1. (14 pts) Determine the magnitude of the reaction at the roller support. A separate, complete FBD is required for full credit.

\[ 160 \text{ lb} \]

\[ 160 \text{ lb} \]

\[ A_x \]

\[ A_y \]

\[ B_y \]

\[ \sum M_A = -80(1.5) + 160(2) - 120(7) + B_y(4) = 0 \]

\[ B_y = 160 \text{ lb} \]

\[ \sum F_y = A_y - 160 = 0 \Rightarrow A_y = 160 \text{ lb} \]

\[ \sum F_x = A_x - B_x = 0 \Rightarrow A_x = B_x = 10.92 \text{ lb} \]

\[ m = \frac{A_x}{A_y} = \frac{10.92}{160} = 0.068 \]

2. (14 pts) A 12 foot long, 60 pound ladder leans against a frictionless wall as shown. Determine the minimum coefficient of static friction between the ladder and the ground so the ladder does not slip. A separate, complete FBD is required for full credit.

\[ 60 \text{ lb} \]

\[ B_x \]

\[ A_x \]

\[ A_y \]

\[ \sum M_a = 60(13) \cos 70^\circ + B_x(12) \sin 70^\circ = 0 \Rightarrow B_x = 10.92 \text{ lb} \]

\[ \sum F_x = A_x - B_x = 0 \Rightarrow A_x = 10.92 \text{ lb} \]

\[ m = \frac{A_x}{A_y} = \frac{10.92}{60} = 0.182 \]

3. (14 pts) The Mythbusters are using a 3/8 inch diameter cable with a yield strength of 30,000 psi to accelerate a 3000 pound car at 9 ft/s². What is the factor of safety of the cable against yielding?

\[ 4.44 \]

\[ \sum F_x = T = \frac{3000 \text{ lb}}{\frac{3}{8} \text{ in}} \Rightarrow T = 745.3 \text{ lb} \]

\[ F_S = \frac{\text{Strength}}{\text{Load}} = \frac{30000 \text{ psi}}{6748 \text{ psi}} = 4.445 \]

4. (14 pts) A satellite is orbiting the earth such that its period is 2 days. Determine the height of the satellite above the earth and how fast the satellite is moving.

\[ h = 6.677 \times 10^8 \text{ m} \]

\[ V = 2440 \text{ m/s} \]

\[ f = \frac{1}{2 \text{ days}} = 0.5 \text{ rev/day} \]

\[ \omega = \frac{0.5 \text{ rev}}{\text{day}} \times 2\pi \text{ rad/rev} = 3.142 \text{ rad/day} \]

\[ \omega = \frac{\sqrt{\frac{G m_e}{r^3}}}{r} = \frac{[6.674 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2} \text{ m}^{-2}] (2.97 \times 10^3 \text{ kg})^{1/3}}{(3.142 \text{ rad/day})(3 \text{ days})^{2/3}} \]

\[ h = \left( \frac{G m_e}{r^2} \right)^{1/3} \cdot \frac{1}{r} = \left[ \frac{6.674 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2} \text{ m}^{-2}}{(3.142 \text{ rad/day})(3 \text{ days})^{2/3}} \right]^{1/3} \]

\[ V = \omega r = 3.63 \times 10^5 \text{ m/s} \]

\[ 4 \text{ not correct} \]

\[ -4 \text{ wrong } \omega \]

\[ -2 \text{ } V = \omega r \]
5. (14 pts) A grain barge displaces 11,000 ft³ of water when empty. It displaces 78,400 ft³ of water when full. How many bushels of corn can the barge hold? A bushel of corn weighs 70 pounds.

\[ V = V_{\text{full}} - V_{\text{empty}} = 78400 - 11000 = 67400 \text{ ft}^3 \]

\[ W_{\text{corn}} = \frac{67400 \text{ ft}^3}{\text{ft}^3} \times 62.4 \text{ lb/ft}^3 = 4,204,000 \text{ lb} \]

\[ \text{bushel} = \frac{2,000 \text{ lb}}{70 \text{ lb}} \]

\[ 6000 \text{ bushels} \]

-3 ignored barge
-6 didn't multiply by \( \rho_g \) (ans. 96.3)
-4 used mass density

6. (14 pts) 40 gallons per minute of water is required to flow from a 1 inch diameter opening at the bottom of a large water tank. Determine the required height of water in the tank to maintain this flow. 1 gallon = 231 m³

\[ V = \frac{Q}{A} = \frac{40 \text{ gal/min}}{60 \text{ sec}} \times \frac{231 \text{ m}^3}{1 \text{ gal}} \times \frac{1 \text{ ft}^3}{1 \text{ m}^3} \]

\[ v = \frac{16.34 \text{ ft}^3}{2 \text{ sec}} \]

\[ h = \frac{1}{2} v^2 \]

\[ h = \frac{1}{2} (16.34 \text{ ft})^2 = 14.196 \text{ ft} \]

-4 used \( Q \) instead of \( v \)
-4 wrong \( v \)
-4 assumed initial pressure or velocity
-2 mismatched units
-4 metric \( \rho_g \) + units
-2 canceled \( gh \) = \( 2uv^2 \)

7. (14 pts) A 7000 Pa pressure difference causes 0.001 m³/sec of ketchup to flow through a 12 m long horizontal 0.04 m radius pipe. Determine the viscosity of the ketchup.

\[ Q = \frac{\pi r^4}{8 h} \]

\[ \eta = \frac{\pi r^4}{8 Q L} \]

\[ Q = \frac{\pi (0.04m)^4}{8 (2000 \text{ m}^3/\text{sec})(12m)} = 0.586 \text{ Pa} \cdot \text{s} \]

-4 reciprocal
-1 bad algebra
-2 forget \( \pi \)
-10 using \( F = \pi r A \)

8. (2 pts) A boat carrying a large chunk of steel is floating on a lake. The chunk is then thrown overboard and sinks. What happens to the water level in the lake (with respect to the shore)?

a. rises
b. drops
c. remains the same
d. depends on the size of the steel

all or nothing (2 pts)