PROBLEM 3.75

The two shafts of a speed-reducer unit are subjected to couples of magnitude $M_1 = 15$ lb-ft and $M_2 = 3$ lb-ft, respectively. Replace the two couples with a single equivalent couple, specifying its magnitude and the direction of its axis.

SOLUTION

$M_1 = (15 \text{ lb} \cdot \text{ft}) \hat{k}$

$M_2 = (3 \text{ lb} \cdot \text{ft}) \hat{i}$

$M = \sqrt{M_1^2 + M_2^2}$

$= \sqrt{(15)^2 + (3)^2}$

$= 15.30 \text{ lb} \cdot \text{ft}$

$tan \theta_x = \frac{15}{3} = 5$

$\theta_x = 78.7^\circ$

$\theta_y = 90^\circ$

$\theta_z = 90^\circ - 78.7^\circ$

$= 11.30^\circ$

$M = 15.30 \text{ lb} \cdot \text{ft}; \ \theta_x = 78.7^\circ, \ \theta_y = 90.0^\circ, \ \theta_z = 11.30^\circ$
**PROBLEM 3.82**

A 30-lb vertical force $P$ is applied at $A$ to the bracket shown, which is held by screws at $B$ and $C$. 

(a) Replace $P$ with an equivalent force-couple system at $B$. 

(b) Find the two horizontal forces at $B$ and $C$ that are equivalent to the couple obtained in part $a$.

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**SOLUTION**

(a) $M_B = (30 \text{ lb})(5 \text{ in.}) = 150.0 \text{ lb} \cdot \text{in.}$

(b) $B = C = \frac{150 \text{ lb} \cdot \text{in.}}{3.0 \text{ in.}} = 50.0 \text{ lb}$

F = 30.0 \text{ lb} →, \quad M_B = 150.0 \text{ lb} \cdot \text{in.} \quad \downarrow$

$B = 50.0 \text{ lb} \leftarrow; \quad C = 50.0 \text{ lb} \rightarrow$
**PROBLEM 3.93**

An antenna is guyed by three cables as shown. Knowing that the tension in cable $AB$ is 288 lb, replace the force exerted at $A$ by cable $AB$ with an equivalent force-couple system at the center $O$ of the base of the antenna.

**SOLUTION**

We have

$$d_{AB} = \sqrt{(-64)^2 + (-128)^2 + (16)^2} = 144 \text{ ft}$$

Then

$$T_{AB} = \frac{288 \text{ lb}}{144} \frac{(-64i - 128j + 16k)}{(-4i - 8j + k)}$$

$$= (32 \text{ lb})(-4i - 8j + k)$$

Now

$$M = M_D = r_{A/O} \times T_{AB}$$

$$= 128j \times 32(-4i - 8j + k)$$

$$= (4096 \text{ lb} \cdot \text{ft})i + (16,384 \text{ lb} \cdot \text{ft})k$$

The equivalent force-couple system at $O$ is

$$F = -(128.0 \text{ lb})i - (256 \text{ lb})j + (32.0 \text{ lb})k$$

$$M = (4.10 \text{ kip} \cdot \text{ft})i + (16.38 \text{ kip} \cdot \text{ft})k$$
PROBLEM 3.153

The tension in the cable attached to the end $C$ of an adjustable boom $ABC$ is 560 lb. Replace the force exerted by the cable at $C$ with an equivalent force-couple system $(a)$ at $A$, $(b)$ at $B$.

SOLUTION

(a) Based on $\Sigma F$: $F_A = T = 560$ lb

or $F_A = 560 \text{ lb} \searrow 20.0^\circ$

$\Sigma M_A$: $M_A = (T \sin 50^\circ)(d_A)$

$= (560 \text{ lb} \sin 50^\circ)(18 \text{ ft})$

$= 7721.7 \text{ lb} \cdot \text{ft}$

or $M_A = 7720 \text{ lb} \cdot \text{ft}$

(b) Based on $\Sigma F$: $F_B = T = 560$ lb

or $F_B = 560 \text{ lb} \searrow 20.0^\circ$

$\Sigma M_B$: $M_B = (T \sin 50^\circ)(d_B)$

$= (560 \text{ lb} \sin 50^\circ)(10 \text{ ft})$

$= 4289.8 \text{ lb} \cdot \text{ft}$

or $M_B = 4290 \text{ lb} \cdot \text{ft}$
PROBLEM 3.157

A mechanic uses a crowfoot wrench to loosen a bolt at C. The mechanic holds the socket wrench handle at Points A and B and applies forces at these points. Knowing that these forces are equivalent to a force-couple system at C consisting of the force $C = (8 \text{ lb})\mathbf{i} + (4 \text{ lb})\mathbf{k}$ and the couple $M_C = (360 \text{ lb} \cdot \text{in.})\mathbf{i}$, determine the forces applied at A and at B when $A_z = 2 \text{ lb}$.

SOLUTION

We have

$\Sigma F: \quad A + B = C$

or

$F_z: \quad A_z + B_z = 8 \text{ lb}$

$$B_z = -(A_z + 8 \text{ lb}) \quad (1)$$

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

or

$A_y = -B_y \quad (2)$

$\Sigma F_x: \quad 2 \text{ lb} + B_x = 4 \text{ lb}$

or

$B_x = 2 \text{ lb} \quad (3)$

We have

$\Sigma M_C: \quad \mathbf{r}_{BC} \times \mathbf{B} + \mathbf{r}_{AC} \times \mathbf{A} = M_C$

$$\begin{vmatrix} i & j & k \\ 8 & 0 & 2 \\ B_x & B_y & 2 \end{vmatrix} + \begin{vmatrix} i & j & k \\ 8 & 0 & 8 \\ A_x & A_y & 2 \end{vmatrix} \text{ lb} \cdot \text{in.} = (360 \text{ lb} \cdot \text{in.})\mathbf{i}$$

or

$(2B_y - 8A_y)i + (2B_x - 16 + 8A_x - 16)j$

$+(8B_y + 8A_y)k = (360 \text{ lb} \cdot \text{in.})\mathbf{i}$

From

i-coefficient:

$$2B_y - 8A_y = 360 \text{ lb} \cdot \text{in.} \quad (4)$$

j-coefficient:

$$-2B_x + 8A_x = 32 \text{ lb} \cdot \text{in.} \quad (5)$$

k-coefficient:

$$8B_y + 8A_y = 0 \quad (6)$$
PROBLEM 3.157 (Continued)

From Equations (2) and (4):
\[ 2B_y - 8(-B_y) = 360 \]
\[ B_y = 36 \text{ lb} \quad A_y = 36 \text{ lb} \]

From Equations (1) and (5):
\[ 2(-A_x - 8) + 8A_x = 32 \]
\[ A_x = 1.6 \text{ lb} \]

From Equation (1):
\[ B_x = -(1.6 + 8) = -9.6 \text{ lb} \]

\[ \mathbf{A} = (1.600 \text{ lb}) \mathbf{i} - (36.0 \text{ lb}) \mathbf{j} + (2.00 \text{ lb}) \mathbf{k} \]

\[ \mathbf{B} = -(9.60 \text{ lb}) \mathbf{i} + (36.0 \text{ lb}) \mathbf{j} + (2.00 \text{ lb}) \mathbf{k} \]