Minds•On Physics Activity

AT•5

Reasoning About Circular Motion

Purpose and Expected Outcome

In this activity you will reason about the forces exerted on objects undergoing circular motion. You will learn more about how to relate the net force on an object to its acceleration. You will also confront some common points of confusion about circular motion.

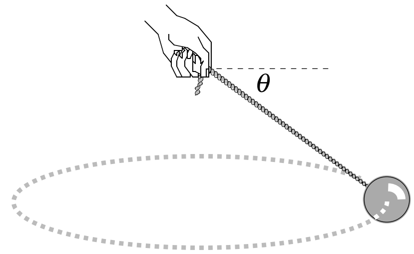
Prior Experience / Knowledge Needed

You should be familiar with the relationship between speed, radius of curvature and radial acceleration ($a_r = v^2/R_c$, where v is the speed of the object and R_c is the radius of curvature). You should know how to identify common forces (such as the tension force, the normal force, static and kinetic friction forces, and the spring force), and you should be able to draw free-body diagrams. You should know Newton's 2nd law. You should be familiar with tangential acceleration and be able to determine it in simple situations.

Explanation of Activity

Use your knowledge of circular motion and Newton's 2nd law to answer these questions.

A1. A ball is attached to a flexible cord and swung in a horizontal circle as shown. The angle θ between the cord and the horizontal is less than 45°.

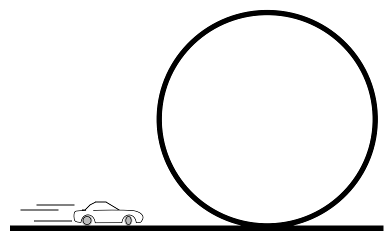


(a) Which is larger, the horizontal or vertical component of the tension force? Explain.

(b) Which is larger, the vertical component of the tension force or the gravitational force? Explain.

(c) Is the acceleration of the ball larger than, smaller than, or the same as the acceleration of a ball falling freely in a gravitational field? Explain.

A2. A toy race car travels around a vertical circle on a curved length of track without ever losing contact.

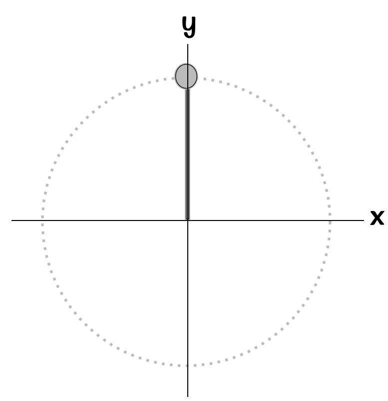


(a) Where is the car when its radial acceleration is smallest? Explain.

(b) Where is the car when its tangential acceleration is smallest? Explain.

(c) When the car is at the top of the circle, is the acceleration larger than, smaller than, or the same as the acceleration of an object falling freely in a gravitational field? Explain.

A3. A ball is attached to a light metal rod, which pivots frictionlessly as shown. The arrangement is released from rest at the instant shown.



(a) Where is the ball when its radial acceleration is largest? Explain.

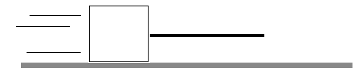
(b) Where is the ball when its tangential acceleration is largest? Explain.

Assume now that the ball is given a strong push at the top (instead of being released from rest).

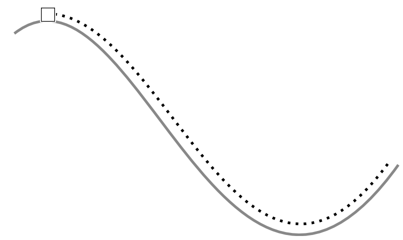
(c) Would the maximum radial acceleration change? How? Would the maximum tangential acceleration change? How?

continued

A4. A box of mass m is pulled with a force F along a rough surface having a coefficient of kinetic friction of μ_k. If the tension in the string is doubled, what will happen to the radial and tangential components of acceleration?



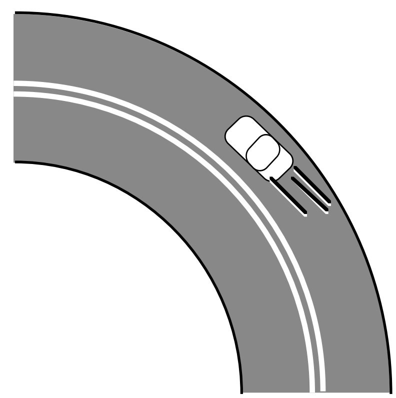
A5. A block is released from rest at the top of a frictionless curved surface and follows the path shown. On a copy of this drawing...



(a) ... indicate the point(s) where the radial acceleration of the block is largest. Explain.

(b) ... indicate the point(s) where the tangential acceleration of the block is largest. Explain.

A6. A car is traveling at constant speed around a curve in the road. (The road is not banked.)



(a) Which force on the car is larger, the normal force exerted by the road or the gravitational force? Why?

(b) Which force is larger, the friction force exerted by the road or the gravitational force? Explain.

A7. A race car is traveling at a certain speed around a banked curve, whose angle is about 15° above the horizontal. At this particular speed, the friction force between the tires and the road is essentially zero. Which is larger, the force of gravitation or the normal force exerted by the road? Explain.

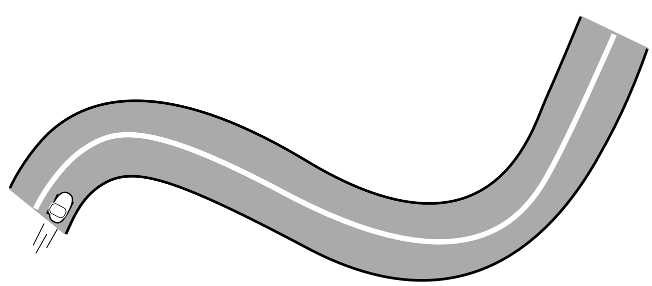
A8. A car travels along a curved road at roughly constant speed as shown below. On a copy of this diagram...

(a) ... indicate where the acceleration of the car is greatest.

(b) ... indicate where its acceleration is least.

(c) ... indicate where its acceleration is about zero.

(d) ... indicate where the car is most likely to slide.



Reflection

R1. (a) For which of the situations did you not draw a free-body diagram? Why not?

(b) For those situations, draw a free-body diagram, and answer the questions again.

(c) Do any of your answers change as a result of drawing and using a free-body diagram? Explain.

R2. In three of the situations, the acceleration of the object is vertical (that is, perpendicular to the ground) at least once during its motion.

(a) Which three situations?

(b) How do you know the acceleration is vertical?

(c) Where is the object when its acceleration is vertical?

R3. In at least one situation, the acceleration of the object is horizontal (that is, parallel to the ground) at least once during its motion.

(a) How many situations? Which one(s)?

(b) How do you know the acceleration is horizontal?

(c) Where is the object when its acceleration is horizontal?

R4. (a) Is it possible for the acceleration of an object to have both horizontal and vertical components? Explain. If it is possible, give at least one example.

(b) Is it possible for the acceleration of an object to have both radial and tangential components? Explain. If it is possible, give at least one example.

(c) Is it possible for the radial acceleration to have both horizontal and vertical components? Explain. If it is possible, give at least one example.

R5. Reconsider situation A5, in which a block slides frictionlessly along a curved surface.

(a) Where is the block when its speed is largest?

(b) Where is the block when its tangential acceleration is largest?

(c) Are these two locations the same? Why or why not?

(d) Create a situation in which the tangential acceleration of something is largest at the same time as its speed is smallest.

R6. Reconsider situation A8, in which a car is traveling at roughly constant speed along a curved road. Is your answer to part (d) consistent with your answer to part (a)? Explain.