A Text Book on

Industrial Engineering, Robotics and Mechatronics

Useful for IAS / GATE / ESE / PSUs and other competitive examinations

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Corporate Office: 44-A/4, Kalu Sarai (Near Hauz Khas Metro Station), New Delhi-110016
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A text book on Industrial Engineering, Robotics and Mechatronics

First Edition: 2016
Reprint: 2019
Reprint: 2022
Reprint: 2023

Reprint: 2024

FOREWORD

In my long teaching career I have come across many other fellow teachers but Dr. Swadesh Singh is unique. He has the rare combination of being Ex-IES officer in Govt. of India, a Ph.D from reputed Indian Institute of Technology Delhi, a Young Scientist award winner and a Career Award winner for teaching. As a teacher, he is one of those who really tries to understand the students from their perspective and helps them. He has a penchant for guiding and counseling students in choosing their careers and preparing them for their competitive exams. Many students have benefited from him and holds regard for him even years after graduating. Dr. Singh's book on Production Technology has become popular and is a standard among the students who are top rankers in competitive exams like GATE, CIVIL SERVICES etc. and the present book on Industrial engineering should stand testimony to the expertise of Dr. Singh's in presenting in a compact book what is just appropriate for preparing for such exams.

This book is a must-have for those who are serious in finding success in competitive exams.

Prof. P. S. Raju
Director
GRIET, Hyderabad, India

PREFACE

After the overwhelming response of my first book on Production Engineering, I thought of writing another book on the core subject of Industrial Engineering. After teaching for various competitive examinations for about 16 years, I found that although there are so many books available on the fundamentals of Industrial Engineering but there is no book available for competitive examinations. The book which student can have and crack any question that appears in examination like GATE, IES and other public sector examination. So in the present book my effort is to teach fundamentals by problem solving so that students can understand well. Apart from the solved example-problems, numerous objective-type practice problems from various competitive examinations are given, along with the answer keys. The first edition of this book I released in 2011. Since most of the work including the typesetting, editing and so on was carried out by me, there were many grammatical mistakes in that edition. While teaching and students solving the problem we have corrected the text thoroughly and I have also added some more relevant text in each topic making it more suitable for the competitive examinations. Along with Dr. Rajesh Purohit of MANIT Bhopal, I have added Robotics and Mechatronics to make the book suitable for IES and other competitive examinations.

I express my gratitude to my spiritual teacher who has given me inspiration to write this book. Every subject matter can be learned through the medium of a teacher only. He thought me both his precept and by his personal example how to be sincere at work and what is good for me and how can I help others in a genuine way.

The authors are thankful to Sunil Kumar, Deepen Banoriya, Utkarsh Pandey, Bhrant Kumar, Harish, Limbadri, Prudvi, Gangadhar and Srinivasu for taking pain in correcting the manuscript many times. We also thank MADE EASY proof editing staff and CMD Sri B. Singh for their full support in publishing this book.

We hope that aspirants of scoring high in GATE, ESE, IAS, PSU and any competitive exams find this book as a helpful aid in their preparations.

Dr. Swadesh Kumar Singh

Dr. Rajesh Purohit

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CHAPTER 2

Simplex Method

2.1 INTRODUCTION

When there are more than two variables, graphical method cannot be used to solve optimization problems. As it was explained in the previous chapter that optimal solution exists always at the corner point at the feasible region, the simplex method is a systematic procedure at finding corner point solution and taking them for optimality. Simplex procedures are meant for profit maximization and if our objective is loss minimization then the problems has to be converted into profit maximization by multiplying the objective function by '–' sign before starting the simplex procedures.

While solving problems using simplex methods, we take slack variables, surplus variables and artificial variables. After solving the simplex problem, we can do the verification test of the result to make sure that the answer is correct. In many practical problems we want to find not only an optimal solution but also want to determine what happens to this optimal solution when certain changes are made in the system. For this we do the sensitivity. While doing sensitivity analysis if negative value appears in solution matrix, the matrix is not an optimum one and we move towards optimality by dual simplex procedure.

While solving problems using simplex methods if many artificial variables are to be used we will write a dual problem for the given problem and then solve it by simplex procedure. The intermediate steps and fundamentals involved in simplex procedure are given in the following problems.

Slack variables are those which are added to the constraint equations to get equal to sign ('=')

Example: 2.1

Assume that the following specify a generalized linear programming problem:

Maximize: $Z = x_1 - x_2 + 3x_3$

Subjected to $2x_1 - x_3 \le 2$

$x_1 + x_2 - x_3 \le 10$

$2x_1 - 2x_2 + 3x_3 \le 0$

$x_1, x_2, x_3 \ge 0$

Solve it by using Simplex Method.

Solution:

Let s_1, s_2, s_3 be slack variables then the constraints become

$$2x_1 - x_3 + s_1 = 2; \qquad x_1 + x_2 - x_3 + s_2 = 10$$

$$2x_1 - 2x_2 + 3x_3 + s_3 = 0; \qquad x_1, x_2, x_3, s_1, s_2, s_3 \ge 0$$

$$\Rightarrow \quad \text{Max } Z = x_1 - x_2 + 3x_3 + 0s_1 + 0s_2 + 0s_3$$

PRACTICE QUESTIONS

1. Which one of the following subroutines does a computer implementations linear programming by the Simplex method use?
(a) Finding a root of a polynomial
(b) Finding the determinant of a matrix
(c) Finding the Eigen values of a matrix
(d) Solving a system of linear equations

2. A variable which has no physical meaning, but is used to obtain an initial basic feasible solution to the linear programming problem is referred to as:
(a) Basic variable
(b) Non-basic variable
(c) Artificial variable
(d) Basis

3. In the solution of a linear programming problem by simplex method, if during iteration, all ratios of right-hand side b_1 to the coefficients of entering variable a are found to be negative, it implies that the problem has:
(a) Infinite number of solutions
(b) Infeasible solution
(c) Degeneracy
(d) unbound solutions

4. Consider the following statements regarding the characteristics of the standard form of a linear programming problem:
1. All the constraints are expressed in the form of equations.
2. The right-hand .side of each constraint equation is non-negative.
3. All the decision variables are non-negative.
Which of these statements are correct?
(a) 1, 2 and 3
(b) 1 and 2
(c) 2 and 3
(d) 1 and 3

5. Consider the following statements:
1. A linear programming problem with three variables and two constraints can be solved by graphical method.
2. For solutions of a linear programming problem with mixed constraints, Big-M method can be employed.
3. In the solution process of a linear programming problem using Big-M method, when an artificial variable leaves the basis, the column of the artificial variable can be removed from all subsequent tables.
Which of these statements are correct?
(a) 1, 2 and 3
(b) 1 and 2
(c) 1 and 3
(d) 2 and 3

6. Consider the following statements regarding linear programming:
1. Dual of a dual is the primal.
2. When two minimum ratios of the right-hand side to the coefficient in the key column are equal, degeneracy may take place.
3. When an artificial variable leaves the basis, its column can be deleted from the subsequent Simplex tables.
Select the correct answer from the codes given below:
(a) 1, 2 and 3
(b) 1 and 2
(c) 2 and 3
(d) 1 and 3

24. Which one of the following is true in case of simplex method oflinear programming?
(a) The constants of constraints equation may be positive or negative.
(b) Inequalities are not converted into equations.
(c) It cannot be used for two-variable problems.
(d) The simplex algorithm is an iterative procedure.

25. Match **List-I (Persons with whom the models are associated)** with **List-II (Models)** and select the correct answer:

List-I	List-II
A. J. Von Newmann	**1.** Waiting lines
B. G. Dantzig	**2.** Simulation
C. A.K. Erlang	**3.** Dynamic programming
D. Richard Bellman	**4.** Competitive strategies
	5. Allocation by simplex method

Codes:

	A	B	C	D
(a)	2	1	5	4
(b)	4	5	1	3
(c)	2	5	1	4
(d)	4	1	5	3

❍❍❍❍

ANSWERS

SIMPLEX METHOD

1. (d)	**2.** (c)	**3.** (d)	**4.** (a)	**5.** (d)	**6.** (a)	**7.** (b)
8. (d)	**9.** (d)	**10.** (a)	**11.** (d)	**12.** (b)	**13.** (a)	**14.** (a)
15. (d)	**16.** (d)	**17.** (a)	**18.** (b)	**19.** (d)	**20.** (b)	**21.** (a)
22. (d)	**23.** (b)	**24.** (d)	**25.** (b)			

CHAPTER 4

Assignment and Sequencing

4.1 ASSIGNMENT

Assignment problems are solved for cost minimization.

Example: 4.1

Five jobs I, II, III, IV & V and five machines *A*, *B*, *C*, *D*, *E*, time taken for each machine to do a particular job is given in minutes.

	I	II	III	IV	V
A	6	5	8	11	16
B	1	13	16	1	10
C	16	11	8	8	8
D	9	14	12	10	16
E	10	13	11	8	16

Assign the jobs to machines to minimize the total processing time. And find the minimum time taken.

Solution:

	I	II	III	IV	V
A	1	0	3	6	11
B	0	12	15	0	9
C	8	3	0	0	0
D	0	5	3	1	7
E	2	5	3	0	8

Steps-IV : If the number of lines is equal to the order of matrix then it is the optimal table.

If the number of lines is less than the order of matrix, then select the minimum number which is not covered by the lines. Subtract this value from each and every element which is uncovered and add this value at the intersection point of lines. Here adding “3" minimum uncovered value at intersection and subtracting at non-covered values.

	I	II	III	IV	V
A	4	0	3	9	11
B	0	9	12	0	6
C	11	3	0	3	0
D	0	2	0	1	4
E	2	2	0	0	5

We will continue to repeat step IV, till number of lines are equal to the order of the matrix.Now number of lines are equal to the order of the matrix, so select zeros such that every column and row consists of one zero i.e., one allocation for one machine.

	I	II	III	IV	V
A	4	0	3	9	11
B	0	9	13	0	6
C	11	3	0	3	0
D	0	2	0	1	4
E	2	2	0	0	5

Assignment is *A*-II, *B*-IV, *C*-V, *D*-I, *E*-III

4.2 TRANSFERRING THE SOLUTIONS TO THE MAIN MATRIX

	I	II	III	IV	V
A	6	5	8	11	16
B	1	13	6	1	10
C	16	11	8	8	8
D	9	14	12	10	16
E	10	13	11	8	16

The total processing time is 34.
The matrix also has another solution: by observation it is *A*-II, *B*-I, *C*-V, *D*-III, *E*-IV.
I solution represented by circles and II solution is represented by boxes.

Example: 4.2

Following is the profit matrix. Find the allocations to maximize the profit.

	I	II	III	IV	V
A	30	40	40	25	29
B	37	24	32	38	62
C	40	27	33	49	41
D	28	21	30	36	34
E	40	36	35	36	39

CHAPTER 7

Project Management

7.1 INTRODUCTION

- Node or event is any point in time space and in between the two nodes there will be an activity which consumes time.

Activity: It is the time consuming effort represented by a line with an arrow head pointing in the direction of progress of completion of work.

Event: An event is a point in time where one or more activities start and/or finish. It is a part of accomplishment and/or decision. A circle is used to represent an event.

- Every project involves some group of activities and some of these activities will be performed parallely.
- Before starting any activity like construction of a pillar in building, the activities like bringing cement, bricks have to be completed. These activities are called "Predecessor activities".

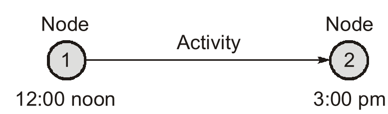


Fig : 7.1

- The activity which is followed is called "successor activity".
- When all the predecessor and successor activities are arranged in the form of a diagram it is called "precedence diagram".

7.2 RULES FOR CONSTRUCTION OF PRECEDENCE DIAGRAM

1. Project start or project completion is to be considered as only one event in time space and hence cannot be represented by more than one node. So the node at which the project starts can be the 'Burst node' and the node at which the project completes can be the 'Converging Node'. i.e., Many activities can start from one node and can finish at one node only i.e. There should be only one initial and one terminal node.

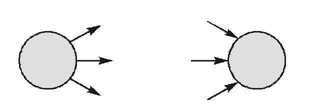


Fig: 7.2

2. While constructing the diagram different activities should not cross each other.

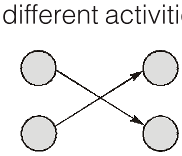


Fig: 7.3

3. More than one activity cannot start at same node and also finish at the same node.

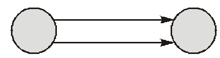


Fig: 7.4

Case (2) and (3) can be avoided by introducing dummy activity.

7.2.1 Dummy Activity

Dummy activities don't consume any time and are used just to complete the precedence diagram. Dummy activities are used only in case of absolute necessity i.e., minimum number of dummy activities must be used.

Dummy activity should be represented by a dotted line.

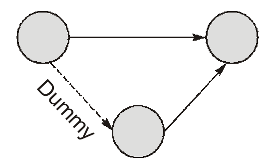


Fig: 7.5

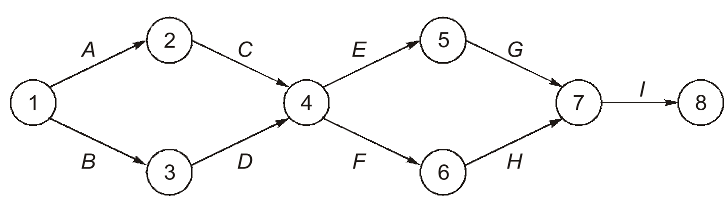
4. Time always flow from left to right.
5. All nodes, with the exception of the terminal node, must have at least one successor.
6. All nodes, except the first, must have at least one predecessor.
7. An arrow specifies only precedence relations; its length has no significance with respect to the time duration accompanying either of the activities that it connects.
8. Cycles or closed-loop paths through the network are not permitted. They imply that an activity is a successor of another activity that depends on it.

Example: 7.1

Draw the precedence diagram for the following data:

Activity	A	B	C	D	E	F	G	H	I
Predecessor	–	–	A	B	C, D	C, D	E	F	G, H

Solution:

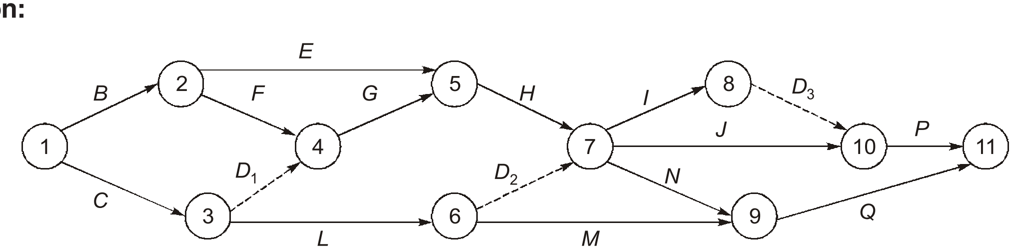


Example: 7.2

Draw the precedence diagram for the following data:

Activity	B	C	E, F	L	G	H	I	M	N	J	P	Q
Predecessor	–	–	B	C	C, F	E, G	H, L	L	H, L	H, L	I, J	M, N

Solution:



Here D_1, D_2, D_3 are dummy activities.

CHAPTER 9

Value Engineering & Work Study

9.1 INTRODUCTION

Value Engineering (VE) is a systematic method to improve the "value" of goods or products and services by using an examination of function. Value, as define, is the ratio of function to cost. Value can therefore be increased by either improving the function or reducing the cost. It is a primary principle of value engineering that basic functions should be preserved and not be reduced as a consequence of pursuing value improvements.

In the United States, value engineering is specifically spelled out in Public Law 104-106, which states "Each executive agency shall establish and maintain cost-effective value engineering procedures and processes". Value engineering is sometimes taught within the project management or industrial engineering body of knowledge as a technique in which the value of a system's outputs is optimized by crafting a mix of performance (function) and costs. In most cases this practice identifies and removes unnecessary expenditures, thereby increasing the value for the manufacturer and/or their customers.

Value Engineering follows structured thought process that is based exclusively on "function", i.e., what something "does" not what it is. For example a screw driver that is being used to stir a can of paint has a "function" of mixing the contents of a point can and not the original connotation of securing a screw into a screw-hole. In value engineering "functions" are always described in a two word abridgment consisting of an active verb and measurable noun (what is being done – the verb – and what is being done to – the noun) and to do so in the most non-prescriptive way possible. In the screw driver and can of paint example, the most basic function would be "blend liquid" which is less prescriptive than 'stir paint" which can be seen to limit the action (by stirring) and to limit the application (only considers paint.) This is the basis of what value engineering refers to as "function analysis".

Value engineering uses rational logic (a unique "how" – "why" questioning technique) and the analysis of function of identify relationships that increases value. It is considered a quantitative method similar to the scientific method, which focuses on hypothesis-conclusion approaches to test relationships, and operations research, which uses model building to identify predictive relationships. Value engineering is also referred to as "value management" and "value methodology" (VM), and 'value analysis" (VA). VE is above all a structured problem solving process based on function analysis – understanding something with such clarity that it can be described in two words, the active verb and measurable noun abridgement. For example, the function of a pencil is to "make marks". This then facilities considering what else can make marks. From a spray can, lipstick, a diamond on glass to astick in the sand, one can then clearly decide upon which alternative solution is most appropriate.

$$\text{Value} = \frac{\text{Function(or)Quality}}{\text{Cost}}$$

PRACTICE QUESTIONS

1. In the study, the rating factor is applied to determine.
   (a) Standard time of a job (b) Merit rating of the worker
   (c) Fixation of incentive rate (d) Normal time of job

2. Work study is mainly aimed at
   (a) Determining the most efficient method of performing a job.
   (b) Establishing the minimum time of completion of job.
   (c) Developing the standard method and standard time of a job.
   (d) Economizing the motions involved on the part of the worker while performing a job.

3. Consider the following factors.
   1. Adequate incentive 2. Ease of administration
   3. Flexibility 4. Guaranteed basic pay
   5. Higher wages 6. Simplicity
   Among these, the factors which are to be considered while developing a good wage incentive plan would include.
   (a) 1, 2, 3 and 5 (b) 2, 3, 4 and 5
   (c) 1, 2, 4 and 6 (d) 1, 2, 5 and 6

4. Which of the following charts are used for plant layout design?
   1. Operation process chart 2. Man machine chart
   3. Correlation chart 4. Travel chart
   Select the correct answer using the codes given below:
   (a) 1, 2, 3 and 4 (b) 1, 2 and 4
   (c) 1, 3 and 4 (d) 2 and 3

5. In value engineering important consideration is given to
   (a) Cost reduction (b) Profit maximization
   (c) Function concept (d) Customer satisfaction

6. Match **List-I (Object)** with **List-II (Tool)** and select the correct answer:

	List-I		List-II
A.	Improving utilization of supervisory staff	1.	Micromotion study
B.	Improving plant layout	2.	Work sampling
C.	Improving work place layout	3.	Flow process chamber
D.	Improving highly repetitive hand movements	4.	Chronocyclegraph

Codes:

	A	B	C	D
(a)	2	3	1	4
(b)	3	2	1	4
(c)	2	3	4	1
(d)	3	2	4	1

7. Determination of standard time in complex job system is best done through:
   (a) Stop watch time study (b) Analysis of micro motions
   (c) Group timing techniques (d) Analysis of standard date system

CHAPTER 10

Robots

10.1 INTRODUCTION

Robot is an automatically controlled material handling unit that is widely used in the manufacturing industry. It is generally used for high volume production and better quality. Implementation of robot technology with integration of automatic system can contribute to increase in productivity of the company and enhances its profitability.

Another definition from Robot Institute of America is that the robot is a programmable multi function manipulator designed to move and manipulate material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of specified tasks.

There are a number of successful examples of robot applications such as the following:

Robots perform more than 98 percent of the spot welding on Ford's Taurus and Sable cars in USA. A robot drills holes in the vertical tail fins at general dynamics compared to man when the job was done manually. Robots insert disk drives into personal computers and snap keys onto electronic type writer keyboards.

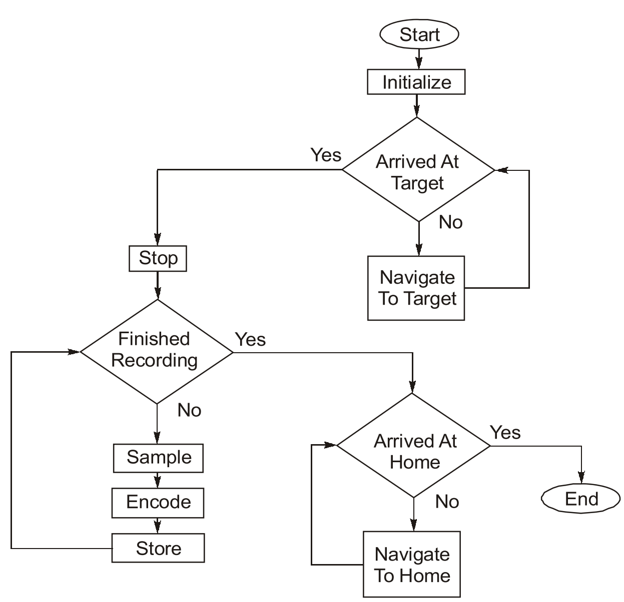
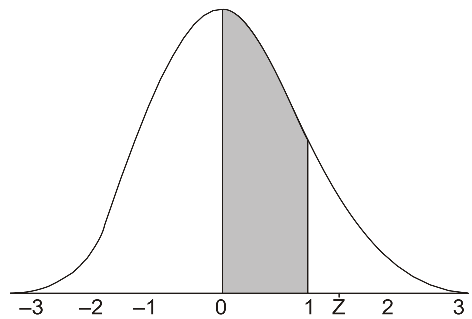


Fig: 10.1 The simple robotic flow chart



Normal Distribution Table
(Table shows total area under distribution up to “X”)

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	D.5O00	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	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.3238	0.8264	0.8289	0.8315	0.8340	08365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.85S4	0.8577	0.8599	0.8621
1.1	0.8643	0.8685	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	0.8960	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	09115	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	0.9464	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.S641	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	0.9642	0.9846	0.9650	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9587	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	09946	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	09974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9962	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
3.5	0.9998	0.9998	0.9998	0.9998	0.9998	0.9996	0.9998	0.9998	0.9998	0.9998
3.6	0.9996	0.9998	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999
3.7	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999
3.8	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999
3.9	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

CHAPTER 15

Control Systems

15.1 INTRODUCTION

Control systems in an interdisciplinary field covering many areas of engineering and sciences. It is a device that controls the behavior of other devices. It is working as an interconnection between connected components or related in such a manner as to give commands, or regulate other component or itself. It is found in abundance in all sectors of industry, such as quality control of manufactured products, automatic assembly lines, machine-tool control, space technology, computer control, transportation systems, power systems, robotics, Micro-Electro-Mechanical Systems (MEMS), nanotechnology, and many others.

The study and design of automatic control system is also a field known as control engineering. In the modern era, it has become a part of everyday life. From device simple as a toaster to complex systems like space shuttle control engineering plays a crucial role. The control system is a component that is added to other components to increase system functionality and also to get the desired output from the system.

The basic ingredients of a control system can be described by:

1. Objectives of control.
2. Control-system components.
3. Results or outputs.

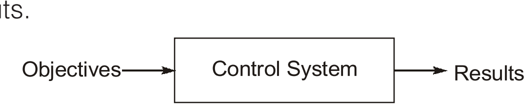


Fig: 15.1 Basic components of Control System

The basic relationship among these three components is illustrated in Fig. 15.1. In more technical terms, the objectives can be identified with inputs, or actuating signals, and the results are also called outputs, or controlled variables. In general, the objective of the control system is to control the outputs in some prescribed manner by the inputs through the elements of the control system.

15.2 CHARACTERISTICS OF CONTROL SYSTEMS

A good control system must have the following characteristics:

Accuracy: It is the measurement tolerance of any instrument and it defines the limit of error that instrument can make in working condition. It can be improved by feedback element and the detector must be present in the control system.

PRACTICE QUESTIONS

1. As a result of introduction of negative feedback which of the following will not decrease?
(a) Bandwidth (b) Overall gain
(c) Distortion (d) Instability

2. Which of the following should be done to make an unstable system stable?
(a) The gain of the system should be decreased.
(b) The gain of the system should be increased.
(c) The number of poles to the loop transfer function should be increased.
(d) The number of zeros to the loop transfer function should be increased.

3. Regenerative feedback implies feedback with
(a) oscillations (b) step input
(c) negative sign (d) positive sign

4. The output of a feedback control system must be a function of
(a) Reference and output (b) reference and input
(e) input and feedback signal (d) output and feedback signal

5. ______ is an open loop control system.
(a) Ward Leonard control (b) Field controlled D.C. motor
(c) Stroboscope (d) Metadyne

6. Band width of a control system for better frequency response should be
(a) High (b) Low
(c) Medium (d) Does not depend on bandwidth

7. The band width, in a feedback amplifier:
(a) remains unaffected
(b) decreases by the same amount as the gain increase
(c) increases by the same amount as the gain decrease
(d) decreases by the same amount as the gain decrease

8. The system output can be delayed by a finite, predetermined amount of time is known as
(a) Delay (b) Idle delay
(c) Time shift (d) Delay margin

9. On which of the following factors does the sensitivity of a closed loop system to gainc hanges and load disturbances depend?
(a) Frequency (b) Loop gain
(c) Forward gain (d) All of the above

10. The transient response, with feedback system,
(a) rises slowly (b) rises quickly
(c) decays slowly (d) decays quickly

11. For stability oscillation of the control system should be:
(a) Minimum (b) Constant
(c) Both of above (d) Either (a) or (b)

ANSWERS

CONTROL SYSTEMS

1. (a)	**2.** (b)	**3.** (d)	**4.** (a)	**5.** (b)	**6.** (a)	**7.** (c)
8. (b)	**9.** (d)	**10.** (d)	**11.** (d)	**12.** (c)	**13.** (a)	**14.** (a)
15. (c)	**16.** (a)	**17.** (c)	**18.** (d)	**19.** (c)	**20.** (b)	**21.** (b)
22. (b)	**23.** (c)	**24.** (b)	**25.** (c)	**26.** (b)	**27.** (b)	**28.** (b)
29. (a)	**30.** (a)	**31.** (c)	**32.** (c)	**33.** (a)	**34.** (a)	**35.** (b)
36. (a)	**37.** (b)	**38.** (d)	**39.** (b)	**40.** (a)	**41.** (a)	**42.** (b)
43. (b)	**44.** (d)	**45.** (c)	**46.** (a)	**47.** (d)	**48.** (d)	**49.** (a)
50.(a)	**51.** (a)	**52.** (a)				