

According to New Revised Credit System Syllabus

SPPU

Third Year Degree Course In  
ELECTRONICS & TELECOMMUNICATION ENGG. (Sem - I)

# MECHATRONICS

## Includes

- Model Question Papers For Practice  
(In Sem-30 Marks & End Sem- 70 Marks)



Dr. R. C. JAISWAL  
Dr. Y. S. ANGAL

[www.pragationline.com](http://www.pragationline.com)

 [www.facebook.com/niralibooks](https://www.facebook.com/niralibooks)

 **NIRALI**  
PRAKASHAN  
ADVANCEMENT OF KNOWLEDGE

A TEXT BOOK OF  
**MECHATRONICS**

FOR  
SEMESTER – I  
THIRD YEAR DEGREE COURSE IN  
ELECTRONICS & TELECOMMUNICATION ENGINEERING

Strictly According to New Revised Credit System Syllabus  
of Savitribai Phule Pune University  
(w.e.f. June 2017)

**Dr. R. C. JAISWAL**

ME Ph.D,  
Associate Professor,  
Electronics & Telecom. Dept.  
Pune Institute of Technology, (PICT)  
Dhankawadi, Pune.

**Dr. Y. S. ANGAL**

ME Ph.D,  
Dean Academics & Head,  
Electronics & Telecom. Dept.  
JSPM's Bhivarabai Sawant  
Institute of Technology & Research  
Wagholi, Pune.

**Price ₹ 300.00**

 **NIRALI**<sup>®</sup>  
**PRAKASHAN**  
ADVANCEMENT OF KNOWLEDGE

**N 4185**

**First Edition : July 2017****© : Authors**

The text of this publication, or any part thereof, should not be reproduced or transmitted in any form or stored in any computer storage system or device for distribution including photocopy, recording, taping or information retrieval system or reproduced on any disc, tape, perforated media or other information storage device etc., without the written permission of Authors with whom the rights are reserved. Breach of this condition is liable for legal action.

Every effort has been made to avoid errors or omissions in this publication. In spite of this, errors may have crept in. Any mistake, error or discrepancy so noted and shall be brought to our notice shall be taken care of in the next edition. It is notified that neither the publisher nor the authors or seller shall be responsible for any damage or loss of action to any one, of any kind, in any manner, therefrom.

**Published By :****NIRALI PRAKASHAN**

Abhyudaya Pragati, 1312, Shivaji Nagar,  
Off J.M. Road, Pune – 411005  
Tel - (020) 25512336/37/39, Fax - (020) 25511379  
Email : niralipune@pragationline.com

**Polyplate****Printed By :****YOGIRAJ PRINTERS AND BINDERS**

Survey No. 10/1A, Ghule Industrial Estate  
Nanded Gaon Road  
Nanded, Pune - 411041  
Mobile No. 9404233041/9850046517

**DISTRIBUTION CENTRES****PUNE**

**Nirali Prakashan** : 119, Budhwar Peth, Jogeshwari Mandir Lane, Pune 411002, Maharashtra  
Tel : (020) 2445 2044, 66022708, Fax : (020) 2445 1538

Email : bookorder@pragationline.com, niralilocal@pragationline.com

**Nirali Prakashan** : S. No. 28/27, Dhyari, Near Pari Company, Pune 411041

Tel : (020) 24690204 Fax : (020) 24690316

Email : dhyari@pragationline.com, bookorder@pragationline.com

**MUMBAI**

**Nirali Prakashan** : 385, S.V.P. Road, Rasdhara Co-op. Hsg. Society Ltd.,  
Girgaum, Mumbai 400004, Maharashtra

Tel : (022) 2385 6339 / 2386 9976, Fax : (022) 2386 9976

Email : niralimumbai@pragationline.com

**DISTRIBUTION BRANCHES****JALGAON**

**Nirali Prakashan** : 34, V. V. Golani Market, Navi Peth, Jalgaon 425001,  
Maharashtra, Tel : (0257) 222 0395, Mob : 94234 91860

**KOLHAPUR**

**Nirali Prakashan** : New Mahadvar Road, Kedar Plaza, 1<sup>st</sup> Floor Opp. IDBI Bank  
Kolhapur 416 012, Maharashtra. Mob : 9850046155

**NAGPUR**

**Pratibha Book Distributors:** Above Maratha Mandir, Shop No. 3, First Floor,  
Rani Jhanshi Square, Sitabuldi, Nagpur 440012, Maharashtra  
Tel : (0712) 254 7129

**DELHI**

**Nirali Prakashan** : 4593/21, Basement, Aggarwal Lane 15, Ansari Road, Daryaganj  
Near Times of India Building, New Delhi 110002  
Mob : 08505972553

**BENGALURU**

**Pragati Book House** : House No. 1, Sanjeevappa Lane, Avenue Road Cross,  
Opp. Rice Church, Bengaluru – 560002.  
Tel : (080) 64513344, 64513355, Mob : 9880582331, 9845021552  
Email: bharatsavla@yahoo.com

**CHENNAI**

**Pragati Books** : 9/1, Montieth Road, Behind Taas Mahal, Egmore,  
Chennai 600008 Tamil Nadu, Tel : (044) 6518 3535,  
Mob : 94440 01782 / 98450 21552 / 98805 82331,  
Email : bharatsavla@yahoo.com

[niralipune@pragationline.com](mailto:niralipune@pragationline.com) | [www.pragationline.com](http://www.pragationline.com)

Also find us on  [www.facebook.com/niralibooks](http://www.facebook.com/niralibooks)

**Dedicated to**

**Shri Sant Sadguru Gajanan Maharaj,  
Shegaon**



## ACKNOWLEDGEMENTS

All praise, land and honour to “Lord Shree Ganesha”, and our “Gurudevas” and grace and inspirations.

We would like to express our sincere thanks to **Management & Dr. P. T. Kulkarni** (Principal PICT, Pune) and **Dr. T. K. Nagaraj** (Principal, BSIOTR Wagholi, Pune) for their untiring support in our work.

Our special thanks to **Prof. Vijay S. Sawant** and **Dr. S. N. Patil** (Campus Director, BSIOTR Wagholi Pune) for their constant support and encouragement to write a book.

We would like to thank all faculty of Savitribai Phule Pune University, who provided us valuable suggestions throughout the preparation of the book.

Blessings of our **Parents** and **Relatives** helped us to complete the book in time frame.

During the course of writing this book, we were cherished by love of our kids Rucha Jaiswal, Parimal Jaiswal, Mugdha Angal and Ajinkya Angal.

We will be missing if we don't thank our wife namely Mrs. Gauri Jaiswal and Mrs. Preeti Angal whose moral support and wishes have gone a long way in making of this book.

We also take this opportunity to express our sincere thanks to Shri. Dineshbhai Furia, Shri. Jignesh Furia, Mrs. Nirali Verma, Shri. M. P. Munde and entire team of Nirali Prakashan namely Mrs. Deepali Lachake (Co-ordinator), Mrs. Shilpa Kale, Miss. Sneha Patil, who really have taken keen interest and untiring efforts in publishing this text.

Constructive criticisms for improvement of this book are welcome.

**3 July 2017**

**Pune**

**Authors**



## PREFACE

It gives us great pleasure to present the book '**Mechatronics**' for the students of Third Year Degree Course in Electronics & Telecommunication Engineering of the Savitribai Phule Pune University. This book is strictly as per the new revised syllabus 2015 Pattern with effect from the Academic Year (2017-18).

As per New Revised Examination Scheme which has been implemented from this academic year, In-semester assessment carries 30 marks over first three units and End Semester Examination carries 70 marks over entire syllabus out of which first three units will carry 20 marks and units 4, 5, 6 will carry 50 marks. The theory course will have 4 credits.

The book is written such that all the basic concepts are explained in simplified manner. It is presented in a more conceptual manner rather than mathematical, as required by the new examination system. It is our objective to keep the presentation systematic, consistent, intensive and clear through explanatory notes and figures. Main feature of this book is, **Complete Coverage** of the New Credit System Syllabus with large number of Worked Solved Examples, Exercises, **Model Question Papers of In Sem.** and **End Sem. Exams.**

**Mechatronics** is a concept of Japanese origin was first introduced during early 1960's to qualify the dual alliance of electronics and computer technology to practical applications in mechanical systems. The Japanese were quick to exploit the advantages of this integrated technology through their consumer products while other are yet adopting this concept to realize its benefits.

**Mechatronics** aims at lending better value to products and systems. The combination of mechanical, electronics and information engineering is optimized to take full advantage of ability of microelectronics to reduce the demand on mechanical systems of product.

The integration of various theories, principles techniques, methodolocs and standards to cater to the pressing needs have long been emerging as new disciplines.

In future, the subject **Mechatronics** is likely to find a place in the curriculum of many engineering disciplines.

This book consists of 6 Units and each unit includes Learning Objectives and Exercises in detail.

The topics of each unit then divided into labeled sections containing explanation, illustrations examples and, where appropriate, practical applications are also given. A wide variety of problems with step by step solutions are also included. Each unit ends with subjective type of questions and exercises.

**Unit I :** The broad knowledge accommodating the Principle of Mechatronics has been described logistically, so that the readers can grasp the essence of the topics. Real Life Examples are also discussed with a Case Study in brief. This unit gives significance / importance of the subject.

**Unit II :** It deals with Basic Transduction Principle of Transducers. Selection Criterion of Transducers / Sensors are discussed. This unit also deals with Characteristics and Applications of Various Transducers like Pressure, Flow, Motion, Temperature etc. Introduction to Smart Sensors and MEM'S is also given in this Unit.

**Unit III :** It is concerned with principles of Fluid Power Systems comprising especially Hydraulic Systems / Hydraulic Fluid Power Systems.

**Unit IV :** Gives introduction to Pneumatic Systems with Pneumatic Actuator Physical Components of Pneumatic Circuits are discussed in this Unit. At the end Case Study with Robotic Pick and Place Robot is explained.

**Unit V :** Selection and Specifications of Stepper Motors is explained in this unit. Electrical Actuators like Solenoid Valves, Electromechanical Relays.

**Unit VI :** Gives Role of Mechatronics in Automobile Industry. It also presents design approach and a collection of Case Studies of Mechatronics. Examples of Auto Pilot System, Car Parking System Engine Management System, High Speed Tilting Train, Anti Locks Brake Systems (ABS), CNC Machines are discussed here.

The books is written in a very user friendly language. We are confident that this book will be appreciated by the students and they will secure great success in this subject.

**We are sure that this book will cater to all needs of students for this subject.**

However, we will be highly obliged if the students and teachers, criticize or to bring to our notice any misprints, corrections, additions etc. necessary for improvement in this book.

**Pune**

**Authors**

# SYLLABUS

## Unit I : Introduction to Mechatronics

(6 Hrs)

**Basics of Mechatronics Systems :** Definition of Mechatronics, Key elements of Mechatronics Systems, Levels of mechatronics systems, Measurement Characteristics, Examples of Mechatronics systems in daily life as, Washing Machines, Digital Cameras, CD Players, camcorders, Mechatronics design process, phases of mechatronics design process, integrated design approach.

**Mechanical Components and Servo Mechanism :** Mechanical System and Motion, Mass Inertia and Dashpot, Gears, types of Gears, Servomechanism(Concepts and Theory, Problems). Case study Mechatronics Design of Coin Counter/Coin Separator

## Unit II : Overview of Sensors, Transducers and their Characteristics Specifications

(8 Hrs)

Specifications related to selection criterion for force, pressure, temperature and motion (Rotary and Linear). Classification and selection of transducers:

**Force:** Load Cell, Cantilever Beam (Design aspect example).

**Pressure:** Strain Gauge, Piezoelectric.

**Motion:** Rotary and Linear motions, Proximity sensors Inductive, Capacitive and Magnetic, sources detectors in optical proximity sensors. Comparison of Various proximity sensors.

**Temperature:** Optical Fibre and its use in temperature measurement, Fibre Optic Temperature sensors, Ultrasonic Transducers for applications as position, level, flow measurement. Gas sensors, Wind sensors: Gyroscope, Accelerometer, Magnetometer (As used in smart phones)

**Smart Sensors:** Concept, Radiation Sensors - Smart Sensors - Film sensor, IR- temperature sensors Introduction to MEMS & Nano Sensors . Rotary Optical Encoder

## Unit III : Hydraulic Systems

(6 Hrs)

**Introduction to Hydraulic Actuators, Fluid Power Systems:** Concept of Actuators, Classification of Actuators: Pneumatic, Hydraulic and Electrical Actuators, Fluid Power systems

**Hydraulic Systems:** Physical Components of a Hydraulic systems, Hydraulic Pumps (e.g. Gear Pumps, Vane Pumps, Piston Pumps and Axial Piston Pumps), Filters and Pressure Regulation, Relief Valve, Accumulator.

## Unit IV : Pneumatic Systems

(6 hrs)

Introduction to Pneumatic a Actuators Physical Components of a Pneumatic Systems, Pneumatic Cylinders, Pneumatic Actuators (e.g. Spring Actuator and Spring Actuator with positioner), Air compressor, Air Receiver, Air Dryer Air Service Treatment: Air Filter, air regulator and Gauge, Air Lubricator and Pressure regulation Intake and Air Filter. Case study of Robotic Pick and Place robot

## Unit V : Electrical Actuators, Electron-Mechanical Actuators

(6 Hrs)

**Electrical-Actuation System:** Selection criteria and specifications of stepper motors, solenoid valves, relays (Solid State relays and Electromechanical relays). Selection Criterion of control valve, Single acting and Double acting Cylinders. Electro-Pneumatic: Pneumatic Motors, Valves: Electro Hydraulic: 3/2 Valves, 4/2 Valves, 5/3 Valves Cables: Power cable and Signal cables

## Unit VI : Mechatronics Systems in Automobile

(6 Hrs)

(Treatment with Block Diagram Approach) Boat Autopilot, High Speed tilting trains, Automatic car parking systems, Engine Management systems, Antilock Brake systems (ABS), CNC Machines(Only Block Diagram and explanation)

# CONTENTS

<b>Unit I : Introduction to Mechatronics</b>	<b>1.1-1.66</b>
1.1 Basics of Mechatronics Systems	1.1
1.1.1 Definitions of Mechatronics	1.1
1.2 Key Elements of Mechatronics System	1.1
1.3 Levels of Mechatronics System	1.4
1.4 Mechatronics Design (Conventional and Integrated Approach)	1.5
1.5 Mechatronics Design Process	1.7
1.6 System	1.8
1.7 Measurement Systems	1.9
1.8 Measurement Characteristics	1.10
1.9 Mechatronics Systems in Daily Life	1.15
1.10 Washing Machine System	1.16
1.11 Automatic Camera System	1.21
1.12 Camcorder Control System	1.24
1.12.1 Lens	1.25
1.12.2 Imager	1.25
1.12.3 Recorder	1.26
1.12.4 Analog vs Digital	1.26
1.13 Audio CD Player Control System	1.30
1.13.1 Specifications of Typical CD Player	1.31
1.13.2 Optical Playback from Optical Disc [CD Reading/CD Playback]	1.32
1.14 Mechanical Components and Servo Mechanisms	1.34
1.15 Types of Systems and System Modelling	1.34
1.15.1 Translational System Modelling	1.35
1.15.2 Rotational System Modelling	1.36
1.15.3 Electrical System Modelling	1.38
1.15.4 Example of Building Mechanical System (Translational)	1.38
1.15.5 Examples of Building Mechanical System (Rotational)	1.39
1.15.6 Examples of Building Electrical System	1.40
1.16 Gears and Gear Trains	1.42
1.16.1 Types of Gears	1.43
1.16.2 Terminology Used in Gears (Gear Nomenclature)	1.46
1.16.3 Gear Trains	1.47
1.17 Servomechanisms	1.48
1.17.1 The Servomechanism System	1.50
1.17.2 A Practical Servo Example	1.51

1.17.3	Working Principle of Servo Motor	1.52
1.17.4	Servo Motor Control	1.53
1.17.5	Continuous Rotation Servo Motors	1.55
1.18	Case Study of Mechatronics (Design of a Coin Counter/Coin Separator)	1.56
•	Case Study	1.57
•	Learning Objectives Covered	1.66
•	Exercise	1.66

**Unit II : Overview of Sensors, Transducers and Their Characteristics Specifications 2.1-2.140**

2.1	Introduction to Sensors and Transducers	2.1
2.2	Sensors Classification / Transducers Classification	2.4
2.3	Transducers / Sensors Selection Criteria	2.6
2.4	Typical Characteristics / Specifications of Sensors / Transducers	2.7
2.5	Transducers in Details	2.7
2.6	Force Transducers	2.7
2.7	Load Cell	2.8
2.7.1	Strain Gauge	2.8
2.7.2	Strain-Gauge Load Cells	2.12
2.7.3	Strain Gauge Basics	2.14
2.7.4	Types of Commercial Strain Gauge Load Cells	2.16
2.7.5	The Simple Cantilever Beam Design Considerations	2.17
2.7.6	Load Cell Performance Comparison	2.18
2.7.7	Typical Load Cells Specifications	2.20
2.8	Pressure Transducers	2.21
2.8.1	Types of Pressure Measurements	2.23
2.8.2	Pressure-Sensing Technology	2.23
2.9	Strain Gauge Pressure Transducers	2.25
2.9.1	Wire Gauges	2.26
2.9.2	Foil Gauges	2.29
2.9.3	Thin Film Gauges	2.30
2.10	Strain Gauge Measuring Circuits	2.31
2.10.1	Quarter Bridge Configuration	2.31
2.10.2	Quarter-Bridge Circuit	2.33
2.10.3	Half-Bridge Circuit	2.33
2.10.4	Full-Bridge Circuit	2.34
2.10.5	Temperature Compensation	2.34
2.11	Piezoelectric Pressure Transducers	2.36
2.12	Force-Summing Devices for Pressure Measurement	2.41
2.13	Pressure Measurement Methods	2.44

2.14	Motion/Displacement Transducers	2.45
2.14.1	Linear Potentiometer Transducers	2.46
2.14.2	Linear Motion Variable Inductance Transducers	2.47
2.14.3	Proximity Inductance Transducers	2.48
2.14.4	Capacitive Displacement/Motion Transducers	2.50
2.14.5	Linear Voltage Differential Transformer (LVDT)	2.52
2.15	Rotary Motion Transducers	2.54
2.16	Self-Generating Rotary Motion Transducers	2.54
2.17	Non Self-Generating Type (Variable Inductance Type) Rotary Motion Transducers	2.55
2.18	Non Self-Generating Type (Rotary Variable Differential Transformer)	2.56
2.19	Digital Rotary Transducers	2.58
2.19.1	Tachometer Encoder	2.58
2.19.2	Incremental Encoder	2.59
2.19.3	Absolute Encoder	2.60
2.19.4	Rotary Encoder	2.61
2.19.5	Linear Encoder	2.62
2.20	Proximity Sensors	2.63
2.20.1	Inductive Proximity Sensors	2.64
2.20.2	Capacitive Proximity Sensors	2.66
2.20.3	Photoelectric Proximity Sensors	2.67
2.20.4	Through-Beam Proximity Sensors	2.68
2.20.5	Retro-Reflective Proximity Sensors	2.69
2.20.6	Diffuse Proximity Sensors	2.69
2.20.7	Ultrasonic Proximity Sensors	2.71
2.20.8	Comparison of Proximity Sensors	2.72
2.20.9	Applications of Proximity Sensors	2.73
2.21	Temperature Sensors	2.73
2.22	Resistance Temperature Detector (RTD)	2.74
2.23	Thermocouple	2.77
2.24	Thermistor	2.83
2.25	Optical Pyrometer for Temperature Measurement	2.85
2.26	Optical Fiber For Temperature Measurement	2.86
2.26.1	Temperature Measurement with Fiber-Optics and GaAs Semiconductor	2.88
2.26.2	Temperature Measurement with Fiber Bragg Gratings (FBG)	2.91

2.27	Ultrasonic Transducers For Position Measurement	2.93
2.27.1	Ultrasonic Distance Measurement System	2.94
2.27.2	Ultrasonic Linear Position Sensors and Switches Information	2.96
2.28	Ultrasonic Level Transducers	2.97
2.29	Ultrasonic Flow Transducers	2.99
2.29.1	The Doppler Effect Ultrasonic Flow Meter	2.99
2.29.2	The Time of Flight Ultrasonic Flow Meter	2.101
2.30	Gas Sensors	2.102
2.30.1	Catalytic Gas Detector	2.103
2.30.2	Infrared Gas Sensors	2.104
2.30.3	Electrochemical-Type Gas Sensors	2.104
2.30.4	Semiconductor Gas Detector	2.105
2.31	Wind Sensors	2.106
2.32	Anemometer	2.106
2.33	Gyroscope	2.108
2.34	Accelerometer	2.110
2.34.1	Types of Accelerometer	2.111
2.34.2	What is Acceleration?	2.111
2.34.3	Piezoelectric Accelerometer	2.112
2.35	Magnetometer	2.115
2.35.1	Types of Magnetometers	2.117
2.35.2	Coil Magnetometer	2.117
2.35.3	Applications of Magnetometer	2.118
2.36	Smart Sensors	2.118
2.37	Radiation Sensors	2.121
2.37.1	Scintillation Detector	2.121
2.37.2	Gas Filled Detector	2.122
2.38	Film Sensors	2.123
2.39	IR Temperature Sensors	2.127
2.40	MEMS Sensors	2.128
2.40.1	MEMS Accelerometer	2.130
2.41	Nano Sensors	2.133
•	Learning Objectives Covered	2.138
•	Exercise	2.138

### **Unit III : Hydraulic Systems**

**3.1-3.20**

#### **Fluid Power Systems**

3.1	Concept of Actuators	3.1
3.2	Classification of Actuators	3.2
3.3	Fluid Power System (Hydraulic & Pneumatic) Usage	3.3
3.4	Hydraulic Actuator Systems	3.4

## Hydraulic Systems

3.5	Physical Components of a Hydraulic System	3.6
3.6	Hydraulic Pumps and Pressure Regulation	3.8
3.7	Filters Used in Hydraulic System	3.13
3.8	Pressure Regulation System	3.14
3.9	Relief Valve System	3.14
3.10	Accumulator System	3.15
3.11	Hydraulic Systems and Fluid Selection	3.16
3.11.1	What is a Hydraulic System?	3.16
3.11.2	Hydraulic Fluids	3.17
3.11.3	Fluid Properties	3.18
3.11.4	Consolidating Hydraulic Fluids	3.19
•	Learning Objectives Covered	3.19
•	Exercise	3.20

## Unit IV : Pneumatic Systems 4.1-4.36

4.1	Introduction to Pneumatic System	4.1
4.2	Physical Components of Pneumatic System	4.4
4.3	Signal Flow in Pneumatic System	4.5
4.4	Pneumatic Cylinders/Pneumatic Actuators	4.6
4.5	Types of Pneumatic Cylinders	4.7
4.5.1	Single-Acting Cylinders (Spring Actuator)	4.8
4.5.2	Double-Acting Cylinders	4.9
4.5.3	Multi-Stage, Telescoping Cylinder	4.10
4.5.4	Other Types	4.10
4.5.5	Rodless Cylinders	4.11
4.5.6	Spring Actuator with Positioners	4.11
4.6	Air Compressors	4.13
4.6.1	Blower (Centrifugal Type) (Dynamic Compressors)	4.14
4.6.2	Screw Compressor	4.15
4.7	Air Receiver or Receiver Tank	4.16
4.8	Air Treatment Stages	4.16
4.9	Air Pressure Gauge	4.26
4.10	Pick N Place Robot	4.28
4.11	Pneumatic, Hydraulic and Electrical Systems (Why to use Pneumatics)	4.33
•	Learning Objectives Covered	4.35
•	Exercise	4.35

## Unit V : Electrical Actuators, Electro-Mechanical Actuators 5.1 – 5.50

5.0	Introduction to Electric Actuators	5.1
5.1	Main Components of an Electric Actuator	5.1
5.2	Advantages & Disadvantages of Electric Actuator	5.2
5.3	Solenoids and Relays	5.2
5.3.1	Selection Considerations of Solenoid, Relay and Contactors	5.4
5.4	Types of Motors	5.5

# Mechatronics



60%  
OFF

Publisher : **Nirali Prakashan**

ISBN : 9789386700094

Author : **Dr. R. C. Jaiswal,**  
**Dr. Y. S. Angal**

Type the URL : <http://www.kopykitab.com/product/20811>



Get this eBook