

8

Lösungen

8.1 Lösungen zu Kapitel 1

Aufgabe 1-1

$$F_1 = 17.3 \text{ kN } \swarrow, F_2 = 10.0 \text{ kN } \nearrow$$

Aufgabe 1-2

$$S_1 = 29.1 \text{ kN}, S_2 = 25.2 \text{ kN}$$

Aufgabe 1-3

$$S_{AC} = 1.79 \text{ kN}, S_{BC} = 1.46 \text{ kN}$$

Aufgabe 1-4

$$S_1 = 0.86 F, S_2 = 0.50 F$$

Aufgabe 1-5

$$N_1 = 23.03 \text{ kN}, N_2 = 30.76 \text{ kN}$$

Aufgabe 1-6

$$S = G \frac{L}{\sqrt{L^2 - r^2}}, K = G \frac{r}{\sqrt{L^2 - r^2}}$$

Aufgabe 1-7

$$\alpha_1 = 61.0, \alpha_2 = 43.4$$

Aufgabe 1-8

$$S_1 = 7.46 \text{ kN}, S_2 = 7.46 \text{ kN}$$

Aufgabe 1-9

$$R = 5.3 \text{ kN}, \alpha_R = 78.6, \beta_R = 39.8, \gamma_R = 52.5$$

Aufgabe 1-10

$$F = 10.0 \text{ kN}, S = 27.0 \text{ kN}, \alpha = 17.7$$

Aufgabe 1-11

$$S = 1.58 G, \alpha = 18.4$$

Aufgabe 1-12

$$F = 366 \text{ N}, \alpha = 30$$

Aufgabe 1-13

$$S = \frac{2}{\sqrt{3}} G, F_1 = F_2 = 3G, K_1 = K_2 = \frac{4}{\sqrt{3}} G$$

Aufgabe 1-14

$$R = \sqrt{3} \text{ kN}, \alpha = 60, x = \frac{7}{3} a$$

Aufgabe 1-15

$$R = 8.7 \text{ kN}, \alpha = 76.7, x = 4.06 L$$

Aufgabe 1-16

$$R = 6.94 F, \alpha = 77, x = 4.13$$

Aufgabe 1-17

$$R = 170 \text{ kN}, \alpha = 75.6, x = 5.26$$

Aufgabe 1-18

$$R = 19.7 \text{ kN}, \alpha = 24, x = 3.24$$

Aufgabe 1-19

$$\text{a) } R = 57.18 \text{ kN}, \alpha = 64.5, x = 6.83$$

$$\text{b) } S_1 = -22.4 \text{ kN}, S_2 = 12.4 \text{ kN}, S_3 = 58.7 \text{ kN}$$

Aufgabe 1-20

$$\text{a) } R = 69.1 \text{ kN}, \alpha = 13, x = -7.1$$

$$\text{b) } S_1 = 91.5 \text{ kN}, S_2 = -48.47 \text{ kN}, S_3 = 57.7 \text{ kN}$$

Aufgabe 1-21

$$\sum F = 0: -F_1 + F_2 - F_3 + F_4 - F_5 = 0$$

$$\sum M = 0: -F_2 \cdot a + F_3 \cdot 2a - F_4 \cdot 3a + F_5 \cdot 4a = 0$$

Aufgabe 1-22

$$\text{a) } x = \frac{LB \cos \alpha_2}{G}$$

$$\text{b) } A = \frac{G \sin \alpha_2}{\sin \alpha_2 \cos \alpha_1 + \cos \alpha_2 \sin \alpha_1}, B = \frac{G \sin \alpha_1}{\sin \alpha_2 \cos \alpha_1 + \cos \alpha_2 \sin \alpha_1}$$

8.2 Lösungen zu Kapitel 2

Aufgabe 2-1

$$y_S = 33.4 \text{ cm}, z_S = 25.9 \text{ cm}$$

Aufgabe 2-2

$$y_S = 1.88 \text{ cm}, z_S = 7.19 \text{ cm}$$

Aufgabe 2-3

- a) $y_S = 0.0 \text{ mm}$, $z_S = -17.7 \text{ mm}$
 b) $y_S = -13.1 \text{ mm}$, $z_S = -17.7 \text{ mm}$

Aufgabe 2-4

- a) $x_S = 2.2 L$, $y_S = 2.4 L$
 b) $x_S = \frac{19}{12} L$, $y_S = \frac{11}{9} L$

Aufgabe 2-5

$$\alpha = \frac{16}{9}$$

Aufgabe 2-6

$$x_S = 0.86 L, y_S = 0.86 L$$

Aufgabe 2-7

$$x_S = 0.0 \text{ cm}, y_S = 28.8 \text{ cm}$$

Aufgabe 2-8

- a) $y_S = \frac{6RH + 2H^2 + 3\pi R^2 - 4R^2}{6H + 3\pi R}$
 b) $\frac{H}{R} \leq \sqrt{2}$

Aufgabe 2-9

$$y_S = 0, z_S = \frac{\frac{\pi}{16} R_a R_i^2 - \frac{2}{3} R_i^3}{\pi R_a^2 - \frac{5}{8} \pi R_i^2}$$

Aufgabe 2-10

- a) $y_S = 0$, $z_S = \frac{(\frac{3}{4}\pi + 1)R}{\frac{3}{2}\pi - 2}$
 b) $y_S = -\frac{2r}{\pi}$, $z_S = -\frac{1}{2}r$

Aufgabe 2-11

$$x_S = \frac{29}{50} b, y_S = \frac{3}{10} h$$

Aufgabe 2-12

- a) $x_S = 1$, $y_S = \frac{\pi}{8} A$
 b) $x_S = \frac{\frac{1}{3}\pi - \frac{1}{120}\pi^3}{1 - \frac{1}{48}\pi^2}$, $y_S = \frac{\frac{1}{6}\pi - \frac{1}{120}\pi^3 + \frac{1}{8064}\pi^7}{\pi^2 - \frac{1}{48}\pi^4}$

Aufgabe 2-13

$$x_S = R, y_S = \frac{2R}{\pi}$$

Aufgabe 2-14

$$x_S = 1.18 \text{ m}, y_S = 2.75 \text{ m}$$

Aufgabe 2-15

$$x_S = 1.30 \text{ m}, y_S = 0.98 \text{ m}$$

Aufgabe 2-16

$$x_S = 0, y_S = -\frac{R \sin \alpha}{180 - \alpha}$$

8.3 Lösungen zu Kapitel 3

Aufgabe 3-1

$$A_x = \frac{10}{\sqrt{2}} \text{ kN}, A_y = 9.7 \text{ kN}, B = 12.4 \text{ kN}$$

Aufgabe 3-2

$$A_x = -4.27 \text{ kN}, A_y = -0.17 \text{ kN}, B = 0.44 \text{ kN}$$

Aufgabe 3-3

$$A_x = -4.5 \text{ kN}, A_y = 0.8 \text{ kN}, B = 6.1 \text{ kN}$$

Aufgabe 3-4

$$A_H = 4.0 \text{ kN}, A_V = 15.0 \text{ kN}, M_A = -29.7 \text{ kNm}$$

Aufgabe 3-5

$$A_H = -10 \text{ kN}, A_V = 20 \text{ kN}, M_A = -50 \text{ kNm}$$

Aufgabe 3-6

$$A_x = 2.66 \text{ kN}, A_y = 1.48 \text{ kN}, B = 0.79 \text{ kN}$$

Aufgabe 3-7

$$A_x = 3.38 \text{ kN}, A_y = 14.70 \text{ kN}, B = 29.54 \text{ kN}$$

Aufgabe 3-8

$$A = \frac{\sqrt{2}}{2} F_3 + \frac{\sqrt{2}}{4} F_2 - \frac{\sqrt{6}}{4} F_2, B_x = -\frac{1}{2} F_3 - \left(\frac{1}{4} + \frac{\sqrt{3}}{4}\right) F_2, B_y = F_1 + \left(\frac{3}{4}\sqrt{3} - \frac{1}{4}\right) F_2 - \frac{1}{2} F_3$$

Aufgabe 3-9

$$A_x = -1.07 \text{ kN}, A_y = 5.55 \text{ kN}, S = 1.62 \text{ kN}$$

Aufgabe 3-10

$$A_x = 6.3 \text{ kN}, A_y = 6.0 \text{ kN}, B = 14.0 \text{ kN}$$

Aufgabe 3-11

$$A = 3.84 \text{ kN}, B_x = -3.18 \text{ kN}, B_y = 2.34 \text{ kN}$$

Aufgabe 3-12

$$A_x = -0.5 \text{ kN}, A_y = 3.0 \text{ kN}, B = 1.5 \text{ kN}$$

Aufgabe 3-13

$$A_x = -7.00 \text{ kN}, A_y = 10.85 \text{ kN}, B = 16.15 \text{ kN}$$

Aufgabe 3-14

$$A = 4.7 \text{ kN}, B = 5\sqrt{5} \text{ kN}, C = 2.3 \text{ kN}$$

Aufgabe 3-15

$$A_x = 0.0 \text{ kN}, A_y = 30.2 \text{ kN}, B = 36.0 \text{ kN}$$

Aufgabe 3-16

$$\text{a) } A_x = 1.92 \text{ kN}, A_y = 5.44 \text{ kN}, B = 3.20 \text{ kN}$$

$$\text{b) } A = 3.20 \text{ kN}, B_x = -1.92 \text{ kN}, B_y = 5.44 \text{ kN}$$

Aufgabe 3-17

$$A_x = 0.0 \text{ kN}, A_y = 23.8 \text{ kN}, B = 71.2 \text{ kN}$$

Aufgabe 3-18

$$A_x = 0.0 \text{ kN}, A_y = \frac{35}{6} \text{ kN}, B = \frac{37}{6} \text{ kN}$$

Aufgabe 3-19

$$A_x = 0.0 \text{ kN}, A_y = \frac{33}{7} \text{ kN}, B = \frac{9}{7} \text{ kN}$$

Aufgabe 3-20

$$A_x = 0 \text{ kN}, A_y = 7 \text{ kN}, B = 7 \text{ kN}$$

Aufgabe 3-21

$$A_x = 0 \text{ kN}, A_y = \frac{25}{6} \text{ kN}, B = \frac{25}{3} \text{ kN}$$

Aufgabe 3-22

$$A_x = 0.0 \text{ kN}, A_y = 17.2 \text{ kN}, B = 14.8 \text{ kN}$$

Aufgabe 3-23

$$A_x = 0 \text{ kN}, A_y = 15 \text{ kN}, B = 15 \text{ kN}$$

Aufgabe 3-24

$$A_x = 0 \text{ kN}, A_y = -45 \text{ kN}, M_A = 0 \text{ kNm}$$

Aufgabe 3-25

$$A_x = 0 \text{ kN}, A_y = 0 \text{ kN}, A_z = 15 \text{ kN}, M_{A,x} = 75 \text{ kNm}, M_{A,y} = -30 \text{ kNm}, M_{A,z} = 0 \text{ kNm}$$

Aufgabe 3-26

$$F_A = 4F, F_B = 0, F_C = 0, F_D = F, F_F = -F$$

Aufgabe 3-27

$$A_x = 0 \text{ kN}, A_y = 0 \text{ kN}, A_z = 10 \text{ kN}, M_{A,x} = 30 \text{ kNm}, M_{A,y} = -10 \text{ kNm}, M_{A,z} = 0 \text{ kNm}$$

Aufgabe 3-28

$$A_x = qL, A_y = -qL, A_z = 0.5qL, M_{A,x} = qL, M_{A,y} = qL, M_{A,z} = 0,$$

$$B_x = -qL, B_y = 0, B_z = -0.5qL, C_x = 0, C_y = qL, C_z = 2qL$$

Aufgabe 3-29

$$A_x = 0, A_y = -F, A_z = 0, M_{A,x} = 0, M_{A,y} = 0, M_{A,z} = -Fa, B_x = 0, B_y = 2F, B_z = 0, \\ C_x = C_y = C_z = 0, D_x = D_y = D_z = 0$$

Aufgabe 3-30

$$A_x = -2 \text{ kN}, A_y = 2 \text{ kN}, A_z = -1 \text{ kN}, M_{A,x} = 4 \text{ kNm}, M_{A,y} = 0 \text{ kNm}, M_{A,z} = -8 \text{ kNm}, \\ B_x = B_y = 0 \text{ kN}, B_z = 3 \text{ kN}, C_x = 0 \text{ kN}, C_y = -2 \text{ kN}, C_z = 0 \text{ kN}, D_x = D_y = 0 \text{ kN}, \\ D_z = 2 \text{ kN}$$

Aufgabe 3-31

$$A_x = A_y = 0 \text{ kN}, A_z = \frac{4}{3} \text{ kN}, M_{A,x} = 0 \text{ kNm}, M_{A,y} = \frac{20}{3} \text{ kNm}, M_{A,z} = 0 \text{ kNm}, \\ B_x = B_y = B_z = 0 \text{ kN}, C_x = C_y = 0 \text{ kN}, C_z = \frac{23}{3} \text{ kN} \text{ (für } M_T = 5 \text{ kNm, } q_0 = 3 \frac{\text{kN}}{\text{m}}), \\ D_x = D_y = D_z = 0 \text{ kN}$$

Aufgabe 3-32

$$A_V = 5 \text{ kN}, A_H = 0 \text{ kN}, B = -10 \text{ kN}, C = 44 \text{ kN}, D = -16 \text{ kN}, \\ G_{1,V} = -5 \text{ kN}, G_{1,H} = 0 \text{ kN}, G_{2,V} = 5 \text{ kN}, G_{2,H} = 0 \text{ kN}$$

Aufgabe 3-33

$$A_V = -0.75 \text{ kN}, A_H = -2.00 \text{ kN}, B = 3.00 \text{ kN}, C = -5.00 \text{ kN}, D = 1.25 \text{ kN}, \\ G_{1,V} = 1.25 \text{ kN}, G_{1,H} = 2.00 \text{ kN}, G_{2,V} = -1.25 \text{ kN}, G_{2,H} = 2.00 \text{ kN}$$

Aufgabe 3-34

$$A_V = 18.47 \text{ kN}, A_H = 0.00 \text{ kN}, B = 34.24 \text{ kN}, C = 31.00 \text{ kN}, D = 13.29 \text{ kN}, \\ G_{1,V} = 12.71 \text{ kN}, G_{1,H} = 0.00 \text{ kN}, G_{2,V} = -14.29 \text{ kN}, G_{2,H} = 0.00 \text{ kN}$$

Aufgabe 3-35

$$A_V = 4.50 \text{ kN}, A_H = 0.00 \text{ kN}, M_A = -\frac{23}{3} \text{ kNm}, B = 12.25 \text{ kN}, \\ G_V = 3.50 \text{ kN}, G_H = 0.00 \text{ kN}$$

Aufgabe 3-36

$$A_H = 55.23 \text{ kN}, A_V = 56.18 \text{ kN}, M_A = -102.36 \text{ kNm}, \\ B_H = -29.83 \text{ kN}, B_V = 49.72 \text{ kN}, G_{1,H} = -55.23 \text{ kN}, G_{1,V} = 21.18 \text{ kN}, \\ G_{2,H} = -29.83 \text{ kN}, G_{2,V} = -49.72 \text{ kN}$$

Aufgabe 3-37

$$A = 4.50 \text{ kN}, B_H = 0.00 \text{ kN}, B_V = 18.00 \text{ kN}, C = -4.50 \text{ kN}, \\ G_H = 6.75 \text{ kN}, G_V = -4.50 \text{ kN}$$

Aufgabe 3-38

$$A = -24.5 \text{ kN}, B_V = 61.5 \text{ kN}, B_H = -20.0 \text{ kN}, C = 52.0 \text{ kN}, D = -32 \text{ kN}, \\ G_{1,V} = -12.0 \text{ kN}, G_{1,H} = 20.0 \text{ kN}, G_{2,V} = 20.0 \text{ kN}, G_{2,H} = -12.0 \text{ kN}$$

8.4 Lösungen zu Kapitel 4

Aufgabe 4-1

a) $7 + 3 = 2 \cdot 5$

b) $A_V = 3.0F, A_H = 2.5F, B = -4.5F$

c) $S_1 = -F, S_2 = -F, S_3 = -\frac{3}{4}\sqrt{5}F, S_4 = 0, S_5 = \sqrt{5}F, S_6 = -\frac{9}{4}F, S_7 = \frac{9}{4}\sqrt{5}F$

Aufgabe 4-2

a) $9 + 3 = 2 \cdot 6$

b) $A_V = \frac{11}{4}F, A_H = -F, B = \frac{11}{4}F$

c) $S_1 = -\frac{8}{3}F, S_2 = \frac{55}{12}F, S_3 = -F, S_4 = -\frac{8}{3}F, S_5 = \frac{5}{4}F, S_6 = \frac{25}{6}F, S_7 = -\frac{5}{4}F,$
 $S_8 = -\frac{11}{3}F, S_9 = \frac{55}{12}F$

Aufgabe 4-3

a) $13 + 3 = 8 \cdot 2$

b) $A = -100.0 \text{ kN}, B_V = 150.0 \text{ kN}, B_H = 20.0 \text{ kN}$

c) $S_1 = 60.0 \text{ kN}, S_2 = -116.6 \text{ kN}, S_3 = 38.9 \text{ kN}, S_4 = -116.7 \text{ kN}, S_5 = 40.0 \text{ kN},$
 $S_6 = -155.5 \text{ kN}, S_7 = -141.7 \text{ kN}, S_8 = 100.0 \text{ kN}, S_9 = -141.5 \text{ kN}, S_{10} = 47.2 \text{ kN},$
 $S_{11} = 0.0 \text{ kN}, S_{12} = 100.0 \text{ kN}, S_{13} = -94.3 \text{ kN}$

Aufgabe 4-4

a) $11 + 3 = 2 \cdot 7$

b) $A_V = -2.00F, A_H = -(1 + \sqrt{3})F, B = 0.73F$

c) $S_1 = \frac{1}{\sqrt{3}}F, S_2 = F, S_3 = (2 - \frac{\sqrt{3}}{3})F$

Aufgabe 4-5

b) $A = \frac{2}{3}F, B = -\frac{13}{3}F, C_V = -\frac{4}{3}F, C_H = \frac{16}{3}F$

c) $S_1 = -\frac{20}{3}F, S_2 = \frac{4}{3}\sqrt{2}F, S_3 = \frac{13}{3}F, S_4 = -F, S_5 = -\frac{20}{3}F, S_6 = -\frac{1}{3}\sqrt{2}F, S_7 = -\frac{22}{3}F,$
 $S_8 = \frac{1}{3}\sqrt{2}F, S_9 = -F, S_{10} = -\frac{22}{3}F, S_{11} = -F, S_{12} = 0, S_{13} = -\frac{22}{3}F, S_{14} = 0$

Aufgabe 4-6

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Aufgabe 4-7

a) $10 + 4 = 7 \cdot 2$

b) $A = -F, B_V = -\frac{5}{2}F, B_H = -F, C = \frac{1}{2}F$

c) Keine Nullstäbe vorhanden.

d) $S_1 = \frac{3}{2}\sqrt{2}F, S_2 = \frac{1}{2}F, S_3 = -\frac{\sqrt{2}}{2}F$

Aufgabe 4-8

a) $14 + 4 = 2 \cdot 9$

b) $A = \frac{3}{4}\sqrt{2}F, B_V = -\frac{1}{2}F, B_H = -\frac{3}{4}F, C = \frac{3}{4}F$

c) $S_2, S_4, S_5, S_6, S_9, S_{10}, S_{14}$

d) $S_1 = -\frac{3}{4}\sqrt{2}F, S_2 = 0, S_3 = -\frac{1}{4}\sqrt{10}, S_4 = 0, S_5 = 0, S_6 = 0, S_7 = \frac{1}{8}F,$
 $S_8 = -\frac{3}{8}\sqrt{5}F, S_9 = 0, S_{10} = 0, S_{11} = \frac{1}{8}F, S_{12} = \frac{3}{8}\sqrt{5}F, S_{13} = -\frac{3}{4}F, S_{14} = 0$

Aufgabe 4-9

a) $13 + 3 = 2 \cdot 8$

b) $A_V = \frac{19}{8}F, A_H = F, B = -\frac{3}{8}F$

c) $S_1, S_5, S_8, S_{11}, S_{13}$

d) $S_1 = 0, S_2 = -0.5F, S_3 = -0.5F, S_4 = -F, S_5 = 0, S_6 = -\frac{19}{8}F, S_7 = \frac{5}{8}F,$
 $S_8 = 0, S_9 = -\frac{5}{8}F, S_{10} = \frac{3}{8}F, S_{11} = 0, S_{12} = -F, S_{13} = 0$

Aufgabe 4-10

- a) $A_H = -F$, $A_V = 4F$, $B = -2F$
 b) S_3, S_8, S_{10}, S_{15}
 c) $S_1 = F$, $S_2 = -2\sqrt{2}F$, $S_4 = F$, $S_5 = 2\sqrt{2}F$, $S_6 = -4F$, $S_7 = -5F$, $S_9 = 3\sqrt{2}F$,
 $S_{11} = -4F$, $S_{12} = -5F$, $S_{13} = \sqrt{2}F$, $S_{14} = 2F$

Aufgabe 4-11

- a) $15 + 3 = 2 \cdot 9$
 b) $A_H = 0$, $A_V = F$, $B = F$
 c) $S_1 = \frac{3}{2}F$, $S_2 = F$, $S_3 = \frac{3}{2}F$, $S_4 = -\frac{2}{5}F$, $S_5 = -\frac{3}{10}\sqrt{29}F$, $S_6 = \frac{\sqrt{5}}{2}F$, $S_7 = \frac{\sqrt{5}}{2}F$,
 $S_8 = -\frac{3}{10}\sqrt{29}F$, $S_9 = -\frac{2}{5}F$, $S_{10} = \frac{\sqrt{29}}{5}F$, $S_{11} = 0$, $S_{12} = 0$, $S_{13} = \frac{\sqrt{29}}{5}F$,
 $S_{14} = -F$, $S_{15} = -F$

Aufgabe 4-12

- a) $9 + 3 = 6 \cdot 2$
 b) $A_H = 0$, $A_V = 15 \text{ kN}$, $B = 15 \text{ kN}$
 c) $S_1 = -30 \text{ kN}$, $S_2 = -60 \text{ kN}$, $S_3 = -30 \text{ kN}$, $S_4 = 15\sqrt{5} \text{ kN}$, $S_5 = -15 \text{ kN}$,
 $S_6 = 15\sqrt{5} \text{ kN}$, $S_7 = 15\sqrt{5} \text{ kN}$, $S_8 = -15 \text{ kN}$, $S_9 = 15\sqrt{5} \text{ kN}$

Aufgabe 4-13

- a) $A_H = \frac{5}{2}F$, $A_V = 3F$, $B = \frac{7}{2}F$
 b) S_5, S_9, S_{12}
 c) $S_1 = -\frac{11}{2}F$, $S_2 = -3\sqrt{2}F$, $S_3 = \frac{11}{2}F$, $S_4 = -\frac{11}{2}\sqrt{2}F$, $S_6 = -\frac{11}{2}\sqrt{2}F$, $S_7 = -\frac{13}{2}F$,
 $S_8 = \frac{5}{2}\sqrt{2}F$, $S_{10} = \frac{5}{2}\sqrt{2}F$, $S_{11} = -\frac{11}{2}F$, $S_{13} = \frac{5}{2}F$

Aufgabe 4-14

- a) $3 + 9 = 2 \cdot 6$
 b) Kein einfach abbaubares Fachwerk.
 c) $A_H = -3F$, $A_V = 0F$, $B_H = 3F$, $B_V = 3F$
 d) $S_1 = 3F$, $S_2 = -2F$, $S_3 = 0$, $S_4 = 0$

Aufgabe 4-15

- a) $3 + 21 = 2 \cdot 12$
 b) $A_H = 2F$, $A_V = 4F$, $B = 2F$
 c) Horizontalstab an Auflager (B), Vertikalstab an Knoten in Ecke über (B).
 d) $S_1 = -F$, $S_2 = -11F$, $S_3 = -\frac{3}{2}\sqrt{5}F$, $S_4 = -2F$, $S_5 = \frac{\sqrt{5}}{2}F$

Aufgabe 4-16

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Aufgabe 4-17

- a) $3 + 19 = 2 \cdot 11$
 b) $A = F$, $B_H = F$, $B_V = F$
 c) Keine Nullstäbe vorhanden.
 d) $S_1 = \sqrt{2}F$, $S_2 = -\sqrt{2}F$, $S_3 = -F$, $S_4 = F$

Aufgabe 4-18

- a) $A_H = \frac{3}{2}F$, $A_V = 3F$, $B = -\frac{3}{2}F$
 b) Unbelasteter Zweischlag am rechten Außenrand.
 c) $S_1 = -\frac{9}{2}\sqrt{2}F$, $S_2 = -3\sqrt{2}F$, $S_3 = -2F$, $S_4 = 4F$, $S_5 = -\frac{3}{2}F$, $S_6 = -\frac{3}{2}\sqrt{2}F$

Aufgabe 4-19

- a) $A_H = 0.5\sqrt{2}F_2 - 2.0qL$, $A_V = 0.7F_1 + 0.8\sqrt{2}F_2 - 0.4qL$, $B = 0.3(F_1 - \sqrt{2}F_2) + 0.4qL$
 b) Alle Stäbe die rechts von Auflager (B) liegen sind Nullstäbe.
 c) $S_1 = S_2 = -0.3(F_1 - \sqrt{2}F_2) - 0.4qL$, $S_3 = 0.0$, $S_4 = 0.4F_1$

Aufgabe 4-20

- a) $4 + 26 = 2 \cdot 15$
 b) $A_H = 10 \text{ kN}$, $A_V = 10 \text{ kN}$, $B_H = -20 \text{ kN}$, $B_V = 20 \text{ kN}$
 c) $S_1 = 20 \text{ kN}$, $S_2 = -10\sqrt{10} \text{ kN}$, $S_3 = 0$, $S_4 = 20 \text{ kN}$, $S_5 = 0$, $S_6 = -10\sqrt{10} \text{ kN}$,
 $S_7 = -20\sqrt{2} \text{ kN}$, $S_8 = 10 \text{ kN}$, $S_9 = 0$, $S_{10} = -10\sqrt{10} \text{ kN}$, $S_{11} = 0$, $S_{12} = 10 \text{ kN}$,
 $S_{13} = -10\sqrt{10} \text{ kN}$, $S_{14} = 40 \text{ kN}$, $S_{15} = -20\sqrt{10} \text{ kN}$, $S_{16} = 0$, $S_{17} = 40 \text{ kN}$, $S_{18} = 0$,
 $S_{19} = -20\sqrt{10} \text{ kN}$, $S_{20} = -40\sqrt{10} \text{ kN}$, $S_{21} = 40 \text{ kN}$, $S_{22} = 0$, $S_{23} = -20\sqrt{10} \text{ kN}$,
 $S_{24} = 0$, $S_{25} = 40 \text{ kN}$, $S_{26} = -20\sqrt{10} \text{ kN}$

Aufgabe 4-21

- a) $9 + 9 = 3 \cdot 6$
 b) $A_x = -\frac{25}{4} \text{ kN}$, $A_y = 5.00 \text{ kN}$, $A_z = \frac{25}{4} \text{ kN}$, $B_x = 0.00 \text{ kN}$, $B_y = -10.00 \text{ kN}$,
 $B_z = -10.00 \text{ kN}$, $C_x = \frac{25}{4} \text{ kN}$, $C_y = 5.00 \text{ kN}$, $C_z = \frac{35}{4} \text{ kN}$
 c) $S_1 = 10\sqrt{2} \text{ kN}$, $S_2 = -5\sqrt{2} \text{ kN}$, $S_3 = -\frac{15}{2}\sqrt{2} \text{ kN}$, $S_4 = -\frac{15}{4}\sqrt{2} \text{ kN}$, $S_5 = 0.00 \text{ kN}$,
 $S_6 = \frac{15}{2}\sqrt{2} \text{ kN}$, $S_7 = \frac{5}{4}\sqrt{26} \text{ kN}$, $S_8 = -\frac{15}{2}\sqrt{2} \text{ kN}$, $S_9 = -5.00 \text{ kN}$

8.5 Lösungen zu Kapitel 5

Aufgabe 5-1

- a) $A_H = -2F$, $A_V = -\frac{1}{2}F$, $B = \frac{3}{2}F$
 b) $0 \leq x \leq L$ $N = 2F$ $Q = -\frac{1}{2}F$ $M(0) = 0$
 $L \leq x \leq \frac{3}{2}L$ $N = 2F$ $Q = F$ $M(L) = -\frac{1}{2}F$

Aufgabe 5-2

- a) $A_H = 10.0 \text{ kN}$, $A_V = 6.0 \text{ kN}$, $M_A = -25.5 \text{ kNm}$
 b) $0.0 \leq x \leq 1.5$ $N = -10.0 \text{ kN}$ $Q = 6.0 \text{ kN}$ $M(0.0) = -25.5 \text{ kNm}$
 $1.5 \leq x \leq 3.0$ $N = -10.0 \text{ kN}$ $Q = 3.0 \text{ kN}$ $M(1.5) = -16.5 \text{ kNm}$
 $3.0 \leq x \leq 4.5$ $N = -10.0 \text{ kN}$ $Q = 0.0 \text{ kN}$ $M(3.0) = -12.0 \text{ kNm}$
 $0.0 \leq x \leq 1.2$ $N = 0.0 \text{ kN}$ $Q = 10.0 \text{ kN}$ $M(4.5) = -12.0 \text{ kNm}$
 $M(1.2) = 0.0 \text{ kNm}$

Aufgabe 5-3

- a) $A_H = 0$, $A_V = -1.0 \text{ kN}$, $B = 8.0 \text{ kN}$

$$\begin{aligned}
 \text{b) } 0.0 \leq x \leq 2.0 \quad Q &= 0.0 \text{ kN} & M(2.0) &= 0.0 \text{ kNm} \\
 2.0 \leq x \leq 6.0 \quad Q &= -1.0 \text{ kN} & M(4.0) &= -2.0 \text{ kNm} \\
 & & Q(6.0) &= 4.0 \text{ kN} & M(6.0) &= 0.0 \text{ kNm} \\
 & & Q(8.0) &= 0.0 \text{ kN} & M(7.0) &= -1.0 \text{ kNm}
 \end{aligned}$$

Aufgabe 5-4

$$\begin{aligned}
 \text{a) } A_H &= -14.93 \text{ kN}, A_V = 0.92 \text{ kN}, B = -7.76 \text{ kN} \\
 \text{b) } 0.0 \leq x \leq 5.0 \quad Q &= 12.50 \text{ kN} & M(2.5) &= 31.25 \text{ kNm} \\
 & & Q(5.0) &= 12.50 \text{ kN} & M(5.0) &= 62.50 \text{ kNm} \\
 & & Q(7.5) &= -12.50 \text{ kN} & M(7.5) &= 62.50 \text{ kNm} \\
 & & Q(10.0) &= -37.50 \text{ kN} & M(10.0) &= 0.00 \text{ kNm}
 \end{aligned}$$

Aufgabe 5-5

$$\begin{aligned}
 \text{a) } A_H &= 0, A_V = 12.5 \text{ kN}, B = 37.5 \text{ kN} \\
 \text{b) } Q(5.0) &= 12.5 \text{ kN} & M(5.0) &= 62.5 \text{ kNm} \\
 & Q(7.5) &= -12.5 \text{ kN} & M(7.5) &= 62.5 \text{ kNm} \\
 & Q(10.0) &= -37.5 \text{ kN} & M(10.0) &= 0.0 \text{ kNm}
 \end{aligned}$$

Aufgabe 5-6

$$\begin{aligned}
 \text{a) } A_H &= -21.0 \text{ kN}, A_V = 7.5 \text{ kN}, B = 2.5 \text{ kN} \\
 \text{b) } 0.0 \leq x \leq 1.5 \quad N &= -21.0 \text{ kN} & Q &= 7.5 \text{ kN} & M(1.5) &= 11.25 \text{ kNm} \\
 1.5 \leq x \leq 3.0 \quad N &= -21.0 \text{ kN} & Q &= -2.5 \text{ kN} & M(3.0) &= 7.50 \text{ kNm} \\
 3.0 \leq x \leq 6.0 \quad N(4.0) &= 14.0 \text{ kN} & Q &= -2.5 \text{ kN} & M(4.5) &= 3.75 \text{ kNm} \\
 & N(5.0) &= 7.0 \text{ kN} & & & \\
 & N(6.0) &= 0.0 \text{ kN} & & &
 \end{aligned}$$

Aufgabe 5-7

$$\begin{aligned}
 \text{a) } A_H &= 0, M_A = 480.0 \text{ kNm}, B = 120.0 \text{ kN} \\
 \text{b) } Q(0.0) &= 0.0 \text{ kN} & M(0.0) &= 480.0 \text{ kNm} \\
 & Q(4.0) &= -60.0 \text{ kN} & M(4.0) &= 360.0 \text{ kNm} \\
 & Q(8.0) &= -120.0 \text{ kN} & M(8.0) &= 0.0 \text{ kNm}
 \end{aligned}$$

Aufgabe 5-8

$$\begin{aligned}
 \text{a) } A_H &= 0, A_V = -0.83 \text{ kN}, B = 23.33 \text{ kN} \\
 \text{b) } & Q(0.0) = -0.83 \text{ kN} & M(2.5) &= -4.66 \text{ kNm} \\
 & Q(2.5) = -3.95 \text{ kN} & M(5.0) &= -25.00 \text{ kNm} \\
 & Q(5.0) = -13.33 \text{ kN} & M(6.0) &= -15.00 \text{ kNm} \\
 5.0 \leq x \leq 7.5 \quad Q &= 10.00 \text{ kN} & M(7.5) &= 0.00 \text{ kNm}
 \end{aligned}$$

Aufgabe 5-9

$$\begin{aligned}
 \text{a) } A_H &= 3.38 \text{ kNm}, A_V = 14.71 \text{ kN}, B = 29.54 \text{ kN} \\
 \text{b) } 0.0 \leq x \leq 1.5 \quad N &= 0.0 \text{ kN} & Q &= -5.00 \text{ kN} & M(1.5) &= -7.50 \text{ kNm} \\
 1.5 \leq x \leq 3.5 \quad N &= -3.38 \text{ kN} & Q &= 9.71 \text{ kN} & M(3.5) &= 11.29 \text{ kNm} \\
 3.5 \leq x \leq 5.5 \quad N &= -3.38 \text{ kN} & Q &= -0.29 \text{ kN} & M_{links}(5.5) &= 11.34 \text{ kNm} \\
 5.5 \leq x \leq 7.0 \quad N &= -3.38 \text{ kN} & Q &= -13.29 \text{ kN} & M_{rechts}(5.5) &= 31.34 \text{ kNm} \\
 7.0 \leq x \leq 8.0 \quad N &= -3.38 \text{ kN} & Q &= -22.29 \text{ kN} & M(7.0) &= 11.40 \text{ kNm} \\
 8.0 \leq x \leq 9.5 \quad N &= -3.38 \text{ kN} & Q &= 7.25 \text{ kN} & M(8.0) &= -10.88 \text{ kNm}
 \end{aligned}$$

Aufgabe 5-10

a) $A_H = 0$, $A_V = 5.67 \text{ kN}$, $B = 4.33 \text{ kN}$

b)		$Q(0.0) = 5.67 \text{ kN}$	$M(1.0) = 5.67 \text{ kNm}$
	$1.0 \leq x \leq 2.0$	$Q = 2.67 \text{ kN}$	$M(2.0) = 8.34 \text{ kNm}$
	$2.0 \leq x \leq 3.0$	$Q = 0.17 \text{ kN}$	$M(3.0) = 8.51 \text{ kNm}$
		$Q(4.0) = -2.33 \text{ kN}$	$M(4.0) = 8.00 \text{ kNm}$
		$Q(5.0) = -3.83 \text{ kN}$	$M(5.0) = 4.25 \text{ kNm}$
		$Q(6.0) = -4.33 \text{ kN}$	$M(6.0) = 0.0 \text{ kNm}$

Aufgabe 5-11

a) $A_H = 0$, $A_V = 30.00 \text{ kN}$, $M_A = -229.20 \text{ kNm}$

b)	$0.0 \leq x \leq 5.0$	$Q = 30.00 \text{ kN}$	$M(0.0) = -229.20 \text{ kNm}$
		$Q(7.5) = 16.25 \text{ kN}$	$M(5.0) = -79.20 \text{ kNm}$
		$Q(10.0) = 0.00 \text{ kN}$	$M(7.5) = -20.83 \text{ kNm}$

Aufgabe 5-12

ohne Lösungsangabe

Aufgabe 5-13

a) $A_H = 0$, $A_V = 10 \text{ kN}$, $M_A = -30 \text{ kNm}$, $B = 0$

b)	$0.0 \leq x \leq 3.0$	$Q = 10.0 \text{ kN}$	$M(0.0) = -30.0 \text{ kNm}$
			$M(1.5) = -15.0 \text{ kNm}$
	$3.0 \leq x \leq 15.0$	$Q = 0.0 \text{ kN}$	$M = 0.0 \text{ kNm}$

Aufgabe 5-14

a) $A_H = 0$, $A_V = 5.0 \text{ kN}$, $B = 12.5 \text{ kN}$, $C = -7.0 \text{ kN}$, $D = 1.5 \text{ kN}$

b)	$0.0 \leq x \leq 2.0$	$Q = 5.0 \text{ kN}$	$M(2.0) = 10.0 \text{ kNm}$
	$2.0 \leq x \leq 4.0$	$Q = -10.0 \text{ kN}$	$M(4.0) = -10.0 \text{ kNm}$
	$4.0 \leq x \leq 10.0$	$Q = 2.5 \text{ kN}$	$M(8.0) = 0.0 \text{ kNm}$
	$10.0 \leq x \leq 14.0$	$Q = -2.5 \text{ kN}$	$M(10.0) = 5.0 \text{ kNm}$
	$14.0 \leq x \leq 16.0$	$Q = 5.5 \text{ kN}$	$M(12.0) = 0.0 \text{ kNm}$
	$16.0 \leq x \leq 20.0$	$Q = -1.5 \text{ kN}$	$M(14.0) = -5.0 \text{ kNm}$

Aufgabe 5-15

a) $A_H = -0.50 \text{ kN}$, $A_V = 2.55 \text{ kN}$, $B = 1.95 \text{ kN}$

b)	$0.0 \leq x \leq 2.0$	$N = 0.50 \text{ kN}$	$Q = 2.55 \text{ kN}$	$M(2.0) = 5.10 \text{ kNm}$
	$2.0 \leq x \leq 4.0$	$N = 0.50 \text{ kN}$	$Q = 0.55 \text{ kN}$	$M_{links}(4.0) = 6.20 \text{ kNm}$
	$4.0 \leq x \leq 10.0$	$N = 0.0 \text{ kN}$	$Q = -1.95 \text{ kN}$	$M_{rechts}(4.0) = 7.70 \text{ kNm}$
				$M_{links}(7.0) = 1.85 \text{ kNm}$
				$M_{rechts}(7.0) = 5.85 \text{ kNm}$

Senkrechter Arm:

$$0.0 \leq x \leq 2.0 \quad N = 2.50 \text{ kN} \quad Q = -0.50 \text{ kN} \quad M(2.0) = -2.50 \text{ kNm}$$

Unterer Arm:

$$0.0 \leq x \leq 1.0 \quad N = 0.50 \text{ kN} \quad Q = 2.50 \text{ kN} \quad M(1.0) = 0.00 \text{ kNm}$$

Aufgabe 5-16

- a) $A_H = 0$, $A_V = 18.47 \text{ kN}$, $B = 34.24 \text{ kN}$, $C = 31.00 \text{ kN}$, $D = 13.29 \text{ kN}$
- b)
- | | | | | | | |
|------------------------|------------|-----|---------------------|-----------|-----|---------------------|
| | $Q(0.0)$ | $=$ | 18.47 kN | $M(0.0)$ | $=$ | 0.00 kNm |
| | $Q(2.31)$ | $=$ | 0.00 kN | $M(2.5)$ | $=$ | 21.19 kNm |
| | $Q(5.0)$ | $=$ | -21.53 kN | $M(5.0)$ | $=$ | -7.63 kNm |
| $5.0 \leq x \leq 6.5$ | Q | $=$ | 12.71 kN | $M(6.5)$ | $=$ | 11.44 kNm |
| $6.5 \leq x \leq 8.5$ | Q | $=$ | 0.71 kN | $M(8.5)$ | $=$ | 12.86 kNm |
| $8.5 \leq x \leq 10.0$ | Q | $=$ | -14.29 kN | $M(10.0)$ | $=$ | -8.57 kNm |
| | $Q(10.0)$ | $=$ | 16.71 kN | $M(12.5)$ | $=$ | 25.72 kNm |
| | $Q(12.79)$ | $=$ | 0.00 kN | | | |
| | $Q(15.0)$ | $=$ | -13.29 kN | | | |

Aufgabe 5-17

- a) $A_H = -12.5 \text{ kN}$, $A_V = 12.5 \text{ kN}$, $B_H = 9.0 \text{ kN}$, $B_V = -7.5 \text{ kN}$
- b) $0.0 \leq x \leq 2.0$ $N = -9.0 \text{ kN}$ $Q = -7.5 \text{ kN}$ $M(2.0) = -15.0 \text{ kNm}$
 $2.0 \leq x \leq 5.0$ $N = 3.5 \text{ kN}$ $Q = 5.0 \text{ kN}$

Oberer Arm:

$$0.0 \leq x \leq 2.0 \quad N = 12.5 \text{ kN} \quad Q = 12.5 \text{ kN} \quad M(2.0) = 25.0 \text{ kNm}$$

Senkrechter Arm:

$$0.0 \leq x \leq 2.0 \quad N = 12.5 \text{ kN} \quad Q = -12.5 \text{ kN} \quad M(2.0) = 0.00 \text{ kNm}$$

Aufgabe 5-18

- a) $A_H = 0$, $A_V = \frac{qL}{2}$, $M_A = -\frac{q}{2}e(L - e)$
 $B_H = 0$, $B_V = \frac{qL}{2}$, $M_B = -\frac{q}{2}e(L - e)$
- b) $e = \frac{L}{2}(1 \pm \frac{\sqrt{2}}{2})$

Aufgabe 5-19

- a) $A_H = 6.25 \text{ kN}$, $A_V = 25.0 \text{ kN}$, $B_H = -6.25 \text{ kN}$, $B_V = 25.0 \text{ kN}$
- b)

Linker Teil:

$$0.0 \leq x \leq 3.0 \quad N = -25.0 \text{ kN} \quad Q = -6.25 \text{ kN} \quad M_{links}(3.0) = -18.75 \text{ kNm}$$

$$3.0 \leq x \leq 4.0 \quad N = 0.00 \text{ kN} \quad Q = -6.25 \text{ kN} \quad M_{rechts}(3.0) = 6.25 \text{ kNm}$$

Oberer Teil:

$$0.0 \leq x \leq 8.0 \quad N = -6.25 \text{ kN} \quad Q = 0.00 \text{ kN} \quad M = 0.00 \text{ kNm}$$

Mittlere Teile:

$$0.0 \leq x \leq 1.0 \quad N = 0.00 \text{ kN} \quad Q_{links} = 25.00 \text{ kN} \quad M(0.0) = -25.00 \text{ kNm}$$

$$0.0 \leq x \leq 1.0 \quad N = 0.00 \text{ kN} \quad Q_{rechts} = -25.00 \text{ kN} \quad M(0.0) = -25.00 \text{ kNm}$$

Rechter Teil:

$$0.0 \leq x \leq 1.0 \quad N = 0.00 \text{ kN} \quad Q = 6.25 \text{ kN} \quad M_{links}(1.0) = 6.25 \text{ kNm}$$

$$1.0 \leq x \leq 4.0 \quad N = -25.00 \text{ kN} \quad Q = 6.25 \text{ kN} \quad M_{rechts}(1.0) = -18.75 \text{ kNm}$$

Aufgabe 5-20

- a) $A_H = 3.00 \text{ kN}$, $A_V = 14.17 \text{ kN}$, $B = 10.83 \text{ kN}$
- b)
- Senkrechter Teil:

$$0.0 \leq x \leq 5.0 \quad N = -14.17 \text{ kN} \quad Q = -3.00 \text{ kN} \quad M(5.0) = -15.00 \text{ kNm}$$

Waagerechter Teil:

$$0.0 \leq x \leq 2.0 \quad N = 0.00 \text{ kN} \quad Q = 14.17 \text{ kN} \quad M(1.06) = 0.00 \text{ kNm}$$

$$2.0 \leq x \leq 4.0 \quad N = 0.00 \text{ kN} \quad Q = 4.17 \text{ kN} \quad M(2.00) = 13.33 \text{ kNm}$$

$$4.0 \leq x \leq 6.0 \quad N = 0.00 \text{ kN} \quad Q = -10.83 \text{ kN} \quad M(4.00) = 21.67 \text{ kNm}$$

Aufgabe 5-21

a) $A = 74.3 \text{ kN}$, $B_H = 42.4 \text{ kN}$, $B_V = 90.4 \text{ kN}$

b)

Schräger Teil:

$$0.0 \leq x \leq 2.33 \quad N = -38.3 \text{ kN} \quad Q = 63.7 \text{ kN} \quad M(2.33) = 148.6 \text{ kNm}$$

$$2.33 \leq x \leq 5.83 \quad N = -38.3 \text{ kN} \quad Q = 33.7 \text{ kN} \quad M(5.83) = 266.6 \text{ kNm}$$

Waagerechter Teil:

$$0.0 \leq x \leq 4.0 \quad N = -15.5 \text{ kN} \quad Q = -21.5 \text{ kN} \quad M(4.0) = 180.8 \text{ kNm}$$

$$4.0 \leq x \leq 6.0 \quad N = -15.5 \text{ kN} \quad Q = -90.4 \text{ kN} \quad M(6.0) = 0.0 \text{ kNm}$$

Aufgabe 5-22

a) $A_V = 9.0 \text{ kN}$, $A_H = 3.0 \text{ kN}$, $B_V = 3.0 \text{ kN}$, $B_H = -3.0 \text{ kN}$

b)

Linker Teil:

$$0.0 \leq x \leq 4.0 \quad N = -9.0 \text{ kN} \quad Q = -3.0 \text{ kN} \quad M(4.0) = -12.0 \text{ kNm}$$

Oberer Teil:

$$0.0 \leq x \leq 4.0 \quad N = -3.0 \text{ kN} \quad Q(0.0) = 9.0 \text{ kN} \quad M(2.0) = 0.0 \text{ kNm}$$

$$Q(3.0) = 0.0 \text{ kN} \quad M(4.0) = 0.0 \text{ kNm}$$

$$4.0 \leq x \leq 8.0 \quad N = -3.0 \text{ kN} \quad Q = -3.0 \text{ kN} \quad M(8.0) = -12.0 \text{ kNm}$$

Rechter Teil:

$$0.0 \leq x \leq 4.0 \quad N = -3.0 \text{ kN} \quad Q = 3.0 \text{ kN} \quad M(4.0) = 0.0 \text{ kNm}$$

Aufgabe 5-23

a) $A_V = 40.00 \text{ kN}$, $A_H = 18.75 \text{ kN}$, $B_V = 40.00 \text{ kN}$, $B_H = -18.75 \text{ kN}$

b)

Linker Teil:

$$0.0 \leq x \leq 4.0 \quad N = -40.00 \text{ kN} \quad Q = -18.75 \text{ kN} \quad M(4.0) = -75.00 \text{ kNm}$$

Oberer Teil:

$$0.0 \leq x \leq 8.0 \quad N = -18.75 \text{ kN} \quad Q(0.0) = 40.00 \text{ kN} \quad M(3.0) = 0.00 \text{ kNm}$$

$$Q(3.0) = 10.00 \text{ kN} \quad M(4.0) = 5.00 \text{ kNm}$$

Rechter Teil:

$$0.0 \leq x \leq 4.0 \quad N = -40.00 \text{ kN} \quad Q = 18.75 \text{ kN} \quad M(4.0) = 0.0 \text{ kNm}$$

Aufgabe 5-24

a) $A_V = 12.63 \text{ kN}$, $A_H = 5.88 \text{ kN}$, $B_V = 11.37 \text{ kN}$, $B_H = -7.38 \text{ kN}$

b)

Linker Teil:

$$0.0 \leq x \leq 4.0 \quad N = -12.63 \text{ kN} \quad Q = -5.88 \text{ kN} \quad M(4.0) = -23.52 \text{ kNm}$$

Oberer Teil:

$$0.0 \leq x \leq 8.0 \quad N = -7.38 \text{ kN} \quad Q(4.2) = 0.00 \text{ kN} \quad M(4.0) = 0.00 \text{ kNm} \\ Q(8.0) = -11.37 \text{ kN} \quad M(4.2) = 3.09 \text{ kNm}$$

Rechter Teil:

$$0.0 \leq x \leq 2.5 \quad N = -11.37 \text{ kN} \quad Q = 7.38 \text{ kN} \quad M(2.5) = 0.0 \text{ kNm}$$

Aufgabe 5-25

a) $A_V = 42.50 \text{ kN}$, $A_H = -8.00 \text{ kN}$, $M_A = -55.13 \text{ kNm}$, $B = 15.00 \text{ kN}$

b)

Unterer Teil:

$$0.0 \leq x \leq 4.0 \quad N = -42.50 \text{ kN} \quad Q = 8.00 \text{ kN} \quad M(4.0) = -23.13 \text{ kNm}$$

Oberer Teil:

$$0.0 \leq x \leq 2.0 \quad N = -8.00 \text{ kN} \quad Q = -15.00 \text{ kN} \quad M(2.0)_{links} = -30.00 \text{ kNm} \\ 2.0 \leq x \leq 10.5 \quad N = 0.00 \text{ kN} \quad Q(7.5) = 0.00 \text{ kN} \quad M(2.0)_{rechts} = -53.13 \text{ kNm} \\ Q(10.5) = -15.00 \text{ kN} \quad M(7.5) = 22.5 \text{ kNm}$$

Aufgabe 5-26

a) $A_V = 40.3 \text{ kN}$, $A_H = 20.3 \text{ kN}$, $B_V = 39.7 \text{ kN}$, $B_H = -22.8 \text{ kN}$

b)

Linker Teil:

$$0.0 \leq x \leq 4.0 \quad N = -40.3 \text{ kN} \quad Q = -20.3 \text{ kN} \quad M(4.0) = -81.2 \text{ kNm}$$

Oberer Teil:

$$0.0 \leq x \leq 8.0 \quad N = -40.3 \text{ kN} \quad Q(4.03) = 0.0 \text{ kN} \quad M(4.03) = \text{ kNm} \\ Q(8.0) = -39.7 \text{ kN} \quad M(8.0) = -78.9 \text{ kNm}$$

Rechter Teil:

$$0.0 \leq x \leq 2.5 \quad N = -39.7 \text{ kN} \quad Q(1.25) = 31.5 \text{ kN} \quad M(2.5) = 0.0 \text{ kNm}$$

Aufgabe 5-27

a) $A_V = 10.0 \text{ kN}$, $A_H = 0.0 \text{ kN}$, $M_A = 100.0 \text{ kNm}$

b) $0.0 \leq s \leq 5\pi$ $N(s) = 10.0 \text{ kN} \cdot \cos\left(\frac{36}{\pi}s\right)$ $Q(s) = -10.0 \text{ kN} \cdot \sin\left(\frac{36}{\pi}s\right)$
 $M(s) = -50.0 \text{ kNm} \cdot \left(1 - \cos\left(\frac{36}{\pi}s\right)\right)$
 $5\pi \leq s \leq 5\pi + 8$ $N = -10.0 \text{ kN}$ $Q = 0.0 \text{ kN}$
 $M = -100.0 \text{ kNm}$

Aufgabe 5-28

a) $A_V = 2.66 \text{ F}$, $A_H = 1.91 \text{ F}$, $B_V = 0.76 \text{ F}$, $B_H = -0.49 \text{ F}$

$$\begin{aligned}
\text{b) } 0.0 \leq \varphi \leq \frac{\pi}{3} \quad N(\varphi) &= -(1.91 \sin \varphi + 2.66 \cos \varphi) \cdot F \\
&Q(\varphi) = (2.66 \sin \varphi - 1.91 \cos \varphi) \cdot F \\
&M(\varphi) = 4 \cdot (2.66 - 2.66 \cos \varphi - 1.91 \sin \varphi) \cdot Fa \\
\frac{\pi}{3} \leq \varphi \leq 0.42\pi \quad N(\varphi) &= -(1.66 \cos \varphi + 1.91 \sin \varphi) \cdot F \\
&Q(\varphi) = (1.66 \sin \varphi - 1.91 \cos \varphi) \cdot F \\
&M(\varphi) = (8.66 - 6.64 \cos \varphi - 7.64 \sin \varphi) \cdot Fa \\
0.42\pi \leq \varphi \leq \frac{3}{4}\pi \quad N(\varphi) &= -(0.66 \cos \varphi + 1.91 \sin \varphi) \cdot F \\
&Q(\varphi) = (0.66 \sin \varphi - 1.91 \cos \varphi) \cdot F \\
&M(\varphi) = (7.64 - 7.64 \sin \varphi - 2.64 \cos \varphi) \cdot Fa \\
\text{mit :} \quad \psi = \pi - \varphi \\
\frac{3}{4}\pi \leq \varphi \leq \pi \quad N(\psi) &= -(0.49 \sin \psi + 0.76 \cos \psi) \cdot F \\
&Q(\psi) = -(0.76 \sin \psi - 0.49 \cos \psi) \cdot F \\
&M(\psi) = (3.04 - 3.04 \cos \psi - 1.96 \sin \psi) \cdot Fa
\end{aligned}$$

Aufgabe 5-29

a) $A = 5.0 \text{ kN}, B_V = 10.0 \text{ kN}, B_H = 0.0 \text{ kN}$

$$\begin{aligned}
\text{b) } 0.0 \leq x \leq 2.0 \quad N &= 0.0 \text{ kN} \quad Q = 5.0 \text{ kN} \\
&M(x_1) = 5.0 \text{ kN} \cdot x_1 \\
0.0 \leq \varphi \leq \pi \quad N(\varphi) &= -5.0 \text{ kN} \cdot \cos \varphi \quad Q(\varphi) = 5.0 \text{ kN} \cdot \sin \varphi \\
&M(\varphi) = (3 - \cos \varphi) \cdot 5.0 \text{ kNm} \\
4.0 \leq x \leq 6.0 \quad N &= 0.0 \text{ kN} \quad Q = -10.0 \text{ kN} \\
&M(x_2) = 20.0 \text{ kNm} - 10.0 \text{ kN} \cdot x_2
\end{aligned}$$

Aufgabe 5-30

a) $A = 25.0 \text{ kN}, B_V = 30.0 \text{ kN}, B_H = -26.0 \text{ kN}$

$$\begin{aligned}
\text{b) } 0.0 \leq \varphi \leq \frac{\pi}{6} \quad N(\varphi) &= -25.0 \text{ kN} \cdot \cos \varphi \\
&Q(\varphi) = 25.0 \text{ kN} \cdot \sin \varphi \\
&M(\varphi) = 50.0 \text{ kNm} \cdot (1 - \cos \varphi) \\
\frac{\pi}{6} \leq \varphi \leq \frac{\pi}{3} \quad N(\varphi) &= -(10.0 \text{ kN} \cdot \cos \varphi + 25.9 \text{ kN} \cdot \sin \varphi) \\
&Q(\varphi) = 10.0 \text{ kN} \cdot \sin \varphi - 25.9 \text{ kN} \cdot \cos \varphi \\
&M(\varphi) = 24.1 \text{ kNm} - 20.0 \text{ kNm} \cdot \cos \varphi \\
\frac{\pi}{3} \leq \varphi \leq \frac{\pi}{2} \quad N(\varphi) &= -25.9 \text{ kN} \cdot \sin \varphi \\
&Q(\varphi) = -25.9 \text{ kN} \cdot \cos \varphi \\
&M(\varphi) = 40.0 \text{ kNm} - 52.0 \text{ kNm} \cdot \sin \varphi \\
\text{mit :} \quad \psi = \pi - \varphi \\
\frac{\pi}{2} \leq \varphi \leq \frac{2\pi}{3} \quad N(\psi) &= -(10.0 \text{ kN} \cdot \cos \psi + 26.0 \text{ kN} \cdot \sin \psi) \\
&Q(\psi) = 26.0 \text{ kN} \cdot \cos \psi - 10.0 \text{ kN} \cdot \sin \psi \\
&M(\psi) = 40.0 \text{ kNm} - 20.0 \text{ kNm} \cdot \cos \psi - 52.0 \text{ kNm} \cdot \sin \psi \\
\frac{2\pi}{3} \leq \varphi \leq \pi \quad N(\psi) &= -(26.0 \text{ kN} \cdot \sin \psi + 30.0 \text{ kN} \cdot \cos \psi) \\
&Q(\psi) = 26.0 \text{ kN} \cdot \cos \psi - 30.0 \text{ kN} \cdot \sin \psi \\
&M(\psi) = -52.0 \text{ kNm} \cdot \sin \psi + 60.0 \text{ kNm} - 60.0 \text{ kNm} \cdot \cos \psi
\end{aligned}$$

Aufgabe 5-31

a) $A = 1.0 \text{ kN}, B_V = 5.0 \text{ kN}, B_H = -1.0 \text{ kN}$

$$\begin{array}{llll}
\text{b) } 0.0 \leq x_1 \leq 2.0 & N & = & -1.0 \text{ kN} \\
& Q & = & 0.0 \text{ kN} \\
& M & = & 0.0 \text{ kNm} \\
2.0 \leq x_1 \leq 4.0 & N & = & -1.0 \text{ kN} \\
& Q & = & -5.0 \text{ kN} \\
& M(x_1) & = & 10.0 \text{ kNm} - 5.0 \text{ kN} \cdot x_1 \\
0.0 \leq \varphi \leq \pi & N(\varphi) & = & -(5.0 \text{ kN} \cdot \sin \varphi + 1.0 \text{ kN} \cdot \cos \varphi) \\
& Q(\varphi) & = & 1.0 \text{ kN} \cdot \sin \varphi - 5.0 \text{ kN} \cdot \cos \varphi \\
& M(\varphi) & = & -(10.0 \text{ kNm} \cdot \sin \varphi + 2.0 \text{ kNm} \cdot \cos \varphi + 8.0 \text{ kNm}) \\
0.0 \leq x_2 \leq 1.0 & N & = & 1.0 \text{ kN} \\
& Q & = & 5.0 \text{ kN} \\
& M(x_2) & = & 6.0 \text{ kNm} - 5.0 \text{ kN} \cdot x_2 \\
0.0 \leq x_3 \leq 1.0 & N & = & -5.0 \text{ kN} \\
& Q & = & 1.0 \text{ kN} \\
& M(x_3) & = & 1.0 \text{ kN} \cdot x_3 - 1.0 \text{ kNm}
\end{array}$$

Aufgabe 5-32

a) $A_V = A_H = 5.0 \text{ kN}$, $B_V = 5.0 \text{ kN}$, $B_H = -5.0 \text{ kN}$, $C_V = C_H = 5.0 \text{ kN}$

$$\begin{array}{ll}
\text{b) } 0.0 \leq \varphi_1 \leq \frac{\pi}{2} & N(\varphi_1) = -5.0 \text{ kN} \cdot (\sin \varphi_1 + \cos \varphi_1) \\
& Q(\varphi_1) = 5.0 \text{ kN} \cdot (\sin \varphi_1 - \cos \varphi_1) \\
& M(\varphi_1) = 20.0 \text{ kNm} \cdot (1 - \sin \varphi_1 - \cos \varphi_1) \\
0.0 \leq \varphi_2 \leq \frac{\pi}{2} & N(\varphi_2) = -5.0 \text{ kN} \cdot (\sin \varphi_2 + \cos \varphi_2) \\
& Q(\varphi_2) = 5.0 \text{ kN} \cdot (\sin \varphi_2 - \cos \varphi_2) \\
& M(\varphi_2) = 20.0 \text{ kNm} \cdot (\sin \varphi_2 + \cos \varphi_2 - 1)
\end{array}$$

Aufgabe 5-33

a) $A = 25\sqrt{2} \text{ kN}$, $B_V = 5 \text{ kN}$, $B_H = 25 \text{ kN}$, $M_B = 0$, $G_x = -25 \text{ kN}$, $G_y = 5 \text{ kN}$

$$\begin{array}{llll}
\text{b) } 0.0 \leq x \leq 2.0 & N = 0 & Q = -10 \text{ kN} & M = -10x \\
2.0 \leq x \leq 4.0 & N = -25 \text{ kN} & Q = 25 - 5x & M = -\frac{5}{2}x^2 + 25x - 60 \\
4.0 \leq x \leq 6.0 & N = -25 \text{ kN} & Q = 25 - 5x & M = -\frac{5}{2}x^2 + 25x - 60
\end{array}$$

Aufgabe 5-34

a) $A_V = 4.8 \text{ kN}$, $A_H = 11.4 \text{ kN}$, $B = \frac{57}{10}\sqrt{5} \text{ kN}$

$$\begin{array}{llll}
\text{b) } 0.0 \leq x_1 \leq 2\sqrt{2} & N = -8.1\sqrt{2} \text{ kN} & Q = -3.3\sqrt{2} \text{ kN} & M = -3.3\sqrt{2}x_1 \\
0.0 \leq x_2 \leq 4.0 & N = -11.4 \text{ kN} & Q = 4.8 - 2x_2 & M = -x_2^2 + 4.8x_2 - 13.2 \\
4.0 \leq x_2 \leq 8.0 & N = 0 & Q = 2.5 \text{ kN} & M = 2.5x_2 - 20
\end{array}$$

Aufgabe 5-35

a) $A_V = 0$, $A_H = -15 \text{ kN}$, $B = 5 \text{ kN}$, $C = 20\sqrt{2} \text{ [kN]}$

$$\begin{array}{llll}
\text{b) } 0.0 \leq x_1 \leq 3.0 & N = 15 \text{ kN} & Q = 0 & M = 0 \\
3.0 \leq x_1 \leq 6.0 & N = 20 \text{ kN} & Q = 0 & M = 0 \\
0.0 \leq x_2 \leq 1.0 & N = 0 & Q = 5 \text{ kN} & M = 5x_2 \\
1.0 \leq x_2 \leq 2.0 & N = 0 & Q = -5 \text{ kN} & M = 10 - 5x_2
\end{array}$$

Aufgabe 5-36

a) $A_H = 2.5 \text{ kN}$, $M_A = 10 \text{ kNm}$, $B = \frac{15}{4}\sqrt{5} \text{ kN}$, $C = \frac{5}{4}\sqrt{5} \text{ [kN]}$

$$\begin{array}{llll}
 \text{b) } 0.0 \leq x \leq 2.0 & N = -2.5 \text{ kN} & Q = 0 & M = 10 \text{ kNm} \\
 2.0 \leq x \leq 4.0 & N = -2.5 \text{ kN} & Q = -5 \text{ kN} & M = 20 - 5x \\
 4.0 \leq x \leq 6.0 & N = -6.25 \text{ kN} & Q = 2.5 \text{ kN} & M = 2.5x - 10 \\
 6.0 \leq x \leq 8.0 & N = -6.25 \text{ kN} & Q = -2.5 \text{ kN} & M = -2.5x + 20 \\
 8.0 \leq x \leq 10.0 & N = 0 & Q = 0 & M = 0
 \end{array}$$

Aufgabe 5-37

$$\begin{array}{ll}
 \text{a) } A_V = \frac{40}{3} \text{ kN}, A_H = 0, M_A = -\frac{215}{3} \text{ kNm}, B = -\frac{20}{3} \text{ kN} \\
 \text{b) } 0.0 \leq x \leq 5.0 & N = 0 \quad Q = \frac{40}{3} \text{ kN} \quad M = -\frac{215}{3} + \frac{40}{3}x \\
 5.0 \leq x \leq 9.0 & N = 0 \quad Q = \frac{5}{4}(9-x)^2 - \frac{20}{3} \quad M = -\frac{5}{12}(9-x)^3 - \frac{20}{3}x + 60
 \end{array}$$

Aufgabe 5-38

$$\begin{array}{ll}
 \text{a) } A = -\frac{8}{9}\sqrt{2}q_0L, B_V = \frac{1}{9}q_0L, B_H = -\frac{8}{9}q_0L, G_x = \frac{8}{9}q_0L, G_y = \frac{8}{9}q_0L \\
 \text{b) } 0.0 \leq x_1 \leq 2.0L & N = 0 \quad Q = -\frac{1}{4}q_0\frac{x^2}{L} \quad M = -\frac{1}{12}q_0\frac{x^3}{L} \\
 2.0L \leq x_1 \leq 3.0L & N = -\frac{8}{9}q_0L \quad Q = -\frac{1}{9}q_0L \quad M = -\frac{1}{9}q_0Lx - \frac{1}{9}q_0L^2 \\
 0.0 \leq x_2 \leq \sqrt{2}L & N = -\frac{1}{2}\sqrt{2}q_0L \quad Q = \frac{7}{18}\sqrt{2}q_0L \quad M = \frac{7}{18}\sqrt{2}q_0Lx_2 - \frac{7}{9}q_0L^2
 \end{array}$$

Aufgabe 5-39

$$\begin{array}{ll}
 \text{a) } A_V = 3.55 \text{ kN}, A_H = -\frac{5}{2}\sqrt{2} \text{ kN}, B = 6.22 \text{ kN} \\
 \text{b) } S_1 = -5 \text{ kN}, S_2 = 5 \text{ kN}, S_3 = -10 \text{ kN}, S_4 = 5 \text{ kN}
 \end{array}$$

oberer Teil:

$$\begin{array}{llll}
 0.0 \leq x \leq 2.0 & N = -2.5\sqrt{2} \text{ kN} & Q = 2.5\sqrt{2} \text{ kN} & M = 2.5\sqrt{2}x \\
 2.0 \leq x \leq 6.0 & N = -2.5\sqrt{2} \text{ kN} & Q = -2.5\sqrt{2} \text{ kN} & M = -2.5\sqrt{2}x \\
 6.0 \leq x \leq 8.0 & N = 2.5\sqrt{2} \text{ kN} & Q = 2.5\sqrt{2} \text{ kN} & M = 2.5\sqrt{2}x - 20\sqrt{2}
 \end{array}$$

unterer Teil:

$$\begin{array}{llll}
 0.0 \leq x \leq 2.0 & N = 5\sqrt{2} \text{ kN} & Q = 1.78 \text{ kN} & M = 1.78x \\
 2.0 \leq x \leq 8.0 & N = 2.5\sqrt{2} \text{ kN} & Q = 3.55 \text{ kN} & M = 3.55x \\
 8.0 \leq x \leq 10.0 & N = 2.5\sqrt{2} \text{ kN} & Q = -4.45 \text{ kN} & M = -4.45x \\
 10.0 \leq x \leq 12.0 & N = -2.5\sqrt{2} \text{ kN} & Q = -7.98 \text{ kN} & M = -7.98x + 127.64
 \end{array}$$

Aufgabe 5-40

$$\begin{array}{ll}
 \text{a) } A = 3.05 \text{ kN}, B_V = 1.55 \text{ kN}, B_H = -\frac{9}{4}\sqrt{2} \text{ kN} \\
 \text{b) } \text{waagerechter Stab: } N = 3.05 \text{ kN}, \text{senkrechter Stab: } N = -3.05 \text{ kN}, \\
 \text{linker Stab: } N = 3.84 \text{ kN}, \text{rechter Stab: } N = 3.84 \text{ kN}
 \end{array}$$

waagerechter Teil:

$$\begin{array}{llll}
 0.0 \leq x \leq 3.0 & N = -3.05 \text{ kN} & Q = 3.09 \text{ kN} & M = 3.09 \\
 0.0 \leq x \leq 3\sqrt{2} & N = 0.86 \text{ kN} & Q = 0.86 \text{ kN} & M = 3.86 + 9.27 \\
 3\sqrt{2} \leq x \leq 6\sqrt{2} & N = 0.86 \text{ kN} & Q = -3.64 \text{ kN} & M = -3.64x + 18.82
 \end{array}$$

Aufgabe 5-41

$$\begin{array}{ll}
 \text{a) } A_V = 1.75 \text{ kN}, A_H = -2 \text{ kN}, B = 7.25 \text{ kN} \\
 \text{b) } \text{waagerechter Stab: } N = -5.5 \text{ kN}, \text{linker Stab: } N = \frac{21}{8} \text{ kN}, \text{rechter Stab: } N = \frac{33}{8} \text{ kN}, \\
 \text{linker schräger Stab: } N = -\frac{35}{8} \text{ kN}, \text{rechter schräger Stab: } N = -\frac{55}{8} \text{ kN}
 \end{array}$$

$$\begin{array}{llll}
0.0 \leq x \leq 4.0 & N = 5.5 \text{ kN} & Q = -\frac{7}{8} \text{ kN} & M = -\frac{7}{8}x \\
4.0 \leq x \leq 6.0 & N = 5.5 \text{ kN} & Q = 1.75 \text{ kN} & M = 1.75x - 10.5 \\
6.0 \leq x \leq 8.0 & N = 5.5 \text{ kN} & Q = 10.75 - 1.5x & M = -0.75x^2 + 10.75x - 28.5 \\
8.0 \leq x \leq 12.0 & N = -5.5 \text{ kN} & Q = -\frac{3}{2}x + \frac{119}{8} & M = -\frac{3}{4}x^2 + \frac{119}{8}x - \frac{141}{2}
\end{array}$$

Aufgabe 5-42

a) $A_V = \frac{15}{8} \text{ kN}$, $A_H = \frac{15}{7} \text{ kN}$, $B_V = \frac{225}{8} \text{ kN}$, $B_H = -\frac{225}{7} \text{ kN}$

b) linker Stab: $N = -\frac{190}{7} \text{ kN}$, rechter Stab: $N = \frac{300}{7} \text{ kN}$,

linker schräger Stab: $N = -5.34 \text{ kN}$, rechter schräger Stab: $N = 80.1 \text{ kN}$

linker Teil:

$$\begin{array}{llll}
0.0 \leq x \leq 1.5 & N = 0 & Q = \frac{20}{7} \text{ kN} & M = \frac{20}{7}x \\
1.5 \leq x \leq 3.5 & N = -\frac{15}{8} \text{ kN} & Q = -\frac{15}{7} \text{ kN} & M = -\frac{15}{7}x + 7.5
\end{array}$$

rechter Teil:

$$\begin{array}{llll}
0.0 \leq x \leq 1.5 & N = 0 & Q = -\frac{300}{7} \text{ kN} & M = -\frac{300}{7}x \\
1.5 \leq x \leq 3.5 & N = -\frac{225}{8} \text{ kN} & Q = \frac{225}{7} \text{ kN} & M = \frac{225}{7}x - 112.5
\end{array}$$

Aufgabe 5-43

a) $A_V = -\frac{80}{3} \text{ kN}$, $A_H = -30 \text{ kN}$, $M_A = \frac{800}{3} \text{ kN}$, $B = \frac{560}{3} \text{ kN}$

b) senkrechter Stab: $N = -\frac{560}{3} \text{ kN}$, linker schräger Stab: $N = 166.62 \text{ kN}$, rechter schräger

Stab: $N = 150.94 \text{ kN}$

waagerechter Teil:

$$\begin{array}{llll}
0.0 \leq x \leq 4.0 & N = 30 \text{ kN} & Q = -\frac{80}{3} - 20x & M = \frac{800}{3} - \frac{80}{3}x - 10x^2 \\
4.0 \leq x \leq 7.0 & N = -98 \text{ kN} & & \\
7.0 \leq x \leq 11.0 & N = -98 \text{ kN} & &
\end{array}$$

Aufgabe 5-44

a) $Q(x) = -qx + \frac{1}{2}qL$, $M(x) = -\frac{1}{2}qx^2 + \frac{1}{2}qLx$, $M(0) = 0$, $M(L) = 0$

b) $Q(x) = \frac{1}{2}q_0 \frac{x^2}{L} - q_0x + \frac{1}{3}q_0L$, $M(x) = -\frac{1}{2}q_0x^2 + \frac{1}{6}q_0 \frac{x^3}{L} + \frac{1}{3}q_0Lx$, $M(0) = 0$, $M(L) = 0$

c) $Q(x) = -\frac{4}{3}q_0 \frac{x^3}{L^2} + 2q_0 \frac{x^2}{L} - q_0x + \frac{1}{6}q_0L$, $M(x) = -\frac{1}{3}q_0 \frac{x^4}{L^2} + \frac{2}{3}q_0 \frac{x^3}{L} - \frac{1}{2}q_0x^2 + \frac{1}{6}q_0Lx$
 $M(0) = 0$, $M(L) = 0$

d) $Q(x) = -qx + \frac{1}{2}qL - \frac{M_A}{L}$, $M(x) = -\frac{1}{2}qx^2 + \frac{1}{2}qLx - \frac{M_A}{L}x + M_A$
 $M(0) = M_A$, $M(L) = 0$

e) $Q(x) = -2q_0 \frac{L}{\pi} \sin \frac{\pi}{2L}x + 4q_0 \frac{L}{\pi^2}$, $M(x) = 4q_0 \frac{L^2}{\pi^2} \cos \frac{\pi}{2L}x + 4q_0 \frac{L}{\pi^2}x - 4q_0 \frac{L^2}{\pi^2}$
 $M(0) = 0$, $M(L) = 0$

f) $Q(x) = -2q_0 \frac{L}{\pi} \sin \frac{\pi}{2L}x$, $M(x) = 4q_0 \frac{L^2}{\pi^2} \cos \frac{\pi}{2L}x$, $Q(L) = 0$, $M(L) = 0$

Aufgabe 5-45

$$N(x) = -nx + nL, \quad N(L) = 0$$

Aufgabe 5-46

$$\begin{array}{llll}
\text{a) } 0 \leq x \leq a & Q_I(x) = \frac{Fa}{L} - F & M(x)_I = \left(\frac{Fa}{L} - F\right)x \\
a \leq x \leq L & Q(x)_{II} = \frac{Fa}{L} & M(x)_{II} = \frac{Fa}{L}x - Fa \\
M_I(0) = 0, M_{II}(L) = 0, & M_I(a) = M_{II}(a), & Q_{II}(a) - Q_I(a) = F
\end{array}$$

$$\begin{aligned} \text{b) } 0 \leq x \leq \frac{L}{2} \quad Q_I(x) &= -q_0 \frac{x^2}{L} - \frac{5}{12} q_0 L & M(x)_I &= -\frac{1}{3} q_0 \frac{x^3}{L} + \frac{1}{12} q_0 L \\ \frac{L}{2} \leq x \leq L \quad Q(x)_{II} &= q_0 \frac{x^2}{L} - 2q_0 x + \frac{1}{12} q_0 L & M(x)_{II} &= \frac{1}{3} q_0 \frac{x^3}{L} - q_0 x^2 + \frac{1}{12} q_0 L x + \frac{7}{12} q_0 L^2 \\ M_I(0) = 0, M_{II}(L) = 0, M_I(\frac{L}{2}) &= M_{II}(\frac{L}{2}), Q_I(\frac{L}{2}) = Q_{II}(\frac{L}{2}) \end{aligned}$$

$$\begin{aligned} \text{c) } 0 \leq x \leq a: Q_I(x) &= q, M(x)_I = qx \\ a \leq x \leq L: Q(x)_{II} &= -qx + \frac{1}{a-L}(qa + 0.5qa^2 - 0.5qL^2), \\ M(x)_{II} &= -0.5qx^2 + \frac{1}{a-L}(qa + 0.5qa^2 - 0.5qL^2)x + 0.5qL^2 + \frac{1}{a-L}(0.5qL^3 - qaL - 0.5qa^2L) \\ M_I(0) = 0, M_{II}(L) = 0, M_I(a) &= M_{II}(a), Q_{II}(a) = Q_I(a) \end{aligned}$$

$$\begin{aligned} \text{d) } 0 \leq x \leq a \quad Q_I(x) &= -qx + \frac{M_B}{L} - \frac{1}{2}q \frac{a^2}{L} + qa & M(x)_I &= -\frac{1}{2}qx^2 + \frac{M_B}{L}x - \frac{1}{2}q \frac{a^2}{L}x + qa \\ a \leq x \leq L \quad Q(x)_{II} &= \frac{M_B}{L} - \frac{1}{2}q \frac{a^2}{L} & M(x)_{II} &= \left(\frac{M_B}{L} - \frac{1}{2}q \frac{a^2}{L}\right)x - \frac{1}{2}qa^2 \\ M_I(0) = 0, M_{II}(L) = M_B, M_I(a) &= M_{II}(a), Q_{II}(a) = Q_I(a) \end{aligned}$$

8.6 Lösungen zu Kapitel 6

Aufgabe 6-1

$$B = 10 \text{ kN}, S_1 = -16.25 \text{ kN}$$

Aufgabe 6-2

$$A_H = 2F, A_V = -F, M_A = M_0 + 7FL$$

Aufgabe 6-3

$$A_V = 47.5 \text{ kN}, S_1 = -65 \text{ kN}$$

Aufgabe 6-4

$$B = 101.25 \text{ kN}, S_1 = -101.25 \text{ kN}$$

Aufgabe 6-5

$$A_H = B_H = 0, A_V = -\frac{160}{3} \text{ kN}, B_V = \frac{220}{3} \text{ kN}, S_1 = 45.83 \text{ kN}, S_2 = 27.5 \text{ kN}$$

Aufgabe 6-6

$$M_k = 750 \text{ kNm}$$

Aufgabe 6-7

$$B = \frac{10}{3}F, S_1 = \frac{10}{3}\sqrt{2}F, S_2 = \frac{1}{3}\sqrt{2}F$$

Aufgabe 6-8

$$B = \frac{5}{4}gL, C = 0$$

Aufgabe 6-9

$$B = \frac{1}{3}F, M_k = \frac{1}{6}FL$$

Aufgabe 6-10

$$M_0 = -\frac{1}{6} \text{ kNm}$$

Aufgabe 6-11

$$B = \frac{3}{2}gL, S_1 = 2.5gL, S_2 = -\sqrt{2}gL$$

Aufgabe 6-12

$$B = 2.5gL, S_1 = 6F$$

Aufgabe 6-13

$$B = \frac{29}{16} \text{ kN}, M_E = -7.9 \text{ kNm}, Q_B^{(r)} = -\frac{11}{24} \text{ kN}$$

Aufgabe 6-14

$$B = \frac{2}{3}F + \frac{1}{2}gL, S_1 = -\frac{1}{3}\sqrt{2}F - \frac{\sqrt{2}}{4}qL$$

Aufgabe 6-15

$$A_V = 9 \text{ kN}, M_A = 9 \text{ kNm}, Q_{G_2}^{(l)} = -16.36 \text{ kN}$$

Aufgabe 6-16

- a) 5 Gleichgewichtslagen
b) 3 stabile Gleichgewichtslagen

Aufgabe 6-17

- a) $F_{krit} = \frac{c_M}{3L}, \frac{3FL}{c_M} > 1$ stabile GGL, $\frac{3FL}{c_M} < 1$ instabile GGL
b) $F_{krit} = \frac{2F}{3c_FL}, \frac{3F}{2c_FL} < 1$ stabile GGL, $\frac{3F}{2c_FL} > 1$ instabile GGL
c) $F_{krit} = \frac{4L^2c_F+c_M}{3L}, \frac{4L^2c_F+c_M}{3FL} > 1$ stabile GGL, $\frac{4L^2c_F+c_M}{3FL} < 1$ instabile GGL

Aufgabe 6-18

- a) $F_{krit} = (\frac{1}{2}k_1 + 2k_2)L, \frac{(0.5k_1+2k_2)L}{F} > 1$ stabile GGL, $\frac{(0.5k_1+2k_2)L}{F} < 1$ instabile GGL
b) $F_{krit} = \frac{2c}{L}, \frac{FL}{2c} < 1$ stabile GGL, $\frac{FL}{2c} > 1$ instabile GGL

Aufgabe 6-19

$$F_{krit} = \frac{k}{2L}, \frac{2F}{k} < 1 \text{ stabile GGL}, \frac{2F}{k} > 1 \text{ instabile GGL}$$

Aufgabe 6-20

- a) $\varphi_1 = \frac{\pi}{2}, \varphi_2 = -\frac{\pi}{2}, \varphi_3 = \arcsin \frac{G+F}{4kL}$
b) φ_1 : stabil für $\frac{G+F}{4kL} < 1$, instabil für $\frac{G+F}{4kL} > 1$
 φ_2 : stabil
 φ_3 : stabil für $\frac{4kL-G}{F} < 1$, instabil für $\frac{4kL-G}{F} > 1$

Aufgabe 6-21

- a) $\varphi_1 = 2n\pi, n = 0, 1, 2, \dots, \varphi_2 = (2n+1)\pi, n = 0, 1, 2, \dots, \varphi_3 = \arccos \frac{G}{kR}$
b) φ_1 : stabil für $\frac{G}{kR} < 1$, instabil für $\frac{G}{kR} > 1$
 φ_2 : stabil
 φ_3 : stabil für $\frac{G^2}{k^2R^2} > 1$, instabil für $\frac{G^2}{k^2R^2} < 1$

8.7 Lösungen zu Kapitel 7

Aufgabe 7-1

$$\text{a) } F = \frac{\mu_0 G}{\cos \alpha - \mu_0 \sin \alpha}$$

$$\text{b) } \alpha^* = \arctan \frac{1}{\mu_0}$$

Aufgabe 7-2

$$\text{a) } H_1 = \frac{V(\sin \alpha - \mu_0 \cos \alpha)}{\mu_0 \sin \alpha + \cos \alpha}$$

$$\text{b) } H_2 = \frac{V(\sin \alpha + \mu_0 \cos \alpha)}{\cos \alpha - \mu_0 \sin \alpha}$$

$$\text{c) } \alpha^* = \arctan \mu_0$$

Aufgabe 7-3

$$\alpha = \arctan \mu_0$$

Aufgabe 7-4

$$\alpha = 59^\circ$$

Aufgabe 7-5

$$F = \frac{\mu_0 G H}{H - H_0(1 - \tan \alpha)}$$

Aufgabe 7-6

$$\text{a) } F = -\frac{G h \sin \alpha}{2 h_0}, \mu_0 = \tan \alpha \left(1 - \frac{h}{2 h_0}\right)$$

$$\text{b) } F = \frac{1}{2 h_0} G (b \cos \alpha - h \sin \alpha), \mu_0 = \frac{1}{2 h_0} b + \tan \alpha \left(1 - \frac{h}{2 h_0}\right)$$

Aufgabe 7-7

$$\text{a) } F = \frac{(\mu_{0,A} + \mu_{0,B}) G_A + \mu_{0,B} G_B (1 - \mu_{0,A} \tan \alpha)}{1 - \mu_{0,A} \tan \alpha}$$

$$\text{b) } \alpha^* = \arctan \frac{1}{\mu_{0,A}}$$

Aufgabe 7-8

$$\alpha \approx 27.6$$

Aufgabe 7-9

$$L_0 \geq 0.6 L$$

Aufgabe 7-10

...

Aufgabe 7-11

$$\text{a) } \mu_{0,S} = 2 \frac{G_K}{G_S} \tan \alpha$$

$$\text{b) } \mu_{0,S}^* = 1$$

Aufgabe 7-12

a) Kiste bleibt nicht in Ruhe

$$\text{b) } \frac{\mu_{0,A}}{\mu_{0,B}} \geq \frac{G_A + G_B}{G_A}$$

$$\text{c) } F \leq \mu_{0,B} (G_A + G_B) + \mu_{0,C} (G_A + G_B + G_C)$$

Aufgabe 7-13

$$\text{a) } M = \frac{G r_2}{2 \cos \alpha - \sin \alpha \left(\mu_0 + \frac{1}{\mu_0}\right)}$$

b) ...

Aufgabe 7-14

$$\text{a) } \frac{G_2}{G_1} L e^{-0.2\pi} \leq x \leq \frac{G_2}{G_1} L e^{0.2\pi}$$

$$\text{b) } \frac{G_2}{G_1} = e^{\mu_0\pi}$$

Aufgabe 7-15

$$\text{a) } S = F \frac{x}{h}$$

$$\text{b) } \frac{G}{F} h e^{-\mu_0 \frac{\pi}{2}} \leq x \leq \frac{G}{F} h e^{\mu_0 \frac{\pi}{2}}$$

Aufgabe 7-16

$$\mu_0 \geq \frac{\ln 5}{3\pi} \approx 0.17$$

Aufgabe 7-17

$$\text{a) } M = 0.4F(1 - e^{0.3\pi})$$

$$\text{b) } M = 0.4F(1 - e^{-0.3\pi})$$

Aufgabe 7-18

$$\text{a) } G_1 \geq G_2(\sin \alpha - \mu_0 \cos \alpha) e^{-3\mu_0(\frac{\pi}{2} + \alpha)}$$

$$\text{b) } G_1 \leq G_2(\sin \alpha - \mu_0 \cos \alpha) e^{3\mu_0(\frac{\pi}{2} + \alpha)}$$

Aufgabe 7-19

$$F = \left(1 + \frac{(1+\mu_0)^2}{1+\mu_0^2}\right) G e^{\mu_0\pi}$$