Question #1 [20 points]:

Label the following statements as True (T) or False (F) between the brackets. The given space is a workspace for you. you DO NOT have to provide additional explanation for your choice:

1. Depth-First search using iterative deepening can be made to return the same solution as Breadth-First search. (_____)

2. Meta-heuristic algorithms are generally used to find the exact optimal solution. (_____)

3. The solution path found by Uniform-Cost search *may change* if we add the same positive constant, *c*, to every arc cost. (_____)

4. Simulated annealing is more likely to accept a bad move late in the search than earlier. (_____)

5. If h1 and h2 are both admissible heuristics, h1+h2 is also admissible. (_____)

6. Hill-climbing moves to the best successor of the current state. (_____)

7. Depth-first search has higher memory requirement than breadth-first search. (_____)

8. Genetic algorithms maintain several possible solutions, whereas simulated annealing works with one solution. (_____)

9. Uniform-cost search is a special case of Breadth-first search. (_____)

10. Beam search uses randomness for avoiding getting trapped in local maxima. (_____)

11. The minimax and alpha-beta procedures will always back up identical values to the root node of a game tree for any possible static evaluation function. (_____)

12. Genetic algorithms are used for minimization problems while simulated annealing is used for maximization problems. (_____)

13. A drawback of game playing strategies using the minimax and alpha-beta algorithms is that one can't make sacrifices where an immediate loss is permitted in order to obtain a subsequent advantage. (_____)

14. Let f(s) be the fitness score of state s. Genetic Algorithm is expected to work better than Simulated Annealing, if in the middle of the search we suddenly change f(s). (_____)

15. Alpha-beta pruning prunes the same number of subtrees independent of the order in which successor states are expanded. (_____)

16. Binary coding of genotypes is better than gray coding since small changes in the genotype cause small changes in the phenotype. (_____)

17. In Tabu search, the Tabu list is based on recency of occurrence (_____)

18. Given Parent X and Parent Y as shown below, if we apply single arithmetic crossover with k=5 and $\alpha = 0.5$, one of the children of this operation is child A. (_____)

Parent X	0.2	0.1	0.3	0.8	0.4	0.6	0.7
Parent Y	0.6	0.3	0.1	0.4	0.2	0.9	0.5
Child A	0.2	0.3	0.3	0.4	0.3	0.6	0.7

19. In genetic algorithms, crossover helps enhance the exploitation of the state space while mutation helps enhance the exploration of it. (_____)

20. Simulated Annealing with a linearly decreasing temperature is guaranteed to converge to a global optimal solution after a finite number of iterations. (_____)

Question #2 [10 points]:

Short Answer questions:

a) **[2 points]** Explain the difference between “parameter tuning” and “parameter control”

b) **[2 points]** Describe how will a Genetic algorithm with population size N=1 operate discussing crossover, and mutation.

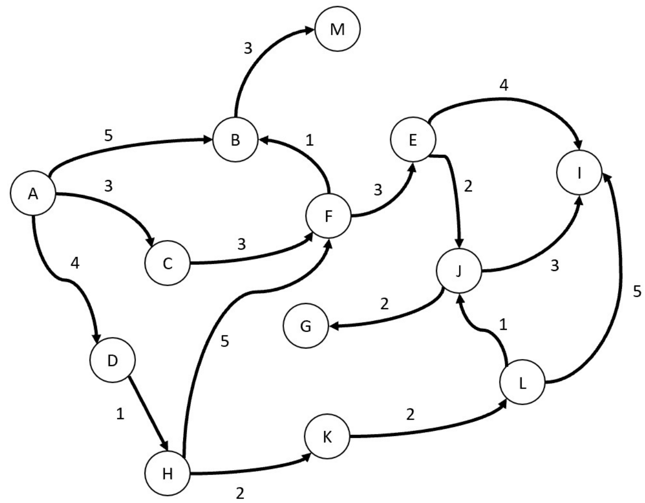
c) **[2 points]** What is the difference between the cost function and heuristic function portions of the A* evaluation function?

d) **[2 points]** Explain the role of short-term memory and long-term memory in Tabu search for balancing diversification and intensification.

e) **[2 points]** Discuss one scenario in which population-based methods are preferred over trajectory methods.

Question #3: [16 Marks]

Consider the **directed** search graph below. Assume that A is the starting node, and G is the goal node. Edges are labeled with the actual costs of the associated action and each node has a heuristic evaluation reported in the table. Nodes are expanded in lexical order if there are no other criteria of choice (for example node B has priority over node C).



A	10
B	9
C	8
D	7
E	4
F	6
G	0
H	6
I	4
J	2
K	4
L	3
M	8

a) **[4 points]** draw the search tree that is produced, showing the cost at each node (hint: no loops should be in the generated tree)

b) **[5 points]** Including the start node and the goal node, **<u>how many</u>** nodes are there in the order in which the nodes are **expanded** by:

i. Breadth-first search

ii. Depth-first search

iii. Uniform-cost search

iv. greedy search

v. A* search.

c) **[5 points]** <u>State the route</u> that is taken by each algorithm to the goal and give the total cost:

i. Breadth-first search

ii. Depth-first search

iii. Uniform-cost search

iv. greedy search

v. A* search.

d) **[2 points]** Are the heuristic values coming from an admissible function? Explain why.

Question #4 [20 points]:

Simple ACO is being used in a traveling salesman problem. Assume 4 cities {A, B, C, D}, which are represented by a fully connected graph. The following tables represent the pheromone levels on each edge of the graph and the distances between each city (assume the pheromone levels and distances are symmetric).

	Pheromone Levels			
	A	B	C	D
A				
B	0.25			
C	0.11	0.98		
D	0.34	0.54	0.67	

	Distances			
	A	B	C	D
A				
B	12			
C	10	6		
D	8	15	3	

a) **[6 points]** Assume an ant started its journey at city A and has travelled to city C. Assume alpha and beta are set to 1. Using the formula described in the lectures
   i) What is the probability that the ant will travel to city A?

   ii) What is the probability that the ant will travel to city B?

   iii) What is the probability that the ant will travel to city D?

b) **[3 points]** Assume the number of ants is initialized to 5. At each iteration of applying ACO how many times the update rule is used if
   i) Online step-by-step update rule is applied

   ii) Online delayed update rule is applied

   iii) Offline update rule is applied (Global update)

c) **[2 points]** Online step-by-step update rule can use an ant density model or an ant quantity model. Briefly explain the difference between these two models.

d) **[4 points]** In simple ACO algorithm, ant k located at node i selects the next node during its forward movement based on the below equation.

$$P_{ij}{}^{k} = \begin{cases} \dfrac{(\tau_{ij})^{\alpha}(\eta_{ij})^{\beta}}{\sum_{l \in N_i{}^{k}}(\tau_{il})^{\alpha}(\eta_{il})^{\beta}} & \text{if } j \in N_i{}^{k} \\ 0 & \text{if } j \notin N_i{}^{k} \end{cases}$$

where

$N_i{}^{k}$: Neighborhood of ant k when it is in node i,

η_{ij} : the heuristical desirability for choosing edge (i, j),

τ_{ij} : the amount of pheromone on edge (i, j),

α and β : relative influence of heuristics vs. pheromone.

Comment on the next node selection behavior of simple ACO ant for case α=0 and $\beta = 0$ by explaining the role of parameters α and β.

e) **[5 points]** What variation of ACO each statement below is describing? Choose from the list below:

<u>List:</u> *Simple ACO, Ant System, Ant Colony System, Max-Min Ant System, ACSGA, Near Parameter Free ACS, heterogeneous Ant Colony, Coarse-grained Homogeneous Ant Colony*

i) Each ant has its own parameter values adaptively selected using an ant approach

ii) The values of the pheromone are restricted in a range to allow high exploration in the beginning and more intensification later. This variation of ACO overcomes stagnation.

iii) A GA algorithm runs on top of the ACS to optimize its parameter values

iv) The transition rule is based on Elitist strategy which is called pseudo-random proportional rule.

v) The online delayed pheromone update is adopted using all the solutions of the current iteration.

Question #5 [15 points]:

a) **[5 points]** In PSO, each particle shares its personal best information with other particles. Selecting a proper neighborhood affects the convergence and also helps in avoiding getting stuck at local minima. What topology each statement below is describing? Choose from the list:

List: *Star topology, ring topology, Von Neumann Model, physical neighbors, social neighbors*

i) Choose the particles that are the closest to particle m in the search space. The notion of closest is based on the distance in the cartesian space. This approach is computationally expensive.

ii) This topology has the fastest propagation of information in a population. Particles can easily get stuck in local minima.

iii) The particles are kept in a matrix data structure. Particles next to particle m in the matrix are picked as neighbors.

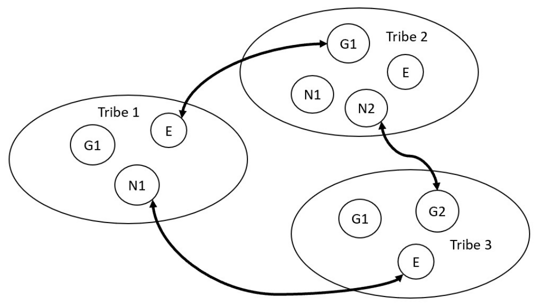
iv) The most successful neighborhood structure which is formed by arranging the particles in a grid and connecting each to 4 other particles.

v) The propagation of information is the slowest but does not easily get stuck in local minima. It might increase computational cost.

b) **[5 points]** PSO can be used for permutation problems by re-defining three operations: adding velocity to a position, subtracting two positions, and multiplying a velocity by a constant. Suppose that particle m is currently at position X1 and the velocity is V1. Calculate the updated velocity V2 and position X2 given the information below:

X1=[14285673]
V1= {(1,3), (5,8), (2,7)}
Pbest=[16285473]
Nbest=[14275683]
W= 1/3, c1=c2=2, r1=r2=0.5

c) **[5 points]** Consider the adaptive parameter free PSO that is referred to as Tribes method. A tribe refers to a group of connected particles. The main point in this method is to adapt the number of particles used in the search. Assume the figure below is the situation of tribes at the end of current iteration in which G is a good particle, N is a neutral particle, and E is an excellent particle. G1 is a better particle than G2 and N1 is a better particle than N2.



The random number generator has generated this sequence of random numbers: [0.83, 0.52, 0.23] whose ith element is used to evaluate ith tribe for being good or bad. Draw the situation of the tribes at the beginning of next iteration assuming any new generated particle is neutral.

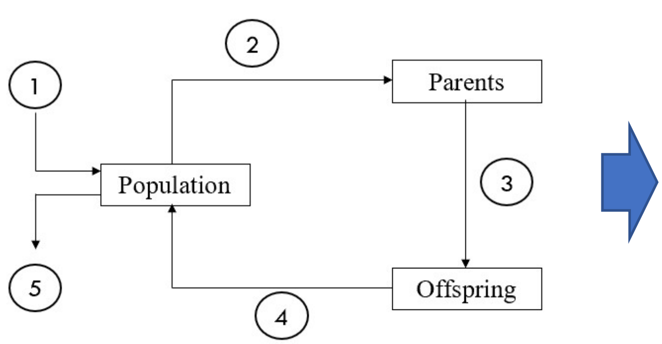
Hint: A tribe is marked as good if the ratio of good particles G to all particles T in that tribe is greater than a random number r. Good tribes shrink, bad tribes generate new particles. Tribes should maintain connection.

Question #6 [24 points]:

a) **[4 points]** Discuss <u>two</u> drawbacks of the roulette wheel selection mechanism, and <u>name</u> two methods to avoid (or minimise) these drawbacks.

b) **[2 points]** One-Point Crossover is not suitable for The Travelling Salesman Problem (TSP). Explain why and show an example.

c) **[5 points]** Fill the numbered items below showing the steps of Simple Genetic Algorithm (SGA)



1……………………

2……………………

3……………………

4……………………

5……………………

d) **[3 points]** The following table shows sizes and playing times of 10 different video files. It is required to store a subset of these files onto a DVD such that (1) the files have combined size of at most 4500 MB (i.e. the size of the DVD) and (2) the total playing time of the stored files is as large as possible.

File No.	1	2	3	4	5	6	7	9	9	10
Size (in MB)	800	700	650	750	600	900	975	875	1050	1500
Playing time (in mins)	121	95	85	100	78	125	130	128	135	120

i) Compute the size of the search space of this problem.

ii) Represent the problem domain as a chromosome.

iii) Define a fitness function to evaluate the performance of each chromosome.

e) **[10 points]** Suppose a genetic algorithm uses chromosomes of the form x=abcdefgh with a fixed length of eight genes in a permutation problem. Digits between 1 and 8 can be used once in the genes to represent a feasible solution. let the initial population consist of four individuals with the following chromosomes:

X1=14285673
X2=86752341
X3=18362745
X4=48372651

i) Perform the PMX crossover to generate **<u>two</u>** children from **X1** and **X2** when <u>[bcd]</u> segment is selected to be copied as the result of the first step of the PMX technique. (The PMX crossover procedure is given below)

1. Choose random segment and copy it from P1,
2. Starting from the first crossover point look for elements in that segment of P2 that have not been copied,
3. For each of these i, look in the offspring to see what element j has been copied in its place from P1,
4. Place i into the position occupied j in P2, since we know that we will not be putting j there (as is already in offspring).
5. If the place occupied by j in P2 has already been filled in the offspring k, put i in the position occupied by k in P2,
6. Having dealt with the elements from the crossover segment, the rest of the offspring can be filled from P2. Second child is created analogously.

ii) Perform the cycle crossover to generate **<u>two</u>** children from **X3** and **X4**. (The cycle crossover steps are given below)

1. Make a cycle of alleles from P1 in the following way.
    (a) Start with the first allele of P1.
    (b) Look at the allele at the same position in P2.
    (c) Go to the position with the same allele in P1.
    (d) Add this allele to the cycle.
    (e) Repeat step b through d until you arrive at the first allele of P1.
2. Put the alleles of the cycle in the first child on the positions they have in the first parent.
3. Take next cycle from second parent
4. Repeat until all the genes have cycles.