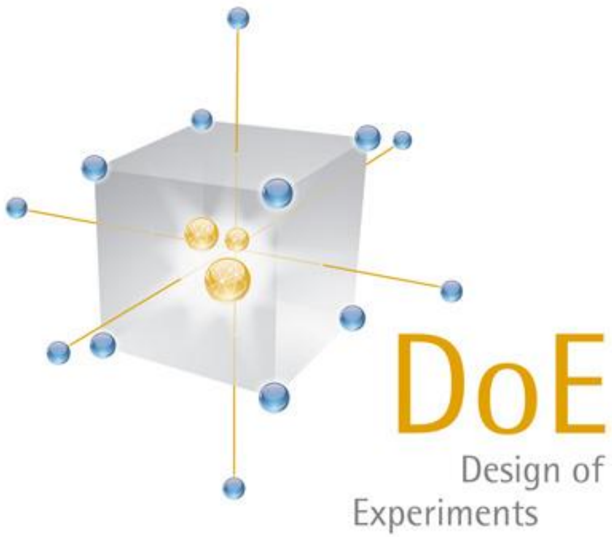


DoE

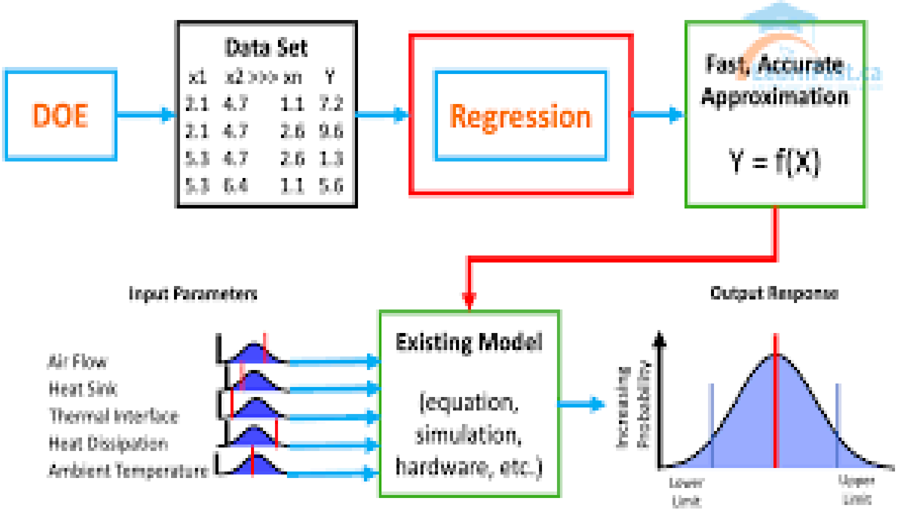
DESIGN OF EXPERIMENTS

MAIN CONTENTS

01 OVERVIEW

CONCEPT & BENEFITS

- **Design of Experiments (DOE)** is a systematic **method** to **plan, conduct, analyze,** and **interpret** experiments
  - → **Explore the relationship** between input factors (independent variables) and output responses (dependent variables)
  - → **Optimize performance** or **improve processes**
- **Design of Experiments (DOE)** helps:
  - → **Understand interactions** between factors
  - → **Optimize** product or process characteristics
  - → **Minimize** the number of experiments while ensuring reliable results

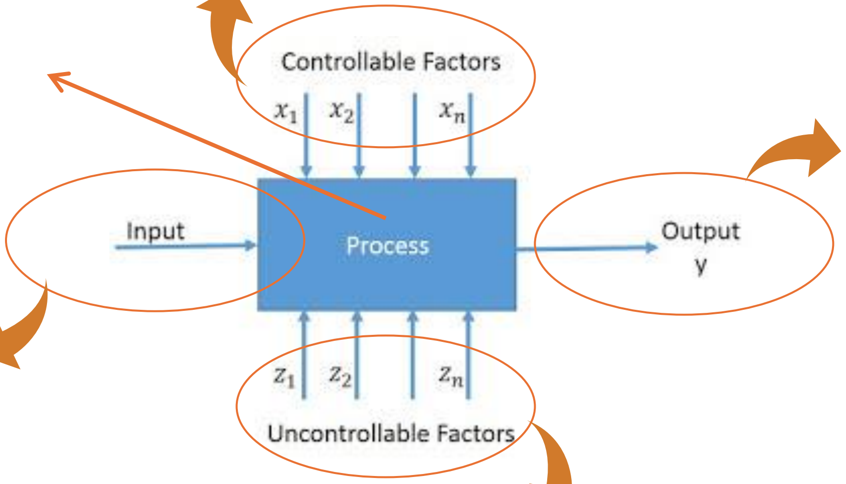


01 OVERVIEW

COMPONENTS

- Factors that **can be controlled** during the experiment
- Include **parameters or conditions** that can be adjusted, such as temperature, pressure, speed, or time,...

The process or system that **transforms the input factors into the output**.



- The **result** or **response** of the process based on the input factors.

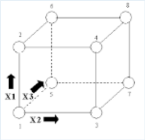
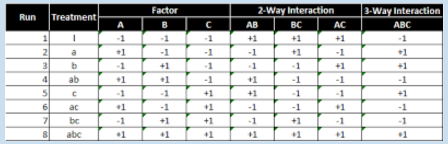
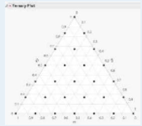
- Factors involves in the process to produce the output

- Factors that **cannot be controlled** or **are difficult to control** during the experiment
- Examples include variations in ambient temperature, humidity, or random errors from equipment.

01 OVERVIEW

METHODS

<table>
<tr><th>Name</th><th>Features</th></tr>
<tr><td>One-Factor-at-a-Time (OFAT)

</td><td>Study each factor individually while keeping other factors constant.
→ Simple but ineffective because it does not account for interactions between factors.</td></tr>
<tr><td>Full Factorial Design

</td><td>Consider all possible combinations of factors and levels.
→ Suitable when the number of factors and levels is small</td></tr>
<tr><td>Fractional Factorial Design

<table>
<tr><th rowspan="2">Run</th><th rowspan="2">Treatment</th><th colspan="3">Factor</th><th colspan="3">2-Way Interaction</th><th>3-Way Interaction</th></tr>
<tr><th>A</th><th>B</th><th>C</th><th>AB</th><th>BC</th><th>AC</th><th>ABC</th></tr>
<tr><td>1</td><td>I</td><td>-1</td><td>-1</td><td>-1</td><td>+1</td><td>+1</td><td>+1</td><td>-1</td></tr>
<tr><td>2</td><td>a</td><td>+1</td><td>-1</td><td>-1</td><td>-1</td><td>+1</td><td>-1</td><td>+1</td></tr>
<tr><td>3</td><td>b</td><td>-1</td><td>+1</td><td>-1</td><td>-1</td><td>-1</td><td>+1</td><td>+1</td></tr>
<tr><td>4</td><td>ab</td><td>+1</td><td>+1</td><td>-1</td><td>+1</td><td>-1</td><td>-1</td><td>-1</td></tr>
<tr><td>5</td><td>c</td><td>-1</td><td>-1</td><td>+1</td><td>+1</td><td>-1</td><td>-1</td><td>+1</td></tr>
<tr><td>6</td><td>ac</td><td>+1</td><td>-1</td><td>+1</td><td>-1</td><td>-1</td><td>+1</td><td>-1</td></tr>
<tr><td>7</td><td>bc</td><td>-1</td><td>+1</td><td>+1</td><td>-1</td><td>+1</td><td>-1</td><td>-1</td></tr>
<tr><td>8</td><td>abc</td><td>+1</td><td>+1</td><td>+1</td><td>+1</td><td>+1</td><td>+1</td><td>+1</td></tr>
</table></td><td>Select only a subset of combinations to reduce the number of experiments.
→ Effective when the number of factors is large, but care must be taken not to miss important interactions</td></tr>
<tr><td>Mixture Design
</td><td>Apply when the output depends on the proportion of components in the mixture</td></tr>
</table>

01 OVERVIEW

STEP FOR IMPLEMENTATION

1. Define Objectives
- Measure the impact of which factors?
- Optimize which dependent variable?

→

2. Select Factors and Levels
- Identify controllable factors and their corresponding levels.

→

3. Choose a Design
- OFAT [One Factor At a Time], full factorial, fractional factorial, or mixture design?

↓

4. Collect Data
- Conduct experiments and record results.

←

5. Analyze Data
- Use software or statistical models to identify influencing factors and interactions

←

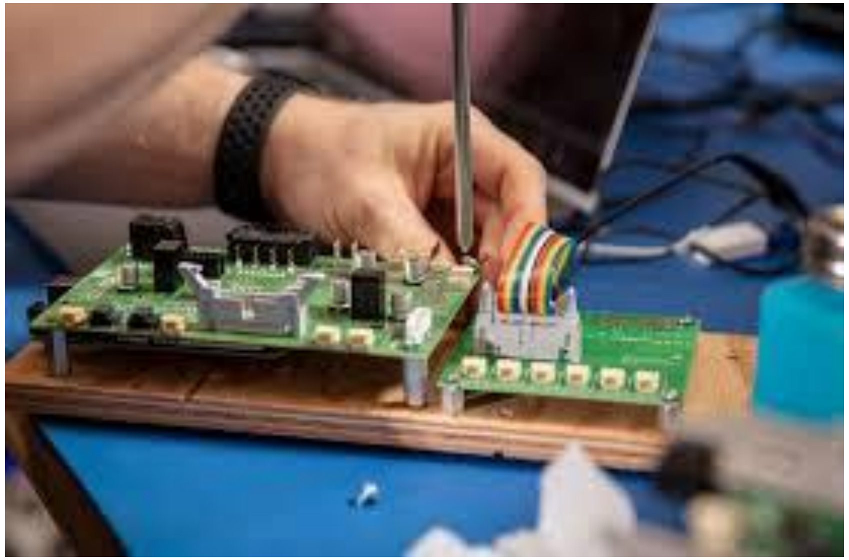
6. Verify
- Perform additional experiments to validate the results

02 APLICATIONS OF DOE IN ELECTRONICS ENGINEERING

Optimizing Electronic Circuit Design

•**Objective**: Improve circuit performance, reduce power consumption, or increase stability.

•**Applying DOE**:
→ Analyze factors such as resistor values, capacitor values, and input current.
→ Conduct experiments at different levels of each factor to identify the optimal combination.



02 APLICATIONS OF DOE IN ELECTRONICS ENGINEERING

Calibration and Testing of Sensors

•**Objective**: Ensure accuracy and sensitivity of sensors under varying environmental conditions.

•**Applying DOE**:
→ Use full factorial or fractional factorial designs to identify which factors most significantly affect sensor performance.

02 APLICATIONS OF DOE IN ELECTRONICS ENGINEERING

Optimizing Wireless and IoT Systems

•**Objective**: Improve signal transmission, save energy, and reduce interference.

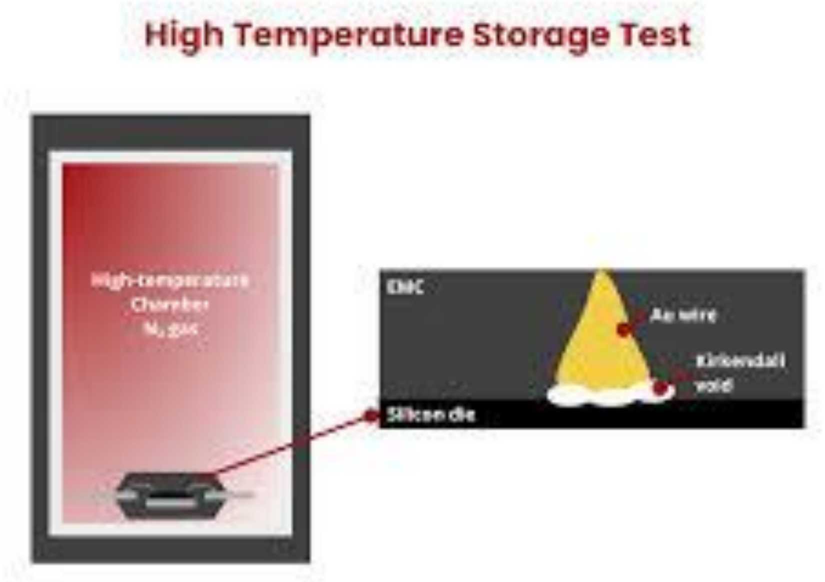
•**Applying DOE**:
→ Analyze the effects of factors such as antenna gain, operating frequency, and surrounding material types.

02 APLICATIONS OF DOE IN ELECTRONICS ENGINEERING

Testing Circuit Reliability and Fault Tolerance

•**Objective**: Ensure the circuit operates stably under harsh conditions.

•**Applying DOE**:
→ Use full factorial design to analyze factors such as temperature, humidity, and supply voltage.



03 DEMONSTRATION EXPERIMENT

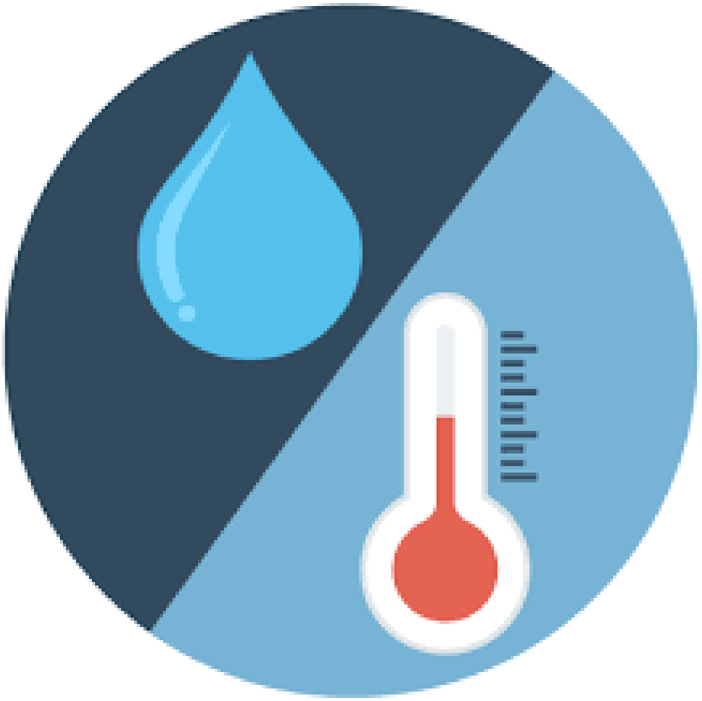
Experiment with ESP32 and DHT11/DHT22 Sensors for Measuring Temperature and Humidity

•**Objective**: Determine the impact of two factors: **voltage supply** and **data reading frequency** on the accuracy of the sensor

•**Experiment Description**:

→ A circuit using ESP32 connected to the DHT11/DHT22 sensor → measure the temperature and humidity of the environment.

→ The sensor readings will be compared with data from a reference device (reference thermometer) to evaluate accuracy.



03 DEMONSTRATION EXPERIMENT

Experiment with ESP32 and DHT11/DHT22 Sensors for Measuring Temperature and Humidity

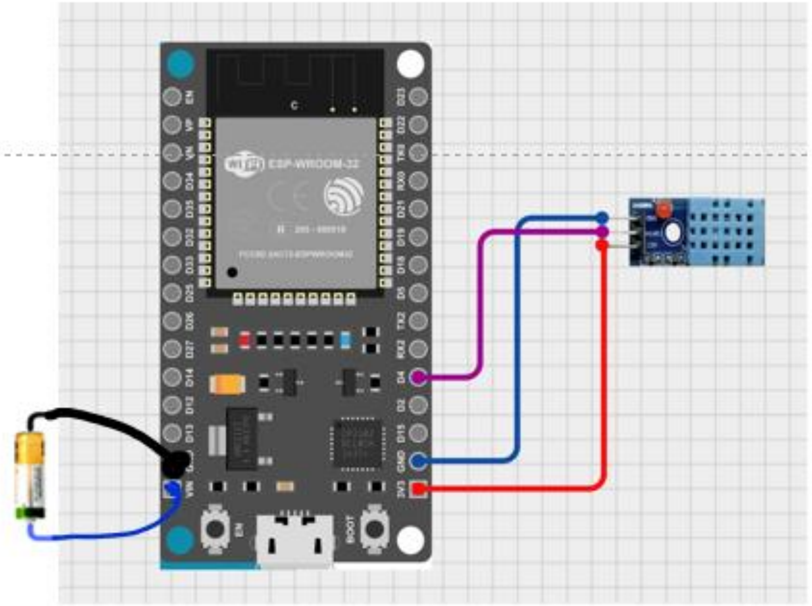
- **Factors**:

→ **Voltage Supply (Voltage):** Two levels: 3.3V and 5V.

→ **Data Reading Frequency (Frequency):** Two levels: one read per second and one read every 5 seconds.

- **Response**:

→ Mean Absolute Error (MAE) between DHT11/DHT22 data and reference device data.



Schematic of Component Connections

03 DEMONSTRATION EXPERIMENT

Experiment with ESP32 and DHT11/DHT22 Sensors for Measuring Temperature and Humidity

- **Experiment Design**: A full factorial design is used to test all combinations of the factors:

Voltage (V)	Reading Frequency (Hz)	MAE (°C and %RH)
3.3V	1 read/second	±0.5°C, ±2% RH
3.3V	1 read every 5 seconds	±0.3°C, ±1.5% RH
5V	1 read/second	±0.7°C, ±3% RH
5V	1 read every 5 seconds	±0.4°C, ±2% RH

03 DEMONSTRATION EXPERIMENT

Experiment with ESP32 and DHT11/DHT22 Sensors for Measuring Temperature and Humidity

- **Conducting the Experiment**

1. Hardware Setup

•Connect the power and signal pins of the DHT11/DHT22 to the ESP32.
•Ensure a pull-up resistor on the signal pin.

2. Software Setup

•Use the DHT library on the Arduino IDE to read data from the sensor.

•Program the ESP32 to read temperature and humidity at the set frequency and log the results.

3. Conduct the Experiment

•Change the voltage supply levels (3.3V or 5V).
•Change the reading frequency (one read per second or one read every 5 seconds).

4. Comparing Results

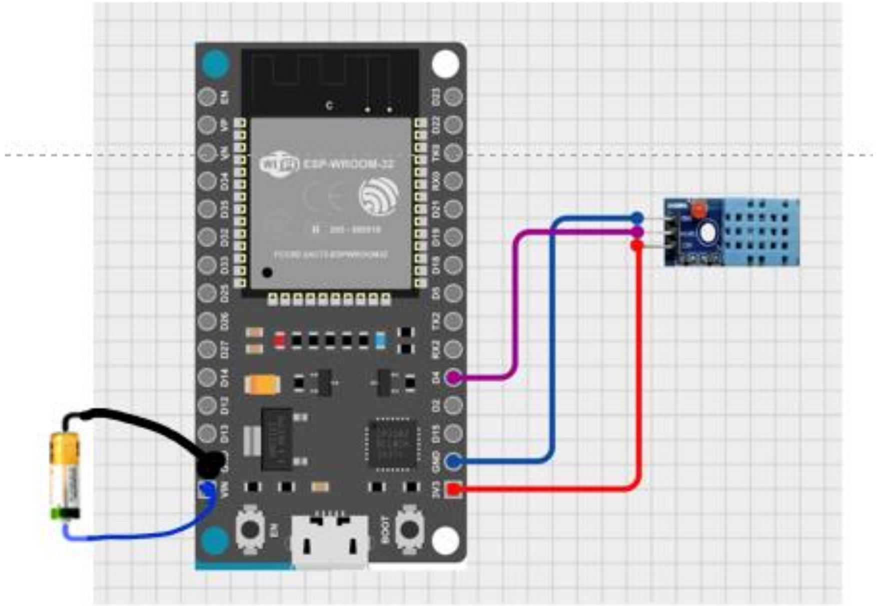
•Calculate the mean absolute error (MAE) between DHT11/DHT22 results and the reference device.

03 DEMONSTRATION EXPERIMENT

Experiment with ESP32 and DHT11/DHT22 Sensors for Measuring Temperature and Humidity

- **Conducting the Experiment**

Link code



Schematic of Component Connections

03 DEMONSTRATION EXPERIMENT

Experiment with ESP32 and DHT11/DHT22 Sensors for Measuring Temperature and Humidity

- **Data Analysis:**

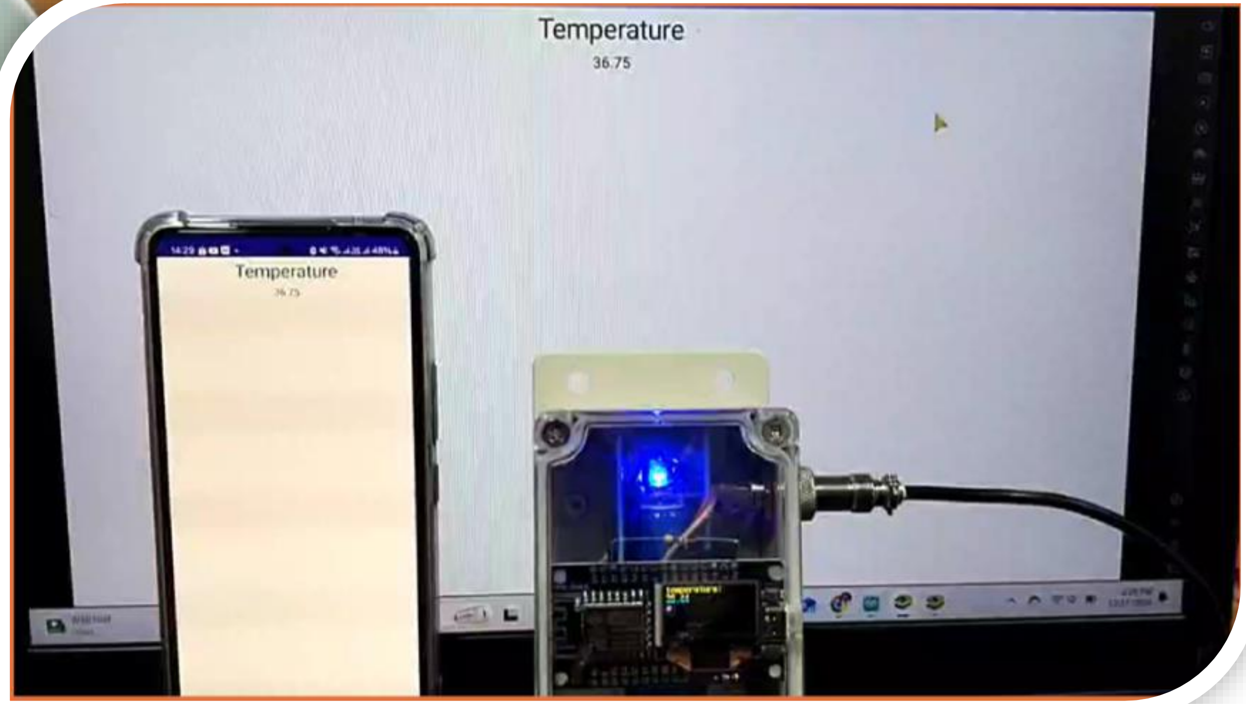
Voltage: Low voltage (3.3V) may lead to higher error due to unstable sensor operation.

Reading Frequency: Too high reading frequency (one read per second) may increase error as the sensor does not have enough time to respond.

Voltage (V)	Reading Frequency (Hz)	MAE (°C and %RH)
3.3V	1 read/second	±0.5°C, ±2% RH
3.3V	1 read every 5 seconds	±0.3°C, ±1.5% RH
5V	1 read/second	±0.7°C, ±3% RH
5V	1 read every 5 seconds	±0.4°C, ±2% RH

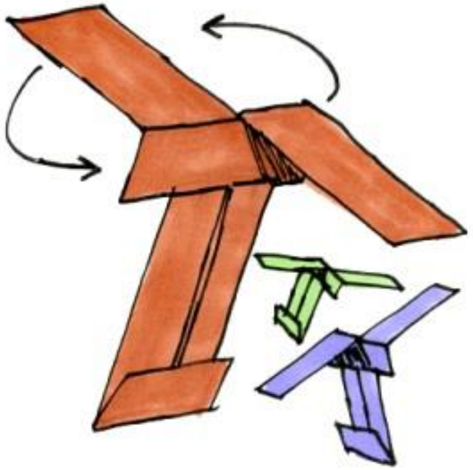
03 DEMONSTRATION EXPERIMENT

03 DEMONSTRATION EXPERIMENT



03 DEMONSTRATION EXPERIMENT

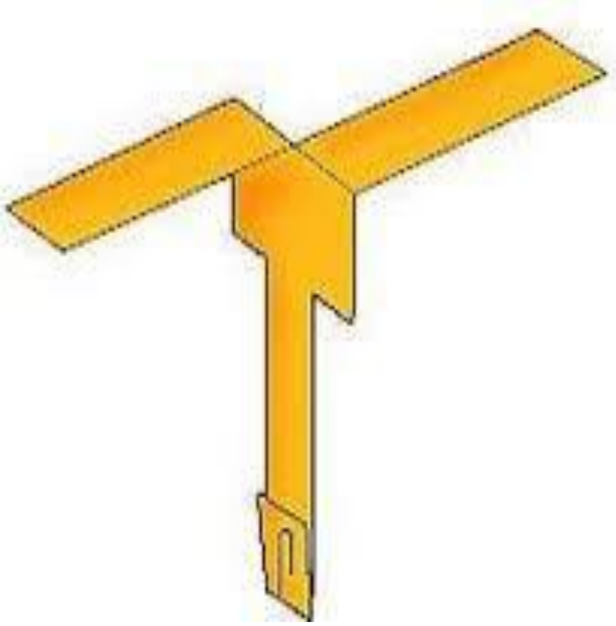
Let design a paper helicopter



03 DEMONSTRATION EXPERIMENT

Objectives

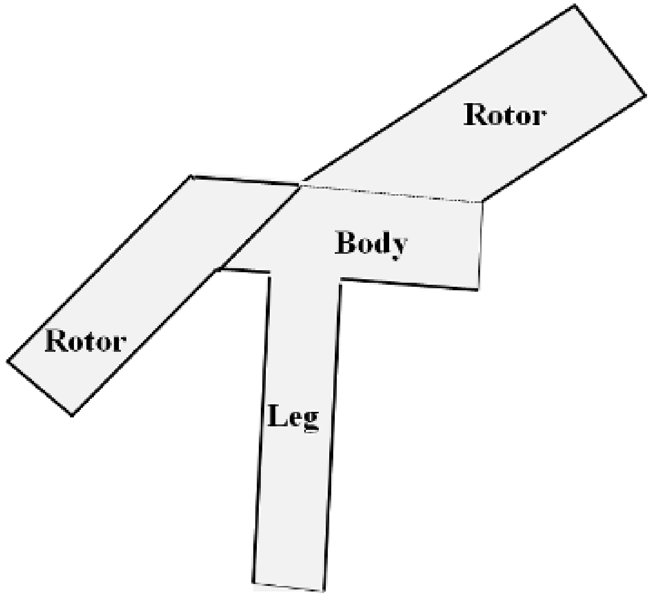
- To increase the flight time: stay in the air for longer time
- To analyze the main effects



03 DEMONSTRATION EXPERIMENT

Influence factors

- ❑ Paper type
- ❑ Rotor length
- ❑ Leg length
- ❑ Leg width
- ❑ Number of clips
- ❑ Wing shapes



03 DEMONSTRATION EXPERIMENT

Instruction

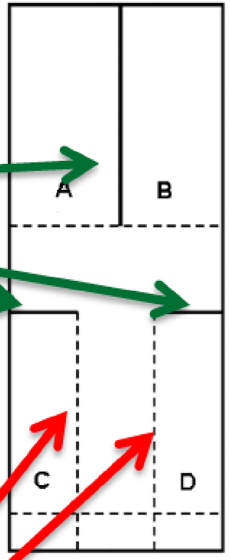
Making your paper helicopter:

Materials:

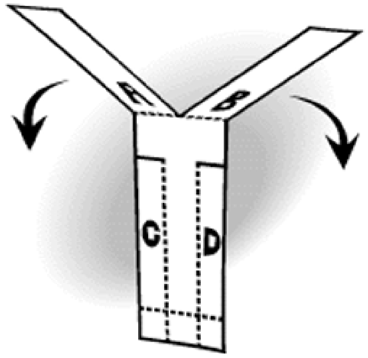
- One paper helicopter template
- 2-3 paper clips
- Scissors

1) The paper has three rectangles. Each rectagle will make a helicopter.

2) First cut the solid lines on the paper given to you. Do not cut the dotted lines.
    - Cut around the border
    - Cut the three places that the arrows point



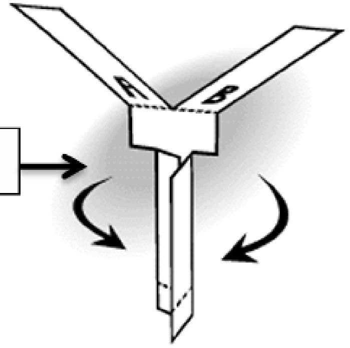
3) Fold A toward you and B away from you so that it makes a T shape



The flaps are the propellers

4) Next fold Section C and Section D along the dotted lines to make a tail.

The tail is where you hold it

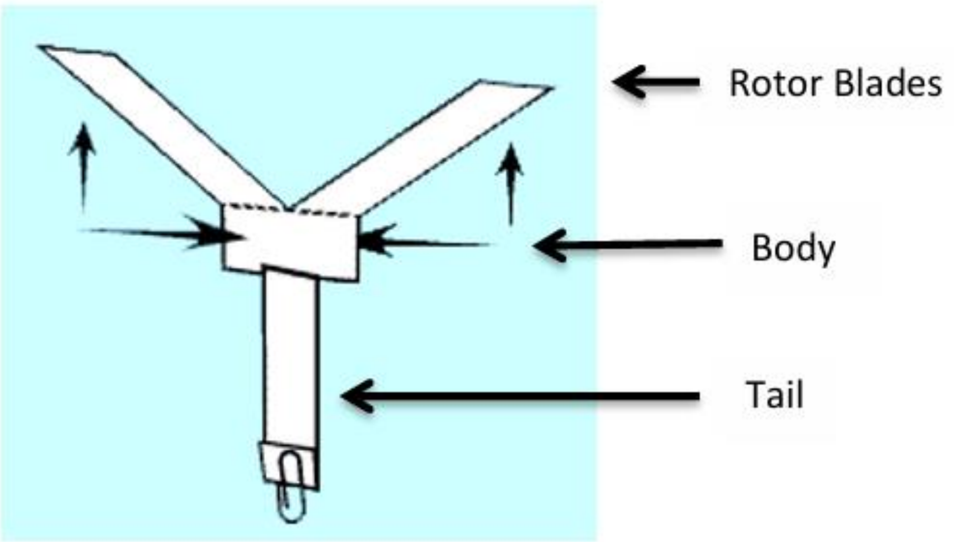


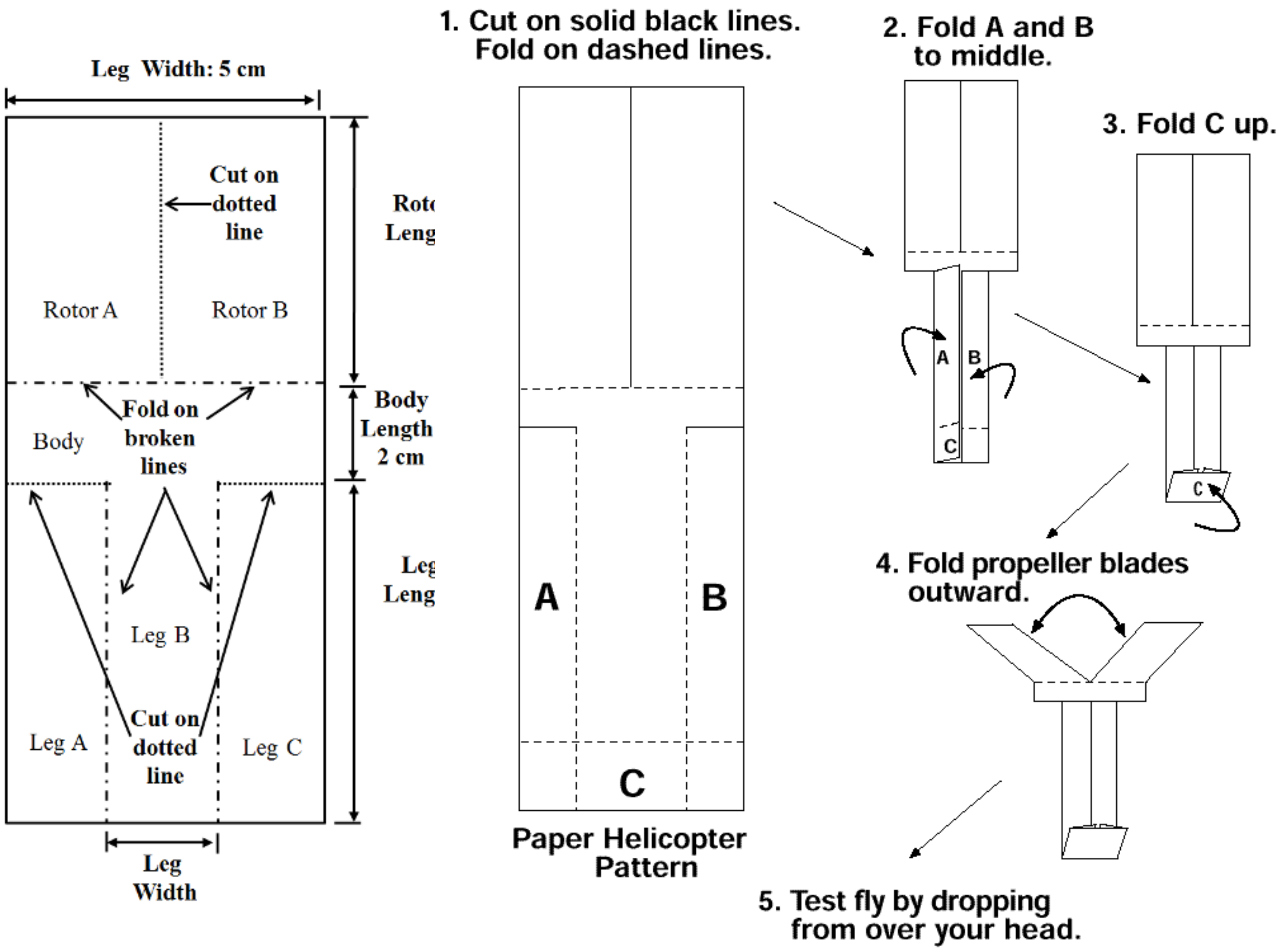
5) Lastly, Fold the bottom up and use a paperclip to hold it in place.

03 DEMONSTRATION EXPERIMENT

Instruction

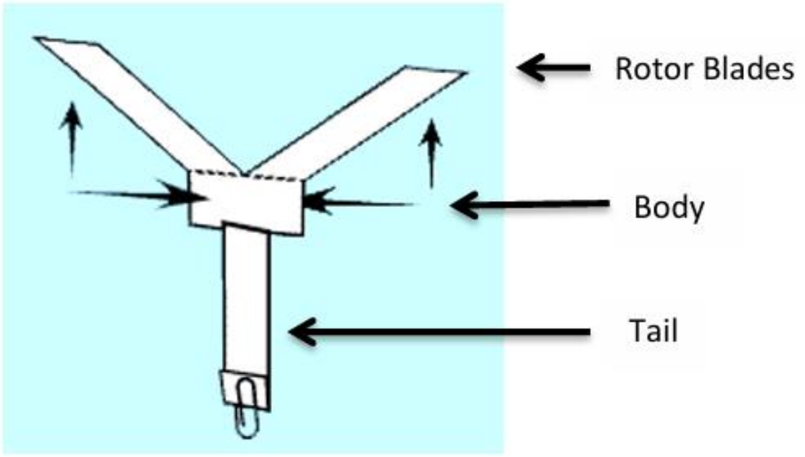
Making your paper helicopter:

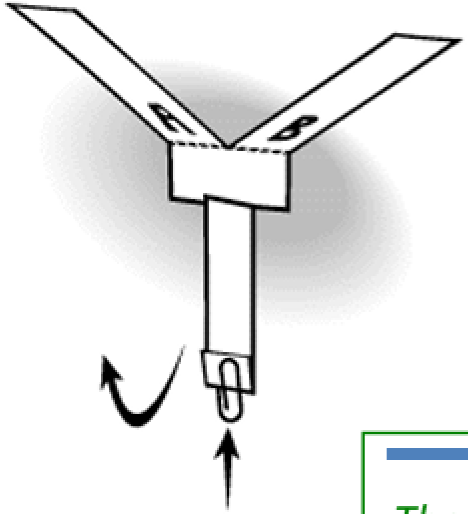




03 DEMONSTRATION EXPERIMENT

Instruction





Now, test it for the first time.
Hold it up as high as you can and drop it!
What do you see?
Now use the back of the page to do an experiment.

The Goal: Longest Hover Time

Ask: What effects hover time?
Imagine: Length and width of the parts effect flight
Plan: Change only one width or length
Create: Make a helicopter with only one change
Improve: Test my prototype and try other variables

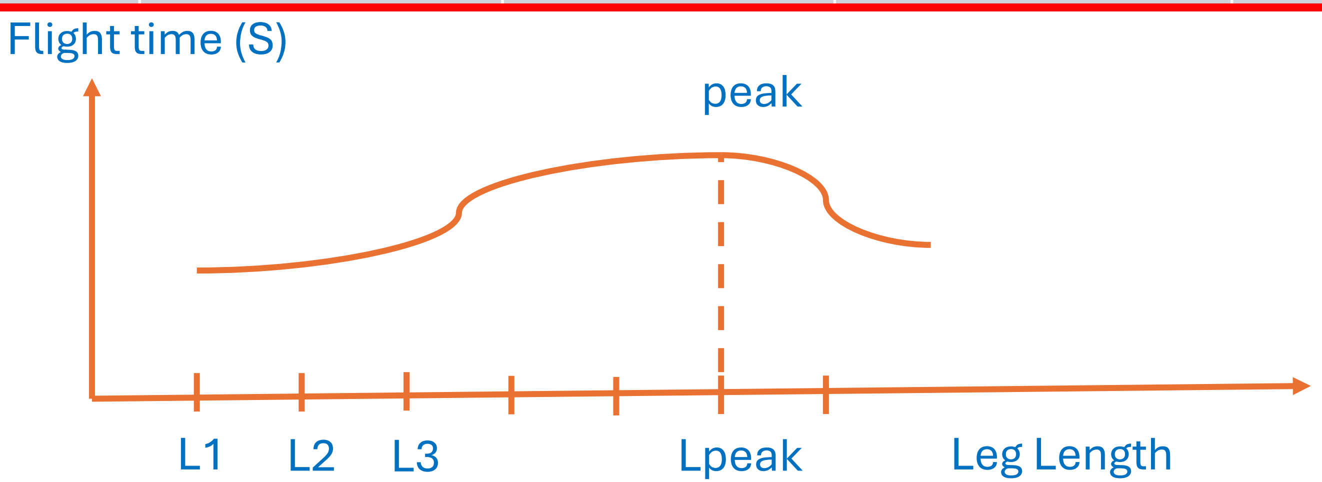
What can be Changed?

Rotor blade length	*Rotor blade width*
Body width	*Body length*
Tail length	*Tail width*
Weight	

03 DEMONSTRATION EXPERIMENT

Experiment Results

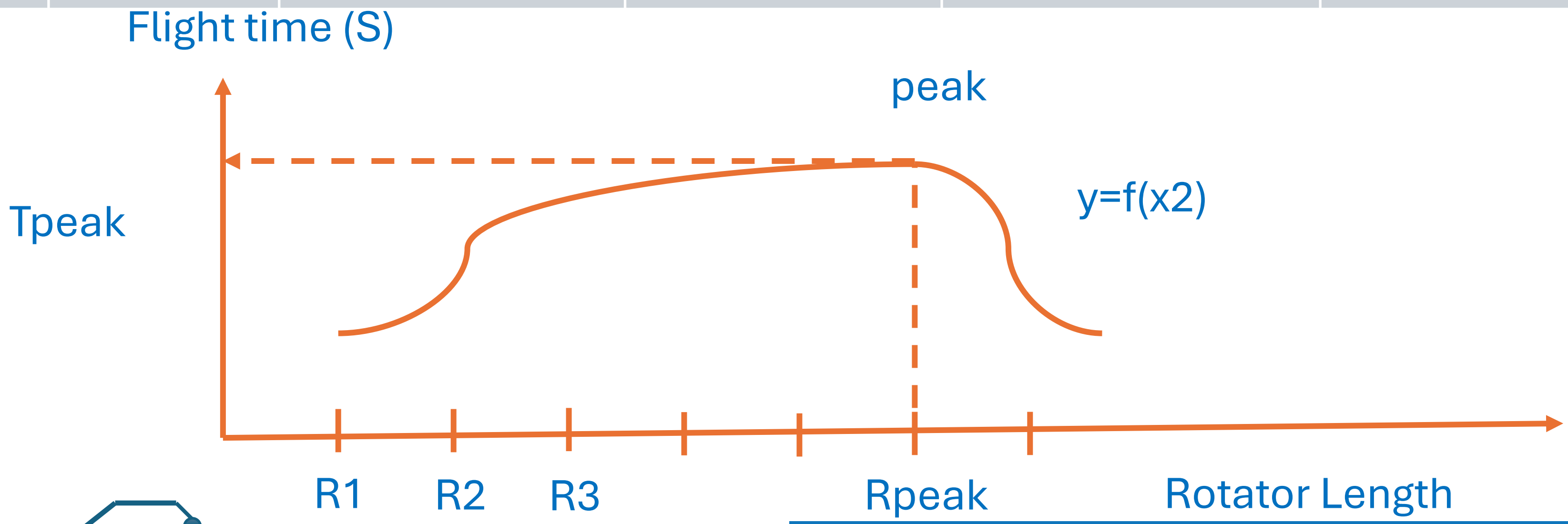
No.	Rotor Length	Leg Length	Leg Width	Paper Clip On	Flight time (second)
1	R1	L1	W1	Yes	?
2	R1	L2	W1	Yes	?
3	R1	L3	W1	Yes	?



03 DEMONSTRATION EXPERIMENT

Experiment Results

No.	Rotor Length	Leg Length	Leg Width	Paper Clip On	Flight time (second)
5	R2	Lpeak	W1	Yes	?
6	R3	Lpeak	W1	Yes	?
7	R4	Lpeak	W1	Yes	?



THANK YOU