2–1. The steel framework is used to support the reinforced stone concrete slab that is used for an office. The slab is 200 mm thick. Sketch the loading that acts along members \( BE \) and \( FED \). Take \( a = 2 \text{ m}, b = 5 \text{ m}. \)

\[ \text{Hint: See Tables 1.2 and 1.4.} \]

**SOLUTION**

**Beam \( BE \).** Since \( \frac{b}{a} = \frac{5}{2} = 2.5 \), the concrete slab will behave as a one-way slab. Thus, the tributary area for this beam is rectangular, as shown in Fig. \( a \), and the intensity of the uniform distributed load is

\[
200 \text{ mm thick reinforced stone concrete slab:} \\
\frac{(23.6 \text{ kN/m}^2)(0.2 \text{ m})(2 \text{ m})}{2} = 9.44 \text{ kN/m}
\]

Live load for office: \( (2.40 \text{ kN/m}^2)(2 \text{ m}) = 480 \text{ kN/m} \)

\[ \text{Ans.} \]

Due to symmetry, the vertical reactions at \( B \) and \( E \) are

\[ B_y = E_y = (14.24 \text{ kN/m})(5)/2 = 35.6 \text{ kN} \]

The loading diagram for beam \( BE \) is shown in Fig. \( b \).

**Beam \( FED \).** The only load this beam supports is the vertical reaction of beam \( BE \) at \( E \), which is \( E_y = 35.6 \text{ kN} \). The loading diagram for this beam is shown in Fig. \( c \).
2–2. Solve Prob. 2–1 with \(a = 3\, \text{m}, \, b = 4\, \text{m}\).

**SOLUTION**

**Beam \(BE\).** Since \(\frac{b}{a} = \frac{4}{3} < 2\), the concrete slab will behave as a two-way slab.

Thus, the tributary area for this beam is the hexagonal area shown in Fig. \(a\), and the maximum intensity of the distributed load is:

- 200-mm-thick reinforced stone concrete slab: \((23.6\, \text{kN/m}^3)(0.2\, \text{m})(3\, \text{m}) = 14.16\, \text{kN/m}\)

  - Live load for office: \((2.40\, \text{kN/m}^2)(3\, \text{m})\) = 7.20 kN/m

  \[\text{Ans.}\]

Due to symmetry, the vertical reactions at \(B\) and \(E\) are

\[B_y = E_y = \frac{2}{2} \left[ \frac{1}{2} (21.36\, \text{kN/m})(1.5\, \text{m}) + (21.36\, \text{kN/m})(1\, \text{m}) \right] = 26.70\, \text{kN}\]

The loading diagram for beam \(BE\) is shown in Fig. \(b\).

**Beam \(FED\).** The loadings that are supported by this beam are the vertical reaction of beam \(BE\) at \(E\), which is \(E_y = 26.70\, \text{kN}\) and the triangular distributed load of which its tributary area is the triangular area shown in Fig. \(a\). Its maximum intensity is

- 200-mm-thick reinforced stone concrete slab: \((23.6\, \text{kN/m}^3)(0.2\, \text{m})(1.5\, \text{m}) = 7.08\, \text{kN/m}\)

  - Live load for office: \((2.40\, \text{kN/m}^2)(1.5\, \text{m})\) = \(\frac{3.60\, \text{kN/m}}{10.68\, \text{kN/m}}\) \[\text{Ans.}\]

The loading diagram for beam \(FED\) is shown in Fig. \(c\).
2–3. The floor system used in a school classroom consists of a 4-in. reinforced stone concrete slab. Sketch the loading that acts along the joist BF and side girder ABCDE. Set \( a = 10 \text{ ft}, \ b = 30 \text{ ft} \). \textit{Hint:} See Tables 1.2 and 1.4.

**SOLUTION**

**Joist BF.** Since \( \frac{b}{a} = \frac{30 \text{ ft}}{10 \text{ ft}} = 3 \), the concrete slab will behave as a one-way slab. Thus, the tributary area for this joist is the rectangular area shown in Fig. a, and the intensity of the uniform distributed load is

\[
\text{4-in.-thick reinforced stone concrete slab: } (0.15 \text{ k/ft}^3) \left( \frac{4}{12} \text{ ft} \right) (10 \text{ ft}) = 0.5 \text{ k/ft}
\]

Live load for classroom: \((0.04 \text{ k/ft}^2)(10 \text{ ft}) = 0.4 \text{ k/ft}\)

Due to symmetry, the vertical reactions at \( B \) and \( F \) are

\[ B_y = F_y = (0.9 \text{ k/ft})(30 \text{ ft})/2 = 13.5 \text{ k} \]

The loading diagram for joist BF is shown in Fig. b.

**Girder ABCDE.** The loads that act on this girder are the vertical reactions of the joists at \( B, C, \) and \( D \), which are \( B_y = C_y = D_y = 13.5 \text{ k} \), and 6.75-k end loads from the joists at \( A \) and \( E \). The loading diagram for this girder is shown in Fig. c.

**Ans.**

Live load for classroom: 0.9 k/ft

\( B_y = 13.5 \text{ k} \)
SOLUTION

**Joist BF.** Since \( \frac{b}{a} = \frac{15 \text{ ft}}{10 \text{ ft}} = 1.5 < 2 \), the concrete slab will behave as a two-way slab. Thus, the tributary area for the joist is the hexagonal area, as shown in Fig. a, and the maximum intensity of the distributed load is:

4-in.-thick reinforced stone concrete slab: \((0.15 \text{ k/ft}^3)\left(\frac{4}{12} \text{ ft}\right)(10 \text{ ft}) = 0.5 \text{ k/ft}\)

Live load for classroom: \((0.04 \text{ k/ft}^2)(10 \text{ ft}) = 0.4 \text{ k/ft}\)

**Ans.**

Due to symmetry, the vertical reactions at \( B \) and \( G \) are

\[
B_y = F_y = \frac{2}{2} \left[ \frac{1}{2} (0.9 \text{ k/ft})(5 \text{ ft}) + (0.9 \text{ k/ft})(5 \text{ ft}) \right] = 4.50 \text{ k}
\]

**Ans.**

The loading diagram for beam \( BF \) is shown in Fig. b.

**Girder ABCDE.** The loadings that are supported by this girder are the vertical reactions of the joist at \( B, C \) and \( D \), which are \( B_x = C_y = D_y = 4.50 \text{ k} \), the 2.25-k end loads from the joists at \( A \) and \( E \), and the triangular distributed load shown in Fig. a. Its maximum intensity is

4-in.-thick reinforced stone concrete slab:

\((0.15 \text{ k/ft}^3)\left(\frac{4}{12} \text{ ft}\right)(5 \text{ ft}) = 0.25 \text{ k/ft}\)

Live load for classroom: \((0.04 \text{ k/ft}^2)(5 \text{ ft}) = 0.20 \text{ k/ft}\)

**Ans.**

The loading diagram for the girder \( ABCDE \) is shown in Fig. c.
2–5. Solve Prob. 2–3 with \( a = 7.5 \text{ ft} \), \( b = 20 \text{ ft} \).

**SOLUTION**

**Beam BF.** Since \( \frac{b}{a} = \frac{20 \text{ ft}}{7.5 \text{ ft}} = 2.7 > 2 \), the concrete slab will behave as a one-way slab. Thus, the tributary area for this beam is a rectangle, as shown in Fig. \( a \), and the intensity of the distributed load is:

- 4-in.-thick reinforced stone concrete slab: \((0.15 \text{ k/ft}^3) \left( \frac{4}{12} \text{ ft} \right) (7.5 \text{ ft}) = 0.375 \text{ k/ft}\)
- Live load from classroom: \((0.04 \text{ k/ft}^2)(7.5 \text{ ft}) = 0.300 \text{ k/ft}\)

Due to symmetry, the vertical reactions at \( B \) and \( F \) are

\[
B_y = F_y = \frac{(0.675 \text{ k/ft})(20 \text{ ft})}{2} = 6.75 \text{ k}
\]

The loading diagram for beam \( BF \) is shown in Fig. \( b \).

**Beam ABCD.** The loading diagram for this beam is shown in Fig. \( c \).
2–6. The frame is used to support the wood deck in a residential dwelling where the live load is 40 lb/ft². Sketch the loading that acts along members BG and ABCD. Set \( b = 10 \text{ ft}, a = 5 \text{ ft}. \)

**SOLUTION**

From Table 1–4,

\[ LL = 40 \text{ psf} \]

\[ \frac{L_2}{L_1} = \frac{b}{a} = \frac{10}{5} = 2 \leq 2 \]

Two-way slab:

- Reaction at B: 750 lb↑
- Reaction at A: 1.5 k↑

---

Answer:

Reaction at B: 750 lb↑
Reaction at A: 1.5 k↑
2–7. Solve Prob. 2–6 if \( b = 8 \) ft, \( a = 8 \) ft.

**SOLUTION**

From Table 1–4,

\[ LL = 40 \text{ psf} \]

\[ \frac{L_2}{L_1} = \frac{b}{a} = \frac{8}{8} = 1 \geq 2 \]

Two-way slab:

- Reaction at \( B \): 640 lb↑
- Reaction at \( A \): 1920 lb↑

Ans.

Ans.
*2–8. Solve Prob. 2–6 if \( b = 15 \) ft, \( a = 10 \) ft.

**SOLUTION**

From Table 1.4.

\( LL = 40 \text{ psf} \)
\( \frac{b}{a} = \frac{15}{10} = 1.5 \leq 2 \)

Two-way slab:

- Reaction at \( B \): 2 k\( \uparrow \)
- Reaction at \( A \): 4.5 k\( \uparrow \)

Ans.

Ans.

Ans.

Reaction at \( B \): 2 k\( \uparrow \)
Reaction at \( A \): 4.5 k\( \uparrow \)
2–9. The steel framework is used to support the 4-in. reinforced stone concrete slab that carries a uniform live loading of 400 lb/ft². Sketch the loading that acts along members BE and FED. Set \( a = 9 \text{ ft}, b = 12 \text{ ft} \). *Hint:* See Table 1.2.

**SOLUTION**

**Beam BE.** Since \( \frac{b}{a} = \frac{12 \text{ ft}}{9 \text{ ft}} = \frac{4}{3} < 2 \), the concrete slab will behave as a two-way slab. Thus, the tributary area for this beam is the shaded octagonal area shown in Fig. a, and the maximum intensity of the trapezoidal distributed load is:

- 4-in.-thick reinforced stone concrete slab: \((0.15 \text{ k/ft}^3) \left( \frac{4}{12} \text{ ft} \right) (9 \text{ ft}) = 0.45 \text{ k/ft} \)
- Floor live load: \((0.4 \text{ k/ft}^2)(9 \text{ ft}) = \frac{3.60 \text{ k/ft}}{4.05 \text{ k/ft}} \)

Due to symmetry, the vertical reactions at \( B \) and \( E \) are

\[
B_y = E_y = \frac{1}{2} \frac{(4.05 \text{ k/ft})(3 \text{ ft} + 12 \text{ ft})}{2} = 15.2 \text{ k}
\]

The loading diagram for beam BE is shown in Fig. a.

**Beam FED.** The loadings that are supported by this beam are the vertical reactions of beam BE at \( E \), which is \( E_y = 15.19 \text{ k} \) and the triangular distributed load contributed by dotted triangular tributary area shown in Fig. a. Its maximum intensity is

- 4-in.-thick concrete slab: \((0.15 \text{ k/ft}^3) \left( \frac{4}{12} \text{ ft} \right) (4.5 \text{ ft}) = 0.225 \text{ k/ft} \)
- Floor live load: \((0.4 \text{ k/ft}^2)(4.5 \text{ ft}) = \frac{1.800 \text{ k/ft}}{2.025 \text{ k/ft}} \)

The loading diagram for beam FED is shown in Fig. c.

**Beam BE.** \( w_{\text{max}} = 4.05 \text{ k/ft} \)

**Beam FED.** 15.2 k at \( E \), \( w_{\text{max}} = 2.025 \text{ k/ft} \)
2–10. Solve Prob. 2–9, with \( a = 6 \text{ ft}, b = 18 \text{ ft} \).

**SOLUTION**

**Beam BE.** Since \( \frac{b}{a} = \frac{18}{6} = 3 > 2 \), the concrete slab will behave as a one-way slab. Thus, the tributary area for this beam is the shaded rectangular area shown in Fig. a, and the intensity of the uniform distributed load is:

4-in.-thick reinforced stone concrete slab: \((0.15 \text{ k/ft}^3)(\frac{4}{12} \text{ ft})(6 \text{ ft}) = 0.30 \text{ k/ft} \)

Floor live load: \((0.4 \text{ k/ft}^2)(6 \text{ ft}) = \frac{2.40 \text{ k/ft}}{2.70 \text{ k/ft}} \) \hspace{1cm} Ans.

Due to symmetry, the vertical reactions at \( B \) and \( E \) are

\[ B_y = E_y = \frac{(2.70 \text{ k/ft})(18 \text{ ft})}{2} = 24.3 \text{ k} \]

The loading diagram of this beam \( BE \) is shown in Fig. b.

**Beam FED.** The only load this beam supports is the vertical reaction of beam \( BE \) at \( E \), which is \( E_y = 24.3 \text{ k} \).

The loading diagram of beam \( FED \) is shown in Fig. c.
2–11. Classify each of the structures as statically determinate, statically indeterminate, or unstable. If indeterminate, specify the degree of indeterminacy.

**SOLUTION**

(a) \( r = 2 \quad 3n = 3(1) = 3 \)
\[ r < 3n \]
Unstable

(b) \( r = 4 \quad 3n = 3(1) = 3 \)
\[ r - 3n = 4 - 1 = 1 \]
Stable and statically indeterminate to the first degree

(c) \( r = 9 \quad 3n = 3(3) = 9 \)
\[ r = 3n \]
Stable and statically determinate

(d) \( r = 8 \quad 3n = 3(2) = 6 \)
\[ r - 3n = 8 - 6 = 2 \]
Stable and statically indeterminate to the second degree

(e) \( r = 7 \quad 3n = 3(2) = 6 \)
\[ r - 3n = 7 - 6 = 1 \]
Stable and statically indeterminate to the first degree
*2-12. Classify each of the structures as statically determinate, statically indeterminate, or unstable. If indeterminate, specify the degree of indeterminacy.

SOLUTION

(a) \( r > 3n \)
\[ 4 > 3(1) \]
Statically indeterminate to the first degree.

(b) Parallel reactions
Unstable.

(c) \( r > 3n \)
\[ 6 > 3(1) \]
Statically indeterminate to the third degree.

(d) Parallel reactions
Unstable.

Ans.

(e)

(f)

(g)

(h)

Ans.

(a) Statically indeterminate to the first degree
(b) Unstable
(c) Statically indeterminate to the first degree
(d) Unstable
2-13. Classify each of the structures as statically determinate, statically indeterminate, or unstable. If indeterminate, specify the degree of indeterminacy. The supports or connections are to be assumed as stated.

SOLUTION

(a) \( r = 7 \quad 3n = 3(2) = 6 \quad r - 3n = 7 - 6 = 1 \)
Stable and statically indeterminate to first degree  Ans.

(b) \( r = 6 \quad 3n = 3(2) = 6 \quad r = 3n \)
Stable and statically determinate  Ans.

(c) \( r = 4 \quad 3n = 3(1) = 3 \quad r - 3n = 4 - 3 = 1 \)
Stable and statically indeterminate to first degree  Ans.
2-14. Classify each of the structures as statically determinate, statically indeterminate, or unstable. If indeterminate, specify the degree of indeterminacy. The supports or connections are to be assumed as stated.

**SOLUTION**

(a) \( r = 5 \quad 3n = 3(2) = 6 \)
\[ r < 3n \]
Unstable

Ans.

(b) \( r = 9 \quad 3n = 3(3) = 9 \)
\[ r = 3n \]
Stable and statically determinate

Ans.

(c) \( r = 8 \quad 3n = 3(2) = 6 \)
\[ r - 3n = 8 - 6 = 2 \]
Stable and statically indeterminate to the second degree

Ans.

---

Ans.

(a) Unstable
(b) Stable and statically determinate
(c) Stable and statically indeterminate to the second degree
2–15. Classify each of the structures as statically determinate, statically indeterminate, or unstable. If indeterminate, specify the degree of indeterminacy.

SOLUTION

(a) Since the lines of action of the reactive forces are concurrent, the structure is **unstable**.

(b) \( r = 6 \quad 3n = 3(2) = 6 \)
\[ r = 3n \]
Stable and statically determinate

(c) \( r = 3 \quad 3n = 3(1) = 3 \)
\[ r = 3n \]
Stable and statically determinate

 Ans. (a) Unstable
(b) Stable and statically determinate
(c) Stable and statically determinate
*2–16. Classify each of the structures as statically determinate, statically indeterminate, or unstable. If indeterminate, specify the degree of indeterminacy.

SOLUTION

(a) \( r = 6 \quad 3n = 3(1) = 3 \)
\[ r - 3n = 6 - 3 = 3 \]
Stable and statically indeterminate to the third degree  

(b) \( r = 5 \quad 3n = 3(1) = 3 \)
\[ r - 3n = 5 - 3 = 2 \]
Stable and statically indeterminate to the second degree  

(c) \( r = 5 \quad 3n = 3(1) = 3 \)
\[ r - 3n = 5 - 3 = 2 \]
Stable and statically indeterminate to the second degree  

(d) \( r = 6 \quad 3n = 3(2) = 6 \)
\[ r = 3n \]
Stable and statically determinate.
2–17. Classify each of the structures as statically determinate, statically indeterminate, or unstable. If indeterminate, specify the degree of indeterminacy.

**SOLUTION**

(a) \( r = 2 \quad 3n = 3(1) = 3 \quad r < 3n \)
Unstable.

(b) \( r = 12 \quad 3n = 3(2) = 6 \quad r > 3n \)
\[ r - 3n = 12 - 6 = 6 \]
Statically indeterminate to the sixth degree.

(c) \( r = 6 \quad 3n = 3(2) = 6 \)
\[ r = 3n \]
Stable and statically determinate.

(d) Unstable since the lines of action of the reactive force components are concurrent.

---

Ans.
(a) Unstable
(b) Statically indeterminate to the sixth degree
(c) Stable and statically determinate
(d) Unstable since the lines of action of the reactive force components are concurrent
2–18. Determine the reactions on the beam.

SOLUTION

Equations of Equilibrium. Referring to the FBD of the beam shown in Fig. a, $N_A$ and $B_y$ can be determined directly by writing the moment equations of equilibrium about points $B$ and $A$, respectively.

\[ \sum M_B = 0; \quad \frac{1}{2} (3)(12)(4) + 3(12)(6) + 12(12) - N_A(24) = 0 \]

$N_A = 18.0 \text{ k}$  

\[ \sum M_A = 0; \quad B_y(24) - 12(12) - 3(12)(18) - \frac{1}{2} (3)(12)(20) = 0 \]

$B_y = 48.0 \text{ k}$  

Write the force equation of equilibrium along the $x$-axis.

\[ \sum F_x = 0, \quad b_x = 0 \]

$N_A = 18.0 \text{ k}$  

$B_y = 48.0 \text{ k}$  

$b_x = 0$
2–19. Determine the reactions at the supports.

SOLUTION

Equations of Equilibrium. Referring to the FBD of the beam shown in Fig. a, \( N_B \) and \( A_y \) can be determined directly by writing the moment equations of equilibrium about points \( A \) and \( B \), respectively.

\[
\sum M_A = 0; \quad N_B(18) - \frac{1}{2}(3)(18)(9) - \frac{1}{2}(3)(9)(24) = 0
\]

\( N_B = 31.5 \text{ k} \quad \text{Ans.} \)

\[
\sum M_B = 0; \quad \frac{1}{2}(3)(18)(9) - \frac{1}{2}(3)(9)(6) - A_y(18) = 0
\]

\( A_y = 9.00 \text{ k} \quad \text{Ans.} \)

Write the force equation of equilibrium along the \( x \) axis.

\[
\sum F_x = 0; \quad A_x = 0
\]

\( \text{Ans.} \)
*2–20. Determine the reactions on the beam.

**SOLUTION**

**Equations of Equilibrium.** Referring to the FBD of the beam shown in Fig. a, \( N_A \) can be obtained directly by writing the moment equation of equilibrium about point \( B \).

\[
\sum M_B = 0; \quad 10(8.667) + B(6.50) + 25(4.333) - N_A(13) = 0
\]

\( N_A = 21.5 \text{ k} \)

Using this result to write the force equation of equilibrium along the \( x \) and \( y \) axis,

\[
\sum F_x = 0; \quad B_x + 21.5 \left( \frac{5}{13} \right) - (10 + 13 + 25) \left( \frac{5}{13} \right) = 0
\]

\( B_x = 10.19 \text{ k} = 10.2 \text{ k} \)

\[
\sum F_y = 0; \quad B_y + 21.5 \left( \frac{12}{13} \right) - (10 + 13 + 25) \left( \frac{12}{13} \right) = 0
\]

\( B_y = 24.46 \text{ k} = 24.5 \text{ k} \)
2–21. Determine the reactions at the supports A and B of the compound beam. There is a pin at C.

**SOLUTION**

Member AC:
\[ \downarrow \sum M_C = 0; \quad -A_y(6) + 12(2) = 0 \]

\[ A_y = 4.00 \text{ kN} \quad \text{Ans.} \]

\[ + \uparrow \sum F_y = 0; \quad C_y + 4.00 - 12 = 0 \]

\[ C_y = 8.00 \text{ kN} \]

\[ \rightarrow \sum F_x = 0; \quad C_x = 0 \]

Member CB:
\[ \downarrow \sum M_B = 0; \quad -M_B + 8.00(4.5) + 9(3) = 0 \]

\[ M_B = 63.0 \text{ kN} \cdot \text{m} \quad \text{Ans.} \]

\[ + \uparrow \sum F_y = 0; \quad B_y - 8 - 9 = 0 \]

\[ B_y = 17.0 \text{ kN} \quad \text{Ans.} \]

\[ \rightarrow \sum F_x = 0; \quad B_x = 0 \quad \text{Ans.} \]
2-22. Determine the reactions at the supports.

\[ \begin{align*}
\sum F_x &= 0; \quad A_x = 0 \quad \text{Ans.} \\
\sum M_B &= 0; \quad 900(4.5) + 200(1.333) - A_y(9) = 0 \quad \text{Ans.} \\
A_y &= 480 \text{ lb} \\
\sum F_y &= 0; \quad 480 - 1100 + B_y = 0 \quad \text{Ans.} \\
B_y &= 620 \text{ lb} 
\end{align*} \]
2–23. Determine the reactions at the supports A and C of the compound beam. Assume C is fixed, B is a pin, and A is a roller.

**SOLUTION**

**Equations of Equilibrium.** First consider the equilibrium of the FBD of segment AB in Fig. a. \( N_A \) and \( B_y \) can be determined directly by writing the moment equations of equilibrium about points B and A, respectively.

\[ \Sigma M_B = 0; \quad \frac{1}{2} (15)(3)(2) - N_A(3) = 0 \quad N_A = 15.0 \text{ kN} \quad \text{Ans.} \]

\[ \Sigma M_A = 0; \quad B_y(3) - \frac{1}{2} (15)(3)(1) = 0 \quad B_y = 7.50 \text{ kN} \quad \text{Ans.} \]

Write the force equation of equilibrium along the x axis.

\[ \Sigma F_x = 0; \quad B_x = 0. \]

Then consider the equilibrium of the FBD of segment BC using the results of \( B_x \) and \( B_y \).

\[ \Sigma M_C = 0; \quad 7.50(2) + 20(1) - M_C = 0 \quad M_C = 35.0 \text{ kN} \cdot \text{m} \quad \text{Ans.} \]

\[ \Sigma F_y = 0; \quad C_y - 20 - 7.50 = 0 \quad C_y = 27.5 \text{ kN} \quad \text{Ans.} \]
*2–24. Determine the reactions on the beam. The support at B can be assumed to be a roller.

**SOLUTION**

*Equations of Equilibrium:*

\[ \sum M_A = 0; \quad N_B(24) - 2(12)(6) - \frac{1}{2} (2)(12)(16) = 0 \quad N_B = 14.0 \text{ k} \]

\[ \sum M_B = 0; \quad \frac{1}{2} (2)(12)(8) + 2(12)(18) - A_y(24) = 0 \quad A_y = 22.0 \text{ k} \]

\[ \rightarrow \sum F_x = 0; \quad A_x = 0 \]

\[ \rightarrow \sum F_y = 0; \quad \frac{1}{2} (2)(12) k \]

\[ \rightarrow \sum F_z = 0; \quad 2(12) k \]

**Ans.**

\[ N_B = 14.0 \text{ k} \]

\[ A_y = 22.0 \text{ k} \]

\[ A_x = 0 \]
2-25. Determine the horizontal and vertical components of reaction at the pins A and C.

**SOLUTION**

**Equations of Equilibrium.** Referring to the FBD of the beam shown in Fig. a, \( F_{AB} \) and \( C_y \) can be determined directly by writing the moment equations of equilibrium about points C and B, respectively,

\[
\begin{align*}
\sum M_C &= 0; \quad \frac{1}{2} (12)(6)(2) + 60 - (F_{AB} \sin 60^\circ)(6) = 0 \\
F_{AB} &= 25.40 \text{ kN} \\
\sum M_B &= 0; \quad C_y(6) + 60 - \frac{1}{2} (12)(6)(4) = 0 \\
C_y &= 14.0 \text{ kN}
\end{align*}
\]

Using the result of \( F_{AB} \) to write the force equation of equilibrium along the x axis,

\[
\sum F_x = 0; \quad 25.40 \cos 60^\circ - C_x = 0 \quad C_x = 12.70 \text{ kN} = 12.7 \text{ kN}
\]

Referring to the FBD of pin A, Fig. b, the force equations of equilibrium written along the x and y axis give

\[
\begin{align*}
\sum F_x &= 0; \quad A_x - 25.40 \cos 60^\circ = 0 \quad A_x = 12.70 \text{ kN} = 12.7 \text{ kN} \\
\sum F_y &= 0; \quad A_y - 25.40 \sin 60^\circ = 0 \quad A_y = 22.0 \text{ kN}
\end{align*}
\]

\( \text{Ans.} \)

\( C_y = 14.0 \text{ kN} \)
\( C_x = 12.7 \text{ kN} \)
\( A_x = 12.7 \text{ kN} \)
\( A_y = 22.0 \text{ kN} \)
2–26. Determine the reactions at the truss supports $A$ and $B$. The distributed loading is caused by wind.

![Diagram of a truss structure with distributed loads and support points A and B.]

**SOLUTION**

\[ \sum M_A = 0; \quad B_y(96) + \left( \frac{12}{13} \right) 20.8(72) - \left( \frac{5}{13} \right) 20.8(10) \]
\[ - \left( \frac{12}{13} \right) 31.2(24) - \left( \frac{5}{13} \right) 31.2(10) = 0 \]
\[ B_y = 5.117 \text{ k} = 5.12 \text{ k} \]

Ans.

\[ + \sum F_y = 0; \quad A_y - 5.117 + \left( \frac{12}{13} \right) 20.8 - \left( \frac{12}{13} \right) 31.2 = 0 \]
\[ A_y = 14.7 \text{ k} \]

Ans.

\[ \sum F_x = 0; \quad - B_x + \left( \frac{5}{13} \right) 31.2 + \left( \frac{5}{13} \right) 20.8 = 0 \]
\[ B_x = 20.0 \text{ k} \]

Ans.

\[ B_x = 5.12 \text{ k} \]
\[ A_y = 14.7 \text{ k} \]
\[ B_x = 20.0 \text{ k} \]
2–27. The compound beam is fixed at \( E \) and supported by rockers at \( A \) and \( B \). There are hinges (pins) at \( C \) and \( D \). Determine the reactions at the supports. The 4-kN load is applied just to the right of the pin at \( D \).

**SOLUTION**

**Equations of Equilibrium.** Consider the equilibrium of the FBD of segment \( CD \), Fig. \( b \), first

\[
\begin{align*}
\downarrow + \Sigma M_C &= 0; \quad D_y(3) - \frac{1}{2}(6)(3)(2) = 0 \quad D_y = 6.00 \text{ kN} \\
\downarrow + \Sigma M_D &= 0; \quad \frac{1}{2}(6)(3)(1) - C_y(3) = 0 \quad C_y = 3.00 \text{ kN} \\
\uparrow \Sigma F_x &= 0; \quad D_x - C_x = 0 \quad (1)
\end{align*}
\]

Then, using the result of \( C_y \), the equilibrium of the FBD of segment \( ABC \), Fig. \( a \), gives

\[
\begin{align*}
\downarrow + \Sigma M_A &= 0; \quad N_B(4) - 6(2) - 3.00(6) = 0 \quad N_B = 7.50 \text{ kN} \quad \text{Ans.} \\
\downarrow + \Sigma M_B &= 0; \quad 6(2) - 3.00(2) - N_A(4) = 0 \quad N_A = 150 \text{ kN} \quad \text{Ans.} \\
\uparrow \Sigma F_x &= 0; \quad C_x = 0
\end{align*}
\]

Then from Eq (1), \( D_x = 0 \)

Finally, using the results of \( D_x \) and \( D_y \), the equilibrium of the FBD of segment \( DE \) gives

\[
\begin{align*}
\uparrow \Sigma F_y &= 0; \quad E_y = 0 \\
\downarrow + \Sigma F_x &= 0; \quad E_y - 4 - 6.00 = 0 \quad E_y = 10.0 \text{ kN} \quad \text{Ans.} \\
\downarrow + \Sigma M_E &= 0; \quad 4(3) + 6.00(3) - M_E = 0 \quad M_E = 30.0 \text{ kN} \cdot \text{m} \quad \text{Ans.}
\end{align*}
\]

**SOLUTION**

\[ \sum M_A = 0; \quad -20 \text{kN}(3 \text{ m}) - 20 \text{kN}(6 \text{ m}) - 20 \text{kN}(9 \text{ m}) - 20 \text{kN}(12 \text{ m}) - 8 \text{kN}(\sin 60^\circ)(15 \text{ m}) + B_y(9 \text{ m}) = 0 \]

\[ B_y = 78.2 \text{ kN} \quad \text{Ans.} \]

\[ \sum F_x = 0; \quad -A_x + 8 \text{kN}(\cos 60^\circ) = 0 \]

\[ A_x = 4 \text{ kN} \quad \text{Ans.} \]

\[ \sum F_y = 0; \quad -20 \text{kN} - 20 \text{kN} - 20 \text{kN} - 20 \text{kN} - 8 \text{kN}(\sin 60^\circ) + 78.2 \text{ kN} + A_y = 0 \]

\[ A_y = 8.71 \text{ kN} \quad \text{Ans.} \]
2-29. The construction features of a cantilever truss bridge are shown in the figure. Here it can be seen that the center truss \( CD \) is suspended by the cantilever arms \( ABC \) and \( DEF \). 

\( C \) and \( D \) are pins. Determine the vertical reactions at the supports \( A, B, E, \) and \( F \) if a 15-k load is applied to the center truss.

**SOLUTION**

**Truss CD:**
\[ \sum M_D = 0; \quad 15(200) - C_y(300) = 0 \]
\[ C_y = 10.0 \text{ k} \]
\[ \quad \sum F_y = 0; \quad -15 + 10 + D_y = 0 \]
\[ D_y = 5.0 \text{ k} \]

**Truss ABC:**
\[ \sum M_A = 0; \quad B_y(200) - 10(300) = 0 \]
\[ B_y = 15.0 \text{ k} \quad \text{Ans.} \]
\[ \quad \sum F_y = 0; \quad 15 - 10 - A_y = 0 \]
\[ A_y = 5.0 \text{ k} \quad \text{Ans.} \]

**Truss DEF:**
\[ \sum M_F = 0; \quad 5(300) - E_y(150) = 0 \]
\[ E_y = 10.0 \text{ k} \quad \text{Ans.} \]
\[ \quad \sum F_y = 0; \quad -5 + 10 - F_y = 0 \]
\[ F_y = 5.0 \text{ k} \quad \text{Ans.} \]
2-30. Determine the reactions at the supports A and C of the compound beam. Assume C is a roller, B is a pin, and A is fixed.

SOLUTION

**Equations of Equilibrium.** Consider the equilibrium of the FBD of segment BC, Fig. b, first.

\[ \downarrow \Sigma M_B = 0; \quad N_c(6) - \frac{1}{2} (12)(6)(2) = 0 \quad N_c = 12.0 \text{kN} \quad \text{Ans.} \]

\[ \downarrow \Sigma M_C = 0; \quad \frac{1}{2} (12)(6)(4) - B_y(6) = 0 \quad B_y = 24.0 \text{kN} \]

\[ \uparrow \Sigma F_x = 0; \quad B_x = 0 \]

Using the results of \( B_x \) and \( B_y \), the equilibrium of the FBD of segment AB, Fig. a, gives

\[ \downarrow \Sigma F_x = 0; \quad A_x = 0 \quad \text{Ans.} \]

\[ + \uparrow \Sigma F_y = 0; \quad A_y - 12(3) - 24.0 = 0 \quad A_y = 60.0 \text{kN} \quad \text{Ans.} \]

\[ \downarrow \Sigma M_A = 0; \quad M_A - 12(3)(1.5) - 24.0(3) = 0 \]

\[ M_A = 126 \text{kN} \cdot \text{m} \quad \text{Ans.} \]
2–31. The beam is subjected to the two concentrated loads as shown. Assuming that the foundation exerts a linearly varying load distribution on its bottom, determine the load intensities \( w_1 \) and \( w_2 \) for equilibrium (a) in terms of the parameters shown; (b) set \( P = 500 \text{ lb, } L = 12 \text{ ft} \).

**SOLUTION**

**Equations of Equilibrium:** The load intensity \( w_1 \) can be determined directly by summing moments about point \( A \).

\[
\downarrow \sum M_A = 0; \quad P \left( \frac{L}{3} \right) - w_1 L \left( \frac{L}{6} \right) = 0
\]

\[
w_1 = \frac{2P}{L}
\]

\[\text{Ans.}\]

\[
+ \uparrow \sum F_y = 0; \quad \frac{1}{2} \left( w_2 - \frac{2P}{L} \right) L + \frac{2P}{L} (L) - 3P = 0
\]

\[
w_2 = \left( \frac{4P}{L} \right)
\]

\[\text{Ans.}\]

If \( P = 500 \text{ lb and } L = 12 \text{ ft} \),

\[
w_1 = \frac{2(500)}{12} = 83.3 \text{ lb/ft}
\]

\[\text{Ans.}\]

\[
w_2 = \frac{4(500)}{12} = 167 \text{ lb/ft}
\]

\[\text{Ans.}\]
Solution

Equations of Equilibrium. Referring to the FBD of the beam shown in Fig. a, $F_{BC}$ can be obtained directly by writing the moment equation of equilibrium about point A.

$$\sum M_A = 0; \quad F_{BC}(\frac{4}{5})(0.3) + F_{BC}(\frac{3}{5})(4) - 3(4)(2) - 6(6) = 0$$

$$F_{BC} = 22.73 \text{ kN}$$

Using the result of $F_{BC}$, to write the force equation of equilibrium along the x and y axis,

$$\sum F_x = 0; \quad 22.73\left(\frac{4}{5}\right) - A_x = 0 \quad A_x = 18.18 \text{ kN} = 18.2 \text{ kN} \quad \text{Ans.}$$

$$\sum F_y = 0; \quad A_y + 22.73\left(\frac{3}{5}\right) - 3(4) - 6 = 0 \quad A_y = 4.364 \text{ kN} = 4.36 \text{ kN} \quad \text{Ans.}$$

Using the result of $F_{BC}$, write the force equation of equilibrium along the x and y axis by referring to the FBD of pin C, Fig. b,

$$\sum F_x = 0; \quad C_x - 22.73\left(\frac{4}{5}\right) = 0 \quad C_x = 18.18 \text{ kN} = 18.2 \text{ kN} \quad \text{Ans.}$$

$$\sum F_y = 0; \quad C_y - 22.73\left(\frac{3}{5}\right) = 0 \quad C_y = 13.64 \text{ kN} = 13.6 \text{ kN} \quad \text{Ans.}$$

Ans.

$A_x = 18.2 \text{ kN}$

$A_y = 4.36 \text{ kN}$

$C_x = 18.2 \text{ kN}$

$C_y = 13.6 \text{ kN}$
2-33. Determine the horizontal and vertical components of reaction at the supports A and C.

SOLUTION

Equations of Equilibrium. Member BC is a two-force member, which is reflected in the FBD diagram of member AB, Fig. a. \( F_{BC} \), \( A_x \), can be determined directly by writing the moment equations of equilibrium about A and B, respectively.

\[
\begin{align*}
\sum M_A &= 0; \quad F_{BC} \left( \frac{3}{5} \right) (4) - 24(2) = 0 \quad F_{BC} = 20.0 \text{ kN} \\
\sum M_B &= 0; \quad 24(2) - A_x (4) = 0 \quad A_x = 12.0 \text{ kN} \quad \text{Ans.}
\end{align*}
\]

Write the force equation of equilibrium along the y axis using the result of \( F_{BC} \).

\[
\begin{align*}
\uparrow \sum F_y &= 0; \quad 20.0 \left( \frac{4}{5} \right) - A_y = 0 \quad A_y = 16.0 \text{ kN} \quad \text{Ans.}
\end{align*}
\]

Then consider the FBD of pin at C, Fig. b.

\[
\begin{align*}
\sum F_x &= 0; \quad 20.0 \left( \frac{3}{5} \right) - C_x = 0 \quad C_x = 12.0 \text{ kN} \quad \text{Ans.}
\end{align*}
\]

\[
\begin{align*}
\uparrow \sum F_y &= 0; \quad C_y - 20.0 \left( \frac{4}{5} \right) = 0 \quad C_y = 16.0 \text{ kN} \quad \text{Ans.}
\end{align*}
\]
2–34. Determine the horizontal and vertical components of force at the connections A, B, and C. Assume each of these connections is a pin.

SOLUTION

Member \(AB\):

\[ \sum M_A = 0; \quad B_x(12) - 4.8(6) = 0 \]
\[ B_x = 2.40 \text{ k} \quad \text{Ans.} \]

\[ \sum F_x = 0; \quad A_x + 2.4 - 4.8 = 0 \]
\[ A_x = 2.40 \text{ k} \quad \text{Ans.} \]

\[ \sum F_y = 0; \quad A_y - B_y = 0 \]
\[ (1) \]

Member \(BC\):

\[ \sum M_C = 0; \quad -B_y(13) + 4(9) + 3(3) = 0 \]
\[ B_y = 3.46 \text{ k} \quad \text{Ans.} \]

\[ \sum F_y = 0; \quad C_y + 3.46 - 4 - 3 = 0 \]
\[ C_y = 3.54 \text{ k} \quad \text{Ans.} \]

\[ \sum F_x = 0; \quad C_x - 2.40 = 0 \]
\[ C_x = 2.40 \text{ k} \quad \text{Ans.} \]

From Eq. (1),
\[ A_y = 3.46 \text{ k} \quad \text{Ans.} \]
2–35. Determine the reactions at the supports $A$ and $B$ of the frame. Assume that the support at $A$ is a roller.

SOLUTION

$\sum M_B = 0;
-(0.5)(6) + (2)(6) - (7)(6) - (5)(14) + A_y(14) = 0$

$A_y = 7.36 \text{k}$

Ans.

$\sum F_y = 0;
7.36 - 5 - 7 - 10 - 2 + B_y = 0$

$B_y = 16.6 \text{k}$

Ans.

$\sum F_x = 0;
-0.5 + B_x = 0$

$B_x = 0.500 \text{k}$

Ans.
*2–36. Determine the resultant forces at pins B and C on member ABC of the four-member frame.

**SOLUTION**

\[ \sum M_A = 0; \quad -150(7)(3.5) + \frac{4}{5} F_{BE}(5) - F_{CD}(7) = 0 \]  
\[ \sum M_F = 0; \quad F_{CD}(7) - \frac{4}{5} F_{BE}(2) = 0 \]

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

\[ F_{BE} = 1531 \text{ lb} = 1.53 \text{ k (C)} \]  
\[ F_{CD} = 350 \text{ lb (T)} \]  

**Ans.**

\[ F_{BE} = 1.53 \text{ k (C)} \]  
\[ F_{CD} = 350 \text{ lb (T)} \]  

**Ans.**
2-37. Determine the horizontal and vertical reactions at A and C of the two-member frame.

**SOLUTION**

**Equations of Equilibrium.** First, consider the equilibrium of the FBD of segment AB, Fig. a.

\[ \sum M_A = 0; \quad B_y(4) - 2(4)(2) = 0 \quad B_y = 4.00 \text{kN} \]

\[ \sum M_B = 0; \quad 2(4)(2) - A_y(4) = 0 \quad A_y = 4.00 \text{kN} \]

Ans.

\[ \sum F_x = 0; \quad A_x - B_x = 0 \]

Then, using the result of \( B_y \), the equilibrium of the FBD of Segment BC, Fig. b, gives

\[ \sum M_C = 0; \quad \frac{1}{2} (12)(3)(1) - 4.00(4) - B_x(3) = 0 \quad B_x = 0.6667 \text{kN} \]

Ans.

\[ \sum F_x = 0; \quad C_x + 0.6667 - \frac{1}{2} (12)(3) = 0 \quad C_x = 17.33 \text{kN} = 17.3 \text{kN} \]

Ans.

\[ \sum F_y = 0; \quad C_y - 4.00 = 0 \quad C_y = 4.00 \text{kN} \]

Ans.

From Eq. (1),

\[ A_x = 0.6667 \text{kN} = 0.667 \text{kN} \]

Ans.
2–38. The frame supports a load of 600 lb. Determine the horizontal and vertical components of reaction at the pins \( A \) and \( D \). Also, what is the force in the cable?

**SOLUTION**

**Equations of Equilibrium.** First, consider the equilibrium of pulley \( E \), Fig. \( a \).

\[
+ \sum F_y = 0; \quad 2T - 600 = 0 \quad T = 300 \text{ lb}
\]

Then, consider the equilibrium of member \( ABC \), Fig. \( b \).

\[
\begin{align*}
\sum M_A &= 0; \quad 300(12) + 300(13.5) - 300(1.5) - B_y(6) = 0 \\
B_y &= 1200 \text{ lb} \\
\sum M_B &= 0; \quad 300(6) + 300(7.5) - 300(1.5) - A_y(6) = 0 \\
A_y &= 600 \text{ lb} \\
\sum F_y &= 0; \quad 300 + B_x - A_x = 0 \quad (1)
\end{align*}
\]

Finally, consider the equilibrium of member \( BD \), Fig. \( c \).

\[
\begin{align*}
\sum N_D &= 0; \quad 1200(6) - 300(4.5) - B_x(6) = 0 \quad B_x = 975 \text{ lb} \\
\sum F_x &= 0; \quad D_x - 300 - 975 = 0 \quad D_x = 1275 \text{ lb} \\
\sum F_y &= 0; \quad D_y - 1200 = 0 \quad D_y = 1200 \text{ lb}
\end{align*}
\]

Substitute the result of \( B_x \) into Eq (1).

\[
300 + 975 - A_x = 0 \quad A_x = 1275 \text{ lb}
\]
2–39. Determine the horizontal and vertical force components that the pin supports at C and D exert on members AC and BD, respectively.

**SOLUTION**

**Equations of Equilibrium.** The equilibrium of the FBD of member shown in Fig. a will be considered first.

\[ \sum M_C = 0; \quad 3(3)(1.5) - \frac{1}{2}(3)(3)(2) - F_{AB}(3) = 0 \quad F_{AB} = 7.50 \text{ kN} \]

\[ \sum M_A = 0; \quad C_y(3) - \frac{1}{2}(3)(3)(1) - 3(3)(1.5) = 0 \quad C_y = 6.00 \text{ kN} \quad \text{Ans.} \]

\[ \sum F_x = 0; \quad C_x = 0 \quad \text{Ans.} \]

Then using the result of \( F_{AB} \) to consider the equilibrium of the FBD of member BD shown in Fig. b,

\[ \sum M_D = 0; \quad 7.50(3) - 4(3)(1.5) - F_{BC}(\frac{3}{5})(3) = 0 \quad F_{BC} = 2.50 \text{ kN} \]

\[ \sum M_B = 0; \quad -D_y(3) + 4(3)(1.5) = 0 \quad D_y = 6.00 \text{ kN} \quad \text{Ans.} \]

\[ \sum F_x = 0; \quad 2.5(\frac{4}{5}) - D_x = 0 \quad D_x = 2.00 \text{ kN} \quad \text{Ans.} \]
*2–40. Determine the reactions at the supports \( A \) and \( D \). Assume \( A \) is fixed and \( B, C, \) and \( D \) are pins.

**SOLUTION**

Member \( BC \):

\[ \sum F_x = 0; \quad C_x = 0 \]
\[ \sum F_y = 0; \quad D_y = 0 \]
\[ \sum M_B = 0; \quad C_y - (1.5wL) \left( \frac{1.5L}{2} \right) = 0 \]
\[ C_y = 0.75wL \]
\[ B_y = 1.5wL + 0.75wL = 0 \]

\( B_y = 0.75wL \)

Member \( CD \):

\[ \sum F_x = 0; \quad C_x = 0 \]
\[ \sum F_y = 0; \quad D_y = 0 \]
\[ \sum M_D = 0; \quad C_y = 0 \]
\[ D_y = 0.75wL \]

Member \( AB \):

\[ \sum F_x = 0; \quad A_x = wL \leftarrow \]
\[ \sum F_y = 0; \quad A_y = 0 \]
\[ \sum M_A = 0; \quad M_A - wL \left( \frac{1}{2} \right) = 0 \]
\[ M_A = \left( \frac{wL^2}{2} \right) \]

\( A_x = wL \)
\( A_y = 0.75wL \)
\( M_A = \left( \frac{wL^2}{2} \right) \)

\( D_x = 0 \)
\( D_y = 0.75wL \)
\( A_x = wL \leftarrow \)
\( A_y = 0.75wL \)
\( M_A = \left( \frac{wL^2}{2} \right) \)
2–41. Determine the components of reaction at the pinned supports \( A \) and \( C \) of the two-member frame. Neglect the thickness of the members. Assume \( B \) is a pin.

**SOLUTION**

**Equations of Equilibrium.** Referring to the FBD of members \( AB \) and \( BC \) shown in Fig. \( a \) and \( b \), respectively, we notice that \( B_x \) and \( B_y \) can be determined by solving simultaneously the moment equations of equilibrium written about \( A \) and \( C \), respectively.

\[
\sum M_A = 0; \quad B_x(6.5) + B_y(6) - (6)(\sqrt{42.25})(\frac{2.5}{\sqrt{42.25}})(5.25)
\]

\[
- (6)(\sqrt{42.25}) \left( \frac{6}{\sqrt{42.25}} \right) (3) - (2)(4)(2) = 0
\]

\[6.5B_x + 6B_y = 202.75 \quad (1)\]

\[
\sum M_C = 0; \quad (6)(\sqrt{42.25}) \left( \frac{2.5}{\sqrt{42.25}} \right)(5.25) + (6)(\sqrt{42.25}) \left( \frac{6}{\sqrt{42.25}} \right) (3)
\]

\[
+ B_y(6) - B_x(6.5) = 0
\]

\[6.5B_x - 6B_y = 186.75 \quad (2)\]
Solving Eq (1) and (2) yields

\[ B_x = 29.96 \text{ k} \quad B_y = 1.333 \text{ k} \]

Using these results and writing the force equation of equilibrium by referring to the FBD of member AB, Fig a,

\[ \sum F_x = 0; \quad 2(4) + (6)(\sqrt{42.25}) \left( \frac{2.5}{\sqrt{42.25}} \right) - 29.96 + A_x = 0 \]

\[ A_x = 6.962 \text{ k} = 6.96 \text{ k} \quad \text{Ans.} \]

\[ + \sum F_y = 0; \quad A_y + 1.333 - 6(\sqrt{42.25}) \left( \frac{6}{\sqrt{42.25}} \right) = 0 \]

\[ A_y = 34.67 \text{ k} = 34.7 \text{ k} \quad \text{Ans.} \]

Referring to the FBD of member BC, Fig b,

\[ \sum F_x = 0; \quad 29.96 - (6)(\sqrt{42.25}) \left( \frac{2.5}{\sqrt{42.25}} \right) - C_x = 0 \]

\[ C_x = 14.96 \text{ k} = 15.0 \text{ k} \quad \text{Ans.} \]

\[ + \sum F_y = 0; \quad C_y - 1.333 - (6)(\sqrt{42.25}) \left( \frac{6}{\sqrt{42.25}} \right) = 0 \]

\[ C_y = 37.33 \text{ k} = 37.3 \text{ k} \quad \text{Ans.} \]
2-42. Determine the horizontal and vertical components of reaction at A, B, and D. Assume the frame is pin connected at A, B, and D, and there is a fixed-connected joint at C.

**SOLUTION**

**Equations of Equilibrium.** We will consider the equilibrium of the FBD of member AB shown in Fig. a first.

\[ \Sigma M_A = 0; \quad B_x(20) - 6(20) - 12(12) = 0 \quad B_x = 13.2 \text{ k} \quad \text{Ans.} \]

\[ \Sigma M_B = 0; \quad 12(8) - A_y(20) = 0 \quad A_y = 4.80 \text{ k} \quad \text{Ans.} \]

\[ \Sigma F_y = 0; \quad B_y - A_y = 0 \quad (1) \]

Using the result of \( B_y \) to consider the equilibrium of the FBD of member BCD shown in Fig. b,

\[ \Sigma M_D = 0; \quad \frac{1}{2}(2)(6)(4) + 2(6)(9) - 13.2(12) + B_x(12) = 0 \]

\[ B_x = 2.20 \text{ k} \quad \text{Ans.} \]

\[ \Sigma F_x = 0; \quad 13.2 - D_x = 0 \quad D_x = 13.2 \text{ k} \quad \text{Ans.} \]

\[ \Sigma F_y = 0; \quad D_y - 2(6) - \frac{1}{2}(2)(6) - 2.20 = 0 \quad D_y = 20.2 \text{ k} \quad \text{Ans.} \]

From Eq. (1),

\[ 2.20 - A_y = 0 \quad A_y = 2.20 \text{ k} \quad \text{Ans.} \]
2–43. The bridge frame consists of three segments which can be considered pinned at $A$, $D$, and $E$, rocker supported at $C$ and $F$, and roller supported at $B$. Determine the horizontal and vertical components of reaction at all these supports due to the loading shown.

**SOLUTION**

*Equations of Equilibrium.* We will consider the equilibrium of the FBD of member $BD$ shown in Fig. $b$ first.

\[ \sum \Sigma M_D = 0; \quad 30(10) - N_B(18) = 0 \quad N_B = 16.67 \text{k} = 16.7 \text{k} \]
\[ \sum \Sigma M_B = 0; \quad D_y(18) - 30(8) = 0 \quad D_y = 13.33 \text{k} = 13.3 \text{k} \]
\[ \sum \Sigma F_x = 0; \quad D_x = 0 \]

Next, using the result of $N_B$ to consider the equilibrium of the FBD of member $ABC$, shown in Fig. $a$,

\[ \sum \Sigma M_A = 0; \quad N_C(4) - 4(10)(5) - 16.67(10) = 0 \quad N_C = 91.67 \text{k} = 91.7 \text{k} \]
\[ \sum \Sigma F_x = 0; \quad A_x = 0 \]
\[ \sum \Sigma F_y = 0; \quad 91.67 - 4(10) - 16.67 - A_y = 0 \quad A_y = 35.0 \text{k} \]

Finally, using the result of $D_x$ and $D_y$, the equilibrium of the FBD of member $DEF$, Fig. $c$ gives

\[ \sum \Sigma M_E = 0; \quad 10(5) + 13.33(10) - N_F(4) = 0 \quad N_F = 45.83 \text{k} = 45.8 \text{k} \]
\[ \sum \Sigma F_x = 0; \quad E_x = 0 \]
\[ \sum \Sigma F_y = 0; \quad 45.83 - 13.33 - 10 - E_y = 0 \quad E_y = 22.5 \text{k} \]

**Ans.**

$N_B = 16.7 \text{k}$

$D_y = 13.3 \text{k}$

$D_x = 0$

$N_C = 91.7 \text{k}$

$A_x = 0$

$A_y = 35.0 \text{k}$

$N_F = 45.8 \text{k}$

$E_x = 0$

$E_y = 22.5 \text{k}$
*2–44. Determine the horizontal and vertical reactions at the connections $A$ and $C$ of the gable frame. Assume that $A$, $B$, and $C$ are pin connections. The purlin loads such as $D$ and $E$ are applied perpendicular to the center line of each girder.

**SOLUTION**

Member $AB$:

\[ \sum M_A = 0; \quad B_x(15) + B_y(12) - (1200)(5) - 600\left(\frac{12}{13}\right)(6) - 600\left(\frac{5}{13}\right)(12.5) \]

\[ -400\left(\frac{12}{13}\right)(12) - 400\left(\frac{5}{13}\right)(15) = 0 \]

\[ B_x(15) + B_y(12) = 18,946.154 \quad (1) \]

Member $BC$:

\[ \sum M_C = 0; \quad -B_x(15) + B_y(12) + 600\left(\frac{12}{13}\right)(6) + 600\left(\frac{5}{13}\right)(12.5) \]

\[ 400\left(\frac{12}{13}\right)(12) + 400\left(\frac{5}{13}\right)(15) = 0 \]

\[ B_x(15) - B_y(12) = 12,446.15 \quad (2) \]

Solving Eqs. (1) and (2),

\[ B_x = 1063.08 \text{ lb} \quad B_y = 250.0 \text{ lb} \]

Member $AB$:

\[ \sum F_x = 0; \quad -A_x + 1200 + 1000\left(\frac{5}{13}\right) - 1063.08 = 0 \]

\[ A_x = 522 \text{ lb} \]

\[ \sum F_y = 0; \quad A_y - 800 - 1000\left(\frac{12}{13}\right) + 250 = 0 \]

\[ A_y = 1473 \text{ lb} \]

Member $BC$:

\[ \sum F_x = 0; \quad -C_x - 1000\left(\frac{5}{13}\right) + 1063.08 = 0 \]

\[ C_x = 678 \text{ lb} \]

\[ \sum F_y = 0; \quad C_y - 800 - 1000\left(\frac{12}{13}\right) - 250.0 = 0 \]

\[ C_y = 1973 \text{ lb} \]

\[ A_x = 522 \text{ lb} \]

\[ A_y = 1473 \text{ lb} \]

\[ C_x = 678 \text{ lb} \]

\[ C_y = 1973 \text{ lb} \]
2–1P. The railroad trestle bridge shown in the photo is supported by reinforced concrete bents. Assume the two simply supported side girders, track bed, and two rails have a weight of 0.5 k/ft and the load imposed by a train is 7.2 k/ft. Each girder is 20 ft long. Apply the load over the entire bridge and determine the compressive force in the columns of each bent. For the analysis assume all joints are pin connected and neglect the weight of the bent. Are these realistic assumptions?

SOLUTION

Maximum reactions occur when the live load is over the entire span.

Load = 7.2 + 0.5 = 7.7 k/ft

\[ R = 7.7(10) = 77 \text{ k} \]

Then \[ P = \frac{2(77)}{2} = 77 \text{ k} \]

All members are two-force members.

\[ \sum M_B = 0; \quad -77(8) + F \sin 75^\circ(8) = 0 \]

\[ F = 79.7 \text{ k} \]

Ans.

It is not reasonable to assume the members are pin connected, since such a framework is unstable.

Ans.