PHYSICS INVESTIGATORY PROJECT

DESIGNING A MINI DRONE

AND INVESTIGATING ITS PHYSICAL PRINCIPLES
AND APPLICATIONS IN SCHOOL

Submitted in partial fulfilment of the requirements for
PHYSICS — CLASS XII

Submitted by:

Name: _____

Class & Section: XII _____

Roll No.: _____

School:

_____

_____

Session: 2026–27

Submitted to:

_____

Physics Department

CERTIFICATE

This is to certify that _____, a student of Class XII, has successfully completed the Physics investigatory project entitled **“Designing a Mini Drone and Investigating Its Physical Principles and Applications in School”** during the academic session 2026–27 under my guidance and supervision.

The project investigates Newton’s laws of motion, force and equilibrium, torque, rotational motion, electrical power, energy and stability through theoretical analysis, experimental observations and calculations.

Teacher’s Signature: _____

Teacher’s Name: _____

External Examiner: _____

Date: _____

School Seal

DECLARATION

I hereby declare that this project has been prepared as part of my Class XII Physics investigatory work. It aims to understand the Physics of a quadcopter through theory, laboratory-style measurements, calculations and analysis. External educational sources used have been acknowledged in the bibliography.

Student’s Signature: _____
Name: _____
Class: XII _____ **Roll No.:** _____

ACKNOWLEDGEMENT

I express my sincere gratitude to my Physics teacher, _____, for guidance and encouragement throughout this project. The investigation helped me connect textbook concepts with a working technological system.

I also thank my school for providing the laboratory environment and equipment required for measurement and testing, and my parents and friends for their support during construction, testing and documentation.

I acknowledge the scientific and educational resources listed in the bibliography, particularly NASA’s educational material on quadcopters, forces and unmanned aircraft.

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1. AIM, RESEARCH QUESTION & HYPOTHESIS

Aim: To design and investigate a miniature quadcopter and experimentally study the relationship between thrust, motor power, drone mass, payload, flight time and stability using Class XII Physics concepts.

Research Question: How do thrust, mass, electrical power and centre of gravity affect the flight performance and stability of a miniature quadcopter, and how can these principles be applied to useful activities within a school?

Hypothesis: As electrical power supplied to the motors increases, propeller thrust will increase. Increasing total mass will increase the thrust required for hovering and reduce flight endurance. Stable hovering will occur when total upward thrust approximately equals gravitational force.

It is also expected that a centrally located centre of gravity will provide better stability than an unevenly distributed load.

> The project therefore treats the drone as a **Physics experiment** rather than merely an electronic model.

Key objectives

• Demonstrate Newton's Third Law through propeller-generated thrust.

• Apply Newton's Second Law to vertical drone motion.

• Verify the hovering condition $T \approx mg$.

• Investigate power versus thrust and payload versus endurance.

• Study torque, pitch, roll, yaw and centre-of-gravity effects.

• Identify safe and educational school applications.

2. APPARATUS AND MATERIALS

Drone components

• Lightweight quadcopter frame

• Four miniature DC/brushless motors and four propellers

• Flight-control board and receiver

• Remote transmitter

• Rechargeable battery and connector

• Connecting wires and lightweight landing supports

• Protective propeller guards

Laboratory and testing equipment

• Digital weighing balance

• Digital multimeter

• Stopwatch

• Ruler and measuring scale

• Thrust-measurement arrangement/load cell or spring balance

• Known small masses for payload testing

• Laptop/mobile phone for data recording

• Safety goggles and protective test enclosure

Experimental variables

Experiment	Independent Variable	Measured Quantity
1	Electrical power	Total thrust
2	Payload mass	Flight time
3	Drone mass	Required hovering thrust
4	Payload position	Stability/correction

If the project is physically tested, the numerical observations should be replaced by the student’s actual readings before submission.

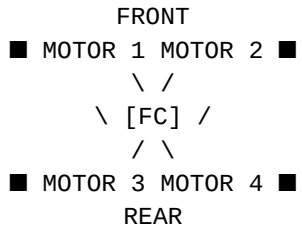
3. INTRODUCTION AND DRONE DESIGN

A quadcopter is a small unmanned aircraft that uses four rotating propellers. Each propeller produces thrust by accelerating air, and the combined thrust determines whether the drone descends, hovers or rises.

The drone provides a compact demonstration of Newton's laws, equilibrium, force, torque, rotational motion, electrical power and energy.

Electrical Energy → Motor Rotation → Propeller Motion → Airflow → Thrust → Drone Motion

Basic quadcopter configuration



FC denotes the flight controller. Two diagonal propellers rotate in one direction and the other two in the opposite direction, helping cancel reaction torque during hovering.

Design priorities: low mass, rigid frame, symmetrical geometry, correct propeller orientation and centrally distributed battery/electronics.

4. THEORY — FORCES, THRUST AND NEWTON'S LAWS

Newton's First Law: The drone changes its state of motion only when an unbalanced external force acts on it.

Newton's Second Law

$$F = ma$$

For vertical drone motion:

$$F_{net} = T - mg \quad \text{and} \quad T - mg = ma$$

Therefore:

$$T = m(g + a)$$

Newton's Third Law: The propellers push air downward; the air exerts an equal and opposite reaction force upward on the drone. This reaction produces thrust.

Weight

$$W = mg$$

For m = 0.400 kg and g = 9.8 m/s²: W = 0.400 × 9.8 = **3.92 N**.

Hovering: T = W = mg. The net vertical force is zero, so vertical acceleration is zero.

Rising: T > mg **Descending:** T < mg

5. THEORY — TORQUE, STABILITY AND POWER

Thrust-to-weight ratio

$$TWR = T / W$$

A ratio close to 1 is sufficient only for hovering. A larger ratio provides a margin for take-off, manoeuvring and disturbance rejection.

Torque

$$\tau = rF \sin\theta$$

Unequal motor thrusts create turning moments and allow pitch, roll and yaw. Opposite propeller rotation helps cancel reaction torque.

Motion	Axis	Effect
Pitch	Lateral	Nose tilts forward/backward
Roll	Longitudinal	Drone tilts left/right
Yaw	Vertical	Drone rotates clockwise/anticlockwise

Electrical power: $P = VI$. For 7.4 V and 4 A, $P = 29.6$ W.

Battery energy: $E \approx V \times Ah$. For 7.4 V, 1.5 Ah, $E \approx 11.1$ Wh.

The centre of gravity should remain near the geometric centre; an off-centre payload creates gravitational torque that the flight controller must counteract.

6. CONSTRUCTION AND EXPERIMENTAL PROCEDURE

Construction methodology

• Select a lightweight, symmetrical four-arm frame.

• Mount four motors at approximately equal distances from the centre.

• Install propellers in the correct rotational pairs.

• Mount the flight controller near the centre.

• Place the battery close to the centre to reduce unwanted torque.

• Connect receiver, motors and power system.

• Calibrate the flight controller.

• Perform low-power bench tests before free flight.

General testing procedure

• Measure unloaded drone mass.

• Measure voltage and current at selected motor-power levels.

• Measure total thrust using a controlled test stand.

• Repeat thrust readings for several power settings.

• Add known payloads and measure flight endurance under similar conditions.

• Compare total mass with theoretical hovering thrust mg.

• Move a fixed payload away from the centre and observe stability.

• Plot the measured relationships and compare them with theory.

Safety: free-flight testing must be conducted only in a safe, open, approved area under supervision.

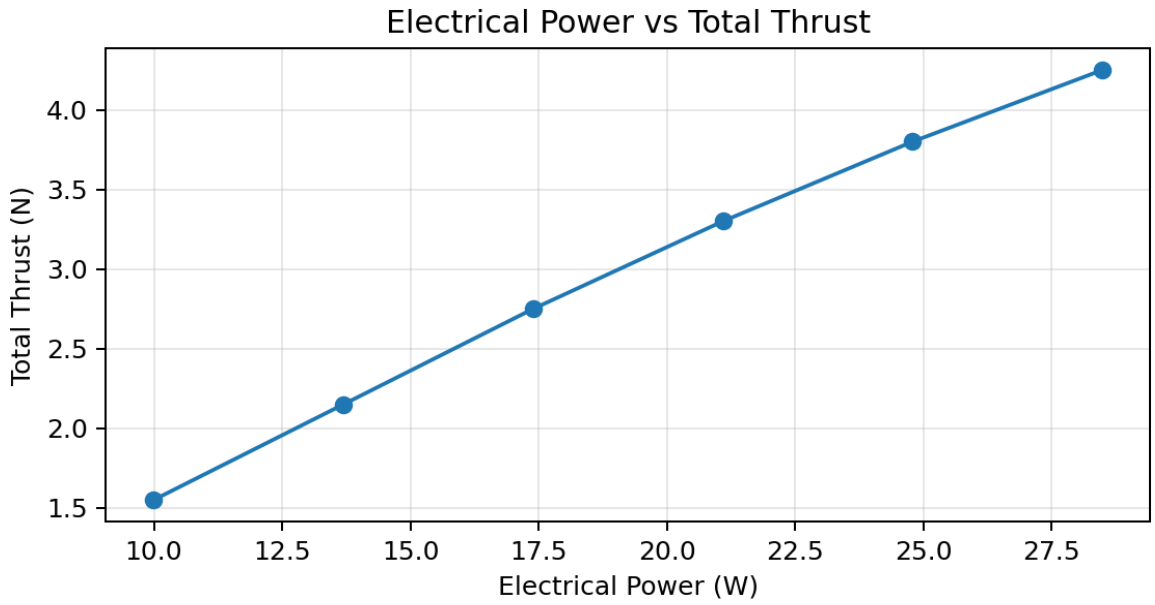
7. EXPERIMENT 1 — ELECTRICAL POWER VS THRUST

Objective: To investigate how electrical power supplied to the motors affects total propeller thrust.

Procedure: Secure the drone/motor assembly to a thrust stand, measure voltage and current, calculate P = VI, record thrust at each setting and repeat where possible.

Trial	V (V)	I (A)	P (W)	Thrust (N)
1	7.4	1.35	9.99	1.55
2	7.4	1.85	13.69	2.15
3	7.4	2.35	17.39	2.75
4	7.4	2.85	21.09	3.30
5	7.4	3.35	24.79	3.80
6	7.4	3.85	28.49	4.25

Sample calculation: P = 7.4 × 2.35 = **17.39 W**; measured thrust = **2.75 N**.



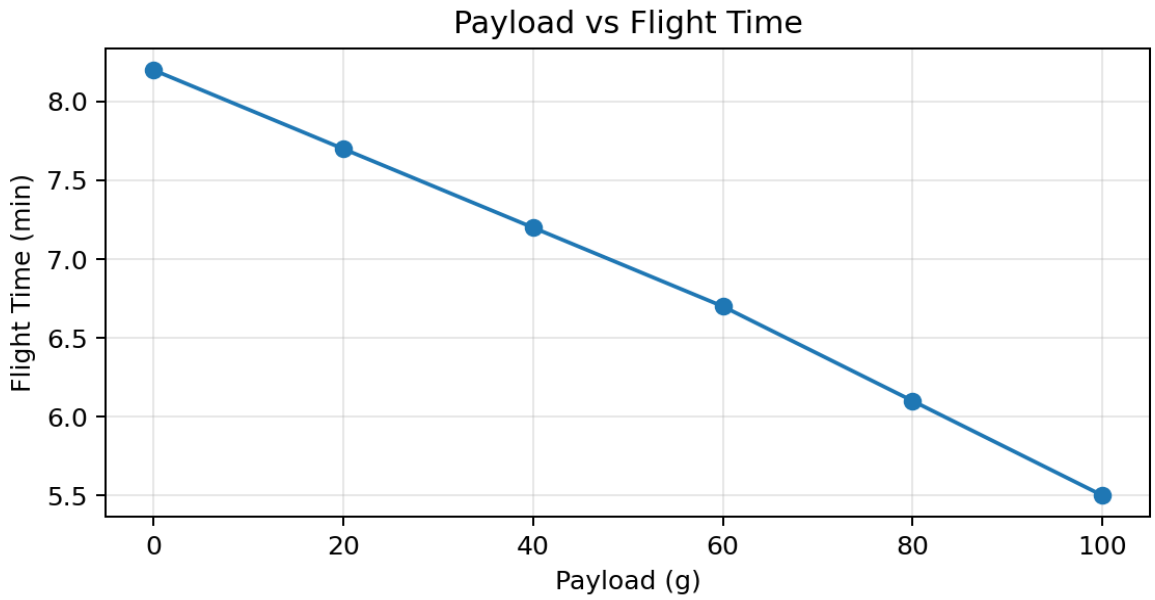
8. EXPERIMENT 2 — PAYLOAD VS FLIGHT TIME

Objective: To investigate how increasing payload affects flight endurance.

Adding payload increases total mass and therefore weight. More thrust is needed to maintain altitude, increasing motor effort and battery consumption.

Payload (g)	Total Mass (g)	Mass (kg)	Weight (N)	Flight Time (min)
0	400	0.400	3.92	8.2
20	420	0.420	4.12	7.7
40	440	0.440	4.31	7.2
60	460	0.460	4.51	6.7
80	480	0.480	4.70	6.1
100	500	0.500	4.90	5.5

Sample calculation: for 80 g payload, m = 0.480 kg; W = 0.480 × 9.8 = **4.704 N**.



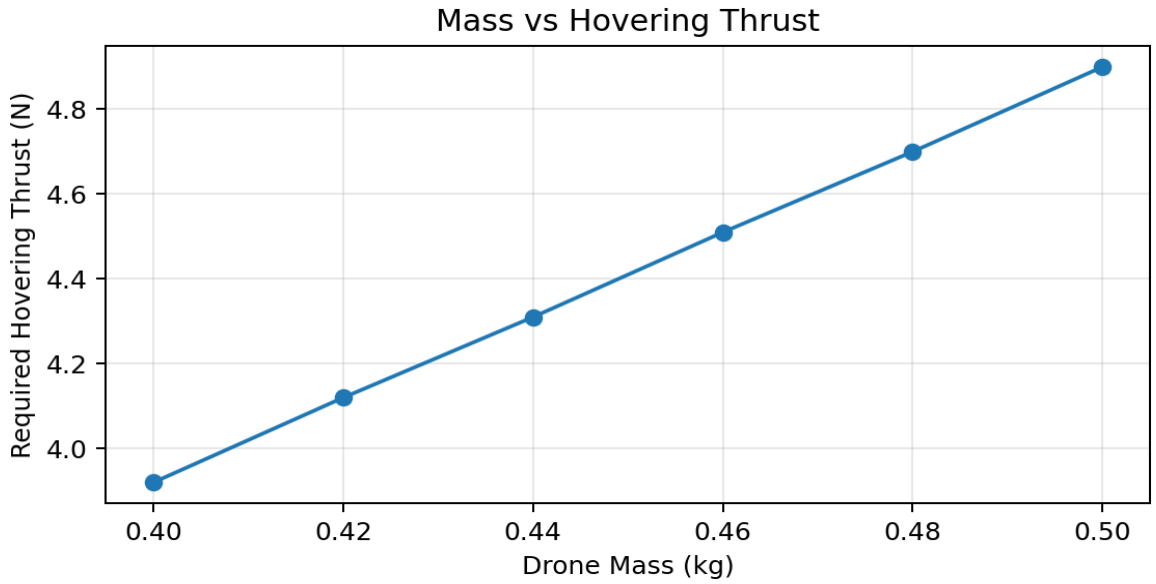
9. EXPERIMENT 3 — MASS VS HOVERING THRUST

Objective: To verify the relationship between total drone mass and minimum thrust required for hovering.

For stable hovering, T = mg. Therefore, required thrust should increase linearly with mass.

Mass (kg)	Weight (N)	Hover Thrust (N)	Observed condition
0.400	3.92	3.92	Stable hover
0.420	4.12	4.12	Stable hover
0.440	4.31	4.31	Stable hover
0.460	4.51	4.51	Stable with higher power
0.480	4.70	4.70	Hover possible
0.500	4.90	4.90	Beyond practical test margin

Measured maximum total thrust for the test configuration: approximately **4.25 N**. For the 400 g drone: TWR = 4.25/3.92 ≈ **1.08**.



10. EXPERIMENT 4 — CENTRE OF GRAVITY AND STABILITY

Objective: To study the effect of moving a fixed payload away from the geometric centre.

For a perpendicular force, $\tau = rF$. As the distance r from the centre increases, the destabilising torque increases.

Payload position	Offset	Stability	Controller correction
Centre	0 cm	Very stable	Low
Slightly forward	2 cm	Stable	Low–moderate
Forward	4 cm	Noticeable tilt	Moderate
Far forward	6 cm	Significant tilt	High
Side-mounted	6 cm	Lateral instability	High

Sample torque calculation: $m = 0.050$ kg $\rightarrow F = 0.050 \times 9.8 = 0.49$ N. At $r = 0.06$ m, $\tau = 0.06 \times 0.49 =$ **0.0294 N·m**.

> The result shows why the battery and other heavy components should be placed near the centre and why the frame should remain symmetrical.

11. CALCULATIONS AND GRAPHICAL ANALYSIS

Hovering thrust for 400 g: $T = mg = 0.400 \times 9.8 =$ **3.92 N**.

Thrust-to-weight ratio: $TWR = 4.25 / 3.92 =$ **1.08**.

Electrical power: $P = VI = 7.4 \times 4 =$ **29.6 W**.

Battery energy: $E \approx V \times Ah = 7.4 \times 1.5 =$ **11.1 Wh**.

Experimental mass–thrust slope: $\Delta T/\Delta m = (4.90 - 3.92)/(0.500 - 0.400) =$ **9.8 N/kg**, closely matching g.

Graphical interpretation

The power–thrust graph shows a positive trend. The payload–flight-time graph shows a decreasing trend. The mass–hover-thrust graph is approximately linear, as predicted by $T = mg$.

Together, the graphs support the hypothesis and show the trade-off between lifting capacity, motor power and endurance.

12. RESULTS AND DISCUSSION

Results

• Increasing electrical power increased generated thrust.

• The power–thrust relationship was positive but not perfectly linear because of motor, electrical and aerodynamic losses.

• Required hovering thrust increased directly with drone mass.

• Experimental and theoretical hovering values followed $T \approx mg$.

• Increasing payload reduced flight time.

• Moving payload away from the centre increased instability and corrective action.

• The measured TWR of about 1.08 showed only a small thrust margin.

Discussion

Electrical energy drives motor rotation; rotating propellers transfer momentum to the air; the reaction force produces thrust; the resultant force determines acceleration; and differential motor speeds create the torque required for controlled orientation.

> Thus mass, thrust, power, battery endurance and stability are interconnected design variables. The investigation supports the hypothesis within the tested operating range.

13. APPLICATIONS OF THE MINI DRONE IN SCHOOL

1. STEM and Physics education: Demonstrates Newton’s laws, equilibrium, torque, rotational motion, electricity, energy and control systems.

2. Physics demonstrations: Students can observe the effect of changing mass, thrust and motor speed rather than treating equations as purely theoretical.

3. Campus mapping: With permission, aerial images can support basic mapping of outdoor areas, sports grounds and vegetation.

4. Infrastructure inspection: A camera drone could inspect rooftops, solar panels or elevated structures that are difficult to access safely.

5. Environmental monitoring: Aerial observations could document tree cover, gardens, waste accumulation or waterlogging over time.

6. Sports analysis: An aerial camera view may support field-use and formation analysis, subject to privacy safeguards.

7. Emergency assessment: After severe weather, a drone may provide initial visual information from inaccessible areas without sending students into unsafe locations.

8. Robotics and coding: A programmable drone introduces sensors, navigation, obstacle avoidance, control algorithms, GPS and computer vision.

Proposed model: Drone → Camera/Sensors → Flight Controller → Data Collection → Ground Station → Teacher/Administrator

All applications require school permission, trained supervision and responsible operation.

14. ADVANTAGES, LIMITATIONS AND SOURCES OF ERROR

Advantages

• Makes Physics concepts observable and measurable.

• Encourages experimental and engineering thinking.

• Combines Physics with electronics, robotics and programming.

• Can support controlled educational and infrastructure applications.

Limitations

• Small batteries provide limited flight duration.

• Payload increases required thrust and energy consumption.

• Wind and airflow can affect stability.

• Motor and propeller efficiency is less than ideal.

• A small TWR margin restricts payload and manoeuvrability.

Sources of error

• Battery voltage changes during testing.

• Current and thrust measurement uncertainty.

• Propeller imbalance and motor heating.

• Air turbulence and vibration.

• Payload placement and stopwatch reaction time.

• Small variations in motor speed and calibration.

15. SAFETY, RESPONSIBLE USE AND FUTURE SCOPE

Safety precautions

• Never touch a rotating propeller.

• Inspect propellers and connections before testing.

• Use a controlled test area and protective guards.

• Keep people away from the flight path and never fly over crowds.

• Handle rechargeable batteries carefully; do not use damaged or swollen cells.

• Begin testing at low power and supervise flight tests.

• Follow applicable aviation and school rules.

Responsible school use

The drone should operate only with permission, within an approved area, and with a trained operator. Cameras should be used only for legitimate educational purposes, respecting privacy and consent. It should never become an unrestricted surveillance tool.

Future scope

• Obstacle detection using distance sensors.

• Autonomous waypoint flight and GPS navigation.

• Computer vision for controlled educational experiments.

• Environmental sensors for temperature, humidity or air quality.

• Improved battery and propeller designs.

• Flight-data logging for altitude, acceleration, current and voltage.

• Comparison of motor–propeller combinations using thrust-per-watt.

16. CONCLUSION

The project successfully connects the design and operation of a miniature quadcopter with fundamental Class XII Physics.

The propellers generate thrust by accelerating air downward, demonstrating Newton's Third Law. Newton's Second Law describes the resulting motion through $T - mg = ma$. For hovering, upward thrust approximately equals weight: $T = mg$.

The experiments showed that increasing motor power increases thrust, increasing payload reduces flight time, and increasing mass increases the thrust required for hovering. The centre-of-gravity experiment showed that an off-centre payload creates additional torque and reduces stability.

The investigation therefore establishes that **mass, thrust, power, energy, torque and stability are interconnected design parameters**. A successful mini drone is not simply a collection of motors and electronics; it is a practical system governed by measurable physical laws.

The project also demonstrates meaningful school applications in STEM education, Physics demonstrations, controlled campus observation, environmental studies and robotics. These applications must always be balanced with safety, privacy and responsible operation.

> "The laws studied in a classroom are not isolated equations; they are the principles that make real technologies work."

Final finding: Stable and useful drone operation depends on maintaining an appropriate relationship between thrust, weight, power, mass distribution and control.

17. BIBLIOGRAPHY AND VIVA-VOCE

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Viva-Voce — Short Answers

Q1. Why does a drone fly? — Its propellers generate upward thrust that balances or exceeds its weight.

Q2. Which Newton's law explains thrust? — Newton's Third Law.

Q3. Condition for hovering? — $T = mg$.

Q4. Why do opposite propellers rotate oppositely? — To reduce net reaction torque.

Q5. What is torque? — The turning effect of a force, $\tau = rF \sin\theta$.

Q6. Why does payload reduce flight time? — More mass requires more thrust and energy.

Q7. Formula for electrical power? — $P = VI$.

Q8. What is TWR? — T/W, the ratio of available thrust to drone weight.

Q9. Why is centre of gravity important? — An off-centre mass creates torque and reduces stability.

Q10. Key finding? — Stable flight depends on thrust, weight, power, mass distribution and control.

END OF PROJECT