2.004: MODELING, DYNAMICS, & CONTROL II
Spring Term 2003

Experiment 3: Rod Pendulum: Rigid body dynamics I

Introduction:

We will modeling 2D dynamics of an "extended" rigid body. We will consider a rod shaped pendulum linked to a fixed support by two tethers. The experiment is an exercise to model the kinematics of different points on the rigid body. Again, we will see that geometric constraints, such as the length and the separation of the tether, are important in modifying the dynamics of the system.

Learning Goals:

(1) Measuring and describing the kinematics at different points of a rigid body
(2) Predicting the dynamics of a rigid body
(3) Examining the effect of geometric constrains
(4) Linearizating at equilibrium position and modeling small perturbations
(5) Looking at the modification of natural modes by geometric constrains
(6) Understanding translation versus rotation

Experimental procedures:

A pendulum is constructed by suspending a rod using two light weight tethers. The construction involves four pin joints. For now, we will assume that the joints between the string and the surface and between the string and the pendulum are frictionless. The trajectories of different points on the rod pendulum will be visualized by placing visual markers on them. The separations of the pin joints on the support and the bar pendulum are not necessarily equal. The kinematics of the bar will be recorded and analyzed using a camera system. Image analysis algorithms will be provided to extract the trajectory of the visual markers.
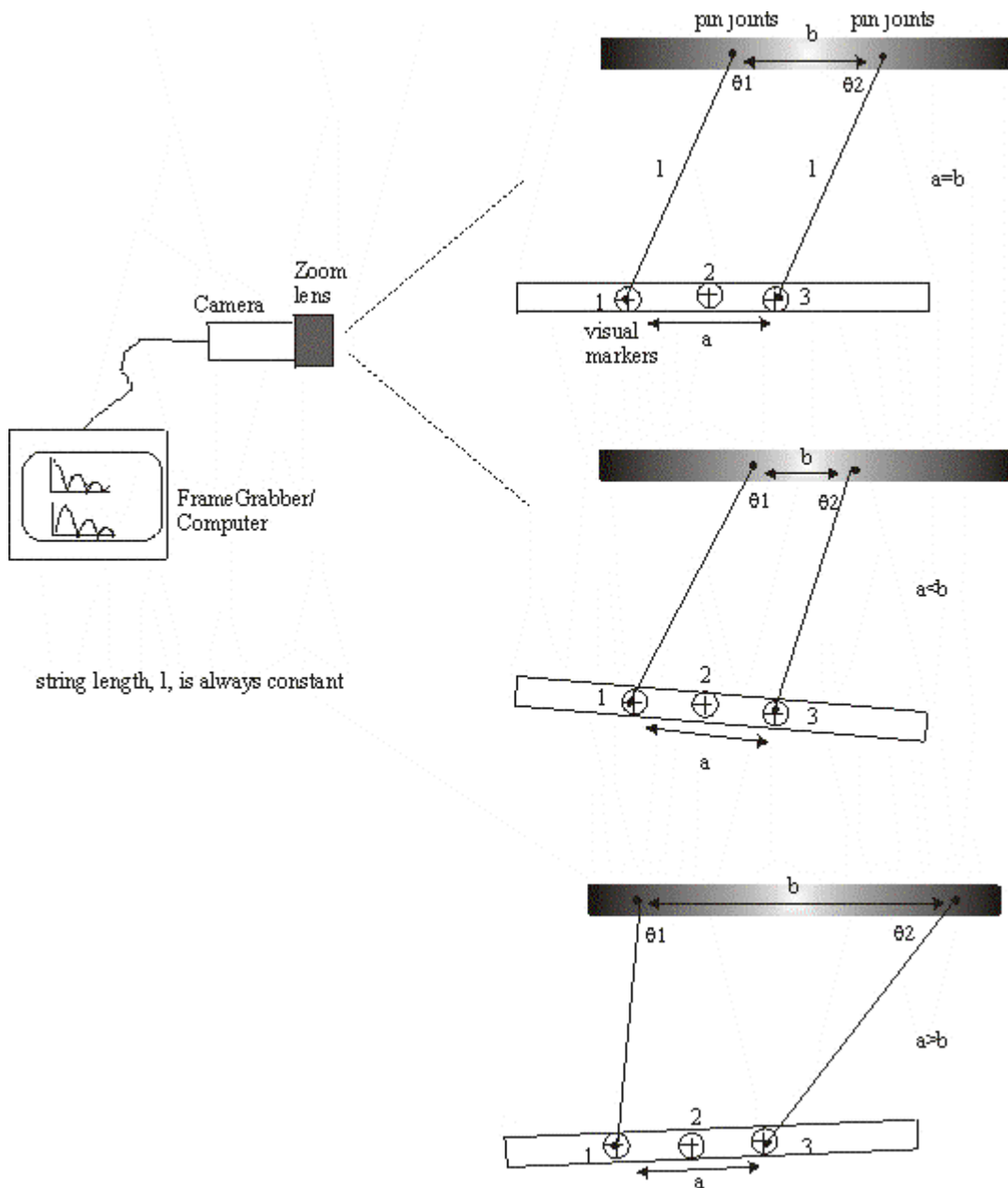
Task 0: Locate the center of mass (CM) of the rod. How would you find it? Place a visual marker at the CM.

Task 1: Set up the bar pendulum such that the a=b. Place marker 1 at the contact point of one tether; marker 2 at the center of mass, and marker 3 at the contact point of another tether.

Measure the motion of the center of mass (marker 2) of the bar pendulum. Set the pendulum swinging by deflecting the bar until the tethers are 15 degrees from vertical. Prepare the camera and record the motion of the pendulum for 5-10 swings.

Analysis:

   (a) How does the trajectories measured compare with the theoretical model?
   (b) Deduce $v_x(t)$, $v_y(t)$, $v_r(t)$, $v_\theta(t)$.
   (c) Deduce $a_x(t)$, $a_y(t)$, $a_r(t)$, $a_\theta(t)$.
   (d) Calculate the forces $F_x(t)$, $F_y(t)$ at the center of mass.
   (e) From kinematics, theoretically deduce the motion (position and velocities) of markers 1 or 3 and compare with experiment.
   (f) Deduce the natural frequency of the pendulum and compare with experiment.

Task 2: Set up the bar pendulum such that the a<b. Repeat the experiment and analysis as in Task 1.

Task 3: If you have time, set up the bar pendulum such that the b<a.

Report content:

   (1) Record your results from all tasks.
   (2) Please consider four additional questions related to this experiment.

         (a) Is the linear momentum conserve in these systems if one can ignore fiction?
         (b) In which case(s) is(are) the bar pendulum rotating?
         (c) Quantify the torque exerted on this system if there are any?
         (d) Is the angular momentum conserve in these systems if one can ignore fiction?