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15. Rebounding capsule

Patrik Penc
Budapest University Of Technology and Economics

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The Problem

A **spherical ball** dropped onto a hard surface **will never rebound to the release height**, even if it has an **initial spin**. A **capsule-shaped object** (i.e. Tic Tac mint) on the other hand may **exceed the initial height**. Investigate this phenomenon.

Qualitative explanation – Ball

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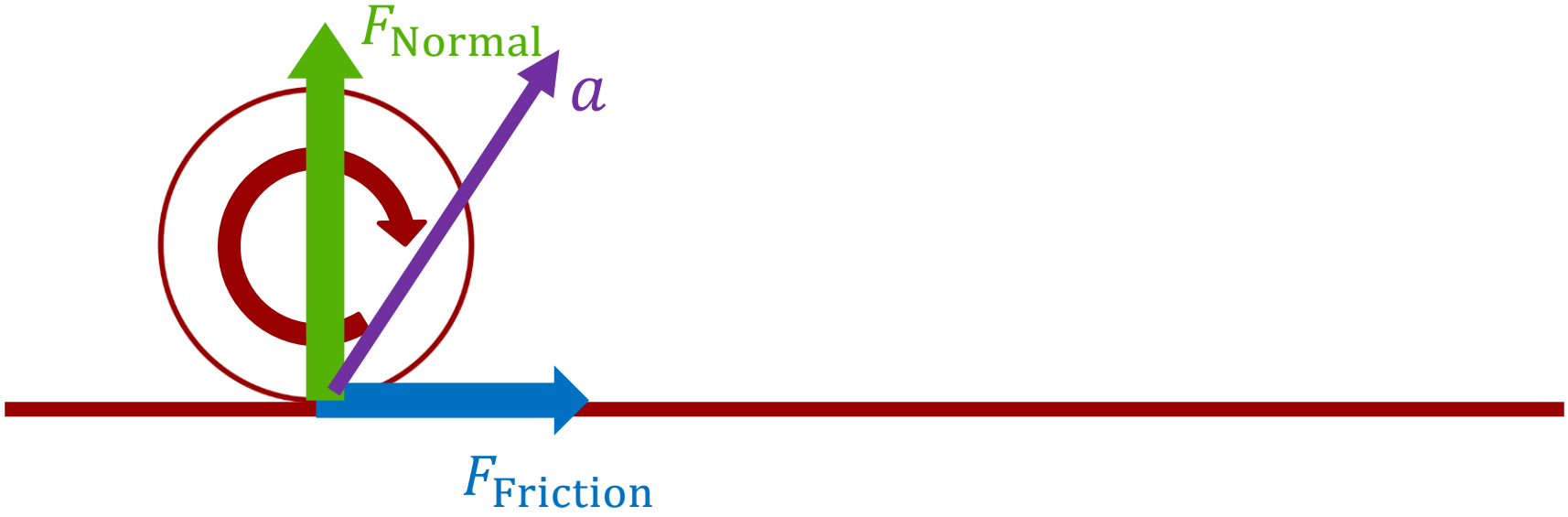
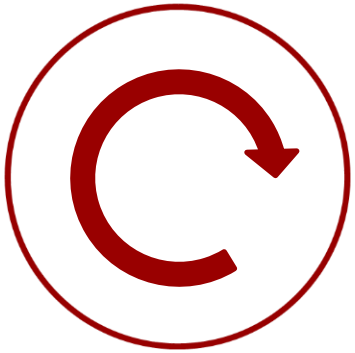
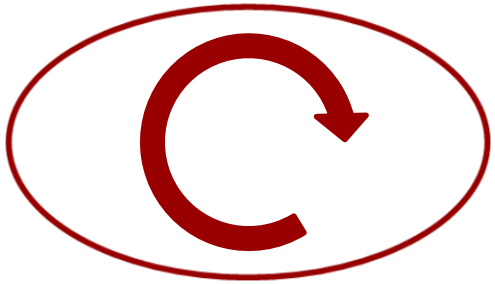


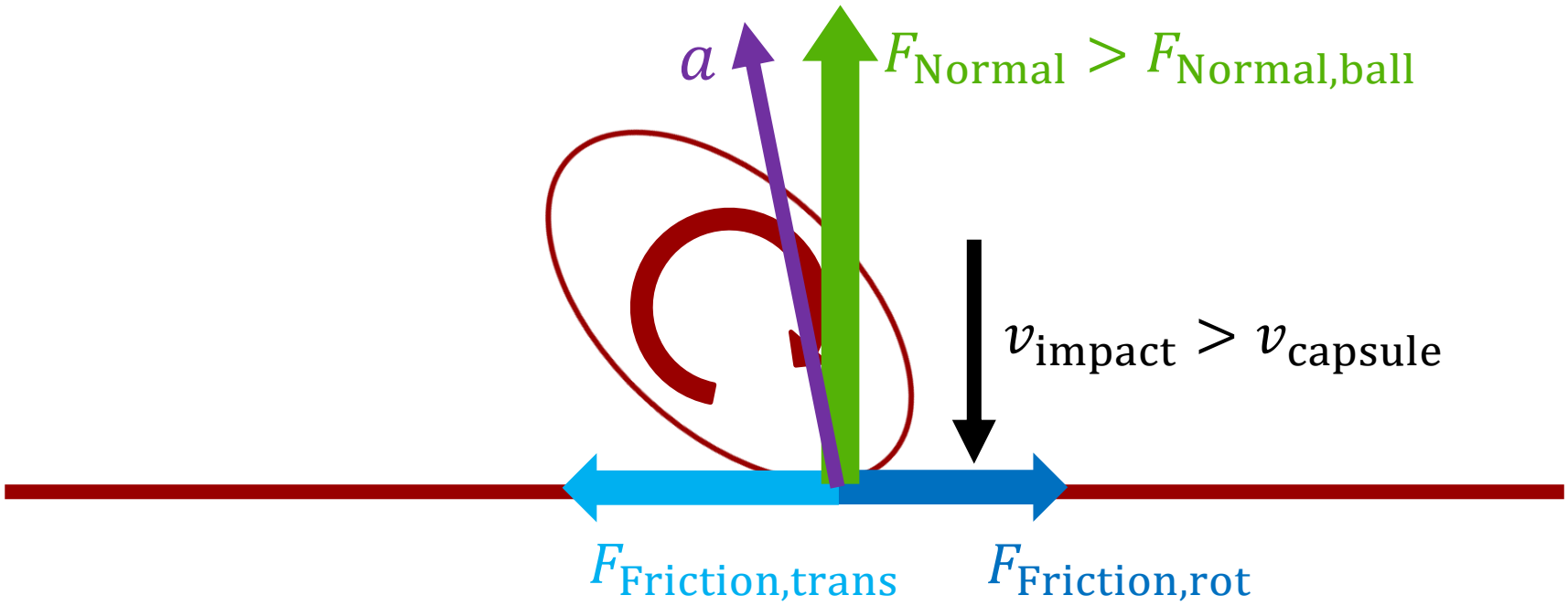
Qualitative explanation – Ball



Qualitative explanation – Capsule



Qualitative explanation – Capsule



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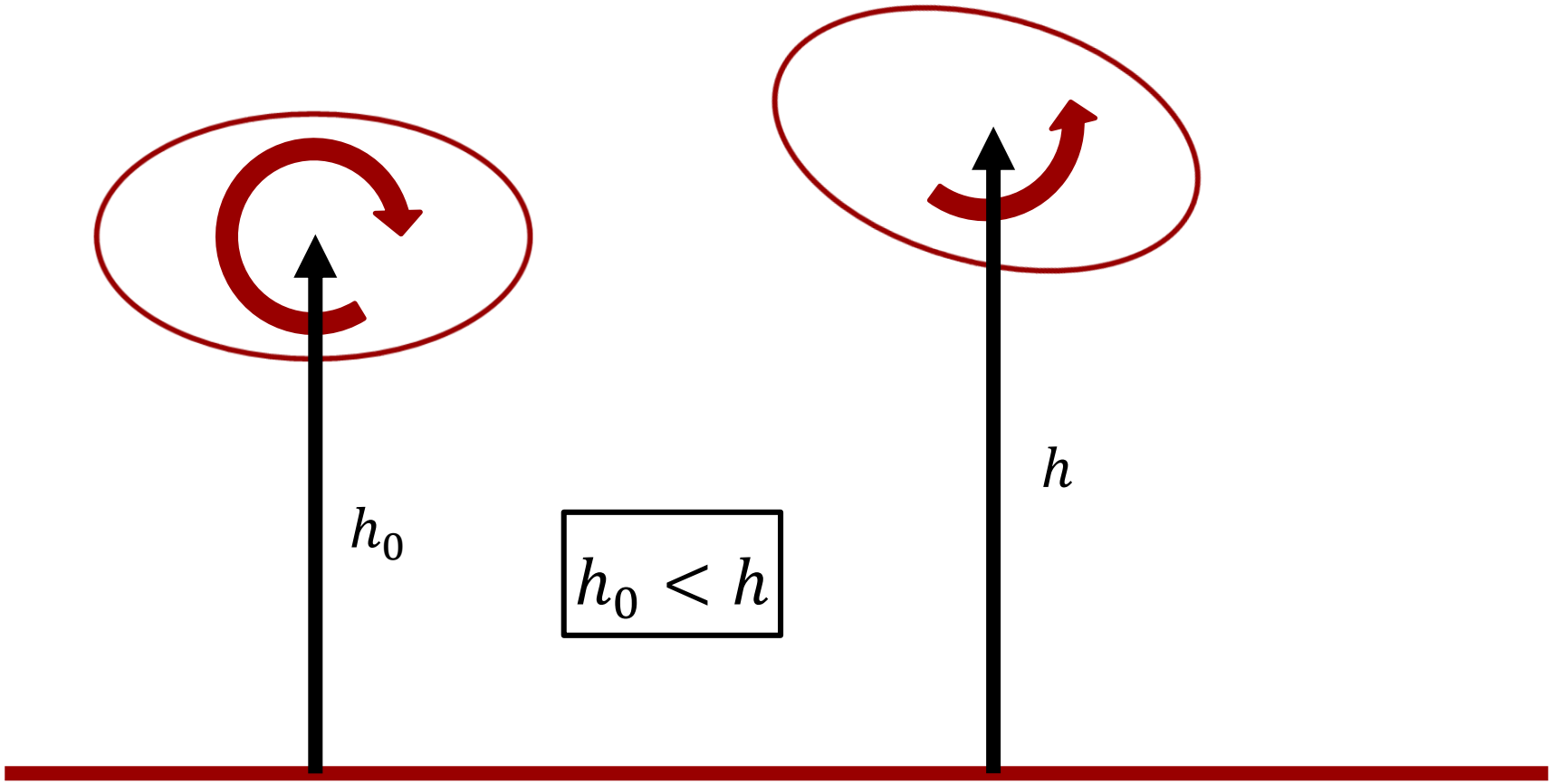
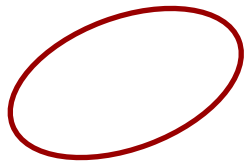


Optimal setup

- Same initial starting conditions
- Easy parameter variation



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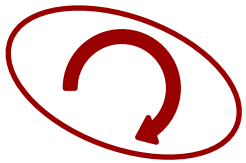

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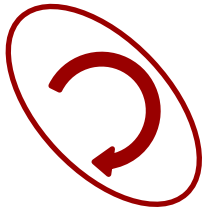

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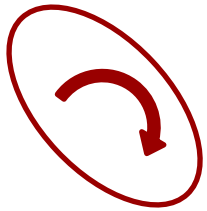


Quantitative theory – Conservation of energy

- Conservation of energy
  - Assumption: no loss of energy from the impact
  - Energies: rotational, potential, kinetic

$$\frac{1}{2}I\omega^2 + mgh + \frac{1}{2}mv^2 = \frac{1}{2}I\omega'^2 + mgh' + \frac{1}{2}mv'^2$$

$$\frac{1}{2}I\omega^2 + mgh + \frac{1}{2}mv^2 = \frac{1}{2}I\omega'^2 + mgh'$$

$$\xi(\varphi, h, v, \omega) = \frac{mgh'}{mgh' + \frac{1}{2}I\omega'^2}$$

  - ξ: ratio of potential energy to the total energy
  - φ: Impact angle with the ground
  - Most amount of energy to be converted to potential energy: $\xi \approx 1, \omega' \approx 0$

Quantitative theory – Xi function

$$\xi(\varphi, h, v, \omega) = \frac{mgh'}{mgh' + \frac{1}{2} I \omega'^2} \qquad mgh' = \xi(\varphi, h, v, \omega)\, E_{\text{total}}$$

- Multiple throws:
  - Measure: velocity – v, angular velocity – ω, height of fall – h
  - φ– random variable
    - Why is it random?
    - Really fast spinning → Can't predict how it would impact the ground

→ ξ and φ have a connection between them → find this connection or the expected value of ξ and φ

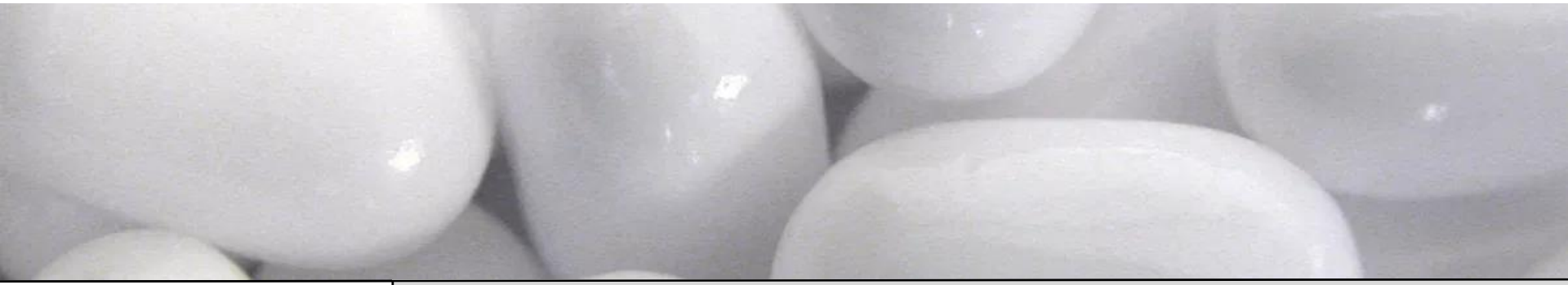
Solving the problem – basic level

- Build a setup where you can throw the capsule the same way every time
- Measure lots of different parameters → maximum value of ξ at each parameter
- → Maximal achieved height difference before and after the bounce

Solving the problem – advanced level

- Try to find the probability density function of φ at different (h, v, ω) parameters
- $\xi(\varphi, h, v, \omega)$ find the expected value at fixed h, v, ω
- Include the loss of energy at the rebound
- Find the best parameters to get the highest jump

Thank you for your attention



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