

Scaling Laws and Machine Learning for Drag-Governed Projectile Motion

Naren Raghavan | Signature School | HSEF 2026

Purpose and Background

Problem:

45° is only optimal without air resistance. Quadratic drag changes optimal angle.

Since drag force depends on velocity, standard analytical equations can't be easily used.

Goal:

Identify a single dimensionless parameter that collapses optimal angle behavior across diverse object geometries, and validate it using machine learning.

Methodology

6 Object Geometries x 20 Velocity Values
= **120 Total Parameter Combinations**

$$F_D = \frac{1}{2} C_D A v^2$$

$$\text{Pi} = C_D A v^2 / 2mg$$

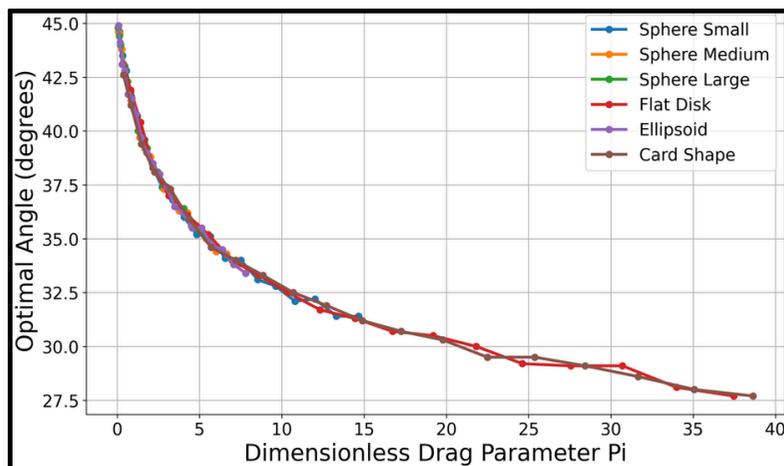
Machine Learning:
Random Forest Regressor
trained on simulation dataset
(80/20 split)

RMSE = 0.6

R² = 0.98

Key Results

All geometries collapse onto **ONE universal curve**



Conclusions/Future Work

- ✓ Optimal angle < 45° under drag
- ✓ Pi collapses all behavior onto one universal curve
- ✓ ML achieves R²=0.98, RMSE=0.6°

Future Work:

- Experimental validation via computer vision trajectory tracking
- 3D drag + Magnus effect
- Apply PINNs to recover governing equations from raw data