Unit 1

Section One: Reading Comprehension

Failure by Elastic Deflections

The maximum load that may be applied to a member without causing it to cease to function properly may be limited by the permissible elastic strain or deflection of the member. Elastic deflection that may cause damage to a member can occur under these different conditions:

(a) Deflection under conditions of stable equilibrium, such as the stretch of a tension member, the angle of twist of a shaft, and the deflection of a beam, Particularly under gradually applied (so-called static) loads.

(b) Buckling, or the rather sudden deflection associated with unstable equilibrium and often resulting in total collapse of the member, which occurs, for example, when an axial load that is applied gradually to a very slender column exceeds slightly the Euler critical load, or when an external fluid pressure is applied to a cylindrical shell or thin-walled pipe that suddenly collapses when the pressure reaches a critical value.

(c) Elastic deflections that are the amplitudes of the vibration of a member sometimes are associated with failure of the member resulting from objectionable noise, shaking force, collision of moving parts with stationary parts, etc., which result from the vibration.

When a member fails by elastic deformation, the significant equations for design are those that relate loads and elastic deflection. For example, the equations for the three members mentioned under (a) are: $e = PL / (AE)$, $\theta = TL / (GJ)$, and $\delta = \alpha\, [WL^3 / (EI)]$ in which α is a constant for a given beam and given location in the beam depending on the type of supports and the type of loading. It will be noted that these equations contain the significant property of the material involved in the elastic deflection, namely the modulus of elasticity E (sometimes called the stiffness) or $G = E / [2 (1 + v)]$. The stresses set up by the loads are not the significant quantities; that is, the stresses do not limit the loads that can be applied to the member without causing structural damage and, hence, the strength properties of the material (e.g., yield stress) are not of primary importance. In different words, if a member of given dimensions fails to perform its load resisting function because of excessive elastic deflection, its load carrying capacity is not increased by making the member of stronger material, but rather by making it stiffer by using a material with a higher modulus of elasticity or by changing the shape and dimensions of the member. As a rule, however, the most effective method of decreasing the deflection of a member is by changing the shape or increasing the dimensions of its cross section, rather than by making the member of a stiffer material; moreover, if a member is made of steel, its stiffness cannot be increased greatly by substituting another material, since steel is one of the stiffest of structural materials available.

Boresi A. P. & Sidebottom O. M. (1985). Advanced Mechanics of Materials. Wiley & Sons Inc., p. 100.

Part I. Comprehension Exercises

A. Put "T" for true and "F" for false statements. Justify your answers.

.... 1. A member, if pulled, may fail by elastic deflection.

.... 2. Elastic deflections are vibration amplitudes of a member.

.... 3. Failure by buckling is not considered a deflection failure.

.... 4. Changing the cross-section shape is the best way to reduce deflections.

.... 5. By strengthening a material, one does not reduce the deflections.

B. Choose a, b, c, or d which best completes each item.

1. A stable member ....
   a. may not fail by excessive elastic deflection
   b. would probably buckle prior to failure
   c. would become unstable when an axial load is applied at its ends
   d. may fail by excessive elastic deflection
2. When an object collides with a stationary member, ...
   a. the member will buckle
   b. the member may fail because of vibrations
   c. the stresses set up by the object are insignificant
   d. it will crack
3. When one speaks of failure due to the elastic deflection, he is concerned about ....
   a. axial and flexural deformation
   b. torsional twist
   c. only flexural deformation
   d. strength
4. Regarding a steel member, the author believes that the ....
   a. material strength is always the prime cause of failure
   b. member becomes stiffer if its modulus of elasticity is increased
   c. member becomes stiffer if the dimension of its cross-section is increased
   d. stiffer members are stronger
5. When a member fails due to excessive deflection, its load-carrying capacity will increase ....
   a. if it is replaced by a stronger material (higher yield point)
   b. if a stiffer material with higher modulus of elasticity is used
   c. if it is made of steel
   d. if its weight changes

C. Answer the following questions orally.

1. What factors could decrease deflection of a member?
2. Under which conditions, could a member be damaged due to elastic deflection?
3. What relationship ought to be used for the design of a beam, to prevent it from failing by elastic deflection due to torsion?
4. Why should a designer be concerned with deflection?
5. What is the best way to increase the strength of a steel member?

Part II. Language Practice

A. Choose a, b, c, or d which best completes each item.

1. .... of a material is defined as its ability to absorb energy.

   a. Elasticity　　b. Breaking

   c. Toughness　　d. Resiling

2. If the .... of a simply supported steel beam at its midspan is high, it is prudent to use a larger section.

   a. elasticity　　b. stress

   c. toughness　　d. deflection

3. Over the years, at least six failure .... have been proposed.

   a. criteria　　b. suggestions

   c. characters　　d. facts

4. Experimental evidence indicates that some materials fail due to excessive ....

   a. toughness　　b. elasticity

   c. compressibility　　d. shearing stress

5. A rational procedure of .... requires that a general mode of failure under assumed service conditions be determined.

   a. designing　　b. design

   c. failing　　d. breaking

B. Fill in the blanks with the appropriate forms of the words given.

1. fail

a. Glass .... in a brittle manner.

b. The .... of steel members is initiated by yielding.

2. plastic

a. The .... index is a measure of the soil's strength

b. In general, ... have nonlinear stress-strain relationships.

3. stable

a. The study of the .... of structural members is very complicated.

b. A column may become .... if the axial load is increased substantially.

4. ductile

a. Steel is classified as a .... material.

b. The .... of steel is inversely proportional to its strength.

5. stiff

a. The .... of a member increases as it is shortened.

b. By .... a member, its deformation decreases.

C. Fill in the blanks with the following words.

recrystallization	columns	failure	metal
yielding	inplane	modes	axially

Another condition that may cause a member to fail is inelastic (plastic) deformation of a considerable portion of the member, denoted by extensive .... to differentiate it from (localized) yielding of a very small portion of a member. Again, we note that these modes of .... are most significant with regard to simple structural members such as .... loaded members, torsion members, ..., or possibly thin sheets or plates subject to .... forces. These .... of failure may also be applied fairly directly to pressure vessels and pipes, for example. Extensive yielding of a (an) .... member may result from either one of the two different conditions, depending on whether the existing temperature of the member is above or below the .... temperature of the metal.

D. Put the following sentences in the right order to form a paragraph. Write the corresponding letters in the boxes provided.

a. In particular, it requires a comprehensive stress analysis of the system.

b. To design a structural part or system to perform a given function, the designer must have a clear understanding of the possible ways or modes by which the part or system may fail to perform the function.

c. Since the response of a structural system depends strongly on the material used, the mode of failure depends strongly on the type of material.

d. In general, the determination of modes of failure requires extensive knowledge of the response of a structural system to loads.

e. In other words, the designer must determine possible modes of failure of the system and establish suitable failure criteria that accurately predict the various modes of failure.

1	2	3	4	5

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Section Two: Further Reading

Modes of Failure

When a structural member is subjected to loads, its response depends not only on the type of material from which it is made, but also on the environmental conditions and the manner of loading. Depending on how the member is loaded, it may fail by *excessive displacement*, which results in the member being unable to perform its design function; it may fail by *plastic deformation (yielding)*, which may cause a permanent undesirable change in shape; it may fail due to a fracture (break), which depending on the material and the nature of loading, may be of a *ductile type* preceded by appreciable plastic deformation or of a *brittle type* with little or no prior plastic deformation. Materials such as glasses, ceramics, rocks, plain concrete, and cast iron are examples of materials (brittle materials) that fracture in a brittle manner under normal environmental conditions and the slow application of tension load. In uniaxial compression, they also fracture in a brittle manner, but the nature of the fracture is quite different from that in tension. Depending on a number of conditions such as environment, rate of load, nature of loading, and presence of cracks or flaws, structural metals may exhibit ductile or brittle fracture.

One type of loading that may result in brittle fracture of ductile metals is that of repeated loads. For example, if a uniaxially loaded bar with smooth surface is subjected to repeated cycles of alternately applied tensile and compressive loads of equal magnitude, it may fail by fracture (usually in a brittle manner for high cycle fatigue) at a stress level considerably below the magnitude of stress that causes failure by fracture under a noncyclic static load. Fracture of a structural member under repeated loads is commonly called *fatigue fracture* or *failure*. Fracture by fatigue may start by the initiation of one or more small cracks, usually in the neighborhood of the maximum critical stress in the member. Repeated cycling of the load causes the crack or cracks to propagate until the structural member is no longer able to carry the load across the cracked region, and the member ruptures.

Another manner in which a structural member may fail is that of elastic or plastic instability. In this failure mode the structural member may undergo large displacement from its design configuration when the applied load reaches a critical value, the so-called *buckling load* (or *instability load*). This type of failure may result in excessive displacement or loss of ability (because of yielding or fracture) to carry the design load. In addition to the above failure modes, a structural member may fail because of environmental corrosion (chemical action).

To elaborate upon the modes of failure of structural members we discuss more fully the following categories of failure modes:

1. Failure by excessive deflection
2. Failure by yielding
   (a) Ordinary (room) temperatures
   (b) Elevated temperatures (creep)
3. Failure by fracture
   (a) Sudden fracture of brittle materials
   (b) Fracture of cracked or flawed members
   (c) Progressive fracture (fatigue)
   (d) Fracture with time at elevated temperatures

These failure modes and their associated failure criteria are most meaningful for simple structural members (for example, tension members, columns, beams, circular cross section torsion members). For more complicated two and three-dimensional problems, the significance of such simple failure modes is open to question.

Many of these modes of failure for simple structural members are well-known to engineers. However, under unusual conditions of load or environment, new types of failure modes may occur. For example in nuclear reactor systems, cracks in pipe loops have been attributed to stress-assisted corrosion cracking, with possible side effects attributable to residual welding stresses.

Boresi A. P. & Sidebottom O. M. (1985). Advanced Mechanics of Materials. Wiley & Sons Inc., p. 100.

Comprehension Exercises

A. Put "T" for true and "F" for false statements. Justify your answers.

…….. 1. Concrete is a ductile material.

…….. 2. When a member buckles, it may fail by excessive deflection.

…….. 3. A member may fail by a load below its load-carrying capacity.

…….. 4. Fatigue is the fracture of a material under repeated loading.

…….. 5. Failure by fatigue is always accompanied by cracks.

B. Choose a, b, c, or d which best completes each item.

1. In general glass breaks in a brittle manner which ....

   a. can be sudden

   b. is quite common in plastics

   c. occurs at high temperatures

   d. is accompanied by large deformations

2. Fracture of structural members under cyclic loading is called ....

   a. ductile fracture b. brittle fracture

   c. fatigue failure d. lamellar tear

3. When a member fails due to fatigue, the stress level in the member ....

   a. is always below the stress level that causes failure by fracture

   b. may be below the stress level that causes failure by fracture

   c. is usually more than the material's yield strength

   d. is always above the stress level that causes failure by fracture

4. In general flaws in glass promote ....

   a. ductile fracture b. fatigue failure

   c. brittle fracture d. rupture

5. In addition to the environment and load rate, ... affects the type of failure.

   a. Poisson's ratio b. crack

   c. density of the member d. shear lag

C. Write answers to the following questions.

1. What are the different modes of failure?
2. Why do flaws decrease the load-carrying capacity of a member?
3. Which factors affect fatigue cracking?
4. Why does glass break in a brittle manner?
5. Which factors affect the type of failure?

❋ ❋ ❋

Section Three: Translation Activities

A. Translate the following passage into Persian.

Fracture of Cracked or Flawed Members

A member made of ductile material and subjected to uniaxial stress rarely fractures under static loads because structural damage (failure) usually occurs by general yielding force before fracture takes place. However, at regions of abrupt changes in section and at edges of defects, for example, where the disruption of stress is nonuniform and the state of stress is more generally triaxial, failure of the member sometimes occurs as a brittle fracture, especially when subzero temperatures are encountered, even though the material is classed as ductile and the member is subjected to static loads. If high stress concentrations are present, the tendency toward brittle fracture is greatly increased; the tendency is further increased under a combination of impact loads and subzero temperatures.

B. Find the Persian equivalents of the following items and write them in the spaces provided.

1. brittle ....

2. buckling ....
3. cast ....
4. ceramics ....
5. collapse ....
6. crack ....
7. cyclic ....
8. deflection ....
9. ductile ....
10. equilibrium ....
11. failure ....
12. fatigue ....
13. flaw ....
14. fracture ....
15. instability ....
16. noncyclic ....
17. propagation ....
18. recrystallization ....
19. rupture ....
20. stiffness ....
21. triaxial ....
22. twist ....
23. uniaxially ....
24. yielding ....

Unit 2

Section One: Reading Comprehension

Force Systems

Force

Before dealing with a group or *system* of forces it is necessary for us to examine the properties of a single force in some detail. A force has been defined as the action of one body on another. We find that force is a vector quantity, since its effect depends on the direction as well as on the magnitude of the action and since forces may be combined according to the parallelogram law of vector combination. The action of the cable tension on the bracket in Figure 2-1a is represented in Figure 2-1b by the force vector **P** of magnitude P. The effect of this action on the bracket will depend 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, as could be detected, for instance, by the force in one of the bolts which secure the bracket to the base or the internal stress and strain 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*, in which case it is treated as a fixed vector.

Force is applied either by direct mechanical contact or by remote action. Gravitational and magnetic forces are applied by remote action. All other forces are applied through direct physical contact.

The action of a force on a body can be separated into two effects, *external* and *internal*. For the bracket of Figure 2-1 the effects of **P** external to the bracket are the reactions or forces (not shown) exerted on the bracket

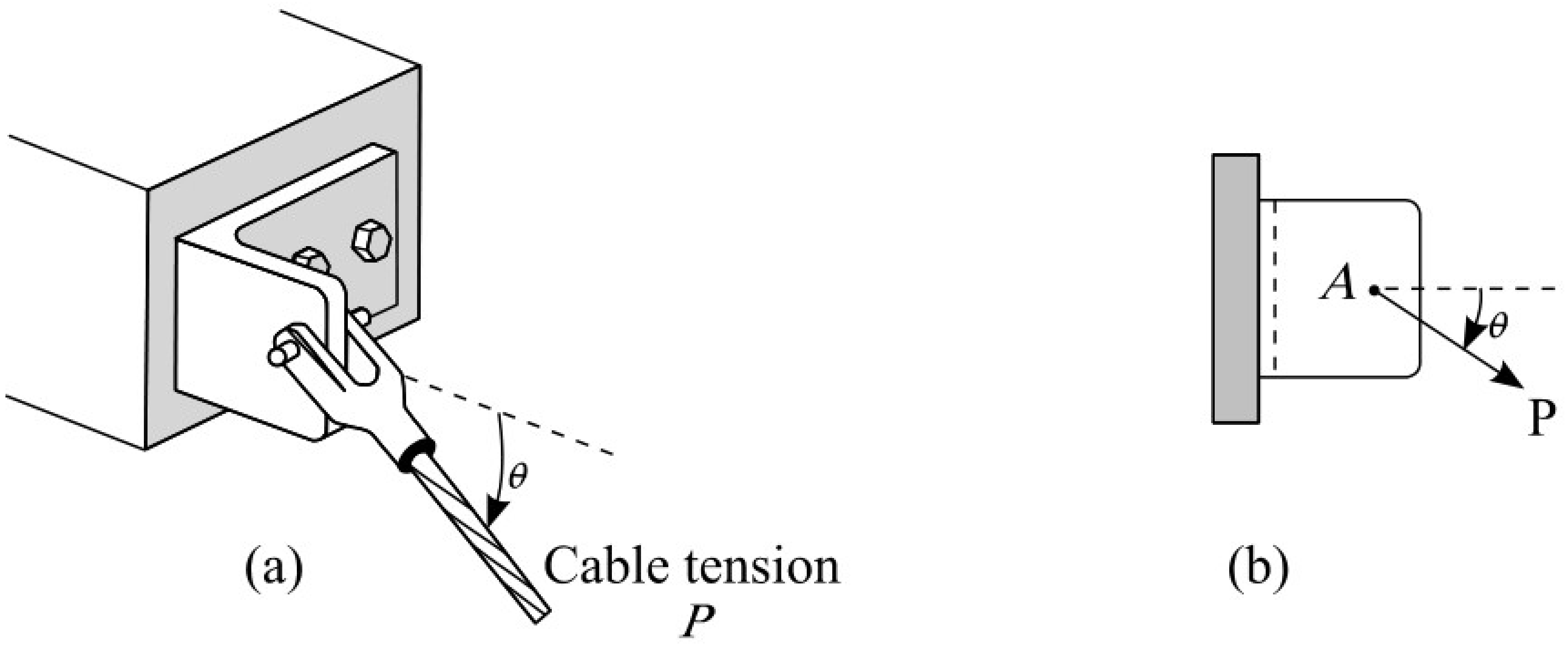


Figure 2-1.

by the foundation and bolts because of the action of **P**. Forces external to a body are then of two kinds, *applied* forces and *reactive* forces. The effects of **P** internal to the bracket are the resulting internal stresses and strains distributed throughout the material of the bracket. The relation between internal forces and internal strains involves the material properties of the body and is studied in strength of materials, elasticity, and plasticity.

In dealing with the mechanics of rigid bodies, where concern is given only to the net *external* effects of forces, experience shows us that it is not necessary to restrict the action of an applied force to a given point. Hence the force **P** acting on the rigid plate in Figure 2-2 may be applied at *A* or at *B* or at any other point on its action line, and the net external effects of **P** on the bracket will not change. The external effects are the force exerted on the plate by the bearing support at *O* and the force exerted on the plate by the roller support at *C*. This conclusion is described by the *principle of transmissibility*, which states that a force may be applied at any point on its given line of action without altering the resultant effects of the force *external* to the *rigid* body on which it acts. When only the resultant external effects of a force are to be investigated, the force may be treated as a *sliding* vector, and it is necessary and sufficient to specify the *magnitude*, *direction*, and *line of action of the force*. Since this book deals essentially with the mechanics of rigid bodies, we will treat almost all forces as sliding vectors for the rigid body on which they act.

Forces may be either *concentrated* or *distributed*. Actually every contact force is applied over a finite area and is therefore a distributed force. When the dimensions of the area are very small compared with the other dimensions of the body, we may consider the force to be concentrated at a point with negligible loss of accuracy. Force may be distributed over an area, as in the case of mechanical contact, or it may be distributed over a volume when gravity or magnetic force is acting. The *weight* of a body is the force of gravitational attraction distributed over its volume and may be taken as a concentrated force acting through the center of gravity. The position of the center of gravity is frequently obvious from considerations of symmetry. If the position is not obvious, then a separate calculation will be necessary to locate the center of gravity.

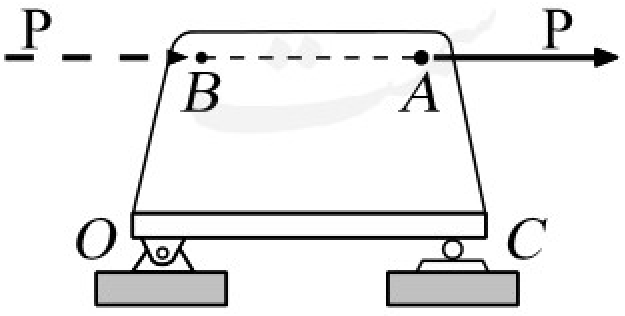


Figure 2-2.

Meriam, J. L. Engineers Mechanics, Volume 1, Statics. Wiley and Sons Inc., p. 14.

Part I. Comprehension Exercises

A. Put "T" for true and "F" for false statements. Justify your answers.

…….. 1. The complete specification of a force includes its magnitude, direction and point of application.

…….. 2. Weight of a body is not considered as a force.

.... 3. The principle of transmissibility applies only to both internal and external forces.

.... 4. Elasticity relates stresses and stains within a body.

.... 5. The principle of transmissibility only applies to rigid bodies.

B. Choose a, b, c, or d which best completes each item.

1. Using the principle of transmissibility, one ....
   a. can alter the point of application of a given load acting on a rigid body
   b. can find the resultant of a few forces acting on a rigid body
   c. may solve for statically determinate structures
   d. may find the direction, magnitude and line of action of a force
2. The principle of transmissibility is applicable to ....
   a. rigid bodies
   b. internal forces
   c. both internal and external forces
   d. the resultant of a set of forces
3. According to the passage the weight of a body may be considered as a (an) ....
   a. external force which may be treated as a sliding vector
   b. internal force acting over the volume of the body
   c. concentrated force acting through the center of gravity
   d. uniformly distributed load acting through the center of gravity
4. Point of application of a force on a rigid body ....
   a. lies at the center of gravity of the body
   b. lies along the line of action of the force
   c. is sufficient for determining the resulting force on the body
   d. is determined by the line of action
5. In general, weight of a body is classified as a (an) ....
   a. distributed force

b. concentrated force

c. internal distributed force

d. internal concentrated force

C. Answer the following questions orally.

1. What types of forces can act on a body?
2. When can one alter the point of application of a force on a body?
3. What simplification could be made for showing the weight of a body?
4. Where is the point of application of the body weight?
5. Which specifications are required to define the complete action of a force?

Part II. Language Practice

A. Choose a, b, c, or d which best completes each item.

1. The .... of a system of forces is the simplest force combination that can replace the original forces.

a. average b. minimal

c. resultant d. norm

2. Varingnon's .... is the same as the principle of moments.

a. principle b. theorem

c. methodology d. phenomenon

3. In general, a force can be .... into three components.

a. resulted b. assembled

c. computed d. resolved

4. The moment direction is ....

a. straight b. cyclic

c. circular d. counterclockwise

5. The .... of a force is always accompanied by an equal and opposite force.

a. aim	b. result
c. action	d. dimension

B. Fill in the blanks with the appropriate forms of the words given.

1. concurrent

a. The point of .... of two vectors is the point they intersect.

b. Parallel forces are always non-.......... .

2. result

a. The .... of two vectors A and B is a vector.

b. The .... findings of this article should be used to investigate the characteristics of vectors.

3. gravity

a. It can be stated that the geometric center of a mass and its center of .... could be the same point.

b. The .... forces are directed towards the center of earth.

4. force

a. In general, a body could be .... to deform in a desired fashion.

b. All .... acting on a body may be replaced by one force.

5. elastic

a. Steel is an .... material.

b. Theory of .... includes discussions of stress and strain.

C. Fill in the blanks with the following words.

earth	experiment	mass	resultant	force
body	structures	remote	symmetry	

One of the most common forces is due to gravitational attraction. This .... affects all elements of .... of a body and is, therefore, distributed throughout it. The .... of the gravitational forces on all elements is the weight W = mg of the body, which passes through the center of mass G and is directed towards the center of .... for earthbound .... The position of G is frequently obvious from the geometry of the ...., particularly where conditions of .... exist. When the position is not readily apparent, the location of G must be calculated or determined by .... Similar remarks apply to the .... action of magnetic and electric forces.

D. Put the following sentences in the right order to form a paragraph. Write the corresponding letters in the boxes provided.

a. Most problems in mechanics deal with a system of forces and it is generally necessary to reduce the system to its simplest form in describing its actions.

b. The equilibrium of a body is the condition where the resultant of all forces that act on it is zero.

c. In the previous four articles we have developed the properties of force, moment and couple.

d. With the aid of these descriptions we are now ready to describe the resultant action of a system of forces.

e. The resultant of a system of forces is the simplest force combination that can replace the original forces without altering the external effect of the system on the rigid body to which the forces are applied.

1	2	3	4	5

Force

A force may be measured either by comparison with other known forces, using a mechanical balance, or by the calibrated movement of an elastic element. All such comparisons or calibrations have as their basis a primary standard. The standard unit of force in SI units is the newton (N) and in the U.S. customary system is the pound (lb).

The characteristics of a force expressed by Newton's third law must be carefully observed. The *action* of a force is always accompanied by an *equal* and *opposite* reaction. It is essential for us to fix clearly in mind which force of the pair is being considered. The answer is always clear when the body in question is *isolated* and the force exerted *on* that body (not *by* the body) is represented. It is very easy to make a careless mistake and consider the wrong force of the pair unless we distinguish carefully between action and reaction.

Two forces $\mathbf{F}_1$ and $\mathbf{F}_2$ that are concurrent may be added by the parallelogram law in their common plane to obtain their sum or *resultant* **R** as shown in Figure 2-3a. If the two concurrent forces lie in the same plane but are applied at two different points as in Figure 2-3b, by the principle of transmissibility we may move them along their lines of action and complete their vector sum **R** at the point of concurrency. The resultant **R** may replace $\mathbf{F}_1$ and $\mathbf{F}_2$ without altering the external effects on the body upon which they act. The triangle law may also be used to obtain **R**, but it will require moving the line of action of one of the forces as shown in Figure 2-3c. In Figure 2-3d the same two forces are added, and although the correct magnitude and direction of **R** are preserved, we lose the correct line of action, since **R** obtained in the way does not pass through A. This type of combination should be avoided. Mathematically the sum of the two forces may be written by the vector equation

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

In addition to the need for combining forces to obtain their resultant, we often have occasion to replace a force by its *components* which act in two specified directions. Thus the force **R** in Figure 2-3a may be replaced by or *resolved* into two components $\mathbf{F}_1$ and $\mathbf{F}_2$ with these specified directions merely by completing the parallelogram as shown to obtain the magnitudes $\mathbf{F}_1$ and $\mathbf{F}_2$.

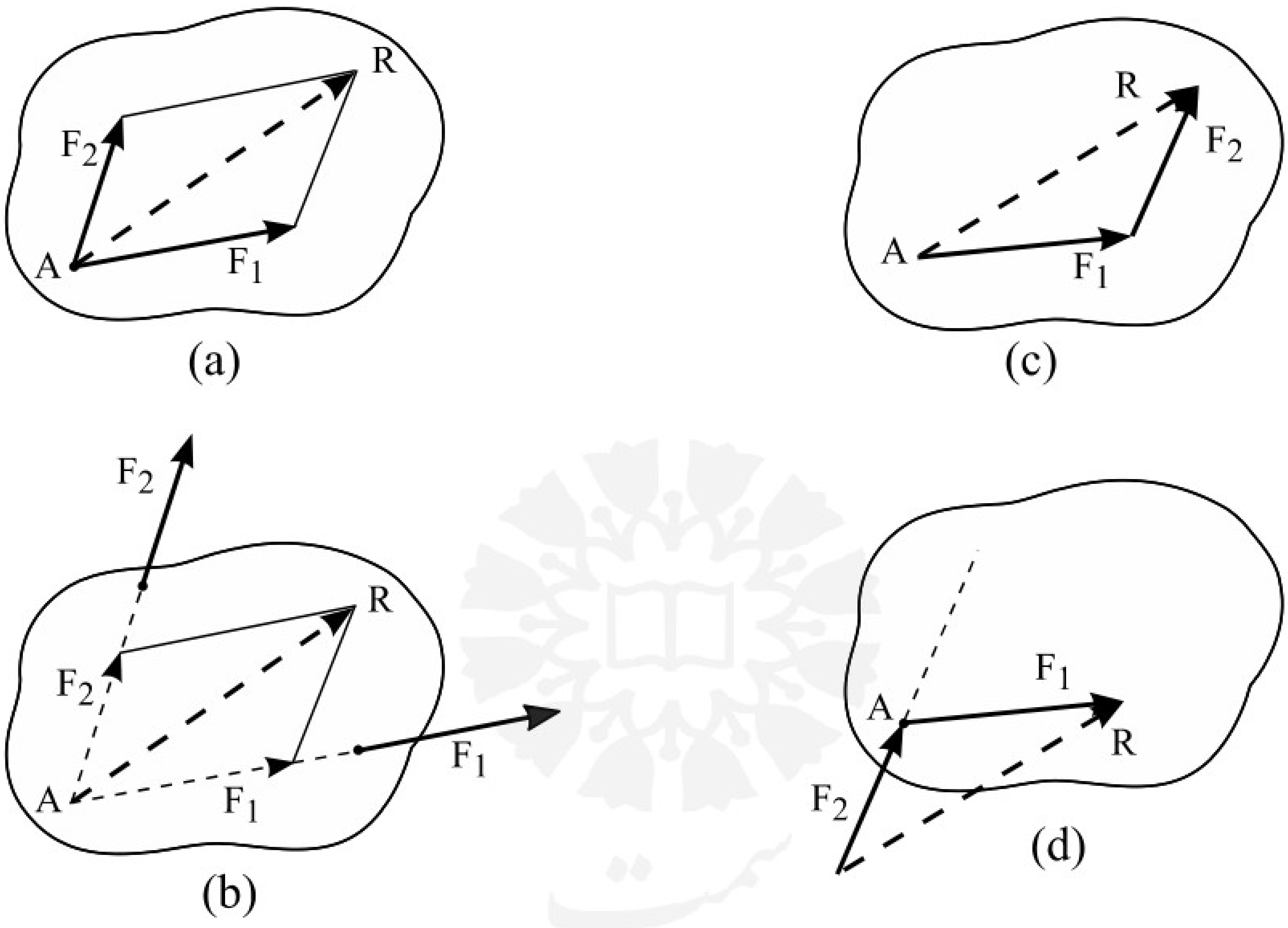


Figure 2-3.

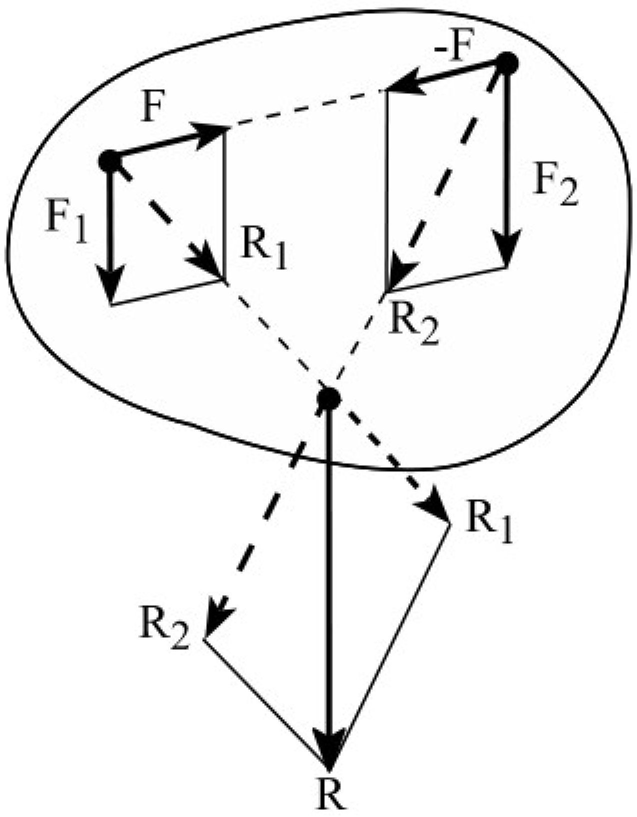


Figure 2-4.

A special case of addition is presented when the two forces $\mathbf{F}_1$ and $\mathbf{F}_2$ are parallel, Figure 2-4. They may be combined by first adding two equal, opposite, and collinear forces **F** and **-F** of convenient magnitude which taken together produce no external effect on the body. Adding $\mathbf{F}_1$ and **F** to produce $\mathbf{R}_1$ and combining with the sum $\mathbf{R}_2$ of $\mathbf{F}_2$ and -**F** yield the resultant **R** correct in magnitude, direction, and line of action. This procedure is also useful in obtaining a graphical combination of two forces that are almost parallel and hence have a point of concurrency which is remote and inconvenient.

Two-Dimensional Force Systems – Rectangular Components

The most common two-dimensional resolution of a force **F** is resolution into *rectangular components* $\mathbf{F}_x$ and $\mathbf{F}_y$ as shown in Figure 2-5. It should be immediately evident from the Figure that:

$$\mathbf{F}_x = \mathbf{F}\cos\theta \qquad \mathbf{F} = (\mathbf{F}_x^{\,2} + \mathbf{F}_y^{\,2})^{½} \qquad (2\text{-}1)$$

$$\mathbf{F}_y = \mathbf{F}\sin\theta \qquad \theta = \tan^{-1}(\mathbf{F}_y / \mathbf{F}_x$$

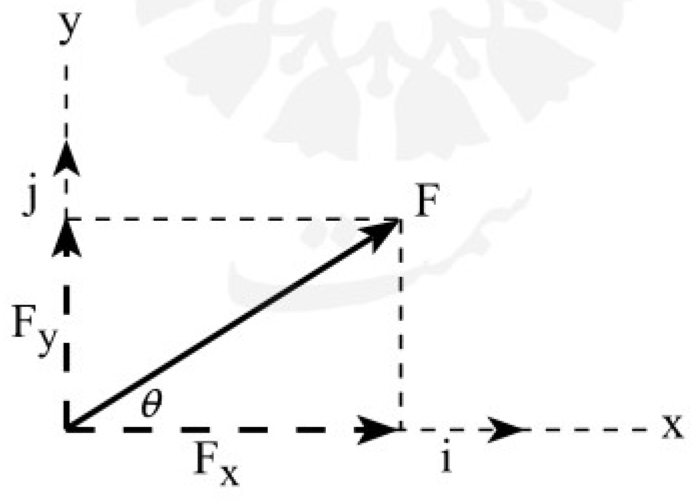


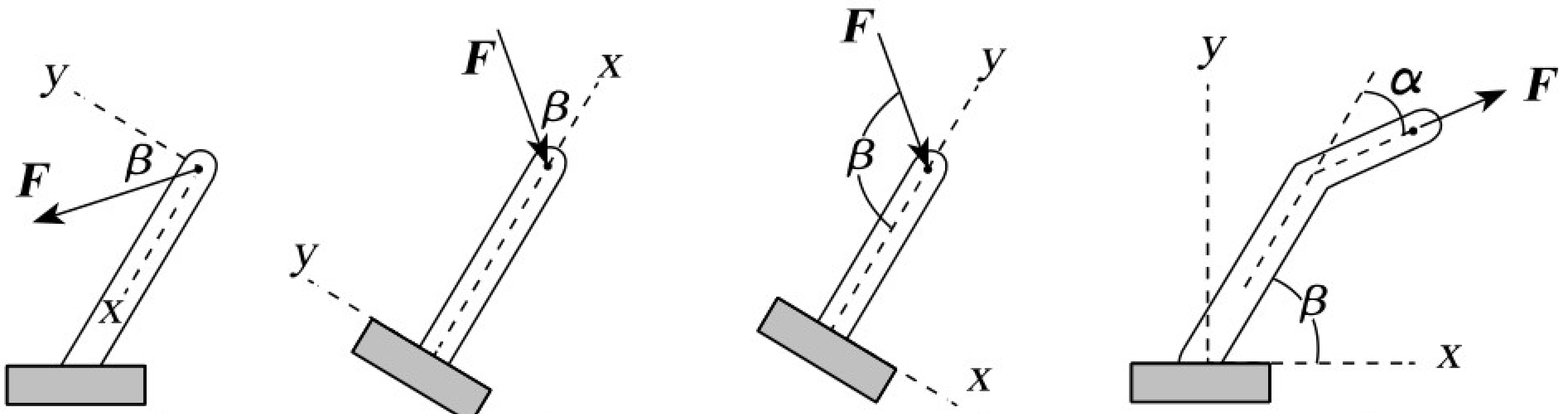
Figure 2-5.

Where **F** is the magnitude of **F** and where $\mathbf{F}_x$ and $\mathbf{F}_y$ are the magnitudes of $\mathbf{F}_x$ and $\mathbf{F}_y$. If we introduce unit vectors **i** and **j** in the x- and y-directions as shown in Figure 2-5, we may write the vector equation

$$\mathbf{F} = \mathbf{F}_x + \mathbf{F}_y = \mathrm{i}\mathbf{F}_x + \mathrm{j}\mathbf{F}_y \qquad (2\text{-}2)$$

To eliminate any ambiguity it is desirable to show the components of a force in dotted lines, as in Figure 2-5, and the force in a full line, or vice versa. With either of these conventions it will always be clear that a force and its components are being represented and not three separate forces as would be implied by three solid-line vectors.

Actual problems do not come with reference axes, so their assignment is a matter of arbitrary convenience, and the choice is frequently up to the student. The logical choice is usually indicated by the manner in which the geometry of the problem is specified. When the principal dimensions of a body are given in the horizontal and vertical directions, for example, then assignment of reference axes in these directions is generally convenient. However, dimensions are not always given in horizontal and vertical directions, angles need not be measured counterclockwise from the x-axis, and the origin of coordinates need not be on the line of action of a force. Therefore, it is essential that we be able to determine the correct components of a force no matter how the axes are oriented or how the angles are measured. Figure 2-6 suggests a few typical examples of resolution situations in two dimensions, the results of which should be readily apparent. Thus it is seen that memorization of Eqs. 2/1 is not a substitute for an understanding of the parallelogram law and for the correct projection of a vector onto a reference axis. A neatly drawn sketch always helps to clarify the geometry and avoid error.



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

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

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

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

Figure 2-6.

Meriam, J. L. Engineers Mechanics, Volume 1, Statics. Wiley and Sons Inc., p. 18.

Comprehension Exercises

A. Put "T" for true and "F" for false statements. Justify your answers.

…….. 1. Newton's third law states: The action of a force is always accompanied by an equal and opposite reaction.

…….. 2. Under given circumstances, one may move the load along its line of action.

…….. 3. There is no special regulation for selecting a coordinate system.

…….. 4. The origin of a coordinate system must be along the line of action of a force.

…….. 5. The parallelogram law does not apply to concurrent forces.

B. Choose a, b, c, or d which best completes each item.

1. The logical choice for selecting a coordinate system ....

   a. depends on the manner in which the geometry of the problem is specified

   b. depends on horizontal and vertical directions

   c. is demonstrated by a mathematical formula

   d. depends on the resultant

2. The resultant of two forces can be determined by ....

   a. projecting the forces b. finding their components

   c. the parallelogram law d. two equal and opposite forces

3. The resultant of two forces $\mathbf{F}_1$ and $\mathbf{F}_2$ ....

   a. may not replace the two forces

   b. may replace the two forces

   c. can always have altering effects

   d. has usually no specified dimension

4. Given the magnitudes of two concurrent forces, one ....

   a. can determine their resultant

b. can guess the magnitude of their resultant

c. can determine both the magnitude and the direction of the resultant

d. cannot determine their resultant

5. The resultant of two collinear forces ....

a. cannot be determined directly by their summation

b. could only be determined by the parallelogram law

c. lies along the line of action of the forces

d. is always equal to zero

C. Write answers to the following questions.

1. What does Newton's third law say?
2. Which point does the resultant of two concurrent forces pass through?
3. What is a logical choice for selecting a coordinate system?
4. Why does one need to determine the components of a force?
5. What are the benefits of using the principle of transmissibility?

❋ ❋ ❋

Section Three: Translation Activities

A. Translate the following passage into Persian.

Couple

The moment produced by two equal and opposite noncollinear forces is known as a *couple*. Couples have certain unique properties and have important applications in mechanics.

Consider the action of two equal and opposite forces **F** and **-F**, a distance **d** apart, Figure 2-7a. These two forces cannot be combined into a single force since their sum in every direction is zero. Their effect is entirely to produce a tendency of rotation. The combined moment of the two forces about an axis normal to their plane and passing through any point such as *O* in their plane is the couple **M**. It has a magnitude

$$\mathbf{M} = \mathbf{F}(a+d) - \mathrm{F}a$$

or

$$\mathbf{M} = \mathbf{F}d$$

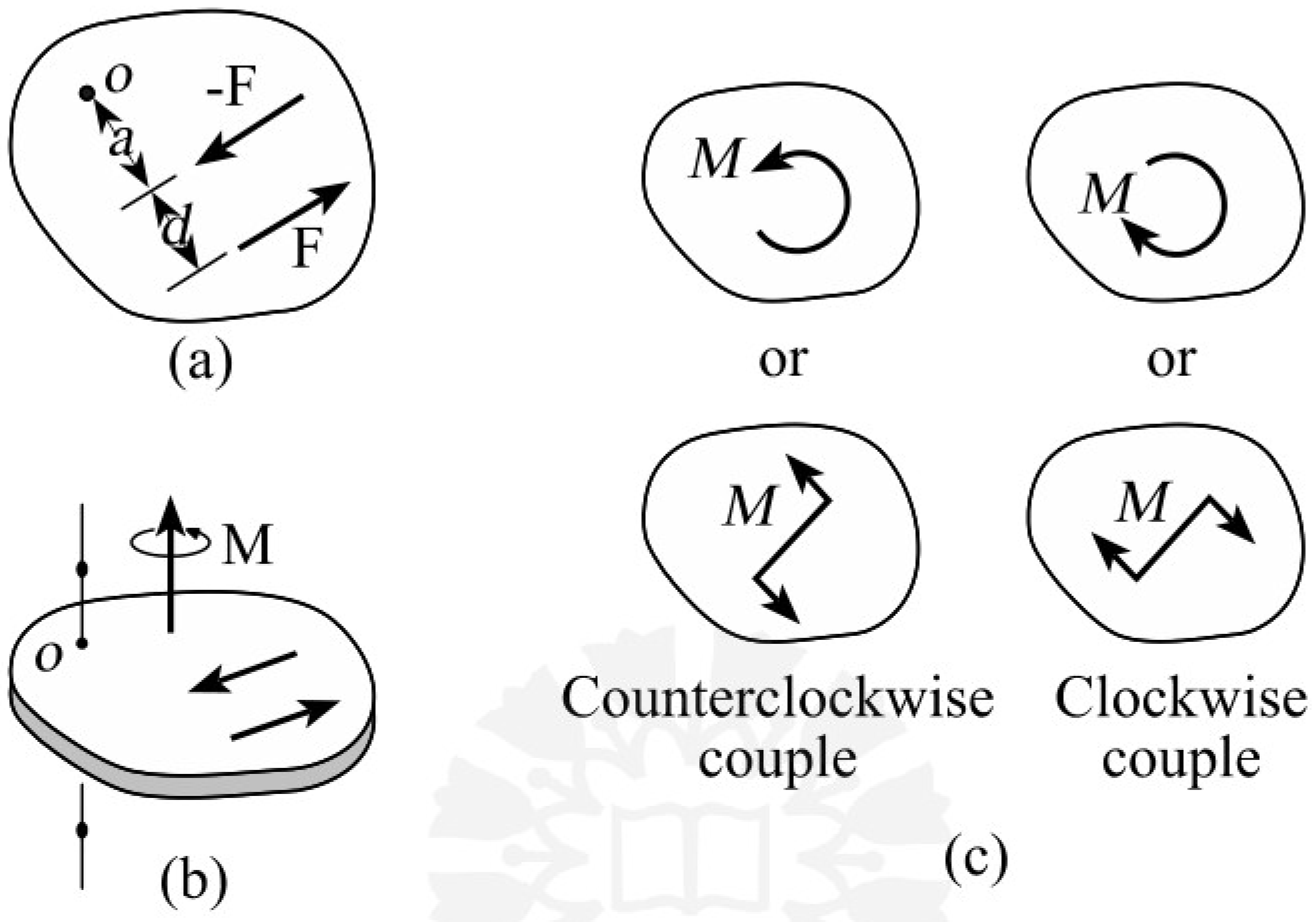


Figure 2-7.

and is in the counterclockwise direction when viewed from above for the case illustrated. Note especially that the magnitude of the couple contains no reference to the dimension *a* which locates the forces with respect to the moment center *O*.

B. Find the Persian equivalents of the following items and write them in the spaces provided.

1. active force ....
2. axis ....
3. bracket ....
4. component ....

5. concentrated ....
6. concurrent ....
7. contact force ....
8. coordinate ....
9. coplanner ....
10. elasticity ....
11. external force ....
12. force ....
13. gravitational ....
14. internal force ....
15. magnetic ....
16. magnitude ....
17. plasticity ....
18. principle ....
19. reactive ....
20. rectangular ....
21. resultant ....
22. rigid body ....
23. roller support ....
24. strain ....
25. stress ....
26. transmissibility ....
27. vector ....