

Falling stick

Aim: To show that a movement of a tipping object is determined by friction between the object and the surface on which it falls.

Subjects: 1K10 (Dynamic Torque)
1K20 (Friction)

Diagram:



Equipment: Stick ($l=2m$) with a wheel. It's center is clearly marked.

Presentation: Hold the stick so that it is standing on its wheel. Incline the stick about 20° from the vertical. Indicate to the audience the marked center of mass. This point is right in front of your belly.

Let the stick go and it will hit the floor. The marked center is right in front of your toes, so this point moved vertically down.

The demonstration is done once more but now the wheel cannot move since your foot blocks it. Let the stick go and observe that the stick falls with the center of mass on the left of yourself; it even jumps away from your right foot to the left!

Explanation: The behavior of the stick depends on the friction force between the tip and the floor on which it rests. When there is frictionless interaction the only forces acting on the pencil are its weight and the normal force, both of which are vertical. There are no horizontal forces on the stick. (See figure 1.)

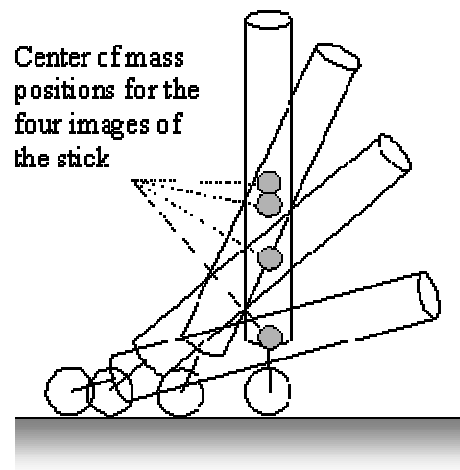


Figure 1

The 20° inclination is to skip the region where the wheel has too much friction to roll. In the first 20° the stick receives so much impulse from friction of the wheel that the centre of mass moves..

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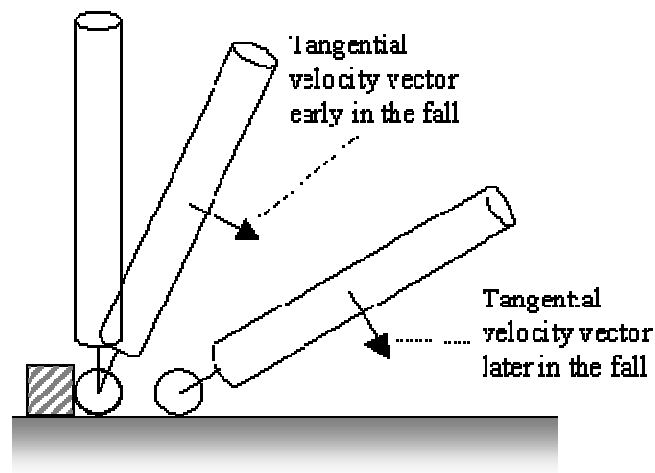


Figure 2

When there is friction (figure 2), then, as the stick falls, the tip does not slip. The horizontal friction force causes a horizontal momentum, which increases during the fall. The velocity vector of the center of mass of the stick is approaching a vertical orientation as the stick nears the floor. In the beginning the velocity of the center of mass is increasing in the horizontal direction, but since this velocity is becoming more vertical, something must happen to maintain the horizontal momentum. As a result, the stick does not continue to rotate simply about its tip, but takes on a horizontal translational velocity in the direction of the fall.

Remarks: Students can perform the demonstration themselves using a pencil. For the first demonstration, the sharpened pencil rests with its point on a glass surface. For the second demonstration, the pencil rests with its rubber top on a piece of sandpaper.

Sources:

- [Jewett Jr., John W., Physics Begins With Another M... : Mysteries, Magic, Myth, and Modern Physics](#), pag. 91