Lab Evaluation : Graph Theory

Max. Marks : 15

Q : Consider the following input data that defines a graph :

```
5

1 2  9
1 3 12
2 4 18
2 3  6
2 5 20
3 5 15
0
1 5
```

The input starts with a line that tells how many vertices the graph has. (five vertices).

Let the vertices be numbered 1, 2, 3, 4 and 5. In general, if there are *n* vertices, then they are numbered 1, …, *n*.

Following the first line are the edges, one per line. Each edge line has three integers on it. For example, if a line is `2 4 50.0`, it indicates that there is an edge between vertices 2 and 4, and that its weight is 50.

The end of the input is signalled by a line that contains just a 0.

After that 0 line is a line containing two integers: a start vertex and an end vertex.

i. Write a program to represent the graph as an adjacency list and display it **[3]**

ii. Compute the shortest from the start vertex to the end vertex. **[7]**

Your solution should be generic and not specific to the problem. It will be evaluated on another set of inputs.

OR

ii. Write a function **spanningTree()** which takes as input the graph defined above and returns an integer denoting the sum of weights of the edges of the Minimum Spanning Tree. **[7]**

Your solution should be generic and not specific to the problem. It will be evaluated on another set of inputs.

iii. Let us play a game with the above graph. The rules of the game are as follows: **[5]**

On each vertex of the graph there is a coin. A player has to collect them all starting with some vertex. From current vertex, player can visit only those vertices which are connected to it by an edge. Also if a vertex is visited it cannot be visited again.

The question is whether all the coins can be collected. Write a program to answer the question in **Yes** or **No.**

INDIAN INSTITUTE OF INFORMATION TECHNOLOGY, ALLAHABAD

Quiz2, 2022

Paper Title: Graph Theory

Max Marks: 40 **Duration: 1 hour 15 minutes**

Note: The question paper has 10 questions and covers two pages.
Answer All questions. The marks for each question has been provided alongside.

Introduction : Fundamental Concepts **[15 marks]**

Q1: Consider the graph G = (V, E) with V = (1, 2, 3, 4, 5) and E = (1 2, 1 3, 2 3, 2 4, 3 4, 4 5)
Give the set of edges, the incidence and adjacency matrices, and a drawing of the graphs G^c, $G - 4$ **[4]**

Q2 : Give the set of edges and a drawing of the graphs K_3 union P_3 and $K_3 \times P_3$, assuming that the sets of vertices of K_3 and P_3 are disjoint **[4]**

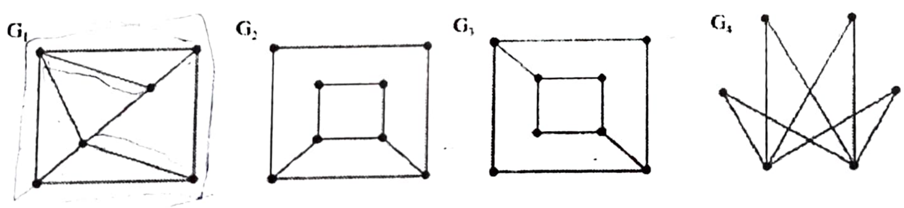
Q3 : Suppose a graph has nine vertices each of degree 5 or 6. Prove that at least five vertices have degree 6 or at least six vertices have degree 5 **[4]**

Q4 : How many edges does a self-complementary graph of order n have? **[3]**

Connectivity in Graphs **[10 marks]**

Q5 : Count the number of spanning cycles (also called Hamiltonian circuits) in K_n for $n > 3$ **[4]**

Q6 : For each of the following graphs, either find an Eulerian circuit or prove that there is not one. **[3]**



Q7 : Find the eccentricities, the radius and the central vertices of : **[3]**
$G = ([8], \{12, 14, 15, 23, 34, 38, 46, 47, 56, 67, 78\})$

Graph Traversal and Trees **[15 marks]**

Q8 : Use the algorithm DFS to find out whether the following graphs, given by their adjacency lists, are connected, and otherwise determine their connected components. Consider that the set of vertices is alphabetically ordered. **[5]**

a	b	c	d	e	f	g	h	i	j
d	d	h	a	a	a	b	c	b	b
e	g		b	d	d	i		g	g
f	i		e			j			
	j		f						

MIOT Graph Theory, Autumn 2022 - 2023
Quiz 1

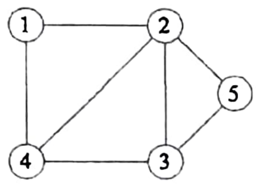
Maximum marks: 30 **Time: 13-Sep-2023** **Duration: 45 minutes**

Q1. Prove or disprove: The complement of a simple disconnected graph must be connected. **[5]**

Q2. (a) Is the following sequence a graphic sequence (5; 5; 5; 4; 2; 1; 1; 1) ?
If it is graphic, produce a realization of the sequence, else prove why it is not graphic. **[4]**

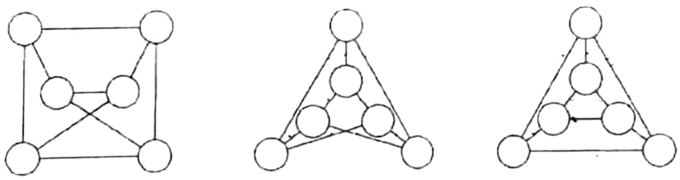
(b) Show that there exists a simple graph with 12 vertices and 28 edges such that degree of each vertex is either 3 or 5. **[5]**

Q3. Identify whether the following graph is Bipartite :



Obtain the complement of the Graph? Is the complement bipartite? **[6]**

Q4. Determine if the following three graphs are isomorphic **[3]**



(a) (b) (c)

Q5. Show that the sum of the diagonal elements of the second power of adjacency matrix is twice the number of edges of the graph. **[4]**

Q6. Show that tree is a bipartite graph **[3]**

Convex Optimization

C3

Time: 2 hrs

MM 100

Note: *Attempt all questions*

1. Consider the optimization problem

$$\min x^2 + 1$$
$$\text{subject to } (x - 2)(x - 4) \leq 0.$$

i. Is the problem convex? Give the feasible set.
ii. Is Slater's condition satisfied?
iii. Find the primal optimal value, and primal optimal point(s).
iv. Find the Lagrangian and the Lagrange dual function.
v. State the dual problem.
vi. Find the dual optimal value, and dual optimal point(s).
vii. Verify that strong duality holds. Can you conclude this directly?

2. Consider the constrained minimization problem

$$\min (x_1 - 1)^2 + x_2 - 1$$
$$\text{subject to } x_2 - x_1 = 1$$
$$x_2 + x_1 \leq 2$$

i. Write the Karush-Kuhn-Tucker conditions for the above problem.
ii. Use these conditions to find the optimal point(s) and optimal value.

3. Consider the following problem.

$$f(x, y) = \exp\left(-\frac{1}{3}x^3 + x - y^2\right)$$

Suppose you want to do it using pure Newton's method. Is $x_0 = \begin{bmatrix} -1 \\ -1 \end{bmatrix}$ good starting point?

4. Consider the function $f(x) = (2x_1 + x_2^2)^2$

i. Compute the gradient of $f(x)$.
ii. At the point $s = [0;\ 1]^T$, we consider the search direction $d = [1;\ -2]^T$. Show that d is a descent direction.
iii. Assume we do a line search from the point s in the direction of d. Find the stepsize α that minimizes $f(s + \alpha d)$. For the optimal α, find the value $f(s + \alpha d)$.
iv. Compute the Hessian of $f(x)$.
v. Run one Newton's step with fixed stepsize $t = 1$ starting from $s = [0;\ 1]^T$. What is the resulting $f(x)$? Does this outperform the method considered in (iii)?

Convex Optimization
MTech 2nd semester and BTech 6th Semester
C2 Review -2022

MM: 100	Time: 60 minutes
Note: Attempt all questions. For objective questions, a brief explanation is necessary. • A correct choice with no explanation – Zero marks • A correct choice with correct explanation – Full marks • A correct choice with wrong explanation – Negative marks ? • Wrong Choice – Zero marks	

1.	A point x minimizes a convex, differentiable function f over a convex set C if and only if: ☐ a. $\nabla f(x)^T(y-x) \geq 0$ for all $y \in C$; ☐ b. $\nabla f(x)^T(x-y) \geq 0$ for all $y \in C$; ☑ c. $f(y) \geq f(x) + \nabla f(y)^T(y-x)$ for all $y \in C$; ☐ d. $(\nabla f(y) - \nabla f(x))^T(x-y) \geq 0$ for all $y \in C$.
2.	The dual of a linear program is another linear program. ☐ True ☐ False
3.	A linear program can have duality gap equal to 1. ☐ True ☐ False
4.	The dual of a quadratic program is another quadratic program. ☐ True ☐ False
5.	Strong duality always holds in a convex optimization problem. ☐ True ☐ False
6.	The dual problem is always easier to solve than the primal, but it is simply not always calculable. ☐ True ☐ False
7.	The dual is always a convex optimization problem, no matter the original primal problem. ☐ True ☐ False
8.	Strong duality, in convex optimization: ☐ a. holds for LPs, but not in generality, beyond this class; ☐ b. holds for LPs and QPs, but not in generality, beyond these classes; ☐ c. holds when there exists a strictly feasible point (satisfies all inequality constraints strictly, and satisfies equality constraints); ☐ d. always holds.
9.	The dual problem: ☐ a. always has more variables than the primal; ☐ b. always has less variables than the primal; ☐ c. is always easier to solve than the primal, but it is simply not always calculable; ☐ d. none of the above.
10.	Expressing a primal solution in terms of a dual solution can be done with: ☐ a. the KKT primal and dual feasibility conditions; ☐ b. the KKT complementary slackness condition, under strong duality; ☐ c. the KKT stationarity condition, always; ☐ d. the KKT stationarity condition, under strong duality.

11. The KKT conditions are sufficient for optimality, even for a nonconvex optimization problem.

☐ True

☐ False

12. The KKT conditions give a direct solution to the problem of minimizing a quadratic function subject to equality constraints.

☐ True

☐ False

13. If f is strictly convex, then $\nabla f^*(y) = \mathrm{argmin}_x\,(f(x) - y^T x)$.

☐ True

☑ False

14. The dual of $\min_x\ f(x) + g(x)$, in terms of the conjugates f^*, g^* of f, g, respectively, is:

☐ a. $\max_u\ f^*(u) + g^*(-u)$;

☐ b. $\max_u\ f^*(u) + g^*(u)$;

☐ c. $\max_u\ -f^*(u) - g^*(u)$;

☐ d. $\max_u\ -f^*(u) - g^*(-u)$.

15. The conjugate f^* of $f(x) = \frac{1}{2}x^T Q x$, where $Q \succ 0$, is defined by:

☐ a. $f^*(y) = -\frac{1}{2}y^T Q^{-1} y$;

☑ b. $f^*(y) = \frac{1}{2}y^T Q^{-1} y$;

☐ c. $f^*(y) = \frac{1}{2}y^T Q y$;

☐ d. none of the above.

16. If f is convex and closed, then $y \in \partial f(x) \iff x \in \partial f^*(y)$.

☐ True

☐ False

17. For a problem of the form $\min_x\ f(x) + g(Ax)$, duality can "shift" the appearance of the linear transformation A, meaning that A will appear in the conjugate of f in the dual criterion, rather than in the conjugate of g.

☐ True

☐ False

18. The conjugate f^* of a function f is always convex.

☑ True

☐ False

19. Which of the following statements comparing Newton's method and gradient descent is not accurate (for convex problems)?

☐ a. One Newton iteration is typically more computationally costly than one gradient descent iteration.

☐ b. Newton's method has faster local rate of convergence under suitable assumptions.

☐ c. Each Newton step can be viewed as an exact minimization of a suitable quadratic approximation, whereas that is not the case for gradient descent.

☑ d. In both Newton's method and gradient descent, we can use backtracking to ensure global convergence.

20. Generally speaking, Newton's method can be used for: a. finding the roots of a nonlinear equation, b. minimizing a function. These ideas are completely separate (they don't have any relationship).

☐ True

☑ False

21. Compared to gradient descent, Newton's method, roughly speaking:

☑ a. uses more accurate quadratic approximations, admits more expensive iterations, but requires fewer iterations to converge to high accuracy;

☐ b. uses less accurate quadratic approximations, and cheaper iterations, so it requires more iterations to converge to high accuracy;

☐ c. uses cubic approximations, and its iterations and convergence are not really comparable to gradient descent;

☐ d. only approximates the smooth part of the criterion by a quadratic, and thus applies to a broader class of nonsmooth optimization problems.

22.	Pure Newton's method (with step sizes equal to 1) will always converge on a convex function. ☐ True ☐ False
23.	Let f^* denote the optimal criterion value of the convex problem $$\min_x f(x) \text{ subject to } h_j(x) \le 0,\ j = 1, \dots, m,$$ and $x^*(t)$ denote the solution in the barrier problem $$\min_x tf(x) + \phi(x).$$ Then $f(x^*(t)) - f^* \le m/t$. ☐ True ☐ False
24.	Each main iteration of the barrier method performs just one one Newton update. ☐ True ☐ False
25.	The main idea behind the barrier method is add terms to the criterion that: ☐ a. smoothly approximate indicator functions of the constraints; ☐ b. make the new criterion strongly convex; ☐ c. make the new criterion smooth; ☐ d. get rid of equality constraints.
26.	The barrier method solves the problem: $$\min_x f(x) \text{ subject to } h_j(x) \le 0,\ j = 1, \dots, m,$$ by solving a: ☐ a. single problem of the form $\min_x (tf(x) + \phi(x))$, where $\phi(x) = -\sum_{j=1}^m \log(-h_j(x))$ and $t > 0$; ☐ b. sequence of problems of the form $\min_x (t_k f(x) + \phi(x))$. where $\phi(x) = -\sum_{j=1}^m \log(-h_j(x))$ and $t_k \to \infty$; ☐ c. sequence of problems of the form $\min_x (t_k f(x) + \phi(x))$, where $\phi(x) = -\sum_{j=1}^m \log(-h_j(x))$ and $t_k \to 0$; ☐ d. sequence of problems of the form $\min_x (t_k f(x) + \phi(x))$, where $\phi(x) = \sum_{j=1}^m \log(-h_j(x))$ and $t_k \to \infty$; ☐ e. sequence of problems of the form $\min_x (t_k f(x) + \phi(x))$, where $\phi(x) = \sum_{j=1}^m \log(-h_j(x))$ and $t_k \to 0$.
27.	For constrained convex minimization, barrier methods approach the solution from the outside of the constraint set. ☐ True ☐ False
28.	Which of the following statements about the barrier method and the primal-dual interior-point method is not true (for convex problems)? ☐ a. Both barrier method and primal-dual interior-point method can be interpreted as solving a perturbed version of the KKT conditions. ☐ b. Both methods have local $O(\log(1/\epsilon))$ rate of convergence. ☐ c. Primal-dual interior-point method is more commonly used in practice because it tends to be more efficient. ☐ d. Both methods perform just one Newton update before taking a step along the central path (adjusting the barrier parameter t).
29.	The iterates of the primal-dual interior-point method are always primal and dual feasible. ☐ True ☐ False

30. Which of the following statements about the barrier method and the primal-dual interior-point method is not true (for convex problems)?

- ☐ a. Both barrier method and primal-dual interior-point method can be interpreted as solving a perturbed version of the KKT conditions.
- ☐ b. Both require solving a linear system at the lowest level of iteration.
- ☐ c. Both methods have local $O(\log(1/\epsilon))$ rate of convergence.
- ☐ d. Both yield feasible primal and dual iterates at every step.

31. DFP and BFGS differ in that only one of them satisfies the secant equation.

- ☐ True
- ☐ False

32. DFP and BFGS differ in that only one of them preserves positive definiteness (of the approximated Hessian, from one iteration to the next).

- ☐ True
- ☐ False

33. In the DFP and BFGS updates, each update on the approximation to the Hessian matrix and its inverse are:

- ☐ a. symmetric rank-one updates for both the Hessian and its inverse;
- ☐ b. symmetric rank-two updates for both the Hessian and its inverse;
- ☐ c. a symmetric rank-one update for the Hessian and a rank-two update for its inverse;
- ☐ d. a symmetric rank-two update for the Hessian and a rank-one update for its inverse.

34. In the barrier method, at any point $x(t)$ along the central path we can always construct points $u(t), v(t)$ that are feasible for the dual of the original optimization problem.

- ☐ True
- ☐ False

~~40~~ Consider a convex optimization problem

$$\begin{array}{ll} \text{minimize} & f_0(x) \\ \text{subject to} & f_i(x) \leq 0, \quad i = 1, \ldots, m \\ & Ax = b, \end{array}$$

that satisfies Slater's constraint qualification.

35 The primal and dual problems have the same objective value.

a. True.

b. False.

36 The primal problem has a unique solution.

a. True.

b. False.

37 The dual problem is not unbounded.

a. True.

b. False.

38 Suppose $x^\star$ is optimal, with $f_1(x^\star) = -0.2$. Then for every dual optimal point $(\lambda^\star, \nu^\star)$, we have $\lambda_1^\star = 0$.

a. True.

b. False.

39 Write down the KKT conditions for a convex program

Indian Institute of Information Technology, Allahabad
Aug-Dec 2022 – C1 Exam
Deep Learning (DL)

Max. Marks: 20

Instructions:

- The Electronic Materials such as **calculator, phone, laptop,** etc. are not allowed.
- Write your answers *very precisely and to the point only.*
- Attempt all questions. All parts of a question should be attempted at the same place.
- Do not follow any malpractice during the examination.
- Attach this question paper with answer sheet.

Q1. [5 Marks] Multiple Choice Questions (Write only one most suitable answer)

1. [1 Mark] Which of the following functions can be used as the class score layer to generate the probabilities for n classes (p1, p2, ..., pn) such that sum of p over all n equals to 1?
(a) Softmax (b) ReLU (c) Sigmoid (d) Tanh

2. [1 Mark] You are solving the binary classification task of classifying images as cat vs. non-cat. You design a CNN with a single output neuron. Let the output of this neuron be z. The final output of your network, y' is given by: y' = Sigmoid(ReLU(z)). You classify all inputs with a final value y' ≥ 0.5 as cat images. What problem are you going to encounter?
(a) All the inputs will be classified as cat.
(b) There will not be any problem.
(c) All the inputs will be classified as non-cat.
(d) Cat inputs will be classified as non-cat and non-cat inputs will be classified as cat.

3. [1 Mark] Which of the following propositions are true about a CONV layer?
(a) The number of biases is equal to the number of input channels.
(b) The total number of parameters depends on the stride.
(c) The number of weights depends on the depth of the input volume.
(d) The total number of parameters depends on the padding.

4. [1 Mark] Which statement is true for a neural network?
(a) Neural network cannot handle the non-linearity
(b) More number of neurons increases the capacity of the network
(c) Neural network is same as the SVM
(d) Neural network is made with only one hidden layer

5. [1 Mark] Which one of the following is a regularization technique?
(a) Xavier Initialization
(b) Batch Normalization
(c) ReLU
(d) Adam

Q2. [5 Marks] Classifiers

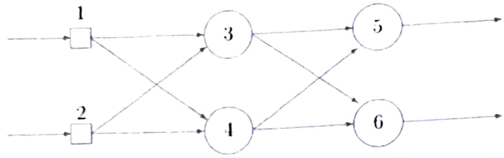
a) [2 Marks] Explain K-Nearest Neighbor classifier. What is role of *k* in KNN? Explain with the help of example.

b) [2 Marks] How non-linearity is introduced in non-linear SVM? What is kernel trick in non-linear SVM?

c) [1 Mark] Compare Softmax classifier with SVM classifier.

Q3. [5 Marks] Neural Networks

a) [2 Marks] The following diagram represents a feed-forward neural network with one hidden layer:



A weight on connection between nodes i and j is denoted by w_{ij}, such as w_{13} is the weight on the connection between nodes 1 and 3. The following table lists all the weights in the network:

$w_{13} = -2$	$w_{35} = 1$
$w_{23} = 3$	$w_{45} = -1$
$w_{14} = 4$	$w_{36} = -1$
$w_{24} = -1$	$w_{46} = 1$

Each of the nodes 3, 4, 5 and 6 uses the following activation function:

$$\varphi(v) = \begin{cases} 1 & \text{if } v \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

where v denotes the weighted sum of a node. Each of the input nodes (1 and 2) can only receive binary values (either 0 or 1). Calculate the output of the network (y_5 and y_6) when the input is 1 for Node 1 and 0 for Node 2. Consider no bias in the network.

b) [1 Mark] What is role of activation function in deep learning?

c) [2 Marks] Explain ReLU activation function with Equation and Characteristics diagram.

Q4. [5 Marks] Convolutional Neural Networks

a) [2 Marks] Explain Convolutional Neural Networks (CNN) for image classification with diagram. Why CNN is better suited for image data?

b) [3 Marks] What will be the output size and no. of parameters in the following scenario:

i) Input volume: 30x30x256. Use Max pooling layer having 2x2 kernel size with stride 2 and pad 0.

ii) Input volume: 128x128x3. Use Batch Normalization layer.

iii) Input volume: 16x16x16. Use Conv layer having 8 5x5 filters with stride 2 and pad 2.

Indian Institute of Information Technology, Allahabad
Aug-Dec 2022 – C3 Exam
Deep Learning (DL)

Max. Marks: 40 **Duration:** 3 Hours

Instructions:

- The Electronic Materials such as **calculator, phone, laptop,** etc. are not allowed.
- Write your answers very precisely and to the point only.
- Attempt all questions. All parts of a question should be attempted at the same place.
- Do not follow any malpractice during the examination.

Q1. [5 Marks] Classifier

a) [3 Marks] What is logistic regression? If the objective function of logistic regression is given as $(-\log \sigma(y_i w^T x_i))$, where x_i and y_i are the input sample and class label, w is the parameter and σ is a sigmoid function. Then derive the update rule for parameter w using SGD. Use η as learning rate.

b) [2 Marks] Explain the role of Bias and Variance in deep learning with diagrams and examples.

Q2. [5 Marks] Neural Networks

Explain the followings in deep learning:

a) [1 Mark] Dropout

b) [1 Mark] Batch Normalization

c) [1 Mark] Parametric ReLU

d) [1 Mark] Problems with Vanilla SGD

e) [1 Mark] Weight Initialization

Q3. [5 Marks] Convolutional Neural Networks

a) [2.5 Marks] Explain squeeze and excitation network with diagram. Why it can lead to better performance?

b) [1.5 Marks] Explain the advantage of using 3 Conv layers with 3×3 kernels instead of 1 Conv layer with 7×7 kernels with diagrams and examples.

c) [1 Mark] What will be the output size and no. of parameters in the following scenario:

i) Input volume: 128x128x3. Use Conv layer having 64 7x7 filters with stride 3 and pad 1.

ii) Input volume: 30x30x256. Use Max pooling layer having 2x2 kernel size with stride 2 and pad 0.

Q4. [5 Marks] CNN Architectures

a) [2 Marks] Explain ResNet model with diagram.

b) [1 Mark] How skip connection leads to better optimization of deep ResNet models?

c) [2 Marks] Explain the concept of inception module with diagram.

Q5. [5 Marks] Object Detection/Segmentation

a) [2 Marks] Explain Faster R-CNN model for object detection with the help of diagrams.

b) [1 Mark] How Faster R-CNN is different from Fast R-CNN?

c) [2 Marks] Explain U-Net architecture for semantic segmentation with diagrams.

Q6. [5 Marks] Generative Adversarial Network

a) [3 Marks] Explain Generative Adversarial Network with diagram and objective function. Clearly mention the role of different networks.

b) [2 Mark] Highlight the limitations of Pix2Pix model. How CycleGAN tackles these problems?

Q7. [5 Marks] Recurrent Neural Networks

a) [3 Marks] Explain Gated Recurrent Unit (GRU) with diagrams. Clearly mention the purpose of different Gates in GRU.

b) [2 Marks] Explain how RNN based models can be used for sentiment classification with diagrams and examples.

Q8. [5 Marks] Attention in RNN

a) [3 Marks] Explain sequence-to-sequence with RNNs and attention with diagrams. Clearly mention the purpose of attention in sequence-to-sequence model.

b) [2 Marks] Explain how attention can be utilized for image captioning problem using RNN based models with diagram and example.

<u>**C3 Review Test, 2022**</u>

Paper Title: Graph Theory

Max Marks: 60 **Duration: 2 hours**

Answer All questions. The marks for each question has been provided alongside.

Q1. (a) State True or False (with Justification): **[5+5=10]**

i. A matching M in a graph G=(V,E) is a maximum matching if and only if there is no M-augmenting path in G

ii. A disconnected simple acyclic graph does not have a spanning tree.

iii. The endpoints of a cut-edge are both cut-vertices.

Q1. (b) For each situation, would you find an Euler circuit or a Hamilton Circuit?

i. The department of Public Works must inspect all streets in the city to remove dangerous debris.

ii. Relief food supplies must be delivered to eight emergency shelters located at different sites in a large city.

iii. The Department of Public Works must inspect traffic lights at intersections in the city to determine which are still working.

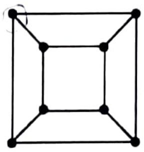
Q2. (a) For each of the graphs : K_n, P_n, C_n and W_n, **[6+3+3+3=15]**
Give the order, the size, the maximum degree and the minimum degree in terms of n.

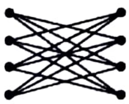
Q2. (b) Draw a bipartite graph of order 6. Give its adjacency list and a drawing.

Q2. (c) Consider the graphs G1 = (V1; E1) and G2 = (V2; E2). Give the order, the degree of the vertices and the size of G1 × G2 in terms of those of G1 and G2.

Q2. (d) Prove or give a counterexample: any two graphs with the same degree sequence are isomorphic

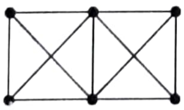
Q3. Consider the following graphs : **[5]**





(a) Do they have an Eulerian circuit? **(b)** Do they have an Hamiltonian Cycle?
(c) Exhibit a matching if they have?

Q4. (a) Is this graph a planar graph? Justify. **[3+2+2+3=10]**



(b) Give the line graph of C_5 and G = ({1, 2, 3, 4, 5}; {1 2 , 2 3 , 2 4 , 2 5 , 3 4; 3 5 , 4 5})

(c) Find the diameter (maximum of all vertex eccentricities) of the Peterson's graph.

(d) Give a connected graph G = (V, E) and a vertex u ∈ V for the following relation :

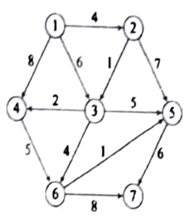
D(G) = D(G − u). D is the diameter of G (maximum of all vertex eccentricities)

Q5. (a): Let us consider the graph whose adjacency list is given. **[5+5+5=15]**

a	b	c	d	e	f	g	h	i	j
d	d	h	a	a	a	b	c	b	b
e	g		b	d	d	i		g	g
f	i		e			j			
	j		f						

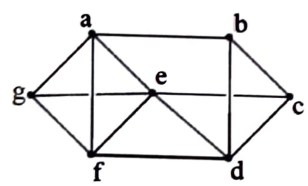
i. Draw the graph
ii. Using the algorithm BFS, find the distance from the vertices a and b to each of the other vertices of the connected component to which they belong
[Note : You are expected to show the BFS traversal as intermediary steps for distance computation]

Q5.(b) Using the Dijkstra's algorithm, obtain the shortest distance and shortest path from vertex 1 in the network shown below :



Q5. (c) Prove that : Every tree with two or more vertices is 2-chromatic.

Q6. (a) Find the chromatic number of the following graph **[2+3=5]**



Q6.(b) For the following bipartite graph, provide the maximum matching, minimum vertex cover, maximum independent set and minimum edge cover