



TP B.20

Peak forces during a break shot



supporting:
 “The Illustrated Principles of Pool and Billiards”
<http://billiards.colostate.edu>
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$m_b := 6 \cdot \text{oz}$	ball mass
$m_s := 19 \cdot \text{oz}$	typical cue mass
$m_{rack} := \frac{3}{2} \cdot m_b$	effective mass of a rack of balls from: http://billiards.colostate.edu/high_speed_videos/new/HSVB-45.htm
$v_b := 25 \cdot \text{mph}$	ball speed after impact (for a fast-speed break shot)
$\Delta t_{tip} := 0.0005 \cdot \text{s}$	typical tip-ball contact time (with a hard tip at fast speed) from: http://billiards.colostate.edu/threads/cue_tip.html#contact
$\Delta t_{ball} := 0.00025 \cdot \text{s}$	typical ball-ball contact time from: http://billiards.colostate.edu/threads/balls.html#contact

The momentum of the CB is created by the impulse between the tip and CB.
 Assuming a triangular and symmetric impulse-force profile (at peak force F_{peak}):

$$\frac{1}{2} \cdot F_{peak} \cdot \Delta t_{tip} = m_b \cdot v_b$$

So the peak force between the tip and CB is:

$$F_{peak} := \frac{2 \cdot m_b \cdot v_b}{\Delta t_{tip}} = 1709 \text{ lbf}$$

This corresponds to a peak acceleration (in units of g):

$$a_{peak} := \frac{F_{peak}}{m_b} = 4559 \text{ g}$$

When the CB hits the rack of balls and bounces back (with speed $v_{b'}$), both momentum and energy are conserved (assuming a perfect collision):

$$m_b \cdot v_b = m_{rack} \cdot v_{rack} - m_b \cdot v_{b'}$$

$$\frac{1}{2} \cdot m_b \cdot v_b^2 = \frac{1}{2} \cdot m_b \cdot v_{b'}^2 + \frac{1}{2} \cdot m_{rack} \cdot v_{rack}^2$$

Re-writing and solving these equations for $v_{b'}$ gives:

$$v_b = \frac{3}{2} \cdot v_{rack} - v_{b'}$$

$$v_b^2 = v_{b'}^2 + \frac{3}{2} \cdot v_{rack}^2$$

$$\left(v_b^2 = v_{b'}^2 + \frac{2}{3} \cdot (v_b + v_{b'})^2 \right) \xrightarrow{\text{solve, } v_{b'}} \begin{bmatrix} 5 \cdot mph \\ -25 \cdot mph \end{bmatrix}$$

$$v_{b'} := 5 \cdot mph$$

The impulse between the CB and the rack is equal to the change in momentum of the CB:

$$\frac{1}{2} \cdot F_{peak} \cdot \Delta t_{ball} = m_b \cdot (v_b + v_{b'})$$

So the peak force between the CB and rack is:

$$F_{peak} := \frac{2 \cdot m_b \cdot (v_b + v_{b'})}{\Delta t_{ball}} = 4103 \text{ lbf}$$

This corresponds to a peak acceleration (in units of g) of:

$$a_{peak} := \frac{F_{peak}}{m_b} = 10940 \text{ g}$$