STAEDTLER® No. 937 811E Engineer's Computation Pad

**•28** The high-speed winds around a tornado can drive projectiles into trees, building walls, and even metal traffic signs. In a laboratory simulation, a standard wood toothpick was shot by pneumatic gun into an oak branch. The toothpick's mass was 0.13 g, its speed before entering the branch was 220 m/s, and its penetration depth was 15 mm. If its speed was decreased at a uniform rate, what was the magnitude of the force of the branch on the toothpick?

$\vec{F}^{\text{net}}_{\text{on toothpick}} = m_{\text{toothpick}}\vec{a}_{\text{of toothpick}}$

$\vec{F}^{\text{net}}_{\text{pick}} = m_{\text{pick}}\vec{g} + \vec{F}_{\text{on pick, by tree}}$

$F^{\text{net}}_{\text{horizontal}} = m_p a_{\text{horizontal}} \Rightarrow F_{\text{pick, tree}} = m_p a_h$

$v_x^2 = v_{ox}^2 + 2a_x(x - x_o) \Rightarrow 0 = +v_{ox}^2 + 2a_x(x - x_o)$ when stopped by tree

$\Rightarrow a_x = -v_{ox}^2 / 2(x - x_o)$

$= -(200\ \text{m/s})^2 / 2(15 \times 10^{-3}\ \text{m})$

$= -1.3 \times 10^6\ \text{m/s}^2$

$\Rightarrow F_{\text{on pick by tree}} = m_p a_x = 0.13 \times 10^{-3}\ \text{kg}\left(-1.3 \times 10^6 \frac{\text{m}}{\text{s}^2}\right)$

$= F^{\text{net}}_{x,\text{pick}} = -170\ \text{N}$

Compare this to the y-Component of $\vec{F}^{\text{net}}_{\text{pick}}$

$= F^{\text{net}}_{y,\text{pick}} = -mg =$ weight of toothpick

$= -0.13 \times 10^{-3}\ \text{kg}\,(9.80\ \text{m/s}^2)$

$= -1.3 \times 10^{-3}\ \text{N}$

