①

Factors that Affect Air Resistance of Round Objects

Hyogo Prefecture, Kakogawa Higashi High School
Science & Math Course　Science Research Group **3**

Motivation

fo: air resistance

$$fo = kv$$

(k : Proportional constant, *v* : *velocity)*

f_1: Drag force related to v [N]

$$f_1 = 6\pi r\eta v = k_1 v$$

(r: Radius of sphere [m]　η: Viscosity coefficient [$kg/m \cdot s$]
v: velocity [m/s])

f_2: Drag force related to v^2 [N]

$$f_2 = \frac{\pi\rho r^2 v^2}{4} = k_2 v^2$$

(ρ: air density [kg/m^3]　r: Radius of sphere [m]
v: velocity [m/s])

④

f : ***Total air resistance*** **[N]**

$$f = f_1 + f_2 = k_1 v + k_2 v$$

Experiment

・use a stopwatch and a camera at 1/8th speed (240fps)

・drop balls from different heights every 0.5 m from 1.0 m - 5.0 m ＊deviation: less than 0.03 s

・record time and distance

Type of sphere (number) [g],[cm]	
Golf ball	45.83g, *2.134cm
Ping-pong ball	2.38g, 1.927cm
Basketball(7)	580g, *12.25cm
Soft tennis ball	29.88g, *3.3cm
Styrofoam ball	4.85g, 3.949cm

*using official standard values

Reference (graph) 【image of how to find k_1, k_2】

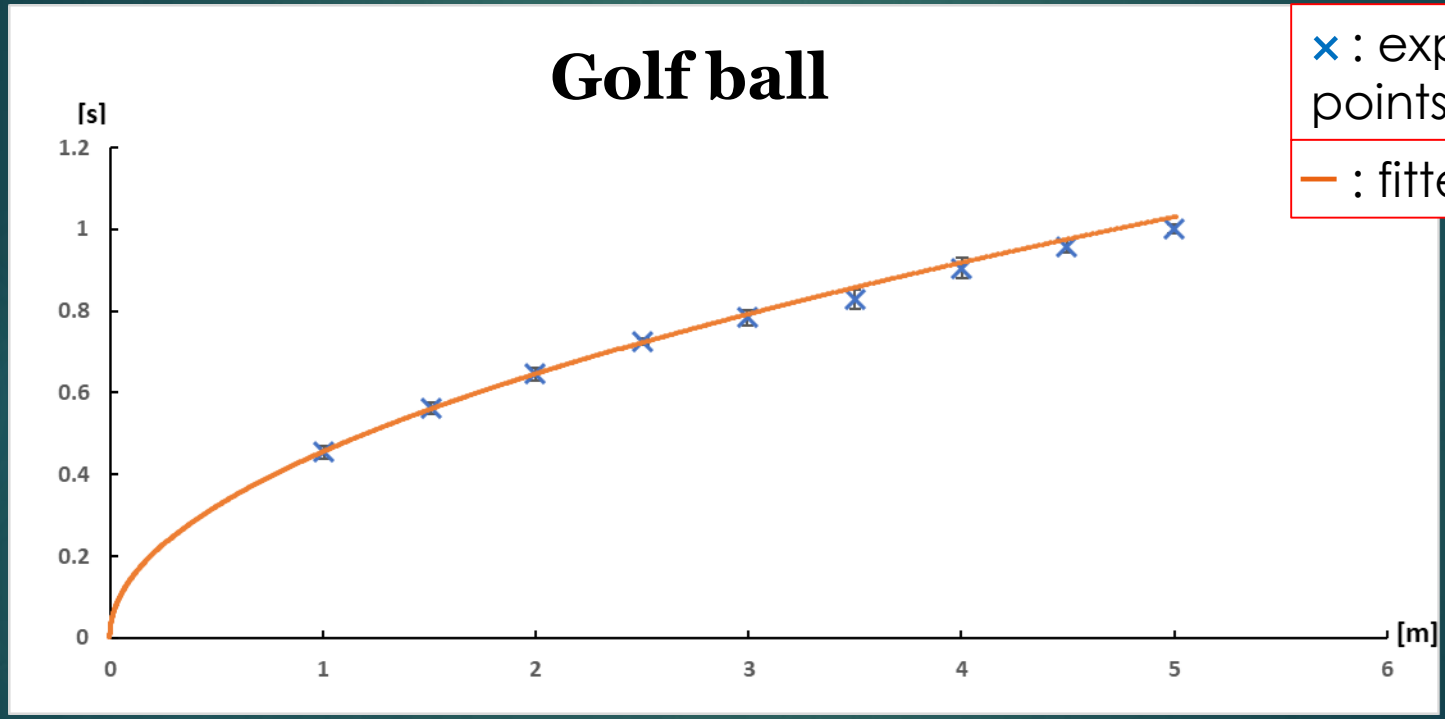
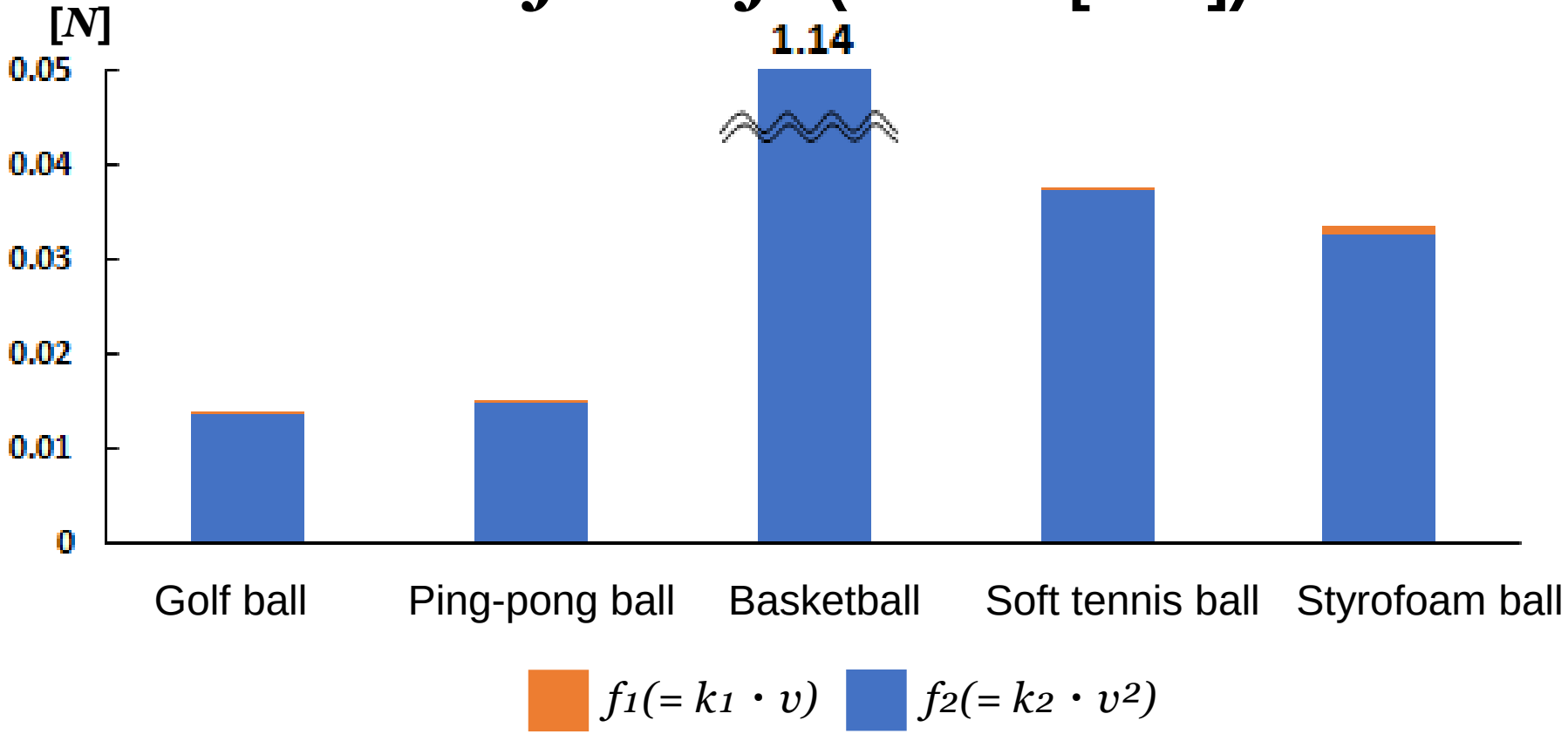
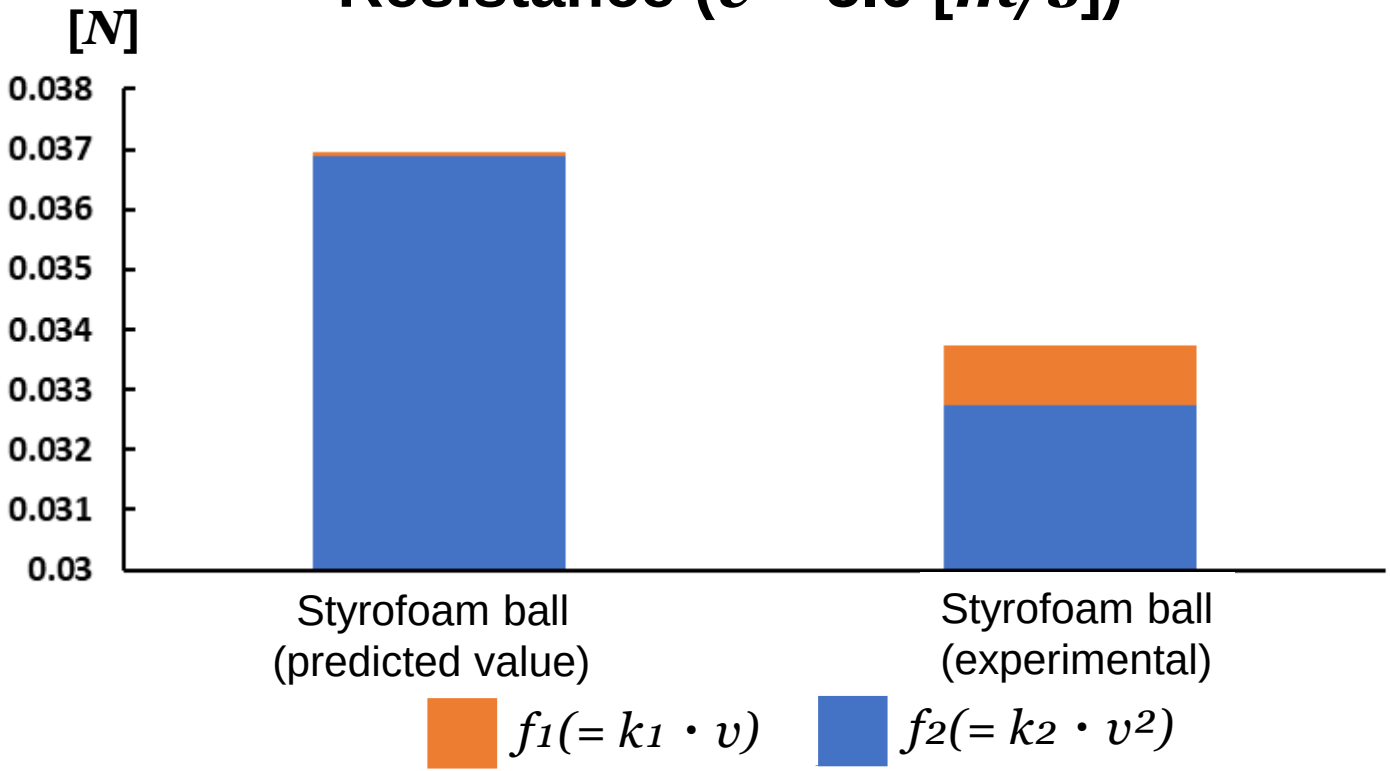


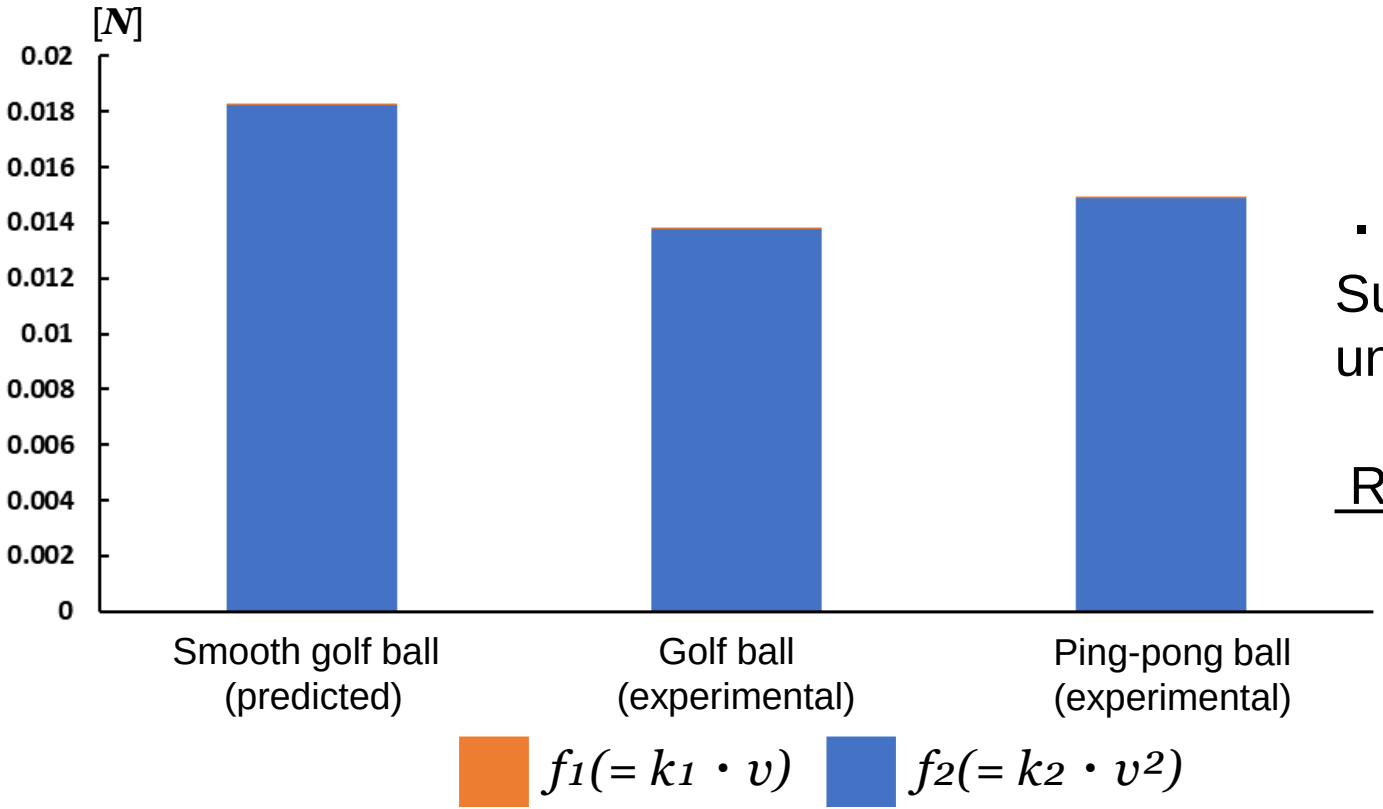
Figure 2 Resistance for all tested objects due to f_1 and f_2 (v = 5.0 [m/s])

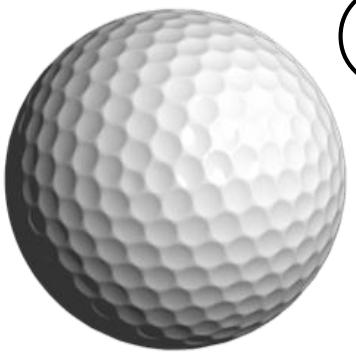


Predicted VS experimental resistance of a Styrofoam ball



Predicted VS experimental resistance of a golf ball [N] (v = 5.0 [m/s])





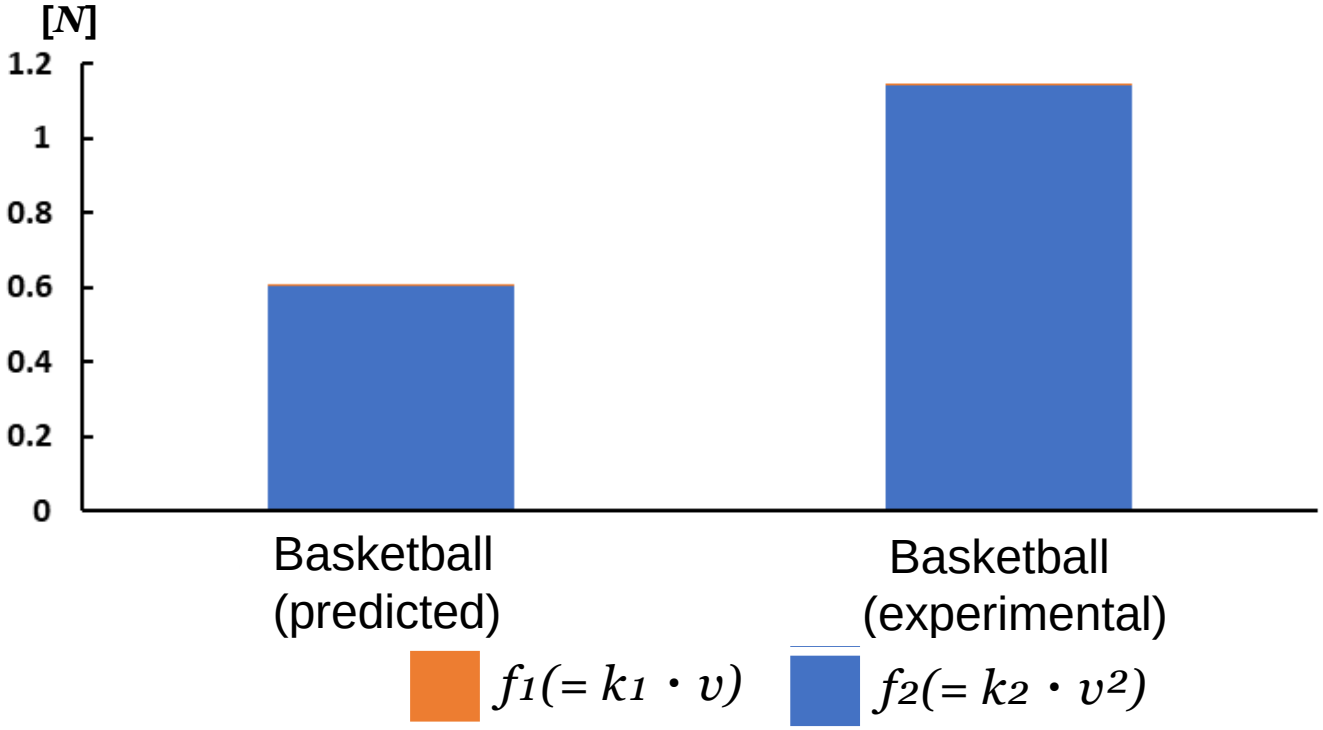
・**Dimples**

Surface of golf balls is uneven

↓

Reduces resistance

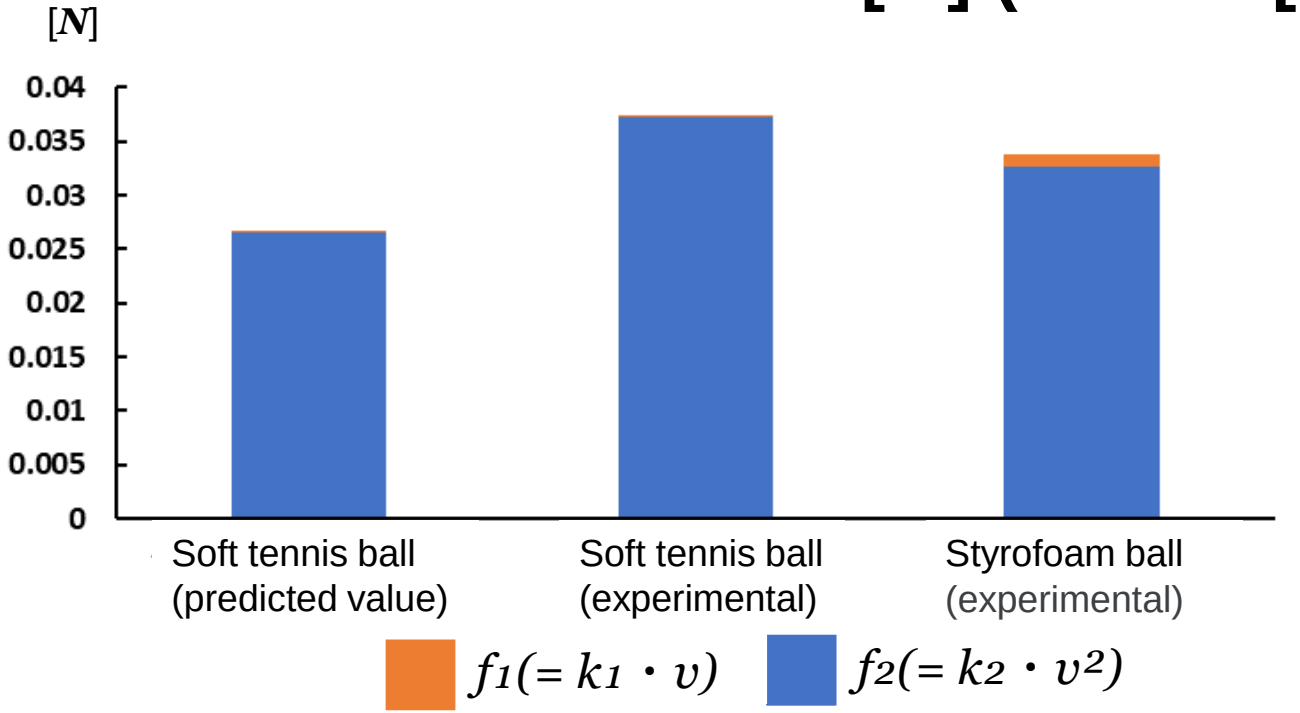
Predicted VS experimental resistance of a basketball [N] (v = 5.0 [m/s])



・bumpy basketball surface

・misalignment when experimenting

Predicted VS experimental resistance of a soft tennis ball [N] (v = 5.0 [m/s])



Soft tennis ball is soft

Deforms as it moves through air

Conclusion

- With smooth spheres, drag force 1 is almost negligible at high speeds.

- Both drag forces can be significantly affected depending on the surface of the ball.

Future prospects

- Whether the unevenness of the styrofoam surface has the same function as the dimples

- Whether the basketball surface affects the resistance

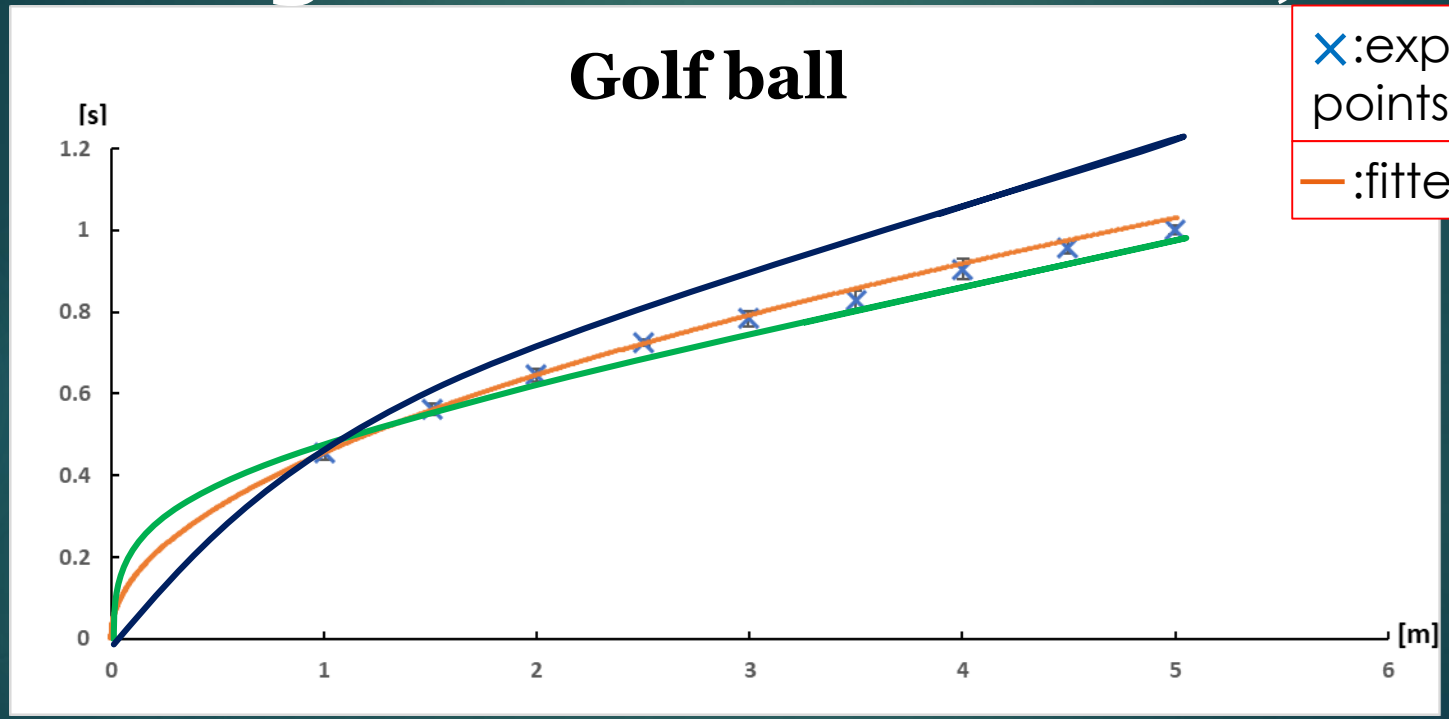
- Investigate the relationship between radius and resistance for different types of surfaces

References

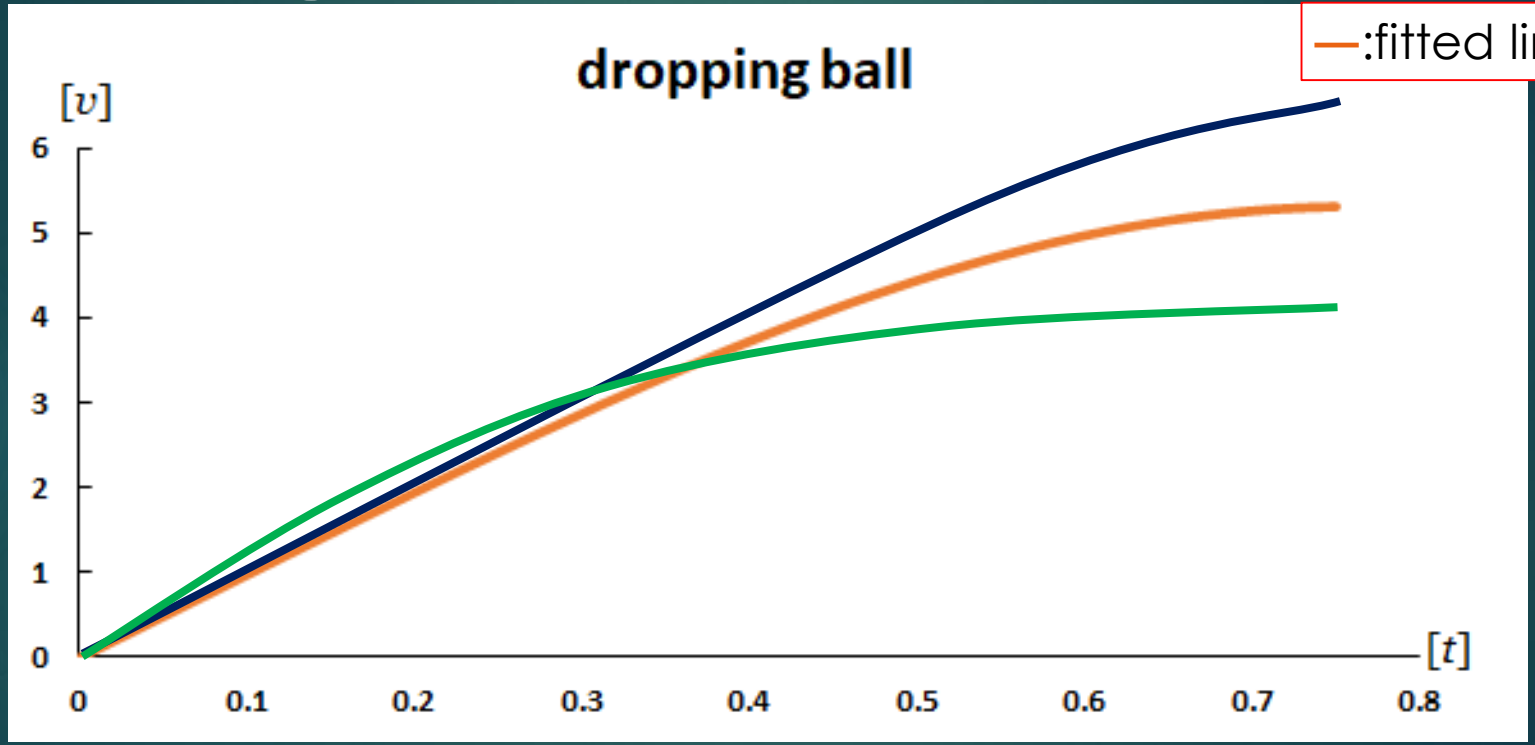
・Revised Physics, Author:Miura Noboru and fifteen others, Issuer: Tokyo syoseki corporation, date of issue:R2. February 10

・Correct Understanding of Air Resistance in High School Physics : Through observation of wind tunnel device, theoretical analysis, drop experiment and data analysis 37-42,2019

Reference (graph) 【image of how to find k_1, k_2】

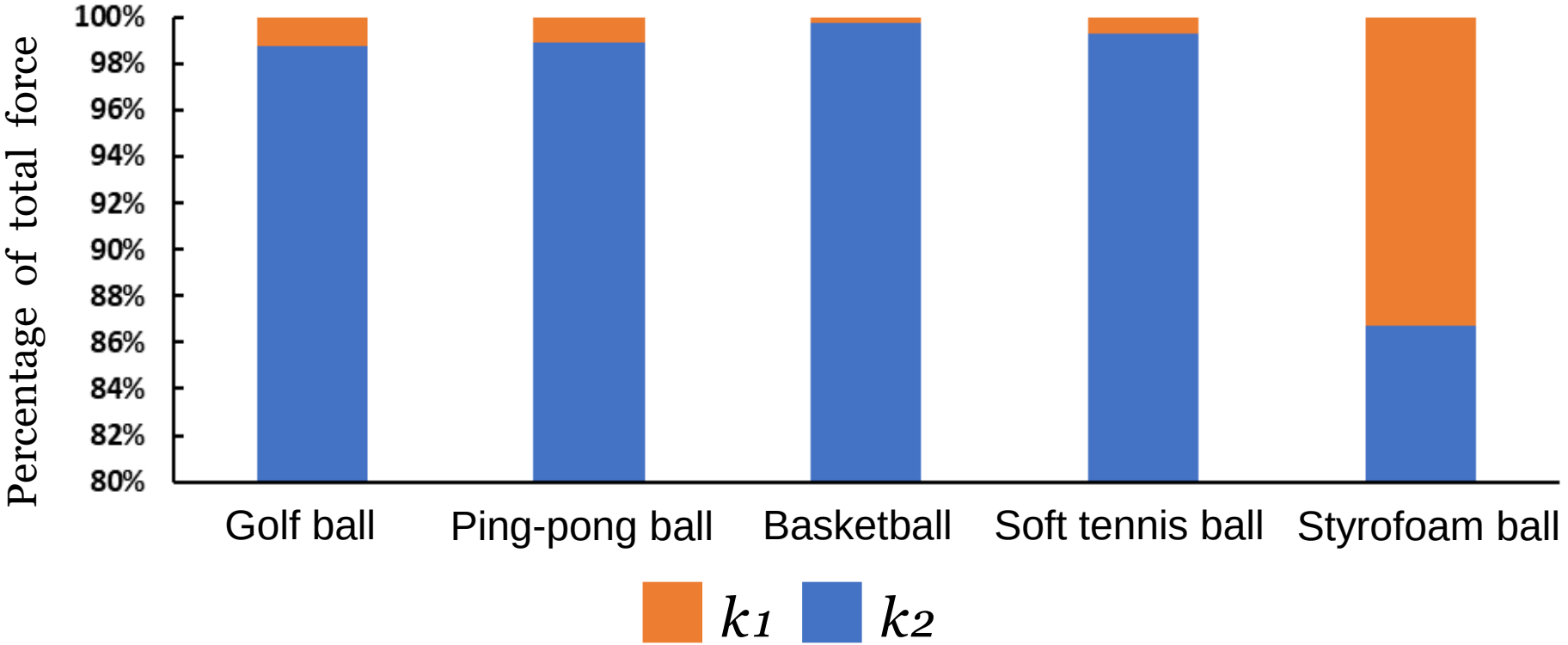


Reference (graph)
【image of how to find k_1, k_2】

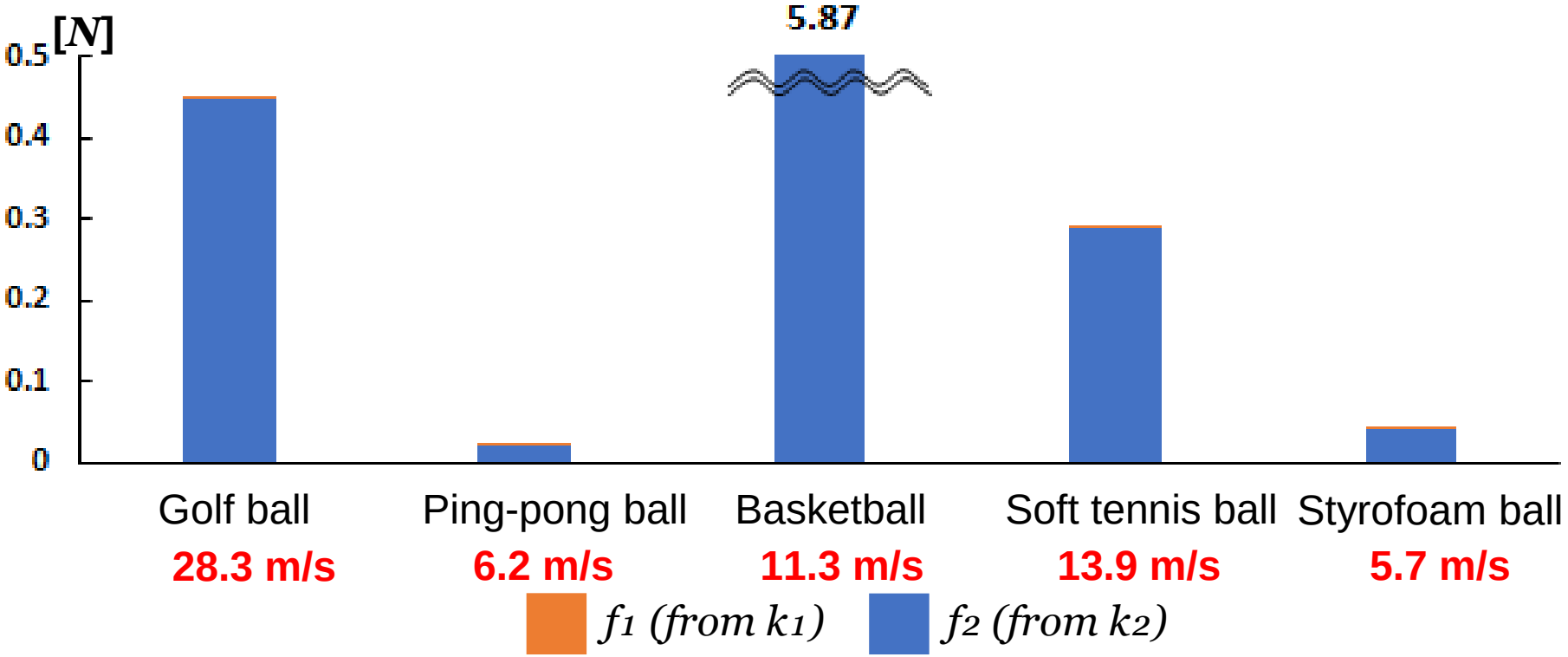


Percentage of k_1 and k_2

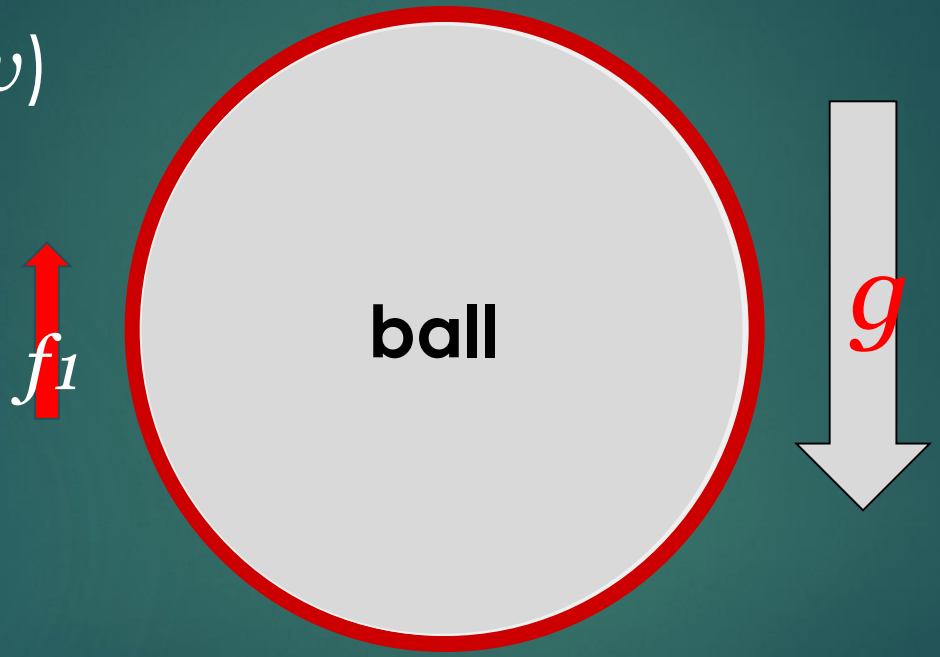
(k_1: Proportional constant of Viscous resistance, k_2: Proportional constant of Inertial resistance)

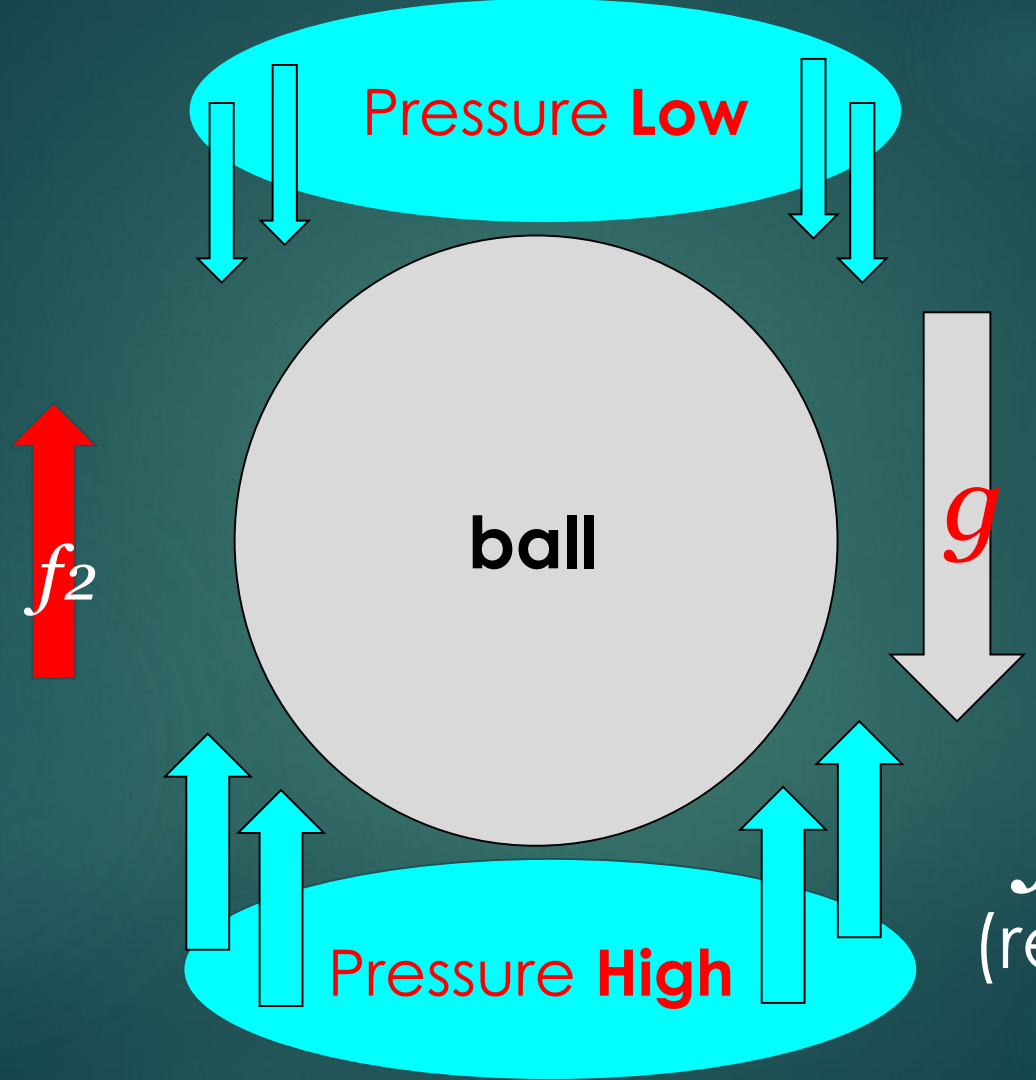


Resistance of 5 ball at terminal velocity



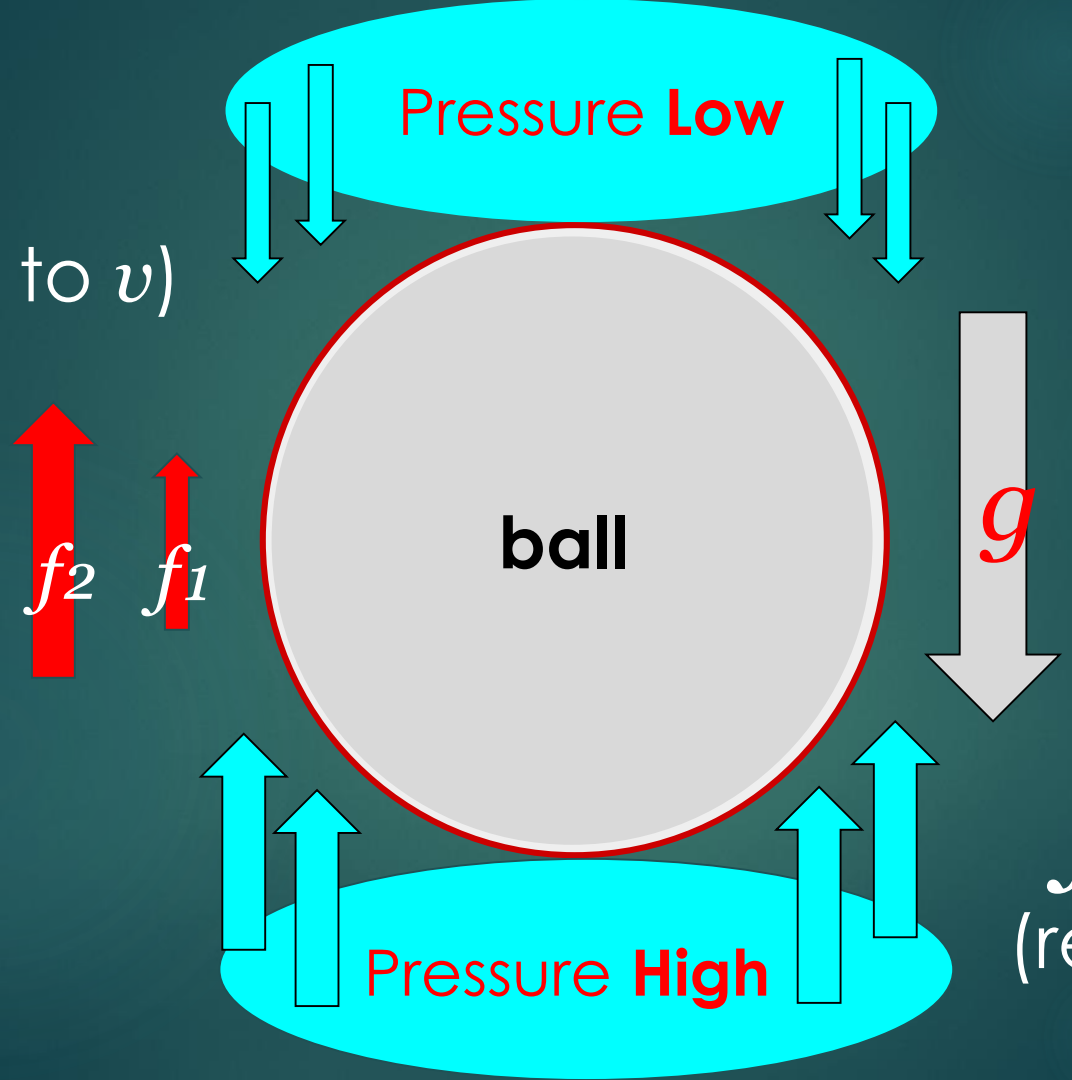
f_1
(related to v)





f_2
(related to v^2)

f_1
(related to v)



f_2
(related to v^2)