

**Problem Set No. 2**

Out: Wednesday, September 22, 2004

Due: Wednesday, September 29, 2004 at the beginning of class

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**Problem 1**

Show that for any  $3 \times 3$  skew-symmetric matrix  $A$ , there exists a 3-dimensional vector  $\omega$  such that for any three-dimensional vector  $x$ ,

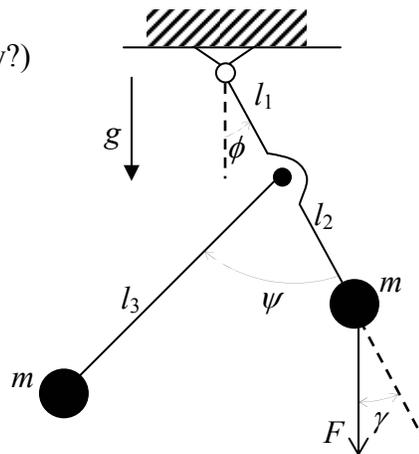
$$Ax = \omega \times x.$$

**Problem 2**

Consider the coupled pendula shown in the figure below. Both rods are massless, with point masses  $m$  attached to their ends. Both joints shown in the figure are frictionless. The external force  $F$  encloses a fixed angle  $\gamma$  with the line of the pendulum shown. The masses never collide. The constant of gravity is  $g$ .

Questions:

- Identify the constraints.
- Determine the number of degrees of freedom.
- Find the equations of motion for  $\phi$  and  $\psi$ .
- Find the constraint forces.
- Is the system conservative? (Why?)



### Problem 3

Determine the angular velocity of a cone rolling on the  $XY$ -plane without slipping, as shown.

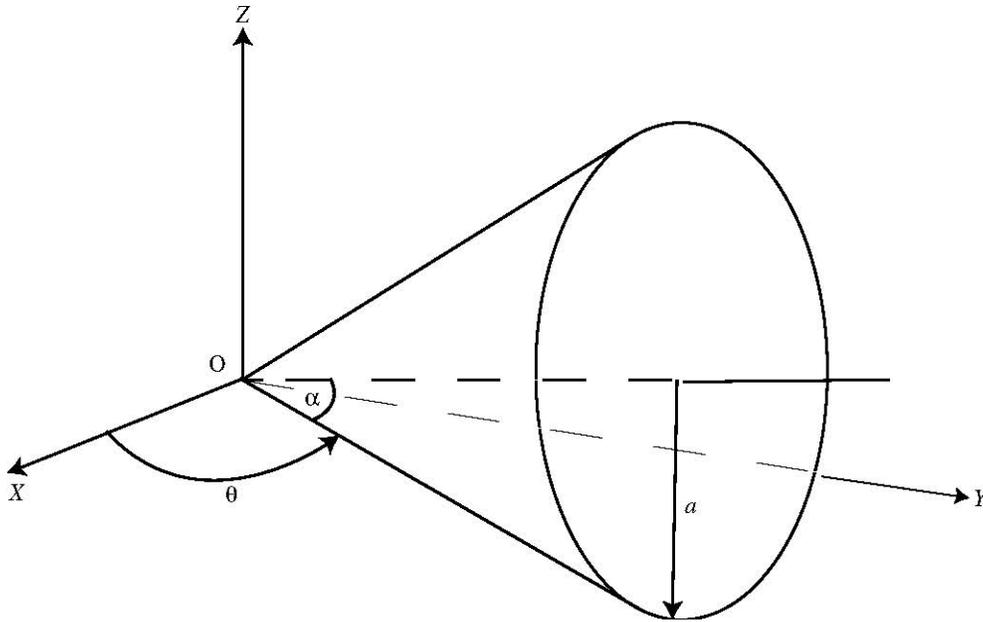


Figure by OCW.

**Problem 4** (adapted from Ginsberg, 3-22)

The disk rotates at  $\omega_1$  about its axis, and the rotation rate of the forked shaft is  $\omega_2$ . Both rates are constant. Determine the velocity and acceleration of an arbitrarily selected point B on the perimeter. Describe the results in terms of components relative to the  $xyz$  axes in the sketch.

