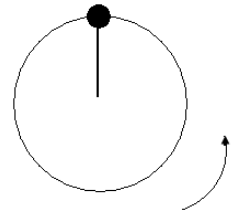


Multiple-Choice Questions

1. A ball with a mass  $m$  is fastened to a string and is swung in a vertical circle. When the ball is at the highest point of the circle the tension in the string is:  
 (A)  $mg$  (B)  $mg + ma$  (C)  $ma - mg$  (D)  $mg/ma$



2. A motorcyclist moves at a constant speed down one hill and up another hill along the smooth curved surface. When the motorcyclist reaches the lowest point of the curve its velocity and acceleration directions are:

- (A)  $\frac{v}{a}$  (B)  $\frac{\uparrow v}{\leftarrow a}$  (C)  $\frac{\rightarrow v}{\uparrow a}$  (D)  $\frac{\downarrow v}{\rightarrow a}$

3. A car moves along the curved track. What is the direction of  $F_N$  of the driver when the car reaches the lowest point of the curve?  
 (A) Upward (B) Downward (C) Forward (D) Backward



Questions 4-5

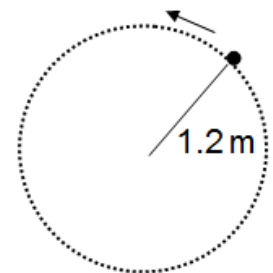
A 0.2 kg ball rotates at a constant speed of 3 m/s on the end of 1.2 m long string. The string describes a horizontal circle.

4. What is the centripetal acceleration of the object?

- (A)  $1.2 \text{ m/s}^2$  (B)  $3.0 \text{ m/s}^2$  (C)  $7.5 \text{ m/s}^2$  (D)  $3.2 \text{ m/s}^2$

5. What is the centripetal force exerted on the object?

- (A) 1.0 N (B) 1.2 N (C) 0.2 N (D) 1.5 N



6. When a student stands on a rotating table, the frictional force exerted on the student by the table is
- (A) greater in magnitude than the frictional force exerted on the table by the student
  - (B) less in magnitude than the frictional force exerted on the table by the student
  - (C) equal in magnitude than the frictional force exerted on the table by the student
  - (D) directed away from the center of the table
7. A centripetal force  $F$  is applied to an object moving at a constant speed  $v$  in a horizontal circle of radius  $r$ . If the radius is quadrupled and the speed is doubled, what happens to the centripetal force?
- (A) Increased by a factor of 2
  - (B) decreased by a factor of 2
  - (C) doesn't change
  - (D) increased by a factor of  $\sqrt{2}$
8. A roller coaster car is on a track that forms a circular loop of radius  $R$  in the vertical plane. If the car is to just maintain contact with track at the top of the loop, what is the minimum value for its velocity at this point?
- (A)  $gR$       (B)  $0.5gR$       (C)  $2gR$       (D)  $(gR)^{1/2}$
9. A car goes around a curve of radius  $r$  at a constant speed  $v$ . The coefficient of static friction between the tires and the surface is  $\mu$ . What is the maximum value of the car's velocity in order to prevent car from skidding of the road?
- (A)  $(\mu rg)^2$       (B)  $\mu r/g$       (C)  $(\mu rg)^{0.5}$       (D)  $g/\mu r$
10. A heavy (2.0 kg) point-like object rests 2.0m from the center of a rough turntable as the turntable rotates. The period of the turntable's rotation is 5.0 seconds. The coefficient of static friction is 0.80. What is the magnitude of the force of friction acting on the object?
- (A) 19.6N      (B) 16.0N      (C) 9.8N      (D) 6.3N

## Multi-Correct Questions

Directions: For each of the following, two of the suggested answers will be correct. Select the best two choices to earn credit. No partial credit will be earned if only one correct choice is selected.

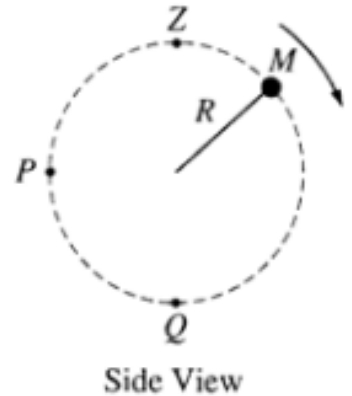
11. Four particles have the following masses (in terms of  $m$ ), speeds (in terms of  $v$ ), and radii (in terms of  $r$ ). Which two particles have the same centripetal force?

Particle	Mass	Speed	Radius
1	$m$	$v$	$r$
2	$m/2$	$2v$	$2r$
3	$2m$	$v/2$	$r$
4	$1$	$2v$	$3r$

- (A) Particle 1  
(B) Particle 2  
(C) Particle 3  
(D) Particle 4
12. A stone is tied to a string and whirled in a vertical circle at a radius. Which of the following cannot be true?
- (A) The string is most likely to break at the bottom of the circle.  
(B) The tension force is the same everywhere in the circle.  
(C) The tension force and the weight of the stone always affect the centripetal force.  
(D) The tension is the least when the stone is at the top of the circle.

## Free Response

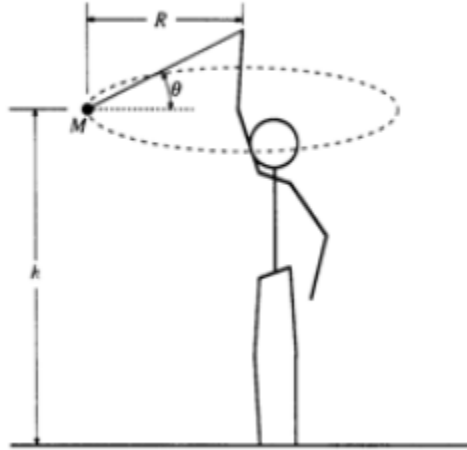
1. A ball of mass  $M$  is attached to a string of length  $R$  and negligible mass. The ball moves clockwise in a vertical circle, as shown above. When the ball is at point  $P$ , the string is horizontal. Point  $Q$  is at the bottom of the circle and point  $Z$  is at the top of the circle. Air resistance 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.



2. 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  $v_0$  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  $h$ ,  $v_0$ , and  $g$ .
- The time required for the object to hit the ground after the string breaks
  - The horizontal distance the object travels from the time the string breaks until it hits the ground
  - 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  $M$ ,  $R$ ,  $v_0$ , and  $g$ .

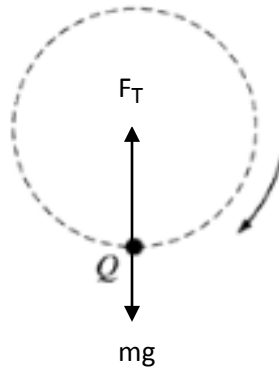
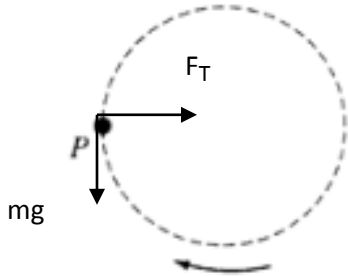
Multiple Choice Answers

1. C
2. C
3. A
4. C
5. D
6. C
7. C
8. D
9. C
10. D
11. A, B
12. B, C

Free Response Answers

1.

a.



b.  $V_{\min} = \sqrt{Rg}$

c.  $V = \sqrt{R\left(\frac{T_{MAX}}{M} - g\right)}$

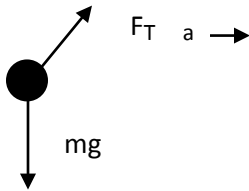
d. Velocity is upwards, acceleration is g down

2. a. i.  $t = \sqrt{2h/g}$

ii.  $x = v_0 \sqrt{2h/g}$

iii.  $v = \sqrt{v_0^2 + 2gh}$

b.



c.  $T = m\sqrt{\frac{v_0^4}{R^2} + g^2}$