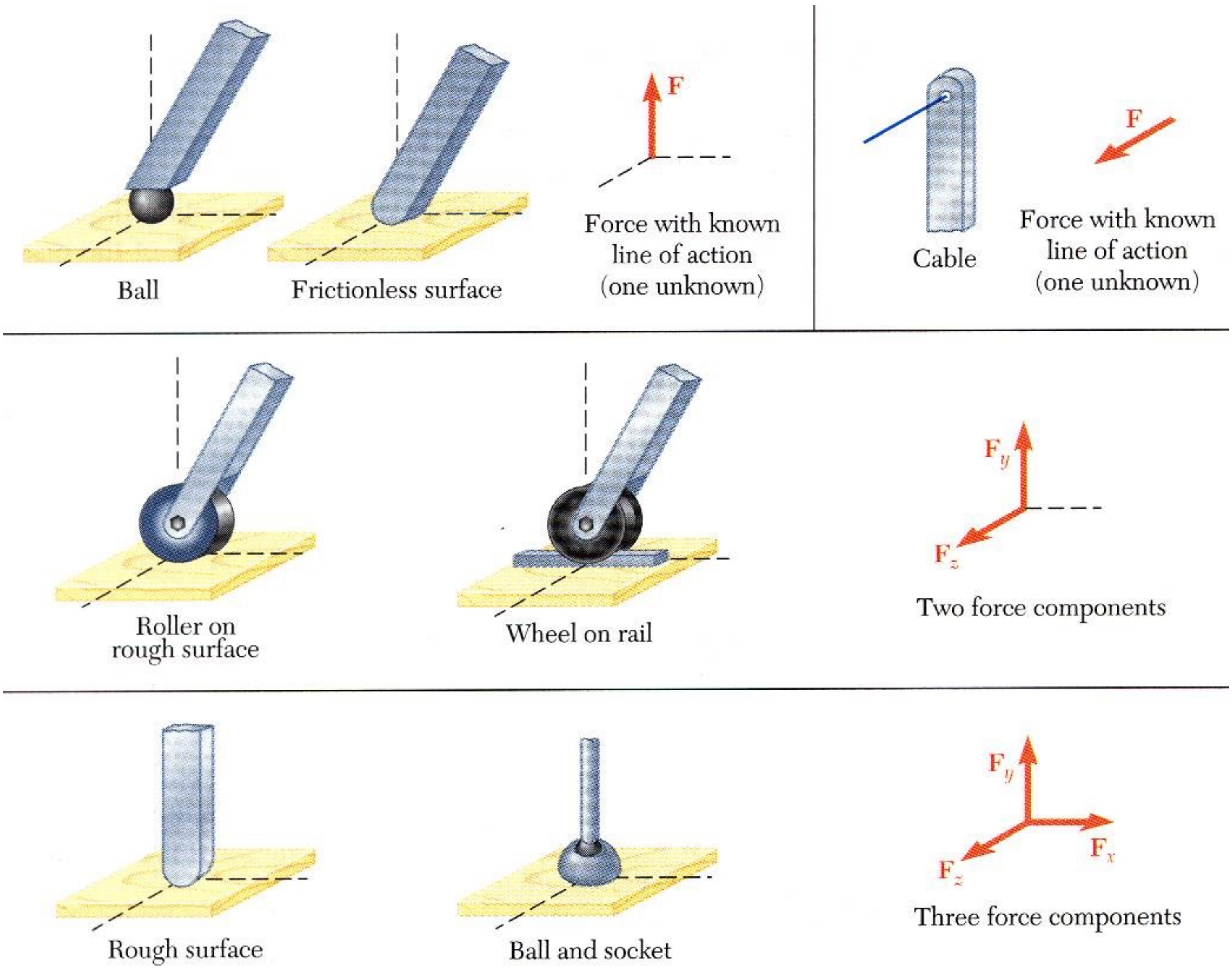
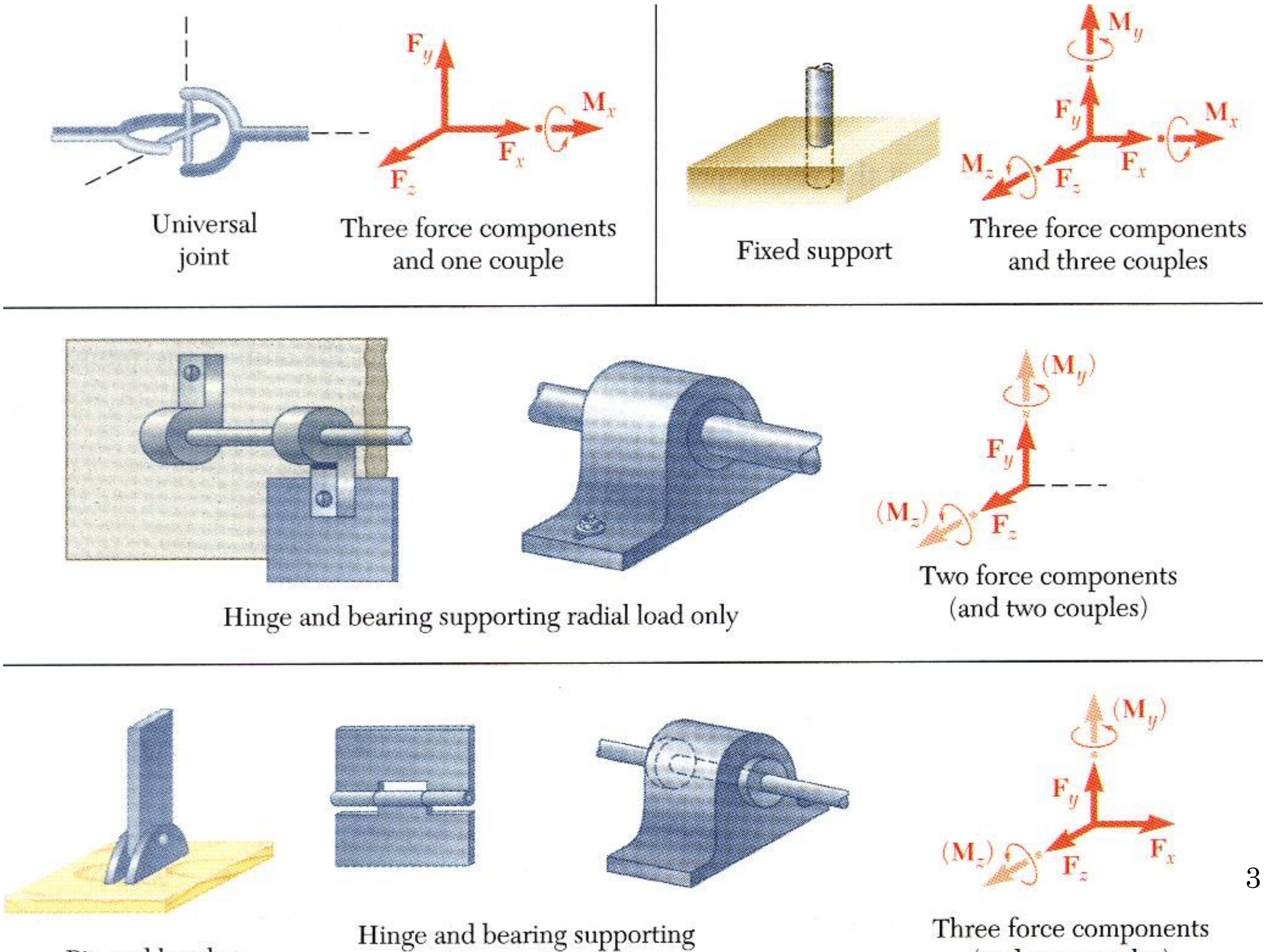
Engineering Mechanics

3D Equilibrium

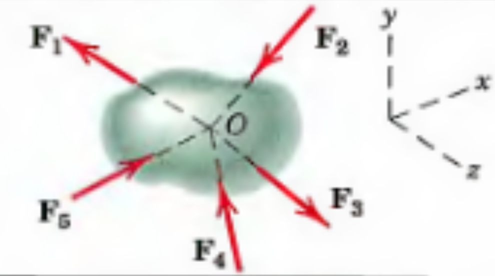
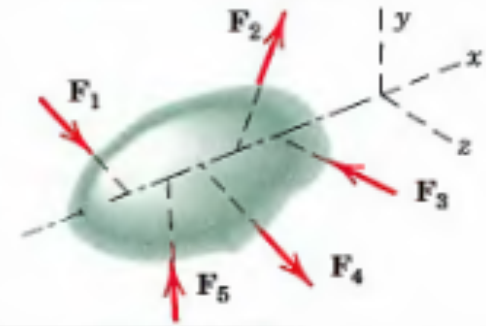
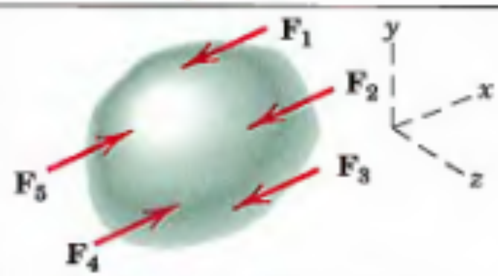
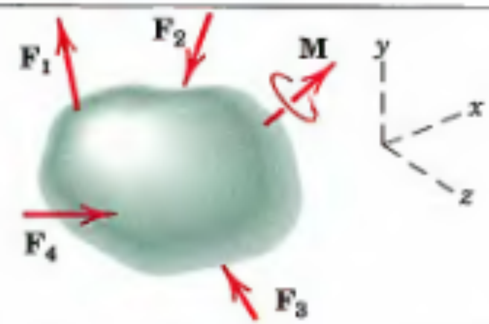
Support reactions in 3D structures



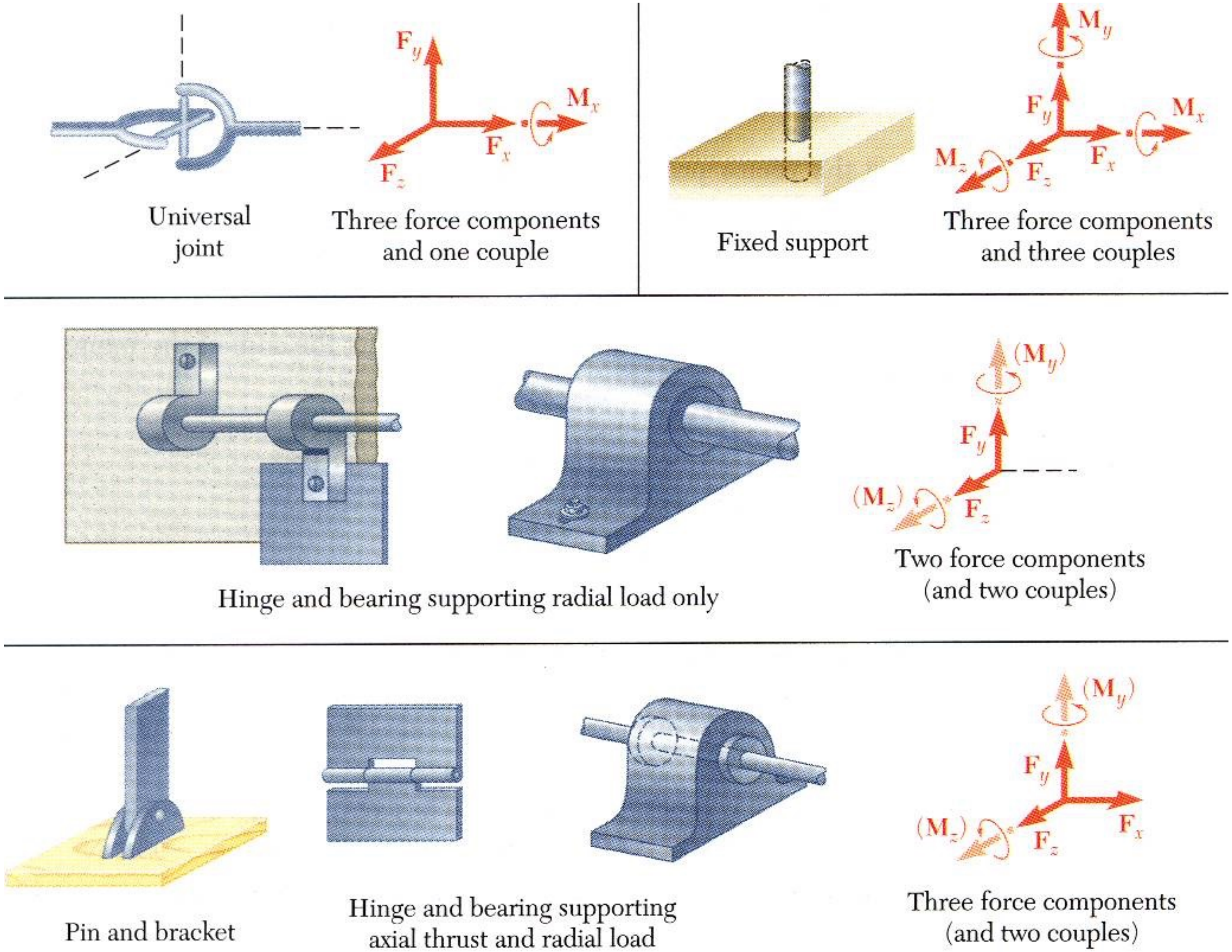
Support reactions in 3D Struct.



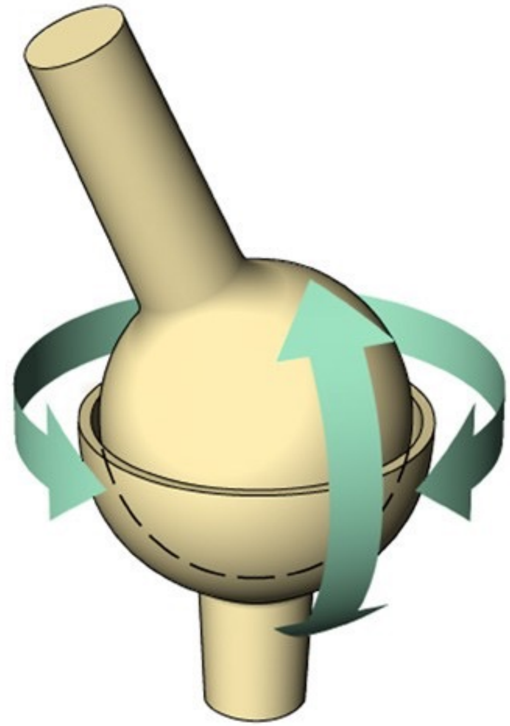
Categories of Equilibrium in 3D

CATEGORIES OF EQUILIBRIUM IN THREE DIMENSIONS		
Force System	Free-Body Diagram	Independent Equations
1. Concurrent at a point		$\Sigma F_x = 0$ $\Sigma F_y = 0$ $\Sigma F_z = 0$
2. Concurrent with a line		$\Sigma F_x = 0$ $\Sigma M_y = 0$ $\Sigma F_y = 0$ $\Sigma M_z = 0$ $\Sigma F_z = 0$
3. Parallel		$\Sigma F_x = 0$ $\Sigma M_y = 0$ $\Sigma M_z = 0$
4. General		$\Sigma F_x = 0$ $\Sigma M_x = 0$ $\Sigma F_y = 0$ $\Sigma M_y = 0$ $\Sigma F_z = 0$ $\Sigma M_z = 0$

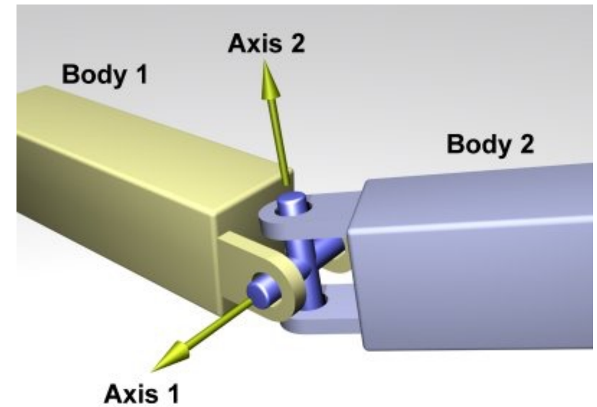
Reactions at Supports and Connections for a Three-Dimensional Structure



Ball Support (or ball caster)

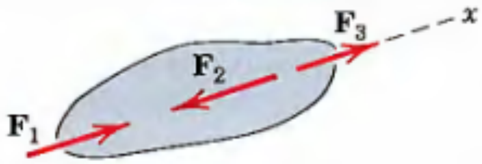
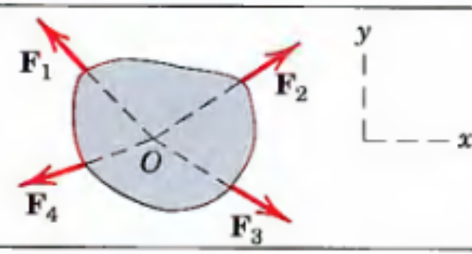
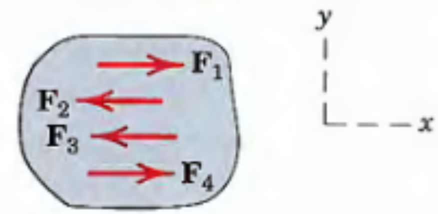
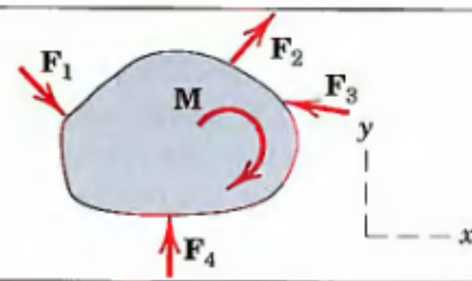


Ball and socket joint

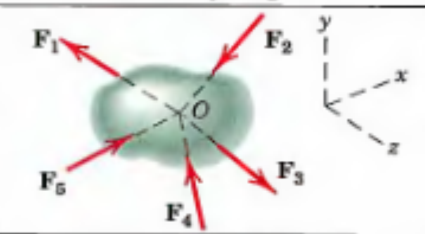
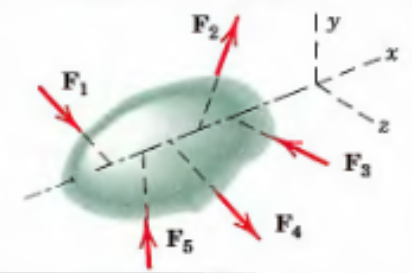
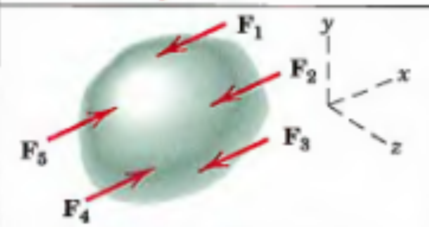
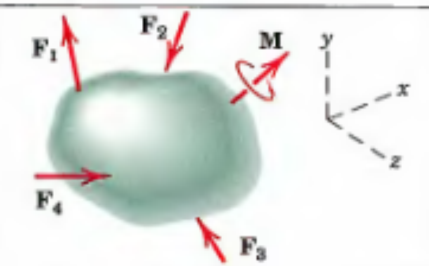


Universal Joint

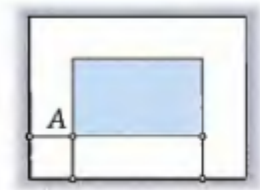
Categories of Equilibrium in 2D

CATEGORIES OF EQUILIBRIUM IN TWO DIMENSIONS		
Force System	Free-Body Diagram	Independent Equations
1. Collinear		$\Sigma F_x = 0$
2. Concurrent at a point		$\Sigma F_x = 0$ $\Sigma F_y = 0$
3. Parallel		$\Sigma F_x = 0$ $\quad \Sigma M_z = 0$
4. General		$\Sigma F_x = 0$ $\quad \Sigma M_z = 0$ $\Sigma F_y = 0$

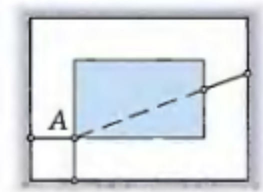
Conditions of Equilibrium

CATEGORIES OF EQUILIBRIUM IN THREE DIMENSIONS			
Force System	Free-Body Diagram	Independent Equations	
1. Concurrent at a point		$\Sigma F_x = 0$ $\Sigma F_y = 0$ $\Sigma F_z = 0$	
2. Concurrent with a line		$\Sigma F_x = 0$ $\Sigma F_y = 0$ $\Sigma F_z = 0$	$\Sigma M_y = 0$ $\Sigma M_z = 0$
3. Parallel		$\Sigma F_x = 0$	$\Sigma M_y = 0$ $\Sigma M_z = 0$
4. General		$\Sigma F_x = 0$ $\Sigma F_y = 0$ $\Sigma F_z = 0$	$\Sigma M_x = 0$ $\Sigma M_y = 0$ $\Sigma M_z = 0$

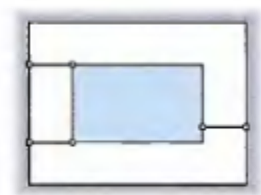
Adequacy of Constraints



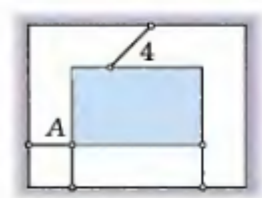
(*a*) Complete fixity
Adequate constraints



(*b*) Incomplete fixity
Partial constraints



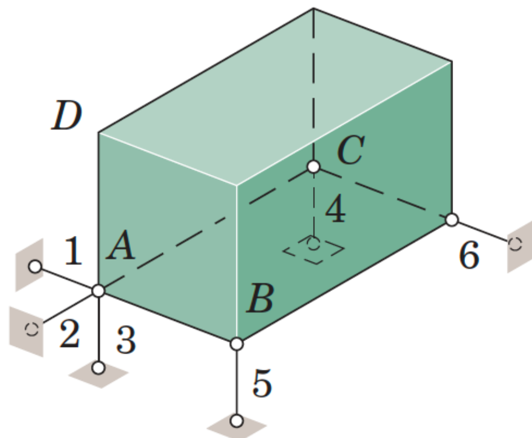
(*c*) Incomplete fixity
Partial constraints



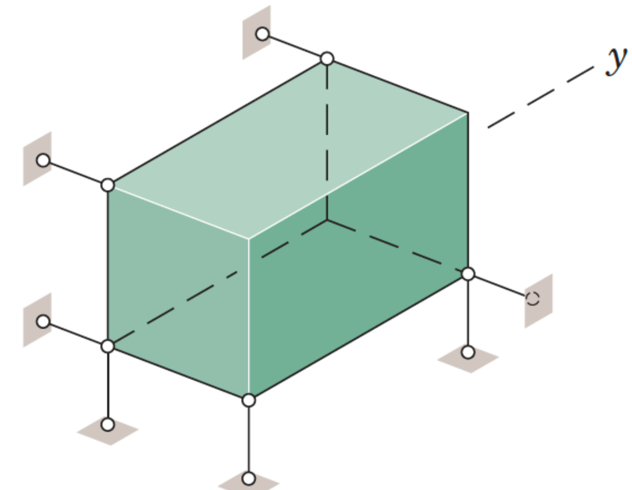
(*d*) **Excessive fixity**
Redundant constraint

Adequacy of Constraints

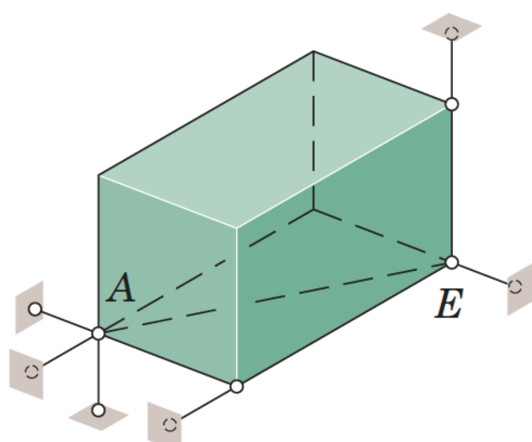
In



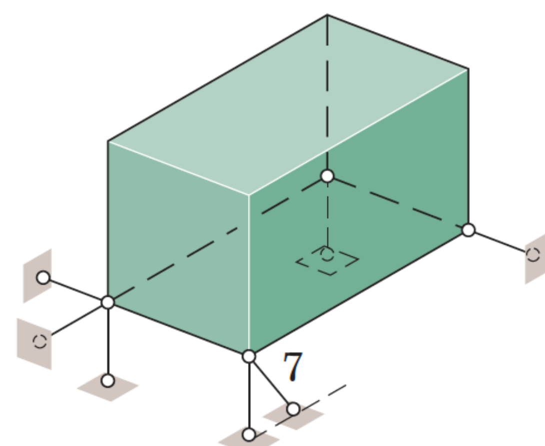
(a) Complete fixity
Adequate constraints



(c) Incomplete fixity
Partial constraints



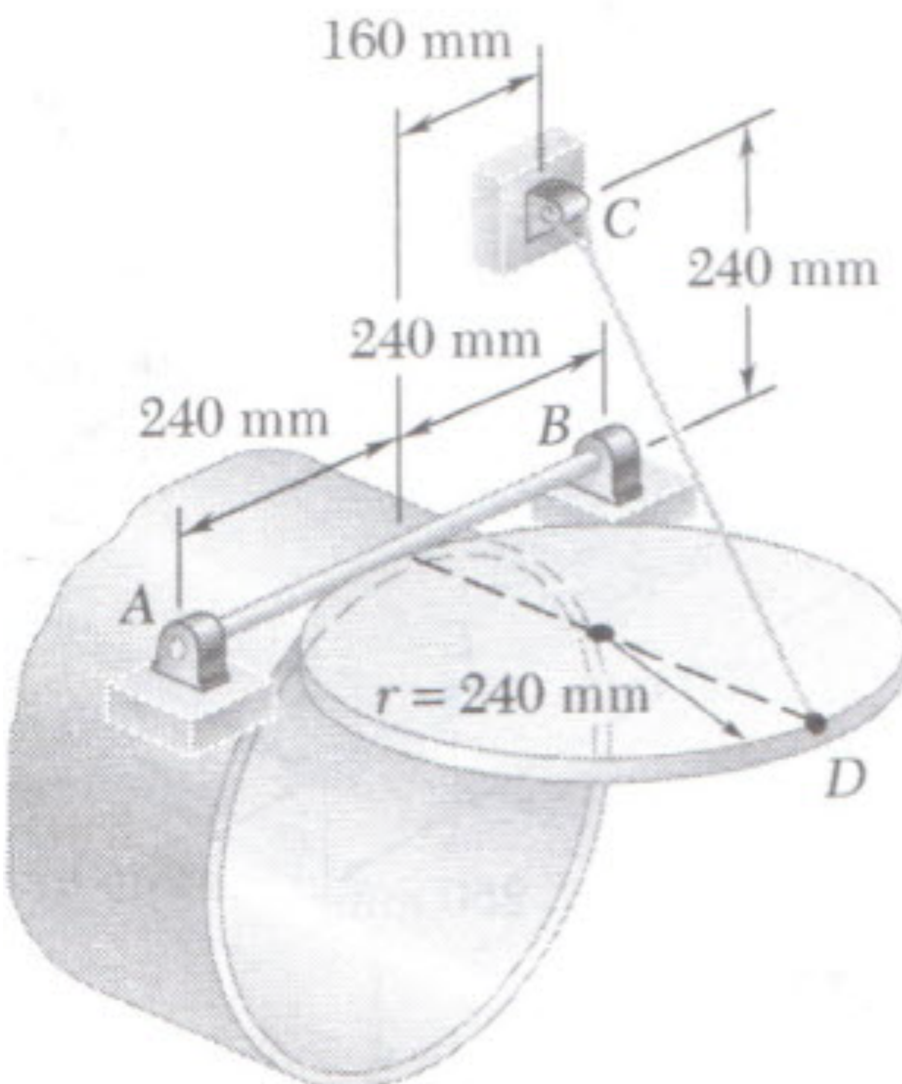
(b) Incomplete fixity
Partial constraints

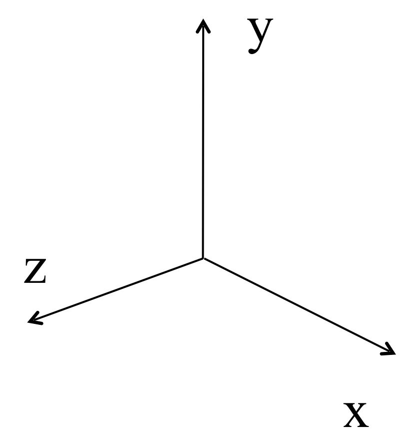


(d) Excessive fixity
Redundant constraints

Problem 23

A uniform pipe cover of radius r = 240 mm and mass 30 kg is held in a horizontal position by the cable CD. Determine the tension in the cable.

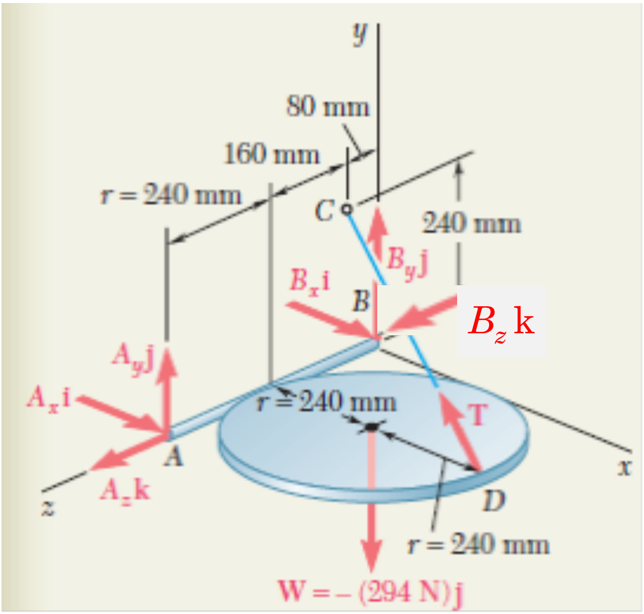




Problem 23 - Solution

Weight of pipe cover, W = 30 kg x 9.81 m/s^2 = 294 N

The reactions acting at points A and B would also consist of couples about the x and y axes. However these couples are not shown in the FBD as they are not significant in this problem and the tension in the cable can be obtained without taking these couples into consideration.



The self weight and cable tension acting on the pipe cover can be represented as follows:

$$\vec{W} = (-294N)\vec{j}$$

$$\vec{T} = T\hat{r}_{DC}$$

$$B = (0,0,0),\ C \equiv (0, 240mm, 80mm),\ D \equiv (480mm, 0, 240mm),$$

$$\vec{r}_{DC} = \vec{r}_{BC} - \vec{r}_{BD} = (-480mm)\vec{i} + (240mm)\vec{j} + (-160mm)\vec{k}$$

$$|\vec{r}_{DC}| = \sqrt{((480mm)^2 + (240mm)^2 + (160mm)^2)} = 560mm$$

$$\hat{r}_{DC} = \left(-\frac{6}{7}\right)\vec{i} + \left(\frac{3}{7}\right)\vec{j} + \left(-\frac{2}{7}\right)\vec{k}$$

Problem 23 - Solution

$$\vec{W} = (-294N)\vec{j}$$

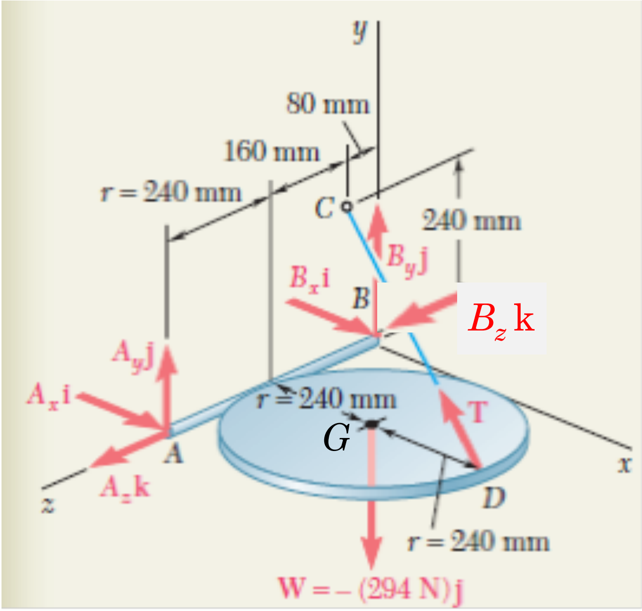
$$\vec{T} = T\left[\left(-\frac{6}{7}\right)\vec{i} + \left(\frac{3}{7}\right)\vec{j} + \left(-\frac{2}{7}\right)\vec{k}\right]$$

$$\sum M_{Bz} = 0$$

$$\vec{k}.\vec{r}_{BG} \times W + \vec{k}.\vec{r}_{BD} \times \vec{T} = 0$$

$$\vec{r}_{BG} = (240mm)\vec{i} + (240mm)\vec{k}$$

$$\vec{r}_{BD} = (480mm)\vec{i} + (240mm)\vec{k}$$



$$\therefore \begin{vmatrix} 0 & 0 & 1 \\ 240mm & 0 & 240mm \\ 0 & -294N & 0 \end{vmatrix} + T\begin{vmatrix} 0 & 0 & 1 \\ 480mm & 0 & 240mm \\ -\frac{6}{7} & \frac{3}{7} & -\frac{2}{7} \end{vmatrix} = 0$$

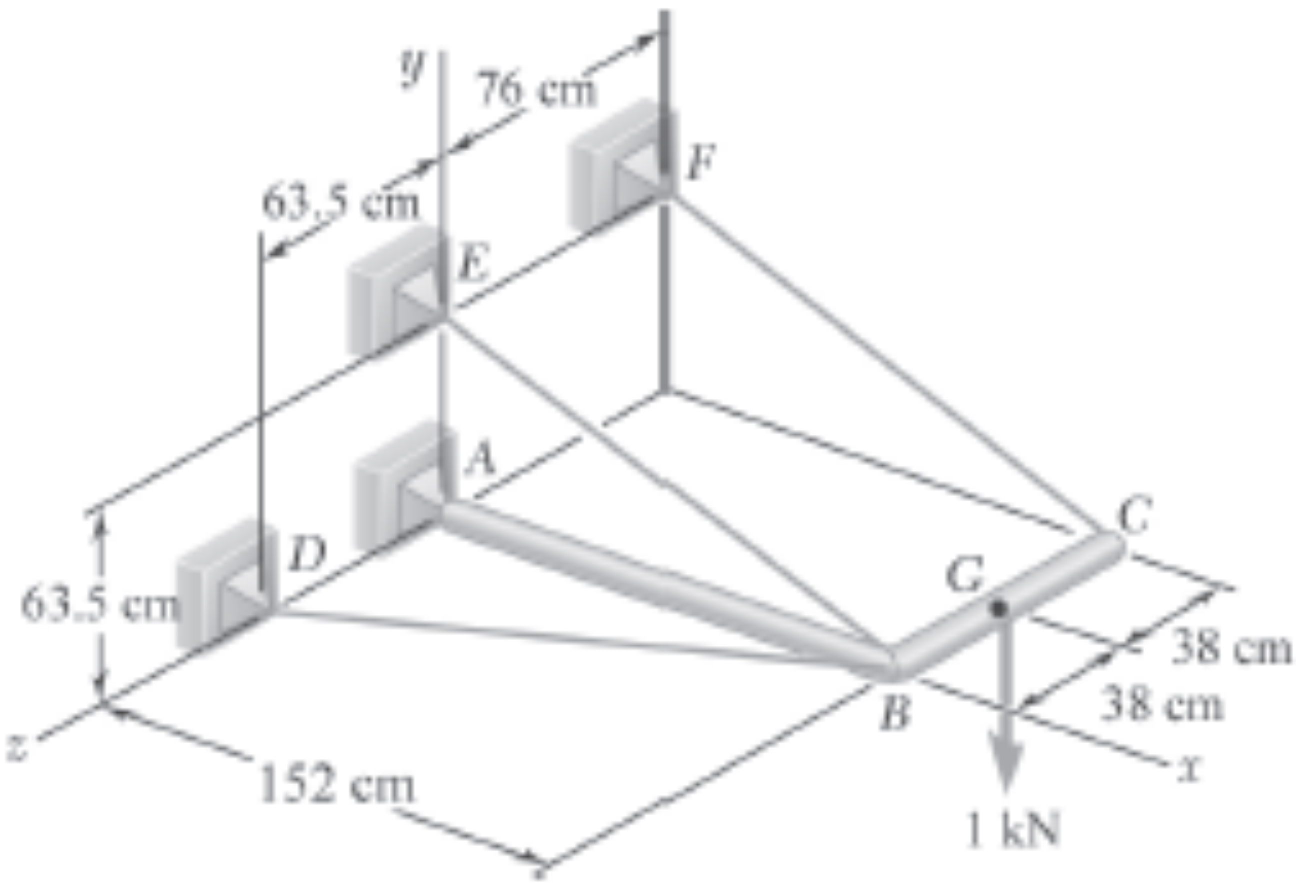
$$\Rightarrow (-294N)(240mm) + T.\frac{3}{7}(480mm) = 0$$

$$\Rightarrow T = \frac{(294N)(240mm)}{\frac{3}{7}(480mm)}$$

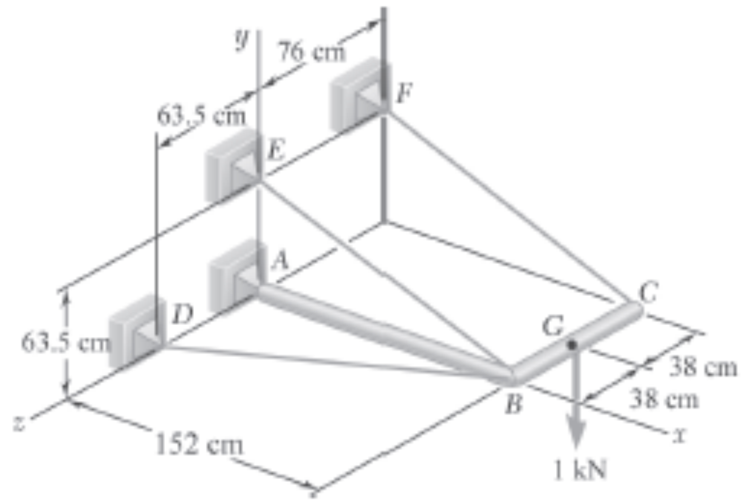
$$T = 343N$$

Problem 24

The rigid L-shaped member ABC is supported by a ball-and-socket joint at A and by three cables. Determine the tension in each cable and the reaction at A caused by the 1 kN load applied at G.



Problem 24 - Solution



$A \equiv (0,0,0)$, $B \equiv (152,0,0)$, $C \equiv (152,0,-76)$,

$D \equiv (0,0,63.5)$, $E \equiv (0,63.5,0)$,

$F \equiv (0,63.5,-76)$, $G \equiv (152,0,-38)$.

$$\vec{r}_{BD} = \vec{r}_{AD} - \vec{r}_{AB} = (-152cm)\vec{i} + (63.5cm)\vec{k} \Rightarrow \hat{r}_{BD} = -0.923\vec{i} + 0.385\vec{k}$$

$$\vec{r}_{BE} = \vec{r}_{AE} - \vec{r}_{AB} = (-152cm)\vec{i} + (63.5cm)\vec{j} \Rightarrow \hat{r}_{BE} = -0.923\vec{i} + 0.385\vec{j}$$

$$\vec{r}_{CF} = \vec{r}_{AF} - \vec{r}_{AC} = (-152cm)\vec{i} + (63.5cm)\vec{j} \Rightarrow \hat{r}_{CF} = -0.923\vec{i} + 0.385\vec{j}$$

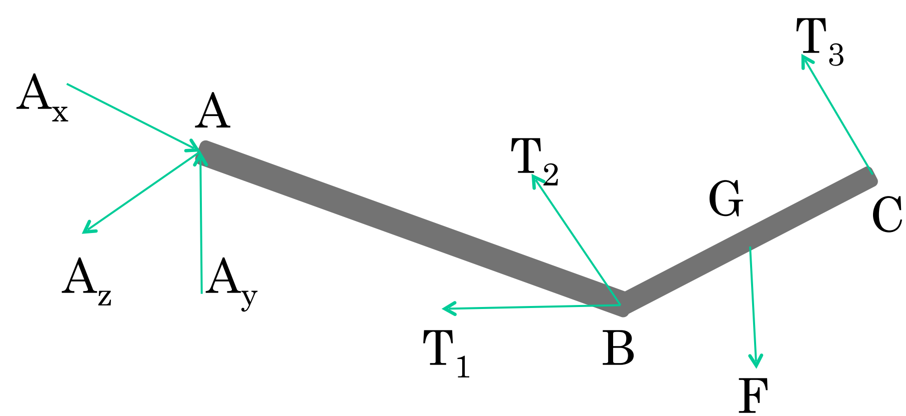
$$\vec{T}_1 = T_1\hat{r}_{BD} = T_1(-0.923\vec{i} + 0.385\vec{k})$$

$$\vec{T}_2 = T_2\hat{r}_{BE} = T_2(-0.923\vec{i} + 0.385\vec{j})$$

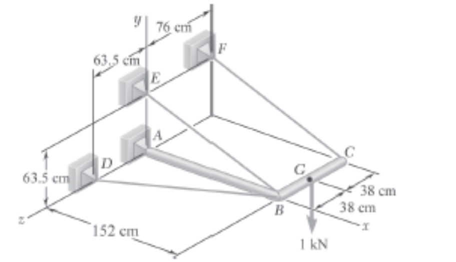
$$\vec{T}_3 = T_3\hat{r}_{CF} = T_3(-0.923\vec{i} + 0.385\vec{j})$$

$$\vec{F} = 1(-\vec{j})kN$$

$$\vec{R}_A = A_x\vec{i} + A_y\vec{j} + A_z\vec{k}$$



Problem 24 - Solution



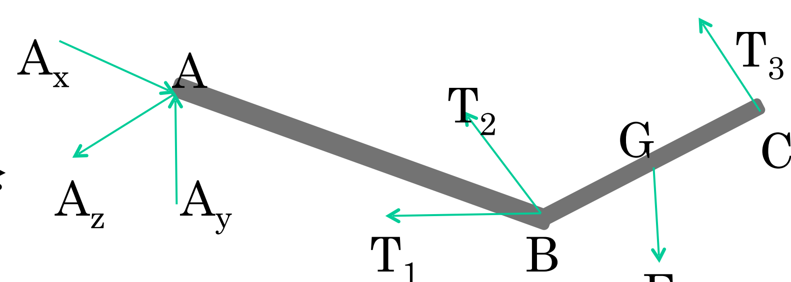
$$\vec{T}_1 = T_1\hat{r}_{BD} = T_1(-0.923\vec{i} + 0.385\vec{k})$$
$$\vec{T}_2 = T_2\hat{r}_{BE} = T_2(-0.923\vec{i} + 0.385\vec{j})$$
$$\vec{T}_3 = T_3\hat{r}_{CF} = T_3(-0.923\vec{i} + 0.385\vec{j})$$
$$\vec{F} = 1(-\vec{j})kN$$
$$\vec{R}_A = A_x\vec{i} + A_y\vec{j} + A_z\vec{k}$$

$$\sum \vec{M}_A = 0 \Rightarrow \vec{r}_{AB}\times\vec{T}_1 + \vec{r}_{AB}\times\vec{T}_2 + \vec{r}_{AG}\times\vec{F} + \vec{r}_{AC}\times\vec{T}_3 = 0$$

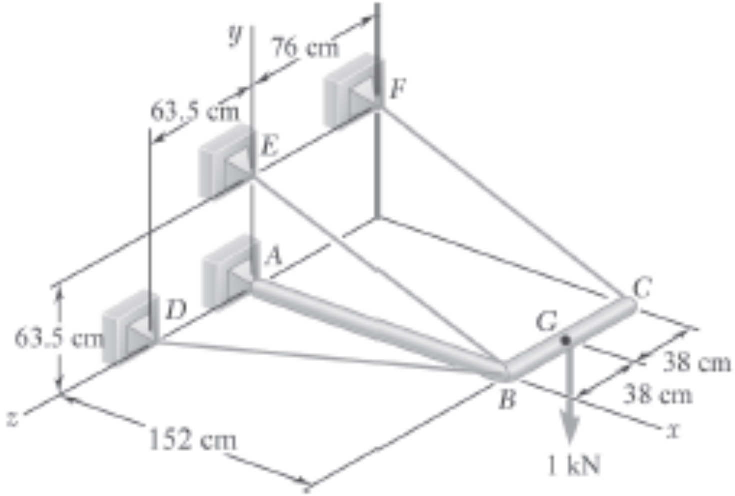
$$\Rightarrow T_1\begin{vmatrix}\vec{i} & \vec{j} & \vec{k}\\ 152cm & 0 & 0\\ -0.923 & 0 & 0.385\end{vmatrix} + T_2\begin{vmatrix}\vec{i} & \vec{j} & \vec{k}\\ 152cm & 0 & 0\\ -0.923 & 0.385 & 0\end{vmatrix}$$

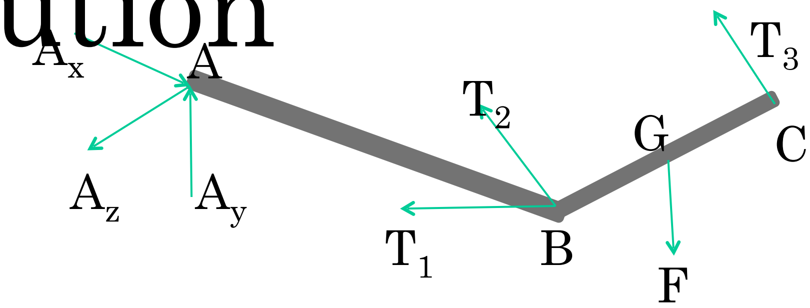
$$+\begin{vmatrix}\vec{i} & \vec{j} & \vec{k}\\ 152cm & 0 & -38cm\\ 0 & -1 & 0\end{vmatrix} + T_3\begin{vmatrix}\vec{i} & \vec{j} & \vec{k}\\ 152cm & 0 & -76cm\\ -0.923 & 0.385 & 0\end{vmatrix} = 0$$

$$\Rightarrow T_1(-58.52\vec{j}) + T_2(58.52\vec{k}) + (-38\vec{i} - 152\vec{k})$$
$$+ T_3(29.26\vec{i} + 70.148\vec{j} + 58.52\vec{k}) = 0$$
$$\Rightarrow (-38 + 29.26T_3)\vec{i} + (-58.52T_1 + 70.148T_3)\vec{j}$$
$$+ (58.52T_2 - 152 + 58.52T_3)\vec{k} = 0$$



Problem 24 - lution





$$\sum M_A = (-38 + 29.26T_3)\vec{i} + (-58.52T_1 + 70.148T_3)\vec{j}$$

$$+ (58.52T_2 - 152 + 58.52T_3)\vec{k} = 0$$

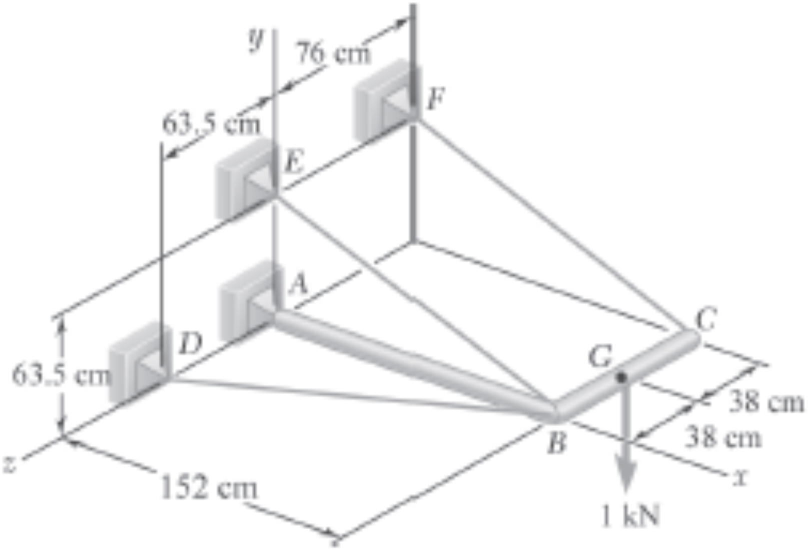
Equating the individual moment components of M_A to zero we get three equations of equilibrium as shown below:

$$-38 + 29.26T_3 = 0 \qquad T_3 = 1.3kN$$

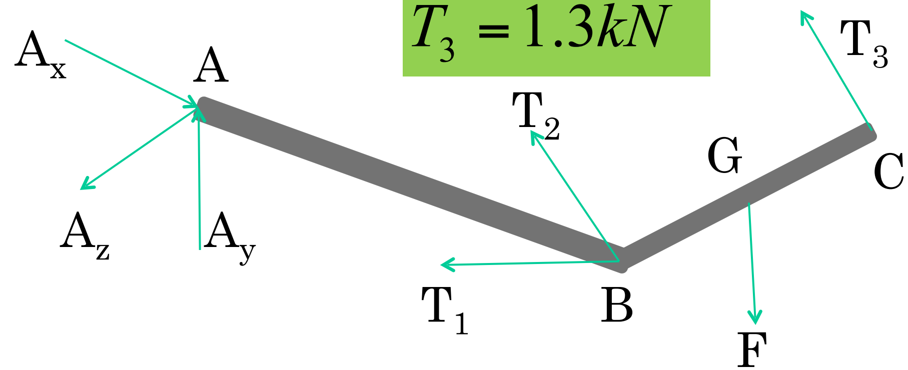
$$-58.52T_1 + 70.148T_3 = 0 \qquad T_1 = 1.56kN$$

$$58.52T_2 - 152 + 58.52T_3 = 0 \qquad T_2 = 1.3kN$$

Problem 24 - Solution



$$T_1 = 1.56kN$$
$$T_2 = 1.3kN$$
$$T_3 = 1.3kN$$



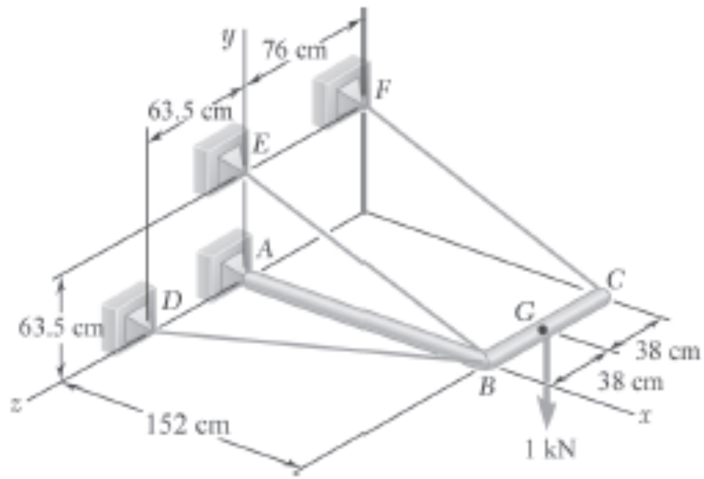
$$\vec{T}_1 = T_1\hat{r}_{BD} = T_1(-0.923\vec{i} + 0.385\vec{k})$$
$$\vec{T}_2 = T_2\hat{r}_{BE} = T_2(-0.923\vec{i} + 0.385\vec{j})$$
$$\vec{T}_3 = T_3\hat{r}_{CF} = T_3(-0.923\vec{i} + 0.385\vec{j})$$
$$\vec{F} = 1(-\vec{j})kN$$
$$\vec{R}_A = A_x\vec{i} + A_y\vec{j} + A_z\vec{k}$$

$$\sum \vec{F} = 0 \Rightarrow \vec{T}_1 + \vec{T}_2 + \vec{T}_3 + \vec{F} + \vec{R}_A = 0.$$

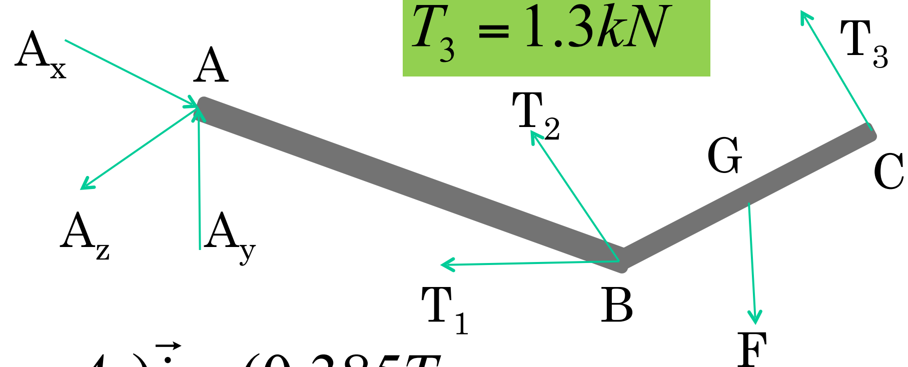
$$T_1(-0.923\vec{i} + 0.385\vec{k}) + T_2(-0.923\vec{i} + 0.385\vec{j})$$
$$+ T_3(-0.923\vec{i} + 0.385\vec{j}) + 1(-\hat{j}) + A_x\vec{i} + A_y\vec{j} + A_z\vec{k} = 0$$

$$(-0.923T_1 - 0.923T_2 - 0.923T_3 + A_x)\vec{i} + (0.385T_2 +$$
$$0.385T_3 + A_y - 1)\vec{j} + (0.385T_1 + A_z)\vec{k} = 0$$

Problem 24 - Solution



$$T_1 = 1.56kN$$
$$T_2 = 1.3kN$$
$$T_3 = 1.3kN$$



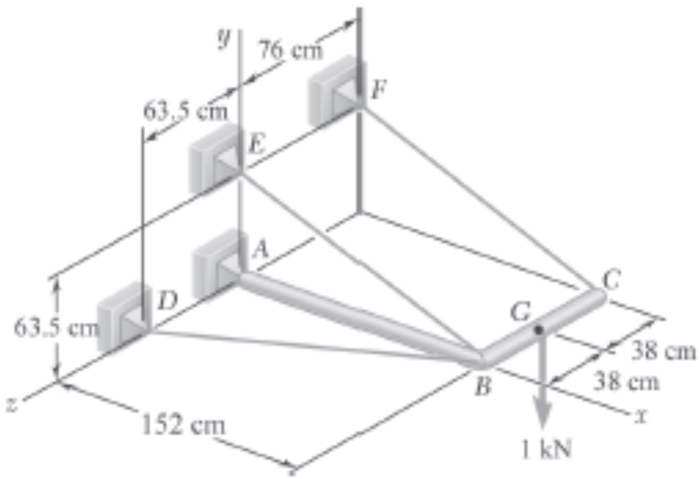
$$\sum \vec{F} = (-0.923T_1 - 0.923T_2 - 0.923T_3 + A_x)\vec{i} + (0.385T_2 + 0.385T_3 + A_y - 1)\vec{j} + (0.385T_1 + A_z)\vec{k} = 0$$

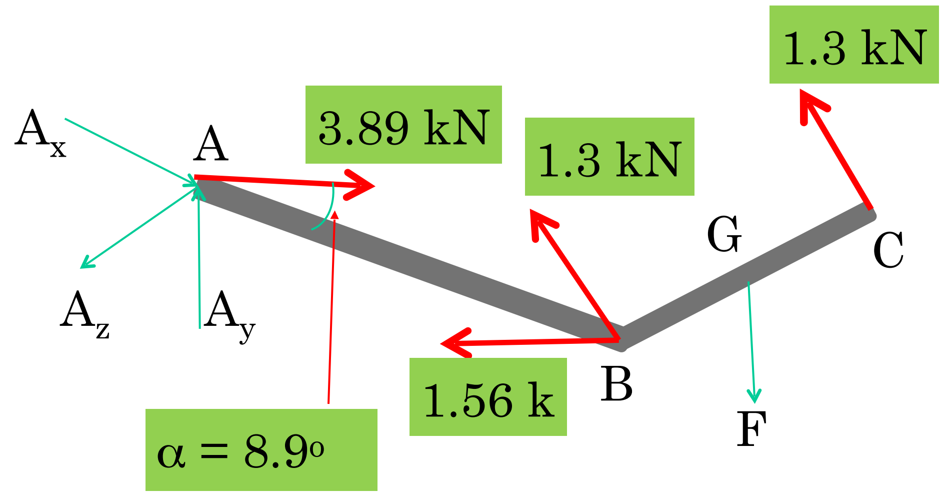
Equating the individual force components to zero we get three equations of equilibrium as shown below:

$$-0.923T_1 - 0.923T_2 - 0.923T_3 + A_x = 0$$
$$0.385T_2 + 0.385T_3 + A_y - 1 = 0$$
$$0.385T_1 + A_z = 0$$

$$A_x = 3.84kN$$
$$A_y = 0$$
$$A_z = -0.6kN$$

Problem 24 - Solution





$$A_x = 3.84kN$$
$$A_y = 0$$
$$A_z = -0.6kN$$

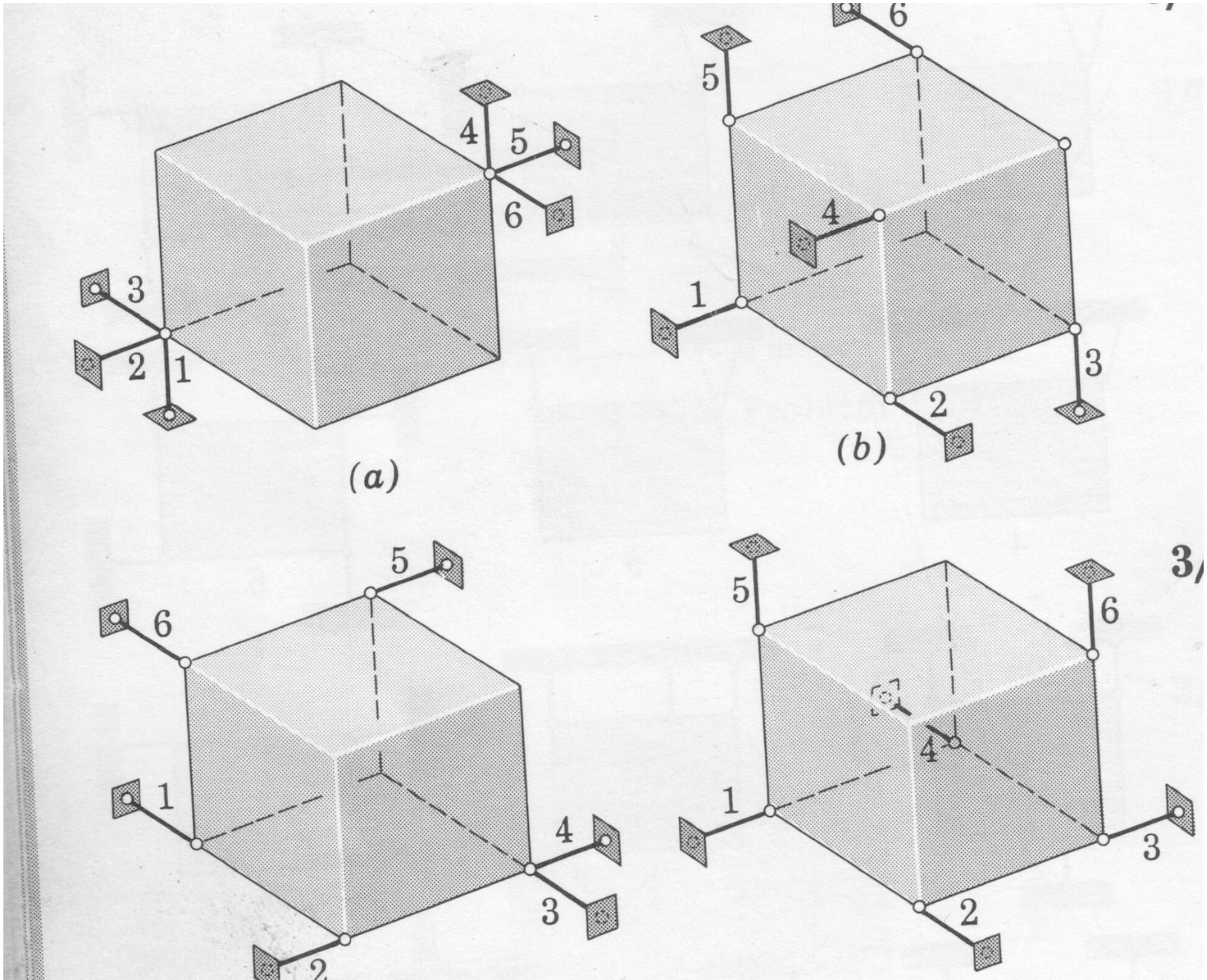
$$T_1 = 1.56kN$$
$$T_2 = 1.3kN$$
$$T_3 = 1.3kN$$

$$R_A = \sqrt{A_x^2 + A_y^2 + A_z^2} = 3.89kN$$

$$\alpha = \tan^{-1}\left(\frac{A_z}{A_x}\right) = \tan^{-1}\left(\frac{0.6N}{3.84N}\right)$$

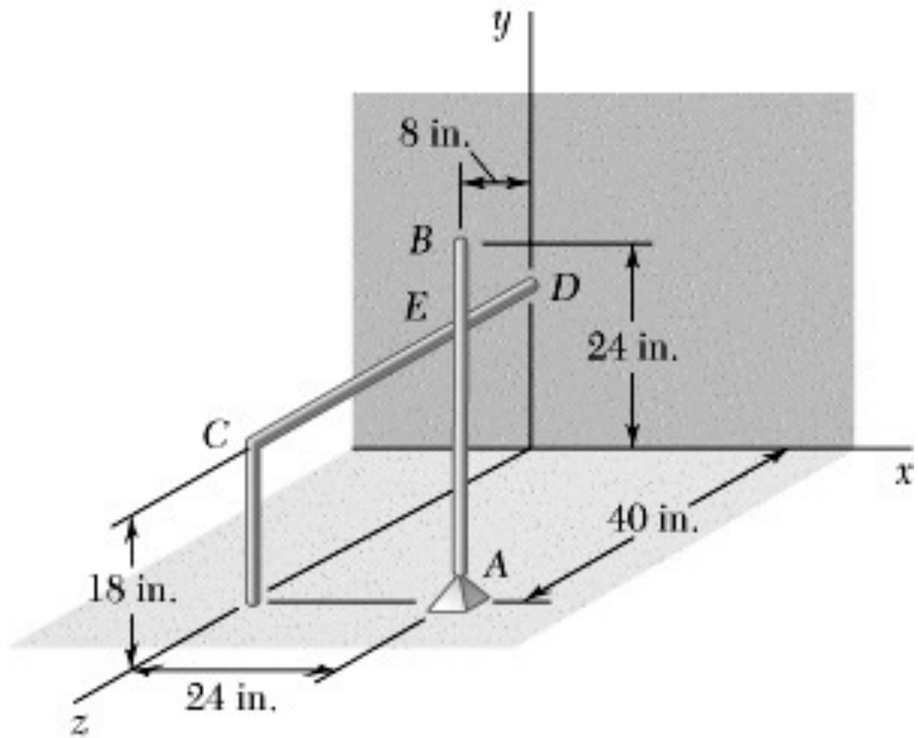
$$\alpha = 8.9^O$$

Check Stability



Problem A

- The uniform 10-lb rod *AB* is supported by a ball-and-socket joint at *A* and leans against both the rod *CD* and the vertical wall. Neglecting the effects of friction, determine (*a*) the force which rod *CD* exerts on *AB*, (*b*) the reactions at *A* and *B*.

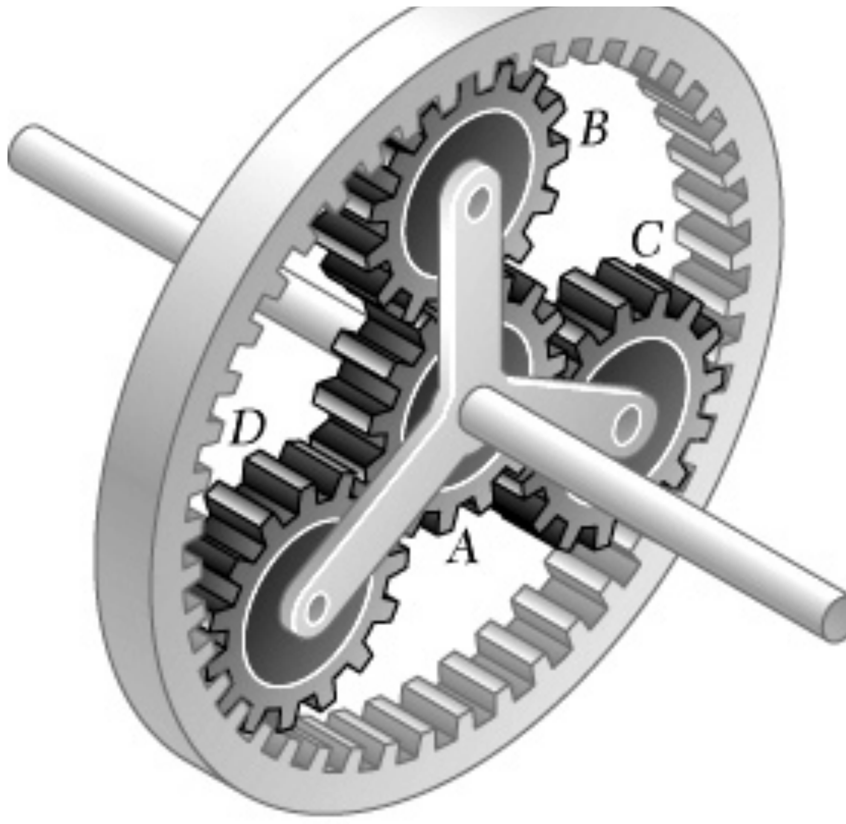


$\mathbf{B} = (3.00 \text{ lb})\mathbf{k}$ $\mathbf{E} = (3.20 \text{ lb})\mathbf{i} + (4.27 \text{ lb})\mathbf{j}$ $\mathbf{A} = -(3.20 \text{ lb})\mathbf{i} + (5.73 \text{ lb})\mathbf{j} - (3.00 \text{ lb})\mathbf{k}$

Problem B

In the planetary gear system shown, the radius of the central gear *A* **is** $\boldsymbol{a}$ **= 24 mm**, the radius of the planetary gears is b, and the radius of the outer gear *E* is

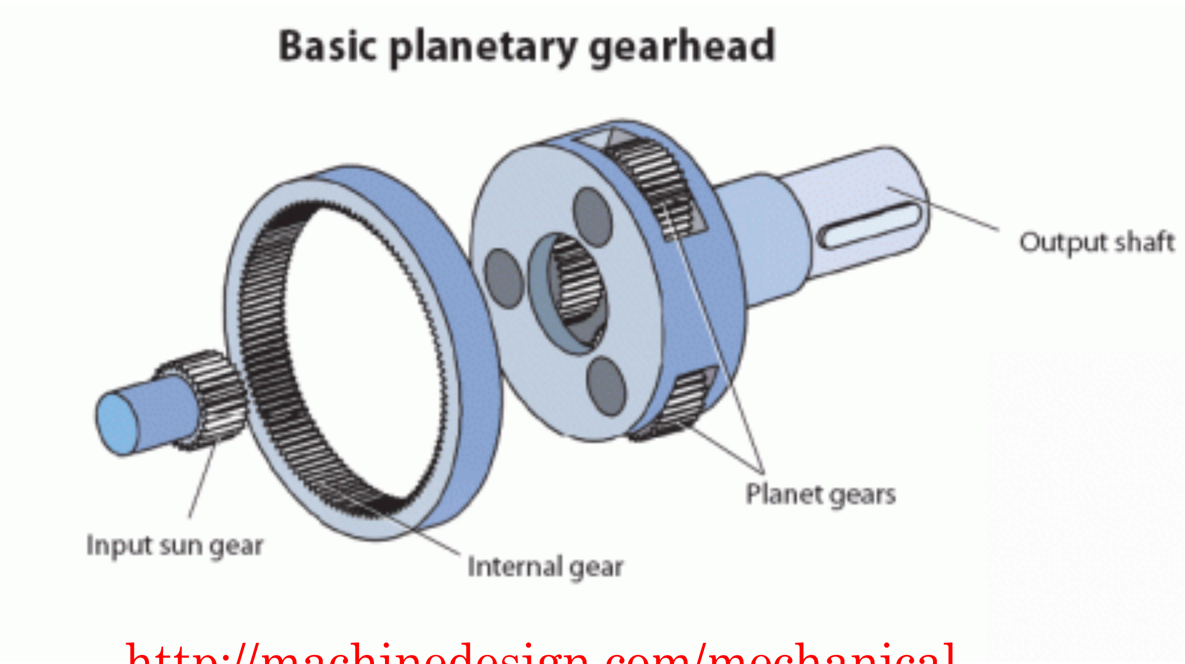
(a+2b). A clockwise couple of magnitude 15N.m is applied to the central gear *A*, and a counterclockwise couple of magnitude 75N.m is applied to the spider *BCD*. If the system is to be in equilibrium, determine (*a*) the required radius b of the planetary gears, (*b*) the couple M_E that must be applied to the outer gear *E*.



$r_B = 36.0$ mm

$\mathbf{M}_E = 60.0\ \mathrm{N \cdot m}$

Planetary Gear

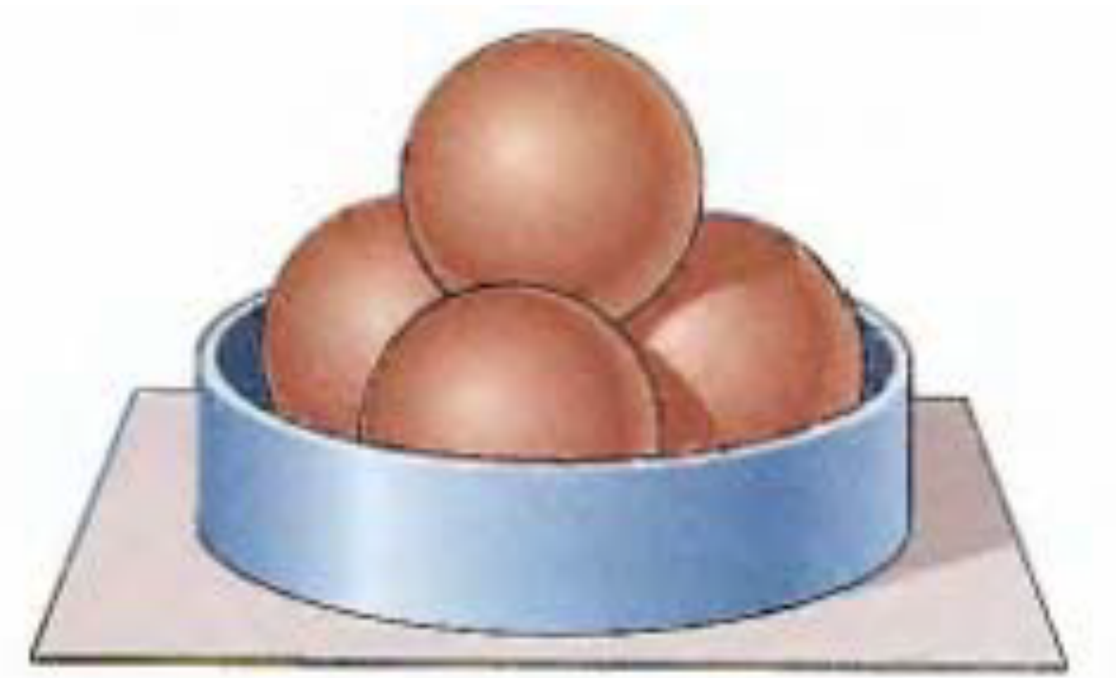


http://machinedesign.com/mechanical-drives/planetary-gears-review-basic-design-criteria-and-new-options-sizing

Problem 25

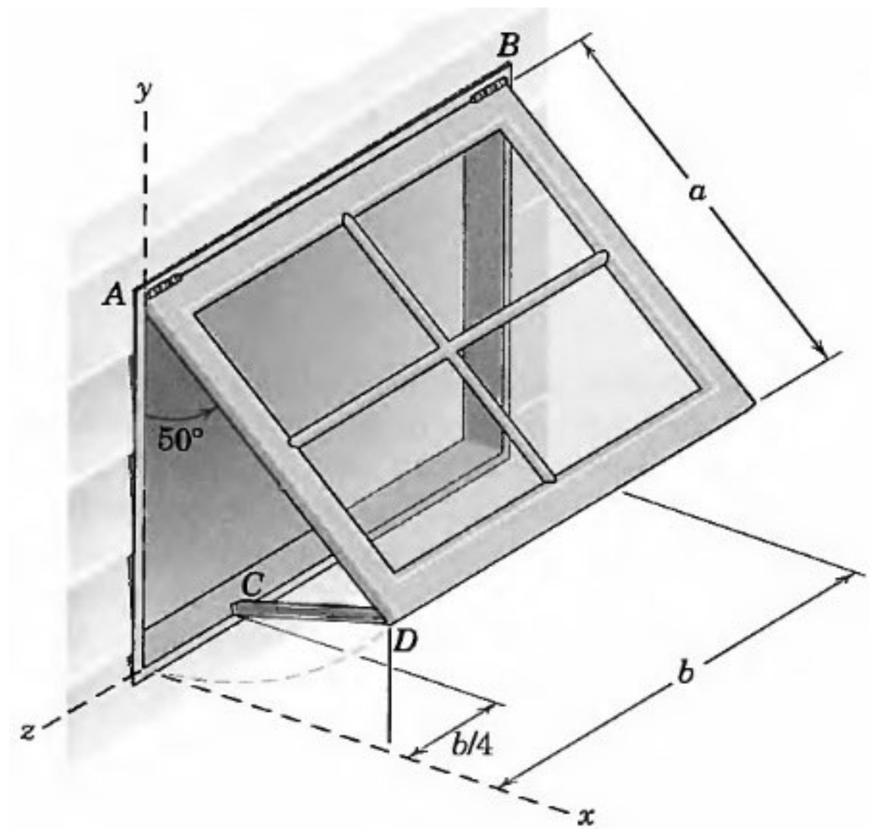
Three identical steel balls, each of mass m, are placed in the cylindrical ring which rests on a horizontal surface and whose height is slightly greater than the radius of the balls. The diameter of the ring is such that the balls are virtually touching one another. A fourth identical ball is then placed on top of the three balls. Determine the force P exerted by the ring on each of the three lower balls.

$$P = \frac{mg}{3\sqrt{2}}$$

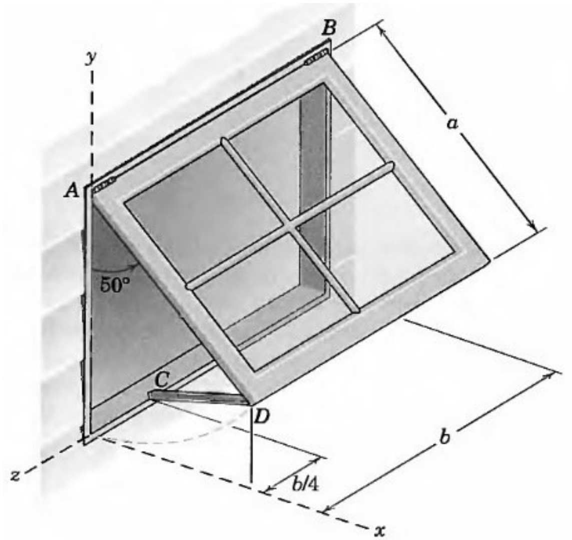


Problem 26

A window is temporarily held open in the 50° position shown by a wooden prop CD until a crank-type opening mechanism can be installed. If a=0.8m and b=1.2 m and the mass of the window is 50 kg with mass center at its geometric center, determine the compressive force F_{CD} in the prop.



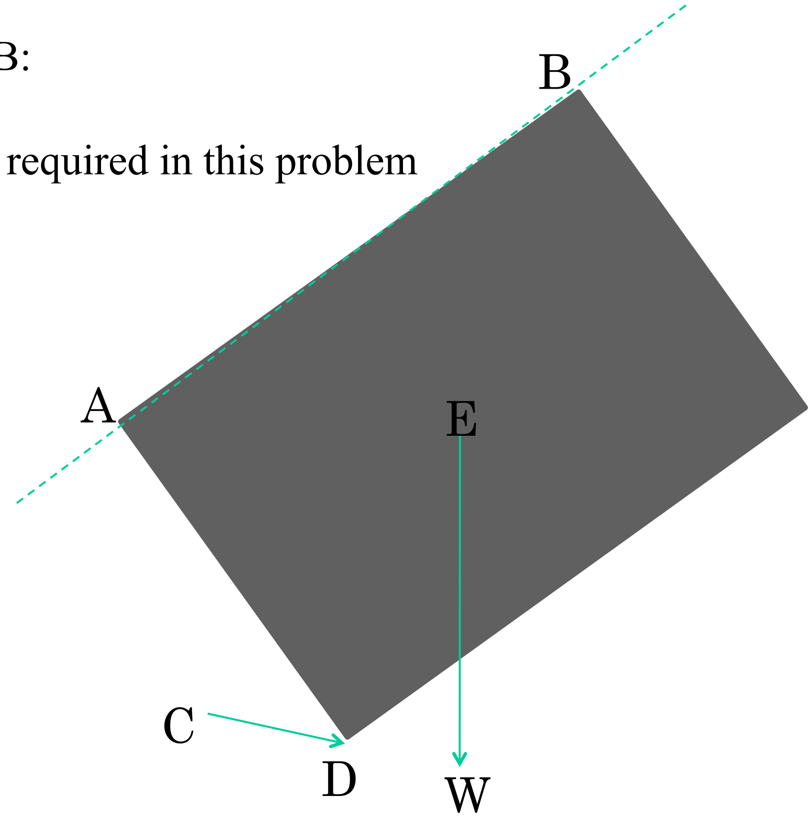
Problem 26 - Solution



Reactions at hinges A and B:

(i) No M_z Reactions

(ii)Other Reactions are not required in this problem



$$\vec{r}_A = a\vec{j};\ \vec{r}_B = a\vec{j} - b\vec{k};\ \vec{r}_C = -\frac{b}{4}\vec{k};$$

$$\vec{r}_D = a\sin\theta\vec{i} + a(1-\cos\theta)\vec{j};$$

$$\vec{r}_E = \frac{a}{2}\sin\theta\vec{i} + a\left(1-\frac{\cos\theta}{2}\right)\vec{j} - \frac{b}{2}\vec{k}.$$

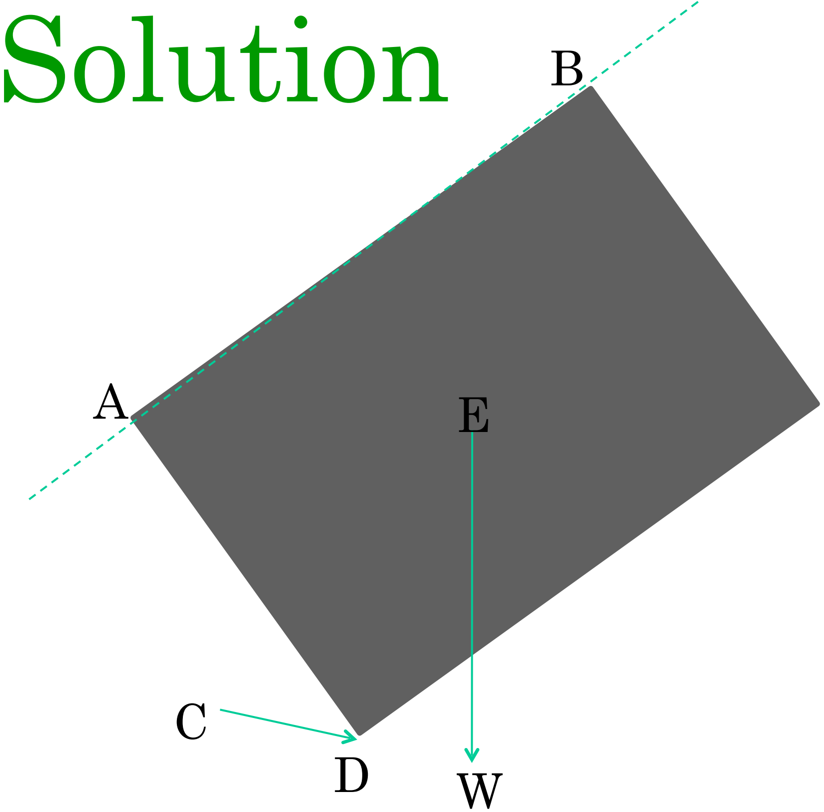
$$\vec{r}_{CD} = a\sin\theta\vec{i} + a(1-\cos\theta)\vec{j} + \frac{b}{4}\vec{k}$$

$$\vec{r}_{AE} = \frac{a}{2}\sin\theta\vec{i} - \frac{a}{2}\cos\theta\vec{j} - \frac{b}{2}\vec{k}$$

$$\left|\vec{r}_{CD}\right| = \sqrt{(a\sin\theta)^2 + (a(1-\cos\theta))^2 + \left(\frac{b}{4}\right)^2}$$

$$\vec{r}_{AD} = a\sin\theta\vec{i} - a\cos\theta\vec{j}$$

Problem 26 - Solution



$$\vec{r}_{AE} = \frac{a}{2}\sin\theta\vec{i} - \frac{a}{2}\cos\theta\vec{j} - \frac{b}{2}\vec{k}$$

$$\vec{r}_{AD} = a\sin\theta\vec{i} - a\cos\theta\vec{j}$$

$$\vec{r}_{CD} = a\sin\theta\vec{i} + a(1-\cos\theta)\vec{j} + \frac{b}{4}\vec{k}$$

$$\left|\vec{r}_{CD}\right| = \sqrt{(a\sin\theta)^2 + (a(1-\cos\theta))^2 + \left(\frac{b}{4}\right)^2}$$

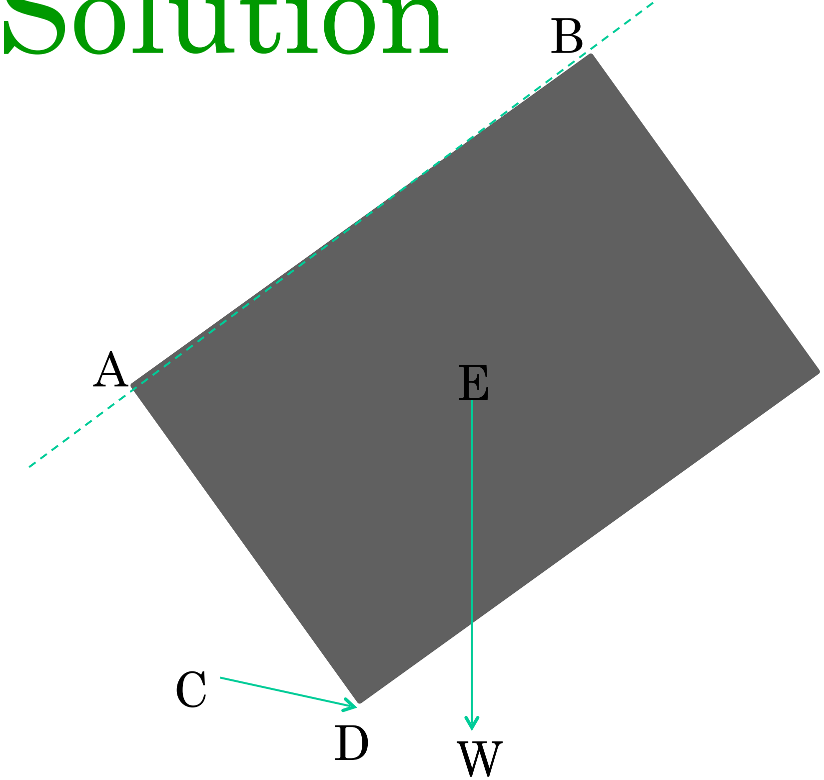
$$\vec{W} = -W\vec{j}$$

$$\vec{F}_{CD} = F_{CD}\hat{r}_{CD} = \frac{F_{CD}}{\left|\vec{r}_{CD}\right|}\left(a\sin\theta\vec{i} + a(1-\cos\theta)\vec{j} + \frac{b}{4}\vec{k}\right)$$

$$Let\ \vec{F}_{CD} = F\left(a\sin\theta\vec{i} + a(1-\cos\theta)\vec{j} + \frac{b}{4}\vec{k}\right)$$

$$F = \frac{F_{CD}}{\left|\vec{r}_{CD}\right|} = \frac{F_{CD}}{\sqrt{(a\sin\theta)^2 + (a(1+\cos\theta))^2 + \left(b/4\right)^2}}$$

Problem 26 - Solution



$$\vec{r}_{AE} = \frac{a}{2}\sin\theta\hat{i} - \frac{a}{2}\cos\theta\hat{j} - \frac{b}{2}\hat{k}$$

$$\vec{r}_{AD} = a\sin\theta\hat{i} - a\cos\theta\hat{j}$$

$$\vec{r}_{CD} = a\sin\theta\vec{i} + a(1-\cos\theta)\vec{j} + \frac{b}{4}\vec{k}$$

$$\left|\vec{r}_{CD}\right| = \sqrt{(a\sin\theta)^2 + (a(1-\cos\theta))^2 + \left(\frac{b}{4}\right)^2}$$

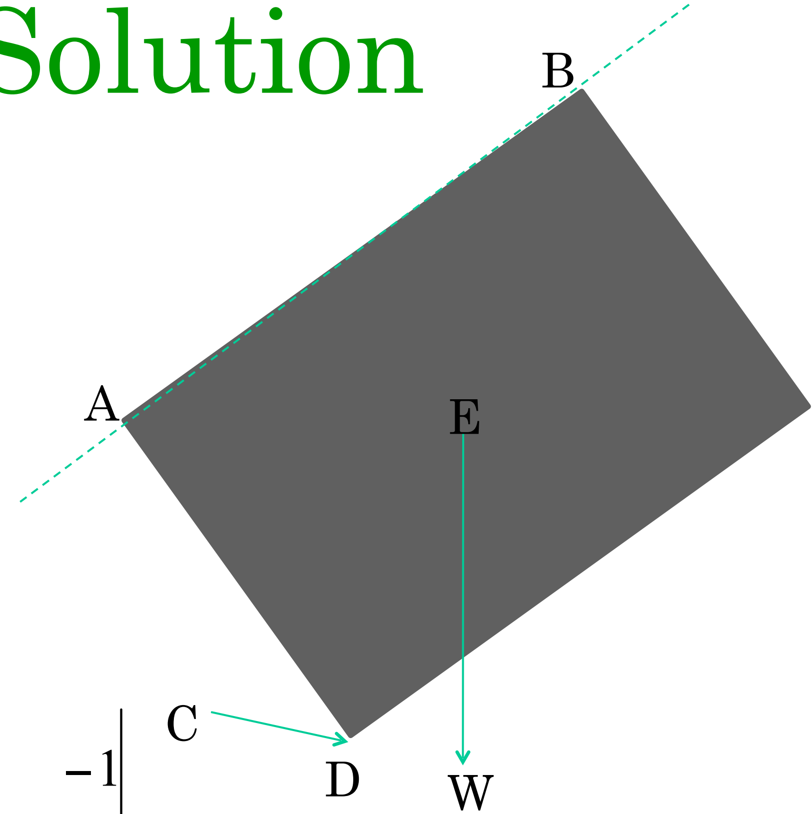
$$\vec{W} = -W\vec{j}$$

$$\vec{F}_{CD} = F\left(a\sin\theta\vec{i} + a(1-\cos\theta)\vec{j} + \frac{b}{4}\vec{k}\right) \qquad F = \frac{F_{CD}}{\left|\vec{r}_{CD}\right|} = \frac{F_{CD}}{\sqrt{(a\sin\theta)^2 + (a(1+\cos\theta))^2 + \left(b/4\right)^2}}$$

$$\sum M_{AB} = -\vec{k}.\vec{r}_{AE}\times W - \vec{k}.\vec{r}_{AD}\times\vec{F}_{CD} = 0$$

$$\Rightarrow \begin{vmatrix} 0 & 0 & -1 \\ \frac{a}{2}\sin\theta & -\frac{a}{2}\sin\theta & -\frac{b}{2} \\ 0 & -W & 0 \end{vmatrix} + F\begin{vmatrix} 0 & 0 & -1 \\ a\sin\theta & -a\cos\theta & 0 \\ a\sin\theta & a(1-\cos\theta) & \frac{b}{4} \end{vmatrix} = 0$$

Problem 26 - Solution



$$\vec{W} = -W\vec{j}$$

$$\vec{F}_{CD} = F\left(a\sin\theta\vec{i} + a(1-\cos\theta)\vec{j} + \frac{b}{4}\vec{k} \right)$$

$$F = \frac{F_{CD}}{\left|\vec{r}_{CD}\right|} = \frac{F_{CD}}{\sqrt{(a\sin\theta)^2 + (a(1+\cos\theta))^2 + \left(b/4\right)^2}}$$

$$\sum M_{AB} = \vec{k}.\vec{r}_{AE} \times \vec{W} + \vec{k}.\vec{r}_{AD} \times \vec{F}_{CD} = 0$$

$$\Rightarrow \begin{vmatrix} 0 & 0 & -1 \\ \frac{a}{2}\sin\theta & -\frac{a}{2}\sin\theta & -\frac{b}{2} \\ 0 & -W & 0 \end{vmatrix} + F\begin{vmatrix} 0 & 0 & -1 \\ a\sin\theta & -a\cos\theta & 0 \\ a\sin\theta & a(1-\cos\theta) & \frac{b}{4} \end{vmatrix} = 0$$

$$W\frac{a}{2}\sin\theta - Fa^2(\sin\theta(1-\cos\theta) + \sin\theta\cos\theta) = 0$$

$$W\frac{a}{2}\sin\theta - Fa^2\sin\theta = 0$$

$$F = \frac{W}{2a}$$

Problem 26 - Solution

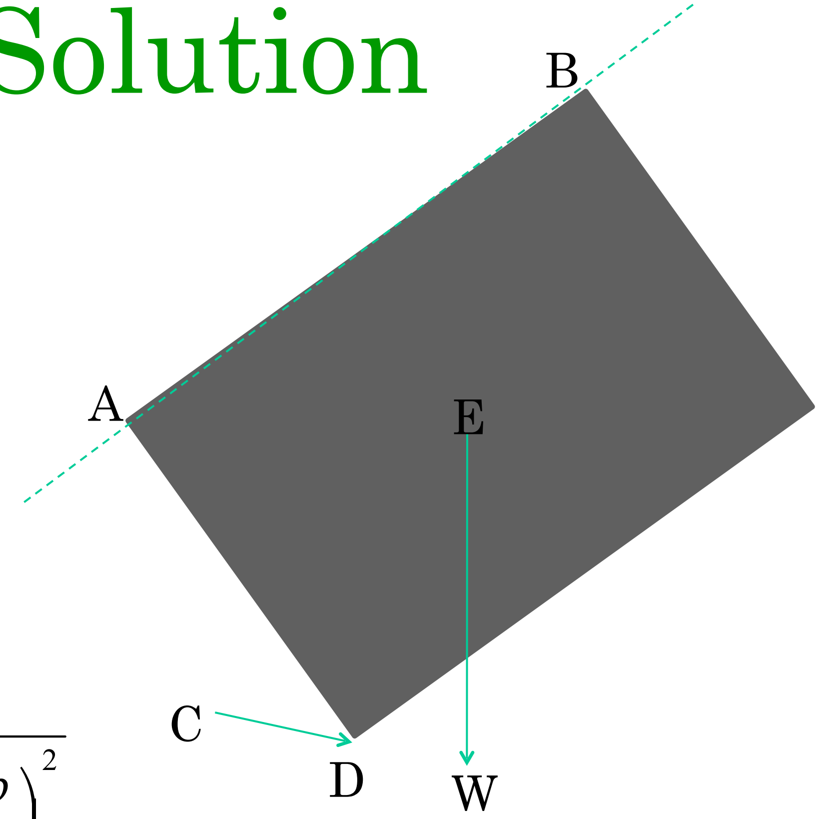
$$\vec{W} = -W\vec{j}$$

$$\vec{F}_{CD} = F\left(a\sin\theta\vec{i} + a(1-\cos\theta)\vec{j} + \frac{b}{4}\vec{k}\right)$$

$$F = \frac{F_{CD}}{|\vec{r}_{CD}|} = \frac{F_{CD}}{\sqrt{(a\sin\theta)^2 + (a(1+\cos\theta))^2 + \left(b/4\right)^2}}$$

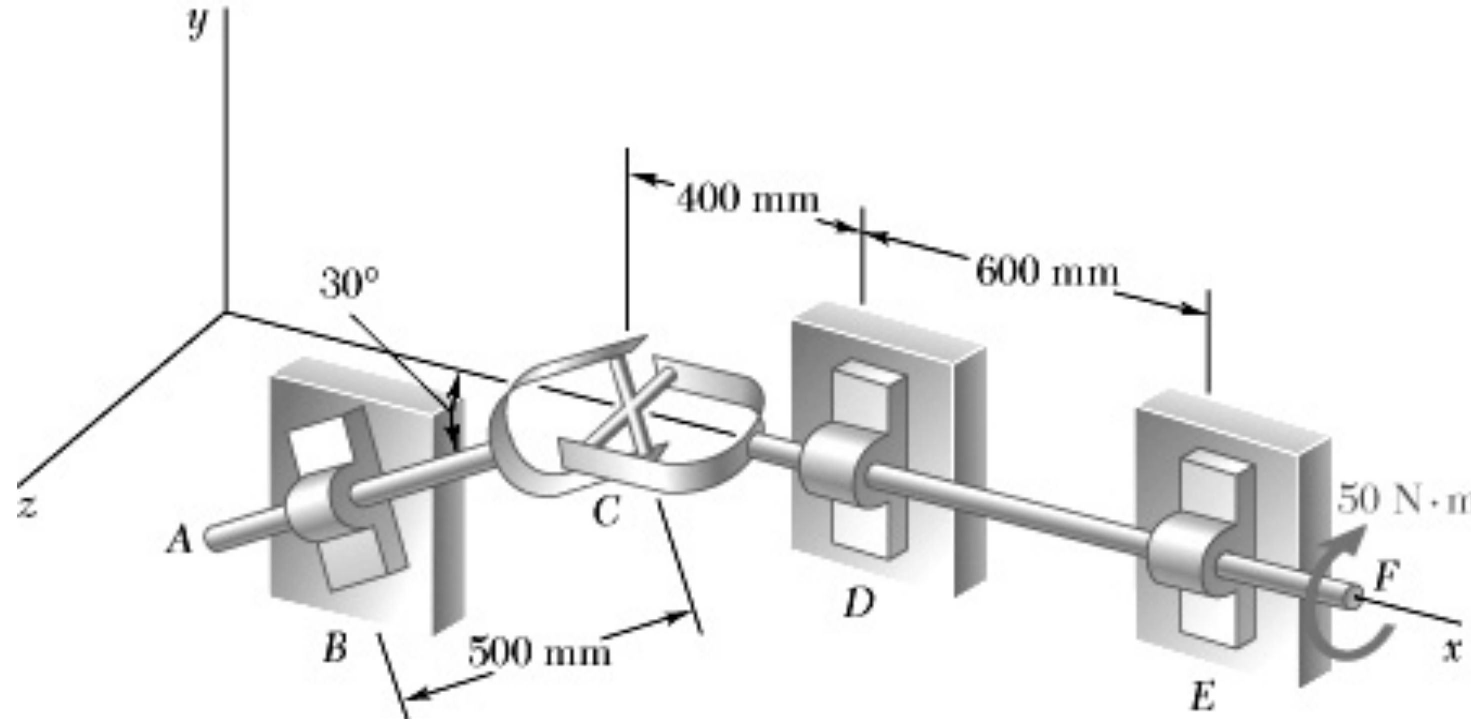
$$F = \frac{W}{2a}$$

$$F_{CD} = F|\vec{r}_{CD}| = \frac{W}{2a}\sqrt{(a\sin\theta)^2 + (a(1-\cos\theta))^2 + \left(\frac{b}{4}\right)^2}$$



Putting $W = mg$; $m = 50$ kg; $g = 9.81$ m/s^2; $a = 0.8$ m; $b = 1.2$ m; $\theta = 50^{\circ}$

$$\boxed{F_{CD} = 226.9\,N}$$



- Two shafts *AC* and *CF*, which lie in the vertical *xy* plane, are connected by a universal joint at *C*. The bearings at *B* and *D* do not exert any axial force. A couple of magnitude (clockwise when viewed from the positive *x* axis) is applied to shaft *CF* at *F*. At a time when the arm of the crosspiece attached to shaft *CF* is horizontal, determine (*a*) the magnitude of the couple which must be applied to shaft *AC* at *A* to maintain equilibrium, (*b*) the reactions at *B*, *D*, and *E*.

Universal Joint

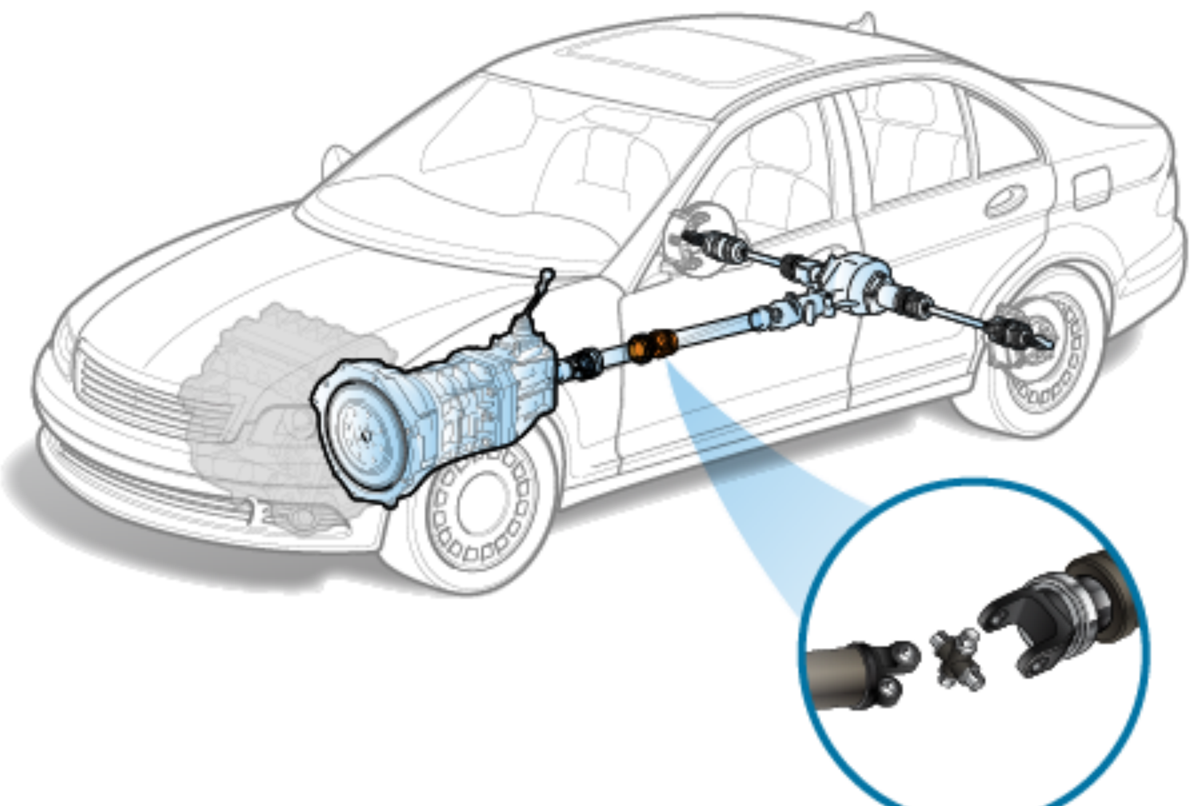
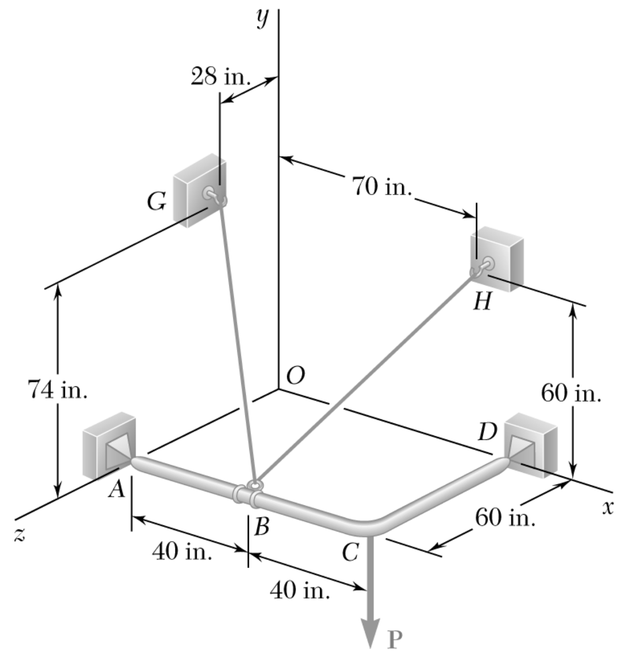


Image courtesy of ClearMechanic.com

Problem 1

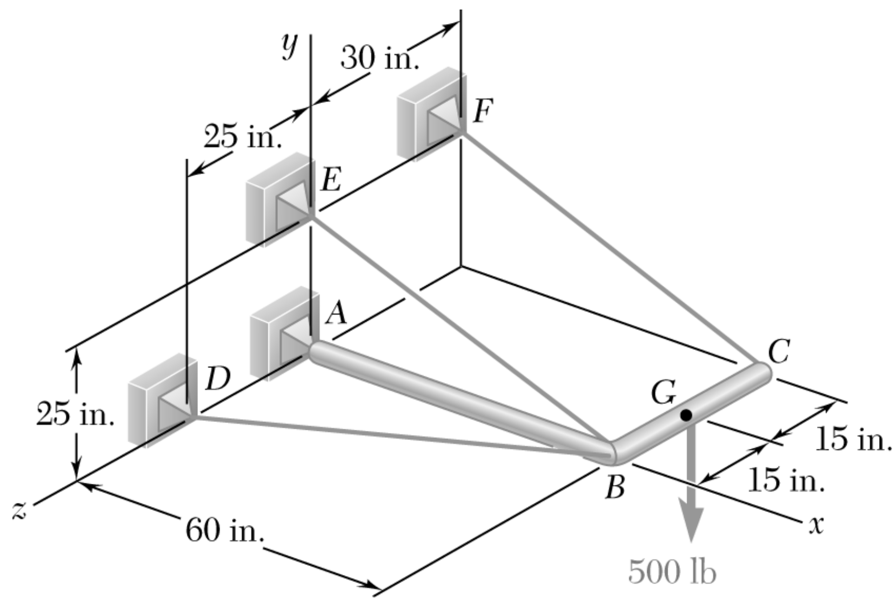
- The frame *ACD* is supported by ball-and-socket joints at *A* and *D* and by a cable that passes through a ring at *B* and is attached to hooks at *G* and *H*. Knowing that the frame supports at point *C* a load of magnitude determine the tension in the cable.



$T = 100.7$ lb

Problem 2

- The rigid L-shaped member *ABC* is supported by a ball and socket at *A* and by three cables. Determine the tension in each cable and the reaction at *A* caused by the 500-lb load applied at *G*.



$T_{CF} = 650 \text{ lb}$

$T_{BD} = 780 \text{ lb}$

$T_{BE} = 650 \text{ lb}$

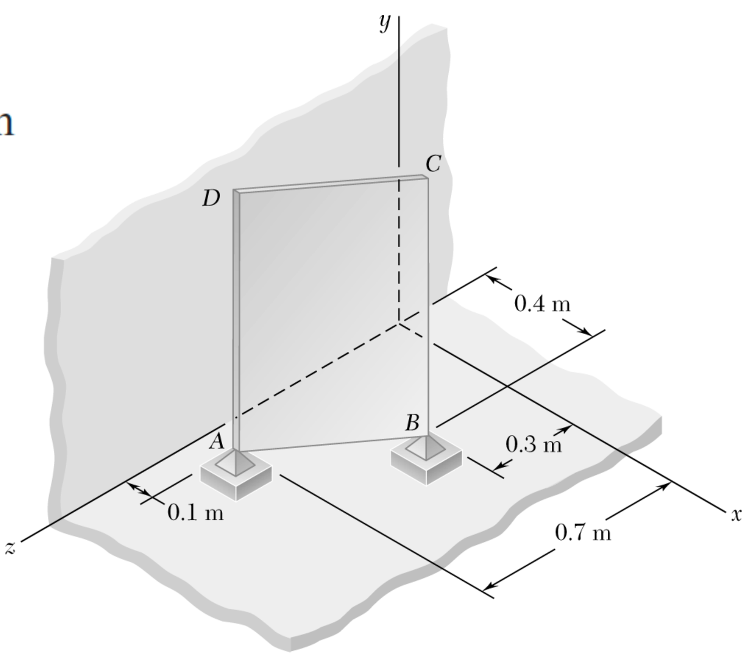
$$\mathbf{A} = (1920 \text{ lb})\mathbf{i} - (300 \text{ lb})\mathbf{k}$$

Problem 3

- A uniform 0.5 x 0.75m steel plate *ABCD* has a mass of 40 kg and is attached to ball-and-socket joints at *A* and *B*. Knowing that the plate leans against a frictionless vertical wall at *D*, determine (*a*) the location of *D*, (*b*) the reaction at *D*.

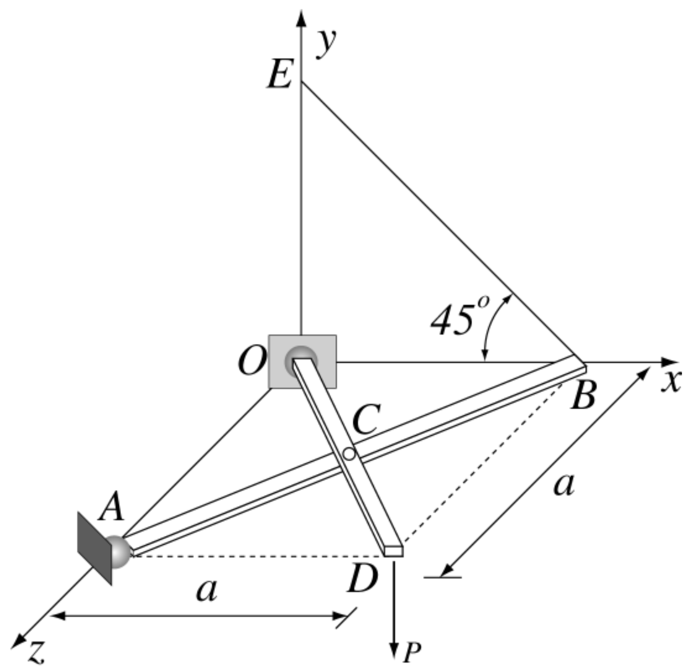
$x = 0,\ y = 0.740\text{ m},\ z = 0.625\text{ m}$

$\mathbf{N}_D = (41.455\text{ N})\mathbf{i}$



Problem 4

- The two bars AB and OD, pinned together at C, form the diagonals of a horizontal square $AOBD$. The ends A and O are attached to a vertical wall by ball and socket joint, point B is supported by a cable BE, and a vertical load P is applied at D. Find the components of the reactions at A and O.

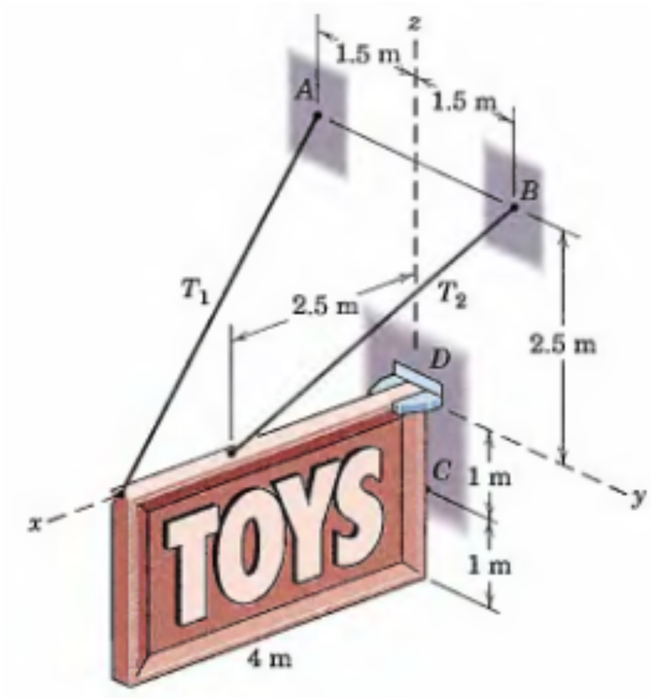


Problem 5

- Three identical steel balls, each of mass m, are placed in the cylindrical ring which rests on a horitontal surface and whose height is slightly greater than the radius of the balls. The diameter of the ring is such that the balls are virtually touching one another. A fourth identical ball is then placed on top of the three balls. Determine the force P exerted by the ring on each of the three lower balls.

Problem 6

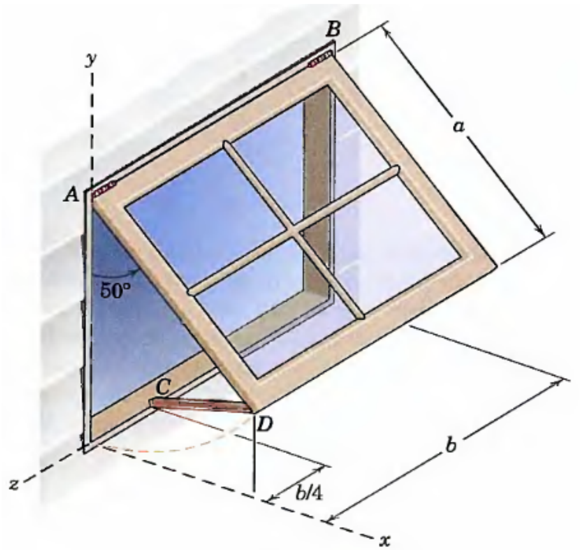
- A rectangular sign over a store has a mass of 100kg, with the center of mass in the center of the rectangle. The support against the wall at point C may be treated as a ball-and-socket joint. At corner D support is provided in the y-direction only. Calculate the tensions $T1$ and $T2$ in the supporting wires, the total force supported at C, and the lateral force R supported at D



$$T_1 = 347 \text{ N}, T_2 = 431 \text{ N}$$
$$R = 63.1 \text{ N}, C = 768 \text{ N}$$

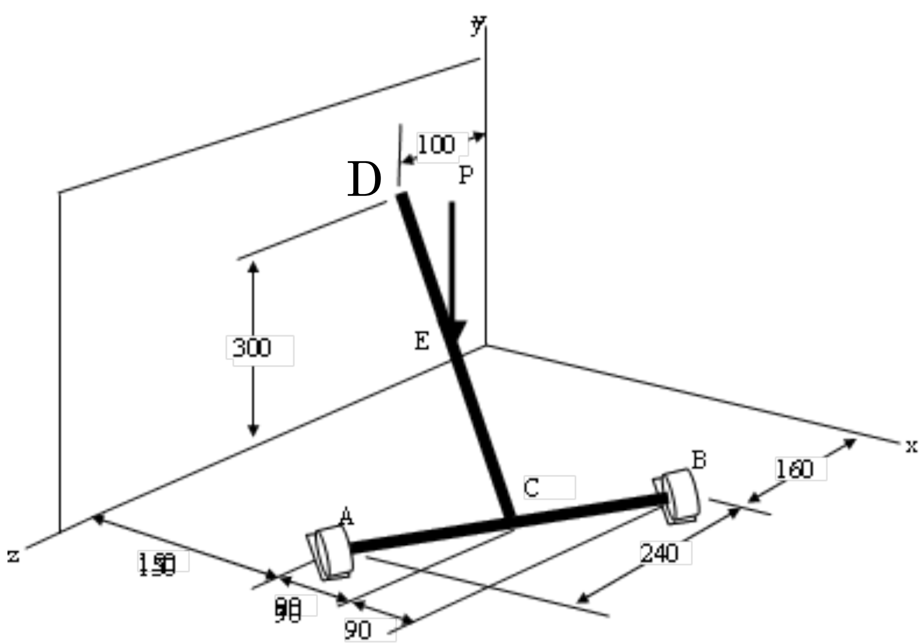
Problem 7

- A window is temporarily held open in the 50o position shown by a wooden prop CD until a crank-type opening mechanism can be installed. If a=0.8m and b=1.2 m and the mass of the window is 50 kg with mass center at its geometric center, determine the compressive force FCD in the prop.

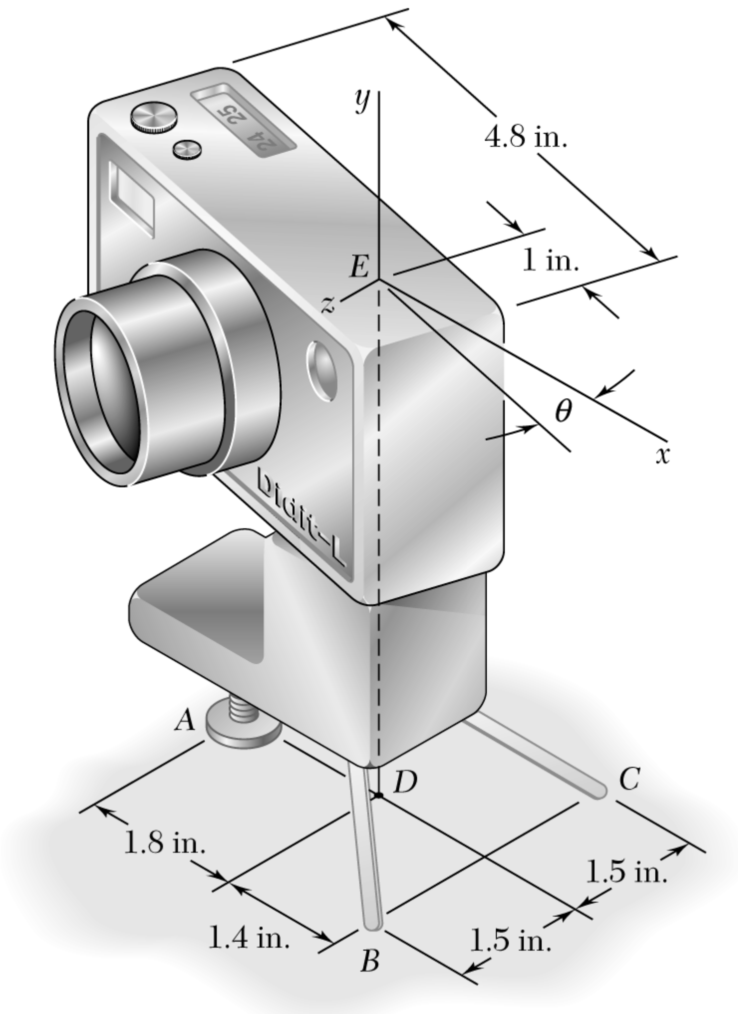


Problem 1

- Two rods are welded together to form a T-shaped lever which leans against a frictionless wall at *D* and is supported by bearings at *A* and *B*. A vertical force *P* of magnitude 600 N is applied at the midpoint *E* of rod *DC*. Determine the reaction at *D*. [F_D = 375 N]



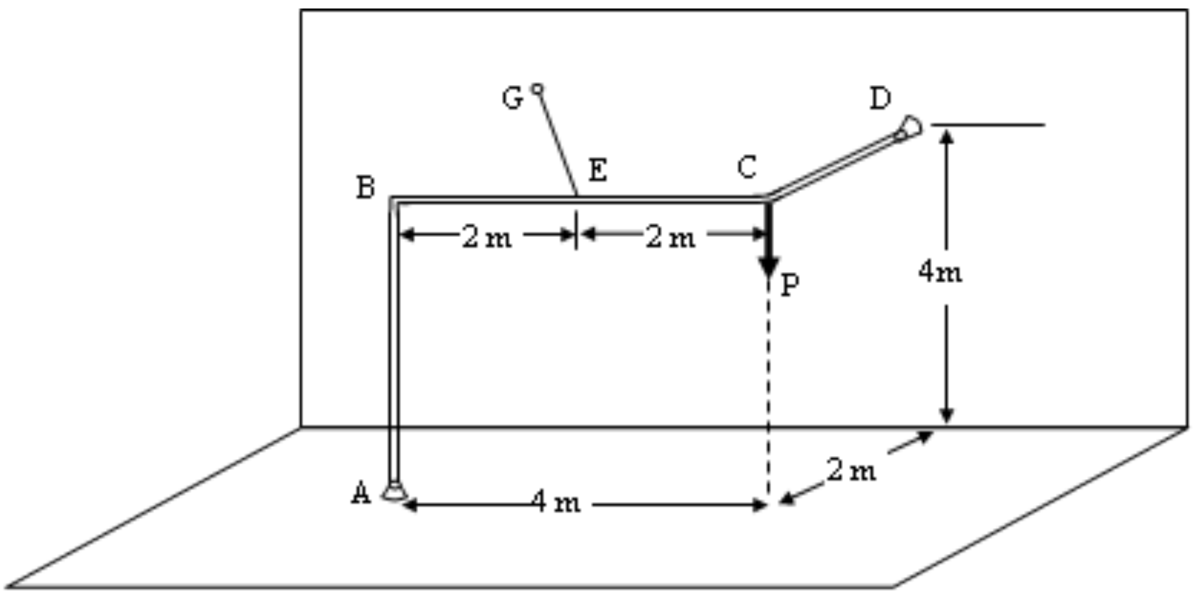
Problem 2



- A camera weighing 0.53 lb is mounted on a small tripod weighing 0.44 lb on a smooth surface. Assuming that the weight of the camera is uniformly distributed and that the line of action of the weight of the tripod passes through *D*, determine (*a*) the vertical components of the reactions at *A*, *B*, and *C* when θ = 0 (*b*) the maximum value of θ if the tripod is not to tip over. [(a) Na= 0.656lb, NB= NC= 0.157lb, (b) min = 62deg.]

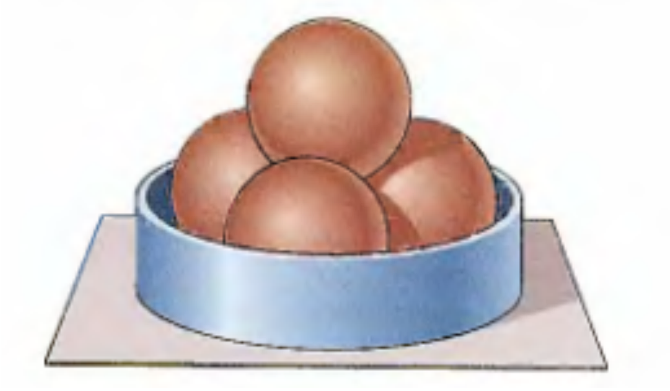
Problem 3

- A 450 N load P is applied at the corner C of rigid pipe $ABCD$ which has been bent as shown. The pipe is supported by the ball and socket joints A and D, fastened respectively to the floor and to a vertical wall, and by a cable attached at the midpoint E of the portion BC of the pipe and at a point G on the wall. Determine (a) where G should be located if the tension in the cable is to be minimum, (b) the corresponding minimum value of the tension. [(a) height of G = 5m from A, same horizontal component as A, on the wall (b) Tmin = 300N]

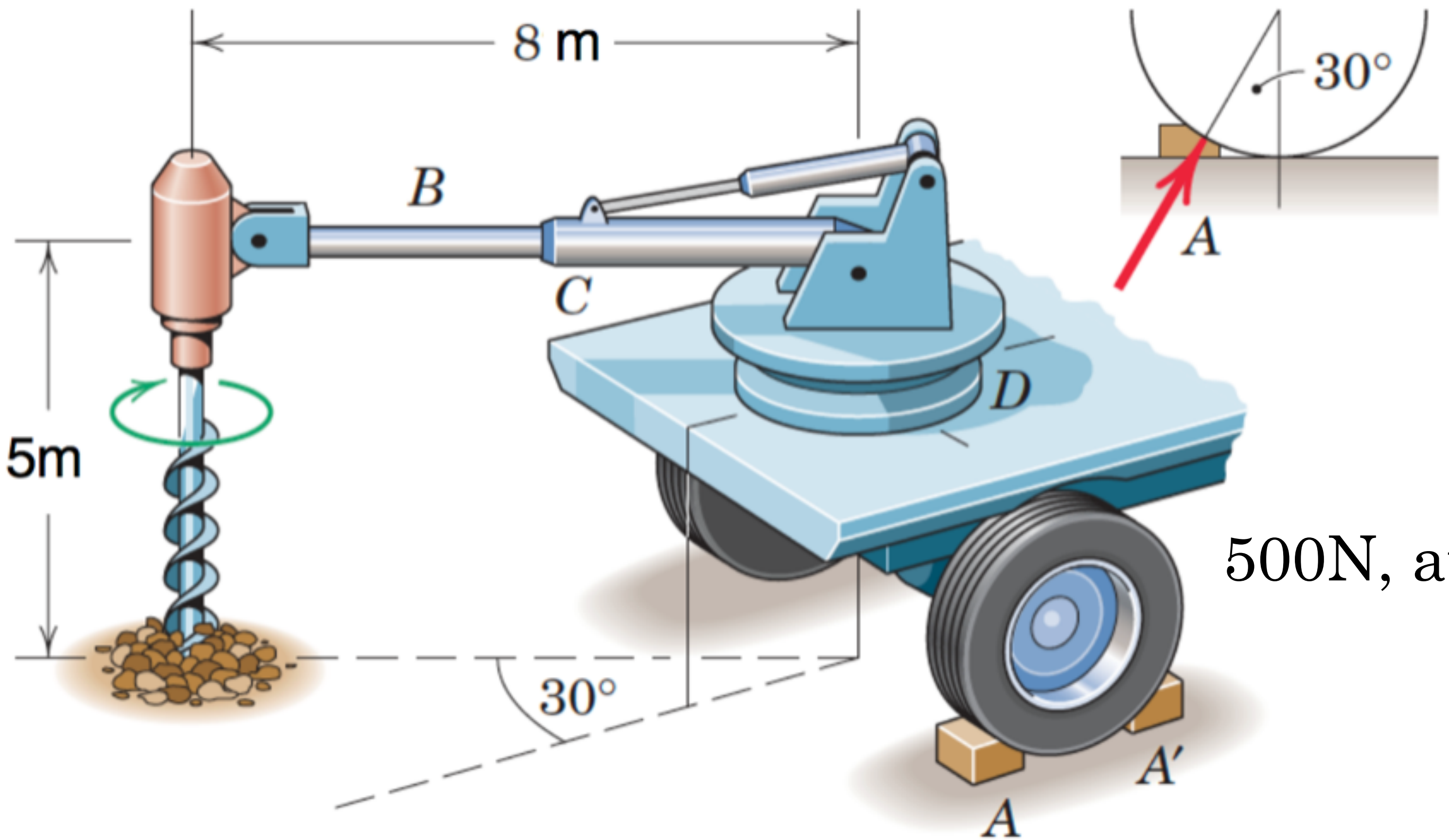


Problem 4

- Three identical steel balls, each of mass m, are placed in the cylindrical ring which rests on a horitontal surface and whose height is slightly greater than the radius of the balls. The diameter of the ring is such that the balls are virtually touching one another. A fourth identical ball is then placed on top of the three balls. Determine the force P exerted by the ring on each of the three lower balls. [$N = W/3\sqrt{2}$]



3) The power unit of the post-hole digger supplies a torque of 4000 N.m to the auger. The arm *B* is free to slide in the supporting sleeve *C* but is not free to rotate about the horizontal axis of *C*. If the unit if free to swivel about the vertical axis of the mount *D*, determine the force exerted against the right rear wheel by the block *A* (or *A'*), which prevents the unbraced truck from rolling. (*Hint* : view the system from above.)



500N, at A'