# IPS Analytical Lab 1 —Aerodynamics & Flight Mechanics

# Purpose

This MATLAB-based lab builds on Aerodynamics & Flight Mechanics. You will simulate propeller forces, analyze quadcopter dynamics, and—most importantly—critically reflect on your results to connect theory with realistic drone design.

# Learning Outcomes

By the end of this lab, you will be able to:

* Implement aerodynamic models of thrust and torque in MATLAB.
* Evaluate hover conditions, yaw control, and parameter sensitivities.
* Interpret discrepancies between idealized models and physical expectations.
* Justify modeling assumptions and propose amendments for more realistic design.

# Parameters for MATLAB Simulation

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| --- | --- | --- | --- | --- |
| Parameter | Symbol | Value | Unit | Notes / Reflection Hints |
| Air density | ρ | 1.2 | kg/m³ | Sea level, 20°C. Lower in hot/humid climates. |
| Propeller diameter | D | 0.23 | m | ~9-inch prop. Larger props = more thrust at lower RPM. |
| Drone mass | m | 1.2 | kg | Represents a small quad. Racing vs survey drones—compare. |
| Gravity | g | 9.81 | m/s² | Standard gravity. Would altitude change results? |
| Yaw inertia | Iz | 0.04 | kg·m² | Represents resistance to yaw. Heavier frame → larger inertia. |
| Thrust coefficient | CT | 0.10 | - | Assumed constant. In reality varies with RPM & AoA. |
| Torque coefficient | CQ | 0.010 | - | Simplified constant. Strongly depends on blade shape. |
| RPM range | n | 5,000–24,000 | RPM | Practical motor range. |
| Yaw Δn | Δn | 50 | RPS | Represents yaw maneuver input (~3000 RPM difference). |
| C\_T uncertainty | ±5% | - | – | For error analysis. Real props may vary more. |
| Density variation | ±8% | - | – | Weather/altitude effects (e.g., Hanoi summer vs highlands). |
| Diameter variation | ±5% | - | – | Represents prop tolerance. More impactful than density. |

# MATLAB Setup

Insert these constants at the top of your `.m` file:

rho = 1.2; % air density (kg/m^3)  
D = 0.23; % prop diameter (m)  
m = 1.2; % quad mass (kg)  
g = 9.81; % gravity (m/s^2)  
Iz = 0.04; % yaw inertia (kg·m^2)  
  
CT = 0.10; % thrust coefficient  
CQ = 0.010; % torque coefficient  
  
n = linspace(80, 400, 15); % RPS grid (~5k–24k RPM)  
dn = 50; % yaw control test (RPS)

# Tasks & Reflection Questions

## Parameter Reflection

Before coding: write which parameter (ρ, D, CT, CQ, m, Iz) you believe is most critical for quad performance. Justify using physics and design considerations.

## Part A — Thrust & Torque Models (20 min)

* Implement

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Plot thrust & torque vs RPM.

* Reflection Q1: Why do real propellers deviate from at high RPM? What if blade twist is ignored?

## Part B — Hover Analysis

* Find hover RPM and total hover power for m=1.2 kg.
* Reflection Q2: Is your hover RPM typical of racing or survey drones? Which trade-off (prop size, motor efficiency, weight) dominates? Suggest a design change that reduces hover power but impacts maneuverability.

## Part C — Yaw Control

* With Δn=50 RPS, compute yaw torque and angular acceleration.
* Reflection Q3: Why is yaw weaker than pitch/roll? How would doubling prop diameter affect yaw? Is stronger yaw agility always desirable?

## Part D — Sensitivity

* Vary D ±5%, ρ ±8%. Compute hover power and show in 3D mesh plot.
* Reflection Q4: Which parameter dominates hover performance? If a drone must work at sea level and mountains, which parameter would you optimize first and why?

## Part E — Uncertainty & Amendments

* Apply ±5% uncertainty in C\_T. Compute hover RPM range.
* Reflection Q5: Is ±5% realistic in practice? If uncertainty is large, which two amendments would reduce error (e.g., nonlinear CT(n), motor efficiency curve)? How would you validate experimentally?

## Final Reflection

Summarize in 3–5 sentences:  
1. The most surprising or counterintuitive result.  
2. One assumption that caused the largest discrepancy.  
3. One amendment you would recommend for more realistic MATLAB models.

# Deliverables - PDF file includes Equations, MATLAB code, calculations, plots, and reflections.