APPLIED MECHANICS

RUPINDER KAUR
B.Sc., M.Sc., B.Ed., M.PhiI.
***Astt. Professor* (*Physics*)**
Naraini Group of Institute
Chirao, Karnal

AN ISO 9001:2008 CERTIFIED COMPANY
VAYU EDUCATION OF INDIA
2/25, Ansari Road, Darya Ganj, New Delhi-110 002

Applied Mechanics

ISBN: 978-93-81348-52-9

First Edition: 2012

Price: ₹ 180/-

Printed & bound in India

Published by:

AN ISO 9001:2008 CERTIFIED COMPANY

VAYU EDUCATION OF INDIA

2/25, Ansari Road, Darya Ganj, New Delhi-110 002
Ph.: 91-11-47236600, 41564445
Fax: 91-11-41564440
E-mail: vei@veiindia.com
Web: www.veiindia.com

This book is dedicated
to my
Respected, caring
and
loving parents
S. Swaran Singh & Satvinder Kaur

PREFACE

Engineering is the discipline and profession of applying technical and **scientific knowledge** and utilizing natural laws and physical resources in order to design and implement **materials, structures, machines, devices, systems,** and processes that safely realize a desired objective and meet specified criteria. The **American Engineers' Council for Professional Development** has defined engineering as follows: "(The creative application of scientific principles to design for develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behaviour under specific operating conditions; all as respects an intended function, economics of operation and safety to life property.)" One Who practices engineering is called an engineer. The concept of engineering has existed since ancient times as humans devised fundamental inventions such as the **pulley, lever** and **wheel.** Engineers apply the sciences of physics and mathematics to find suitable solutions to problems or to make improvements to the status quo. More than ever, Engineers are now required to have knowledge or relevant sciences for their design projects, as a result, they keep on learning new material throughout their career. Engineers typically attempt to predict how well their designs will perform to their specifications prior to full-scale production. Engineers typically include a **factor of safety** in their designs to reduce the risk of unexpected failure. However, the greater the safety factor, the less efficient the design may be. By its very nature engineering is bound up with society and human behaviour. Every product or construction used by modern society will have been influenced by engineering design. Engineering design is a very powerful tool to make changes to environment, society and economies, and its application brings with it a great responsibility as presented by many of the **Engineering Institutions** code of practice and **ethics.** Just a few examples of this from different engineering disciplines are the development of **nuclear weapons,** the **Three Gorges Dam,** the design and use of **Sports Utility Vehicles** and the extraction of oil. For all these needs fulfilled students has to go through various books. The present book aim to cover all requirements of the subject in a single book.

Applied mechanics is a branch of the **physical sciences** and the practical application of mechanics. Applied mechanics examines the *response of bodies (solids and fluids) or system of bodies to external forces.* Some examples of mechanical systems include the flow of a liquid under pressure, the fracture of a solid from an applied force, or the vibration of an ear in response to sound. A practitioner of the discipline is

known as a **mechanician.** Applied mechanics, as its name suggests, bridges the gap between physical theory and its application to *technology.* As such, applied mechanics is used in many fields of engineering, especially mechanical engineering. In this context, it is commonly referred to as engineering mechanics. Much of modern **engineering mechanics** is based on Issac Newton's laws of motion while the modern practice of their application can be traced back to Stephen Timoshenko, who is said to be the father of modern engineering mechanics. Within the theoretical sciences, who is said to be the useful in formulating new ideas and theories, discovering and interpreting phenomena, and developing experimental and computational tools.

People are judged by what they know more than their friend-ships or what school they went to. It's a technical business ... if you're technically competent you'll do very well".

A good book with detail and clear study material can help you to improve and increase your knowledge This book is mainly useful for diploma level students. The salient feature of book are:

- A moderately concise and compact book covering all major topics
- Simple language to make it useful even to the average weak students
- Large number of solved examples
- Theoretical questions as well as sufficient number of unsolved problems at the end of each chapter.
- Multiple choice and objective types questions

Chapter 1 and 2 covers introduction and Different Laws of forces and their applications. Chapters 3 and 4 covers moments. Varignon's Theorem and its applications. Chapters 5 explains Center of gravity of different bodies such as cone, cylinder, hemisphere etc. Chapter 6 covers Applications of laws of motion & Chapter 7 covers most important topic Simple Machines.

Though students are expected to exert and solve the numerical problems given at the end of each chapter, hints to most of the these are given.

In preparing the book, I relied heavily on the works of renowned authors whose writings are considered in the same field. I am indeed indebted to them. I am sincerely acknowledge the help of my many colleagues & friends, who helped me in one form or other. I also acknowledge the efforts of the editorial and production staff of Vayu Education of India, Darya Ganj, New Delhi for taking pains in bringing out this book in an excellent format.

Finally, I am also indebted to my husband, Vikas Sharma, and my parents my sister Ravinder, my family for being patient with me while I went about arduous task of preparing the book. Without their cooperation and love I was not able to complete the book.

A creation by a human being can never be perfect. A number of mistakes might have crept in the text. I shall be highly grateful to the readers for their uninhibited comments and pointing out errors.

Rupinder Kaur

SYLLABUS

APPLIED MECHANICS

L T P
3 - 2

RATIONALE

The subject Applied Mechanics deals with basic concepts of mechanics like laws of forces, moments, friction, centre of gravity, laws of motion and simple machines whichare required by the students for further understanding of other allied subjects. The subject enhances the analytical ability of the students.

DETAILED CONTENTS

1. Introduction (6 hrs)

1.1 Concept of engineering mechanics, definition of mechanics, statics, dynamics, application of engineering mechanics in practical fields

1.2 Concept of rigid body

2. Laws of forces (6 hrs)

2.1 Different force systems (coplanar and non-coplanar), principle of transmissibility of forces

2.2 Parallelogram law of forces, triangle law of forces, polygon law of forces (graphically and analytically) resolution of forces, resolving a force into two rectangular components

2.3 Free body diagram

2.4 Equilibrium force and its determination

2.5 Lami's theorem

3. Moment (6 hrs)

3.1 Concept of moment

3.2 Moment of a force and units of moment

3.3 Varignon's theorem (definition only)

3.4 Principle of moment and its applications
3.5 Parallel forces (like and unlike) and calculating their resultant
3.6 Concept of couple, its properties and effects
3.7 General conditions of equilibrium of bodies under co-planar forces
3.8 Position of resultant force by moment

4. Friction (6 hrs)

4.1 Definition and concept of friction, types of friction
4.2 Laws of static friction, coefficient of friction, angle of friction, angle of repose, cone of friction
4.3 Equilibrium of a body lying on a horizontal plane, equilibrium of a body lying on a rough inclined plane, friction in simple screw jack
4.4 Calculation of least force required to maintain equilibrium of a body on a rough inclined plane subjected to a force:
a) acting along the inclined plane
b) horizontally
c) at some angle with the inclined plane

5. CENTRE OF GRAVITY (6 HRS)

5.1 Concept, definition of center of gravity and centroid of plain figure and symmetrical solid body
5.2 Determination of centroid of plain and composite lamina using moment method, centroid of bodies with removed portion
5.3 Determination of center of gravity of solid bodies - cone, cylinder, hemisphere and sphere; composite bodies and bodies with portion removed
6. Application of the laws of motion (10 hrs) Simple problems on second law of motion, piles, lift, bodies tied with strings

7. SIMPLE MACHINES (8 HRS)

7.1 Definition of effort, velocity ratio, mechanical advantage and efficiency of a machine and their relationship, law of machine
7.2 Simple and compound machine
7.3 Definition of ideal machine, reversible and self locking machine
7.4 Effort lost in friction, determination of maximum mechanical advantage and maximum efficiency
7.5 System of pulley (first, second, third system of pulleys), determination of velocity ratio, mechanical advantage and efficiency
7.6 Working principle and application of wheel and axle, different pulley blocks, simple screw jack, worm and worm wheel, single and double purchase winch

crab, expression for their velocity ratio and field of their application

Note: Simple problem/numericals may be included in all the above topics wherever feasible

LIST OF PRACTICALS

1. Verification of the following laws:
   (a) Parallelogram law of forces
   (b) Triangle law of forces
   (c) Polygon law of forces
2. To verify the forces in different members of a jib crane
3. To verify the reaction at the supports of a simply supported beam
4. To find the mechanical advantage, velocity ratio and efficiency in case of an inclined plane
5. To find the mechanical advantage, velocity ratio and efficiency of a screw jack
6. To find the mechanical advantage, velocity ratio and efficiency of worm and worm wheel
7. To find mechanical advantage, velocity ratio and efficiency of single purchase winch crab
8. To find center of gravity of regular lamina
9. To find center of gravity of irregular lamina
10. To determine coefficient of friction between different surfaces on horizontal plane.

CONTENTS

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

Science: The word science comes from a lotion verb "Scientia" which means "to know". So science means to know about our surroundings and our needs & requirement to meet our day to day needs, and to upgrade our living. Science means to explore our knowledge in each and every field of life.

In fact, "Science" means to knew our need or problem and finding solutions through careful observations and experimentation.

The world of science in so vast that it has so many branches : Physics, chemistry, mathematics, biology, etc.

As we all know that today we are living in a era of science and technology. So the present day scientists and technologists (engineers) have to come together to group the various areas of scientific work to facilitate their training and research programmes to achieve more advancement in each field. The branch of science whose theories and research are used for practical utility and services of human life is known as **applied science.**

1.1 Physics — The Fundamental Science

Physics is a very fundamental and vast science, of which the subject of mechanics forms one of the most impartment foundation stones. Physics is the most basic of physical science, as its principles constitutes the basis of other sciences such as chemistry, geology, electronics, meteorology ; various branches of engineering and the biological subjects etc. The concepts and the laws of physics are based on human intuition and are derived in a self-consistent manner from the basis experimental facts, and systematic mathematical reasoning.

Mechanics : It is the branch of physics, which deals with the motion of material. macroscopic bodies with velocities much less of mechanics like Newton's three laws, or the concepts like force momentum, energy, work, angular, momentum, torque etc. were suggested by experimental or observational facts as found by Galileo, Kepler and many others.

The concepts developed in mechanics form the basis of the development of other branches of science like — Engineering.

The logics used in mechanics — its postulates and theories — are not borrowed from other sciences experimental facts, and under no conditions contradictory to them. It is always the new experimental facts that give size to the new concepts and logic ; and the self-consistency and continuity of logic are assured by the mathematical tools which the subject of mechanics used for an engineer in planning, designing and constructing of his various types of structures, design and machines.

The study of mechanics can be broadly classified into two categories:

(a) Static's

(b) Dynamics

Static's : Statics is the study of objects at rest. In the study of static's.

Dynamics : It is that branch of mechanics in which not only the motion but cause of motion is also considered. It is further divide into parts.

(i) Kinetics : In this type of mechanics, the forces which are responsible for motion and resource of these forces are also taken into account.

(ii) Kinematics : It is that branch of the mechanics which deals with motion without considering the cause of motion.

Some important related terms and definitions Unit : The reference standard used for measurement is called unit.

Fundamental units : The units used for measurement of three fundamental quantities (mass, length tine) are called fundamental units.

Derived units : The units which are obtained from fundamental units e.g. velocity:

$$\frac{Displacement}{Time} = \frac{L}{T} = LT^{-1}$$

Area = Length × Breadth = L × L = L^2

1.2 System of units :

(i) FPS system or British system : In this system of units, mass, length and time are measure in pound, foot and second respectively.

(ii) CGS system : In this system of units; man, length and time are measured in gram, centimeter and second respectively. This is an improved version of FPS and is an metric system.

(iii) MKS system : In this system of units; mass, length and time are measured in kilogram, meter and second respectively.

(iv) To overcome the practical difficulties of various systems of units a single common system of units based upon scientific and practical value was developed. It comprises the seven supplementary units.

S. No.	Physical Quantity	Unit	Symbol
1.	Mass	Kilogram	Kg.
2.	Length	Meter	M
3.	Time	Second	S
4.	Electric Current	Ampere	A
5.	Temperature	Kelvin	K
6.	Intensity or Luminous intensity	Candle	Cd
7.	Amount of matter or substance	Mole	Mole

Some Important Quantities and their units

S. No.	Quantity	MKS System		SI System	
		Units	Symbol	Units	Symbol
1.	Velocity	Meter per second	M/s	Meter per	M/s
2.	Acceleration	Meter per second	M/s^2	Meter per (second)2	M/s^2
3.	Area	Square meter	M^2	Square meter	M^2
4.	Volume	Cubic Meter	M^3	Cubic Meter	M^3
5.	Force	Kilogram force of Newton	Kgf or N or kg m/s^2	Newton	N
6.	Density	Kilogram per cubic meter	Kg/m^3	Kilogram per cubic meter	Kg/m^3
7.	Temperature	Celsius or Kelvin	°C or K	Kelvin	K
8.	Plane angle	Radians	Rad	Radian	Rad
9.	Solid angle	Steradians	Sr.	Steradians	Sr.
10.	Angular acceleration	$Radions/sec^2$	Rad/S^2	$Radions/sec^2$	Rad/S^2

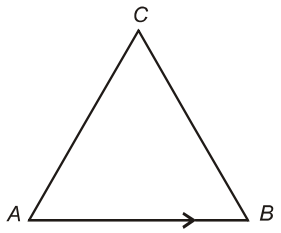
1.3 Rigid Body

A body having definite and size, and its dimensions did not change under the effect of forces. During motion all the particles of the rigid body do not change their position and they remain in their respective positions.

1.4 Displacement

The minimum distance between the initial and the final destination points which represents the change in position of which represents the change in position of a body from initial to final points.

Let a body starts from A and reaches at via ACB. Then AB shows its displacement. It is a vector quantity.



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Publisher : Vayu Education ISBN : 9789381348529 Author : Rupender Kaur