

Rubric and Methodology for Aerodynamic Experiment using Load Cells

Note: Along with the rubric components, also include Objective(s) and Theory.

I. Rubric Components

Component	Details	Weight (%)
Experimental Setup	Proper mounting, alignment, calibration of load cells	15%
Instrumentation & Data Acquisition	Arduino integration, sampling rate, wiring, data reliability	15%
Data Processing	Raw force conversion, filtering, tare removal	15%
Aerodynamic Coefficient Calculation	CL, CD, use of dynamic pressure, projected area	20%
Plotting & Trends	CD vs CL, CL/CD vs α behavior with angle of attack, stall point	10%
Sensitivity & Uncertainty	Repeatability, standard deviation, error propagation, sensor accuracy	15%
Interpretation & Discussion	Coherence with expected trends, NACA data matching, flow physics explanation	10%

II. Experimental Methodology

1. Setup & Coordinate System:

- Two perpendicular load cells: Drag (horizontal), Lift (vertical)

- Airfoil: NACA 4318 mounted on a sting balance or internal frame
- Arduino reads voltage (use HX711 for strain gauge cells)

2. Tare Removal (Zeroing Baseline):

Before turning on flow:

```
long tareLift = analogRead(liftPin);
```

```
long tareDrag = analogRead(dragPin);
```

Then during data acquisition:

```
liftCorrected = analogRead(liftPin) - tareLift;
```

```
dragCorrected = analogRead(dragPin) - tareDrag;
```

3. Force to Newton Conversion:

Use calibration from known weights (linear fit):

$\text{Voltage_out} = a \times \text{Force} + b \rightarrow \text{Force} = (\text{Voltage_out} - b)/a$

III. Aerodynamic Coefficient Computation

Let:

- L = Lift (N), D = Drag (N)

- $q = 0.5 \times \rho \times U^2$ (Dynamic Pressure)

- S = Projected area = chord \times span

Then:

$CL = L / (qS)$, $CD = D / (qS)$

IV. Uncertainty & Sensitivity Analysis

A. Standard Deviation:

B. Propagation of Uncertainty:

C. Sensitivity to Angle of Attack:

Plot CL vs α , compute $dCL/d\alpha$ in linear region

D. Repeatability Check:

Perform multiple runs, compare standard deviation of CL, CD

V. Recommended Plots

- CL vs α
- CD vs α
- CD vs CL (drag polar)
- Cl/Cd vs α
- Tare stability (voltage vs time at zero flow)
- Error bars from uncertainty analysis

VI. Additional Tips

- Use median filtering or moving average for Arduino data smoothing
- Calibrate with known weights before experiment
- Ensure wind tunnel blockage ratio <10%
- Save Arduino data in .csv for MATLAB/Python analysis