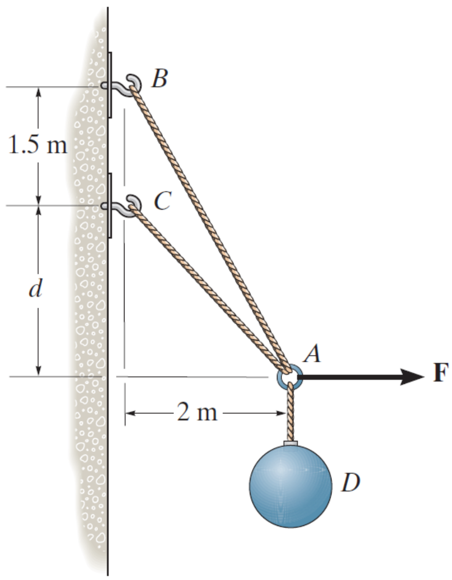
Problem 3-39

The ball D has a mass of 20 kg. If a force of $F = 100$ N is applied horizontally to the ring at A, determine the dimension d so that the force in cable AC is zero.



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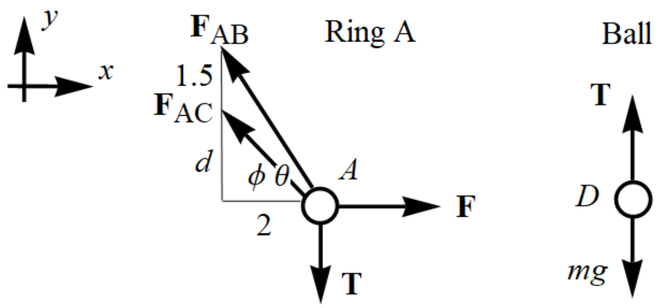
Solution

Draw free-body diagrams for ring A and the ball. Let ϕ and θ be the angles that $\mathbf{F}_{\text{AC}}$ and $\mathbf{F}_{\text{AB}}$ make with the horizontal, respectively.



In order for the system to be in equilibrium, the sum of the forces in each direction must be zero.

$$\sum F_x = 0: \qquad F - F_{\text{AB}}\cos\theta - F_{\text{AC}}\cos\phi = 0 \qquad 0 = 0$$

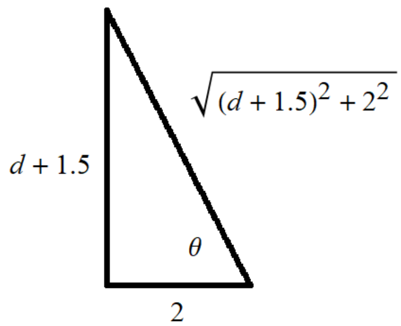
$$\sum F_y = 0: \qquad F_{\text{AB}}\sin\theta + F_{\text{AC}}\sin\phi - T = 0 \qquad T - mg = 0$$

Since the force in cable AC is zero, set $F_{\text{AC}} = 0$. Also, plug in $T = mg$.

$$F - F_{\text{AB}}\cos\theta = 0 \tag{1}$$

$$F_{\text{AB}}\sin\theta - mg = 0 \tag{2}$$

Use the Pythagorean theorem to find the triangle's hypotenuse.



As a result,

$$\cos\theta = \frac{2}{\sqrt{(d+1.5)^2+2^2}} \quad \text{and} \quad \sin\theta = \frac{d+1.5}{\sqrt{(d+1.5)^2+2^2}},$$

and equations (1) and (2) become

$$F - F_{\text{AB}}\frac{2}{\sqrt{(d+1.5)^2+2^2}} = 0 \tag{3}$$

$$F_{\text{AB}}\frac{d+1.5}{\sqrt{(d+1.5)^2+2^2}} - mg = 0 \tag{4}$$

Solve equation (3) for F_{AB}

$$F_{\text{AB}} = \frac{\sqrt{(d+1.5)^2+2^2}}{2}F$$

and plug it into equation (4).

$$\left[\frac{\sqrt{(d+1.5)^2+2^2}}{2}F\right]\frac{d+1.5}{\sqrt{(d+1.5)^2+2^2}} - mg = 0$$

$$\frac{(d+1.5)F}{2} - mg = 0$$

$$d = \frac{2mg}{F} - 1.5$$

Set $m = 20$ kg and $g = 9.81$ m/s^2 and $F = 100$ N.

$$d \approx 2.42 \text{ m}$$