Revolving Bucket

Subject Area	Physics.
Age or Grade	Elementary high school physics.
Estimated Length	One 45-minute lesson.
Prerequisite knowledge and skills	Forces and Newton's laws of motion, centripetal force.
Lesson Goals and New Content	Students gain an understanding of centripetal and centrifugal force and learn to differentiate the two, and practice using a force analysis to solve circular motion problems. The goal is for the students to correctly use inertia and centripetal force to explain why we "feel" a centrifugal force when moving in a circle.
Materials Needed	Bucket (transparent works best) with water. Rope. Worksheet.
Procedure	**Opener** (~10 min.) (When doing this lesson, be sure to practice ahead of time, and be careful of your surroundings!) Bring out the bucket with a bit of water in the bottom. Have a rope tied to the bucket prior to class. Show the students that there is water in the bottom, and take a poll on who thinks you can keep it in the bucket when you swing it. Then, swing it in both a horizontal and a vertical circle. You can also invite some of the students to come try it themselves; most find it surprising how heavy the

	bucket feels when being swung. **Development** (~25 min.) Distribute the worksheet and have the students start the problems on the front. The problems on the front do not require any calculations, but it is my experience that the questions can start some good discussions. In particular, since the students already know that anything moving in a circle has a centripetal force acting on it, many of them find it contradictory that this force helps *keep* the water in the bucket, when it points *out* of the bucket, not in. Walk around and listen in on the groups, but allow the discussions to take their course. If some groups progress quickly, you can have them begin the problems on the back. **Closure** (~10 min.) Briefly go over the worksheet front with them. Take a poll to see what people decided on for their free-body diagram in problem 1 b. In my experience, a large fraction will choose free-body diagram B, since they expect a force to keep the water in the bucket. If this is the case, introduce as a discrepant event the fact that the bucket moves in a circle, and lead them towards the concept of centripetal force. Conclude with them that the correct free-body diagram is diagram A. Now, ask them how this is consistent with the water staying in the bucket. Some will probably have figured out that inertia is responsible, but you can

	ask them some leading questions to help them along. Ask them what path the bucket will follow if the rope suddenly breaks. You can also have them think back on the inertia lesson, if you did it with them earlier. You should leave them with the conclusion that the centripetal force always points towards the center of the circle, and that the inertia of the water is what keeps it from falling out.
Evaluation	For evaluation, you can use the worksheet as homework. Have the students fill out the front, or finish the work they didn't complete in class. You can also assign them a similar problem and have them explain as on the worksheet. (I.e., a car driving on a circular track or a roller coaster doing a loop. In both cases, you feel pushed to the outside, even though the centripetal force is directed towards the center of the circle.)
Extensions	After the students gain some more practice with the centripetal force equation, continue to the universal law of gravitation as an example of a central force.