Dept. of Medical Instrumentation Engineering

First Stage

Academic Year: 2020-2021

Subject: Mechanics

Instructor: Assist. Prof. Dr. Saad Alkhfaji

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Reference: Engineering Mechanics, Statics, J. L. Meriam and L. G. Kraige, John Wiley & Sons, Inc.

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LECTURE 1:

Introduction to Mechanics and Resultant of Force Systems

Mechanics:

Mechanics is the physical science which deals with the effects of forces on objects. No other subject plays a greater role in engineering analysis than mechanics. Although the principles of mechanics are few, they have wide application in engineering. The principles of mechanics are central to research and development in the fields of vibrations, stability and strength of structures and machines, robotics, rocket and spacecraft design, automatic control, engine performance, fluid flow, electrical machines and apparatus, and molecular, atomic, and sub-atomic behavior**.** The subject of mechanics is logically divided into two parts: statics, which concerns the equilibrium of bodies under action of forces, and dynamics, which concerns the motion of bodies.

Basic Concepts:

The following concepts and definitions are basic to the study of mechanics, and they should be understood at the outset.

Space is the geometric region occupied by bodies whose positions are described by linear and angular measurements relative to a coordinate system. For three-dimensional problems, three independent coordinates are needed. For two-dimensional problems, only two coordinates are required.

Time is the measure of the succession of events and is a basic quantity in dynamics. Time is not directly involved in the analysis of statics problems.

Mass is a measure of the inertia of a body, which is its resistance to a change of velocity. Mass can also be thought of as the quantity of matter in a body. The mass of a body affects the gravitational attraction force between it and other bodies. This force appears in many applications in statics.

Force is the action of one body on another. A force tends to move a body in the direction of its action. The action of a force is characterized by its magnitude, by the direction of its action, and by its point of application. Thus, force is a vector quantity.

A particle is a body of negligible dimensions. In the mathematical sense, a particle is a body whose dimensions are considered to be near zero so that we may analyze it as a mass concentrated at a point. We often choose a particle as a differential element of a body. We may treat a body as a particle when its dimensions are irrelevant to the description of its position or the action of forces applied to it.

Rigid body: A body is considered rigid when the change in distance between any two of its points is negligible for the purpose at hand. For instance, the calculation of the tension in the cable which supports the boom of a mobile crane under load is essentially unaffected by the small internal deformations in the structural members of the boom. For the purpose, then, of determining the external forces which act on the boom, we may treat it as a rigid body. Statics deals primarily with the calculation of external forces which act on rigid bodies in equilibrium. Determination of the internal deformations belongs to the study of the mechanics of deformable bodies, which normally follows statics in the curriculum.

Scalars and Vectors:

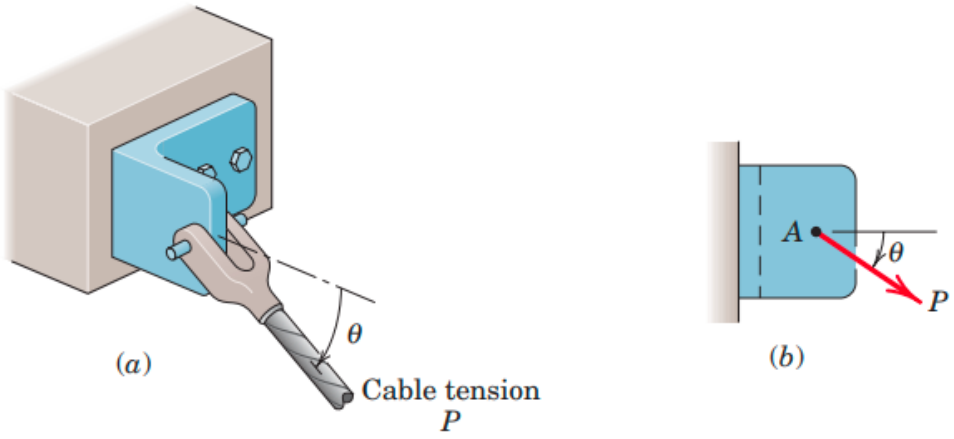
We use two kinds of quantities in mechanics—scalars and vectors. Scalar quantities are those with which only a magnitude is associated. Examples of scalar quantities are time, volume, density, speed, energy. Vector quantities, on the other hand, possess

direction as well as magnitude, and must obey the parallelogram law of addition. Examples of vector quantities are displacement, velocity, acceleration, force, moment, and momentum.

Resultant of Force Systems

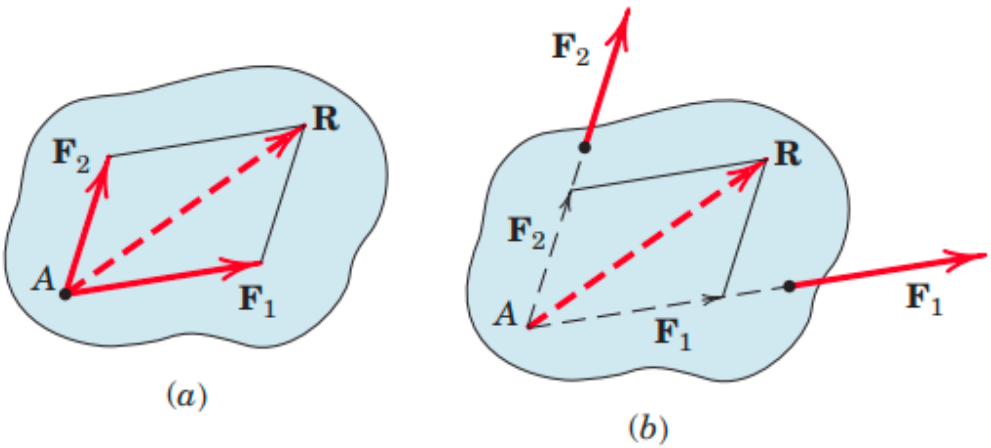
Force

Before dealing with a group or system of forces, it is necessary to examine the properties of a single force in some detail. A force is an action of one body on another. A force is a vector quantity, because its effect depends on the direction as well as on the magnitude of the action. Thus, forces may be combined according to the parallelogram law of vector addition.



We can express the sum of the two forces mathematically by the vector equation:

$$\mathbf{R} = \mathbf{F}_1 + \mathbf{F}_2$$



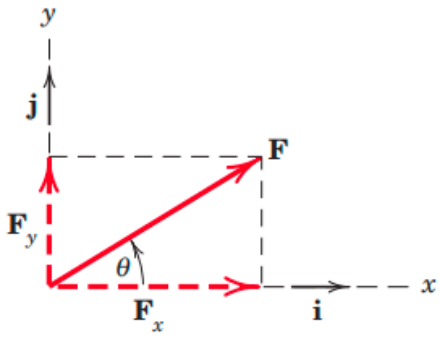
TWO-DIMENSIONAL FORCE SYSTEMS

Rectangular Components

The most common two-dimensional resolution of a force vector is into rectangular components. It follows from the parallelogram rule that the vector **F** of Fig. 2/5 may be written as

$$\mathbf{F} = \mathbf{F}_x + \mathbf{F}_y$$

where $\mathbf{F}_x$ and $\mathbf{F}_y$ are *vector components* of **F** in the x- and y-directions. Each of the two vector components may be written as a scalar times the



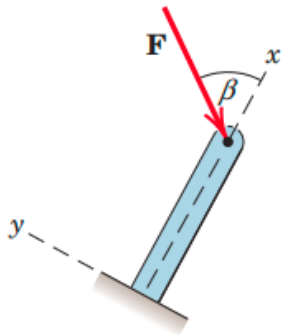
appropriate unit vector. In terms of the unit vectors **i** and **j** $\mathbf{F}_x = F_x\mathbf{i}$ and $\mathbf{F}_y = F_y\mathbf{j}$, and thus we may write

$$\mathbf{F} = F_x\mathbf{i} + F_y\mathbf{j}$$

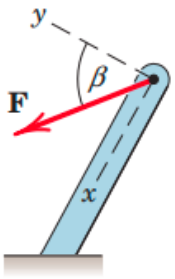
where the scalars F_x and F_y are the x and y *scalar components* of the vector **F**.

$$F_x = F\cos\theta \qquad F = \sqrt{F_x^2 + F_y^2}$$

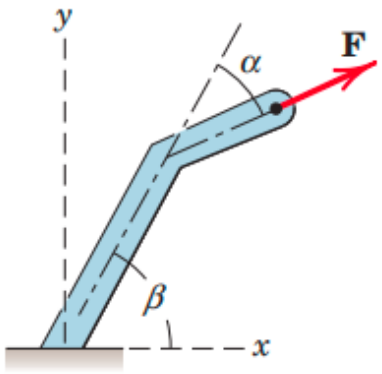
$$F_y = F\sin\theta \qquad \theta = \tan^{-1}\frac{F_y}{F_x}$$



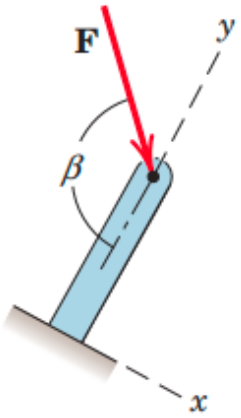
$F_x = -F\cos\beta$
$F_y = -F\sin\beta$



$F_x = F\sin\beta$
$F_y = F\cos\beta$



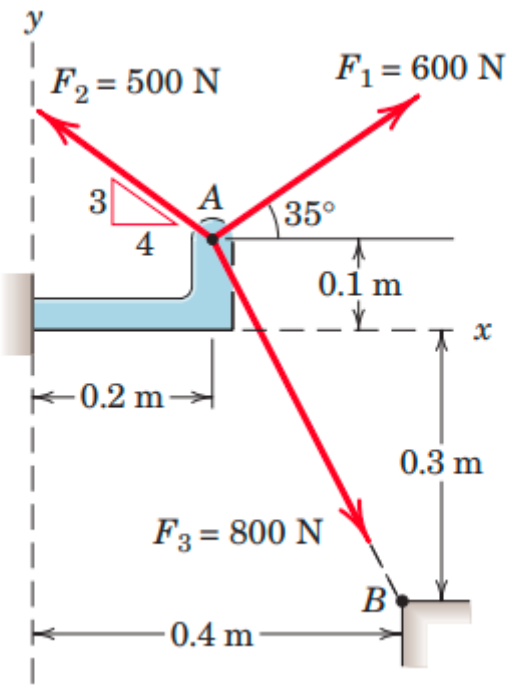
$F_x = F\cos(\beta - \alpha)$
$F_y = F\sin(\beta - \alpha)$



$F_x = F\sin(\pi - \beta)$
$F_y = -F\cos(\pi - \beta)$

Example 1:

The forces $\mathbf{F}_1$, $\mathbf{F}_2$, and $\mathbf{F}_3$, all of which act on point A of the bracket, are specified in three different ways. Determine the x and y scalar components of each of the three forces.



Solution. The scalar components of $\mathbf{F}_1$, from Fig. *a*, are

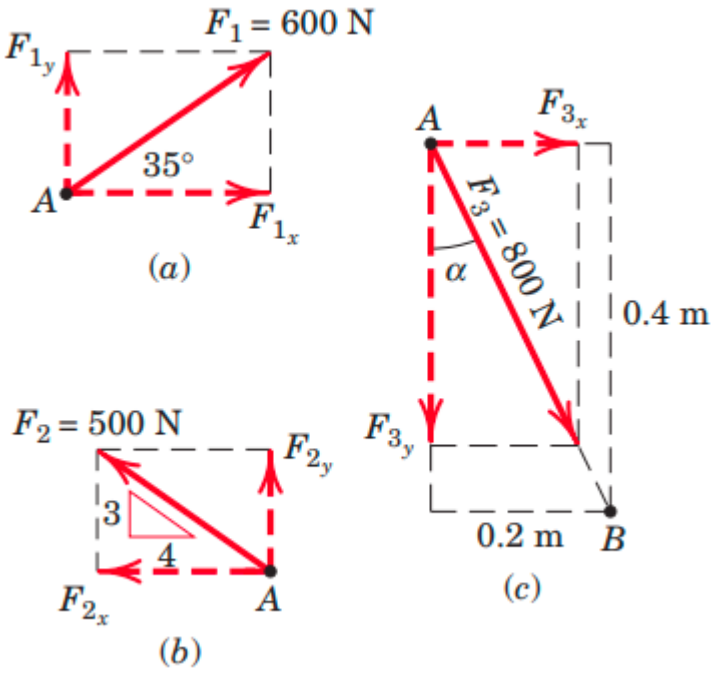
$$F_{1_x} = 600 \cos 35° = 491 \text{ N} \qquad \textit{Ans.}$$

$$F_{1_y} = 600 \sin 35° = 344 \text{ N} \qquad \textit{Ans.}$$

The scalar components of $\mathbf{F}_2$, from Fig. *b*, are

$$F_{2_x} = -500(\tfrac{4}{5}) = -400 \text{ N} \qquad \textit{Ans.}$$

$$F_{2_y} = 500(\tfrac{3}{5}) = 300 \text{ N} \qquad \textit{Ans.}$$



Note that the angle which orients $\mathbf{F}_2$ to the x-axis is never calculated. The cosine and sine of the angle are available by inspection of the 3-4-5 triangle. Also note that the x scalar component of $\mathbf{F}_2$ is negative by inspection.

The scalar components of $\mathbf{F}_3$ can be obtained by first computing the angle α of Fig. c.

$$\alpha = \tan^{-1}\left[\frac{0.2}{0.4}\right] = 26.6°$$

Then, $F_{3_x} = F_3 \sin\alpha = 800 \sin 26.6° = 358$ N *Ans.*

$F_{3_y} = -F_3 \cos\alpha = -800 \cos 26.6° = -716$ N *Ans.*