11.D4 This problem asks us to rank four alloys (brass, steel, titanium, and aluminum), from least to greatest weight for a structural member to support a 44,400 N (10,000 lb_f) load without experiencing plastic deformation. From Equation 6.1, the cross-sectional area (A_0) must necessarily carry the load (F) without exceeding the yield strength (σ_y), as

$$A_0 = \frac{F}{\sigma_y}$$

Now, given the length l, the volume of material required (V) is just

$$V = lA_0 = \frac{lF}{\sigma_y}$$

Finally, the mass of the member (m) is

$$m = V\rho = \frac{\rho l F}{\sigma_y}$$

Here ρ is the density. Using the values given for these alloys

$$m(\text{brass}) = \frac{(8.5 \text{ g/cm}^3)(25 \text{ cm})(44,400 \text{ N})}{(345 \times 10^6 \text{ N/m}^2)\left(\dfrac{1 \text{ m}}{10^2 \text{ cm}}\right)^2} = 273 \text{ g}$$

$$m(\text{steel}) = \frac{(7.9 \text{ g/cm}^3)(25 \text{ cm})(44,400 \text{ N})}{(690 \times 10^6 \text{ N/m}^2)\left(\dfrac{1 \text{ m}}{10^2 \text{ cm}}\right)^2} = 127 \text{ g}$$

$$m(\text{aluminum}) = \frac{(2.7 \text{ g/cm}^3)(25 \text{ cm})(44,400 \text{ N})}{(275 \times 10^6 \text{ N/m}^2)\left(\dfrac{1 \text{ m}}{10^2 \text{ cm}}\right)^2} = 109 \text{ g}$$

$$m(\text{titanium}) = \frac{(4.5 \text{ g/cm}^3)(25 \text{ cm})(44,400 \text{ N})}{(480 \times 10^6 \text{ N/m}^2)\left(\dfrac{1 \text{ m}}{10^2 \text{ cm}}\right)^2} = 104 \text{ g}$$

Thus, titanium would have the minimum weight (or mass), followed by aluminum, steel, and brass.