MuJoCo Joint Parameter Calculation

A **friendly, step-by-step** guide to compute the core joint parameters needed for realistic MuJoCo simulations:

- **Armature**: Rotational inertia seen at the joint.
- **Friction Loss**: Damping coefficient that resists motion.
- **Actuator Range**: Maximum torque or force your motor and gearbox can apply.
- **Joint Limits**: The physical angle (or distance) you allow the joint to travel.
- **PD Gains (kp, kv)**: Proportional and derivative gains for MuJoCo's built-in position actuator.

Key Terms Sources

Parameter	**Meaning**	**Source**
		armature
Rotational inertia (kg·m^2)	CAD inertia tool frictionloss	Viscous damping (N·m·s/rad)
No-load torque vs. speed test actuator range	Torque limits (continuous	peak) (N·m)
Motor	gearbox datasheet joint limits	Mechanical angle or distance bounds
CAD stops or measurement kp, kv	PD gains for smooth position control	Desired rise time + armature

How to Calculate Each Parameter

1. Armature (Rotational Inertia)

1. Export the inertia tensor I_{COM} from your CAD model (about the link's COM).
2. Define the joint axis as a unit vector $\mathbf{a}$.
3. Compute motor-side inertia:
$$I_{motor} = \mathbf{a}^T I_{COM} \mathbf{a}.$$
4. If you have a gearbox ratio r (output:motor):
$$I_{joint} = I_{motor} \times r^2.$$

2. Friction Loss (Damping)

1. Run the motor+gear unloaded at constant speed ω (rad/s).
2. Measure steady torque T_f needed to hold speed.
3. Calculate:
$$b = \frac{T_f}{\omega} \quad (\mathrm{N \cdot m \cdot s/rad}).$$

3. Actuator Range (Torque Limits)

Continuous torque τ_{rated}:

`actuatorfrcrange="-\tau_{rated} \tau_{rated}"`

Peak torque τ_{peak}:

`actuatorfrcrange="-\tau_{peak} \tau_{peak}"`

4. Joint Limits (Range)

In XML:

Radians or meters, derived from CAD or physical testing.

5. PD Gains (kp, kv)

Design for rise time t_r and critical damping ():

$$\omega_n = \frac{1.8}{t_r}, 6pt]k_p \qquad = I_{joint}\omega_n^2, 6pt]k_v = 2I_{joint}\omega_n.$$

Example: With $I_{joint} = 0.0435$ kg·m^2, $t_r = 0.2$ s, $\omega_n = 9$ rad/s:

$$k_p \approx 3.5, \ k_v \qquad \approx 0.78.$$

Quick MuJoCo Integration

In your block:

Replace with your values.

Tips Best Practices

- Export inertia from a high-resolution mesh for accuracy.
- Average torque readings for smoother friction estimates.
- Start with formulas for PD gains, then fine-tune in simulation.

This README is your quick-reference cheat-sheet. For full derivations and examples, see `docs/Calculating`$_M uJoCo_J oint_{PD}$