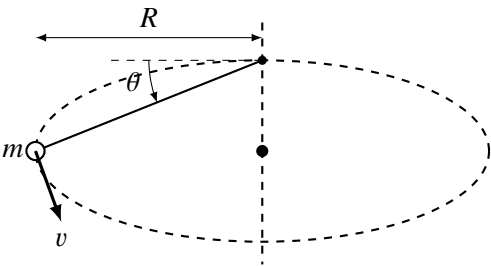


AP PHYSICS C: CIRCULAR MOTION

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box on the student answer sheet.

Note: To simplify calculations, you may use $g = 10\text{ m/s}^2$ in all problems.

1. A girl stands on a rotating merry-go-round without holding on to a rail. The force that keeps her moving in a circle is the
- (A) frictional force on the girl directed away from the center of the merry-go-round
 - (B) frictional force on the girl directed toward the center of the merry-go-round
 - (C) normal force on the girl directed away from the center of the merry-go-round
 - (D) normal force on the girl directed toward the center of the merry-go-round
 - (E) weight of the girl



Questions 2–3

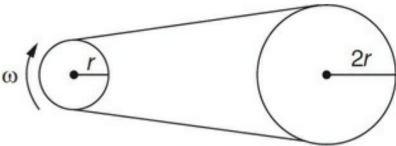
A ball of mass m and weight W on the end of a string is swung in a horizontal circle of radius R with a speed v . The string makes an angle θ below the horizontal, as shown. The magnitude of the tension in the string is T .

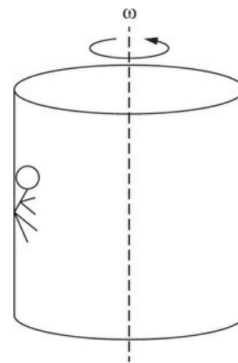
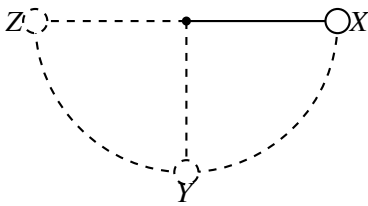
2. Which of the following diagrams best shows the forces acting on the ball as it moves in a circle?
- (A)
 - (B)
 - (C)
 - (D)
 - (E)
3. In terms of m , R , v , and θ , the magnitude of the tension T is
- (A) $\frac{mv^2}{R}$
 - (B) $\frac{mv^2}{R \sin \theta}$
 - (C) $\frac{mv^2}{R \cos \theta}$
 - (D) $\frac{mv^2}{R \sin \theta}$
 - (E) $mvR \sin \theta$

4. A ball of mass m is swung in a vertical circle of radius R . The speed of the ball at the bottom of the circle is v . The tension in the string at the bottom of the circle is
- (A) mg
 - (B) $mg + \frac{mv^2}{R}$
 - (C) $mg - \frac{mv^2}{R}$
 - (D) $\frac{mv^2}{R}$
 - (E) 0
5. A car of mass m drives on a flat circular track of radius R . To maintain a constant speed v on the track, the coefficient of friction μ between the tires and the road must be
- (A) mg
 - (B) $mg + \frac{mv^2}{R}$
 - (C) $mg - \frac{mv^2}{R}$
 - (D) $\frac{v^2}{gR}$
 - (E) $\sqrt{\frac{v^2}{gR}}$

Questions 6–7

6. A ball on the end of a string is swung in a circle of radius 2 m according to the equation $\theta = 4t^2 + 3t$, where θ is in radians and t is in seconds. The angular acceleration of the ball is
- (A) 6 rad/s²
 - (B) $4t^2 + 3t$ rad/s²
 - (C) $8t + 3$ rad/s²
 - (D) $\frac{3}{4}t^3 + 3t^2$ rad/s²
 - (E) 8 rad/s²
7. The linear speed v of the ball at $t = 3$ s is
- (A) 27 m/s
 - (B) 54 m/s
 - (C) 108 m/s
 - (D) 135 m/s
 - (E) 210 m/s
8. A belt is wrapped around two wheels as shown. The smaller wheel has a radius r , and the larger wheel has a radius $2r$. When the wheels turn, the belt does not slip on the wheels, and gives the smaller wheel an angular speed ω . The angular speed of the larger wheel is
- (A) $\frac{1}{4}\omega$
 - (B) $\frac{1}{2}\omega$
 - (C) ω
 - (D) 2ω
 - (E) 4ω



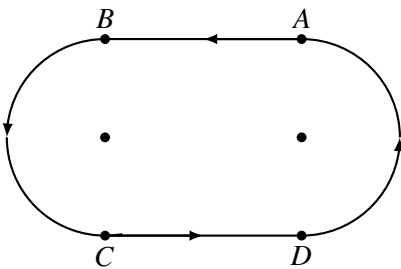


9. A ball on the end of a string is released from rest at point X as shown. The ball swings under the influence of gravity from point X through points Y and Z . What are the directions of the acceleration vectors at points Y and Z , respectively?

- (A) Point Y : \uparrow Point Z : \leftarrow
 (B) Point Y : \downarrow Point Z : \downarrow
 (C) Point Y : \swarrow Point Z : \searrow
 (D) Point Y : \searrow Point Z : \leftarrow
 (E) Point Y : \downarrow Point Z : \searrow

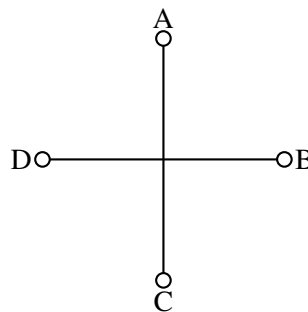
10. A merry-go-round is initially at rest, and begins to rotate with a constant angular acceleration α . The angular speed ω of the merry-go-round after making two complete revolutions is

- (A) 2α
 (B) 4α
 (C) $\sqrt{2\pi\alpha}$
 (D) $4\pi\alpha$
 (E) $\sqrt{8\pi\alpha}$



11. A speed skater races around a track in which the sides are equal length and parallel and the curves are semicircular. The skater keeps a constant speed throughout one entire lap. She starts at point A and travels counterclockwise around the track for one lap. Which of the following graphs best represents the magnitude of the skater's acceleration as a function of time for one lap?

- (A)
- (B)
- (C)
- (D)
- (E)



Questions 13–14

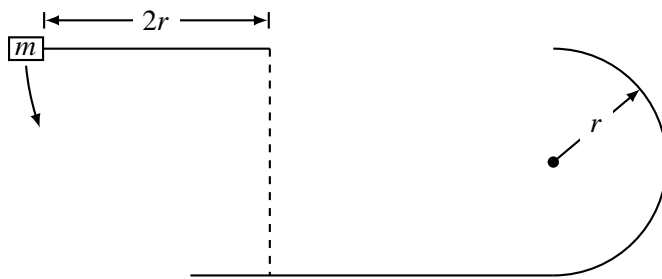
Two balls of equal mass are attached to each end of a rod that is spinning about its center in the vertical plane with a constant angular speed ω . Each ball is a radius r from the center of the rod. A bug holds on to one of the balls as the system rotates. Four points, A , B , C , and D , are marked at the quarter circle points on the circle.

13. At which point would the bug need to apply the most adhesive force to remain on the ball?
- (A) A
 (B) B
 (C) C
 (D) D
 (E) The bug would apply the same force at all points to remain on the ball.
14. The minimum force necessary the bug would have to apply to remain on the ball at point C is
- (A) $m\omega r$
 (B) $m\omega^2 r$
 (C) mg
 (D) $m\omega^2 r - mg$
 (E) $m\omega^2 r + mg$

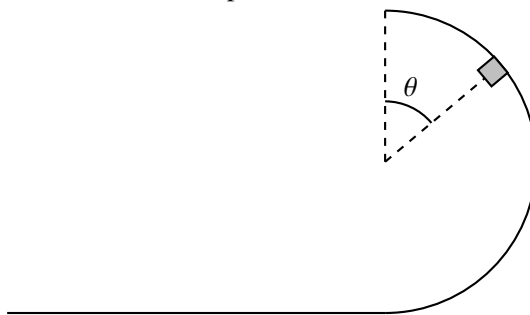
AP PHYSICS C: CIRCULAR MOTION
SECTION II
2 Questions

Directions: Answer all questions. The parts within a question may not have equal weight. All final numerical answers should include appropriate units. Credit depends on the quality of your solutions and explanations, so you should show your work. Credit also depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should clearly indicate which part of a question your work is for.

1. A mass m attached to a string of length $2r$ swings, starting at rest when the string is horizontal, until the string is vertical. At the instant the string is vertical, the mass makes contact with the horizontal surface, the string is cut, and the mass continues along a frictionless track as shown below.

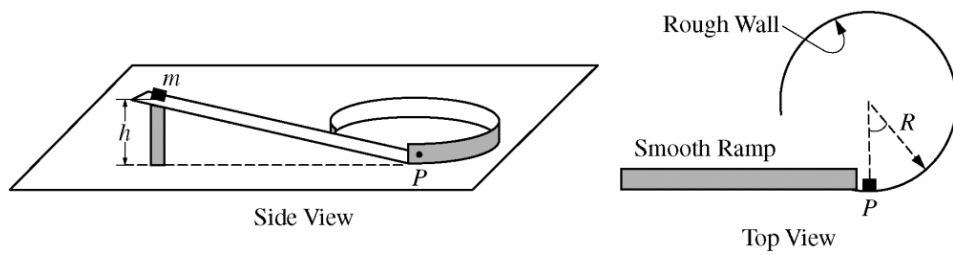


- (a) What is the speed of the mass attached to the string the instant the string is cut?
(b) Sketch the forces acting on the mass when it is in the position shown below.



When the mass is in the position shown above,

- (c) Find the object's speed as a function of θ
(d) Find the object's centripetal acceleration as a function of θ
(e) Determine at what angle θ the mass will fall off the track



2. A small block of mass m starts from rest at the top of a frictionless ramp, which is at a height h above a horizontal tabletop, as shown in the side view above. The block slides down the smooth ramp and reaches point P with a speed v_0 . After the block reaches point P at the bottom of the ramp, it slides on the tabletop guided by a circular vertical wall with radius R , as shown in the top view. The tabletop has negligible friction, and the coefficient of kinetic friction between the block and the circular wall is μ .

- (a) Derive an expression for the height of the ramp h . Express your answer in terms of v_0 , m , and fundamental constants, as appropriate.

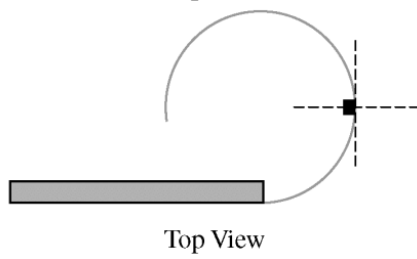
A short time after passing point P , the block is in contact with the wall and moves with a speed of v .

- (b) i. Is the vertical component of the net force on the block upward, downward, or zero?

____ Upward ____ Downward ____ Zero

Justify your answer.

- ii. On the figure below, draw an arrow starting on the block to indicate the direction of the horizontal component of the net force on the moving block when it is at the position shown.



Express your answers to the following in terms of v_0 , v , m , R , μ , and fundamental constants, as appropriate.

- (c) Determine an expression for the magnitude of the normal force N exerted on the block by the circular wall as a function of v .
- (d) Derive an expression for the magnitude of the tangential acceleration of the block at the instant the block has attained a speed of v .
- (e) Derive an expression for $v(t)$, the speed of the block as a function of time t after passing point P on the track.