Task 3

In robotic systems, the behavior can differ significantly from that of real objects due to the simplifications made in modeling, sensor and actuator delays, and the idealized nature of control algorithms. Real-world objects are governed by complex physical properties, including nonlinearities in elasticity, friction, and material resistance, which are difficult to capture in a robotic system. In contrast, robotic systems are typically modeled using linear control algorithms (such as impedance control) that do not account for these nonlinear material behaviors, leading to discrepancies in their responses when interacting with the environment.

A major cause of undesired oscillations or sustained bouncing in robotic systems is insufficient damping. The system is said to be underdamped when the damping coefficient bbb is too small, causing the system to fail to dissipate the energy introduced by external forces. This results in the system oscillating around the desired equilibrium point. The equation of motion for the system is given by:

$$m\ddot{z} + b\dot{z} + kz = F_{sensor}$$

Where **m** is the mass, **b** is the damping coefficient, **k** is the spring constant, and $\mathbf{F_{sensor}}$ is the external force applied to the object. When the damping **b** is too small, the system will oscillate and take longer to settle into its equilibrium position.

Another contributor to bouncing is high stiffness, represented by the spring constant **k**. The spring force is given by:

$$F_{spring} = -kz$$

Feedback delay is another significant factor. In robotic systems, the control algorithm takes time to detect and react to changes in position or force. This delay causes the system to apply corrections too late, which can result in overcorrection, thereby causing oscillations. Furthermore, numerical instabilities in the simulation can contribute to this behavior. For example, when using Euler's method for numerical integration, large time steps Δt can lead to inaccurate updates in position and velocity, resulting in unstable oscillations.

To summarize, the key cause of sustained bouncing in robotic systems lies in the lack of proper damping, high stiffness values, and feedback delays. Real-world objects, on the other hand, exhibit natural damping due to their complex material properties, which automatically suppress oscillations. By adjusting damping parameters and improving feedback control, robotic systems can be made to behave more similarly to real-world objects, avoiding persistent bouncing.