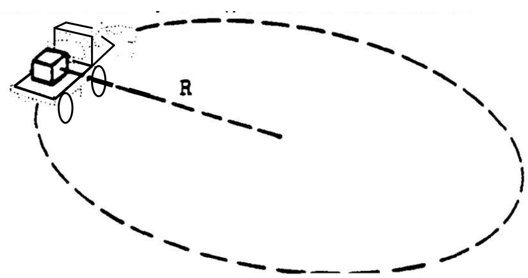
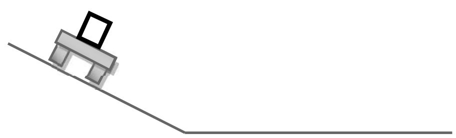
SECTION B – Circular Motion



1977 B2. A box of mass M, held in place by friction, rides on the flatbed of a truck which is traveling with constant speed v. The truck is on an unbanked circular roadway having radius of curvature R.

a. On the diagram provided above, indicate and clearly label all the force vectors acting on the box.

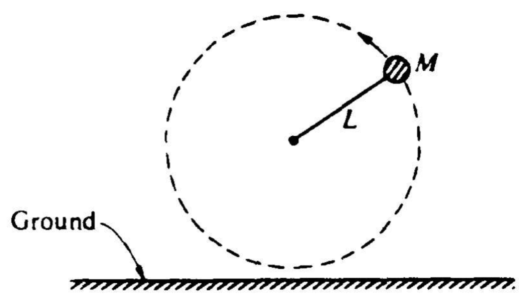
b. Find what condition must be satisfied by the coefficient of static friction μ between the box and the truck bed. Express your answer in terms of v, R, and g.



If the roadway is properly banked, the box will still remain in place on the truck for the same speed v even when the truck bed is frictionless.

c. On the diagram above indicate and clearly label the two forces acting on the box under these conditions

d. Which, if either, of the two forces acting on the box is greater in magnitude?



1984B1. A ball of mass M attached to a string of length L moves in a circle in a vertical plane as shown above. At the top of the circular path, the tension in the string is twice the weight of the ball. At the bottom, the ball just clears the ground. Air resistance is negligible. Express all answers in terms of M, L, and g.

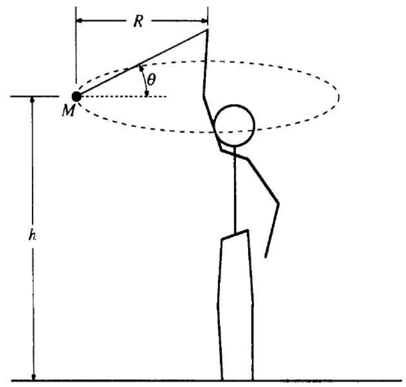
a. Determine the magnitude and direction of the net force on the ball when it is at the top.

b. Determine the speed v_o of the ball at the top.

The string is then cut when the ball is at the top.

c. Determine the time it takes the ball to reach the ground.

d. Determine the horizontal distance the ball travels before hitting the ground.

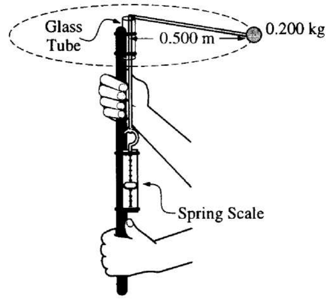


1989B1. An object of mass M on a string is whirled with increasing speed in a horizontal circle, as shown above. When the string breaks, the object has speed v_o and the circular path has radius R and is a height h above the ground. Neglect air friction.

a. Determine the following, expressing all answers in terms of h, v_o, and g.
   i. The time required for the object to hit the ground after the string breaks
   ii. The horizontal distance the object travels from the time the string breaks until it hits the ground
   iii. The speed of the object just before it hits the ground

b. On the figure below, draw and label all the forces acting on the object when it is in the position shown in the diagram above.

c. Determine the tension in the string just before the string breaks. Express your answer in terms of M, R, v_o, & g.



Not Necessarily
To Scale

1997B2 (modified) To study circular motion, two students use the hand-held device shown above, which consists of a rod on which a spring scale is attached. A polished glass tube attached at the top serves as a guide for a light cord attached the spring scale. A ball of mass 0.200 kg is attached to the other end of the cord. One student swings the teal around at constant speed in a horizontal circle with a radius of 0.500 m. Assume friction and air resistance are negligible.

a. Explain how the students, by using a timer and the information given above, can determine the speed of the ball as it is revolving.

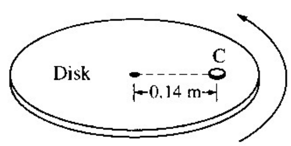
b. The speed of the ball is determined to be 3.7 m/s. Assuming that the cord is horizontal as it swings, calculate the expected tension in the cord.

c. The actual tension in the cord as measured by the spring scale is 5.8 N. What is the percent difference between this measured value of the tension and the value calculated in part b.?

The students find that, despite their best efforts, they cannot swing the ball so that the cord remains exactly horizontal.

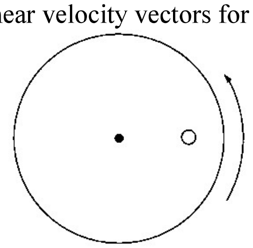
d. i. On the picture of the ball below, draw vectors to represent the forces acting on the ball and identify the force that each vector represents.

ii. Explain why it is not possible for the ball to swing so that the cord remains exactly horizontal.
iii. Calculate the angle that the cord makes with the horizontal.



1999B5 A coin C of mass 0.0050 kg is placed on a horizontal disk at a distance of 0.14 m from the center, as shown above. The disk rotates at a constant rate in a counterclockwise direction as seen from above. The coin does not slip, and the time it takes for the coin to make a complete revolution is 1.5 s.

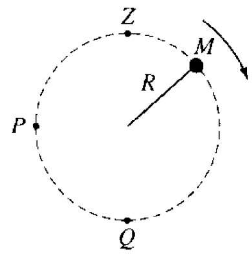
a. The figure below shows the disk and coin as viewed from above. Draw and label vectors on the figure below to show the instantaneous acceleration and linear velocity vectors for the coin when it is at the position shown.



b. Determine the linear speed of the coin.

c. The rate of rotation of the disk is gradually increased. The coefficient of static friction between the coin and the disk is 0.50. Determine the linear speed of the coin when it just begins to slip.

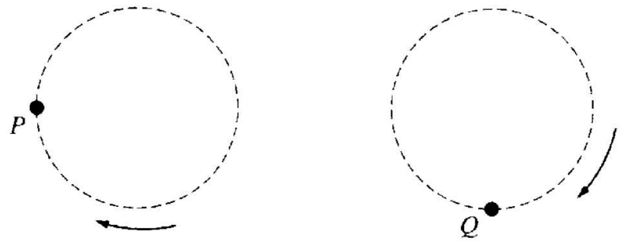
d. If the experiment in part (c) were repeated with a second, identical coin glued to the top of the first coin, how would this affect the answer to part (c)? Explain your reasoning.



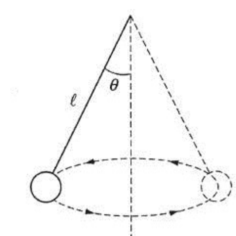
Side View

2001B1. A ball of mass M is attached to a string of length R and negligible mass. The ball moves clockwise in a vertical circle, as shown above. When the ball is at point P, the string is horizontal. Point Q is at the bottom of the circle and point Z is at the top of the circle. Air resistance is negligible. Express all algebraic answers in terms of the given quantities and fundamental constants.

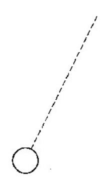
a. On the figures below, draw and label all the forces exerted on the ball when it is at points P and Q, respectively.



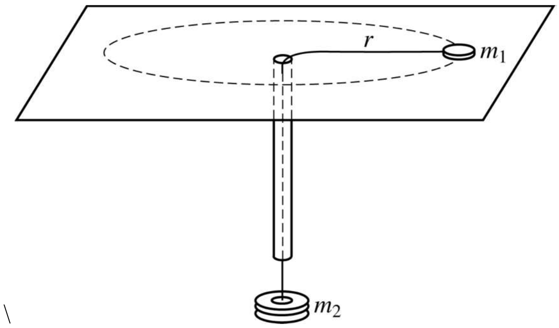
b. Derive an expression for v_{min} the minimum speed the ball can have at point Z without leaving the circular path.
c. The maximum tension the string can have without breaking is T_{max} Derive an expression for v_{max}, the maximum speed the ball can have at point Q without breaking the string.
d. Suppose that the string breaks at the instant the ball is at point P. Describe the motion of the ball immediately after the string breaks.



2002B2B A ball attached to a string of length *l* swings in a horizontal circle, as shown above, with a constant speed. The string makes an angle θ with the vertical, and *T* is the magnitude of the tension in the string. Express your answers to the following in terms of the given quantities and fundamental constants.
a. On the figure below, draw and label vectors to represent all the forces acting on the ball when it is at the position shown in the diagram. The lengths of the vectors should be consistent with the relative magnitudes of the forces.



b. Determine the mass of the ball.
c. Determine the speed of the ball.
d. Determine the frequency of revolution of the ball.
e. Suppose that the string breaks as the ball swings in its circular path. Qualitatively describe the trajectory of the ball after the string breaks but before it hits the ground.



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2009Bb1 An experiment is performed using the apparatus above. A small disk of mass m_1 on a frictionless table is attached to one end of a string. The string passes through a hole in the table and an attached narrow, vertical plastic tube. An object of mass m_2 is hung at the other end of the string. A student holding the tube makes the disk rotate in a circle of constant radius r, while another student measures the period P.

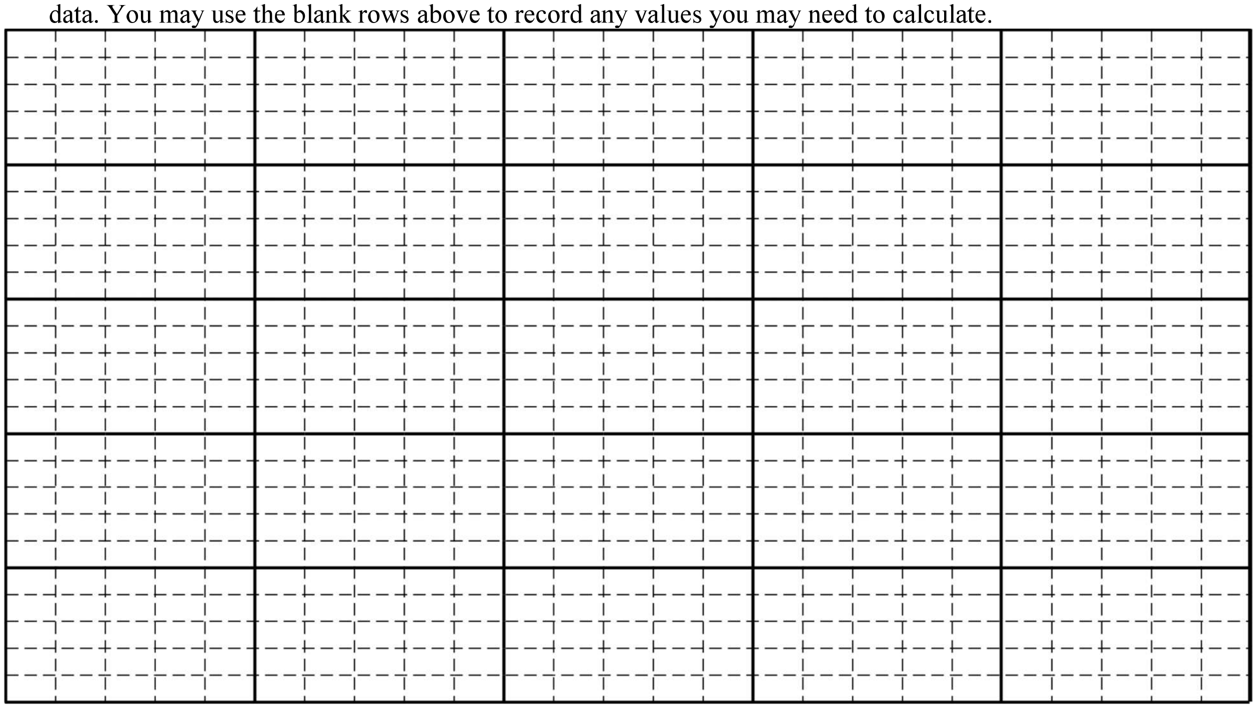
a. Derive the equation $P = 2\pi\sqrt{\frac{m_1 r}{m_2 g}}$ that relates P and m_2.

The procedure is repeated, and the period P is determined for four different values of m_2, where $m_1 = 0.012$ kg and $r = 0.80$ m. The data, which are presented below, can be used to compute an experimental value for g.

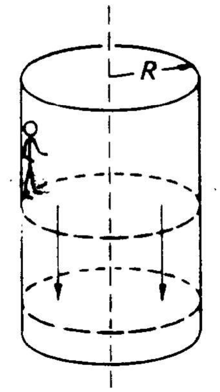
m_2 (kg)	0.020	0.040	0.060	0.080
P (s)	1.40	1.05	0.80	0.75

b. What quantities should be graphed to yield a straight line with a slope that could be used to determine g?

c. On the grid below, plot the quantities determined in part (b), label the axes, and draw the best-fit line to the data. You may use the blank rows above to record any values you may need to calculate.

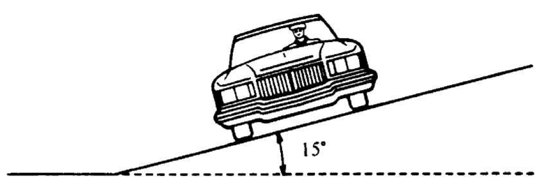


d. Use your graph to calculate the experimental value of g.



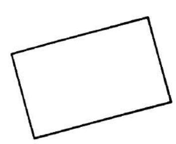
*1984M1 (modified) An amusement park ride consists of a rotating vertical cylinder with rough canvas walls. The floor is initially about halfway up the cylinder wall as shown above. After the rider has entered and the cylinder is rotating sufficiently fast, the floor is dropped down, yet the rider does not slide down. The rider has mass of 50 kilograms, The radius R of the cylinder is 5 meters, the frequency of the cylinder when rotating is $1/\pi$ revolutions per second, and the coefficient of static friction between the rider and the wall of the cylinder is 0.6.

a. On the diagram above, draw and identify the forces on the rider when the system is rotating and the floor has dropped down.
b. Calculate the centripetal force on the rider when the cylinder is rotating and state what provides that force.
c. Calculate the upward force that keeps the rider from falling when the floor is dropped down and state what provides that force.
d. At the same rotational speed, would a rider of twice the mass slide down the wall? Explain your answer.

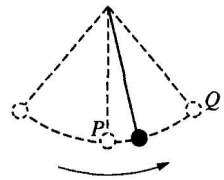


1988M1. A highway curve that has a radius of curvature of 100 meters is banked at an angle of 15° as shown above.
a. Determine the vehicle speed for which this curve is appropriate if there is no friction between the road and the tires of the vehicle.

On a dry day when friction is present, an automobile successfully negotiates the curve at a speed of 25 m/s.

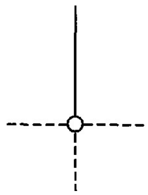


b. On the diagram above, in which the block represents the automobile, draw and label all of the forces on the automobile.
c. Determine the minimum value of the coefficient of friction necessary to keep this automobile from sliding as it goes around the curve.

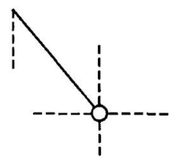


1998B6 A heavy ball swings at the end of a string as shown above, with negligible air resistance. Point P is the lowest point reached by the ball in its motion, and point Q is one of the two highest points.

a. On the following diagrams draw and label vectors that could represent the velocity and acceleration of the ball at points P and Q. If a vector is zero, explicitly state this fact. The dashed lines indicate horizontal and vertical directions.

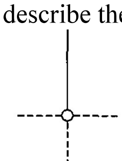


i. Point P

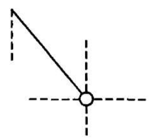


ii. Point Q

b. After several swings, the string breaks. The mass of the string and air resistance are negligible. On the following diagrams, sketch the path of the ball if the break occurs when the ball is at point P or point Q. In each case, briefly describe the motion of the ball after the break.



i. Point P



ii. Point Q