1. Problem Identification

The natural beauty and aerodynamic capability of butterfly wings have inspired innovations in robotics, art, and wearable technology. However, replicating their elegance and functionality in a technological product remains a challenge. The main problem lies in:

- Mimicking **natural wing motion** accurately
- Incorporating **aesthetic appeal** with **mechanical functionality**
- Creating a **controllable, programmable model** that reacts to user input or environmental conditions

2. Objective

To design and develop a **mechanically animated butterfly** prototype, called *"Marvel Butterfly"*, with enchanting wings that:

- Flap realistically using servo/micro motors
- React to sensors (light/sound/motion)
- Can be used for education, décor, or artistic installations

3. Scope of the Project

- Design lightweight, colorful butterfly wings
- Integrate actuators for wing movement
- Use a microcontroller (e.g., Arduino) for control
- Include interaction features (sound/light sensors or remote control)
- Provide aesthetic appeal through LEDs or painted wings

4. Requirements

Hardware:

- Arduino Nano/Uno
- Servo motors/micro motors
- Lightweight wing materials (plastic, fabric, or paper)

- Ultrasonic/Light/Sound sensors
- LED strips (optional)
- Battery and power supply

Software:

- Arduino IDE
- Embedded C/C++ for control logic

5. Constraints

- Power efficiency to support mobile use
- Lightweight structure to allow free wing movement
- Compact design resembling a real butterfly
- Limited torque must be handled by small motors

6. Methodology

1. Study natural butterfly wing mechanics
2. Design mechanical structure using CAD or sketches
3. Choose appropriate actuators and sensors
4. Develop embedded code for wing control and sensor response
5. Assemble the prototype and test the flapping mechanism
6. Add enchantment features (e.g., glowing wings, sound)
7. Conduct final testing and validation.

7. Expected Outcomes

- A visually enchanting butterfly with programmable wing movement
- Realistic wing-flapping that mimics butterfly behavior
- Interactive responses based on environmental input (light/sound)

8. Risk Management

- **Wing imbalance** – ensure symmetry and test materials
- **Motor overheating** – implement proper duty cycles and cooling
- **Power drain** – use sleep modes and sensor-based activation

9. Applications

- STEM learning kits
- Decorative art for exhibitions
- Bio-inspired robotics
- Children’s interactive toys