GWANDA STATE UNIVERSITY

FACULTY OF ENGINEERING AND THE ENVIRONMENT

DEPARTMENT OF MINING ENGINEERING

OPERATIONS RESEARCH

EMN 3106

Examination Paper

SEPTEMBER 2024

This examination paper consists of 8 printed pages

Time Allowed: **3 hours**

Total Marks: **100**

Examiner's Name: **Mr. R. G. Moyo**

INSTRUCTIONS

Candidates should answer **ALL** questions in section A and **THREE** questions in section B.

ADDITIONAL REQUIREMENTS

Scientific calculator

SECTION A (40 marks)

Answer ALL questions from this section.

A1. Define the following terms

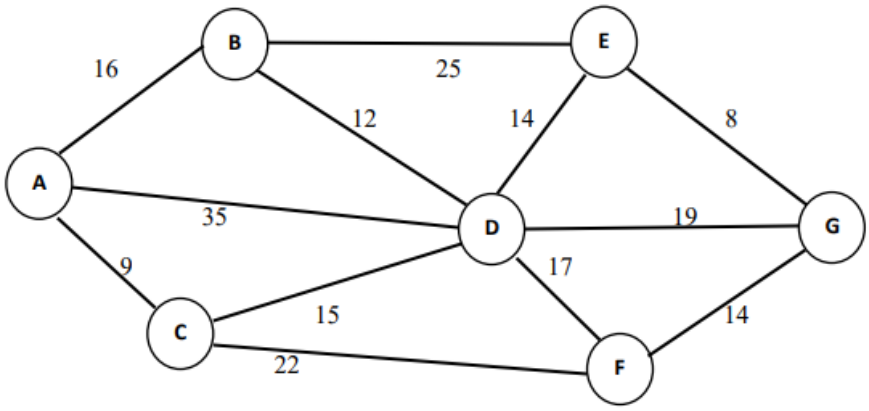
(i) Maximal flow [2]

(ii) Maximum crushing [2]

(iii) Post optimality test [2]

(iv) Critical path [2]

A2. The Coalmine Co. is planning to lay a water pipeline network to provide water supply to various mining sites in a remote region. The nodes of the network represent the mining sites that need to be connected, and the arcs represent the distance (in km) between the sites. The company wants to find the minimum length of the pipeline required to connect all the mining sites.
Given the following network diagram, determine the minimal spanning tree that will allow Coalmine Co. to reach all the mining sites with the minimum length of the primary pipeline. [6]



A3. Progress Mining Company produces three types of mining equipment: Drill A, Drill B, and Shovel C. Each equipment type requires a certain amount of labor, machine time, and raw materials. The company wants to determine the optimal production plan to maximize its total profit.Given the following information:

Profits: Drill A: profit of $50,000 per unit
Drill B: profit of $75,000 per unit
Shovel C: profit of $60,000 per unit

Resource Requirements:
Labor: 20 hours per unit of Drill A, 30 hours per unit of Drill B, 25 hours per unit of Shovel C

Machine time: 40 hours per unit of Drill A, 50 hours per unit of Drill B, 45 hours per unit of Shovel C
Raw materials: 500 pounds per unit of Drill A, 800 pounds per unit of Drill B, 600 pounds per unit of Shovel C

Available Resources per Month:
Labor: 12,000 hours
Machine time: 15,000 hours
Raw materials: 40,000 pounds

(i) Formulate, without solving it, the linear programming model for the above scenario so as to maximize the total profit. Do not solve the problem. [6]

(ii) Use **APPENDIX A** to write a report advising Progress Mining Company on the mining equipment they should produce. On your report highlight the expected profits, units they should produce per equipment, comments on shadow prices, allowable increases and allowable decreases. [20]

SECTION B (60 marks)

Answer ANY THREE questions from this section.

B4. A construction company has just made the winning bid of \$5.4 million to construct a new plant for a major mining company. The mining company need the plant to go into operation within a year, so the contract includes the following provisions:

- A penalty of \$300 000 if the company has not completed construction by the deadline of 47 weeks from now.
- To provide additional incentive for speedy construction, a bonus of \$150 000 will be paid to the construction company if the plant is completed within 40 weeks.

The information about the activities of the plant is provided in the following table. Duration given is in weeks.

Activity	Immediate Predecessors	Normal Duration	Crash Duration	Normal Cost(\$)	Crash Cost(\$)
A	-	2	1	180 000	280 000
B	A	4	2	320 000	280 000
C	B	10	7	620 000	420 000
D	C	6	4	260 000	340 000
E	C	4	3	410 000	570 000
F	E	5	3	180 000	260 000
G	D	7	4	900 000	1 020 000
H	E,G	9	6	200 000	380 000
I	C	7	5	210 000	270 000
J	F,I	8	6	430 000	490 000
K	J	4	3	160 000	200 000
L	J	5	3	250 000	350 000
M	H	2	1	100 000	200 000
N	K,L	6	3	330 000	510 000

(i) Draw the network diagram for this problem and calculate the critical path. [7]

(ii) Make a cost analysis of the problem and calculate the least expensive way of crashing the above activities. [13]

B5. (i) Define degeneracy in transportation problem problem and state when it can occur. [3]

(ii) Trukumb Mines is a registered mining company based in Filabusi, Zimbabwe. The company has three gold processing plants (destinations) and three gold ore extraction sites (source). Each day, the company is expected to transport gold ore extracted from the extraction sites to the processing plants. The mine extracts 40 tonnes, 20 tonnes and 40 tonnes of gold ore per day from site 1, 2, 3 respectively. The processing capacity of plants A, B and C are given as 25 tonnes, 55 tonnes

SOURCE	Destination A	Destination B	Destination C	SUPPLY
1	10	7	8	**40**
2	15	12	9	**20**
3	1.3	1.81	1.8	**40**
DEMAND	**25**	**55**	**20**	

and 20 tonnes per day respectively. The transportation costs(in $s) per tonne are summarized in the table.

Find the optimum transportation schedule and minimum total cost of transportation using

(a) Least cost Method [3]

(b) North-west corner method [3]

(c) Vogel approximation method [5]

(iii) Is the solution obtained using the Vogels' approximation method optimal? Justify your answer. [6]

B6. During the first semester of each year, mining engineering students' arrival for equipment distribution at Gwanda State University follow a Poisson probability distribution, with a mean arrival rate of 24 students per hour, and the service times follow an exponential probability distribution. Arriving students get the required mining equipment and then go to the service window to pay for the equipment. The following three service alternatives are being considered:

- A single-channel operation where one employee distributes the mining equipment and receives the payment from the students. The average service time for this alternative is 2 minutes.
- A single-channel operation where one employee distributes the mining equipment and a second employee collects the payment from the student. The average service time for this alternative is 1.25 minutes.
- A two-channel operation with two service windows and two employees. The employee stationed at each window distributes the mining equipment and collects the payment. The average service time for this alternative is 2 minutes for each channel.

(i) Complete the following operating characteristics for each alternative:

(a) The probability that there are no students in the system [4]

(b) The average number of students waiting for service [4]

(c) The average time a student waits for service. [4]

(ii) What is the lowest-cost design for the equipment distribution process if the following cost information is available? [8]

- Students' waiting time is valued at $25 per hour to reflect that waiting time is costly to the university.

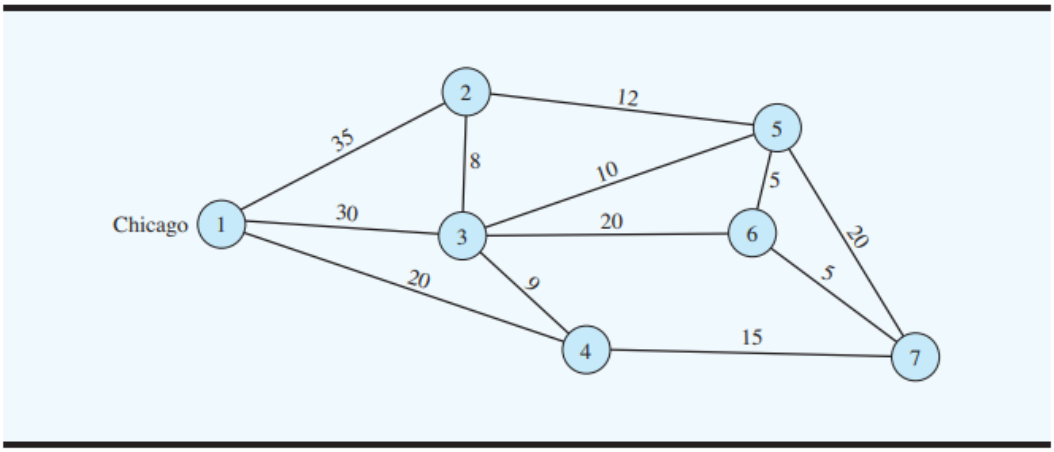
- The cost of each employee is \$6.50 per hour.
- To account for equipment and space, additional costs of \$20 per hour is attributed to each channel.

B7. (i) Suppose that a mining company has 4 different types of heavy machinery (excavators, bulldozers, haul trucks, and loaders) and 4 mining sites that require these machines. Each type of machine has a different efficiency score at each site, based on factors like terrain, material characteristics, and operator experience. We want to assign the machines to the sites in a way that maximizes the overall efficiency. The efficiency scores for each machine-site pair are shown in the following table:

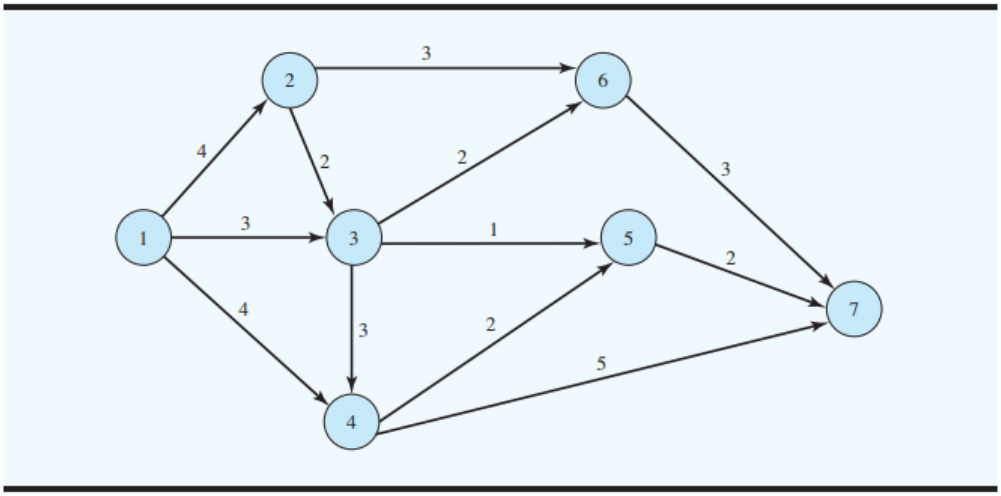
	Site A	**Site B**	**Site C**	**Site D**
Excavator	8	6	7	5
Bulldozer	7	9	6	8
Haul Truck	6	7	8	7
Loader	8	7	6	6

Use the Hungarian Method to assign the 4 machinery to 4 sites so as to maximize the overal efficiency. [7]

(ii) Find the shortest route of the following network diagram from Chicago to all other nodes using the Dijkstra's Algorithm [7]



(iii) A mining company uses a network of conveyor belts to transport ore and other materials between different processing facilities at a mining site. The capacity of each conveyor belt segment is shown in thousands of metric tons that can be transported per hour. A portion of the company's material transportation network is shown in the following diagram:



To keep up with the high volume of materials that need to be transported between the various processing facilities, the mining company wants to determine the maximum amount of material that can be transported from the facility located at node 1 to the facility located at node 7.

Use the given network information to calculate the maximum number of metric tons of material that can be transported per hour from the facility at node 1 to the facility at node 7 using the Ford-Fulkerson method. [6]

END OF QUESTION PAPER

APPENDIX A

Microsoft Excel 16.0 Answer Report

Objective Cell (Max)

Cell	Name	Original Value	Final Value
$B$15	Maximize total Profit Drill A	4000000	4000000

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$B$13	Equipment Produced Drill A	0	0	Contin
$C$13	Equipment Produced Drill B	0	0	Contin
$D$13	Equipment Produced Shovel C	0	66.66666667	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$B$19	Labor Resources used	1666.666667	$B$19<=$D$19	Not Binding	10333.33333
$B$20	Machine Time Resources used	3000	$B$20<=$D$20	Not Binding	12000
$B$21	Raw materials Resources used	40000	$B$21<=$D$21	Binding	0

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$B$13	Equipment Produced Drill A	0	0	50000	0	1E+30
$C$13	Equipment Produced Drill B	0	-5000	75000	5000	1E+30
$D$13	Equipment Produced Shovel C	66.66666667	0	60000	1E+30	0

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$B$19	Labor Resources used	1666.666667	0	12000	1E+30	10333.33333
$B$20	Machine Time Resources used	3000	0	15000	1E+30	12000
$B$21	Raw materials Resources used	40000	100	40000	160000	40000

Cell	Variable Name	Value	Lower Limit	Objective Result	Upper Limit	Objective Result
$B$13	Equipment Produced Drill A	0	0	4000000	1.45519E-14	4000000
$C$13	Equipment Produced Drill B	0	0	4000000	9.09495E-15	4000000
$D$13	Equipment Produced Shovel C	66.66666667	0	0	66.66666667	4000000