An apparatus to simulate an amusement park rotor

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The rotor is a device that can be found in many amusement parks.[1] In the literature there are various articles about this topic. The rotor is a hollow cylindrical room, covered inside with canvas and which can be rotated about the central vertical axis. People stand upright, with their backs against the internal face of the device. When it reaches a certain angular speed, the floor moves down and people don't fall; they are apparently stuck to the walls of the rotating cylinder.

In physics books this topic is often approached, and authors usually ask some questions in which the students must work out the mathematical equations to calculate the values of physical dimensions/magnitude so that people won't fall when the floor opens up.[2] For example: What is the minimum coefficient of static friction between the person and the wall? What is the minimum diameter of the device? What is the minimum angular speed of the cylinder? What is the minimum period of rotation?

For students who have never experienced this device, it is difficult to understand how it works. There are also no demonstrations that could be used for students to visualize this effect in a classroom context. In previous articles, I have already explained how parts of junked computers can be reused for demonstration purposes.[3,4] In this article, I explain how to make an inexpensive apparatus to simulate the functioning of a rotor. The apparatus is simple, cheap, and it works.

I picked up an old computer, opened its hard disk drive and fastened to it an empty food storage cylinder made of transparent acrylic. I did this by cutting a circle in the bottom of the cylinder to fit the motor of the disk, and then attaching the cylinder with screws that were already on the hard drive. The device was held in place on a wooden base with small surrounding pieces of wood for stability during rotation. After switching on the motor to make the cylinder rotate, I put a body made of expanded polystyrene (which simulates a person) in contact with the internal surface and let it go to demonstrate the effect (Fig. 1). The body was painted red for better visibility. The body goes around and doesn't fall down!

More than one attempt may be needed to achieve the desired result, but it's worth it. As the body may be projected out of the cylinder, glasses must be used to protect the eyes. Toward the end of the demonstration, it is very important to switch off the motor and verify that as the speed slows down, it will reach a certain value at which the body will fall down.

Fig. 1. Rotor.

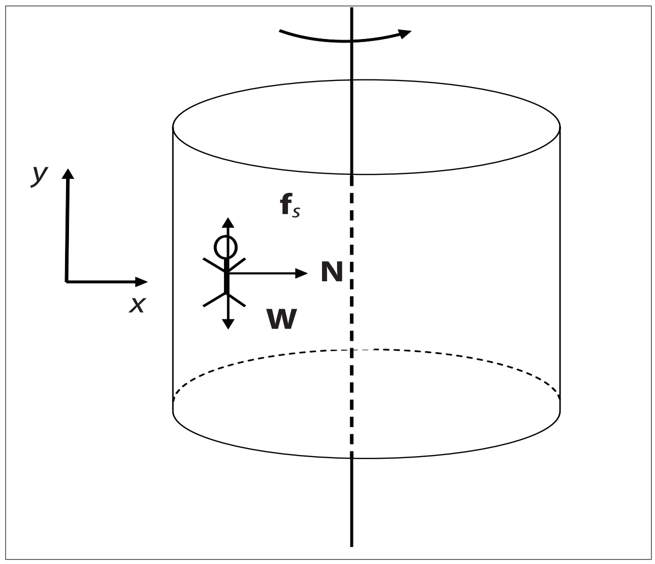

Fig. 2. Forces applied to the body.

That value corresponds to the minimum speed necessary to hold the object in place.

The greatest difficulty in building this device is finding an electric motor with enough rotation speed to keep the body from falling. Let's estimate the necessary value. I used a cylinder with a radius of 5 cm. Now let's suppose that the coefficient of friction is 0.1. The forces applied are the weight **W**, the normal force **N**, and the force of friction $\mathbf{f}_s$ (Fig. 2). Let's analyze the situation using Newton's second law. As the object does not move in the y direction, the frictional force acting upward must balance the object's weight, i.e., $f_s = mg$. In the horizontal direction, the wall exerts a normal force **N**, which is responsible for the circular trajectory,

$$N = \frac{mv^2}{R}.$$

We also know that $f_s = \mu N$. We obtain

$$v = \sqrt{\frac{gR}{\mu}}.$$

Calculating the value of the minimum tangential speed, we get $v = 2.2$ m/s. Let's now calculate the rotational speed the cylinder must maintain in order that the body doesn't fall. As

$$f = \frac{v}{2\pi R},$$

we obtain about 7 rps (420 rpm). In the technical information of computer hard disks, we can verify that the rotation speed is 7200 rpm.[5,6] This value is much greater than the one estimated above; consequently, it is quite easy to build this device using a hard disk motor.

All physics teachers know how hard it is for students to represent the forces that act in circular motion, and the formula

$$F_c = \frac{mv^2}{R}$$

is often learned by heart.[7] I hope this device may promote discussion among students and assist teachers in helping students overcome the misconceptions they formulate when studying circular motion.[8]

Acknowledgment

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References

1. Carole Escobar, "Amusement park physics," *Phys. Teach.* **28**, 446–453 (Oct. 1990).
2. David Halliday and Robert Resnick, *Physics* (Wiley, 1978), pp. 104–105.
3. Carlos Saraiva, "An inexpensive apparatus for demonstrating magnetic levitation," *Phys. Teach.* **45**, 311 (May 2007).
4. Carlos Saraiva, "Recycling makes colour clear," *Phys. Educ.* **43**, 252–253 (May 2008).
5. See Technical Details, Samsung HDD; www.dooyoo.co.uk/hard-disk-drives/samsung-spinpoint-f1-hd103uj-1-tb/details/.
6. See Technical Details, Western HDD; www.hardwaresecrets.com/article/567.
7. Paulen Smith, "Let's get rid of 'centripetal force,'" *Phys. Teach.* **30**, 316–317 (May 1992).
8. Boon Lan, "Overcoming students' misconception of centripetal force," *Phys. Educ.* **37**, 361 (July 2002).

Fermi Questions

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Question 1: Revolving Door

How much thermal energy is lost when a person exits a building through an exterior door in winter? What is the cost of this energy? Consider both revolving and standard doors.

Question 2: Toll Plaza

How much money is collected per hour during rush hour at the George Washington Bridge which connects New York City and New Jersey? *(Thanks to Chuck Adler from St. Mary's University for the question.)*

Look for the answers online at www.aapt.org/tpt. For more Fermi questions and answers, see *Guesstimation: Solving the World's Problems on the Back of a Cocktail Napkin,* by Lawrence Weinstein and John Adam (Princeton University Press, 2008), available from AAPT.