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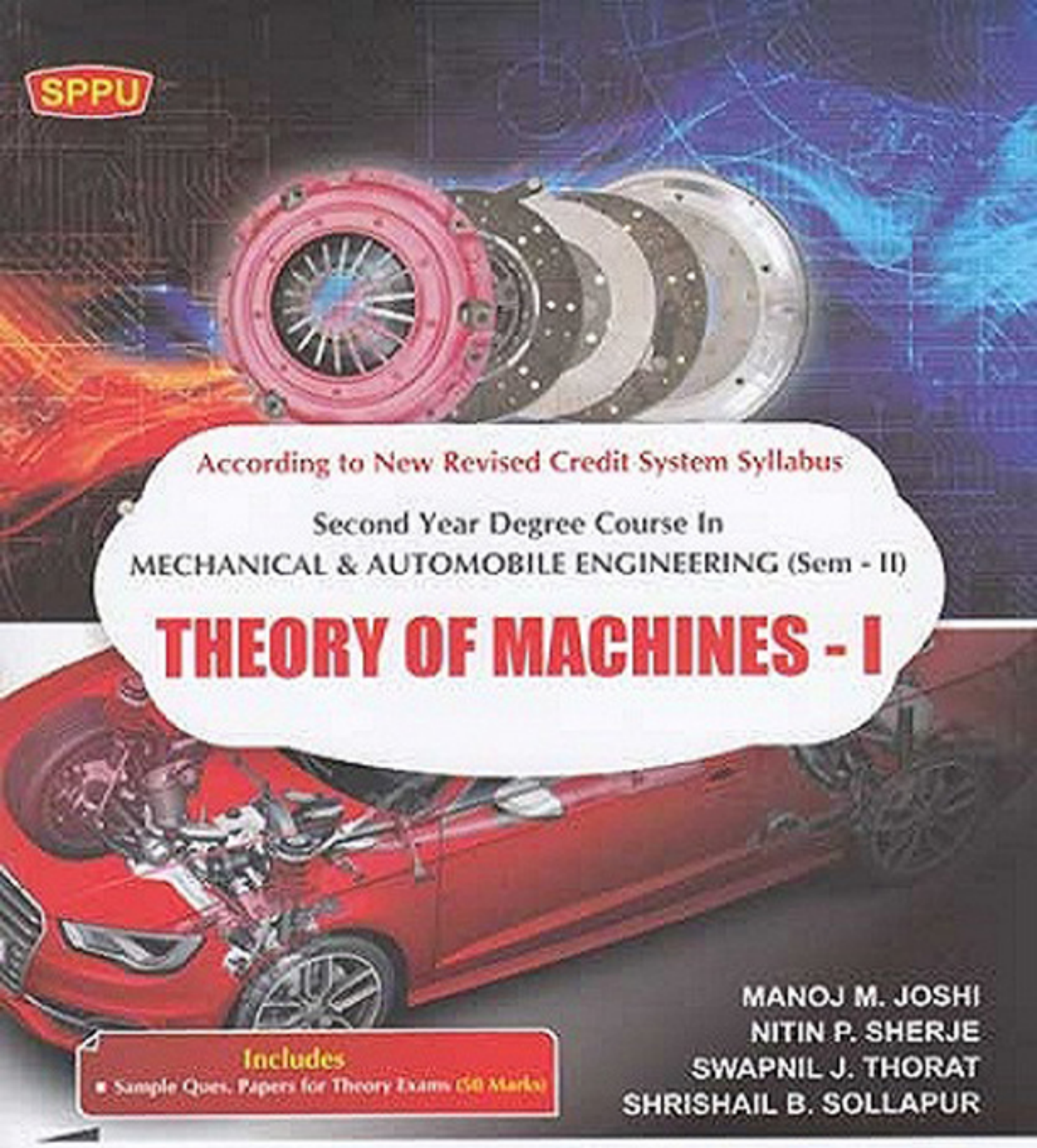

According to New Revised Credit System Syllabus

Second Year Degree Course In

MECHANICAL & AUTOMOBILE ENGINEERING (Sem - II)

THEORY OF MACHINES - I

Includes

- Sample Ques. Papers for Theory Exam (50 Marks)

MANOJ M. JOSHI
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NIRALI PRAKASHAN
ADVANCEMENT OF KNOWLEDGE

A TEXT BOOK OF

THEORY OF MACHINES - I

FOR

SEMESTER – II

SECOND YEAR DEGREE COURSE IN MECHANICAL AND AUTOMOBILE ENGINEERING

Strictly According to New Revised Credit System Syllabus of Savitribai Phule Pune University

(w.e.f June 2016)

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PREFACE

It gives us great pleasure in publishing this text book on "**Theory of Machines - I**" for the students of Second Year Degree Course in Mechanical and Automobile Engineering. This book is strictly written according to **New Revised Credit System Syllabus** of Savitribai Phule Pune University (2015 Pattern).

As per the policy of the University, Engineering Syllabi is revised every five years. Last revision was in the year 2012. New revision is coming little earlier, as university has introduced **Online System of Examination** from year 2012.

As per the **New Credit System**, the **Online Examinations** Phase-I will be conducted based on First & Second Units and Phase II on Third & Fourth Units. The **Online** examinations will have objective types of questions with multiple choices. End Sem. Theory Examination will be based on all the six units and that will be conducted in traditional way and the Theory Course will have 4 credits.

This text book covers the following objectives :

Unit I : It covers fundamentals related to machine, mechanism, kinematic chain, basics of theory of machines, various rules pertaining to mechanisms, straight line mechanism, Grashob's law, steering gear mechanisms in a simple and lucid manner.

Unit II : It covers static and dynamic force analysis of IC engines and introduction to friction.

Unit III : It covers the theories like uniform pressure and uniform wear theory applied to friction clutches viz. single plate, multiplate, conical clutches and centrifugal clutches. Further the analysis of different types of brakes like shoe, band, band and block, internal expanding shoe brake and various transmission and absorption dynomometers is discussed at length.

Unit IV : It covers kinematic analysis of slider crank mechanism and four bar chain mechanism. Methods of analysis are analytical, complex algebra and vector algebra method. Analysis of Hooke's joint is also dealt with at the end.

Unit V : It covers velocity and acceleration analysis using graphical methods viz. relative velocity method, instantaneous centre method of rotation (ICR), relative acceleration method.

Unit VI : It covers problems related to Corioli's component of acceleration and graphical method of kinematic analysis of slider chain mechansism using Klein's construction.

Main feature of this book is, **Complete Coverage** of the New Credit System Syllabus with large number of **Worked (Solved) Examples, Exercise and University Question Papers.**

We have given Separate Book of Multiple Choice Questions (MCQ's) which will be very useful to the students especially for Online Examinations.

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

The advice and suggestions of our esteemed readers to improve the text are most welcomed, and will be highly appreciated.

Pune **Authors**

SYLLABUS

Unit I Fundamentals of Kinematics and Mechanisms (10 Hrs)

Kinematic link, Types of links, Kinematic pair, Types of constrained motions, Types of Kinematic pairs, Kinematic chain, Types of joints, Mechanism, Machine, Degree of freedom (Mobility),Kutzbach crieterion, Grubler's criterion. Four bar chain and its inversions, Grashoff's law, Slider crank chain and its inversions, Double slider crank chain and its inversions. Straight line mechanisms such as: Peaucellier Mechanism, Scott Russell Mechanism, Grasshopper Mechanism, watt mechanism. Equivalent linkage of mechanisms., Steering gear mechanisms: Condition for correct steering, Davis steering gear mechanism, Ackermann steering gear mechanism.

Unit II: Static and Dynamic Force Analysis (8Hrs)

Theory and analysis of Compound Pendulum, Concept of equivalent length of simple pendulum, Bifilar suspension, Trifilar suspension.

Dynamics of reciprocating engines: Two mass statically and dynamically equivalent system, correction couple, static and dynamic force analysis of reciprocating engine mechanism (analytical method only), Crank shaft torque, Introduction to T-θ diagram.

Friction: Friction in turning pair, friction circle, friction axis, friction in slider crank mechanism.

Unit III: Friction Clutches, Brakes and Dynamometer (8 Hrs.)

Pivot and collar friction, Classification of Clutches, torque transmitting capacity of - plate clutch, cone clutch and centrifugal clutch, Classification of brakes, braking torque of - shoe brakes, internal shoe brake, disc brake, brake power of absorption and transmission type dynamometers – prony brake, rope brake, belt transmission, epicyclic train and Bevis-Gibson torsion

Unit IV: Kinematic Analysis of Mechanisms: Analytical Method (8 Hrs)

Analytical method for displacement, velocity and acceleration analysis of slider crank Mechanism.

Position analysis of links with vector and complex algebra methods, Loop closure equation, Chase solution, Velocity and acceleration analysis of four bar and slider crank mechanisms using vector and complex algebra methods.

Hooke's joint, Double Hooke's joint.

Unit V: Velocity and Acceleration Analysis of Simple Mechanisms: Graphical Methods-I

Relative velocity method: Relative velocity of a point on a link, Angular velocity of a link, Sliding velocity, Velocity polygons for simple mechanisms.

Relative acceleration method: Relative acceleration of a point on a link, Angular acceleration of a link, Acceleration polygons for simple mechanisms.

(limit to only 4 link mechanisms)

Instantaneous center of rotation (ICR) method: Definition of ICR, Types of ICRs, Methods of locating

ICRs (limit to only 6 link mechanisms), Kennedy's Theorem, Body and space centrode.

Unit VI: Velocity and Acceleration Analysis of Mechanisms: Graphical Methods-II (8 Hrs)

Velocity and acceleration diagrams for the mechanisms involving Coriolis component of acceleration.

(limit to only 4 link mechanisms) Klein's construction.

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Unit I

FUNDAMENTALS OF KINEMATICS AND MECHANISMS

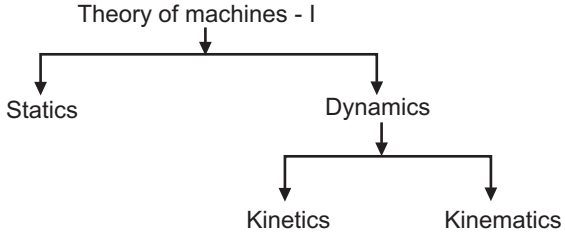
1.1 INTRODUCTION

Machine : A device which receives energy in some available form and uses it to do some particular kind of work. For example, a lathe receives electrical energy from the belt and uses that energy to do machining work.

Mechanism : If a number of bodies are assembled in such a way that the motion of one causes **constrained** and **predictable** motion to the others, it is known as a mechanism.

Difference between a Machine and Mechanism : A machine is a mechanism or combination of mechanisms. Machine is involved in transmitting and modifying the available mechanical energy into some kind of desired work.

Theory of machines is an **applied science** compressing of the study of the relative **motion** between the parts of machine and the study of **forces** which act on these parts.



(a) Statics : This branch of theory of machines deals with the forces and their effects while the machine parts are at rest. Mass of parts is assumed to be negligible.

(b) Dynamics : It deals with the forces and their effects while acting upon the machine parts in motion.

Kinetics : It deals with the inertia forces which arise from the combined effect of mass and motion of the machine parts.

Kinematics : It deals with the relative motion between the various parts of the machines.

Study of a mechanism involves its **analysis** as well as **synthesis**.

Analysis is the study of motions and forces concerning different parts of an existing mechanism, whereas synthesis involves the design of its different parts.

1.2 KINEMATIC LINK OR ELEMENT (Dec. 10, 13; May 11, 13)

Rigid and Resistant Bodies : A body is said to be rigid if under the action of forces, it does not suffer any distortion or the distance between any two points on it remains constant.

Resistant body is the one which is capable of transmitting the required motion and the forces with negligible deformation.

For example :

- Belt is rigid when subjected to tension and undergoes negligible deformation. Hence, belt drives act as resistance bodies.
- Fluids used in hydraulic presses are referred as resistant bodies.
- Springs used in watches are also resistant bodies.

Each part of a machine or assembly of resistant bodies (a resistant body), which moves relative to some other part, is known as a **kinematic link or element.**

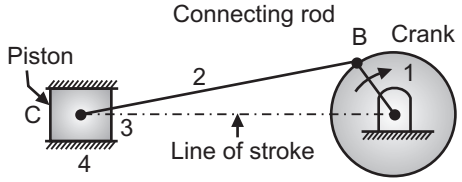
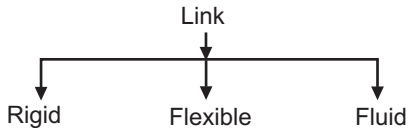


Fig. 1.1 : Slider crank mechanism

In Fig. 1.1, crank, crankshaft and flywheel – link 1 connecting rod with big and small end bearing – link 2 piston, piston rod and crosshead – link 3. Cylinder, engine frame and main bearings – link 4.

1.2.1 Types of Links

(A) For transmitting motion, the driver and follower may be connected by the following three types of links.



Rigid Link : As the deformation of a connecting rod, crank, piston are not applicable, they can be considered as rigid links.

Flexible Link : It is partly deformed in a manner not to affect the transmission of motion.

For example, belts, ropes, chains, springs and wires are flexible links and transmit tensile forces only.

Fluid Link : Motion is transmitted through the fluid by pressure or compression only. e.g. hydraulic presses, jack and brakes.

(B) Link can be classified into binary, ternary and quaternary depending upon their ends on which revolute or turning pairs can be placed. Refer Fig. 1.2.

Fig. 1.2 (a) : Types of rigid links

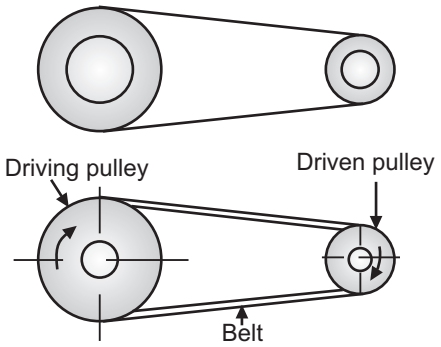
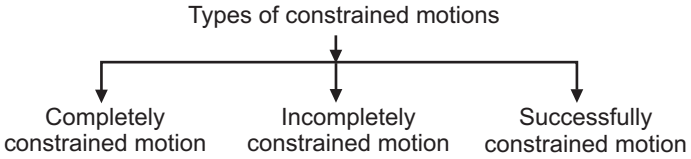


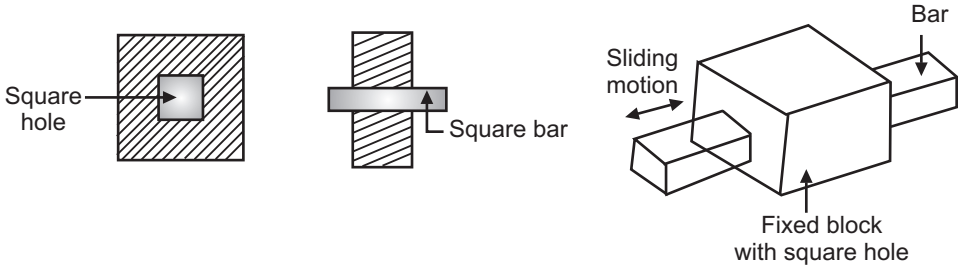
Fig. 1.2 (b) : Types of links

1.3 KINEMATIC PAIR

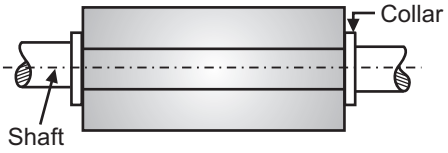
Before defining kinetic pair, it would be apt to know what are types of constrained motion.



(i) Completely Constrained Motion :



(a) Square bar in a square hole



(b) Shaft with collars in a round hole

Fig 1.3

This motion is in a definite direction. For example : a square bar moving in a square hole [Fig. 1.3 (a)] and a shaft with collars at its ends moving in a round hole [Fig. 1.3 (b)]. In both the above cases, the square bar can have only reciprocating motion and cannot have rotary motion. Also, the shaft can only rotate but cannot reciprocate due to provision of collars.

(ii) Incompletely Constrained Motion :

This type of motion takes place in more than one direction.

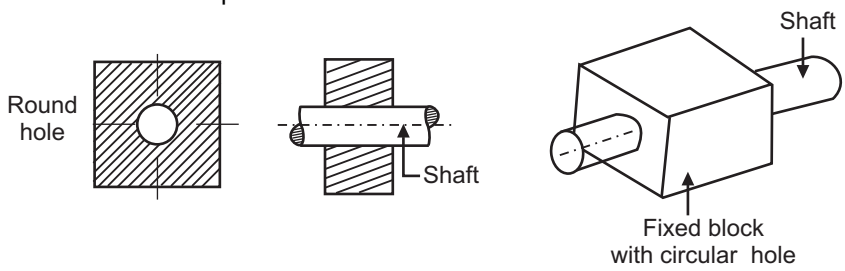


Fig. 1.3 (c) : Motion of a shaft in a circular hole

Example : A circular shaft moving in a circular hole may have two types of motions (a) Rotary and (b) Reciprocating. Both the motions are independent of each other. So the motion is incompletely constrained.

(iii) Successfully Constrained Motion :

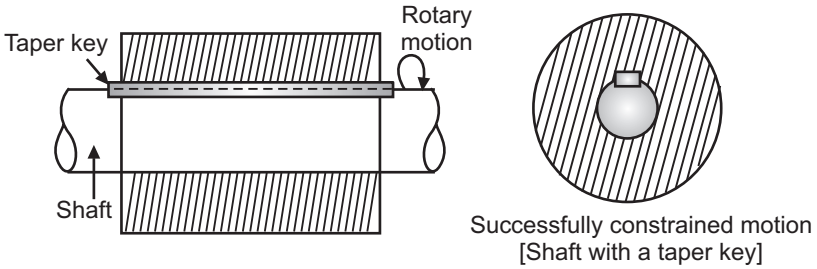


Fig. 1.3 (d) : Successfully constrained motion (shaft with a taper key)

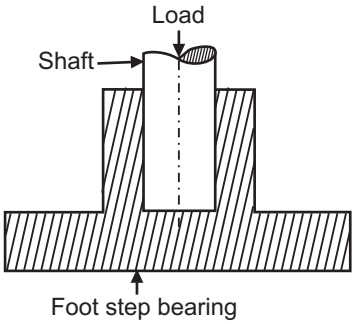


Fig. 1.3 (e) : Shaft in a footstep bearing

When the motion between the elements, forming a pair, is such that the constrained motion is not completed by itself, but by some other means, then the motion is said to be successfully constrained motion.

Theory Of Machines - I

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