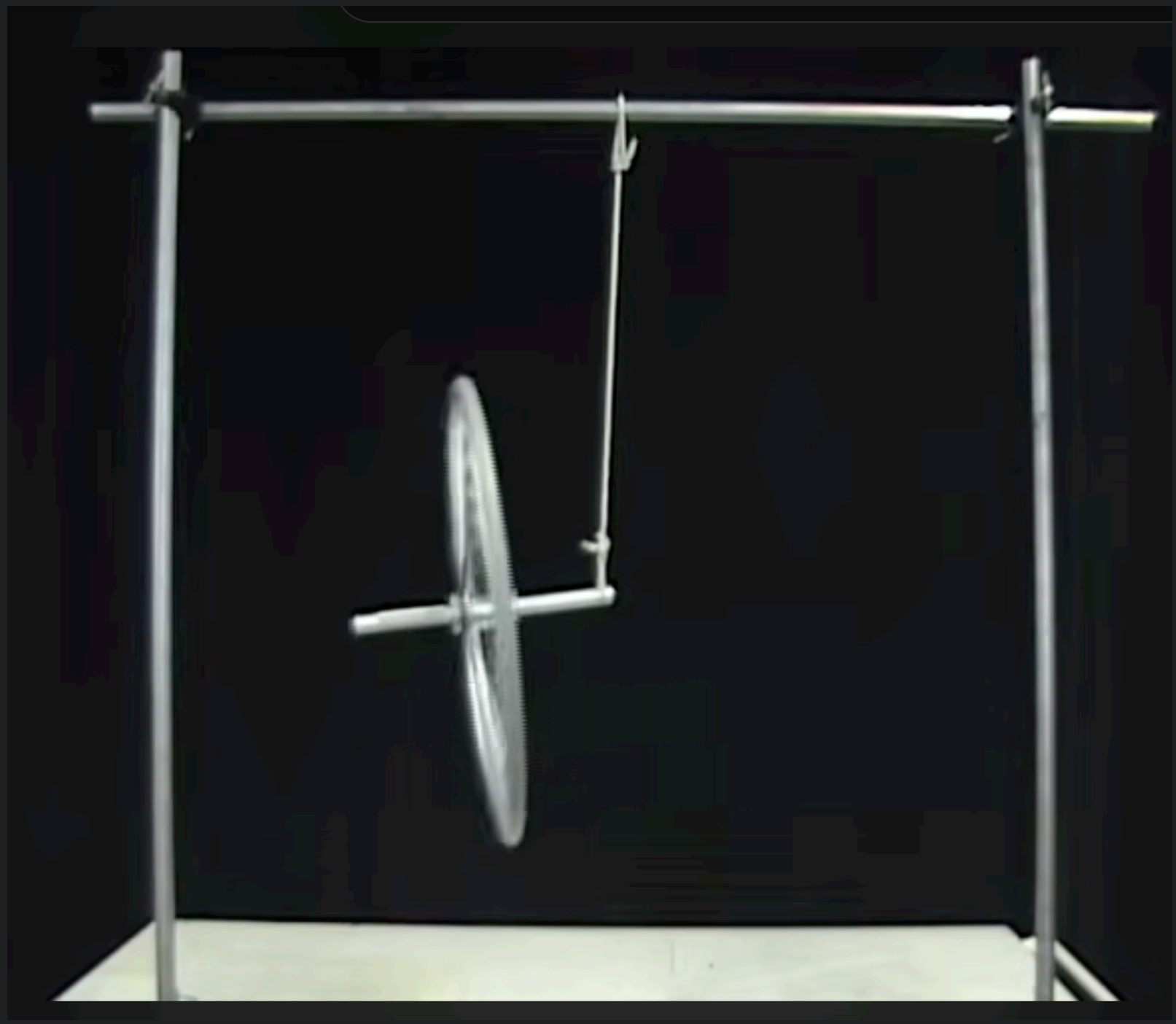
wheel flop

a mechanics lab at your door step

“He’s no fun, he fell right over.”
—The Firesign Theatre

Nick Tufillaro AAPT Corvallis, OR 2026-10-17

some surpising (dynamic) bicycle demonstrations



another dynamic suprising effect - stablity

stabilizing an unstable pendulum



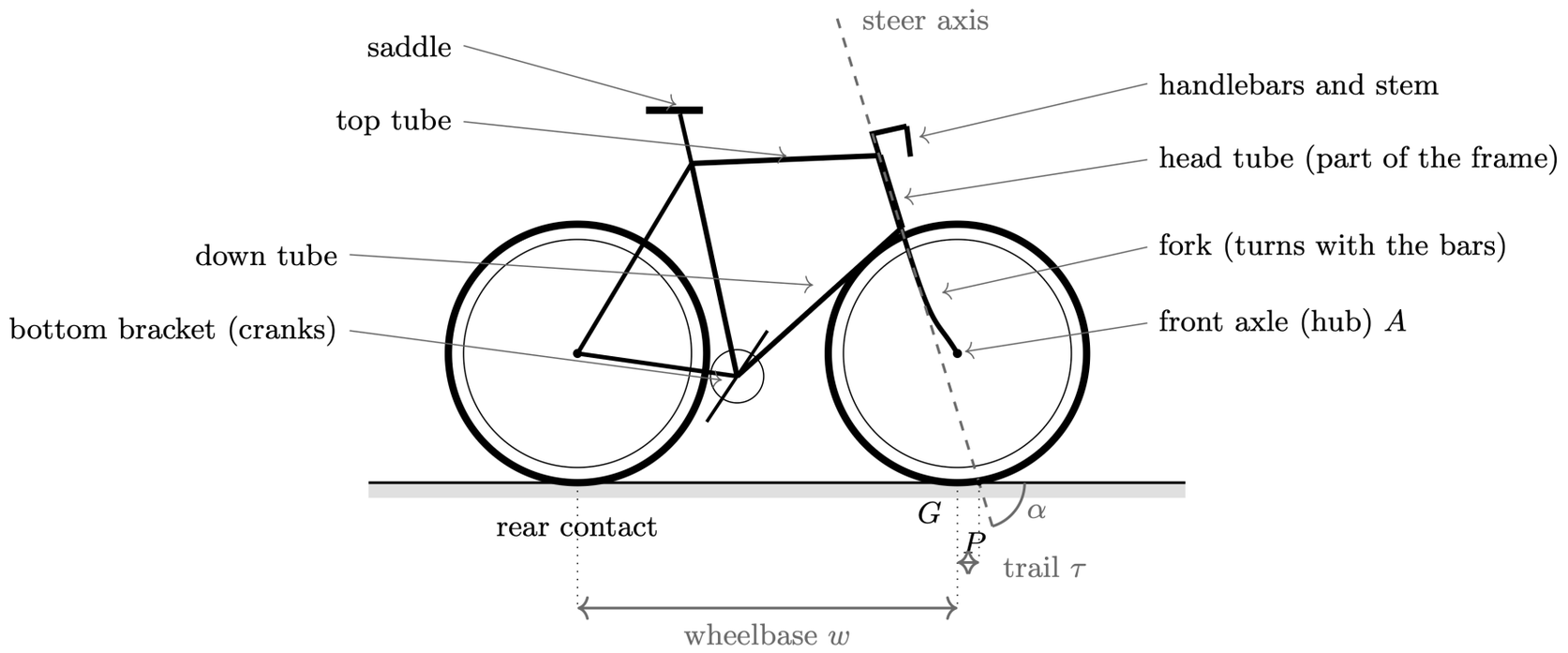
is there a static ‘kinematic’ surprise?

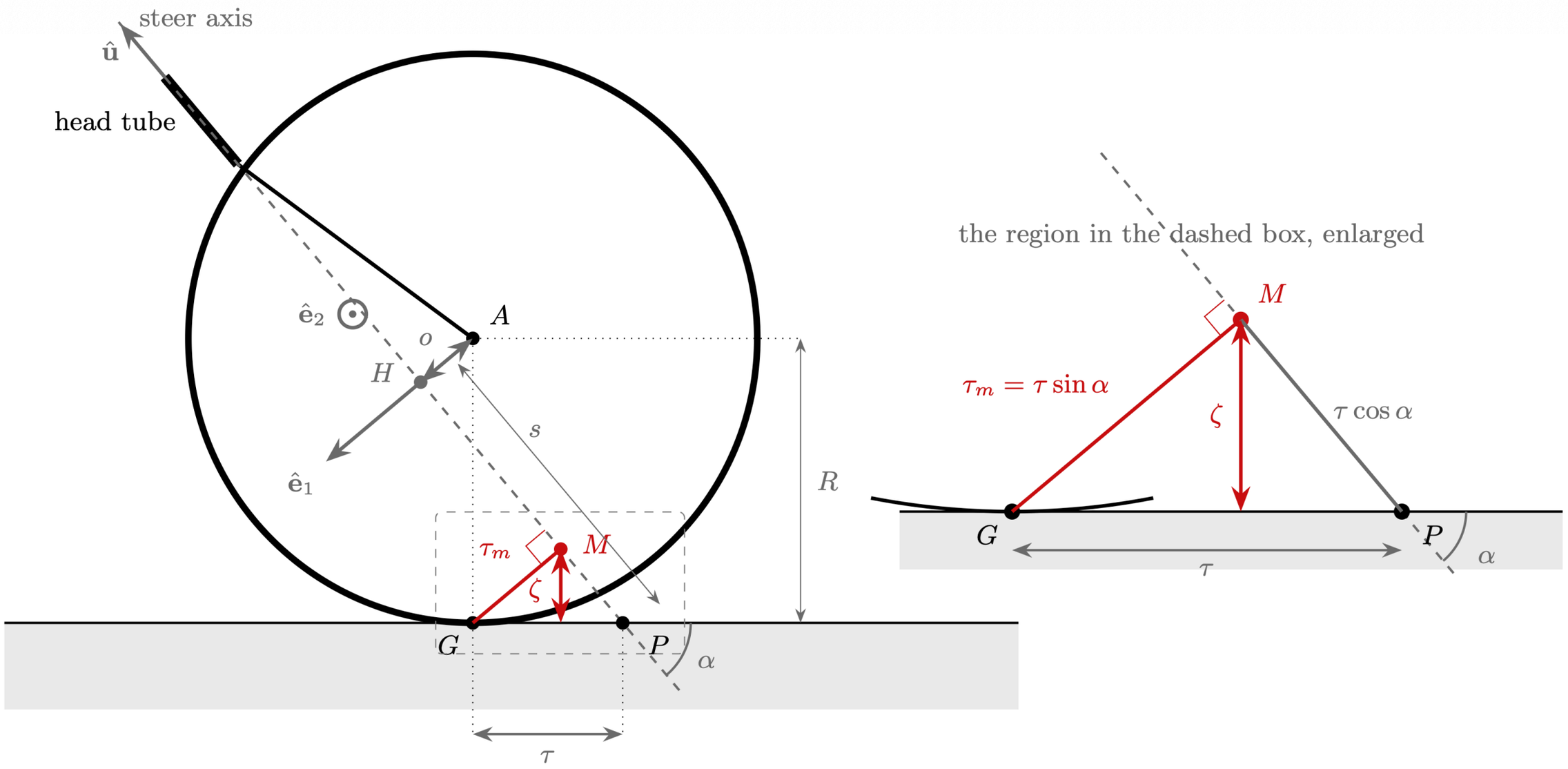
is there a static ‘kinematic’ surprise?

Question: What happens if i hold the bike upright and turn the steering column away from forward.

is there a static ‘kinematic’ surprise?

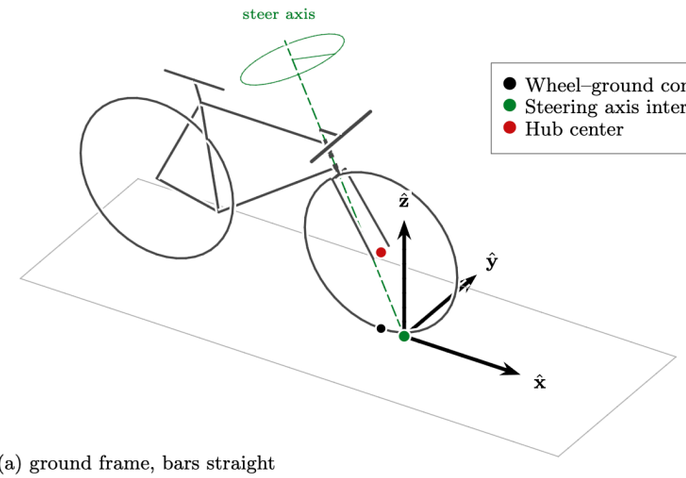
wheel flop


steer axis
saddle
top tube
down tube
bottom bracket (cranks)
handlebars and stem
head tube (part of the frame)
fork (turns with the bars)
front axle (hub) A
rear contact
G
P
α
trail τ
wheelbase w

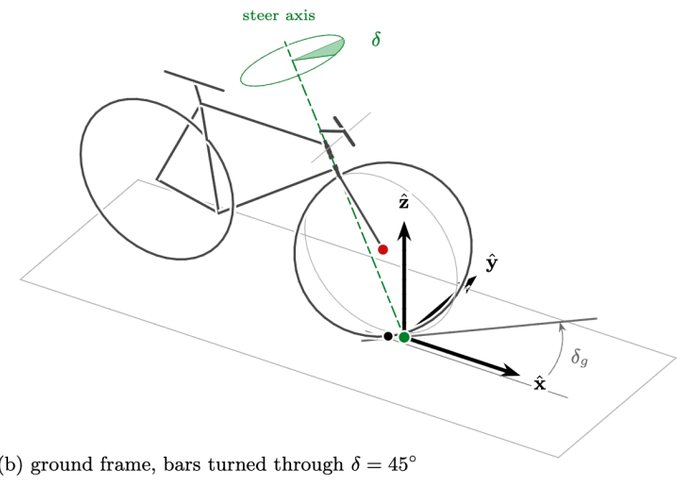

steer axis
$\hat{\mathbf{u}}$
head tube
$\hat{\mathbf{e}}_2$
A
o
H
$\hat{\mathbf{e}}_1$
s
R
τ_m
M
ζ
G
P
α
τ
the region in the dashed box, enlarged
M
$\tau_m = \tau \sin\alpha$
ζ
$\tau \cos\alpha$
G
P
τ
α

a useful exercise in frames of reference transformations

ground frame

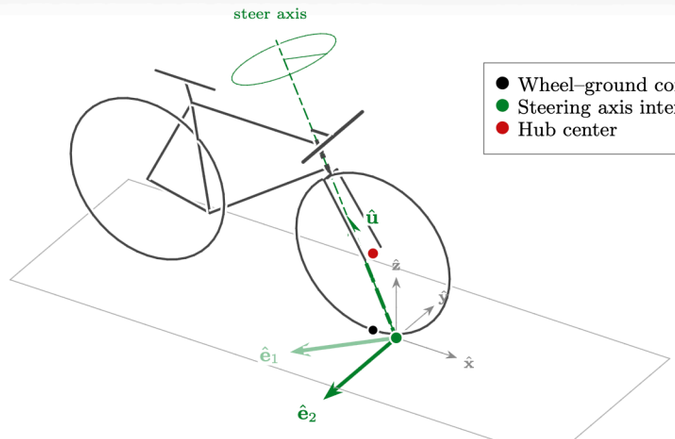


(a) ground frame, bars straight

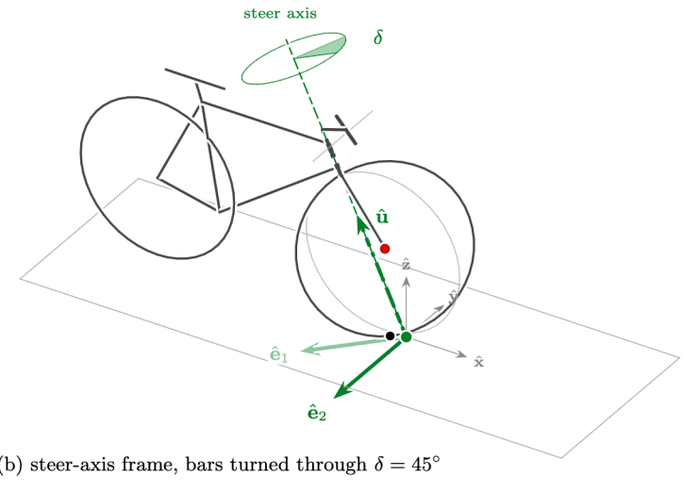


(b) ground frame, bars turned through $\delta = 45°$

steer-axis frame

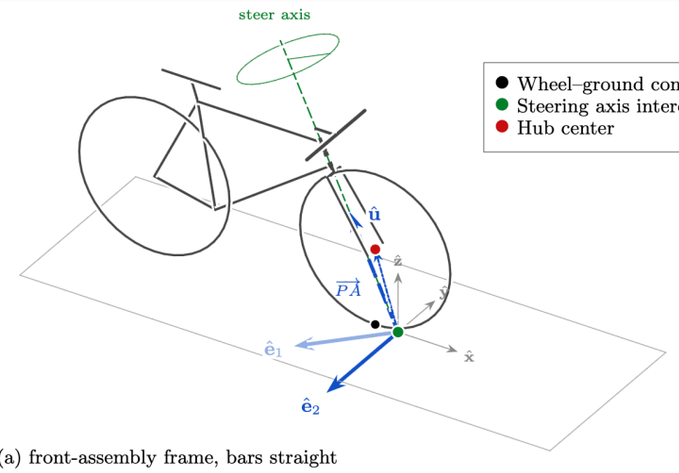


(a) steer-axis frame, bars straight

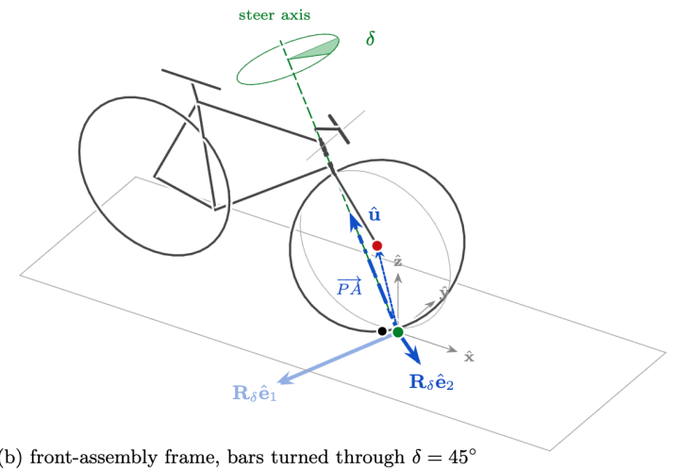


(b) steer-axis frame, bars turned through $\delta = 45°$

front-assembly frame



(a) front-assembly frame, bars straight



(b) front-assembly frame, bars turned through $\delta = 45°$

$$\mathbf{R}_\delta\,\mathbf{r} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\delta & -\sin\delta \\ 0 & \sin\delta & \cos\delta \end{pmatrix} \begin{pmatrix} r_\parallel \\ r_1 \\ r_2 \end{pmatrix}$$

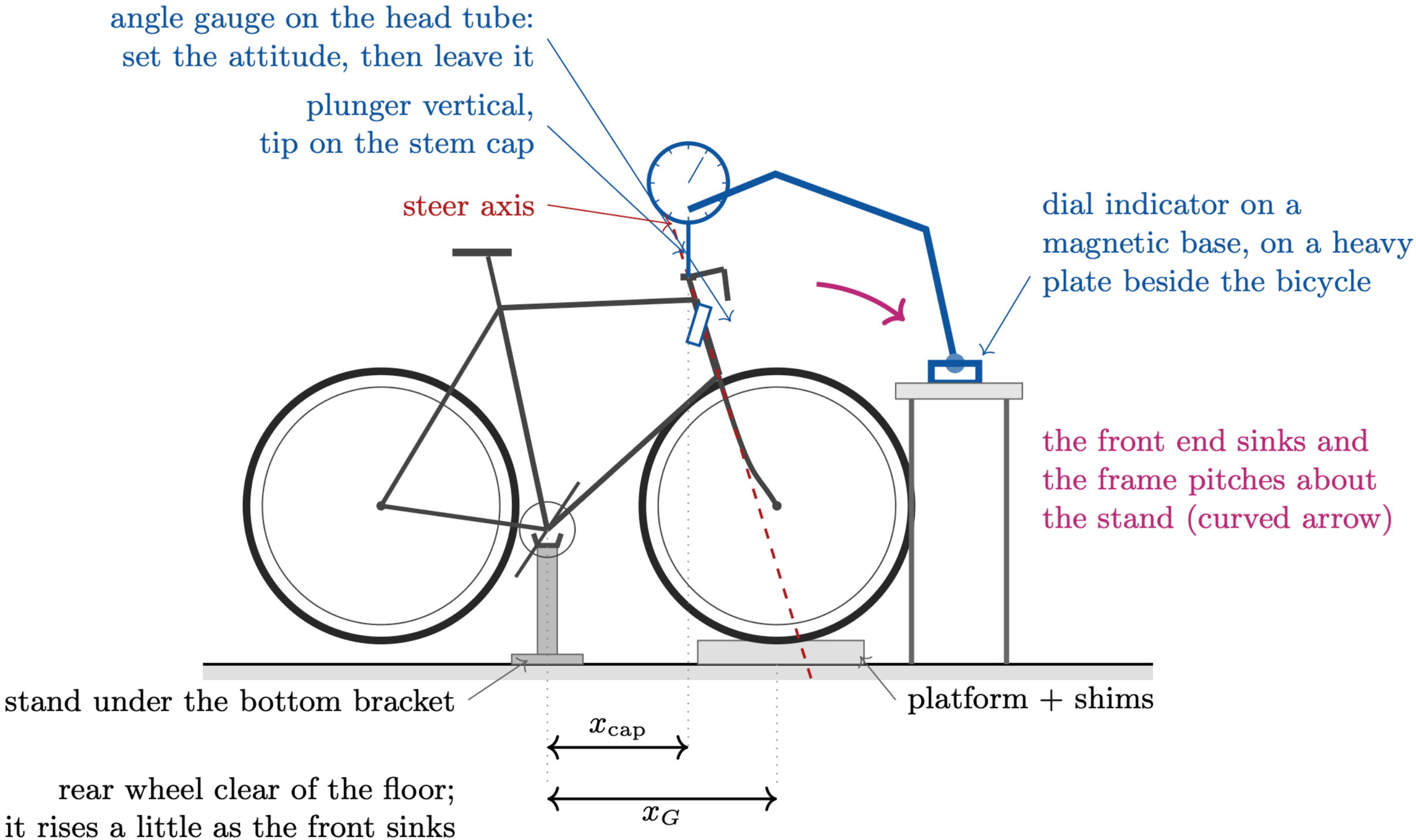
$$\boxed{\left[(\mathbf{R}_\delta - \mathbf{I})\,\mathbf{r}\right] \cdot \hat{\mathbf{z}} = -\cos\alpha\left[(\cos\delta - 1)\,r_1 - \sin\delta\, r_2\right].}$$

Flop Factor — how much the front of the frame drops

$$\zeta \equiv \tau \sin\alpha \cos\alpha = \tau_m \cos\alpha = \cos\alpha\,(R\cos\alpha - o),$$

$$\text{drop is } \zeta(1-\cos\delta)$$

Symbol	Name, where defined	Significance
α	head angle, Fig. 2	the tilt of the steer axis from the ground; the most sensitive input, since ζ changes by 13–16% per degree
o	fork offset, Fig. 3	how far the axle sits ahead of the steer axis; the designer's second free choice
τ	ground trail, Eq. (8)	GP along the ground; the number on a geometry chart
τ_m	mechanical trail, Eq. (9)	MG, the lever arm by which the ground acts on the steering
ζ, ζ_{eff}	flop factor, Eqs. (15), (24)	the height of M; the curvature of the drop at $\delta = 0$; with the tire, $\cos\alpha[(R-\rho)\cos\alpha - o]$
δ	steer angle, Sec. 3	how far the bars have been turned; positive to the left


angle gauge on the head tube:
set the attitude, then leave it
plunger vertical,
tip on the stem cap
steer axis
dial indicator on a
magnetic base, on a heavy
plate beside the bicycle
the front end sinks and
the frame pitches about
the stand (curved arrow)
stand under the bottom bracket
platform + shims
x_{cap}
rear wheel clear of the floor;
it rises a little as the front sinks
x_G

There is a maximum drop at about 60 deg: δ_*

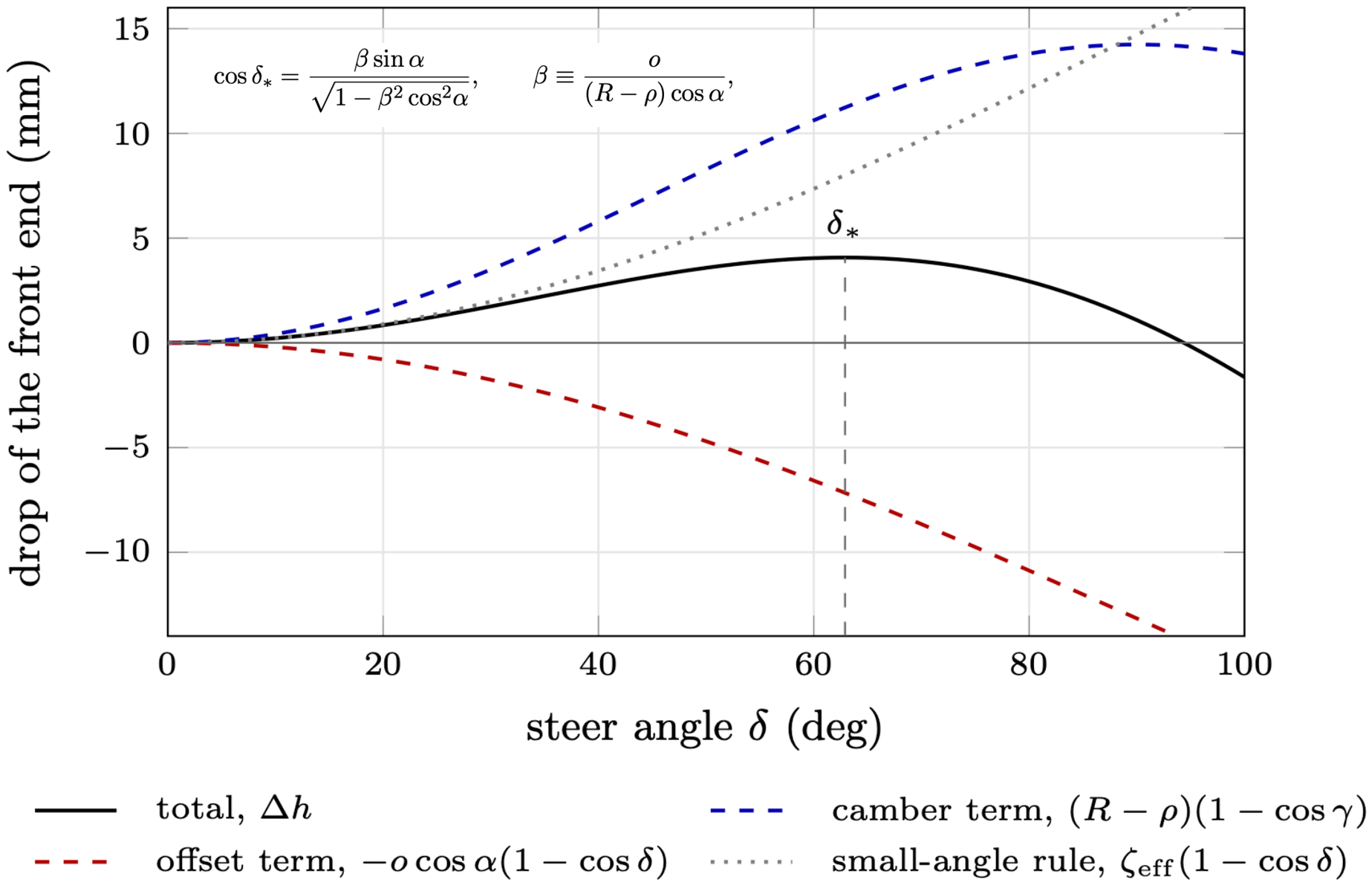


Figure 11: The drop of the front end, Eq. (22) with the tire correction of Sec. 5, for the road geometry of Table 2, together with its two terms and the small-angle rule. The camber term drops the frame and the offset term lifts it; their sum is largest at the flop angle $\delta_* = 63°$ and falls thereafter, while the rule keeps climbing.

Drop Exact in terms of Measurable Bike Geometry Parmaters

$$\Delta h(\delta) = R\,(1 - \cos\gamma) - o\cos\alpha\,(1 - \cos\delta), \qquad \sin\gamma = \cos\alpha\,\sin\delta.$$

Drop Approximate - Frame Builders Rule

For small angles $1 - \cos\gamma \simeq \frac{1}{2}\cos^2\alpha\,\delta^2$, and Eq. (22) reduces to

$$\Delta h \simeq \zeta\,(1 - \cos\delta) \simeq \tfrac{1}{2}\,\zeta\,\delta^2, \qquad \zeta = \cos\alpha\,(R\cos\alpha - o),$$

drop = flop factor * steer_angle^2

Experiment:

Measure Geometric Parameters Once: alpha, R, o

Vary Steer Angle: delta

Measure change in drop: h(delta)

why is this ‘flop factor’ important ....

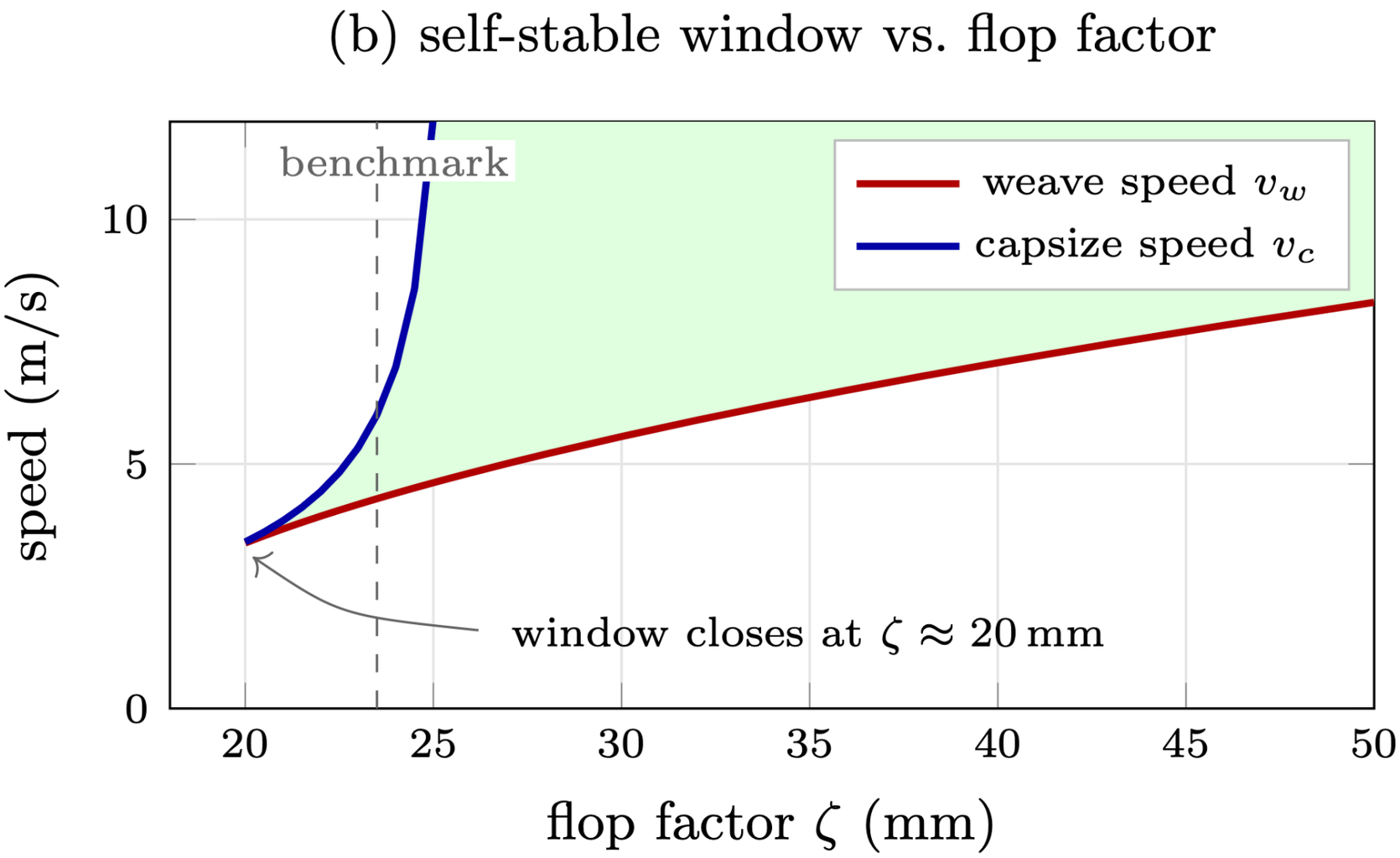


Figure 14: (a) The four eigenvalues of Eq. (28) for the benchmark bicycle [8] as functions of speed: real parts in black, one curve per eigenvalue, and the imaginary part of the complex (weave) pair in blue. The self-stable band, where all four real parts are negative, is shaded. (b) Weave and capsize speeds when the flop contribution to S_A of Eq. (31) is varied with every other parameter held fixed. Below $\zeta \approx 20\,\mathrm{mm}$ the two curves meet and the self-stable window vanishes. The capsize curve leaves the plot near $\zeta \approx 25\,\mathrm{mm}$; beyond $\zeta \approx 25.5\,\mathrm{mm}$ no capsize instability was found at any speed up to $30\,\mathrm{m/s}$, so the self-stable band is open above.

Preliminary Draft of Lab Packet

http://www.aquahue.net/aquahue/flop/flop_lab.zip

Draft of Paper in Development

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