10 Circular Motion

Name_____

Reading: CENTRIPETAL vs. CENTRIFUGAL FORCE

AP/Inquiry Physics

You are riding in your car down a straight stretch of road. Everything seems fine as you lazily daydream in the warm sun. *Everything is explainable*, you think confidently. *I've learned how the laws of physics explain the motions of everything. I can analyze the motion of a ball being thrown, or dropped, a hockey puck standing still on the ice, or accelerating in proportion to the force exerted on it by the player's stick, moving in a straight line with a constant velocity after the player lets it go. Forces act in action-reaction pairs and momentum is conserved in an isolated system, so the hockey player is accelerated backward as he pushes the puck forward. WOW! It feels great to know so much!*

In your daydreaming, you forget to slow down for the sharp right curve just ahead. You are able to slow down enough to keep the car on the road, but as you are turning you notice something. Something seems to be pushing you against the car door!

It takes you a little while to get over the scare of having to negotiate the turn at a higher than normal speed, and the experience is uppermost in your thoughts. *What was pushing me against the car door while I was turning? Pushes are forces and forces have causes, but what caused this force? Obviously it had something to do with my turning the car because the force didn't exist while I was driving straight. Also, the force's direction seemed to be outward. What could cause an outward force acting only when I turn?*

As you continue driving, you think about the circular motion investigation you just completed in physics class.

When an object moves in a circle (and a curve in the road could be seen as a partial circle) there must be a ***center-directed*** *force pulling it out of straight-line motion,* you think to yourself.

At this point, you see three cows grazing in the field next to the road and a hawk perching on a telephone pole. You don't know it, but you missed seeing three hawks in the past two miles. *Aw, who thinks about physics outside of class on a day like this! Forget the problem!*

But the problem will not go away. You can't help thinking about it. The force inward was centripetal force so from Newton's Third Law of Action-Reaction, the outward force must have been ***centrifugal force***. You recall the lecture in physics class in which Mr. Meador mentioned how Isaac Newton coined the word *centripetal* for "inward" and also *centrifugal* for "outward." A smart-aleck friend of yours actually reads the book, and told you that centripetal force acts to pull a circling body inward while "in an accelerated frame of reference, a 'centrifugal force' is said to push outward on circling bodies."

After wiping the tears from your eyes as you recall how silly Mr. Meador looked as he twirled his stopper and gestured in his inimitable way about the forces, you think, *I must have been experiencing centrifugal force when I was thrown to the side of the car on the curve. But wait a minute. If centrifugal and centripetal forces are both acting on the same object, they are equal and opposite forces so the net force should be zero newtons and the circling object should be experiencing Newton's First Law of Motion which is motion at a constant speed in a straight line!*

"Oh, dear. This is getting to be too much," you say aloud. "Why don't I go back to watching the cows and the hawks." You see a hawk flying lazily over a field with two small birds flying alongside apparently pestering the hawk since it occasionally veers toward one of them as if to drive it off. But it is always to no avail; the small birds are much more maneuverable and choose to stay with the hawk. Suddenly the hawk dives downward to the ground and you don't see it again, so you decide it must have seen and captured some prey. It is probably already feasting on some lunch, with the little birds close by hoping for some free scraps.

I can always ask Mr. Meador about this in class tomorrow, you think to yourself, not realizing your thoughts have drifted back to the circular motion problem. *But how could Newton's Third Law apply to circular motion? The action and reaction forces don't have to be on the same body, in fact, they* ***can't*** *be if any acceleration is to occur. So what is the reaction force to the centripetal force and on which body does it act? Could it be that the reaction force is on the object being circled? It would be a force acting outward in the direction of the circling body. If that is the case, then the centripetal force is the only net force acting on the body moving in a circle. Centripetal force is then pulling it out of the straight line motion that Newton's Laws would proscribe for an object on which no net force acts. The opposite force then acts outward on the object in the center.*

So, when my car was traveling around the curve, it was being pulled out of straight line motion by forces acting between the car and the ground. Each of the two front tires were interacting with the pavement to pull the car toward the center of the curve's circle. These frictional forces were then acting as the centripetal force.

But why did I move against the car door? Because even though the car was turning, Newton's First Law was acting on me. My inertia was keeping my motion in a straight line. The frictional forces between me and the car seat were sufficient to bend my motion from straight-line motion, but not sufficient to keep me moving with the car. The car door came to my rescue and the centripetal force acting on the car was then acting on me also. So ***centrifugal*** *force was not acting on me. Centrifugal force is a* ***fictitious*** *outward force on the* ***circling body****. By the third law, there is always an outward force on the body* ***being circled****, but that is not centrifugal force. The force on the body being circled is merely a third law `reaction' force. Finally, the supposed force acting on me in the car is really my moving according to Newton's First Law while the car was accelerating inward by Newton's Second Law.*

So now you've explained the mysterious "force" that acted upon you in the car by identifying it as your own inertial tendencies, not a force at all. You feel you understand circular motion better than you did before. You continue driving along the road, finally able to watch the cows and hawks. But, you're careful that you watch the road. You watch especially for the curves. You would not want the centripetal force needed to turn your car to be greater than the force available from the friction between your tires and the pavement.