ATZG 2024

Magnus Glider Looping Phase in Microgravity

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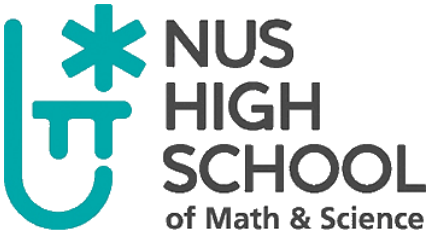

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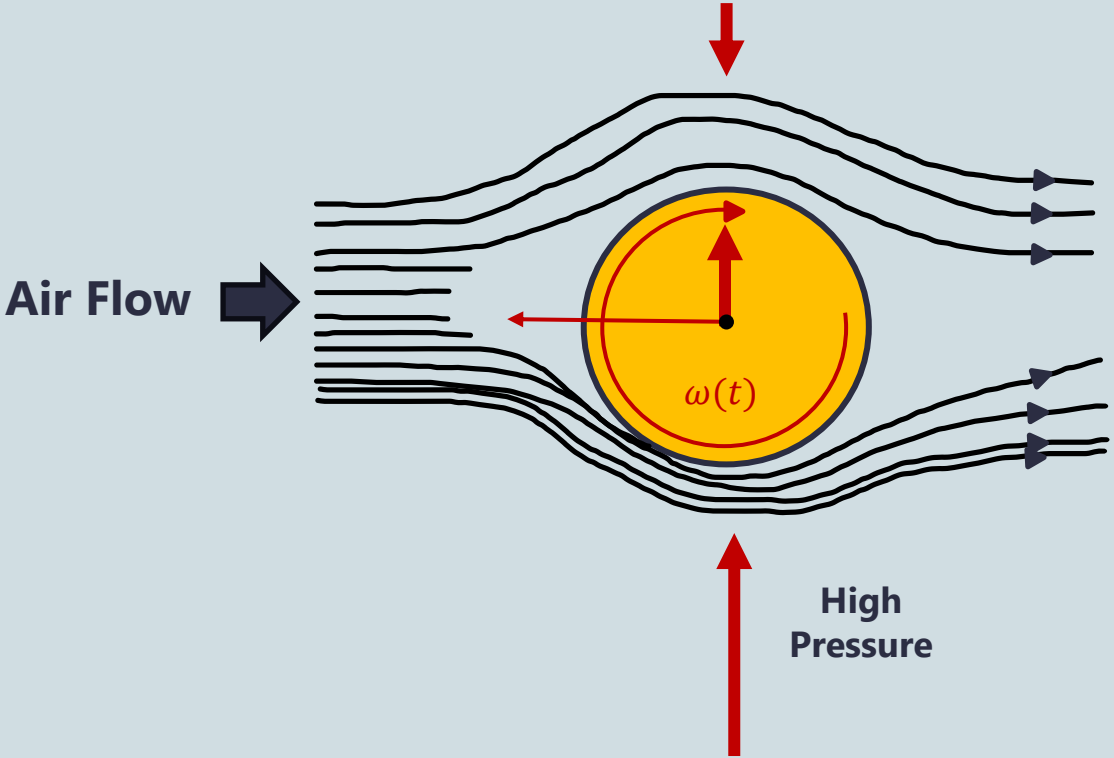
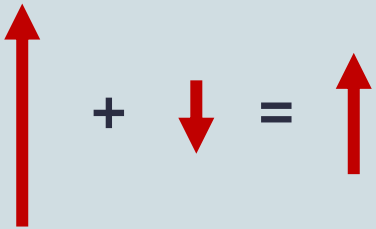
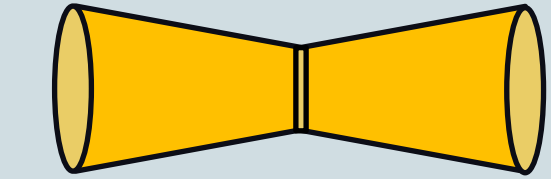
Magnus Effect

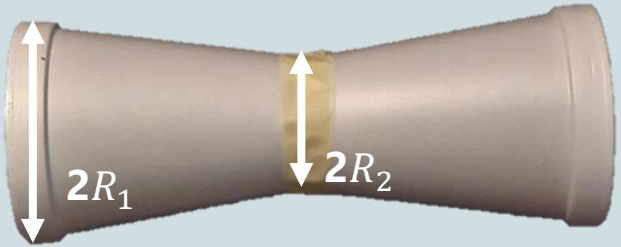


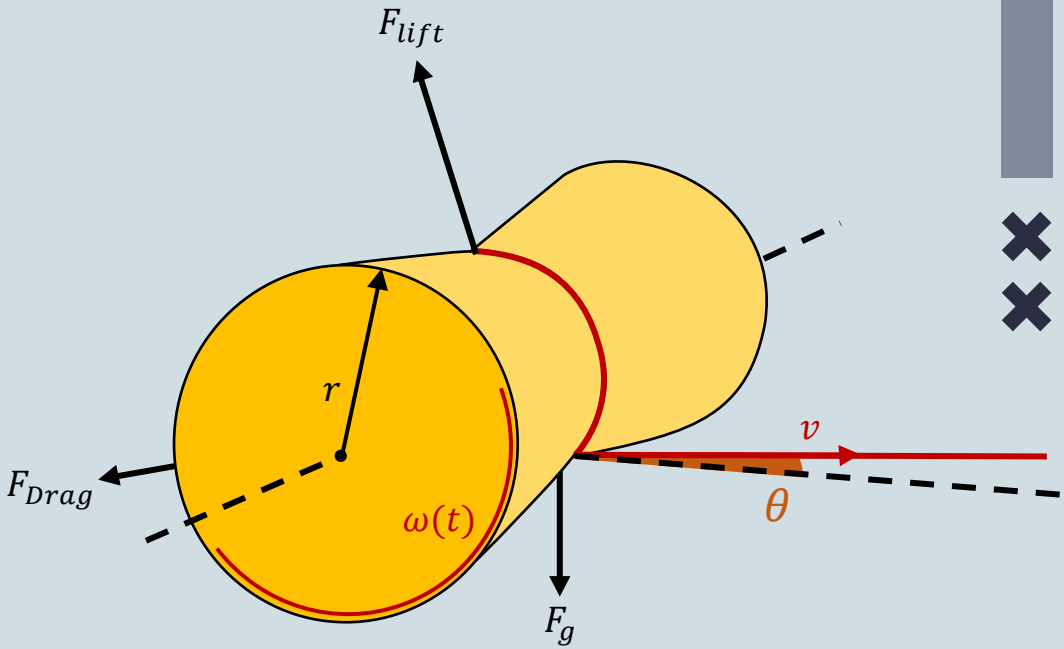
Bernoulli's Principle



Bernoulli's Principle



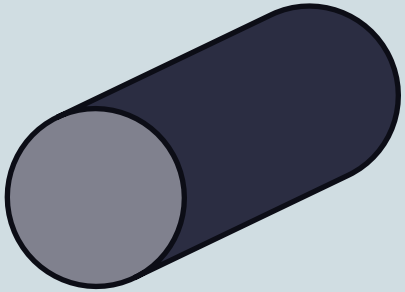


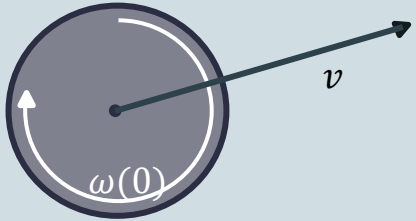


$$ma = mg + F_L + F_D$$

Kutta-Joukowski Lift Theorem

Normal

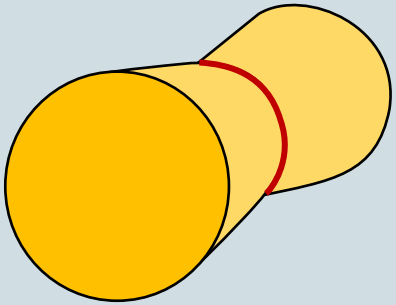


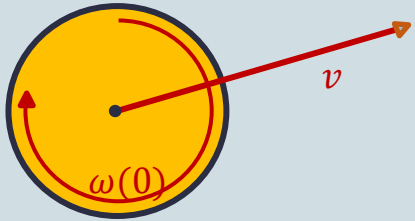


Determines

F_L

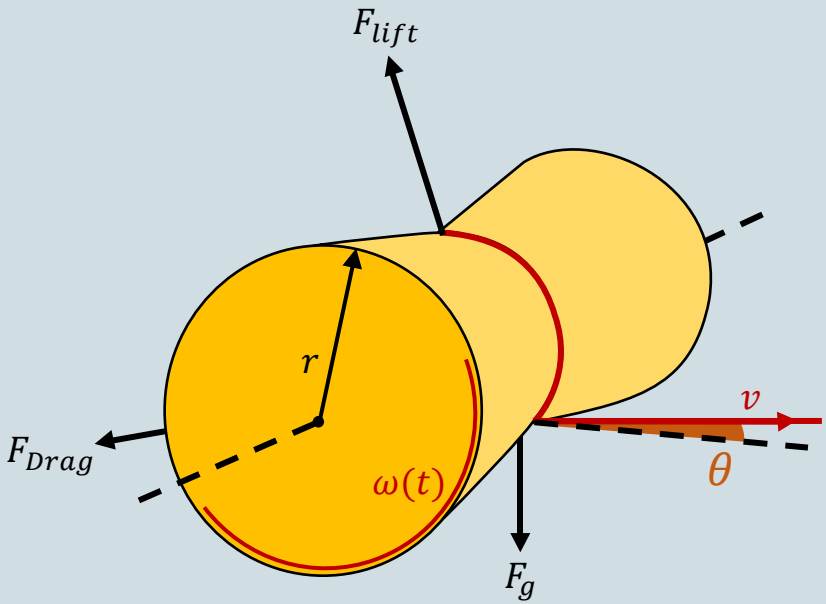
Modified





Force Analysis

$$ma = mg + F_L + F_D$$



$$F_L = \frac{4}{3}\alpha\omega\rho VL(R_1^2 + R_1R_2 + R_2^2)$$

$$F_D = \frac{4}{3}\alpha\omega\rho VL(R_1^2 + R_1R_2 + R_2^2)$$

$$m\frac{dv_y}{dt} = \left[-\frac{1}{2}C_D\rho S\right]V_y|V_y| - \rho V_y(2\pi r^2\omega)$$

$$m\frac{dv_x}{dt} = \left[-\frac{1}{2}C_D\rho S\right]V_y|V_y| - mg + \rho V_x(2\pi r^2\omega)$$

Fitted
from experiments on Earth

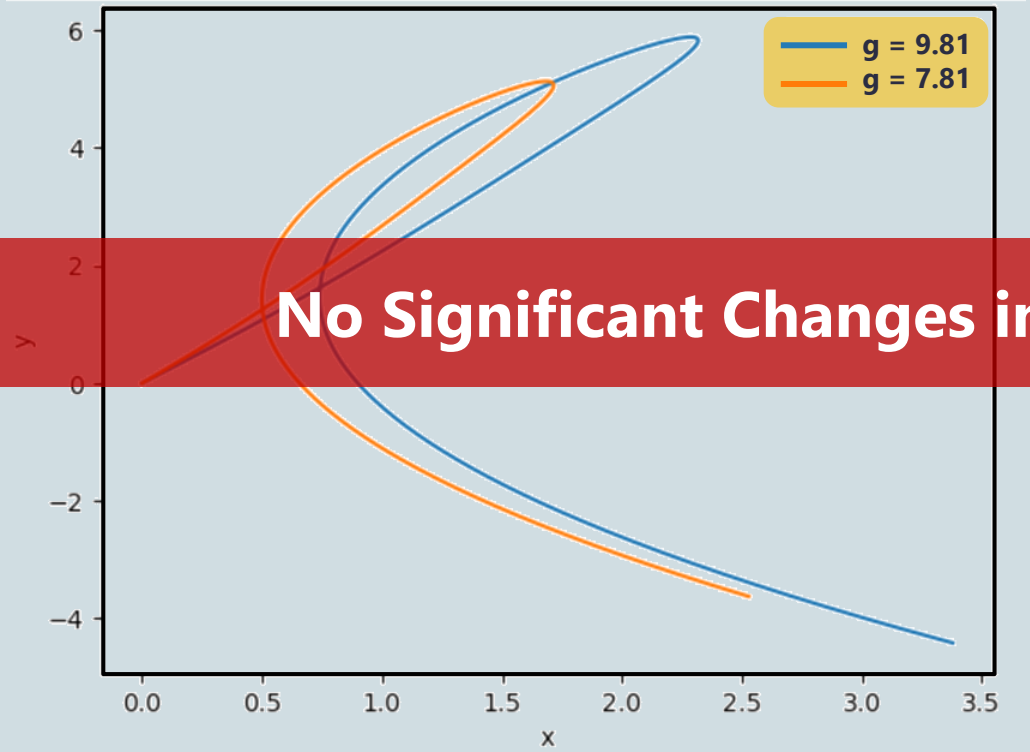
Reynold's Number

Characteristic of Flow (Laminar vs Turbulent)

Spin Coefficient

$$S = \frac{\omega R}{V}$$

Parameters



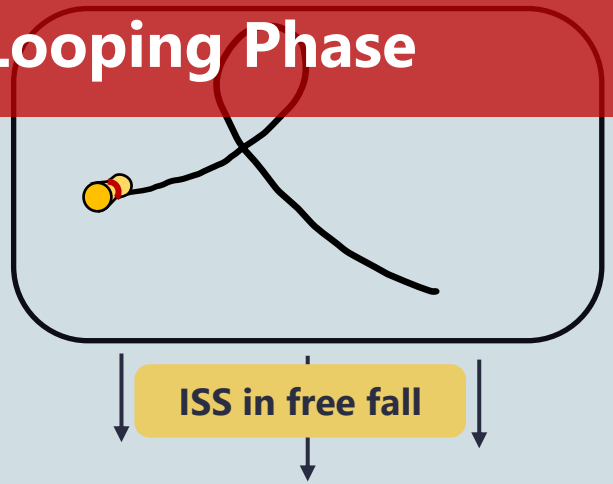
m = 17.4 g

R_1 = 5.01 cm

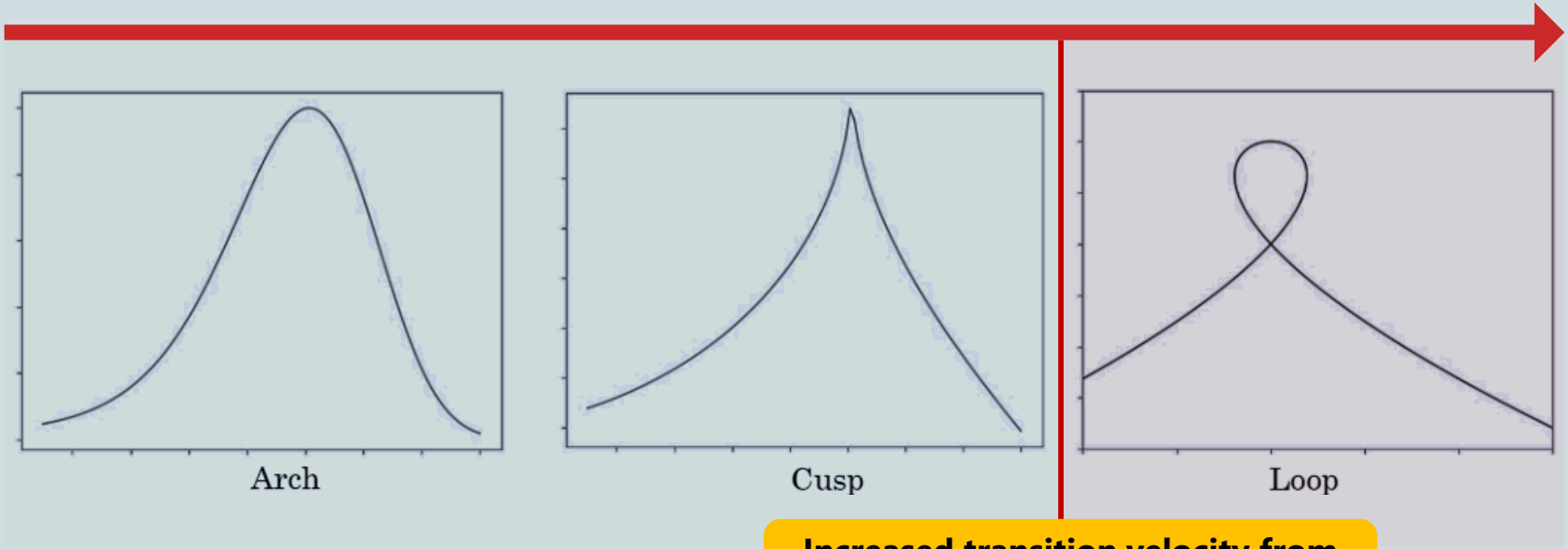
R_2 = 8.00 cm

Fixed Reference Frame

No Significant Changes in Looping Phase



Trajectories



Increased transition velocity from Cusp to Loop phase at ISS

Experimental Setting

Low Earth Orbit

$g = 7.81\ m/s^2$

Only qualitative discussion possible

Variations

Run#	1	2	3	4
				
	Number of Turns of Rubber Band: 2 Direction: Horizontal	Number of Turns of Rubber Band: 4 Direction: Horizontal	Number of Turns of Rubber Band: 2 Direction: Downward	Number of Turns of Rubber Band: 4 Direction: Downward

Horizontal

Downward

Results

Horizontal

Too high horizontal speed

=

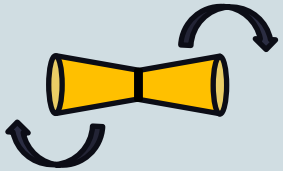
Strong lift forces

=

Wobbly, turbulent pathway

Results

Horizontal



Unstable state

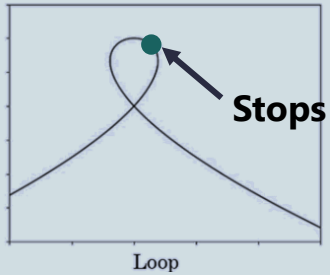
Reynold's Number

↑ Turbulence

Spin Coefficient

$$S = \frac{\omega R}{V}$$

Results



Downward

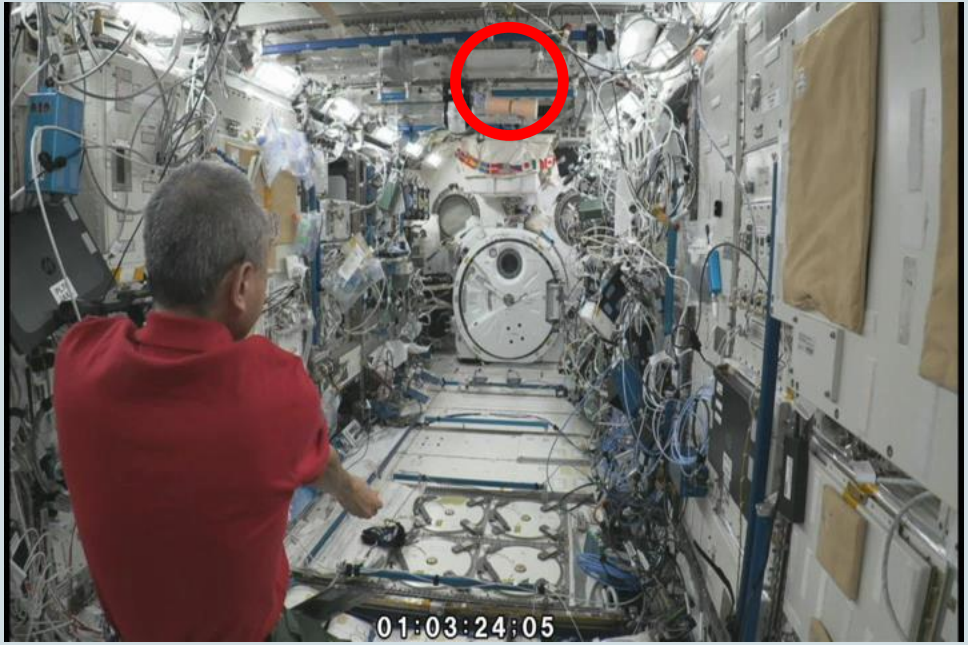
Optimal Downward movement

Initial Looping seen

Numerical prediction looping time: **3.50s**

Actual looping time: **3.12 s**

Results



Downward

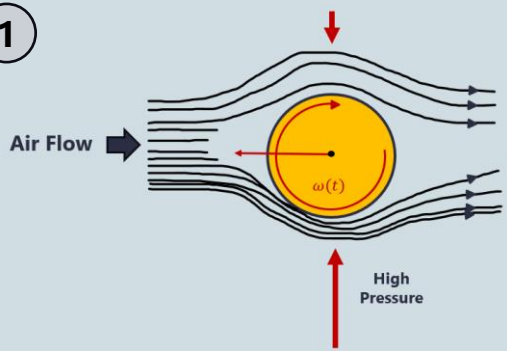
Arbitrary floating motion ?

Moving Reference Frame

Free fall of ISS

Conclusion

1



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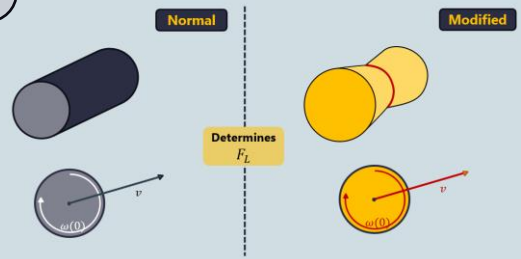

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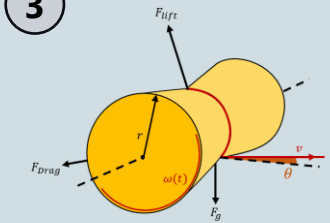


$$ma = mg + F_L + F_D$$

$$\mathbf{F}_D = C_d(\mathrm{Re}, S_p)\frac{\rho S V^2}{2}\tilde{\mathbf{v}}$$

$$\mathbf{F}_L = C_l(\mathrm{Re}, S_p)\frac{\rho S \tilde{V}^2}{2}\tilde{\omega} \times \tilde{\mathbf{v}},$$

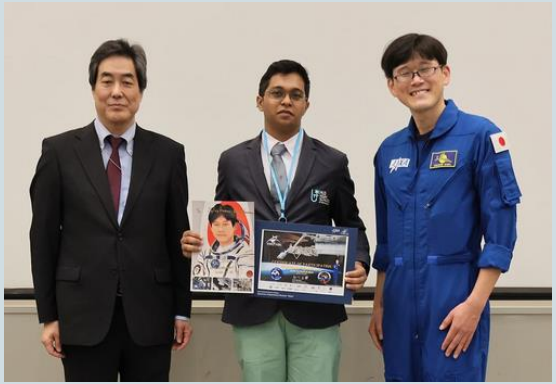
Reynold's Number — Spin Coefficient

References

1. *Houston, C. (2017, October 28). Magnus Glider Construction. Instructables. https://www.instructables.com/Magnus-Glider/*

2. *Plihon, N., Legrand, G., Pagaud, F., Chemin, A., Ferrand, J., & Taberlet, N. (2021, August 26). The physics of magnus gliders. American Journal of Physics. https://hal.science/hal-03326471*

3. *Rafeii, P. (2015). Magnus glider - Young Scientist Research Journal. Research: Persian Young Physicists' Tournament. https://journal.ayimi.org/wp-content/uploads/sites/7/2018/12/Rafeii-P33-37.pdf*



Thank You !