

CONTENTS

1 AUTOMATION

1-31

1.1	Introduction	1
1.1.1	History of Automation	1
1.1.2	Current Emphases in Automation	3
1.1.3	Development of the History of Automation Date Development	4
1.1.4.	Reasons for Automating	5
1.2	Elements of Automation	6
1.2.1	Power Source	6
1.2.2	Feedback Controls	7
1.2.3	Machine Programming	8
1.3	Types of Automation Systems	10
1.3.1	Hard Automation	10
1.3.2	Soft Automation (Flexible Automation)	11
1.4	Applications of Automation	12
1.4.1	Automated Production Lines	12
1.4.2	Numerical Control	12
1.4.3	Automated Assembly	14
1.4.4	Robots in Manufacturing	14
1.4.5	Flexible Manufacturing Systems	15
1.4.6	A Building Automation System (BAS)	15
1.4.7	CAD/CAM and Computer Integrated Manufacturing	17
1.4.8	Automation in Daily Life	18
1.5	Goals of Automation	19
1.6	Automation and Society: Social Economic Impacts of Automation	20
1.6.1	Automation and Society	20
1.6.2	Employment	20
1.6.3	Automation and the Individual	21
1.7	Advantages and Disadvantages of Automation	22
1.8	Low Cost Automation	23
1.8.1	Introduction	23
1.8.2	Advantages	23
1.9	Hierarchical Levels in Industrial Automation Systems	23
1.9.1	Field Level	24
1.9.2	Cell Level	24
1.9.3	Area Level	25
1.9.4	Plant Level	25
1.10	Manufacturing System Integration	25
1.10.1	Information Technology Metrology for Manufacturing	25
1.10.2	Manufacturing Enterprise Integration	25
1.10.3	Manufacturing Simulation and Visualization	26
1.10.4	Integrated Nano-to-millimeter Manufacturing	27
1.10.5	Product Engineering	27
1.10.6	System Integration for Manufacturing Applications (SIMA)	28

Summary	28
Review Questions	29
Short Answer Type Questions	29
Objective Type Questions	30

2 BASICS OF FLUID POWER

32-44

2.1 Introduction	32
2.2 Historical Background	33
2.3 Classification of Fluid Power Systems	33
2.4 Fluid Power Advantages	34
2.5 Comparison of Electrical, Hydraulic and Pneumatic Systems	35
2.6 Future Trends and Developments in Fluid Power	36
2.6.1 Components in Modular Block Form	36
2.6.2 Noise Control	36
2.6.3 Electro-modulated Components	37
2.6.4 Computer Control	37
2.6.5 Electronic Position Sensors	37
2.7 Logic Gates	37
2.7.1. Introduction	37
2.7.2. Truth Tables	38
2.7.3. Basic Rules of Boolean Algebra	38
Summary	43
Review Questions	43
Short Answer Type Questions	43
Objective Type Questions	43

3 HYDRAULIC FLUID POWER SYSTEMS

45-112

3.1 Introduction	45
3.2 Fundamental Terms and Principles	46
3.2.1 Mass and Weight	46
3.2.2 Density and Specific Gravity	46
3.2.3 Force and Inertia	46
3.2.4 Pressure	47
3.2.5 Atmospheric, Gauge and Absolute Pressure	47
3.2.6 Pascal's Law	48
3.2.7 Flow	49
3.2.8 Streamline and Turbulent Flow	49
3.2.9 Work, Energy and Power	49
3.2.10 Bernoulli's Principle	50
3.3 Components of Hydraulic Fluid Power System	51
3.4 Hydraulic Fluids	51
3.4.1 Properties of Hydraulic Fluids	52
3.4.2 Types of Hydraulic Fluids	54
3.5 Pumps	55
3.5.1 Performance Parameters	55
3.5.2 Classification of Pumps	56
3.5.3 Rotary Pumps	59

3.5.4	Reciprocating Pumps	63
3.5.5	Cavitation Problem in Pumps	66
3.5.6	Selection of Pumps	67
3.6	Fluid Lines and Fittings	67
3.6.1	Fluid Lines	68
3.6.2	Connectors and Fittings	71
3.7	Control Valves	73
3.7.1	Directional Control Valves	73
3.7.2	Pressure Control Valves	80
3.7.3	Flow Control Valves	85
3.8	Sealing Devices and Materials	87
3.9	Hydraulic Actuators	89
3.9.1	Cylinders	89
3.9.2	Motors	91
3.10	Reservoirs	92
3.11	Hydraulic Accumulator	93
3.12	Oil Cleanliness	94
3.13	Design of Hydraulic Circuits	95
3.13.1	Meter-in Circuits	96
3.13.2	Meter-out Circuits	96
3.13.3	Bleed-off Circuits	96
3.13.4	Open Center Circuits	97
3.13.5	Closed Center Circuits	97
3.13.6	Accumulator Circuits	97
3.13.7	Sequencing Circuits	98
3.14	Servo Valves	98
3.15	Hand-Operated Hydraulic Pump	100
3.16.	Pump-Driven Hydraulic Pumps	101
3.17,	Variable-Delivery Piston Pumps	104
3.18.	Hydraulic Motors	106
	Summary	107
	Review Questions	107
	Short Answer Type Questions	107
	Objective Type Questions	109

4

PNEUMATIC FLUID POWER SYSTEMS

113-133

4.1	Introduction	113
4.2	Kinetic Theory of Gases	113
4.3	Characteristics of Gases	114
4.4	Gas Laws	114
4.5	Components of a Pneumatic System	115
4.6	Pneumatic Gases	116
4.7	Air Compressors	117
4.8	Contamination Control	119
4.8.1	Air Filters	120
4.8.2	Removal of Moisture	120
4.8.3	Air Dryers	121
4.9	Air Regulators	122

4.10	Lubricators	123
4.11	Modular Unit	123
4.12	Fluidics	124
4.12.1	Bistable Amplifier	125
4.12.2	Proportional Amplifier	125
4.13	Pneumatic Controls	125
4.13.1	Elements of Pneumatic Systems	126
4.14	The Cascade Method	127
4.14.1	Example	127
4.15	Design of Pneumatic Circuits For Sequence Control	130
	Summary	131
	Review Questions	131
	Short Answer Type Questions	132
	Objective Type Questions	132

5 ASSEMBLY AUTOMATION EQUIPMENT 134-205

5.1	Material Handling	134
5.1.1	Principles of Material Handling	135
5.1.2	Material Handling Equipment	136
5.1.3	Wheel Conveyor	137
5.1.4	Gravity Roller Conveyor	138
5.1.5	Powered Roller Conveyor	138
5.1.6	Chain Conveyor	139
5.1.7	Flat Belt Conveyor	139
5.1.8	Magnetic Belt Conveyor	140
5.1.9	Bucket Conveyor	140
5.1.10	Vibrating Conveyor	140
5.1.11	Screw Conveyor	141
5.1.12	Vertical Lift Conveyor	141
5.1.13	Trolley Conveyor	142
5.1.14	Sortation Conveyor: Pop-Up Device	142
5.1.15	Cranes and Hoists	149
5.1.16	Storage Equipment	153
5.1.17	Automatic Storage/Retrieval Systems (AS/RS)	158
5.1.18	Automated Guided Vehicle (AGV)	162
5.2	Assembly Automation Equipment	170
5.2.1	Handling	171
5.3	Feeder Units	173
5.3.1	Feeder Units for Parts with One Arrangement Feature	173
5.3.2	Feeder Units for Parts with Several Arrangement Criteria	178
5.4	Transfer Equipment	182
5.4.1	Cycled Transfer Equipment	182
5.4.2	Cyclic Longitudinal Transfer Equipment	186
5.4.3	Non-cycled Transfer Equipment	189
5.5	Types of Automated Assembly Machines	190
5.5.1	Dial Indexing Machines	191
5.5.2	In-Line Machine	192
5.5.3	Floating Work Platform Machines	192

5.5.4	Continuous-Motion Machines	193
5.6	Design of Assembly Machines	194
5.6.1	Single-station Assembly Machines	194
5.6.2	Multi-station Assembly Machines	194
5.6.3	Combining Assembly Machines to form Assembly Lines	196
5.6.4	Integration of Manual Work Points in Automated Assembly Lines	199
	Summary	202
	Review Questions	203
	Short Answer Type Questions	203
	Objective Type Questions	204

6 ELECTRICAL AND ELECTRONIC CONTROLS 206-233

6.	Control System	206
6.1.1	Open- and Closed-Loop Control.....	206
6.1.2	Applications for Feedback Systems	207
6.1.3	Advantages of Feedback Control	207
6.2	Programmable Logic Controllers (PLC)	208
6.2.1	Discrete Applications	209
6.2.2	Process Control Applications	209
6.2.3	Advanced PLC	209
6.3	Purpose and Orgion of PLC	209
6.4	Architecture of PLC	210
6.4.1	CPU	211
6.5	Ladder Logic	212
6.5.1	Ladder Schematics	212
6.5.2	Ladder Diagrams	213
6.5.3	Basic Input and Output Symbols of a Ladder Diagram	214
6.5.4	Digital Logic Functions	215
6.5.5	Latching	217
6.5.6	Ladder Diagram Rules	218
6.6	Microprocessors	221
6.6.1	Microprocessor Functioning.....	221
6.6.2	Microprocessor Instructions	224
6.7	Integration of Mechanical System with Computer and Electronics Systems: A Mechatronics System	224
6.8	Feedback Devices	225
6.8.1	Linear Variable Differential Transformers (LVDTs)	225
6.8.2	Linear/Rotary Encoders	226
6.8.3	Incremental Rotary Encoders	226
6.8.4	Absolute Encoders	227
6.8.5	Resolvers	228
6.8.6	Potentiometer	229
	Summary	230
	Review Questions	230
	Short Answer Type Questions	231
	Objective Type Questions	232

7.1	What is a Robot?	234
7.1.1	Laws of Robotics	234
7.1.2	Some History	234
7.1.3	Definition of a Robot Revisited	236
7.2	Anatomy of a Robot	236
7.2.1	The Manipulator Linkage	237
7.2.2	Actuators	237
7.2.3	Transmissions	237
7.2.4	Sensors	238
7.2.5	Controller	239
7.2.6	The User Interface	239
7.2.7	The Power Conversion Unit	239
7.3	Robotic Arms	239
7.3.1	Degree of Freedom	239
7.3.2	Joint	240
7.4	Robot Classification	240
7.4.1	Robot Classification Based on Geometry (Basic Configurations)	240
7.4.2	The LERT (Left Right) Classification System	242
7.4.3	Robot Wrist	243
7.5	Robot Control System	243
7.5.1	Path Control System	244
7.5.2	Chain and Linkage Drives	244
7.6	Robot End Effectors	245
7.6.1	Grippers	245
7.6.2	Tools	249
7.7	Robotic Sensors	250
7.7.1	Tactile Sensing	251
7.8	Technical Terms in Robotics	259
7.9	Robot Workspace	260
7.10	Robot Kinematics	261
7.10.1	Matrix Representations	263
7.10.2	Representation of Transformations	264
7.10.3	Links, Joints and Their Parameters	265
7.10.4	The Denavit-Hartenberg Representation	267
7.10.5	Finding Wrist Accessible Position Vector	269
7.10.6	Robot Kinematics Examples	271
7.11	Robot Calibration Techniques	279
7.11.1	Joint Calibration	279
7.11.2	Closed-Loop Calibration	279
7.11.3	Open-Loop Calibration	280
7.12	Computer Aided Robot Control (CARC)	282
7.13	Vocabulary of Important Robotics Terms	284
	Summary	301
	Review Questions	301
	Short Answer Type Questions	304
	Objective Type Questions	305

8 ROBOT APPLICATIONS**307–328**

8.1	Introduction	307
8.2	Current Applications	308
8.2.1	Welding Applications	309
8.3	Robot Material Handling Applications	314
8.3.1	Pick and Place Robot	314
8.3.2	Parts Sorting Operations	315
8.3.3	Palletizing Robot	315
8.3.4	Robot Press Tending	316
8.3.5	Robot Part Transfer	316
8.3.6	Robotic Order Picking	317
8.4	Machine Tool Applications	317
8.4.1	Robotic Grinding	317
8.4.2	Robot Drilling	318
8.4.3	Thermal Spray Application	319
8.4.4	Bonding and Sealing Robots	319
8.4.5	Robotic Painting	320
8.4.6	Robotic Deburring	321
8.5	Robotic Assembly	321
8.6	Robotic Inspection	323
8.7	Other Current and Future Applications	323
8.7.1	Assembly and Disassembly	324
8.7.2	Aerospace Industry	324
8.7.3	Manufacturing	324
8.7.4	Food and Consumer Good Industries	324
8.7.5	Construction	324
8.8	Robot System Integration	325
	Summary	327
	Review Questions	327
	Short Answer Type Questions	327

9 ROBOT PROGRAMMING**329–348**

9.1	Introduction	329
9.2	Programming Techniques	329
9.2.1	On-line Programming	329
9.2.2	Off-line Programming	330
9.3	Programming Methods	330
9.3.1	Lead-through Method (Teach by Showing)	330
9.3.2	Language Based Textual Programming Level	331
9.3.3	Robot-oriented Programming Level	332
9.3.4	Task Level Programming	332
9.4	Robot Program Synthesis	333
9.5	VAL Robot Programming	334
9.5.1	Robot Locations	334
9.5.2	Defining Variables	335
9.5.3	Motion Commands	336
9.5.4	Gripper Commands	337

9.5.5	Speed Command and Command to Operate Sensors	338
9.5.6	Collision Free Programming Commands	338
9.5.7	Operators	339
9.5.8	Edit Commands	339
9.5.9	Programming a Material Handling Robot	340
9.5.10	Welding Instructions	340
9.6	Robot/Machine Vision	341
9.7	Collision Free Motion Planning	345
9.7.1	Potential Field Method of Collision Free Motion Planning	346
	Summary	347
	Review Questions	347
	Short Answer Type Questions	348

10 FUTURE TRENDS IN AUTOMATED SYSTEMS 349–371

10.1	Artificial Intelligence	349
10.1.1	Is AI Possible?	350
10.1.2	Some AI Tasks	351
10.1.3	AI Techniques	351
10.2	Introduction to Neural Networks	352
10.2.1	Definitions	352
10.2.2	Importance of Artificial Neural Networks	353
10.2.3	Goals of Neural Network Research	353
10.2.4	Learning in Neural Networks	353
10.2.5	Some Current Artificial Neural Network Applications	354
10.3	What are Genetic Algorithms?	354
10.3.1	Characteristics of Genetic Algorithms	354
10.3.2	Important Parameters in GAs	355
10.3.3	A Robust Search Technique	355
10.3.4	Use of Genetic Algorithms	356
10.3.5	Genetic Algorithms vs Traditional Algorithm	356
10.3.6	Applications of Genetic Algorithms	356
10.4	Simulation	357
10.4.1	Simulation Example	357
10.4.2	Modeling Concepts	359
10.4.3	Advantages and Disadvantages of Simulation	362
10.4.4	Steps in a Simulation Study	365
10.5	Fuzzy Logic	368
	Summary	370
	Review Questions	370
	Short Answer Type Questions	371

11 FLEXIBLE MANUFACTURING SYSTEMS (FMS) 372–387

11.1	Introduction	372
11.2	Different FMS Levels	373
11.3	Advantages and Disadvantages of FMS Implementation	374
11.3.1	Advantages	374
11.3.2	Disadvantages	374

11.4	Flexibility	374
11.4.1	Definition	375
11.4.2	Classification of Flexibility	376
11.5	Automated Guided Vehicle Systems	379
11.5.1	Introduction	379
11.5.2	AGVS Controller Structure	380
11.5.3	AGVS Classification	383
	Summary	386
	Review Questions	387
	Short Answer Type Questions	387

MODEL QUESTION PAPERS**389-394****INDEX****395-398**