

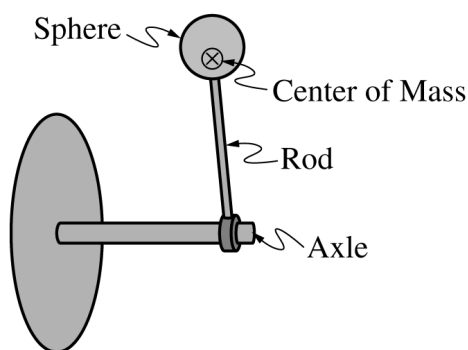


Figure 1

(7 points, suggested time 13 minutes)

A rod with a sphere attached to the end is connected to a horizontal mounted axle and carefully balanced so that it rests in a position vertically upward from the axle. The center of mass of the rod-sphere system is indicated with a $\otimes$, as shown in Figure 1. The sphere is lightly tapped, and the rod-sphere system rotates clockwise with negligible friction about the axle due to the gravitational force.

A student takes a video of the rod rotating from the vertically upward position to the vertically downward position. Figure 2 shows five frames (still shots) that the student selected from the video.

Note: these frames are not equally spaced apart in time.

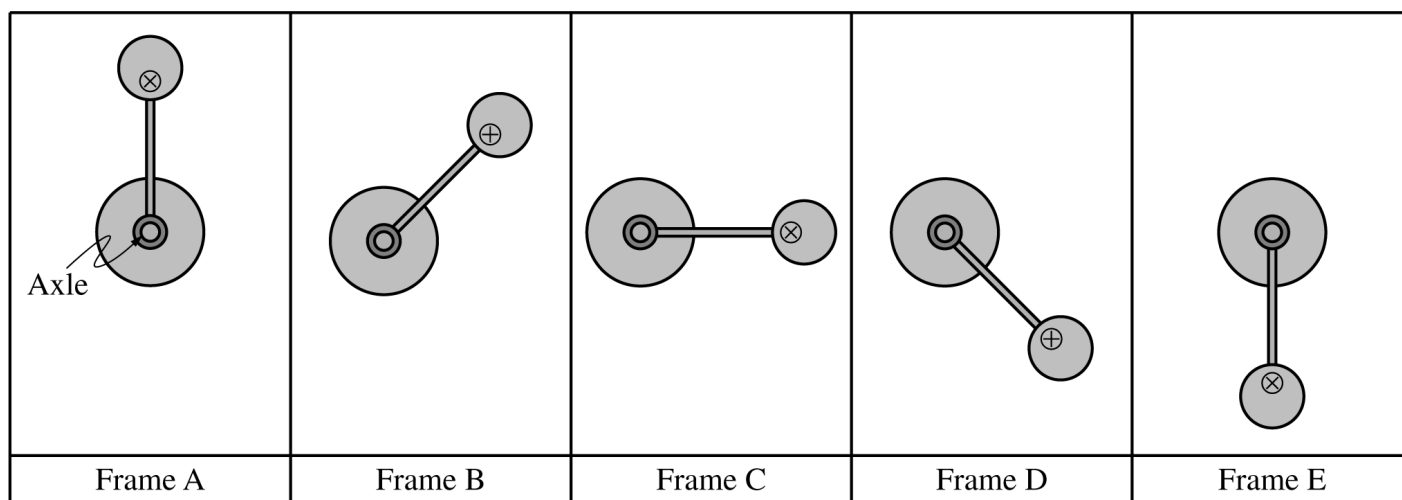


Figure 2

GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 5** on this page.

(a) Use the frames of the video shown in Figure 2 to answer the following questions.

- i. In which frame is the angular acceleration of the rod-sphere system the greatest? Justify your answer.

- ii. In which frame is the rotational kinetic energy of the rod-sphere system the greatest? Briefly justify your answer.

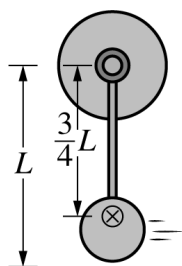


Figure 3

(b) The rod-sphere system has mass M and length L , and the center of mass is located a distance $\frac{3}{4}L$ from the axle, shown in Figure 3.

- i. Derive an expression for the change in kinetic energy of the rod-sphere-Earth system from the moment shown in Frame A to the moment shown in Frame E. Express your answer in terms of M , L , and fundamental constants, as appropriate.

- ii. Briefly explain why the rod and sphere gain kinetic energy, even if Earth is not included in the system.

GO ON TO THE NEXT PAGE.

STOP

END OF EXAM