Chapter 09  Homework Solutions

P: 1, 5, 6, 7, 12, 18, 22, 25*, 27*, 31*, 35*, 36, 39, 50*, 53*, 55*

Problem 1. Three forces are applied to a tree sapling, as shown in Fig. 9-41, to stabilize it. If \( \vec{F}_A = 310 \text{ N} \) and \( \vec{F}_B = 425 \text{ N} \), find \( \vec{F}_C \) in magnitude and direction.

Solution:
\[
\sum \vec{F} = 0
\]
\[
\sum F_x = 0 \quad \Rightarrow \quad F_A + F_B \cos(110^\circ) + F_{Cx} = 0
\]
\[
F_{Cx} = - F_A - F_B \cos(110^\circ) = - 164.6 \text{ N}
\]
\[
\sum F_y = 0 \quad \Rightarrow \quad F_B \sin(110^\circ) + F_{Cy} = 0
\]
\[
F_{Cy} = - F_B \sin(110^\circ) = - 399.4 \text{ N}
\]
\[
F_C = \sqrt{(F_{Cx})^2 + (F_{Cy})^2} = 432.0 \text{ N} \approx 4.3 \times 10^3 \text{ N}
\]
\[
\theta = \tan^{-1} \left( \frac{F_{Cy}}{F_{Cx}} \right) = 67.6^\circ \quad \phi = 180^\circ - 67.6^\circ = 112.4^\circ
\]

Problem 5. Two cords support a chandelier in the manner shown in Fig. 9-4 except that the upper wire makes an angle of 45° with the ceiling. If the cords can sustain a force of 1550 N without breaking, what is the maximum chandelier weight that can be supported?

Solution:
\[ \sum F_x = 0 \]
\[ F_B - F_A \cos(45^\circ) = 0 \]
\[ \Rightarrow F_A = \frac{F_B}{\cos(45^\circ)} > F_B \]
\[ \Rightarrow \text{The limit will be } F_A = 1550 \text{ N and } F_B \text{ is something less.} \]

\[ \sum F_y = 0 \]
\[ F_A \sin(45^\circ) - mg = 0 \]
\[ mg = F_A \sin(45^\circ) = (1550 \text{ N}) \sin(45^\circ) = 1.1 \times 10^3 \text{ N} \]

**Problem 6.** Calculate the forces \( F_A \) and \( F_B \) that the supports exert on the diving board of Fig. 9-42 when a 58-kg person stands at its tip
(a) Ignore the weight of the board.
(b) Take into account the boards' mass of 35 kg. Assume the boards' CG is at its center.

**Solution:**

![Diagram of diving board with Forces](image)

(a)  
\[ \sum \tau = 0 \quad \text{about the left end of the board} \]
\[ F_A(0 \text{ m}) + F_B(1.0 \text{ m}) - (0 \text{ kg})(9.8 \text{ m/s}^2)(2.0 \text{ m}) - \]
\[ - (58.0 \text{ kg})(9.8 \text{ m/s}^2)(4.0 \text{ m}) = 0 \]
\[ F_B = 2.3 \times 10^3 \text{ N} \]

(b)  
\[ \sum F = 0 \]
\[ F_A + Mg - F_B = 0 \]
\[ F_A = F_B - Mg = 1.7 \times 10^3 \text{ N} \]

(b)  
\[ \sum \tau = 0 \quad \text{about the left end of the board} \]
\[ F_A(0 \text{ m}) + F_B(1.0 \text{ m}) - (35.0 \text{ kg})(9.8 \text{ m/s}^2)(2.0 \text{ m}) - \]
\[ - (58.0 \text{ kg})(9.8 \text{ m/s}^2)(4.0 \text{ m}) = 0 \]
\[ F_B = 3.0 \times 10^3 \text{ N} \]
\[ \sum F = 0 \]
\[ F_A + mg + Mg - F_B = 0 \]
\[ F_A = F_B - (m + M)g = 2.0 \times 10^3 N \]

**Problem 7.** A uniform steel beam has a mass of 940 kg. On it is resting half of an identical beam, as shown in Fig. 9-44. What is the vertical support force at each end?

**Solution:**

\[ \sum \tau = 0 \quad \text{about the left end} \]
\[ F_A(0 m) - \frac{1}{2} Mg(\frac{l}{4}) - Mg(\frac{l}{2}) + F_B(l) = 0 \]
\[ F_B = \frac{5}{8} Mg = 5.8 \times 10^3 N \]

\[ \sum F_y = 0 \]
\[ F_A - \frac{1}{2} Mg - Mg + F_B = 0 \]
\[ F_A = \frac{7}{8} Mg = 8.1 \times 10^3 N \]

**Problem 12.** Find the tension in the two wires supporting the traffic light shown in Fig. 9-46.

**Solution:**
Problem 18. Calculate (a) the tension $F_T$ in the wire that supports the 27-kg beam shown in Fig. 9-52 and (b) the force $F_W$ exerted by the wall on the beam (give magnitude and direction).

Solution:

\[ \sum F_x = 0 \]
\[ F_{T1x} - F_{T2x} = 0 \]

\[ \sum F_y = 0 \]
\[ F_{T1y} + F_{T2y} - mg = 0 \]

\[ F_{T1}\cos(37^\circ) - F_{T2}\cos(53^\circ) = 0 \]
\[ F_{T1}\sin(37^\circ) + F_{T2}\sin(53^\circ) - mg = 0 \]

\[ F_{T2} = \frac{F_{T1}\cos(37^\circ)}{\cos(53^\circ)} \]
\[ F_{T1}\sin(37^\circ) + \left( \frac{F_{T1}\cos(37^\circ)}{\cos(53^\circ)} \right)\sin(53^\circ) - mg = 0 \]

\[ F_{T1} = 1.9 \times 10^2 \text{N} \]
\[ F_{T2} = 2.6 \times 10^2 \text{N} \]
Problem 22. The 72-kg man's hands in Fig 9-56 are 36 cm apart. His CG is located 75% of the distance from his right hand toward his left. Find the force on each hand due to the ground.

Solution:

(a) \[ \sum \tau = 0 \quad \text{about the left end of the beam} \]

\[ F_{W_y}(0.0 \text{ m}) - mg \left( \frac{l}{2} \right) + F_{Ty}(l) = 0 \]

\[ F_T \sin(40^\circ) = \frac{mg}{2} \]

\[ F_T = 2.1 \times 10^2 \text{N} \]

(b) \[ \sum F_x = 0 \]

\[ F_{W_x} - F_{T_x} = 0 \]

\[ F_{W_x} = F_{T_x} = 157.7 \text{ N} \]

\[ \sum F_y = 0 \]

\[ F_{W_y} + F_{T_y} - mg = 0 \]

\[ F_{W_y} = mg - F_{T_y} = 132.3 \text{ N} \]

\[ F_W = \sqrt{(F_{W_x})^2 + (F_{W_y})^2} = 2.1 \times 10^2 \text{N} \]

\[ \theta = \tan^{-1} \left( \frac{F_{W_y}}{F_{W_x}} \right) = 40^\circ \]
\[ \sum \tau = 0 \] about his right arm

\[ F_{N\text{right}}(0.0 \text{m}) - mg(0.27 \text{ m}) + F_{N\text{left}}(0.36 \text{ m}) = 0 \]

\[ F_{N\text{left}} = 5.3 \times 10^2 \text{N} \]

\[ \sum F_y = 0 \]

\[ F_{N\text{right}} + F_{N\text{left}} - mg = 0 \]

\[ F_{N\text{right}} = mg - F_{N\text{left}} = 1.8 \times 10^2 \text{N} \]
**Problem 31.** Approximately what magnitude force, $F_M$, must the extensor muscle in the upper arm exert on the lower arm to hold a 7-3 kg shot put. Assume the lower arm has a mass of 2.8 kg and its CG is 12 cm from the elbow-joint pivot.

**Solution:**

\[ \sum r = 0 \quad \text{about the elbow joint} \]

\[ + F_M(d) + F_J(0.0 \text{ m}) - mg(D) - Mg(L) = 0 \]

\[ F_M = \frac{mg(D+L)}{d} = 9.9 \times 10^2 \text{ N} \]
Problem 35. Redo Example 9-9 assuming now that the person is less bent over so that the 30 degree in Fig. 9-14b is instead 45°. What will be the magnitude of $F_V$ on the vertebra?

Solution:

\[ W_T = 0.46w \]
\[ W_H = 0.07w \]
\[ W_A = 0.12w \]

\[ \sum T = 0 \quad \text{about the base of the spine} \]
\[ F_{M\perp}(0.48 \text{ m}) - W_{H\perp}(0.72 \text{ m}) - W_{A\perp}(0.48 \text{ m}) - W_{T\perp}(0.36 \text{ m}) = 0 \]
\[ F_M \sin(12^\circ)(0.48 \text{ m}) - W_H \sin(45^\circ)(0.72 \text{ m}) - W_A \sin(45^\circ)(0.48 \text{ m}) - W_T \sin(45^\circ)(0.36 \text{ m}) = 0 \]
\[ F_M = 1.94w \]

\[ \sum F_y = 0 \]
\[ F_{Vy} - F_{My} - W_T - W_H - W_A = 0 \]
\[ F_{Vy} - F_M \sin(33^\circ) - 0.46w - 0.07w - 0.12w = 0 \]
\[ F_{Vy} = 1.71w \]

\[ \sum F_x = 0 \]
\[ F_{Vx} - F_{Mx} = 0 \]
\[ F_{Vx} = 1.63w \]

\[ F_V = \sqrt{(1.63w)^2 + (1.71w)^2} = 2.4w \]
Problem 39. A marble column of cross-sectional area 1.2 m$^2$ supports a mass of 25 000 kg. (a) What is the stress within the column? (b) What is the strain?

Solution:

(a) Stress \( F = \frac{mg}{A} \frac{(25000 \text{ kg})(9.8 \text{ m/s}^2)}{(1.2 \text{ m}^2)} = 2.042 \times 10^5 \text{ N/m}^2 \)

(b) Strain \( \frac{\text{Stress}}{\text{Young's Modulus}} = \frac{2.042 \times 10^5 \text{ N/m}^2}{50 \times 10^9 \text{ N/m}^2} = 4.1 \times 10^{-6} \)