

Introduction

In this chapter, you consider structures and machines that typically have more members and connections than previously studied. Again the basic foundation of static analysis is to construct correct free body diagrams (FBD). They can be drawn for the complete system, for the connecting joints, and/or for selected sections through the system.

Today the majority of truss and frame systems are solved by energy methods (to be considered later). That is because energy methods can find all the joint forces, member forces, and joint displacement; even for statically indeterminate systems. The energy methods are also more easily automated for computer solutions. Nevertheless, it is important to learn to draw joint and section FBDs as applied in the following examples.

There are problems that are statically indeterminate (have more external unknowns than independent equilibrium equations). Examples of that are shown in Figure 1. The members in that figure do not have connected multiple parts. To solve them you would have to develop additional equations defining how the forces or moments deform the material. Those relations are taught in a course on the mechanics of materials. Here, you will encounter systems that are externally indeterminate, but have connected parts that provide enough FBDs that the entire system can be solved by statics (see Example 6.9 below).

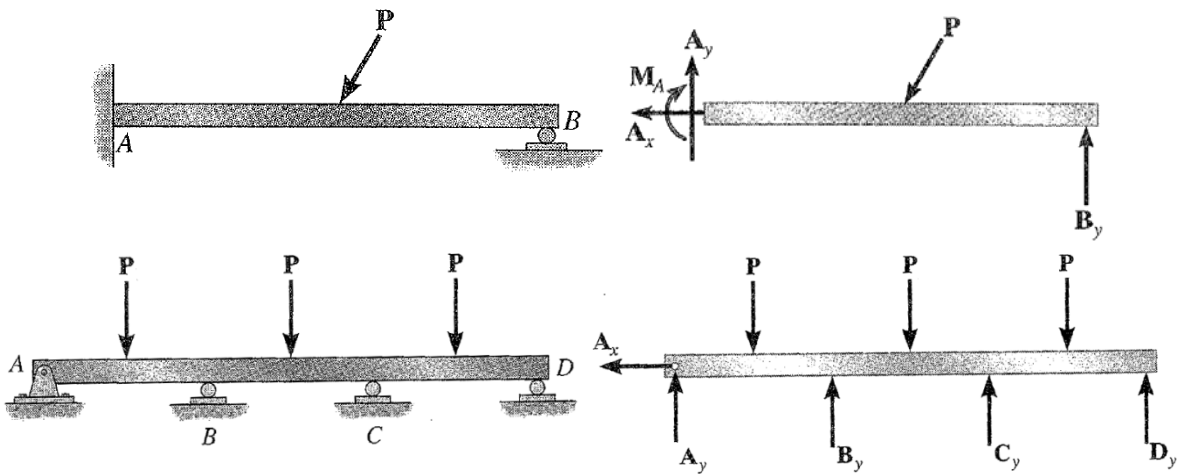


Figure 1 Two statically indeterminate systems

Example 6.1

This system (shown in Figure 1 with its external reactions), is a simple statically determinate truss with four joints and five members. It has a pin support at the top and a vertical roller at the lower wall support. Usually you neglect the member weights in a preliminary study. Once you have an initial solution you can select the size (cross-sectional area) of each member. Then you repeat the analysis including the member weights and iterate until all design considerations are met. At times some members, like AB and BC seem un-needed because they initially carry no load. But they might be needed to make the system stable (or to reduce buckling concerns). The FBDs in Figure 2 show weight loads not included in the original analysis statement. For the first pass, the member weight per unit length will be set to zero.

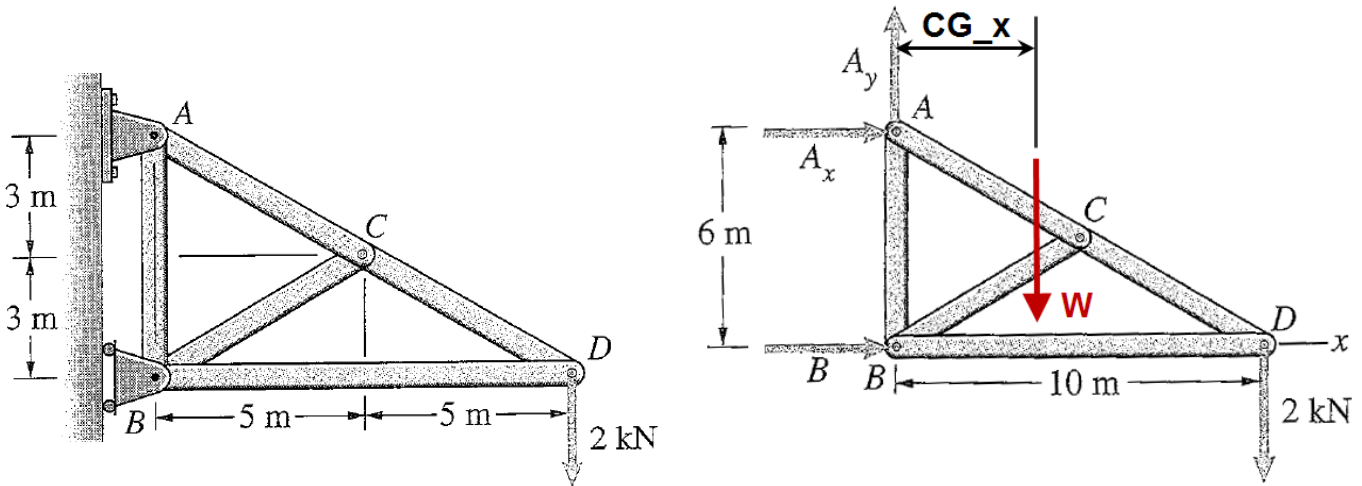


Figure 1 A five member planar truss

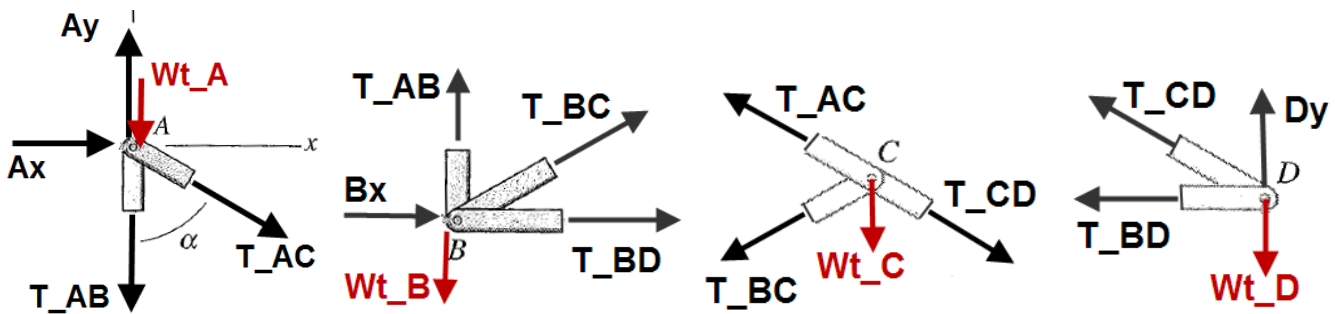


Figure 2 Truss joint free body diagrams (including weight)

However, they are included in the supplemented equilibrium rules given in Figure 3. That example assumes equal areas. Often members are made the same size to ease their assembly. Of course, you could modify the rules to give each member a different cross-section and supply the material weight per unit volume. The initial results, neglecting weight, are given in Figure 4. They agree with the text values. Then assuming a reasonable weight per unit length of 100 N/m the reactions and member forces change significantly as seen in Figure 5.

Including the member weights always causes members AB and BC to help in supporting the weight. Note that when weights are included the tension in AC is greater than that in member CD. There is also about a 40% increase in the compression of member T_{BD}. There are more restrictions in selecting members to restrict compression than there is for tension members.

For truss members, half the weight acts on each end. For most members you only know that the weight acts at the center of mass, or centroid (reviewed in the next chapter). Here, the center of gravity is simply the mid-point of the member. You could rewrite the sum of moments about point A using lever arms measured from those points. You will get the same results as above (try it).

Once you have found the reactions needed to hold the system in equilibrium (or from material in the next chapter), you can determine the horizontal distance to the point through which the weight of all the members acts. In the rules provided, that point is denoted as CG_x.

Example 6.2

This is a small input modification of the above example. None of the rules has to be changed. Here, the goal is to find the downward force at D that would either cause a maximum compression of 2 kN, or 10 kN in tension (note the difference in allowable loadings). To solve this, first neglect the weight and, set compression member T_{BC} to have a force of -2,000 N and solve for the applied force. Then set the maximum tension (in AC) to 10,000 N and solve for the same force. Those two results are given in Figure 6.

Status	Rule
Comment	; Bedford-Fowler Ex 6.1 3rd Ed, modified
Comment	; Total weight at each joint
Satisfied	$Wt_A = (Wt_AB + Wt_AC)/2$
Satisfied	$Wt_B = (Wt_AB + Wt_BC + Wt_BD)/2$
Satisfied	$Wt_C = (Wt_AC + Wt_BC + Wt_CD)/2$
Satisfied	$Wt_D = (Wt_BD + Wt_CD)/2$
Satisfied	$Weight = Wt_A + Wt_B + Wt_C + Wt_D$
Comment	; System equilibrium (with half of member weight at its end points)
Satisfied	$Ay - Weight + Dy = 0$; $\Sigma F_y = 0$
Satisfied	$Ax + Bx = 0$; $\Sigma F_x = 0$
Satisfied	$Bx * L_AB - Wt_C * L_BD / 2 - Wt_D * L_BD + Dy * L_BD = 0$; $\Sigma M_A = 0$
Satisfied	$Bx * L_AB - Weight * CG_x + Dy * L_BD = 0$; x Center of Gravity
Comment	; Equilibrium of joints (with half member weight to each end point)
Satisfied	$\alpha = \text{atan}(L_BD / L_AB)$; Angle from NEGATIVE y
Satisfied	$Ax + T_AC * \sin(\alpha) = 0$; Jt A $\Sigma F_x = 0$
Satisfied	$Ay - T_AB - T_AC * \cos(\alpha) - Wt_A = 0$; Jt A $\Sigma F_y = 0$
Satisfied	$Bx + T_BD + T_BC * \sin(\alpha) = 0$; Jt B $\Sigma F_x = 0$
Satisfied	$T_AB + T_BC * \cos(\alpha) - Wt_B = 0$; Jt B $\Sigma F_y = 0$
Satisfied	$-T_AC * \sin(\alpha) - T_BC * \sin(\alpha) + T_CD * \sin(\alpha) = 0$; Jt C $\Sigma F_x = 0$
Satisfied	$T_AC * \cos(\alpha) - T_BC * \cos(\alpha) - T_CD * \cos(\alpha) - Wt_C = 0$; Jt C $\Sigma F_y = 0$
Satisfied	$-T_BD - T_CD * \sin(\alpha) = 0$; Jt D $\Sigma F_x = 0$
Satisfied	$T_CD * \cos(\alpha) - Wt_D + Dy = 0$; Jt D $\Sigma F_y = 0$
Comment	; Member weights ASSUMING equal areas
Satisfied	$Wt_AB = L_AB * \text{unit_wt}$
Satisfied	$Wt_AC = L_AC * \text{unit_wt}$
Satisfied	$Wt_BC = L_BC * \text{unit_wt}$
Satisfied	$Wt_BD = L_BD * \text{unit_wt}$
Satisfied	$Wt_CD = L_CD * \text{unit_wt}$
Satisfied	$Weight = Wt_AB + Wt_AC + Wt_BC + Wt_CD + Wt_BD$
Satisfied	$L_AC^2 = (L_AB/2)^2 + (L_BD/2)^2$
Satisfied	$L_BC = L_AC$
Satisfied	$L_CD = L_AC$

Figure 3 Geometry and equilibrium rules (including member weights)

Input	Name	Output	Unit	Comment
				; Bedford-Fowler Ex 6.1 3rd Ed, modified
	α	59.03624	degrees	Member angle from vertical
6	L_AB		m	Member length
	L_AC	5.830952	m	Member length
	L_BC	5.830952	m	Member length
10	L_BD		m	Member length
	L_CD	5.830952	m	Member length
	Wt_A	0	N	Total weight at joint
	Wt_B	0	N	Total weight at joint
	Wt_C	0	N	Total weight at joint
	Wt_D	0	N	Total weight at joint
0	unit_wt		N/m	Weight per unit length (for equal areas)
	Ax	-3333.333	N	Support force
	Ay	2000	N	Support force
	Bx	3333.333	N	Support force
-2000	Dy		N	Applied joint load
				Member forces
	T_AC	3887.301	N	Force (+ tension, - compression)
	T_AB	2.27E-13	N	Force (+ tension, - compression)
	T_BD	-3333.333	N	Force (+ tension, - compression)
	T_BC	-4.42E-13	N	Force (+ tension, - compression)
	T_CD	3887.301	N	Force (+ tension, - compression)
	Wt_AB	0	N	Member weight
	Wt_AC	0	N	Member weight
	Wt_BC	0	N	Member weight
	Wt_BD	0	N	Member weight
	Wt_CD	0	N	Member weight

Figure 4 Truss force results, neglecting member weights

Input	Name	Output	Unit	Comment
100	unit_wt		N/m	Weight per unit length (for equal areas)
	Ax	-5381.448	N	Support force
	Ay	5349.286	N	Support force
	Bx	5381.448	N	Support force
-2000	Dy		N	Applied joint load
				Member forces
	T_AC	6275.793	N	Force (+ tension, - compression)
	T_AB	1528.869	N	Force (+ tension, - compression)
	T_BD	-4652.579	N	Force (+ tension, - compression)
	T_BC	-850	N	Force (+ tension, - compression)
	T_CD	5425.793	N	Force (+ tension, - compression)
	CG_x	3.669048	m	x center of gravity location

Figure 5 Force results including truss member weights

Input	Name	Output	Unit	Comment
	Ax	-2000	N	Support force
	Ay	1200	N	Support force
	Bx	2000	N	Support force
	Dy	-1200	N	Applied joint load
				Member forces
	T_AC	2332.381	N	Force (+ tension, - compression)
	T_AB	-1.36E-13	N	Force (+ tension, - compression)
-2000	T_BD		N	Force (+ tension, - compression)
	T_BC	2.65E-13	N	Force (+ tension, - compression)
	T_CD	2332.381	N	Force (+ tension, - compression)

Input	Name	Output	Unit	Comment
	Ax	-8574.929	N	Support force
	Ay	5144.958	N	Support force
	Bx	8574.929	N	Support force
	Dy	-5144.958	N	Applied joint load
				Member forces
10000	T_AC		N	Force (+ tension, - compression)
	T_AB	1.82E-12	N	Force (+ tension, - compression)
	T_BD	-8574.929	N	Force (+ tension, - compression)
	T_BC	-3.54E-12	N	Force (+ tension, - compression)
	T_CD	10000	N	Force (+ tension, - compression)

Figure 6 Finding compression and tension limits for applied force Dy

For the compression limit, the downward force at point D cannot exceed 1,200 N. The tension limit restricts the applied load at D to about 5,140 N downward. Clearly, the compression limit governs the allowable load here. Who would the force limits change if you include the member weights? (Try it and see.)

Example 6.7

This cable-frame-pulley system, and its external FBD, is shown in Figure 7. The pulley is frictionless, so the cable tension just changes in direction, not in value. Pin joints are employed, and the weight supported by the cable is 40 lb. Initially the member weights will be ignored. There are three external unknowns (Ax, Ay, Dx) so they could be found just from the FBD of the system. The five internal unknowns (Cx, Cy, Gx, Gy, R) will require a minimum of five equations, involving at least two general two-dimensional FBDs. The cable tension is equal to the weight by inspection (for a statics problem, but not so later in dynamics). From the pulley FBD you see there is only one unknown in each direction to oppose the cable forces. So, you should also see by inspection that $G_x = T$ and $G_y = T$. The geometry rules and selected equilibrium rules are given in Figure 9. It is important to note that the FDB has the assumed direction (tension or compression) given on each FBD. Those assumptions are used in the rules given in the Rules Sheet. If a force is computed to have a negative sign, then that means the force is actually in the opposite direction. Some authors always recommending that

an unknown force is in tension. Then a sign change simply means the force is compressive, and you do not have to refer back to your FBD to know the true state of a force.

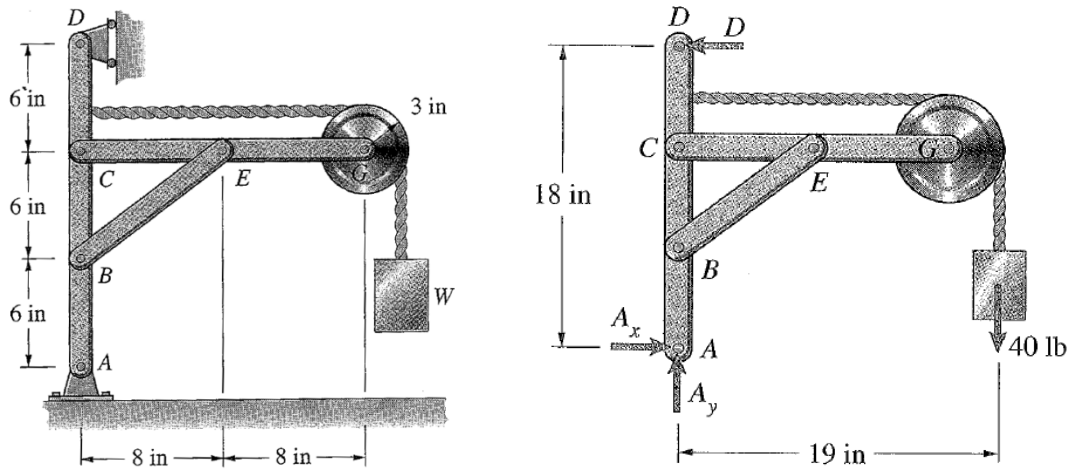


Figure 7 Cable-frame-pulley system

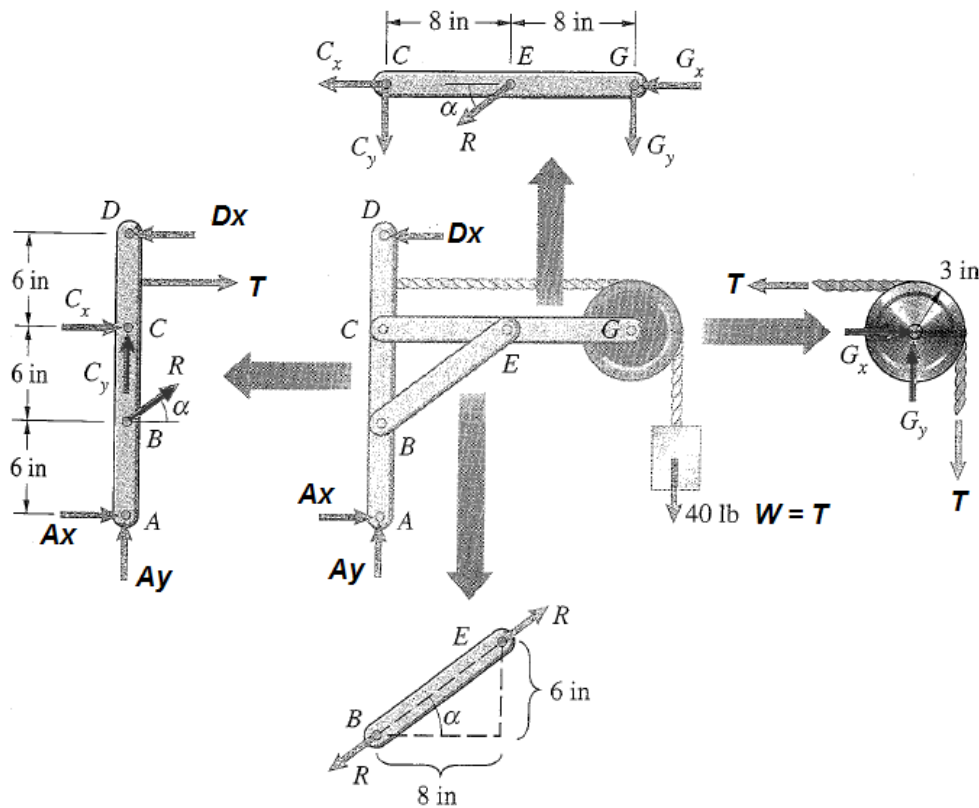


Figure 8 Available free body diagrams

Status	Rule
Comment	; Bedford-Fowler Ex 6.7, 3rd Ed
Comment	; Force directions (signs) shown in FBDs
Comment	; System equilibrium
Satisfied	$A_x * L_{AD} - W * L_{AW} = 0$; $\Sigma M_D = 0$, external
Satisfied	$A_x - D_x = 0$; $\Sigma F_x = 0$, external
Satisfied	$A_y - W = 0$; $\Sigma F_y = 0$, external
Satisfied	$L_{AW} = L_{CG} + \text{Radius}$; Geometry
Satisfied	$\tan(\alpha) = (L_{AD} / 3) / (L_{CG}/2)$; Geometry
Satisfied	$R_x = R * \cos(\alpha)$; Geometry
Satisfied	$R_y = R * \sin(\alpha)$; Geometry
Comment	; Equilibrium of members
Comment	; FBD for CEG
Satisfied	$R_y * L_{CG}/2 + C_y * L_{CG} = 0$; Moment about point G
Satisfied	$-C_x - R_x - G_x = 0$; $\Sigma F_x = 0$
Satisfied	$-C_y - R_y - G_y = 0$; $\Sigma F_y = 0$
Comment	; FBD for ABCD, moment about point A
Satisfied	$-R_x * L_{AD}/3 - C_x * L_{AD} * 2/3 - T * (L_{AD} * 2/3 + \text{Radius}) + D_x * L_{AD} = 0$
Satisfied	$A_x + R_x + C_x + T - D_x = 0$; $\Sigma F_x = 0$
Satisfied	$A_y + R_y + C_y = 0$; $\Sigma F_y = 0$
Satisfied	$T = W$; by inspection $\Sigma F_y = 0$
Satisfied	$G_x = T$; by inspection $\Sigma F_x = 0$
Satisfied	$G_y = T$; by inspection $\Sigma F_y = 0$

Figure 9 Selected force and moment equilibrium for the cable-frame-pulley system

Again, remember that you have a wide choice in where you select points in a FBD about which you require moment equilibrium. You can select as many moment equilibrium points as you wish in any FBD. Therefore, the choices given in Figure 9 are not unique. The external equilibrium rules are sufficient to find the support forces. However, to determine the internal connection forces TK requires a starting guess for one of the unknowns. This is seen in Figure 10, where the diagonal member BE is guessed to be in tension. The converged iterative solution of the equilibrium equations is given in Figure 11. Those results show that the diagonal member is actually in compression. Note that the diagonal brace BE carries the largest force in the system. Where would you place connection point E in order to reduce the diagonal brace force? Try changing the rule for the tangent of the angle to check your reasoning.

Status	Input	Name	Output	Unit	Comment
					Bedford-Fowler Ex 6.7, 3rd Ed
		α	36.8699	degrees	Inclined member angle from horizontal
	18	L_AD		in	Member length
		L_AW	19	in	Weight location
	16	L_CG		in	Member length
	3	Radius		in	Pulley radius
	40	W		lb	Weight
		Ax	42.2222	lb	External support force (+ for compression)
		Ay	40	lb	External support force (+ for compression)
		Dx	42.2222	lb	External support force (+ for compression)
		Cy		lb	Connection force (+ for compression)
		Cx		lb	Connection force (+ for compression)
		Gx	40	lb	Pulley support force (+ for compression)
		Gy	40	lb	Pulley support force (+ for compression)
		Rx		lb	Inclined member component (+ for tension)
		Ry		lb	Inclined member component (+ for tension)
Guess	100	R		lb	Inclined member force (+ for tension)
		T	40	lb	Cable force (+ for tension)

Figure 10 External equilibrium results and initial guess for internal results

Input	Name	Output	Unit	Comment
	Cy	40	lb	Connection force (+ for compression)
	Cx	66.6667	lb	Connection force (+ for compression)
	Gx	40	lb	Pulley support force (+ for compression)
	Gy	40	lb	Pulley support force (+ for compression)
	Rx	-106.667	lb	Inclined member component (+ for tension)
	Ry	-80	lb	Inclined member component (+ for tension)
	R	-133.333	lb	Inclined member force (+ for tension)
	T	40	lb	Cable force (+ for tension)

Figure 11 Internal equilibrium results

Example 6.7, with member weights

As the next step in the study of the above system, you would include the weights of the members and the pulley. The weight of the cable is neglected since it is taken to be straight. (Including the weight of a cable requires solving a differential equation for a non-straight shape, as will be seen in a later chapter.) Member BE is a truss member (two-force member), so its weight is split between its two support ends (on members AD and CG). The vertical and horizontal bars have more than two support points. Their weights are taken to act at their center points (which is always true for rectangular shaped members). The horizontal force equilibrium equations are unchanged. Of course, the moment equilibrium equations must include the lever arm to each weight term in the FBD. The modified rules are given in Figure 12, and the new results are in Figure 13.

Status	Rule
Comment	; Bedford-Fowler Ex 6.7, 3rd Ed, Force directions (signs) shown in FBDs
Comment	; Member weights base on length
Satisfied	$Wt_AD = unit_wt * L_AD$
Satisfied	$Wt_BE = unit_wt * L_BE$
Satisfied	$Wt_CG = unit_wt * L_CG$
Satisfied	$Wt_sys = Wt_AD + Wt_BE + Wt_CG + Wt_p$
Comment	; System FBD, $\Sigma M_D = 0$
Satisfied	$Ax * L_AD - W * L_AW - Wt_p * L_CG - Wt_CG * L_CG/2 - Wt_BE * L_CG/4 = 0$
Satisfied	$Ax - Dx = 0$; $\Sigma F_x = 0$, external
Satisfied	$Ay - W - Wt_sys = 0$; $\Sigma F_y = 0$, external
Satisfied	$L_BE^2 = (L_AD/3)^2 + (L_CG/2)^2$; Geometry
Satisfied	$L_AW = L_CG + Radius$; Geometry
Satisfied	$\tan(\alpha) = (L_AD / 3) / (L_CG/2)$; Geometry
Satisfied	$Rx = R * \cos(\alpha)$; Geometry
Satisfied	$Ry = R * \sin(\alpha)$; Geometry
Comment	; Equilibrium of internal forces
Comment	; FBD for CEG
Satisfied	$(Ry + Wt_BE/2) * L_CG/2 + Cy * L_CG + Wt_CG * L_CG/2 = 0$; Moment wrt G
Satisfied	$-Cx - Rx - Gx = 0$; $\Sigma F_x = 0$
Satisfied	$-Cy - Ry - Gy - Wt_CG - Wt_BE/2 = 0$; $\Sigma F_y = 0$
Comment	; FBD for ABCD, moment about point A
Satisfied	$-Rx * L_AD/3 - Cx * L_AD * 2/3 - T * (L_AD * 2/3 + Radius) + Dx * L_AD = 0$
Satisfied	$Ax + Rx + Cx + T - Dx = 0$; $\Sigma F_x = 0$
Satisfied	$Ay + Ry + Cy - Wt_AD - Wt_BE/2 = 0$; $\Sigma F_y = 0$
Satisfied	$T = W$; by inspection $\Sigma F_y = 0$
Satisfied	$Gx = T$; by inspection $\Sigma F_x = 0$
Satisfied	$Gy - T - Wt_p = 0$; $\Sigma F_y = 0$

Figure 12 Including member weights in the cable-frame-pulley system

Input	Name	Output	Unit	Comment
				Bedford-Fowler Ex 6.7, 3rd Ed, with weights
	α	36.8699	degrees	Inclined member angle from horizontal
18	L_AD		in	Member length
	L_AW	19	in	Weight location
	L_BE	10	in	Member length
16	L_CG		in	Member length
3	Radius		in	Pulley radius
40	W		lb	Weight
	Ax	52.4444	lb	External support force (+ for compression)
	Ay	84.9998	lb	External support force (+ for compression)
	Dx	52.4444	lb	External support force (+ for compression)
	Cy	41	lb	Connection force (+ for compression)
	Cx	97.3332	lb	Connection force (+ for compression)
	Gx	40	lb	Pulley support force (+ for compression)
	Gy	41	lb	Pulley support force (+ for compression)
	Rx	-137.333	lb	Inclined member component (+ for tension)
	Ry	-103	lb	Inclined member component (+ for tension)
	R	-171.667	lb	Inclined member force (+ for tension)
	T	40	lb	Cable force (+ for tension)
1	unit_wt		lb/in	Weight per unit length
	wt_AD	17.9999	lb	Member weight (at center)
	wt_BE	9.99996	lb	Member weight (half at each end)
	wt_CG	15.9999	lb	Member weight (at center)
1	wt_p		lb	Pulley weight
	wt_sys	44.9998	lb	Total weight of bars and pulley

Figure 13 Forces considering the effects of member weights

Example 6.9

This is an example of a system that is statically indeterminate, but contains parts that provide additional FBds that allow a full statics solution. The truck-trailer system has a parking brake applied only to wheel B. That is, only that wheel can apply a force tangent to the inclined plane. You also know that the internal connect between the cab and trailer at point D is a smooth pin (a ball joint in 3-D). The planar system FBD in Figure 14 has four unknowns. However, you can only create three independent equilibrium equations. Therefore, the external forces cannot be determined from that FBD alone. You can split the two bodies apart and introduce equal and opposite forces at point D. The assumed component directions for the force at D are shown on the trailer FBD in Figure 15. Be alert for the change in directions (signs) of those components when the cab FBD is considered. In the rules given in Figure 16, the components of the weights are defined in the positive x- and y-directions (but given the correct negative signs).

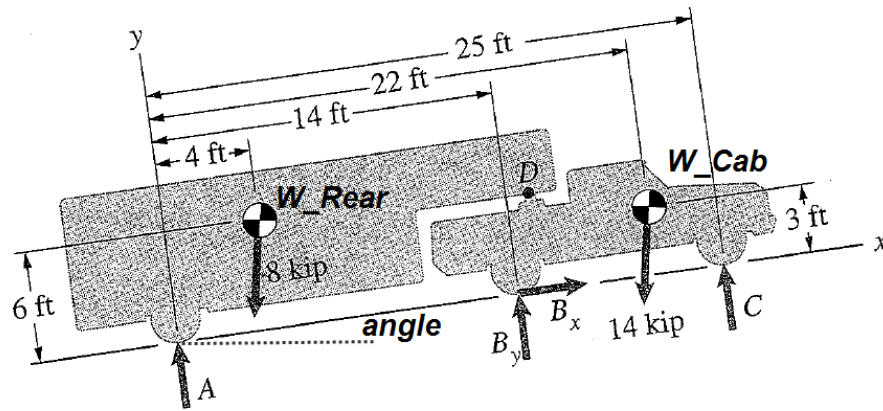


Figure 14 Externally indeterminate truck-trailer system

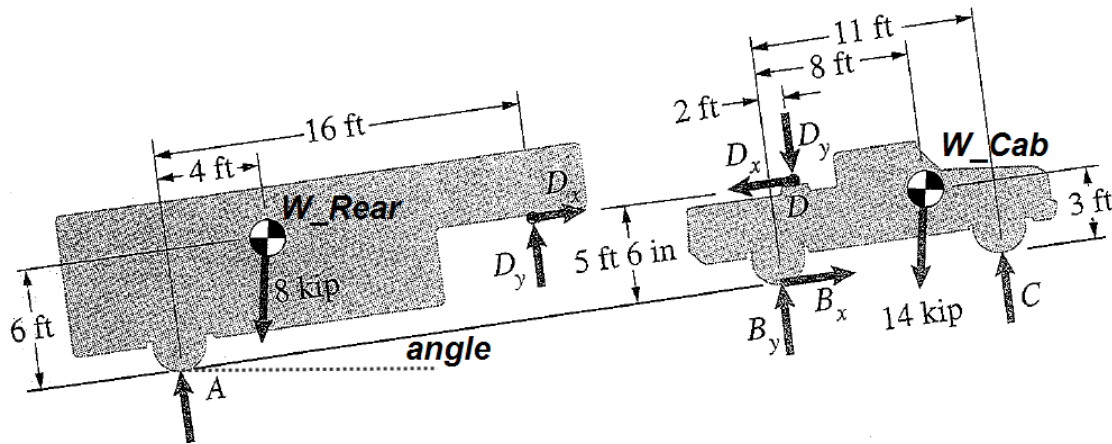


Figure 15 Statically determinate trailer system and truck system

You can select FBDs in any order. Start with the trailer FBD since it has only three unknowns compared to the five for the cab (and four for the system). Once you know the values of A, D_x and D_y , both the remaining FBDs will have only three unknowns each. Of course, with TK Solver you do not have to see that you can just write the rules for each FBD.

Here, rules were written for all three FBDs to provide both a solution and a validation of that solution. The outputs, in Figure 16, agree with those of the text.

Status	Rule
Comment	; Bedford-Fowler Example 6.9, 3rd Ed.
Comment	; An externally statically indeterminate system, with determinate members
Satisfied	$W_{Cabx} = -W_{Cab} * \sin(\text{angle})$; weight component
Satisfied	$W_{Caby} = -W_{Cab} * \cos(\text{angle})$; weight component
Satisfied	$W_{Rearx} = -W_{Rear} * \sin(\text{angle})$; weight component
Satisfied	$W_{Reary} = -W_{Rear} * \cos(\text{angle})$; weight component
Comment	
Comment	; Rear section FBD, $M_z = r_x * F_y - r_y * F_x = +- d * F$
Satisfied	$MRear_D = (X_{rear} - L_{AD}) * W_{Reary} - (Y_{rear} - Y_D) * W_{Rearx}$; Wt moment
Satisfied	$(-L_{AD} * A - 0) + MRear_D = 0$; $\Sigma M_D = 0$
Satisfied	$W_{Rearx} + Dx = 0$; $\Sigma F_x = 0$
Satisfied	$A + W_{Reary} + Dy = 0$; $\Sigma F_y = 0$
Comment	
Comment	; Cab section FBD, $M_z = r_x * F_y - r_y * F_x = +- d * F$
Comment	; Equal and opposite force at D. $D_{cab} = -D_{rear}$ <<<<<
Satisfied	$MCab_B = (X_{cab} - L_{AB}) * W_{Caby} - (Y_{cab}) * W_{Cabx}$; Wt moment
Satisfied	$(L_{AD} - L_{AB}) * (-Dy) - Y_D * (-Dx) + MCab_B + (L_{AC} - L_{AB}) * C = 0$; $\Sigma M_B = 0$
Satisfied	$Bx + (-Dx) + W_{Cabx} = 0$; $\Sigma F_x = 0$
Satisfied	$By + (-Dy) + W_{Caby} + C = 0$; $\Sigma F_y = 0$
Comment	
Comment	; Validate results: system FBD, $M_z = r_x * F_y - r_y * F_x = +- d * F$
Satisfied	$MRear_A = X_{rear} * W_{Reary} - Y_{rear} * W_{Rearx}$; Wt moment
Satisfied	$MCab_A = X_{cab} * W_{Caby} - Y_{cab} * W_{Cabx}$; Wt moment
Satisfied	$MRear_A + L_{AB} * By + MCab_A + L_{AC} * C = 0$; $\Sigma M_A = 0$
Satisfied	$Bx + W_{Rearx} + W_{Cabx} = 0$; $\Sigma F_x = 0$
Satisfied	$A + W_{Reary} + By + W_{Caby} + C = 0$; $\Sigma F_y = 0$

Figure 16 Externally indeterminate truck and trailer with determinate parts

Input	Name	Output	Unit	Comment
				Bedford-Fowler Example 6.9, 3rd Ed.
10	angle		degrees	Angle of plane from horizontal
14000	W_Cab		lb	Weight of cab
8000	W_Rear		lb	Weight of trailer
14	L_AB		ft	Geometric data
25	L_AC		ft	Geometric data
16	L_AD		ft	Geometric data
22	X_cab		ft	Geometric data
3	Y_cab		ft	Geometric data
4	X_rear		ft	Geometric data
6	Y_rear		ft	Geometric data
5.5	Y_D		ft	Geometric data
	A	5952.259	lb	Trailer wheel force
	Bx	3820.26	lb	Force on cab wheel B
	By	6693.773	lb	Force on cab wheel B
	C	9019.739	lb	Force on cab wheel C
	Dy	1926.203	lb	Coupling force acting on trailer
	Dx	1389.185	lb	Coupling force acting on trailer
	W_Cabx	-2431.074	lb	Component of weight
	W_Caby	-13787.31	lb	Component of weight
	W_Rearx	-1389.185	lb	Component of weight
	W_Reary	-7878.462	lb	Component of weight
	MCab_A	-296027.4	ft-lb	Cab weight moment at A
	MCab_B	-103005.2	ft-lb	Cab weight moment at B
	MRear_A	-23178.72	ft-lb	Trailer weight moment at A
	MRear_D	95236.08	ft-lb	Trailer weight moment at D

Figure 16 Outputs for the trailer-truck system