MECHANICAL DESIGN OF A SELF-BALANCING ROBOT

Manual 2

Mechanical design is **50% of success**.
Even perfect code cannot balance a badly designed robot.

This manual gives you ALL the mechanical rules.

The Golden Rule: High → Stable? No! Low → Stable

A self-balancing robot is an **inverted pendulum**.
Its stability is determined by:

$$\text{Stability} = \frac{\text{Height of center of gravity}}{\text{Wheelbase}}$$

- High center of gravity → falls FAST → HARD to control
- Low center of gravity → falls slowly → EASY to control

📌 **Beginner rule:**
Place **battery at the bottom**.
Place MPU6050 **near the center**, not at top.

Ideal Robot Dimensions

Recommended dimensions for best balancing:

- Height: **15–20 cm**
- Width (wheel-to-wheel): **12–16 cm**
- Wheel diameter: **6–10 cm**
- Body thickness: **6–8 cm**

Why?

- Too tall → unstable
- Too small → vibrations
- Too heavy → motors struggle
- Too light → jitter and overshoot

Wheel Selection

Wheels are CRITICAL.
Wrong wheels = impossible to balance.

Recommended:

✓ Rubber wheels
✓ 65mm or 80mm wheels
✓ Good friction
✓ Lightweight
✓ Straight (not wobbly)

Avoid:

❌ Hard plastic wheels
❌ Dirty/torn tires
❌ Very large wheels (>10cm)
❌ Very small wheels (<5cm)

Why?

- Big wheels → more inertia → slow correction
- Small wheels → too twitchy
- Low friction → slipping
- Heavy wheels → slow acceleration

Motor Selection

Even with L293D (low power), robot can balance **IF mechanics are good**.

Minimum Motor Specs:

- **6V or 12V DC gear motor**
- Speed: **150–300 RPM**
- Torque: **1–2 kg·cm**
- Shaft: **6mm D-shaft** ideally

Why torque matters:

Robot must quickly move wheels to correct tilt.
Low torque motors → slow → robot falls.

Why speed matters:

Too slow (<100 RPM) → can't catch fall
Too fast (>500 RPM) → jerky, overly sensitive

Weight Placement

The best design:

- **Battery at lowest position** → for stability
- **Motors at bottom** → unavoidable
- **UNO on middle**
- **MPU6050 exactly at center of robot**
- **Wires short and neat**

Why MPU must be at center?

Because the robot rotates around its **center of mass**.
If MPU is off-center → angle readings include extra vibration and linear acceleration errors.

Chassis Material

Best options:

✔ Acrylic sheet (4–5 mm)
✔ PVC foam board
✔ Laser-cut plywood
✔ 3D printed PLA

Worst:

❌ Thick metal (too heavy)
❌ Cardboard (flexes and vibrates)

Chassis Shape

Simple rectangle works best.

Dimensions like:

```
15 cm height
10 cm width
8 cm depth
```

Do NOT build complex shapes.
Balancing robots work best with:

- Balanced weight
- Symmetry
- Vertical frames

Vibration Reduction (VERY IMPORTANT)

Vibration will destroy your readings.

How to reduce:

- Tighten all screws
- Use rubber grommets for wheels
- Ensure wheels do not wobble
- Mount MPU on foam or tape (not directly screwed)
- Avoid long wires
- Balance left and right weights equally

Wheelbase Width (Very Important)

Your robot should NOT be too narrow.

Ideal wheelbase:

12–16 cm between wheels.

Why?

- Too narrow → robot shakes left/right
- Too wide → unnecessary weight and difficulty turning

Summary of Mechanical Rules

Here is your entire mechanical checklist:

✔ Good wheels (65–80 mm rubber)

✔ Motors around 200 RPM, 1–2 kg cm torque

✔ Battery at bottom

✔ MPU at center

✔ **Robot height ≈ 15–20 cm**

✔ **Tight, symmetrical chassis**

✔ **Low center of gravity**

✔ **Medium wheelbase (12–16 cm)**

If you follow all these rules → the robot will balance smoothly.

If you violate them → robot will never balance, no matter the code.
