CHAPTER 11

INDUSTRIAL ENGINEERING

YEAR 2012 **ONE MARK**

MCQ 11.1 Which one of the following is NOT a decision taken during the aggregate production planning stage ?

(A) Scheduling of machines

(B) Amount of labour to be committed

(C) Rate at which production should happen

(D) Inventory to be carried forward

YEAR 2012 **TWO MARKS**

• Common Data For Q.2 and Q.3

For a particular project, eight activities are to be carried out. Their relationships with other activities and expected durations are mentioned in the table below.

Activity	Predecessors	Durations (days)
a	-	3
b	a	4
c	a	5
d	a	4
e	b	2
f	d	9
g	c, e	6
h	f, g	2

MCQ 11.2 The critical path for the project is

(A) $a - b - e - g - h$ (B) $a - c - g - h$

(C) $a - d - f - h$ (D) $a - b - c - f - h$

MCQ 11.3 If the duration of activity f alone is changed from 9 to 10 days, then the

(A) critical path remains the same and the total duration to complete the

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project changes to 19 days.

(B) critical path and the total duration to complete the project remains the same.

(C) critical path changes but the total duration to complete the project remains the same.

(D) critical path changes and the total duration to complete the project changes to 17 days.

YEAR 2011 ONE MARK

MCQ 11.4 Cars arrive at a service station according to Poisson's distribution with a mean rate of 5 per hour. The service time per car is exponential with a mean of 10 minutes. At steady state, the average waiting time in the queue is

(A) 10 minutes (B) 20 minutes

(C) 25 minutes (D) 50 minutes

MCQ 11.5 The word 'kanban' is most appropriately associated with

(A) economic order quantity

(B) just-in-time production

(C) capacity planning

(D) product design

YEAR 2011 TWO MARKS

• Common Data For Q.6 and Q.7

One unit of product P_1 requires 3 kg of resources R_1 and 1 kg of resources R_2. One unit of product P_2 requires 2 kg of resources R_1 and 2 kg of resources R_2. The profits per unit by selling product P_1 and P_2 are Rs. 2000 and Rs. 3000 respectively. The manufacturer has 90 kg of resources R_1 and 100 kg of resources R_2.

MCQ 11.6 The unit worth of resources R_2, i.e., dual price of resources R_2 in Rs. per kg is

(A) 0 (B) 1350

(C) 1500 (D) 2000

MCQ 11.7 The manufacturer can make a maximum profit of Rs.

(A) 60000 (B) 135000

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(C) 150000 (D) 200000

YEAR 2010 ONE MARK

MCQ 11.8 The demand and forecast for February are 12000 and 10275, respectively. Using single exponential smoothening method (smoothening coefficient $= 0.25$), forecast for the month of March is

(A) 431 (B) 9587

(C) 10706 (D) 11000

MCQ 11.9 Little's law is a relationship between

(A) stock level and lead time in an inventory system

(B) waiting time and length of the queue in a queuing system

(C) number of machines and job due dates in a scheduling problem

(D) uncertainty in the activity time and project completion time

MCQ 11.10 Vehicle manufacturing assembly line is an example of

(A) product layout (B) process layout

(C) manual layout (D) fixed layout

MCQ 11.11 Simplex method of solving linear programming problem uses

(A) all the points in the feasible region

(B) only the corner points of the feasible region

(C) intermediate points within the infeasible region

(D) only the interior points in the feasible region

YEAR 2010 TWO MARKS

MCQ 11.12 Annual demand for window frames is 10000. Each frame cost Rs. 200 and ordering cost is Rs. 300 per order. Inventory holding cost is Rs. 40 per frame per year. The supplier is willing of offer 2% discount if the order quantity is 1000 or more, and 4% if order quantity is 2000 or more. If the total cost is to be minimized, the retailer should

(A) order 200 frames every time

(B) accept 2% discount

(C) accept 4% discount

(D) order Economic Order Quantity

MCQ 11.13 The project activities, precedence relationships and durations are described in the table. The critical path of the project is

Activity	Precedence	Duration (in days)
P	-	3
Q	-	4
R	P	5
S	Q	5
T	R, S	7
U	R, S	5
V	T	2
W	U	10

(A) P-R-T-V
(B) Q-S-T-V
(C) P-R-U-W
(D) Q-S-U-W

• Common Data For Q.14 and Q.15

Four jobs are to be processed on a machine as per data listed in the table.

Job	Processing time (in days)	Due date
1	4	6
2	7	9
3	2	19
4	8	17

MCQ 11.14 If the Earliest Due Date (EDD) rule is used to sequence the jobs, the number of jobs delayed is

(A) 1
(B) 2
(C) 3
(D) 4

MCQ 11.15 Using the Shortest Processing Time (SPT) rule, total tardiness is

(A) 0
(B) 2
(C) 6
(D) 8

YEAR 2009 ONE MARK

MCQ 11.16 The expected time (t_e) of a $PERT$ activity in terms of optimistic time t_0, pessimistic time (t_p) and most likely time (t_l) is given by

(A) $t_e = \dfrac{t_o + 4t_l + t_p}{6}$
(B) $t_e = \dfrac{t_o + 4t_p + t_l}{6}$

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(C) $t_e = \frac{t_o + 4t_l + t_p}{3}$

(D) $t_e = \frac{t_o + 4t_p + t_l}{3}$

MCQ 11.17 Which of the following forecasting methods takes a fraction of forecast error into account for the next period forecast ?

(A) simple average method

(B) moving average method

(C) weighted moving average method

(D) exponential smoothening method

YEAR 2009 TWO MARKS

MCQ 11.18 A company uses 2555 units of an item annually. Delivery lead time is 8 days. The reorder point (in number of units) to achieve optimum inventory is

(A) 7

(B) 8

(C) 56

(D) 60

MCQ 11.19 Consider the following Linear Programming Problem (LPP):

Maximize $Z = 3x_1 + 2x_2$

Subject to

$$x_1 \le 4$$
$$x_2 \le 6$$
$$3x_1 + 2x_2 \le 18$$
$$x_1 \ge 0, x_2 \ge 0$$

(A) The LPP has a unique optimal solution

(B) The LPP is infeasible.

(C) The LPP is unbounded.

(D) The LPP has multiple optimal solutions.

MCQ 11.20 Six jobs arrived in a sequence as given below:

Jobs	Processing Time (days)
I	4
II	9
III	5
IV	10
V	6
VI	8

Average flow time (in days) for the above jobs using Shortest Processing time rule is

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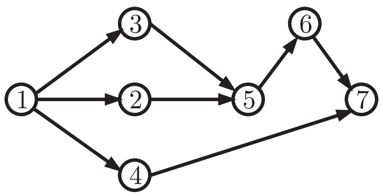
(A) 20.83 (B) 23.16
(C) 125.00 (D) 139.00

• Common Data For Q.21 and Q.22

Consider the following PERT network:



The optimistic time, most likely time and pessimistic time of all the activities are given in the table below:

Activity	Optimistic time (days)	Most likely time (days)	Pessimistic time (days)
1 - 2	1	2	3
1 - 3	5	6	7
1 - 4	3	5	7
2 - 5	5	7	9
3 - 5	2	4	6
5 - 6	4	5	6
4 - 7	4	6	8
6 - 7	2	3	4

MCQ 11.21 The critical path duration of the network (in days) is
(A) 11 (B) 14
(C) 17 (D) 18

MCQ 11.22 The standard deviation of the critical path is
(A) 0.33 (B) 0.55
(C) 0.77 (D) 1.66

YEAR 2008 ONE MARK

MCQ 11.23 In an $M/M/1$ queuing system, the number of arrivals in an interval of length T is a Poisson random variable (i.e. the probability of there being arrivals in an interval of length T is $\frac{e^{-\lambda T}(\lambda T)^n}{n!}$). The probability density function

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$f(t)$ of the inter-arrival time is

(A) $\lambda^2(e^{-\lambda^2 t})$ (B) $\frac{e^{-\lambda^2 t}}{\lambda^2}$

(C) $\lambda e^{-\lambda t}$ (D) $\frac{e^{-\lambda t}}{\lambda}$

MCQ 11.24 A set of 5 jobs is to be processed on a single machine. The processing time (in days) is given in the table below. The holding cost for each job is Rs. K per day.

Job	Processing time
P	5
Q	2
R	3
S	2
T	1

A schedule that minimizes the total inventory cost is

(A) T-S-Q-R-P (B) P-R-S-Q-T

(C) T-R-S-Q-P (D) P-Q-R-S-T

YEAR 2008 TWO MARKS

MCQ 11.25 For the standard transportation linear programme with m source and n destinations and total supply equaling total demand, an optimal solution (lowest cost) with the smallest number of non-zero x_{ij} values (amounts from source i to destination j) is desired. The best upper bound for this number is

(A) mn (B) $2(m+n)$

(C) $m+n$ (D) $m+n-1$

MCQ 11.26 A moving average system is used for forecasting weekly demand $F_1(t)$ and $F_2(t)$ are sequences of forecasts with parameters m_1 and m_2, respectively, where m_1 and $m_2(m_1 > m_2)$ denote the numbers of weeks over which the moving averages are taken. The actual demand shows a step increase from d_1 to d_2 at a certain time. Subsequently,

(A) neither $F_1(t)$ nor $F_2(t)$ will catch up with the value d_2

(B) both sequences $F_1(t)$ and $F_2(t)$ will reach d_2 in the same period

(C) $F_1(t)$ will attain the value d_2 before $F_2(t)$

(D) $F_2(t)$ will attain the value d_2 before $F_1(t)$

MCQ 11.27 For the network below, the objective is to find the length of the shortest

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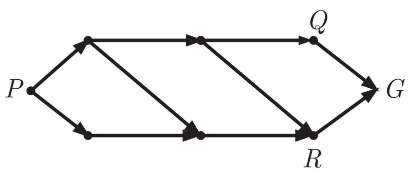
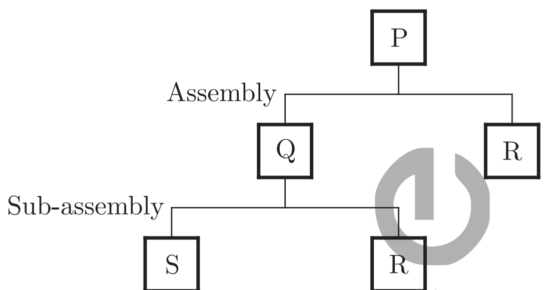
path from node P to node G.
Let d_{ij} be the length of directed arc from node i to node j.
Let S_j be the length of the shortest path from P to node j. Which of the following equations can be used to find S_G ?



(A) $S_G = \text{Min}\{S_Q, S_R\}$
(B) $S_G = \text{Min}\{S_Q - d_{QG}, S_R - d_{RG}\}$
(C) $S_G = \text{Min}\{S_Q + d_{QG}, S_R + d_{RG}\}$
(D) $S_G = \text{Min}\{d_{QG}, d_{RG}\}$

MCQ 11.28 The product structure of an assembly P is shown in the figure.



Estimated demand for end product P is as follows

Week	1	2	3	4	5	6
Demand	1000	1000	1000	1000	1200	1200

ignore lead times for assembly and sub-assembly. Production capacity (per week) for component R is the bottleneck operation. Starting with zero inventory, the smallest capacity that will ensure a feasible production plan up to week 6 is

(A) 1000
(B) 1200
(C) 2200
(D) 2400

• Common Data For Q.29 and Q.30

Consider the Linear Programme (LP)

Max $4x + 6y$

Subject to $3x + 2y \le 6$

$2x + 3y \le 6$

$x, y \ge 0$

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MCQ 11.29 After introducing slack variables s and t, the initial basic feasible solution is represented by the table below (basic variables are $s = 6$ and $t = 6$, and the objective function value is 0)

	-4	-6	0	0	0
s	3	2	1	0	6
t	2	3	0	1	6
	x	y	s	t	RHS

After some simplex iterations, the following table is obtained

	0	0	0	2	12
s	$5/3$	0	1	$-1/3$	2
y	$2/3$	1	0	$1/3$	2
	x	y	s	t	RHS

From this, one can conclude that
(A) the LP has a unique optimal solution
(B) the LP has an optimal solution that is not unique
(C) the LP is infeasible
(D) the LP is unbounded

MCQ 11.30 The dual for the LP in Q. 29 is

(A) Min $6u + 6v$
subject to
$3u + 2v \geq 4$
$2u + 3v \geq 6$
$u, v \geq 0$

(B) Max $6u + 6v$
subject to
$3u + 2v \leq 4$
$2u + 3v \leq 6$
$u, v \geq 0$

(C) Max $4u + 6v$
subject to
$3u + 2v \geq 6$
$2u + 3v \geq 6$
$u, v \geq 0$

(D) Min $4u + 6v$
subject to
$3u + 2v \leq 6$
$2u + 3v \leq 6$
$u, v \geq 0$

YEAR 2007 **TWO MARKS**

MCQ 11.31 Capacities of production of an item over 3 consecutive months in regular time are 100, 100 and 80 and in overtime are 20, 20 and 40. The demands over those 3 months are 90, 130 and 110. The cost of production in regular time and overtime are respectively Rs. 20 per item and Rs. 24 per item.

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Inventory carrying cost is Rs. 2 per item per month. The levels of starting and final inventory are nil. Backorder is not permitted. For minimum cost of plan, the level of planned production in overtime in the third month is

(A) 40 (B) 30

(C) 20 (D) 0

MCQ 11.32 The maximum level of inventory of an item is 100 and it is achieved with infinite replenishment rate. The inventory becomes zero over one and half month due to consumption at a uniform rate. This cycle continues throughout the year. Ordering cost is Rs. 100 per order and inventory carrying cost is Rs. 10 per item per month. Annual cost (in Rs.) of the plan, neglecting material cost, is

(A) 800 (B) 2800

(C) 4800 (D) 6800

MCQ 11.33 In a machine shop, pins of 15 mm diameter are produced at a rate of 1000 per month and the same is consumed at a rate of 500 per month. The production and consumption continue simultaneously till the maximum inventory is reached. Then inventory is allowed to reduced to zero due to consumption . The lot size of production is 1000. If backlog is not allowed, the maximum inventory level is

(A) 400 (B) 500

(C) 600 (D) 700

MCQ 11.34 The net requirements of an item over 5 consecutive weeks are 50-0-15-20-20. The inventory carrying cost and ordering cost are Rs. 1 per item per week and Rs. 100 per order respectively. Starting inventory is zero. Use “ Least Unit Cost Technique” for developing the plan. The cost of the plan (in Rs.) is

(A) 200 (B) 250

(C) 225 (D) 260

YEAR 2006 ONE MARK

MCQ 11.35 The number of customers arriving at a railway reservation counter is Poisson distributed with an arrival rate of eight customers per hour. The reservation clerk at this counter takes six minutes per customer on an average with an exponentially distributed service time. The average number of the customers in the queue will be

(A) 3 (B) 3.2

(C) 4 (D) 4.2

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MCQ 11.36 In an MRP system, component demand is

(A) forecasted

(B) established by the master production schedule

(C) calculated by the MRP system from the master production schedule

(D) ignored

YEAR 2006 **TWO MARKS**

MCQ 11.37 An manufacturing shop processes sheet metal jobs, wherein each job must pass through two machines ($M1$ and $M2$, in that order). The processing time (in hours) for these jobs is

Machine	Jobs					
	P	Q	R	S	T	U
$M1$	15	32	8	27	11	16
$M2$	6	19	13	20	14	7

The optimal make-span (in-hours) of the shop is

(A) 120 (B) 115

(C) 109 (D) 79

MCQ 11.38 Consider the following data for an item.
Annual demand : 2500 units per year, Ordering cost : Rs. 100 per order,
Inventory holding rate : 25% of unit price
Price quoted by a supplier

Order quantity (units)	Unit price (Rs.)
< 500	10
≥ 500	9

The optimum order quantity (in units) is

(A) 447 (B) 471

(C) 500 (D) ≥ 600

MCQ 11.39 A firm is required to procure three items (P, Q, and R). The prices quoted for these items (in Rs.) by suppliers $S1$, $S2$ and $S3$ are given in table. The management policy requires that each item has to be supplied by only one supplier and one supplier supply only one item. The minimum total cost (in Rs.) of procurement to the firm is

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Item	Suppliers		
	$S1$	$S2$	$S3$
P	110	120	130
Q	115	140	140
R	125	145	165

(A) 350
(B) 360
(C) 385
(D) 395

MCQ 11.40 A stockist wishes to optimize the number of perishable items he needs to stock in any month in his store. The demand distribution for this perishable item is

Demand (in units)	2	3	4	5
Probability	0.10	0.35	0.35	0.20

The stockist pays Rs. 70 for each item and he sells each at Rs. 90. If the stock is left unsold in any month, he can sell the item at Rs. 50 each. There is no penalty for unfulfilled demand. To maximize the expected profit, the optimal stock level is

(A) 5 units
(B) 4 units
(C) 3 units
(D) 2 units

MCQ 11.41 The table gives details of an assembly line.

Work station	I	II	III	IV	V	VI
Total task time at the workstation (in minutes)	7	9	7	10	9	6

What is the line efficiency of the assembly line ?

(A) 70%
(B) 75%
(C) 80%
(D) 85%

MCQ 11.42 The expected completion time of the project is

(A) 238 days
(B) 224 days
(C) 171 days
(D) 155 days

MCQ 11.43 The standard deviation of the critical path of the project is

(A) $\sqrt{151}$ days
(B) $\sqrt{155}$ days
(C) $\sqrt{200}$ days
(D) $\sqrt{238}$ days

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YEAR 2005 ONE MARK

MCQ 11.44 An assembly activity is represented on an Operation Process Chart by the symbol

(A) □ (B) A

(C) D (D) O

MCQ 11.45 The sales of a product during the last four years were 860, 880, 870 and 890 units. The forecast for the fourth year was 876 units. If the forecast for the fifth year, using simple exponential smoothing, is equal to the forecast using a three period moving average, the value of the exponential smoothing constant α is

(A) $\frac{1}{7}$ (B) $\frac{1}{5}$

(C) $\frac{2}{7}$ (D) $\frac{2}{5}$

MCQ 11.46 Consider a single server queuing model with Poisson arrivals ($\lambda = 4$/hour) and exponential service ($\mu = 4$/hour). The number in the system is restricted to a maximum of 10. The probability that a person who comes in leaves without joining the queue is

(A) $\frac{1}{11}$ (B) $\frac{1}{10}$

(C) $\frac{1}{9}$ (D) $\frac{1}{2}$

YEAR 2005 TWO MARKS

MCQ 11.47 A component can be produced by any of the four processes I, II, III and IV. Process I has a fixed cost of Rs. 20 and variable cost of Rs. 3 per piece. Process II has a fixed cost Rs. 50 and variable cost of Rs. 1 per piece. Process III has a fixed cost of Rs. 40 and variable cost of Rs. 2 per piece. Process IV has a fixed cost of Rs. 10 and variable cost of Rs. 4 per piece. If the company wishes to produce 100 pieces of the component, form economic point of view it should choose

(A) Process I (B) Process II

(C) Process III (D) Process IV

MCQ 11.48 A welding operation is time-studied during which an operator was pace-rated as 120%. The operator took, on an average, 8 minutes for producing the weld-joint. If a total of 10% allowances are allowed for this operation. The expected standard production rate of the weld-joint (in units per 8 hour day) is

(A) 45 (B) 50

(C) 55 (D) 60

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MCQ 11.49 The distribution of lead time demand for an item is as follows:

Lead time demand	Probability
80	0.20
100	0.25
120	0.30
140	0.25

The reorder level is 1.25 times the expected value of the lead time demand. The service level is

(A) 25% (B) 50%

(C) 75% (D) 100%

MCQ 11.50 A project has six activities (A to F) with respective activity duration 7, 5, 6, 6, 8, 4 days. The network has three paths A-B, C-D and E-F. All the activities can be crashed with the same crash cost per day. The number of activities that need to be crashed to reduce the project duration by 1 day is

(A) 1 (B) 2

(C) 3 (D) 6

MCQ 11.51 A company has two factories $S1$, $S2$, and two warehouses $D1$, $D2$. The supplies from $S1$ and $S2$ are 50 and 40 units respectively. Warehouse $D1$ requires a minimum of 20 units and a maximum of 40 units. Warehouse $D2$ requires a minimum of 20 units and, over and above, it can take as much as can be supplied. A balanced transportation problem is to be formulated for the above situation. The number of supply points, the number of demand points, and the total supply (or total demand) in the balanced transportation problem respectively are

(A) 2, 4, 90 (B) 2, 4, 110

(C) 3, 4, 90 (D) 3, 4, 110

• Common Data For Q.52 and Q.53

Consider a linear programming problem with two variables and two constraints. The objective function is : Maximize $X_1 + X_2$. The corner points of the feasible region are (0, 0), (0, 2), (2, 0) and (4/3, 4/3)

MCQ 11.52 If an additional constraint $X_1 + X_2 \leq 5$ is added, the optimal solution is

(A) $\left(\frac{5}{3}, \frac{5}{3}\right)$ (B) $\left(\frac{4}{3}, \frac{4}{3}\right)$

(C) $\left(\frac{5}{2}, \frac{5}{2}\right)$ (D) (5, 0)

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MCQ 11.53 Let Y_1 and Y_2 be the decision variables of the dual and v_1 and v_2 be the slack variables of the dual of the given linear programming problem. The optimum dual variables are

(A) Y_1 and Y_2 (B) Y_1 and v_1

(C) Y_1 and v_2 (D) v_1 and v_2

YEAR 2004 ONE MARK

MCQ 11.54 In PERT analysis a critical activity has

(A) maximum Float (B) zero Float

(C) maximum Cost (D) minimum Cost

MCQ 11.55 For a product, the forecast and the actual sales for December 2002 were 25 and 20 respectively. If the exponential smoothing constant (α) is taken as 0.2, then forecast sales for January 2003 would be

(A) 21 (B) 23

(C) 24 (D) 27

MCQ 11.56 There are two products P and Q with the following characteristics

Product	Demand (Units)	Order cost (Rs/order)	Holding Cost (Rs./ unit/ year)
P	100	50	4
Q	400	50	1

The economic order quantity (EOQ) of products P and Q will be in the ratio

(A) 1 : 1 (B) 1 : 2

(C) 1 : 4 (D) 1 : 8

YEAR 2004 TWO MARKS

MCQ 11.57 A standard machine tool and an automatic machine tool are being compared for the production of a component. Following data refers to the two machines.

	Standard Machine Tool	Automatic Machine Tool
Setup time	30 min	2 hours
Machining time per piece	22 min	5 min
Machine rate	Rs. 200 per hour	Rs. 800 per hour

The break even production batch size above which the automatic machine

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tool will be economical to use, will be

(A) 4 (B) 5

(C) 24 (D) 225

MCQ 11.58 A soldering operation was work-sampled over two days (16 hours) during which an employee soldered 108 joints. Actual working time was 90% of the total time and the performance rating was estimated to be 120 per cent. If the contract provides allowance of 20 percent of the time available, the standard time for the operation would be

(A) 8 min (B) 8.9 min

(C) 10 min (D) 12 min

MCQ 11.59 An electronic equipment manufacturer has decided to add a component sub-assembly operation that can produce 80 units during a regular 8-hours shift. This operation consist of three activities as below

Activity	Standard time (min)
M. Mechanical assembly	12
E. Electric wiring	16
T. Test	3

For line balancing the number of work stations required for the activities M, E and T would respectively be

(A) 2, 3, 1 (B) 3, 2, 1

(C) 2, 4, 2 (D) 2, 1, 3

MCQ 11.60 A maintenance service facility has Poisson arrival rates, negative exponential service time and operates on a 'first come first served' queue discipline. Breakdowns occur on an average of 3 per day with a range of zero to eight. The maintenance crew can service an average of 6 machines per day with a range of zero to seven. The mean waiting time for an item to be serviced would be

(A) $\frac{1}{6}$ day (B) $\frac{1}{3}$ day

(C) 1 day (D) 3 day

MCQ 11.61 A company has an annual demand of 1000 units, ordering cost of Rs. 100 / order and carrying cost of Rs. 100/ unit/year. If the stock-out cost are estimated to be nearly Rs. 400 each time the company runs out-of-stock, then safety stock justified by the carrying cost will be

(A) 4 (B) 20

(C) 40 (D) 100

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MCQ 11.62 A company produces two types of toys : P and Q. Production time of Q is twice that of P and the company has a maximum of 2000 time units per day. The supply of raw material is just sufficient to produce 1500 toys (of any type) per day. Toy type Q requires an electric switch which is available @ 600 pieces per day only. The company makes a profit of Rs. 3 and Rs. 5 on type P and Q respectively. For maximization of profits, the daily production quantities of P and Q toys should respectively be

(A) 1000, 500
(B) 500, 1000
(C) 800, 600
(D) 1000, 1000

YEAR 2003 ONE MARK

MCQ 11.63 The symbol used for Transport in work study is

(A) $\Rightarrow$
(B) T
(C) $\square$
(D) ∇

YEAR 2003 TWO MARKS

MCQ 11.64 Two machines of the same production rate are available for use. On machine 1, the fixed cost is Rs. 100 and the variable cost is Rs. 2 per piece produced. The corresponding numbers for the machine 2 are Rs. 200 and Re. 1 respectively. For certain strategic reasons both the machines are to be used concurrently. The sales price of the first 800 units is Rs. 3.50 per unit and subsequently it is only Rs. 3.00. The breakeven production rate for each machine is

(A) 75
(B) 100
(C) 150
(D) 600

MCQ 11.65 A residential school stipulates the study hours as 8.00 pm to 10.30 pm. Warden makes random checks on a certain student 11 occasions a day during the study hours over a period of 10 days and observes that he is studying on 71 occasions. Using 95% confidence interval, the estimated minimum hours of his study during that 10 day period is

(A) 8.5 hours
(B) 13.9 hours
(C) 16.1 hours
(D) 18.4 hours

MCQ 11.66 The sale of cycles in a shop in four consecutive months are given as 70, 68, 82, 95. Exponentially smoothing average method with a smoothing factor of 0.4 is used in forecasting. The expected number of sales in the next month is

(A) 59
(B) 72
(C) 86
(D) 136

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MCQ 11.67 Market demand for springs is 8,00,000 per annum. A company purchases these springs in lots and sells them. The cost of making a purchase order is Rs. 1200. The cost of storage of springs is Rs. 120 per stored piece per annum. The economic order quantity is

(A) 400

(B) 2,828

(C) 4,000

(D) 8,000

MCQ 11.68 A manufacturer produces two types of products, 1 and 2, at production levels of x_1 and x_2 respectively. The profit is given is $2x_1 + 5x_2$. The production constraints are

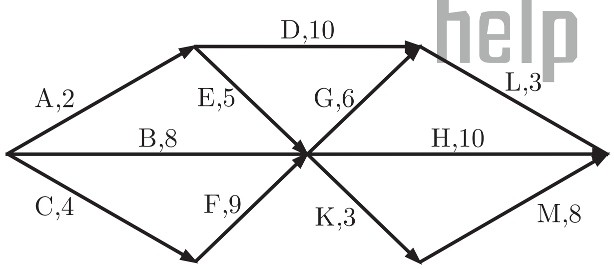
$$x_1 + 3x_2 \le 40$$
$$3x_1 + x_2 \le 24$$
$$x_1 + x_2 \le 10$$
$$x_1 > 0,\ x_2 > 0$$

The maximum profit which can meet the constraints is

(A) 29 (B) 38

(C) 44 (D) 75

MCQ 11.69 A project consists of activities A to M shown in the net in the following figure with the duration of the activities marked in days



The project can be completed

(A) between 18, 19 days (B) between 20, 22 days

(C) between 24, 26 days (D) between 60, 70 days

MCQ 11.70 The principles of motion economy are mostly used while conducting

(A) a method study on an operation

(B) a time study on an operation

(C) a financial appraisal of an operation

(D) a feasibility study of the proposed manufacturing plant

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YEAR 2002 ONE MARK

MCQ 11.71 The standard time of an operation while conducting a time study is
(A) mean observed time + allowances
(B) normal time + allowances
(C) mean observed time × rating factor + allowances
(D) normal time × rating factor + allowances

MCQ 11.72 In carrying out a work sampling study in a machine shop, it was found that a particular lathe was down for 20% of the time. What would be the 95% confidence interval of this estimate, if 100 observations were made ?
(A) $(0.16, 0.24)$
(B) $(0.12, 0.28)$
(C) $(0.08, 0.32)$
(D) None of these

MCQ 11.73 An item can be purchased for Rs. 100. The ordering cost is Rs. 200 and the inventory carrying cost is 10% of the item cost per annum. If the annual demand is 4000 unit, the economic order quantity (in unit) is
(A) 50
(B) 100
(C) 200
(D) 400

YEAR 2002 TWO MARKS

MCQ 11.74 Arrivals at a telephone booth are considered to be Poisson, with an average time of 10 minutes between successive arrivals. The length of a phone call is distributed exponentially with mean 3 minutes. The probability that an arrival does not have to wait before service is
(A) 0.3
(B) 0.5
(C) 0.7
(D) 0.9

MCQ 11.75 The supplies at three sources are 50, 40 and 60 unit respectively whilst the demands at the four destinations are 20, 30, 10 and 50 unit. In solving this transportation problem
(A) a dummy source of capacity 40 unit is needed
(B) a dummy destination of capacity 40 unit is needed
(C) no solution exists as the problem is infeasible
(D) no solution exists as the problem is degenerate

MCQ 11.76 A project consists of three parallel paths with mean durations and variances of $(10, 4)$, $(12, 4)$ and $(12, 9)$ respectively. According to the standard PERT assumptions, the distribution of the project duration is
(A) beta with mean 10 and standard deviation 2
(B) beta with mean 12 and standard deviation 2

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(C) normal with mean 10 and standard deviation 3

(D) normal with mean 12 and standard deviation 3

YEAR 2001 ONE MARK

MCQ 11.77 Production flow analysis (PFA) is a method of identifying part families that uses data from

(A) engineering drawings (B) production schedule

(C) bill of materials (D) route sheets

MCQ 11.78 When using a simple moving average to forecast demand, one would

(A) give equal weight to all demand data

(B) assign more weight to the recent demand data

(C) include new demand data in the average without discarding the earlier data

(D) include new demand data in the average after discarding some of the earlier demand data

YEAR 2001 TWO MARKS

MCQ 11.79 Fifty observations of a production operation revealed a mean cycle time of 10 min. The worker was evaluated to be performing at 90% efficiency. Assuming the allowances to be 10% of the normal time, the standard time (in second) for the job is

(A) 0.198 (B) 7.3

(C) 9.0 (D) 9.9

****

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SOLUTION

SOL 11.1 Option (A) is correct.

Costs relevant to aggregate production planning is as given below.

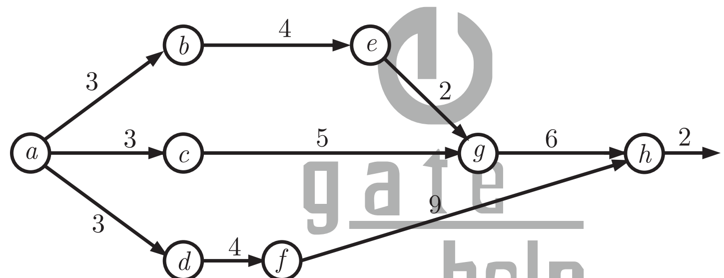
(i) Basic production cost : Material costs, direct labour costs, and overhead cost.

(ii) Costs associated with changes in production rate : Costs involving in hiring, training and laying off personnel, as well as, overtime compensation.

(iii) Inventory related costs.

Hence, from above option (A) is not related to these costs. Therefore option (A) is not a decision taken during the APP.

SOL 11.2 Option (C) is correct.



For path	Duration
$a - b - e - g - h$	$= 3 + 4 + 2 + 6 + 2 = 17$ days
$a - c - g - h$	$= 3 + 5 + 6 + 2 = 16$ days
$a - d - f - h$	$= 3 + 4 + 9 + 2 = 18$ days

The critical path is one that takes longest path.

Hence, path $a - d - f - h = 18$ days is critical path

SOL 11.3 Option (A) is correct.

From previous question

For critical path

a-d-f-$h = 18$ days, the duration of activity f alone is changed from 9 to 10 days, then

$$a - d - f - h = 3 + 4 + 10 + 2 = 19 \text{ days}$$

Hence critical path remains same and the total duration to complete the project changes to 19 days.

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SOL 11.4 Option (D) is correct.

Given : $\lambda = 5$ per hour, $\mu = \frac{1}{10} \times 60$ per hour $= 6$ per hour

Average waiting time of an arrival

$$W_q = \frac{\lambda}{\mu(\mu - \lambda)} = \frac{5}{6(6-5)}$$

$$= \frac{5}{6} \text{ hours } = 50 \text{ min}$$

SOL 11.5 Option (B) is correct.

Kanban Literally, a "Visual record"; a method of controlling materials flow through a Just-in-time manufacturing system by using cards to authorize a work station to transfer or produce materials.

SOL 11.6 Option (A) is correct.

Since, in Z_j Row of final (second) obtimum table the value of slack variable S_2 showns the unit worth or dual price of Resource R_2 and the value of S_2 in given below table is zero. Hence the dual Price of Resource R_2 is zero.

$$\text{Max } Z = 2000P_1 + 3000P_2$$

S.T. $3P_1 + 2P_2 \le 90$ $\rightarrow R_1$ – Resource

$P_1 + 2P_2 \le 100$ $\rightarrow R_2$ – Resource

$P_1, P_2 \ge 0$

Solution : $Z = 2000P_1 + 3000P_2 + 0.S_1 + 0.S_2$

S.T. $3P_1 + 2P_2 + S_1 = 90$

$P_1 + 2P_2 + S_2 = 100$

$P_1 \ge 0,\ P_2 \ge 0,\ S_1 \ge 0,\ S_2 \ge 0$

First table :-

		C_j	2000	3000	0	0
C_B	S_B	P_B	P_1	P_2	S_1	S_2
0	S_1	90	3	$\boxed{2} \rightarrow$	1	0
0	S_2	100	1	2	0	1
	Z_j		0	0	0	0
	$Z_j - C_j$		-2000	$-3000 \uparrow$	0	0

Second Table :-

		C_j	2000	3000	0	0
C_B	S_B	P_B	P_1	P_2	S_1	S_2
3000	P_2	$\boxed{45}$	3/2	1	1/2	0

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0	S_2	10	-2	0	-1	1
		Z_j	4500	3000	1500	$\boxed{0}$ → unit worth of R_2
		$Z_j - C_j$	2500	0	1500	0

SOL 11.7 Option (B) is correct.

Since all $Z_j - C_j \geq 0$, an optimal basic feasible solution has been attained. Thus, the optimum solution to the given LPP is

$$\text{Max } Z = 2000 \times 0 + 3000 \times 45 = \text{Rs.}135000 \text{ with } P_1 = 0 \text{ and } P_2 = 45$$

SOL 11.8 Option (C) is correct.

Given, forecast for February $F_{t-1} = 10275$

Demand for February $D_{t-1} = 12000$

Smoothing coefficient $\alpha = 0.25$

Which is The forecast for the next period is given by,

$$\begin{aligned} F_t &= \alpha(D_{t-1}) + (1-\alpha) \times F_{t-1} \\ &= 0.25 \times (12000) + (1-0.25) \times (10275) \\ &= 10706.25 \simeq 10706 \end{aligned}$$

Hence, forecast for the month of march is 10706.

SOL 11.9 Option (B) is correct.

Little's law is a relationship between average waiting time and average length of the queue in a queuing system.

The little law establish a relation between Queue length (L_q), Queue waiting time (W_q) and the Mean arrival rate λ.

So, $$L_q = \lambda W_q$$

SOL 11.10 Option (A) is correct.

Vehicle manufacturing assembly line is an example of product layout.

A product-oriented layout is appropriate for producing one standardized product, usually in large volume. Each unit of output requires the same sequence of operations from beginning to end.

SOL 11.11 Option (D) is correct.

Simplex method provides an algorithm which consists in moving from one point of the region of feasible solutions to another in such a manner that the value of the objective function at the succeeding point is less (or more, as the case may be) than at the preceding point. This procedure of jumping from one point to another is then repeated. Since the number of points is

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finite, the method leads to an optimal point in a finite number of steps. Therefore simplex method only uses the interior points in the feasible region.

SOL 11.12 Option (C) is correct.

Given : $D = 10000$

Ordering cost $C_o = \text{Rs.}\,300$ per order

Holding cost $C_h = \text{Rs.}\,40$ per frame per year

Unit cost, $C_u = \text{Rs.}\,200$

$$EOQ = \sqrt{\frac{2C_o D}{C_h}} = \sqrt{\frac{2\times 300\times 10000}{40}} \simeq 387 \text{ units}$$

Total cost = Purchase cost + holding cost + ordering cost

For $EOQ = 387$ units

$$\text{Total cost} = D\times C_u + \frac{Q}{2}\times C_h + \frac{D}{Q}\times C_o$$

Where $Q = EOQ = 387$ units

$$\text{Total cost} = 10000\times 200 + \frac{387}{2}\times 40 + \frac{10000}{387}\times 300$$

$$= 2000000 + 7740 + 7752 = \text{Rs.}\,2015492$$

Now supplier offers 2% discount if the order quantity is 1000 or more.

For $Q = 1000$ units

$$\text{Total cost} = 10000\times(200\times 0.98) + \frac{1000}{2}\times 40 + \frac{10000}{1000}\times 300$$

$$= 1960000 + 20000 + 3000 = \text{Rs.}\,1983000$$

Supplier also offers 4% discount if order quantity is 2000 or more.

For $Q = 2000$ units

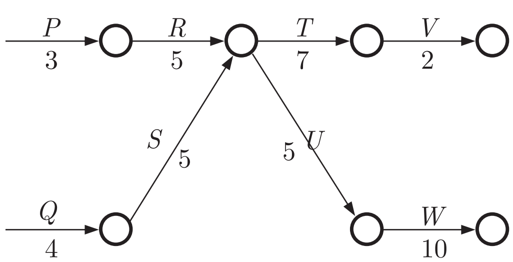
$$\text{Total cost} = 10000\times(200\times 0.96) + \frac{2000}{2}\times 40 + \frac{10000}{2000}\times 300$$

$$= 1920000 + 40000 + 1500 = \text{Rs.}\,1961500$$

It is clearly see that the total cost is to be minimized, the retailer should accept 4% discount.

SOL 11.13 Option (D) is correct.

We have to draw a arrow diagram from the given data.



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Here Four possible ways to complete the work.

	Path	**Total duration (days)**
(i)	$P-R-T-V$	$T=3+5+7+2=17$
(ii)	$Q-S-T-V$	$T=4+5+7+2=18$
(iii)	$Q-S-U-W$	$T=4+5+5+10=24$
(iv)	$P-R-U-W$	$T=3+5+5+10=23$

The critical path is the chain of activities with the longest time durations.

So, Critical path $= Q-S-U-W$

SOL 11.14 Option (C) is correct.

In the Earliest due date (EDD) rule, the jobs will be in sequence according to their earliest due dates.

Table shown below :

Job	Processing time (in days)	Due date	Operation start	Operation end
1	4	6	0	$0+4=4$
2	7	9	4	$4+7=11$
4	8	17	11	$11+8=19$
3	2	19	19	$19+2=21$

We see easily from the table that, job 2, 4, & 3 are delayed.

Number of jobs delayed is 3.

SOL 11.15 Option (D) is correct.

By using the shortest processing time (SPT) rule & make the table

Job	**Processing time (in days)**	**Flow time**		**Due date**	**Tradiness**
		Start	**End**		
3	2	0	2	19	0
1	4	2	$2+4=6$	6	0
2	7	6	$6+7=13$	9	4
4	8	13	$13+8=21$	17	4

So, from the table

Total Tradiness $= 4+4=8$

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SOL 11.16 Option (A) is correct.

Under the conditions of uncertainty, the estimated time for each activity for PERT network is represented by a probability distribution. This probability distribution of activity time is based upon three different time estimates made for each activity. These are as follows.

t_o = the optimistic time, is the shortest possible time to complete the activity if

all goes well.

t_p = the pessimistic time, is the longest time that an activity could take if every

thing goes wrong

t_l = the most likely time, is the estimate of normal time an activity would take.

The expected time (t_e) of the activity duration can be approximated as the arithmetic mean of $(t_o + t_p)/2$ and $2t_l$. Thus

$$(t_e) = \frac{1}{3}\left[2t_l + \frac{(t_o + t_p)}{2}\right] = \frac{t_o + 4t_l + t_p}{6}$$

SOL 11.17 Option (D) is correct.

Exponential smoothing method of forecasting takes a fraction of forecast error into account for the next period forecast.

The exponential smoothed average u_t, which is the forecast for the next period $(t+1)$ is given by.

$$\begin{aligned} u_t &= \alpha y_t + \alpha(1-\alpha) y_{t-1} + \ldots.\alpha(1-\alpha)^n y_{t-n} + \ldots..\infty \\ &= \alpha y_t + (1-\alpha)[\alpha y_{t-1} + \alpha(1-\alpha) y_{t-2} + \ldots + \alpha(1-\alpha)^n y_{t-(n-1)} + \ldots] \\ &= u_{t-1} + \alpha(y_t - u_{t-1}) \\ &= u_{t-1} + \alpha e_t \end{aligned}$$

where $e_t = (y_t - u_{t-1})$ is called error and is the difference between the least observation, y_t and its forecast a period earlier, u_{t-1}.

The value of α lies between 0 to 1.

SOL 11.18 Option (C) is correct.

In figure,

$$\begin{aligned} \text{ROP} &= \text{Reorder point} \\ LT &= \text{Lead Time} = 8 \text{ days} \\ TT &= \text{Total Time} = 365 \text{ days} \\ q &= \text{stock level} = 2555 \text{ units} \end{aligned}$$

Let the reorder quantity be x

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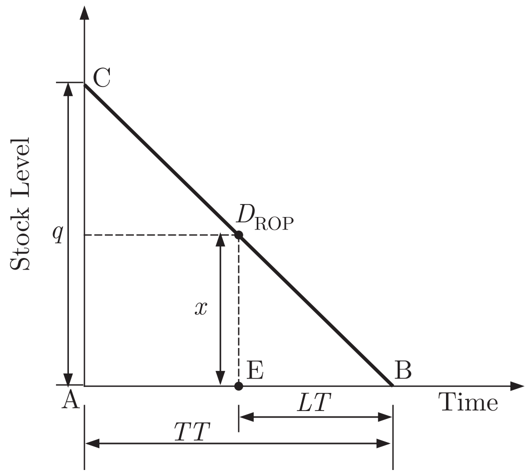


Now from the similar triangles

ΔABC & ΔBDE

$$\frac{q}{TT} = \frac{x}{LT}$$

$$\Rightarrow \qquad \frac{2555}{365} = \frac{x}{8}$$

$$x = \frac{2555}{365} \times 8 = 56 \text{ Units}$$

Alternate Method

Given,

$$\text{Demand in a year } D = 2555 \text{ Units}$$

$$\text{Lead time } T = 8 \text{ days}$$

Now, Number of orders to be placed in a year

$$N = \frac{\text{Number. of days in a year}}{\text{Lead Time}} = \frac{365}{8} \text{ orders}$$

Now, quantity ordered each time or reorder point.

$$Q = \frac{\text{Demand in a years}}{\text{Number of orders}} = \frac{2555}{\frac{365}{8}} = 56 \text{ Units}$$

SOL 11.19 Option (D) is correct.

Given objective function

$$Z_{\max} = 3x_1 + 2x_2$$

and constraints are

$$x_1 \le 4 \qquad \text{...(i)}$$

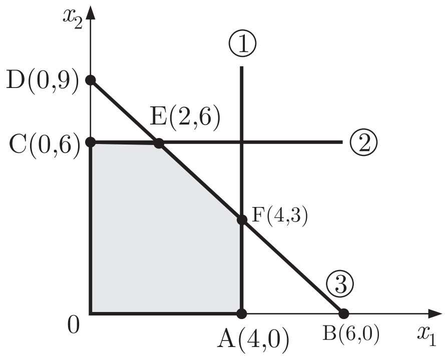
$$x_2 \le 6 \qquad \text{...(ii)}$$

$$3x_1 + 2x_2 \le 18 \qquad \text{...(iii)}$$

$$x_1 \ge 0$$

$$x_2 \ge 0$$

Plot the graph from the given constraints and find the common area.



Now, we find the point of intersection E & F.

For E, $$3x_1 + 2x_2 = 18$$

(E is the intersection point of equation. (ii) & (iii))

$$x_2 = 6$$

So, $$3x_1 + 12 = 18$$
$$x_1 = 2$$

For F, $$3x_1 + 2x_2 = 18$$
$$x_1 = 4$$

So, $$3 \times 4 + 2x_2 = 18$$
$$x_2 = 3$$

Hence,

$E(2,6)$ or $F(4,3)$

Now at point $E(2,6)$

$$Z = 3 \times 2 + 2 \times 6$$
$$= 18$$

At point $F(4,3)$

$$Z = 3 \times 4 + 2 \times 3$$
$$= 18$$

The objective function and the constraint (represent by equation (iii)) are equal.

Hence, the objective function will have the multiple solutions as at point E & F, the value of objective function ($Z = 3x_1 + 2x_2$) is same.

SOL 11.20 Option (A) is correct.

In shortest processing time rule, we have to arrange the jobs in the increasing order of their processing time and find total flow time.

So, job sequencing are I - III - V - VI - II - IV

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Jobs	Processing Time (days)	Flow time (days)
I	4	4
III	5	$4+5=9$
V	6	$9+6=15$
VI	8	$15+8=23$
II	9	$23+9=32$
IV	10	$32+10=42$

Now Total flow time $T = 4+9+15+23+32+42$

$$= 125$$

$$\text{Average flow time} = \frac{\text{Total flow time}}{\text{Number of jobs}}$$

$$T_{average} = \frac{125}{6} = 20.83 \text{ days}$$

SOL 11.21 Option (D) is correct.

Make the table and calculate the excepted time and variance for each activity

Activity	Optimistic time (days) t_o	Most likely time (days) t_m	Pessimistic time (days) t_p	Expected Time (days) $t_e = \frac{t_o+4t_m+t_p}{6}$	Variance $\sigma^2 = \left(\frac{t_p-t_o}{6}\right)^2$
1 - 2	1	2	3	$\frac{1+8+3}{6}=2$	$\left(\frac{3-1}{6}\right)^2=\frac{1}{9}$
1 - 3	5	6	7	$\frac{5+24+7}{6}=6$	$\left(\frac{7-5}{6}\right)^2=\frac{1}{9}$
1 - 4	3	5	7	$\frac{3+20+7}{6}=5$	$\left(\frac{7-3}{6}\right)^2=\frac{4}{9}$
2 - 5	5	7	9	$\frac{5+28+9}{6}=7$	$\left(\frac{9-5}{6}\right)^2=\frac{4}{9}$
3 - 5	2	4	6	$\frac{2+16+6}{6}=4$	$\left(\frac{6-2}{6}\right)^2=\frac{4}{9}$
5 - 6	4	5	6	$\frac{4+20+6}{6}=5$	$\left(\frac{6-4}{6}\right)^2=\frac{1}{9}$
4 - 7	4	6	8	$\frac{4+24+8}{6}=6$	$\left(\frac{8-4}{6}\right)^2=\frac{4}{9}$
6 - 7	2	3	4	$\frac{2+12+4}{6}=3$	$\left(\frac{4-2}{6}\right)^2=\frac{1}{9}$

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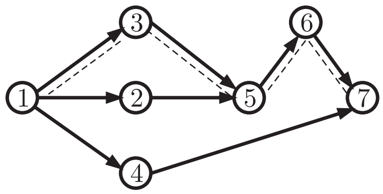

Now, the paths of the network & their durations are given below in tables.

	Paths	Expected Time duration (in days)
i	Path 1-3-5-6-7	$T = 6 + 4 + 5 + 3 = 18$
ii	Path 1-2-5-6-7	$T = 2 + 7 + 5 + 3 = 17$
iii	Path 1-4-7	$T = 5 + 6 = 11$

Since path 1-3-5-6-7 has the longest duration, it is the critical path of the network and shown by dotted line.
Hence,
The expected duration of the critical path is 18 days.

SOL 11.22 Option (C) is correct.
The critical path is 1-3-5-6-7
Variance along this critical path is,

$$\sigma^2 = \sigma^2_{1-3} + \sigma^2_{3-5} + \sigma^2_{5-6} + \sigma^2_{6-7}$$
$$= \frac{1}{9} + \frac{4}{9} + \frac{1}{9} + \frac{1}{9} = \frac{7}{9}$$

We know,

$$\text{Standard deviation} = \sqrt{\text{Variance}\,(\sigma^2)}$$
$$= \sqrt{\frac{7}{9}} = 0.88$$

The most appropriate answer is 0.77.

SOL 11.23 Option (C) is correct.
The most common distribution found in queuing problems is poisson distribution. This is used in single-channel queuing problems for random arrivals where the service time is exponentially distributed.
Probability of n arrivals in time t

$$P = \frac{(\lambda T)^n \cdot e^{-\lambda T}}{n!} \qquad \text{where } n = 0, 1, 2.......$$

So, Probability density function of inter arrival time (time interval between two consecutive arrivals)

$$f(t) = \lambda \cdot e^{-\lambda t}$$

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SOL 11.24 Option (A) is correct.

Total inventory cost will be minimum, when the holding cost is minimum. Now, from the Johnson's algorithm, holding cost will be minimum, when we process the least time consuming job first. From this next job can be started as soon as possible.

Now, arrange the jobs in the manner of least processing time.

T-S-Q-R-P or T-Q-S-R-P (because job Q and S have same processing time).

SOL 11.25 Option (D) is correct.

In a transportation problem with m origins and n destinations, if a basic feasible solution has less than $m+n-1$ allocations (occupied cells), the problem is said to be a degenerate transportation problem.

So, the basic condition for the solution to be optimal without degeneracy is.

$$\text{Number of allocations} = m+n-1$$

SOL 11.26 Option (D) is correct.

Here $F_1(t)$ & $F_2(t)$ = Forecastings

m_1 & m_2 = Number of weeks

A higher value of m results in better smoothing. Since here $m_1 > m_2$ the weightage of the latest demand would be more in $F_2(t)$.

Hence, $F_2(t)$ will attain the value of d_2 before $F_1(t)$.

SOL 11.27 Option (C) is correct.

There are two paths to reach from node P to node G.

(i) Path P-Q-G (ii) Path P-R-G

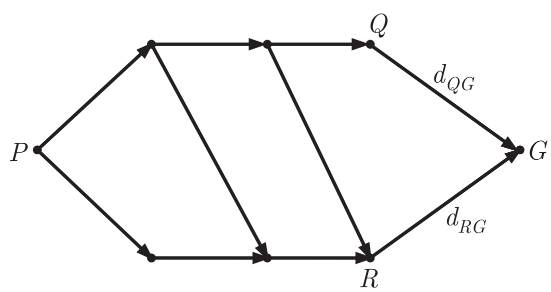
For Path P-Q-G,

Length of the path $S_G = S_Q + d_{QG}$

For path P-R-G,

Length of the path $S_G = S_R + d_{RG}$

So, shortest path $S_G = \text{Min}\{S_Q + d_{QG}, S_R + d_{RG}\}$



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SOL 11.28 Option (C) is correct.

From the product structure we see that 2 piece of R is required in production of 1 piece P.

So, demand of R is double of P

Week	Demand (P)	Demand (R)	Inventory level I = Production – Demand
1	1000	2000	$R - 2000$
2	1000	2000	$2R - 4000$
3	1000	2000	$3R - 6000$
4	1000	2000	$4R - 8000$
5	1200	2400	$5R - 10400$
6	1200	2400	$6R - 12800$

We know that for a production system with bottleneck the inventory level should be more than zero.

So,

$$6R - 12800 \geq 0$$

For minimum inventory

$$6R - 12800 = 0$$
$$6R = 12800$$
$$R = 2133$$
$$\simeq 2200$$

Hence, the smallest capacity that will ensure a feasible production plan up to week 6 is 2200.

SOL 11.29 Option (B) is correct.

The LP has an optimal solution that is not unique, because zero has appeared in the non-basic variable (x and y) column, in optimal solution.

SOL 11.30 Option (A) is correct.

The general form of LP is

$$\text{Max } Z = CX$$

Subject to $AX \leq B$

And dual of above LP is represented by

$$\text{Min } Z = B^T Y$$

Subject to $A^T Y \geq C^T$

So, the dual is Min $6u + 6v$

Subject to $3u + 2v \geq 4$

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$$2u + 3v \geq 6$$
$$u, v \geq 0$$

SOL 11.31 Option (B) is correct.

We have to make a table from the given data.

Month	Production (Pieces)		Demand	Excess or short form (pieces)	
	In regular time	In over time		Regular	Total
1	100	20	90	10	$10 + 20 = 30$
2	100	20	130	-30	$-30 + 20 = -10$
3	80	40	110	-30	$-30 + 40 = 10$

From the table,

For 1st month there is no need to overtime, because demand is 90 units and regular time production is 100 units, therefore 10 units are excess in amount. For 2nd month the demand is 130 unit and production capacity with overtime is $100 + 20 = 120$ units, therefore 10 units $(130 - 120 = 10)$ are short in amount, which is fulfilled by 10 units excess of 1st month. So at the end of 2nd month there is no inventory.

Now for the 3rd month demand is 110 units and regular time production is 80 units. So remaining $110 - 80 = 30$ units are produced in overtime to fulfill the demand for minimum cost of plan.

SOL 11.32 Option (D) is correct.

Total annual cost = Annual holding cost + Annual ordering cost

Maximum level of inventory $N = 100$

So, Average inventory $= \frac{N}{2} = 50$

Inventory carrying cost C_h = Rs. 10 per item per month

= Rs. 10×12 per item per year

= Rs. 120 per item per year

So, Annual holding cost $= \frac{N}{2} \times C_h$

$C_{hA} = 50 \times 120$

= Rs.6000 item per year

And, Ordering cost C_o = 100 per order

Number of orders in a year $= \frac{12}{1.5}$ order

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$$= 8 \text{ order}$$

$$\text{So, Annual ordering cost } C_{oA} = \text{ordering cost per order} \times \text{no. of orders}$$
$$= 100 \times 8$$
$$= \text{Rs.}800 \text{ per order}$$

Hence,

$$\text{Total Annual cost} = 6000 + 800$$
$$= \text{Rs.}6800$$

SOL 11.33 Option (B) is correct.

Given :

Number of items produced per moth

$$K = 1000 \text{ per month}$$

Number of items required per month

$$R = 500 \text{ per month}$$

$$\text{Lot size } q_0 = 1000$$

When backlog is not allowed, the maximum inventory level is given by,

$$I_m = \frac{K - R}{K} \times q_o = \frac{1000 - 500}{1000} \times 1000 = 500$$

SOL 11.34 Option (B) is correct.

Given :

$$C_h = \text{Rs. 1 per item per week}$$

$$C_o = \text{Rs. 100 per order}$$

Requirements = 50 - 0 - 15 - 20 - 20

Total cost is the cost of carrying inventory and cost of placing order.

Case (I) Only one order of 105 units is placed at starting.

Weeks	Quantity			Cost		
	Inventory	Used	Carried forward	Order	Carrying	Total
1.	105 (ordered)	50	55	100	55	155
2.	55	0	55	0	55	55
3.	55	15	40	0	40	40
4.	40	20	20	0	20	20
5.	20	20	0	0	0	0

$$\text{Total cost of plan} = 155 + 55 + 40 + 20 = 270 \text{ Rs.}$$

Case (II) Now order is placed two times, 50 units at starting and 55 units after 2nd week.

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Weeks	Quantity			Cost		
	Inventory	Used	Carried forward	Ordering Rs.	Carrying Rs.	Total Rs.
1.	50 (ordered)	50	0	100	0	100
2.	0	0	0	0	0	0
3.	55 (ordered)	15	40	100	40	140
4.	40	20	20	0	20	20
5.	20	20	0	0	0	0

Total cost of plan $= 100 + 140 + 20 = 260$ Rs.

Case (III) The order is placed two times, 65 units at starting and 40 units after 3[rd] week.

Weeks	Quantity			Cost		
	Inventory	Used	Carried forward	Ordering Rs.	Carrying Rs.	Total Rs.
1.	65 (ordered)	50	15	100	15	115
2.	15	0	15	0	15	15
3.	15	15	0	0	0	0
4.	40 (ordered)	20	20	100	20	120
5.	20	20	0	0	0	0

Total cost of plan $= 115 + 15 + 120 = 250$ Rs.

Case (IV) Now again order is placed two times, 85 units at starting and 20 units after 4[th] week.

Weeks	Quantity			Cost		
	Inventory	Used	Carried forward	Order	Carrying	Total
1.	85 (ordered)	50	35	100	35	135
2.	35	0	35	0	35	35
3.	35	15	20	0	20	20
4.	20	20	0	0	0	0
5.	20 (ordered)	20	0	100	0	100

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Total cost of plan $= 135 + 35 + 20 + 100 = 290$ Rs.
So, The cost of plan is least in case (III) & it is 250 Rs.

SOL 11.35 Option (B) is correct.

Given :

$$\lambda = 8 \text{ per hour}$$
$$\mu = 6 \text{ min per customer}$$
$$= \frac{60}{6} \text{ customer/hours} = 10 \text{ customer/hour}$$

We know, for exponentially distributed service time.
Average number of customers in the queue.

$$L_q = \frac{\lambda}{\mu} \times \frac{\lambda}{(\mu - \lambda)} = \frac{8}{10} \times \frac{8}{(10 - 8)} = 3.2$$

SOL 11.36 Option (C) is correct.

MRP (Material Requirement Planning) :

MRP function is a computational technique with the help of which the master schedule for end products is converted into a detailed schedule for raw materials and components used in the end product.

Input to MRP

(i) Master production schedule.

(ii) The bill of material

(iii) Inventory records relating to raw materials.

SOL 11.37 Option (B) is correct.

First finding the sequence of jobs, which are entering in the machine. The solution procedure is described below :

By examining the rows, the smallest machining time of 6 hours on machine $M2$. Then scheduled Job P last for machine $M2$

					P

After entering this value, the next smallest time of 7 hours for job U on machine $M2$. Thus we schedule job U second last for machine $M2$ as shown below

				U	P

After entering this value, the next smallest time of 8 hours for job R on machine $M1$. Thus we schedule job R first as shown below.

R				U	P

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After entering this value the next smallest time of 11 hours for job T on machine $M1$. Thus we schedule job T after the job R.

R	T			U	P

After this the next smallest time of 19 hours for job Q on machine $M2$. Thus schedule job Q left to the U and remaining job in the blank block.
Now the optimal sequence as :

R	T	S	Q	U	P

Then calculating the elapsed time corresponding to the optimal sequence, using the individual processing time given in the problem.
The detailed are shown in table.

Jobs	$M1$		$M2$	
	In	**Out**	**In**	**Out**
R	0	8	8	$8+13=21$
T	8	$8+11=19$	21	$21+14=35$
S	19	$19+27=46$	46	$46+20=66$
Q	46	$46+32=78$	78	$78+19=97$
U	78	$78+16=94$	97	$97+7=104$
P	94	$94+15=109$	109	$109+6=115$

We can see from the table that all the operations (on machine 1st and machine 2nd) complete in 115 hours. So the optimal make-span of the shop is 115 hours.

SOL 11.38 Option (C) is correct.

Given : $D = 2500$ units per year

$C_o =$ Rs. 100 per order

$C_h = 25\%$ of unit price

Case (I) : When order quantity is less than 500 units.

Then, Unit price $= 10$ Rs.

and $C_h = 25\%$ of $10 = 2.5$ Rs.

$$EOQ = \sqrt{\frac{2C_0 D}{C_h}} = \sqrt{\frac{2\times 100\times 2500}{2.5}}$$

$$Q = 447.21 \simeq 447 \text{ units}$$

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$$\text{Total cost} = D \times \text{unit cost} + \frac{Q}{2} \times c_h + \frac{D}{Q} \times c_o$$

$$= 2500 \times 10 + \frac{447}{2} \times 2.5 + \frac{2500}{447} \times 100$$

$$= 25000 + 558.75 + 559.75 = 26118 \text{ Rs.}$$

Case (II) : when order Quantity is 500 units. Then unit prize $= 9$ Rs.

$$\text{and } c_h = 25\% \text{ of } 9 = 2.25 \text{ Rs.}$$

$$Q = 500 \text{ units}$$

$$\text{Total cost} = 2500 \times 9 + \frac{500}{2} \times 2.25 + \frac{2500}{500} \times 100$$

$$= 22500 + 562.5 + 500 = 23562.5 \text{ Rs.}$$

So, we may conclude from both cases that the optimum order quantity must be equal to 500 units.

SOL 11.39 Option (C) is correct.

Given, In figure

	$S1$	$S2$	$S3$
P	110	120	130
Q	115	140	140
R	125	145	165

Step (I) : Reduce the matrix :

In the effectiveness matrix, subtract the minimum element of each row from all the element of that row. The resulting matrix will have at least one zero element in each row.

	$S1$	$S2$	$S3$
P	0	10	20
Q	0	25	25
R	0	20	40

Step (II) : Mark the column that do not have zero element. Now substract the minimum element of each such column for all the elements of that column.

	$S1$	$S2$	$S3$
P	0	0	0
Q	0	15	5
R	0	10	20

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Step (III) : Check whether an optimal assignment can be made in the reduced matrix or not.

For this, Examine rows successively until a row with exactly one unmarked zero is obtained. Making square ($\square$) around it, cross ($\times$) all other zeros in the same column as they will not be considered for making any more assignment in that column. Proceed in this way until all rows have been examined.

	$S1$	$S2$	$S3$
P	$\boxed{0}$	$\cancel{0}$	$\cancel{0}$
Q	$\cancel{0}$	15	5
R	$\cancel{0}$	10	20

In this there is not one assignment in each row and in each column.

Step (IV) : Find the minimum number of lines crossing all zeros. This consists of following substep

(A) Right marked ( ) the rows that do not have assignment.

(B) Right marked ( ) the column that have zeros in marked column (not already marked).

(C) Draw straight lines through all unmarked rows and marked columns.

	$S1$	$S2$	$S3$	
P	$\boxed{0}$	$\cancel{0}$	$\cancel{0}$	
Q	$\cancel{0}$	15	5	$\checkmark$
R	$\cancel{0}$	10	20	$\checkmark$
	$\checkmark$			

Step (V) : Now take smallest element & add, where two lines intersect.
No change, where single line & subtract this where no lines in the block.

	$S1$	$S2$	$S3$	
P	5	$\boxed{0}$	$\cancel{0}$	
Q	$\cancel{0}$	10	$\boxed{0}$	$\checkmark$
R	$\boxed{0}$	5	15	$\checkmark$
	$\checkmark$			

So, minimum cost is $= 120 + 140 + 125 = 385$

SOL 11.40 Option (A) is correct.

$$\text{Profit per unit sold} = 90 - 70 = 20\ \text{Rs.}$$

$$\text{Loss per unit unsold item} = 70 - 50 = 20\ \text{Rs.}$$

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Now consider all the options :

Cases	Units in stock	Unit sold (Demand)	Profit	Probability	Total profit
Option (D)	2	2	$2\times 20 = 40$	0.1	4
Option (C)	3	2	$2\times 20 - 1\times 20 = 20$	0.1	2
	3	3	$3\times 20 = 60$	0.35	21
					23
Option (B)	4	2	$2\times 20 - 2\times 20 = 0$	0	0
	4	3	$3\times 20 - 1\times 20 = 40$	0.35	14
	4	4	$4\times 20 = 80$	0.35	28
					42
Option (A)	5	2	$2\times 20 - 3\times 20 = -20$	0.10	-2
	5	3	$3\times 20 - 2\times 20 = 20$	0.35	7
	5	4	$4\times 20 - 1\times 20 = 60$	0.35	21
	5	5	$5\times 20 = 100$	0.20	20
					46

Thus, For stock level of 5 units, profit is maximum.

SOL 11.41 Option (C) is correct.

$$\text{Total time used} = 7+9+7+10+9+6$$
$$= 48 \text{ min}$$
$$\text{Number of work stations} = 6$$

Maximum time per work station (cycle time) $= 10$ min

We know,

$$\text{Line efficiency } \eta_L = \frac{\text{Total time used}}{\text{Number of work stations} \times \text{cycle time}}$$

$$\eta_L = \frac{48}{6\times 10} = 0.8 = 80\%$$

SOL 11.42 Option (D) is correct.

We have to make a network diagram from the given data.

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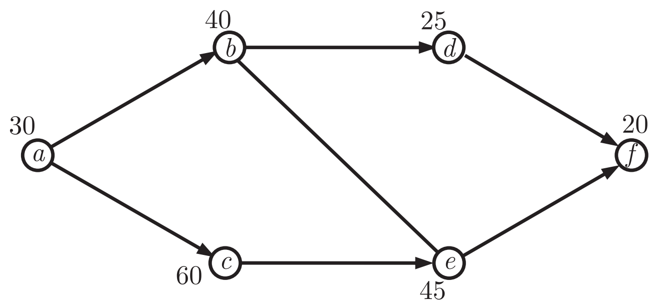

For simple projects, the critical path can be determined quite quickly by enumerating all paths and evaluating the time required to complete each. There are three paths between a and f. The total time along each path is

(i) For path a-b-d-f

$$T_{abdf} = 30 + 40 + 25 + 20 = 115 \text{ days}$$

(ii) For path a-c-e-f

$$T_{acef} = 30 + 60 + 45 + 20 = 155 \text{ days}$$

(iii) For path a-b-e-f

$$T_{abef} = 30 + 40 + 45 + 20 = 135 \text{ days}$$

Now, path a-c-e-f be the critical path time or maximum excepted completion time $T = 155$ days

SOL 11.43 Option (A) is correct.

The critical path of the network is a-c-e-f.

Now, for variance.

Task	Variance (days^2)
a	25
c	81
e	36
f	9

Total variance for the critical path

$$V_{critical} = 25 + 81 + 36 + 9$$

$$= 151 \text{ days}^2$$

We know the standard deviation of critical path is

$$\sigma = \sqrt{V_{critical}} = \sqrt{151} \text{ days}$$

SOL 11.44 Option (D) is correct.

In operation process chart an assembly activity is represented by the symbol O

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SOL 11.45 Option (C) is correct.

Gives :

Sales of product during four years were 860, 880, 870 and 890 units.

Forecast for the fourth year $u_4 = 876$

Forecast for the fifth year, using simple exponential smoothing, is equal to the forecast using a three period moving average.

So,
$$u_5 = \frac{1}{3}(880 + 870 + 890)$$
$$u_5 = 880 \text{ unit}$$

By the exponential smoothing method.
$$u_5 = u_4 + \alpha(x_4 - u_4)$$
$$880 = 876 + \alpha(890 - 876)$$
$$4 = \alpha(14)$$
$$\alpha = \frac{4}{14} = \frac{2}{7}$$

SOL 11.46 Option (A) is correct.

Given : $\lambda = 4/\text{hour}$, $\mu = 4/\text{hour}$

The sum of probability $\sum_{n=0}^{n=10} P_n = 1$ $\qquad n = 10$
$$P_0 + P_1 + P_2 ..... + P_{10} = 1$$

In the term of traffic intensity $\rho = \frac{\lambda}{\mu}$ $\Rightarrow \rho = \frac{4}{4} = 1$

So,
$$P_0 + \rho P_0 + \rho^2 P_0 + \rho^3 P_0 + ...\rho^{10} P_0 = 1 \qquad P_1 = \rho P_0, P_2 = \rho^2 P_0 \text{ and so on}$$
$$P_0(1 + 1 + 1 + ...) = 1$$
$$P_0 \times 11 = 1$$
$$P_0 = \frac{1}{11}$$

Hence, the probability that a person who comes in leaves without joining the queue is,
$$P_{11} = \rho^{11} \cdot P_0$$
$$P_1 = 1^{11} \times \frac{1}{11} = \frac{1}{11}$$

SOL 11.47 Option (B) is correct.

For economic point of view, we should calculate the total cost for all the four processes.
$$\text{Total cost} = \text{Fixed cost} + \text{Variable cost} \times \text{Number of piece}$$

For process (I) :

$$\text{Fixed cost} = 20\,\text{Rs.}$$
$$\text{Variable cost} = 3\,\text{Rs. per piece}$$
$$\text{Number of pieces} = 100$$
$$\text{Total cost} = 20 + 3 \times 100 = 320\,\text{Rs.}$$

For process (II) :

$$\text{Total cost} = 50 + 1 \times 100 = 150\,\text{Rs.}$$

For process (III) :

$$\text{Total cost} = 40 + 2 \times 100 = 240\,\text{Rs.}$$

For process (IV) :

$$\text{Total cost} = 10 + 4 \times 100 = 410\,\text{Rs.}$$

Now, we can see that total cost is minimum for process (II). So process (II) should choose for economic point of view.

SOL 11.48 Option (A) is correct.

Given : $\text{Rating factor} = 120\%$

$$\text{Actual time } T_{actual} = 8\,\text{min}$$
$$\text{Normal time } T_{normal} = \text{actual time} \times \text{Rating factor}$$
$$T_{normal} = 8 \times \frac{120}{100} = 9.6\,\text{min}$$

10% allowance is allowed for this operation.

So, standard time,

$$T_{standard} = \frac{T_{normal}}{1 - \frac{10}{100}} = \frac{9.6}{0.9} = 10.67\,\text{min}$$

Hence, standard production rate of the weld joint

$$= \frac{8 \times 60}{10.67} = 45\,\text{units}$$

SOL 11.49 Option (D) is correct.

The expected value of the lead time demand

$$= 80 \times 0.20 + 100 \times 0.25 + 120 \times 0.30 + 140 \times 0.25$$
$$= 112$$

Reorder level is 1.25 time the lead time demand.

So, reorder value $= 1.25 \times 112 = 140$

Here both the maximum demand or the reorder value are equal.

Hence, $\text{service level} = 100\%$

SOL 11.50 Option (C) is correct.

The 3 activity need to be crashed to reduce the project duration by 1 day.

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SOL 11.51 Option (C) is correct.

First we have to make a transportation model from the given details.

Warehouse \ Factories	S_1	S_2	Supply
D_1			20 to 40 units
D_2			≥ 20
Demand	50	40	

We know,

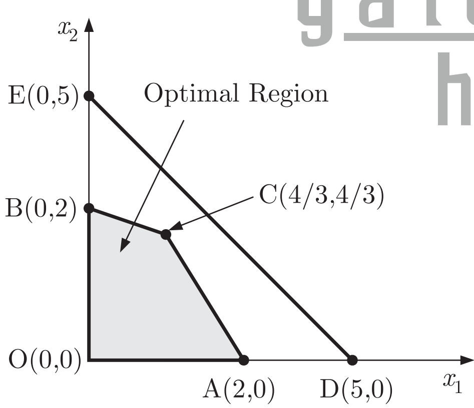
Basic condition for transportation model is balanced, if it contains no more than $m+n-1$ non-negative allocations, where m is the number of rows and n is the number of columns of the transportation problem.

$$\text{So, Number of supply point (allocations)} = m+n-1$$
$$= 2+2-1 = 3$$
$$\text{Number of demand points} = 4\,(\text{No. of blank blocks})$$
$$\text{Total supply or demand} = 50+40 = 90$$

SOL 11.52 Option (B) is correct.

Given : Objective function $Z = X_1 + X_2$

From the given corners we have to make a graph for X_1 and X_2



From the graph, the constraint $X_1 + X_2 \leq 5$ has no effect on optimal region.

Now, checking for optimal solution

	Point	$Z = X_1 + X_2$
(i)	$O(0,0)$	$Z = 0$
(ii)	$A(2,0)$	$Z = 2+0 = 2$
(iii)	$B(0,2)$	$Z = 0+2 = 2$
(iv)	$C(4/3,4/3)$	$Z = 4/3+4/3 = 8/3$

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The optimal solution occurs at point $C(4/3, 4/3)$

SOL 11.53 Option (D) is correct.
We know,
The inequality constraints are changed to equality constraints by adding or subtracting a non-negative variable from the left-hand sides of such constraints. These variable is called slack variables or simply slacks.
They are added if the constraints are $(\leq)$ and subtracted if the constraints are $(\geq)$. These variables can remain positive throughout the process of solution and their values in the optimal solution given useful information about the problem.
Hence, Optimum dual variables are v_1 and v_2.

SOL 11.54 Option (B) is correct.
PERT (Programme Evaluation and Review Technique) uses even oriented network in which successive events are joined by arrows.
Float is the difference between the maximum time available to perform the activity and the activity duration. In PERT analysis a critical activity has zero float.

SOL 11.55 Option (C) is correct.
Given :

$$\text{Forecast sales for December } u_t = 25$$
$$\text{Actual sales for December } X_t = 20$$
$$\text{Exponential smoothing constant } \alpha = 0.2$$

We know that, Forecast sales for January is given by

$$u_{t+1} = u_t + \alpha[X_t - u_t]$$
$$= 25 + 0.2(20 - 25)$$
$$= 25 + 0.2 \times (-5) = 25 - 1 = 24$$

Hence, Forecast sales for January 2003 would be 24.

SOL 11.56 Option (C) is correct.
For product P : $D = 100$ units, $C_o = 50$ Rs./order, $C_h = 4$ Rs./unit/year
Economic order quantity (EOQ) for product P,

$$(\text{EOQ})_P = \sqrt{\frac{2C_o D}{C_h}}$$

$$(\text{EOQ})_P = \sqrt{\frac{2 \times 50 \times 100}{4}} = \sqrt{2500} = 50 \qquad ...(i)$$

For product Q :

$$D = 400 \text{ Units} \quad C_o = 50 \text{ Rs. order}, \quad C_h = 1 \text{ Rs. Unit/year}$$

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EOQ For Product Q,

$$(\text{EOQ})_Q = \sqrt{\frac{2C_oD}{C_h}}$$

$$= \sqrt{\frac{2 \times 50 \times 400}{1}} = \sqrt{40000} = 200 \qquad ...(ii)$$

From equation (i) & (ii),

$$\frac{(\text{EOQ})_P}{(\text{EOQ})_Q} = \frac{50}{200} = \frac{1}{4}$$

$$(\text{EOQ})_P : (\text{EOQ})_Q = 1:4$$

SOL 11.57 Option (D) is correct.

Let, The standard machine tool produce x_1 number of components.

For standard machine tool,

$$\text{Total cost} = \text{Fixed cost} + \text{Variable cost} \times \text{Number. of components}$$

$$(\text{TC})_{SMT} = \left[\frac{30}{60} + \frac{22}{60} \times x_1\right] \times 200$$

$$= \frac{30}{60} \times 200 + \frac{22}{60} \times x_1 \times 200 = 100 + \frac{220}{3} x_1 \qquad ...(i)$$

If automatic machine tool produce x_2 Number of components, then the total cost for automatic machine tool is

$$(\text{TC})_{AMT} = \left(2 + \frac{5}{60} x_2\right) 800$$

$$= 1600 + \frac{200}{3} x_2 \qquad ....(ii)$$

Let, at the breakeven production batch size is x and at breakeven point.

$$(\text{TC})_{SMT} = (\text{TC})_{AMT}$$

$$100 + \frac{220x}{3} = 1600 + \frac{200x}{3}$$

$$\frac{220x}{3} - \frac{200x}{3} = 1600 - 100$$

$$\frac{20x}{3} = 1500$$

$$x = \frac{1500 \times 3}{20} = 225$$

So, breakeven production batch size is 225.

SOL 11.58 Option (D) is correct.

Given :

$$\text{Total time } T = 16 \text{ hours} = 16 \times 60 = 960 \text{ min}$$

Actual working time was 90% of total time

So, Actual time, $T_{actual} = 90\% \text{ of } 960$

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$$= \frac{90}{100} \times 960, \; T_{actual} = 864 \text{ min}$$

Performance rating was 120 percent.

So, Normal time, $T_{normal} = 120\%$ of 864

$$= \frac{120}{100} \times 864 = 1036.8 \text{ min}$$

Allowance is 20% of the total available time.

$$\text{So total standard time } T_{standard} = \frac{T_{normal}}{\left(1 - \frac{20}{100}\right)} = \frac{1036.8}{1 - 0.2} = \frac{1036.8}{0.8}$$

$$= 1296 \text{ min}$$

Number of joints soldered, $N = 108$

Hence,

$$\text{Standard time for operation} = \frac{1296}{108} = 12 \text{ min}$$

SOL 11.59 Option (A) is correct.

Given :

Number of units produced in a day $= 80$ units

Working hours in a day $= 8$ hours

Now, Time taken to produce one unit is,

$$T = \frac{8}{80} \times 60 = 6 \text{ min}$$

Activity	**Standard time (min)**	**No. of work stations** ($S.T/T$)
M. Mechanical assembly	12	$12/6 = 2$
E. Electric wiring	16	$16/6 = 2.666 = 3$
T. Test	3	$3/6 = 0.5 = 1$

Number of work stations are the whole numbers, not the fractions.

So, number of work stations required for the activities M, E and T would be 2, 3 and 1, respectively.

SOL 11.60 Option (A) is correct.

Given :

Mean arrival rate $\lambda = 3$ per day

Mean service rate $\mu = 6$ per day

We know that, for first come first serve queue.

Mean waiting time of an arrival,

$$t = \frac{\lambda}{\mu(\mu - \lambda)} = \frac{3}{6(6-3)} = \frac{1}{6}\text{ day}$$

SOL 11.61 Option (C) is correct.

Given : $D = 1000$ units, $C_o = 100/\text{order}$, $C_h = 100$ unit/year

$C_s = 400$ Rs.

We know that, optimum level of stock out will be,

$$\text{S.O} = \sqrt{\frac{2DC_o}{C_h}} \times \sqrt{\frac{C_s}{C_h + C_s}}$$

$$\text{S.O} = \sqrt{\frac{2 \times 1000 \times 100}{100}} \times \sqrt{\frac{400}{100 + 400}}$$

$$= 44.72 \times 0.895 = 40$$

SOL 11.62 Option (A) is correct.

Solve this problem, by the linear programming model.

We have to make the constraints from the given conditions.

For production conditions

$$P + 2Q \le 2000 \qquad \text{...(i)}$$

For raw material

$$P + Q \le 1500 \qquad \text{...(ii)}$$

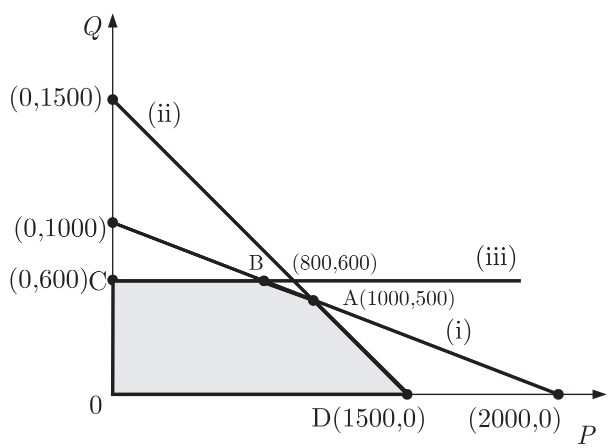
For electric switch

$$Q \le 600 \qquad \text{...(iii)}$$

For maximization of profit, objective function

$$Z = 3P + 5Q \qquad \text{...(iv)}$$

From the equations (i), (ii) & (iii), draw a graph for toy P and Q



Line (i) and line (ii) intersects at point A, we have to calculate the intersection point.

$$P + 2Q = 2000$$

$$P + Q = 1500$$

After solving there equations, we get $A(1000, 500)$

For point B,

$$P + 2Q = 2000$$
$$Q = 600$$
$$P = 2000 - 1200 = 800$$

So, $B(800, 600)$

Here shaded area shows the area bounded by the three line equations (common area)

This shaded area have five vertices.

	Vertices	**Profit** $Z = 3P + 5Q$
(i)	$0(0, 0)$	$Z = 0$
(ii)	$A(1000, 500)$	$Z = 3000 + 2500 = 5500$
(iii)	$B(800, 600)$	$Z = 2400 + 3000 = 5400$
(iv)	$C(0, 600)$	$Z = 3000$
(v)	$D(1500, 0)$	$Z = 4500$

So, for maximization of profit

$$P = 1000 \qquad \text{from point(ii)}$$
$$Q = 500$$

SOL 11.63 Option (A) is correct.

The symbol used for transport in work study is given by, $\Rightarrow$

SOL 11.64 Option (A) is correct.

Given : For machine $M1$:

$$\text{Fixed cost} = 100 \text{ Rs.}$$
$$\text{Variable cost} = 2 \text{ Rs. per piece}$$

For machine $M2$:

$$\text{Fixed cost} = 200 \text{ Rs.}$$
$$\text{Variable cost} = 1 \text{ Rs. per piece}$$

Let, n number of units are produced per machine, when both the machines are to be used concurrently.

We know that,

$$\text{Total cost} = \text{Fixed cost} + \text{Variable cost} \times \text{Number of units}$$

For $M1$, Total cost of production $= 100 + 2 \times n$

For $M2$, Total cost of production $= 200 + n$

Hence,

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Total cost of production on machine $M1$ & $M2$ is

$$= 100 + 2n + 200 + n = 300 + 3n$$

We know, Breakeven point is the point, where total cost of production is equal to the total sales price.
Assuming that Number of units produced are less than 800 units and selling price is Rs. 3.50 per unit.
So at breakeven point,

$$300 + 3n = 3.50(n + n)$$

$$300 + 3n = 3.50 \times 2n$$

$$300 = 4n$$

$$n = \frac{300}{4} = 75 \text{ units}$$

SOL 11.65 Option (C) is correct.
Warden checks the student 11 occasions a day during the study hours over a period of 10 days.
So, Total number of observations in 10 days.

$$= 11 \times 10 = 110 \text{ observations}$$

Study hours as 8.00 pm to 10.30 pm.
So, total study hours in 10 days

$$= 2.5 \times 10 = 25 \text{ hours.}$$

Number of occasions when student studying $= 71$
So, Probability of studying

$$P = \frac{\text{No. of observations when student studying}}{\text{Total observations}} = \frac{71}{110} = 0.645$$

Hence,
Minimum hours of his study during 10 day period is

$$T = P \times \text{Total study hours in 10 days} = 0.645 \times 25 = 16.1 \text{ hours}$$

SOL 11.66 Option (B) is correct.
We know, from the exponential and smoothing average method, the exponential smoothed average $u_{(t+1)}$ which is the forecast for the next period $(t+1)$ is given by

$$u_{(t+1)} = \alpha u_t + \alpha(1-\alpha)u_{t-1} + ...\alpha(1-\alpha)^n u_{t-n} + ...\infty$$

Now, for sales of the fifth month put $t = 4$ in the above equation,

So, $$u_5 = \alpha u_4 + \alpha(1-\alpha)u_3 + \alpha(1-\alpha)^2 u_2 + \alpha(1-\alpha)^3 u_1$$

where u_1, u_2, u_3 and u_4 are 70, 68, 82, and 95 respectively and $\alpha = 0.4$

Hence $$u_5 = 0.4 \times 95 + 0.4(1-0.4)82 + 0.4(1-0.4)^2 \times 68 + 0.4(1-0.4)^3 \times 70$$

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$$u_5 = 38 + 19.68 + 9.792 + 6.048 = 73.52$$

SOL 11.67 Option (C) is correct.

Given :

$$D = 800000 \text{ per annum}$$
$$C_o = 1200 \text{ Rs.}$$
$$C_h = 120 \text{ per piece per annum}$$

We know that,

$$\text{Economic order quantity } (EOQ) = N = \sqrt{\frac{2C_oD}{C_h}}$$

$$N = \sqrt{\frac{2 \times 1200 \times 800000}{120}} = \sqrt{16 \times 10^6}$$
$$= 4 \times 10^3 = 4000$$

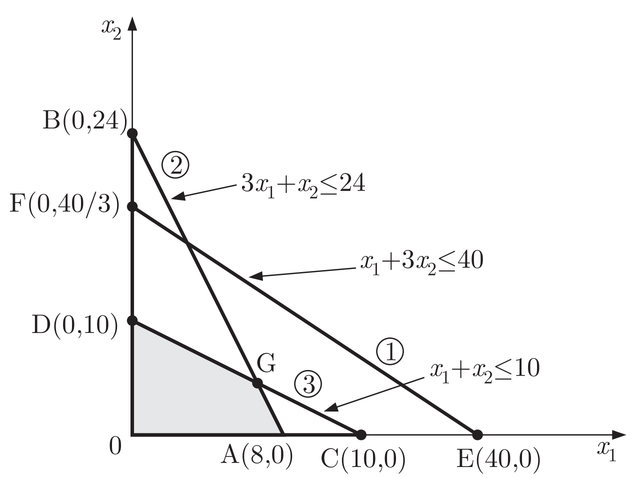
SOL 11.68 Option (A) is correct.

Given : Objective function, $Z = 2x_1 + 5x_2$

and
$$x_1 + 3x_2 \le 40$$
$$3x_1 + x_2 \le 24$$
$$x_1 + x_2 \le 10$$
$$x_1 > 0$$
$$x_2 > 0$$

First we have to make a graph from the given constraints. For draw the graph, substitute alternatively x_1 & x_2 equal to zero in each constraints to find the point on the x_1 & x_2 axis.

Now shaded area shows the common area. Note that the constraint $x_1 + 3x_2 \le 40$ does not affect the solution space and it is the redundant constraint. Finding the coordinates of point G by the equations.



$$3x_1 + x_2 = 24$$

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$$x_1 + x_2 = 10$$

Subtract these equations,

$$(3x_1 - x_1) + 0 = 24 - 10$$

$$2x_1 = 14 \Rightarrow x_1 = 7$$

$$x_2 = 10 - x_1 = 10 - 7 = 3$$

So, point $G(7,3)$

So, maximum profit which can meet the constraints at $G(7,3)$ is

$$Z_{\max} = 2 \times 7 + 5 \times 3 = 14 + 15 = 29$$

SOL 11.69 Option (C) is correct.

The various path and their duration are :-

Path	**Duration (days)**
A-D-L	$2 + 10 + 3 = 15$
A-E-G-L	$2 + 5 + 6 + 3 = 16$
A-E-H	$2 + 5 + 10 = 17$
B-H	$8 + 10 = 18$
C-F-K-M	$4 + 9 + 3 + 8 = 24$
C-F-H	$4 + 9 + 10 = 23$
A-E-K-M	$2 + 5 + 3 + 8 = 18$
B-G-L	$8 + 6 + 3 = 17$
B-K-M	$8 + 3 + 8 = 19$
C-F-G-L	$4 + 9 + 6 + 3 = 22$

Here maximum time along the path C-F-K-M. So, it is a critical path and project can be completed in 24 days.

SOL 11.70 Option (A) is correct.

The principal of motion economy are used while conduction a method study on an operation.

Method study consist of the sequence of operation, which are performing on a machine. From the sequencing, the idle time of the machine reduced to a certain amount and the operation becomes faster and smooth. Also the productivity of the plant increases by the principle of motion economy.

SOL 11.71 Option (B) is correct.

$$\text{Standard Time} = \text{Normal time} + \text{Allowance}$$

SOL 11.72 Option (B) is correct.

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Percentage Error $E = 20\%$ or 0.20

Standard deviation $S = \sqrt{\frac{E \times (1-E)}{n}}$

where $n =$ No. of observation

$$S = \sqrt{\frac{0.20\,(1-0.20)}{100}} = 0.04$$

For 95% confidence level, $\sigma = \pm\, 2$

So, upper control limit UCL $= E + \sigma \times S$

$= 0.20 + 2 \times 0.04 = 0.28$

Lower control Limit LCL $= E - \sigma \times S$

$= 0.20 - 2 \times 0.04 = 0.12$

Hence 95% confidence interval of this estimate is (0.12, 0.28)

SOL 11.73 Option (D) is correct.

Given : $C_o = 200$ Rs

$D = 4000$ units per annum

$C_h = 10\%$ of $100 = 10$ Rs per annum

The Economic order quantity is,

$$EOQ = \sqrt{\frac{2C_oD}{C_h}} = \sqrt{\frac{2 \times 200 \times 4000}{10}} = 400 \text{ unit}$$

SOL 11.74 Option (C) is correct.

Given :

Average time between arrivals $= 10$ min

Mean arrival rate (Number of arrivals per unit time) $\lambda = 6$ per hour

Average time between call $= 3$ min

Mean service rate $\mu = \frac{60}{3} = 20$ per hour

So, the probability that an arrival does not have to wait before service is,

$$P_O = 1 - \frac{\lambda}{\mu} = 1 - \frac{6}{20} = 1 - 0.3 = 0.7$$

SOL 11.75 Option (B) is correct.

Total supply $= 50 + 40 + 60 = 150$ units

Total demand $= 20 + 30 + 10 + 50 = 110$ units

In this question, the total availability (supply) may not be equal to the total demand, i.e.,

$$\sum_{i=1}^{m} a_i \neq \sum_{j=1}^{n} b_j$$

Such problems are called unbalanced transportation problems.

Here total availability is more than the demand. So we add a dummy

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destination to take up the excess capacity and the costs of shipping to this destination are set equal to zero.
So, a dummy destination of capacity 40 unit is needed.

SOL 11.76 Option (B) is correct.
In PERT analysis, a Beta distribution is assumed because it is unimodal, has non-negative end points, and is approximately symmetric.
Here three parallel paths are given. But the critical path is one with the longest time durations.
Two paths have same time duration of 12.

So, $\text{mean} = 12$

The PERT analysis has a beta (β) distribution and Standard deviation $= \sqrt{\text{variance}} = \sqrt{4} = 2$.

SOL 11.77 Option (D) is correct.
Production flow analysis (PFA) is a comprehensive method for material analysis, Part family formation, design of manufacturing cells and facility layout design. These informations are taken from the route sheet.

SOL 11.78 Option (D) is correct.
The simple moving average method can be used if the underlying demand pattern is stationary. This method include new demand data in the average after discarding some of the earlier demand data.

Let m_t = moving average at time t

y_t = demand in time t and

n = moving average period

$$m_{t+1} = \frac{y_{t+1} - y_{t-n+1}}{n}$$

SOL 11.79 Option (D) is correct.
Given : Mean cycle time $= 10\text{ min}$
The workers performing at 90% efficiency.

So, $$\text{Normal time} = 10 \times \frac{90}{100} = 9\text{ min}$$

Allowance = 10%

$$\text{Standard time} = \text{Normal time} + \text{Allowance}$$
$$= 9 + 9 \times \frac{10}{100} = 9 + 0.9 = 9.9\text{ min}$$

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2.5 Transformation of stress and strain
2.6 Design of beams and shafts
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2.8 Column
2.9 Energy methods

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3.2 Design of joints
3.3 Design of shaft and shaft components
3.4 Design of spur gears
3.5 Design of bearings
3.6 Design of clutch and brakes

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4.2 Velocity and acceleration
4.3 Dynamic analysis of slider-crank and cams
4.4 Gear-trains
4.5 Flywheel
4.6 vibration

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5.1 Basic concepts and properties of fluids
5.2 Pressure and fluid statics
5.3 Fluid kinematics and Bernoulli Equation
5.4 Flow analysis using control volume
5.5 Flow analysis using differential method
5.6 Internal flow
5.7 External flow
5.8 Open channel flow
5.9 Turbomachinary

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6.2 Fundamentals of conduction
6.3 Steady heat conduction
6.4 Transient heat conduction
6.5 Fundamentals of convection
6.6 Free convection
6.7 Forced convection
6.8 Fundamentals of thermal radiation
6.9 Radiation Heat transfer
6.10 Heat exchangers.

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7.2 Properties of pure substances
7.3 Energy analysis of closed system
7.4 Mass and energy analysis of control volume
7.5 Second law of thermodynamics
7.6 Entropy
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7.8 Vapour and combined power cycles
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