

Flying Time

by

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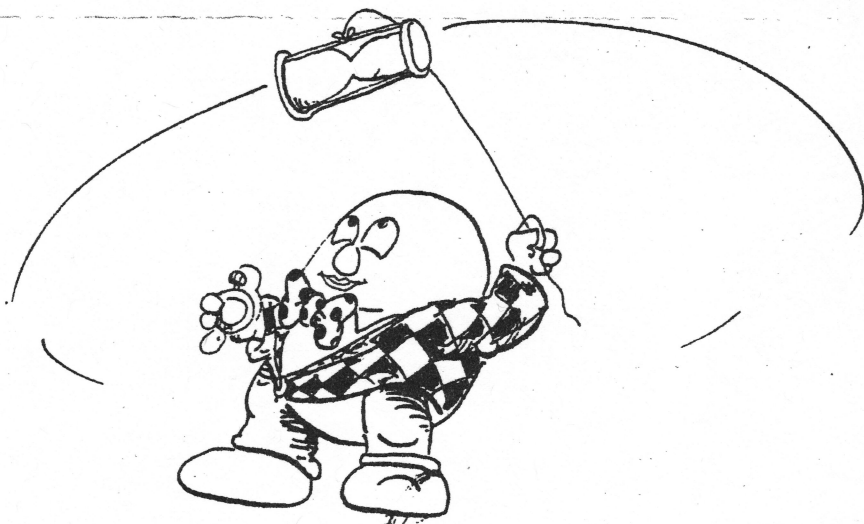
This is a demonstration of centrifugal force.

MATERIALS

- two 3-minute egg timers (the type with falling sand)
- string

PROCEDURE

1. Ask the question "How can I get the sand to the other side of the egg timer faster?" This could be given as a challenge question to the students the night before.
2. Tie a string to one of the egg timers.
3. For comparison, turn over the timer without the string so that the sand begins to drain from one end to the other.
4. Ensure the sand of the other timer is near the string. Then swing the egg timer in a circle which is in a vertical plane pointing away from the students. A horizontal plane of swing is too dangerous because, if the timer should break, there is no way of predicting the direction the pieces will fly. You do not have to swing the timer very fast (2 to 3 Hz works well). Make sure you check the construction of the timer before you swing it. The timer may require additional glue to ensure it does not fly apart.
5. After less than one minute, you should be able to stop swinging the timer and the sand will be all in the other side. The sand in the other timer will still be falling and make a nice comparison.



Drawing by Patrick McWade

DISCUSSION

In order to make the demonstration quantitative, we will assume that the rate at which the sand falls is proportional to the force acting on it. Therefore, the time (t) required for all the sand to fall is inversely proportional to the force (F).

Let:

t_1 = time required for sand to fall under gravity alone (3 minutes)

F_1 = force of gravity = mg

t_2 = time required for sand to fall under centrifugal force alone

F_2 = centrifugal force = $4m\pi^2r/T^2$
where

m = sand's mass

r = radius of curvature

T = period of rotation

To compare the times, since $t \propto 1/F$

$$\frac{t_1}{t_2} = \frac{4m\pi^2r/T^2}{mg} = \frac{4\pi^2r}{gT^2}$$

therefore,

$$t_2 = \frac{gT^2t_1}{4\pi^2r}$$

Using a radius of curvature of 30 cm ($r = 0.3$ m) and swinging the timer around twice a second ($T = 0.5$ s) causes the 3-minute egg timer to drain in about 37 s, which agrees well with what is actually observed. (Therefore, our assumption that the rate of fall is proportional to the force must be pretty good.)

I have not included the effect of gravity on the vertical plane on swing because the effect of gravity at the top of the swing cancels the effect at the bottom.

QUESTIONS

1. How long would it take an hour glass to drain if swung at 5 Hz using a string 40 cm long?
2. Does shaking an egg timer speed the rate at which the sand falls?
3. How could you stop an hour glass from draining?
4. Does the force of gravity affect the rate at which the sand falls when the timer is swung in a vertical plane? If so, how?
5. How long would it take an hour glass to drain if it was on the moon where the force of gravity is about 1/6 that of Earth's?

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Submissions describing demonstrations will be gladly received by the column editor.