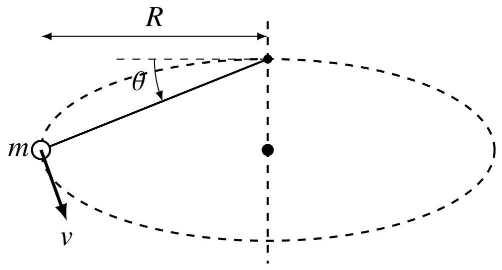
Student #: ______________________ Student Name: ______________________________

AP PHYSICS C: CICULAR 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.

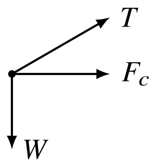
Note: To simplify calculations, you may use $g = 10\,\text{m/s}^2$ in all problems.

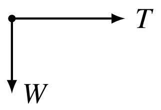
1. A girl stands on a rotating merry-go-round without holding on to a rail. The force that keeps her moving in a circle is the
   - (A) frictional force on the girl directed away from the center of the merry-go-round
   - (B) frictional force on the girl directed toward the center of the merry-go-round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

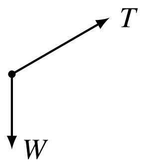


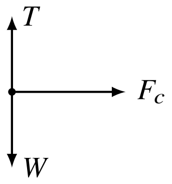
Questions 2–3 A ball of mass m and weight W on the end of a string is swung in a horizontal circle of radius R with a speed v. The string makes an angle θ below the horizontal, as shown. The magnitude of the tension in the string is T.

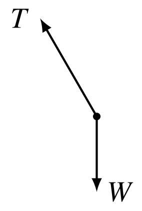
2. Which of the following diagrams best shows the forces acting on the ball as it moves in a circle?

(A) 

(B) 

(C) 

(D) 

(E) 

3. In terms of m, R, v, and θ, the magnitude of the tension T is
   - (A) $\dfrac{mv^2}{R}$
   - (B) $\dfrac{mv^2}{R\sin\theta}$
   - (C) $\dfrac{mv^2}{R\cos\theta}$
   - (D) $\dfrac{mv}{R\sin\theta}$
   - (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) $mg + \dfrac{mv^2}{R}$
   - (C) $mg - \dfrac{mv^2}{R}$
   - (D) $\dfrac{mv^2}{R}$
   - (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) $mg + \dfrac{mv^2}{R}$
   - (C) $mg - \dfrac{mv^2}{R}$
   - (D) $\dfrac{v^2}{gR}$
   - (E) $\sqrt{\dfrac{v^2}{gR}}$

Questions 6–7

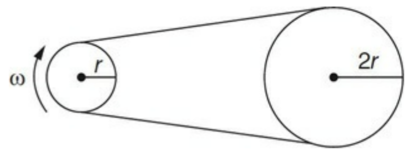
6. A ball on the end of a string is swung in a circle of radius 2 m according to the equation $\theta = 4t^2 + 3t$, where θ is in radians and t is in seconds. The angular acceleration of the ball is
   - (A) $6\,\text{rad/s}^2$
   - (B) $4t^2 + 3t\,\text{rad/s}^2$
   - (C) $8t + 3\,\text{rad/s}^2$
   - (D) $\frac{3}{4}t^3 + 3t^2\,\text{rad/s}^2$
   - (E) $8\,\text{rad/s}^2$

$\omega = \dot{\theta}$

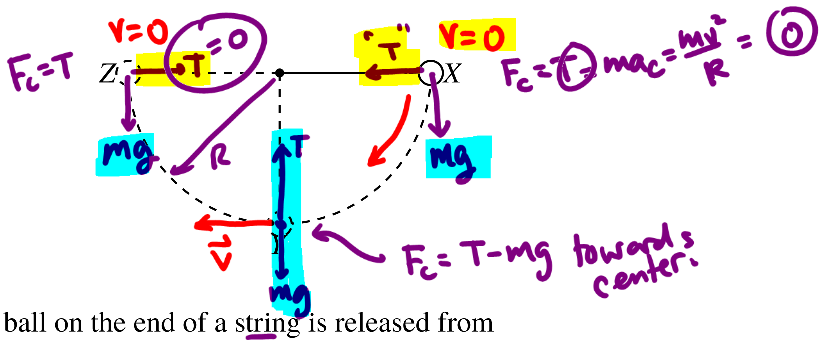
$\alpha = \dot{\omega} = \ddot{\theta}$

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) ω
   - (B) 2ω
   - (C) $\frac{1}{2}\omega$
   - (D) $\frac{1}{4}\omega$
   - (E) 4ω

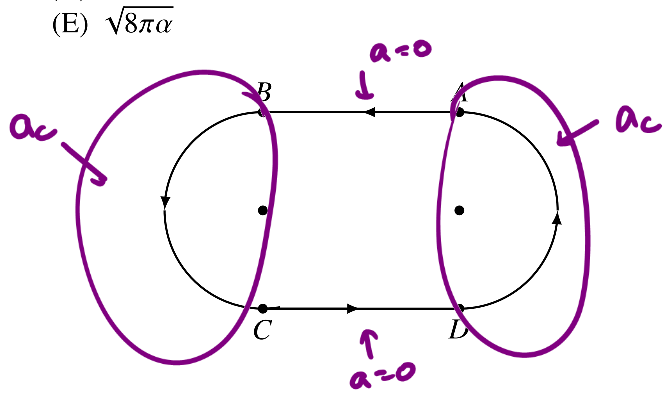


9. A ball on the end of a string is released from rest at point X as shown. The ball swings under the influence of gravity from point X through points Y and Z. What are the directions of the acceleration vectors at points Y and Z, respectively?

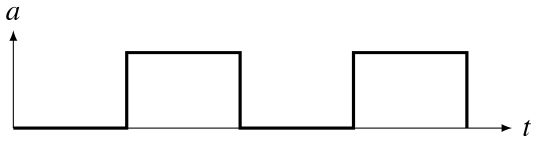
   (A) Point Y: ↑ Point Z: ←
   (B) Point Y: ↓ Point Z: ↓
   (C) Point Y: ↖ Point Z: ↘
   (D) Point Y: ↘ Point Z: ←
   (E) Point Y: ↓ Point Z: ↘

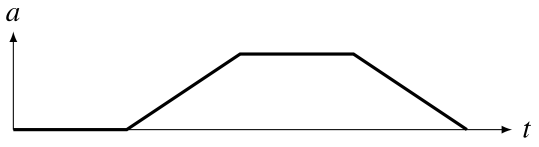
10. A merry-go-round is initially at rest, and begins to rotate with a constant angular acceleration α. The angular speed ω of the merry-go-round after making two complete revolutions is

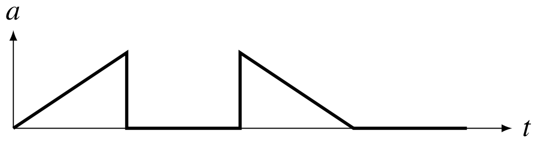
    (A) 2α
    (B) 4α
    (C) $\sqrt{2\pi\alpha}$
    (D) $4\pi\alpha$
    (E) $\sqrt{8\pi\alpha}$

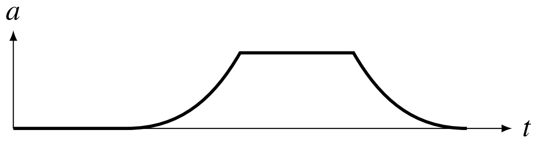


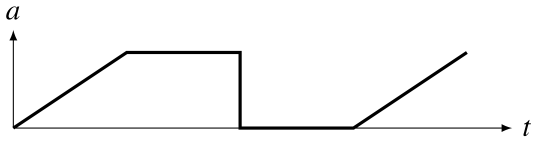
11. A speed skater races around a track in which the sides are equal length and parallel and the curves are semicircular. The skater keeps a constant speed throughout one entire lap. She starts at point A and travels counterclockwise around the track for one lap. Which of the following graphs best represents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

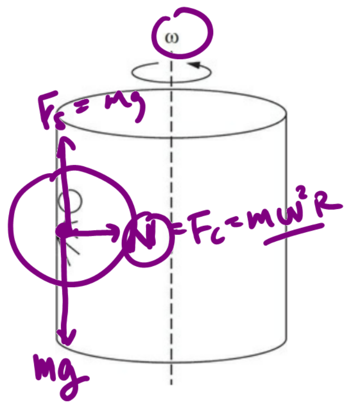
    (A) 

    (B) 

    (C) 

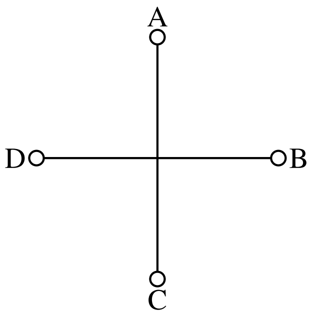
    (D) 

    (E) 



12. An amusement park ride consists of a cylindrical room that spins so that people leaning up against the wall can stick to the wall even if the floor is lowered out from under them. The rotating room reaches a maximum angular speed ω, the floor is lowered, and the riders stick to the wall. Which of the following statements is true?

    (A) The weight of each rider provides the centripetal force keeping the rider moving in a circle.
    (B) The normal force applied by the wall must equal the weight of the rider.
    (C) The difference between the normal force applied by the wall and the weight of the rider is equal to the centripetal force acting on the rider.
    (D) The frictional force between the wall and the rider must equal the weight of the rider.
    (E) The frictional force between the wall and the rider provides the centripetal force acting on the rider.



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?

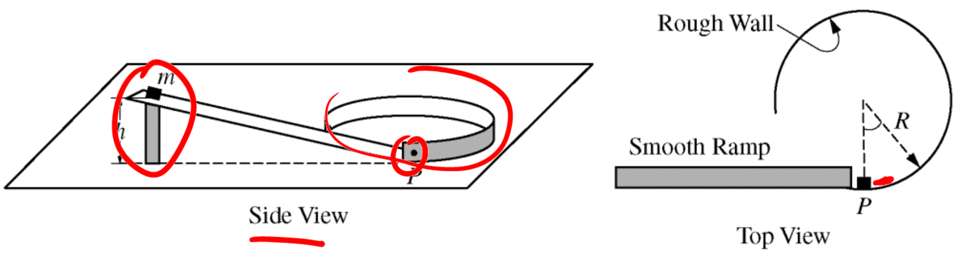
    (A) A
    (B) B
    (C) C
    (D) D
    (E) The bug would apply the same force at all points to remain on the ball.

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
1 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.



Side View Top View

1. 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.

(2) (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.

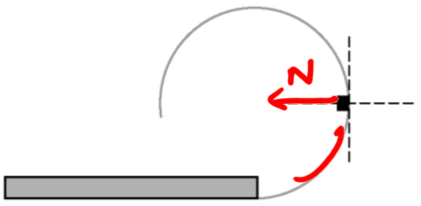
A short time after passing point P, the block is in contact with the wall and moves with a speed of v.

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

____ Upward ____ Downward __✓__ Zero

Justify your answer. no vertical motion → no vertical acceleration → no vertical net force

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.



Top View

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

(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.

(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.

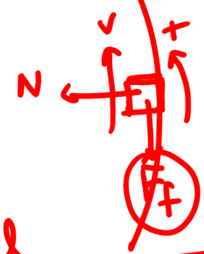
$$mgh = \frac{1}{2}mv_0^2 \rightarrow \boxed{h = \frac{v_0^2}{2g}}$$

(1) (1)

(c)
normal force = centripetal force

$$N = F_c = \boxed{\frac{mv^2}{R}}$$

(3)



$$-F_f = ma_T$$
$$-\mu N = ma_T$$
$$-\mu \frac{mv^2}{R} = ma_T$$
$$\boxed{a_T = -\frac{\mu v^2}{R}}$$

slows down

differential equation

$$\frac{dv}{dt} = \frac{-\mu v^2}{R}$$

$$\int \frac{dv}{v^2} = \left(\frac{-\mu}{R}\right)\int dt$$

$$\left(-\frac{1}{v}\right)\Bigg|_{v_0}^{v} = \frac{-\mu t}{R}\Bigg|_{0}^{t}$$

at t → v

at t=0, v=v₀

$$\frac{1}{v} - \frac{1}{v_0} = \frac{\mu t}{R}$$

$$\boxed{v = \frac{Rv_0}{R+\mu v_0 t}} \qquad \boxed{v = \frac{v_0}{1+\frac{\mu v_0 t}{R}}}$$