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QNO-1

Illustration - 1

Nine villages in a certain administrative area contain 720, 130, 150, 240, 960, 100, 52, 36, 532 fields respectively. Make a random selection of six fields using the random number tables.

Illustration - 2

Frontier Bakery keeps stock of a popular brand of cake. Daily demand based on past experience is as given below:-

Experience indicates

QNO-2

Daily demand	0	15	25	35	45	50
Probability	0.01	0.15	0.20	0.50	0.12	0.02

Consider the following sequence of random numbers:- R. No. 48, 78, 09, 51, 56, 77, 15, 14, 68, 09.

Using the sequence, simulate the demand for the next 10 days

Find out the stock situation if the owner of the bakery decides to make 35 cakes every day. Also estimate the daily average demand for the cakes on the basis of simulated data.

QNO3

Illustration - 3

The management of ABC company is considering the question of marketing a new product. The fixed cost required in the project is Rs. 4,000. Three factors are uncertain viz. the selling price, variable cost and the annual sales volume. The product has a life of only one year. The management has the data on these three factors as under:

Selling price Rs.	Probability	Variable Cost Rs.	Probability	Sales volume (Units)	Probability
3	0.2	1	0.3	2,000	0.3
4	0.5	2	0.6	3,000	0.3
5	0.3	3	0.1	5,000	0.4

Consider the following sequence of thirty random numbers:

81 32 60 04 46 31 67 25 24 10 40 02 39 68
08 59 66 90 12 64 79 31 86 68 82 89
25 11 98 16

Using the sequence (First 3 random numbers for the first trial, etc.) simulate the average profit for the above project on basis of 10 trials.

QNO-4

QNO-3 4

A car rental agency has collected the following data on the demand for five seater vehicles over the past 50 days.

Daily Demand	4	5	6	7	8
No. of Days	4	10	16	14	6

The agency has only 6 cars currently.

- 1) Use the following 5 random numbers to generate 5 days of demand for the rental agency. Random No.:- 15, 48, 71, 56, 90
- 2) What is the average number of cars rented per day for the 5 days?
- 3) How many rentals will be lost over the 5 days?

Illustration - 5
 2000 - Nov [6] (b) A retailer deals in a perishable commodity. The daily demand and supply are variables. The data for the past 500 days, show the following demand and supply:

Supply Availability (k.g.)	No. of days	Demand (kg.)	No. of days
10	40	10	50
20	50	20	110
30	190	30	200
40	150	40	100
50	70	50	40

The retailer buys the commodity at Rs. 20 per kg. and sells it at Rs. 30 per kg. Any commodity remains at the end of the day, has no saleable value. Moreover, the loss (unearned profit) on any unsatisfied demand is Rs. 8 per kg. Given the following pair of random numbers, simulate 6 days sales, demand and profit.

(31, 18): (63, 84): (15, 79): (07, 32): (43, 75): (81, 27)

The first random number in the pair is for supply and the second random number is for demand viz. in the first pair (31, 18), use 31 to simulate supply and 18 to simulate demand. Ans: Rs. 400

Illustration - 6
 2001 - May [6] (b) An investment company wants to study the investment projects based on market demand, profit and the investment required. Which are independent of each other. Following probability distributions are estimated for each of these three factors:

Annual demand (Units in thousands)	:	25	30	35	40	45	50	55
Probability	:	0.05	0.10	0.20	0.30	0.20	0.10	0.05
Profit per Unit	:	3.00	5.00	7.00	9.00	10.00		
Probability	:	0.10	0.20	0.40	0.20	0.10		
Investment Required (in thousands of Rupees)	:	2,750	3,000	3,500				
Probability	:	0.25	0.50	0.25				

Using simulation process, repeat the trial 10 times, compute the investment on each trial taking these factors into trial. What is the most likely return?

Use the following random numbers:

(30, 12, 16); (59, 09, 69); (63, 94, 26); (27, 08, 74);
 (64, 60, 61); (28, 28, 72); (31, 23, 57); (54, 85, 20);
 (64, 68, 18); (32, 31, 87)

In the bracket above, the first random number is for annual demand, the second one is for profit and the last one is for the investment required. (10 marks) [S. A. 39] Ans:- The highest likely return is 13.33%, which corresponds to annual demand of 40,000 units resulting in a profit of Rs. 10 per unit requiring an investment of Rs. 30,00,000.

Illustration - 7
 2004 - May [6] (c) A company manufactures a component which requires a high degree of precision. Each unit of the component is therefore subjected to a strict quality control test to ascertain whether there is any defect in it. The defects are classified into three categories viz. A, B and C. If defect A occurs in the output, it is scrapped. If defect B or C occurs in the output, it is reworked to rectify the defect. The machine time required to rework defect B component is 30 minutes and that for defect C is 45 minutes. The probabilities are as under:

	Defect A	Defect B	Defect C
Defect occurring	0.15	0.20	0.10
Defect not occurring	0.85	0.80	0.90

Using the following random numbers, simulate a study of 10 items of output and determine the number of items with no defects, number of items scrapped due to occurrence of defect A and the total machine time required for rework due to occurrence of defect B or C.

Random number for defect A:
 48 55 91 40 93 01 83 63 47 52
 Random number for defect B:
 47 36 57 04 79 55 10 13 57 09
 Random number for defect C:
 82 95 18 96 20 84 56 11 52 03

(7 marks) [S. A. 27]

Ans:- Rectification time required on networking is 165 minutes.

Illustration - 236 8

Dr. STRONG is a dentist who schedules all her patients for 30 minutes appointments. Some of the patients take more or less than 30 minutes depending on the type of dental work to be done. The following summary shows the various categories of work, their probabilities and the time needed to complete the work:

Category	Time Required	Probability of Category
Filling	45 minutes	0.40
Crown	60 minutes	0.15
Cleaning	15 minutes	0.15
Extraction	45 minutes	0.10
Checkup	15 minutes	0.20

Stimulate the dentist's clinic for four hours and determine the average waiting time for the patients as well as the idleness of the doctor. Assume that all the patients show up at the clinic at exactly their scheduled arrival time starting at 8.00 a.m. Use the following random numbers for handling the above problem.

40 82 11 34 25 66 17 79

Illustration - 239 9

A company manufactures 30 items per day. The sales of these items depends upon demand which has the following distribution:

Sales (Units)	Probability
27	0.10
28	0.15
29	0.20
30	0.35
31	0.15
32	0.05

The production cost and sales price of each unit are Rs. 40 and Rs. 50 respectively. Any unsold product is to be disposed off at a loss of Rs. 15 per unit. There is a penalty of Rs. 5 per unit if the demand is not met.

Using the following random numbers estimate total profit / loss for the company for the next 10 days:

10, 99, 65, 99, 95, 01, 79, 11, 16, 20

If the company decides to produce 29 items per day, what is the advantage or disadvantage to the company?

QNO-10

2000 - May [5] (c) A book - store wishes to carry System Analysis and Design in stock. Demand is probabilistic and replenishment of stock takes 2 days (i.e., if an order is placed in March 1, it will be delivered at the end of the day on March 3). The probabilities of demand are given below:

Demand (daily)	:	0	1	2	3	4
Probability	:	0.05	0.10	0.30	0.45	0.10

Each time an order is placed, the store incurs an ordering cost of Rs. 10 per order. The store also incurs a carrying cost of Rs. 0.50 per book per day. The inventory carrying cost is calculated on the basis of stock at the end of each day. The manager of the book-store wishes to compare two options for his inventory decision:

- Order 5 books, when the inventory at the beginning of the day plus orders outstanding is less than 8 books.
- Order 8 books, when the inventory at the beginning of the day plus orders outstanding is less than 8 books.

Currently (beginning of the 1st day) the store has stock of 8 books plus 6 books ordered 2 days ago and expected to arrive next day. Using Monte- Carlo simulation for 10 cycles, recommend which option the manager should choose?

The two digit random number are given

below: 89, 34, 78, 63, 61, 81, 39, 16, 13, 73

Ans:- The Manager should go for Option B, as its Total Cost Rs. 42.50 is less than Option A

Illustration 249:-

XYZ airline operating 7 days a week has given the following time - table. Crews must have a minimum layover of 5 hours between flights. Obtain the pairing flights and minimizes layover time away from home. For any given pairing the crew will be based at the city that results in the smaller layover: Ans = 40 HRS

Chennai Mumbai			Mumbai - Chennai		
Flight Number	Depart.	Arrive	Flight Number	Depart.	Arrive
A 1	6 AM	8 AM	B 1	8 AM	10 AM
A 2	8 AM	10 AM	B 2	9 AM	11 AM
A 3	2 PM	4 PM	B 3	2 PM	4 PM
A 4	8 PM	10 PM	B 4	7 PM	9 PM

An accounts Officer has 4 subordinates and 4 tasks. The subordinates differ in efficiency. The tasks also differ in their intrinsic difficulty. His estimates of the time each would take to perform each task is given in the matrix below. How should the tasks be allocated one to one man, so that the total man hours are minimized?

	I	II	III	IV
1	8	26	17	11
2	13	28	4	26
3	38	19	18	15
4	19	26	24	10

Let us apply the above steps take the above example.
Ans = 41 HRS.

Illustration 254:-

A manager has 5 jobs to be done. The following matrix shows the time taken by the j-th job (j = 1,2...5) on the i-th machine (I = 1,2,3...5). Assign 5 jobs to the 5 machines so that the total time taken is minimized

	Jobs				
	1	2	3	4	5
I	9	3	4	2	10
II	12	10	8	11	9
III	11	2	9	0	8
IV	8	0	10	2	1
V	7	5	6	2	9

Ans = 19 HRS

Illustration 240:-

A factory is going to modify of a plant layout to install four new machines M1, M2, M3 and M4. There are 5 vacant places J, K, L, M and N available. Because of limited space machine M2 cannot be placed at L and M3 cannot be placed at J. The cost of locating machine to place in Rupees is shown below:

	Depots				
	J	K	L	M	N
M ₁	18	22	30	20	22
M ₂	24	18	-	20	18
M ₃	-	22	28	22	14
M ₄	28	16	24	14	16

Required:
Determine the optimal assignment schedule in such a manner that the total costs are kept at a minimum.
Ans = 64

Illustration ~~201~~ 15

A manufacturing company, four has zones A, B, C, D and four sales engineers P, Q, R, S respectively for assignment. Since the zones are not equally rich in sales potential, therefore it is estimated that a particular engineer operating in particular zone will bring the following sales:

Zone A	:	4,20,000
Zone B	:	3,36,000
Zone C	:	2,94,000
Zone D	:	4,62,000

The engineers are having different sales ability. Working under the same conditions, their yearly sales are proportional to 14, 9, 11 and 8 respectively. The criteria of maximum expected total sales is to be met by assigning the best engineer to the richest zone, the next best to the second richest zone and so on.
Find the optimum assignment and the maximum sales. Ans = 3,92,000

Illustration ~~202~~ 16

An Electric Data Processing (ED) centre has three expert Software professionals. The centre wants three application software programs to be developed. The head of EDP centre estimates the computer time in minutes required by the experts for development of Application Software Programs as follows:

Software programs	Computer time (in minutes) required by software Professionals
1	100 85 70
2	50 70 110
3	110 120 130

Assign the software professionals to the application software programs to ensure minimum usage of computer time.

Illustration ~~255~~ 17

A marketing manager has 4 subordinates and 4 tasks. The subordinates differ in efficiency. The tasks also differ in their intrinsic difficulty. His estimates of the time each subordinate would take to perform each task is given in the matrix below. How should the task be allocated one to one man so that the total man - hours are minimized?

	I	II	III	IV
1	16	52	34	22
2	26	56	8	52
3	76	38	36	30
4	38	52	48	20

Ans = 82

Illustration ~~207~~ 18

The cost matrix giving selling costs per unit of a product by salesman A, B, C and D in regions R₁, R₂, R₃ and R₄ is given below:

	A	B	C	D
R ₁	4	12	16	8
R ₂	20	28	32	24
R ₃	36	44	48	40
R ₄	52	60	64	56

- Assign one salesman to one region to minimize the selling cost.
- If the selling price of the product is Rs. 200 per unit and variable cost excluding the selling cost given in the table is Rs. 100 per unit, find the assignment that would maximize the contribution.

The Transportation Problem

Chapter 13. TRANSPORTATION

Q. 278. 19 Solve the following transportation problem for minimum cost.

	D 1	D 2	D 3	D 4	
Q 1	5	3	6	2	19
Q 2	4	7	9	1	37
Q 3	3	4	7	5	34
	16	18	31	25	

Ans : - 355

Q. 279. 20

Factory	Destination			
	1	2	3	Supply to be exhausted
A	5	1	7	10
B	6	4	5	80
C	3	2	5	15
Demand	75	20	50	

Since there is not enough supply, some of the demands at the three destinations may not be satisfied. For the unsatisfied demands, let the penalty costs be rupees 1, 2 and 3 for destinations (1), (2) and (3) respectively. Find the optimal allocation that minimizes the transportation and penalty cost.

Solution = 505

Q. 278. 21 The Link manufacturing company has several plants, three of which manufacture two principal products, standard card table and deluxe card table. A new deluxe card table will be introduced which much be considered in term of selling price & costs. The selling prices are : Standard Rs. 14.95, Deluxe Rs. 18.95, and new Deluxe Rs. 21.95.

Requirements		Variable costs			Available plant capacity	
Model	Quantity	Plant A	Plant B	Plant C	Plant	capacity
Standard	450	8.00	7.95	8.10	A	800
Deluxe	1,050	8.50	8.60	8.45	B	600
New Deluxe	600	9.25	9.20	9.30	C	700

Solve this problem for maximum contribution

Q. 278. 22 The cost per unit of transporting goods from the factories X, Y, Z to destinations. A, B and C, and the quantities demanded and supplied are tabulated below. As the company is working out the optimum logistics, the Govt.; has announced a fall in oil prices. The revised unit costs are exactly half the costs given in the table. You are required to evaluate the minimum transportation cost.

Destinations Factories	A	B	C	Supply
X	15	9	6	10
Y	21	12	6	10
Z	6	18	9	10
Demand	10	10	10	30

Answer = 105

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The Transportation Problem

- Q. 230. PradeepPatil enterprises is having three plants manufacturing dry – cells, located at different locations. Production cost differs from plant to plant. There are five sales offices of the company located in different regions of the country. The sales prices can differ from region to region. The shipping cost from each plant to each sales office and other data are given by following table:

Production cost per unit	Production data table Maximum capacity in No. of units	Plant No.
20	150	1
22	200	2
18	125	3

Shipping cost & demand & sales price table
Shipping cost

	Sales office 1	Sales office 2	Sales office 3	Sales office 4	Sales office 5
Plant 1	1	1	5	9	4
Plant 2	9	7	8	3	6
Plant 3	4	5	3	2	7

Demand & Sales prices

	Sales office 1	Sales office 2	Sales office 3	Sales office 4	Sales office 5
Demand	80	100	75	45	125
Sales price	30	32	31	34	29

Find the production and distribution schedule most profitable to the company (10 marks) Ans : 3,170

- Q. 241. Tayal and Co. has provided the following data seeking your advice on optimum Investment strategy:

Investment made at the beginning of the year	Net return data (in paise) of selected investments				Amount available (Rs. In lakhs)
	P	Q	R	S	
1	95	80	70	60	70
2	75	65	60	50	40
3	70	45	50	40	90
4	60	40	40	30	30
Maximum Investment (Lakhs)	40	50	60	60	-

The following additional information are also provided

- P, Q, R and S represents the selected investments
- The company has decided to have four years investment plan
- The policy of the company is that amount invested in any year will remain so until the end of the fourth year.
- The values (Paise) in the table represent net returns on investment of one Rupee till the end of the planning horizon (for example, a Rupee invested in investment P at the beginning of year 1 will grow to Rs. 1.95 by the end of the fourth year, yielding a return of 95 paise). Using the above, determine the optimum investment strategy.

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The Transportation Problem

Q.252. The following table shows all the necessary information on the available supply to each warehouse, the requirement of each market and the unit transportation cost from each warehouse to each market:

	Market				
	I	II	III	IV	Supply
A	5	2	4	3	22
Warehouse B	4	8	1	6	15
C	4	6	7	5	8

Requirement

7

12

17

9

The shipping clerk has worked out the following schedule from his experience: 12 Units from A to II

1 unit from A to III

9 Units from A to IV

15 Units from B to III

7 Units from C to I and

1 Unit from C to III

You are required to answer the following:

- Check and see if the clerk has the optimal schedule;
- Find the optimal schedule and minimum total shipping cost; and Answer : 104

Q.256. A company has three warehouses W₁, W₂ and W₃. It is required to deliver a product from these warehouses to three customers A, B and C. These warehouses have the following units in stock.

Warehouse:	W ₁	W ₂	W ₃
No. of units:	65	42	43

And customer requirements are:

Customer:	A	B	C
No. of units:	70	30	50

The table below shows the costs transporting one unit from warehouse to the customer:

	Warehouse		
	W ₁	W ₂	W ₃
A	5	7	8
Customer B	4	4	6
C	6	7	7

Find the optimal transaction routes.

Answer :- Total cost = Rs. 830

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The Transportation Problem

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~~Q.284-4899~~ – May [3] (b) A company has three warehouses W_1, W_2 , and W_3 . It is required to deliver a product from these warehouses to three customers A, B and C. The warehouses have the following units in stock:

Warehouse :	W_1	W_2	W_3
No. of Units :	65	42	43

and customer requirements are:

Customer :	A	B	C
No. of Units :	70	30	50

The table below shows the costs of transporting one unit from warehouse to the customer:

		Warehouse		
		W_1	W_2	W_3
Customer	A	5	7	8
	B	4	4	6
	C	6	7	7

Find the optimal transaction route.

(10 marks) [S.A. 25]

Ans:-	Warehouse	Customer	Unit	Total Cost (Rs.)	
	W_1	A	65	325	
	W_2	A	5		35
	W_2	B	30		120
	W_2	C	7		49
	W_3	C	43		301
		Total			830

28

~~Q.285-2087~~ – May [1] {C} (b) The initial allocation of a transportation problem, along with the unit cost of transportation from each origin to destination is given below. You are required to arrive at the minimum transportation cost by the Vogel's Approximation method and check for optimality. (Hint: Candidates may consider $U_1 = 0$ at Row 1 for initial cell evaluation)

Requirement

			8		6		4	
11		2	8		6		2	18
	10							
9		9	12		9		6	10
				8				
7		6	3		7		7	8
	2					2		
9		3	5		6		11	4

Availability								
12	8	8	8	4				40

Answer :- Optimal cost = Rs. 204

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The Transportation Problem

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Q.286/2008 – May [6] (a) Goods manufactured at 3 plants, A, B and C are required to be transported to sales outlets X, Y and Z. The unit of transporting the goods from the plants to the outlets are given below:

Plant	A	B	C	Total Demand
Sales outlets				
X	3	9	6	20
Y	4	4	6	40
Z	8	3	5	60
Total supply	40	50	30	120

You are required to:

- Compute the initial allocation by North – West Corner Rule.
- Compute the initial allocation by Vogel's approximation method and check whether it is optional.
- State your analysis on the optionality of allocation under North – West corner Rule and Vogel's Approximation method. (10 marks) [S.A. 20]

Ans:- (i) Initial Total Cost 460
(ii) Initial solution 460, It is optimal
(iii) Solution under both methods is optimal

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Learning Curve

Chapter 12. LEARNING CURVE THEORY

Question ~~271~~ 30

A company has 10 direct workers, who work for 25 days a month of 8 hours per day. The estimated down times 25% of the total available time. The company received an order for a new product. The first unit of the new product requires 40 direct labour hours to manufacture the product. The company expects 80% (index is 0.322) learning curve for this type of work. The company uses standard absorption costing and the cost data are as under:

Direct materials	Rs. 60 per unit
Direct labour	Rs. 6 per direct labour hour
Variable overheads	Rs. 5 per direct labour hour
Fixed overheads	Rs. 7,500 per month.

(i) Calculate the cost per unit of the first order of 30 units.

(ii) If the company receives a repeat order for 20 units, what price will be quoted to yield a profit of 25% on selling price?

Question ~~202~~ 31

An electronics firm which has developed a new type of fire-alarm system has been asked to quote for a prospective contract. The customer requires separate price quotations for each of the following possible orders:

Order	Number of fire-alarm systems
First	100
Second	60
Third	40

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Learning Curve

The firm estimates the following cost per unit for the first order:

Direct materials - Rs. 500

Direct Labour -

Deptt. A (Highly automatic) 20 hours at Rs. 10 per hour.

Deptt. B (Skilled labour) 40 hours at Rs. 15 per hour.

Variable overheads 20% of direct labour

Fixed overheads absorbed:

Deptt. A Rs. 8 per hour

Deptt. B Rs. 5 per hour

Determine a price per unit for each of the three orders, assuming the firm uses a mark up of 25% on total costs and allows for an 80% learning curve.

Extract from 80% Learning curve table:

X	1.0	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
Y(%)	100.0	91.7	89.5	87.6	86.1	84.4	83.0	81.5	80.0

x represents the cumulative total volume produced to date expressed as a multiple of the initial order.

Y is the learning curve factor, for a given X value, expressed as a percentage of the cost of the initial order.

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Learning Curve

Question ~~228~~ 32

XYZ & Co. has given the following data:

80% Average — Time Curve

Cumulative Units (X)	Average Hours	Total-Hours	Marginal Hours
1	100	100	100
2	80	160	60
3	?	?	?
4	64	256	?

Required : Fill in the blanks.

Question ~~224~~ 33

A customer has asked your company to prepare a bid on supplying 800 units of a new product. Production will be in batches of 100 units. You estimate that costs for the first batch of 100 units will average Rs. 100 a unit. You also expect that a 90% learning curve will apply to the cumulative labour cost on this contract.

Required :

- (a) Prepare an estimate of the labour costs of fulfilling this contract.
- (b) Estimate the Incremental labour cost of extending the production run to produce an additional 800 units.
- c) Estimate the incremental labour cost of extending the production run from 800 units to 900 units.

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Learning Curve

Question ~~275~~ 34

CYZ Co., has observed that a 90% learning curve ratio applies to all labour related costs each time a new model enters production. It is anticipated that 320 units will be manufacture during 1999. Direct labour cost for the first lot of 10 units amounts to 1,000 hours at Rs. 8 per hour. Variable overhead cost is assigned to products at the rate of Rs. 2 per direct labour hour. You are required to determine :

- i) Total labour and labour.related costs to manufacture 320 units of output
- ii) Average cost of (a) the first 40 units produced (b) the first 80 units, (c) the first 100 units. -
- iii) Incremental cost of (a) units 41 – 80 and (b) units 101 – 200.

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Illustration 35

Bosch Ltd. has developed a special product. Details are as follows: The product will have a life cycle of 5,000 units. It is estimated that market can absorb first 4,500 units at ₹ 64 per unit and then the product will enter the "decline" stage of its life cycle.

The company estimates the following cost structure:

Direct Labour..... ₹ 6 per hour

Other variable costs..... ₹ 19 per unit

Fixed costs will be ₹ 40,000 over the life cycle of the product. The 'labour rate' and both of these costs will not change throughout the product's life cycle.

The first batch of 100 units will take 1,000 labour hours to produce. There will be an 80% learning curve that will continue until 2,500 units have been produced. Batches after this level will each take the same amount of time as the 25th batch. The batch size will always be 100 units.

Required

CALCULATE average selling price of the final 500 units that will allow the company to earn a total profit of ₹ 80,000 from the product if average time for 24 batches is 359.40 hours.

(Note: Learning coefficient is -0.322 for learning rate of 80%).

The values of Logs have been given for calculation purpose:

$\log 2 = 0.30103$; $\log 3 = 0.47712$; $\log 5 = 0.69897$; antilog of 2.534678 = 342.51; antilog of 2.549863 = 354.70; antilog of 2.555572 = 359.40; antilog of 2.567698 = 369.57

Solution**Average 'Selling Price' of the final 500 units**

Particulars	Amount (₹)
Direct Labour [(8,867.50 hrs. + 241.90 hrs. × 25 batches) × ₹ 6]	89,490
Add: Other Variable Costs (5,000 units × ₹ 19)	95,000
Add: Fixed Costs	40,000
Total Life Cycle Cost	2,24,490
Add: Desired Profit	80,000
Expected Sales Value (5,000 units × ₹ 19)	3,04,490
Less: Sales Value (4,500 units × ₹ 64)	2,88,000
Sales Value (Decline Stage) ... (A)	16,490
Sales Units (Decline Stage) ... (B)	500
Average Sales Price per unit ... (A) / (B)	32.98

Workings

- (i) The cumulative average time per batch for the first 25 batches

The usual learning curve model is

$$y = ax^b$$

Where

y = Average time per batch (hours) for x batches

a = Time required for first batch (hours)

x = Cumulative number of batches produced

b = Learning coefficient

The Cumulative Average Time per batch for the first 25 batches

$$y = 1,000 \times (25)^{-0.322}$$

$$\begin{aligned}
 \log y &= \log 1,000 - 0.322 \times \log 25 \\
 \log y &= \log 1,000 - 0.322 \times \log (5 \times 5) \\
 \log y &= \log 1,000 - 0.322 \times [2 \times \log 5] \\
 \log y &= 3 - 0.322 \times [2 \times 0.69897] \\
 \log y &= 2.549863 \\
 y &= \text{antilog of } 2.549863 \\
 y &= 354.70 \text{ hours}
 \end{aligned}$$

(ii) The time taken for the 25th batch

$$\begin{aligned}
 \text{Total Time for first 25 batches} &= 354.70 \text{ hours} \times 25 \text{ batches} \\
 &= 8,867.50 \text{ hours} \\
 \text{Total Time for first 24 batches} &= 359.40 \text{ hours} \times 24 \text{ batches} \\
 &= 8,625.60 \text{ hours} \\
 \text{Time taken for 25th batch} &= 8,867.50 \text{ hours} - 8,625.60 \text{ hours} \\
 &= 241.90 \text{ hours}
 \end{aligned}$$

Competition-Based Pricing Method

When a company sets its price mainly on the consideration of *what its competitors are charging*, its pricing policy under such a situation is called competitive pricing or competition-oriented pricing. It is not necessary under competitive pricing to charge the same price as charged by the concern's competitors. But under such a pricing the concern may keep its prices lower or higher than its competitors by a certain percentage. Its *own costs or demand may* change, but the concern maintains its price because its competitors maintain their prices. Conversely, the concern will change its price when its competitors change their price, even if its own costs or demand have not altered. Different types of competitive pricing in vogue are as follows:

Going Rate Pricing

It is a competitive pricing method under which a firm tries to *keep its price at the average level charged by the industry*. The use of such a practice of pricing is especially *useful where it is difficult to measure costs*. Adoption of going rate pricing will not only yield fair return but would be least disruptive for industry's harmony.

Going rate pricing primarily characterises pricing practice in *homogeneous product* markets. The concern selling a homogeneous product in a highly competitive market has actually very little choice about the setting of its price. There is apt to be a market determined price for the product, which is not established by any single firm or clique of firms but through the collective interaction of buyers and sellers. The concern which is going to charge more than the going rate would attract virtually no customers. The concern should not charge less because it can dispose of its entire output at the going rate.

Illustration 36

City International Co. is a multiproduct firm and operates standard costing and budgetary control system. During the month of June firm launched a new product. An extract from performance report prepared by Sr. Accountant is as follows:

Particulars	Budget	Actual
Output	30 units	25 units
Direct Labour Hours	180.74 hrs.	118.08 hrs.
Direct Labour Cost	₹1,19,288	₹79,704

Sr. Accountant prepared performance report for new product on certain assumptions but later on he realized that this new product has similarities with other existing product of the company. Accordingly, the rate of learning should be 80% and that the learning would cease after 15 units. Other budget assumptions for the new product remain valid.

The original budget figures are based on the assumption that the labour has learning rate of 90% and learning will cease after 20 units, and thereafter the time per unit will be the same as the time of the final unit during the learning period, i.e. the 20th unit. The time taken for 1st unit is 10 hours.

Required

Show the variances that reconcile the actual labour figures with revised budgeted figures in as much detail as possible.

Note:

The learning index values for a 90% and a 80% learning curve are -0.152 and -0.322 respectively.
 [log 2 = 0.3010, log 3 = 0.47712, log 5 = 0.69897, log 7 = 0.8451, antilog of 0.6213 = 4.181, antilog of 0.63096 = 4.275]

Solution**Working Note**

The usual learning curve model is

$$y = ax^b$$

Where

- y = Average time per unit for x units
- a = Time required for first unit
- x = Cumulative number of units produced
- b = Learning coefficient

W.N.1

Time required for first 15 units based on revised learning curve of 80% (when the time required for the first unit is 10 hours)

$$\begin{aligned}
 y &= 10 \times (15)^{-0.322} \\
 \log y &= \log 10 - 0.322 \times \log 15 \\
 \log y &= \log 10 - 0.322 \times \log (5 \times 3) \\
 \log y &= \log 10 - 0.322 \times [\log 5 + \log 3] \\
 \log y &= 1 - 0.322 \times [0.69897 + 0.47712] \\
 \log y &= 0.6213 \\
 y &= \text{antilog of } 0.6213 \\
 y &= 4.181 \text{ hours}
 \end{aligned}$$

$$\begin{aligned}
 \text{Total time for 15 units} &= 15 \text{ units} \times 4.181 \text{ hours} \\
 &= 62.72 \text{ hours}
 \end{aligned}$$

Time required for first 14 units based on revised learning curve of 80% (when the time required for the first unit is 10 hours)

$$\begin{aligned}
 y &= 10 \times (14)^{-0.322} \\
 \log y &= \log 10 - 0.322 \times \log 14 \\
 \log y &= \log 10 - 0.322 \times \log (2 \times 7) \\
 \log y &= \log 10 - 0.322 \times [\log 2 + \log 7] \\
 \log y &= 1 - 0.322 \times [0.3010 + 0.8451] \\
 \log y &= 0.63096 \\
 y &= \text{antilog of } 0.63096 \\
 y &= 4.275 \text{ hrs}
 \end{aligned}$$

$$\begin{aligned}
 \text{Total time for 14 units} &= 14 \text{ units} \times 4.275 \text{ hrs} \\
 &= 59.85 \text{ hrs}
 \end{aligned}$$

Time required for 25 units based on revised learning curve of 80% (when the time required for the first unit is 10 hours)

$$\begin{aligned}
 \text{Total time for first 15 units} &= 62.72 \text{ hrs} \\
 \text{Total time for next 10 units} &= 28.70 \text{ hrs } [(62.72 - 59.85) \text{ hours} \times 10 \text{ units}] \\
 \text{Total time for 25 units} &= 62.72 \text{ hrs} + 28.70 \text{ hrs} \\
 &= 91.42 \text{ hrs}
 \end{aligned}$$

W.N.2**Computation of Standard and Actual Rate**

Standard Rate	=	$\frac{₹1,19,288}{180.74 \text{ hrs.}}$
	=	₹ 660.00 per hr.
Actual Rate	=	$\frac{₹79,704}{118.08 \text{ hrs.}}$
	=	₹ 675.00 per hr.

W.N.3**Computation of Variances**

Labour Rate Variance	=	Actual Hrs × (Std. Rate – Actual Rate)
	=	118.08 hrs × (₹660.00 – ₹675.00)
	=	₹1,771.20 (A)
Labour Efficiency Variance	=	Std. Rate × (Std. Hrs – Actual Hrs)
	=	₹660 × (91.42 hrs – 118.08 hrs)
	=	₹17,595.60 (A)

Statement of Reconciliation (Actual Figures Vs Budgeted Figures)

Particulars	₹
Actual Cost	79,704.00
Less: Labour Rate Variance (Adverse)	1,771.20
Less: Labour Efficiency Variance (Adverse)	17,595.60
Budgeted Labour Cost (Revised)*	60,337.20

Budgeted Labour Cost (Revised)*

$$\begin{aligned}
 &= \text{Std. Hrs.} \times \text{Std. Rate} \\
 &= 91.42 \text{ hrs.} \times ₹660 \\
 &= ₹ 60,337.20
 \end{aligned}$$

Relevant Cost Approach to Variance Analysis

Traditional approach to variance analysis is to compute variances based on total actual cost for production inputs and total standard cost applied to the production output. This is ambiguous, when inputs are limited. Failure to use limited inputs properly leads not only to increased acquisition cost but also to a lost contribution. Therefore, it is necessary to consider the lost contribution in variance analysis. When this approach is used, price or expenditure variances are not affected.

Chapter 14. Linear Programming Problem

Q 287

Q 287. A tonic feed for cattle is to be prepared using two types of grain X_1 and X_2 . Each unit of grain X_1 weights 4 gms, and contain 2 gms of protein. Each unit of grain X_2 weights 5 gms. and contains 1 gm. of protein. The feed is to weight at most 40 gms. and must contain at least 10 gms. of protein. If the grain X_1 cost 30 paise a unit and that X_2 costs 10 paise a unit, determine by graphical method the amount of two types of grain to be used in the preparation of the feed to minimize the cost yet meeting the requirements. Formulate LP model for this problem.

Q 288

Q 288. A manufacturer makes two products P_1 and P_2 using two machinery M_1 and M_2 . Product P_1 requires 2 hours on machine and 6 hours on machine M_2 . Product P_2 requires 5 hours on machine M_1 and no time on machine M_2 . There are 16 hours of time per day available on machine M_1 and 30 hours on M_2 . Profit margin from P_1 and P_2 is Rs. 2 and Rs. 10 per unit respectively. Formulate LP model for this problem.

Q 289

Q 289. A firm manufactures two products A and B on which profits earned per unit are RS. 3 and Rs. 4 respectively. Each product is processed on two machines, M_1 and M_2 . The product A requires one minute of processing time on M_1 and two minutes on M_2 while B requires one minute on M_1 and one minute on M_2 . Machine M_1 is available for use for not more than 7 hours 30 minutes, while M_2 is available for 10 hours during any working day. Formulate LP model for this problem.

Q 290

Q 290. A company produces two products X and Y, each of which requires processing in three machines. The first machine can be used at most 70 hours; the second machine at most 40 hours; and the third machine at most 90 hours. The product X requires 2 hours on machine 1, 1 hour on machine 2, and 1 hour on machine 3; the product Y requires 1 hour each on machines 1 and 2, and 3 hours on the third machine. The profit is Rs. 50 per unit of X and Rs. 30 per unit of Y. Formulate LP model for this problem.

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L.P.P.

L.P.P.

Q 268 41

Maximize $Z = 3x_1 + 4x_2$
 Subject to $2x_1 + 3x_2 \leq 16$ (machining time)
 $4x_1 + 2x_2 \leq 16$ (assembly time)

 $x_1 \geq 0, x_2 \geq 0$

Q 269 42

A farm is engaged in breeding pigs. The pigs are fed on various products grown in the farm. In view of the need to ensure certain nutrient constituents (call them X, Y and Z), it becomes necessary to buy two additional products say, A and B. One unit of product A contains 36 units of X, 3 units of Y and 20 units of Z. One unit of product B contains 6 units of X, 12 units of Y and 10 units of Z. The minimum requirement of X, Y and Z is 108 units, 36 units and 100 units respectively. Product A costs Rs. 20 per unit and product B Rs. 40 per unit.

Formulate the above as a linear programming problem to minimize the total cost and solve this problem by using graphic method.

Q 268 43

WELL TYPE Manufacturing Company produces three types of typewriters; Manual type-writer Electronic typewriters, and Deluxe Electronic typewriters. All the three models are required to be machined first and then assembled. The time required for the various models are as follows:

Type	Machine Time (in hour)	assembly Time (in hour)
Manual Typewriter	15	4
Electronic Typewriter	12	3
Deluxe Electronic Typewriter	14	5

The total available machine time and assembly time are 3,000 hours and 1,200 hours respectively. The data regarding the selling price and variable costs for the three types are:

	Manual	Electronic	Deluxe Electronic
Selling Price (Rs.)	4,100	7,500	14,600
Labour, Material and other			
Variable costs (Rs.)	2,500	4,500	9,000

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L.P.P.

The company sells all the three types on credit basis, but will collect the amounts on the first of next month. The labour, material and other variable expenses will have to be paid in cash. This company has taken a loan of Rs. 40,000 from a co-operative bank and this company will have to repay it to be bank on 1st April, 1999. The TNC bank from whom this company has borrowed Rs. 60,000 has expressed its approval to renew the loan.

The Balance Sheet of this company as on 31.3.99 is as follows:

Liabilities	Rs.	Assets	Rs.
Equity share capital	1,50,000	Land	90,000
Capital Reserve	15,000	Buildings	70,000
General Reserve	1,10,000	Plant & Machinery	1,00,000
Profit & Loss A/c	25,000	Furniture & Fixtures	15,000
Loan term loan	1,00,000	Vehicles	30,000
Loan from TNC Bank	60,000	Inventory	5,000
Loan from Co-op bank	40,000	Receivables	50,000
		Cash	1,40,000
Total	5,00,000	Total	5,00,000

The company will have to pay a sum of Rs. 10,000 towards the salary from top management executives and other fixed overheads for the month. Interest on long terms loans is to be paid every month at 24% per annum. Interest on loan from TNC and Co-operative Banks may be taken to be Rs. 1,200 for the month. Also this company has promised to deliver 2 Manual typewriters and 8 Deluxe Electronic typewriters to one of its valued customers next month.

Also make sure that the level of operations in this company is subject to the availability of cash next month. This company will also be able to sell all their types of typewriter in the market. The senior Manager of this company desires to know as to how many units of each typewriter must be manufactured in the factory next month so as to maximize the profits of the company. Formulate this as a linear programming problem. The formulated problem need not be/solved.

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L.P.P.

Deluxe rose 12 red roses Rs. 12

12 white roses

12 yellow roses

Formulate a linear programming problem which allows the florist company to determine how many units of each arrangement should be made up in order to maximize profits assuming all arrangements can be sold.

The formulated LP problem is not required to be solved.

Q 303. The Sonu Paper Company produces rolls of paper used in cash registers. Each roll of paper is 500 ft. in length and can be produced in widths of 1,2,3 and 5 inch. The company's production process results in 500 rolls that are 12 inches in width. Thus the company must cut its 12 inch roll to the desired width. It has six basic cutting alternatives as follows:

Cutting Alternative	No. of Rolls				Waste (Inches)
	1"	2"	3"	5"	
1	6	3	0	0	0
2	0	3	2	0	0
3	1	1	1	1	1
4	0	0	2	1	1
5	0	4	1	0	1
6	4	2	1	0	1

The maximum demand requirements for the four rolls are as follows:

Roll Width (inches)	Demand Requirements (Rolls)
1	3000
2	2000
3	1500
5	1000

The company wishes to minimize the waste generated by its production meeting its demand requirements. Formulate the LP model.

45

Linear Programming

~~Q-316~~ 2002 - Nov [6] (c) A company manufactures two products namely A and B. The contribution per kg of output is Rs. 240 and Rs. 140 respectively for products A and B. The total fixed costs amount to Rs. 1,200 per week

The production of two products is restricted by limited supplies of three items of raw materials namely P, Q and R. The quantities of P, Q and R which are necessary to produce single units of the products A and B together with the total stock of materials available each week are given below:

	Product A	Product B	Total Quantity available per week kg
Raw material P	16	20	160
Q	10	25	150
R	4	0	32

Using the graphical approach of Linear Programming (LP), calculate the maximum Profit per week. (8 marks) [S. A. 19]

Ans:- Maximum Profit is Rs. 944

----- Space to write important points for revision -----

~~Q-317~~ 46 2003 - Nov [5] (b) A manufacture produces two products D₁ and D₂ using two machines R₁ and R₂. Products D₁ requires 2 hours on machine R₁ and 6 hours on machine R₂. Product D₂ utilises 5 hours of machine R₁ only. Total hours available per day on machine R₁ is 16 and R₂ is 30. Profit margin from D₁ and D₂ is Rs. 2 and Rs. 10 per unit respectively. Using simplex method find out the daily production mix to optimis profit. (8 marks) [S.A. 17]

Ans:- 32

----- Space to write important points for revision -----

~~Q-318~~ 47 2004 - May [5] (c) The budgeted data relating to two products manufactured by a company for a month are as under:

	Product A	Product B
Selling price	300	200
Variable manufacturing costs	160	60
Sales commission	60	40

Each unit of product incurs costs in the company's two departments P and Q. The total capacity available for the month under review is budgeted to be 1,400 hours in department P and 2,000 hours in department Q. The capacity costs amount to Rs. 14,000 and Rs. 20,000 respectively per month for P and Q irrespective of the level of usage made of it. The number of hours required in each of these departments to complete one unit of output is as under:

		A	B
Department	P	2	4
Department	Q	5	4

The maximum output which the company can sell in the month is restricted to 400 units of either of the products.

You are required to formulate the Linear Programming (LP) model and solve it graphically to determine the optimal product mix and profit. (8 marks) [S.A. 22]

Ans:- (i) Optimal Profit Rs. 7,000

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Linear Programming

48
Q 3112009 - May [6] (a) Formulate the dual for the following linear program:
Maximise: $100x_1 + 90x_2 + 40x_3 + 60x_4$
Subject to

$$6x_1 + 4x_2 + 8x_3 + 4x_4 \leq 140$$

$$10x_1 + 10x_2 + 2x_3 + 6x_4 \leq$$

$$120 \quad 10x_1 + 12x_2 + 6x_3 +$$

$$2x_4 \leq 50 \quad x_1, x_2, x_3, x_4 \geq 0$$

(Only formulation is required. Please do not solve). (6 marks) [S. A. 20] Ans:- Minimise $140y_1 + 120y_2 + 50y_3$, Subject to; $6y_1 + 10y_2 + 10y_3 \geq 100$; $4y_1 + 10y_2 + 12y_3 \geq 90$; $8y_1 + 2y_2 + 6y_3 \geq 40$; $4y_1 + 6y_2 + 2y_3 \geq 60$; $y_1, y_2, y_3, y_4 > 0$.

----- Space to write important points for revision -----

49
Q 3122000 - Nov [1] {C} (b) A manufacture produces three products three products Y_1, Y_2, Y_3 from three raw materials X_1, X_2, X_3 . The cost of raw materials X_1, X_2 and X_3 is Rs. 30, Rs. 50 and Rs. 120 per kg respectively and they are available in a limited quantity viz. 20 kg of X_1 , 15 kg of X_2 and X_3 . The selling price of Y_1, Y_2 and Y_3 is Rs. 90, Rs. 100 and Rs. 120 per kg respectively. In order to produce 1 kg of Y_1 , $\frac{1}{2}$ kg of X_1 , $\frac{1}{4}$ kg of X_2 and $\frac{1}{4}$ kg of X_3 are required. Similarly to produce 1 kg of Y_2 , $\frac{3}{7}$ kg of X_1 , $\frac{2}{7}$ kg of X_2 and $\frac{2}{7}$ kg of X_3 and to produce 1 kg Y_3 , $\frac{2}{3}$ kg of X_2 and $\frac{1}{3}$ kg of X_3 will be required.

Formulate the linear programming problem to maximize the profit. (10 marks) [S.A. 22]
Ans:-Maximise $Z = 32.50y_1 + 38.57y_2 + 46.67y_3$

Subject to Constraints

$$7y_1 + 6y_2 \leq 280$$

$$21y_1 + 24y_2 + 56y_3 \leq 1260$$

$$21y_1 + 24y_2 + 28y_3 \leq 840$$

Q 322. 2007 - May [4] (a) A gear manufacturing company makes two types of gears - A and B. Both gears are processed on 3 machines, Hobbing M/c, Shaping M/c and Grinding M/c. The time required by each gear and total time available per week on each M/c is as follows:

Machine	Gear (A) (Hours)	Gear (B) (Hours)	Available Hours
Hobbing M/s	3	3	36
Shaping M/s	5	2	60
Grinding M/c	2	6	60
Other data:			
Selling price (Rs.)	820	960	
Variable cost (Rs.)	780	900	

Determine the optimum production plan and the maximum contribution for the next by simplex method. The initial table is given below:

		C ₁	40	60	0	0	0
		Qty.					
C ₁	Variable		x ₁	x ₂	x ₃	x ₄	x ₅
0	x ₃	36	3	3	1	0	0
0	x ₄	60	5	2	0	1	0
0	x ₅	60	2	6	0	0	1

Ans:- Optimum Z = 660 with X₁ = 40 and X₂ = 60

----- Space to write important points for revision -----

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Chapter 15 & 16 CPM PERT51
Q 324

Activity	Duration
1 - 2	3 days
1 - 3	7 days
2 - 3	5 days
2 - 4	8 days
3 - 4	4 days

With the help of the activities given above draw a network. Determine its critical path, earliest start time, earliest finish time, latest start time, latest finish time, total float, free float and independent float.

Q 325-52

Activity	Duration
1 - 2	9 days
1 - 3	8 days
1 - 4	15 days
2 - 4	5 days
3 - 4	10 days
4 - 5	2 days

With the help of the activities given above draw a network. Determine its critical path, earliest start time, earliest finish time, latest start time, latest finish time, total float, free float and independent float.

Q 326-53

Activity	Duration
1 - 2	4 days
1 - 3	12 days
1 - 4	10 days
2 - 4	8 days
2 - 5	6 days
3 - 6	8 days
4 - 6	10 days
5 - 7	10 days
6 - 7	0 days
6 - 8	8 days
7 - 8	10 days
8 - 9	6 days

With the help of the activities given above draw a network. Determine its critical path, earliest start time, earliest finish time, latest start time, latest finish time, total float, free float and independent float.

54

Q331. 15.29 mod.

CPM PERT

A project consists of eight activities with the following relevant information:

Activity	Immediate Predecessor	Estimated Duration (days)		
		Optimistic	Most Likely	Pessimistic
A	-	1	1	7
B	-	1	4	7
C	-	2	2	8
D	A	1	1	1
E	B	2	5	14
F	C	2	5	8
G	D, E	3	6	15
H	F, G	1	2	3

- (i) Draw the PERT network and find out the expected project completion time.
(ii) What duration will have 95% confidence for project completion?

(iii) If the Avg. duration for Activity F increases to 14 days, what will be its effect on the expected project completion time which will have 95% confidence??

Q332.

A project consists of seven activities and the time estimates of the activities are furnished as under:

Activity	Optimistic Days	Most likely days	Pessimistic days
1 - 2	4	10	16
1 - 3	3	6	9
1 - 4	4	7	16
2 - 5	5	5	5
3 - 5	8	11	32
4 - 6	4	10	16
5 - 6	2	5	8

Required:

- (i) Draw the network diagram
(ii) Identify the critical path and its duration
(iii) What is the probability that the project will be completed in 5 days earlier than the critical path duration?
(iv) What project duration will provide 95% confidence level of completion ($Z_{0.95} = 1.65$)?

Given

Z	1.00	1.09	1.18	1.25	1.33
Probability	0.1587	0.1379	0.1190	0.1056	0.0918

Q-346. 56

2002 – May [5] (b) small project consists of jobs as given in the table below. Each job is listed with its normal time and a minimum or crash time (in days). The cost (in Rs. per day) for each job is also given :

Job (i-j)	Normal duration (in days)	Minimum (crash) Duration (in days)	Cost of Crashing (Rs. per day)
1-2	9	6	20
1-3	8	5	25
1-4	15	10	30
2-4	5	3	10
3-4	10	6	15
4-5	2	1	40

- (i) What is the normal project length and the minimum project length?
 (ii) Determine the minimum crashing cost of schedules ranging from normal length down to, and including, the minimum length schedule. That is, if L = Length of the schedule, find the costs of schedules which are $L, L-1, L-2$ and so on.
 (iii) Overhead costs total Rs 60 per day. What is the optimum length schedule in terms of both crashing and overhead cost? List the schedule duration of each job for your solution. (10 marks)

Q-347. 57

2003 – May [6] (c) A project consists of the following activities, whose time estimates are given against each as under :

Activity	Optimistic	Estimated duration (weeks)		Pessimistic
		Most likely		
1-2	3	6		15
1-3	2	5		14
1-4	6	12		30
2-5	2	5		8
2-6	5	11		17
3-6	3	6		15
4-7	3	9		27
5-7	1	4		7
6-7	4	19		28

Required :

- (i) Draw the project network.
 (ii) Find the expected duration and variance of each activity.
 (iii) Determine the critical path and the expected project duration.
 (iv) What is the probability that the project will be completed in 38 weeks?
 (v) What project duration will have 95% chance of completion. ($Z_{0.95} = 1.65$)

Given :

Z	0.21	0.41	0.82	
ϕ	0.0832	0.1591	0.2939	(8 marks)

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Q-342. 58

2004-May [6] A project is composed of seven activities as per details given below:

Activity	Normal Time (Days)	Crash Time (Days)	Normal Cost Rs.	Crash Cost Rs.
1-2	4	3	1,500	2,000
1-3	2	2	1,000	1,000
1-4	5	4	1,875	2,250
2-3	7	5	1,000	1,500
2-5	7	6	2,000	2,500
3-5	2	1	1,250	1,625
4-5	5	4	1,500	2,125

Indirect cost per day of the project is Rs. 500

Required :

- Draw the project network
- Determine the critical path and its duration
- Find the optimum duration and the resultant cost of the project (8 marks)

Q-343. 59

2010 - May [5] (b) A small project is composed of seven activities, whose time estimates are listed below. Activities are identified by their beginning (i) and ending (j) node numbers:

Activity (i-j)	Estimated durations (in days)		
	Optimistic	Most likely	Pessimistic
1-2	2	2	14
1-3	2	8	14
1-4	4	4	16
2-5	2	2	2
3-5	4	10	28
4-6	4	10	16
5-6	6	12	30

- Draw the project network
- Find the expected duration and variance for each activity. What is expected Project length?

Given : Z	0.50	0.67	1.00	1.33	2.00
P	0.3085	0.2514	0.1587	0.0918	0.0228

(4 marks)

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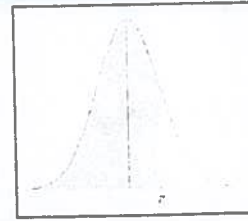
APPENDIX

Standard Normal Cumulative Probability Table

Cumulative probabilities for NEGATIVE z-values are shown in the following table:

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-3.4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002
-3.3	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
-3.2	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005
-3.1	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
-3.0	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
-2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
-2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
-2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
-2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
-2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
-2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
-2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
-2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
-2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
-2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
-1.9	0.0297	0.0291	0.0284	0.0278	0.0272	0.0266	0.0259	0.0254	0.0249	0.0243
-1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
-1.7	0.0446	0.0438	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
-1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
-1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
-1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
-1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
-1.2	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
-1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
-1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
-0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
-0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
-0.7	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2177	0.2148
-0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2579	0.2548	0.2514	0.2483	0.2451
-0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
-0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
-0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
-0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
-0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641

Standard Normal Cumulative Probability Table



Cumulative probabilities for POSITIVE z-values are shown in the following table:

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8079	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998

LOGARITHMS

TABLE I

N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	5	9	13	17	21	26	30	34	38
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	12	16	20	24	28	32	36
12	0792	0828	0864	0899	0933	0969	1004	1038	1072	1106	3	7	11	14	18	21	25	28	32
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	19	22	25	28
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	23	26
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	10	13	16	19	22	25
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	3	5	8	10	13	16	19	22	25
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	17	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3765	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	13	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6600	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8

LOGARITHMS

TABLE 1 (Continued)

N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
50	6990	6998	7007	7016	7025	7033	7042	7050	7059	7067	1	2	3	4	5	6	7	8	9
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	4	5	6	7	8	9
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	4	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	4	4	5	6	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	4	4	5	6	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	4	4	5	6	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	4	4	5	6	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	4	4	5	6	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	4	4	5	6	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	3	4	4	5	6	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	3	4	4	5	6	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	3	4	4	5	6	6
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	3	4	4	5	6	6
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	3	4	4	5	6	6
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	3	4	4	5	6	6
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	3	4	4	5	6	6
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	3	4	4	5	6	6
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	3	4	4	5	6	6
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	3	4	4	5	6	6
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	3	4	4	5	6	6
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	3	4	4	5	6	6
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	3	4	4	5	6	6
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	3	4	4	5	6	6
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	3	4	4	5	6	6
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	3	4	4	5	6	6
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	3	4	4	5	6	6
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	3	4	4	5	6	6
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	3	3	4	4	5
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	3	3	4	4	5
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	3	3	4	4	5
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	3	3	4	4	5
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	3	3	4	4	5
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	3	3	4	4	5
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	3	3	4	4	5
94	9731	9735	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	3	3	4	4	5
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	3	3	4	4	5
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	3	3	4	4	5
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	3	3	4	4	5
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	3	3	4	4	5
99	9956	9961	9965	9969	9974	9978	9983	9987	9992	9996	0	1	1	2	3	3	4	4	5

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TABLE II

N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1	1	2	2	2
01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1	1	2	2	2
02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1	1	2	2	2
03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1	1	2	2	2
04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1	2	2	2	2
05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1	2	2	2	2
06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1	2	2	2	2
07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1	2	2	2	2
08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1	2	2	2	3
09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1	2	2	2	3
10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1	2	2	2	3
11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	1	2	2	2	3
12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	1	2	2	2	3
13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	1	1	2	2	2	3
14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	1	1	2	2	2	3
15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	1	1	2	2	2	3
16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	1	1	2	2	2	3
17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	1	1	2	2	2	3
18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	1	1	2	2	2	3
19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	1	1	2	2	2	3
20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	1	1	2	2	2	3
21	1622	1626	1629	1633	1637	1641	1645	1648	1652	1656	0	1	1	1	1	2	2	2	3
22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	1	1	2	2	2	3
23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	1	1	1	2	2	2	3
24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	1	1	2	2	2	3
25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	1	1	2	2	2	3
26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	1	1	2	2	2	3
27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	1	1	2	2	2	3
28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	1	1	2	2	2	3
29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	1	1	1	2	2	2	3
30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	1	1	2	2	2	3
31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	1	1	1	2	2	2	3
32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	1	1	2	2	2	3
33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	1	1	2	2	2	3
34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	2	2	2	2	3
35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	2	2	2	2	2	2	3
36	2291	2296	2301	2307	2312	2317	2323	2328	2334	2339	1	1	2	2	2	2	2	2	3
37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	2	2	2	2	3
38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	2	2	2	2	3
39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	2	2	2	2	3
40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	2	2	2	2	3
41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1	1	2	2	2	2	2	2	3
42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	2	2	2	2	2	2	3
43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	2	2	2	2	2	3
44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	2	2	2	2	2	3
45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	2	2	2	2	2	3
46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	2	2	2	2	2	3
47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	2	2	2	2	2	3
48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	2	2	2	2	2	3
49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	2	2	2	2	2	3

ANTILOGARITHMS

TABLE II (Continued)

N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
.50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4	4	5	6	7
.51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3301	1	2	2	3	4	5	5	6	7
.52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4	5	6	6	7
.53	3388	3395	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4	5	6	6	7
.54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4	5	6	7	7
.55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4	5	6	7	8
.56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4	5	6	7	8
.57	3715	3724	3732	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4	5	6	7	8
.58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	5	5	6	7	8
.59	3890	3899	3908	3917	3926	3935	3944	3953	3962	3972	1	2	3	4	5	5	6	7	8
.60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	2	4	5	6	6	7	8
.61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5	6	7	8	9
.62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4255	1	2	3	4	5	6	7	8	9
.63	4266	4275	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5	6	7	8	9
.64	4365	4375	4385	4395	4405	4415	4426	4436	4446	4457	1	2	3	4	5	6	7	8	9
.65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5	6	7	8	9
.66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5	6	7	8	9
.67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5	7	8	9	10
.68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6	7	8	9	10
.69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	2	5	6	7	8	9	10
.70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	4	5	6	7	8	9	11
.71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6	7	8	10	11
.72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6	7	9	10	11
.73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	2	4	5	6	8	9	10	12
.74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	3	4	5	7	8	9	10	12
.75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7	8	9	11	12
.76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7	8	10	11	12
.77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	6	7	8	10	11	13
.78	6026	6039	6053	6067	6081	6095	6109	6123	6138	6152	1	3	4	6	7	9	10	11	13
.79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7	9	10	12	13
.80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7	9	10	12	13
.81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	2	3	5	6	8	9	11	12	14
.82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8	9	11	13	14
.83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8	10	11	13	15
.84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8	10	11	13	15
.85	7079	7095	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8	10	12	13	15
.86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8	10	12	14	16
.87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	3	5	7	9	11	12	14	16
.88	7586	7603	7621	7638	7656	7673	7691	7709	7727	7745	2	4	5	7	9	11	13	14	16
.89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	5	7	9	11	13	14	16
.90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9	11	13	15	17
.91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9	11	13	15	17
.92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10	12	14	16	18
.93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10	12	14	16	18
.94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10	12	14	16	18
.95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099	2	4	6	8	10	12	15	17	19
.96	9120	9141	9162	9183	9204	9225	9247	9268	9290	9311	2	4	6	8	11	13	15	17	19
.97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528	2	4	7	9	11	13	15	17	20
.98	9550	9572	9594	9616	9638	9660	9682	9705	9727	9750	2	4	7	9	11	14	16	18	20
.99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11	14	16	18	20