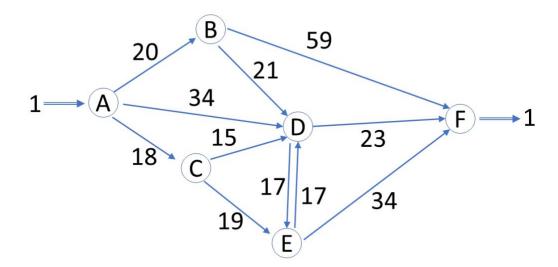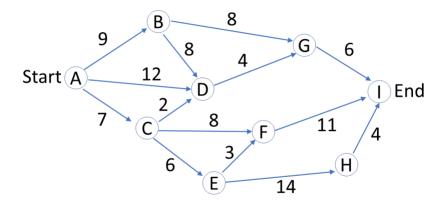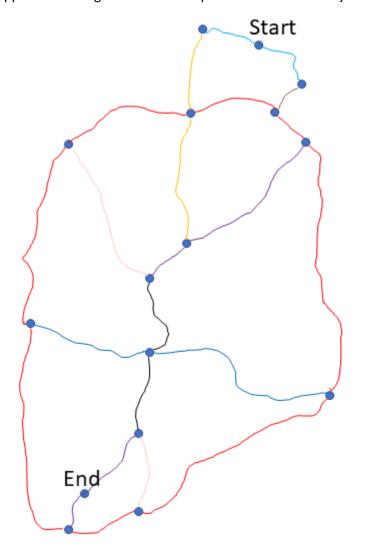**Exercises -** Section 2: Lecture 11 – Shortest Path - Questions

1. Given the shortest path network picture below, create corresponding mathematical and gurobipy models that can be used to find the shortest route from start (A) to end (F), and solve the gurobipy model to find the shortest route from A to F.

2. Given the shortest path network picture below, create corresponding mathematical and gurobipy models that can be used to find the shortest route from start (A) to end (I), and solve the gurobipy model to find the shortest route from A to I.

3. Given the Atlanta road network picture below, create corresponding mathematical and gurobipy models that can be used to find the shortest route from the start node (a country club) to the end node (the airport). The roads are color-coded as shown, and every road can be traveled in both directions. [In practice, because travel times on each piece of road can differ depending on current traffic, a system using this model would be created to work in conjunction with another application that gives current and predicted travel times .]

4. A company plans to purchase a fleet of cars to give to its salespeople, so they can drive to customer sites without having to put a lot of mileage on their own cars. The company is trying to plan in advance how long it will keep a car before selling it (used) and purchasing another new one. Based on past data, the company has estimates for how much a car will cost in maintenance each year based on its age, how much it can be sold for, and how much a new car will cost, all adjusted to today's dollars.

Car age (years)	New car cost	Revenue if used car is sold	Expected maintenance cost
1	$ 36,000	$ 27,000	$ 300
2	$ 36,000	$ 20,000	$ 400
3	$ 36,000	$ 15,000	$ 600
4	$ 36,000	$ 12,000	$ 900
5	$ 36,000	$ 9,000	$ 1,300
6	$ 36,000	$ 7,000	$ 1,800
7	$ 36,000	$ 5,000	$ 2,400
8	$ 36,000	$ 4,000	$ 3,100
9	$ 36,000	$ 3,000	$ 3,800
10	$ 36,000	$ 2,000	$ 4,500

Note: All dollar amounts are converted to today's dollars

The company wants to minimize its total car costs over the next ten years. Draw a network picture you can use to help the company minimize its costs. You do not need to model it mathematically or in gurobipy (though you can if you want to). [HINT: Let each year be a node, and an arc from node i to node j be the cost of keeping a car for (j-i) years and then selling it and buying a new one.]
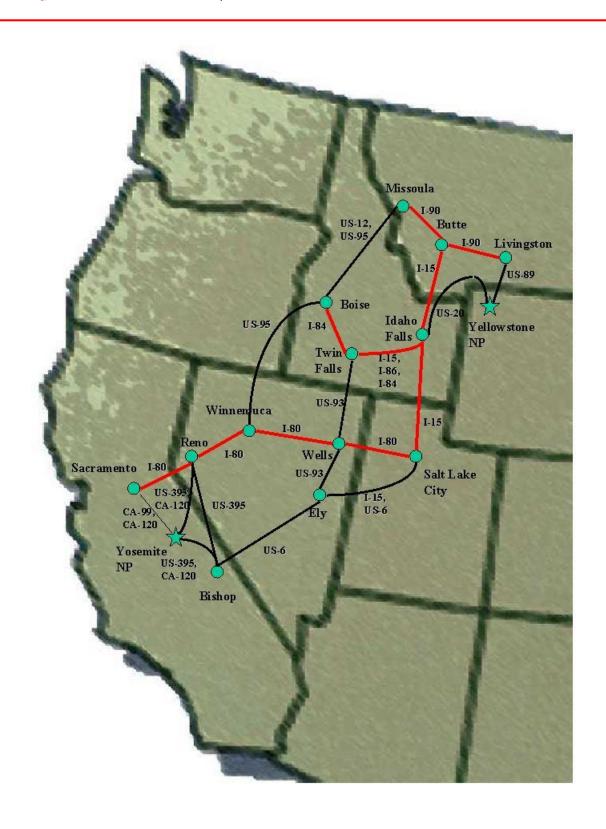
5. Two of the United States' most-visited national parks are Yellowstone National Park (located mostly in Wyoming, but extending slightly across the border into Idaho and Montana) and Yosemite National Park (located in California). A company specializing in nature tours offers two-location camping trips at Yellowstone and Yosemite. Customers drive to their choice of either of the two parks, and the company provides tours of the parks, as well as bus service between the parks. Every few days a bus drives from one park to the other. A bus from Yosemite to Yellowstone, for example, might have some Yosemite-based campers on their way to the second part of their tour, and also some Yellowstone-based campers who are heading back at the end of their tour.

The company has identified all of the major roads that might be used as part of the bus route between the two parks. The roads include, in decreasing order of size and speed, interstate highways, U.S. highways, and state highways. Interstate highways are denoted by an "I" before the highway number, U.S. highways by "US" before the highway number, and state highways by the state's abbreviation (for example, "CA") before the highway number. A map of the highways, as well as a table of the city-to-city connections, is included below.

Write mathematical and gurobipy optimization models that the company can use to find the shortest route for the tour buses to take. Solve the gurobipy model once to find the shortest-distance route, and once to find the shortest-time route. [Hint: You should not need different gurobipy code for the two solutions, just different data.]

Road Segment Endpoints		Highway(s)	Time (Min)	Distance (Miles)
Yellowstone N.P., WY	Livingston, MT	US-89	84	59
Yellowstone N.P., WY	Idaho Falls, ID	US-20	128	100
Livingston, MT	Butte, MT	I-90	100	104
Butte, MT	Idaho Falls, ID	I-15	210	205
Butte, MT	Missoula, MT	I-90	110	119
Missoula, MT	Boise, ID	US-12, US-95	475	371
Idaho Falls, ID	Salt Lake City, UT	I-15	206	208
Idaho Falls, ID	Twin Falls, ID	I-15, I-86, I-84	155	161
Boise, ID	Twin Falls, ID	I-84	128	131
Boise, ID	Winnemuca, NV	US-95	303	256
Twin Falls, ID	Wells, NV	US-93	141	118
Salt Lake City, UT	Wells, NV	I-80	174	181
Salt Lake City, UT	Ely, NV	I-15, US-6	262	241
Wells, NV	Winnemuca, NV	I-80	162	175
Wells, NV	Ely, NV	US-93	180	140
Winnemuca, NV	Reno, NV	I-80	153	164
Ely, NV	Bishop, CA	US-6	337	283
Reno, NV	Bishop, CA	US-395	255	205
Reno, NV	Sacramento, CA	I-80	152	133
Reno, NV	Yosemite N.P., CA	US-395, CA-120	225	154
Sacramento, CA	Yosemite N.P., CA	CA-99, CA-120	277	193
Bishop, CA	Yosemite N.P., CA	US-395, CA-120	132	65

6. A budget traveler is trying to find the least-expensive way to fly from Savannah, GA to
   Wellington, NZ. The traveler has found the following set of flights that could be combined into
   one Savannah-Wellington itinerary. Assume that all flight times match up (so you don't have to
   worry about whether one flight arrives too late to take the next; the traveler has already made
   sure the flight times work out):

From	To	Cost
Savannah	Atlanta	$ 254
Savannah	New York	$ 49
Savannah	Los Angeles	$ 128
Savannah	Dallas	$ 190
Dallas	Sydney	$ 1616
Dallas	Auckland	$ 1343
Dallas	Los Angeles	$ 180
Dallas	Honolulu	$ 725
Atlanta	Los Angeles	$ 129
Atlanta	Honolulu	$ 850
New York	Los Angeles	$ 119
New York	Honolulu	$ 394
Los Angeles	Sydney	$ 1298
Los Angeles	Auckland	$ 1115
Los Angeles	Honolulu	$ 136
Honolulu	Melbourne	$ 460
Melbourne	Wellington	$ 386
Sydney	Wellington	$ 357
Auckland	Wellington	$ 212

   (a) Draw a network picture, and build mathematical and gurobipy models that the traveler
       could use to find the minimum-cost set of tickets to get from Savannah to Wellington. Solve
       the gurobipy model.

   (b) The lowest quoted one-way fare (with multiple stops) from Savannah to Wellington is
       $1457. Will the budget traveler save money by building his own set of flights?

NOTES: