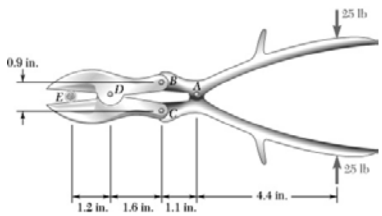


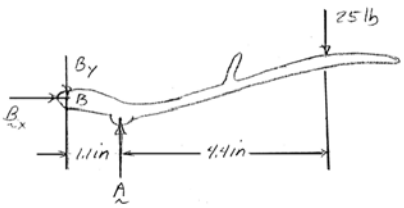
PROBLEM 6.146

The bone rongeur shown is used in surgical procedures to cut small bones. Determine the magnitude of the forces exerted on the bone at *E* when two 25-lb forces are applied as shown.

SOLUTION

Note: By symmetry the horizontal components of pin forces at *A* and *D* are zero.

FBD handle AB:

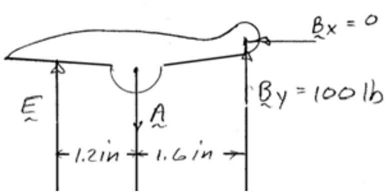


$$\xrightarrow{} \Sigma F_x = 0: \ B_x = 0$$

$$\circlearrowleft \Sigma M_A = 0: \ (1.1 \text{ in.}) B_y - (4.4 \text{ in.})(25 \text{ lb})$$

$$B_y = 100 \text{ lb}$$

FBD Blade BD:



$$\circlearrowleft \Sigma M_A = 0: \ (1.6 \text{ in.})(100 \text{ lb}) - (1.2 \text{ in.})(E) = 0$$

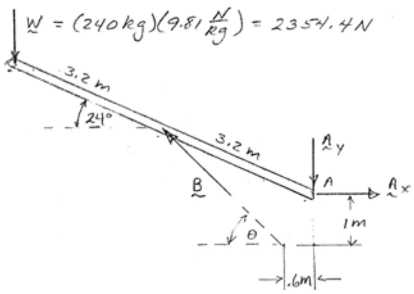
$$E = 133.3 \text{ lb} \blacktriangleleft$$

PROBLEM 6.147

The telescoping arm *ABC* is used to provide an elevated platform for construction workers. The workers and the platform together have a mass of 240 kg and have a combined center of gravity located directly above *C*. For the position when $\theta = 24^\circ$, determine (*a*) the force exerted at *B* by the single hydraulic cylinder *BD*, (*b*) the force exerted on the supporting carriage at *A*.

SOLUTION

FBD boom:



Note:

$$\theta = \tan^{-1}\frac{(3.2\sin 24^\circ - 1)\text{ m}}{(3.2\cos 24^\circ - 0.6)\text{ m}}$$

$$\theta = 44.73^\circ$$

(*a*)

$$\Sigma M_A = 0: \left[(6.4\text{ m})\cos 24^\circ\right](2.3544\text{ kN}) - \left[(3.2\text{ m})\cos 24^\circ\right]B\sin 44.73^\circ$$

$$+\left[(3.2\text{ m})\sin 24^\circ\right]B\cos 44.73^\circ = 0$$

$B = 12.153$ kN $\qquad\qquad \mathbf{B} = 12.15\text{ kN} \measuredangle\, 44.7^\circ$ ◀

$$\Sigma F_x = 0: A_x - (12.153\text{ kN})\cos 44.73^\circ = 0$$

$$\mathbf{A}_x = 8.633\text{ kN} \longrightarrow$$

(*b*)

$$\Sigma F_y = 0: \; -2.3544\text{ kN} + (12.153\text{ kN})\sin 44.73^\circ - A_y = 0$$

$$\mathbf{A}_y = 6.198\text{ kN} \downarrow$$

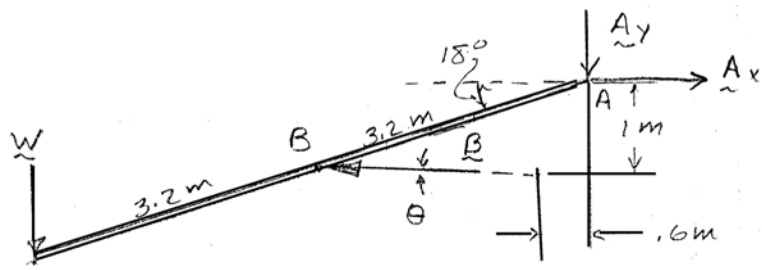
On boom: $\mathbf{A} = 10.63\text{ kN} \measuredangle\, 35.7^\circ$

On carriage: $\mathbf{A} = 10.63\text{ kN} \measuredangle\, 35.7^\circ$ ◀

PROBLEM 6.148

The telescoping arm *ABC* can be lowered until end *C* is close to the ground, so that workers can easily board the platform. For the position when $\theta = -18^\circ$, determine (*a*) the force exerted at *B* by the single hydraulic cylinder *BD*, (*b*) the force exerted on the supporting carriage at *A*.

SOLUTION



FBD boom:

$$\theta = \tan^{-1}\frac{1\text{ m} - 3.2\text{ m}\sin 18^\circ}{3.2\text{ m}\cos 18^\circ - 0.6\text{ m}}$$

$$\theta = 0.2614^\circ$$

$$\mathbf{W} = (240\text{ kg})(9.81\text{ N/kg}) = 2354.4\text{ N}$$

(*a*)

$$\circlearrowleft \Sigma M_A = 0: \left[(6.4\text{ m})\cos 18^\circ\right]2.3544\text{ kN} - \left[(3.2\text{ m})\cos 18^\circ\right]B\sin(0.2614^\circ)$$

$$-\left[(3.2\text{ m})\sin 18^\circ\right]B\cos(0.2614^\circ) = 0$$

$$B = 14.292\text{ kN} \qquad \mathbf{B} = 14.29\text{ kN} \searrow .261^\circ \blacktriangleleft$$

(*b*)

$$\longrightarrow \Sigma F_x = 0: A_x - B\cos(0.2614^\circ) = 0$$

$$A_x = (14.292\text{ kN})\cos(0.2614^\circ) = 14.292\text{ kN}$$

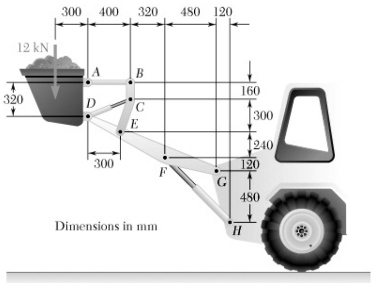
$$\uparrow \Sigma F_y = 0: A_y + B\sin(0.2614^\circ) - 2.3544\text{ kN} = 0$$

$$A_y = 2.3544\text{ kN} - (14.292\text{ kN})\sin(0.2614^\circ)$$

$$A_y = 2.2892\text{ kN}$$

On boom: $\mathbf{A} = 14.47\text{ kN} \searrow 9.10^\circ$

On carriage: $\mathbf{A} = 14.47\text{ kN} \searrow 9.10^\circ \blacktriangleleft$

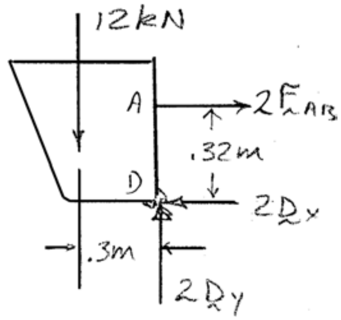


PROBLEM 6.149

The bucket of the front-end loader shown carries a 12-kN load. The motion of the bucket is controlled by two identical mechanisms, only one of which is shown. Knowing that the mechanism shown supports one-half of the 12-kN load, determine the force exerted (*a*) by cylinder *CD*, (*b*) by cylinder *FH*.

SOLUTION

FBD bucket:



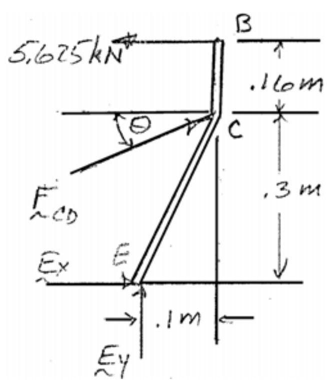
(*a*)

$$\circlearrowleft \Sigma M_D = 0: (0.3\text{ m})(12\text{ kN}) - (0.32\text{ m})(2F_{AB}) = 0 \quad F_{AB} = 5.625\text{ kN}$$

$$\longrightarrow \Sigma F_x = 0: 2F_{AB} - 2D_x = 0 \qquad D_x = F_{AB} = 5.625\text{ kN}$$

$$\uparrow \Sigma F_y = 0: D_y - 12\text{ kN} = 0 \qquad D_y = 12\text{ kN}$$

FBD link BCE:



$$\theta = \tan^{-1}\frac{160}{400} = 21.801°$$

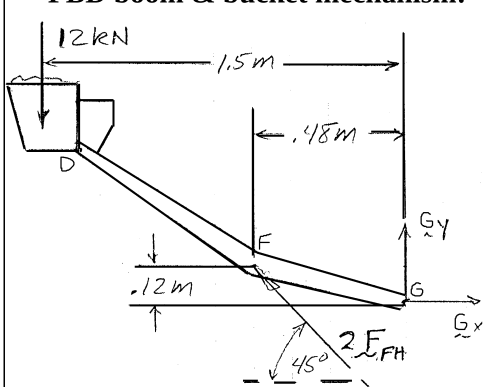
$$\circlearrowleft \Sigma M_E = 0: (0.46\text{ m})(5.625\text{ kN}) + (0.1\text{ m})(F_{CD}\sin 21.801°)$$

$$-(0.3\text{ m})(F_{CD}\cos 21.801°) = 0$$

$$F_{CD} = 10.7185\text{ kN} \quad (\text{C})$$

On *BCE*: $\mathbf{F}_{CD} = 10.72\text{ kN} \measuredangle 21.8°$ ◀

FBD boom & bucket mechanism:



(*b*)

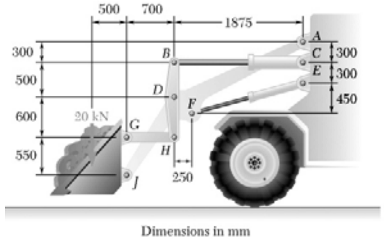
$$\circlearrowleft \Sigma M_G = 0: (1.5\text{ m})(12\text{ kN}) + (0.12\text{ m})(2F_{FH}\cos 45°)$$

$$-(0.48\text{ m})(2F_{FH}\sin 45°) = 0$$

$$F_{FH} = 35.4\text{ kN C}$$

On *DFG*: $\mathbf{F}_{FH} = 35.4\text{ kN} \searrow 45°$ ◀

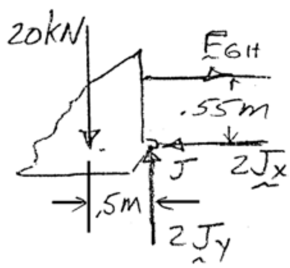
PROBLEM 6.150



The motion of the bucket of the front-end loader shown is controlled by two arms and a linkage which are pin-connected at *D*. The arms are located symmetrically with respect to the central, vertical, and longitudinal plane of the loader; one arm *AFJ* and its control cylinder *EF* are shown. The single linkage *GHBD* and its control cylinder *BC* are located in the plane of symmetry. For the position shown, determine the force exerted (*a*) by cylinder *BC*, (*b*) by cylinder *EF*.

SOLUTION

FBD bucket:

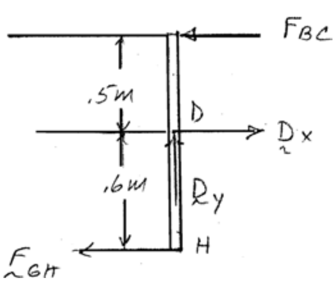


(*a*)

$$\circlearrowleft \Sigma M_J = 0:\ (0.5\text{ m})(20\text{ kN}) - (0.55\text{ m})F_{GH} = 0$$

$$F_{GH} = 18.1818\text{ kN}$$

FBD link BH:

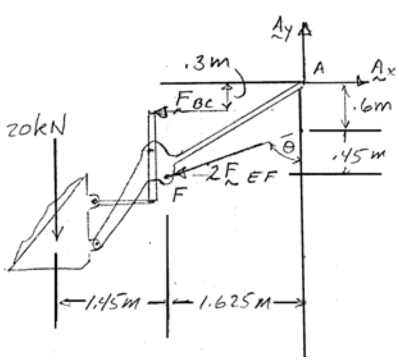


$$\circlearrowleft \Sigma M_D = 0:\ (0.5\text{ m})F_{BC} - (0.6\text{ m})F_{GH} = 0$$

$$F_{BC} = \frac{6}{5}F_{GH} = \frac{6}{5}18.1818\text{ kN} = 21.818\text{ kN}$$

On *BH*: $\mathbf{F}_{BC} = 21.8\text{ kN} \longleftarrow$ ◀

FBD mechanism with bucket:



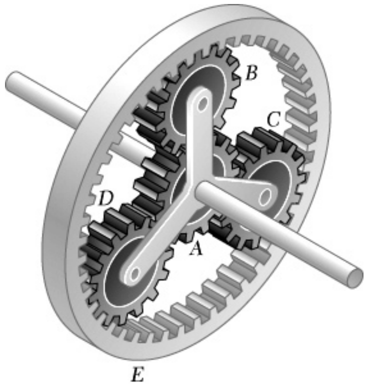
(*b*)

$$\theta = \tan^{-1}\frac{1.625\text{ m}}{0.45\text{ m}} = 74.521°$$

$$\Sigma M_A = (3.075\text{ m})(20\text{ kN}) - (0.3\text{ m})(28.818\text{ kN})$$

$$-(0.6\text{ m})(2F_{EF}\sin 74.521°) = 0$$

On *AF*: $\mathbf{F}_{EF} = 47.5\text{ kN} \measuredangle\ 15.48°$ ◀

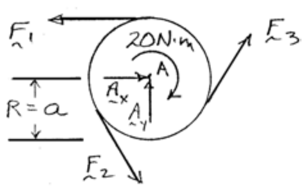


PROBLEM 6.151

In the planetary gear system shown, the radius of the central gear A is $a = 20$ mm, the radius of the planetary gear is b, and the radius of the outer gear E is $(a+2b)$. A clockwise couple of magnitude $M_A = 20\ \text{N}\cdot\text{m}$ is applied to the central gear A, and a counterclockwise couple of magnitude $M_S = 100\ \text{N}\cdot\text{m}$ 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 $\mathbf{M}_E$ that must be applied to the outer gear E.

SOLUTION

FBD Gear A:

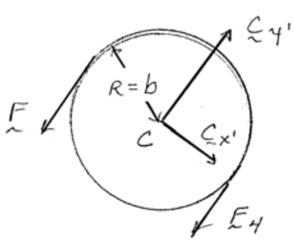


(*a*) By symmetry $F_1 = F_2 = F_3 = F$

$$\Sigma M_A = 0:\ 3aF - 20\ \text{N}\cdot\text{m} = 0$$

$$F = \frac{20}{3a}\ \text{N}\cdot\text{m}$$

FBD Gear C:



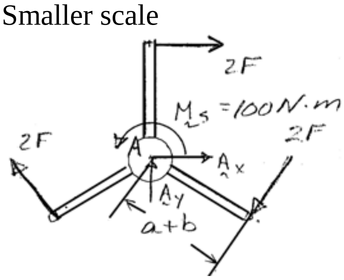
$$\Sigma F_{x'} = 0:\ C_{x'} = 0$$

$$\Sigma M_C = 0:\ bF - bF_4 = 0 \qquad F_4 = F = \frac{20\ \text{N}\cdot\text{m}}{3a}$$

$$\Sigma F_{y'} = 0:\ C_{y'} - F - F_4 = 0 \qquad C_{y'} = 2F = \frac{40\ \text{N}\cdot\text{m}}{3a}$$

By symmetry central forces on gears B and D are the same

FBD Spider:
Smaller scale



$$\Sigma M_A = 0:\ M_S - (a+b)2F = 0$$

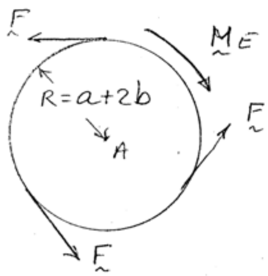
$$100\ \text{N}\cdot\text{m} = 6(a+b)F = (a+b)\frac{40}{a}\ \text{N}\cdot\text{m}$$

$$\frac{100}{40} = 1 + \frac{b}{a} \qquad \frac{b}{a} = \frac{3}{2}$$

$a = 20$ mm so that $b = 30.0$ mm ◀

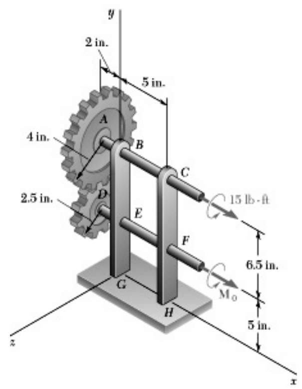
PROBLEM 6.151 CONTINUED

FBD Outer gear:



(b) $\Sigma M_A = 0: 3(a + 2b)F - M_E = 0$

$$M_E = 3(20 \text{ mm} + 60 \text{ mm})\frac{20 \text{ N}\cdot\text{m}}{3(20 \text{ mm})} = 80.0 \text{ N}\cdot\text{m} \blacktriangleleft$$

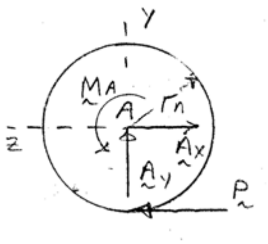


PROBLEM 6.152

Gears A and D are rigidly attached to horizontal shafts that are held by frictionless bearings. Determine (a) the couple $\mathbf{M}_0$ that must be applied to shaft DEF to maintain equilibrium, (b) the reactions at G and H.

SOLUTION

FBD Gear A: looking from C



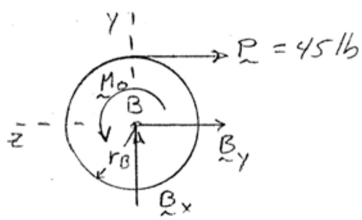
(a)

$$M_A = 15 \text{ lb}\cdot\text{ft} \qquad r_A = 4 \text{ in.}$$

$$\circlearrowleft \Sigma M_A = 0: M_A - P r_A = 0 \qquad P = \frac{M_A}{r_A} = \frac{180 \text{ lb}\cdot\text{in.}}{4 \text{ in.}}$$

$$P = 45 \text{ lb}$$

FBD Gear B: looking from F

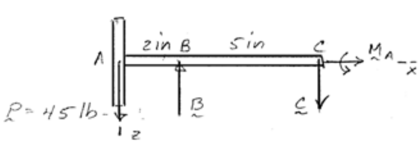


$$\circlearrowleft \Sigma M_B = 0: M_0 - r_B P = 0$$

$$M_0 = r_B P = (2.5 \text{ in.})(45 \text{ lb}) = 112.5 \text{ lb}\cdot\text{in.} \circlearrowright$$

$$\mathbf{M}_0 = 112.5 \text{ lb}\cdot\text{in. } \mathbf{i} \blacktriangleleft$$

FBD ABC: looking down

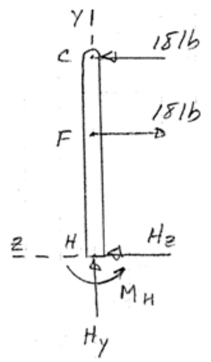


(b)

$$\circlearrowleft \Sigma M_B = 0: (2 \text{ in.})(45 \text{ lb}) - (5 \text{ in.})C = 0 \qquad \mathbf{C} = 18 \text{ lb } \mathbf{k}$$

$$\downarrow \Sigma F_z = 0: 45 \text{ lb} - B + 18 \text{ lb} = 0 \qquad \mathbf{B} = -63 \text{ lb } \mathbf{k}$$

FBD BEG:



By analogy, using FBD *DEF* $\mathbf{E} = 63\text{ lb }\mathbf{k}$ $\mathbf{F} = 18\text{ lb }\mathbf{k}$

$$\Sigma F_z = 0: G_z + 63\text{ lb} - 63\text{ lb} = 0$$

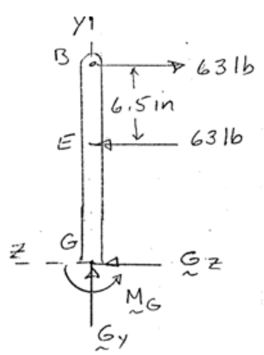
$$G_z = 0$$

$$\Sigma F_y = 0 \qquad G_y = 0$$

$$\Sigma M_G = 0 \qquad M_G - (6.5\text{ in.})(63\text{ lb}) = 0$$

$$\mathbf{M}_G = (410\text{ lb}\cdot\text{in.})\mathbf{i} \blacktriangleleft$$

FBD CFH:



$$\Sigma\mathbf{F} = 0: H_z = H_y = 0$$

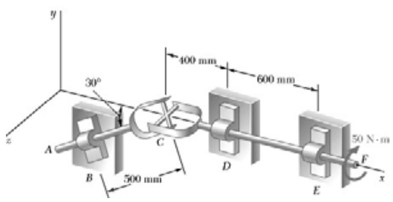
$$\Sigma M_H = 0$$

$$M_H = -(6.5\text{ in.})(18\text{ lb})$$

$$= -117\text{ lb}\cdot\text{in.}$$

$$\mathbf{M}_G = -(117.0\text{ lb}\cdot\text{in.})\mathbf{i} \blacktriangleleft$$

PROBLEM 6.153



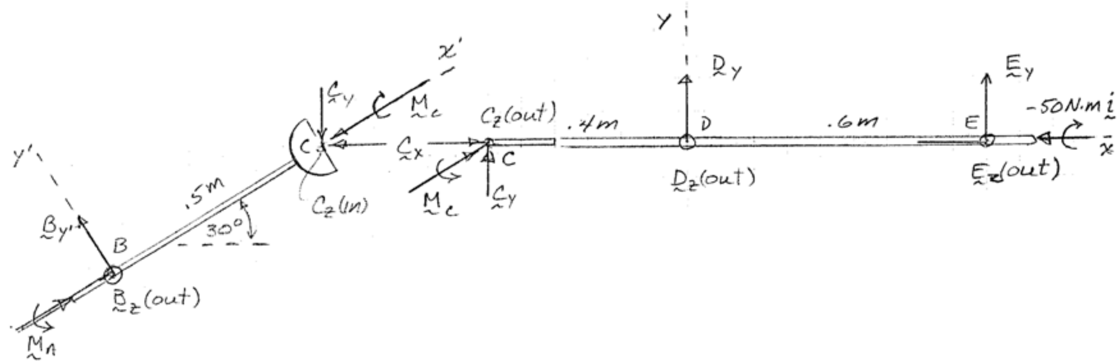
Two shafts AC and CF, which lie in the vertical xy plane, are connected by a universal joint at C. The bearings at B and D do ot exert any axial force. A couple of magnitude $50\ \text{N}\cdot\text{m}$ (clockwise when viewed from the positive x axis) is applied to shaft CF at F. At a time when the arm 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. (*Hint:* The sum of the couples exerted on the crosspiece must be zero).

SOLUTION

Note: The couples exerted by the two yokes on the crosspiece must be equal and opposite. Since neither yoke can exert a couple along the arm of the crosspiece it contacts, these equal and opposite couples must be normal to the plane of the crosspiece.

If the crosspiece arm attached to shaft CF is horizontal, the plane of the crosspiece is normal to shaft AC, so couple $\mathbf{M}_C$ is along AC.

FBDs shafts with yokes:



(a) FBD CDE: $\Sigma M_x = 0$: $\quad M_C \cos 30° - 50\ \text{N}\cdot\text{m} = 0 \qquad M_C = 57.735\ \text{N}\cdot\text{m}$

FBD BC: $\Sigma M_{x'} = 0$: $M_A - M_C = 0 \qquad M_A = 57.7\ \text{N}\cdot\text{m}$ ◀

(b) $\Sigma \mathbf{M}_C = 0$: $M_A\,\mathbf{i}' + (0.5\ \text{m})B_z\,\mathbf{j}' - (0.5\ \text{m})B_{y'}\,\mathbf{k} = 0 \qquad \mathbf{B} = 0$ ◀

$\Sigma \mathbf{F} = 0$: $\mathbf{B} + \mathbf{C} = 0$ so $\mathbf{C} = 0$

FBD CDF: $\Sigma M_{Dy} = 0$: $-(0.6\ \text{m})E_z + (57.735\ \text{N}\cdot\text{m})\sin 30° = 0$

$\mathbf{E}_z = 48.1\ \text{N}\ \mathbf{k}$

$\Sigma F_x = 0$: $E_x = 0$

$\Sigma M_{Dz} = 0$: $(0.6\ \text{m})E_y = 0 \qquad E_y = 0$ so $\mathbf{E} = (48.1\ \text{N})\mathbf{k}$ ◀

$\Sigma \mathbf{F} = 0$: $\cancel{\mathbf{C}}^{\,0} + \mathbf{D} + \mathbf{E} = 0 \qquad \mathbf{D} = -\mathbf{E} = -(48.1\ \text{N})\mathbf{k}$ ◀