Mechanics Practice Exam for AP Physics C

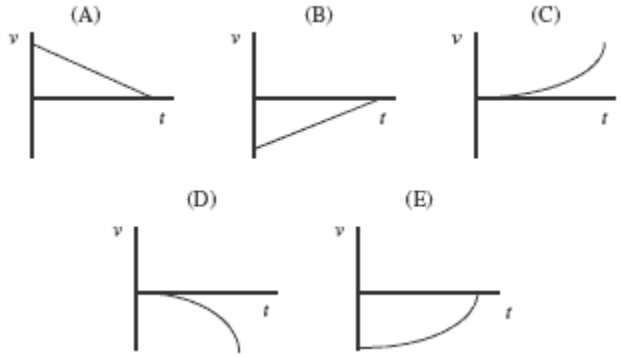
Below is a Mechanics practice exam for AP Physics C exam. There are two sections in this practice exam. Section I has 35 multiple choice questions. Section II has three free response questions.

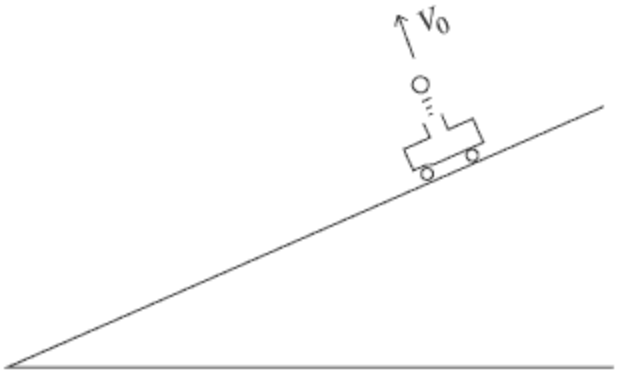
Problems

Multiple Choice Questions

Time: 45 minutes. You may refer to the Constants sheet. However, you may not use the Equations sheet, and you may not use a calculator on this portion of the exam.

1. A cannon is mounted on a truck that moves forward at a speed of 5 m/s. The operator wants to launch a ball from a cannon so the ball goes as far as possible before hitting the level surface. The muzzle velocity of the cannon is 50 m/s. What angle from the horizontal should the operator point the cannon?
   A. 5°
   B. 41°
   C. 45°
   D. 49°
   E. 85°
2. A car moving with speed v reaches the foot of an incline of angle θ. The car coasts up the incline without using the engine. Neglecting friction and air resistance, which of the following is correct about the magnitude of the car's horizontal acceleration a_x and vertical acceleration a_y?
   A. $a_x = 0$; $a_y < g$
   B. $a_x = 0$; $a_y = g$
   C. $a_x < g$; $a_y < g$
   D. $a_x < g$; $a_y = g$
   E. $a_x < g$; $a_y > g$
3. A bicycle slows down with an acceleration whose magnitude increases linearly with time. Which of the following velocity–time graphs could represent the motion of the bicycle?



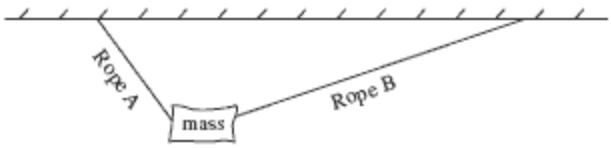


4. A cart is sliding down a low friction incline. A device on the cart launches a ball, forcing the ball perpendicular to the incline, as shown above. Air resistance is negligible. Where will the ball land relative to the cart, and why?
    A. The ball will land in front of the cart, because the ball's acceleration component parallel to the plane is greater than the cart's acceleration component parallel to the plane.
    B. The ball will land in front of the cart, because the ball has a greater magnitude of acceleration than the cart.
    C. The ball will land in the cart, because both the ball and the cart have the same component of acceleration parallel to the plane.
    D. The ball will land in the cart, because both the ball and the cart have the same magnitude of acceleration.
    E. The ball will land behind the cart, because the ball slows down in the horizontal direction after it leaves the cart.
5. The quantity "jerk," j, is defined as the time derivative of an object's acceleration,

$$j = \frac{da}{dt} = \frac{d^3x}{dt^3}.$$

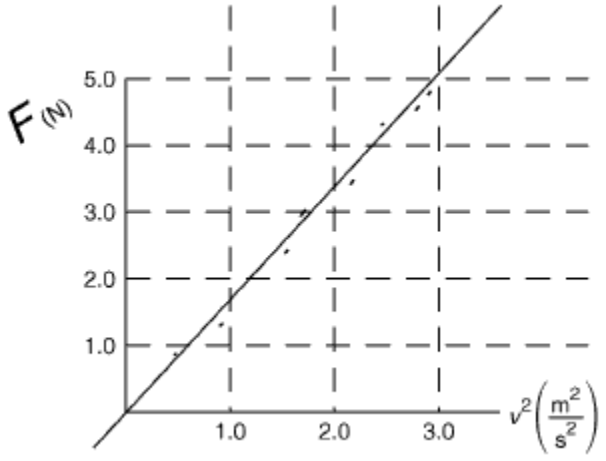
What is the physical meaning of the area under a graph of jerk vs. time?

    A. The area represents the object's acceleration.
    B. The area represents the object's change in acceleration.
    C. The area represents the object's change in velocity.
    D. The area represents the object's velocity.
    E. The area represents the object's change in position.
6. A particle moves along the x-axis with a position given by the equation $x(t) = 5 + 3t$, where x is in meters, and t is in seconds. The positive direction is east. Which of the following statements about the particle is FALSE.
    0. The particle is east of the origin at $t = 0$.
    1. The particle is at rest at $t = 0$.
    2. The particle's velocity is constant.
    3. The particle's acceleration is constant.
    4. The particle will never be west of position $x = 0$.



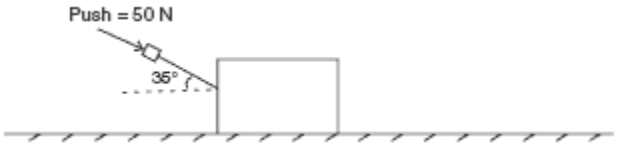
7. A mass hangs from two ropes at unequal angles, as shown above. Which of the following makes correct comparisons of the horizontal and vertical components of the tension in each rope?

	Horizontal Tension	Vertical Tension
(A)	greater in rope *B*	greater in rope *B*
(B)	equal in both ropes	greater in rope *A*
(C)	greater in rope *A*	greater in rope *A*
(D)	equal in both ropes	equal in both ropes
(E)	greater in rope *B*	equal in both ropes



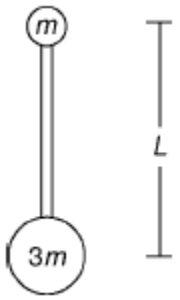
8. The force of air resistance F on a mass is found to obey the equation $F = bv^2$, where v is the speed of the mass, for the range of speeds investigated in an experiment. A graph of F_N vs. v^2 is shown above. What is the value of b?
   . 0.83 kg/m
   A. 1.7 kg/m
   B. 3.0 kg/m
   C. 5.0 kg/m
   D. 1.0 kg/m
   E. zero

9. A box sits on an inclined plane without sliding. As the angle of the plane (measured from the horizontal) increases, the normal force
   . increases linearly
   A. decreases linearly
   B. does not change
   C. decreases nonlinearly
   D. increases nonlinearly
10. Which of the following conditions are necessary for an object to be in static equilibrium?
   . The vector sum of all torques on the object must equal zero.
   I. The vector sum of all forces on the object must equal zero.
   II. The sum of the object's potential and kinetic energies must be zero.
      c. I only
      d. II only
      e. III only
      f. I and II only
      g. I, II, and III

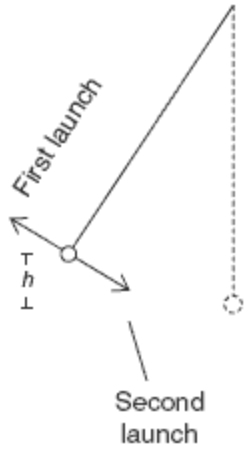


11. A student pushes a big 16-kg box across the floor at constant speed. He pushes with a force of 50 N angled 35° from the horizontal, as shown in the diagram above. If the student pulls rather than pushes the box at the same angle, while maintaining a constant speed, what will happen to the force of friction?
   a. It must increase.
   b. It must decrease.
   c. It must remain the same.
   d. It will increase only if the speed is greater than 3.1 m/s.
   e. It will increase only if the speed is less than 3.1 m/s.
12. Consider a system consisting only of the Earth and a bowling ball, which moves upward in a parabola above Earth's surface. The downward force of Earth's gravity on the ball, and the upward force of the ball's gravity on the Earth, form a Newton's third law force pair. Which of the following statements about the ball is correct?
   a. The ball must be in equilibrium since the upward forces must cancel downward forces.
   b. The ball accelerates toward the Earth because the force of gravity on the ball is greater than the force of the ball on the Earth.
   c. The ball accelerates toward the Earth because the force of gravity on the ball is the only force acting on the ball.
   d. The ball accelerates away from Earth because the force causing the ball to move upward is greater than the force of gravity on the ball.

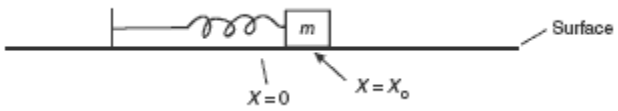
e. The ball accelerates away from Earth because the force causing the ball to move upward plus the force of the ball on the Earth are together greater than the force of gravity on the ball.



13. A mass *m* is attached to a mass 3*m* by a rigid bar of negligible mass and length *L*. Initially, the smaller mass is located directly above the larger mass, as shown above. How much work is necessary to flip the rod 180° so that the larger mass is directly above the smaller mass?
    a. 4*mgL*
    b. 2*mgL*
    c. *mgL*
    d. 4*pmgL*
    e. 2*pmgL*
14. A ball rolls horizontally with speed *v* off of a table a height *h* above the ground. Just before the ball hits the ground, what is its speed?
    a. $\sqrt{2gh}$
    b. $v\sqrt{2gh}$
    c. $\sqrt{v^2+2gh}$
    d. v
    e. $v+\sqrt{2gh}$



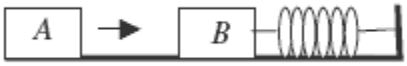
15. A pendulum is launched into simple harmonic motion in two different ways, as shown above, from a point that is a height *h* above its lowest point. During both launches, the bob is given an initial speed of 3.0 m/s. On the first launch, the initial velocity of the bob is directed upward along the pendulum's path, and on the second launch it is directed downward along the pendulum's path. Which launch will cause the pendulum to swing with the larger amplitude?
    a. the first launch
    b. the second launch
    c. Both launches produce the same amplitude.
    d. The answer depends on the initial height *h*.
    e. The answer depends on the length of the supporting rope.



16. The mass *M* is moving to the right with velocity v_0 at position $x = x_0$. Neglect friction. The spring has force constant *k*. What is the total mechanical energy of the block at this position?

(A) $\frac{1}{2}mv_0^2$
(B) $\frac{1}{2}mv_0^2 + \frac{1}{2}kx_0^2$
(C) $\frac{1}{2}mv_0^2 + \frac{1}{2}kx_0^2 + mgx_0$
(D) $mgx_0 + \frac{1}{2}mv_0^2$
(E) $mgx_0 + \frac{1}{2}kx_0^2$

17. A sphere, a cube, and a cylinder, all of equal mass, are released from rest from the top of a short incline. The surface of the incline is extremely slick, so much so that the objects do not rotate when released, but rather slide with negligible friction. Which reaches the base of the incline first?
    a. the sphere
    b. the cube
    c. the cylinder
    d. All reach the base at the same time.
    e. The answer depends on the relative sizes of the objects.



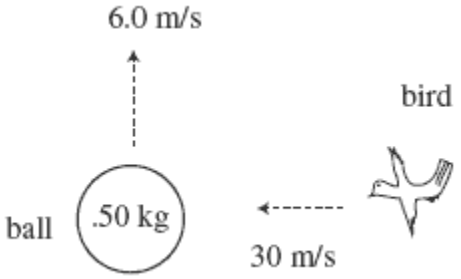
18. Block B is at rest on a smooth tabletop. It is attached to a long spring, which is in turn anchored to the wall. Block *A* slides toward and collides with block B. Consider two possible collisions:

    Collision I: Block *A* bounces back off of block *B*.

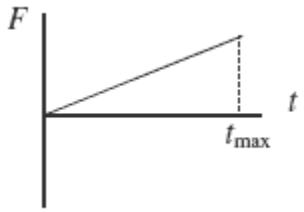
    Collision II: Block *A* sticks to block *B*.

Which of the following is correct about the speed of block *B* immediately after the collision?

A. It is faster in case II than in case I ONLY if block *B* is heavier.
B. It is faster in case I than in case II ONLY if block *B* is heavier.
C. It is faster in case II than in case I regardless of the mass of each block.
D. It is faster in case I than in case II regardless of the mass of each block.
E. It is the same in either case regardless of the mass of each block.

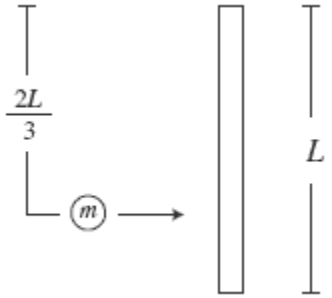


19. A 0.30-kg bird is flying from right to left at 30 m/s. The bird collides with and sticks to a 0.50-kg ball which is moving straight up with speed 6.0 m/s. What is the magnitude of the momentum of the ball/bird combination immediately after collision?
    . 12.0 N•s
    A. 9.5 N•s
    B. 9.0 N•s
    C. 6.0 N•s
    D. 3.0 N•s



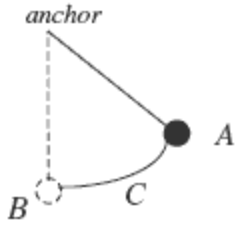
20. The force *F* on a mass is shown above as a function of time *t*. Which of the following methods can be used to determine the impulse experienced by the mass?
    . multiplying the average force by t_{max}
    I. calculating the area under the line on the graph
    II. taking the integral $\int_0^{t_{max}} F \cdot dt$
    C. II only
    D. III only
    E. II and III only
    F. I and II only
    G. I, II, and III
21. A projectile is launched on level ground in a parabolic path so that its range would normally be 500 m. When the projectile is at the peak of its flight, the projectile breaks into two pieces of equal mass. One of these pieces falls straight down, with no further horizontal motion. How far away from the launch point does the other piece land?
    . 250 m
    A. 375 m
    B. 500 m
    C. 750 m
    D. 1000 m

Questions 22 and 23



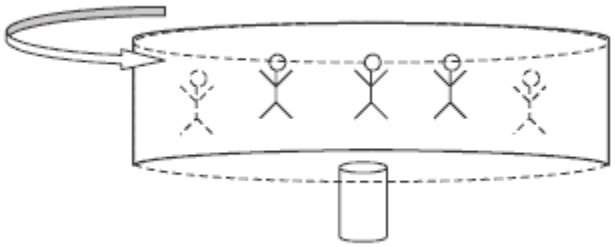
A rigid rod of length L and mass M is floating at rest in space far from a gravitational field. A small blob of putty of mass $m < M$ is moving to the right, as shown above. The putty hits and sticks to the rod a distance $2L/3$ from the top end.

22. How will the rod/putty contraption move after the collision?
    . The contraption will have no translational motion, but will rotate about the rod's center of mass.
    A. The contraption will have no translational motion, but will rotate about the center of mass of the rod and putty combined.
    B. The contraption will move to the right and rotate about the position of the putty.
    C. The contraption will move to the right and rotate about the center of mass of the rod and putty combined.
    D. The contraption will move to the right and rotate about the rod's center of mass.
23. What quantities are conserved in this collision?
    . linear and angular momentum, but not kinetic energy
    A. linear momentum only
    B. angular momentum only
    C. linear and angular momentum, and linear but not rotational kinetic energy
    D. linear and angular momentum, and linear and rotational kinetic energy
24. A car rounds a banked curve of uniform radius. Three forces act on the car: a friction force between the tires and the road, the normal force from the road, and the weight of the car. Which provides the centripetal force which keeps the car in circular motion?
    . the friction force alone
    A. the normal force alone
    B. the weight alone
    C. a combination of the normal force and the friction force
    D. a combination of the friction force and the weight



25. A ball of mass *m* anchored to a string swings back and forth to a maximum position *A*, as shown above. Point *C* is partway back to the vertical position. What is the direction of the mass's acceleration at point *C*?

. along the mass's path toward point *B*
A. toward the anchor
B. away from the anchor
C. between a line toward the anchor and a line along the mass's path
D. along the mass's path toward point *A*



26. In a carnival ride, people of mass m are whirled in a horizontal circle by a floorless cylindrical room of radius *r*, as shown in the diagram above. If the coefficient of friction between the people and the tube surface is μ, what minimum speed is necessary to keep the people from sliding down the walls?

(A) $\sqrt{\mu rg}$

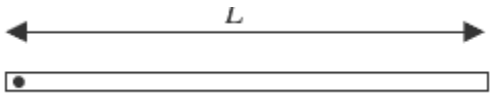
(B) $\sqrt{\frac{rg}{\mu}}$

(C) $\sqrt{\frac{\mu}{rg}}$

(D) $\sqrt{\frac{1}{\mu rg}}$

(E) $\sqrt{\mu mg}$

Questions 27 and 28



The uniform, rigid rod of mass *m*, length *L*, and rotational inertia *I* shown above is pivoted at its left-hand end. The rod is released from rest from a horizontal position.

27. What is the linear acceleration of the rod's center of mass the moment after the rod is released?

(A) $\frac{mgL^2}{2I}$

(B) $\frac{mgL^2}{4I}$

(C) $\frac{mgL^2}{I}$

(D) $\frac{mgL}{2I}$

(E) $\frac{2mgL^2}{I}$

28. What is the linear speed of the rod's center of mass when the mass passes through a vertical position?

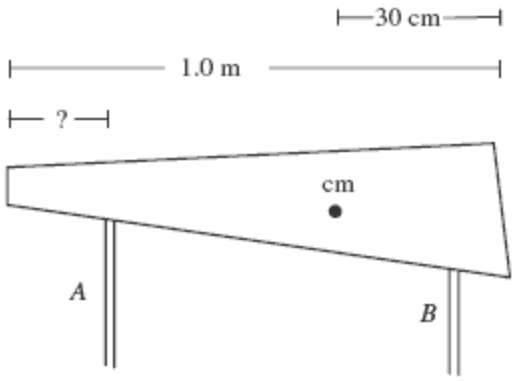
(A) $\sqrt{\frac{mgL^3}{8I}}$

(B) $\sqrt{\frac{mg\pi L^3}{4I}}$

(C) $\sqrt{\frac{mg\pi L^3}{8I}}$

(D) $\sqrt{\frac{mgL^3}{4I}}$

(E) $\sqrt{\frac{mgL^3}{2I}}$



29. The 1.0-m-long non-uniform plank, shown above, has weight 1000 N. It is to be supported by two rods, *A* and *B*, as shown above. The center of mass of the plank is 30 cm from the right edge. Each support bears half the weight of the plank. If support *B* is 10 cm from the right-hand edge, how far from the left-hand edge should support *A* be?
    . 0 cm
    A. 10 cm
    B. 30 cm
    C. 50 cm
    D. 70 cm
30. A mass *m* on a spring oscillates on a horizontal surface with period *T*. The total mechanical energy contained in this oscillation is *E*. Imagine that instead a new mass 4*m* oscillates on the same spring with the same amplitude. What is the new period and total mechanical energy?

	Period	Total Mechanical Energy
(A)	T	E
(B)	$2T$	E
(C)	$2T$	$2E$
(D)	T	$4E$
(E)	$2T$	$16E$

31. A mass *m* is attached to a horizontal spring of spring constant *k*. The spring oscillates in simple harmonic motion with amplitude *A*. What is the maximum speed of this simple harmonic oscillator?

(A) $2\pi\sqrt{\frac{m}{k}}$

(B) $2\pi A\sqrt{\frac{m}{k}}$

(C) $2\pi A\sqrt{\frac{k}{m}}$

(D) $A\sqrt{\frac{k}{m}}$

(E) $A\sqrt{\frac{m}{k}}$

32. An empty bottle goes up and down on the surface of the ocean, obeying the position function $x = A\cos(\omega t)$. How much time does this bottle take to travel once from its lowest position to its highest position?

(A) $\frac{2\pi}{\omega}$

(B) $\frac{\pi}{\omega}$

(C) $\frac{4\pi}{\omega}$

(D) $\frac{\pi}{2\omega}$

(E) $\frac{\pi}{4\omega}$

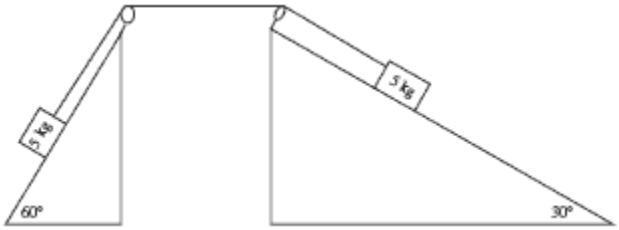
33. The Space Shuttle orbits 300 km above the Earth's surface; the Earth's radius is 6400 km. What is the acceleration due to Earth's gravity experienced by the Space Shuttle?
    . $4.9\ m/s^2$
    A. $8.9\ m/s^2$
    B. $9.8\ m/s^2$
    C. $0.8\ m/s^2$
    D. zero
34. An artificial satellite orbits Earth just above the atmosphere in a circle with constant speed. A small meteor collides with the satellite at point *P* in its orbit, increasing its speed by 1%, but not changing the instantaneous direction of the satellite's velocity. Which of the following describes the satellite's new orbit?
    . The satellite now orbits in an ellipse, with *P* as the farthest approach to Earth.
    A. The satellite now orbits in an ellipse, with *P* as the closest approach to Earth.
    B. The satellite now orbits in a circle of larger radius.
    C. The satellite now orbits in a circle of smaller radius.
    D. The satellite cannot maintain an orbit, so it flies off into space.
35. Mercury orbits the sun in about one-fifth of an Earth year. If 1 AU is defined as the distance from the Earth to the sun, what is the approximate distance between Mercury and the sun?
    . (1/25) AU
    A. (1/9) AU
    B. (1/5) AU
    C. (1/3) AU
    D. (1/2) AU

STOP. End of Physics C—Mechanics Practice Exam—Multiple-Choice Questions

Free Response

Time: 45 minutes. You may refer to the Constants sheet and Equations sheet in the Appendixes. You may also use a calculator on this portion of the exam.

CM 1



Two 5-kg masses are connected by a light string over two massless, frictionless pulleys. Each block sits on a frictionless inclined plane, as shown above. The blocks are released from rest.

a. Determine the magnitude of the acceleration of the blocks.

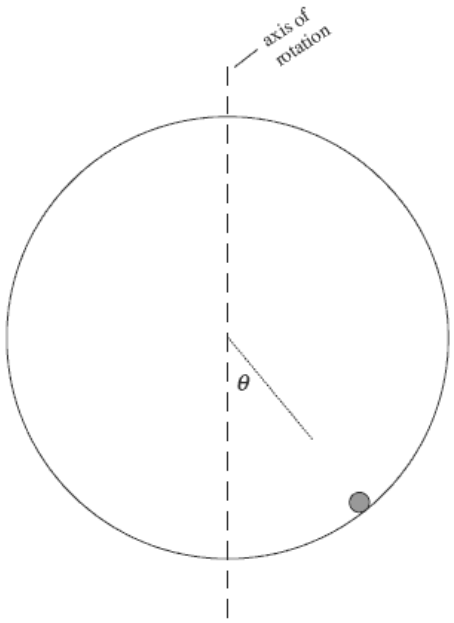
b. Determine the tension in the string.

Now assume that the 30° incline is rough, so that the coefficient of friction between the block and the plane is 0.10. The 60° incline is still frictionless.

1. Determine the magnitude of the acceleration of the blocks.

2. Determine the tension in the string.

CM 2



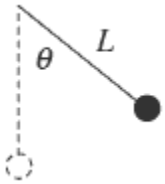
A hollow glass sphere of radius 8.0 cm rotates about a vertical diameter with frequency 5 revolutions per second. A small wooden ball of mass 2.0 g rotates inside the sphere, as shown in the diagram above.

a. Draw a free-body diagram indicating the forces acting on the wooden ball when it is at the position shown in the picture above.
b. Calculate the angle θ, shown in the diagram above, to which the ball rises.

c. Calculate the linear speed of the wooden ball as it rotates.

d. The wooden ball is replaced with a steel ball of mass 20 g. Describe how the angle θ to which the ball rises will be affected. Justify your answer.

CM 3



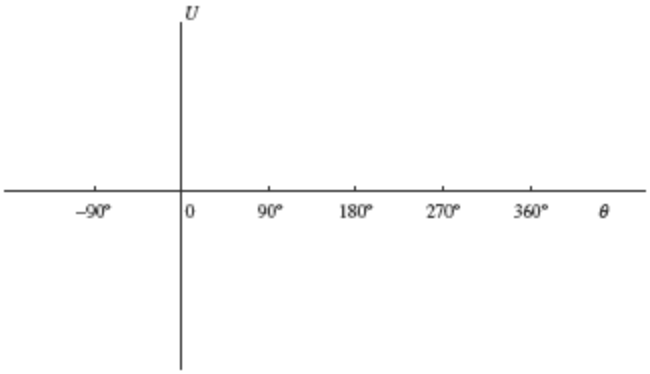
A heavy ball of mass *m* is attached to a light but rigid rod of length *L*. The rod is pivoted at the top and is free to rotate in a circle in the plane of the page, as shown above.

a. The mass oscillates to a maximum angle θ. On the picture of the mass *m* below, draw a vector representing the direction of the NET force on the mass while it is at angle θ. Justify your choice of direction.

b. Is the magnitude of the net force at the maximum displacement equal to *mg* sinθ or *mg* cosθ? Choose one and justify your choice.

c. Derive an expression for the ball's potential energy *U* as a function of the angle θ. Assume that a negative angle represents displacement from the vertical in the clockwise direction.

d. On the axes below, sketch a graph of the mass's potential energy *U* as a function of the angle θ for angles between –90° and +360°. Label maximum and minimum values on the vertical axis.



e. The pendulum is considered a classic example of simple harmonic motion when it undergoes small-amplitude oscillation. With specific reference to the graph you made in part (d), explain why the assumption of simple harmonic motion is valid.

STOP. End of Physics C—Mechanics Practice Exam—Free-Response Questions