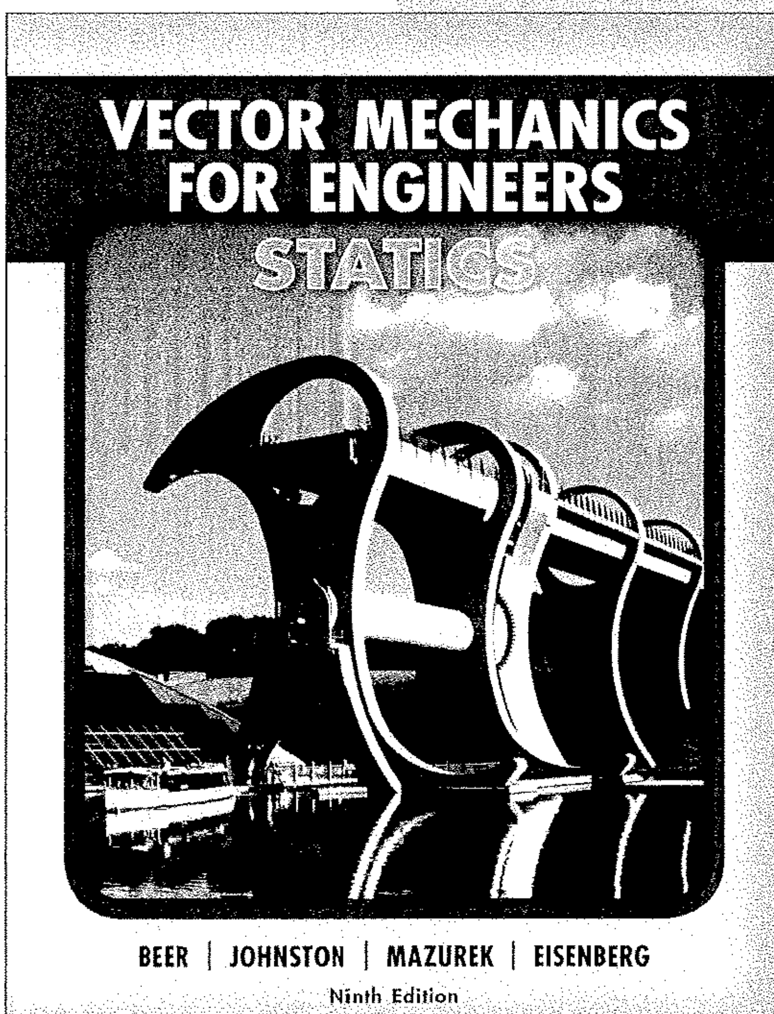
Instructor's and Solutions Manual
Volume 1, Chapters 2-5

to accompany



Instructor's and Solutions Manual

to accompany

Vector Mechanics for Engineers, Statics

Ninth Edition

Volume 1, Chapters 2–5

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VECTOR MECHANICS FOR ENGINEERS, STATICS, NINTH EDITION
Ferdinand P. Beer, E. Russell Johnston, Jr., David F. Mazurek, and Elliot Eisenberg

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TO THE INSTRUCTOR

As indicated in its preface, *Vector Mechanics for Engineers: Statics* is designed for the first course in statics offered in the sophomore year of college. New concepts have, therefore, been presented in simple terms and every step has been explained in detail. However, because of the large number of optional sections which have been included and the maturity of approach which has been achieved, this text can also be used to teach a course which will challenge the more advanced student.

The text has been divided into units, each corresponding to a well-defined topic and consisting of one or several theory sections, one or several Sample Problems, a section entitled *Solving Problems on Your Own*, and a large number of problems to be assigned. To assist instructors in making up a schedule of assignments that will best fit their classes, the various topics covered in the text have been listed in Table I and a suggested number of periods to be spent on each topic has been indicated. Both a minimum and a maximum number of periods have been suggested, and the topics which form the standard basic course in statics have been separated from those which are optional. The total number of periods required to teach the basic material varies from 26 to 39, while covering the entire text would require from 41 to 65 periods. If allowance is made for the time spent for review and exams, it is seen that this text is equally suitable for teaching a basic statics course to students with limited preparation (since this can be done in 39 periods or less) and for teaching a more complete statics course to advanced students (since 41 periods or more are necessary to cover the entire text). In most instances, of course, the instructor will want to include some, but not all, of the additional material presented in the text. In addition, it is noted that the text is suitable for teaching an abridged course in statics which can be used as an introduction to the study of dynamics (see Table I).

The problems have been grouped according to the portions of material they illustrate and have been arranged in order of increasing difficulty, with problems requiring special attention indicated by asterisks. We note that, in most cases, problems have been arranged in groups of six or more, all problems of the same group being closely related. This means that instructors will easily find additional problems to amplify a particular point which they may have brought up in discussing a problem assigned for homework. A group of problems designed to be solved with computational software can be found at the end of each chapter. Solutions for these problems, including analyses of the problems and problem solutions and output for the most widely used computational programs, are provided at the instructor s edition of the text's website:
http://www.mhhe.com/beerjohnston.

To assist in the preparation of homework assignments, Table II provides a brief description of all groups of problems and a classification of the problems in each group according to the units used. It should also be noted that the answers to all problems are given at the end of the text, except for those with a number in italic. Because of the large number of problems available in both systems of units, the instructor has the choice of assigning problems using SI units and problems using U.S. customary units in whatever proportion is found to be most desirable for a given class. To illustrate this point, sample lesson schedules are shown in Tables III, IV, and V, together with various alternative lists of assigned homework problems. Half of the problems in each of the six lists suggested in Table III and Table V are stated in SI units and half in U.S. customary units. On the other hand, 75% of the problems in the four lists suggested in Table IV are stated in SI units and 25% in U.S. customary units.

Since the approach used in this text differs in a number of respects from the approach used in other books, instructors will be well advised to read the preface to *Vector Mechanics for Engineers,* in which the authors have outlined their general philosophy. In addition, instructors will find in the following pages a description, chapter by chapter, of the more significant features of this text. It is hoped that this material will help instructors in organizing their courses to best fit the needs of their students. The authors wish to acknowledge and thank Amy Mazurek of Williams Memorial Institute for her careful preparation of the solutions contained in this manual.

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David Mazurek
Elliot R Eisenberg

DESCRIPTION OF THE MATERIAL CONTAINED IN *VECTOR MECHANICS FOR ENGINEERS: STATICS*, Ninth Edition

Chapter 1 Introduction

The material in this chapter can be used as a first assignment or for later reference. The six fundamental principles listed in Sec. 1.2 are introduced separately and are discussed at greater length in the following chapters. Section 1.3 deals with the two systems of units used in the text. The SI metric units are discussed first. The base units are defined and the use of multiples and submultiples is explained. The various SI prefixes are presented in Table 1.1, while the principal SI units used in statics and dynamics are listed in Table 1.2. In the second part of Sec. 1.3, the base U.S. customary units used in mechanics are defined, and in Sec. 1.4, it is shown how numerical data stated in U.S. customary units can be converted into SI units, and vice versa. The SI equivalents of the principal U.S. customary units used in statics and dynamics are listed in Table 1.3.

The instructor's attention is called to the fact that the various rules relating to the use of SI units have been observed throughout the text. For instance, multiples and submultiples (such as kN and mm) are used whenever possible to avoid writing more than four digits to the left of the decimal point or zeros to the right of the decimal point. When 5-digit or larger numbers involving SI units are used, spaces rather than commas are utilized to separate digits into groups of three (for example, 20 000 km). Also, prefixes are never used in the denominator of derived units; for example, the constant of a spring which stretches 20 mm under a load of 100 N is expressed as 5 kN/m, not as 5 N/mm.

In order to achieve as much uniformity as possible between results expressed respectively in SI and U.S. customary units, a center point, rather than a hyphen, has been used to combine the symbols representing U.S. customary units (for example, 10 lb · ft); furthermore, the unit of time has been represented by the symbol s, rather than sec, whether SI or U.S. customary units are involved (for example, 5 s, 50 ft/s, 15 m/s). However, the traditional use of commas to separate digits into groups of three has been maintained for 5-digit and larger numbers involving U.S. customary units.

Chapter 2 Statics of Particles

This is the first of two chapters dealing with the fundamental properties of force systems. A simple, intuitive classification of forces has been used: forces acting on a particle (Chap. 2) and forces acting on a rigid body (Chap. 3).

Chapter 2 begins with the parallelogram law of addition of forces and with the introduction of the fundamental properties of vectors. In the text, forces and other vector quantities are always shown in bold-face type. Thus, a force **F** (boldface), which is a vector quantity, is clearly distinguished from the magnitude *F* (italic) of the force, which is a scalar quantity. On the blackboard and in handwritten work, where bold-face lettering is not practical, vector quantities can be indicated by underlining. Both the magnitude and the direction of a vector quantity must be given to completely define that quantity. Thus, a force **F** of magnitude $F = 280$ lb, directed upward to the right at an angle of 25° with the horizontal, is indicated as $\mathbf{F} = 280 \text{ lb} \measuredangle 25^\circ$ when printed or as $\underline{F} = 280 \text{ lb} \measuredangle 25^\circ$ when handwritten. Unit vectors i and j are introduced in Sec. 2.7, where the rectangular components of forces are considered.

In the early sections of Chap. 2 the following basic topics are presented: the equilibrium of a particle, Newton's first law, and the concept of the free-body diagram. These first sections provide a review of the methods of plane trigonometry and familiarize the students with the proper use of a calculator. A general procedure for the solution of problems involving concurrent forces is given: when a problem involves only three forces, the use of a force triangle and a trigonometric solution is preferred; when a problem involves more than three forces, the forces should be resolved into rectangular components and the equations $\Sigma F_x = 0$, $\Sigma F_y = 0$ should be used.

The second part of Chap. 2 deals with forces in space and with the equilibrium of particles in space. Unit vectors are used and forces are expressed in the form $\mathbf{F} = F_x\mathbf{i} + F_y\mathbf{j} + F_z\mathbf{k} = F\lambda$, where **i**, **j**, and **k** are the unit vectors directed respectively along the x, y, and z axes, and λ is the unit vector directed along the line of action of **F**.

Note that since this chapter deals only with particles or bodies which can be considered as particles, problems involving compression members have been postponed with only a few exceptions until Chap. 4, where students will learn to handle rigid-body problems in a uniform fashion and will not be tempted to erroneously assume that forces are concurrent or that reactions are directed along members.

It should be observed that when SI units are used a body is generally specified by its mass expressed in kilograms. The weight of the body, however, should be expressed in newtons. Therefore, in many equilibrium problems involving SI units, an additional calculation is required before a free-body diagram can be drawn (compare the example in Sec. 2.11 and Sample Probs. 2.5 and 2.9). This apparent disadvantage of the SI system of units, when compared to the U.S. customary units, will be offset in dynamics, where the mass of a body expressed in kilograms can be entered directly into the equation $\mathbf{F} = m\mathbf{a}$, whereas with U.S. customary units the mass of the body must first be determined in $\mathrm{lb \cdot s^2/ft}$ (or slugs) from its weight in pounds.

Chapter 3
Rigid Bodies:
Equivalent Systems of Forces

The principle of transmissibility is presented as the basic assumption of the statics of rigid bodies. However, it is pointed out that this principle can be derived from Newton s three laws of motion (see Sec. 16.5 of *Dynamics*). The vector product is then introduced and used to define the moment of a force about a point. The convenience of using the determinant form (Eqs. 3.19 and 3.21) to express the moment of a force about a point should be noted. The scalar product and the mixed triple product are introduced and used to define the moment of a force about an axis. Again, the convenience of using the determinant form (Eqs. 3.43 and 3.46) should be noted. The amount of time which should be assigned to this part of the chapter will depend on the extent to which vector algebra has been considered and used in prerequisite mathematics and physics courses. It is felt that, even with no previous knowledge of vector algebra, a maximum of four periods is adequate (see Table I).

In Secs. 3.12 through 3.15 couples are introduced, and it is proved that couples are equivalent if they have the same moment. While this fundamental property of couples is often taken for granted, the authors believe that its rigorous and logical proof is necessary if rigor and logic are to be demanded of the students in the solution of their mechanics problems.

In Sections 3.16 through 3.20, the concept of equivalent systems of forces is carefully presented. This concept is made more intuitive through the extensive use of *free-body-diagram equations* (see Figs. 3.39 through 3.46). Note that the *moment* of a force is either not shown or is represented by a green vector (Figs. 3.12 and 3.27). A red vector with the symbol is used only to represent a *couple*, that is, an actual system consisting of two forces (Figs. 3.38 through 3.46). Section 3.21 is optional; it introduces the concept of a *wrench* and shows how the most general system of forces in space can be reduced to this combination of a force and a couple with the same line of action.

Since one of the purposes of Chap. 3 is to familiarize students with the fundamental operations of vector algebra, students should be encouraged to solve all problems in this chapter (two-dimensional as well as three-dimensional) using the methods of vector algebra. However, many students may be expected to develop solutions of their own, particularly in the case of two-dimensional problems, based on the direct computation of the moment of a force about a given point as the product of the magnitude of the force and the perpendicular distance to the point considered. Such alternative solutions may occasionally be indicated by the instructor (as in Sample Prob. 3.9), who may then wish to compare the solutions of the sample problems of this chapter with the solutions of the same sample problems given in Chaps. 3 and 4 of the parallel text *Mechanics for Engineers*. It should be pointed out that in later chapters the use of vector products will generally be reserved for the solution of three-dimensional problems.

Chapter 4
Equilibrium of Rigid Bodies

In the first part of this chapter, problems involving the equilibrium of rigid bodies in two dimensions are considered and solved using ordinary algebra, while problems involving three dimensions and requiring the full use of vector algebra are discussed in the second part of the chapter. Particular emphasis is placed on the correct drawing and use of free-body diagrams and on the types of reactions produced by various supports and connections (see Figs. 4.1 and 4.10). Note that a distinction is made between hinges used in pairs and hinges used alone; in the first case the reactions consist only of force components, while in the second case the reactions may, if necessary, include couples.

For a rigid body in two dimensions, it is shown (Sec. 4.4) that no more than three independent equations can be written for a given free body, so that a problem involving the equilibrium of a single rigid body can be solved for no more than three unknowns. It is also shown that it is possible to choose equilibrium equations containing only one unknown to avoid the necessity of solving simultaneous equations. Section 4.5 introduces the concepts of statical indeterminacy and partial constraints. Sections 4.6 and 4.7 are devoted to the equilibrium of two- and three-force bodies; it is shown how these concepts can be used to simplify the solution of certain problems. This topic is presented only after the general case of equilibrium of a rigid body to lessen the possibility of students misusing this particular method of solution.

The equilibrium of a rigid body in three dimensions is considered with full emphasis placed on the free-body diagram. While the tool of vector algebra is freely used to simplify the computations involved, vector algebra does not, and indeed cannot, replace the free-body diagram as the focal point of an equilibrium problem. Therefore, the solution of every sample problem in this section begins with a reference to the drawing of a free-body diagram. Emphasis is also placed on the fact that the number of unknowns and the number of equations must be equal if a structure is to be statically determinate and completely constrained.

Chapter 5
Distributed Forces: Centroids and Centers of Gravity

Chapter 5 starts by defining the center of gravity of a body as the point of application of the resultant of the weights of the various particles forming the body. This definition is then used to establish the concept of the centroid of an area or line. Section 5.4 introduces the concept of the first moment of an area or line, a concept fundamental to the analysis of shearing stresses in beams in a later study of mechanics of materials. All problems assigned for the first period involve only areas and lines made of simple geometric shapes; thus, they can be solved without using calculus.

Section 5.6 explains the use of differential elements in the determination of centroids by integration. The theorems of Pappus-Guldinus are given in Sec. 5.7. Sections 5.8 and 5.9 are optional; they show how the resultant of a distributed load can be determined by evaluating an area and by locating its centroid. Sections 5.10 through 5.12 deal with centers of gravity and centroids of volumes. Here again the determination of the centroids of composite shapes precedes the calculation of centroids by integration.

It should be noted that when SI units are used, a given material is generally characterized by its density (mass per unit volume, expressed in kg/m^3), rather than by its specific weight (weight per unit volume, expressed in N/m^3). The specific weight of the material can then be obtained by multiplying its density by $g = 9.81$ m/s^2 (see footnote, page 222 of the text).

Chapter 6
Analysis of Structures

In this chapter students learn to determine the internal forces exerted on the members of pin-connected structures. The chapter starts with the statement of Newton s third law (action and reaction) and is divided into two parts: (*a*) trusses, that is, structures consisting of two-force members only, (*b*) frames and machines, that is, structures involving multiforce members.

After trusses and simple trusses have been defined in Secs. 6.2 and 6.3, the method of joints and the method of sections are explained in detail in Sec. 6.4 and Sec. 6.7, respectively. Since a discussion of Maxwell's diagram is not included in this text, the use of Bow's notation has been avoided, and a uniform notation has been used in presenting the method of joints and the method of sections.

In the method of joints, a free-body diagram should be drawn for each pin. Since all forces are of known direction, their magnitudes, rather than their components, should be used as unknowns. Following the general procedure outlined in Chap. 2, joints involving only three forces are solved using a force triangle, while joints involving more than three forces are solved by summing x and y components. Sections 6.5 and 6.6 are optional. It is shown in Sec. 6.5 how the analysis of certain trusses can be expedited by recognizing joints under special loading conditions, while in Sec. 6.6 the method of joints is applied to the solution of three-dimensional trusses.

It is pointed out in Sec. 6.4 that forces in a simple truss can be determined by analyzing the truss joint by joint and that joints can always be found that involve only two unknown forces. The method of sections

(Sec. 6.7) should be used (*a*) if only the forces in a few members are desired, or (*b*) if the truss is not a simple truss and if the solution of simultaneous equations is to be avoided (for example, Fink truss). Students should be urged to draw a separate free-body diagram for each section used. The free body obtained should be emphasized by shading and the intersected members should be removed and replaced by the forces they exerted on the free body. It is shown that, through a judicious choice of equilibrium equations, the force in any given member can be obtained in most cases by solving a single equation. Section 6.8 is optional; it deals with the trusses obtained by combining several simple trusses and discusses the statical determinacy of such structures as well as the completeness of their constraints.

Structures involving multiforce members are separated into frames and machines. Frames are designed to support loads, while machines are designed to transmit and modify forces. It is shown that while some frames remain rigid after they have been detached from their supports, others will collapse (Sec. 6.11). In the latter case, the equations obtained by considering the entire frame as a free body provide necessary but not sufficient conditions for the equilibrium of the frame. It is then necessary to dismember the frame and to consider the equilibrium of its component parts in order to determine the reactions at the external supports. The same procedure is necessary with most machines in order to determine the output force **Q** from the input force **P** or inversely (Sec. 6.12).

Students should be urged to resolve a force of unknown magnitude and direction into two components but to represent a force of known direction by a single unknown, namely its magnitude. While this rule may sometimes result in slightly more complicated arithmetic, it has the advantage of matching the numbers of equations and unknowns and thus makes it possible for students to know at any time during the computations what is known and what is yet to be determined.

Chapter 7
Forces in Beams and Cables

This chapter consists of five groups of sections, all of which are optional. The first three groups deal with forces in beams and the last two groups with forces in cables. Most likely the instructor will not have time to cover the entire chapter and will have to choose between beams and cables.

Section 7.2 defines the internal forces in a member. While these forces are limited to tension or compression in a straight two-force member, they include a shearing force and a bending couple in the case of multiforce members or curved two-force members. Problems in this section do not make use of sign conventions for shear and bending moment and answers should specify which part of the member is used as the free body.

In Secs. 7.3 through 7.5 the usual sign conventions are introduced and shear and bending-moment diagrams are drawn. All problems in these sections should be solved by drawing the free-body diagrams of the various portions of the beams.

The relations among load, shear, and bending moment are introduced in Sec. 7.6. Problems in this section should be solved by evaluating areas under load and shear curves or by formal integration (as in Probs. 7.87 and 7.88). Some instructors may feel that the special methods used in this section detract from the unity achieved in the rest of the text through the use of the free-body diagram, and they may wish to omit Sec. 7.6. Others will feel that the study of shear and bending-moment diagrams is incomplete without this section, and they will want to include it. The latter view is particularly justified when the course in statics is immediately followed by a course in mechanics of materials.

Sections 7.7 through 7.9 are devoted to cables, first with concentrated loads and then with distributed loads. In both cases, the analysis is based on free-body diagrams. The differential-equation approach is considered in the last problems of this group (Probs. 7.124 through 7.126). Section 7.10 is devoted to catenaries and requires the use of hyperbolic functions.

Chapter 8
Friction

This chapter not only introduces the general topic of friction but also provides an opportunity for students to consolidate their knowledge of the methods of analysis presented in Chaps. 2, 3, 4, and 6. It is recommended that each course in statics include at least a portion of this chapter.

The first group of sections (Secs. 8.1 through 8.4) is devoted to the presentation of the laws of dry friction and to their application to various problems. The different cases which can be encountered are illustrated by diagrams in Figs. 8.2, 8.3, and 8.4. Particular emphasis is placed on the fact that no relation exists between the friction force and the normal force except when motion is impending or when motion is actually taking place. Following the general procedure outlined in Chap. 2, problems involving only three forces are solved by a force triangle, while problems involving more than three forces are solved by summing x and y components. In the first case the reaction of the surface of contact should be represented by the resultant **R** of the friction force and normal force, while in the second case it should be resolved into its components **F** and **N**.

Special applications of friction are considered in Secs. 8.5 through 8.10. They are divided into the following groups: wedges and screws (Secs. 8.5 and 8.6); axle and disk friction, rolling resistance (Secs. 8.7 through 8.9); belt friction (Sec. 8.10). The sections on axle and disk friction and on rolling resistance are not essential to the understanding of the rest of the text and thus may be omitted.

Chapter 9
Distributed Forces Moments of Inertia

The purpose of Sec. 9.2 is to give motivation to the study of moments of inertia of areas. Two examples are considered: one deals with the pure bending of a beam and the other with the hydrostatic forces exerted on a submerged circular gate. It is shown in each case that the solution of the problem reduces to the computation of the moment of inertia of an area. The other sections in the first assignment are devoted to the definition and the computation of rectangular moments of inertia, polar moments of inertia, and the corresponding radii of gyration. It is shown how the same differential element can be used to determine the moment of inertia of an area about each of the two coordinate axes.

Sections 9.6 and 9.7 introduce the parallel-axis theorem and its application to the determination of moments of inertia of composite areas. Particular emphasis is placed on the proper use of the parallel-axis theorem (see Sample Prob. 9.5). Sections 9.8 through 9.10 are optional; they are devoted to products of inertia and to the determination of principal axes of inertia.

Sections 9.11 through 9.18 deal with the moments of inertia of masses. Particular emphasis is placed on the moments of inertia of thin plates (Sec. 9.13) and on the use of these plates as differential elements in the computation of moments of inertia of symmetrical three-dimensional bodies (Sec. 9.14). Sections 9.16 through 9.18 are optional but should be used whenever the following dynamics course includes the motion of rigid bodies in three dimensions. Sections 9.16 and 9.17 introduce the moment of inertia of a body with respect to an arbitrary axis as well as the concepts of mass products of inertia and principal axes of inertia. Section 9.18 discusses the determination of the principal axes and principal moments of inertia of a body of arbitrary shape.

When solving many of the problems of Chap. 5, information on the specific weight of a material was generally required. This information was readily available in problems stated in U.S. customary units, while it had to be obtained from the density of the material in problems stated in SI units (see the last paragraph of our discussion of Chap. 5). In Chap. 9, when SI units are used, the mass and mass moment of inertia of a given body are respectively obtained in kg and $kg \cdot m^2$ directly from the dimensions of the body in meters and from its density in kg/m^3. However, if U.S. customary units are used, the density of the body must first be calculated from its specific weight or, alternatively, the weight of the body can be obtained from its dimensions and specific weight and then converted into the corresponding mass expressed in $lb \cdot s^2/ft$ (or slugs). The mass moment of inertia of the body is then obtained in $lb \cdot ft \cdot s^2$ (or $slug \cdot ft^2$). Sample Problem 9.12 provides an example of such a computation. Attention is also called to the footnote on page of the 513 regarding the conversion of mass moments of inertia from U.S. customary units to SI units.

Chapter 10
Method of Virtual Work

While this chapter is optional, the instructor should give serious consideration to its inclusion in the basic statics course. Indeed, students who learn the method of virtual work in their first course in mechanics will remember it as a fundamental and natural principle. They may, on the other hand, consider it as an artificial device if its presentation is postponed to a more advanced course.

The first group of sections (Secs. 10.2 through 10.5) is devoted to the derivation of the principle of virtual work and to its direct application to the solution of equilibrium problems. The second group of sections (Secs. 10.6 through 10.9) introduces the concept of potential energy and shows that equilibrium requires that the derivative of the potential energy be zero. Section 10.5 defines the mechanical efficiency of a machine and Sec. 10.9 discusses the stability of equilibrium.

The first groups of problems in each assignment utilize the principle of virtual work as an alternative method for the computation of unknown forces. Subsequent problems call for the determination of positions of equilibrium, while other problems combine the conventional methods of statics with the method of virtual work to determine displacements (Probs. 10.55 through 10.58).

TABLE I: LIST OF THE TOPICS COVERED IN *VECTOR MECHANICS FOR ENGINEERS: STATICS*

Sections	Topics	Suggested Number of Periods Basic Course	Additional Topics	Abridged Course to be used as an introduction to dynamics+
1. INTRODUCTION				
1.1–6	This material may be used for the first assignment or for later reference			
2. STATICS OF PARTICLES				
2.1–6	Addition and Resolution of Forces	0.5–1		0.5–1
2.7–8	Rectangular Components	0.5–1		0.5–1
2.9–11	Equilibrium of a Particle	1		1
2.12–14	Forces in Space	1		1
2.15	Equilibrium in Space	1		1
3. RIGID BODIES: EQUIVALENT SYSTEMS OF FORCES				
3.1–8	Vector Product; Moment of a Force about a Point	1–2		1–2
3.9–11	Scalar Product; Moment of a Force about an Axis	1–2		1–2
3.12–16	Couples	1		1
3.17–20	Equivalent Systems of Forces	1–1.5		1–1.5
*3.21	Reduction of a Wrench		0.5–1	
4. EQUILIBRIUM OF RIGID BODIES				
4.1–4	Equilibrium in Two Dimensions	1.5–2		1.5–2
4.5	Indeterminate Reactions; Partial Constraints	0.5–1		
4.6–7	Two- and Three-Force Bodies	1		
4.8–9	Equilibrium in Three Dimensions	2		2
5. CENTROIDS AND CENTERS OF GRAVITY				
5.1–5	Centroids and First Moments of Areas and Lines	1–2		
5.6–7	Centroids by Integration	1–2		
*5.8–9	Beams and Submerged Surfaces		1–1.5	
5.10–12	Centroids of Volumes	1–2		
6. ANALYSIS OF STRUCTURES				
6.1–4	Trusses by Method of Joints	1–1.5		
*6.5	Joints under Special Loading Conditions		0.25–0.5	
*6.6	Space Trusses		0.5–1	
6.7	Trusses by Method of Sections	1–2		
*6.8	Combined Trusses		0.25–0.5	
6.9–11	Frames	2–3		1–2
6.12	Machines	1–2		0.5–1.5
7. FORCES IN BEAMS AND CABLES				
*7.1–2	Internal Forces in Members		1	
*7.3–5	Shear and Moment Diagrams by FB Diagram		1–2	
*7.6	Shear and Moment Diagrams by Integration		1–2	
*7.7–9	Cables with Concentrated Loads; Parabolic Cable		1–2	
*7.10	Catenary		1	
8. FRICTION				
8.1–4	Laws of Friction and Applications	1–2		1–2
8.5–6	Wedges and Screws	1		
*8.7–9	Axle and Disk Friction; Rolling Resistance		1–2	
8.10	Belt Friction	1		
9. MOMENTS OF INERTIA				
9.1–5	Moments of Inertial of Areas	1		
9.6–7	Composite Areas	1–2		
*9.8–9	Products of Inertia; Principal Axes		1–2	
*9.10	Mohr's Circle		1	
9.11–15	Moments of Inertia of Masses#		1–2	
*9.16–18	Mass Products of Inertia; Principal Axes and Principal Moments of Inertia		1–2	
10. METHOD OF VIRTUAL WORK				
10.1–4	Principle of Virtual Work		1–2	
10.5	Mechanical Efficiency		0.5–1	
10.6–9	Potential Energy; Stability		1–1.5	
	Total Number of Periods	26–39	15–26	14–21

+ A sample assignment schedule for a course in dynamics including this minimum amount of introductory material in statics is given Table V. It is recommended that a more complete statics course, such as the one outlined in Tables III and IV of this manual, be used in curricula which include the study of mechanics of materials.

Mass moments of inertia have not been included in the basic statics course since this material is often taught in dynamics.

TABLE II: CLASSIFICATION AND DESCRIPTION OF PROBLEMS

Problem Number* SI Units	U.S. Units	Problem Description
		CHAPTER 2: STATICS OF PARTICLES
		FORCES IN A PLANE
		Resultant of concurrent forces
2.1, *4*	2.2, 3	graphical method
2.7, 8	2.5, *6*	law of sines
2.9, 10	2.11, *12*	
2.13	2.14	special problems
2.17, *18*	2.15, 16	laws of cosines and sines
2.19, *20*		
		Rectangular components of force
2.21, *24*	2.22, 23	simple problems
2.26, 27	2.25, 30	more advanced problems
2.28, 29		
2.32, 34	2.31, *33*	Resultant by $\Sigma F_x = 0$, $\Sigma F_y = 0$
2.35, 36	2.37, *38*	
2.39, 40	2.*41*, 42	Select force so that resultant has a given direction
		Equilibrium. Free-Body Diagram
2.43, *44*	2.47, 48	equilibrium of 3 forces
2.45, *46*		
2.51, 52	2.49, *50*	equilibrium of 4 forces
2.55, 56	2.53, *54*	
2.57, 60	2.*58*, 59	find parameter to satisfy specified conditions
2.61, 62	2.63, *64*	
2.65, *66*	2.67, 68	special problems
2.69, *70*		
		FORCES IN SPACE
		Rectangular components of a force in space
2.71, 72	2.*75*, 76	given F, θ, and ϕ, find components and direction angles
2.73, 74	2.77, *78*	
2.79, *80*	2.81, 82	relations between components and direction angles
2.*83*, 84		
2.87, *88*	2.85, 86	direction of force defined by two points on its line of action
2.89, *90*		
2.91, 92	2.*93*, 94	resultant of two or three forces
2.95, 96	2.97, *98*	
		Equilibrium of a particle in space
2.99, *100*	2.103, 104	load applied to three cables, introductory problems
2.101, *102*		
2.107, 108	2.105, *106*	intermediate problems
2.111, 112	2.109, *110*	
2.115, 116	2.113, 114	advanced problems
2.117, 118	2.*119*, *120*	

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Answers are not given to problems with a number set in italic type.

TABLE II: CLASSIFICATION AND DESCRIPTION OF PROBLEMS (CONTINUED)

Problem Number*		
SI Units	**U.S. Units**	**Problem Description**
2.121, *122*		problems involving cable through ring
2.123, *124*		
	2.125, 126	special problems
2.131, *132*	2.127, *128*	Review problems
2.135, 136	2.*129*, 130	
2.137, *138*	2.133, 134	
2.C1, C3	2.C2	Computer problems
2.C4	2.C5	
	CHAPTER 3: RIGID BODIES; EQUIVALENT SYSTEMS OF FORCES	
		Moment of a force about a point: Two dimensions
3.1, 2	3.5, *6*	introductory problems
3.3, 4	3.7, *8*	
3.9, 10	3.12, 13	direction of a force defined by two points on its line of action
3.*11*, *14*		
3.15		derivation of a formula
3.16, 17	3.*18*	applications of the vector product
		Moment of a force about a point: Three dimensions
3.19	3.*20*	computing $\mathbf{M} = \mathbf{r} \times \mathbf{F}$, introductory problems
3.21, 22	3.24, 26	computing $\mathbf{M} = \mathbf{r} \times \mathbf{F}$, more involved problems
3.*23*, *25*		
3.27, 28	3.*29*, 30	using **M** to find the perpendicular distance from a point to a line
3.31, 32	3.33, *34*	
3.35	3.36	Scalar Product
3.37, *38*	3.39, 40	Finding the angle between two lines
3.41, *42*	3.43, 44	
3.45	3.46	Mixed triple product
3.47, 48	3.51, *52*	Moment of a force about the coordinate axes
3.49, 50	3.53, *54*	
3.55, 56	3.59, *60*	Moment of a force about an oblique axis
3.57, 58	3.61, *62*	
	3.63	
*3.*64*, *65	*3.68, *69	Finding the perpendicular distance between two lines
*3.66, **67*		
3.70, 72	3.71, *73*	Couples in two dimensions
	3.*74*	
3.76	3.75, 77	Couples in three dimensions
3.79, 80	3.78	
3.83, *84*	3.81, 82	Replacing a force by an equivalent force-couple system: two dimensions
3.85, *86*		
3.87, 88	3.89, 90	Replacing a force-couple system by an equivalent force or forces
3.*91*, *92*		
3.93, 94	3.95, *96*	Replacing a force by an equivalent force-couple system: three dimensions
3.97, 98	3.99, *100*	

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TABLE II: CLASSIFICATION AND DESCRIPTION OF PROBLEMS (CONTINUED)

Problem Number*		
SI Units	**U.S. Units**	**Problem Description**
3.101, 102	3.104	Equivalent force-couple systems
3._103_		
3._107_	3.105, 106	Finding the resultant of parallel forces: two dimensions
3.111, 112	3.108, 109	Finding the resultant and its line of action: two dimensions
3.115, 116	3.110, 113	
3.118	3._114_, _117_	
3.119, 120	3.121, 122	Reducing a three-dimensional system of forces to a single force-couple system
3.124, 125	3._123_, _126_	
3.127, 128	3.129, 130	Finding the resultant of parallel forces: three dimensions
*3._131_, *_132_		
		Reducing three-dimensional systems of forces or forces and couples to a wrench
*3.133, *_135_	*3.134, *136	axis of wrench is parallel to a coordinate axis or passes through _O_
*3.137		force-couple system parallel to the coordinate axes
*3._139_, 140	*3._138_	general, three-dimensional case
*3.141	*3._142_	special cases where the wrench reduces to a single force
*3.143, *144	*3.145, *146	special, more advanced problems
3.147, 148	3.149, 151	Review problems
3._150_, _154_	3._152_, 153	
3.155, 157	3.156, _158_	
3.C1, C4	3.C2, C3	Computer problems
3.C5	3.C6	

CHAPTER 4: EQUILIBRIUM OF RIGID BODIES

EQUILIBRIUM IN TWO DIMENSIONS

4.2, 3	4.1, 4	Parallel forces
4.5, 6	4._7_, _8_	
4.9, _10_	4.11, 14	Parallel forces, find range of values of loads to satisfy multiple criteria
4.12, _13_		
4.15, _16_	4.17, 18	Rigid bodies with one reaction of unknown direction and one of known direction
4.19, _20_		
4.21, 26	4._22_, 23	
4.27, 28	4.24, _25_	
4.30, _31_	4.29, 33	
4._32_, 34		
4.37, 38	4.35, 36	Rigid bodies with three reactions of known direction
4.41, 42	4._39_, _40_	
4.43, 46	4.44, _45_	Rigid bodies with a couple included in the reactions
4.49, 50	4.47, _48_	
4.51, 53	4.52, 54	Find position of rigid body in equilibrium
4._55_, _56_	4.57, 58	
4.59	4._60_	Partial constraints, statical indeterminacy

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Answers are not given to problems with a number set in italic type.

Problem Number* SI Units	U.S. Units	Problem Description
		Three-force bodies
4.61, 62	4.63, 64	simple geometry, solution of a right triangle required
4.66, 67	4.*65*, *68*	simple geometry, frame includes a two-force member
4.69, 70	4.71, 74	more involved geometry
4.*72*, *73*		
4.*76*, 77	4.75, 81	
4.*78*, 79	4.82	
4.80		
4.83, 84	4.*86*, 87	find position of equilibrium
4.85, 88	4.*89*, 90	
		EQUILIBRIUM IN THREE DIMENSIONS
4.92, 93	4.91, 94	Rigid bodies with two hinges along a coordinate axis and an additional reaction parallel to another coordinate axis
4.*95*, *96*		
4.97, 98	4.99, 100	Rigid bodies supported by three vertical wires or by vertical reactions
4.101, 102	4.*103*, *104*	
4.106, 107	4.105, 108	Derrick and boom problems involving unknown tension in two cables
4.109, 110	4.*111*, *112*	
4.113, 114	4.117, 118	Rigid bodies with two hinges along a coordinate axis and an additional reaction not parallel to a coordinate axis
4.*115*, *116*		
4.119, 122	4.120, 121	Problems involving couples as part of the reaction at a hinge
4.125, 126	4.*123*, *124*	Advanced problems
4.129, 130	4.127, 128	
4.*131*, *132*		
4.135, 136	4.133, 134	Problems involving taking moments about an oblique line passing through two supports
4.*140*, *141*	4.137, 138	
	4.139	
4.142, 143	4.*144*, 146	Review problems
4.145, *149*	4.*147*, 148	
4.150, *151*	4.152, 153	
4.C2, C5	4.C1, C3	Computer problems
4.C6	4.C4	
		CHAPTER 5: DISTRIBUTED FORCES: CENTROIDS AND CENTERS OF GRAVITY
		Centroid of an area formed by combining
5.1, 2	5.3, 4	rectangles and triangles
5.6, 9	5.5, *7*	rectangles, triangles, and portions of circular areas
	5.*8*	
5.*10*, 12	5.11, 14	triangles, portions of circular or elliptical areas, and areas of analytical functions
5.*13*, *15*		
5.16	5.17	Derive expression for location of centroid
5.*19*	5.18	Find ratio of dimensions so that centroid is at a given point
5.20, *23*	5.21, 22	First moment of an area
5.24, *25*	5.26, *27*	Center of gravity of a wire figure
5.29, 30	5.28, *31*	Equilibrium of wire figures
	5.32, 33	Find dimension to maximize distance to centroid

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TABLE II: CLASSIFICATION AND DESCRIPTION OF PROBLEMS (CONTINUED)

Problem Number* SI Units	U.S. Units	Problem Description
		Use integration to find centroid of
5.35, *36*	5.34	simple areas
5.*38*, 39	5.37	areas obtained by combining shapes of Fig. 5.8A
5.40	5.41	
5.42		parabolic area
	5.*43*, 44	areas defined by different functions over the interval of interest
5.45, 46	*5.*47*	homogeneous wires
*5.48, *49		areas defined by exponential or cosine functions
	5.50, 51	areas defined by a hyperbola
		Find areas or volumes by Pappus - Guldinus
5.52, 53	5.54, *55*	rotate simple geometric figures
5.56, 57		
5.59, 61	5.58, *60*	practical applications
5.62, **65*	5.63, 64	
		Distributed load on beams
5.67	5.66	resultant of loading
5.68, 71	5.69, *70*	reactions at supports
5.73	*5.72*	
5.74, *75*	5.76, 77	special problems
5.78, *79*		
		Forces on submerged surfaces
5.80, 82	5.81, 84	reactions on dams or vertical gates
5.83, *86*	5.85	
5.87		
5.88, 89	5.90, 91	reactions on non-vertical gates
5.93, 94	*5.92*	
	5.95	special applications
		Centroids and centers of gravity of three-dimensional bodies
5.96, 99	5.97, 98	composite bodies formed from two common shapes
5.100, 101	5.103, 104	composite bodies formed from three or more elements
5.*102*, *105*		
5.106, 107	5.108, *109*	composite bodies formed from a material of uniform thickness
5.110, 112	5.111, *113*	
5.114, 115	5.*116*, 117	composite bodies formed from a wire or structural shape of uniform cross section
5.118, 121	5.119, *120*	composite bodies made of two different materials
		use integration to locate the centroid of
5.123, 124	5.122	standard shapes: single integration
5.*126*, *127*	5.125	bodies of revolution: single integration
*5.128, *129		
5.132	*5.130, *131*	special applications: single integration
	5.133, 134	special applications: double integration
5.*135*, *136		bodies formed by cutting a standard shape with an oblique plane: single integration

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Answers are not given to problems with a number set in italic type.

TABLE II: CLASSIFICATION AND DESCRIPTION OF PROBLEMS (CONTINUED)

Problem Number* SI Units	U.S. Units	Problem Description
5.137, *139*	5.138, 140	Review problems
5.143, *144*	5.141, *142*	
5.147, 148	5.*145*, 146	
5.C2, C3	5.C1, C4	Computer problems
5.C5, C6	*5.C7	
		CHAPTER 6: ANALYSIS OF STRUCTURES
		TRUSSES
		Method of joints
6.1, 3	6.2, *4*	simple problems
6.6, 7	6.5, *8*	
6.9, 10	6.11, 12	problems of average difficulty
6.*13*, *14*	6.15, 16	
6.19, 20	6.*17*, *18*	more advanced problems
6.23, 24	6.21, 22	
6.*25*, *26*	6.27	
6.28		
6.29	6.30	designate simple trusses
6.31, 32		find zero-force members
6.*33*, *34*		
*6.36, *37	*6.35, *38	space trusses
*6.39, *40	*6.*41*, **42*	
		Method of sections
6.45, 46	6.43, 44	two of the members cut are parallel
6.*47*, *48*		
6.49, 50	6.51, 52	none of the members cut are parallel
6.53, 54	6.57, 58	
6.55, 56	6.*59*, *60*	
6.61, 62	6.*63*, *64*	K-type trusses
6.65, 66	6.67, 68	trusses with counters
6.70, 71	6.69, 72	Classify trusses according to constraints
6.*73*, *74*		
		FRAMES AND MACHINES
		Analysis of Frames
6.75, 76	6.77, 78	easy problems
6.81, 82	6.*79*, *80*	
6.83, 84	6.87, 88	problems where internal forces are changed by repositioning a couple or by moving a force along its line of action
6.*85*, *86*	6.89	
6.90		replacement of pulleys by equivalent loadings
6.91, 92	6.93, 94	analysis of frames supporting pulleys or pipes
	6.95, 96	analysis of highway vehicles

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Answers are not given to problems with a number set in italic type.

TABLE II: CLASSIFICATION AND DESCRIPTION OF PROBLEMS (CONTINUED)

Problem Number*		
SI Units	**U.S. Units**	**Problem Description**
6.*97*, *98*	6.99, 100	analysis of frames consisting of multiforce members
6.101, 102	6.103, 104	
6.*105*, *106*		
6.107, 108	6.109, 110	problems involving the solution of simultaneous equations
6.111, *112*	6.115, 116	
6.113, *114*		
6.119, *120*	6.117, 118	unusual floor systems
	6.*121*	
		Analysis of Machines
6.*124*, *125*	6.122, 123	toggle-type machines
6.126, 127		
6.128		
6.129, 130	6.131, 132	machines involving cranks
6.133, 134		
6.137, 138	6.*135*, *136*	machines involving a crank with a collar
6.139, 140		robotic machines
6.143, 144	6.*141*, 142	tongs
6.146, 148	6.145, *147*	pliers, boltcutters, pruning shears
	6.149, 150	find force to maintain position of toggle
6.151, 154		garden shears, force in hydraulic cylinder
6.*152*, *153*	6.155, 156	large mechanical equipment
	6.*157*, *158*	
6.159, 160	*6.*161*, **162*	gears and universal joints
*6.163		special tongs
6.*165*, 166	6.164, 168	Review problems
6.167, 170	6.*169*, 171	
6.172, *174*	6.*173*, 175	
6.C2, C4	6.C1, C3	Computer problems
6.C6	6.C5	

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TABLE II: CLASSIFICATION AND DESCRIPTION OF PROBLEMS (CONTINUED)

Problem Number* SI Units	U.S. Units	Problem Description
		CHAPTER 7: FORCES IN BEAMS AND CABLES
		Internal forces in members
7.3, 4	7.1, 2	simple frames
7.5, *6*		
7.7, 8	7.9, 10	curved members
7.13, 14	*7.11, 12*	
7.15, 16	7.19, 20	frames with pulleys or pipes
7.17, 18		
	7.21, 22	effect of supports
7.23, 25	7.24, 28	bending moment in circular rods due to their own weight
7.26, 27		
		BEAMS
		Shear and bending-moment diagrams using portions of beam as free bodies
7.29, 30	7.31, 32	problems involving no numerical values
	7.33, 34	
7.35, 36	*7.37, 38*	beams with concentrated loads
7.39, 40	7.41, 42	beams with mixed loads
7.43, 44	7.45, 46	beams resting on the ground
7.47, 48		
7.49, *50*	7.52, 53	beams subjected to forces and couples
7.51, 54		
7.55, 56	7.58, 59	find value of parameter to minimize absolute value of bending moment
7.57, *62	*7.60, 61*	
		Shear and bending-moment diagrams using relations among ω, V, and M
7.63, 64	7.65, 66	problems involving no numerical values
7.67, 68		
7.69, 70	7.73, 74	problems involving numerical values
7.71, 72	*7.75, 76*	
7.77, 78	7.79, 80	find magnitude and location of maximum bending moment
7.83, 84	*7.81, 82*	
7.87, 88	7.85, 86	Determine V and M by integrating ω twice
7.89, 90	*7.91, *92	Find values of loads for which $\lvert M \rvert_{max}$ is as small as possible
		CABLES
		Cables with concentrated loads
7.93, 94	7.95, 96	vertical loads
7.97, 98	*7.99, 100*	
7.103, 104	7.101, 102	horizontal and vertical loads
7.105, 106		
		Parabolic cables
7.107, 108	7.109, 110	supports at the same elevation
7.111, 112	7.113, 114	
7.117, 118	7.115, 116	supports at different elevations

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Answers are not given to problems with a number set in italic type.

TABLE II: CLASSIFICATION AND DESCRIPTION OF PROBLEMS (CONTINUED)

Problem Number* SI Units	U.S. Units	Problem Description
*7.<u>119</u>		Derive analogy between a beam and a cable
7.120, 121	7.*122, 123*	use analogy to solve previous problems
*7.<u>124</u>	*7.<u>125</u>, *<u>126</u>	Derive or use $d^2y/dx^2 = w(x)\ T_0$
		Catenary
7.127, 129	7.128, 130	given length of cable and sag or T_m, find span of cable
7.*131, 132*		
7.133, 135	7.134, 136	given span and length of cable, find sag and/or weight
7.139, 140	7.*137, 138*	given span, T_m, and w, find sag
7.143, 144	7.141, 142	given T_0, w, and sag or slope, find span or sag
7.*145, 146*	*7.147, *148	
*7.151, *<u>152</u>	7.<u>*149*</u>, **150*	special problems
*7.<u>153</u>		
7.154, 155	7.156, 157	Review problems
7.159, <u>*161*</u>	7.*158*, 160	
7.164, *165*	7.162, *163*	
7.C2, C4	7.C1, C3	Computer problems
7.C5, C6		
		<u>CHAPTER 8: FRICTION</u>
8.3, 4	8.1, 2	For given loading, determine whether block is in equilibrium and find friction force
8.5, 6	8.*8, 10*	Find minimum force required to start, maintain, or prevent motion
8.7, 9		
8.11, 12		Analyze motion of several blocks
8.*13, 14*		
	8.15, 16	Sliding and/or tipping of a rigid body
8.19, 20	8.<u>17</u>, <u>18</u>	Problems involving wheels and cylinders
8.21, *22*	8.<u>23</u>, <u>*24*</u>	Problems involving rods
8.26, 28	8.25, 27	Analysis of mechanisms with friction
8.29, *32*	8.30, 31	
8.*33*		
8.36, 37	8.34, *35*	Analysis of more advanced rod and beam problems
8.38	8.39, *40*	
8.42, 43	8.41, <u>45</u>	Analysis of systems with possibility of slippage for various loadings
8.44		
8.48, 49	8.46, 47	Wedges, introductory problems
8.*50, 51*	8.52	
8.53, 54		
8.55		
8.57, 60	8.56, *58*	Wedges, more advanced problems
8.61	8.<u>*59*</u>, 62	
*8.64, *65	8.63	
8.<u>66</u>	8.*67, 68*	Square-threaded screws
8.69, 70	8.72, 73	
8.*71, 74*		

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TABLE II: CLASSIFICATION AND DESCRIPTION OF PROBLEMS (CONTINUED)

Problem Number* SI Units	U.S. Units	Problem Description
8.76, 77	8.75, *81*	Axle friction
9.78, 79	8.82, *84*	
8.80, *83*	8.85, 86	
8.88, *89*	8.87	
8.91, *<u>92</u>	8.90, 95	Disk friction
*8.<u>*93*</u>, *<u>*94*</u>		
8.96, 99	8.97, 98	Rolling resistance
8.100		

		Belt friction
8.102, 103	8.101, 104	belt passing over fixed drum
8.*105*, *106*		
8.107, 108	8.110, 111	transmission belts and band brakes
8.109, 112	8.*113*, *114*	
	8.115	
8.116, 117	8.*118*, *119*	advanced problems
8.122, 123	8.120, 121	
8.126, *127*	8.124, 125	
8.*130*, 131	8.<u>128</u>, <u>129</u>	derivations, V belts

8.132, *134*	8.133, 136	Review problems
8.<u>135</u>, 139	8.*137*, <u>138</u>	
8.142, *143*	8.140, *141*	

8.C1, C3	8.C2, <u>C5</u>	Computer problems
8.C4, C6	8.C7	
8.C8		

<u>CHAPTER 9: DISTRIBUTED FORCES: MOMENTS OF INERTIA</u>

MOMENTS OF INERTIA OF AREAS

		Find by direct integration
9.<u>1</u>, <u>3</u>	9.<u>2</u>, <u>4</u>	moments of inertia of an area
9.<u>6</u>, <u>7</u>	9.<u>*5*</u>, <u>*8*</u>	
9.<u>9</u>, <u>10</u>	9.<u>11</u>, <u>12</u>	
9.<u>*13*</u>, <u>*14*</u>		
9.<u>15</u>, <u>17</u>	9.<u>16</u>, <u>18</u>	moments of inertia and radii of gyration of an area
9.<u>*19*</u>, 9.<u>*20*</u>		
9.<u>21</u>, <u>23</u>	9.<u>22</u>, <u>25</u>	polar moments of inertia and polar radii of gyration of an area
9.<u>24</u>, <u>28</u>	9.<u>*26*</u>, <u>*27*</u>	
*9.<u>29</u>	*9.<u>30</u>	Special problems
		Parallel-axis theorem applied to composite areas to find
9.31, 33	9.32, 34	moment of inertia and radius of gyration
9.*35*, *36*		
9.37, 38	9.39, *40*	centroidal moment of inertia, given I or J
9.41, 42	9.43, 44	centroidal moments of inertia

* Problems which do not involve any specific system of units have been indicated by underlining their number. Answers are not given to problems with a number set in italic type.

TABLE II: CLASSIFICATION AND DESCRIPTION OF PROBLEMS (CONTINUED)

Problem Number* SI Units	U.S. Units	Problem Description
9.45, 46	*9.47, 48*	centroidal polar moment of inertia
		centroidal moments of inertia of composite areas consisting of rolled-steel shapes:
9.49, 51	9.50, 52	symmetrical composite areas
9.53, 55	*9.54, 56*	singly-symmetrical composite areas (first locate centroid of area)
		Center of pressure
9.<u>57</u>, <u>58</u>	9.<u>59</u>, *9.<u>60</u>	for end panel of a trough
9.61, *9.62*		for a submerged vertical gate or cover
*9.64	*9.<u>63</u>	used to locate centroid of a volume
*9.<u>65</u>	*9.<u>66</u>	special problems
		Products of inertia of areas found by
9.<u>67</u>, <u>68</u>	9.<u>69</u>, *<u>70</u>*	direct integration
9.71, 72	*9.73*, 74	parallel-axis theorem
9.75, 78	*9.76, 77*	
		Using the equations defining the moments and products of inertia with respect to rotated axes to find
9.<u>79</u>, 80	9.81, 83	$I_{x'}$, $I_{y'}$, $I_{x'y'}$ for a given angle of rotation
9.82, 84		
9.<u>85</u>, 86	9.87, 89	principal axes and principal moments of inertia
9.88, 90		
		Using Mohr's circle to find
9.<u>91</u>, 92	9.93, 95	$I_{x'}$, $I_{y'}$, $I_{x'y'}$ for a given angle of rotation
9.94, 96		
9.<u>97</u>, 98	9.99, 100	principal axes and principal moments of inertia
	9.101, 102	
9.104, 105	9.103, *106	
9.107, 108	*9.109, 110*	Special problems
		MOMENTS OF INERTIA OF MASSES
		Mass moment of inertia
9.<u>111</u>, <u>114</u>	9.<u>112</u>, <u>113</u>	of thin plates: two-dimensions
9.<u>115</u>, <u>116</u>	*9.<u>117</u>, <u>118</u>*	
9.<u>119</u>, <u>122</u>	9.<u>120</u>, <u>121</u>	of simple geometric shapes by direct single integration
9.<u>123</u>, <u>126</u>	*9.<u>124</u>, *<u>125</u>	
9.127	9.128	and radius of gyration of composite bodies
9.<u>129</u>, *<u>130</u>*	*9.132*, 133	special problems using the parallel-axis theorem
9.131, <u>134</u>		
9.135, 136	9.137, 138	of bodies formed of sheet metal or of thin plates: three-dimensions
*9.139, *140*		
9.141, 144	9.142, *143*	of machine elements and of bodies formed of homogeneous wire
9.145, 148	*9.146*, 147	
		Mass products of inertia
9.149, 150	9.151, 152	of machine elements
9.153, 154		of bodies formed of sheet metal or of thin plates
9.155, 156		
9.<u>157</u>, 159	9.<u>158</u>, <u>160</u>	of bodies formed of homogeneous wire
9.<u>162</u>	9.<u>161</u>	Derivation and special problem

* Problems which do not involve any specific system of units have been indicated by underlining their number. Answers are not given to problems with a number set in italic type.

TABLE II: CLASSIFICATION AND DESCRIPTION OF PROBLEMS (CONTINUED)

Problem Number* SI Units	U.S. Units	Problem Description
9.165, 166	9.*163*, *164*	Mass moment of inertia of a body with respect to a skew axis
9.169, 170	9.167, 168	
	9.*171*, *172*	
9.173, 174	9.175, 176	Ellipsoid of inertia and special problems
9.*177*, *178*		
*9.179, *180	*9.182, *183	Principal mass moments of inertia and principal axes of inertia
*9.*181*, **184*		
9.185, *186*	9.187, 188	Review problems
9.189, 190	9.191, *192*	
9.195, *196*	9.193, *194*	
9.C3, C5	9.C1, C2	Computer problems
*9.C7, *C8	9.C4, C6	

CHAPTER 10: METHOD OF VIRTUAL WORK

SI Units	U.S. Units	Problem Description
		For linkages and simple machines, find
10.1, 3	10.2, 4	force or couple required for equilibrium (linear relations among displacements)
10.7, 8	10.5, *6*	
10.11, 12	10.9, 10	force required for equilibrium (trigonometric relations among displacements)
10.*13*, *14*		
10.15, 18	10.16, 17	couple required for equilibrium (trigonometric relations among displacements)
10.*19*, *20*	10.21, 22	force or couple required for equilibrium
		Find position of equilibrium
10.24, 25	10.*23*, *27*	for numerical values of loads
10.26, 28		
10.29, 32	10.30, 31	linear springs included in mechanism
10.33, *34*	10.36, 37	
10.35, 38		
10.39, 40		torsional spring included in mechanism
10.43, 44	10.*41*, *42*	Problems requiring the use of the law of cosines
	10.45, 46	
10.49, *50*	10.47, *48*	Problems involving the effect of friction
10.51, 52		
		Use method of virtual work to find:
10.53, 54		reactions of a beam
10.*55*	10.*56*	internal forces in a mechanism
	10.57, 58	movement of a truss joint
		Potential energy method used to
10.61, 63	10.59, 60	solve problems from Sec. 10.4
10.65, 66	10.62, 64	
10.67	10.68	establish that equilibrium is neutral
		find position of equilibrium and determine its stability for a system involving:
10.71, 72	10.69, *70*	gears and drums
10.73, 74		torsional springs
10.77, 79	10.*75*, *76*	linear springs

* Problems which do not involve any specific system of units have been indicated by underlining their number. Answers are not given to problems with a number set in italic type.

TABLE II: CLASSIFICATION AND DESCRIPTION OF PROBLEMS (CONTINUED)

Problem Number*		
SI Units	**U.S. Units**	**Problem Description**
10.80, *82*	10.78, 81	
10.*87*, 88	10.85, 86	
10.83, *84*		two applied forces
		determine stability of a known position of equilibrium for a system with
10.92, 93	10.*89*, 90	one degree of freedom
10.94, 96	10.91, *95*	
*10.*97*, *98	*10.*99*, *100	two degrees of freedom
10.104, *105*	10.101, 102	Review problems
10.106, 110	10.*103*, 107	
10.*111*, 112	10.108, *109*	
10.C2, C3	10.C1, C4	Computer problems
10.C5, C6		
10.C7		

* Problems which do not involve any specific system of units have been indicated by underlining their number.
Answers are not given to problems with a number set in italic type.

TABLE III: SAMPLE ASSIGNMENT SCHEDULE FOR A COURSE IN STATICS

This schedule includes all of the material of *VECTOR MECHANICS FOR ENGINEERS: STATICS* with the exception of Sections 3.21, 6.6, 7.7–7.10, 8.7–8.9, and 9.18.

50% OF THE PROBLEMS IN EACH OF THE FOLLOWING LISTS USE SI UNITS AND 50% U.S. CUSTOMARY UNITS

			ANSWERS TO ALL OF THESE PROBLEMS ARE GIVEN IN THE BACK OF THE BOOK				NO ANSWERS ARE GIVEN IN THE BOOK FOR ANY OF THESE PROBLEMS	
Period	Sections	Topics	List 1	List 2	List 3	List 4	List 5	List 6
1	1.1–6	Introduction						
2	2.1–8	Addition and Resolution of Forces	2.7, 15, 27, 37	2.9, 16, 26, 31	2.5, 19, 25, 35	2.11, 17, 30, 32	2.6, 20, 28, 38	2.12, 18, 29, 33
3	2.9–11	Equilibrium of a Particle	2.47, 52, 59, 69	2.48, 51, 63, 65	2.45, 53, 57, 68	2.43, 49, 60, 67	2.46, 54, 58, 70	2.44, 50, 64, 66
4	2.12–14	Forces in Space	2.74, 82, 89, 94	2.71, 81, 87, 97	2.76, 84, 85, 96	2.77, 79, 86, 95	2.78, 83, 90, 98	2.75, 80, 88, 93
5	2.15	Equilibrium in Space	2.103, 111, 114, 123	2.104, 107, 113, 121	2.99, 109, 116, 126	2.101, 105, 117, 125	2.100, 110, 119, 124	2.102, 106, 120, 122
6	3.1–8	Vector Product, Moment of a Force about a Point	3.1, 13, 21, 30	3.3, 12, 22, 33	3.5, 9, 24, 28	3.7, 10, 26, 32	3.8, 14, 25, 29	3.6, 11, 23, 34
7	3.9–11	Scalar Product, Moment of a Force about an Axis	3.39, 50, 59, *66	3.40, 47, 61, *65	3.41, 53, 55, *69	3.37, 51, 56, *68	3.42, 52, 62, *67	3.38, 54, 60, *64
8	3.12–16	Couples	3.70, 81, 87, 99	3.72, 82, 88, 95	3.71, 85, 89, 94	3.75, 83, 90, 93	3.74, 86, 91, 100	3.73, 84, 92, 96
9	3.17–20	Equivalent Systems of Forces	3.105, 111, 121, 127	3.106, 112, 122, 128	3.101, 108, 119, 129	3.102, 109, 120, 130	3.103, 117, 123, *132	3.107, 114, 126, *131
10		EXAM NUMBER ONE						
11	4.1–4	Equilibrium in Two Dimensions	4.2, 14, 19, 24	4.3, 11, 15, 23	4.1, 9, 17, 28	4.4, 12, 18, 21	4.7, 13, 16, 25	4.8, 10, 20, 22
12	4.1–5	Equilibrium in Two Dimensions	4.29, 41, 44, 53	4.33, 42, 47, 51	4.30, 36, 46, 57	4.34, 35, 43, 54	4.32, 40, 45, 56	4.31, 39, 48, 55
13	4.6–7	Two- and Three-Force Bodies	4.61, 74, 77, 87	4.62, 71, 79, 90	4.63, 70, 75, 88	4.64, 69, 81, 83	4.65, 73, 78, 89	4.68, 72, 76, 86
14	4.8–9	Equilibrium in Three Dimensions	4.91, 100, 105, 114	4.94, 99, 108, 113	4.92, 98, 106, 118	4.93, 97, 107, 117	4.95, 104, 111, 116	4.96, 103, 112, 115
15	4.8–9	Equilibrium in Three Dimensions	4.119, 128, 135	4.122, 127, 136	4.120, 130, 138	4.121, 129, 133	4.123, 132, 140	4.124, 131, 141
16	5.1–5	Centroids and First Moments	5.2, 14, 24, 28	5.1, 11, 20, 26	5.4, 12, 22, 30	5.3, 10, 21, 29	5.7, 15, 23, 31	5.8, 13, 25, 27
17	5.6–7	Centroids by Integration	5.37, 40, 58, 59	5.34, 46, 54, 61	5.35, 41, 52, 63	5.39, 44, 53, 64	5.38, 43, 55, *65	5.36, *47, 60, 62
18	5.8–9	Beams and Submerged Surfaces	5.67, 77, 80, 91	5.68, 76, 83, 90	5.66, 74, 81, 89	5.69, 78, 84, 88	5.70, 75, 86, 95	5.72, 79, 87, 92
19	5.10–12	Centroids of Volumes	5.104, 107, 117, 124	5.103, 106, 119, 123	5.101, 111, 114, 125	5.100, 108, 115, 122	5.102, 113, 120, 127	5.105, 109, 116, 126
20		EXAM NUMBER TWO						
21	6.1–5	Trusses: Method of Joints	6.1, 12, 23, 30	6.7, 11, 24, 27	6.2, 10, 21, 29	6.5, 9, 22, 28	6.4, 13, 25, 34	6.8, 14, 26, 33
22	6.7–8	Trusses: Method of Sections	6.43, 54, 68, 71	6.44, 53, 67, 70	6.45, 58, 65, 69	6.46, 57, 61, 72	6.48, 60, 64, 74	6.47, 59, 63, 73
23	6.9–11	Analysis of Frames	6.75, 89, 101, 110	6.76, 88, 102, 109	6.77, 83, 99, 108	6.78, 84, 100, 107	6.79, 85, 105, 114	6.80, 86, 106, 112
24	6.12	Analysis of Machines	6.122, 130, 145, 154	6.123, 134, 142, 151	6.127, 132, 144, 156	6.126, 131, 148, 155	6.124, 136, 141, 153	6.125, 135, 147, 152
25	6.1–12	Review of Chapter 6	6.20, 52, 91, 150	6.51, 92, 149, 166	6.15, 50, 93, 139	6.16, 49, 94, 128	6.17, 47, 97, 158	6.18, 48, 98, 157
26	7.1–2	Internal Forces in Members	7.1, 8, 20, 27	7.2, 14, 19, 23	7.4, 10, 16, 24	7.3, 9, 17, 28	7.5, 11, 21, 26	7.6, 12, 22, 25
27	7.3–5	Beams	7.39, 46, 54, 59	7.35, 45, 49, 58	7.41, 43, 53, 57	7.42, 44, 52, 56	7.38, 48, 50, 61	7.37, 47, 51, 60
28	7.6	Beams	7.65, 70, 79, 90	7.66, 69, 80, 89	7.63, 74, 77, 86	7.64, 73, 78, 85	7.67, 76, 81, 88	7.68, 75, 82, 87
29		EXAM NUMBER THREE						
30	8.1–4	Laws of Friction	8.5, 16, 26, 34	8.9, 15, 28, 39	8.1, 11, 30, 42	8.2, 12, 31, 38	8.8, 14, 32, 35	8.10, 13, 33, 40
31	8.5–6	Wedges and Screws	8.46, 57, 62, 70	8.47, 54, 63, 69	8.48, 56, 60, 73	8.49, 52, 61, 72	8.50, 58, 67, 71	8.51, 59, 68, 74
32	8.10	Belt Friction	8.101, 112, 120, 131	8.104, 109, 121, 126	8.102, 111, 116, 125	8.103, 110, 122, 124	8.105, 113, 118, 127	8.106, 114, 119, 130
33	9.1–5	Moments of Inertia of Areas	9.1, 12, 15, 25	9.7, 11, 17, 22	9.4, 10, 16, 24	9.2, 9, 18, 21	9.8, 13, 19, 27	9.5, 14, 20, 26
34	9.6–7	Composite Areas	9.32, 45, 50, 57	9.34, 41, 52, 58	9.33, 43, 49, 59	9.31, 44, 55, *60	9.35, 47, 56, 62	9.36, 48, 54, 61
35	9.8–9	Product of Inertia	9.75, 83, 86	9.71, 81, 85	9.76, 79, 87	9.74, 80, 89	9.77, 84, 88	9.73, 82, 90
36	9.10	Mohr's Circle	9.93, 103, 107	9.95, 104, *106	9.92, 100, 105	9.91, 99, 108	9.94, 102, 110	9.96, 101, 109
37	9.11–15	Moments of Inertia of Masses	9.111, 121, 135, 147	9.116, 120, 136, 142	9.113, 122, 137, 144	9.112, 119, 138, 141	9.117, 123, 139, 146	9.118, 126, *140, 143
38	9.16–17	Principal Axes	9.151, 159, 167, 174	9.152, 157, 168, 173	9.149, 158, 165, 176	9.150, 160, 166, 175	9.153, 164, 171, 178	9.154, 163, 172, 177
39		EXAM NUMBER FOUR						
40	10.1–5	Virtual Work	10.1, 10, 15, 22	10.8, 9, 18, 21	10.2, 12, 16, 26	10.4, 11, 17, 25	10.5, 14, 19, 27	10.6, 13, 20, 23
41	10.1–5	Virtual Work	10.30, 40, 46, 54	10.31, 38, 45, 53	10.32, 37, 43, 58	10.33, 36, 49, 57	10.29, 41, 48, 55	10.34, 42, 50, 56
42	10.6–9	Potential Energy	10.71, 81, 88, 90	10.74, 78, 83, 91	10.70, 80, 85, 92	10.69, 79, 86, 93	10.75, 82, 87, 95	10.76, 77, 84, 89

TABLE IV: SAMPLE ASSIGNMENT SCHEDULE FOR A COURSE IN STATICS

This schedule includes all of the material of *VECTOR MECHANICS FOR ENGINEERS: STATICS* with the exception of Sections 3.21, 6.6, 7.7–7.10, 8.7–8.9, and 9.18.

75% OF THE PROBLEMS IN EACH OF THE FOLLOWING LISTS USE SI UNITS AND 25% U.S. CUSTOMARY UNITS

ANSWERS TO ALL OF THESE PROBLEMS ARE GIVEN IN THE BACK OF THE BOOK

Period	Sections	Topics	List 1a	List 2a	List 3a	List 4a
1	1.1–6	Introduction				
2	2.1–8	Addition and Resolution of Forces	2.7, 15, 27, 36	2.9, 16, 26, 34	2.8, 19, 25, 35	2.10, 17, 30, 32
3	2.9–11	Equilibrium of a Particle	2.47, 52, 61, 69	2.48, 51, 62, 65	2.45, 56, 57, 68	2.43, 55, 60, 67
4	2.12–14	Forces in Space	2.74, 82, 89, 92	2.71, 81, 87, 91	2.73, 84, 85, 96	2.72, 79, 86, 95
5	2.15	Equilibrium in Space	2.103, 111, 118, 123	2.104, 107, 115, 121	2.99, 112, 116, 126	2.101, 108, 117, 125
6	3.1–8	Vector Product, Moment of a Force about a Point	3.1, 13, 21, 27	3.3, 12, 22, 31	3.2, 9, 24, 28	3.4, 10, 26, 32
7	3.9–11	Scalar Product, Moment of a Force about an Axis	3.39, 50, 57, *66	3.40, 47, 58, *65	3.41, 48, 55, *69	3.37, 49, 56, *68
8	3.12–16	Couples	3.70, 81, 87, 97	3.72, 82, 88, 98	3.76, 85, 89, 94	3.80, 83, 90, 93
9	3.17–20	Equivalent Systems of Forces	3.105, 111, 124, 127	3.106, 112, 125, 128	3.101, 116, 119, 129	3.102, 115, 120, 130
10		EXAM NUMBER ONE				
11	4.1–4	Equilibrium in Two Dimensions	4.2, 14, 19, 27	4.3, 11, 15, 26	4.5, 9, 17, 28	4.6, 12, 18, 21
12	4.1–5	Equilibrium in Two Dimensions	4.29, 41, 50, 53	4.33, 42, 49, 51	4.30, 37, 46, 57	4.34, 38, 43, 54
13	4.6–7	Two- and Three-Force Bodies	4.61, 74, 77, 85	4.62, 71, 79, 84	4.66, 70, 75, 88	4.67, 69, 81, 83
14	4.8–9	Equilibrium in Three Dimensions	4.91, 100, 109, 114	4.94, 99, 110, 113	4.92, 102, 106, 118	4.93, 101, 107, 117
15	4.8–9	Equilibrium in Three Dimensions	4.119, 128, 135	4.122, 127, 136	4.125, 130, 138	4.126, 129, 133
16	5.1–5	Centroids and First Moments	5.2, 14, 24, 33	5.1, 11, 20, 32	5.6, 12, 22, 30	5.9, 10, 21, 29
17	5.6–7	Centroids by Integration	5.37, 40, 56, 59	5.34, 46, 57, 61	5.35, 42, 52, 63	5.39, 45, 53, 64
18	5.8–9	Beams and Submerged Surfaces	5.67, 77, 80, 94	5.68, 76, 83, 93	5.71, 74, 81, 89	5.73, 78, 84, 88
19	5.10–12	Centroids of Volumes	5.104, 107, 118, 124	5.103, 106, 121, 123	5.101, 112, 114, 125	5.100, 110, 115, 122
20		EXAM NUMBER TWO				
21	6.1–5	Trusses: Method of Joints	6.1, 12, 23, 32	6.7, 11, 24, 31	6.6, 10, 21, 29	6.3, 9, 22, 28
22	6.7–8	Trusses: Method of Sections	6.43, 54, 66, 71	6.44, 53, 62, 70	6.45, 56, 65, 69	6.46, 55, 61, 72
23	6.9–11	Analysis of Frames	6.75, 89, 101, 111	6.76, 88, 102, 113	6.81, 83, 99, 108	6.82, 84, 100, 107
24	6.12	Analysis of Machines	6.122, 130, 143, 154	6.123, 134, 146, 151	6.127, 137, 144, 156	6.126, 133, 148, 155
25	6.1–12	Review of Chapter 6	6.20, 52, 91, 129	6.51, 92, 140, 166	6.19, 50, 93, 139	6.49, 94, 128, 167
26	7.1–2	Internal Forces in Members	7.1, 8, 15, 27	7.2, 14, 18, 23	7.4, 13, 16, 24	7.3, 7, 17, 28
27	7.3–5	Beams	7.39, 46, 54, 55	7.35, 45, 49, 58	7.40, 43, 53, 57	7.36, 44, 52, 56
28	7.6	Beams	7.65, 70, 83, 90	7.66, 69, 84, 89	7.63, 72, 77, 86	7.64, 71, 78, 85
29		EXAM NUMBER THREE				
30	8.1–4	Laws of Friction	8.5, 16, 26, 37	8.9, 15, 28, 36	8.3, 11, 30, 42	8.6, 12, 31, 38
31	8.5–6	Wedges and Screws	8.46, 57, *64, 70	8.47, 54, *65, 69	8.48, 55, 60, 73	8.49, 53, 61, 72
32	8.10	Belt Friction	8.101, 112, 123, 131	8.104, 109, 117, 126	8.102, 108, 116, 125	8.103, 107, 122, 124
33	9.1–5	Moments of Inertia of Areas	9.1, 12, 15, 28	9.7, 11, 17, 23	9.6, 10, 16, 24	9.3, 9, 18, 21
34	9.6–7	Composite Areas	9.32, 45, 53, 57	9.34, 41, 51, 58	9.33, 42, 49, 59	9.31, 46, 55, *60
35	9.8–9	Product of Inertia	9.75, 83, 86	9.71, 81, 85	9.72, 79, 87	9.78, 80, 89
36	9.10	Mohr's Circle	9.93, 103, 107	9.95, 104, *106	9.92, 98, 105	9.91, 97, 108
37	9.11–15	Moments of Inertia of Masses	9.111, 121, 135, 148	9.116, 120, 136, 145	9.115, 122, 137, 144	9.114, 119, 138, 141
38	9.16–17	Principal Axes	9.151, 159, 170, 174	9.152, 157, 169, 173	9.149, 155, 165, 176	9.150, 156, 166, 175
39		EXAM NUMBER FOUR				
40	10.1–5	Virtual Work	10.1, 10, 15, 24	10.8, 9, 18, 28	10.3, 12, 16, 26	10.7, 11, 17, 25
41	10.1–5	Virtual Work	10.30, 40, 51, 54	10.31, 38, 44, 53	10.32, 35, 43, 58	10.33, 39, 49, 57
42	10.6–9	Potential Energy	10.71, 81, 88, 96	10.74, 78, 83, 94	10.72, 80, 85, 92	10.73, 79, 86, 93

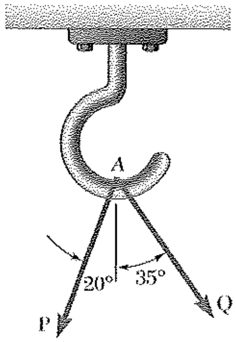
TABLE V: SAMPLE ASSIGNMENT SCHEDULE FOR A COMBINED COURSE IN STATICS AND DYNAMICS

This schedule is intended for a 4-semester-credit-hour course consisting of (1) the abridged Statics course defined in Table I of this manual and (2) the standard Dynamics course defined in Table I of the Dynamics Instructor's Manual. Note that the Statics portion of the course is designed to serve only as an introduction to Dynamics; a more complete coverage of Statics is recommended for curricula including courses in Mechanics of Materials (see Tables III and ff. of the Statics Manual).

50% OF THE PROBLEMS IN EACH OF THE FOLLOWING LISTS USE SI UNITS AND 50% U.S. CUSTOMARY UNITS

			ANSWERS TO ALL OF THESE PROBLEMS ARE GIVEN IN THE BACK OF THE BOOK				NO ANSWERS ARE GIVEN IN THE BOOK FOR ANY OF THESE PROBLEMS	
Period	Sections	Topics	List 1	List 2	List 3	List 4	List 5	List 6
1	1.1–6	Introduction						
2	2.1–8	Addition and Resolution of Forces	2.7, 15, 27, 37	2.9, 16, 26, 31	2.5, 19, 25, 35	2.11, 17, 30, 32	2.6, 20, 28, 38	2.12, 18, 29, 33
3	2.9–11	Equilibrium of a Particle	2.47, 52, 59, 69	2.48, 51, 63, 65	2.45, 53, 57, 68	2.43, 49, 60, 67	2.46, 54, 58, 70	2.44, 50, 64, 66
4	2.12–14	Forces in Space	2.74, 82, 89, 94	2.71, 81, 87, 97	2.76, 84, 85, 96	2.77, 79, 86, 95	2.78, 83, 90, 98	2.75, 80, 88, 93
5	2.15	Equilibrium in Space	2.103, 111, 114, 123	2.104, 107, 113, 121	2.99, 109, 116, 126	2.101, 105, 117, 125	2.100, 110, 119, 124	2.102, 106, 120, 122
6	3.1–8	Vector Product, Moment of a Force about a Point	3.1, 13, 21, 30	3.3, 12, 22, 33	3.5, 9, 24, 28	3.7, 10, 26, 32	3.8, 14, 25, 29	3.6, 11, 23, 34
7	3.9–11	Scalar Product, Moment of a Force about an Axis	3.39, 50, 59, *66	3.40, 47, 61, *65	3.41, 53, 55, *69	3.37, 51, 56, *68	3.42, 52, 62, *67	3.38, 54, 60, *64
8	3.12–16	Couples	3.70, 81, 87, 99	3.72, 82, 88, 95	3.71, 85, 89, 94	3.75, 83, 90, 93	3.74, 86, 91, 100	3.73, 84, 92, 96
9	3.17–20	Equivalent Systems of Forces	3.105, 111, 121, 127	3.106, 112, 122, 128	3.101, 108, 119, 129	3.102, 109, 120, 130	3.103, 117, 123, *132	3.107, 114, 126, *131
10		EXAM NUMBER ONE						
11	4.1–4	Equilibrium in Two Dimensions	4.2, 14, 19, 24	4.3, 11, 15, 23	4.1, 9, 17, 28	4.4, 12, 18, 21	4.7, 13, 16, 25	4.8, 10, 20, 22
12	4.1–5	Equilibrium in Two Dimensions	4.29, 41, 44, 53	4.33, 42, 47, 51	4.30, 36, 46, 57	4.34, 35, 43, 54	4.32, 40, 45, 56	4.31, 39, 48, 55
13	6.9–11	Analysis of Frames	6.75, 89, 101, 110	6.76, 88, 102, 109	6.77, 83, 99, 108	6.78, 84, 100, 107	6.79, 85, 105, 114	6.80, 86, 106, 112
14	6.12	Analysis of Machines	6.122, 130, 145, 154	6.123, 134, 142, 151	6.127, 132, 144, 156	6.126, 131, 148, 155	6.124, 136, 141, 153	6.125, 135, 147, 152
15	4.8–9	Equilibrium in Three Dimensions	4.91, 100, 105, 114	4.94, 99, 108, 113	4.92, 98, 106, 118	4.93, 97, 107, 117	4.95, 104, 111, 116	4.96, 103, 112, 115
16	4.8–9	Equilibrium in Three Dimensions	4.119, 128, 135	4.122, 127, 136	4.120, 130, 138	4.121, 129, 133	4.123, 132, 140	4.124, 131, 141
17	8.1–4	Laws of Friction	8.5, 16, 26, 34	8.9, 15, 28, 39	8.1, 11, 30, 42	8.2, 12, 31, 38	8.8, 14, 32, 35	8.10, 13, 33, 40
18	8.5–6	Wedges and Screws	8.46, 57, 62, 70	8.47, 54, 63, 69	8.48, 56, 60, 73	8.49, 52, 61, 72	8.50, 58, 67, 71	8.51, 59, 68, 74
19		EXAM NUMBER TWO						
20	11.2–3	Rectilinear Motion	11.1, 12, 17, 24	11.2,11,18,23	11.3,10,15,22	11.4,9,16,21	11.7,14,19,30	11.8,13,20,29
21	11.4–6	Uniformly Accelerated Motion	11.33, 40, 49, 56	11.34,39,50,55	11.35,42,47,58	11.36,41,48,57	11.37,46,51,60	11.38,45,52,59
22	11.9–12	Curvilinear Motion (Rect. Comps)	11.97, 108, 117, 128	11.98,105,118,127	11.99,108,119,126	11.100,107,120,125	11.103,110,121,132	11.104,109,122,131
23	11.13–14	Curvilinear Motion (Other Comp.)	11.139, 144, 156, 166	11.141,143,157,165	11.137,146,153,170	11.138,145,154,169	11.140,150,159,168	12.142,149,160,167
24	12.1–6	Equations of Motion	12.5, 19, 28, 47	12.6, 17, 29, 47	12.7, 21, 30, 45	8, 20, 31, 44	12.13, 23, 32, 54	12.14, 22, 33, 52
25	12.7–10	Angular Momentum	12.57, 67, 80, 88	12.58, 66, 81, 87	12.55, 69, 78, 91	12.56, 68, 79, 90	12.59, 73, 83, 93	12.69, 72, 85, 92
26		Review						
27		EXAM NUMBER THREE						
28	13.1–5	Work and Energy, Power	13.7, 16, 28, 42	13.8, 15, 29.41	13.5, 18, 26, 40	13.6, 17, 27, 39	13.11, 20, 34, 48	13.12, 19, 37, 47
29	13.6–8	Conservation of Energy	13.58, 63, 72, 80	13.59, 62, 73, 79	13.55, 65, 70, 82	13.56, 64, 71, 81	13.60, 67, 76, 84	13.61, 66, 77, 83
30	13.9	Application to Space Mechanics	13.85, 96, 100, 110	13.86, 95, 101, 109	13.87, 94, 102, 107	13.88, 93, 103, 106	13.91, 99, 104, 113	13.92, 98, 105, 112
31	13.10–11	Impulse and Momentum	13. 119, 130, 139, 150	13. 122, 129, 140, 148	13. 120, 132, 141, 146	13.121, 131, 142, 145	13.125, 138, 143, 154	13.128, 133, 144, 153
32	13.12–15	Impact	13.157, 165, 178, 185	13.158, 164, 179, 184	13.155, 168, 174, 188	13.156, 167, 175, 186	13.161, 172, 181, 189	13.162, 171182, 187
33	14.1–6	Systems of Particles	14.1, 14, 17, 22	14.2, 13, 18, 21	14.3, 10, 15, 24	14.4, 9, 16, 23	14.5, 12, 19, 26	14.6, 11, 20, 25
34	14.7–9	Systems of Particles	14. 33, 38, 49, 52	14. 34, 37, 50, 51	14.31, 40, 45, 54	14.32, 39, 46, 53	14.35, 44, 47, 56	14.36, 43, 48, 55
35		EXAM NUMBER FOUR						
36	15.1–4	Translation, Rotation	15.1, 11, 18, 29	15.2, 10, 19, 28	15.3, 13, 21, 31	15.4, 12, 22, 30	15.7, 15, 20, 35	15.8, 14, 23, 34
37	15.5–6	General Plane Motion	15.38, 51, 55, 65	15.39, 50, 56, 64	15.40, 49, 57, 69	15.41, 48, 58, 68	15.42, 54, 59, 67	15.43, 53, 62, 66
38	15.7	Instantaneous Center	15.75, 85, 89, 98	15.76, 84, 90, 97	15.73, 83, 92, 96	15.74, 82, 93, 95	15.80, 87, 88, 104	15.81, 86, 91, 101
39	15.8–9	Acceleration in Plane Motion	15.115, 121, 127, 139	15.116, 120, 128, 138	15.112, 122, 129, 141	15.113, 122, 130, 140	15.114, 124, 131, 146	15.117, 123, 134, 145
40	15.10–11	Coriolis Acceleration in Plane Motion	15.151, 163, 168, 178	15.152, 162, 169, 177	15.150, 161, 166, 175	15.153, 160, 167, 174	15.154, 159, 172, 180	15.155, 158, 173, 179
41	9.11–15	Moments of Inertia of Masses	9.111, 121, 135, 147	9.116, 120, 136, 142	9.113, 122, 137, 144	9.112, 119, 138, 141	9.117, 123, 139, 146	9.118, 126, *140, 143
42		Review						
43		EXAM NUMBER FIVE						
44	16.1–7	Plane Motion of Rigid Bodies	16.1, 20, 27, 42	16.2, 17, 28, 41	16.3, 16, 25, 40	16.4, 14, 34, 39	16.9, 18, 32, 44	16.10, 15, 33, 43
45	16.1–7	Plane Motion of Rigid Bodies	16.47, 56, 64, 72	16.48, 55, 65, 71	16.50, 58, 63, 70	16.51, 57, 63, 69	16.53, 62, 68, 74	16.54, 61, 68, 73
46	16.8	Constrained Plane Motion	16.78, 85, 102, 110	16.79, 84, 105, 109	16.76, 87, 98, 107	16.77, 86, 100, 106	16.80, 91, 103, 115	16.83, 90, 104, 114
47	16.8	Constrained Plane Motion	16.119, 125, 133, 143	16.121, 124, 136, 142	16.117, 128, 134, 147	16. 118, 127, 135, 146	16.122, 132, 137, 150	16.123, 131, 140, 149
48	17.1–7	Work and Energy	17.4, 20, 24, 40	17.5, 18, 26, 39	17.8, 17, 28, 37	17.11, 16, 29, 36	17.14, 22, 27, 43	17.15, 21, 32, 41
49	17.8–10	Impulse and Momentum	17.54, 71, 79, 89	17.59, 69, 84, 88	17.52, 72, 77, 95	17.60, 70, 81, 90	17.55, 76, 82, 93	17.58, 73, 85, 91
50	17.11–12	Eccentric Impact	17.98, 106, 114, 122	17.100, 105, 117, 121	17.96, 108, 115, 124	17.97, 107, 116, 123	17.103, 111, 118, 130	17.104, 109, 119, 129
51		Review						
52		EXAM NUMBER SIX						
53	19.1–3	Free Vibrations of Particles	19.3, 13, 17, 26	19.5, 12, 18, 25	19.4, 14, 19, 24	19.6, 11, 20, 23	19.8, 16, 21, 29	19.10, 15, 22, 28
54	19.5	Free Vibrations of Rigid Bodies	19.38, 47, 56, 65	19.40, 44, 58, 63	19.37, 46, 55, 66	19.39, 45, 57, 64	19.41, 51, 60, 68	19.42, 48, 62, 67
55	19.6	Energy Methods	19.69, 79, 84, 92	19.71, 78, 85, 90	19.70, 80, 83, 91	19.72, 77, 88, 89	19.74, 82, 86, 95	19.75, 81, 87, 93
56	19.7	Forced Vibrations	19.100, 106, 113, 122	19.101, 105, 115, 121	19.99, 104, 114, 124	19.102, 107, 116, 123	19.103, 111, 117, 126	19.104, 110, 119, 125

CHAPTER 2

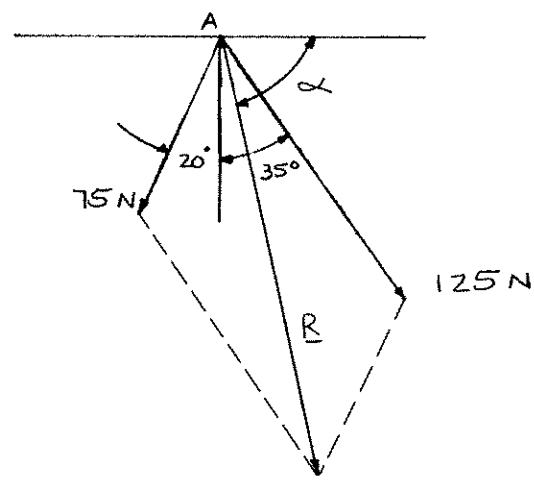


PROBLEM 2.1

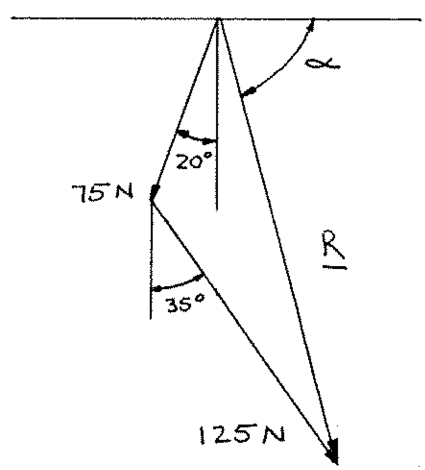
Two forces **P** and **Q** are applied as shown at Point A of a hook support. Knowing that $P = 75$ N and $Q = 125$ N, determine graphically the magnitude and direction of their resultant using (a) the parallelogram law, (b) the triangle rule.

SOLUTION

(a) Parallelogram law:

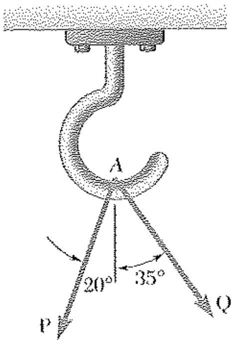


(b) Triangle rule:



We measure: $R = 179$ N, $\alpha = 75.1°$ $\qquad$ $\mathbf{R} = 179$ N $\measuredangle$ 75.1° ◀

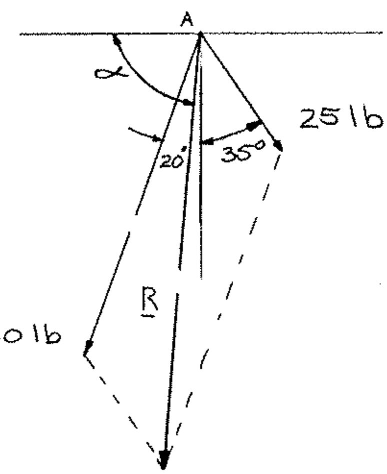
PROBLEM 2.2



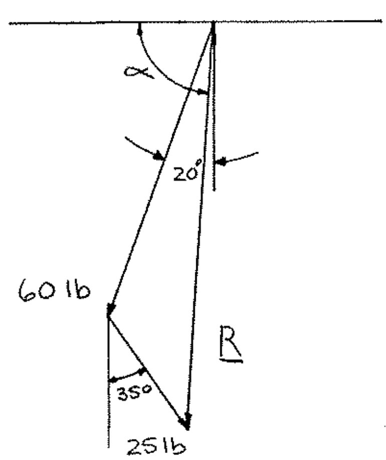
Two forces **P** and **Q** are applied as shown at Point A of a hook support. Knowing that $P = 60$ lb and $Q = 25$ lb, determine graphically the magnitude and direction of their resultant using (*a*) the parallelogram law, (*b*) the triangle rule.

SOLUTION

(*a*) Parallelogram law:

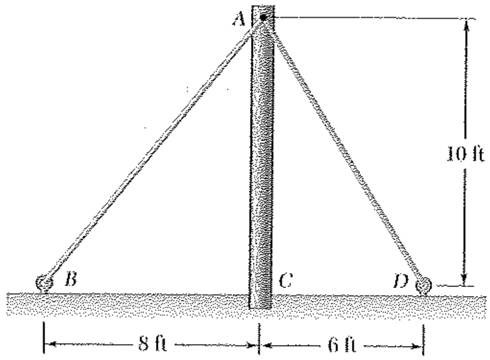


(*b*) Triangle rule:



We measure: $R = 77.1$ lb, $\alpha = 85.4°$

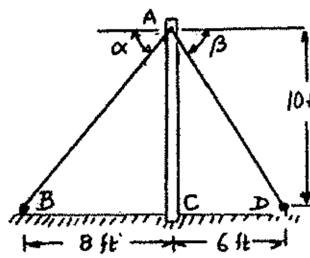
$\mathbf{R} = 77.1$ lb ⦪ 85.4° ◀



PROBLEM 2.3

The cable stays AB and AD help support pole AC. Knowing that the tension is 120 lb in AB and 40 lb in AD, determine graphically the magnitude and direction of the resultant of the forces exerted by the stays at A using (a) the parallelogram law, (b) the triangle rule.

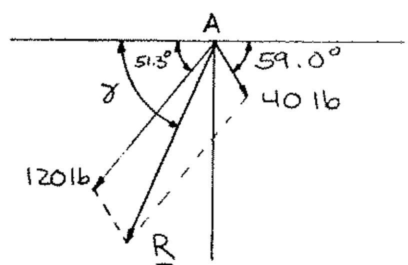
SOLUTION



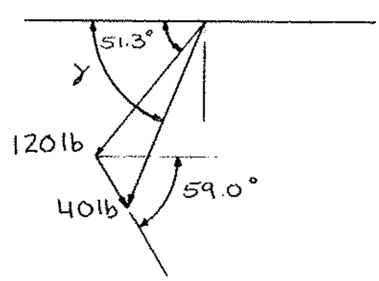
We measure: $\alpha = 51.3°$

$\beta = 59.0°$

(a) Parallelogram law:

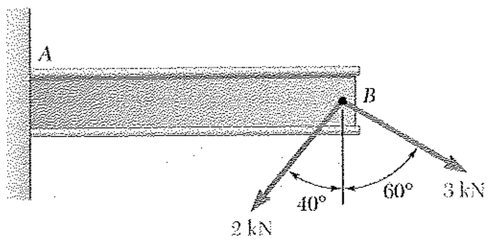


(b) Triangle rule:



We measure: $R = 139.1$ lb, $\gamma = 67.0°$

$R = 139.1$ lb $\measuredangle$ $67.0°$ ◀

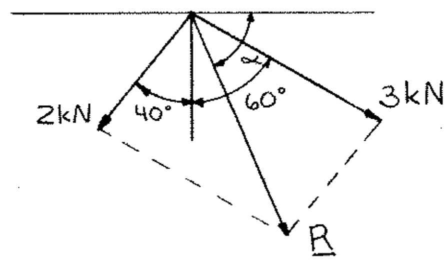


PROBLEM 2.4

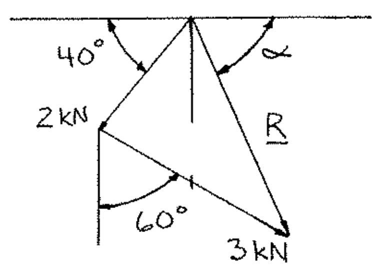
Two forces are applied at Point B of beam AB. Determine graphically the magnitude and direction of their resultant using (a) the parallelogram law, (b) the triangle rule.

SOLUTION

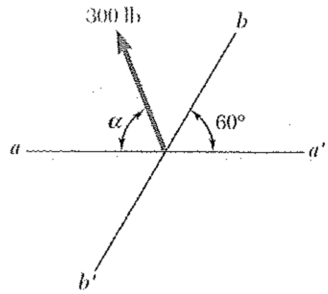
(a) Parallelogram law:



(b) Triangle rule:



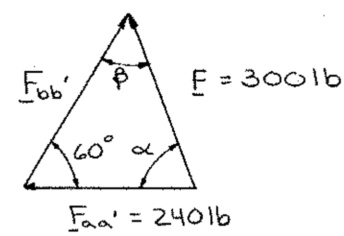
We measure: $R = 3.30$ kN, $\alpha = 66.6°$ $\mathbf{R} = 3.30$ kN ◺ 66.6° ◀



PROBLEM 2.5

The 300-lb force is to be resolved into components along lines a-a' and b-b'. (a) Determine the angle α by trigonometry knowing that the component along line a-a' is to be 240 lb. (b) What is the corresponding value of the component along b-b'?

SOLUTION



(a) Using the triangle rule and law of sines:

$$\frac{\sin\beta}{240\text{ lb}} = \frac{\sin 60^\circ}{300\text{ lb}}$$

$$\sin\beta = 0.69282$$

$$\beta = 43.854^\circ$$

$$\alpha + \beta + 60^\circ = 180^\circ$$

$$\alpha = 180^\circ - 60^\circ - 43.854^\circ$$

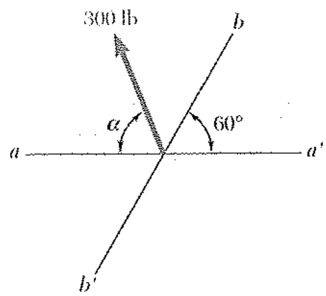
$$= 76.146^\circ$$

$\alpha = 76.1^\circ$ ◀

(b) Law of sines:

$$\frac{F_{bb'}}{\sin 76.146^\circ} = \frac{300\text{ lb}}{\sin 60^\circ}$$

$F_{bb'} = 336$ lb ◀

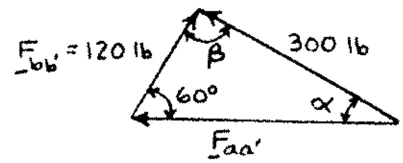


PROBLEM 2.6

The 300-lb force is to be resolved into components along lines a-a' and b-b'. (a) Determine the angle α by trigonometry knowing that the component along line b-b' is to be 120 lb. (b) What is the corresponding value of the component along a-a'?

SOLUTION

Using the triangle rule and law of sines:



(a)

$$\frac{\sin\alpha}{120\text{ lb}} = \frac{\sin 60^\circ}{300\text{ lb}}$$

$$\sin\alpha = 0.34641$$

$$\alpha = 20.268^\circ$$

$\alpha = 20.3^\circ$ ◀

(b)

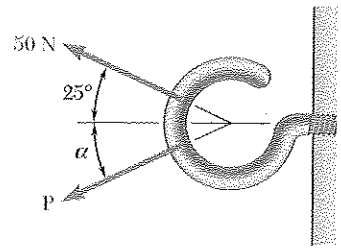
$$\alpha + \beta + 60^\circ = 180^\circ$$

$$\beta = 180^\circ - 60^\circ - 20.268^\circ$$

$$= 99.732^\circ$$

$$\frac{F_{aa'}}{\sin 99.732^\circ} = \frac{300\text{ lb}}{\sin 60^\circ}$$

$F_{aa'} = 341$ lb ◀

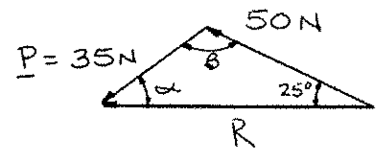


PROBLEM 2.7

Two forces are applied as shown to a hook support. Knowing that the magnitude of **P** is 35 N, determine by trigonometry (*a*) the required angle α if the resultant **R** of the two forces applied to the support is to be horizontal, (*b*) the corresponding magnitude of **R**.

SOLUTION

Using the triangle rule and law of sines:



(*a*)

$$\frac{\sin\alpha}{50\text{ N}} = \frac{\sin 25°}{35\text{ N}}$$

$$\sin\alpha = 0.60374$$

$$\alpha = 37.138°$$

$\alpha = 37.1°$ ◀

(*b*)

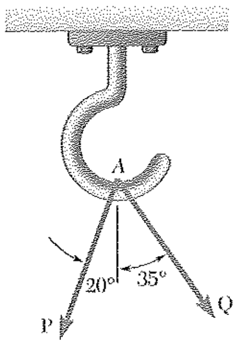
$$\alpha + \beta + 25° = 180°$$

$$\beta = 180° - 25° - 37.138°$$

$$= 117.86°$$

$$\frac{R}{\sin 117.86} = \frac{35\text{ N}}{\sin 25°}$$

$R = 73.2\text{ N}$ ◀

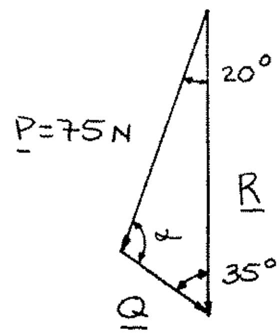


PROBLEM 2.8

For the hook support of Problem 2.1, knowing that the magnitude of **P** is 75 N, determine by trigonometry (*a*) the required magnitude of the force **Q** if the resultant **R** of the two forces applied at *A* is to be vertical, (*b*) the corresponding magnitude of **R**.

PROBLEM 2.1 Two forces **P** and **Q** are applied as shown at Point *A* of a hook support. Knowing that $P = 75$ N and $Q = 125$ N, determine graphically the magnitude and direction of their resultant using (*a*) the parallelogram law, (*b*) the triangle rule.

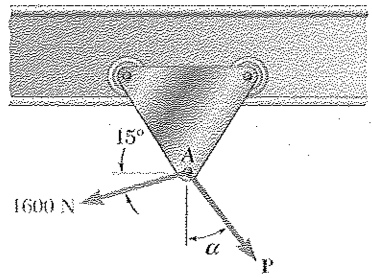
SOLUTION



Using the triangle rule and law of sines:

(*a*)
$$\frac{Q}{\sin 20^\circ} = \frac{75\text{ N}}{\sin 35^\circ}$$
$Q = 44.7$ N ◀

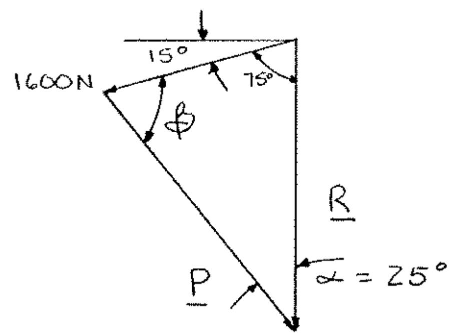
(*b*)
$$\alpha + 20^\circ + 35^\circ = 180^\circ$$
$$\alpha = 180^\circ - 20^\circ - 35^\circ$$
$$= 125^\circ$$
$$\frac{R}{\sin 125^\circ} = \frac{75\text{ N}}{\sin 35^\circ}$$
$R = 107.1$ N ◀



PROBLEM 2.9

A trolley that moves along a horizontal beam is acted upon by two forces as shown. (*a*) Knowing that $\alpha = 25°$, determine by trigonometry the magnitude of the force **P** so that the resultant force exerted on the trolley is vertical. (*b*) What is the corresponding magnitude of the resultant?

SOLUTION



Using the triangle rule and the law of sines:

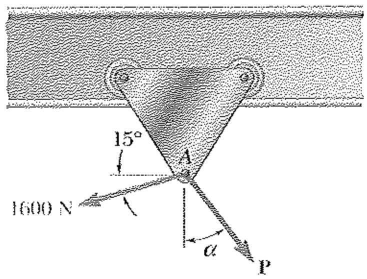
(*a*)
$$\frac{1600\text{ N}}{\sin 25°} = \frac{P}{\sin 75°}$$

$P = 3660\text{ N}$ ◀

(*b*)
$$25° + \beta + 75° = 180°$$
$$\beta = 180° - 25° - 75°$$
$$= 80°$$

$$\frac{1600\text{ N}}{\sin 25°} = \frac{R}{\sin 80°}$$

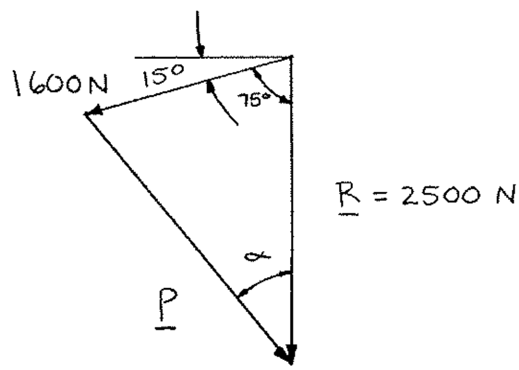
$R = 3730\text{ N}$ ◀



PROBLEM 2.10

A trolley that moves along a horizontal beam is acted upon by two forces as shown. Determine by trigonometry the magnitude and direction of the force **P** so that the resultant is a vertical force of 2500 N.

SOLUTION



Using the law of cosines: $P^2 = (1600\text{ N})^2 + (2500\text{ N})^2 - 2(1600\text{ N})(2500\text{ N})\cos 75°$

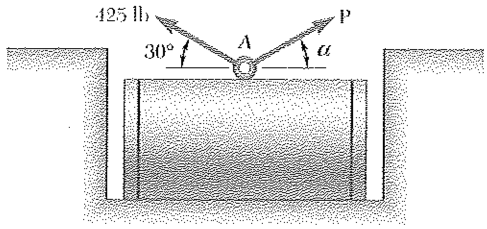
$$P = 2596\text{ N}$$

Using the law of sines: $\dfrac{\sin\alpha}{1600\text{ N}} = \dfrac{\sin 75°}{2596\text{ N}}$

$$\alpha = 36.5°$$

P is directed $90° - 36.5°$ or $53.5°$ below the horizontal.

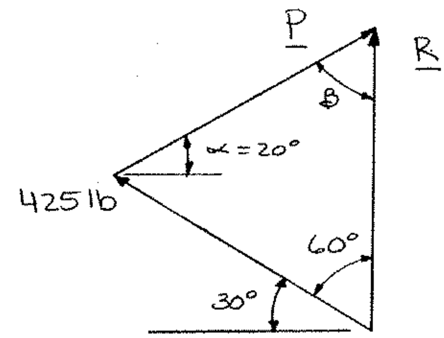
P $= 2600$ N ⦪ $53.5°$ ◀



PROBLEM 2.11

A steel tank is to be positioned in an excavation. Knowing that $\alpha = 20°$, determine by trigonometry (*a*) the required magnitude of the force **P** if the resultant **R** of the two forces applied at A is to be vertical, (*b*) the corresponding magnitude of **R**.

SOLUTION

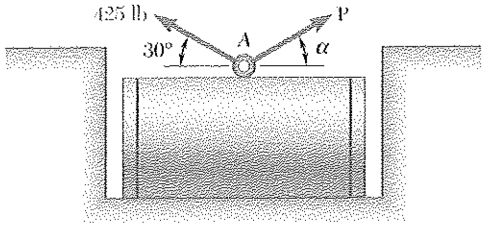


Using the triangle rule and the law of sines:

(*a*)
$$\beta + 50° + 60° = 180°$$
$$\beta = 180° - 50° - 60°$$
$$= 70°$$

$$\frac{425 \text{ lb}}{\sin 70°} = \frac{P}{\sin 60°} \qquad P = 392 \text{ lb} \blacktriangleleft$$

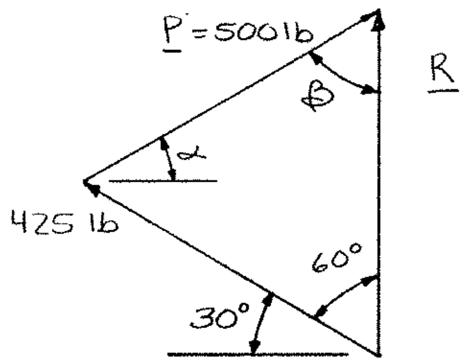
(*b*)
$$\frac{425 \text{ lb}}{\sin 70°} = \frac{R}{\sin 50°} \qquad R = 346 \text{ lb} \blacktriangleleft$$



PROBLEM 2.12

A steel tank is to be positioned in an excavation. Knowing that the magnitude of **P** is 500 lb, determine by trigonometry (*a*) the required angle α if the resultant **R** of the two forces applied at A is to be vertical, (*b*) the corresponding magnitude of **R**.

SOLUTION



Using the triangle rule and the law of sines:

(*a*)

$$(\alpha + 30°) + 60° + \beta = 180°$$

$$\beta = 180° - (\alpha + 30°) - 60°$$

$$\beta = 90° - \alpha$$

$$\frac{\sin(90° - \alpha)}{425 \text{ lb}} = \frac{\sin 60°}{500 \text{ lb}}$$

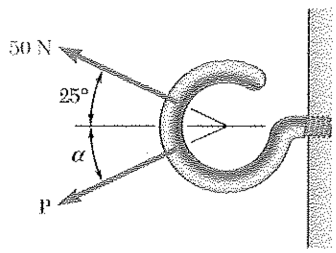
$$90° - \alpha = 47.40°$$

$\alpha = 42.6°$ ◀

(*b*)

$$\frac{R}{\sin(42.6° + 30°)} = \frac{500 \text{ lb}}{\sin 60°}$$

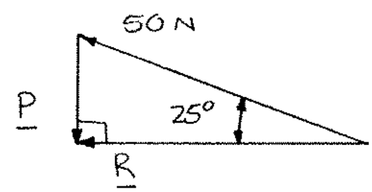
$R = 551 \text{ lb}$ ◀



PROBLEM 2.13

For the hook support of Problem 2.7, determine by trigonometry (*a*) the magnitude and direction of the smallest force **P** for which the resultant **R** of the two forces applied to the support is horizontal, (*b*) the corresponding magnitude of **R**.

SOLUTION

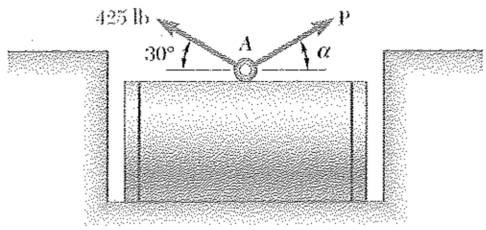


The smallest force P will be perpendicular to R.

(*a*) $P = (50\text{ N})\sin 25°$ $\mathbf{P} = 21.1\text{ N}\downarrow$ ◀

(*b*) $R = (50\text{ N})\cos 25°$ $R = 45.3\text{ N}$ ◀

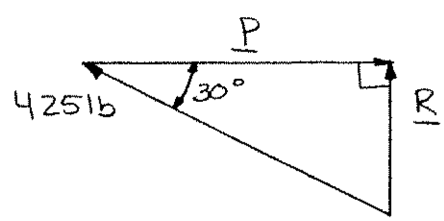
PROBLEM 2.14



For the steel tank of Problem 2.11, determine by trigonometry (*a*) the magnitude and direction of the smallest force **P** for which the resultant **R** of the two forces applied at *A* is vertical, (*b*) the corresponding magnitude of **R**.

PROBLEM 2.11 A steel tank is to be positioned in an excavation. Knowing that $\alpha = 20°$, determine by trigonometry (*a*) the required magnitude of the force **P** if the resultant **R** of the two forces applied at *A* is to be vertical, (*b*) the corresponding magnitude of **R**.

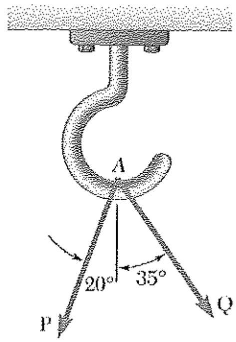
SOLUTION



The smallest force P will be perpendicular to R.

(*a*) $P = (425 \text{ lb})\cos 30°$ $\qquad$ $\mathbf{P} = 368 \text{ lb} \longrightarrow$ ◀

(*b*) $R = (425 \text{ lb})\sin 30°$ $\qquad$ $R = 213 \text{ lb}$ ◀



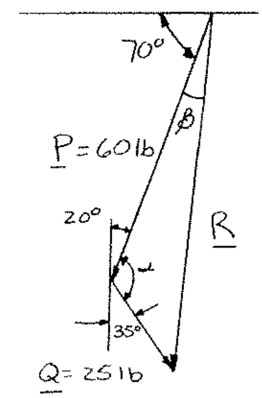
PROBLEM 2.15

Solve Problem 2.2 by trigonometry.

PROBLEM 2.2 Two forces **P** and **Q** are applied as shown at Point A of a hook support. Knowing that $P = 60$ lb and $Q = 25$ lb, determine graphically the magnitude and direction of their resultant using (*a*) the parallelogram law, (*b*) the triangle rule.

SOLUTION

Using the triangle rule and the law of cosines:



$$20° + 35° + \alpha = 180°$$

$$\alpha = 125°$$

$$R^2 = P^2 + Q^2 - 2PQ\cos\alpha$$

$$R^2 = (60 \text{ lb})^2 + (25 \text{ lb})^2 - 2(60 \text{ lb})(25 \text{ lb})\cos 125°$$

$$R^2 = 3600 + 625 + 3000(0.5736)$$

$$R = 77.108 \text{ lb}$$

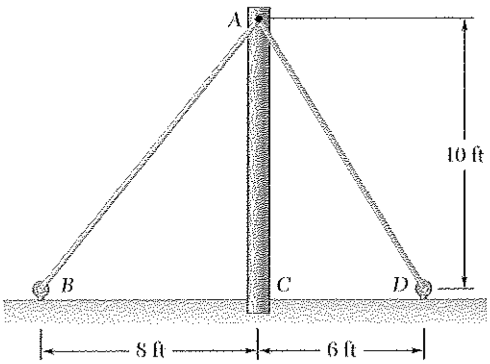
Using the law of sines:

$$\frac{\sin\beta}{25 \text{ lb}} = \frac{\sin 125°}{77.108 \text{ lb}}$$

$$\beta = 15.402°$$

$$70° + \beta = 85.402°$$

R $= 77.1$ lb $\measuredangle$ 85.4° ◀

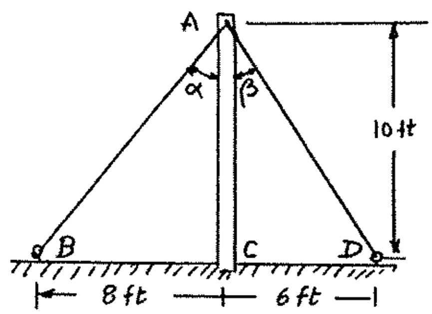


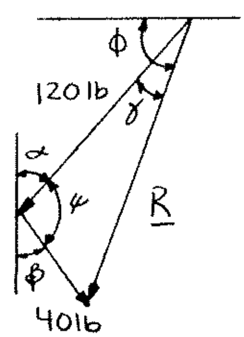
PROBLEM 2.16

Solve Problem 2.3 by trigonometry.

PROBLEM 2.3 The cable stays *AB* and *AD* help support pole *AC*. Knowing that the tension is 120 lb in *AB* and 40 lb in *AD*, determine graphically the magnitude and direction of the resultant of the forces exerted by the stays at *A* using (*a*) the parallelogram law, (*b*) the triangle rule.

SOLUTION





$$\tan\alpha = \frac{8}{10}$$
$$\alpha = 38.66°$$
$$\tan\beta = \frac{6}{10}$$
$$\beta = 30.96°$$

Using the triangle rule:

$$\alpha + \beta + \psi = 180°$$
$$38.66° + 30.96° + \psi = 180°$$
$$\psi = 110.38°$$

Using the law of cosines:

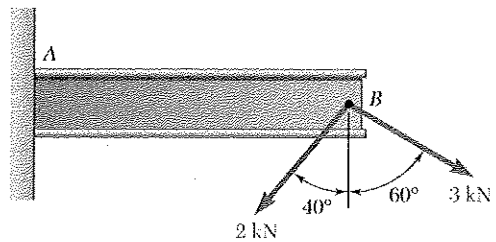
$$R^2 = (120 \text{ lb})^2 + (40 \text{ lb})^2 - 2(120 \text{ lb})(40 \text{ lb})\cos 110.38°$$
$$R = 139.08 \text{ lb}$$

Using the law of sines:

$$\frac{\sin\gamma}{40 \text{ lb}} = \frac{\sin 110.38°}{139.08 \text{ lb}}$$

$$\gamma = 15.64°$$
$$\phi = (90° - \alpha) + \gamma$$
$$\phi = (90° - 38.66°) + 15.64°$$
$$\phi = 66.98°$$

R = 139.1 lb ∠ 67.0° ◀

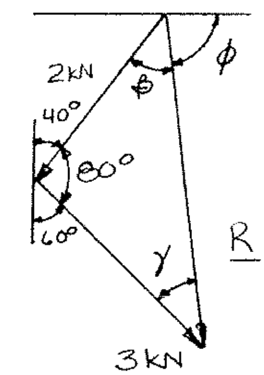


PROBLEM 2.17

Solve Problem 2.4 by trigonometry.

PROBLEM 2.4 Two forces are applied at Point B of beam AB. Determine graphically the magnitude and direction of their resultant using (*a*) the parallelogram law, (*b*) the triangle rule.

SOLUTION



Using the law of cosines:

$$R^2 = (2\text{ kN})^2 + (3\text{ kN})^2 - 2(2\text{ kN})(3\text{ kN})\cos 80°$$

$$R = 3.304\text{ kN}$$

Using the law of sines:

$$\frac{\sin\gamma}{2\text{ kN}} = \frac{\sin 80°}{3.304\text{ kN}}$$

$$\gamma = 36.59°$$

$$\beta + \gamma + 80° = 180°$$

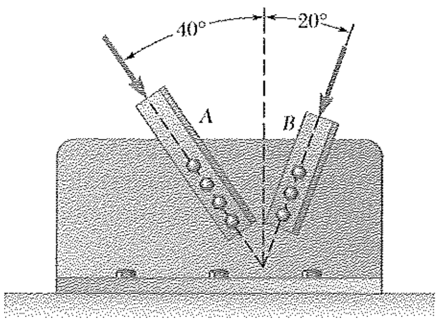
$$\gamma = 180° - 80° - 36.59°$$

$$\gamma = 63.41°$$

$$\phi = 180° - \beta + 50°$$

$$\phi = 66.59°$$

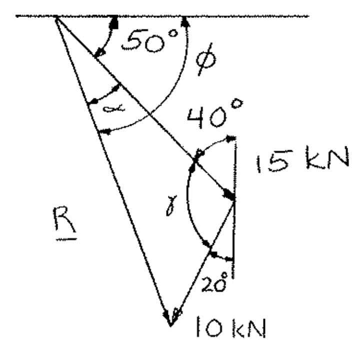
$\mathbf{R} = 3.30\text{ kN} \nwarrow 66.6°$ ◀



PROBLEM 2.18

Two structural members A and B are bolted to a bracket as shown. Knowing that both members are in compression and that the force is 15 kN in member A and 10 kN in member B, determine by trigonometry the magnitude and direction of the resultant of the forces applied to the bracket by members A and B.

SOLUTION



Using the force triangle and the laws of cosines and sines:

We have
$$\gamma = 180° - (40° + 20°)$$
$$= 120°$$

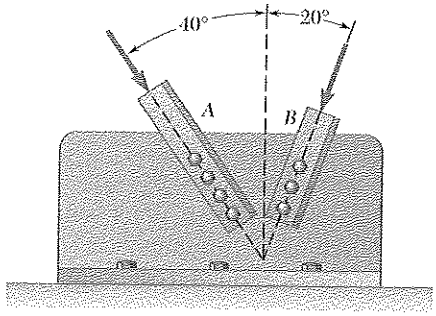
Then
$$R^2 = (15\text{ kN})^2 + (10\text{ kN})^2$$
$$-2(15\text{ kN})(10\text{ kN})\cos 120°$$
$$= 475\text{ kN}^2$$
$$R = 21.794\text{ kN}$$

and
$$\frac{10\text{ kN}}{\sin\alpha} = \frac{21.794\text{ kN}}{\sin 120°}$$
$$\sin\alpha = \left(\frac{10\text{ kN}}{21.794\text{ kN}}\right)\sin 120°$$
$$= 0.39737$$
$$\alpha = 23.414$$

Hence:
$$\phi = \alpha + 50° = 73.414$$

$\mathbf{R} = 21.8\text{ kN} \measuredangle\, 73.4°$ ◀

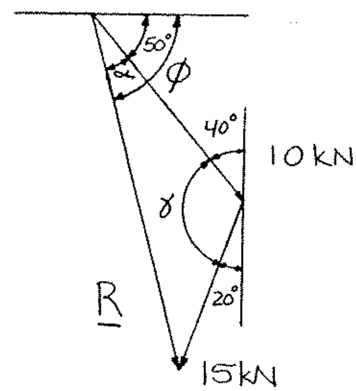
![problem figure]



PROBLEM 2.19

Two structural members *A* and *B* are bolted to a bracket as shown. Knowing that both members are in compression and that the force is 10 kN in member *A* and 15 kN in member *B*, determine by trigonometry the magnitude and direction of the resultant of the forces applied to the bracket by members *A* and *B*.

SOLUTION



Using the force triangle and the laws of cosines and sines

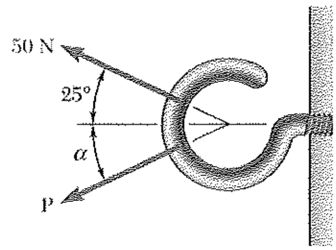
We have
$$\gamma = 180° - (40° + 20°)$$
$$= 120°$$

Then
$$R^2 = (10\text{ kN})^2 + (15\text{ kN})^2 - 2(10\text{ kN})(15\text{ kN})\cos 120°$$
$$= 475\text{ kN}^2$$
$$R = 21.794\text{ kN}$$

and
$$\frac{15\text{ kN}}{\sin\alpha} = \frac{21.794\text{ kN}}{\sin 120°}$$
$$\sin\alpha = \left(\frac{15\text{ kN}}{21.794\text{ kN}}\right)\sin 120°$$
$$= 0.59605$$
$$\alpha = 36.588°$$

Hence:
$$\phi = \alpha + 50° = 86.588°$$

R $= 21.8$ kN ⦬ $86.6°$ ◀



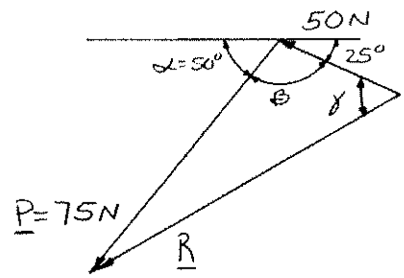
PROBLEM 2.20

For the hook support of Problem 2.7, knowing that $P = 75$ N and $\alpha = 50°$, determine by trigonometry the magnitude and direction of the resultant of the two forces applied to the support.

PROBLEM 2.7 Two forces are applied as shown to a hook support. Knowing that the magnitude of **P** is 35 N, determine by trigonometry (*a*) the required angle α if the resultant **R** of the two forces applied to the support is to be horizontal, (*b*) the corresponding magnitude of **R**.

SOLUTION

Using the force triangle and the laws of cosines and sines:



We have

$$\beta = 180° - (50° + 25°)$$
$$= 105°$$

Then

$$R^2 = (75\text{ N})^2 + (50\text{ N})^2 - 2(75\text{ N})(50\text{ N})\cos 105°$$
$$R^2 = 10066.1\text{ N}^2$$
$$R = 100.330\text{ N}$$

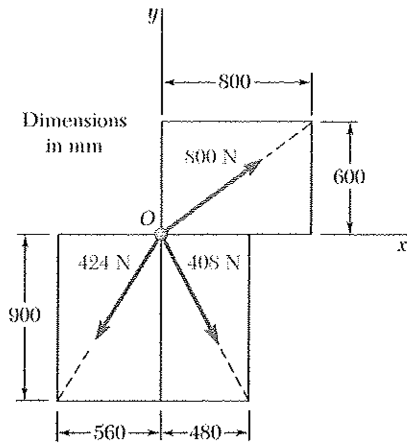
and

$$\frac{\sin\gamma}{75\text{ N}} = \frac{\sin 105°}{100.330\text{ N}}$$
$$\sin\gamma = 0.72206$$
$$\gamma = 46.225°$$

Hence:

$$\gamma - 25° = 46.225° - 25° = 21.225°$$

R $= 100.3$ N ⦣ $21.2°$ ◀

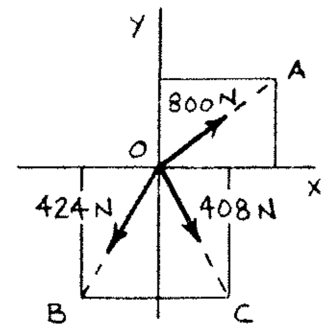


PROBLEM 2.21

Determine the x and y components of each of the forces shown.

SOLUTION

Compute the following distances:



$$OA = \sqrt{(600)^2 + (800)^2}$$
$$= 1000 \text{ mm}$$
$$OB = \sqrt{(560)^2 + (900)^2}$$
$$= 1060 \text{ mm}$$
$$OC = \sqrt{(480)^2 + (900)^2}$$
$$= 1020 \text{ mm}$$

800-N Force:

$$F_x = +(800 \text{ N})\frac{800}{1000} \qquad F_x = +640 \text{ N} \blacktriangleleft$$

$$F_y = +(800 \text{ N})\frac{600}{1000} \qquad F_y = +480 \text{ N} \blacktriangleleft$$

424-N Force:

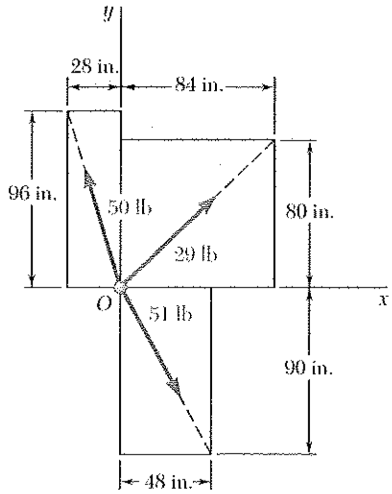
$$F_x = -(424 \text{ N})\frac{560}{1060} \qquad F_x = -224 \text{ N} \blacktriangleleft$$

$$F_y = -(424 \text{ N})\frac{900}{1060} \qquad F_y = -360 \text{ N} \blacktriangleleft$$

408-N Force:

$$F_x = +(408 \text{ N})\frac{480}{1020} \qquad F_x = +192.0 \text{ N} \blacktriangleleft$$

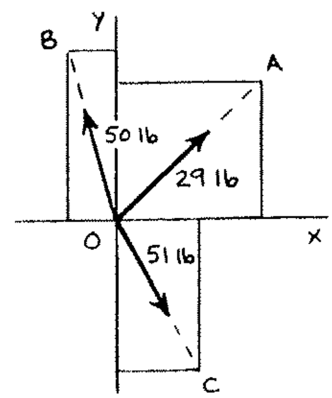
$$F_y = -(408 \text{ N})\frac{900}{1020} \qquad F_y = -360 \text{ N} \blacktriangleleft$$



PROBLEM 2.22

Determine the x and y components of each of the forces shown.

SOLUTION



Compute the following distances:

$$OA = \sqrt{(84)^2 + (80)^2}$$
$$= 116 \text{ in.}$$
$$OB = \sqrt{(28)^2 + (96)^2}$$
$$= 100 \text{ in.}$$
$$OC = \sqrt{(48)^2 + (90)^2}$$
$$= 102 \text{ in.}$$

29-lb Force:

$$F_x = +(29 \text{ lb})\frac{84}{116} \qquad F_x = +21.0 \text{ lb} \blacktriangleleft$$

$$F_y = +(29 \text{ lb})\frac{80}{116} \qquad F_y = +20.0 \text{ lb} \blacktriangleleft$$

50-lb Force:

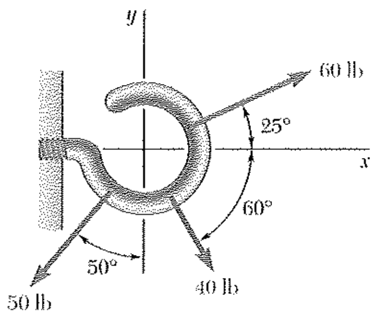
$$F_x = -(50 \text{ lb})\frac{28}{100} \qquad F_x = -14.00 \text{ lb} \blacktriangleleft$$

$$F_y = +(50 \text{ lb})\frac{96}{100} \qquad F_y = +48.0 \text{ lb} \blacktriangleleft$$

51-lb Force:

$$F_x = +(51 \text{ lb})\frac{48}{102} \qquad F_x = +24.0 \text{ lb} \blacktriangleleft$$

$$F_y = -(51 \text{ lb})\frac{90}{102} \qquad F_y = -45.0 \text{ lb} \blacktriangleleft$$

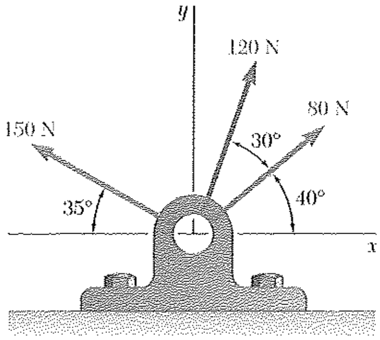


PROBLEM 2.23

Determine the x and y components of each of the forces shown.

SOLUTION

40-lb Force:	$F_x = +(40\text{ lb})\cos 60°$	$F_x = 20.0\text{ lb}$ ◀
	$F_y = -(40\text{ lb})\sin 60°$	$F_y = -34.6\text{ lb}$ ◀
50-lb Force:	$F_x = -(50\text{ lb})\sin 50°$	$F_x = -38.3\text{ lb}$ ◀
	$F_y = -(50\text{ lb})\cos 50°$	$F_y = -32.1\text{ lb}$ ◀
60-lb Force:	$F_x = +(60\text{ lb})\cos 25°$	$F_x = 54.4\text{ lb}$ ◀
	$F_y = +(60\text{ lb})\sin 25°$	$F_y = 25.4\text{ lb}$ ◀

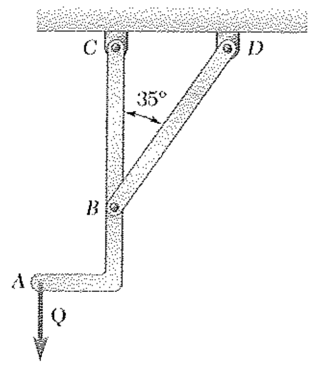


PROBLEM 2.24

Determine the x and y components of each of the forces shown.

SOLUTION

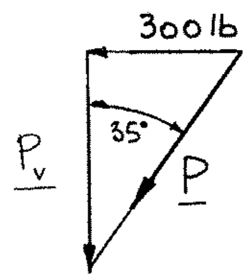
80-N Force:	$F_x = +(80\text{ N})\cos 40°$	$F_x = 61.3\text{ N}$ ◀
	$F_y = +(80\text{ N})\sin 40°$	$F_y = 51.4\text{ N}$ ◀
120-N Force:	$F_x = +(120\text{ N})\cos 70°$	$F_x = 41.0\text{ N}$ ◀
	$F_y = +(120\text{ N})\sin 70°$	$F_y = 112.8\text{ N}$ ◀
150-N Force:	$F_x = -(150\text{ N})\cos 35°$	$F_x = -122.9\text{ N}$ ◀
	$F_y = +(150\text{ N})\sin 35°$	$F_y = 86.0\text{ N}$ ◀



PROBLEM 2.25

Member *BD* exerts on member *ABC* a force **P** directed along line *BD*. Knowing that **P** must have a 300-lb horizontal component, determine (*a*) the magnitude of the force **P**, (*b*) its vertical component.

SOLUTION



(*a*)

$$P \sin 35° = 300 \text{ lb}$$

$$P = \frac{300 \text{ lb}}{\sin 35°}$$

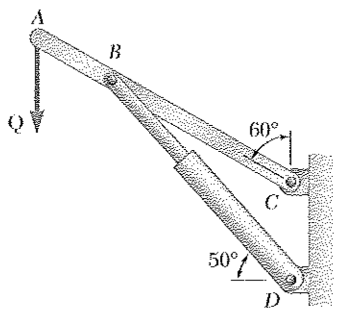
$P = 523$ lb ◀

(*b*) Vertical component

$$P_v = P \cos 35°$$

$$= (523 \text{ lb}) \cos 35°$$

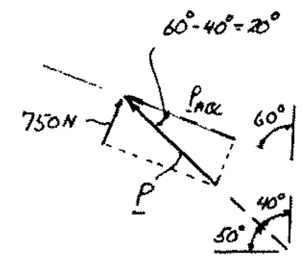
$P_v = 428$ lb ◀



PROBLEM 2.26

The hydraulic cylinder BD exerts on member ABC a force **P** directed along line BD. Knowing that **P** must have a 750-N component perpendicular to member ABC, determine (*a*) the magnitude of the force **P**, (*b*) its component parallel to ABC.

SOLUTION



(*a*)

$$750\text{ N} = P\sin 20°$$

$$P = 2193\text{ N}$$

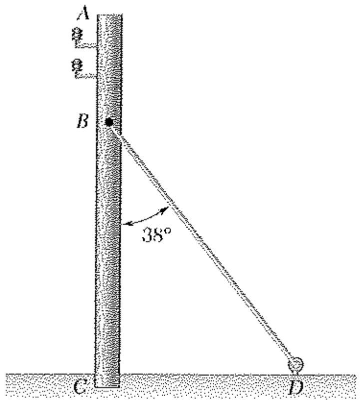
$P = 2190$ N ◀

(*b*)

$$P_{ABC} = P\cos 20°$$

$$= (2193\text{ N})\cos 20°$$

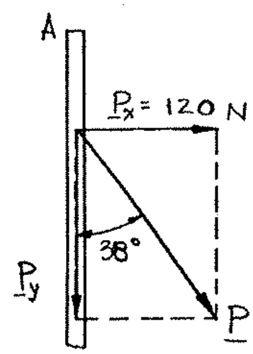
$P_{ABC} = 2060$ N ◀



PROBLEM 2.27

The guy wire BD exerts on the telephone pole AC a force **P** directed along BD. Knowing that **P** must have a 120-N component perpendicular to the pole AC, determine (*a*) the magnitude of the force **P**, (*b*) its component along line AC.

SOLUTION



(*a*)

$$P = \frac{P_x}{\sin 38°}$$

$$= \frac{120 \text{ N}}{\sin 38°}$$

$$= 194.91 \text{ N}$$

or $P = 194.9$ N ◀

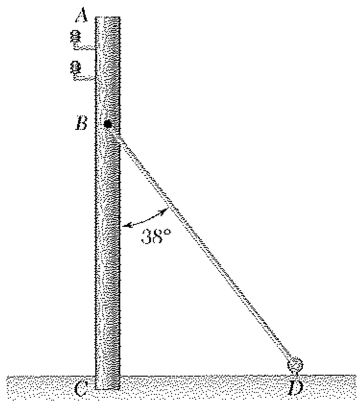
(*b*)

$$P_y = \frac{P_x}{\tan 38°}$$

$$= \frac{120 \text{ N}}{\tan 38°}$$

$$= 153.59 \text{ N}$$

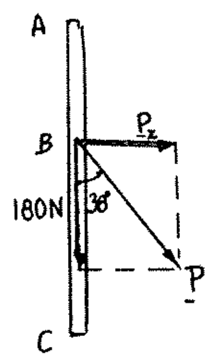
or $P_y = 153.6$ N ◀



PROBLEM 2.28

The guy wire BD exerts on the telephone pole AC a force **P** directed along BD. Knowing that **P** has a 180-N component along line AC, determine (*a*) the magnitude of the force **P**, (*b*) its component in a direction perpendicular to AC.

SOLUTION



(*a*)

$$P = \frac{P_y}{\cos 38°}$$

$$= \frac{180 \text{ N}}{\cos 38°}$$

$$= 228.4 \text{ N}$$

$P = 228 \text{ N}$ ◀

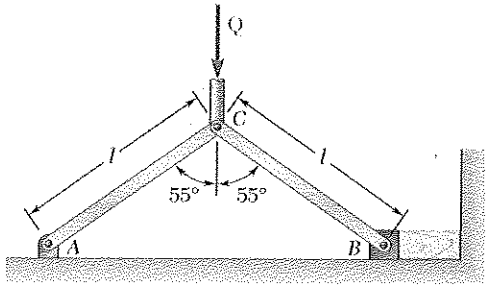
(*b*)

$$P_x = P_y \tan 38°$$

$$= (180 \text{ N}) \tan 38°$$

$$= 140.63 \text{ N}$$

$P_x = 140.6 \text{ N}$ ◀



PROBLEM 2.29

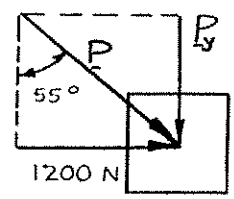
Member CB of the vise shown exerts on block B a force $\mathbf{P}$ directed along line CB. Knowing that $\mathbf{P}$ must have a 1200-N horizontal component, determine (a) the magnitude of the force $\mathbf{P}$, (b) its vertical component.

SOLUTION

We note:

CB exerts force $\mathbf{P}$ on B along CB, and the horizontal component of $\mathbf{P}$ is $P_x = 1200$ N:

Then



(a)

$$P_x = P \sin 55°$$

$$P = \frac{P_x}{\sin 55°} = \frac{1200\text{ N}}{\sin 55°} = 1464.9\text{ N}$$

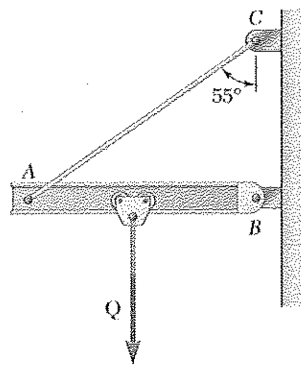
$P = 1465$ N ◀

(b)

$$P_x = P_y \tan 55°$$

$$P_y = \frac{P_x}{\tan 55°} = \frac{1200\text{ N}}{\tan 55°} = 840.2\text{ N}$$

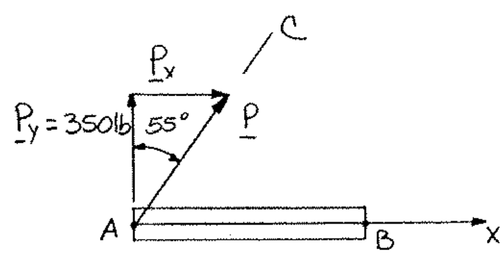
$\mathbf{P}_y = 840$ N$\downarrow$ ◀



PROBLEM 2.30

Cable AC exerts on beam AB a force $\mathbf{P}$ directed along line AC. Knowing that $\mathbf{P}$ must have a 350-lb vertical component, determine (*a*) the magnitude of the force $\mathbf{P}$, (*b*) its horizontal component.

SOLUTION



(*a*)

$$P = \frac{P_y}{\cos 55°}$$

$$= \frac{350 \text{ lb}}{\cos 55°}$$

$$= 610.2 \text{ lb}$$

$P = 610$ lb ◀

(*b*)

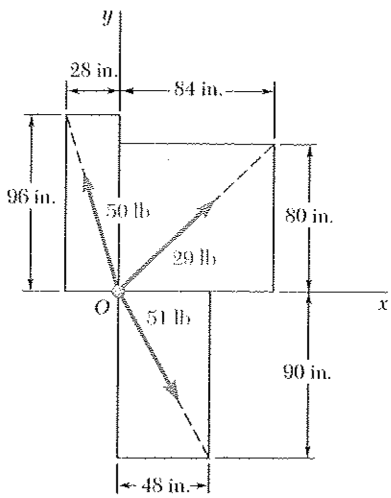
$$P_x = P \sin 55°$$

$$= (610.2 \text{ lb}) \sin 55°$$

$$= 499.8 \text{ lb}$$

$P_x = 500$ lb ◀

PROBLEM 2.31



Determine the resultant of the three forces of Problem 2.22.

PROBLEM 2.22 Determine the x and y components of each of the forces shown.

SOLUTION

Components of the forces were determined in Problem 2.22:

Force	x Comp. (lb)	y Comp. (lb)
29 lb	+21.0	+20.0
50 lb	−14.00	+48.0
51 lb	+24.0	−45.0
	$R_x = +31.0$	$R_y = +23.0$

$$\mathbf{R} = R_x\mathbf{i} + R_y\mathbf{j}$$

$$= (31.0 \text{ lb})\mathbf{i} + (23.0 \text{ lb})\mathbf{j}$$

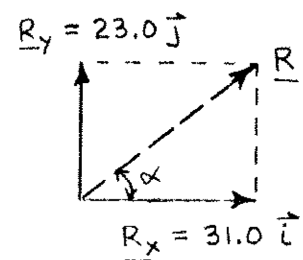
$$\tan\alpha = \frac{R_y}{R_x}$$

$$= \frac{23.0}{31.0}$$

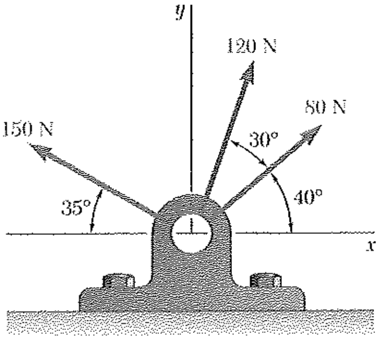
$$\alpha = 36.573°$$

$$R = \frac{23.0 \text{ lb}}{\sin(36.573°)}$$

$$= 38.601 \text{ lb}$$



$\mathbf{R} = 38.6 \text{ lb} \measuredangle 36.6°$ ◀



PROBLEM 2.32

Determine the resultant of the three forces of Problem 2.24.

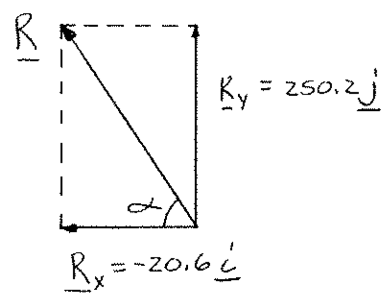
PROBLEM 2.24 Determine the x and y components of each of the forces shown.

SOLUTION

Components of the forces were determined in Problem 2.24:

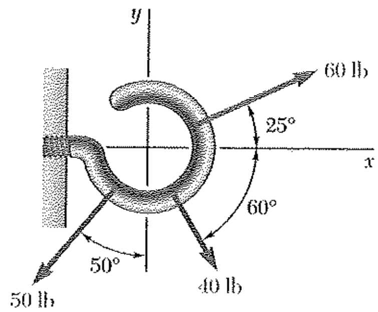
Force	x Comp. (N)	y Comp. (N)
80 N	+61.3	+51.4
120 N	+41.0	+112.8
150 N	−122.9	+86.0
	$R_x = -20.6$	$R_y = +250.2$

$$\mathbf{R} = R_x\mathbf{i} + R_y\mathbf{j}$$
$$= (-20.6\text{ N})\mathbf{i} + (250.2\text{ N})\mathbf{j}$$



$$\tan\alpha = \frac{R_y}{R_x}$$
$$\tan\alpha = \frac{250.2\text{ N}}{20.6\text{ N}}$$
$$\tan\alpha = 12.1456$$
$$\alpha = 85.293°$$
$$R = \frac{250.2\text{ N}}{\sin 85.293°}$$

R = 251 N ⦨ 85.3° ◀



PROBLEM 2.33

Determine the resultant of the three forces of Problem 2.23.

PROBLEM 2.23 Determine the x and y components of each of the forces shown.

SOLUTION

Force	x Comp. (lb)	y Comp. (lb)
40 lb	+20.00	−34.64
50 lb	−38.30	−32.14
60 lb	+54.38	+25.36
	$R_x = +36.08$	$R_y = -41.42$

$$\mathbf{R} = R_x\mathbf{i} + R_y\mathbf{j}$$

$$= (+36.08 \text{ lb})\mathbf{i} + (-41.42 \text{ lb})\mathbf{j}$$

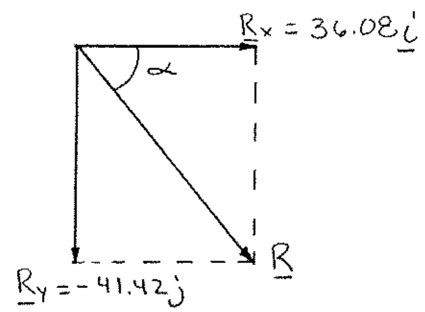
$$\tan\alpha = \frac{R_y}{R_x}$$

$$\tan\alpha = \frac{41.42 \text{ lb}}{36.08 \text{ lb}}$$

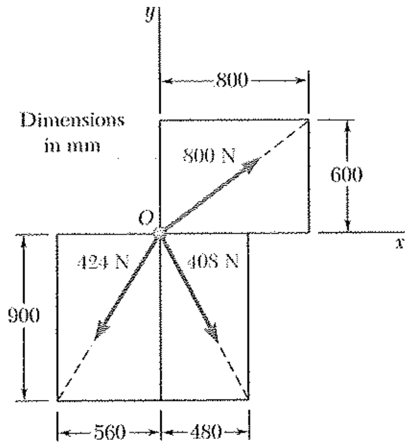
$$\tan\alpha = 1.14800$$

$$\alpha = 48.942°$$

$$R = \frac{41.42 \text{ lb}}{\sin 48.942°}$$



$\mathbf{R} = 54.9$ lb ⦪ 48.9° ◀



PROBLEM 2.34

Determine the resultant of the three forces of Problem 2.21.

PROBLEM 2.21 Determine the x and y components of each of the forces shown.

SOLUTION

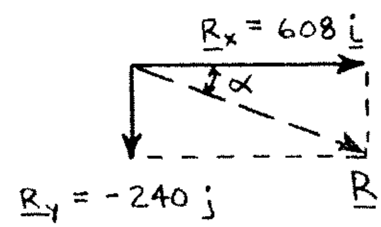
Components of the forces were determined in Problem 2.21:

Force	x Comp. (N)	y Comp. (N)
800 lb	+640	+480
424 lb	−224	−360
408 lb	+192	−360
	$R_x = +608$	$R_y = -240$

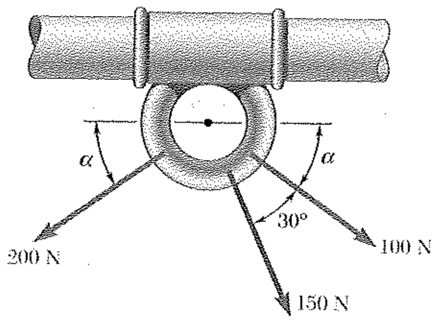
$$\mathbf{R} = R_x\mathbf{i} + R_y\mathbf{j}$$
$$= (608\text{ lb})\mathbf{i} + (-240\text{ lb})\mathbf{j}$$

$$\tan\alpha = \frac{R_y}{R_x}$$
$$= \frac{240}{608}$$
$$\alpha = 21.541°$$

$$R = \frac{240\text{ N}}{\sin(21.541°)}$$
$$= 653.65\text{ N}$$



$\mathbf{R} = 654$ N ⦪ 21.5° ◀



PROBLEM 2.35

Knowing that $\alpha = 35°$, determine the resultant of the three forces shown.

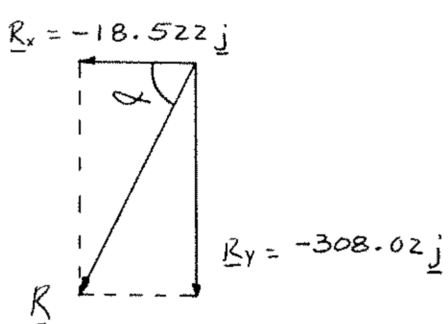
SOLUTION

100-N Force:
$$F_x = +(100\text{ N})\cos 35° = +81.915\text{ N}$$
$$F_y = -(100\text{ N})\sin 35° = -57.358\text{ N}$$

150-N Force:
$$F_x = +(150\text{ N})\cos 65° = +63.393\text{ N}$$
$$F_y = -(150\text{ N})\sin 65° = -135.946\text{ N}$$

200-N Force:
$$F_x = -(200\text{ N})\cos 35° = -163.830\text{ N}$$
$$F_y = -(200\text{ N})\sin 35° = -114.715\text{ N}$$

Force	x Comp. (N)	y Comp. (N)
100 N	+81.915	−57.358
150 N	+63.393	−135.946
200 N	−163.830	−114.715
	$R_x = -18.522$	$R_y = -308.02$



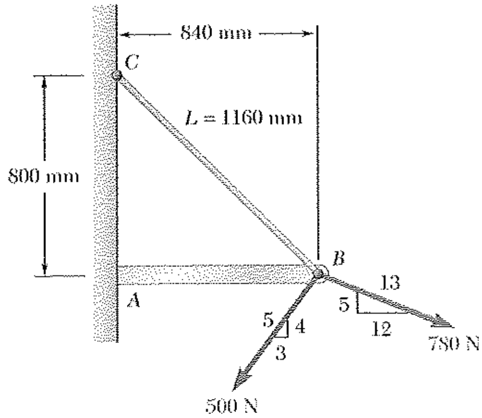
$$\mathbf{R} = R_x\mathbf{i} + R_y\mathbf{j}$$
$$= (-18.522\text{ N})\mathbf{i} + (-308.02\text{ N})\mathbf{j}$$

$$\tan\alpha = \frac{R_y}{R_x}$$
$$= \frac{308.02}{18.522}$$
$$\alpha = 86.559°$$

$$R = \frac{308.02\text{ N}}{\sin 86.559}$$

$\mathbf{R} = 309\text{ N} \measuredangle\ 86.6°$ ◄

PROBLEM 2.36



Knowing that the tension in cable BC is 725 N, determine the resultant of the three forces exerted at Point B of beam AB.

SOLUTION

Cable BC Force:

$$F_x = -(725 \text{ N})\frac{840}{1160} = -525 \text{ N}$$

$$F_y = (725 \text{ N})\frac{840}{1160} = 500 \text{ N}$$

500-N Force:

$$F_x = -(500 \text{ N})\frac{3}{5} = -300 \text{ N}$$

$$F_y = -(500 \text{ N})\frac{4}{5} = -400 \text{ N}$$

780-N Force:

$$F_x = (780 \text{ N})\frac{12}{13} = 720 \text{ N}$$

$$F_y = -(780 \text{ N})\frac{5}{13} = -300 \text{ N}$$

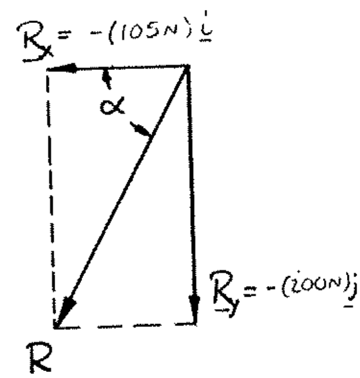
and

$$R_x = \Sigma F_x = -105 \text{ N}$$

$$R_y = \Sigma F_y = -200 \text{ N}$$

$$R = \sqrt{(-105 \text{ N})^2 + (-200 \text{ N})^2}$$

$$= 225.89 \text{ N}$$



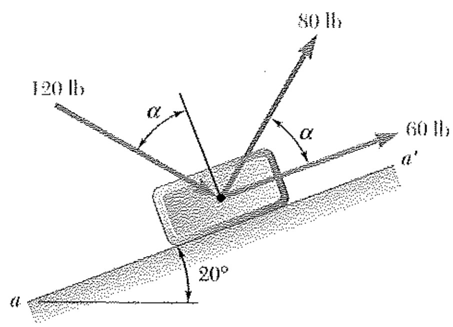
Further:

$$\tan\alpha = \frac{200}{105}$$

$$\alpha = \tan^{-1}\frac{200}{105}$$

$$= 62.3°$$

Thus: **R** = 226 N ⦫ 62.3° ◀



PROBLEM 2.37

Knowing that $\alpha = 40°$, determine the resultant of the three forces shown.

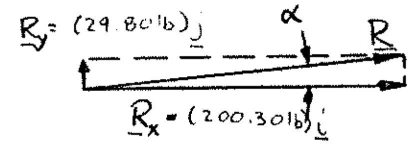
SOLUTION

60-lb Force:

$$F_x = (60\text{ lb})\cos 20° = 56.38\text{ lb}$$
$$F_y = (60\text{ lb})\sin 20° = 20.52\text{ lb}$$

80-lb Force:

$$F_x = (80\text{ lb})\cos 60° = 40.00\text{ lb}$$
$$F_y = (80\text{ lb})\sin 60° = 69.28\text{ lb}$$



120-lb Force:

$$F_x = (120\text{ lb})\cos 30° = 103.92\text{ lb}$$
$$F_y = -(120\text{ lb})\sin 30° = -60.00\text{ lb}$$

and

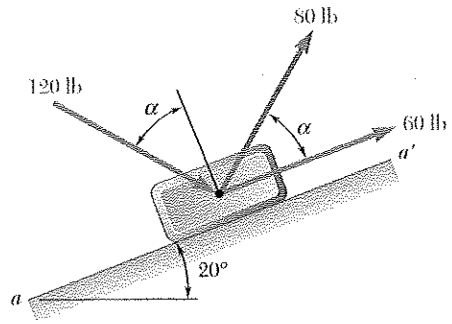
$$R_x = \Sigma F_x = 200.30\text{ lb}$$
$$R_y = \Sigma F_y = 29.80\text{ lb}$$
$$R = \sqrt{(200.30\text{ lb})^2 + (29.80\text{ lb})^2}$$
$$= 202.50\text{ lb}$$

Further:

$$\tan\alpha = \frac{29.80}{200.30}$$

$$\alpha = \tan^{-1}\frac{29.80}{200.30}$$
$$= 8.46°$$

$\mathbf{R} = 203\text{ lb} \measuredangle 8.46°$ ◀



PROBLEM 2.38

Knowing that $\alpha = 75°$, determine the resultant of the three forces shown.

SOLUTION

60-lb Force: $F_x = (60 \text{ lb})\cos 20° = 56.38 \text{ lb}$

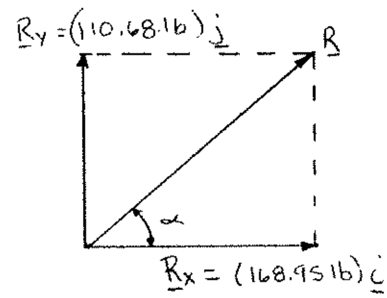
$F_y = (60 \text{ lb})\sin 20° = 20.52 \text{ lb}$

80-lb Force: $F_x = (80 \text{ lb})\cos 95° = -6.97 \text{ lb}$

$F_y = (80 \text{ lb})\sin 95° = 79.70 \text{ lb}$

120-lb Force: $F_x = (120 \text{ lb})\cos 5° = 119.54 \text{ lb}$

$F_y = (120 \text{ lb})\sin 5° = 10.46 \text{ lb}$



Then $R_x = \Sigma F_x = 168.95 \text{ lb}$

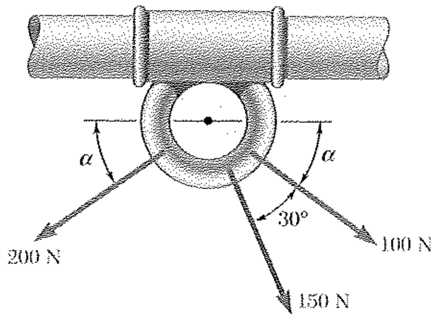
$R_y = \Sigma F_y = 110.68 \text{ lb}$

and

$$R = \sqrt{(168.95 \text{ lb})^2 + (110.68 \text{ lb})^2}$$
$$= 201.98 \text{ lb}$$

$$\tan \alpha = \frac{110.68}{168.95}$$
$$\tan \alpha = 0.655$$
$$\alpha = 33.23°$$

R = 202 lb ∠ 33.2° ◀



PROBLEM 2.39

For the collar of Problem 2.35, determine (*a*) the required value of α if the resultant of the three forces shown is to be vertical, (*b*) the corresponding magnitude of the resultant.

SOLUTION

$$R_x = \Sigma F_x$$
$$= (100\text{ N})\cos\alpha + (150\text{ N})\cos(\alpha + 30°) - (200\text{ N})\cos\alpha$$
$$R_x = -(100\text{ N})\cos\alpha + (150\text{ N})\cos(\alpha + 30°) \qquad (1)$$

$$R_y = \Sigma F_y$$
$$= -(100\text{ N})\sin\alpha - (150\text{ N})\sin(\alpha + 30°) - (200\text{ N})\sin\alpha$$
$$R_y = -(300\text{ N})\sin\alpha - (150\text{ N})\sin(\alpha + 30°) \qquad (2)$$

(*a*) For **R** to be vertical, we must have $R_x = 0$. We make $R_x = 0$ in Eq. (1):

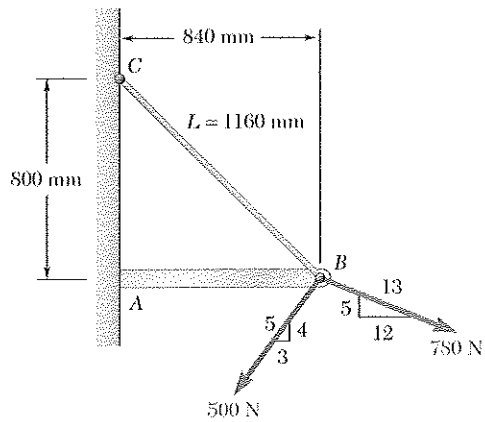
$$-100\cos\alpha + 150\cos(\alpha + 30°) = 0$$
$$-100\cos\alpha + 150(\cos\alpha\cos 30° - \sin\alpha\sin 30°) = 0$$
$$29.904\cos\alpha = 75\sin\alpha$$
$$\tan\alpha = \frac{29.904}{75}$$
$$= 0.3988$$
$$\alpha = 21.74°$$

$\alpha = 21.7°$ ◀

(*b*) Substituting for α in Eq. (2):

$$R_y = -300\sin 21.74° - 150\sin 51.74°$$
$$= -228.9\text{ N}$$
$$R = |R_y| = 228.9\text{ N}$$

$R = 229\text{ N}$ ◀



PROBLEM 2.40

For the beam of Problem 2.36, determine (*a*) the required tension in cable *BC* if the resultant of the three forces exerted at Point *B* is to be vertical, (*b*) the corresponding magnitude of the resultant.

SOLUTION

$$R_x = \Sigma F_x = -\frac{840}{1160}T_{BC} + \frac{12}{13}(780\text{ N}) - \frac{3}{5}(500\text{ N})$$

$$R_x = -\frac{21}{29}T_{BC} + 420\text{ N} \qquad (1)$$

$$R_y = \Sigma F_y = \frac{800}{1160}T_{BC} - \frac{5}{13}(780\text{ N}) - \frac{4}{5}(500\text{ N})$$

$$R_y = \frac{20}{29}T_{BC} - 700\text{ N} \qquad (2)$$

(*a*) For **R** to be vertical, we must have $R_x = 0$

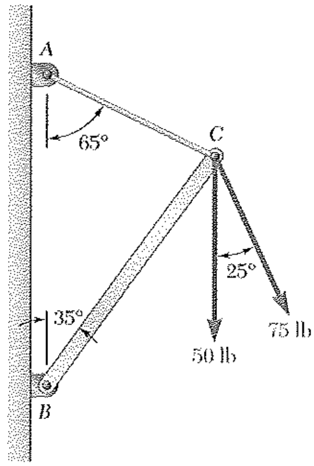
Set $R_x = 0$ in Eq. (1) $\qquad -\frac{21}{29}T_{BC} + 420\text{ N} = 0 \qquad T_{BC} = 580\text{ N}$ ◀

(*b*) Substituting for T_{BC} in Eq. (2):

$$R_y = \frac{20}{29}(580\text{ N}) - 700\text{ N}$$

$$R_y = -300\text{ N}$$

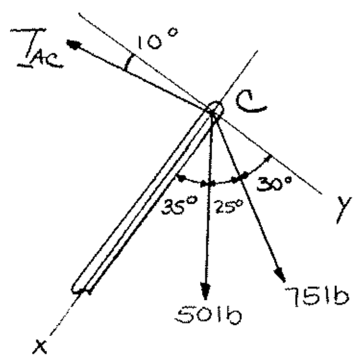
$$R = |R_y| = 300\text{ N} \qquad R = 300\text{ N} \blacktriangleleft$$



PROBLEM 2.41

Determine (a) the required tension in cable AC, knowing that the resultant of the three forces exerted at Point C of boom BC must be directed along BC, (b) the corresponding magnitude of the resultant.

SOLUTION



Using the x and y axes shown:

$$R_x = \Sigma F_x = T_{AC}\sin 10° + (50 \text{ lb})\cos 35° + (75 \text{ lb})\cos 60°$$
$$= T_{AC}\sin 10° + 78.46 \text{ lb} \qquad (1)$$

$$R_y = \Sigma F_y = (50 \text{ lb})\sin 35° + (75 \text{ lb})\sin 60° - T_{AC}\cos 10°$$
$$R_y = 93.63 \text{ lb} - T_{AC}\cos 10° \qquad (2)$$

(a) Set $R_y = 0$ in Eq. (2):

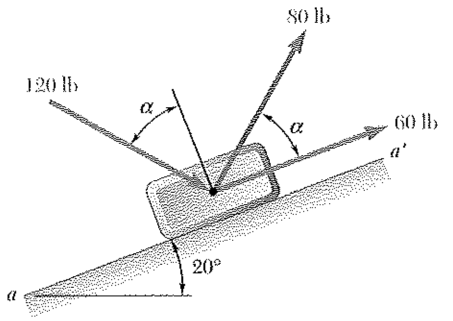
$$93.63 \text{ lb} - T_{AC}\cos 10° = 0$$
$$T_{AC} = 95.07 \text{ lb}$$

$T_{AC} = 95.1$ lb ◀

(b) Substituting for T_{AC} in Eq. (1):

$$R_x = (95.07 \text{ lb})\sin 10° + 78.46 \text{ lb}$$
$$= 94.97 \text{ lb}$$
$$R = R_x$$

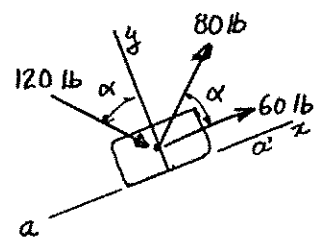
$R = 95.0$ lb ◀



PROBLEM 2.42

For the block of Problems 2.37 and 2.38, determine (*a*) the required value of α if the resultant of the three forces shown is to be parallel to the incline, (*b*) the corresponding magnitude of the resultant.

SOLUTION



Select the x axis to be along $a\,a'$.

Then

$$R_x = \Sigma F_x = (60 \text{ lb}) + (80 \text{ lb})\cos\alpha + (120 \text{ lb})\sin\alpha \tag{1}$$

and

$$R_y = \Sigma F_y = (80 \text{ lb})\sin\alpha - (120 \text{ lb})\cos\alpha \tag{2}$$

(*a*) Set $R_y = 0$ in Eq. (2).

$$(80 \text{ lb})\sin\alpha - (120 \text{ lb})\cos\alpha = 0$$

Dividing each term by $\cos\alpha$ gives:

$$(80 \text{ lb})\tan\alpha = 120 \text{ lb}$$

$$\tan\alpha = \frac{120 \text{ lb}}{80 \text{ lb}}$$

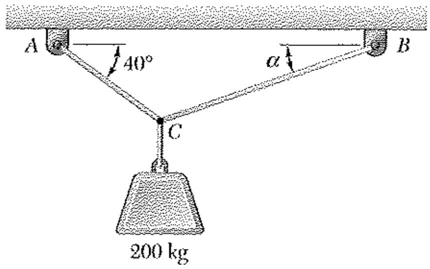
$$\alpha = 56.310^\circ$$

$\alpha = 56.3^\circ$ ◀

(*b*) Substituting for α in Eq. (1) gives:

$$R_x = 60 \text{ lb} + (80 \text{ lb})\cos 56.31^\circ + (120 \text{lb})\sin 56.31^\circ = 204.22 \text{ lb}$$

$R_x = 204 \text{ lb}$ ◀

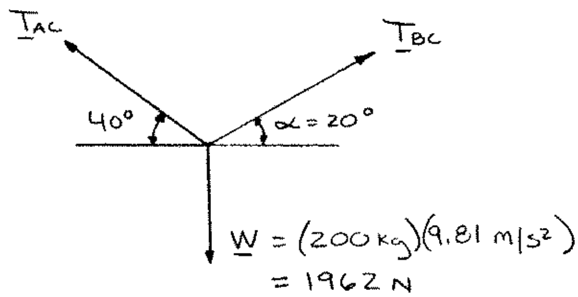


PROBLEM 2.43

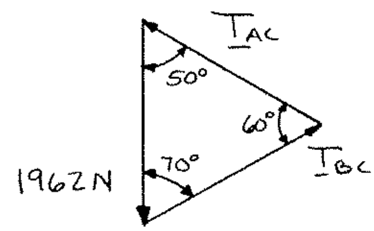
Two cables are tied together at C and are loaded as shown. Knowing that $\alpha = 20°$, determine the tension (*a*) in cable AC, (*b*) in cable BC.

SOLUTION

Free-Body Diagram



Force Triangle



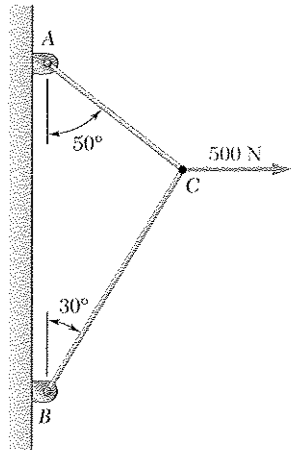
Law of sines:
$$\frac{T_{AC}}{\sin 70°} = \frac{T_{BC}}{\sin 50°} = \frac{1962 \text{ N}}{\sin 60°}$$

(*a*)
$$T_{AC} = \frac{1962 \text{ N}}{\sin 60°} \sin 70° = 2128.9 \text{ N}$$

$T_{AC} = 2.13$ kN ◀

(*b*)
$$T_{BC} = \frac{1962 \text{ N}}{\sin 60°} \sin 50° = 1735.49 \text{ N}$$

$T_{BC} = 1.735$ kN ◀

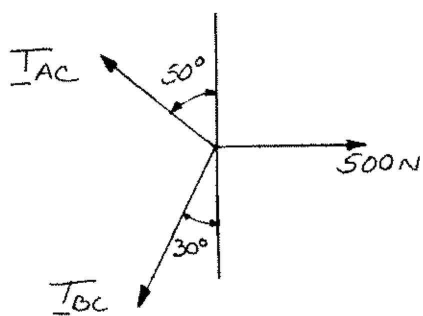


PROBLEM 2.44

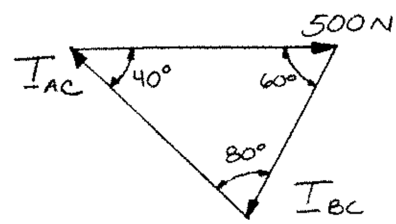
Two cables are tied together at C and are loaded as shown. Determine the tension (a) in cable AC, (b) in cable BC.

SOLUTION

Free-Body Diagram



Force Triangle



Law of sines:

$$\frac{T_{AC}}{\sin 60^\circ} = \frac{T_{BC}}{\sin 40^\circ} = \frac{500\text{ N}}{\sin 80^\circ}$$

(a)

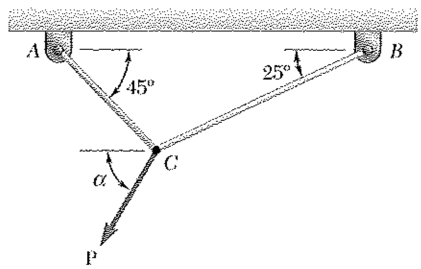
$$T_{AC} = \frac{500\text{ N}}{\sin 80^\circ}\sin 60^\circ = 439.69\text{ N}$$

$T_{AC} = 440\text{ N}$ ◀

(b)

$$T_{BC} = \frac{500\text{ N}}{\sin 80^\circ}\sin 40^\circ = 326.35\text{ N}$$

$T_{BC} = 326\text{ N}$ ◀

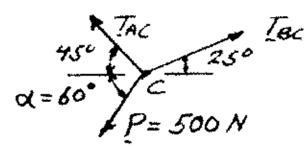


PROBLEM 2.45

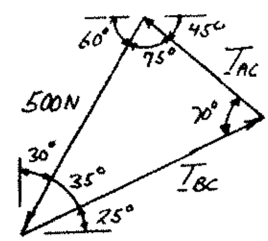
Two cables are tied together at C and are loaded as shown. Knowing that $\mathbf{P} = 500$ N and $\alpha = 60°$, determine the tension in (a) in cable AC, (b) in cable BC.

SOLUTION

Free-Body Diagram



Force Triangle



Law of sines:

$$\frac{T_{AC}}{\sin 35°} = \frac{T_{BC}}{\sin 75°} = \frac{500\text{ N}}{\sin 70°}$$

(a)

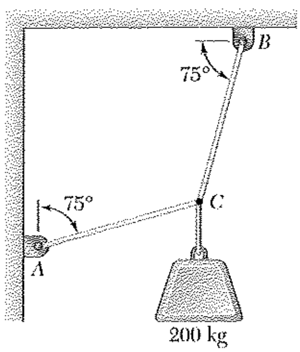
$$T_{AC} = \frac{500\text{ N}}{\sin 70°}\sin 35°$$

$T_{AC} = 305$ N ◀

(b)

$$T_{BC} = \frac{500\text{ N}}{\sin 70°}\sin 75°$$

$T_{BC} = 514$ N ◀

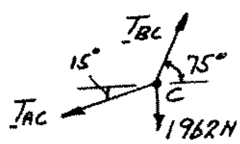


PROBLEM 2.46

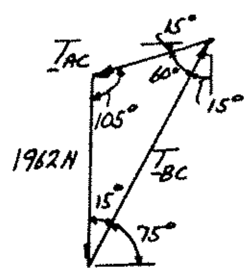
Two cables are tied together at C and are loaded as shown. Determine the tension (*a*) in cable AC, (*b*) in cable BC.

SOLUTION

Free-Body Diagram



Force Triangle



$$\begin{aligned} W &= mg \\ &= (200 \text{ kg})(9.81 \text{ m/s}^2) \\ &= 1962 \text{ N} \end{aligned}$$

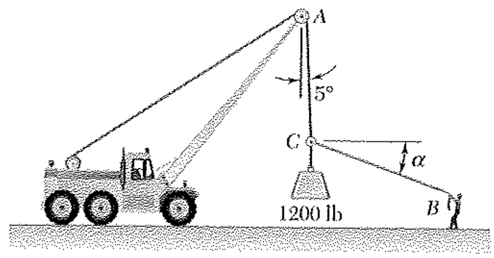
Law of sines: $$\frac{T_{AC}}{\sin 15°} = \frac{T_{BC}}{\sin 105°} = \frac{1962 \text{ N}}{\sin 60°}$$

(*a*) $$T_{AC} = \frac{(1962 \text{ N}) \sin 15°}{\sin 60°}$$

$T_{AC} = 586 \text{ N}$ ◀

(*b*) $$T_{BC} = \frac{(1962 \text{ N}) \sin 105°}{\sin 60°}$$

$T_{BC} = 2190 \text{ N}$ ◀

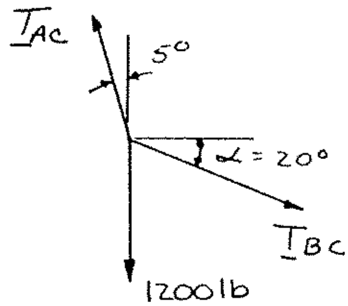


PROBLEM 2.47

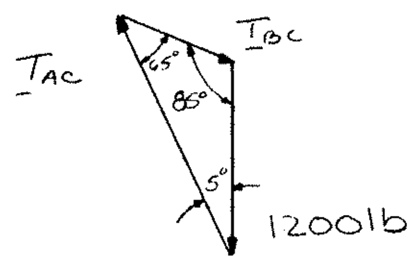
Knowing that $\alpha = 20°$, determine the tension (*a*) in cable *AC*, (*b*) in rope *BC*.

SOLUTION

Free-Body Diagram



Force Triangle



Law of sines:

$$\frac{T_{AC}}{\sin 110°} = \frac{T_{BC}}{\sin 5°} = \frac{1200 \text{ lb}}{\sin 65°}$$

(*a*)

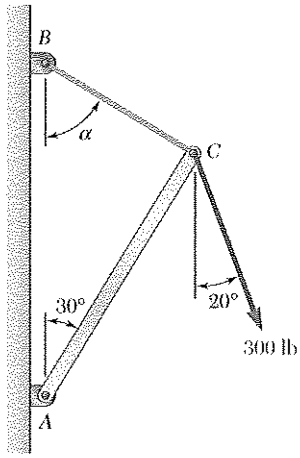
$$T_{AC} = \frac{1200 \text{ lb}}{\sin 65°} \sin 110°$$

$T_{AC} = 1244$ lb ◀

(*b*)

$$T_{BC} = \frac{1200 \text{ lb}}{\sin 65°} \sin 5°$$

$T_{BC} = 115.4$ lb ◀

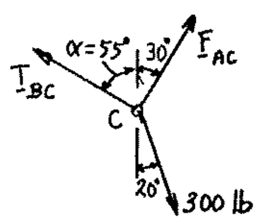


PROBLEM 2.48

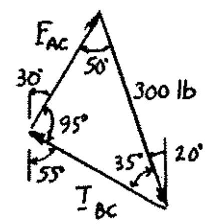
Knowing that $\alpha = 55°$ and that boom AC exerts on pin C a force directed along line AC, determine (*a*) the magnitude of that force, (*b*) the tension in cable BC.

SOLUTION

Free-Body Diagram



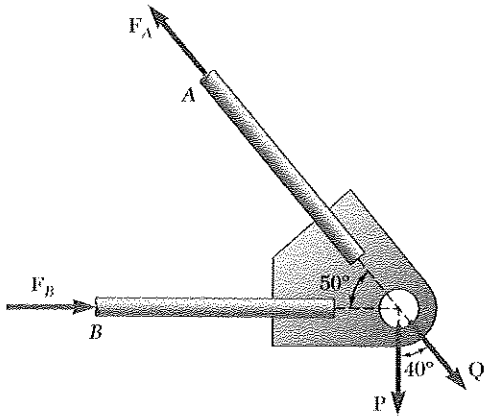
Force Triangle



Law of sines: $$\frac{F_{AC}}{\sin 35°} = \frac{T_{BC}}{\sin 50°} = \frac{300 \text{ lb}}{\sin 95°}$$

(*a*) $$F_{AC} = \frac{300 \text{ lb}}{\sin 95°} \sin 35°$$ $F_{AC} = 172.7 \text{ lb}$ ◀

(*b*) $$T_{BC} = \frac{300 \text{ lb}}{\sin 95°} \sin 50°$$ $T_{BC} = 231 \text{ lb}$ ◀

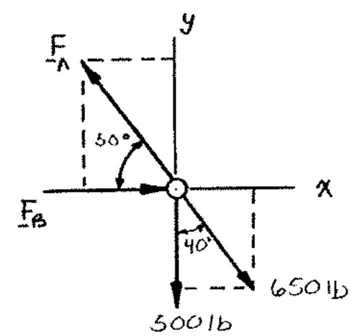


PROBLEM 2.49

Two forces **P** and **Q** are applied as shown to an aircraft connection. Knowing that the connection is in equilibrium and that $P = 500$ lb and $Q = 650$ lb, determine the magnitudes of the forces exerted on the rods A and B.

SOLUTION

Free-Body Diagram



Resolving the forces into x- and y-directions:

$$\mathbf{R} = \mathbf{P} + \mathbf{Q} + \mathbf{F}_A + \mathbf{F}_B = 0$$

Substituting components:

$$\begin{aligned}\mathbf{R} = &-(500\text{ lb})\mathbf{j} + [(650\text{ lb})\cos 50°]\mathbf{i} \\ &-[(650\text{ lb})\sin 50°]\mathbf{j} \\ &+F_B\mathbf{i} - (F_A\cos 50°)\mathbf{i} + (F_A\sin 50°)\mathbf{j} = 0\end{aligned}$$

In the y-direction (one unknown force)

$$-500\text{ lb} - (650\text{ lb})\sin 50° + F_A\sin 50° = 0$$

Thus,

$$F_A = \frac{500\text{ lb} + (650\text{ lb})\sin 50°}{\sin 50°}$$

$$= 1302.70\text{ lb}$$

$F_A = 1303$ lb ◀

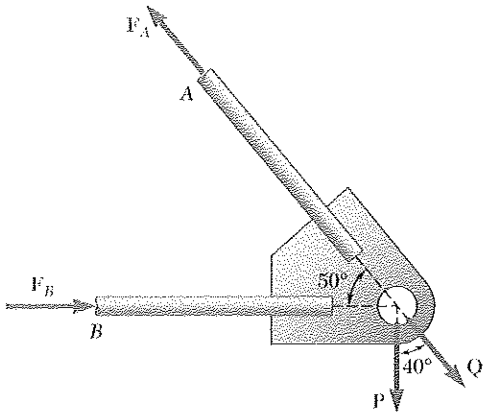
In the x-direction:

$$(650\text{ lb})\cos 50° + F_B - F_A\cos 50° = 0$$

Thus,

$$\begin{aligned}F_B &= F_A\cos 50° - (650\text{ lb})\cos 50° \\ &= (1302.70\text{ lb})\cos 50° - (650\text{ lb})\cos 50° \\ &= 419.55\text{ lb}\end{aligned}$$

$F_B = 420$ lb ◀

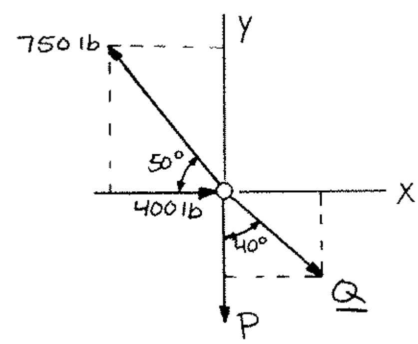


PROBLEM 2.50

Two forces **P** and **Q** are applied as shown to an aircraft connection. Knowing that the connection is in equilibrium and that the magnitudes of the forces exerted on rods A and B are $F_A = 750$ lb and $F_B = 400$ lb, determine the magnitudes of **P** and **Q**.

SOLUTION

Free-Body Diagram



Resolving the forces into x- and y-directions:

$$\mathbf{R} = \mathbf{P} + \mathbf{Q} + \mathbf{F}_A + \mathbf{F}_B = 0$$

Substituting components:

$$\mathbf{R} = -P\mathbf{j} + Q\cos 50°\mathbf{i} - Q\sin 50°\mathbf{j} - [(750\text{ lb})\cos 50°]\mathbf{i} + [(750\text{ lb})\sin 50°]\mathbf{j} + (400\text{ lb})\mathbf{i}$$

In the x-direction (one unknown force)

$$Q\cos 50° - [(750\text{ lb})\cos 50°] + 400\text{ lb} = 0$$

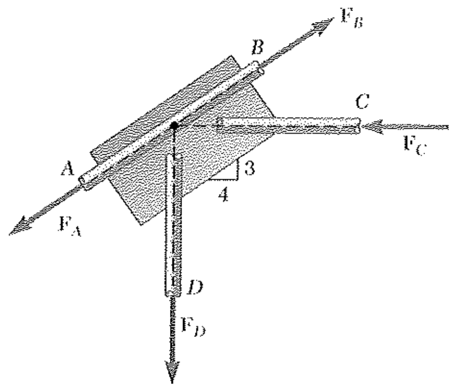
$$Q = \frac{(750\text{ lb})\cos 50° - 400\text{ lb}}{\cos 50°} = 127.710\text{ lb}$$

In the y-direction:

$$-P - Q\sin 50° + (750\text{ lb})\sin 50° = 0$$

$$P = -Q\sin 50° + (750\text{ lb})\sin 50° = -(127.710\text{ lb})\sin 50° + (750\text{ lb})\sin 50° = 476.70\text{ lb}$$

$P = 477$ lb; $Q = 127.7$ lb ◀

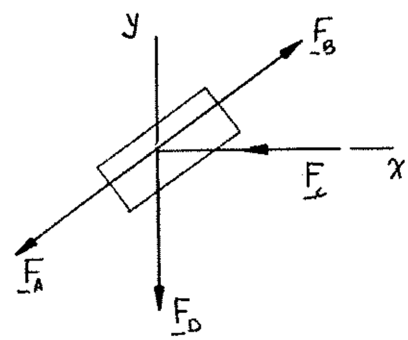


PROBLEM 2.51

A welded connection is in equilibrium under the action of the four forces shown. Knowing that $F_A = 8$ kN and $F_B = 16$ kN, determine the magnitudes of the other two forces.

SOLUTION

Free-Body Diagram of Connection



$$\Sigma F_x = 0: \quad \frac{3}{5}F_B - F_C - \frac{3}{5}F_A = 0$$

With

$$F_A = 8 \text{ kN}$$
$$F_B = 16 \text{ kN}$$

$$F_C = \frac{4}{5}(16 \text{ kN}) - \frac{4}{5}(8 \text{ kN})$$

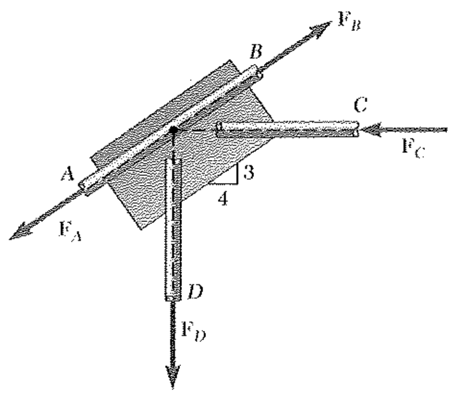
$F_C = 6.40$ kN ◀

$$\Sigma F_y = 0: \quad -F_D + \frac{3}{5}F_B - \frac{3}{5}F_A = 0$$

With F_A and F_B as above:

$$F_D = \frac{3}{5}(16 \text{ kN}) - \frac{3}{5}(8 \text{ kN})$$

$F_D = 4.80$ kN ◀

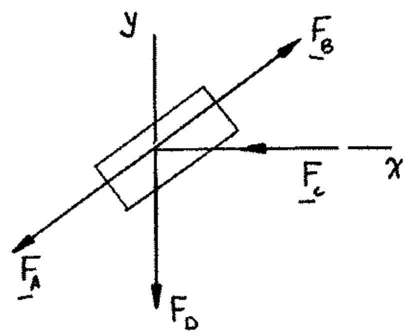


PROBLEM 2.52

A welded connection is in equilibrium under the action of the four forces shown. Knowing that $F_A = 5$ kN and $F_D = 6$ kN, determine the magnitudes of the other two forces.

SOLUTION

Free-Body Diagram of Connection



$$\Sigma F_y = 0: \quad -F_D - \frac{3}{5}F_A + \frac{3}{5}F_B = 0$$

or

$$F_B = F_D + \frac{3}{5}F_A$$

With

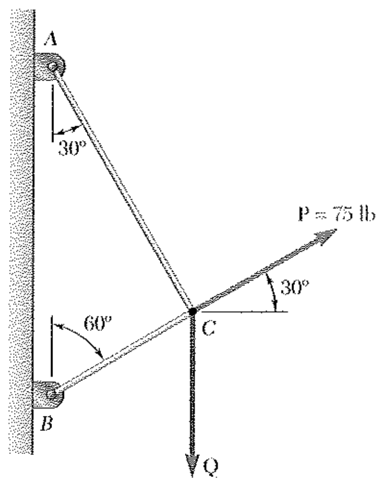
$$F_A = 5\text{ kN}, \quad F_D = 8\text{ kN}$$

$$F_B = \frac{5}{3}\left[6\text{ kN} + \frac{3}{5}(5\text{ kN})\right] \qquad F_B = 15.00\text{ kN} \blacktriangleleft$$

$$\Sigma F_x = 0: \quad -F_C + \frac{4}{5}F_B - \frac{4}{5}F_A = 0$$

$$F_C = \frac{4}{5}(F_B - F_A)$$

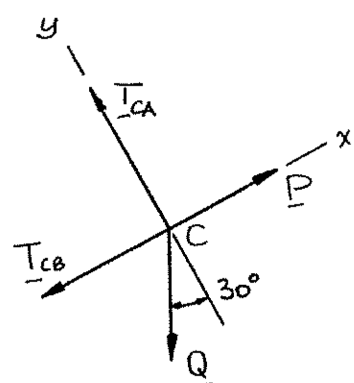
$$= \frac{4}{5}(15\text{ kN} - 5\text{ kN}) \qquad F_C = 8.00\text{ kN} \blacktriangleleft$$



PROBLEM 2.53

Two cables tied together at C are loaded as shown. Knowing that $Q = 60$ lb, determine the tension (a) in cable AC, (b) in cable BC.

SOLUTION



$$\Sigma F_y = 0: \quad T_{CA} - Q\cos 30° = 0$$

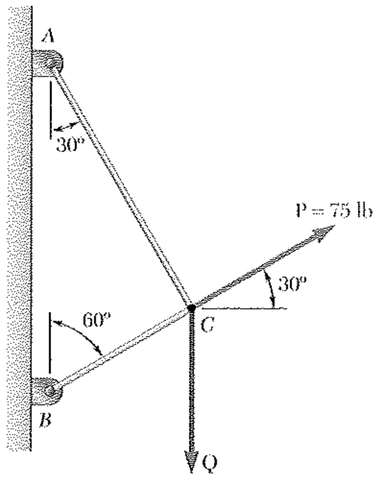
With $\quad Q = 60$ lb

(a) $\quad T_{CA} = (60 \text{ lb})(0.866)$ $\qquad T_{CA} = 52.0$ lb ◀

(b) $\quad \Sigma F_x = 0: \quad P - T_{CB} - Q\sin 30° = 0$

With $\quad P = 75$ lb

$T_{CB} = 75 \text{ lb} - (60 \text{ lb})(0.50)$ $\qquad$ or $T_{CB} = 45.0$ lb ◀

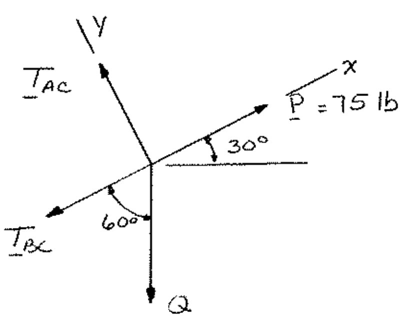


PROBLEM 2.54

Two cables tied together at C are loaded as shown. Determine the range of values of Q for which the tension will not exceed 60 lb in either cable.

SOLUTION

Free-Body Diagram



$\Sigma F_x = 0$: $-T_{BC} - Q\cos 60° + 75 \text{ lb} = 0$

$$T_{BC} = 75 \text{ lb} - Q\cos 60° \quad (1)$$

$\Sigma F_y = 0$: $T_{AC} - Q\sin 60° = 0$

$$T_{AC} = Q\sin 60° \quad (2)$$

Requirement $T_{AC} \le 60$ lb:

From Eq. (2): $Q\sin 60° \le 60$ lb

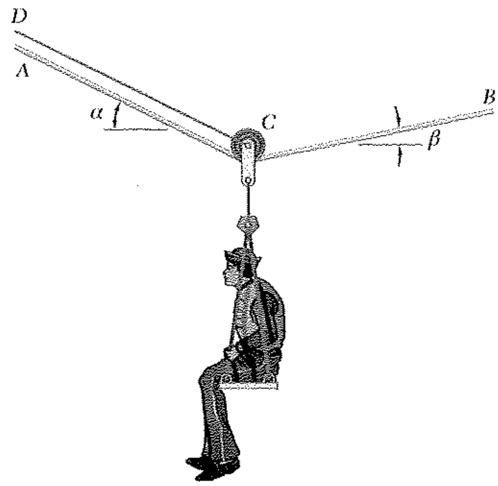
$$Q \le 69.3 \text{ lb}$$

Requirement $T_{BC} \le 60$ lb:

From Eq. (1): $75 \text{ lb} - Q\sin 60° \le 60 \text{ lb}$

$Q \ge 30.0$ lb $\qquad 30.0 \text{ lb} \le Q \le 69.3 \text{ lb}$ ◀

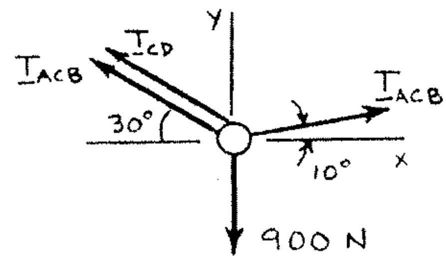
PROBLEM 2.55



A sailor is being rescued using a boatswain's chair that is suspended from a pulley that can roll freely on the support cable ACB and is pulled at a constant speed by cable CD. Knowing that $\alpha = 30°$ and $\beta = 10°$ and that the combined weight of the boatswain's chair and the sailor is 900 N, determine the tension (*a*) in the support cable ACB, (*b*) in the traction cable CD.

SOLUTION

Free-Body Diagram



$$\xrightarrow{+} \Sigma F_x = 0: \quad T_{ACB} \cos 10° - T_{ACB} \cos 30° - T_{CD} \cos 30° = 0$$

$$T_{CD} = 0.137158 T_{ACB} \qquad (1)$$

$$+\uparrow \Sigma F_y = 0: \quad T_{ACB} \sin 10° + T_{ACB} \sin 30° + T_{CD} \sin 30° - 900 = 0$$

$$0.67365 T_{ACB} + 0.5 T_{CD} = 900 \qquad (2)$$

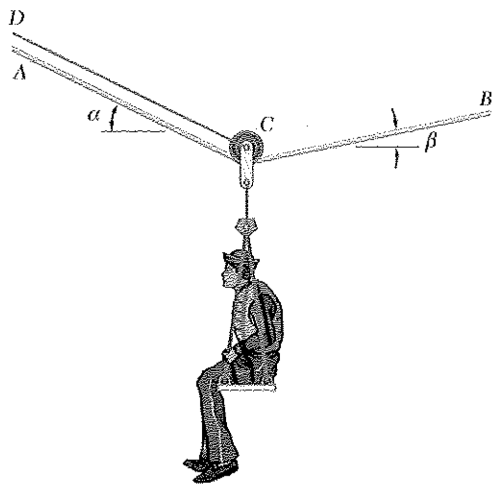
(*a*) Substitute (1) into (2): $0.67365 T_{ACB} + 0.5(0.137158 T_{ACB}) = 900$

$$T_{ACB} = 1212.56 \text{ N}$$

$T_{ACB} = 1213 \text{ N}$ ◀

(*b*) From (1): $T_{CD} = 0.137158(1212.56 \text{ N})$

$T_{CD} = 166.3 \text{ N}$ ◀

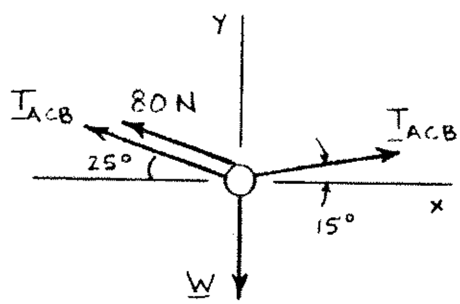


PROBLEM 2.56

A sailor is being rescued using a boatswain's chair that is suspended from a pulley that can roll freely on the support cable ACB and is pulled at a constant speed by cable CD. Knowing that $\alpha = 25°$ and $\beta = 15°$ and that the tension in cable CD is 80 N, determine (*a*) the combined weight of the boatswain's chair and the sailor, (*b*) in tension in the support cable ACB.

SOLUTION

Free-Body Diagram



$\xrightarrow{+} \Sigma F_x = 0$: $\quad T_{ACB}\cos 15° - T_{ACB}\cos 25° - (80\text{ N})\cos 25° = 0$

$$T_{ACB} = 1216.15\text{ N}$$

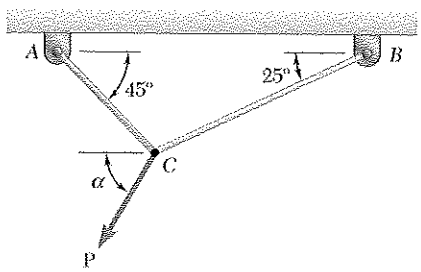
$+\uparrow \Sigma F_y = 0$: $\quad (1216.15\text{ N})\sin 15° + (1216.15\text{ N})\sin 25°$

$$+(80\text{ N})\sin 25° - W = 0$$

$$W = 862.54\text{ N}$$

(*a*) $W = 863\text{ N}$ ◀

(*b*) $T_{ACB} = 1216\text{ N}$ ◀

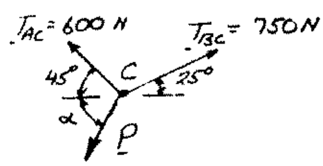


PROBLEM 2.57

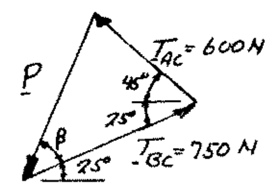
For the cables of Problem 2.45, it is known that the maximum allowable tension is 600 N in cable AC and 750 N in cable BC. Determine (a) the maximum force **P** that can be applied at C, (b) the corresponding value of α.

SOLUTION

Free-Body Diagram



Force Triangle



(a) Law of cosines

$$P^2 = (600)^2 + (750)^2 - 2(600)(750)\cos(25° + 45°)$$

$$P = 784.02 \text{ N}$$

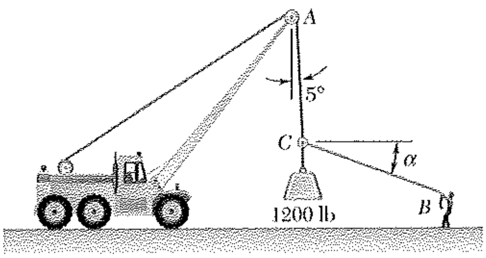
$P = 784$ N ◀

(b) Law of sines

$$\frac{\sin\beta}{600 \text{ N}} = \frac{\sin(25° + 45°)}{784.02 \text{ N}}$$

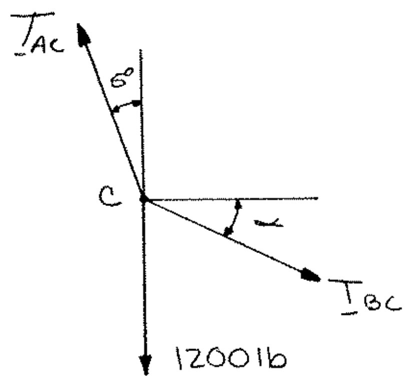
$$\beta = 46.0°$$

$\alpha = 46.0° + 25° = 71.0°$ ◀

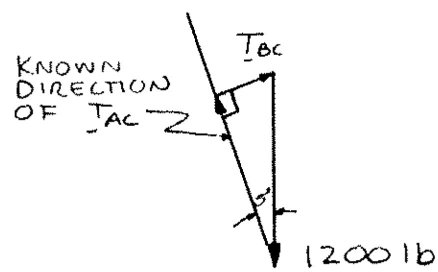
	**PROBLEM 2.58** For the situation described in Figure P2.47, determine (*a*) the value of α for which the tension in rope BC is as small as possible, (*b*) the corresponding value of the tension. **PROBLEM 2.47** Knowing that $\alpha = 20°$, determine the tension (*a*) in cable AC, (*b*) in rope BC.

SOLUTION

Free-Body Diagram



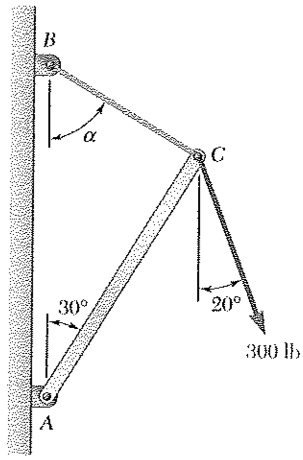
Force Triangle



To be smallest, T_{BC} must be perpendicular to the direction of T_{AC}.

(*a*) Thus, $\alpha = 5°$ $\qquad \alpha = 5.00°$ ◀

(*b*) $T_{BC} = (1200 \text{ lb})\sin 5°$ $\qquad T_{BC} = 104.6 \text{ lb}$ ◀



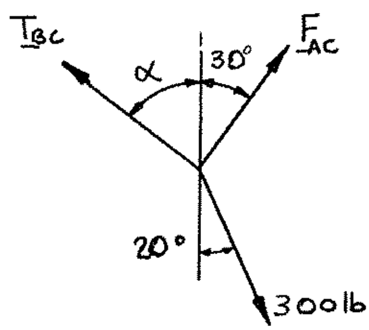
PROBLEM 2.59

For the structure and loading of Problem 2.48, determine (*a*) the value of α for which the tension in cable BC is as small as possible, (*b*) the corresponding value of the tension.

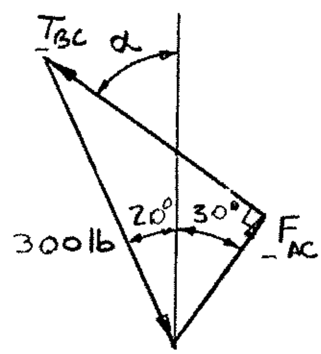
SOLUTION

T_{BC} must be perpendicular to F_{AC} to be as small as possible.

Free-Body Diagram: *C*



Force Triangle is a right triangle

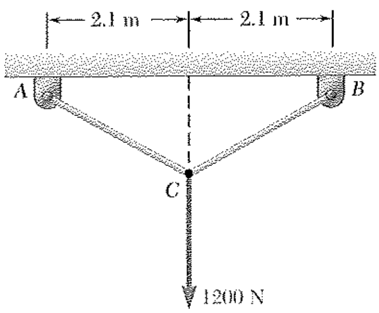


To be a minimum, T_{BC} must be perpendicular to F_{AC}.

(*a*) We observe: $\alpha = 90° - 30°$ $\qquad \alpha = 60.0°$ ◀

(*b*) $T_{BC} = (300 \text{ lb})\sin 50°$

or $T_{BC} = 229.81 \text{ lb}$ $\qquad T_{BC} = 230 \text{ lb}$ ◀



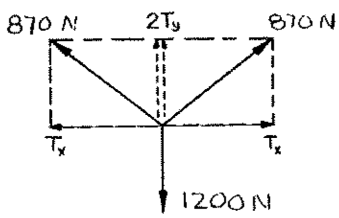
PROBLEM 2.60

Knowing that portions AC and BC of cable ACB must be equal, determine the shortest length of cable that can be used to support the load shown if the tension in the cable is not to exceed 870 N.

SOLUTION

Free-Body Diagram: C

(For $T = 725$ N)



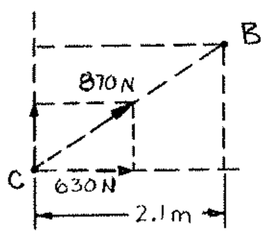
$$+\uparrow \Sigma F_y = 0: \quad 2T_y - 1200\text{ N} = 0$$

$$T_y = 600\text{ N}$$

$$T_x^2 + T_y^2 = T^2$$

$$T_x^2 + (600\text{ N})^2 = (870\text{ N})^2$$

$$T_x = 630\text{ N}$$



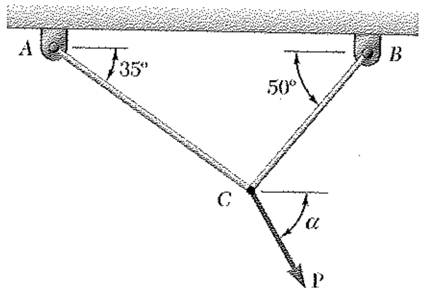
By similar triangles: $$\frac{BC}{870\text{ N}} = \frac{2.1\text{ m}}{630\text{ N}}$$

$$BC = 2.90\text{ m}$$

$$L = 2(BC)$$

$$= 5.80\text{ m}$$

$L = 5.80$ m ◀

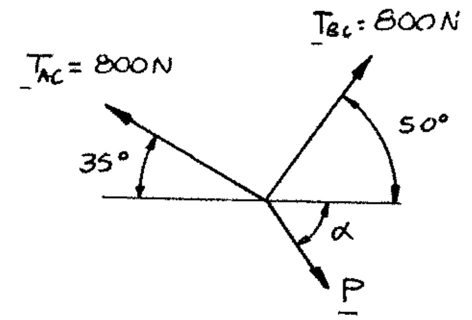


PROBLEM 2.61

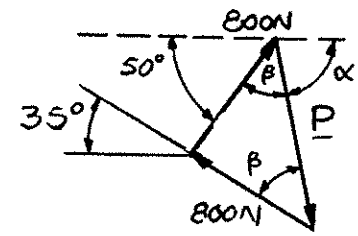
Two cables tied together at C are loaded as shown. Knowing that the maximum allowable tension in each cable is 800 N, determine (a) the magnitude of the largest force $\mathbf{P}$ that can be applied at C, (b) the corresponding value of α.

SOLUTION

Free-Body Diagram: *C*



Force Triangle



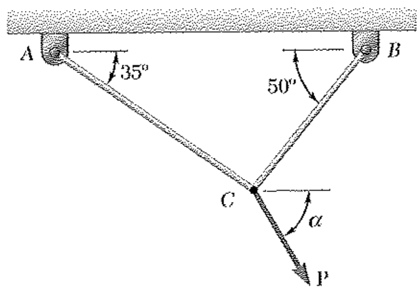
Force triangle is isosceles with

$$2\beta = 180° - 85°$$
$$\beta = 47.5°$$

(a) $$P = 2(800\text{ N})\cos 47.5° = 1081\text{ N}$$

Since $P > 0$, the solution is correct. $P = 1081\text{ N}$ ◀

(b) $$\alpha = 180° - 50° - 47.5° = 82.5°$$ $\alpha = 82.5°$ ◀

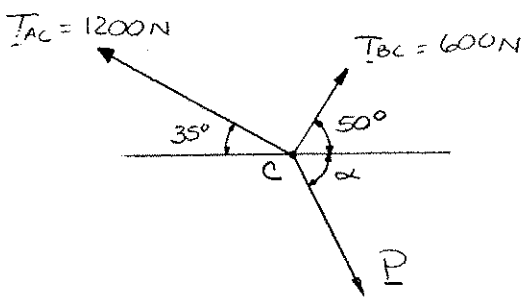


PROBLEM 2.62

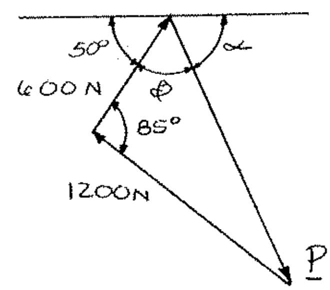
Two cables tied together at C are loaded as shown. Knowing that the maximum allowable tension is 1200 N in cable AC and 600 N in cable BC, determine (a) the magnitude of the largest force **P** that can be applied at C, (b) the corresponding value of α.

SOLUTION

Free-Body Diagram



Force Triangle



(a) Law of cosines:

$$P^2 = (1200\text{ N})^2 + (600\text{ N})^2 - 2(1200\text{ N})(600\text{ N})\cos 85^\circ$$

$$P = 1294\text{ N}$$

Since $P > 1200$ N, the solution is correct.

$P = 1294$ N ◀

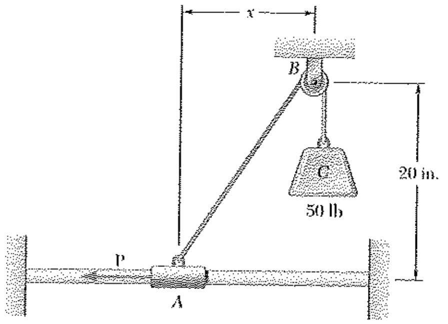
(b) Law of sines:

$$\frac{\sin\beta}{1200\text{ N}} = \frac{\sin 85^\circ}{1294\text{ N}}$$

$$\beta = 67.5^\circ$$

$$\alpha = 180^\circ - 50^\circ - 67.5^\circ$$

$\alpha = 62.5^\circ$ ◀

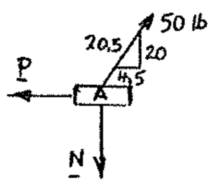


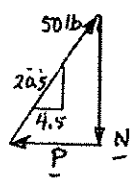
PROBLEM 2.63

Collar A is connected as shown to a 50-lb load and can slide on a frictionless horizontal rod. Determine the magnitude of the force **P** required to maintain the equilibrium of the collar when (*a*) $x = 4.5$ in., (*b*) $x = 15$ in.

SOLUTION

(*a*) **Free Body: Collar** A



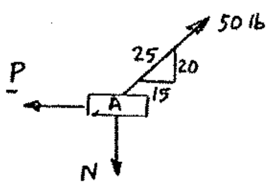


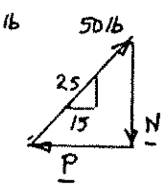
Force Triangle

$$\frac{P}{4.5} = \frac{50 \text{ lb}}{20.5}$$

$P = 10.98$ lb ◀

(*b*) **Free Body: Collar** A

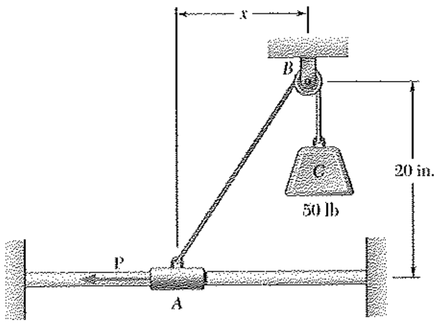




Force Triangle

$$\frac{P}{15} = \frac{50 \text{ lb}}{25}$$

$P = 30.0$ lb ◀

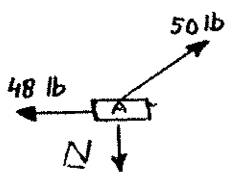


PROBLEM 2.64

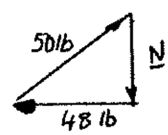
Collar A is connected as shown to a 50-lb load and can slide on a frictionless horizontal rod. Determine the distance x for which the collar is in equilibrium when $P = 48$ lb.

SOLUTION

Free Body: Collar A



Force Triangle

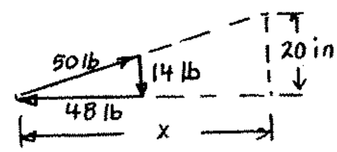


$$N^2 = (50)^2 - (48)^2 = 196$$

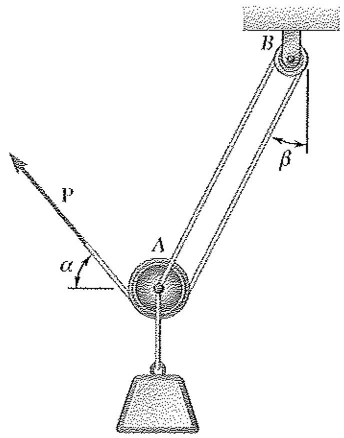
$$N = 14.00 \text{ lb}$$

Similar Triangles

$$\frac{x}{20 \text{ in.}} = \frac{48 \text{ lb}}{14 \text{ lb}}$$



$x = 68.6$ in. ◀

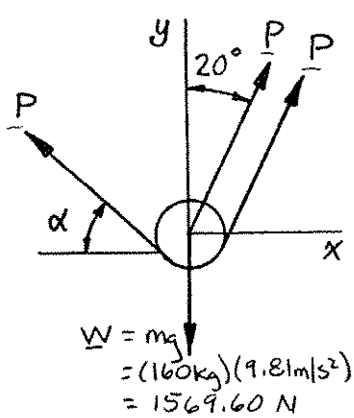


PROBLEM 2.65

A 160-kg load is supported by the rope-and-pulley arrangement shown. Knowing that $\beta = 20°$, determine the magnitude and direction of the force **P** that must be exerted on the free end of the rope to maintain equilibrium. (*Hint:* The tension in the rope is the same on each side of a simple pulley. This can be proved by the methods of Chapter 4.)

SOLUTION

Free-Body Diagram: Pulley *A*



$\xrightarrow{+} \Sigma F_x = 0\colon \quad 2P\sin 20° - P\cos\alpha = 0$

and $\qquad \cos\alpha = 0.8452 \quad \text{or} \quad \alpha = \pm 46.840°$

$\alpha = +46.840$

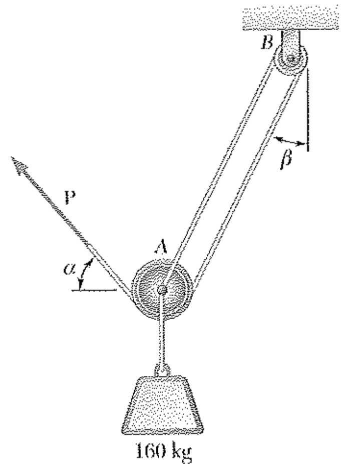
For $\qquad +\!\uparrow \Sigma F_y = 0\colon \quad 2P\cos 20° + P\sin 46.840° - 1569.60\text{ N} = 0$

or $\qquad \mathbf{P} = 602\text{ N} \measuredangle\, 46.8°$ ◀

For $\qquad \alpha = -46.840$

$+\!\uparrow \Sigma F_y = 0\colon \quad 2P\cos 20° + P\sin(-46.840°) - 1569.60\text{ N} = 0$

or $\qquad \mathbf{P} = 1365\text{ N} \measuredangle\, 46.8°$ ◀

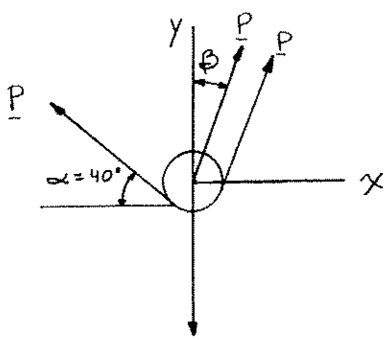


PROBLEM 2.66

A 160-kg load is supported by the rope-and-pulley arrangement shown. Knowing that $\alpha = 40°$, determine (*a*) the angle β, (*b*) the magnitude of the force **P** that must be exerted on the free end of the rope to maintain equilibrium. (See the hint for Problem 2.65.)

SOLUTION

Free-Body Diagram: Pulley *A*



W = mg
= (160 kg)(9.81 m/s²)
= 1569.60 N

(*a*) $\Sigma F_x = 0{:}\quad 2P\sin\sin\beta - P\cos 40° = 0$

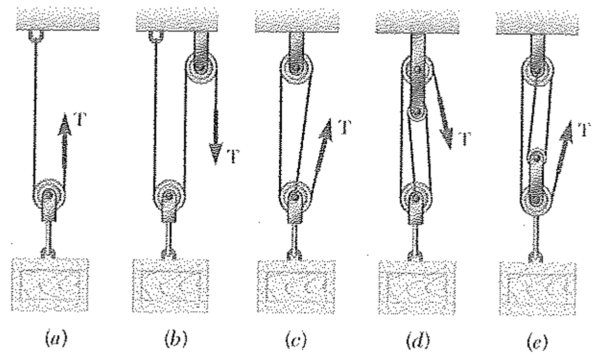
$$\sin\beta = \frac{1}{2}\cos 40°$$

$$\beta = 22.52°$$

$\beta = 22.5°$ ◀

(*b*) $\Sigma F_y = 0{:}\quad P\sin 40° + 2P\cos 22.52° - 1569.60\text{ N} = 0$

$P = 630$ N ◀



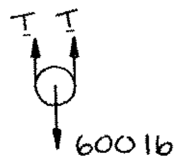
PROBLEM 2.67

A 600-lb crate is supported by several rope-and-pulley arrangements as shown. Determine for each arrangement the tension in the rope. (See the hint for Problem 2.65.)

SOLUTION

Free-Body Diagram of Pulley

(*a*)

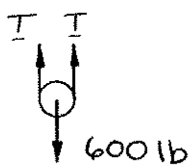


$$+\uparrow \Sigma F_y = 0: \quad 2T - (600\text{ lb}) = 0$$

$$T = \frac{1}{2}(600\text{ lb})$$

$T = 300$ lb ◀

(*b*)

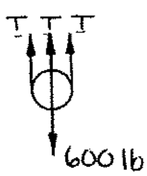


$$+\uparrow \Sigma F_y = 0: \quad 2T - (600\text{ lb}) = 0$$

$$T = \frac{1}{2}(600\text{ lb})$$

$T = 300$ lb ◀

(*c*)

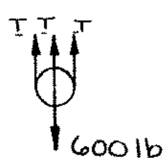


$$+\uparrow \Sigma F_y = 0: \quad 3T - (600\text{ lb}) = 0$$

$$T = \frac{1}{3}(600\text{ lb})$$

$T = 200$ lb ◀

(*d*)

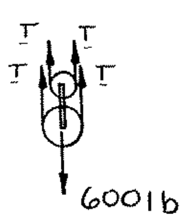


$$+\uparrow \Sigma F_y = 0: \quad 3T - (600\text{ lb}) = 0$$

$$T = \frac{1}{3}(600\text{ lb})$$

$T = 200$ lb ◀

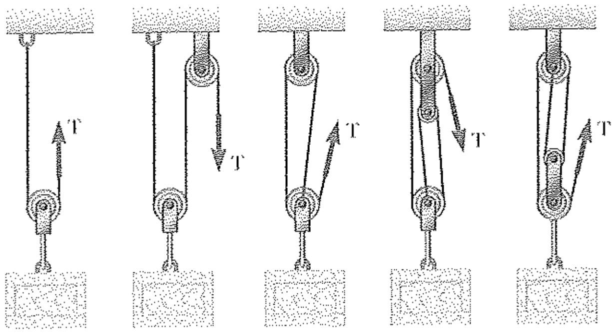
(*e*)



$$+\uparrow \Sigma F_y = 0: \quad 4T - (600\text{ lb}) = 0$$

$$T = \frac{1}{4}(600\text{ lb})$$

$T = 150.0$ lb ◀



(a) (b) (c) (d) (e)

PROBLEM 2.68

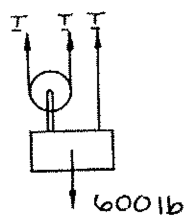
Solve Parts *b* and *d* of Problem 2.67, assuming that the free end of the rope is attached to the crate.

PROBLEM 2.67 A 600-lb crate is supported by several rope-and-pulley arrangements as shown. Determine for each arrangement the tension in the rope. (See the hint for Problem 2.65.)

SOLUTION

Free-Body Diagram of Pulley and Crate

(*b*)

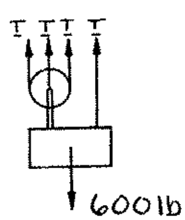


$$+\uparrow \Sigma F_y = 0: \quad 3T - (600 \text{ lb}) = 0$$

$$T = \frac{1}{3}(600 \text{ lb})$$

$T = 200$ lb ◀

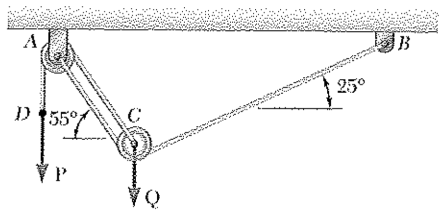
(*d*)



$$+\uparrow \Sigma F_y = 0: \quad 4T - (600 \text{ lb}) = 0$$

$$T = \frac{1}{4}(600 \text{ lb})$$

$T = 150.0$ lb ◀

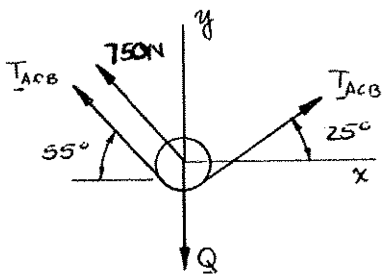


PROBLEM 2.69

A load **Q** is applied to the pulley C, which can roll on the cable ACB. The pulley is held in the position shown by a second cable CAD, which passes over the pulley A and supports a load **P**. Knowing that $P = 750$ N, determine (*a*) the tension in cable ACB, (*b*) the magnitude of load **Q**.

SOLUTION

Free-Body Diagram: Pulley ***C***



(*a*) $\xrightarrow{+} \Sigma F_x = 0$: $T_{ACB}(\cos 25° - \cos 55°) - (750 \text{ N})\cos 55° = 0$

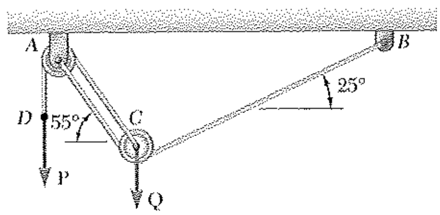
Hence: $T_{ACB} = 1292.88$ N

$T_{ACB} = 1293$ N ◀

(*b*) $+\uparrow \Sigma F_y = 0$: $T_{ACB}(\sin 25° + \sin 55°) + (750 \text{ N})\sin 55° - Q = 0$

$(1292.88 \text{ N})(\sin 25° + \sin 55°) + (750 \text{ N})\sin 55° - Q = 0$

or $Q = 2219.8$ N $\quad Q = 2220$ N ◀

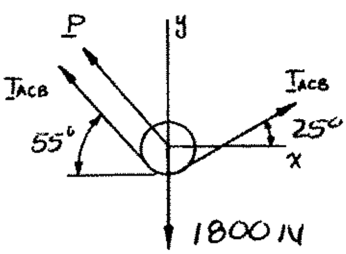


PROBLEM 2.70

An 1800-N load **Q** is applied to the pulley *C*, which can roll on the cable *ACB*. The pulley is held in the position shown by a second cable *CAD*, which passes over the pulley *A* and supports a load **P**. Determine (*a*) the tension in cable *ACB*, (*b*) the magnitude of load **P**.

SOLUTION

Free-Body Diagram: Pulley *C*



$\xrightarrow{+} \Sigma F_x = 0$: $T_{ACB}(\cos 25° - \cos 55°) - P\cos 55° = 0$

or $$P = 0.58010T_{ACB} \quad (1)$$

$+\uparrow \Sigma F_y = 0$: $T_{ACB}(\sin 25° + \sin 55°) + P\sin 55° - 1800 \text{ N} = 0$

or $$1.24177T_{ACB} + 0.81915P = 1800 \text{ N} \quad (2)$$

(*a*) Substitute Equation (1) into Equation (2):

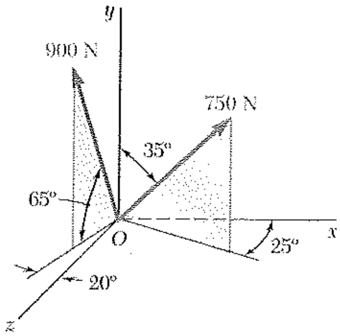
$$1.24177T_{ACB} + 0.81915(0.58010T_{ACB}) = 1800 \text{ N}$$

Hence: $T_{ACB} = 1048.37$ N

$$T_{ACB} = 1048 \text{ N} \blacktriangleleft$$

(*b*) Using (1), $P = 0.58010(1048.37 \text{ N}) = 608.16$ N

$$P = 608 \text{ N} \blacktriangleleft$$

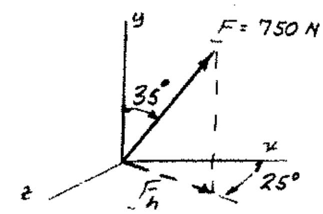


PROBLEM 2.71

Determine (a) the x, y, and z components of the 750-N force, (b) the angles θ_x, θ_y, and θ_z that the force forms with the coordinate axes.

SOLUTION

$$F_h = F\sin 35°$$
$$= (750\text{ N})\sin 35°$$
$$F_h = 430.2\text{ N}$$



(a)

$$F_x = F_h\cos 25° \qquad F_y = F\cos 35° \qquad F_z = F_h\sin 25°$$

$$= (430.2\text{ N})\cos 25° \qquad = (750\text{ N})\cos 35° \qquad = (430.2\text{ N})\sin 25°$$

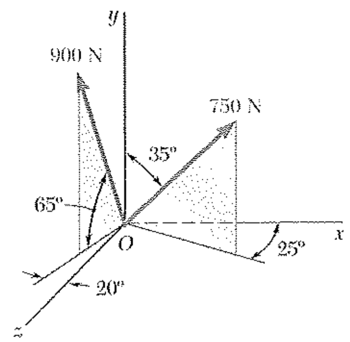
$$F_x = +390\text{ N}, \qquad F_y = +614\text{ N}, \qquad F_z = +181.8\text{ N} \blacktriangleleft$$

(b)

$$\cos\theta_x = \frac{F_x}{F} = \frac{+390\text{ N}}{750\text{ N}} \qquad \theta_x = 58.7° \blacktriangleleft$$

$$\cos\theta_y = \frac{F_y}{F} = \frac{+614\text{ N}}{750\text{ N}} \qquad \theta_y = 35.0° \blacktriangleleft$$

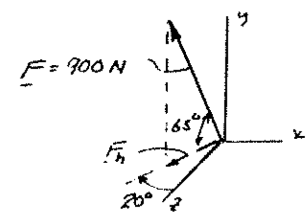
$$\cos\theta_z = \frac{F_z}{F} = \frac{+181.8\text{ N}}{750\text{ N}} \qquad \theta_z = 76.0° \blacktriangleleft$$



PROBLEM 2.72

Determine (*a*) the *x*, *y*, and *z* components of the 900-N force, (*b*) the angles θ_x, θ_y, and θ_z that the force forms with the coordinate axes.

SOLUTION



$$F_h = F\cos 65^\circ$$
$$= (900\text{ N})\cos 65^\circ$$
$$F_h = 380.4\text{ N}$$

(*a*)

$$F_x = F_h \sin 20^\circ \qquad F_y = F\sin 65^\circ \qquad F_z = F_h\cos 20^\circ$$

$$= (380.4\text{ N})\sin 20^\circ \qquad = (900\text{ N})\sin 65^\circ \qquad = (380.4\text{ N})\cos 20^\circ$$

$$F_x = -130.1\text{ N}, \qquad F_y = +816\text{ N}, \qquad F_z = +357\text{ N} \blacktriangleleft$$

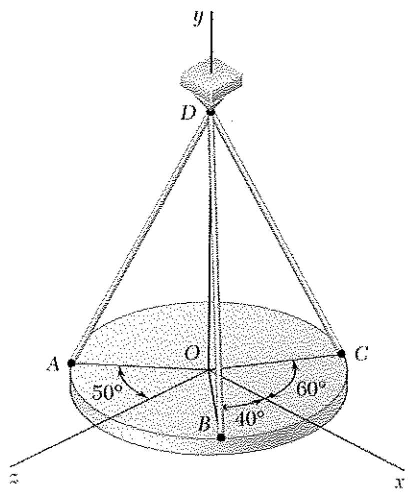
(*b*)

$$\cos\theta_x = \frac{F_x}{F} = \frac{-130.1\text{ N}}{900\text{ N}} \qquad \theta_x = 98.3^\circ \blacktriangleleft$$

$$\cos\theta_y = \frac{F_y}{F} = \frac{+816\text{ N}}{900\text{ N}} \qquad \theta_y = 25.0^\circ \blacktriangleleft$$

$$\cos\theta_z = \frac{F_z}{F} = \frac{+357\text{ N}}{900\text{ N}} \qquad \theta_z = 66.6^\circ \blacktriangleleft$$

PROBLEM 2.73



A horizontal circular plate is suspended as shown from three wires that are attached to a support at D and form 30° angles with the vertical. Knowing that the x component of the force exerted by wire AD on the plate is 110.3 N, determine (a) the tension in wire AD, (b) the angles θ_x, θ_y, and θ_z that the force exerted at A forms with the coordinate axes.

SOLUTION

(a)

$$F_x = F\sin 30^\circ \sin 50^\circ = 110.3 \text{ N} \quad \text{(Given)}$$

$$F = \frac{110.3 \text{ N}}{\sin 30^\circ \sin 50^\circ} = 287.97 \text{ N}$$

$F = 288$ N ◀

(b)

$$\cos\theta_x = \frac{F_x}{F} = \frac{110.3 \text{ N}}{287.97 \text{ N}} = 0.38303$$

$\theta_x = 67.5^\circ$ ◀

$$F_y = F\cos 30^\circ = 249.39$$

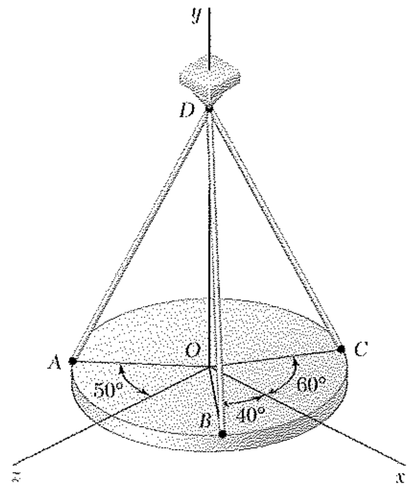
$$\cos\theta_y = \frac{F_y}{F} = \frac{249.39 \text{ N}}{287.97 \text{ N}} = 0.86603$$

$\theta_y = 30.0^\circ$ ◀

$$\begin{aligned} F_z &= -F\sin 30^\circ \cos 50^\circ \\ &= -(287.97 \text{ N})\sin 30^\circ \cos 50^\circ \\ &= -92.552 \text{ N} \end{aligned}$$

$$\cos\theta_z = \frac{F_z}{F} = \frac{-92.552 \text{ N}}{287.97 \text{ N}} = -0.32139$$

$\theta_z = 108.7^\circ$ ◀



PROBLEM 2.74

A horizontal circular plate is suspended as shown from three wires that are attached to a support at D and form 30° angles with the vertical. Knowing that the z component of the force exerted by wire BD on the plate is –32.14 N, determine (a) the tension in wire BD, (b) the angles θ_x, θ_y, and θ_z that the force exerted at B forms with the coordinate axes.

SOLUTION

(a)

$$F_z = -F\sin 30°\sin 40° = 32.14 \text{ N} \quad \text{(Given)}$$

$$F = \frac{32.14}{\sin 30°\sin 40°} = 100.0 \text{ N}$$

$F = 100.0$ N ◀

(b)

$$F_x = -F\sin 30°\cos 40°$$
$$= -(100.0 \text{ N})\sin 30°\cos 40°$$
$$= -38.302 \text{ N}$$

$$\cos\theta_x = \frac{F_x}{F} = \frac{38.302 \text{ N}}{100.0 \text{ N}} = -0.38302$$

$\theta_x = 112.5°$ ◀

$$F_y = F\cos 30° = 86.603 \text{ N}$$

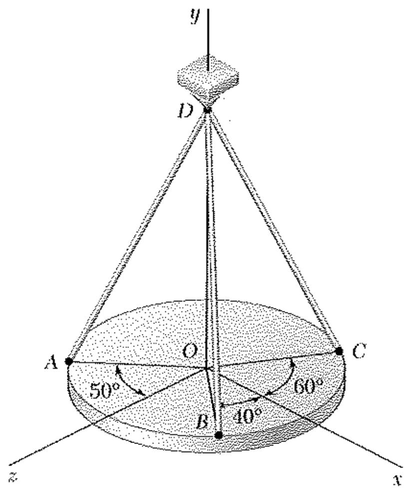
$$\cos\theta_y = \frac{F_y}{F} = \frac{86.603 \text{ N}}{100 \text{ N}} = 0.86603$$

$\theta_y = 30.0°$ ◀

$$F_z = -32.14 \text{ N}$$

$$\cos\theta_z = \frac{F_z}{F} = \frac{-32.14 \text{ N}}{100 \text{ N}} = -0.32140$$

$\theta_z = 108.7°$ ◀



PROBLEM 2.75

A horizontal circular plate is suspended as shown from three wires that are attached to a support at D and form 30° angles with the vertical. Knowing that the tension in wire CD is 60 lb, determine (a) the components of the force exerted by this wire on the plate, (b) the angles θ_x, θ_y, and θ_z that the force forms with the coordinate axes.

SOLUTION

(a)

$$F_x = -(60 \text{ lb})\sin 30°\cos 60° = -15 \text{ lb} \qquad F_x = -15.00 \text{ lb} \blacktriangleleft$$

$$F_y = (60 \text{ lb})\cos 30° = 51.96 \text{ lb} \qquad F_y = +52.0 \text{ lb} \blacktriangleleft$$

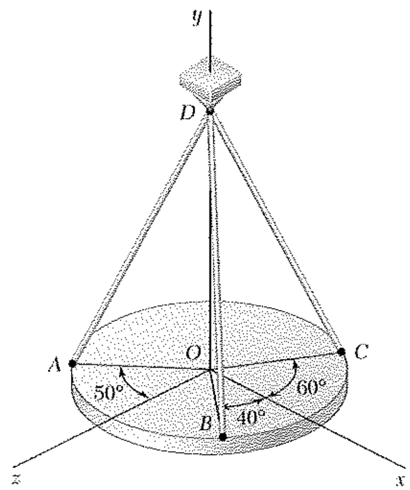
$$F_z = (60 \text{ lb})\sin 30°\sin 60° = 25.98 \text{ lb} \qquad F_z = +26.0 \text{ lb} \blacktriangleleft$$

(b)

$$\cos\theta_x = \frac{F_x}{F} = \frac{-15.0 \text{ lb}}{60 \text{ lb}} = -0.25 \qquad \theta_x = 104.5° \blacktriangleleft$$

$$\cos\theta_y = \frac{F_y}{F} = \frac{51.96 \text{ lb}}{60 \text{ lb}} = 0.866 \qquad \theta_y = 30.0° \blacktriangleleft$$

$$\cos\theta_z = \frac{F_z}{F} = \frac{25.98 \text{ lb}}{60 \text{ lb}} = 0.433 \qquad \theta_z = 64.3° \blacktriangleleft$$



PROBLEM 2.76

A horizontal circular plate is suspended as shown from three wires that are attached to a support at D and form 30° angles with the vertical. Knowing that the x component of the force exerted by wire CD on the plate is –20.0 lb, determine (*a*) the tension in wire CD, (*b*) the angles θ_x, θ_y, and θ_z that the force exerted at C forms with the coordinate axes.

SOLUTION

(*a*)

$$F_x = -F\sin 30°\cos 60° = -20\text{ lb} \quad \text{(Given)}$$

$$F = \frac{20\text{ lb}}{\sin 30°\cos 60°} = 80\text{ lb}$$

$F = 80.0$ lb ◀

(*b*)

$$\cos\theta_x = \frac{F_x}{F} = \frac{-20\text{ lb}}{80\text{ lb}} = -0.25$$

$\theta_x = 104.5°$ ◀

$$F_y = (80\text{ lb})\cos 30° = 69.282\text{ lb}$$

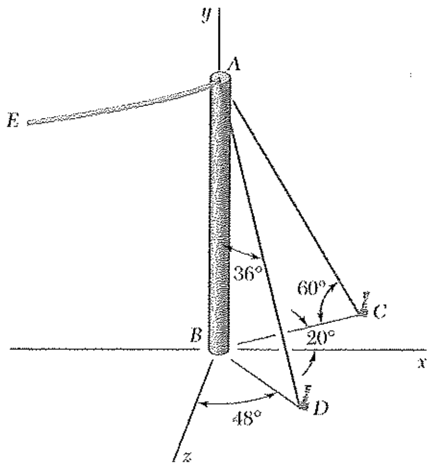
$$\cos\theta_y = \frac{F_y}{F} = \frac{69.282\text{ lb}}{80\text{ lb}} = 0.86615$$

$\theta_y = 30.0°$ ◀

$$F_z = (80\text{ lb})\sin 30°\sin 60° = 34.641\text{ lb}$$

$$\cos\theta_z = \frac{F_z}{F} = \frac{34.641}{80} = 0.43301$$

$\theta_z = 64.3°$ ◀



PROBLEM 2.77

The end of the coaxial cable AE is attached to the pole AB, which is strengthened by the guy wires AC and AD. Knowing that the tension in wire AC is 120 lb, determine (*a*) the components of the force exerted by this wire on the pole, (*b*) the angles θ_x, θ_y, and θ_z that the force forms with the coordinate axes.

SOLUTION

(*a*)

$$F_x = (120 \text{ lb})\cos 60^\circ \cos 20^\circ$$

$$F_x = 56.382 \text{ lb} \qquad F_x = +56.4 \text{ lb} \blacktriangleleft$$

$$F_y = -(120 \text{ lb})\sin 60^\circ$$

$$F_y = -103.923 \text{ lb} \qquad F_y = -103.9 \text{ lb} \blacktriangleleft$$

$$F_z = -(120 \text{ lb})\cos 60^\circ \sin 20^\circ$$

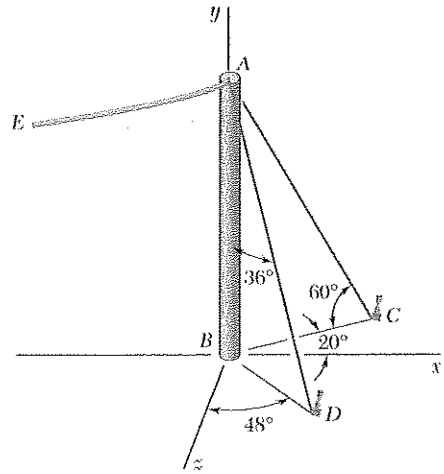
$$F_z = -20.521 \text{ lb} \qquad F_z = -20.5 \text{ lb} \blacktriangleleft$$

(*b*)

$$\cos\theta_x = \frac{F_x}{F} = \frac{56.382 \text{ lb}}{120 \text{ lb}} \qquad \theta_x = 62.0^\circ \blacktriangleleft$$

$$\cos\theta_y = \frac{F_y}{F} = \frac{-103.923 \text{ lb}}{120 \text{ lb}} \qquad \theta_y = 150.0^\circ \blacktriangleleft$$

$$\cos\theta_z = \frac{F_z}{F} = \frac{-20.52 \text{ lb}}{120 \text{ lb}} \qquad \theta_z = 99.8^\circ \blacktriangleleft$$



PROBLEM 2.78

The end of the coaxial cable AE is attached to the pole AB, which is strengthened by the guy wires AC and AD. Knowing that the tension in wire AD is 85 lb, determine (*a*) the components of the force exerted by this wire on the pole, (*b*) the angles θ_x, θ_y, and θ_z that the force forms with the coordinate axes.

SOLUTION

(*a*)

$$F_x = (85\text{ lb})\sin 36°\sin 48°$$

$$= 37.129\text{ lb} \qquad F_x = 37.1\text{ lb} \blacktriangleleft$$

$$F_y = -(85\text{ lb})\cos 36°$$

$$= -68.766\text{ lb} \qquad F_y = -68.8\text{ lb} \blacktriangleleft$$

$$F_z = (85\text{ lb})\sin 36°\cos 48°$$

$$= 33.431\text{ lb} \qquad F_z = 33.4\text{ lb} \blacktriangleleft$$

(*b*)

$$\cos\theta_x = \frac{F_x}{F} = \frac{37.129\text{ lb}}{85\text{ lb}} \qquad \theta_x = 64.1° \blacktriangleleft$$

$$\cos\theta_y = \frac{F_y}{F} = \frac{-68.766\text{ lb}}{85\text{ lb}} \qquad \theta_y = 144.0° \blacktriangleleft$$

$$\cos\theta_z = \frac{F_z}{F} = \frac{33.431\text{ lb}}{85\text{ lb}} \qquad \theta_z = 66.8° \blacktriangleleft$$

PROBLEM 2.79

Determine the magnitude and direction of the force $\mathbf{F} = (320\text{ N})\mathbf{i} + (400\text{ N})\mathbf{j} - (250\text{ N})\mathbf{k}$.

SOLUTION

$$F = \sqrt{F_x^2 + F_y^2 + F_z^2}$$

$$F = \sqrt{(320\text{ N})^2 + (400\text{ N})^2 + (-250\text{ N})^2}$$

$F = 570\text{ N}$ ◀

$$\cos\theta_x = \frac{F_x}{F} = \frac{320\text{ N}}{570\text{ N}}$$

$\theta_x = 55.8°$ ◀

$$\cos\theta_y = \frac{F_y}{F} = \frac{400\text{ N}}{570\text{ N}}$$

$\theta_y = 45.4°$ ◀

$$\cos\theta_y = \frac{F_z}{F} = \frac{-250\text{ N}}{570\text{ N}}$$

$\theta_z = 116.0°$ ◀

PROBLEM 2.80

Determine the magnitude and direction of the force $\mathbf{F} = (240\text{ N})\mathbf{i} - (270\text{ N})\mathbf{j} + (680\text{ N})\mathbf{k}$.

SOLUTION

$$F = \sqrt{F_x^2 + F_y^2 + F_z^2}$$

$$F = \sqrt{(240\text{ N})^2 + (-270\text{ N})^2 + (680\text{ N})} \qquad F = 770\text{ N} \blacktriangleleft$$

$$\cos\theta_x = \frac{F_x}{F} = \frac{240\text{ N}}{770\text{ N}} \qquad \theta_x = 71.8° \blacktriangleleft$$

$$\cos\theta_y = \frac{F_y}{F} = \frac{-270\text{ N}}{770\text{ N}} \qquad \theta_y = 110.5° \blacktriangleleft$$

$$\cos\theta_z = \frac{F_z}{F} = \frac{680\text{ N}}{770\text{ N}} \qquad \theta_z = 28.0° \blacktriangleleft$$

PROBLEM 2.81

A force acts at the origin of a coordinate system in a direction defined by the angles $\theta_x = 70.9°$ and $\theta_y = 144.9°$. Knowing that the z component of the force is –52.0 lb, determine (*a*) the angle θ_z, (*b*) the other components and the magnitude of the force.

SOLUTION

(*a*) We have

$$(\cos\theta_x)^2 + (\cos\theta_y)^2 + (\cos\theta_z)^2 = 1 \Rightarrow (\cos\theta_y)^2 = 1 - (\cos\theta_y)^2 - (\cos\theta_z)^2$$

Since $F_z < 0$ we must have $\cos\theta_z < 0$

Thus, taking the negative square root, from above, we have:

$$\cos\theta_z = -\sqrt{1 - (\cos 70.9°)^2 - (\cos 144.9°)^2} = 0.47282 \qquad \theta_z = 118.2° ◀$$

(*b*) Then:

$$F = \frac{F_z}{\cos\theta_z} = \frac{52.0 \text{ lb}}{0.47282} = 109.978 \text{ lb}$$

and

$$F_x = F\cos\theta_x = (109.978 \text{ lb})\cos 70.9° \qquad F_x = 36.0 \text{ lb} ◀$$

$$F_y = F\cos\theta_y = (109.978 \text{ lb})\cos 144.9° \qquad F_y = -90.0 \text{ lb} ◀$$

$$F = 110.0 \text{ lb} ◀$$

PROBLEM 2.82

A force acts at the origin of a coordinate system in a direction defined by the angles $\theta_y = 55°$ and $\theta_z = 45°$. Knowing that the x component of the force is – 500 lb, determine (*a*) the angle θ_x, (*b*) the other components and the magnitude of the force.

SOLUTION

(*a*) We have

$$(\cos\theta_x)^2 + (\cos\theta_y)^2 + (\cos\theta_z)^2 = 1 \Rightarrow (\cos\theta_y)^2 = 1 - (\cos\theta_y)^2 - (\cos\theta_z)^2$$

Since $F_x < 0$ we must have $\cos\theta_x < 0$

Thus, taking the negative square root, from above, we have:

$$\cos\theta_x = -\sqrt{1-(\cos 55)^2 - (\cos 45)^2} = 0.41353 \qquad \theta_x = 114.4° ◀$$

(*b*) Then:

$$F = \frac{F_x}{\cos\theta_x} = \frac{500\text{ lb}}{0.41353} = 1209.10\text{ lb} \qquad F = 1209\text{ lb} ◀$$

and $$F_y = F\cos\theta_y = (1209.10\text{ lb})\cos 55° \qquad F_y = 694\text{ lb} ◀$$

$$F_z = F\cos\theta_z = (1209.10\text{ lb})\cos 45° \qquad F_z = 855\text{ lb} ◀$$

PROBLEM 2.83

A force **F** of magnitude 210 N acts at the origin of a coordinate system. Knowing that $F_x = 80$ N, $\theta_z = 151.2°$, and $F_y < 0$, determine (*a*) the components F_y and F_z, (*b*) the angles θ_x and θ_y.

SOLUTION

(*a*) $$F_z = F\cos\theta_z = (210 \text{ N})\cos 151.2°$$

$$= -184.024 \text{ N}$$

$F_z = -184.0 \text{ N}$ ◀

Then: $$F^2 = F_x^2 + F_y^2 + F_z^2$$

So: $$(210 \text{ N})^2 = (80 \text{ N})^2 + (F_y)^2 + (184.024 \text{ N})^2$$

Hence: $$F_y = -\sqrt{(210 \text{ N})^2 - (80 \text{ N})^2 - (184.024 \text{ N})^2}$$

$$= -61.929 \text{ N}$$

$F_y = -62.0 \text{ lb}$ ◀

(*b*) $$\cos\theta_x = \frac{F_x}{F} = \frac{80 \text{ N}}{210 \text{ N}} = 0.38095$$

$\theta_x = 67.6°$ ◀

$$\cos\theta_y = \frac{F_y}{F} = \frac{61.929 \text{ N}}{210 \text{ N}} = -0.29490$$

$\theta_y = 107.2$ ◀

PROBLEM 2.84

A force **F** of magnitude 230 N acts at the origin of a coordinate system. Knowing that $\theta_x = 32.5°$, $F_y = -60$ N, and $F_z > 0$, determine (*a*) the components F_x and F_z, (*b*) the angles θ_y and θ_z.

SOLUTION

(*a*) We have

$$F_x = F\cos\theta_x = (230 \text{ N})\cos 32.5° \qquad F_x = -194.0 \text{ N} ◀$$

Then: $F_x = 193.980$ N

$$F^2 = F_x^2 + F_y^2 + F_z^2$$

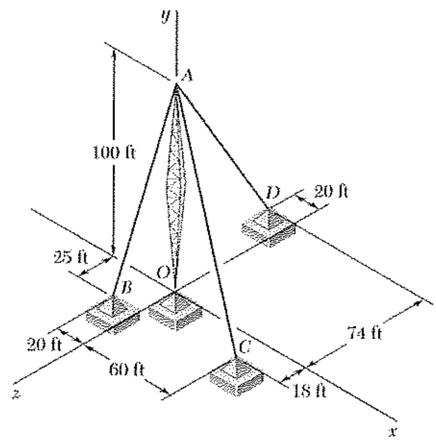
So: $(230 \text{ N})^2 = (193.980 \text{ N})^2 + (-60 \text{ N})^2 + F_z^2$

Hence:
$$F_z = +\sqrt{(230 \text{ N})^2 - (193.980 \text{ N})^2 - (-60 \text{ N})^2} \qquad F_z = 108.0 \text{ N} ◀$$

(*b*) $F_z = 108.036$ N

$$\cos\theta_y = \frac{F_y}{F} = \frac{-60 \text{ N}}{230 \text{ N}} = -0.26087 \qquad \theta_y = 105.1° ◀$$

$$\cos\theta_z = \frac{F_z}{F} = \frac{108.036 \text{ N}}{230 \text{ N}} = 0.46972 \qquad \theta_z = 62.0° ◀$$



PROBLEM 2.85

A transmission tower is held by three guy wires anchored by bolts at B, C, and D. If the tension in wire AB is 525 lb, determine the components of the force exerted by the wire on the bolt at B.

SOLUTION

$$\overrightarrow{BA} = (20\text{ ft})\mathbf{i} + (100\text{ ft})\mathbf{j} - (25\text{ ft})\mathbf{k}$$

$$BA = \sqrt{(20\text{ ft})^2 + (100\text{ ft})^2 + (-25\text{ ft})^2}$$

$$= 105\text{ ft}$$

$$\mathbf{F} = F\boldsymbol{\lambda}_{BA}$$

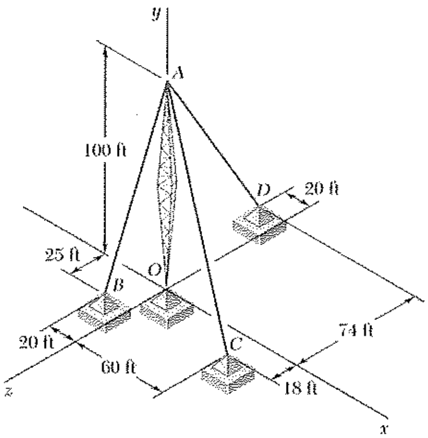
$$= F\frac{\overrightarrow{BA}}{BA}$$

$$= \frac{525\text{ lb}}{105\text{ ft}}[(20\text{ ft})\mathbf{i} + (100\text{ ft})\mathbf{j} - (25\text{ ft})\mathbf{k}]$$

$$\mathbf{F} = (100.0\text{ lb})\mathbf{i} + (500\text{ lb})\mathbf{j} - (125.0\text{ lb})\mathbf{k}$$

$$F_x = +100.0\text{ lb}, \quad F_y = +500\text{ lb}, \quad F_z = -125.0\text{ lb} \blacktriangleleft$$

PROBLEM 2.86



A transmission tower is held by three guy wires anchored by bolts at B, C, and D. If the tension in wire AD is 315 lb, determine the components of the force exerted by the wire on the bolt at D.

SOLUTION

$$\overrightarrow{DA} = (20 \text{ ft})\mathbf{i} + (100 \text{ ft})\mathbf{j} + (70 \text{ ft})\mathbf{k}$$

$$DA = \sqrt{(20 \text{ ft})^2 + (100 \text{ ft})^2 + (+70 \text{ ft})^2}$$

$$= 126 \text{ ft}$$

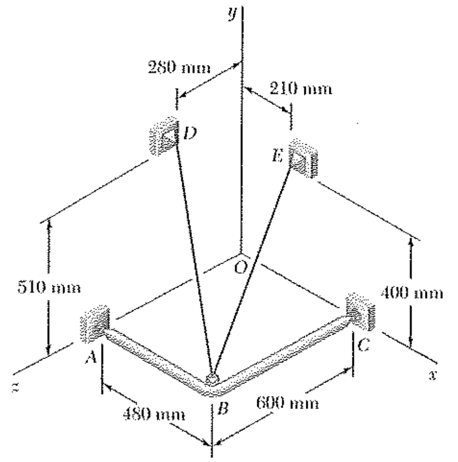
$$\mathbf{F} = F\boldsymbol{\lambda}_{DA}$$

$$= F\frac{\overrightarrow{DA}}{DA}$$

$$= \frac{315 \text{ lb}}{126 \text{ ft}}[(20 \text{ ft})\mathbf{i} + (100 \text{ ft})\mathbf{j} + (74 \text{ ft})\mathbf{k}]$$

$$\mathbf{F} = (50 \text{ lb})\mathbf{i} + (250 \text{ lb})\mathbf{j} + (185 \text{ lb})\mathbf{k}$$

$F_x = +50$ lb, $F_y = +250$ lb, $F_z = +185.0$ lb ◀



PROBLEM 2.87

A frame ABC is supported in part by cable DBE that passes through a frictionless ring at B. Knowing that the tension in the cable is 385 N, determine the components of the force exerted by the cable on the support at D.

SOLUTION

$$\overrightarrow{DB} = (480 \text{ mm})\mathbf{i} - (510 \text{ mm})\mathbf{j} + (320 \text{ mm})\mathbf{k}$$

$$DB = \sqrt{(480 \text{ mm})^2 + (510 \text{ mm}^2) + (320 \text{ mm})^2}$$

$$= 770 \text{ mm}$$

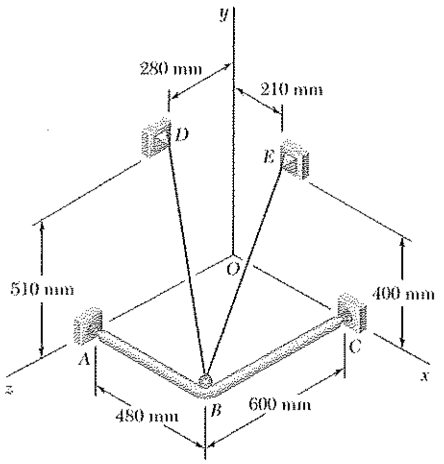
$$\mathbf{F} = F\boldsymbol{\lambda}_{DB}$$

$$= F\frac{\overrightarrow{DB}}{DB}$$

$$= \frac{385 \text{ N}}{770 \text{ mm}}[(480 \text{ mm})\mathbf{i} - (510 \text{ mm})\mathbf{j} + (320 \text{ mm})\mathbf{k}]$$

$$= (240 \text{ N})\mathbf{i} - (255 \text{ N})\mathbf{j} + (160 \text{ N})\mathbf{k}$$

$$F_x = +240 \text{ N}, \quad F_y = -255 \text{ N}, \quad F_z = +160.0 \text{ N} \blacktriangleleft$$



PROBLEM 2.88

For the frame and cable of Problem 2.87, determine the components of the force exerted by the cable on the support at E.

PROBLEM 2.87 A frame ABC is supported in part by cable DBE that passes through a frictionless ring at B. Knowing that the tension in the cable is 385 N, determine the components of the force exerted by the cable on the support at D.

SOLUTION

$$\overrightarrow{EB} = (270\text{ mm})\mathbf{i} - (400\text{ mm})\mathbf{j} + (600\text{ mm})\mathbf{k}$$

$$EB = \sqrt{(270\text{ mm})^2 + (400\text{ mm})^2 + (600\text{ mm})^2}$$

$$= 770\text{ mm}$$

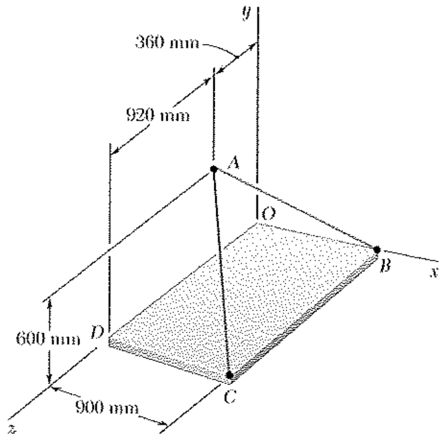
$$\mathbf{F} = F\boldsymbol{\lambda}_{EB}$$

$$= F\frac{\overrightarrow{EB}}{EB}$$

$$= \frac{385\text{ N}}{770\text{ mm}}[(270\text{ mm})\mathbf{i} - (400\text{ mm})\mathbf{j} + (600\text{ mm})\mathbf{k}]$$

$$\mathbf{F} = (135\text{ N})\mathbf{i} - (200\text{ N})\mathbf{j} + (300\text{ N})\mathbf{k}$$

$F_x = +135.0\text{ N}, \quad F_y = -200\text{ N}, \quad F_z = +300\text{ N}$ ◀



PROBLEM 2.89

Knowing that the tension in cable AB is 1425 N, determine the components of the force exerted on the plate at B.

SOLUTION

$$\overrightarrow{BA} = -(900 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k}$$

$$BA = \sqrt{(900 \text{ mm})^2 + (600 \text{ mm})^2 + (360 \text{ mm})^2}$$

$$= 1140 \text{ mm}$$

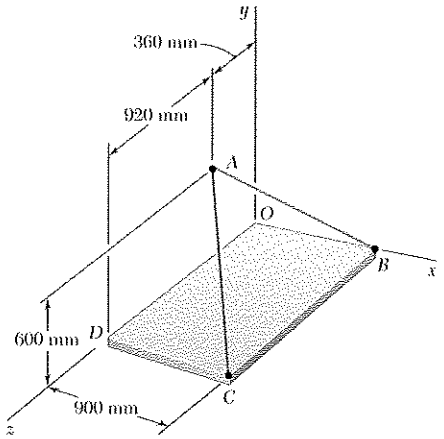
$$\mathbf{T}_{BA} = T_{BA}\boldsymbol{\lambda}_{BA}$$

$$= T_{BA}\frac{\overrightarrow{BA}}{BA}$$

$$\mathbf{T}_{BA} = \frac{1425 \text{ N}}{1140 \text{ mm}}[-(900 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k}]$$

$$= -(1125 \text{ N})\mathbf{i} + (750 \text{ N})\mathbf{j} + (450 \text{ N})\mathbf{k}$$

$$(T_{BA})_x = -1125 \text{ N}, \quad (T_{BA})_y = 750 \text{ N}, \quad (T_{BA})_z = 450 \text{ N} \blacktriangleleft$$



PROBLEM 2.90

Knowing that the tension in cable AC is 2130 N, determine the components of the force exerted on the plate at C.

SOLUTION

$$\overrightarrow{CA} = -(900 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j} - (920 \text{ mm})\mathbf{k}$$

$$CA = \sqrt{(900 \text{ mm})^2 + (600 \text{ mm})^2 + (920 \text{ mm})^2}$$

$$= 1420 \text{ mm}$$

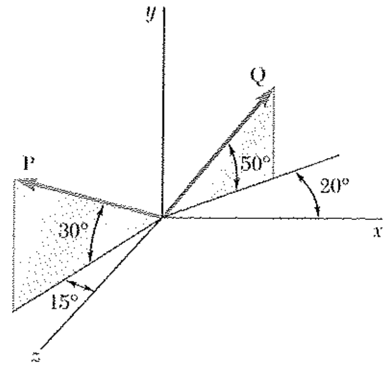
$$\mathbf{T}_{CA} = T_{CA}\lambda_{CA}$$

$$= T_{CA}\frac{\overrightarrow{CA}}{CA}$$

$$\mathbf{T}_{CA} = \frac{2130 \text{ N}}{1420 \text{ mm}}[-(900 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j} - (920 \text{ mm})\mathbf{k}]$$

$$= -(1350 \text{ N})\mathbf{i} + (900 \text{ N})\mathbf{j} - (1380 \text{ N})\mathbf{k}$$

$$(T_{CA})_x = -1350 \text{ N}, \quad (T_{CA})_y = 900 \text{ N}, \quad (T_{CA})_z = -1380 \text{ N} \blacktriangleleft$$



PROBLEM 2.91

Find the magnitude and direction of the resultant of the two forces shown knowing that $P = 300$ N and $Q = 400$ N.

SOLUTION

$$\mathbf{P} = (300\text{ N})[-\cos 30°\sin 15°\mathbf{i} + \sin 30°\mathbf{j} + \cos 30°\cos 15°\mathbf{k}]$$

$$= -(67.243\text{ N})\mathbf{i} + (150\text{ N})\mathbf{j} + (250.95\text{ N})\mathbf{k}$$

$$\mathbf{Q} = (400\text{ N})[\cos 50°\cos 20°\mathbf{i} + \sin 50°\mathbf{j} - \cos 50°\sin 20°\mathbf{k}]$$

$$= (400\text{ N})[0.60402\mathbf{i} + 0.76604\mathbf{j} - 0.21985]$$

$$= (241.61\text{ N})\mathbf{i} + (306.42\text{ N})\mathbf{j} - (87.939\text{ N})\mathbf{k}$$

$$\mathbf{R} = \mathbf{P} + \mathbf{Q}$$

$$= (174.367\text{ N})\mathbf{i} + (456.42\text{ N})\mathbf{j} + (163.011\text{ N})\mathbf{k}$$

$$R = \sqrt{(174.367\text{ N})^2 + (456.42\text{ N})^2 + (163.011\text{ N})^2}$$

$$= 515.07\text{ N}$$

$R = 515$ N ◀

$$\cos\theta_x = \frac{R_x}{R} = \frac{174.367\text{ N}}{515.07\text{ N}} = 0.33853$$

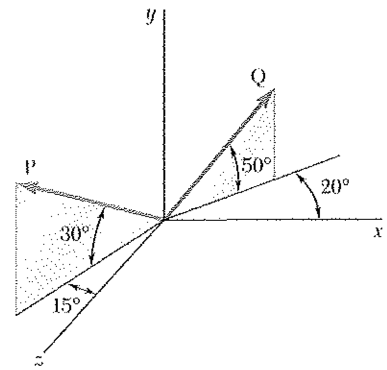
$\theta_x = 70.2°$ ◀

$$\cos\theta_y = \frac{R_y}{R} = \frac{456.42\text{ N}}{515.07\text{ N}} = 0.88613$$

$\theta_y = 27.6°$ ◀

$$\cos\theta_z = \frac{R_z}{R} = \frac{163.011\text{ N}}{515.07\text{ N}} = 0.31648$$

$\theta_z = 71.5°$ ◀



PROBLEM 2.92

Find the magnitude and direction of the resultant of the two forces shown knowing that $P = 400$ N and $Q = 300$ N.

SOLUTION

$$\mathbf{P} = (400\text{ N})[-\cos 30°\sin 15°\mathbf{i} + \sin 30°\mathbf{j} + \cos 30°\cos 15°\mathbf{k}]$$
$$= -(89.678\text{ N})\mathbf{i} + (200\text{ N})\mathbf{j} + (334.61\text{ N})\mathbf{k}$$
$$\mathbf{Q} = (300\text{ N})[\cos 50°\cos 20°\mathbf{i} + \sin 50°\mathbf{j} - \cos 50°\sin 20°\mathbf{k}]$$
$$= (181.21\text{ N})\mathbf{i} + (229.81\text{ N})\mathbf{j} - (65.954\text{ N})\mathbf{k}$$
$$\mathbf{R} = \mathbf{P} + \mathbf{Q}$$
$$= (91.532\text{ N})\mathbf{i} + (429.81\text{ N})\mathbf{j} + (268.66\text{ N})\mathbf{k}$$
$$R = \sqrt{(91.532\text{ N})^2 + (429.81\text{ N})^2 + (268.66\text{ N})^2}$$
$$= 515.07\text{ N}$$

$R = 515$ N ◀

$$\cos\theta_x = \frac{R_x}{R} = \frac{91.532\text{ N}}{515.07\text{ N}} = 0.177708$$

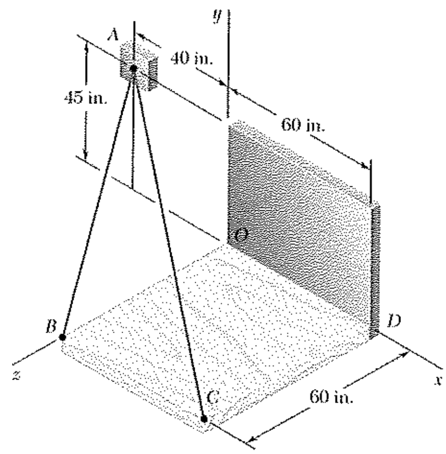
$\theta_x = 79.8°$ ◀

$$\cos\theta_y = \frac{R_y}{R} = \frac{429.81\text{ N}}{515.07\text{ N}} = 0.83447$$

$\theta_y = 33.4°$ ◀

$$\cos\theta_z = \frac{R_z}{R} = \frac{268.66\text{ N}}{515.07\text{ N}} = 0.52160$$

$\theta_z = 58.6°$ ◀



PROBLEM 2.93

Knowing that the tension is 425 lb in cable AB and 510 lb in cable AC, determine the magnitude and direction of the resultant of the forces exerted at A by the two cables.

SOLUTION

$$\overrightarrow{AB} = (40 \text{ in.})\mathbf{i} - (45 \text{ in.})\mathbf{j} + (60 \text{ in.})\mathbf{k}$$

$$AB = \sqrt{(40 \text{ in.})^2 + (45 \text{ in.})^2 + (60 \text{ in.})^2} = 85 \text{ in.}$$

$$\overrightarrow{AC} = (100 \text{ in.})\mathbf{i} - (45 \text{ in.})\mathbf{j} + (60 \text{ in.})\mathbf{k}$$

$$AC = \sqrt{(100 \text{ in.})^2 + (45 \text{ in.})^2 + (60 \text{ in.})^2} = 125 \text{ in.}$$

$$\mathbf{T}_{AB} = T_{AB}\boldsymbol{\lambda}_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB} = (425 \text{ lb})\left[\frac{(40 \text{ in.})\mathbf{i} - (45 \text{ in.})\mathbf{j} + (60 \text{ in.})\mathbf{k}}{85 \text{ in.}}\right]$$

$$\mathbf{T}_{AB} = (200 \text{ lb})\mathbf{i} - (225 \text{ lb})\mathbf{j} + (300 \text{ lb})\mathbf{k}$$

$$\mathbf{T}_{AC} = T_{AC}\boldsymbol{\lambda}_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC} = (510 \text{ lb})\left[\frac{(100 \text{ in.})\mathbf{i} - (45 \text{ in.})\mathbf{j} + (60 \text{ in.})\mathbf{k}}{125 \text{ in.}}\right]$$

$$\mathbf{T}_{AC} = (408 \text{ lb})\mathbf{i} - (183.6 \text{ lb})\mathbf{j} + (244.8 \text{ lb})\mathbf{k}$$

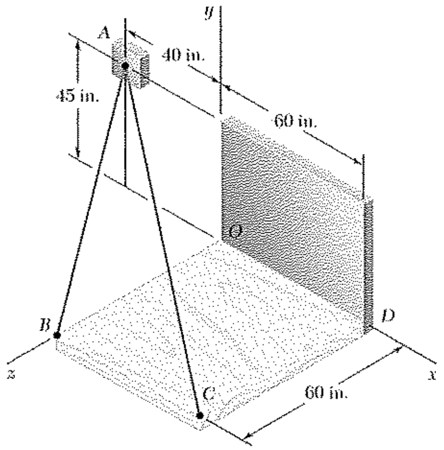
$$\mathbf{R} = \mathbf{T}_{AB} + \mathbf{T}_{AC} = (608)\mathbf{i} - (408.6 \text{ lb})\mathbf{j} + (544.8 \text{ lb})\mathbf{k}$$

Then: $R = 912.92 \text{ lb}$ $\qquad R = 913 \text{ lb}$ ◀

and $\cos\theta_x = \dfrac{608 \text{ lb}}{912.92 \text{ lb}} = 0.66599$ $\qquad \theta_x = 48.2°$ ◀

$\cos\theta_y = \dfrac{408.6 \text{ lb}}{912.92 \text{ lb}} = -0.44757$ $\qquad \theta_y = 116.6°$ ◀

$\cos\theta_z = \dfrac{544.8 \text{ lb}}{912.92 \text{ lb}} = 0.59677$ $\qquad \theta_z = 53.4°$ ◀



PROBLEM 2.94

Knowing that the tension is 510 lb in cable AB and 425 lb in cable AC, determine the magnitude and direction of the resultant of the forces exerted at A by the two cables.

SOLUTION

$$\overrightarrow{AB} = (40\text{ in.})\mathbf{i} - (45\text{ in.})\mathbf{j} + (60\text{ in.})\mathbf{k}$$

$$AB = \sqrt{(40\text{ in.})^2 + (45\text{ in.})^2 + (60\text{ in.})^2} = 85\text{ in.}$$

$$\overrightarrow{AC} = (100\text{ in.})\mathbf{i} - (45\text{ in.})\mathbf{j} + (60\text{ in.})\mathbf{k}$$

$$AC = \sqrt{(100\text{ in.})^2 + (45\text{ in.})^2 + (60\text{ in.})^2} = 125\text{ in.}$$

$$\mathbf{T}_{AB} = T_{AB}\boldsymbol{\lambda}_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB} = (510\text{ lb})\left[\frac{(40\text{ in.})\mathbf{i} - (45\text{ in.})\mathbf{j} + (60\text{ in.})\mathbf{k}}{85\text{ in.}}\right]$$

$$\mathbf{T}_{AB} = (240\text{ lb})\mathbf{i} - (270\text{ lb})\mathbf{j} + (360\text{ lb})\mathbf{k}$$

$$\mathbf{T}_{AC} = T_{AC}\boldsymbol{\lambda}_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC} = (425\text{ lb})\left[\frac{(100\text{ in.})\mathbf{i} - (45\text{ in.})\mathbf{j} + (60\text{ in.})\mathbf{k}}{125\text{ in.}}\right]$$

$$\mathbf{T}_{AC} = (340\text{ lb})\mathbf{i} - (153\text{ lb})\mathbf{j} + (204\text{ lb})\mathbf{k}$$

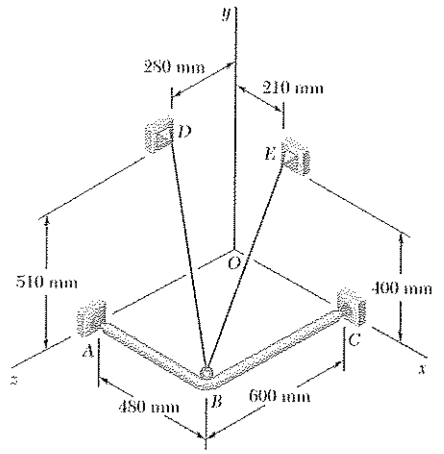
$$\mathbf{R} = \mathbf{T}_{AB} + \mathbf{T}_{AC} = (580\text{ lb})\mathbf{i} - (423\text{ lb})\mathbf{j} + (564\text{ lb})\mathbf{k}$$

Then: $R = 912.92\text{ lb}$ $\qquad R = 913\text{ lb}$ ◀

and $\cos\theta_x = \dfrac{580\text{ lb}}{912.92\text{ lb}} = 0.63532$ $\qquad \theta_x = 50.6°$ ◀

$\cos\theta_y = \dfrac{-423\text{ lb}}{912.92\text{ lb}} = -0.46335$ $\qquad \theta_y = 117.6°$ ◀

$\cos\theta_z = \dfrac{564\text{ lb}}{912.92\text{ lb}} = 0.61780$ $\qquad \theta_z = 51.8°$ ◀



PROBLEM 2.95

For the frame of Problem 2.87, determine the magnitude and direction of the resultant of the forces exerted by the cable at B knowing that the tension in the cable is 385 N.

PROBLEM 2.87 A frame ABC is supported in part by cable DBE that passes through a frictionless ring at B. Knowing that the tension in the cable is 385 N, determine the components of the force exerted by the cable on the support at D.

SOLUTION

$$\overrightarrow{BD} = -(480\text{ mm})\mathbf{i} + (510\text{ mm})\mathbf{j} - (320\text{ mm})\mathbf{k}$$

$$BD = \sqrt{(480\text{ mm})^2 + (510\text{ mm})^2 + (320\text{ mm})^2} = 770\text{ mm}$$

$$\mathbf{F}_{BD} = T_{BD}\boldsymbol{\lambda}_{BD} = T_{BD}\frac{\overrightarrow{BD}}{BD}$$

$$= \frac{(385\text{ N})}{(770\text{ mm})}[-(480\text{ mm})\mathbf{i} + (510\text{ mm})\mathbf{j} - (320\text{ mm})\mathbf{k}]$$

$$= -(240\text{ N})\mathbf{i} + (255\text{ N})\mathbf{j} - (160\text{ N})\mathbf{k}$$

$$\overrightarrow{BE} = -(270\text{ mm})\mathbf{i} + (400\text{ mm})\mathbf{j} - (600\text{ mm})\mathbf{k}$$

$$BE = \sqrt{(270\text{ mm})^2 + (400\text{ mm})^2 + (600\text{ mm})^2} = 770\text{ mm}$$

$$\mathbf{F}_{BE} = T_{BE}\boldsymbol{\lambda}_{BE} = T_{BE}\frac{\overrightarrow{BE}}{BE}$$

$$= \frac{(385\text{ N})}{(770\text{ mm})}[-(270\text{ mm})\mathbf{i} + (400\text{ mm})\mathbf{j} - (600\text{ mm})\mathbf{k}]$$

$$= -(135\text{ N})\mathbf{i} + (200\text{ N})\mathbf{j} - (300\text{ N})\mathbf{k}$$

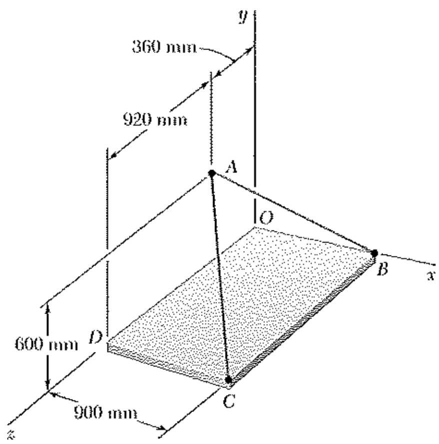
$$\mathbf{R} = \mathbf{F}_{BD} + \mathbf{F}_{BE} = -(375\text{ N})\mathbf{i} + (455\text{ N})\mathbf{j} - (460\text{ N})\mathbf{k}$$

$$R = \sqrt{(375\text{ N})^2 + (455\text{ N})^2 + (460\text{ N})^2} = 747.83\text{ N} \qquad R = 748\text{ N} \blacktriangleleft$$

$$\cos\theta_x = \frac{-375\text{ N}}{747.83\text{ N}} \qquad \theta_x = 120.1° \blacktriangleleft$$

$$\cos\theta_y = \frac{455\text{ N}}{747.83\text{ N}} \qquad \theta_y = 52.5° \blacktriangleleft$$

$$\cos\theta_z = \frac{-460\text{ N}}{747.83\text{ N}} \qquad \theta_z = 128.0° \blacktriangleleft$$



PROBLEM 2.96

For the cables of Problem 2.89, knowing that the tension is 1425 N in cable AB and 2130 N in cable AC, determine the magnitude and direction of the resultant of the forces exerted at A by the two cables.

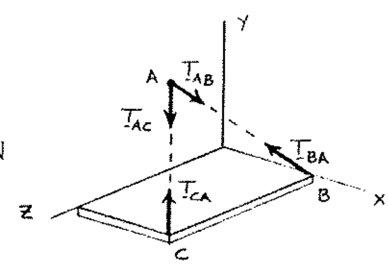
SOLUTION

$$T_{AB} = -T_{BA} \quad \text{(use results of Problem 2.89)}$$

$$(T_{AB})_x = +1125 \text{ N} \quad (T_{AB})_y = -750 \text{ N} \quad (T_{AB})_z = -450 \text{ N}$$

$$T_{AC} = -T_{CA} \quad \text{(use results of Problem 2.90)}$$

$$(T_{AC})_x = +1350 \text{ N} \quad (T_{AC})_y = -900 \text{ N} \quad (T_{AC})_z = +1380 \text{ N}$$



Resultant:

$$R_x = \Sigma F_x = +1125 + 1350 = +2475 \text{ N}$$

$$R_y = \Sigma F_y = -750 - 900 = -1650 \text{ N}$$

$$R_z = \Sigma F_z = -450 + 1380 = +930 \text{ N}$$

$$R = \sqrt{R_x^2 + R_y^2 + R_z^2}$$

$$= \sqrt{(+2475)^2 + (-1650)^2 + (+930)^2}$$

$$= 3116.6 \text{ N}$$

$R = 3120$ N ◀

$$\cos\theta_x = \frac{R_x}{R} = \frac{+2475}{3116.6}$$

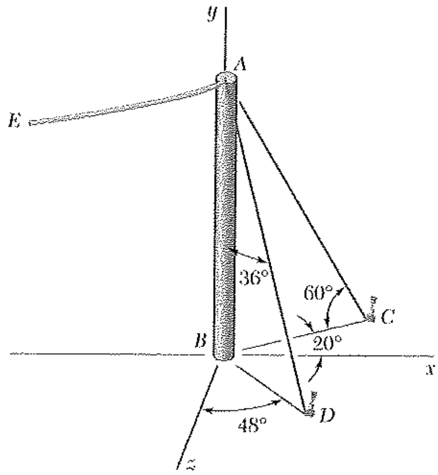
$\theta_x = 37.4°$ ◀

$$\cos\theta_y = \frac{R_y}{R} = \frac{-1650}{3116.6}$$

$\theta_y = 122.0°$ ◀

$$\cos\theta_z = \frac{R_z}{R} = \frac{+930}{3116.6}$$

$\theta_z = 72.6°$ ◀



PROBLEM 2.97

The end of the coaxial cable AE is attached to the pole AB, which is strengthened by the guy wires AC and AD. Knowing that the tension in AC is 150 lb and that the resultant of the forces exerted at A by wires AC and AD must be contained in the xy plane, determine (*a*) the tension in AD, (*b*) the magnitude and direction of the resultant of the two forces.

SOLUTION

$$\begin{aligned}\mathbf{R} &= \mathbf{T}_{AC} + \mathbf{T}_{AD}\\ &= (150 \text{ lb})(\cos 60^\circ \cos 20^\circ \mathbf{i} - \sin 60^\circ \mathbf{j} - \cos 60^\circ \sin 20^\circ \mathbf{k})\\ &\quad + T_{AD}(\sin 36^\circ \sin 48^\circ \mathbf{i} - \cos 36^\circ \mathbf{j} + \sin 36^\circ \cos 48^\circ \mathbf{k}) \qquad (1)\end{aligned}$$

(*a*) Since $R_z = 0$, The coefficient of $\mathbf{k}$ must be zero.

$$(150 \text{ lb})(-\cos 60^\circ \sin 20^\circ) + T_{AD}(\sin 36^\circ \cos 48^\circ) = 0$$

$$T_{AD} = 65.220 \text{ lb} \qquad T_{AD} = 65.2 \text{ lb} \blacktriangleleft$$

(*b*) Substituting for T_{AD} into Eq. (1) gives:

$$\begin{aligned}\mathbf{R} &= [(150 \text{ lb}) \cos 60^\circ \cos 20^\circ + (65.220 \text{ lb}) \sin 36^\circ \sin 48^\circ]\mathbf{i}\\ &\quad - [(150 \text{ lb}) \sin 60^\circ + (65.220 \text{ lb}) \cos 36^\circ]\mathbf{j} + 0\end{aligned}$$

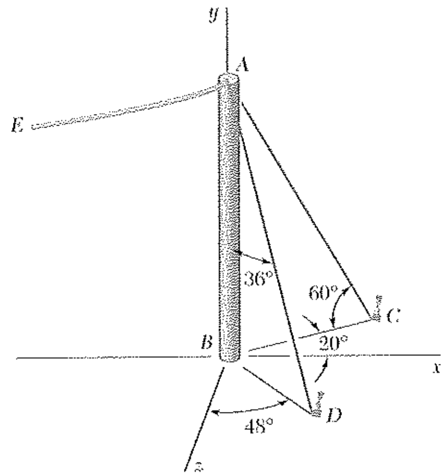
$$\mathbf{R} = (98.966 \text{ lb})\mathbf{i} - (182.668 \text{ lb})\mathbf{j}$$

$$\begin{aligned}R &= \sqrt{(98.966 \text{ lb})^2 + (182.668 \text{ lb})^2}\\ &= 207.76 \text{ lb}\end{aligned} \qquad R = 208 \text{ lb} \blacktriangleleft$$

$$\cos \theta_x = \frac{98.966 \text{ lb}}{207.76 \text{ lb}} \qquad \theta_x = 61.6^\circ \blacktriangleleft$$

$$\cos \theta_y = \frac{182.668 \text{ lb}}{207.76 \text{ lb}} \qquad \theta_y = 151.6^\circ \blacktriangleleft$$

$$\cos \theta_z = 0 \qquad \theta_z = 90.0^\circ \blacktriangleleft$$



PROBLEM 2.98

The end of the coaxial cable AE is attached to the pole AB, which is strengthened by the guy wires AC and AD. Knowing that the tension in AD is 125 lb and that the resultant of the forces exerted at A by wires AC and AD must be contained in the xy plane, determine (*a*) the tension in AC, (*b*) the magnitude and direction of the resultant of the two forces.

SOLUTION

$$\mathbf{R} = \mathbf{T}_{AC} + \mathbf{T}_{AD}$$
$$= T_{AC}(\cos 60°\cos 20°\mathbf{i} - \sin 60°\mathbf{j} - \cos 60°\sin 20°\mathbf{k})$$
$$+ (125 \text{ lb})(\sin 36°\sin 48°\mathbf{i} - \cos 36°\mathbf{j} + \sin 36° \cos 48°\mathbf{k}) \qquad (1)$$

(*a*) Since $R_z = 0$, The coefficient of $\mathbf{k}$ must be zero.

$$T_{AC}(-\cos 60°\sin 20°) + (125 \text{ lb})(\sin 36° \cos 48°) = 0$$
$$T_{AC} = 287.49 \text{ lb} \qquad T_{AC} = 287 \text{ lb} \blacktriangleleft$$

(*b*) Substituting for T_{AC} into Eq. (1) gives:

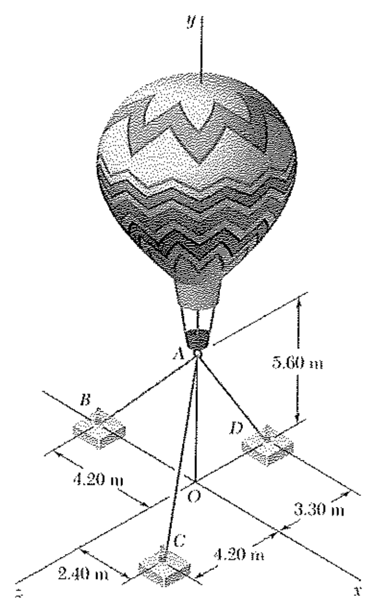
$$\mathbf{R} = [(287.49 \text{ lb}) \cos 60°\cos 20° + (125 \text{ lb})\sin 36°\sin 48°]\mathbf{i}$$
$$-[(287.49 \text{ lb})\sin 60° + (125 \text{ lb})\cos 36°]\mathbf{j} + 0$$

$$\mathbf{R} = (189.677 \text{ lb})\mathbf{i} - (350.10 \text{ lb})\mathbf{j}$$
$$R = \sqrt{(189.677 \text{ lb})^2 + (350.10 \text{ lb})^2}$$
$$= 398.18 \text{ lb} \qquad R = 398 \text{ lb} \blacktriangleleft$$

$$\cos \theta_x = \frac{189.677 \text{ lb}}{398.18 \text{ lb}} \qquad \theta_x = 61.6° \blacktriangleleft$$

$$\cos \theta_y = \frac{350.10 \text{ lb}}{398.18 \text{ lb}} \qquad \theta_y = 151.6° \blacktriangleleft$$

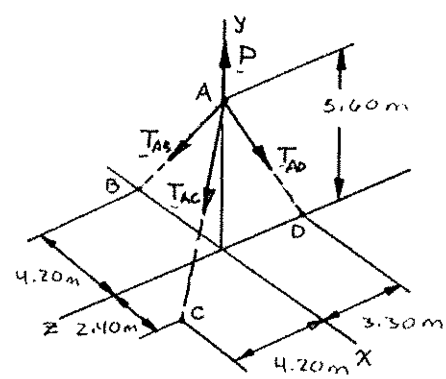
$$\cos \theta_z = 0 \qquad \theta_z = 90.0° \blacktriangleleft$$



PROBLEM 2.99

Three cables are used to tether a balloon as shown. Determine the vertical force **P** exerted by the balloon at A knowing that the tension in cable AB is 259 N.

SOLUTION



The forces applied at A are: $\mathbf{T}_{AB}, \mathbf{T}_{AC}, \mathbf{T}_{AD}$, and $\mathbf{P}$

where $\mathbf{P} = P\mathbf{j}$. To express the other forces in terms of the unit vectors **i**, **j**, **k**, we write

$$\overrightarrow{AB} = -(4.20 \text{ m})\mathbf{i} - (5.60 \text{ m})\mathbf{j} \qquad AB = 7.00 \text{ m}$$

$$\overrightarrow{AC} = (2.40 \text{ m})\mathbf{i} - (5.60 \text{ m})\mathbf{j} + (4.20 \text{ m})\mathbf{k} \qquad AC = 7.40 \text{ m}$$

$$\overrightarrow{AD} = -(5.60 \text{ m})\mathbf{j} - (3.30 \text{ m})\mathbf{k} \qquad AD = 6.50 \text{ m}$$

and

$$\mathbf{T}_{AB} = T_{AB}\boldsymbol{\lambda}_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB} = (-0.6\mathbf{i} - 0.8\mathbf{j})T_{AB}$$

$$\mathbf{T}_{AC} = T_{AC}\boldsymbol{\lambda}_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC} = (0.32432 - 0.75676\mathbf{j} + 0.56757\mathbf{k})T_{AC}$$

$$\mathbf{T}_{AD} = T_{AD}\boldsymbol{\lambda}_{AD} = T_{AD}\frac{\overrightarrow{AD}}{AD} = (-0.86154\mathbf{j} - 0.50769\mathbf{k})T_{AD}$$

PROBLEM 2.99 (Continued)

Equilibrium condition $\Sigma F = 0$: $\mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{T}_{AD} + P\mathbf{j} = 0$

Substituting the expressions obtained for $\mathbf{T}_{AB}$, $\mathbf{T}_{AC}$, and $\mathbf{T}_{AD}$ and factoring **i**, **j**, and **k**:

$$(-0.6T_{AB} + 0.32432T_{AC})\mathbf{i} + (-0.8T_{AB} - 0.75676T_{AC} - 0.86154T_{AD} + P)\mathbf{j}$$
$$+(0.56757T_{AC} - 0.50769T_{AD})\mathbf{k} = 0$$

Equating to zero the coefficients of **i**, **j**, **k**:

$$-0.6T_{AB} + 0.32432T_{AC} = 0 \qquad (1)$$

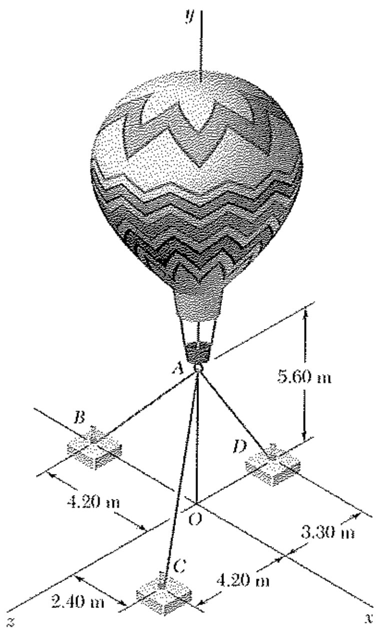
$$-0.8T_{AB} - 0.75676T_{AC} - 0.86154T_{AD} + P = 0 \qquad (2)$$

$$0.56757T_{AC} - 0.50769T_{AD} = 0 \qquad (3)$$

Setting $T_{AB} = 259\text{ N}$ in (1) and (2), and solving the resulting set of equations gives

$$T_{AC} = 479.15\text{ N}$$
$$T_{AD} = 535.66\text{ N}$$

$\mathbf{P} = 1031\text{ N}\uparrow$ ◀



PROBLEM 2.100

Three cables are used to tether a balloon as shown. Determine the vertical force **P** exerted by the balloon at A knowing that the tension in cable AC is 444 N.

SOLUTION

See Problem 2.99 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-0.6T_{AB} + 0.32432T_{AC} = 0 \tag{1}$$

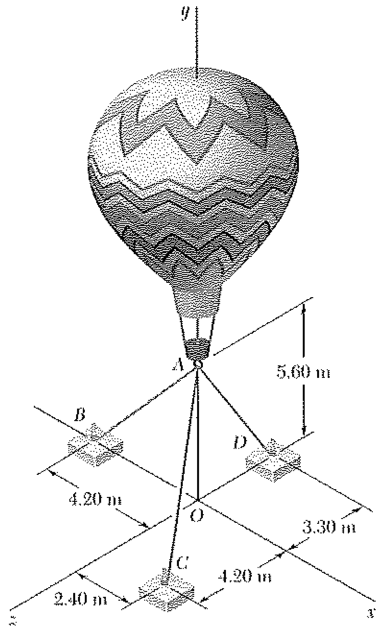
$$-0.8T_{AB} - 0.75676T_{AC} - 0.86154T_{AD} + P = 0 \tag{2}$$

$$0.56757T_{AC} - 0.50769T_{AD} = 0 \tag{3}$$

Substituting $T_{AC} = 444$ N in Equations (1), (2), and (3) above, and solving the resulting set of equations using conventional algorithms gives

$$T_{AB} = 240 \text{ N}$$
$$T_{AD} = 496.36 \text{ N}$$

$\mathbf{P} = 956 \text{ N} \uparrow$ ◀



PROBLEM 2.101

Three cables are used to tether a balloon as shown. Determine the vertical force **P** exerted by the balloon at A knowing that the tension in cable AD is 481 N.

SOLUTION

See Problem 2.99 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3).

$$-0.6T_{AB} + 0.32432T_{AC} = 0 \tag{1}$$

$$-0.8T_{AB} - 0.75676T_{AC} - 0.86154T_{AD} + P = 0 \tag{2}$$

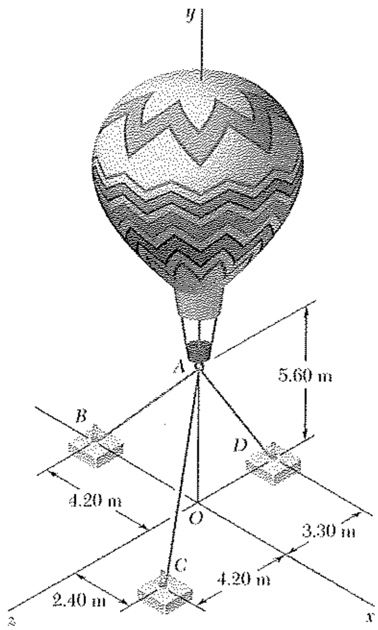
$$0.56757T_{AC} - 0.50769T_{AD} = 0 \tag{3}$$

Substituting $T_{AD} = 481$ N in Equations (1), (2), and (3) above, and solving the resulting set of equations using conventional algorithms gives

$$T_{AC} = 430.26 \text{ N}$$

$$T_{AB} = 232.57 \text{ N}$$

$\mathbf{P} = 926 \text{ N}\uparrow$ ◀



PROBLEM 2.102

Three cables are used to tether a balloon as shown. Knowing that the balloon exerts an 800-N vertical force at A, determine the tension in each cable.

SOLUTION

See Problem 2.99 for the figure and analysis leading to the linear algebraic Equations (1), (2), and (3).

$$-0.6T_{AB} + 0.32432T_{AC} = 0 \quad (1)$$

$$-0.8T_{AB} - 0.75676T_{AC} - 0.86154T_{AD} + P = 0 \quad (2)$$

$$0.56757T_{AC} - 0.50769T_{AD} = 0 \quad (3)$$

From Eq. (1) $\quad T_{AB} = 0.54053T_{AC}$

From Eq. (3) $\quad T_{AD} = 1.11795T_{AC}$

Substituting for T_{AB} and T_{AD} in terms of T_{AC} into Eq. (2) gives:

$$-0.8(0.54053T_{AC}) - 0.75676T_{AC} - 0.86154(1.11795T_{AC}) + P = 0$$

$$2.1523T_{AC} = P; \quad P = 800\text{ N}$$

$$T_{AC} = \frac{800\text{ N}}{2.1523}$$

$$= 371.69\text{ N}$$

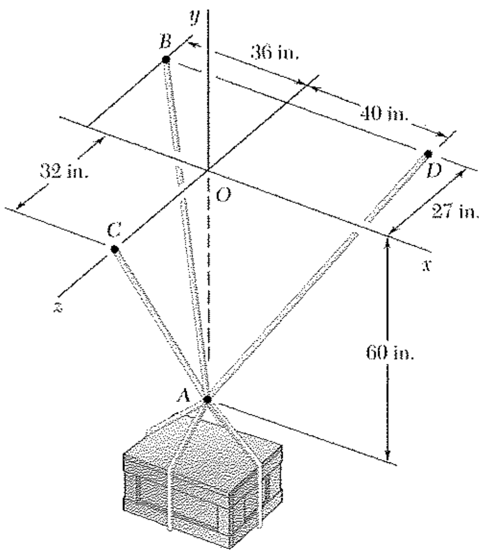
Substituting into expressions for T_{AB} and T_{AD} gives:

$$T_{AB} = 0.54053(371.69\text{ N})$$

$$T_{AD} = 1.11795(371.69\text{ N})$$

$$T_{AB} = 201\text{ N}, \quad T_{AC} = 372\text{ N}, \quad T_{AD} = 416\text{ N} \blacktriangleleft$$

PROBLEM 2.103



A crate is supported by three cables as shown. Determine the weight of the crate knowing that the tension in cable AB is 750 lb.

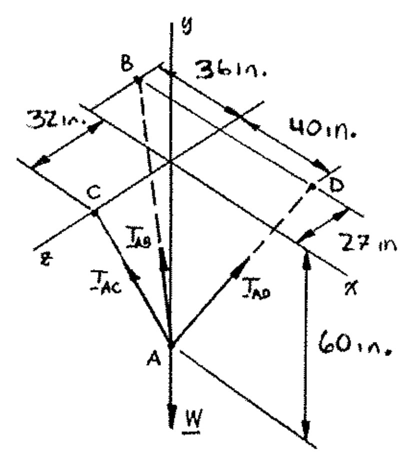
SOLUTION

The forces applied at A are:

$$\mathbf{T}_{AB}, \mathbf{T}_{AC}, \mathbf{T}_{AD} \text{ and } \mathbf{W}$$

where $\mathbf{P} = P\mathbf{j}$. To express the other forces in terms of the unit vectors $\mathbf{i}$, $\mathbf{j}$, $\mathbf{k}$, we write

$$\overrightarrow{AB} = -(36 \text{ in.})\mathbf{i} + (60 \text{ in.})\mathbf{j} - (27 \text{ in.})\mathbf{k}$$
$$AB = 75 \text{ in.}$$
$$\overrightarrow{AC} = (60 \text{ in.})\mathbf{j} + (32 \text{ in.})\mathbf{k}$$
$$AC = 68 \text{ in.}$$
$$\overrightarrow{AD} = (40 \text{ in.})\mathbf{i} + (60 \text{ in.})\mathbf{j} - (27 \text{ in.})\mathbf{k}$$
$$AD = 77 \text{ in.}$$



and

$$\mathbf{T}_{AB} = T_{AB}\boldsymbol{\lambda}_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB}$$
$$= (-0.48\mathbf{i} + 0.8\mathbf{j} - 0.36\mathbf{k})T_{AB}$$
$$\mathbf{T}_{AC} = T_{AC}\boldsymbol{\lambda}_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC}$$
$$= (0.88235\mathbf{j} + 0.47059\mathbf{k})T_{AC}$$
$$\mathbf{T}_{AD} = T_{AD}\boldsymbol{\lambda}_{AD} = T_{AD}\frac{\overrightarrow{AD}}{AD}$$
$$= (0.51948\mathbf{i} + 0.77922\mathbf{j} - 0.35065\mathbf{k})T_{AD}$$

Equilibrium Condition with $\mathbf{W} = -W\mathbf{j}$

$$\Sigma F = 0: \quad \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{T}_{AD} - W\mathbf{j} = 0$$

PROBLEM 2.103 (Continued)

Substituting the expressions obtained for $\mathbf{T}_{AB}$, $\mathbf{T}_{AC}$, and $\mathbf{T}_{AD}$ and factoring **i**, **j**, and **k**:

$$(-0.48T_{AB} + 0.51948T_{AD})\mathbf{i} + (0.8T_{AB} + 0.88235T_{AC} + 0.77922T_{AD} - W)\mathbf{j}$$
$$+(-0.36T_{AB} + 0.47059T_{AC} - 0.35065T_{AD})\mathbf{k} = 0$$

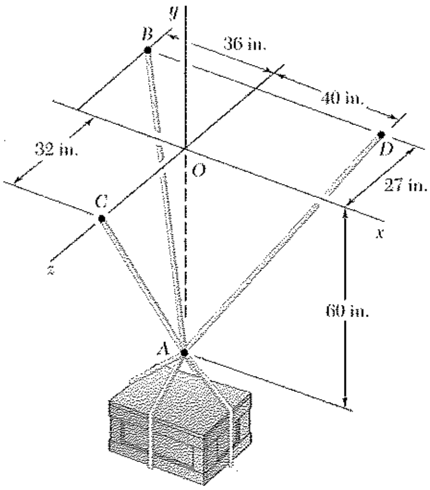
Equating to zero the coefficients of **i**, **j**, **k**:

$$-0.48T_{AB} + 0.51948T_{AD} = 0$$
$$0.8T_{AB} + 0.88235T_{AC} + 0.77922T_{AD} - W = 0$$
$$-0.36T_{AB} + 0.47059T_{AC} - 0.35065T_{AD} = 0$$

Substituting $T_{AB} = 750\text{ lb}$ in Equations (1), (2), and (3) and solving the resulting set of equations, using conventional algorithms for solving linear algebraic equations, gives:

$$T_{AC} = 1090.1\text{ lb}$$
$$T_{AD} = 693\text{ lb}$$

$W = 2100\text{ lb}$ ◀



PROBLEM 2.104

A crate is supported by three cables as shown. Determine the weight of the crate knowing that the tension in cable AD is 616 lb.

SOLUTION

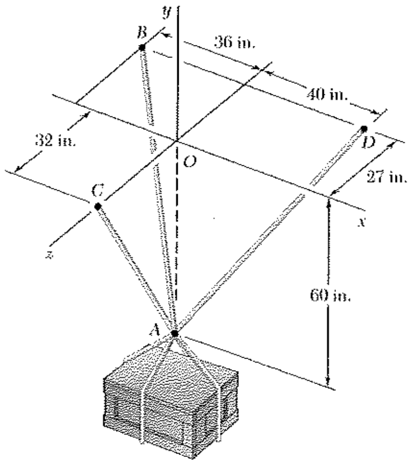
See Problem 2.103 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-0.48T_{AB} + 0.51948T_{AD} = 0$$
$$0.8T_{AB} + 0.88235T_{AC} + 0.77922T_{AD} - W = 0$$
$$-0.36T_{AB} + 0.47059T_{AC} - 0.35065T_{AD} = 0$$

Substituting $T_{AD} = 616 \text{ lb}$ in Equations (1), (2), and (3) above, and solving the resulting set of equations using conventional algorithms, gives:

$$T_{AB} = 667.67 \text{ lb}$$
$$T_{AC} = 969.00 \text{ lb}$$

$W = 1868 \text{ lb}$ ◀



PROBLEM 2.105

A crate is supported by three cables as shown. Determine the weight of the crate knowing that the tension in cable AC is 544 lb.

SOLUTION

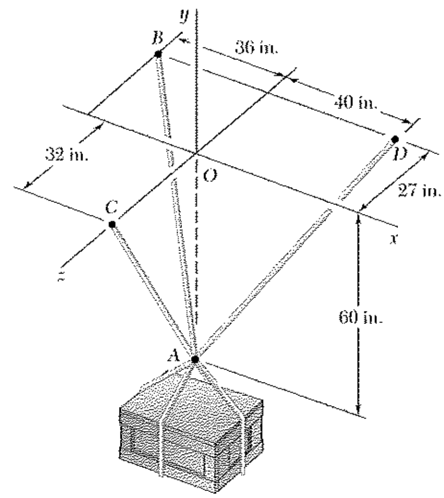
See Problem 2.103 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-0.48T_{AB} + 0.51948T_{AD} = 0$$
$$0.8T_{AB} + 0.88235T_{AC} + 0.77922T_{AD} - W = 0$$
$$-0.36T_{AB} + 0.47059T_{AC} - 0.35065T_{AD} = 0$$

Substituting $T_{AC} = 544 \text{ lb}$ in Equations (1), (2), and (3) above, and solving the resulting set of equations using conventional algorithms, gives:

$$T_{AB} = 374.27 \text{ lb}$$
$$T_{AD} = 345.82 \text{ lb}$$

$W = 1049 \text{ lb}$ ◀



PROBLEM 2.106

A 1600-lb crate is supported by three cables as shown. Determine the tension in each cable.

SOLUTION

See Problem 2.103 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

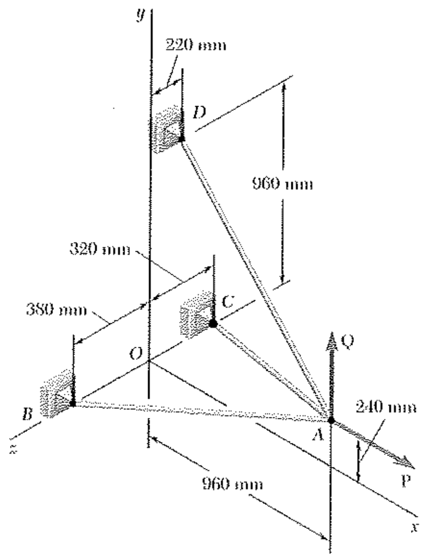
$$-0.48T_{AB} + 0.51948T_{AD} = 0$$
$$0.8T_{AB} + 0.88235T_{AC} + 0.77922T_{AD} - W = 0$$
$$-0.36T_{AB} + 0.47059T_{AC} - 0.35065T_{AD} = 0$$

Substituting $W = 1600$ lb in Equations (1), (2), and (3) above, and solving the resulting set of equations using conventional algorithms, gives:

$T_{AB} = 571$ lb ◀

$T_{AC} = 830$ lb ◀

$T_{AD} = 528$ lb ◀



PROBLEM 2.107

Three cables are connected at A, where the forces **P** and **Q** are applied as shown. Knowing that $Q = 0$, find the value of P for which the tension in cable AD is 305 N.

SOLUTION

$$\Sigma \mathbf{F}_A = 0: \quad \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{T}_{AD} + \mathbf{P} = 0 \quad \text{where} \quad \mathbf{P} = P\mathbf{i}$$

$$\overrightarrow{AB} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} + (380 \text{ mm})\mathbf{k} \qquad AB = 1060 \text{ mm}$$

$$\overrightarrow{AC} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} - (320 \text{ mm})\mathbf{k} \qquad AC = 1040 \text{ mm}$$

$$\overrightarrow{AD} = -(960 \text{ mm})\mathbf{i} + (720 \text{ mm})\mathbf{j} - (220 \text{ mm})\mathbf{k} \qquad AD = 1220 \text{ mm}$$

$$\mathbf{T}_{AB} = T_{AB}\boldsymbol{\lambda}_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB} = T_{AB}\left(-\frac{48}{53}\mathbf{i} - \frac{12}{53}\mathbf{j} + \frac{19}{53}\mathbf{k}\right)$$

$$\mathbf{T}_{AC} = T_{AC}\boldsymbol{\lambda}_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC} = T_{AC}\left(-\frac{12}{13}\mathbf{i} - \frac{3}{13}\mathbf{j} - \frac{4}{13}\mathbf{k}\right)$$

$$\mathbf{T}_{AD} = T_{AD}\boldsymbol{\lambda}_{AD} = \frac{305 \text{ N}}{1220 \text{ mm}}[(-960 \text{ mm})\mathbf{i} + (720 \text{ mm})\mathbf{j} - (220 \text{ mm})\mathbf{k}]$$

$$= -(240 \text{ N})\mathbf{i} + (180 \text{ N})\mathbf{j} - (55 \text{ N})\mathbf{k}$$

Substituting into $\Sigma \mathbf{F}_A = 0$, factoring **i**, **j**, **k**, and setting each coefficient equal to ϕ gives:

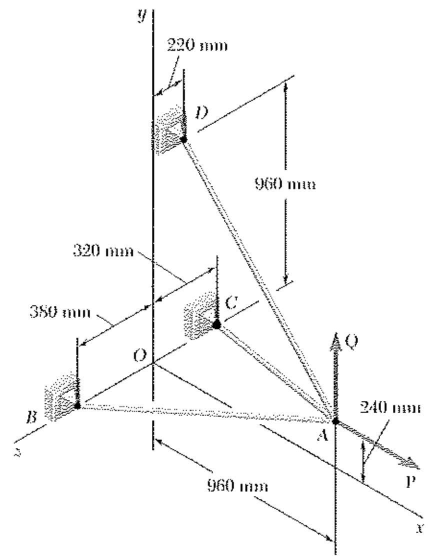
$$\mathbf{i}: \quad P = \frac{48}{53}T_{AB} + \frac{12}{13}T_{AC} + 240 \text{ N} \tag{1}$$

$$\mathbf{j}: \quad \frac{12}{53}T_{AB} + \frac{3}{13}T_{AC} = 180 \text{ N} \tag{2}$$

$$\mathbf{k}: \quad \frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} = 55 \text{ N} \tag{3}$$

Solving the system of linear equations using conventional algorithms gives:

$$T_{AB} = 446.71 \text{ N}$$
$$T_{AC} = 341.71 \text{ N} \qquad P = 960 \text{ N} ◀$$



PROBLEM 2.108

Three cables are connected at A, where the forces $\mathbf{P}$ and $\mathbf{Q}$ are applied as shown. Knowing that $P = 1200$ N, determine the values of Q for which cable AD is taut.

SOLUTION

We assume that $T_{AD} = 0$ and write $\quad \Sigma\mathbf{F}_A = 0: \quad \mathbf{T}_{AB} + \mathbf{T}_{AC} + Q\mathbf{j} + (1200\text{ N})\mathbf{i} = 0$

$$\overrightarrow{AB} = -(960\text{ mm})\mathbf{i} - (240\text{ mm})\mathbf{j} + (380\text{ mm})\mathbf{k} \quad AB = 1060\text{ mm}$$

$$\overrightarrow{AC} = -(960\text{ mm})\mathbf{i} - (240\text{ mm})\mathbf{j} - (320\text{ mm})\mathbf{k} \quad AC = 1040\text{ mm}$$

$$\mathbf{T}_{AB} = T_{AB}\boldsymbol{\lambda}_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB} = \left(-\frac{48}{53}\mathbf{i} - \frac{12}{53}\mathbf{j} + \frac{19}{53}\mathbf{k}\right)T_{AB}$$

$$\mathbf{T}_{AC} = T_{AC}\boldsymbol{\lambda}_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC} = \left(-\frac{12}{13}\mathbf{i} - \frac{3}{13}\mathbf{j} - \frac{4}{13}\mathbf{k}\right)T_{AC}$$

Substituting into $\Sigma\mathbf{F}_A = 0$, factoring $\mathbf{i}$, $\mathbf{j}$, $\mathbf{k}$, and setting each coefficient equal to ϕ gives:

$$\mathbf{i}: \quad -\frac{48}{53}T_{AB} - \frac{12}{13}T_{AC} + 1200\text{ N} = 0 \qquad (1)$$

$$\mathbf{j}: \quad -\frac{12}{53}T_{AB} - \frac{3}{13}T_{AC} + Q = 0 \qquad (2)$$

$$\mathbf{k}: \quad \frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} = 0 \qquad (3)$$

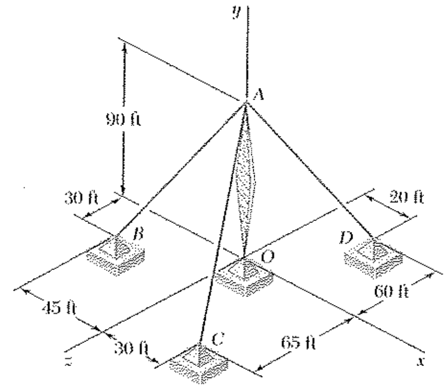
Solving the resulting system of linear equations using conventional algorithms gives:

$$T_{AB} = 605.71\text{ N}$$
$$T_{AC} = 705.71\text{ N}$$
$$Q = 300.00\text{ N}$$

$0 \le Q < 300$ N ◀

Note: This solution assumes that Q is directed upward as shown $(Q \ge 0)$, if negative values of Q are considered, cable AD remains taut, but AC becomes slack for $Q = -460$ N.

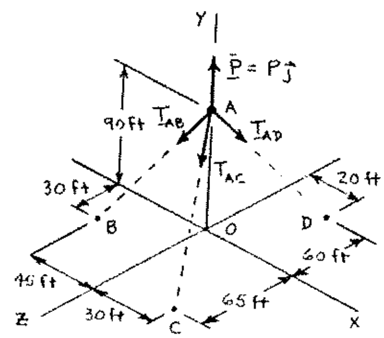
PROBLEM 2.109



A transmission tower is held by three guy wires attached to a pin at A and anchored by bolts at B, C, and D. If the tension in wire AB is 630 lb, determine the vertical force $\mathbf{P}$ exerted by the tower on the pin at A.

SOLUTION

Free Body A:



$$\Sigma\mathbf{F} = 0: \quad \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{T}_{AD} + P\mathbf{j} = 0$$

$$\overrightarrow{AB} = -45\mathbf{i} - 90\mathbf{j} + 30\mathbf{k} \qquad AB = 105 \text{ ft}$$

$$\overrightarrow{AC} = 30\mathbf{i} - 90\mathbf{j} + 65\mathbf{k} \qquad AC = 115 \text{ ft}$$

$$\overrightarrow{AD} = 20\mathbf{i} - 90\mathbf{j} - 60\mathbf{k} \qquad AD = 110 \text{ ft}$$

We write

$$\mathbf{T}_{AB} = T_{AB}\boldsymbol{\lambda}_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB}$$

$$= \left(-\frac{3}{7}\mathbf{i} - \frac{6}{7}\mathbf{j} + \frac{2}{7}\mathbf{k}\right)T_{AB}$$

$$\mathbf{T}_{AC} = T_{AC}\boldsymbol{\lambda}_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC}$$

$$= \left(\frac{6}{23}\mathbf{i} - \frac{18}{23}\mathbf{j} + \frac{13}{23}\mathbf{k}\right)T_{AC}$$

$$\mathbf{T}_{AD} = T_{AD}\boldsymbol{\lambda}_{AD} = T_{AD}\frac{\overrightarrow{AD}}{AD}$$

$$= \left(\frac{2}{11}\mathbf{i} - \frac{9}{11}\mathbf{j} - \frac{6}{11}\mathbf{k}\right)T_{AD}$$

Substituting into the Eq. $\Sigma\mathbf{F} = 0$ and factoring $\mathbf{i}$, $\mathbf{j}$, $\mathbf{k}$:

$$\left(-\frac{3}{7}T_{AB} + \frac{6}{23}T_{AC} + \frac{2}{11}T_{AD}\right)\mathbf{i}$$

$$+\left(-\frac{6}{7}T_{AB} - \frac{18}{23}T_{AC} - \frac{9}{11}T_{AD} + P\right)\mathbf{j}$$

$$+\left(\frac{2}{7}T_{AB} + \frac{13}{23}T_{AC} - \frac{6}{11}T_{AD}\right)\mathbf{k} = 0$$

PROBLEM 2.109 (Continued)

Setting the coefficients of **i**, **j**, **k**, equal to zero:

$$\mathbf{i}: \quad -\frac{3}{7}T_{AB} + \frac{6}{23}T_{AC} + \frac{2}{11}T_{AD} = 0 \tag{1}$$

$$\mathbf{j}: \quad -\frac{6}{7}T_{AB} - \frac{18}{23}T_{AC} - \frac{9}{11}T_{AD} + P = 0 \tag{2}$$

$$\mathbf{k}: \quad \frac{2}{7}T_{AB} + \frac{13}{23}T_{AC} - \frac{6}{11}T_{AD} = 0 \tag{3}$$

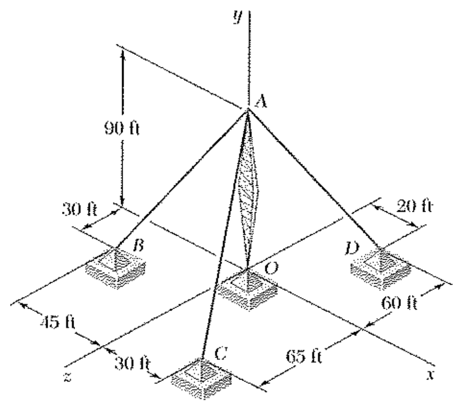
Set $T_{AB} = 630$ lb in Eqs. (1) – (3):

$$-270 \text{ lb} + \frac{6}{23}T_{AC} + \frac{2}{11}T_{AD} = 0 \tag{1$'$}$$

$$-540 \text{ lb} - \frac{18}{23}T_{AC} - \frac{9}{11}T_{AD} + P = 0 \tag{2$'$}$$

$$180 \text{ lb} + \frac{13}{23}T_{AC} - \frac{6}{11}T_{AD} = 0 \tag{3$'$}$$

Solving, $\quad T_{AC} = 467.42$ lb $\quad T_{AD} = 814.35$ lb $\quad P = 1572.10$ lb $\qquad P = 1572$ lb ◀



PROBLEM 2.110

A transmission tower is held by three guy wires attached to a pin at A and anchored by bolts at B, C, and D. If the tension in wire AC is 920 lb, determine the vertical force $\mathbf{P}$ exerted by the tower on the pin at A.

SOLUTION

See Problem 2.109 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-\frac{3}{7}T_{AB} + \frac{6}{23}T_{AC} + \frac{2}{11}T_{AD} = 0 \tag{1}$$

$$-\frac{6}{7}T_{AB} - \frac{18}{23}T_{AC} - \frac{9}{11}T_{AD} + P = 0 \tag{2}$$

$$\frac{2}{7}T_{AB} + \frac{13}{23}T_{AC} - \frac{6}{11}T_{AD} = 0 \tag{3}$$

Substituting for $T_{AC} = 920$ lb in Equations (1), (2), and (3) above and solving the resulting set of equations using conventional algorithms gives:

$$-\frac{3}{7}T_{AB} + 240 \text{ lb} + \frac{2}{11}T_{AD} = 0 \tag{1$'$}$$

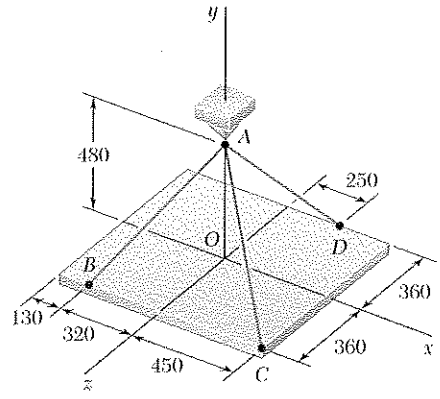
$$-\frac{6}{7}T_{AB} - 720 \text{ lb} - \frac{9}{11}T_{AD} + P = 0 \tag{2$'$}$$

$$\frac{2}{7}T_{AB} + 520 \text{ lb} - \frac{6}{11}T_{AD} = 0 \tag{3$'$}$$

Solving,

$$T_{AB} = 1240.00 \text{ lb}$$
$$T_{AD} = 1602.86 \text{ lb}$$
$$P = 3094.3 \text{ lb}$$

$P = 3090$ lb ◀



Dimensions in mm

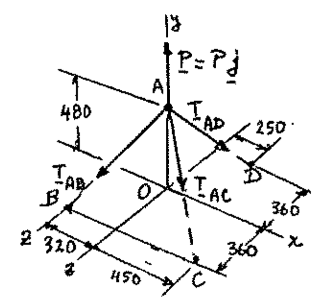
PROBLEM 2.111

A rectangular plate is supported by three cables as shown. Knowing that the tension in cable AC is 60 N, determine the weight of the plate.

SOLUTION

We note that the weight of the plate is equal in magnitude to the force **P** exerted by the support on Point A.

Free Body A:



Dimensions in mm

$$\Sigma F = 0: \quad \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{T}_{AD} + P\mathbf{j} = 0$$

We have:

$$\overrightarrow{AB} = -(320 \text{ mm})\mathbf{i} - (480 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k} \qquad AB = 680 \text{ mm}$$

$$\overrightarrow{AC} = (450 \text{ mm})\mathbf{i} - (480 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k} \qquad AC = 750 \text{ mm}$$

$$\overrightarrow{AD} = (250 \text{ mm})\mathbf{i} - (480 \text{ mm})\mathbf{j} - (360 \text{ mm})\mathbf{k} \qquad AD = 650 \text{ mm}$$

Thus:

$$\mathbf{T}_{AB} = T_{AB}\boldsymbol{\lambda}_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB} = \left(-\frac{8}{17}\mathbf{i} - \frac{12}{17}\mathbf{j} + \frac{9}{17}\mathbf{k}\right)T_{AB}$$

$$\mathbf{T}_{AC} = T_{AC}\boldsymbol{\lambda}_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC} = (0.6\mathbf{i} - 0.64\mathbf{j} + 0.48\mathbf{k})T_{AC}$$

$$\mathbf{T}_{AD} = T_{AD}\boldsymbol{\lambda}_{AD} = T_{AD}\frac{\overrightarrow{AD}}{AD} = \left(\frac{5}{13}\mathbf{i} - \frac{9.6}{13}\mathbf{j} - \frac{7.2}{13}\mathbf{k}\right)T_{AD}$$

Substituting into the Eq. $\Sigma F = 0$ and factoring $\mathbf{i}, \mathbf{j}, \mathbf{k}$:

$$\left(-\frac{8}{17}T_{AB} + 0.6T_{AC} + \frac{5}{13}T_{AD}\right)\mathbf{i}$$

$$+\left(-\frac{12}{17}T_{AB} - 0.64T_{AC} - \frac{9.6}{13}T_{AD} + P\right)\mathbf{j}$$

$$+\left(\frac{9}{17}T_{AB} + 0.48T_{AC} - \frac{7.2}{13}T_{AD}\right)\mathbf{k} = 0$$

PROBLEM 2.111 (Continued)

Setting the coefficient of **i**, **j**, **k** equal to zero:

$$\mathbf{i}: \quad -\frac{8}{17}T_{AB} + 0.6T_{AC} + \frac{5}{13}T_{AD} = 0 \qquad (1)$$

$$\mathbf{j}: \quad -\frac{12}{7}T_{AB} - 0.64T_{AC} - \frac{9.6}{13}T_{AD} + P = 0 \qquad (2)$$

$$\mathbf{k}: \quad \frac{9}{17}T_{AB} + 0.48T_{AC} - \frac{7.2}{13}T_{AD} = 0 \qquad (3)$$

Making $T_{AC} = 60\text{ N}$ in (1) and (3):

$$-\frac{8}{17}T_{AB} + 36\text{ N} + \frac{5}{13}T_{AD} = 0 \qquad (1')$$

$$\frac{9}{17}T_{AB} + 28.8\text{ N} - \frac{7.2}{13}T_{AD} = 0 \qquad (3')$$

Multiply (1′) by 9, (3′) by 8, and add:

$$554.4\text{ N} - \frac{12.6}{13}T_{AD} = 0 \quad T_{AD} = 572.0\text{ N}$$

Substitute into (1′) and solve for T_{AB}:

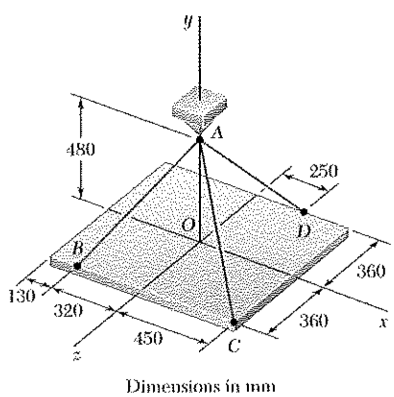
$$T_{AB} = \frac{17}{8}\left(36 + \frac{5}{13} \times 572\right) \qquad T_{AB} = 544.0\text{ N}$$

Substitute for the tensions in Eq. (2) and solve for P:

$$P = \frac{12}{17}(544\text{ N}) + 0.64(60\text{ N}) + \frac{9.6}{13}(572\text{ N})$$

$$= 844.8\text{ N}$$

Weight of plate $= P = 845\text{ N}$ ◀



PROBLEM 2.112

A rectangular plate is supported by three cables as shown. Knowing that the tension in cable AD is 520 N, determine the weight of the plate.

SOLUTION

See Problem 2.111 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-\frac{8}{17}T_{AB} + 0.6T_{AC} + \frac{5}{13}T_{AD} = 0 \tag{1}$$

$$-\frac{12}{17}T_{AB} + 0.64T_{AC} - \frac{9.6}{13}T_{AD} + P = 0 \tag{2}$$

$$\frac{9}{17}T_{AB} + 0.48T_{AC} - \frac{7.2}{13}T_{AD} = 0 \tag{3}$$

Making $T_{AD} = 520\text{ N}$ in Eqs. (1) and (3):

$$-\frac{8}{17}T_{AB} + 0.6T_{AC} + 200\text{ N} = 0 \tag{1'}$$

$$\frac{9}{17}T_{AB} + 0.48T_{AC} - 288\text{ N} = 0 \tag{3'}$$

Multiply (1′) by 9, (3′) by 8, and add:

$$9.24T_{AC} - 504\text{ N} = 0 \quad T_{AC} = 54.5455\text{ N}$$

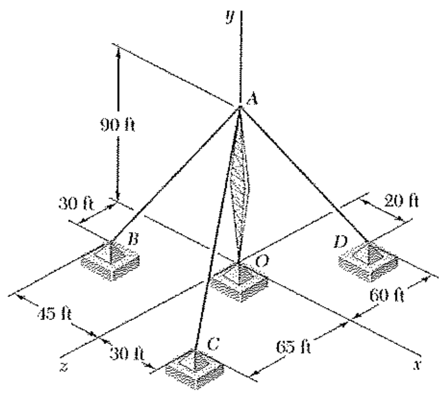
Substitute into (1′) and solve for T_{AB}:

$$T_{AB} = \frac{17}{8}(0.6 \times 54.5455 + 200) \quad T_{AB} = 494.545\text{ N}$$

Substitute for the tensions in Eq. (2) and solve for P:

$$P = \frac{12}{17}(494.545\text{ N}) + 0.64(54.5455\text{ N}) + \frac{9.6}{13}(520\text{ N})$$
$$= 768.00\text{ N}$$

Weight of plate $= P = 768\text{ N}$ ◄



PROBLEM 2.113

For the transmission tower of Problems 2.109 and 2.110, determine the tension in each guy wire knowing that the tower exerts on the pin at A an upward vertical force of 2100 lb.

SOLUTION

See Problem 2.109 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-\frac{3}{7}T_{AB}+\frac{6}{23}T_{AC}+\frac{2}{11}T_{AD}=0 \tag{1}$$

$$-\frac{6}{7}T_{AB}-\frac{18}{23}T_{AC}-\frac{9}{11}T_{AD}+P=0 \tag{2}$$

$$\frac{2}{7}T_{AB}+\frac{13}{23}T_{AC}-\frac{6}{11}T_{AD}=0 \tag{3}$$

Substituting for $P=2100$ lb in Equations (1), (2), and (3) above and solving the resulting set of equations using conventional algorithms gives:

$$-\frac{3}{7}T_{AB}+\frac{6}{23}T_{AC}+\frac{2}{11}T_{AD}=0 \tag{1$'$}$$

$$-\frac{6}{7}T_{AB}-\frac{18}{23}T_{AC}-\frac{9}{11}T_{AD}+2100\text{ lb}=0 \tag{2$'$}$$

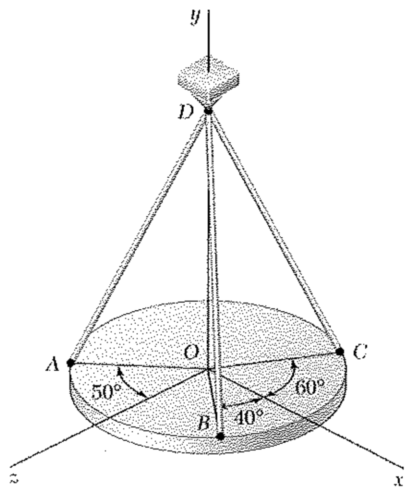
$$\frac{2}{7}T_{AB}+\frac{13}{23}T_{AC}-\frac{6}{11}T_{AD}=0 \tag{3$'$}$$

$$T_{AB}=841.55\text{ lb}$$
$$T_{AC}=624.38\text{ lb}$$
$$T_{AD}=1087.81\text{ lb}$$

$T_{AB}=842$ lb ◀

$T_{AC}=624$ lb ◀

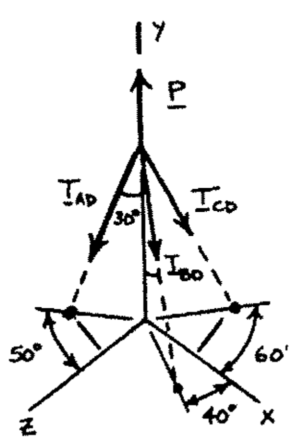
$T_{AD}=1088$ lb ◀



PROBLEM 2.114

A horizontal circular plate weighing 60 lb is suspended as shown from three wires that are attached to a support at D and form 30° angles with the vertical. Determine the tension in each wire.

SOLUTION



$\Sigma F_x = 0$:

$$-T_{AD}(\sin 30°)(\sin 50°) + T_{BD}(\sin 30°)(\cos 40°) + T_{CD}(\sin 30°)(\cos 60°) = 0$$

Dividing through by $\sin 30°$ and evaluating:

$$-0.76604T_{AD} + 0.76604T_{BD} + 0.5T_{CD} = 0 \quad (1)$$

$\Sigma F_y = 0$: $\quad -T_{AD}(\cos 30°) - T_{BD}(\cos 30°) - T_{CD}(\cos 30°) + 60 \text{ lb} = 0$

or $$T_{AD} + T_{BD} + T_{CD} = 69.282 \text{ lb} \quad (2)$$

$\Sigma F_z = 0$: $\quad T_{AD}\sin 30° \cos 50° + T_{BD}\sin 30° \sin 40° - T_{CD}\sin 30° \sin 60° = 0$

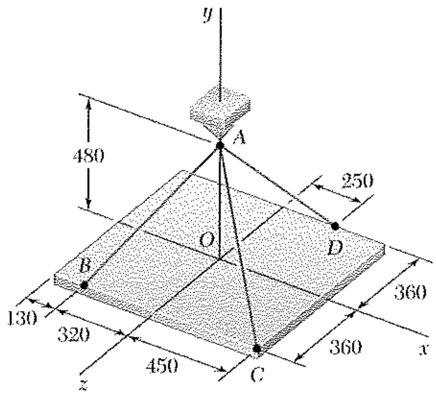
or $$0.64279T_{AD} + 0.64279T_{BD} - 0.86603T_{CD} = 0 \quad (3)$$

Solving Equations (1), (2), and (3) simultaneously:

$T_{AD} = 29.5 \text{ lb}$ ◀

$T_{BD} = 10.25 \text{ lb}$ ◀

$T_{CD} = 29.5 \text{ lb}$ ◀



PROBLEM 2.115

For the rectangular plate of Problems 2.111 and 2.112, determine the tension in each of the three cables knowing that the weight of the plate is 792 N.

SOLUTION

See Problem 2.111 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below. Setting $P = 792$ N gives:

$$-\frac{8}{17}T_{AB} + 0.6T_{AC} + \frac{5}{13}T_{AD} = 0 \tag{1}$$

$$-\frac{12}{17}T_{AB} - 0.64T_{AC} - \frac{9.6}{13}T_{AD} + 792 \text{ N} = 0 \tag{2}$$

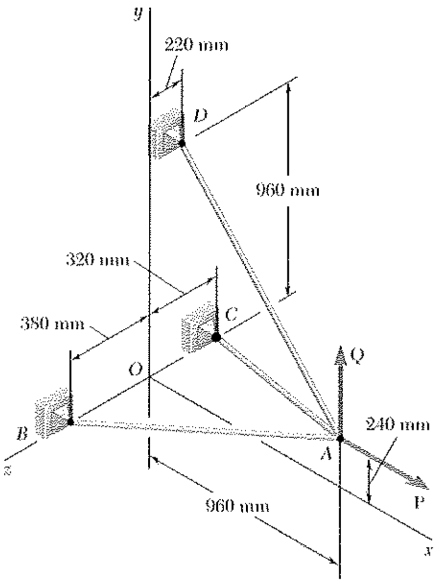
$$\frac{9}{17}T_{AB} + 0.48T_{AC} - \frac{7.2}{13}T_{AD} = 0 \tag{3}$$

Solving Equations (1), (2), and (3) by conventional algorithms gives

$T_{AB} = 510.00$ N $\qquad T_{AB} = 510$ N ◀

$T_{AC} = 56.250$ N $\qquad T_{AC} = 56.2$ N ◀

$T_{AD} = 536.25$ N $\qquad T_{AD} = 536$ N ◀



PROBLEM 2.116

For the cable system of Problems 2.107 and 2.108, determine the tension in each cable knowing that $P = 2880$ N and $Q = 0$.

SOLUTION

$$\Sigma \mathbf{F}_A = 0: \quad \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{T}_{AD} + \mathbf{P} + \mathbf{Q} = 0$$

Where $\qquad \mathbf{P} = P\mathbf{i}$ and $\mathbf{Q} = Q\mathbf{j}$

$$\overrightarrow{AB} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} + (380 \text{ mm})\mathbf{k} \quad AB = 1060 \text{ mm}$$

$$\overrightarrow{AC} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} - (320 \text{ mm})\mathbf{k} \quad AC = 1040 \text{ mm}$$

$$\overrightarrow{AD} = -(960 \text{ mm})\mathbf{i} + (720 \text{ mm})\mathbf{j} - (220 \text{ mm})\mathbf{k} \quad AD = 1220 \text{ mm}$$

$$\mathbf{T}_{AB} = T_{AB}\boldsymbol{\lambda}_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB} = T_{AB}\left(-\frac{48}{53}\mathbf{i} - \frac{12}{53}\mathbf{j} + \frac{19}{53}\mathbf{k}\right)$$

$$\mathbf{T}_{AC} = T_{AC}\boldsymbol{\lambda}_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC} = T_{AC}\left(-\frac{12}{13}\mathbf{i} - \frac{3}{13}\mathbf{j} - \frac{4}{13}\mathbf{k}\right)$$

$$\mathbf{T}_{AD} = T_{AD}\boldsymbol{\lambda}_{AD} = T_{AD}\frac{\overrightarrow{AD}}{AD} = T_{AD}\left(-\frac{48}{61}\mathbf{i} + \frac{36}{61}\mathbf{j} - \frac{11}{61}\mathbf{k}\right)$$

Substituting into $\Sigma \mathbf{F}_A = 0$, setting $P = (2880 \text{ N})\mathbf{i}$ and $Q = 0$, and setting the coefficients of $\mathbf{i}$, $\mathbf{j}$, $\mathbf{k}$ equal to 0, we obtain the following three equilibrium equations:

$$\mathbf{i}: \quad -\frac{48}{53}T_{AB} - \frac{12}{13}T_{AC} - \frac{48}{61}T_{AD} + 2880 \text{ N} = 0 \qquad (1)$$

$$\mathbf{j}: \quad -\frac{12}{53}T_{AB} - \frac{3}{13}T_{AC} + \frac{36}{61}T_{AD} = 0 \qquad (2)$$

$$\mathbf{k}: \quad \frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} - \frac{11}{61}T_{AD} = 0 \qquad (3)$$

PROBLEM 2.116 (Continued)

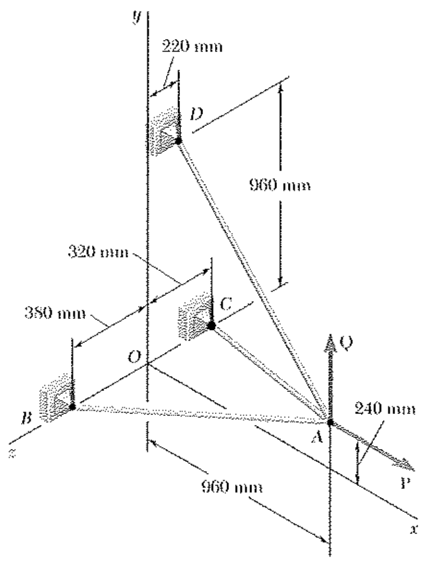
Solving the system of linear equations using conventional algorithms gives:

$$T_{AB} = 1340.14 \text{ N}$$
$$T_{AC} = 1025.12 \text{ N}$$
$$T_{AD} = 915.03 \text{ N}$$

$T_{AB} = 1340 \text{ N}$ ◀

$T_{AC} = 1025 \text{ N}$ ◀

$T_{AD} = 915 \text{ N}$ ◀



PROBLEM 2.117

For the cable system of Problems 2.107 and 2.108, determine the tension in each cable knowing that $P = 2880$ N and $Q = 576$ N.

SOLUTION

See Problem 2.116 for the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-\frac{48}{53}T_{AB} - \frac{12}{13}T_{AC} - \frac{48}{61}T_{AD} + P = 0 \tag{1}$$

$$-\frac{12}{53}T_{AB} - \frac{3}{13}T_{AC} + \frac{36}{61}T_{AD} + Q = 0 \tag{2}$$

$$\frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} - \frac{11}{61}T_{AD} = 0 \tag{3}$$

Setting $P = 2880$ N and $Q = 576$ N gives:

$$-\frac{48}{53}T_{AB} - \frac{12}{13}T_{AC} - \frac{48}{61}T_{AD} + 2880\text{ N} = 0 \tag{1'}$$

$$-\frac{12}{53}T_{AB} - \frac{3}{13}T_{AC} + \frac{36}{61}T_{AD} + 576\text{ N} = 0 \tag{2'}$$

$$\frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} - \frac{11}{61}T_{AD} = 0 \tag{3'}$$

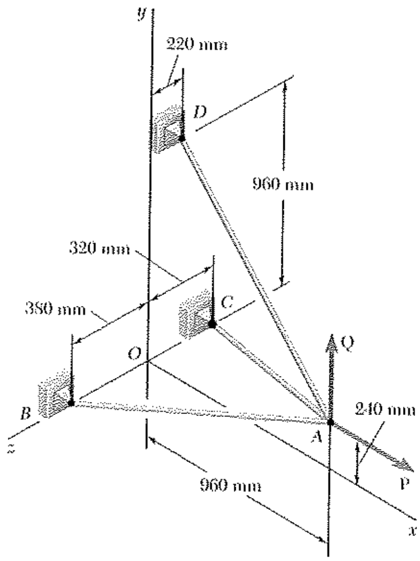
Solving the resulting set of equations using conventional algorithms gives:

$$T_{AB} = 1431.00\text{ N}$$
$$T_{AC} = 1560.00\text{ N}$$
$$T_{AD} = 183.010\text{ N}$$

$T_{AB} = 1431$ N ◀

$T_{AC} = 1560$ N ◀

$T_{AD} = 183.0$ N ◀



PROBLEM 2.118

For the cable system of Problems 2.107 and 2.108, determine the tension in each cable knowing that $P = 2880$ N and $Q = -576$ N. (**Q** is directed downward).

SOLUTION

See Problem 2.116 for the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-\frac{48}{53}T_{AB} - \frac{12}{13}T_{AC} - \frac{48}{61}T_{AD} + P = 0 \tag{1}$$

$$-\frac{12}{53}T_{AB} - \frac{3}{13}T_{AC} + \frac{36}{61}T_{AD} + Q = 0 \tag{2}$$

$$\frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} - \frac{11}{61}T_{AD} = 0 \tag{3}$$

Setting $P = 2880$ N and $Q = -576$ N gives:

$$-\frac{48}{53}T_{AB} - \frac{12}{13}T_{AC} - \frac{48}{61}T_{AD} + 2880 \text{ N} = 0 \tag{1'}$$

$$-\frac{12}{53}T_{AB} - \frac{3}{13}T_{AC} + \frac{36}{61}T_{AD} - 576 \text{ N} = 0 \tag{2'}$$

$$\frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} - \frac{11}{61}T_{AD} = 0 \tag{3'}$$

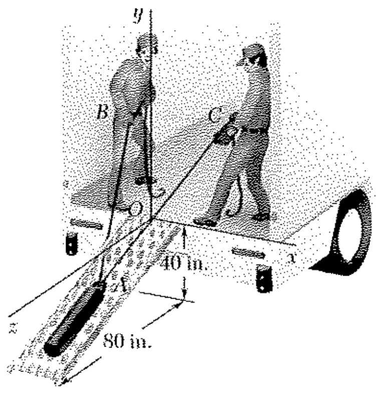
Solving the resulting set of equations using conventional algorithms gives:

$$T_{AB} = 1249.29 \text{ N}$$
$$T_{AC} = 490.31 \text{ N}$$
$$T_{AD} = 1646.97 \text{ N}$$

$T_{AB} = 1249$ N ◀

$T_{AC} = 490$ N ◀

$T_{AD} = 1647$ N ◀



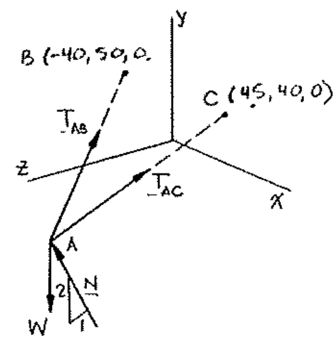
PROBLEM 2.119

Using two ropes and a roller chute, two workers are unloading a 200-lb cast-iron counterweight from a truck. Knowing that at the instant shown the counterweight is kept from moving and that the positions of Points A, B, and C are, respectively, $A(0, -20 \text{ in.}, 40 \text{ in.})$, $B(-40 \text{ in.}, 50 \text{ in.}, 0)$, and $C(45 \text{ in.}, 40 \text{ in.}, 0)$, and assuming that no friction exists between the counterweight and the chute, determine the tension in each rope. (*Hint*: Since there is no friction, the force exerted by the chute on the counterweight must be perpendicular to the chute.)

SOLUTION

From the geometry of the chute:

$$\mathbf{N} = \frac{N}{\sqrt{5}}(2\mathbf{j} + \mathbf{k})$$
$$= N(0.8944\mathbf{j} + 0.4472\mathbf{k})$$



The force in each rope can be written as the product of the magnitude of the force and the unit vector along the cable. Thus, with

$$\overrightarrow{AB} = (40 \text{ in.})\mathbf{i} + (70 \text{ in.})\mathbf{j} - (40 \text{ in.})\mathbf{k}$$
$$AB = \sqrt{(40 \text{ in.})^2 + (70 \text{ in.})^2 + (40 \text{ in.})^2}$$
$$= 90 \text{ in.}$$

$$\mathbf{T}_{AB} = T\boldsymbol{\lambda}_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB}$$
$$= \frac{T_{AB}}{90 \text{ in.}}[(-40 \text{ in.})\mathbf{i} + (70 \text{ in.})\mathbf{j} - (40 \text{ in.})\mathbf{k}]$$
$$\mathbf{T}_{AB} = T_{AB}\left(-\frac{4}{9}\mathbf{i} + \frac{7}{9}\mathbf{j} - \frac{4}{9}\mathbf{k}\right)$$

and

$$\overrightarrow{AC} = (45 \text{ in.})\mathbf{i} + (60 \text{ in.})\mathbf{j} - (40 \text{ in.})\mathbf{k}$$
$$AC = \sqrt{(45 \text{ in.})^2 + (60 \text{ in.})^2 + (40 \text{ in.})^2} = 85 \text{ in.}$$

$$\mathbf{T}_{AC} = T\boldsymbol{\lambda}_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC}$$
$$= \frac{T_{AC}}{85 \text{ in.}}[(45 \text{ in.})\mathbf{i} + (60 \text{ in.})\mathbf{j} - (40 \text{ in.})\mathbf{k}]$$
$$\mathbf{T}_{AC} = T_{AC}\left(\frac{9}{17}\mathbf{i} + \frac{12}{17}\mathbf{j} - \frac{8}{17}\mathbf{k}\right)$$

Then:

$$\Sigma\mathbf{F} = 0: \quad \mathbf{N} + \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{W} = 0$$

PROBLEM 2.119 (Continued)

With $W = 200$ lb, and equating the factors of **i**, **j**, and **k** to zero, we obtain the linear algebraic equations:

$$\mathbf{i}: \quad -\frac{4}{9}T_{AB} + \frac{9}{17}T_{AC} = 0 \tag{1}$$

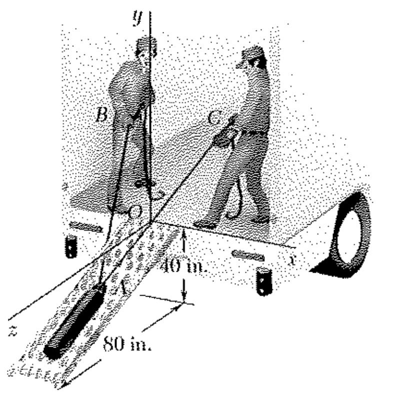
$$\mathbf{j}: \quad \frac{7}{9}T_{AB} + \frac{12}{17}T_{AC} + \frac{2}{\sqrt{5}} - 200 \text{ lb} = 0 \tag{2}$$

$$\mathbf{k}: \quad -\frac{4}{9}T_{AB} - \frac{8}{17}T_{AC} + \frac{1}{\sqrt{5}}N = 0 \tag{3}$$

Using conventional methods for solving linear algebraic equations we obtain:

$T_{AB} = 65.6$ lb ◀

$T_{AC} = 55.1$ lb ◀



PROBLEM 2.120

Solve Problem 2.119 assuming that a third worker is exerting a force $\mathbf{P} = -(40 \text{ lb})\mathbf{i}$ on the counterweight.

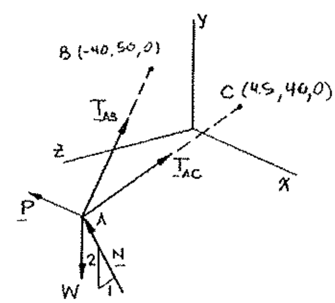
PROBLEM 2.119 Using two ropes and a roller chute, two workers are unloading a 200-lb cast-iron counterweight from a truck. Knowing that at the instant shown the counterweight is kept from moving and that the positions of Points A, B, and C are, respectively, $A(0, -20 \text{ in.}, 40 \text{ in.})$, $B(-40 \text{ in.}, 50 \text{ in.}, 0)$, and $C(45 \text{ in.}, 40 \text{ in.}, 0)$, and assuming that no friction exists between the counterweight and the chute, determine the tension in each rope. (*Hint:* Since there is no friction, the force exerted by the chute on the counterweight must be perpendicular to the chute.)

SOLUTION

See Problem 2.119 for the analysis leading to the vectors describing the tension in each rope.

$$\mathbf{T}_{AB} = T_{AB}\left(-\frac{4}{9}\mathbf{i} + \frac{7}{9}\mathbf{j} - \frac{4}{9}\mathbf{k}\right)$$

$$\mathbf{T}_{AC} = T_{AC}\left(\frac{9}{17}\mathbf{i} + \frac{12}{17}\mathbf{j} - \frac{8}{17}\mathbf{k}\right)$$



Then: $\Sigma \mathbf{F}_A = 0: \quad \mathbf{N} + \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{P} + \mathbf{W} = 0$

Where $\mathbf{P} = -(40 \text{ lb})\mathbf{i}$

and $\mathbf{W} = (200 \text{ lb})\mathbf{j}$

Equating the factors of $\mathbf{i}$, $\mathbf{j}$, and $\mathbf{k}$ to zero, we obtain the linear equations:

$$\mathbf{i}: \quad -\frac{4}{9}T_{AB} + \frac{9}{17}T_{AC} - 40 \text{ lb} = 0$$

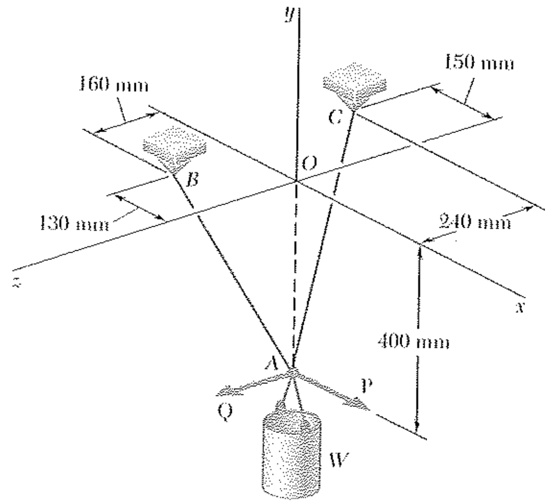
$$\mathbf{j}: \quad \frac{2}{\sqrt{5}}N + \frac{7}{9}T_{AB} + \frac{12}{17}T_{AC} - 200 \text{ lb} = 0$$

$$\mathbf{k}: \quad \frac{1}{\sqrt{5}}N - \frac{4}{9}T_{AB} - \frac{8}{17}T_{AC} = 0$$

Using conventional methods for solving linear algebraic equations we obtain

$T_{AB} = 24.8 \text{ lb}$ ◀

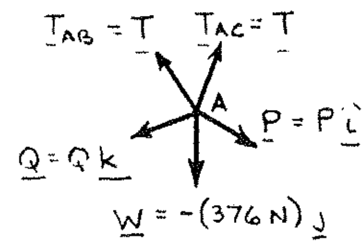
$T_{AC} = 96.4 \text{ lb}$ ◀



PROBLEM 2.121

A container of weight W is suspended from ring A. Cable BAC passes through the ring and is attached to fixed supports at B and C. Two forces $\mathbf{P} = P\mathbf{i}$ and $\mathbf{Q} = Q\mathbf{k}$ are applied to the ring to maintain the container in the position shown. Knowing that $W = 376$ N, determine P and Q. (*Hint:* The tension is the same in both portions of cable BAC.)

SOLUTION



Free Body A:

$$\mathbf{T}_{AB} = T\boldsymbol{\lambda}_{AB}$$

$$= T\frac{\overrightarrow{AB}}{AB}$$

$$= T\frac{(-130\text{ mm})\mathbf{i} + (400\text{ mm})\mathbf{j} + (160\text{ mm})\mathbf{k}}{450\text{ mm}}$$

$$= T\left(-\frac{13}{45}\mathbf{i} + \frac{40}{45}\mathbf{j} + \frac{16}{45}\mathbf{k}\right)$$

$$\mathbf{T}_{AC} = T\boldsymbol{\lambda}_{AC}$$

$$= T\frac{\overrightarrow{AC}}{AC}$$

$$= T\frac{(-150\text{ mm})\mathbf{i} + (400\text{ mm})\mathbf{j} + (-240\text{ mm})\mathbf{k}}{490\text{ mm}}$$

$$= T\left(-\frac{15}{49}\mathbf{i} + \frac{40}{49}\mathbf{j} - \frac{24}{49}\mathbf{k}\right)$$

$$\Sigma F = 0: \quad \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{Q} + \mathbf{P} + \mathbf{W} = 0$$

Setting coefficients of **i**, **j**, **k** equal to zero:

$$\mathbf{i}: \quad -\frac{13}{45}T - \frac{15}{49}T + P = 0 \qquad 0.59501T = P \qquad (1)$$

$$\mathbf{j}: \quad +\frac{40}{45}T + \frac{40}{49}T - W = 0 \qquad 1.70521T = W \qquad (2)$$

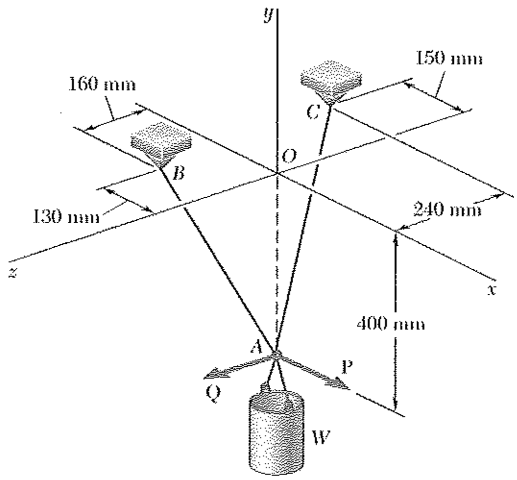
$$\mathbf{k}: \quad +\frac{16}{45}T - \frac{24}{49}T + Q = 0 \qquad 0.134240T = Q \qquad (3)$$

PROBLEM 2.121 (Continued)

Data: $W = 376 \text{ N} \quad 1.70521T = 376 \text{ N} \quad T = 220.50 \text{ N}$

$0.59501(220.50 \text{ N}) = P$ $\qquad P = 131.2 \text{ N}$ ◀

$0.134240(220.50 \text{ N}) = Q$ $\qquad Q = 29.6 \text{ N}$ ◀



PROBLEM 2.122

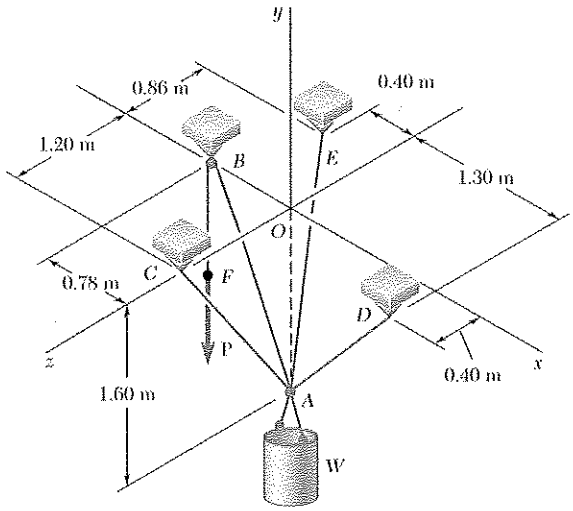
For the system of Problem 2.121, determine W and Q knowing that $P = 164$ N.

PROBLEM 2.121 A container of weight W is suspended from ring A. Cable BAC passes through the ring and is attached to fixed supports at B and C. Two forces $\mathbf{P} = P\mathbf{i}$ and $\mathbf{Q} = Q\mathbf{k}$ are applied to the ring to maintain the container in the position shown. Knowing that $W = 376$ N, determine P and Q. (*Hint:* The tension is the same in both portions of cable BAC.)

SOLUTION

Refer to Problem 2.121 for the figure and analysis resulting in Equations (1), (2), and (3) for P, W, and Q in terms of T below. Setting $P = 164$ N we have:

Eq. (1):	$0.59501T = 164$ N	$T = 275.63$ N
Eq. (2):	$1.70521(275.63 \text{ N}) = W$	$W = 470$ N ◀
Eq. (3):	$0.134240(275.63 \text{ N}) = Q$	$Q = 37.0$ N ◀



PROBLEM 2.123

A container of weight W is suspended from ring A, to which cables AC and AE are attached. A force $\mathbf{P}$ is applied to the end F of a third cable that passes over a pulley at B and through ring A and that is attached to a support at D. Knowing that $W = 1000$ N, determine the magnitude of P. (*Hint:* The tension is the same in all portions of cable $FBAD$.)

SOLUTION

The (vector) force in each cable can be written as the product of the (scalar) force and the unit vector along the cable. That is, with

$$\overrightarrow{AB} = -(0.78 \text{ m})\mathbf{i} + (1.6 \text{ m})\mathbf{j} + (0 \text{ m})\mathbf{k}$$

$$AB = \sqrt{(-0.78 \text{ m})^2 + (1.6 \text{ m})^2 + (0)^2}$$

$$= 1.78 \text{ m}$$

$$\mathbf{T}_{AB} = T\boldsymbol{\lambda}_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB}$$

$$= \frac{T_{AB}}{1.78 \text{ m}}[-(0.78 \text{ m})\mathbf{i} + (1.6 \text{ m})\mathbf{j} + (0 \text{ m})\mathbf{k}]$$

$$\mathbf{T}_{AB} = T_{AB}(-0.4382\mathbf{i} + 0.8989\mathbf{j} + 0\mathbf{k})$$

and

$$\overrightarrow{AC} = (0)\mathbf{i} + (1.6 \text{ m})\mathbf{j} + (1.2 \text{ m})\mathbf{k}$$

$$AC = \sqrt{(0 \text{ m})^2 + (1.6 \text{ m})^2 + (1.2 \text{ m})^2} = 2 \text{ m}$$

$$\mathbf{T}_{AC} = T\boldsymbol{\lambda}_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC} = \frac{T_{AC}}{2 \text{ m}}[(0)\mathbf{i} + (1.6 \text{ m})\mathbf{j} + (1.2 \text{ m})\mathbf{k}]$$

$$\mathbf{T}_{AC} = T_{AC}(0.8\mathbf{j} + 0.6\mathbf{k})$$

and

$$\overrightarrow{AD} = (1.3 \text{ m})\mathbf{i} + (1.6 \text{ m})\mathbf{j} + (0.4 \text{ m})\mathbf{k}$$

$$AD = \sqrt{(1.3 \text{ m})^2 + (1.6 \text{ m})^2 + (0.4 \text{ m})^2} = 2.1 \text{ m}$$

$$\mathbf{T}_{AD} = T\boldsymbol{\lambda}_{AD} = T_{AD}\frac{\overrightarrow{AD}}{AD} = \frac{T_{AD}}{2.1 \text{ m}}[(1.3 \text{ m})\mathbf{i} + (1.6 \text{ m})\mathbf{j} + (0.4 \text{ m})\mathbf{k}]$$

$$\mathbf{T}_{AD} = T_{AD}(0.6190\mathbf{i} + 0.7619\mathbf{j} + 0.1905\mathbf{k})$$

PROBLEM 2.123 (Continued)

Finally,

$$\overrightarrow{AE} = -(0.4 \text{ m})\mathbf{i} + (1.6 \text{ m})\mathbf{j} - (0.86 \text{ m})\mathbf{k}$$

$$AE = \sqrt{(-0.4 \text{ m})^2 + (1.6 \text{ m})^2 + (-0.86 \text{ m})^2} = 1.86 \text{ m}$$

$$\mathbf{T}_{AE} = T\boldsymbol{\lambda}_{AE} = T_{AE}\frac{\overrightarrow{AE}}{AE}$$

$$= \frac{T_{AE}}{1.86 \text{ m}}[-(0.4 \text{ m})\mathbf{i} + (1.6 \text{ m})\mathbf{j} - (0.86 \text{ m})\mathbf{k}]$$

$$\mathbf{T}_{AE} = T_{AE}(-0.2151\mathbf{i} + 0.8602\mathbf{j} - 0.4624\mathbf{k})$$

With the weight of the container $\mathbf{W} = -W\mathbf{j}$, at A we have:

$$\Sigma\mathbf{F} = 0: \quad \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{T}_{AD} - W\mathbf{j} = 0$$

Equating the factors of **i**, **j**, and **k** to zero, we obtain the following linear algebraic equations:

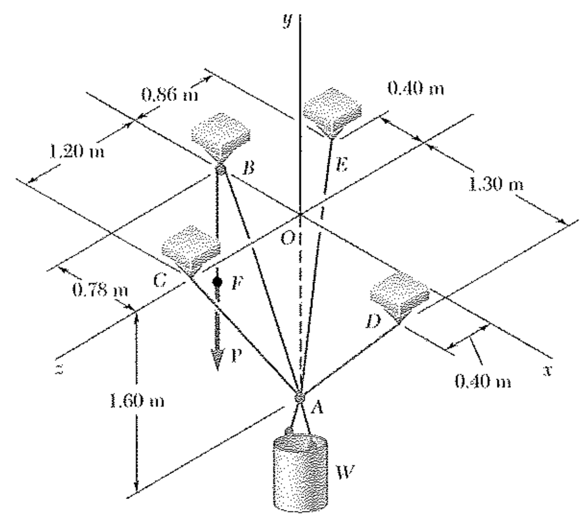
$$-0.4382T_{AB} + 0.6190T_{AD} - 0.2151T_{AE} = 0 \qquad (1)$$

$$0.8989T_{AB} + 0.8T_{AC} + 0.7619T_{AD} + 0.8602T_{AE} - W = 0 \qquad (2)$$

$$0.6T_{AC} + 0.1905T_{AD} - 0.4624T_{AE} = 0 \qquad (3)$$

Knowing that $W = 1000$ N and that because of the pulley system at B $T_{AB} = T_{AD} = P$, where P is the externally applied (unknown) force, we can solve the system of linear Equations (1), (2) and (3) uniquely for P.

$P = 378$ N ◀



PROBLEM 2.124

Knowing that the tension in cable AC of the system described in Problem 2.123 is 150 N, determine (*a*) the magnitude of the force **P**, (*b*) the weight W of the container.

PROBLEM 2.123 A container of weight W is suspended from ring A, to which cables AC and AE are attached. A force **P** is applied to the end F of a third cable that passes over a pulley at B and through ring A and that is attached to a support at D. Knowing that $W = 1000$ N, determine the magnitude of P. (*Hint:* The tension is the same in all portions of cable $FBAD$.)

SOLUTION

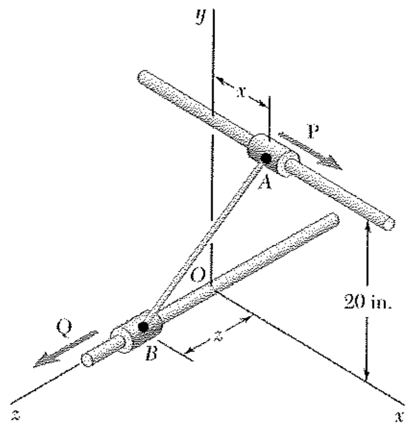
Here, as in Problem 2.123, the support of the container consists of the four cables AE, AC, AD, and AB, with the condition that the force in cables AB and AD is equal to the externally applied force P. Thus, with the condition

$$T_{AB} = T_{AD} = P$$

and using the linear algebraic equations of Problem 2.131 with $T_{AC} = 150$ N, we obtain

(*a*) $P = 454$ N ◀

(*b*) $W = 1202$ N ◀



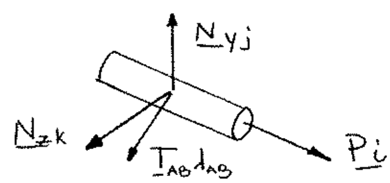
PROBLEM 2.125

Collars A and B are connected by a 25-in.-long wire and can slide freely on frictionless rods. If a 60-lb force **Q** is applied to collar B as shown, determine (*a*) the tension in the wire when $x = 9$ in., (*b*) the corresponding magnitude of the force **P** required to maintain the equilibrium of the system.

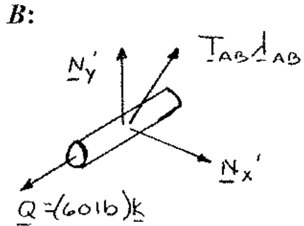
SOLUTION

Free Body Diagrams of Collars:

A:



B:



$$\boldsymbol{\lambda}_{AB} = \frac{\overrightarrow{AB}}{AB} = \frac{-x\mathbf{i} - (20 \text{ in.})\mathbf{j} + z\mathbf{k}}{25 \text{ in.}}$$

Collar A: $\quad \Sigma\mathbf{F} = 0: \quad P\mathbf{i} + N_y\mathbf{j} + N_z\mathbf{k} + T_{AB}\lambda_{AB} = 0$

Substitute for $\boldsymbol{\lambda}_{AB}$ and set coefficient of **i** equal to zero:

$$P - \frac{T_{AB}x}{25 \text{ in.}} = 0 \qquad (1)$$

Collar B: $\quad \Sigma\mathbf{F} = 0: \quad (60 \text{ lb})\mathbf{k} + N_x'\mathbf{i} + N_y'\mathbf{j} - T_{AB}\lambda_{AB} = 0$

Substitute for $\boldsymbol{\lambda}_{AB}$ and set coefficient of **k** equal to zero:

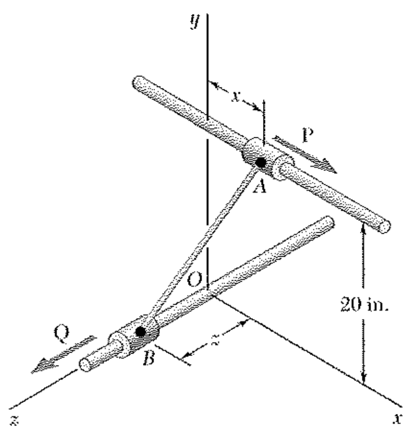
$$60 \text{ lb} - \frac{T_{AB}z}{25 \text{ in.}} = 0 \qquad (2)$$

(*a*) $\quad x = 9$ in. $\quad (9 \text{ in.})^2 + (20 \text{ in.})^2 + z^2 = (25 \text{ in.})^2$

$$z = 12 \text{ in.}$$

From Eq. (2): $\quad \dfrac{60 \text{ lb} - T_{AB}(12 \text{ in.})}{25 \text{ in.}} \qquad T_{AB} = 125.0 \text{ lb}$ ◀

(*b*) From Eq. (1): $\quad P = \dfrac{(125.0 \text{ lb})(9 \text{ in.})}{25 \text{ in.}} \qquad P = 45.0 \text{ lb}$ ◀



PROBLEM 2.126

Collars A and B are connected by a 25-in.-long wire and can slide freely on frictionless rods. Determine the distances x and z for which the equilibrium of the system is maintained when $P = 120$ lb and $Q = 60$ lb.

SOLUTION

See Problem 2.125 for the diagrams and analysis leading to Equations (1) and (2) below:

$$P = \frac{T_{AB}x}{25\text{ in.}} = 0 \tag{1}$$

$$60\text{ lb} - \frac{T_{AB}z}{25\text{ in.}} = 0 \tag{2}$$

For $P = 120$ lb, Eq. (1) yields $\quad T_{AB}x = (25\text{ in.})(20\text{ lb}) \quad (1')$

From Eq. (2) $\quad T_{AB}z = (25\text{ in.})(60\text{ lb}) \quad (2')$

Dividing Eq. (1′) by (2′): $\quad \dfrac{x}{z} = 2 \quad (3)$

Now write $\quad x^2 + z^2 + (20\text{ in.})^2 = (25\text{ in.})^2 \quad (4)$

Solving (3) and (4) simultaneously

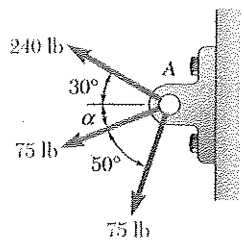
$$4z^2 + z^2 + 400 = 625$$
$$z^2 = 45$$
$$z = 6.708\text{ in.}$$

From Eq. (3)

$$x = 2z = 2(6.708\text{ in.})$$
$$= 13.416\text{ in.}$$

$x = 13.42$ in., $\quad z = 6.71$ in. ◀

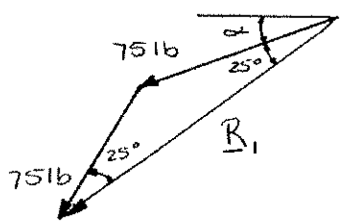
PROBLEM 2.127



The direction of the 75-lb forces may vary, but the angle between the forces is always 50°. Determine the value of α for which the resultant of the forces acting at A is directed horizontally to the left.

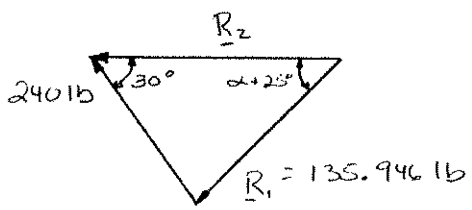
SOLUTION

We must first replace the two 75-lb forces by their resultant $\mathbf{R}_1$ using the triangle rule.



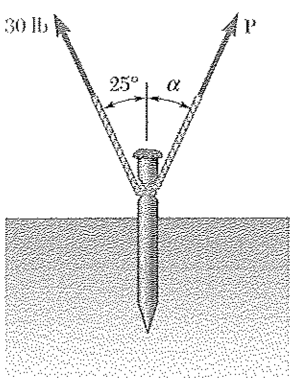
$$\mathbf{R}_1 = 2(75 \text{ lb})\cos 25^\circ$$
$$= 135.946 \text{ lb}$$
$$\mathbf{R}_1 = 135.946 \text{ lb} \measuredangle\ \alpha + 25^\circ$$

Next we consider the resultant $\mathbf{R}_2$ of $\mathbf{R}_1$ and the 240-lb force where $\mathbf{R}_2$ must be horizontal and directed to the left. Using the triangle rule and law of sines,



$$\frac{\sin(\alpha + 25^\circ)}{240 \text{ lb}} = \frac{\sin(30^\circ)}{135.946}$$
$$\sin(\alpha + 25^\circ) = 0.88270$$
$$\alpha + 25^\circ = 61.970^\circ$$
$$\alpha = 36.970^\circ$$

$\alpha = 37.0^\circ$ ◀

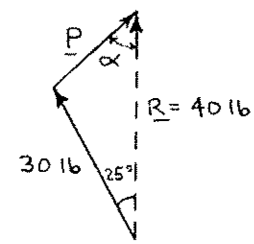


PROBLEM 2.128

A stake is being pulled out of the ground by means of two ropes as shown. Knowing the magnitude and direction of the force exerted on one rope, determine the magnitude and direction of the force **P** that should be exerted on the other rope if the resultant of these two forces is to be a 40-lb vertical force.

SOLUTION

Triangle rule:



Law of cosines: $P^2 = (30)^2 + (40)^2 - 2(30)(40)\cos 25°$

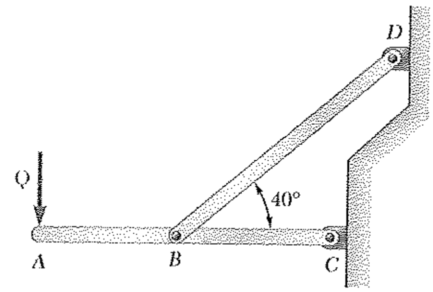
$P = 18.0239 \text{ lb}$

Law of sines: $\dfrac{\sin\alpha}{30 \text{ lb}} = \dfrac{\sin 25°}{18.0239 \text{ lb}}$

$\alpha = 44.703°$

$90° - \alpha = 45.297°$

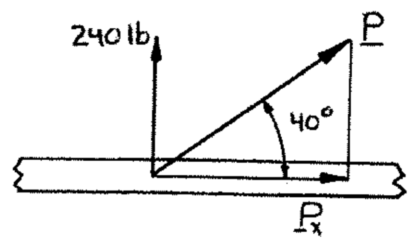
$\mathbf{P} = 18.02 \text{ lb} \measuredangle 45.3°$ ◀



PROBLEM 2.129

Member BD exerts on member ABC a force **P** directed along line BD. Knowing that **P** must have a 240-lb vertical component, determine (*a*) the magnitude of the force **P**, (*b*) its horizontal component.

SOLUTION



(*a*)

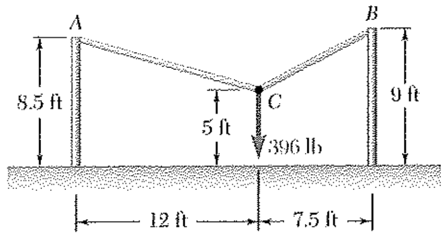
$$P = \frac{P_y}{\sin 35°} = \frac{240 \text{ lb}}{\sin 40°}$$

or $P = 373$ lb ◀

(*b*)

$$P_x = \frac{P_y}{\tan 40°} = \frac{240 \text{ lb}}{\tan 40°}$$

or $P_x = 286$ lb ◀

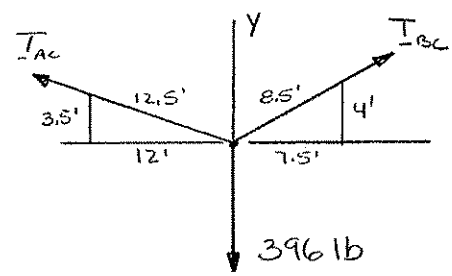


PROBLEM 2.130

Two cables are tied together at C and loaded as shown. Determine the tension (a) in cable AC, (b) in cable BC.

SOLUTION

Free Body Diagram at C:



$$\Sigma F_x = 0: \quad -\frac{12 \text{ ft}}{12.5 \text{ ft}} T_{AC} + \frac{7.5 \text{ ft}}{8.5 \text{ ft}} T_{BC} = 0$$

$$T_{BC} = 1.08800 T_{AC}$$

$$\Sigma F_y = 0: \quad \frac{3.5 \text{ ft}}{12 \text{ ft}} T_{AC} + \frac{4 \text{ ft}}{8.5 \text{ ft}} T_{BC} - 396 \text{ lb} = 0$$

(a)

$$\frac{3.5 \text{ ft}}{12.5 \text{ ft}} T_{AC} + \frac{4 \text{ ft}}{8.5 \text{ ft}} (1.08800 T_{AC}) - 396 \text{ lb} = 0$$

$$(0.28000 + 0.51200) T_{AC} = 396 \text{ lb}$$

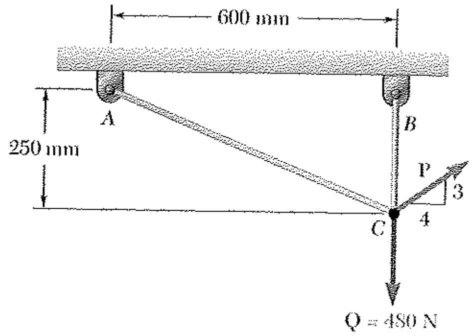
$$T_{AC} = 500.0 \text{ lb}$$

$T_{AC} = 500$ lb ◀

(b)

$$T_{BC} = (1.08800)(500.0 \text{ lb})$$

$T_{BC} = 544$ lb ◀

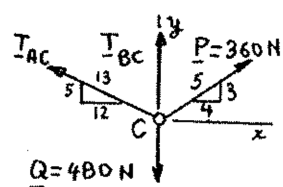


PROBLEM 2.131

Two cables are tied together at C and loaded as shown. Knowing that $P = 360$ N, determine the tension (a) in cable AC, (b) in cable BC.

SOLUTION

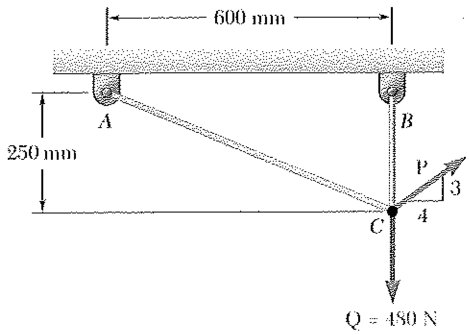
Free Body: C



(a) $\Sigma F_x = 0$: $-\dfrac{12}{13}T_{AC} + \dfrac{4}{5}(360 \text{ N}) = 0$ $\quad T_{AC} = 312 \text{ N}$ ◀

(b) $\Sigma F_y = 0$: $\dfrac{5}{13}(312 \text{ N}) + T_{BC} + \dfrac{3}{5}(360 \text{ N}) - 480 \text{ N} = 0$

$T_{BC} = 480 \text{ N} - 120 \text{ N} - 216 \text{ N}$ $\quad T_{BC} = 144 \text{ N}$ ◀

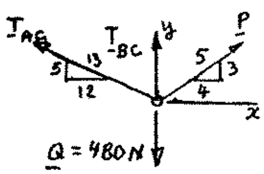


PROBLEM 2.132

Two cables are tied together at C and loaded as shown. Determine the range of values of P for which both cables remain taut.

SOLUTION

Free Body: C



$$\Sigma F_x = 0: \quad -\frac{12}{13}T_{AC} + \frac{4}{5}\mathbf{P} = 0$$

$$T_{AC} = \frac{13}{15}P \qquad (1)$$

$$\Sigma F_y = 0: \quad \frac{5}{13}T_{AC} + T_{BC} + \frac{3}{5}P - 480\text{ N} = 0$$

Substitute for T_{AC} from (1): $\left(\frac{5}{13}\right)\left(\frac{13}{15}\right)P + T_{BC} + \frac{3}{5}P - 480\text{ N} = 0$

$$T_{BC} = 480\text{ N} - \frac{14}{15}P \qquad (2)$$

From (1), $T_{AC} > 0$ requires $P > 0$.

From (2), $T_{BC} > 0$ requires $\frac{14}{15}P < 480\text{ N}$, $\quad P < 514.29\text{ N}$

Allowable range: $0 < P < 514\text{ N}$ ◀

PROBLEM 2.133

A force acts at the origin of a coordinate system in a direction defined by the angles $\theta_x = 69.3°$ and $\theta_z = 57.9°$. Knowing that the y component of the force is –174.0 lb, determine (*a*) the angle θ_y, (*b*) the other components and the magnitude of the force.

SOLUTION

(*a*) To determine θ_y, use the relation

$$\cos^2\theta_y + \cos^2\theta_y + \cos^2\theta_z = 1$$

or

$$\cos^2\theta_y = 1 - \cos^2\theta_x - \cos^2\theta_y$$

Since $F_y < 0$, we must have $\cos\theta_y < 0$

$$\cos\theta_y = -\sqrt{1 - \cos^2 69.3° - \cos^2 57.9°}$$
$$= -0.76985$$

$\theta_y = 140.3°$ ◀

(*b*)

$$F = \frac{F_y}{\cos\theta_y} = \frac{-174.0 \text{ lb}}{-0.76985} = 226.02 \text{ lb}$$

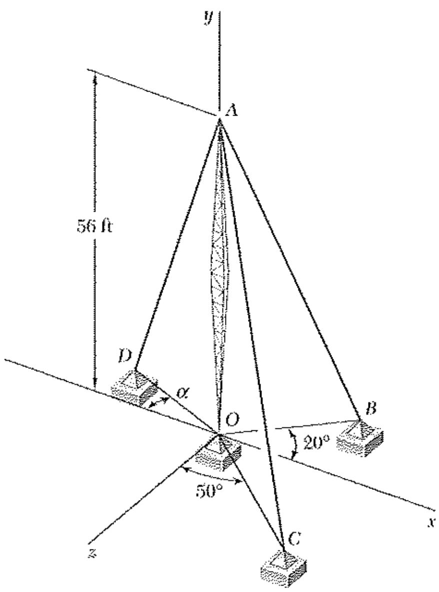
$F = 226$ lb ◀

$$F_x = F\cos\theta_x = (226.02 \text{ lb})\cos 69.3°$$

$F_x = 79.9$ lb ◀

$$F_z = F\cos\theta_z = (226.02 \text{ lb})\cos 57.9°$$

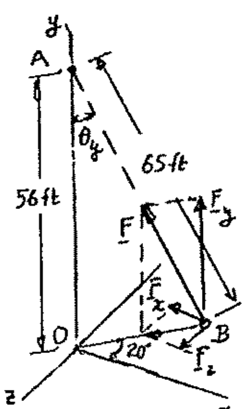
$F_z = 120.1$ lb ◀



PROBLEM 2.134

Cable AB is 65 ft long, and the tension in that cable is 3900 lb. Determine (a) the x, y, and z components of the force exerted by the cable on the anchor B, (b) the angles θ_x, θ_y, and θ_z defining the direction of that force.

SOLUTION



From triangle AOB:

$$\cos\theta_y = \frac{56 \text{ ft}}{65 \text{ ft}} = 0.86154$$

$$\theta_y = 30.51°$$

(a)

$$F_x = -F\sin\theta_y\cos 20° = -(3900 \text{ lb})\sin 30.51°\cos 20°$$

$$F_x = -1861 \text{ lb} \blacktriangleleft$$

$$F_y = +F\cos\theta_y = (3900 \text{ lb})(0.86154) \qquad F_y = +3360 \text{ lb} \blacktriangleleft$$

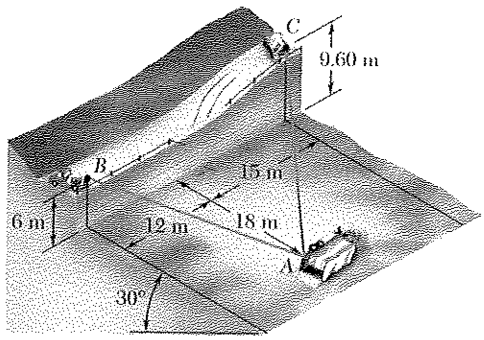
$$F_z = +(3900 \text{ lb})\sin 30.51°\sin 20° \qquad F_z = +677 \text{ lb} \blacktriangleleft$$

(b)

$$\cos\theta_x = \frac{F_x}{F} = -\frac{1861 \text{ lb}}{3900 \text{ lb}} = -0.4771 \qquad \theta_x = 118.5° \blacktriangleleft$$

From above: $\theta_y = 30.51°$ $\qquad \theta_y = 30.5° \blacktriangleleft$

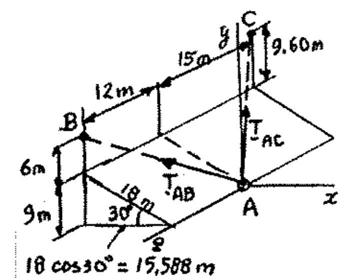
$$\cos\theta_z = \frac{F_z}{F} = +\frac{677 \text{ lb}}{3900 \text{ lb}} = +0.1736 \qquad \theta_z = 80.0° \blacktriangleleft$$



PROBLEM 2.135

In order to move a wrecked truck, two cables are attached at A and pulled by winches B and C as shown. Knowing that the tension is 10 kN in cable AB and 7.5 kN in cable AC, determine the magnitude and direction of the resultant of the forces exerted at A by the two cables.

SOLUTION



$$\overrightarrow{AB} = -15.588\mathbf{i} + 15\mathbf{j} + 12\mathbf{k}$$

$$AB = 24.739 \text{ m}$$

$$\overrightarrow{AC} = -15.588\mathbf{i} + 18.60\mathbf{j} - 15\mathbf{k}$$

$$AC = 28.530 \text{ m}$$

$$\mathbf{T}_{AB} = T_{AB}\boldsymbol{\lambda}_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB}$$

$$\mathbf{T}_{AB} = (10 \text{ kN})\frac{-15.588\mathbf{i} + 15\mathbf{j} + 12\mathbf{k}}{24.739}$$

$$\mathbf{T}_{AB} = (6.301 \text{ kN})\mathbf{i} + (6.063 \text{ kN})\mathbf{j} + (4.851 \text{ kN})\mathbf{k}$$

$$\mathbf{T}_{AC} = T_{AC}\boldsymbol{\lambda}_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC}(7.5 \text{ kN})\frac{-15.588\mathbf{i} + 18.60\mathbf{j} - 15\mathbf{k}}{28.530}$$

$$\mathbf{T}_{AC} = -(4.098 \text{ kN})\mathbf{i} + (4.890 \text{ kN})\mathbf{j} - (3.943 \text{ kN})\mathbf{k}$$

$$\mathbf{R} = \mathbf{T}_{AB} + \mathbf{T}_{AC} = -(10.399 \text{ kN})\mathbf{i} + (10.953 \text{ kN})\mathbf{j} + (0.908 \text{ kN})\mathbf{k}$$

$$R = \sqrt{(10.399)^2 + (10.953)^2 + (0.908)^2}$$

$$= 15.130 \text{ kN}$$

$R = 15.13$ kN ◀

$$\cos\theta_x = \frac{R_x}{R} = \frac{-10.399 \text{ kN}}{15.130 \text{ kN}} = -0.6873$$

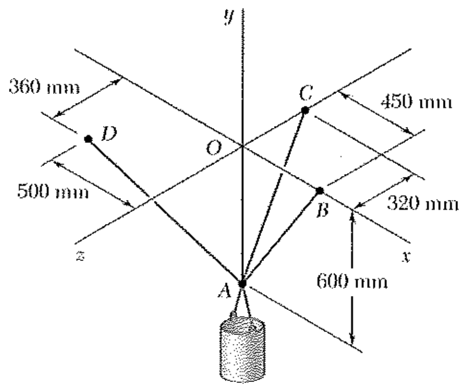
$\theta_z = 133.4°$ ◀

$$\cos\theta_y = \frac{R_y}{R} = \frac{10.953 \text{ kN}}{15.130 \text{ kN}} = 0.7239$$

$\theta_y = 43.6°$ ◀

$$\cos\theta_z = \frac{R_z}{R} = \frac{0.908 \text{ kN}}{15.130 \text{ kN}} = 0.0600$$

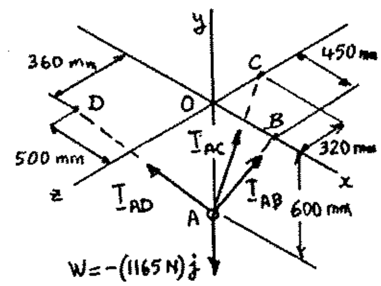
$\theta_z = 86.6°$ ◀



PROBLEM 2.136

A container of weight $W = 1165$ N is supported by three cables as shown. Determine the tension in each cable.

SOLUTION



Free Body: *A* $\qquad \Sigma \mathbf{F} = 0: \quad \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{T}_{AD} + \mathbf{W} = 0$

$$\overrightarrow{AB} = (450 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j}$$

$$AB = 750 \text{ mm}$$

$$\overrightarrow{AC} = (600 \text{ mm})\mathbf{j} - (320 \text{ mm})\mathbf{k}$$

$$AC = 680 \text{ mm}$$

$$\overrightarrow{AD} = (500 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k}$$

$$AD = 860 \text{ mm}$$

We have:

$$\mathbf{T}_{AB} = T_{AB}\lambda_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB} = \left(\frac{450}{750}\mathbf{i} + \frac{600}{750}\mathbf{j}\right)T_{AB}$$

$$= (0.6\mathbf{i} + 0.8\mathbf{j})T_{AB}$$

$$\mathbf{T}_{AC} = T_{AC}\lambda_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC} = \left(\frac{600}{680}\mathbf{j} - \frac{320}{680}\mathbf{k}\right)T_{AC} = \left(\frac{15}{17}\mathbf{j} - \frac{8}{17}\mathbf{k}\right)T_{AC}$$

$$\mathbf{T}_{AD} = T_{AD}\lambda_{AD} = T_{AD}\frac{\overrightarrow{AD}}{AD} = \left(-\frac{500}{860}\mathbf{i} + \frac{600}{860}\mathbf{j} + \frac{360}{860}\mathbf{k}\right)T_{AD}$$

$$\mathbf{T}_{AD} = \left(-\frac{25}{43}\mathbf{i} + \frac{30}{43}\mathbf{j} + \frac{18}{43}\mathbf{k}\right)T_{AD}$$

Substitute into $\Sigma\mathbf{F} = 0$, factor **i**, **j**, **k**, and set their coefficient equal to zero:

$$0.6T_{AB} - \frac{25}{43}T_{AD} = 0 \qquad T_{AB} = 0.96899T_{AD} \tag{1}$$

$$0.8T_{AB} + \frac{15}{17}T_{AC} + \frac{30}{43}T_{AD} - 1165 \text{ N} = 0 \tag{2}$$

$$-\frac{8}{17}T_{AC} + \frac{18}{43}T_{AD} = 0 \qquad T_{AC} = 0.88953T_{AD} \tag{3}$$

PROBLEM 2.136 (Continued)

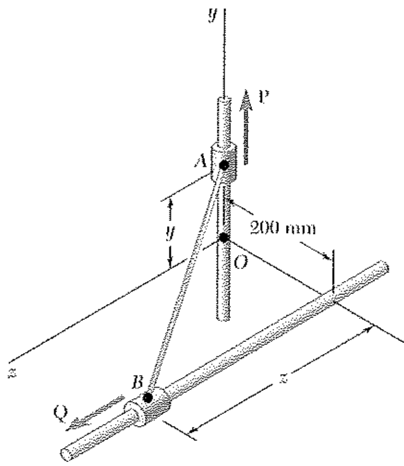
Substitute for T_{AB} and T_{AC} from (1) and (3) into (2):

$$\left(0.8 \times 0.96899 + \frac{15}{17} \times 0.88953 + \frac{30}{53}\right) T_{AD} - 1165 \text{ N} = 0$$

$$2.2578 T_{AD} - 1165 \text{ N} = 0 \qquad T_{AD} = 516 \text{ N} ◀$$

From (1): $T_{AB} = 0.96899(516 \text{ N})$ $\qquad T_{AB} = 500 \text{ N}$ ◀

From (3): $T_{AC} = 0.88953(516 \text{ N})$ $\qquad T_{AC} = 459 \text{ N}$ ◀



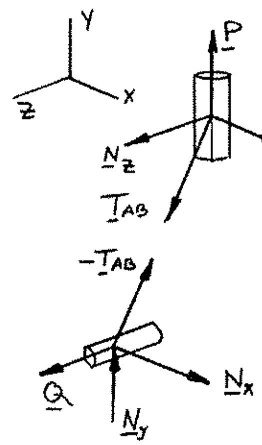
PROBLEM 2.137

Collars A and B are connected by a 525-mm-long wire and can slide freely on frictionless rods. If a force $\mathbf{P} = (341\text{ N})\mathbf{j}$ is applied to collar A, determine (a) the tension in the wire when $y = 155$ mm, (b) the magnitude of the force $\mathbf{Q}$ required to maintain the equilibrium of the system.

SOLUTION

For both Problems 2.137 and 2.138:

Free Body Diagrams of Collars:



$$(AB)^2 = x^2 + y^2 + z^2$$

Here $\quad (0.525\text{ m})^2 = (.20\text{ m})^2 + y^2 + z^2$

or $\quad y^2 + z^2 = 0.23563\text{ m}^2$

Thus, why y given, z is determined,

Now
$$\boldsymbol{\lambda}_{AB} = \frac{\overrightarrow{AB}}{AB}$$
$$= \frac{1}{0.525\text{ m}}(0.20\mathbf{i} - y\mathbf{j} + z\mathbf{k})\text{m}$$
$$= 0.38095\mathbf{i} - 1.90476y\mathbf{j} + 1.90476z\mathbf{k}$$

Where y and z are in units of meters, m.

From the F.B. Diagram of collar A: $\quad \Sigma\mathbf{F} = 0\text{:} \quad N_x\mathbf{i} + N_z\mathbf{k} + P\mathbf{j} + T_{AB}\boldsymbol{\lambda}_{AB} = 0$

Setting the $\mathbf{j}$ coefficient to zero gives: $\quad P - (1.90476y)T_{AB} = 0$

With $\quad P = 341\text{ N}$

$$T_{AB} = \frac{341\text{ N}}{1.90476y}$$

Now, from the free body diagram of collar B: $\quad \Sigma\mathbf{F} = 0\text{:} \quad N_x\mathbf{i} + N_y\mathbf{j} + Q\mathbf{k} - T_{AB}\boldsymbol{\lambda}_{AB} = 0$

Setting the $\mathbf{k}$ coefficient to zero gives: $\quad Q - T_{AB}(1.90476z) = 0$

And using the above result for T_{AB} we have $\quad Q = T_{AB}z = \dfrac{341\text{ N}}{(1.90476)y}(1.90476z) = \dfrac{(341\text{ N})(z)}{y}$

Then, from the specifications of the problem, $y = 155 \text{ mm} = 0.155 \text{ m}$

$$z^2 = 0.23563 \text{ m}^2 - (0.155 \text{ m})^2$$
$$z = 0.46 \text{ m}$$

and

(*a*)

$$T_{AB} = \frac{341 \text{ N}}{0.155(1.90476)}$$
$$= 1155.00 \text{ N}$$

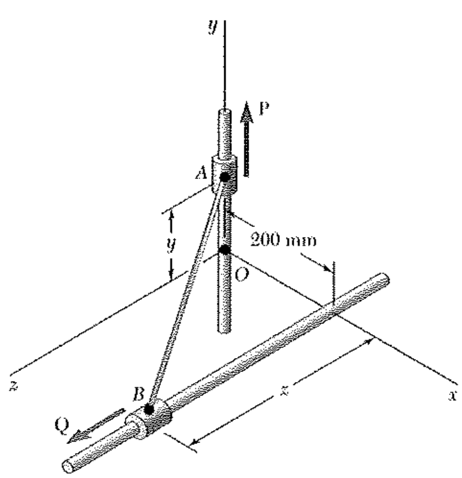
or $T_{AB} = 1.155 \text{ kN}$ ◀

and

(*b*)

$$Q = \frac{341 \text{ N}(0.46 \text{ m})(0.866)}{(0.155 \text{ m})}$$
$$= (1012.00 \text{ N})$$

or $Q = 1.012 \text{ kN}$ ◀



PROBLEM 2.138

Solve Problem 2.137 assuming that $y = 275$ mm.

PROBLEM 2.137 Collars A and B are connected by a 525-mm-long wire and can slide freely on frictionless rods. If a force $\mathbf{P} = (341 \text{ N})\mathbf{j}$ is applied to collar A, determine (*a*) the tension in the wire when $y = 155$ mm, (*b*) the magnitude of the force $\mathbf{Q}$ required to maintain the equilibrium of the system.

SOLUTION

From the analysis of Problem 2.137, particularly the results:

$$y^2 + z^2 = 0.23563 \text{ m}^2$$

$$T_{AB} = \frac{341 \text{ N}}{1.90476y}$$

$$Q = \frac{341 \text{ N}}{y} z$$

With $y = 275 \text{ mm} = 0.275 \text{ m}$, we obtain:

$$z^2 = 0.23563 \text{ m}^2 - (0.275 \text{ m})^2$$

$$z = 0.40 \text{ m}$$

and

(*a*)

$$T_{AB} = \frac{341 \text{ N}}{(1.90476)(0.275 \text{ m})} = 651.00$$

or $T_{AB} = 651 \text{ N}$ ◀

and

(*b*)

$$Q = \frac{341 \text{ N}(0.40 \text{ m})}{(0.275 \text{ m})}$$

or $Q = 496 \text{ N}$ ◀