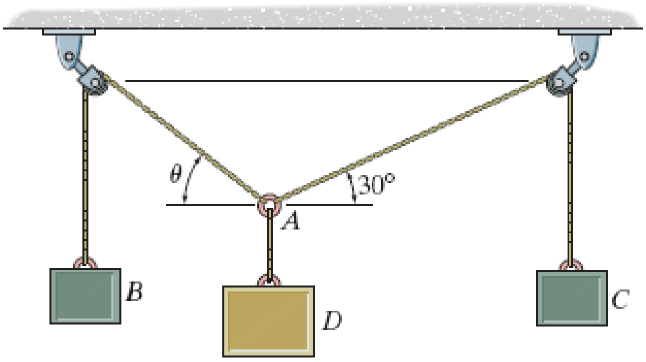
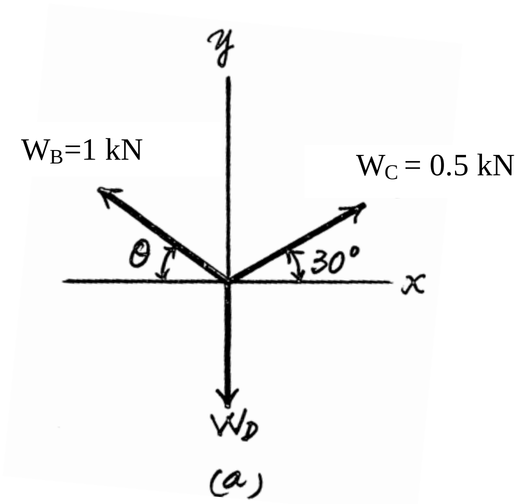
Problems # 2-SOLUTION

Topics Equilibrium of a Particle (Chapter 3 in textbook).

Textbook: Engineering Mechanics, by R.C. Hibbeler, Pearson, 12th Edition.

Problems: ***Use the concept of equilibrium of coplanar and three-dimensional force systems to solve:***
Problems: 3-12 (page 96), 3-20 (page 97), 3-24 (page 98), 3-40 (page 100), 3-56(page 110), 3-60(page 111).





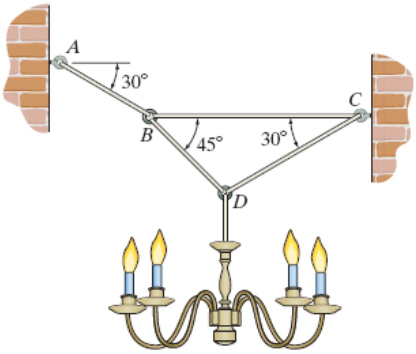
Equations of Equilibrium: Applying the equations of equilibrium along the x and y axes to the free-body diagram shown in Fig. (a),

$\overset{+}{\rightarrow}\Sigma F_x = 0;$ $$0.5cos30 - 1.0cos\theta = 0$$
$$\theta = 64.3^0$$ **Ans.**

Using this result and writing the equation of equilibrium along the y axis, yields

$+\uparrow \Sigma F_y = 0;$ $$0.5\,sin\,30 + 1.0\,sin\,64.3 - W_D = 0$$
$$W_D = 1.15kN$$ **Ans.**

3–20. Determine the tension developed in each wire used to support the 50-kg chandelier.



Equations of Equilibrium: First, we will apply the equations of equilibrium along the x and y axes to the free-body diagram of joint D shown in Fig. (a).

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad F_{CD}\cos 30° - F_{BD}\cos 45° = 0 \qquad (1)$$

$$+\uparrow \Sigma F_y = 0; \qquad F_{CD}\sin 30° + F_{BD}\sin 45° - 50(9.81) = 0 \qquad (2)$$

Solving Eqs. (1) and (2), yields

$$F_{CD} = 359\,\text{N} \qquad F_{BD} = 439.77\,\text{N} = 440\,\text{N} \qquad \textbf{Ans.}$$

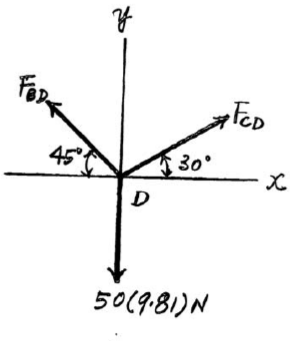
Using the result $F_{BD} = 439.77$ N and applying the equations of equilibrium along the x and y axes to the free-body diagram of joint B shown in Fig. (b),

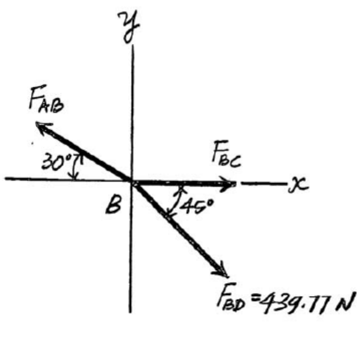
$$+\uparrow \Sigma F_y = 0; \qquad F_{AB}\sin 30° - 439.77\sin 45° = 0$$

$$F_{AB} = 621.93\,\text{N} = 622\,\text{N} \qquad \textbf{Ans.}$$

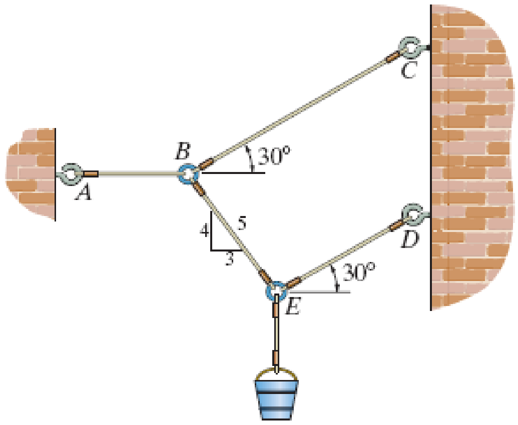
$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad F_{BC} + 439.77\cos 45° - 621.93\cos 30° = 0$$

$$F_{BC} = 228\,\text{N} \qquad \textbf{Ans.}$$





***3–24.** If the bucket weighs 0.25 kN, determine the tension developed in each of the wires.



Equations of Equilibrium: First, we will apply the equation of equilibrium along the *x* and *y* axes to the free-body diagram of joint *E* shown in Fig. (*a*).

$\overset{+}{\rightarrow}\Sigma F_x = 0;$ $$F_{ED}\cos 30 - F_{EB}\left(\frac{3}{5}\right) = 0 \quad (1)$$

$+\uparrow \Sigma F_y = 0;$ $$F_{ED}\sin 30 + F_{EB}\left(\frac{4}{5}\right) - 0.25 = 0 \quad (2)$$

Solving Eqs. (1) and (2), yields

$$F_{ED} = 0.151 kN \qquad F_{EB} = 0.213 kN$$ **Ans.**

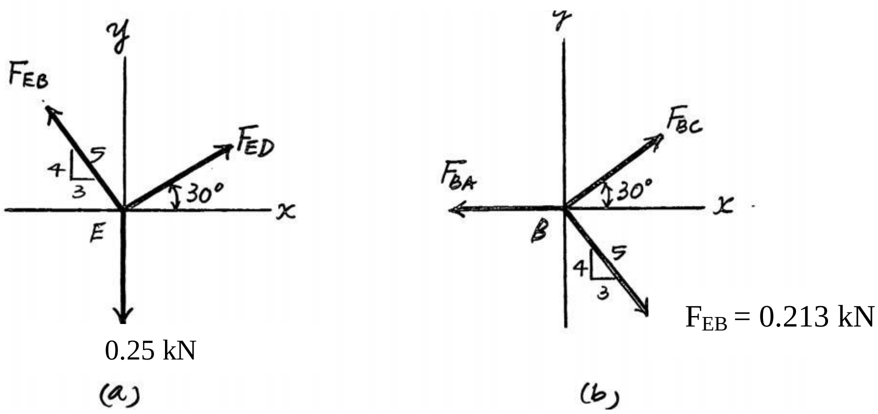
Using the result F_{EB} = 43.61 lb and applying the equation of equilibrium to the free-body diagram of joint *B* shown in Fig. (*b*),

$+\uparrow \Sigma F_y = 0;$ $$F_{BC}\sin 30 - 0.213\left(\frac{4}{5}\right) = 0$$

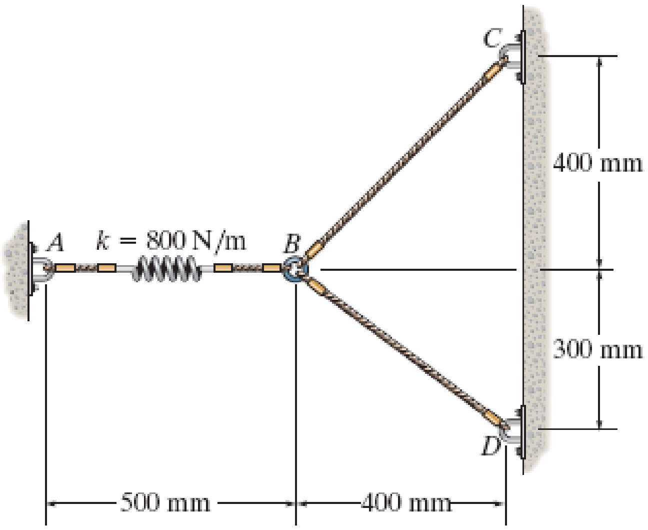
$$F_{BC} = 0.3408 kN$$ **Ans.**

$\overset{+}{\rightarrow}\Sigma F_x = 0;$ $$0.3408\cos 30 + 0.213\left(\frac{3}{5}\right) - F_{BA} = 0$$

$$F_{BA} = 0.433 kN$$ **Ans.**



3–40. The spring has a stiffness of k =800 N/m and an unstretched length of 200 mm. Determine the force in cables *BC* and *BD* when the spring is held in the position shown.



The Force in The Spring : The spring stretches $s = l - l_0 = 0.5 - 0.2 = 0.3$ m. Applying Eq.3 – 2, we have

$$F_{sp} = ks = 800(0.3) = 240 \text{ N}$$

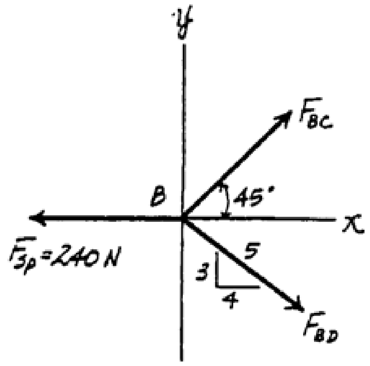
Equations of Equilibrium :

$$\xrightarrow{+} \Sigma F_x = 0; \quad F_{BC}\cos 45° + F_{BD}\left(\frac{4}{5}\right) - 240 = 0$$

$$0.7071F_{BC} + 0.8F_{BD} = 240 \qquad [1]$$

$$+\uparrow \Sigma F_y = 0; \quad F_{BC}\sin 45° - F_{BD}\left(\frac{3}{5}\right) = 0$$

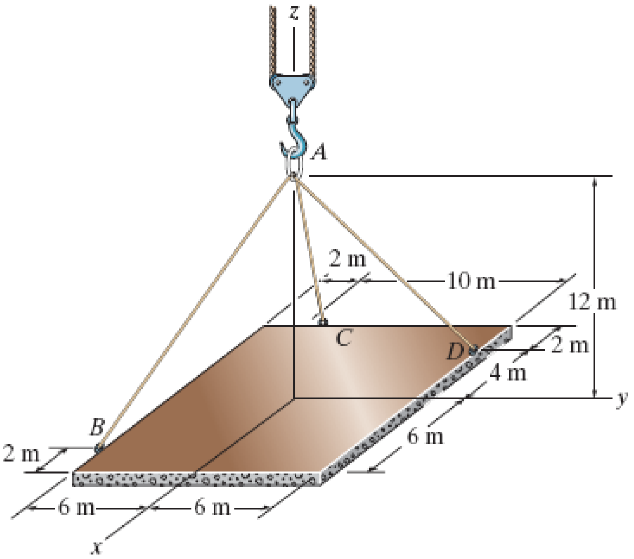
$$F_{BC} = 0.8485F_{BD} \qquad [2]$$



Solving Eqs.[1] and [2] yields,

$$F_{BD} = 171 \text{ N} \qquad F_{BC} = 145 \text{ N} \qquad \textbf{Ans}$$

3–56. The ends of the three cables are attached to a ring at *A* and to the edge of a uniform 150-kg plate. Determine the tension in each of the cables for equilibrium.

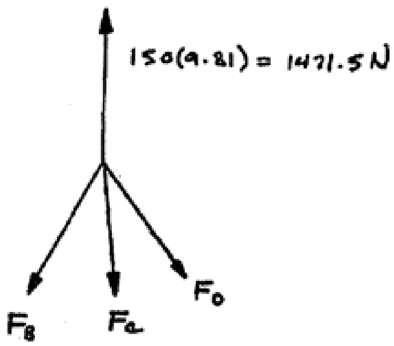


$$\mathbf{P} = 150(9.81)\,\mathbf{k} = 1471.5\,\mathbf{k}$$

$$\mathbf{F}_B = \frac{4}{14}F_B\,\mathbf{i} - \frac{6}{14}F_B\,\mathbf{j} - \frac{12}{14}F_B\,\mathbf{k}$$

$$\mathbf{F}_C = -\frac{6}{14}F_C\,\mathbf{i} - \frac{4}{14}F_C\,\mathbf{j} - \frac{12}{14}F_C\,\mathbf{k}$$

$$\mathbf{F}_D = -\frac{4}{14}F_D\,\mathbf{i} + \frac{6}{14}F_D\,\mathbf{j} - \frac{12}{14}F_D\,\mathbf{k}$$



$$\Sigma F_x = 0; \qquad \frac{4}{14}F_B - \frac{6}{14}F_C - \frac{4}{14}F_D = 0$$

$$\Sigma F_y = 0; \qquad -\frac{6}{14}F_B - \frac{4}{14}F_C + \frac{6}{14}F_D = 0$$

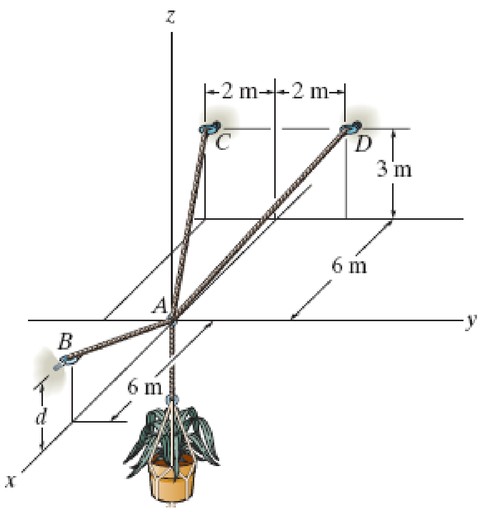
$$\Sigma F_z = 0; \qquad -\frac{12}{14}F_B - \frac{12}{14}F_C - \frac{12}{14}F_D + 1471.5 = 0$$

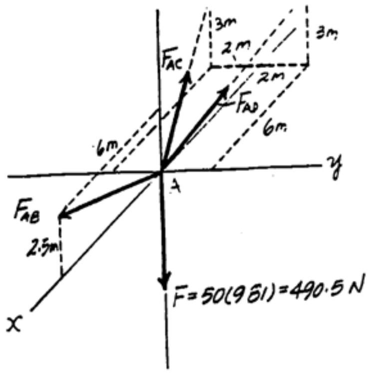
$F_B = 858\text{ N}$ **Ans**

$F_C = 0$ **Ans**

$F_D = 858\text{ N}$ **Ans**

3–60. The 50-kg pot is supported from *A* by the three cables. Determine the force acting in each cable for equilibrium.Take d = 2.5 m.





Cartesian Vector Notation :

$$\mathbf{F}_{AB} = F_{AB}\left(\frac{6\mathbf{i}+2.5\mathbf{k}}{\sqrt{6^2+2.5^2}}\right) = \frac{12}{13}F_{AB}\mathbf{i}+\frac{5}{13}F_{AB}\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left(\frac{-6\mathbf{i}-2\mathbf{j}+3\mathbf{k}}{\sqrt{(-6)^2+(-2)^2+3^2}}\right) = -\frac{6}{7}F_{AC}\mathbf{i}-\frac{2}{7}F_{AC}\mathbf{j}+\frac{3}{7}F_{AC}\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\left(\frac{-6\mathbf{i}+2\mathbf{j}+3\mathbf{k}}{\sqrt{(-6)^2+2^2+3^2}}\right) = -\frac{6}{7}F_{AD}\mathbf{i}+\frac{2}{7}F_{AD}\mathbf{j}+\frac{3}{7}F_{AD}\mathbf{k}$$

$$\mathbf{F} = \{-490.5\mathbf{k}\}\ \mathrm{N}$$

Equations of Equilibrium :

$$\Sigma\mathbf{F} = 0; \quad \mathbf{F}_{AB}+\mathbf{F}_{AC}+\mathbf{F}_{AD}+\mathbf{F} = \mathbf{0}$$

$$\left(\frac{12}{13}F_{AB}-\frac{6}{7}F_{AC}-\frac{6}{7}F_{AD}\right)\mathbf{i}+\left(-\frac{2}{7}F_{AC}+\frac{2}{7}F_{AD}\right)\mathbf{j} +\left(\frac{5}{13}F_{AB}+\frac{3}{7}F_{AC}+\frac{3}{7}F_{AD}-490.5\right)\mathbf{k} = \mathbf{0}$$

Equating **i**, **j** and **k** components, we have

$$\frac{12}{13}F_{AB}-\frac{6}{7}F_{AC}-\frac{6}{7}F_{AD} = 0 \qquad [1]$$

$$-\frac{2}{7}F_{AC}+\frac{2}{7}F_{AD} = 0 \qquad [2]$$

$$\frac{5}{13}F_{AB}+\frac{3}{7}F_{AC}+\frac{3}{7}F_{AD}-490.5 = 0 \qquad [3]$$

Solving Eqs. [1], [2] and [3] yields

$$F_{AC} = F_{AD} = 312\ \mathrm{N}$$

$$F_{AB} = 580\ \mathrm{N} \qquad \textbf{Ans}$$