Roll No. : …….

Galgotias College of Engineering and Technology, Greater Noida

Pre University Test (PUT) : Odd Semester 2024-25

Course/Branch : B Tech - ME **Semester : V**
Subject Name : Industrial Engineering **Max. Marks : 100**
Subject Code : BME503 **Time : 180 min**

CO-1 *: On completion of this course content, the student will be able to understand the concepts of production system, productivity, facility location, plant layout, process planning and line balancing.*
CO-2 *: On completion of this course content, the student will be able to apply the various production planning, control and project measurement techniques.*
CO-3 *: On completion of this course content, the student will be able to apply the concept of break-even analysis, inventory control and resource utilization using queuing theory.*
CO-4 *: On completion of this course content, the student will be able to apply the principles of work study and ergonomics for design of work systems.*
CO-5 *: On completion of this course contents, the students will be able to formulate the mathematical model for solution of industrial problems using linear programming and transportation and assignment model.*

Section – A # 20 Marks (Short Answer Type Questions)

Attempt **ALL** the questions. Each Question is of 2 marks (10 x 2 = 20 marks)

Q. No.		COx	Question Description # Attempt **ALL** the questions. Each Question is of 2 marks	BK L
1	A	CO1	Explain the term "Productivity".	K_2
	B	CO1	Mention any four symptoms of a bad plant layout.	K_2
	C	CO2	Why the dummy activity incorporated in the network diagram?	K_2
	D	CO2	Describe the formula for forecasting through exponential smoothing method?	K_2
	E	CO3	Describe the methods of depreciation.	K_2
	F	CO3	Write about the various types of costs involved in inventory management.	K_2
	G	CO4	Differentiate between Method Study and Work Measurement.	K_2
	H	CO4	Explain concurrent engineering.	K_2
	I	CO5	Why the simplex method is preferred over graphical method in linear programming?	K_2
	J	CO5	Explain slack and surplus variables.	K_2

Section – B # 30 Marks (Long / Medium Answer Type Questions)

Attempt **ALL** the questions. Each Question is of 6 marks (5 x 6 = 30 marks)

Q.2 (CO-1) : Compare the Job-shop, Batch and Mass Production Systems. (K_2)

OR

Differentiate among rural, urban and semi-urban facility locations. (K_2)

Q.3 (CO-2) : The demand for particular product is given for the last 8 periods. Compute the exponential smoothed forecast for the periods taking $\alpha = 0.1$ and 0.3. Which one of these forecast is better? (K_3)

Period	1	2	3	4	5	6	7	8
Demand	10	18	29	15	30	12	16	8

OR

Differentiate between PERT and CPM. (K_2)

Q.4 (CO-3) : Derive the formula of Economic Order Quantity (EOQ) and its associated total cost. (K_2)

OR

A person repairing printer finds that the time spend on the printer has been exponential distributed with mean of 20 min. If the printers are repaired in the order in which they come in and their arrival is approximately Poisson with an average rate at 15 for 8-hour day, what is the repairman's expected idle time each day? How many jobs are ahead of the average set just brought in? (K_3)

Q.5 (CO-4) : Explain the Product Life Cycle. (K_2)

OR

The direct time-study data of an acid mining operation is given below. The rating of workers is 80%. Compute the standard time (consider allowance fraction as 0.1). (K_3)

Cycle Time (min)	2.7	2.7	2.9	3.1	3.2
No of Cycles Observed	3	4	2	1	1

Q.6 (CO-5) : Two products A and B are to be machined on 3 machines, M1, M2 and M3. Product A takes 10 hours on machine M1, 6 hours on machine M2 and 5 hours on machine M3. The product B takes 7.5 hours on machine M1, 9 hours on machine M2 and 13 hours on machine M3. The available machining time (weekly) for machine M1 is 75 hours, for machine M2 is 54 hours and for machine M3 is 65 hours. The products contemplate profit of Rs 80 per product A and Rs 100 per product B. Formulate the LP model for maximum profit and show the feasible region graphically. Find the optimal solution. (K_3)

OR

Use Vogel's approximation method to obtain an initial feasible solution for the given transportation problem : (K_3)

	D1	D2	D3	D4	Availability
S1	11	13	17	14	250
S2	16	18	14	10	300
S3	21	24	13	10	400
Demand	200	225	275	250	

Section – C # 50 Marks (Medium / Long Answer Type Questions)

Attempt **ALL** the questions. Each Question is of 10 marks.

Q.7 (CO-1) : Attempt any ONE question. This question is of 10 marks.

a. Explain various types of plant layouts. (K_2)

b. Design an assembly line for a cycle time of 9 minutes for the following 12 work elements : (K_3)

Element	1	2	3	4	5	6	7	8	9	10	11	12
Immediate Precoder	-	1	2	1	4	3,5	6	7	6	6	10	8, 9, 11
Duration (min)	5	4	4	3	6	5	2	6	1	4	4	9

Draw the precedence diagram and find the line efficiency (not less than 75%) with smoothness index.

Q.8 (CO-2) : Attempt any ONE question. This question is of 10 marks.

a. Describe "Aggregate Production Planning and MRP" or "Master Production Schedule and JIT". (K_2)

b. A project has eight activities, as per given table. Construct the network from given information and compute critical path, showing slack for each activity in a tabular form. (K_3)

Activity	P	Q	R	S	T	U	V	W
Immediate Predecessor	-	-	-	R	P,Q	T,S	S	U,V
Activity Time (weeks)	12	20	28	12	28	12	8	8

Q.9 (CO-3) : Attempt any ONE question. The question is of 10 marks.

a. A manufacturer has to supply his customers with 1200 units of his product per annum. The inventory carrying cost amounts to Rs 1.2 per unit. The set-up cost per run is Rs 160. Find : (K_3)

i) EOQ ii) Minimum average yearly cost

iii) Optimum no of orders per year iv) The optimum time between orders

b. Describe the Kendall's notations for representing the queuing model. (K_2)

Q.10 (CO-4) : Attempt any TWO questions. Each question is of 5 marks.

a. Explain Miniaturization. (K_2)

b. Explain any four Therblig. (K_2)

c. Describe Allowances provided in time-study. (K_2)

Q.11 (CO-5) : Attempt any ONE question. This question is of 10 marks.

a. Solve the given problem using Simplex method : (K_3)

Maximize $Z = 4 X_1 + 10 X_2$

Subject to constraints : $2 X_1 + X_2 \leq 50$

$2 X_1 + 5 X_2 \leq 100$

$2 X_1 + 3 X_2 \leq 90$

Where, X_1 and X_2 are ≥ 0

b. Allocate the sub-assembly to the contractor on one-to-one basis for low-cost bid (minimum total cost). The concerned matric is given below : (K_3)

	Contractors				
		1	2	3	4
Sub-assemblies	1	15	13	14	17
	2	11	12	15	13
	3	13	12	10	11
	4	15	17	14	16

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SOLUTION

Section – A # 20 Marks (Short Answer Type Questions)

Q. No.		Question Description # Attempt **ALL** the questions. Each Question is of 2 marks
1	**A**	**Explain the term "Productivity".** **Solution :** Productivity is the ratio of output produced to the input used. Essentially, productivity assesses how effectively resources like labor, capital, and materials are utilized to generate output.
1	**B**	**Mention any four symptoms of a bad plant layout.** **Solution :** A poor plant layout can lead to numerous operational inefficiencies and problems. Major symptoms are : a. Excessive Material Handling b. High Work-in-Progress Inventory c. Inefficient Workflow d. Congestion and Bottlenecks e. Poor Utilization of Space f. Long Lead Times g. Frequent Accidents and Complaints h. High Labour Costs i. Increased Maintenance Costs j. Not Flexible
1	**C**	**Why the dummy activity incorporated in the network diagram?** **Solution :** Dummy activities are used to represent dependencies between tasks that do not involve the consumption of time or resources. They help in maintaining the correct logical relationships in the network diagram. They provide clarity in complex project schedules by ensuring that the sequence of tasks is accurately represented. Dummy activities ensure that all dependencies are uniquely and correctly identified.
1	**D**	**Describe the formula for forecasting through exponential smoothing method?** **Solution :** $F_t = \alpha \cdot A_{t-1} + (1-\alpha) \cdot F_{t-1}$ Where: • F_t = Forecast for the current period • α = Smoothing constant ($0 < \alpha < 1$) • A_{t-1} = Actual value (demand) of the previous period • F_{t-1} = Forecast for the previous period
1	**E**	**Describe the methods of depreciation.** **Solution :** Depreciation is the process of allocating the cost of a tangible asset over its useful life. It reflects the wear and tear, usage, or obsolescence of the asset. Straight-Line Depreciation is the simplest and most commonly used method. The asset's cost is evenly spread over its useful life. Depreciation Expense = (Cost of Asset−Residual Value) / Useful Life
1	**F**	**Write about the various types of costs involved in inventory management.** **Solution :** There are four major elements of inventory costs that should be taken for analysis, such as : a. Item cost, Rs. P/item b. Setup or Ordering cost, Rs. S / order c. Holding or Carrying cost Rs. H / item / unit time d. Shortage cost Rs. / item/Unit time.
1	**G**	**Differentiate between Method Study and Work Measurement.** **Solution :** The major differences are : a. Method Study focuses on improving how tasks are done, while Work Measurement focuses on how long tasks take.

Q. No.		Question Description # Attempt **ALL** the questions. Each Question is of 2 marks
		b. Method Study aims to enhance efficiency and reduce waste, whereas Work Measurement aims to set standard times for better planning and control. c. Techniques Used: Method Study uses process analysis tools like flow charts, while Work Measurement uses timing and statistical tools like time studies and work sampling.
1	**H**	**Explain concurrent engineering.** **Solution :** Concurrent engineering, also known as simultaneous engineering or integrated product development, is an approach to product design and development where various functional teams work together simultaneously (in parallel), rather than sequentially. This includes integrating design and manufacturing considerations, as well as incorporating feedback from testing and validation phases. This method is used to improve efficiency, reduce time-to-market, and enhance the overall quality of the final product.
1	**I**	**Why the simplex method is preferred over graphical method in linear programming?** **Solution :** **Simplex Method** can handle problems with any number of variables and constraints, making it suitable for complex, high-dimensional problems, provides precise numerical solutions while, **Graphical Method** is limited to problems with only two variables, as it relies on visualizing the feasible region and solution on a two-dimensional graph, not provide very precise solution. Further, **Simplex Method** can handle degeneracy, unboundedness and other special cases systematically, ensuring a reliable solution process.
1	**J**	**Explain slack and surplus variables.** **Solution :** Slack and surplus variables are used in linear programming to convert inequality constraints into equality constraints, making it easier to solve the problem using methods like the Simplex algorithm. **Slack variables** are added to less-than-or-equal-to (≤) constraints to convert them into equalities. They represent the unused or leftover resources in the constraint. **Surplus variables** are subtracted from greater-than-or-equal-to (≥) constraints to convert them into equalities. They represent the excess amount by which the constraint is surpassed.

Section – B # 30 Marks (Long / Medium Answer Type Questions)

Q.2 (CO-1) : Compare the Job-shop, Batch and Mass Production Systems.

Solution : The comparison among Job-shop, Batch and Mass Production Systems is as per following :

Parameter	Job-shop Production	Batch Production	Mass Production
Nature of Production	Custom or unique products	Small to medium-sized batches	Large-scale, continuous production
Product Variety	High variety, low volume	Moderate variety, moderate volume	Low variety, high volume
Flexibility	High flexibility to fulfil custom orders	Moderate flexibility	Low flexibility, standardized products
Production Process	Non-repetitive, variable processes	Repetitive but variable processes	Highly repetitive, standardized processes
Equipment	General-purpose, adaptable	General-purpose, some specialization	Specialized, dedicated machinery
Skill Level	Highly skilled labour	Moderately skilled labour	Low to moderately skilled labour
Lead Time	Long lead times due to customization	Moderate lead times	Short lead times, continuous flow
Setup Time	Long setup times for each job	Moderate setup times for each batch	Minimal setup time, continuous operation
Inventory Levels	Low levels of finished goods inventory	Moderate levels of finished goods inventory	High levels of finished goods inventory
Examples	Custom furniture, specialized machinery	Bakery items, clothing, electronics assembly	Automobiles, consumer electronics, packaged foods

Q.2 (CO-1) : Differentiate among rural, urban and semi-urban facility locations.

Solution :

Parameter	Rural Facility Location	Urban Facility Location	Semi-Urban Facility Location
Population Density	Low	High	Moderate
Land Cost	Low	High	Moderate
Infrastructure	Limited infrastructure, fewer amenities	Advanced infrastructure, ample amenities	Developing infrastructure, balanced amenities
Labor Availability	Limited access to skilled labour	Abundant access to skilled labour	Moderate access to skilled labour
Transportation	Less developed transportation network	Well-developed transportation network	Developing transportation network
Market Proximity	Far from major markets	Close to major markets	Relatively close to major markets
Operational Costs	Lower operational costs	Higher operational costs	Moderate operational costs
Regulatory Environment	Potentially lenient regulations	Strict regulations	Moderately strict regulations
Environmental Impact	Lower pollution and congestion	Higher pollution and congestion	Moderate pollution and congestion
Quality of Life	Peaceful, natural surroundings	Busy, fast-paced lifestyle	Balanced lifestyle, mix of urban and rural
Utilities and Services	May have limited utilities and services	Extensive utilities and services	Moderate availability of utilities and services
Expansion Opportunities	Often ample land for expansion	Limited land for expansion	Somewhat available land for expansion
Community Support	Strong community ties, local support	Diverse community, varied support	Moderate community ties and support

Q.3 (CO-2) : The demand for particular product is given for the last 8 periods. Compute the exponential smoothed forecast for the periods taking α = 0.1 and 0.3. Which one of these forecasts is better?

Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Demand	**10**	**18**	**29**	**15**	**30**	**12**	**16**	**8**

Solution : The formula for exponential smoothed forecast is => $F_t = \alpha \cdot D_{t-1} + (1-\alpha) \cdot F_{t-1}$. Here, F_t is the forecast of current period; F_{t-1} is the forecast of previous (current-1) period; and D_{t-1} is the demand (actual) of previous (current-1) period. To get best fit data, forecast is to be computed for all periods and absolute deviation in both the cases (α = 0.1 and 0.3) is to be calculated. Select that – whose mean of absolute deviation is less. Refer following table for calculations.
Let, the forecast of previous period as demand of previous period (same) – as it is not given.

Period	Demand (D_t)	Forecast (Ft) (at α = 0.1)	Absolute Deviation $\lvert(D_t - F_t)\rvert$	Forecast (Ft) (at α = 0.3)	Absolute Deviation $\lvert(D_t - F_t)\rvert$
1	10	10	0.0	10	0.0
2	18	10	8.0	10.0	8.0
3	29	10.8	18.2	12.4	16.6
4	15	12.6	2.4	16.3	1.3
5	30	12.9	17.1	13.3	16.7
6	12	14.6	2.6	18.0	6.0
7	16	14.3	1.7	13.8	2.2
8	8	14.5	6.5	14.8	6.8
Sum of Absolute Deviations ==>			56.5		57.5
Mean of Absolute Deviations ==>			56.5/8 = 7.06		57.5/8 = 7.19

Data - best fit - with lower mean value of absolute deviation. So, select α = 0.1 (Answer)

Q.3 (CO-2) : Differentiate between PERT and CPM.

Solution :

Parameter	PERT (Program Evaluation and Review Technique)	CPM (Critical Path Method)
Purpose	Used for planning and controlling projects with uncertain activity durations	Used for planning and controlling projects with known activity durations
Focus	Time-oriented, focusing on minimizing project duration	Cost-oriented, focusing on minimizing both time and cost
Activity Duration	Based on probabilistic estimates (optimistic, pessimistic, and most likely)	Based on deterministic estimates (known and fixed)
Application	Suitable for research and development projects with high uncertainty	Suitable for construction and engineering projects with predictable activities
Estimation	Uses three-time estimates (optimistic, most likely, pessimistic) to calculate expected duration	Uses a single time estimate for each activity
Network Diagram	Represented as an activity-on-arrow (AOA) network diagram	Typically represented as an activity-on-node (AON) network diagram
Critical Path	Identified based on expected activity durations and variance	Identified based on the longest path with the least flexibility in start and finish times
Variance Analysis	Provides a measure of the uncertainty and risk associated with the project duration	Focuses more on time-cost trade-offs and resource allocation
Flexibility	More flexible in handling changes in project schedules due to uncertainty	Less flexible as it assumes activity durations are fixed and known
Usage	Often used in projects where time is the primary concern and activities are uncertain	Commonly used in projects where cost optimization and resource management are critical

The choice between PERT and CPM depends on the nature of the project and the specific requirements for planning and control

Q.4 (CO-3) : Derive the formula of Economic Order Quantity (EOQ) and its associated total cost.

Solution : One of the important problems in inventory control is to balance the costs of holding inventories (holding costs) with the costs of placing orders for inventory replenishment (ordering costs). If a firm orders small quantity frequently its holding costs would be low but ordering costs will increase. On the other hand, in case the firm orders large quantities infrequently, its ordering costs will be low but holding costs would rise. A balance should be struck between the ordering costs and holding costs so as to minimize inventory costs. The EOQ (Economic Order quantity) approach is designed to achieve such a balance. Economic order Quantity or optimum order quantity is that size of the order where total inventory costs (holding costs + ordering costs) are minimized. It is also known as "Economic Lot Size". The EOQ approach is based on the following **assumptions** :

- Order costs, holding costs and unit price are known and constant.
- The rate of demand is known (is deterministic).
- Inventory replenishment is done instantaneously.
- No stock-out is allowed.
- Quantity discounts are not allowed – purchase price is constant.
- Lead time is known and fixed.
- Inventory is consumed at a constant rate.
- Lead Time is known and constant.
- Holding costs are proportional to value of stocks held, similarly, order cost varies proportionately with price.

Economic order quantity is defined as the order quantity against which total of OC and ICC is minimum. EOQ will be the order quantity where both ICC and OC curves interest each other. Here, the variables used are :

Q = number of units per order

Q^* = economic order quantity or optimal no. of units per order to minimize total cost

D = annual demand requirement (units per year)

P = cost of 1 unit of item

S = ordering (preparation or set-up) cost of each order

H = holding or carrying cost per unit per period of time

T = length of time between two successive orders

N = no. of orders or manufacturing runs per year

TC = Total Inventory cost

The optimal order quantity (EOQ) is at a point where the ordering cost = holding cost

Equation-1 : Annual ordering cost

Annual Setup Cost = (Numbers of Orders Placed per Year) x (Setup or Order Cost per Order)

$$= \frac{\text{Annual Demand}}{\text{Number of units in each order}} * \text{Setup or Order Cost per Order}$$

$$= \frac{D}{Q} * (S)$$

Equation-2 : Annual holing (or carrying) cost

Annual Holding Cost = Average Inventory Level * Holding Cost per Unit per Year

= ½ of Order Quantity * Holding Cost per Unit per Year

$$= \frac{Q}{2} * H$$

Equating (1) and (2) above

Since the minimum TC occurs at the point where the ordering cost and the inventory carrying costs are equal, we equate the 2 equations above. Solve for Q.

$$\rightarrow \frac{D}{Q} \times S = \frac{Q}{2} \times H \qquad \rightarrow 2DS = Q^2 H \qquad \rightarrow Q^2 = 2DS / H$$

$$\boxed{EOQ = Q^* = \sqrt{\frac{2DS}{H}}}$$

Total Cost or Total Annual Cost ➔ TC = Setup or Order Cost + Holding Cost + Actual Material Cost

$$TC = \left\{\frac{D}{Q} \times S\right\} + \left\{\frac{Q}{2} \times H\right\} + \{P.D\}$$

Q.4 (CO-3) : A person repairing printer finds that the time spend on the printer has been exponential distributed with mean of 20 min. If the printers are repaired in the order in which they come in and their arrival is approximately Poisson with an average rate at 15 for 8-hour day, what is the repairman's expected idle time each day? How many jobs are ahead of the average set just brought in?

Solution : Here,

Arrival Rate (λ) = 15 / (8 x 60) = 1/32 Units per Minute

Service Rate (μ) = 1/20 Units per Minute

Numbers of jobs ahead to the printer brought in – will be the – Average numbers of jobs in the system. So, using :

$Ls = \lambda / (\mu - \lambda) = (1/32) / \{(1/20) - (1/32)\}$ = **5/3 Units # Answer**

Numbers of hours for which the repairman remain busy in an 8 hour day

Busy Time = Day Time x (λ / μ) = 8 x (1/32) / (1/20) = 5 Hours

Time for which repairman remains idle in an 8 hours day

Idle Time = Total Time – Busy Time = 8 – 5 = **3 Hours # Answer**

Q.5 (CO-4) : Explain the Product Life Cycle.

Solution : The Product Life Cycle (PLC) is a model that describes the stages a product goes through from its introduction to the market until its eventual decline and withdrawal. Understanding the PLC helps businesses strategize marketing, sales, and product management efforts at each stage. The typical stages of the Product Life Cycle are :

1. Introduction
   - Description: The product is launched into the market. Sales are usually low, and the focus is on creating awareness.
   - Characteristics: High marketing and promotional costs, low sales volume, limited distribution.
   - Strategies: Heavy advertising, promotions, introductory pricing to attract early adopters.

2. Growth
   - Description: The product gains acceptance, and sales begin to increase rapidly. The market expands.
   - Characteristics: Increasing sales and profits, growing market share, expanding distribution channels.
   - Strategies: Enhance product features, broaden distribution, competitive pricing, increased promotional efforts.
3. Maturity
   - Description: Sales growth slows as the product reaches peak market penetration. The market becomes saturated.
   - Characteristics: High but stable sales, intense competition, possible price reductions to maintain market share.
   - Strategies: Product differentiation, enhancements, loyalty programs, cost control, and efficiency improvements.
4. Decline
   - Description: Sales and profits decline due to market saturation, technological advancements, or changing consumer preferences.
   - Characteristics: Decreasing sales and profits, reduced marketing efforts, potential product discontinuation.
   - Strategies: Cost-cutting, finding niche markets, product discontinuation, or innovation to revive the product.

Q.5 (CO-4) : The direct time-study data of an acid mining operation is given below. The rating of workers is 80%. Compute the standard time (consider allowance fraction as 0.1).

Cycle Time (min)	**2.7**	**2.7**	**2.9**	**3.1**	**3.2**
No of Cycles Observed	**3**	**4**	**2**	**1**	**1**

Solution :

Calculate the Average Observed Time (AOT):

First, we need to find the weighted **Average of the Observed cycle Times**, considering the number of cycles observed for each time. Its formula is =>

$$AOT = \sum(\text{Cycle Time} \times \text{No of Cycles Observed}) / \sum \text{No of Cycles Observed}$$

$$AOT = [(2.7\times3) + (2.7\times4) + (2.9\times2) + (3.1\times1) + (3.2\times1)] / [3+4+2+1+1] = 31/11 = 2.82 \text{ min.}$$

Now, compute Normal Time, which will be :

$$NT = AOT \times \text{Rating Factor} = 2.82 \times 0.80 = 2.256 \text{ min.}$$

Now, compute Standard Time, which is :

$$ST = NT / (1\text{-Allowance}) = 2.256 / (1\text{-}0.1) = 2.256 / 0.9 = 2.50 \text{ min.}$$

Answer : Standard Time is 2.50 min.

Q.6 (CO-5) : Two products A and B are to be machined on 3 machines, M1, M2 and M3. Product A takes 10 hours on machine M1, 6 hours on machine M2 and 5 hours on machine M3. The product B takes 7.5 hours on machine M1, 9 hours on machine M2 and 13 hours on machine M3. The available machining time (weekly) for machine M1 is 75 hours, for machine M2 is 54 hours and for machine M3 is 65 hours. The products contemplate profit of Rs 80 per product A and Rs 100 per product B. Formulate the LP model for maximum profit and show the feasible region graphically. Find the optimal solution.

Solution : Let, quantity of Product-A be manufactured X_1 and for Product-B, quantity is X_2. The formulation LP Model is as per following :

Machine	Product-A (X_1 Units, Profit = 80)	Product-B (X_2 Units, Profit = 100)	Available M/c Time
M1	10	7.5	75
M2	6	9	54
M3	5	13	65

With this, the objective function will be :

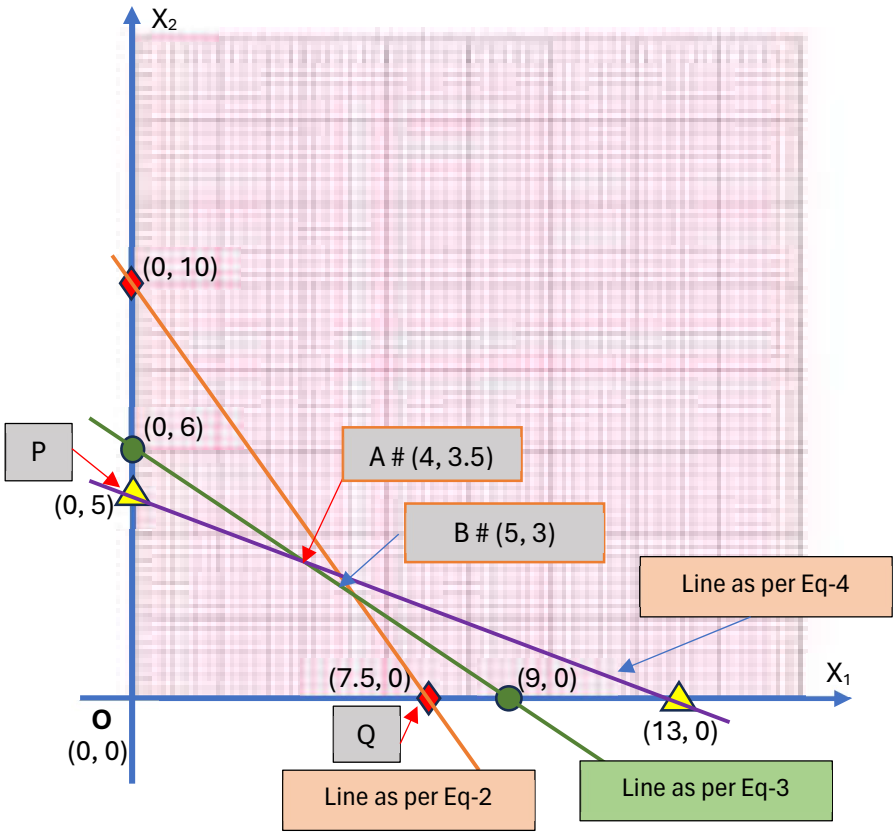
Maximize (profit)	$Z = 80 X_1 + 100 X_2$	# Eq-1
Subject To (constraints)	$10 X_1 + 7.5 X_2 \leq 75$	# Eq-2
	$6 X_1 + 9 X_2 \leq 54$	# Eq-3
	$5 X_1 + 13 X_2 \leq 65$	# Eq-4
Non-negative Constraints	X_1 and $X_2 \geq 0$	

To use graphical method, lines are to be drawn for all constraints equations. Considering (≤) sign as equal, the equations of the lines will be as per following :

Equation No	Equation	X_2 (When X_1=0)	X_1 (when X_2=0)	Coordinates (Point-1)	Coordinates (Point-2)
Eq-2	$10 X_1 + 7.5 X_2 = 75$	10	7.5	(0, 10)	(7.5, 0)
Eq-3	$6 X_1 + 9 X_2 = 54$	6	9	(0, 6)	(9, 0)
Eq-4	$5 X_1 + 13 X_2 = 65$	5	13	(0, 5)	(13, 0)

Drawing these three lines on suitable scale, the graph will be as shown herewith.

The feasible solution will be in the region surrounded by Points O-P-A-B-Q-O.



For the Profit

Eq-1 : $Z = 80 X_1 + 100 X_2$

At Point – A, (4, 3.5):

$Z = (80 \times 4) + (100 \times 3.5)$

$= 320 + 350 =$ **670**

At Point – B, (5, 3):

$Z = (80 \times 5) + (100 \times 3)$

$= 400 + 300 =$ **700**

Answer :

- The feasible regions are the region surrounded by Points O-P-A-B-Q-O.
- For maximum profit, 5 units of product A and 3 units of product B are to be machined on machines M1, M2 and M3.

Q.6 (CO-5) : Use Vogel's approximation method to obtain an initial feasible solution for the given transportation problem :

	D1	D2	D3	D4	Availability
S1	**11**	**13**	**17**	**14**	**250**
S2	**16**	**18**	**14**	**10**	**300**
S3	**21**	**24**	**13**	**10**	**400**
Demand	**200**	**225**	**275**	**250**	

Solution : The major steps in solving transportation problem through Vogel's approximation method are :

1. Compute Penalty cost for each row and column (which is the difference between the lowest and the second-lowest costs in each row / column).
2. Select that row or column that has maximum penalty (in case of tie – select low cell or cost value) and allocate the maximum (whether demand or supply of availability).
3. Recalculate penalties excluding allocation that has zero value (whether row or column) and proceed with the next highest penalty (continue this process until all demands are being done).

In this way, table-1 represents the penalties.

Table-1	D1	D2	D3	D4	Availability	Penalty
S1	11	13	17	14	250	13-11 = 2
S2	16	18	14	10	300	14-10 = 4
S3	21	24	13	10	400	13-10 = 3
Demand	200	225	275	250	X	
Penalty	16-11 = 5	13-18 = 5	14-13 = 1	14-10 = 4	X	

Here, highest penalties are for D1 (5) and D2 (5). Allocate maximum for highest penalties (in case of tie – selecting lower cost value, i.e. 11 of D1). The allocation will be **200 for D1-S1**. Available demand for D1 will be (200-200 = 0) and availability for S1 will be (250-200 = 50). Now, D1 will not be available (value=0)
Again calculate, penalties for updated allocations. In this respect, refer table-2.

Table-2	D1	D2	D3	D4	Availability	Penalty (exclude D1)
S1	~~11~~	13	17	14	50	14-13 = 1
S2	~~16~~	18	14	10	300	14-10 = 4
S3	~~21~~	24	13	10	400	13-10 = 3
Demand	0	225	275	250	X	
Penalty	X	18-13 = 5	14-13 = 1	14-10 = 4	X	

Here, highest penalty is for D2 (5). Allocating maximum for highest penalty and low cost or cell value (i.e. **50 for D2-S1**). The available demand for D2 will be (225-50 = 175) and availability for S1 will be (50-50 = 0). Now, S1 will not be available (value=0) for further allocation. Again calculate, penalties for updated allocations. Further, refer table-3.

Table-3	D1	D2	D3	D4	Availability	Penalty (exclude D1, S1)
S1	~~11~~	~~13~~	~~17~~	~~14~~	0	X
S2	~~16~~	18	14	10	300	14-10 = 4
S3	~~21~~	24	13	10	400	13-10 = 3
Demand	0	175	275	250	X	
Penalty	X	24-18 = 6	14-13 = 1	10-10 = 0	Min. and second min. are same for D4.	

Here, highest penalty is for D2 (6). Allocating maximum for highest penalty and low cost or cell value (i.e. **175 for S2-D2**). The available demand for D2 will be (175-175 = 0) and availability for S2 will be (300-175 = 125). Now, D2 will not be available (value=0) for further allocation. Again calculate, penalties for updated allocations. Further, refer table-4.

Table-4	D1	D2	D3	D4	Availability	Penalty (exclude D1, S1, D2)
S1	~~11~~	~~13~~	~~17~~	~~14~~	0	X
S2	~~16~~	~~18~~	14	10	125	14-10 = 4
S3	~~21~~	~~24~~	13	10	400	13-10 = 3
Demand	0	0	275	250	X	
Penalty	X	X	14-13 = 1	10-10 = 0	Min. and second min. are same for D4.	

Here, highest penalty is for S2 (4). Allocating maximum for highest penalty and low cost cell (i.e. **125 for D4-S2**). The available demand for D4 will be (250-125 = 125) and availability for S2 will be (125-125=0). With this, S2 will not be available (value=0) for further allocation.

Again, calculate penalties for updated allocations. In this respect, refer table-5.

Table-5	D1	D2	D3	D4	Availability	Penalty (exclude D1, S1, D2, S2)
S1	~~11~~	~~13~~	~~17~~	~~14~~	0	X
S2	~~16~~	~~18~~	~~14~~	~~10~~	0	X
S3	~~21~~	~~24~~	13	10	400	13-10 = 3
Demand	0	0	275	125	X	
Penalty	X	X	-	-	Min. and second min. are same for D4.	

Here, the allocation will be based on low cost or cell values. So, **125 will be allocated to D4-S3** (D4 = 125-125=0; and S3 = 400-125 = 275) and then, **275 will be allocated to D3-S3** (D3 = 275-275 = 0 and S3 = 275-275=0).

With this, all the allocations have been done and are as per following table-6 :

Table-6 Allocations	D1		D2		D3		D4		Availability
	Cost	Allocation	Cost	Allocation	Cost	Allocation	Cost	Allocation	
S1	11	200	13	50	17		14		250
S2	16		18	175	14		10	125	300
S3	21		24		13	275	10	125	400
Demand		200		225		275		250	

The total transportation cost (minimum) will be :

= (11x200) + (13x50) + (18x175) + (13x275) + (10x125) + (10x125)
= 2200 + 650 + 3150 + 3575 + 1250 + 1250
= **12,075/- ANSWER**

Section – C # 50 Marks (Medium / Long Answer Type Questions)

Q.7 (CO-1) : Attempt any ONE question. This question is of 10 marks.

a. Explain various types of plant layouts.

Solution : Plant layout is a plan of an optimum arrangement of facilities including personnel, operating equipment, storage space, material handling equipments and all other supporting services along with the design of best structure to contain all these facilities. The overall objective of the plant layout is to design a physical arrangement that meets the required output quality and quantity most economically. The plant layouts can be classified as :

1. Process layout
2. Product layout
3. Combination layout
4. Fixed position layout
5. Group layout

Process layout : It is recommended for batch production. All machines performing similar type of operations are grouped at one location in the process layout e.g., all lathes, milling machines, etc. are grouped in the shop will be clustered in like groups. Thus, in process layout the arrangement of facilities are grouped together according to their functions. The advantages of process layout are :

4. In process layout machines are better utilized and fewer machines are required.
5. Flexibility of equipment and personnel is possible in process layout.
6. Lower investment as less number of machines required and cost of general purpose machines is less.
7. Supervisors will become highly knowledgeable about the functions under their department.

The limitations of process layout are :

1. Backtracking and long movements may occur in material handling and material handling cannot be automated.
2. Process time is prolonged which reduce the inventory turnover and increases the in-process inventory.
3. Lowered productivity due to number of set-ups.
4. Throughput (time gap between in and out in the process) time is longer.

Product Layout : It is suitable for mass production. In this type of layout, machines and auxiliary services are located according to the processing sequence of the product. Special purpose machines are used which perform the required function quickly and reliably. In a strict product layout, machines are not shared by different products. The advantages of product layout are :

1. The flow of product will be smooth and logical in flow lines.
2. In-process inventory, Throughput time and material handling cost (may be automated) will be less.
3. Simplified production, planning and control systems are possible.
4. Less space is occupied by work transit and for temporary storage, better line balancing
5. Manufacturing cycle is short due to uninterrupted flow of materials.
6. Unskilled workers can learn and manage the production.

The limitations of product layout are :

1. A breakdown of one machine in a product line may cause stoppages of machines in the downstream line.
2. A change in product design may require major alterations in the layout.
3. Comparatively high investment in equipments is required.

Combined Layout : A combination of process and product layouts combines the advantages of both types of layouts. A combination layout is possible where an item is being made in different types and sizes. Here machinery is arranged in a process layout but the process grouping is then arranged in a sequence to manufacture various types and sizes of products. It is to be noted that the sequence of operations remains same with the variety of products and sizes.

Fixed Position Layout : This is also called the **project type** of layout. In this type of layout, the material, or major components remain in a fixed location and tools, machinery, men and other materials are brought to this location. This type of layout is suitable when one or a few pieces of identical heavy products are to be manufactured and when the assembly consists of large number of heavy parts, the cost of transportation of these parts is very high. The major advantages of this type of layout are:

1. Helps in job enlargement and upgrades the skills of the operators.
2. Greater flexibility with lower capital investment

Group layout : It is a combination of the product layout and process layout. It combines the advantages of both layout systems. If there are m-machines and n-components, in a group layout (Group-Technology Layout), the m-machines and n-components will be divided into distinct number of machine-component cells (group) such that all the components assigned to a cell are almost processed within that cell itself. Here, the objective is to minimize the intercell movements. The basic aim of a group technology layout is to identify families of components that require similar of satisfying all the requirements of the machines are grouped into cells. Each cell is capable of satisfying all the requirements of the component family assigned to it. The layout design process considers mostly a single objective while designing layouts. Thus, in-group technology layout, the objective is to minimize the sum of the cost of transportation and the cost of equipments. So, this is called as multi-objective layout. The advantages are :

1. Group Technology layout can increase component standardization and rationalization, Reliability of estimates, Effective machine operation and productivity, and Customer service.
2. It can decrease the Paper work and overall production time, Work-in-progress and work movement, and Overall cost.

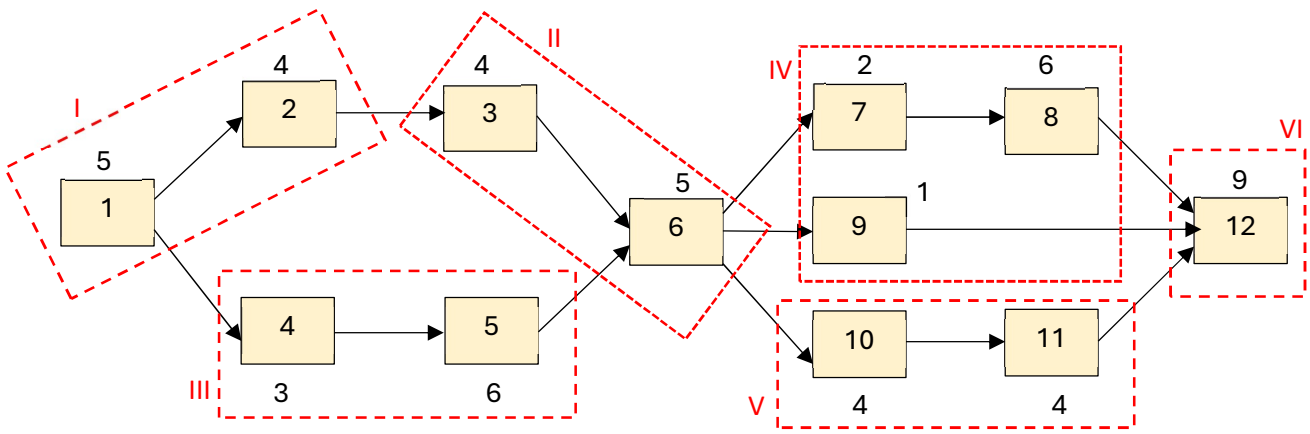
The limitation of Group Technology Layout is that it may not be feasible for all situations. If the product mix is completely dissimilar, then we may not have meaningful cell formation.

b. Design an assembly line for a cycle time of 9 minutes for the following 12 work elements :

Element	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Immediate Precoder	**-**	**1**	**2**	**1**	**4**	**3, 5**	**6**	**7**	**6**	**6**	**10**	**8, 9, 11**
Duration (min)	**5**	**4**	**4**	**3**	**6**	**5**	**2**	**6**	**1**	**4**	**4**	**9**

Draw the precedence diagram and find the line efficiency (not less than 75%) with smoothness index.

Solution : For given set of 12 work elements, the precedence diagram will be :



Group these workstations in such a manner that total working duration of groups elements should not exceeds to cycle time, i.e. 9 min. The grouping is shown by dotted lines. Each group [of work element(s)] is known as work-station. With this configuration, there will be 6 work-stations.

The computations are given in below mentioned table :

Station	Element	Ti (min)	Station Time (Sum, Min)	Idle Time (min) = Cycle Time – Station Time
I	1	5	5+4 = 9	9 – 9 = 0
	2	4		
II	3	4	4=5 = 9	9 – 9 = 0
	6	5		
III	4	3	3+6 = 9	9 – 9 = 0
	5	6		
IV	7	2	2+6+1 = 9	9 – 9 = 0
	8	6		
	9	1		
V	10	4	4+4=8	9 – 8 = 1
	11	4		
VI	12	9	9	9 – 9 = 0
TOTAL N=6	12	53	53	1

Line Efficiency :

= Sum of Station Time for all work elements / [Total No. of Work Stations x Cycle Time]

= 53 / (6 x 9) = 53 / 54 = 0.9815 or **98.15%**

Balance Delay :

= 100 – Line Efficiency in percent = 100 – 98.15 = **1.85**

Smoothness Index :

= [Sum of Squares of Idle Times]$^{1/2}$ = [$0^2 + 0^2 + 0^2 + 0^2 + 1^2 + 0^2$] = **1**

Answer : Line Efficiency = 98.15%; Balance Delay = 1.85; Smoothness Index = 1

Q.8 (CO-2) : Attempt any ONE question. This question is of 10 marks.

a. Describe "Aggregate Production Planning and MRP" or "Master Production Schedule and JIT".

Solution :

Aggregate Production Planning (APP)

APP is a strategic process used by manufacturing and service organizations to determine the optimal production levels, inventory levels, and workforce levels over a medium-term horizon, typically ranging from 6 to 18 months. The goal of APP is to balance supply and demand in a way that minimizes costs while meeting customer demand and ensuring efficient use of resources. Here are the key aspects of Aggregate Production Planning:

1. Objectives of APP

- **Balancing Supply and Demand:** Ensures that production capacity meets demand without excessive inventory or shortages.
- **Minimizing Costs:** Aims to reduce costs associated with production, inventory, labor, and overtime.
- **Optimal Resource Utilization:** Efficiently uses available resources, such as labor, machinery, and materials.
- **Meeting Customer Requirements:** Ensures timely delivery of products to meet customer demand.

2. Inputs to APP

- **Demand Forecasts:** Estimates of future customer demand for products.
- **Production Capacity:** Available capacity of production facilities, including machinery and labor.
- **Inventory Levels:** Current inventory levels and desired inventory policies.
- **Workforce Levels:** Availability and flexibility of the workforce, including regular and overtime labor.
- **Cost Factors:** Costs associated with production, inventory holding, labor, and overtime.

3. APP Strategies

- **Chase Strategy:** Adjusts production rates to match demand by varying workforce levels or using overtime. Minimizes inventory but may result in fluctuating labor costs.
- **Level Strategy:** Maintains a constant production rate and uses inventory to absorb fluctuations in demand. Results in stable workforce levels but may lead to higher inventory costs.
- **Hybrid Strategy:** Combines elements of both chase and level strategies to balance the benefits and drawbacks of each approach.

4. APP Process Steps

1. **Forecast Demand:** Estimate future demand for products based on historical data, market trends etc.
2. **Determine Production Capacity:** Assess available production capacity, including machinery, labour, and other resources.
3. **Develop Alternative Plans:** Create different production plans based on various strategies and scenarios.
4. **Evaluate and Select Plan:** Analyze the costs and benefits of each plan and select the optimal one.
5. **Implement Plan:** Execute the chosen production plan and monitor its progress.
6. **Review and Adjust:** Regularly review the plan and make adjustments as needed to address changes in demand or other factors.

5. Benefits of APP

- **Improved Customer Service:** Ensures timely delivery of products to meet customer demand.
- **Cost Savings:** Reduces costs associated with production, inventory, and labor by optimizing resource use.
- **Efficiency:** Enhances the efficiency of production processes and resource utilization.
- **Flexibility:** Provides a flexible framework to adapt to changes in demand and other external factors.

Material Requirement Planning (MRP)

MRP is a systematic approach to production planning, scheduling, and inventory control. It is designed to ensure that materials and components are available for production, products are available for delivery to customers, and manufacturing activities are planned efficiently. The key aspects of MRP are :

1. Objectives of MRP

- **Ensure Material Availability:** Ensures that the right materials are available at the right time and place to meet production schedules.
- **Minimize Inventory Levels:** Reduces inventory levels to minimize holding costs while avoiding stockouts.
- **Improve Production Efficiency:** Enhances production efficiency by planning and scheduling manufacturing activities effectively.
- **Optimize Use of Resources**: Ensures optimal use of resources such as labor, machinery, and materials**.**

2. Inputs to MRP

- **Master Production Schedule (MPS):** A detailed schedule that outlines the production plans for finished goods over a specific period.
- **Bill of Materials (BOM):** A comprehensive list of all materials, components, and subassemblies required to produce a finished product.
- **Inventory Status Records:** Information on current inventory levels, including on-hand quantities, scheduled receipts, and allocated inventory.

3. MRP Process Steps

1. **Demand Forecasting:** Estimate future demand for finished products based on sales forecasts, historical data, and market trends.
2. **Exploding the BOM**: Use the Bill of Materials to determine the quantity of each component and material needed to meet the production schedule.
3. **Netting Inventory:** Subtract available inventory and scheduled receipts from the total material requirements to determine net requirements.
4. **Lot Sizing:** Determine the optimal order quantity for each material, considering factors such as lead time, order costs, and holding costs.
5. **Scheduling:** Plan the timing of material orders and production activities to ensure that materials are available when needed.
6. **Generating Purchase Orders and Work Orders:** Create purchase orders for external suppliers and work orders for internal production based on the MRP plan.
7. **Monitoring and Adjusting:** Continuously monitor inventory levels, production schedules, and material requirements, and adjust the MRP plan as needed to address changes in demand or supply.

4. Benefits of MRP

- **Improved Inventory Management:** Reduces excess inventory and minimizes stockouts, leading to lower inventory costs.
- **Enhanced Production Planning:** Ensures that production activities are well-coordinated and resources are used efficiently.
- **Better Customer Service:** Improves the ability to meet delivery schedules and respond to changes in demand.
- **Cost Savings:** Reduces costs associated with inventory holding, production delays, and expedited orders.

Master Production Schedule (MPS)

The Master Production Schedule is a detailed plan that specifies what a company intends to produce, in what quantities, and when. It serves as a vital link between the production planning and the manufacturing operations, ensuring that production meets market demand and aligns with strategic objectives. The key details of MPS are :

1. Purpose of MPS

- **Alignment with Demand:** Ensures that production activities are aligned with customer demand and sales forecasts.
- **Resource Allocation:** Helps in planning and allocating resources such as labor, machinery, and materials effectively.
- **Inventory Management:** Aims to balance inventory levels to avoid overstocking or stockouts.
- **Operational Efficiency:** Enhances production efficiency by providing a clear and organized production plan.

2. Inputs to MPS

- **Sales Forecasts:** Predictions of future customer demand based on historical data, market trends, and sales projections.
- **Customer Orders:** Actual orders received from customers, which take priority over forecasts.
- **Inventory Levels:** Current inventory levels, including finished goods and work-in-progress (WIP).
- **Production Capacity:** Available production capacity, including machinery, labor, and other resources.
- **Lead Times:** The time required to procure materials and produce goods.

3. Components of MPS

- **Time Periods:** The schedule is divided into time periods (e.g., weeks or months) to plan production activities over a specific horizon.
- **Production Quantities:** Specifies the quantity of each product to be produced in each time period.
- **Order Due Dates:** Indicates the due dates for customer orders and production batches.
- **Inventory Levels:** Tracks projected inventory levels to ensure they meet demand without excessive stock.

4. MPS Process Steps

1. **Demand Forecasting:** Estimate future demand based on sales forecasts and customer orders.
2. **Inventory Management:** Assess current inventory levels and determine the necessary production quantities.
3. **Capacity Planning:** Evaluate available production capacity and identify any constraints or limitations.
4. **Scheduling:** Develop a detailed production schedule that specifies what, how much, and when to produce.
5. **Coordination:** Coordinate with various departments (e.g., procurement, production, sales) to ensure alignment and smooth execution.
6. **Monitoring and Adjusting:** Continuously monitor the MPS and make adjustments as needed to address changes in demand or production capacity.

5. Benefits of MPS

- **Improved Customer Service:** Ensures timely delivery of products by aligning production with demand.
- **Better Resource Utilization:** Optimizes the use of resources, reducing waste and improving efficiency.
- **Cost Savings:** Minimizes costs associated with inventory holding, production delays, and expedited orders.
- **Enhanced Planning:** Provides a clear and organized production plan that guides manufacturing activities.

Just In Time (JIT)

Just-In-Time (JIT) is a production and inventory management philosophy that aims to improve efficiency and reduce waste by producing and delivering goods only as they are needed in the production process. The overview of JIT is :

1. Purpose of JIT

- **Minimize Inventory:** Reduces the amount of inventory held at any point in time, lowering storage costs and minimizing waste.
- **Improve Efficiency:** Streamlines production processes to reduce lead times and enhance overall efficiency.
- **Enhance Quality:** Focuses on producing high-quality products and reducing defects and rework.

2. Key Principles of JIT

- **Demand-Driven Production:** Goods are produced in response to actual customer demand rather than forecasted demand.
- **Continuous Improvement (Kaizen):** Emphasizes continuous improvement in all aspects of the production process to eliminate waste and improve quality.
- **Pull System:** Uses a pull system where production is triggered by customer demand or downstream processes rather than a push system driven by forecasts.

3. Components of JIT

- **Inventory Management:** Maintaining minimal inventory levels to reduce holding costs and waste.
- **Supplier Relationships:** Developing strong relationships with suppliers to ensure timely delivery of materials and components.
- **Production Scheduling:** Using flexible and efficient production schedules to respond quickly to changes in demand.
- **Quality Control:** Implementing stringent quality control measures to ensure that products meet high-quality standards and reduce defects.

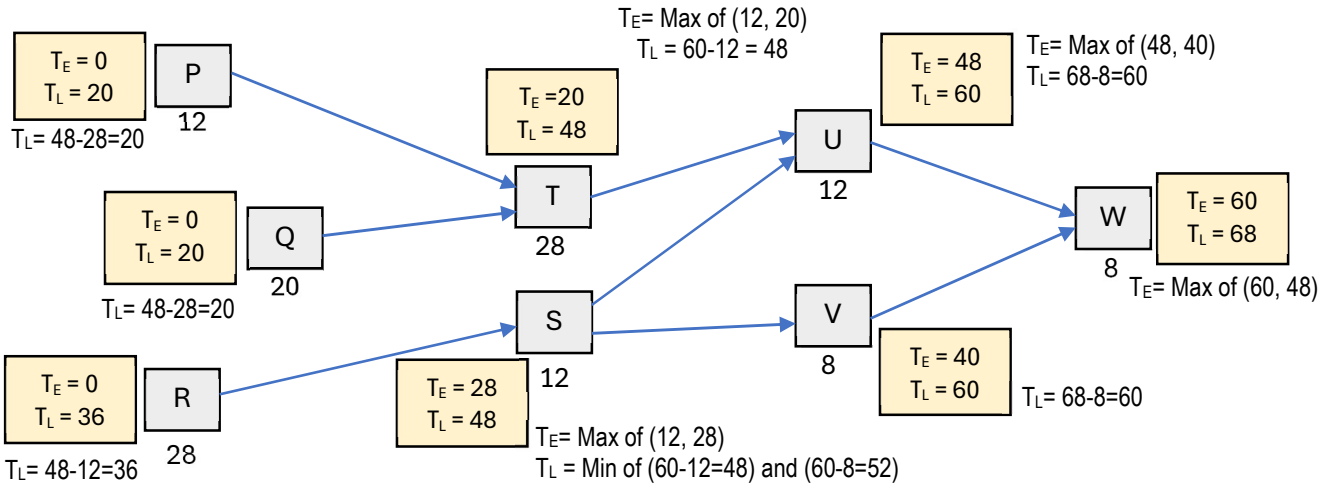
4. Benefits of JIT

- **Reduced Inventory Costs:** Lower inventory levels lead to reduced storage and handling costs.
- **Improved Cash Flow:** Reduced inventory investment frees up capital for other uses.
- **Enhanced Productivity:** Streamlined production processes and reduced lead times improve overall productivity.
- **Higher Quality:** Focus on quality and continuous improvement leads to fewer defects and higher-quality products.
- **Greater Flexibility:** Ability to respond quickly to changes in customer demand and market conditions.

b. A project has eight activities, as per given table. Construct the network from given information and compute critical path, showing slack for each activity in a tabular form.

Activity	P	Q	R	S	T	U	V	W
Immediate Predecessor	-	-	-	R	P, Q	T, S	S	U, V
Activity Time (weeks)	12	20	28	12	28	12	8	8

Solution : The network diagram will be as per following (T_E = Earliest Start Time and T_L = Latest Finish Time) :



The critical path will be the path of activities that has longest activity time. The various paths will be :

Option-1 :	Path P ➔ T ➔ U ➔ W	# Time = 12 + 28 +12 + 8	= 60 Weeks
Option-2 :	Path Q ➔ T ➔ U ➔ W	# Time = 20 + 28 +12 + 8	= 68 Weeks (longest time)
Option-3 :	Path R ➔ S ➔ U ➔ W	# Time = 28 + 12 +12 + 8	= 60 Weeks

So, the critical path will be Path Q ➔ T ➔ U ➔ W (Total Time = 68 Weeks) Answer

Note : Any activity can only be started when all possible outcomes / all of its concerned previous activities have been attained / arrived / completed. E.g. Assembly can be started only when – all of its components are there.

- T_E : The Earliest Start Time - when the activity can be started. It's the maximum time of all possible options.
- T_L : Latest Finish Time – to be computed backward (from the end). It's the minimum of all possible options. (deducting their own time).
- S : Slack is the time difference between T_E and T_L.
- Earliest Finish Time = Earliest Start Time + Activity Time
- Latest Start Time = Latest Finish Time - Activity Time

Using these, the computations are depicted in the network diagram and in below mentioned table :

Activities	Activity Duration	Earliest		Latest		Slack
		Start Time (A)	Finish Time (P)	Start Time (B)	Finish Time (Q)	(B-A) or (Q-P)
P	12	0	12	20-12=8	20	8-0 = 8
Q	20	0	20	20-20 = 0	20	0-0= 0
R	28	0	28	36-28=8	36	8-0=8
S	12	28	40	48-12=36	48	36-28=8
T	28	20	48	48-28=20	48	20-20=0
U	12	48	60	60-12=48	60	48-48=0
V	8	40	48	60-8=52	60	52-40=12
W	8	60	68	68-8=60	68	60-60=0

Q.9 (CO-3) : Attempt any ONE question. The question is of 10 marks.

a. A manufacturer has to supply his customers with 1200 units of his product per annum. The inventory carrying cost amounts to Rs 1.2 per unit. The set-up cost per run is Rs 160. Find :

i) EOQ **ii) Minimum average yearly cost**

iii) Optimum no of orders per year **iv) The optimum time between orders**

Solution :

Given : Demand = D = 1200 Units Setup Cost - S = Rs 160/- Holding Cost = H = Rs 1.2 per unit

(i) Economic Order Quantity (EOQ)

= Q = $\sqrt{}$ [(2DS) / H] = [2 x 1200 x 160 / 1.2]$^{1/2}$ = 565.67 (products cannot be partial) So, **Q = 566 Units**

(ii) Minimum average yearly cost

= [{DS/Q} + {QH/2}] = [{1200 x 160 /566} + {566 x 1.2 / 2}] = **678.8/-**

iii) Optimum Numbers of Orders per year (N)

= N = Demand / EOQ = 1200 / 566 = 2.1 (orders cannot be partial), So, **N=3**

iv) Time between orders in a year

= No of days in a year / total no. of orders in a year = 365 / 3 = **122 days.**

Answer **(i) EOQ=566 Units;** **(ii) Avg Yearly Cost=Rs 678.8;**

(iii) No of Orders per Year = 3; **(iv) Time b/w Orders = 122 days.**

b. Describe the Kendall's notations for representing the queuing model.

Solution : Kendall's notation is a standardized system used to describe the characteristics of queuing models. It provides a concise way to represent the structure and behaviour of a queuing system. The notation is typically written in the form A/B/C/D/E/F, where each letter represents a specific attribute of the queue as per following :

1. Arrival Process (A) : Describes the pattern of arrivals to the queue. The common symbols are :

- M: Poisson (Markovian) arrival process.
- D: Deterministic (fixed) arrival times.
- G: General arrival process (arbitrary distribution).

2. Service Time Distribution (B) : Describes the distribution of service times. The common symbols are :

- M: Exponential (Markovian) service times.
- D: Deterministic (fixed) service times.
- G: General service time distribution (arbitrary distribution).

3. Number of Servers (C)

- Represents the number of servers in the queuing system.
- Denoted by an integer, such as 1, 2, 3, etc.

4. System Capacity (D)

- The maximum number of customers that the system can accommodate, including those in service and in the queue.
- Denoted by an integer (e.g., 10) or ∞ for an unlimited capacity.

5. Population Size (E)

- The size of the population from which customers arrive.
- Denoted by an integer (e.g., 50) or ∞ for an infinite population.

6. Queuing Discipline (F) : Describes the order in which customers are served. The common symbols are :

- **FIFO**: First-In-First-Out (also called FCFS, First-Come-First-Served).
- **LIFO**: Last-In-First-Out.
- **SIRO**: Service In Random Order.
- **PR**: Priority order.

Example: M/M/1/∞/∞/FIFO

- M: Poisson arrival process.
- M: Exponential service times.
- 1: Single server.
- ∞: Unlimited system capacity.
- ∞: Infinite population size.
- FIFO: First-In-First-Out queuing discipline.

Q.10 (CO-4) : Attempt any TWO questions. Each question is of 5 marks.

a. Explain Miniaturization.

Solution : Miniaturization means – more and more (features) in less and less (space). Miniaturization is the process of designing and producing smaller versions of mechanical, electronic, or other complex devices. This process is driven by the need for increased efficiency, portability, and functionality in a smaller footprint. The advantages are :

- **Portability:** Smaller devices are easier to carry and use on the go.
- **Efficiency:** Miniaturized components often consume less power and generate less heat.
- **Cost-Effectiveness:** Reducing the size of components can lower manufacturing costs and material usage.

b. Explain any four Therblig.

Solution : Therbligs are a set of fundamental motions used to analyze and improve manual work processes, developed by Gilbreth. The term "Therblig" is a reversal and variation of the name "Gilbreth." These basic motions help in identifying inefficiencies and optimizing human work for better productivity. There are 18 Therbligs as per following :

- **Search (Sh):** Locating an object or information.
- **Find (F):** Identifying the object or information after searching.
- **Select (St):** Choosing among several objects or pieces of information.
- **Grasp (G):** Taking hold of an object.
- **Transport Loaded (TL):** Moving an object from one place to another.
- **Hold (H):** Keeping an object in place.
- **Release Load (RL):** Letting go of an object.
- **Position (P):** Placing an object in a specific location.
- **Inspect (I):** Checking or examining an object.
- **Assemble (A):** Putting objects together.
- **Disassemble (DA):** Taking objects apart.
- **Rest (R):** Pausing to recover from fatigue.

c. Describe Allowances provided in time-study.

Solution : Allowances in time study are additional time added to the standard time of a task to account for various factors that can affect a worker's performance. These allowances ensure that the standard time reflects a fair and realistic expectation of the time required to complete a task under normal working conditions. These are :

1. Personal Allowance :

- **Purpose:** To account for the time needed for personal needs such as restroom breaks, drinking water etc.
- **Typical Value:** Usually a small percentage (e.g., 5%) of the total time.

2. Fatigue Allowance

- **Purpose:** To compensate for the physical and mental fatigue experienced by workers due to the nature of work.
- **Factors Considered:** Work intensity, environmental conditions, ergonomic factors, and the nature of the task.
- **Typical Value:** Varies based on the task's demands and environmental factors (generally 4% to 10%).

3. Delay Allowance

- **Purpose:** To account for unavoidable delays that occur during work, such as waiting for materials, machine breakdowns, or interruptions.
- **Factors Considered:** Frequency and duration of delays, type of delays, and the work environment.
- **Typical Value:** Depends on the specific conditions of the workplace and the frequency of delays.

4. Contingency Allowance

- **Purpose:** To provide a buffer for unforeseen circumstances or variations in work conditions that are not covered by other allowances.
- **Factors Considered:** The uncertainty or variability in work conditions.
- **Typical Value:** Usually a small percentage (e.g., 1% to 2%) of the total time.

5. Special Allowance

- **Purpose:** To account for specific, infrequent, or irregular tasks that are not part of the normal work cycle but are necessary for job completion.
- **Factors Considered:** Specific job requirements and tasks.
- **Typical Value:** Based on the particular needs of the job.

Q.11 (CO-5) : Attempt any ONE question. This question is of 10 marks.

a. Solve the given problem using Simplex method :

Maximize $Z = 4X_1 + 10X_2$

Subject to constraints : $2X_1 + X_2 \leq 50$

$2X_1 + 5X_2 \leq 100$

$2X_1 + 3X_2 \leq 90$

Where, X_1 **and** X_2 **are** ≥ 0

Solution : The given LP problem has inequalities of "≤" nature. To convert these inequalities, slack variables (S_1, S_2 and S_3) are to be added (to convert "≤" into "="). With this, LP problem will be :

Constraint equations will be ➔ $2X_1 + X_2 + S_1 = 50$

$2X_1 + 5X_2 + S_2 = 100$

$2X_1 + 3X_2 + S_3 = 90$

Where $X_1, X_2, S_1, S_2, S_3 \geq 0$ (non-negative constraints)

The objective function will : ➔ Maximize $Z = 4.X_1 + 10.X_2 + 0.S_1 + 0.S_2 + 0.S_3$

Now, prepare initial feasible table (C_{Bi} are the coefficients of basic variables (BV) – as per Objective function) :

C_{Bi}	C_j	4	10	0	0	0	Solution	Ratio
	BV	X_1	X_2	S_1	S_2	S_3		
0	S_1	2	1	1	0	0	50	50/1 = 50
0	S_2	2	5	0	1	0	100	100/5 = **20**
0	S_3	2	3	0	0	1	90	90/3 = 30
$Z_j = \Sigma(C_{Bi} \times a_{ij})$		(0x2) + (0x2) + (0x2) = 0	(0x1) + (0x5) + (0x3) = 0	(0x1) + (0x0) + (0x0) = 0	(0x0) + (0x1) + (0x0) = 0	(0x0) + (0x0) + (0x1) = 0	(0x50) + (0x100) + (0x90) = 0	
$C_j - Z_j$		4-0 = 4	10-0 = **10**	0-0 = 0	0-0 = 0	0-0 = 0	0-0 = 0	

Key Column [Max ($C_j - Z_j$)] — Key Element — Key Row (Min Ratio)

Here, C_{Bi} are the coefficients of basic variables – as per Objective function. BV are the Basic Variables. For Optimal solution, all values of (Cj – Zj) must be ≤ 0. Here, all the values of (Cj – Zj) are not ≤ 0. Hence, this is not the optimal solution. So, proceed for iteration.

To proceed for iteration, following are the steps to be followed :

a. Find KEY COLUMN [that has maximum value of Cj – Zj)]
b. Find the RATIO (using Ratio = Solution Value / Respective Key Column Value)
c. Select KEY ROW (that has minimum value of Ratio)
d. Identify the KEY ELEMENT (which is the cross-section element of Key Column and Key Row).
e. Find ENTERING VARIABLE (that belongs to Key Column) and LEAVING VARIABLE (that belongs to Key Row).
f. Prepare ITERATION TABLE – Computing all respective a_{ij} values as per following :

$$\text{Value of Entering or New Variable} = \frac{\text{Old Value}}{\text{Key Element}}$$

$$\left(\begin{array}{c}\text{New Value of}\\ \text{Existing Variable}\end{array}\right) = \text{Old Value} - \frac{\text{Corresponding Key Column Value x Corresponding key Row Value}}{\text{Key Element}}$$

Here, Entering Variable is X_2 (basic variable corresponding to Key Column) and Leaving Variable is S_2 (basic variable that belongs to key row). The Iteration-1 table will be as per following :

C_{Bi}	C_j	4	10	0	0	0	Solution	Ratio
	BV	X_1	X_2	S_1	S_2	S_3		
0	S_1	2 – (1x2/5) = 8/5	1 – (1x5/5) = 0	1 – (1x0/5) = 1	0 – (1x1/5) = -1/5	0 – (1x0/5) = 0	50 – (1x100/5) = 30	
10	X_2	2/5	5/5 = 1	0/5 = 0	1/5	0/5 = 0	100/5 = 20	
0	S_3	2 – (3x2/5) = 4/5	3 – (3x5/5) = 0	0 – (3x0/5) = 0	0 – (3x1/5) = -3/5	1 – (3x0/5) = 1	90 – (3x100/5) = 30	
$Z_j = \Sigma(C_{Bi} \times a_{ij})$		(0x8/5) + (10x2/5) + (0x4/5) = 4	(0x0) + (10x1) + (0x0) = 10	(0x1) + (10x0) + (0x0) = 0	(0x0) + (10x1/5) + (0x-3/5) = 2	(0x0) + (10x0) + (0x1) = 0		
$C_j - Z_j$		4-4 = 0	10-10 = 0	0-0 = 0	0-2 = -2	0-0 = 0		

Here, all values of (Cj – Zj) are ≤ 0. Hence, this is the optimal solution. So, $X_2 = 20$ and $X_1 = 0$

With this, Objective Function will be :

Maximize Z = $4 X_1 + 10 X_2$ = (4x0) + (10x20) = **200** **(Answer)**

b. Allocate the sub-assembly to the contractor on one-to-one basis for low-cost bid (minimum total cost).

The concerned matric is given below :

		Contractors			
		1	**2**	**3**	**4**
Sub-assemblies	**1**	**15**	**13**	**14**	**17**
	2	**11**	**12**	**15**	**13**
	3	**13**	**12**	**10**	**11**
	4	**15**	**17**	**14**	**16**

Solution : Here, the Hungarian Method of assignment will be used. Its major steps are :

1. Check the given matrix is square. If not, add suitable row / column with dummy (cell value = 0).
2. Row Reduction : Subtract the smallest element in each row from all the elements in that row.
3. Column Reduction : Subtract the smallest element in each column from all the elements in that column.
4. Examine the row successively for exactly one unmarked zero, and do the assignment for this only zero of the row. After this assignment, cut all other zeros of that column (cell of assignment row).
5. Next, examine columns for single unmarked zero and do the assignment for this only zero of the column. After this assignment, cut all other zeros of that row (containing cell of assignment column).
6. Repeat this process for all allocations, and compute final outcome of assignment (based on assignments done).

With this, the given matrix is square. So, there is no need of adding dummy (row or column with zero values).

After doing row reduction, the obtained matrix will be :

		Contractors			
		1	**2**	**3**	**4**
Sub Assy	**1** (min = 13)	15-13 = 2	**13**-13=0	14-13=1	17-13=4
	2 (min = 11)	**11**-11 = 0	12-11=1	15-11=4	13-11=2
	3 (min = 10)	13-10=3	12-10=2	**10**-10=0	11-10=1
	4 (min=14)	15-14=1	17-14=3	**14**-14=0	16-14=2

After doing column reduction, the obtained matrix will be :

		Contractors			
		1 (min = 0)	**2** (min = 0)	**3** (min = 0)	**4** (min = 1)
Sub Assy	**1**	2	0	1	4-1 = 3
	2	0	1	4	2-1 = 1
	3	3	2	0	1-1 = 0
	4	1	3	0	2-1 = 1

The assignments will be as per following steps (referring above mentioned procedure):

- Examine Row-1 : Single Zero for Contractor-2. Assign Sub-assembly-1 to Contractor-2. Cut all other zeros of concerned column (column of Contractor-2) – None is there.
- Examining Row-2 : Single Zero for Contractor-1. Assign Sub-assembly-2 to Contractor-1. Cut all other zeros of concerned column (column of Contractor-1) – None is there.
- Examining Row-3 : Two Zeros in the row. So, leave it now.
- Examining Row-4 : Two Zeros in the row. So, leave it now.
- Examining Column-1 : Assignment – already done for single zero (Contractor-1 and Sub-assembly-2).
- Examining Column-2 : Assignment – already done for single zero (Contractor-2 and Sub-assembly-1)
- Examining Column-3 : Two Zeros in the column. So, leave it now.
- Examining Column-4 : Single zero for sub-assembly 3. Do this assignment (Contractor-4 with Sub-assembly-3). Cut all other zeros of the concerned row (i.e. row of Sub-assembly-3). The cut zero is of Contractor-3 and Sub-assembly-3.
- Now examine Row-4. It has only one unmarked zero for contractor-3. So do this assignment (Contractor-3 with Sub-assembly-4).

Hence, all the assignments are :

Contractor-1 : Sub-assembly-2 (Cost=11) Contractor-2 : Sub-assembly-1 (Cost=13)
Contractor-3 : Sub-assembly-4 (Cost=14) Contractor-4 : Sub-assembly-3 (Cost=11)

The cost will be : 11 + 13 + 14 + 11 = **49 (Answer)**

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