PROBLEM 13.120

A 2500-lb automobile is moving at a speed of 60 mi/h when the brakes are fully applied, causing all four wheels to skid. Determine the time required to stop the automobile (a) on dry pavement ($\mu_k = 0.75$), (b) on an icy road ($\mu_k = 0.10$).

SOLUTION

\[ v_i = 60 \text{ mph} = 88 \text{ ft/s} \]

\[ mv_i - \mu_k Wt = 0 \]

\[ t = \frac{mv_i}{\mu_k W} = \frac{mv_i}{\mu_k mg} = \frac{v_i}{\mu_k g} \]

(a) For $\mu_k = 0.75$

\[ t = \frac{88 \text{ ft/s}}{(0.75)(32.2 \text{ ft/s}^2)} \]

\[ t = 3.64 \text{ s} \]

(b) For $\mu_k = 0.10$

\[ t = \frac{88 \text{ ft/s}}{(0.10)(32.2 \text{ ft/s}^2)} \]

\[ t = 27.3 \text{ s} \]
PROBLEM 13.121

A sailboat weighing 980 lb with its occupants is running down wind at 8 mi/h when its spinnaker is raised to increase its speed. Determine the net force provided by the spinnaker over the 10-s interval that it takes for the boat to reach a speed of 12 mi/h.

SOLUTION

\[
v_1 = 8 \text{ mi/h} = 11.73 \text{ ft/s} \quad t_{1-2} = 10 \text{ sec}
\]

\[
v_2 = 12 \text{ mi/h} = 17.60 \text{ ft/s}
\]

\[
mv_1 + m \cdot v_1 + \text{imp}_{1-2} = mv_2
\]

\[
m(11.73 \text{ ft/s}) + F_n (10 \text{ s}) = m(17.60 \text{ ft/s})
\]

\[
F_n = \frac{(980 \text{ lb})(17.60 \text{ ft/s} - 11.73 \text{ ft/s})}{(32.2 \text{ ft/s}^2)(10 \text{ s})}
\]

\[
F_n = 17.86 \text{ lb}
\]

Note: \( F_n \) is the net force provided by the sails. The force on the sails is actually greater and includes the force needed to overcome the water resistance on the hull.
PROBLEM 13.124

Steep safety ramps are built beside mountain highways to enable vehicles with defective brakes to stop. A 10-ton truck enters a $15^\circ$ ramp at a high speed $v_0 = 108$ ft/s and travels for 6 s before its speed is reduced to 36 ft/s. Assuming constant deceleration, determine (a) the magnitude of the braking force, (b) the additional time required for the truck to stop. Neglect air resistance and rolling resistance.

SOLUTION

\[ W = 20,000 \text{ lb} \]
\[ m = \frac{20,000}{32.2} = 621.118 \text{ lb} \cdot \text{s}^2 / \text{ft} \]

Momentum in the $x$ direction
\[ x: mv_0 - (F + mg \sin 15^\circ) t = mv_1 \]
\[ 621.118(108) - (F + 621.118 \cdot 36 \sin 15^\circ) 6 = (621.118)(36) \]
\[ F + 621.118 \sin 15^\circ = 7453.4 \]

(a) \[ F = 7453.4 - 20,000 \sin 15^\circ = 2277 \text{ lb} \]
\[ F = 2280 \text{ lb} \]

(b) \[ mv_0 - (F + mg \sin 15^\circ) t = 0 \quad t = \text{total time} \]
\[ 621.118(108) - 7453.4 t = 0; \quad t = 9.00 \text{ s} \]

Additional time = 9 – 6 \[ t = 3.00 \text{ s} \]
PROBLEM 13.129

A light train made of two cars travels at 45 mi/h. Car A weighs 18 tons, and car B weighs 13 tons. When the brakes are applied, a constant braking force of 4300 lb is applied to each car. Determine (a) the time required for the train to stop after the brakes are applied, (b) the force in the coupling between the cars while the train is slowing down.

SOLUTION

(a) Entire train:

\[ v_1 = 45 \text{ mi/h} = 66 \text{ ft/s} \]

\[ W_A + W_B = 18 + 13 = 31 \text{ tons} = 62,000 \text{ lb} \]

\[ \pm 0 = -(4300 + 4300)t_{1-2} + \frac{62,000}{g} \]

\[ t_{1-2} = \frac{(62,000 \text{ lb})(66 \text{ ft/s})}{(32.2 \text{ ft/s}^2)(8600 \text{ lb})} \]

\[ t_{1-2} = 14.78 \text{ s} \]

(b) Car A:

\[ W_A = 18 \text{ tons} = 36,000 \text{ lb}, \quad t_{1-2} = 14.78 \text{ s} \]

\[ \pm 0 - [(4300 \text{ lb}) + F_C][14.78 \text{ s}] = \frac{(36,000 \text{ lb})}{(32.2 \text{ ft/s}^2)}(66 \text{ ft/s}) \]

\[ F_C = 692.5 \text{ lb} \quad F_C = 693 \text{ lb (tension)} \]