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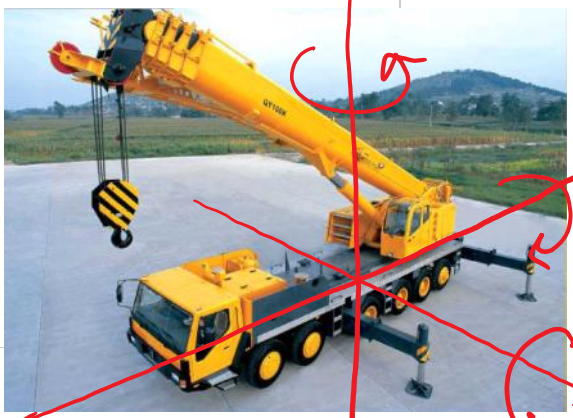
Chapter 5 Part II – 3-D Rigid Body

Equilibrium of a rigid body

tipping

with 2D, only worried about

$\vec{M} = [0, 0, 1]$



$\Sigma f_x = \Sigma f_y = \Sigma F_z = 0$

$\Sigma M_x = \Sigma M_y = \Sigma M_z = 0$

6 equations, can solve for 6 unknowns!


FBSARY

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TABLE 5–2 Supports for Rigid Bodies Subjected to Three-Dimensional Force Systems

Types of Connection	Reaction	Number of Unknowns
(1)  cable		One unknown. The reaction is a force which acts away from the member in the known direction of the cable.
(2)  smooth surface support		One unknown. The reaction is a force which acts perpendicular to the surface at the point of contact.
(3)  roller		One unknown. The reaction is a force which acts perpendicular to the surface at the point of contact.

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TABLE 5–2 Supports for Rigid Bodies Subjected to Three-Dimensional Force Systems

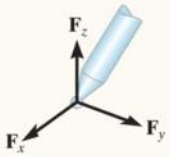
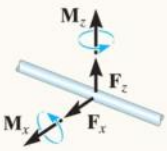
Types of Connection	Reaction	Number of Unknowns
(4)  ball and socket		Three unknowns. The reactions are three rectangular force components.
(5)  single journal bearing		Four unknowns. The reactions are two force and two couple-moment components which act perpendicular to the shaft. Note: The couple moments are *generally not applied* if the body is supported elsewhere. See the examples.

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TABLE 5–2 Continued

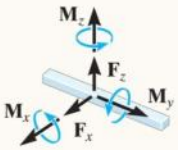
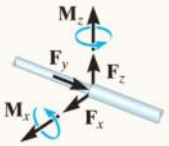
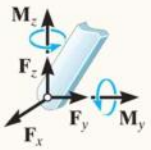
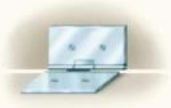
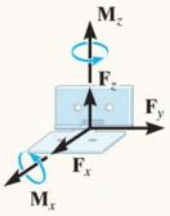
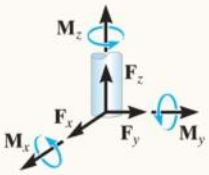
Types of Connection	Reaction	Number of Unknowns
(6)  single journal bearing with square shaft		Five unknowns. The reactions are two force and three couple-moment components. *Note*: The couple moments *are generally not applied* if the body is supported elsewhere. See the examples.
(7)  single thrust bearing		Five unknowns. The reactions are three force and two couple-moment components. *Note*: The couple moments *are generally not applied* if the body is supported elsewhere. See the examples.
(8)  single smooth pin		Five unknowns. The reactions are three force and two couple-moment components. *Note*: The couple moments *are generally not applied* if the body is supported elsewhere. See the examples.

TABLE 5–2 Continued

Types of Connection	Reaction	Number of Unknowns
(9)  single hinge		Five unknowns. The reactions are three force and two couple-moment components. *Note*: The couple moments *are generally not applied* if the body is supported elsewhere. See the examples.
(10)  fixed support		Six unknowns. The reactions are three force and three couple-moment components.

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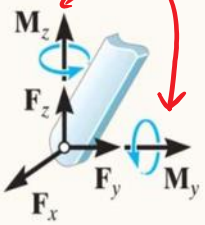
http://web.mst.edu/~ide50-3/schedule/lessons/13_Trusses.pdf

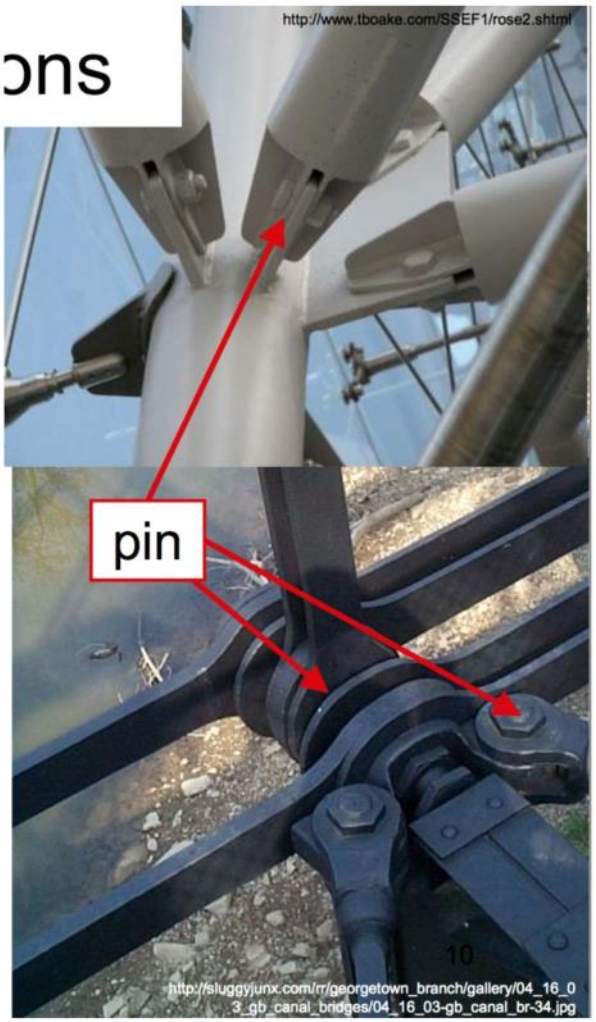
Cannot rotate about z or y, ∴ reactions

(8)

single smooth pin



Able to rotate about x, ∴ no reaction M_x



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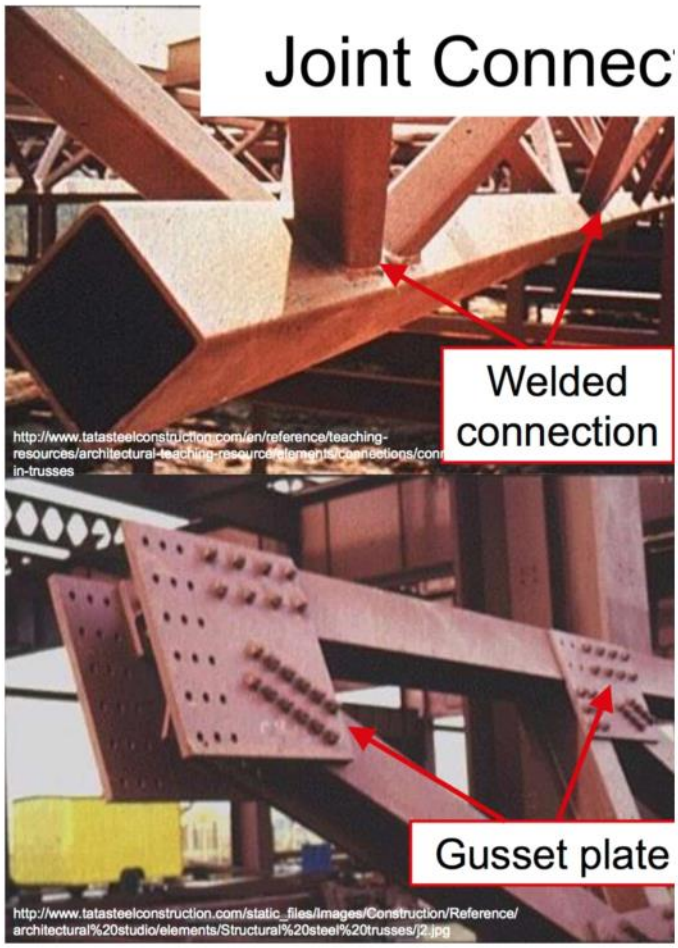
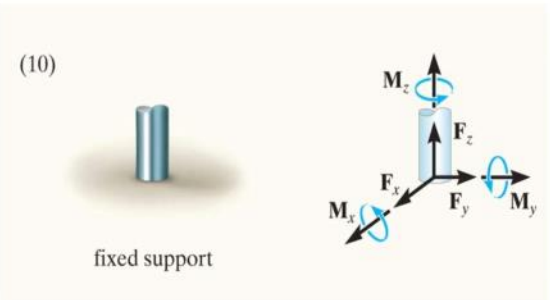


http://web.mst.edu/~ide50-3/schedule/lessons/13_Trusses.pdf



Does not allow ANY translation or rotation!

∴ 6 reaction!

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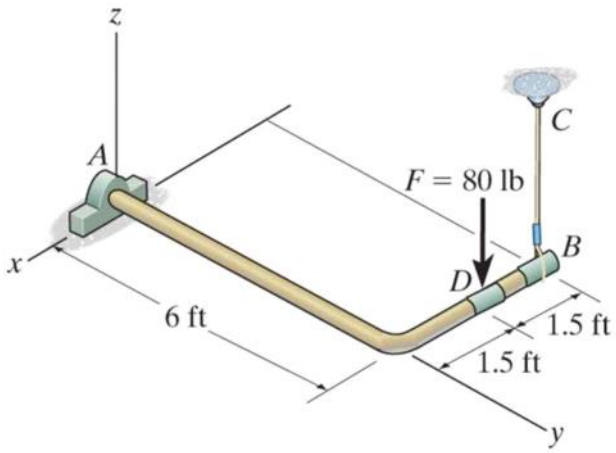
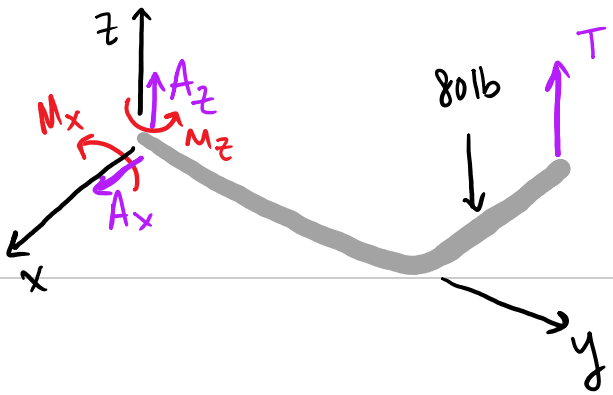


Given: The rod, supported by thrust bearing at A and cable BC, is subjected to an 80 lb force.

Find: Reactions at the thrust bearing A and cable BC.

DRAW the FBD of the ROD:



there ARE 5 unknowns.

eqns. of ΣM.

$\Sigma F_x = 0 \quad \therefore \quad \boxed{A_x = 0}$

$\Sigma F_y = 0$ none

$\Sigma F_z = 0 \quad \therefore \quad A_z + T - 80 = 0$

$$\Sigma M_y = 0 \quad \therefore \quad -80(1.5) + T(3) = 0$$

$$T = \frac{80(1.5)}{3} = \boxed{40 \text{ lb}}$$

$$\therefore \quad A_z = 80 - T = \boxed{40 \text{ lb}}$$

$$\Sigma M_x = 0 \quad \therefore \quad M_{A_x} + T(6) - 80(6) = 0$$

$$M_{A_x} = 6(80 - 40) = \boxed{240 \text{ lb·ft (ccw)}}$$

$$\Sigma M_z = 0 \quad \therefore \quad \boxed{M_{A_z} = 0}$$

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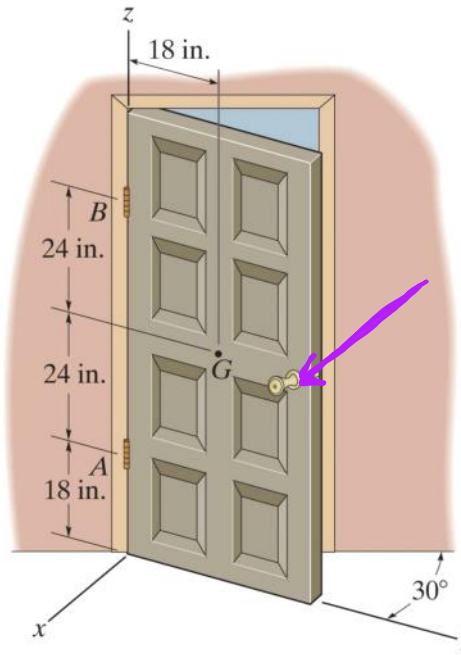
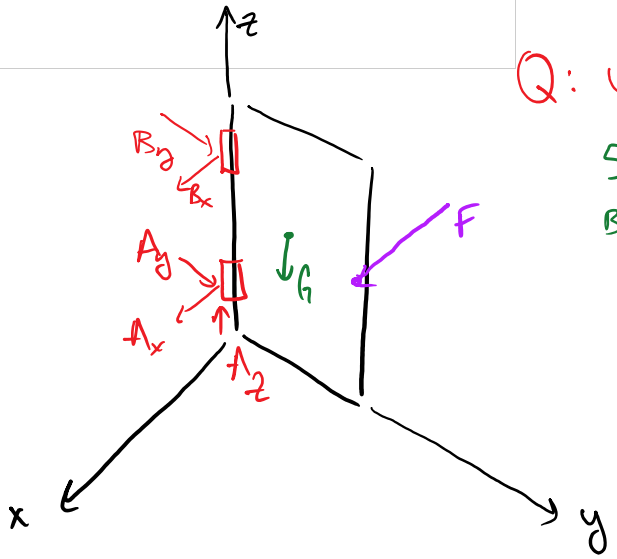


The 100 lb door has its center of gravity at *G*. Determine the components of reaction at hinges *A* and *B* if hinge B resists only forces in the x and y directions and A resists forces in the x, y, z directions.

$\vec{F} = F[1,0,0]$

Force At handle. F

- identify support reactions
- DRAW FBD, coordinates.



Q: unknowns?

5!

$B_x\ B_y\ A_x\ A_y\ A_z$

Sum the forces and moments.

$\Sigma f_x: \quad A_x + B_x + F = 0$

$\Sigma f_y: \quad A_y + B_y = 0$

Σf_y: $A_y + B_y = 0$

Σf_z: $A_z - G = 0 \Rightarrow$ $\boxed{A_z = G}$

ΣM_x: $-B_y(48) - (100)(18) = 0$

$B_y = \frac{-(100)(18)}{48} = \boxed{-37.5 \text{ lb}}$

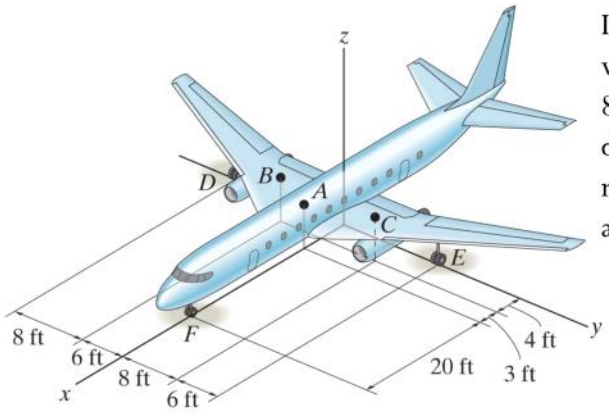
ΣM_y: $B_x(48) + F(24) = 0$

$B_x = -\frac{F(24)}{48} = \boxed{-\frac{F}{2}}$

now using

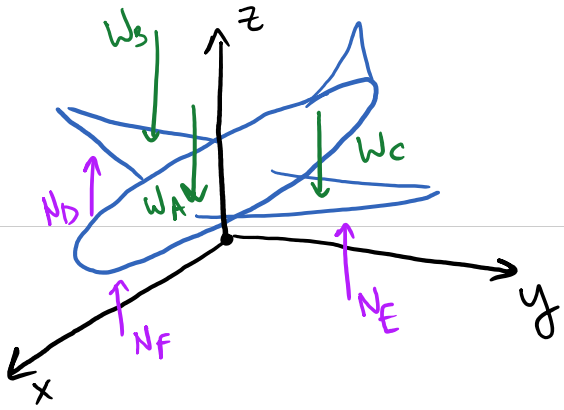
Σf_y: $A_y = -B_y = \boxed{37.5 \text{ lb}}$

Σf_x: $A_x = -B_x - F = \frac{F}{2} - F = \boxed{-\frac{F}{2}}$



If these components have weights $W_A = 45000$ lb, $W_B = 8000$ lb and $W_C = 6000$ lb, determine the normal reactions of the wheels D, E, and F on the ground.

DRAW the FBD of the plane:



3 unknowns.

eqns. of $\equiv M$.

$\Sigma F_x = 0$ none

$\Sigma f_y = 0$ none.

$\Sigma f_z = 0$ $\therefore$ $N_D + N_E + N_F - W_A - W_B - W_C = 0$

$\Sigma M_y = 0$ $\therefore$

$$-N_f(27) + W_A(7) + W_B(4) + W_C(4) = 0$$

$$N_F = \frac{W_A(7) + 4(W_B + W_C)}{27} = \boxed{13.7 \text{ kip}}$$

$\Sigma M_x = 0$ ∴

$$W_B(6) - N_D(14) - W_C(8) + N_E(14) = 0$$

use $\Sigma F_z = 0$, $N_D = W_A + W_B + W_C - N_E - N_f$

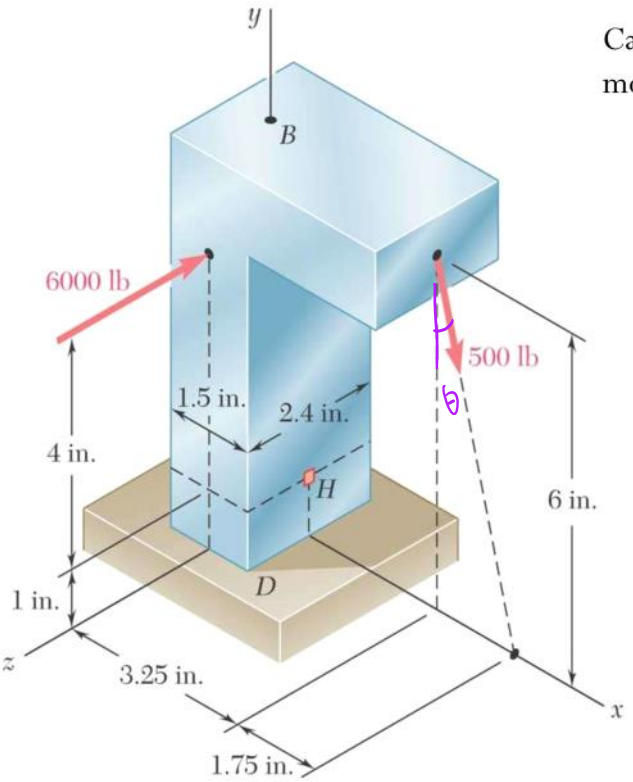
$$W_B(6) - (W_A + W_B + W_C - N_E - N_f)(14) - W_C(8) + N_E(14) = 0$$

Solve for N_E...

$$2N_E(14) = W_C(8) - W_B(6) + (W_A + W_B + W_C - N_F)14$$

$$\boxed{N_E = 22.6 \text{ kip}}$$

$$\boxed{N_D = 22.6 \text{ kip}}$$

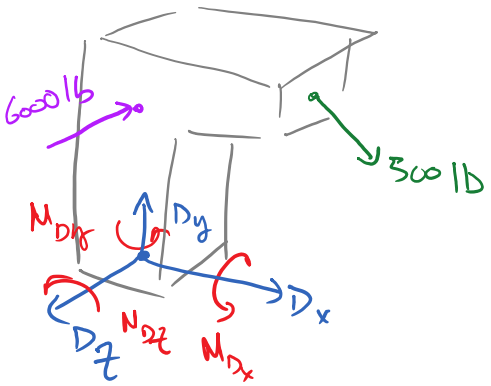


Calculate the reaction forces and moments at the support

- Rigid support w/ 6 unknowns!
- FBD & EoE

DRAW the FBD:

$$\sum \vec{F} = \begin{cases} \sum f_x = 0 \\ \sum f_y = 0 \\ \sum f_z = 0 \end{cases}$$



$$\sum \vec{M} = \begin{cases} \sum M_x = 0 \\ \sum M_y = 0 \\ \sum M_z = 0 \end{cases}$$

$\vec{r}_1 = [0.5, 1.2]$ in

$\vec{r}_2 = [3.25, 6, 0]$ in

$\vec{F}_1 = 6k[0, 0, -1]$ lb

$$\vec{F}_2 = 500[\sin\theta, -\cos\theta, 0]\,lb$$

$$\theta = \tan^{-1}\left(\frac{1.75}{6}\right) = 16.3^\circ$$

eqns. of ΣM:

Σf_x: $D_x + 500\sin\theta = 0$

Σf_y: $D_y - 500\cos\theta = 0$

Σf_z: $D_z - 6000 = 0$

ΣM_x: $M_{Dx} - (5)6000 = 0$

ΣM_y: $M_{Dy} = 0$

ΣM_z: $M_{Dz} - (3.25)500\cos\theta - (6)500\sin\theta = 0$

Solve system of equations!!