Homework 24 – Dynamics & computation/simulation MIPSI project. (Chapters 22, 29, 30)

The objective of a **MIPSI** is to ask and answer a question for a system of your own choosing.
The **2-3** page report **clearly communicates** its question, technical information, and answer.[1]
As necessary, attach an appendix with all supporting sketches, calculations and any computer files (symbolic/numeric).

- **Question** Ask an interesting dynamics question e.g., in biology (exercise, muscle activation, nature), mechanics (robot, vehicle, boat, swing, home appliance, pump, motor), or aerospace (aircraft, helicopter, balloon).
- **Model.** Draw **color**-coded sketches (e.g., **green** for ground). Use physical insight to determine the relevant system components and simplify the model. Report modeling assumptions/approximations for:

Physical objects	(particles, rigid bodies, flexible beams, etc.)
Connections/constraints	(ideal pin joint, ball-and-socket, revolute motor, rolling, closed-chains, bearings)
Actuation/forces	(gravity, friction, springs/dampers, muscles, aerodynamic forces, elasticity)

  Type a **short** problem statement starting with "The figure shows" and then describe all objects. Ensure all physical objects are labeled on sketches and described in text (e.g., airplane A, book B, point P, etc).
- **Identifiers (symbols and values).** Describe all relevant **unit vectors** with text. Unit vectors appear in sketches and 2 of the 3 unit vectors in each set suffice (e.g., if you draw $\hat{\mathbf{n}}_x$ and $\hat{\mathbf{n}}_y$, no need to draw $\hat{\mathbf{n}}_z$).
  Include a table of relevant scalar identifiers (e.g., constants and variables) with four columns, e.g., as:

Description	Symbol	Type	Value
Mass of baseball	m	Constant	0.14 kg
Earth's gravitational acceleration	g	Constant	9.8 $\frac{\text{m}}{\text{s}^2}$
Upward position of baseball	y	Variable	

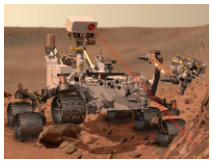
  Estimate numerical values for constants.
  Variables usually appear in your sketches.
- **Physics.** Form equations relating the identifiers to system behavior. **Draw FBDs** (free-body diagrams) and provide MG road-maps or summarize your implementation of Lagrange/Kane's method.

  Attach long calculations and MATLAB®/**M**otion**G**enesis codes in an appendix, e.g., to:
  - Determine the mass of particles/bodies and moments/products of inertia of rigid bodies.
  - Calculate rotation matrices, angular velocities, and angular accelerations.
  - Calculate positions, velocities, and accelerations (e.g., points, particles, and body mass centers).
  - Calculate kinematic constraints (e.g., relationships between generalized coordinates).
  - Calculate/apply relevant contact and distance forces (or torques).
  - Form relevant **equations of motion** (forces and motion).
- **Simplify/Solve.** If helpful, make small angle or linear approximations [e.g., $\sin(\theta) \approx \theta$]. Discuss the process for solving for the unknowns (e.g., by-hand solutions or computer solutions via **M**otion**G**enesis or MATLAB®).
- **Interpret** Answer your question with results easily interpreted by a non-technical person (use words, numbers, plots with descriptive text **adjacent** each plot). **Optional:** Build the physical system, physical demo, video.

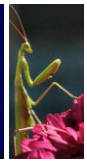
Question
Model
Identifiers
Physics
Simplify & solve
Interpret & design

5%	**Cover-page**: Team **photo** (& names) system **picture**, your **question** and its **answer**.
15%	Detailed modeling assumptions and comprehensible schematics (preferably with photo). Precise description of all physical objects and unit vectors.
10%	Concise accurate tabular description of all **scalar** symbols.
45%	Correct analysis. **Short (2-3 pg.)**, solid report. Appendix of calculations. Correct MG road-map and/or high-level summary of calculations.
15%	Interpret: Relevant text interspersed with relevant plots.
10%	On-schedule. Met with instructor. Technical difficulty, demo/video, interesting problem.

Communicate!




[1] For ideas, see videos at www.MotionGenesis.com ⇒ Textbooks ⇒ Resources or www.YouTube.com.
Public domain CC0 photos (freely used in commercial and private works) are available at www.piqsels.com.

Ideas and previous MIPSI projects

Badminton flight with shuttlecock reversal.	Longitudinal stability of aircraft flight (phugoid mode).
Precession and nutation of spinning gyro .	Trajectory and orientation of a punted football (2D/3D) (effect of air-resistance and initial spin).
Translation and rotation of skateboard on planar curve.	Function of the soleus muscle during calf raise.
Pendulum connected by a revolute joint (with/without viscous friction) to a point moving in horizontal or vertical slot with specified displacement $A\,\sin(\Omega\,t)$.	Tuned oscillation of two particle pendulums (moving in a plane) connected mid-rope by massless rigid rod (analyzed with 3 angles).
Statics/dynamics of equilibrium inclination angle θ of Chair-O-Planes (amusement-ride swing carousel).	Static and dynamic analysis that determines equilibrium inclination angle of amusement-ride swing.
Time-variation of G-force in tea-cup amusement ride.	Dynamics and control of telescope tracking a comet.
Effect of children's pumping frequency on a playground swing's amplitude.	Effect of Earth's spin on a ball dropped from a tower at the equator.
Effect of Earth's spin on a baseball-pitch.	Motion of a pitched curve-ball.
Effect of viscous and aerodynamic damping on a pendulum's amplitude and frequency.	Foucault's pendulum for various locations on Earth.
Bobbing frequency of partially submerged ship, iceberg.	Hip muscle tension for hip flexion.
Flight of a tennis-ball that is connected to a long stretching rubber band that is initially slack.	Spring/mass/damper motion of Tower of terror on passenger acceleration-g (similar to elevator whose cable is cut)
Effect of column stiffness/damping on a single or double-story building in an earthquake.	Effect of tuned damper on the motion of a single-story building in an earthquake.
Dynamics and control of overhead crane.	Input shaping and slewing maneuver for an overhead crane carrying a Boeing aircraft.
Motion of hockey-puck on a spinning playground carousel.	Location of a rider on teacup/other amusement ride.
Effect of deployment of solar panels on spacecraft spin (similar to ice-skater pulling in arms).	Stability of satellite deployment/retrieval from geo-synchronous space-shuttle in Low Earth Orbit.
Satellite orientation control through control-moment gyros.	Particle motion with slight perturbation from geo-synchronous orbit as viewed from Earth or in spacecraft.
Effect on satellite spin-stability from gyros aligned with principal inertia axis.	Dynamics and control of a rocket launch (2D/3D).
Dynamic simulation of the relationship between area traced out by orbiting object and time (Kepler's law).	Optimal orbit transfer (Hohmann orbit transfer).
Muscle activation during a pushup or pullup.	Effect of mass distribution or feet-elevation on required muscle forces during a pushup.
Trajectory of a homerun or stomp-rocket (with and without air-resistance).	Effect of mass distribution or feet-elevation on required muscle forces during a pushup.
Effect of friction and geometry difficulties of a particle sliding on an wire in a vertical plane shaped like an ellipse.	Period of motion of particle sliding on an circular (or elliptical) wire in a vertical plane connected to the circle's center by an ideal spring.
Dynamic simulation of a tippe-top or spun-football that turns upright.	Dynamic simulation of the spin-reversal of a rattleback.
Dynamic simulation of a slipping/rolling bowling ball with or without holes.	Effect of the specified motion associated with kicking a soccer ball (football) on knee reaction forces.
The path painted on a horizontal plane of a rolling sharp-edged disk (wheel).	Dynamics and control of a hula-hoop or "German Wheel".
Dynamics and control of camera tracking a ball in a stadium.	Position, velocity, and acceleration determination from 3 lasers measuring distance, elongation, and elongation-rate.
GPS or other system position and orientation determination of rigid bodies.	Sky-diver before/after parachute deployment or space-jumper with variable gravity/air-density (stratos jump).
Effect of center of mass on frequency of a rocking sailboat.	Effect of gyros on stability and sea-sickness for cruise-ship.
Feed-forward model-based control of SkyCam	Take-off torque and trajectory of XV-15
Dynamics of a golf swing	Feed-forward control of spacecraft with quaternions
Dynamics of active vehicle suspension	Gear train dynamics
Can a ball roll uphill?	Feed-forward model-based control of rolling disk
Aerodynamics of flap-winged aircraft	Rolling ball in vertical tube
Rollover rate of 3-wheeled vehicle	