# TP A.17
# The effect of the amount of friction on throw

supporting:
"The Illustrated Principles of Pool and Billiards"
**http://billiards.colostate.edu**

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**See TP A.14 for background information and fundamental results.**

Typical values for the parameters used in the equations:

| | | |
|---|---|---|
| $\mu := 0.06$ | average coefficient of friction between the balls | |
| $R := \frac{1.125 \cdot in}{m}$ | ball radius converted to meters | $R = 0.029$ |
| $v := \frac{3 \cdot mph}{\frac{m}{s}}$ | average cue ball speed converted to meters/sec | $v = 1.341$ |
| $\omega_{roll} := \frac{v}{R}$ | natural-roll spin rate | |

Relationship between friction and sliding contact speed (from TP A.14):

$$\mu(v_{rel}) := \left(0.009951 + 0.108 \cdot e^{-0.77 \cdot v_{rel}}\right)$$

Relative speed and throw equations from TP A.14:

$$v_{rel}(v, \omega_x, \omega_z, \phi) := \sqrt{\left(v \cdot \sin(\phi) - R \cdot \omega_z\right)^2 + \left(R \cdot \omega_x \cdot \cos(\phi)\right)^2}$$

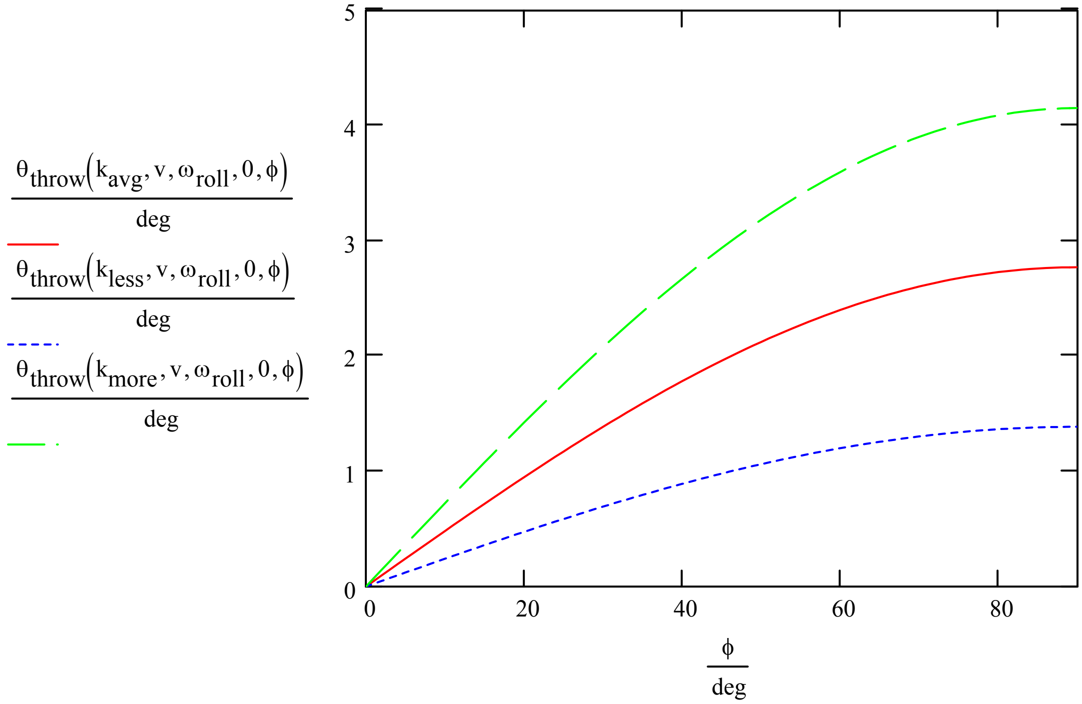
$$\theta_{throw}(k, v, \omega_x, \omega_z, \phi) := \operatorname{atan}\left[\frac{\min\left(\begin{array}{c}\dfrac{k \cdot \mu\left(v_{rel}(v, \omega_x, \omega_z, \phi)\right) \cdot v \cdot \cos(\phi)}{v_{rel}(v, \omega_x, \omega_z, \phi)} \\ \dfrac{1}{7}\end{array}\right) \cdot \left(v \cdot \sin(\phi) - R \cdot \omega_z\right)}{v \cdot \cos(\phi)}\right]$$

Note: A scale factor (k) is added to the friction term to see how changes in friction would affect results.

| | |
|---|---|
| $k_{less} := 0.5$ | for half the amount of typical friction |
| $k_{avg} := 1.0$ | for an average amount of friction |
| $k_{more} := 1.5$ | for 50% more than the typical amount of friction |

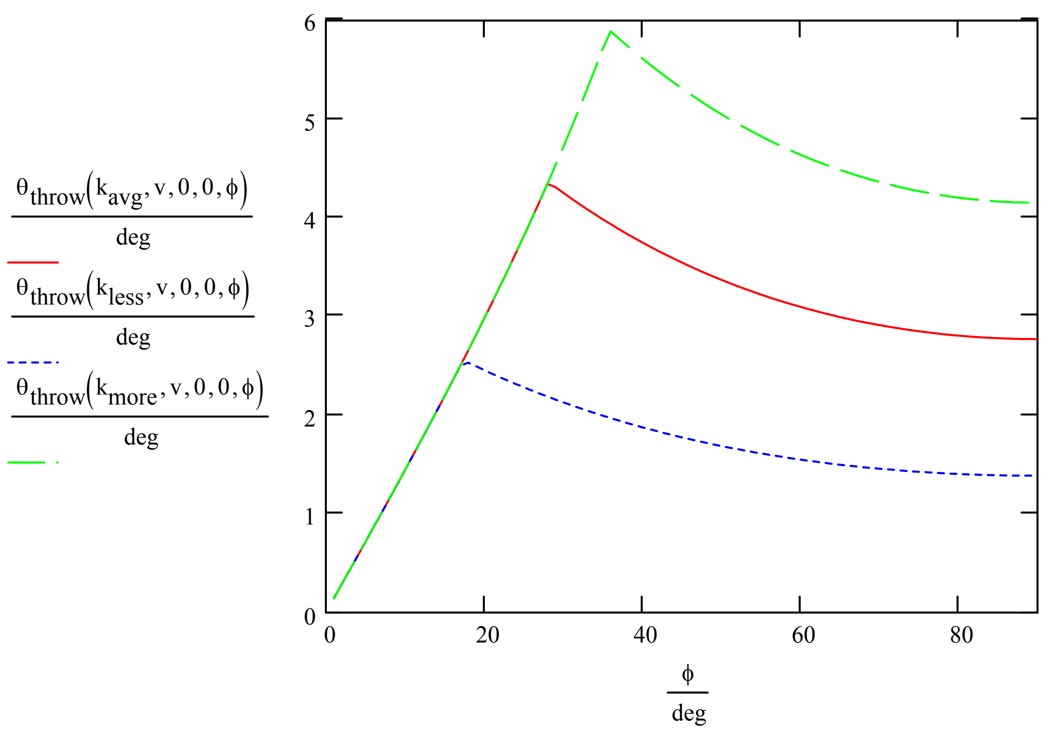
**collision-induced throw vs. cut angle for natural-roll shots with different amounts of friction:**

$$\phi := 0\cdot deg, 1\cdot deg .. 90\cdot deg$$




So, for natural roll shots, there is more collisions-induced throw when there is more friction. No surprise here.

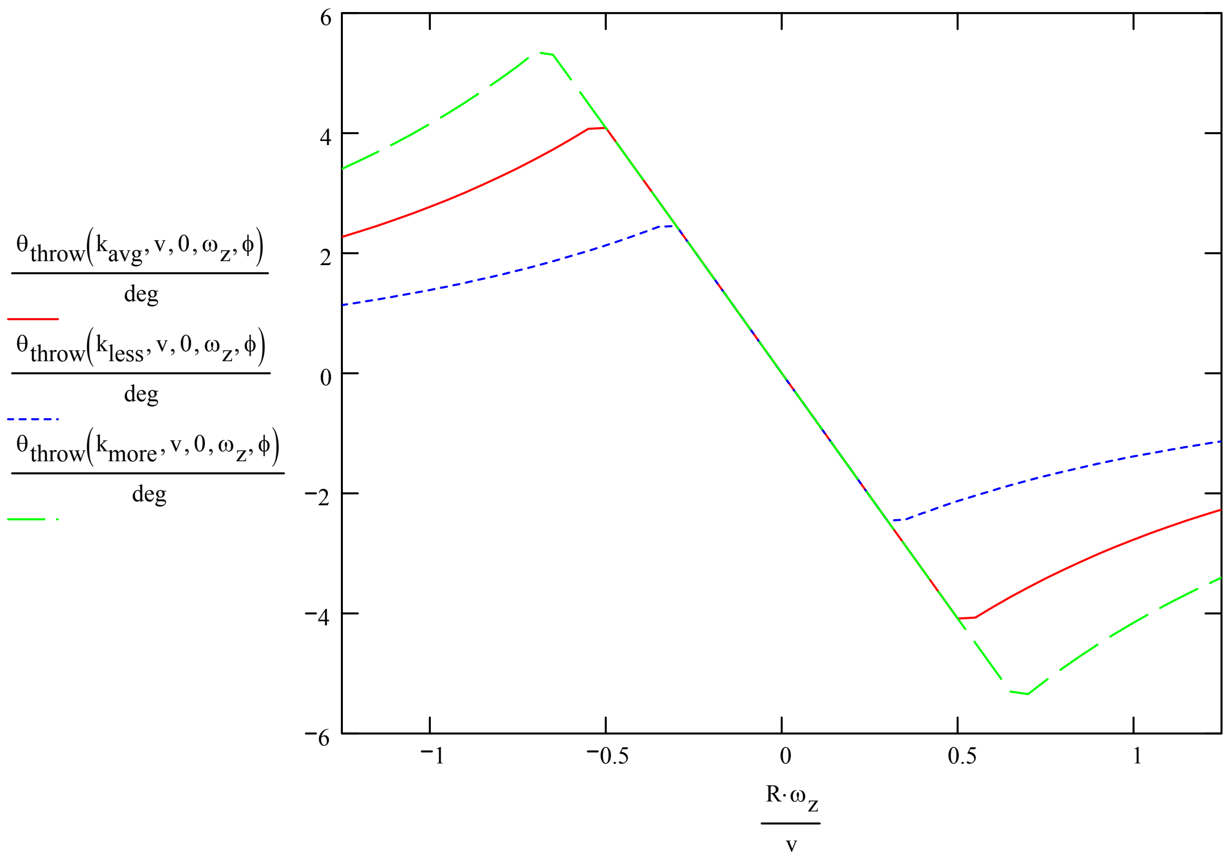
**collision-induced throw vs. cut angle for stun shots with different amounts of friction**




So for small cut angles, the amount of friction does not affect the amount of throw. However, there is more throw with more friction for larger cut angles.

**spin-induced throw vs. sidespin for straight-on stun shots with various amounts of friction**

$\phi := 0$ $\omega_z := -1.25\omega_{roll}, -1.2\cdot\omega_{roll} .. 1.25\omega_{roll}$ (see TP A.12)




So for small amounts of sidespin, the amount of friction does not affect the amount of spin-induced throw. However, with larger amounts of sidespin, there is more throw with more spin (up to a point) and with more friction.