The Fly Did Not Push It In

A Force-Budget Analysis of Tommy Fleetwood's Birdie at Caves Valley, 2025

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Abstract. The last round of the 2025 BMW Championship, played at Caves Valley Golf Club, saw Tommy Fleetwood make a 27-foot birdie putt on the par-4 second hole. The ball came to rest on the front lip of the cup, where it stayed for several seconds. A fly landed on the ball and walked across it. Then, after one second, the ball dropped into the cup. The putt was worth a birdie and approximately \$1.45M in FedEx Cup bonus money. In this paper, we perform a quantitative force-budget analysis based on verified parameters: a TaylorMade TP5x golf ball at the USGA mass ceiling of 45.93 g, a housefly at approximately 15 mg, a bentgrass green at Stimpmeter 12.5, a back-to-front slope of roughly 1.5°, and the weather of August 17, 2025. The slope-tangent force pulls the ball toward the cup with 11.8 mN, while 54.0 mN of static friction holds it, leaving a safety margin of 4.6 times. The fly's added weight is 0.147 mN, which is 0.033% of the ball's weight. A 5 mph wind applies eleven times more force on the ball than the fly does. The fly walking to the top of the ball shifts the center of mass of the system by 0.007 mm, or 0.27% of the 2.56 mm needed to tip the ball. The fly did not cause the ball to drop. The green did.

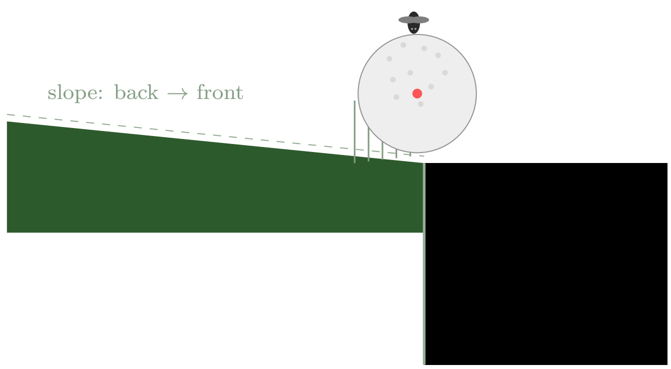

Figure 1: A side view of the metastable equilibrium at hole 2. The ball is resting on the front lip of the cup, with a fly on its upper hemisphere. The center of mass (red dot) of the system is located at a point within 0.007 mm from its position with the fly absent.

1 The Question

On Sunday, August 17, 2025, Tommy Fleetwood faced a 27-foot birdie putt on the par-4 second hole at Caves Valley Golf Club, Owings Mills, Maryland. He rolled it on line. The ball rolled down the slope and stopped at the front lip of the cup.

It did not drop.

For several seconds, the ball was perched on the front lip, partly on the green and partly over the hole. A fly landed on the ball and crawled around its upper surface. Roughly one second later, the ball dropped into the hole.

The clip went viral. The popular explanation, repeated by sports outlets and social media, was clear: the fly knocked the ball into the hole. CBS showed the video in slow motion. The stroke was worth a birdie and approximately $1.45M in FedEx Cup bonus money to Fleetwood. This paper provides the mechanics behind the phenomenon to show why the popular explanation is wrong and why the correct answer is far more interesting.

2 The Players

2.1 The Ball

Fleetwood uses the TaylorMade TP5x golf ball [1, 2]. The mass of a regulation golf ball cannot exceed 45.93 g, and the diameter must be no less than 42.67 mm, according to the USGA Equipment Rules [3]. Independent laboratory testing [4] shows TP5x masses clustering around the USGA mass ceiling, consistent with the engineering practice of maximizing the momentum retention by making Tour balls as heavy as the rules allow. We adopt $m_{\text{ball}} = 45.93e{-}3\,\text{kg}$ and $r_{\text{ball}} = 21.34e{-}3\,\text{m}$ as the characteristic values.

2.2 The Bug

All broadcast footage identified the insect as a fly. Broadcast resolution prevents species-level identification, so we use the following range of estimates: a biting midge at the low end (approximately 1 mg), a housefly (*Musca domestica*) as a central estimate (approximately 15 mg), and a small blowfly at the high end (approximately 30 mg). All the calculations below use $m_{\text{fly}} = 15e - 6\,\text{kg}$. The result is unaffected across the whole range. The ball-to-fly mass ratio is then:

$$\frac{m_{\text{ball}}}{m_{\text{fly}}} = \frac{45.93 \times 10^{-3}}{15 \times 10^{-6}} \approx 3{,}062. \tag{1}$$

For visualization: scaling the fly up to the mass of a Labrador retriever (approximately 30 kg) brings the ball's mass to approximately 92,000 kg, or fifteen adult African elephants.

2.3 The Course and the Green

Caves Valley Golf Club underwent a hundred-day renovation [5] in preparation for the 2025 BMW Championship. Hole 2 plays as a par-4 of approximately 525 yards for the championship, with a 200-yard uphill approach shot to an elevated green sloping back-to-front and left-to-right [6, 7]. The green consists of heat-resistant bentgrass chosen during the renovation. Greens ran at a Stimpmeter reading of 12.5 [8], the same as in 2021. The Stimpmeter measures rolling friction by releasing a ball at a known velocity (approximately 1.83 m/s) and measuring the distance it travels on a level surface; the coefficient of rolling friction comes out to:

$$\mu_r = \frac{v_0^2}{2g\,d} = \frac{(1.83)^2}{2 \cdot 9.81 \cdot 3.81} \approx 0.045. \tag{2}$$

This is rolling friction. The ball at rest on the lip is held by static friction, which is larger on a short-mowed bentgrass canopy. We adopt $\mu_s \approx 0.12$ as the conservative central estimate.

2.4 The Weather

The high and low temperatures recorded at BWI airport on August 17, 2025, were 86 °F and 75 °F, respectively, with light southwesterly winds [9]. At the time of Fleetwood's putt (early afternoon of the last round), we adopt $T = 26.7\,°\text{C}$, RH = 70%, and a surface wind of 2.24 m/s (5 mph). Moist-air density at 500 ft of elevation, accounting for the partial pressure of water vapor, is approximately $1.145\,\text{kg/m}^3$, slightly lower than the standard dry-air value of $1.225\,\text{kg/m}^3$.

3 The Force Budget on the Lip

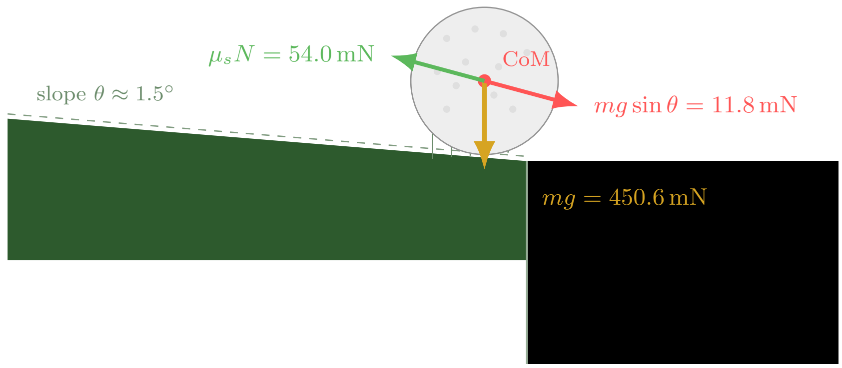

Figure 2: Force diagram of the ball at rest on the lip, all vectors emanating from the center of mass. Gravity acts vertically; its component tangent to the slope drives the ball toward the hole; static friction with the grass canopy opposes the slope force. Slope angle exaggerated for clarity.

3.1 Gravity, slope, and friction

The gravitational force on the ball is $F_g = m_{\text{ball}} \cdot g = 450.57\,\text{mN}$. Its tangential component along a 1.5° slope in the direction of the hole is:

$$F_{\text{slope}} = m_{\text{ball}} \cdot g \cdot \sin\theta \approx 11.8\,\text{mN}. \tag{3}$$

The slope is actually doing some work to pull the ball into the hole, even at rest. Maximum static friction available from the grass canopy is:

$$F_{\text{fric}}^{\text{max}} = \mu_s \cdot m_{\text{ball}} \cdot g \cdot \cos\theta \approx 54.0\,\text{mN}. \tag{4}$$

The friction margin is $F_{\text{fric}}^{\text{max}} / F_{\text{slope}} \approx 4.6$. The ball is held, but by a small margin.

3.2 Fly

We consider three modes of action by the fly: the added weight, the impact of landing, and the tangential force generated by crawling.

Added weight. While on the ball, the fly contributes its own weight:

$$W_{\text{fly}} = m_{\text{fly}} \cdot g \approx 0.147\,\text{mN}, \tag{5}$$

which is 0.033% of the ball's weight. If the fly crawls to the top of the ball, the center of mass of the system shifts by:

$$\Delta x_{\text{CoM}} = \frac{m_{\text{fly}}}{m_{\text{ball}} + m_{\text{fly}}} \cdot r_{\text{ball}} \approx 0.007\,\text{mm}. \tag{6}$$

The shift necessary to tip the ball is approximately $\Delta x_{\text{crit}} = \mu_s \cdot r_{\text{ball}} \approx 2.56\,\text{mm}$. Walking to the top of the ball brings the fly's contribution to 0.27% of the center-of-mass shift required to tip the system. This is the central quantitative claim of this paper.

Landing impact. Houseflies cruise at approximately $2\,\text{m/s}$. Deceleration over the impact timescale of $10\,\text{ms}$ yields an average force of:

$$F_{\text{land}} = \frac{m_{\text{fly}} \cdot v_{\text{fly}}}{\Delta t} \approx 3.0\,\text{mN}, \tag{7}$$

which is 0.67% of the ball's weight. Roughly perpendicular to the ball surface, this is the largest single contribution from the fly, and is still small compared to other ambient forces.

Tangential drag. A housefly pulls tangentially with half its weight, which translates to $F_{\text{crawl}} \approx 0.07\,\text{mN}$. Negligible compared to anything else in the budget.

3.3 Wind, for comparison

Drag force on a sphere of radius r moving at relative velocity v through air of density ρ is $F_d = \frac{1}{2}\rho v^2 C_d A$, with $C_d \approx 0.4$ for a sphere at the relevant Reynolds number and $A = \pi r^2$. For a steady 5 mph wind:

$$F_{\text{wind}} = \tfrac{1}{2}(1.145)(2.24)^2(0.4)\pi(21.34 \times 10^{-3})^2 \approx 1.64\,\text{mN}, \tag{8}$$

which is eleven times stronger than the fly's steady force.

3.4 Summary, drawn to scale

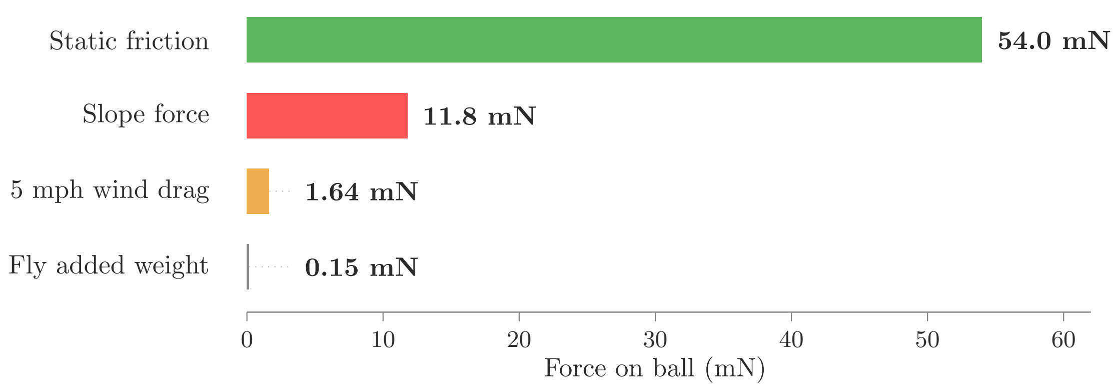

Figure 3: The total force budget, to scale. Green keeps the ball in place. Red is trying to move it. Orange is the wind. Grey is the fly. The fly force is dwarfed by the wind, which is dwarfed by the slope, which is kept under control by friction with a 4.6 margin.

4 Metastable Equilibrium

The ball is held in place, but with a thin margin. This is the hallmark of a metastable system: stable against small perturbations only as long as the holding forces remain what they are now. Three slowly changing processes reduce the holding forces.

Grass-blade creep. Bentgrass maintained at the tournament height (approximately 2.5 mm) supports the ball weight through elastic deformation of a few blades. Under a sustained load, these blades exhibit viscoelastic creep. The ball sinks into the canopy for approximately 10 to 15 seconds, redistributing the load and decreasing the effective contact area with the lip edge. The effective static friction coefficient is not constant: it decreases over time.

Wind variability. "Light" summer winds are 3 m/s to 4.5 m/s gusts above the base wind of 2 m/s. Drag force scales as v^2, so doubling the wind speed to 4.5 m/s (approximately 10 mph) results in 6.6 mN, or more than half of the slope-tangent force.

Moisture variations. The ball at rest on the canopy is held in place, in part, by surface tension between the grass blades due to capillary effects. The canopy's surface moisture content varies throughout the day, affecting the surface-tension contribution to the holding force.

None of these processes is large in itself, but they are large in the sense that they erode the margin holding the ball. The ball is, in essence, in a slow race against the friction reserve.

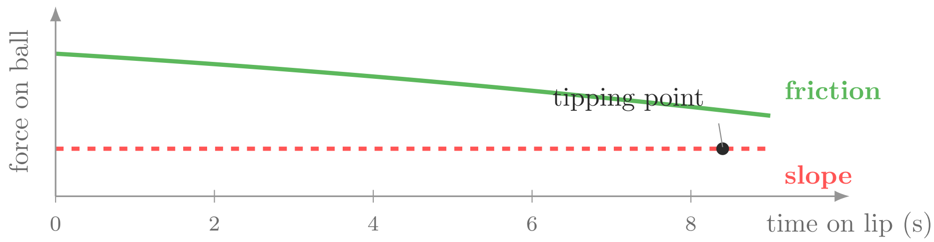

Figure 4: Schematic of friction decay. Slope force (red, dashed line) remains constant. Holding friction (green) decreases with time as grass blades creep and surface moisture varies. The ball tips when the frictional force holding it reaches the slope force. The tipping point is set by the slowly varying factors, not whatever perturbation happens to be around at the time.

5 The Verdict

The popular interpretation that "the fly knocked the ball in" is mechanically false. With a mass ratio of 3,062 to 1, the fly could not possibly apply a large enough force to move the ball against friction. The steady force of a 5 mph wind on the ball is eleven times larger than the fly force. Slope-tangent force is eighty times larger than the fly force, and the ball feels it every second until the tipping point. The cumulative impulse imparted to the ball by the fly over its one-second walk is 0.013% of the impulse applied by the slope over the same interval.

The right interpretation is that the ball was losing the battle with gravity. Slope force is pushing the ball into the hole. Static friction is holding the ball against the component of the gravitational force parallel to the slope, but only by a small margin. The ball will eventually tip over, and likely within the ten-second window provided for such events by the rules. The fly happened to be on the ball at the moment friction lost.

The fly did not push the ball in. The green did.

The Rules of Golf define the overhanging ball in Rule 13.3a [10]: if any part of a ball hangs over the lip of a hole, the player is granted a reasonable time to reach the hole and an additional ten seconds for the ball to drop on its own. Balls hanging over the lip and dropping some time afterward happen frequently enough in elite golf to warrant such a rule. The existence of the rule itself proves our case: if balls over the lip never fell on their own, there would be no need for ten seconds of grace.

Appendix: Numerical Summary

Quantity	Symbol	Value
Ball mass (TP5x, USGA ceiling)	m_{ball}	45.93 g
Ball radius	r_{ball}	21.34 mm
Fly mass (housefly, central)	m_{fly}	15 mg
Ball:fly mass ratio		3,062 : 1
Slope angle, hole 2	θ	1.5°
Stimpmeter	d	12.5 ft
Rolling friction coefficient	μ_r	0.045
Static friction coefficient	μ_s	0.12
Air density (moist, 500 ft elev)	ρ_{air}	1.145 kg/m^3
Ball weight	F_g	450.6 mN
Slope tangent force	F_{slope}	11.8 mN
Max static friction	$F_{\text{fric}}^{\text{max}}$	54.0 mN
Safety margin		$\approx 4.6\times$
Fly added weight	W_{fly}	0.147 mN
Fly landing impact	F_{land}	3.0 mN (momentary)
5 mph wind drag	F_{wind}	1.64 mN
10 mph gust drag		6.6 mN
CoM shift critical to tip	Δx_{crit}	2.56 mm
CoM shift from fly at top	Δx_{CoM}	0.007 mm

Reproducibility: all numbers presented here can be reproduced from the input constants by a short Python script attached to this paper.

References

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[3] United States Golf Association. *Equipment Rules*, 2023 edition.

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