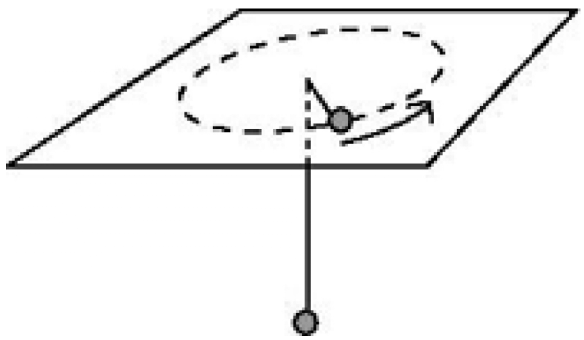
Circular Motion Dynamics
Concept Questions

Problem 1: A puck of mass m is moving in a circle at constant speed on a frictionless table as shown above. The puck is connected by a string to a suspended bob, also of mass m, which is at rest below the table. Half of the length of the string is above the tabletop and half below. What is the magnitude of the centripetal acceleration of the moving puck? Let g be the gravitational constant.



a) The magnitude of the centripetal acceleration of the moving puck is less than g.

b) The magnitude of the centripetal acceleration of the moving puck is equal to g.

c) The magnitude of the centripetal acceleration of the moving puck is greater than g.

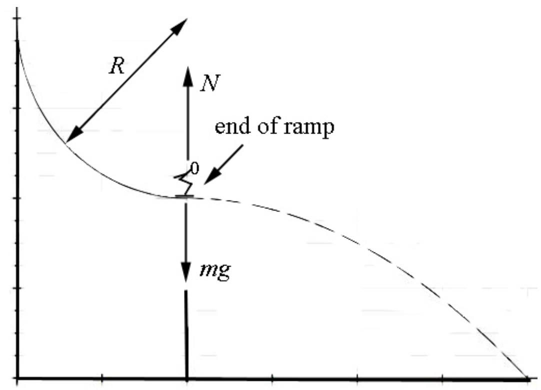
d) The magnitude of the centripetal acceleration of the moving puck is zero.

e) There is not enough information given to determine how the magnitude of the centripetal acceleration of the moving puck compares to g.

Solution (b): Since the suspended object is not accelerating the tension force upwards exactly balances the gravitational force downwards, so $T = mg$. The inward force on the puck is due to the tension in the string which is equal in to the mass times the centripetal acceleration, $T = ma_{centripetal}$. Therefore $mg = ma_{centripetal}$ or $g = a_{centripetal}$.

Problem 2:

A skier of mass M slides down a ramp shaped as a circle of radius R. At the end point of the ramp just before the skier is in the air, the magnitude of the normal force exerted by the ramp on the skier is N. The gravitational constant is g.



1) The magnitude of the normal force N greater than Mg.

2) The magnitude of the normal force N equal to Mg.

3) The magnitude of the normal force N less than Mg.

4) The magnitude of the normal force N can be greater than, equal to, or less than Mg depending on the speed of the skier.

Solution (1): The forces on the skier on shown in the figure below. Since the skier is still undergoing circular motion at the instant just before leaving the track, the skier is accelerating upwards. If the skier has speed v at that instant then applying Newton's Second Law to the skier yields

$$N - Mg = Mv^2 / R$$

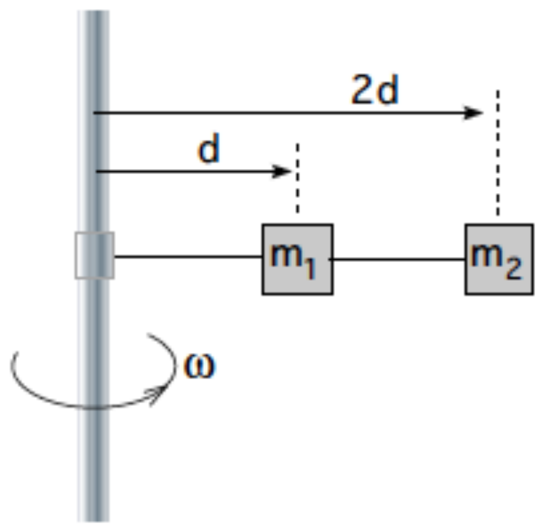
We can solve this for the magnitude of the normal force

$$N = Mg + Mv^2 / R.$$

Therefore the magnitude of the normal force is greater than the magnitude of the gravitational force at the instant just before the skier leaves the track.

Problem 3:

Two blocks 1 and 2 of masses m_1 and m_2 are connected by a string. Block 1 is connected to the shaft by an identical string. The blocks are rotating in a circle with constant angular speed ω. Block 1 is a distance d from the central axis, and block 2 is a distance $2d$ from the axis. You may ignore the mass of the strings and neglect the effect of gravity.



As the angular speed increases

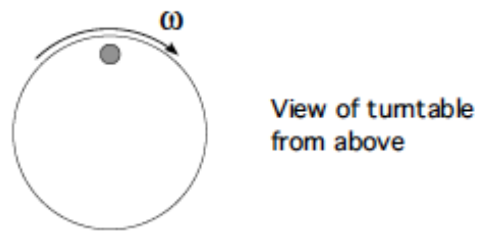
1. The outer string always breaks first.
2. The inner string always breaks first.
3. The outer string only breaks first when $m_1 > m_2$.
4. The outer string only breaks first when $m_1 < m_2$.
5. Both strings always break at the same time.

Answer 2

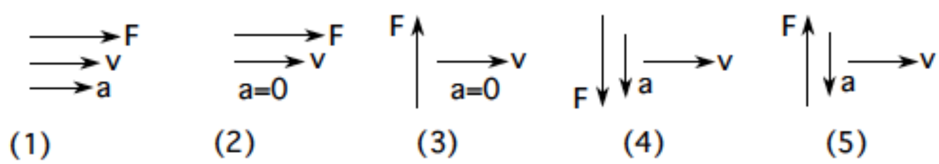
Block 1 is pulled outward by the outer string and inward by the inner string. Its acceleration is radially inward, thus the tension in the inner string must be greater than the tension in the outer string. This is true independent of the ratio of the masses. Thus, the inner string will always break first.

Problem 4:

A small cylinder rests on a circular turntable, rotating about a vertical axis at a constant angular speed ω as illustrated in the diagram below.



The cylinder rotates with the turntable; it does not slip. Which of the vectors 1-5 above best describes the velocity, acceleration and net force acting on the cylinder at the point indicated in the diagram?

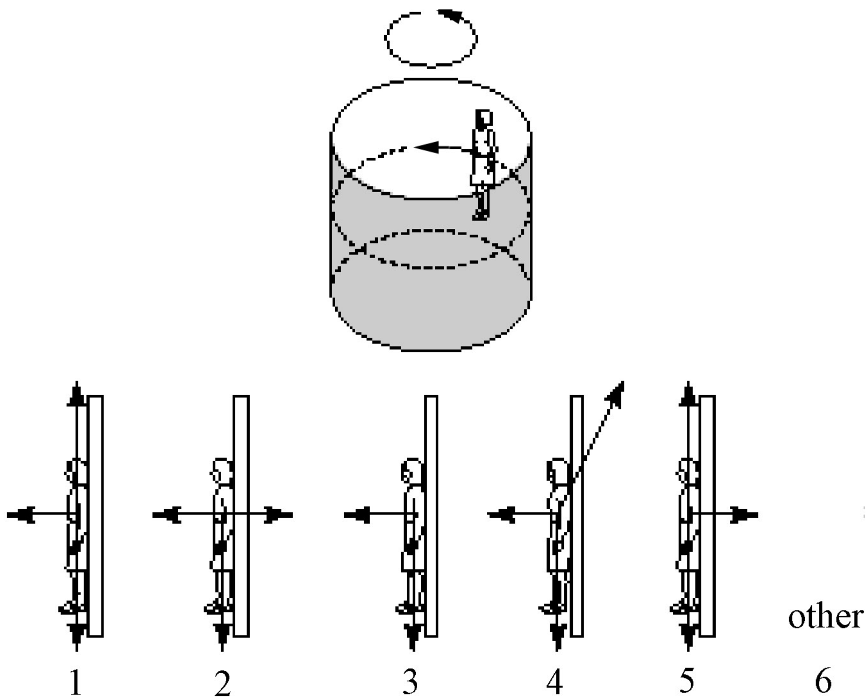


Answer 4

The acceleration is radially inward and non-zero. This eliminates all but 4) and 5).
$\vec{F} = m\vec{a}$, thus $\vec{F}$ must also point radially inward. This eliminates 5).

Problem 5

A rider in a "barrel of fun" finds herself stuck with her back to the wall. Which diagram correctly shows the forces acting on her? Explain your reasoning.



Solution 1. Consider the vertical and horizontal forces on the rider separately. For the rider not to slip in the barrel, there must be no net vertical force acting on her. The two vertical forces acting on her are her weight down and a frictional force between her and the wall acting up. These forces must be equal in magnitude. Then there must also be a force acting on the rider that always points toward the center of the barrel to provide the rider with centripetal acceleration to keep her going in a circle. Where does that force come from? The normal component of the contact force exerted on her by the wall supplies that centripetal acceleration. You may wonder how the wall can exert a normal force on her if there is no other force acting to press her into the wall. Ordinarily we think of contact forces arising because some other force -- typically gravity -- is pushing an object against another object, and the contact force arises in response to that push. If you think carefully about the motion of the rider, her velocity is always directed tangent to the vertical wall of the barrel of fun, so the rider in a sense is constantly colliding with the part of the wall that is right behind her as it travels in a circle. So the wall behind her pushes out on her because otherwise her inertia would mean that she would go straight through the wall, tangent to her velocity at any moment. She exerts a contact force on the wall due to her inertia. As your reading remarked, one thing to be careful about is to realize that "centripetal force" is not an independent force that somehow arises because something is going in a circle. Rather, if an object is going in a circle, there must be a force acting on it from its environment -- a string tied to it or a contact force from an

adjacent surface, for example -- which acts in the appropriate direction to be a centripetal force.

So, in the case of the barrel of fun, there are three forces: gravity, the upward frictional force and the inward normal force, and the correct answer is diagram 1.
Note that it would be possible to combine the friction force and the normal force into a single contact force. This contact force would have upward and inward components, hence directed up and to the left in the diagram. None of the five choices given matches this model (although a case could be made for “other,” but such this would need to be explained).