UNIVERSITY BASRAH

جامعة البصرة
كلية الهندسة
قسم الهندسة الميكانيكية

Engineering Mechanics (static)

By
Assistant Professor
Dr. Abdul Kareem Flaih Hassan

Course Name **Engineering Mechanics (static)**

Engineering Mechanics (static)	Theoretical Hour/week	Tutorial Hour/week	Experimental	Credit Hours
	2	1	--	6

Instructor： Assistant Professor Dr. Abdul Kareem Flaih Hassan
Email： XXXXXXXXXX
Textbook： 1. Engineering Mechanics Statics - Meriam 5th Ed
2. Vector Mechanics for Engineers-*STATICS* (THIRD SI METRIC EDITION) by Beer & Johnston
Reference Book： Engineering Mechanics- Statics by Hibbeler
Engineering Mechanics- Statics by Riley & Sturges
Evaluations: 1st Term : exam. 20% (first term materials)
Quizzes and home works 5%
2nd Term : exam. 20% (second term materials)
Quizzes and home works 5%
Final exam. 50% (all materials)

COURSE LEARNING OUTCOMS

After completing the course, you should be able to:

- **Analyze forces and find out the resultant forces in two and three dimension**
- **Differentiate between various type of supports and draw free-body-diagram**
- **Compute the reaction force, internal forces and bending moment at a specific point on a simple structure (beam, frame, truss)**
- **Compute whether the body or structure in equilibrium or not.**
- **Obtain center of mass and centroid for deferent engineering shapes & moment of inertia for deferent sections.**
- **Deal with friction between surfaces , unwanted and desirable friction.**
- **Obtain the work down by force exerted on the bodies.**

CHAPTER 1
INTRODUCTION TO STATICS

1/1 Mechanics 1/2 Basic Concepts 1/3 Scalars and Vectors 1/4 Newton's Laws 1/5 Units 1/6 Law of Gravitation 1/7 Accuracy, Limits, and Approximations 1/8 Problem Solving in Statics 1/9 Chapter Review

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FORCE SYSTEMS

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TWO-DIMENSIONAL FORCE SYSTEMS : 2/3 Rectangular Components 2/4 Moment 2/5 Couple 2/6 Résultants

THREE-DIMENSIONAL FORCE SYSTEMS: 2/7 Rectangular Components 2/8 Moment and Couple 2/9 Resultants 2/10 Chapter Review

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EQUILIBRIUM

3/1 Introduction

EQUILIBRIUM IN TWO DIMENSIONS: 3/2 System Isolation and the Free-Body Diagram 3/3 Equilibrium Conditions

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CHAPTER 4
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CHAPTER 5
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SECTION A CENTERS OF MASS AND CENTROIDS 5/2 Center of Mass 5/3 Centroids of Lines, Areas, and Volumes 5/4 Composite Bodies and Figures; Approximations 5/5 Theorems of Pappas.

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CHAPTER 6
FRICTION

CHAPTER 7
VIRTUAL WORK

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1. Introduction

Engineering Mechanics:

Mechanics is the physical science which deals with the effects of forces on objects. The subject of mechanics is logically divided into two parts:

Statics: concerns with the equilibrium of bodies under the action of forces.

Dynamics: concerns with the motion of bodies.

Fundamental Concepts

Before we begin our study of engineering mechanics, it is important to understand the meaning of certain fundamental concepts and principles.

Basic Quantities: **The following four quantities are used throughout mechanics.**

Length: ***Length is used to locate the position of a point in space*** and thereby describe the size of a physical system. Once a standard unit of length is defined, one can then use it to define distances and geometric properties of a body as multiples of this unit.

Time: ***Time is conceived as a succession of events.*** Although the principles of statics are time independent, this quantity plays an important role in the study of dynamics.

Mass: ***Mass is a measure of a quantity of matter that is used to compare the action of one body with that of another.*** This property manifests itself as a gravitational attraction between two bodies and provides a measure of the resistance of matter to a change in velocity.

Force: ***In general, force is considered as a "push" or "pull" exerted by one body on another.*** This interaction can occur when there is direct contact between the bodies, such as a person pushing on a wall, or it can occur through a distance when the bodies are physically separated. Examples of the latter type include gravitational, electrical, and magnetic forces. In any case, a force is completely characterized by its magnitude, direction, and point of application.

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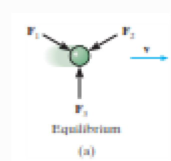
Particle: ***A particle has a mass, but a size that can be neglected.*** For example, the size of the earth is insignificant compared to the size of its orbit, and therefore the earth can be modeled as a particle when studying its orbital motion. When a body is idealized as a particle, the principles of mechanics reduce to a rather simplified form since the geometry of the body will not be involved in the analysis of the problem.

Rigid Body: ***A rigid body can be considered as a combination of a large number of particles in which all the particles remain at a fixed distance from one another, both before and after applying a load.*** This model is important because the material properties of any body that is assumed to be rigid will not have to be considered when studying the effects of forces acting on the body. In most cases the actual deformations occurring in structures, machines, mechanisms, and the like are relatively small, and the rigid-body assumption is suitable for analysis.

Newton's Three Laws of Motion:

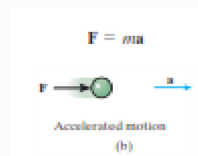
Engineering mechanics is formulated on the basis of Newton's three laws of motion, the validity of which is based on experimental observation. These laws apply to the motion of a particle as measured from a nonaccelerating reference frame. They may be briefly stated as follows.

First Law: ***A particle originally at rest, or moving in a straight line with constant velocity, tends to remain in this state provided the particle is not subjected to an unbalanced force, Fig. 1–1a.***



Second Law: ***A particle acted upon by an unbalanced force (F) experiences an acceleration (a) that has the same direction as the force and a magnitude that is directly proportional to the force*** (Stated another way, the unbalanced force acting on the particle is proportional to the time rate of change of the particle's linear momentum.), ***Fig. 1–1b.*** If F is applied to a particle of mass m, this law may be expressed mathematically as

$$F = ma \qquad (1\text{-}1)$$



Third Law: ***The mutual forces of action and reaction between two particles are equal, opposite, and collinear, Fig. 1–1c.***

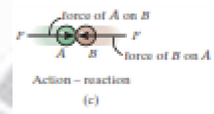


Fig. 1–1

Scalars and vectors: Scalars are those with which only a magnitude is associated. Examples of scalar quantities are time, volume, density, speed, energy, and mass. Vector quantities, on the other hand, possess direction as well as magnitude, and must obey the parallelogram law of addition as described later in this article. Examples of vector quantities are displacement, velocity, acceleration, force, moment, and momentum. Speed is a scalar. It is the magnitude of velocity, which is a vector. Thus velocity is specified by a direction as well as a speed.

Vectors representing physical quantities can be classified as free, sliding, or fixed.

A free vector is one whose action is not confined to or associated with a unique line in space. For example, if a body moves without rotation, then the movement or displacement of any point in the body may be taken as a vector. This vector describes equally well the direction and magnitude of the displacement of every point In the body. Thus, we misrepresent the displacement of such a body by a free vector.

A sliding victor has a unique line of action in space bill mil a unique point of application. For example, whim (in external force ails on a rigid body, the force can be applied at any point along its line of action without changing its effect on the body as a whole, and thus it is a sliding vector.

A fixed vector is one for which a unique point of application is specified. The action of a force on a deformable or nonrigid body must be specified by a fixed vector at the point of application of the force. In this instance the forces and deformations within the body depend on the point of application of the force, as well as on its magnitude and line of action.

Conventions for Equations and Diagrams

A vector quantity V is represented by a line segment. Fig.1/1, having the direction of the vector and having an arrow head to indicate the sense. The length of the directed

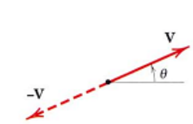


Figure 1/1

line segment represents to some convenient scale the magnitude |V| of the vector and is printed with light-face italic type V. For example, we may choose a scale such that an arrow one inch long represents a force of twenty pounds.

In scalar equations, and frequently on diagrams where only the magnitude of a vector is labeled, the symbol will appear in lightface italic type. Boldface type is used for vector quantities whenever the directional aspect of the vector is a part of its mathematical representation. When writing vector equations, always be certain to preserve the mathematical distinction between vectors and scalars.

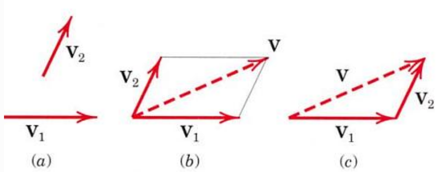


Figure 1/2

In handwritten work, use distinguishing marks for each vector quantity, such as an underline, $\underline{V}$, or an arrow over the symbol, $\vec{V}$, to take the place of boldface type in print.

Working with Vectors: The direction of the vector V may be measured by un angle θ from some known reference direction as shown in Fig. 1/1. The negative of **V** is a vector **-V** having the same magnitude as **V** but directed in the sense opposite to V. ad shown in Fig. 1/1.

Vectors must obey the parallelogram law of combination. This law states that two vectors $\mathbf{V}_1$, and $\mathbf{V}_2$, treated as free vectors. Fig.l.2a, may be replaced by their equivalent vector V. which is the diagonal of the parallelogram formed by $\mathbf{V}_1$, and $\mathbf{V}_2$, as its two sides, as shown in Fig.1.2b. This combination is called the vector sum and is represented by the vector equation.

Geometry of the parallelogram shows that

$$\mathbf{V} \# \mathbf{V}_1 + \mathbf{V}_2$$

Addition of the vectors does not affect their sum, so that

$$\mathbf{V}_1 + \mathbf{V}_2 = \mathbf{V}_2 + \mathbf{V}_1$$

The difference $\boldsymbol{V_1}$-$\boldsymbol{V_2}$ between the two vectors is easily obtained by adding -$\boldsymbol{V_2}$ to $\boldsymbol{V_1}$ as shown in Fig. 1/3, where either the triangle or parallelogram procedure may be used. The difference V between the two vectors is expressed by the vector equation :
V= $\boldsymbol{V_1}$-***V2***
where the minus sign denotes vector subtraction.

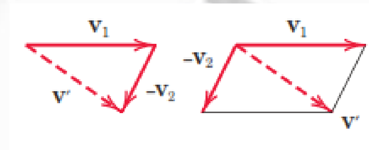


Figure 1/3

Any two or more vectors whose sum equals a certain vector **V** are said to be the components of that vector. Thus, the vectors $\mathbf{V}_1$ ***and*** $\mathbf{V}_2$ In Fig. 1/4a are the components of **V** in the directions 1 and 2, respectively. It is usually most convenient to deal with vector components which are mutually perpendicular; these are called rectangular components. The vectors **V***x* and **Vy** in Fig. 1/4b are the x- and y-components, respectively, of **V.** Likewise, in Fig. 1/4c, $\mathbf{V}_x$ and $\mathbf{V}_y$ are the x- and y-components of **V.** When expressed in rectangular components, the direction of the vector with respect to, say, the x-axis is clearly specified by the angle θ, where

$$\theta = \tan^{-1}\frac{V_y}{V_x}$$

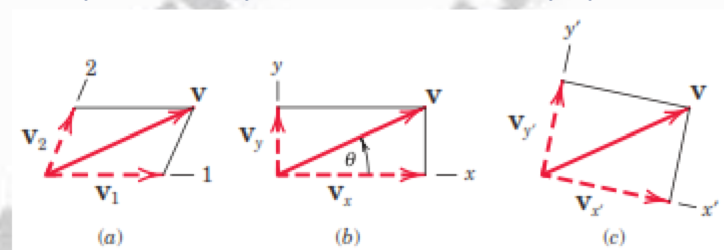


Figure 1/4

A vector **V** may be expressed mathematically by multiplying its magnitude **V** by a vector **n** whose magnitude is one and whose direction coincides with that of **V**. The vector n is called a unit vector. Thus,

V = *V*n

In this way both the magnitude and direction of the vector are conveniently contained in one mathematical expression. In many problems, particularly three-dimensional ones, it is convenient to express the rectangular components of **V,** Fig. 1/5, in terms of unit vectors **i, j,** and **k,** which are vectors in the x-, y-, and z-directions, respectively, with unit magnitudes. Because the vector **V** is the vector sum of the components in the x-, y-, and z-directions, we can express V as follows:

$$\mathbf{V} = V_x\mathbf{i} + V_y\mathbf{j} + V_z\mathbf{k}$$

$$\mathbf{V} = V_x\mathbf{i} + V_y\mathbf{j} + V_z\mathbf{k}$$

We now make use of the *direction cosines* l, m, and n of $\mathbf{V}$, which are defined by:

$$l = \cos\theta_x \qquad m = \cos\theta_y \qquad n = \cos\theta_z$$

Thus, we may write the magnitudes of the components of $\mathbf{V}$ *as*

$$V_x = lV \qquad V_y = mV \qquad V_z = nV$$

Where, from paythagorean theorem $V^2 = {V_x}^2 + {V_y}^2 + {V_z}^2$

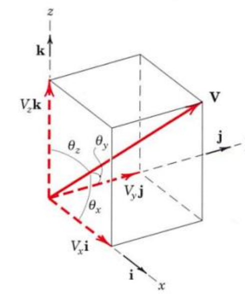


Figure 1/5

Note that this relation implies that

$$l^2 + m^2 + n^2 = 1$$

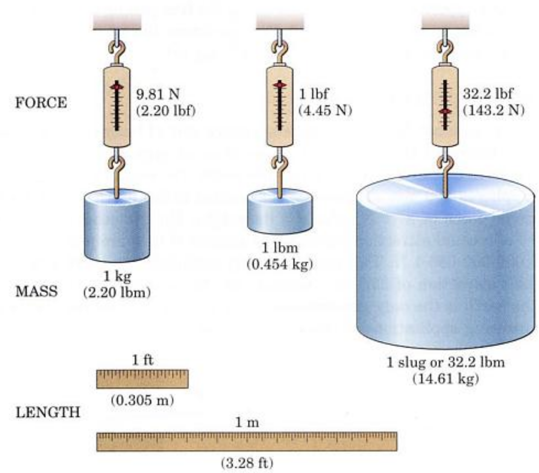
UNITS

QUANTITY	DIMENSIONAL SYMBOL	SI UNITS: UNIT	SI UNITS: SYMBOL	U.S. CUSTOMARY UNITS: UNIT	U.S. CUSTOMARY UNITS: SYMBOL
Mass	M	Base units { kilogram	kg	slug	—
Length	L	meter	m	Base units { foot	ft
Time	T	second	s	second	sec
Force	F	newton	N	pound	lb

SI Units

$$\mathrm{N} = \mathrm{kg \cdot m/s^2}$$

$$W(\mathrm{N}) = m\,(\mathrm{kg}) \times g\,(\mathrm{m/s^2})$$



U.S. Customary Units

$$\text{slug} = \frac{\text{lb-sec}^2}{\text{ft}} \qquad m\,(\text{slugs}) = \frac{W\,(\text{lb})}{g\,(\text{ft/sec}^2)}$$

Unit Conversions

also the force required to give a one-pound mass an acceleration of 32.1740 ft/sec^2.

SI units $\quad g = 9.806\ 65\ \mathrm{m/s^2}$

U.S. units $\quad g = 32.1740\ \mathrm{ft/sec^2}$

SI Units Used in Mechanics

Quantity	Unit	SI Symbol
(Base Units)		
Length	meter*	m
Mass	kilogram	kg
Time	second	s
(Derived Units)		
Acceleration, linear	meter/second^2	m/s^2
Acceleration, angular	radian/second^2	rad/s^2
Area	meter^2	m^2
Density	kilogram/meter^3	kg/m^3
Force	newton	N (= kg · m/s^2)
Frequency	hertz	Hz (= 1/s)
Impulse, linear	newton-second	N · s
Impulse, angular	newton-meter-second	N · m · s
Moment of force	newton-meter	N · m
Moment of inertia, area	meter^4	m^4
Moment of inertia, mass	kilogram-meter^2	kg · m^2
Momentum, linear	kilogram-meter/second	kg · m/s (= N · s)
Momentum, angular	kilogram-meter^2/second	kg · m^2/s (= N · m · s)
Power	watt	W (= J/s = N · m/s)
Pressure, stress	pascal	Pa (= N/m^2)
Product of inertia, area	meter^4	m^4
Product of inertia, mass	kilogram-meter^2	kg · m^2
Spring constant	newton/meter	N/m
Velocity, linear	meter/second	m/s
Velocity, angular	radian/second	rad/s
Volume	meter^3	m^3
Work, energy	joule	J (= N · m)
(Supplementary and Other Acceptable Units)		
Distance (navigation)	nautical mile	(= 1,852 km)
Mass	ton (metric)	t (= 1000 kg)
Plane angle	degrees (decimal)	°
Plane angle	radian	—
Speed	knot	(1.852 km/h)
Time	day	d
Time	hour	h
Time	minute	min

SI Unit Prefixes

Multiplication Factor	Prefix	Symbol
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^9	giga	G
1 000 000 = 10^6	mega	M
1 000 = 10^3	kilo	k
100 = 10^2	hecto	h
10 = 10	deka	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p