جامعة آشور
Ashur University

Dept. of Medical Instrumentation Techniques Engineering
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Level: UG1 / Semester: Two / Module: Mechanics / ECTS: 4.00

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LECTURE 1: Introduction to Mechanics and Force Systems

1. Introduction to Mechanics:

Mechanics is the physical science that 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 havewide applications in engineering. The principles of mechanics are central to research and development in thefields 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 concernsthe equilibrium of bodies under the action of forces, and dynamics, which concerns the motion of bodies.

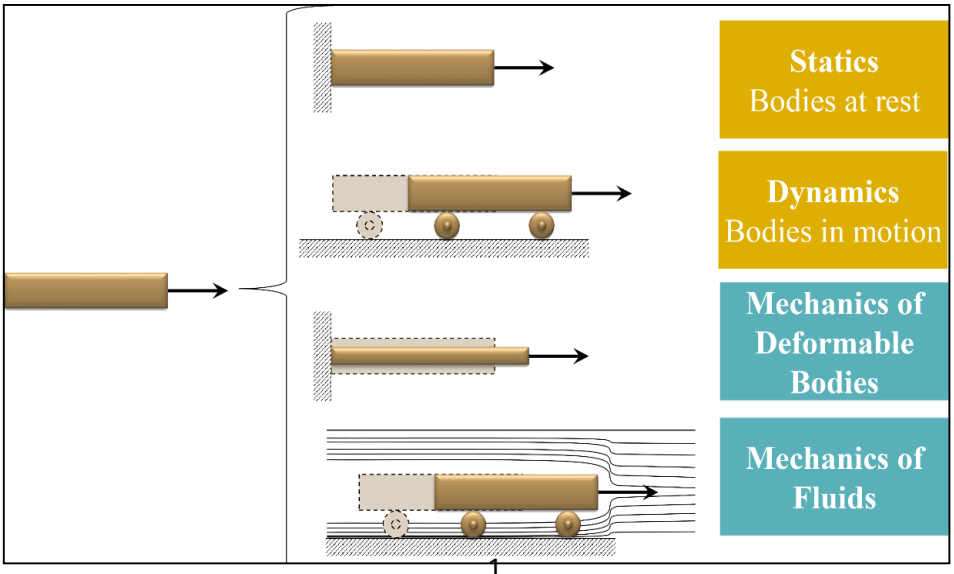


Fig. 1: Mechanics

1.1 Basic Concepts:

The following concepts and definitions are basic to the study of mechanics, and they should be understood atthe 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, 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 theboom of a mobile crane under load is essentially unaffected by the small internal deformations in the structuralmembers 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 internal deformations belongs to the study of the mechanics of deformable bodies, which normally follows statics in the curriculum.

1.2 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, and energy.

Vector quantities, on the other hand, possess 3 directions as well as magnitude, and must obey the parallelogram law of addition. Examples of vector quantities are displacement, velocity, acceleration, force, moment, and momentum.

1.3 Units of Measurement:

SI units: International System of Units, abbreviated SI is accepted in the United States and throughout the world and is a modern version of the metric system. As shown in Table 1. The SI system specifies the length in meters (m), time in seconds (s), and mass in kilograms (kg). The unit of force, called a newton (N), is derived from F=ma. Thus, 1 Newton is equal to a force required to give 1 kilogram of mass and acceleration of 1 m/s 2 (N= kg. $m/s2$).

US Customary:

The U.S. Customary, or British system of units, also called the foot-pound-second (FPS) system, has been the common system in business and industry in English-speaking countries. Although this system will in timebe replaced by SI units, for many more years engineers must be able to work with both SI units and FPS units.Both systems are used freely in Engineering Mechanics. Length is measured in feet (ft), time in seconds (s),and force in pounds (lb.). The unit of mass, called a slug, 1 slug is equal to the amount of matter acceleratedat 1 ft /s2 when acted upon by a force of 1 lb. (1slug=1Ib s^2/ft).

Table 1: Units of measurement

Name	Length	Time	Mass	Force
International Systems of Units SI	meter	seconds	kilogram	Newton
	m	s	kg	N*
US Customary FPS	foot	second	Slug*	Pound
	ft	s	Ib. s^2/ft	Ib

*Derived unit

Table 2: Units conversion

Quantities	Unit of Measurement (FPS)	*equals*	Unit of Measurement (SI)
Force	Lb		4.448 N
Mass	Slug		14.59 kg
Length	Ft		0.3048

1.4 Prefixes

When a numerical quantity is either very large or very small, the units used to define its size may be modified by using a prefix. Some of the prefixes used in the SI system are shown in Table 3. Each represents a multiple or submultiples of a unit which, if applied successively, moves the decimal point of a numerical quantity to

every third place. For example, 4000000N=4000kN (kilo-newton) = 4MN (meganewton), or 0.005m=5mm (millimeter).

Table 3:

	Exponential form	Prefix	SI Symbol
	Multiple		
1000000000	10^9	Giga	G
1000000	10^6	Mega	M
1000	10^3	kilo	K
	Submultiple		
0.001	10^{-3}	mili	m
0.000001	10^{-6}	micro	μ
0.000000001	10^{-9}	nano	n

2. Force and Force Systems

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

The characteristics of a force, which describe its external effect on a rigid body, are

a) its magnitude,

b) its direction (sense and slope), and

c) the location of any point on its line of action.

When several forces act in a given situation, they are called a system of forces or force system. Force systemcan be classified according to the arrangement of the lines of action of the forces of the system as follows:

- **Collinear**: All forces of the system have a common line of action.

- **Concurrent, coplanar:** The action lines of all the forces of the system are in the same plane and

intersectat a common point.

- **Parallel, coplanar:** The action lines of all the forces of the system are parallel and lie in the same plane.
- **Concurrent, noncoplanar:** The action lines of all the forces of the system intersect at a common point,but they are not all in one plane.
- **Parallel, noncoplanar:** The action lines of all the forces of the system are parallel, but they are not all inthe same plane.
- **Nonconcurrent, nonparallel, coplanar:** The action lines of all the forces of the system are in the sameplane, but they are not all parallel and they do not all intersect at a common point.
- **Nonconcurrent, nonparallel, noncoplanar:** The action lines of the forces of the system do not allintersect at a common point, they are not all parallel, and they do not all lie in the same plane.

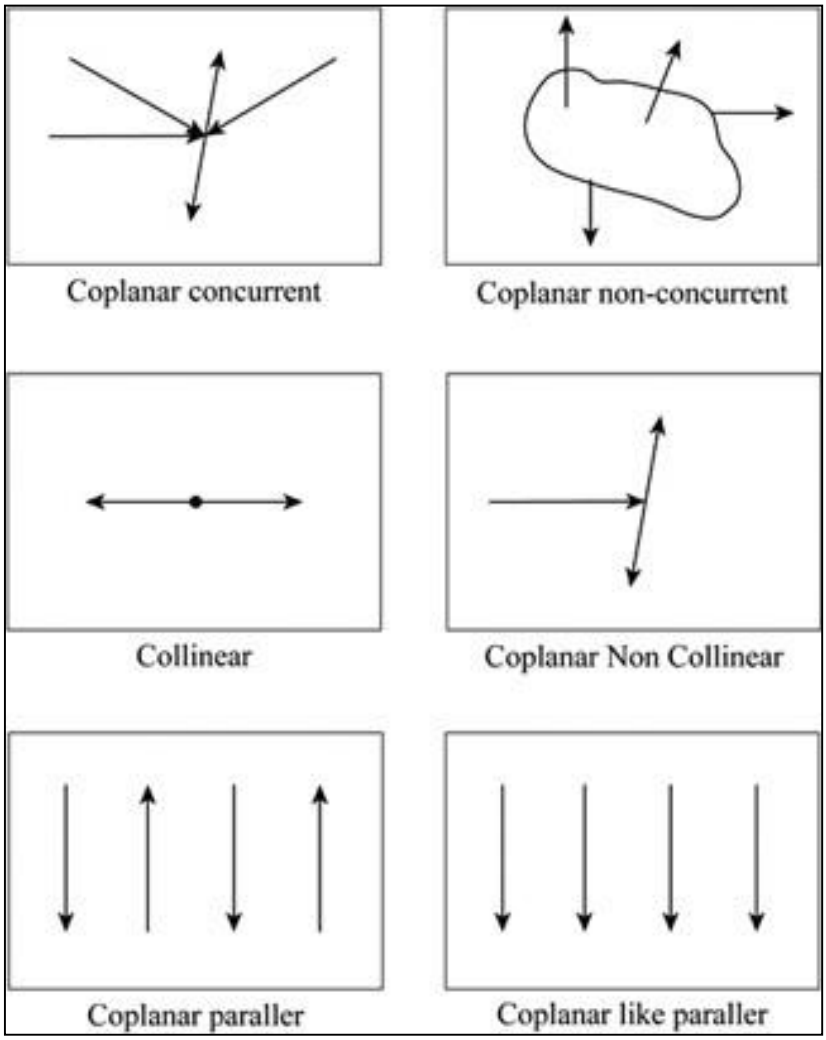


Fig. 2: Force systems

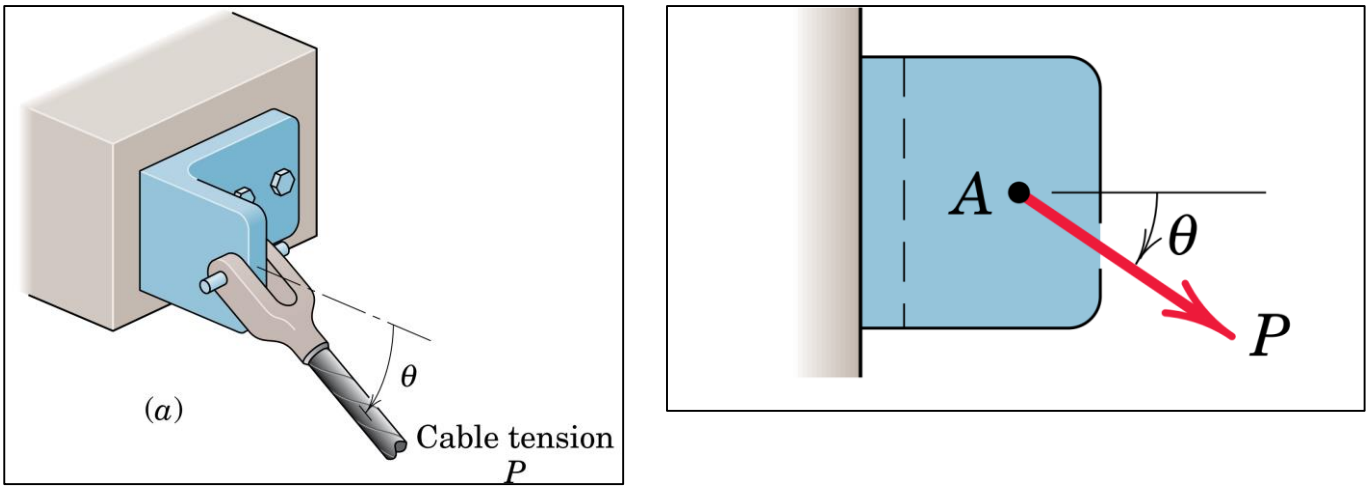


Fig. 3

In Fig 3, the effect of this action on the bracket depends on P, the angle θ , and the location of the point of application A. Changing any one of these three specifications will alter the effect on the bracket, such as the force in one of the bolts which secure the bracket to the base, or the internal force and deformation in the material of the bracket at any point.

Thus, the complete specification of the action of a force must include its *magnitude, direction, and point of application,* and therefore we must treat it as a fixed vector.

3. Two-Dimensional Force Systems

The most common two-dimensional resolution of a force vector is into rectangular components. It follows from the parallelogram rule that the vector $\boldsymbol{F}$ of Fig. 4 may be written as

$$\boldsymbol{F} = \boldsymbol{F}_x + \boldsymbol{F}_y \qquad (1)$$

where $\boldsymbol{F}_x$ and $\boldsymbol{F}_y$ are vector components of $\boldsymbol{F}$ in the x- and y-directions. Each of the two vector components may be written as a scalar times the appropriate unit vector (**i**. and **j).** Thus, we may write:

$$\boldsymbol{F} = F_x\boldsymbol{i} + \boldsymbol{F}_y\boldsymbol{j} \qquad (1)$$

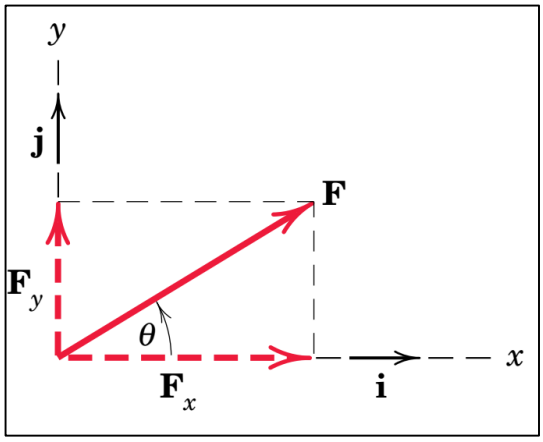


Fig. 4

The scalar components can be positive or negative, depending on the quadrant into which F points. For the force vector of Fig. 4, the x and y scalar components are both positive and are related to the magnitude and direction of F by

$$F_x = F\cos\theta \qquad (2)$$

$$F_y = F\sin\theta \qquad (3)$$

$$F = \sqrt{F_x^2 + F_y^2} \qquad (4)$$

$$\theta = \tan^{-1}\frac{F_y}{F_x} \qquad (5)$$

Example 1:

The forces $F1$, $F2$, and $F3$ in Fig. 5, 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.

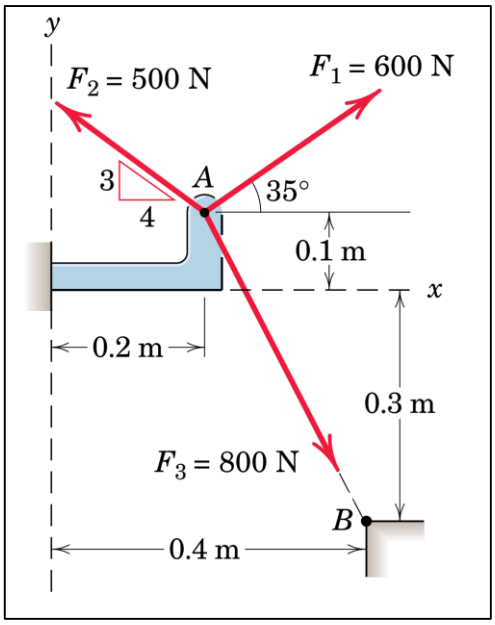


Fig. 5

Solution.

The scalar components of $F1$, from Fig. 6.a, are

$$F1_x = 600\,cos35^0 = 491N$$

$$F1_y = 600\,sin35^0 = 344N$$

The scalar components of F2, from Fig. 6.b, are

$$F2_x = -500 * \frac{4}{5} = -400N$$

$$F2_y = 500 * \frac{3}{5} = 300N$$

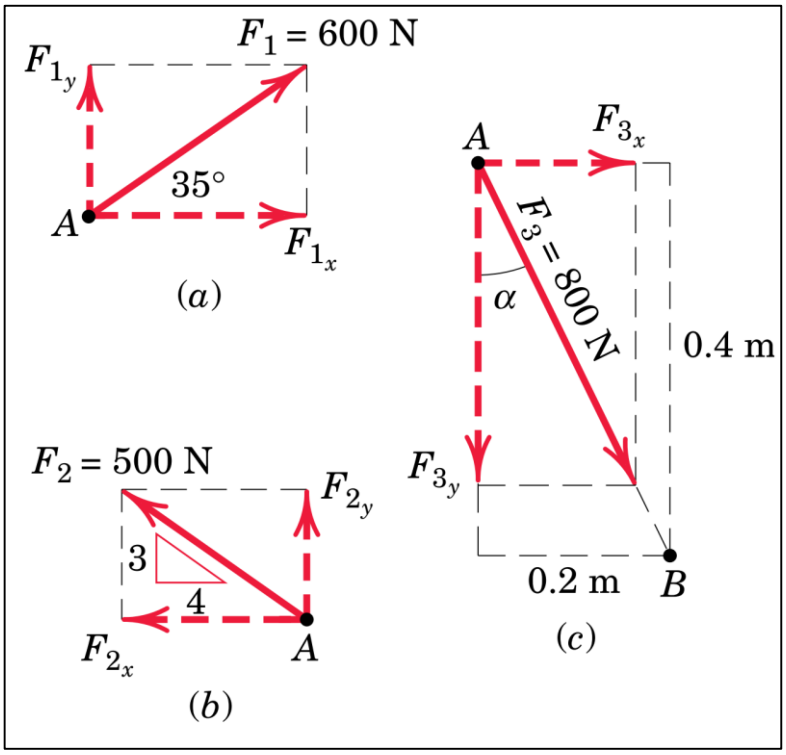


Fig. 6

Note that the angle which orients $F2$ 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 $F2$ is negative by inspection.

The scalar components of $F3$ can be obtained by first computing the angle of Fig. 6.c.

$$\alpha = tan^{-1}\frac{0.2}{0.4} = 26.6^0$$

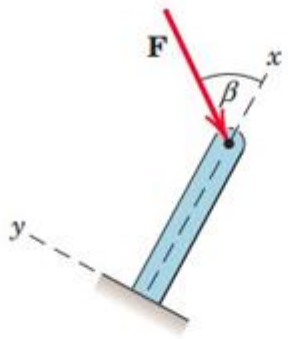
Then,

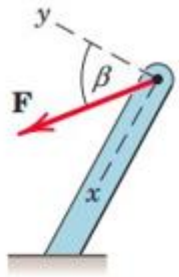
$$F3_x = F3\,sin\alpha = 800\,sin26.6^0 = 358N$$

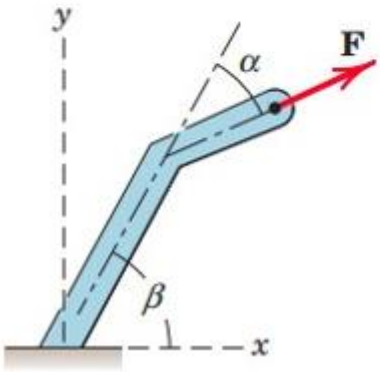
$$F3_y = -F3\,cos\alpha = -800cos26.6^0 = -716N$$

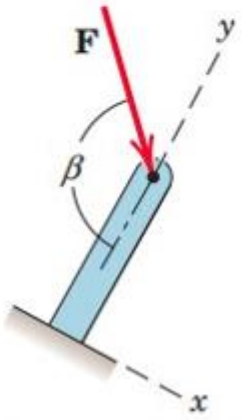
H.W.:

Find the x and y scalar components of the force F for each case shown below:









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