PHYSICS C
Section I
Time–45 minutes
35 Questions

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 $g = 10\,\mathrm{m/s^2}$ in all problems.

1. Which of the following graphs of position d versus time t corresponds to motion of an object in a straight line with positive acceleration?

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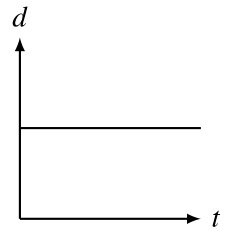
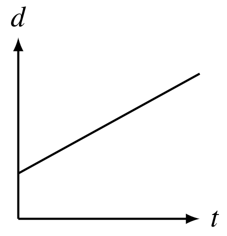


(B)


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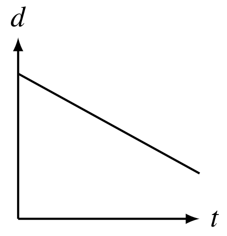

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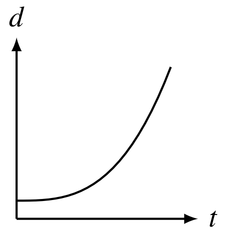

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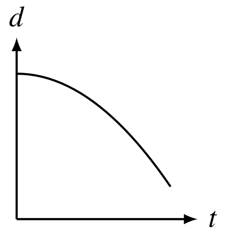


2. A ball is thrown straight up from a point 2 m above the ground. The ball reaches a maximum height of 3 m above its starting point and then falls 5 m to the ground. When the ball strikes the ground, what is its displacement from its starting point?

(A) Zero (B) 8 m below (C) 5 m below (D) 2 m below (E) 3 m above

3. What do acceleration and velocity have in common?

(A) Both are scalars.
(B) Both are vectors.
(C) Both are measured in units of distance divided by time.
(D) Both are measured in units of distance divided by time squared.
(E) They are different names for the same quantity.

4. Two projectiles are launched with the same initial speed from the same location, one at a 30° angle and the other at a 60° angle with the horizontal. They land at the same height at which they were launched. If air resistance is negligible, how do the projectiles' respective maximum heights, H_{30} and H_{60} , and times in the air, T_{30} and T_{60}, compare with each other?

	Maximum Height	Time in Air
(A)	$H_{30} > H_{60}$	$T_{30} > T_{60}$
(B)	$H_{30} > H_{60}$	$T_{30} < T_{60}$
(C)	$H_{30} = H_{60}$	$T_{30} = T_{60}$
(D)	$H_{30} < H_{60}$	$T_{30} > T_{60}$
(E)	$H_{30} < H_{60}$	$T_{30} < T_{60}$

5. An object of mass 100 kg is initially at rest on a horizontal frictionless surface. At time $t = 0$, a horizontal force of 10 N is applied to the object for 1 s and then removed. Which of the following is true of the object at time $t = 2$ s if it is still on the surface?

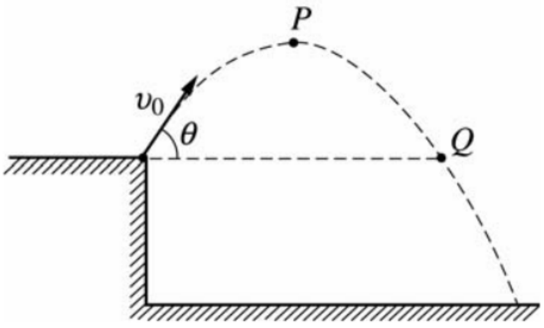
(A) It is at the same position it had at $t = 0$, since a force of 10 N is not large enough to move such a massive object.
(B) It is moving with constant nonzero acceleration.
(C) It is moving with decreasing acceleration.
(D) It is moving at a constant velocity.
(E) It has come to rest some distance away from the position it had at $t = 0$.

6. Several forces act on an object, but the object is in equilibrium. Which of the following statements about the object must be true?

I. It has zero acceleration.
II. The net force acting on it is zero.
III. It is at rest.
IV. It is moving with constant velocity.

(A) I and II (B) I and III (C) I and IV (D) II and III (E) II and IV

Question 7–8



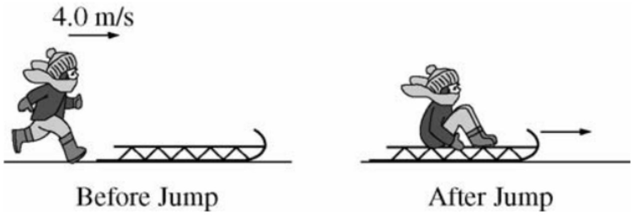
A rock is thrown from the edge of a cliff with an initial velocity v_0 at an angle θ with the horizontal as shown above. Point P is the highest point in the rock's trajectory and point Q is level with the starting point. Assume air resistance is negligible.

7. Which of the following correctly describes the horizontal and vertical speeds and the acceleration of the rock at P?

	Horizontal Speed	Vertical Speed	Acceleration
(A)	$v_0 \cos\theta$	0	g
(B)	0	0	g
(C)	$v_0 \cos\theta$	0	0
(D)	$v_0 \cos\theta$	$v_0 \sin\theta$	0
(E)	0	$v_0 \cos\theta$	0

8. Which of the following correctly describes the horizontal and vertical speeds and the acceleration of the rock at Q?

	Horizontal Speed	Vertical Speed	Acceleration
(A)	$v_0 \cos\theta$	0	g
(B)	0	0	g
(C)	$v_0 \cos\theta$	0	0
(D)	$v_0 \cos\theta$	$v_0 \sin\theta$	0
(E)	0	$v_0 \cos\theta$	0



9. As shown in the figure above, a child of mass 20 kg who is running at a speed of 4.0 m/s jumps onto a stationary sled of mass 5.0 kg on a frozen lake. The speed at which the child and sled begin to slide across the ice is most nearly

(A) 0.20 m/s (B) 0.80 m/s (C) 1.2 m/s (D) 3.2 m/s (E) 16 m/s

10. A toy spacecraft is launched directly upward. When the toy reaches its highest point, a spring is released and the toy splits into two parts with masses of 0.02 kg and 0.08 kg, respectively. Immediately after the separation, the 0.02 kg part moves horizontally due east. Air resistance is negligible. True statements about the 0.08 kg part include which of the following?

I. It could move north immediately after the spring is released.
II. It takes longer to reach the ground than does the 0.02 kg part.
III. It strikes the ground farther from the launch point than does the 0.02 kg part.

(A) None
(B) I only
(C) III only
(D) I and II only
(E) II and III only

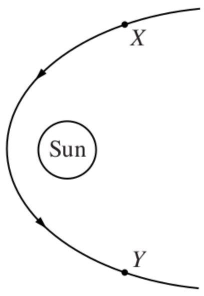
11. A student initially stands on a circular platform that is free to rotate without friction about its center. The student jumps off tangentially, setting the platform spinning. Quantities that are conserved for the student-platform system as the student jumps include which of the following?

I. Angular momentum
II. Linear momentum
III. Kinetic energy

(A) I only (B) II only (C) I and II only (D) II and III only (E) I, II, and III

12. In an experiment with a simple pendulum, measurements of the period T of the pendulum are made for different values of its length L. When plotted on a graph, which of the following should result in a straight-line fit of the data?

(A) $\sqrt{T}$ versus L (B) T versus L (C) T versus L^2 (D) T^2 versus L (E) T^2 versus L^2



13. A comet moves in the Sun's gravitational field, following the path shown above. What happens to its angular momentum as it moves from point X to point Y?

    (A) It increases steadily.
    (B) It remains constant.
    (C) It decreases steadily.
    (D) It increases as it approaches the Sun and decreases as it moves away from the Sun.
    (E) It decreases as it approaches the Sun and increases as it moves away from the Sun.

14. Satellite X moves around Earth in a circular orbit of radius R. Satellite Y is also in a circular orbit around Earth, and it completes one orbit for every eight orbits completed by satellite X. What is the orbital radius of satellite Y?

    (A) $R/4$ (B) $R/2$ (C) $2R$ (D) $4R$ (E) $8R$

15. A newly discovered planet is found to have twice the radius and five times the mass of Earth. If the acceleration of gravity at the surface of Earth is g, the acceleration of gravity at the surface of the new planet is

    (A) $\frac{2g}{5}$ (B) $\frac{4g}{5}$ (C) g (D) $\frac{5g}{4}$ (E) $\frac{5g}{2}$

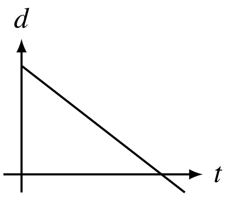
Questions 16–17

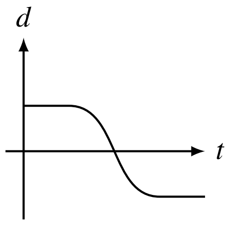
A toy car of mass 6 kg, moving in a straight path, experiences a net force given by the function $F = -3t$. At time $t = 0$, the car has a velocity of $4\,\mathrm{m/s}$ in the positive direction and is located +8 m from the origin.

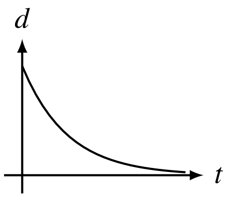
16. The car will come instantaneously to rest at time t equal to

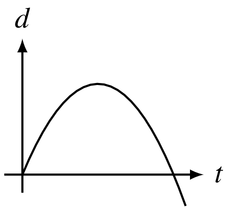
    (A) $\frac{2}{3}$ s (B) $\sqrt{\frac{4}{3}}$ s (C) $\sqrt{\frac{8}{3}}$ s (D) $\sqrt{8}$ s (E) 4 s

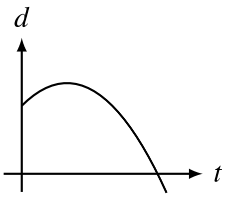
17. Which of the following best shows a graph of position d versus time t for the car?

(A) 

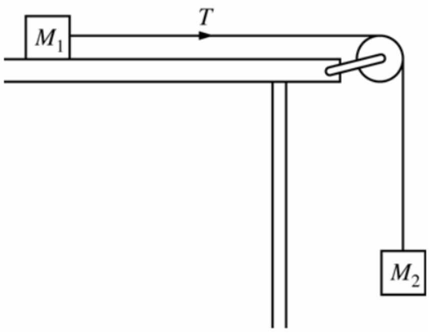
(B) 

(C) 

(D) 

(E) 

Questions 18–19



A block of mass M_1 on a horizontal table is connected to a hanging block of mass M_2 by a string that passes over a pulley, as shown above. The acceleration of the blocks is $0.6g$. Assume that friction and the mass of the string are negligible.

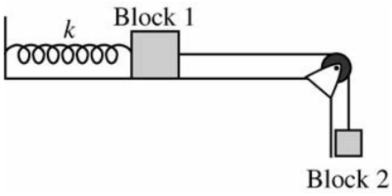
18. The tension T in the string is

    (A) zero (B) $0.4M_2g$ (C) $0.6M_2g$ (D) $1.0M_2g$ (E) $1.6M_2g$

19. The ratio of masses M_2/M_1 is

    (A) 0.67 (B) 1.0 (C) 1.4 (D) 1.5 (E) 1.6

Questions 20–21



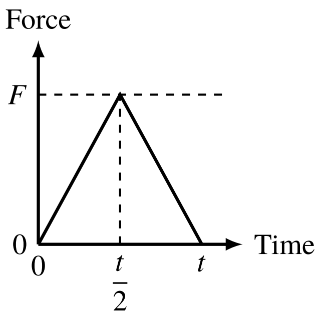
In the system of two blocks and a spring shown above, blocks 1 and 2 are connected by a string that passes over a pulley. The initially unstretched spring connects block 1 to a rigid wall. Block 1 is released from rest, initially slides to the right, and is eventual brought to rest by the spring and by friction on the horizontal surface.

20. Which of the following is true of the energy of the system during this process?

    (A) The total mechanical energy of the system is conserved.
    (B) The total mechanical energy of the system increases.
    (C) The energy lost to friction is equal to the gain in the potential energy of the spring.
    (D) The potential energy lost by block 2 is less in magnitude than the potential energy gained by the spring.
    (E) The potential energy lost by block 2 is greater in magnitude than the potential energy gained by the spring.

21. After block 1 comes to rest, the force exerted on it by the spring must be equal in magnitude to

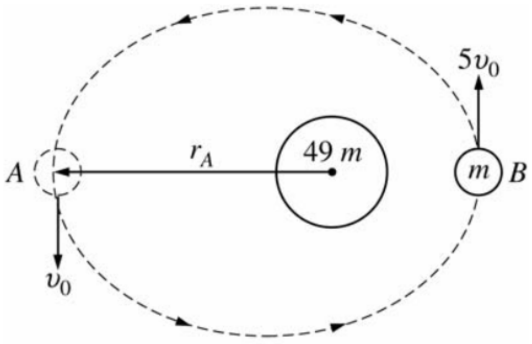
    (A) zero
    (B) the frictional force on block 1
    (C) the vector sum of the forces on block 1 due to friction and tension in the string
    (D) the sum of the weights of the two blocks
    (E) the difference in the weights of the two blocks



22. The graph above shows the force acting on an object as a function of time. The change in momentum of the object from time 0 to t is

    (A) $2Ft$ (B) Ft (C) $\frac{1}{2}Ft$ (D) $\frac{1}{4}Ft$ (E) zero

Questions 23–24



Note: Figure not drawn to scale.

A moon of mass m orbits a planet of mass $49m$ in an elliptical orbit as shown above. When the moon is at point A, its distance from the center of the planet is r_A and its speed is v_0. When the moon is at point B, its speed is $5v_0$.

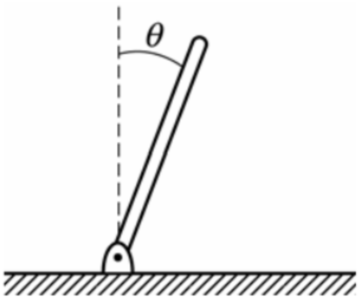
23. When the moon is at point A, the distance from the moon to the center of mass of the planet-moon system is most nearly

    (A) $\frac{1}{50}r_A$ (B) $\frac{1}{7}r_A$ (C) $\frac{1}{2}r_A$ (D) $\frac{6}{7}r_A$ (E) $\frac{49}{50}r_A$

24. When the moon is at point B, the distance from the moon to the center of the planet is most nearly

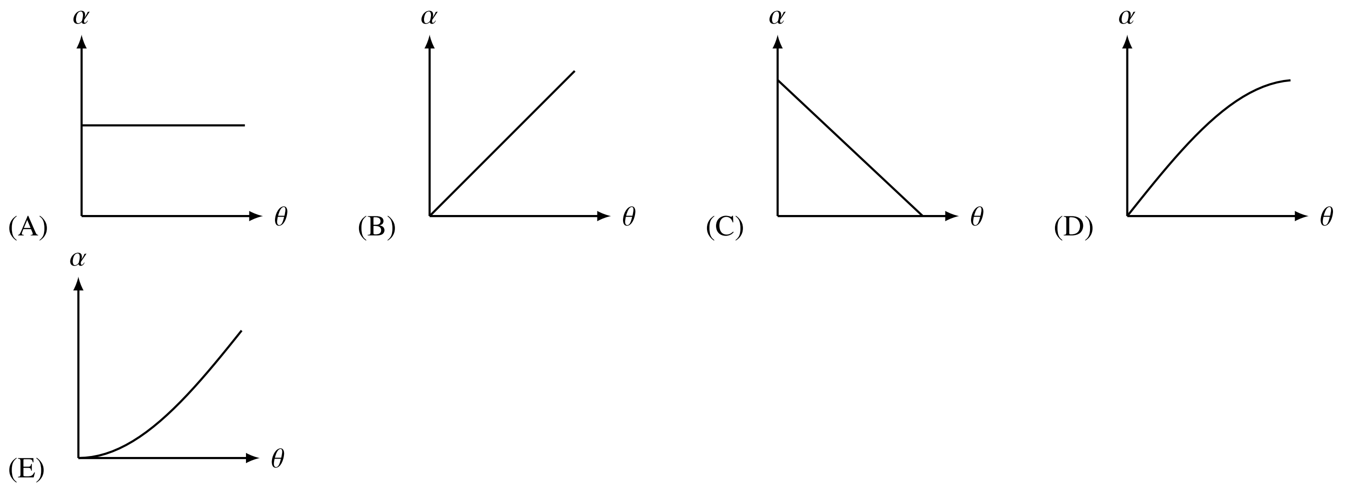
    (A) $\frac{1}{25}r_A$ (B) $\frac{1}{5}r_A$ (C) $\frac{1}{\sqrt{5}}r_A$ (D) r_A (E) $\sqrt{5}r_A$

Questions 25–26

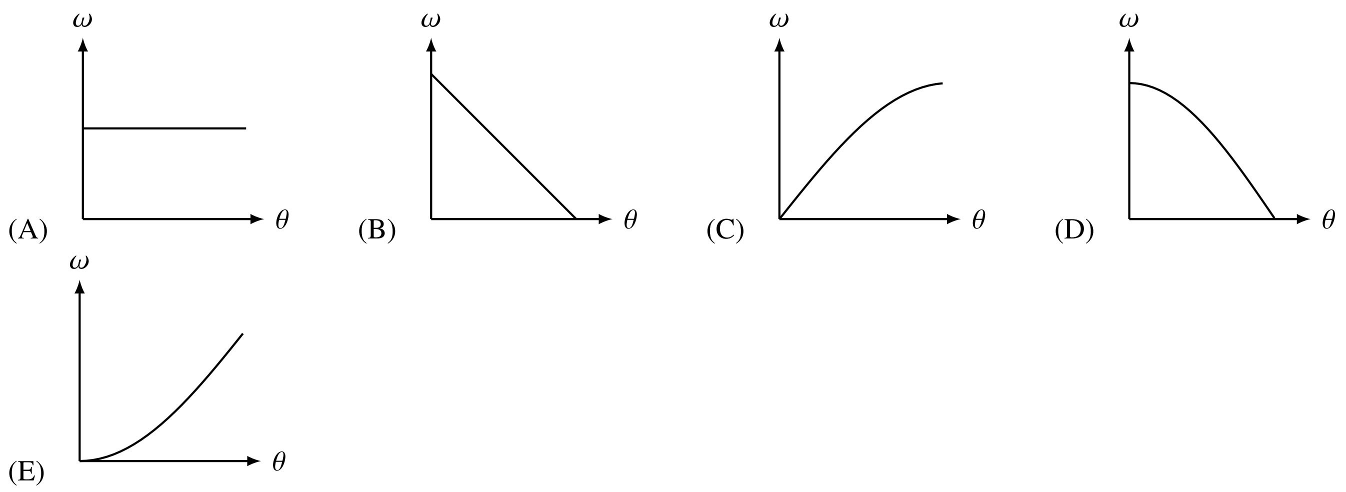


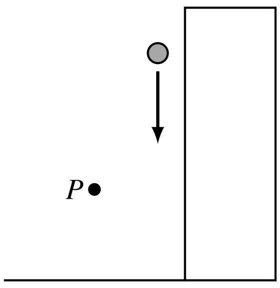
The bar shown above is pivoted about one end and is initially at rest in a vertical position. The bar is displaced slightly and as it falls it makes an angle θ with the vertical at any given time, as shown above.

25. Which of the following graphs best represents the bar's angular acceleration a as a function of angle θ?

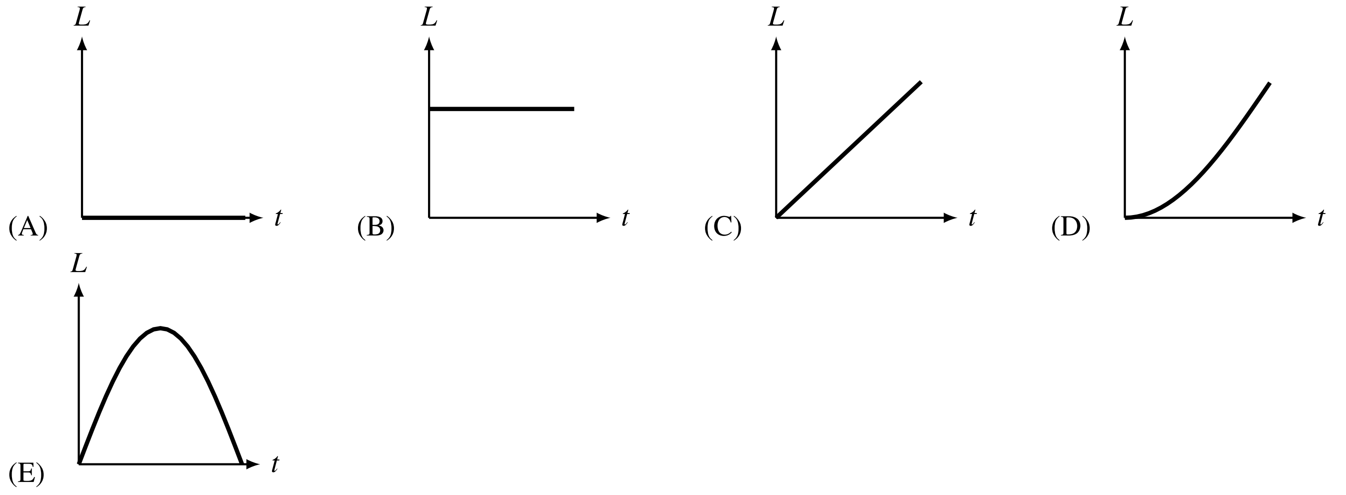


26. Which of the following graphs best represents the bar's angular velocity ω as a function of time?





27. A stone falls from rest from the top of a building as shown above. Which of the following graphs best represents the stone's angular momentum L about the point P as a function of time?



x (m)	F (N)
0	0
1	1
2	8
3	27
4	64

28. A specially designed spring is stretched from equilibrium to the distances x given in the table above, and the restoring force F is measured and recorded in each case. What is the potential energy of the spring when it is stretched 3 m from equilibrium?

(A) $\frac{9}{2}$ J (B) 9 J (C) $\frac{81}{4}$ J (D) 27 J (E) $\frac{81}{2}$ J

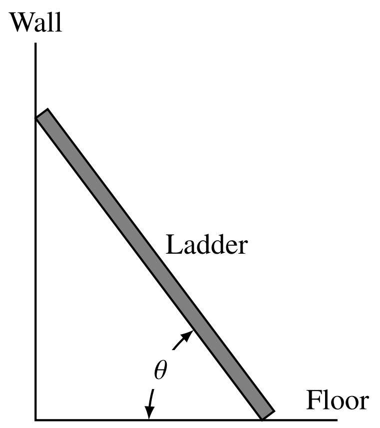
29. An object on the end of a spring with spring constant k moves in simple harmonic motion with amplitude A and frequency f. Which of the following is a possible expression for the kinetic energy of the object as a function of time t?

(A) $kA^2 \sin^2(2\pi f t)$
(B) $\frac{1}{2}kA^2 \cos^2(2\pi f t)$
(C) $\frac{1}{2}kA \sin(2\pi f t)$
(D) $kA \cos(2\pi f t)$
(E) $kA\,(\sin(2\pi f t) + \cos(2\pi f t))$

30. When a certain spring is stretched by an amount x, it produces a restoring force of $F(x) = -ax + bx^2$, where a and b are constants. How much work is done by an external force in stretching the spring by an amount D from its equilibrium length?

(A) $-aD + bD^2$
(B) $a - 2bD$
(C) $\frac{1}{2}aD^2 - \frac{1}{3}bD^3$
(D) $-aD^2 + bD^3$
(E) $-2aD^2 + 3bD^3$

Questions 31–32 refer to the following.



A uniform ladder of weight W leans without slipping against a wall making an angle θ with a floor as shown above. There is friction between the ladder and the floor, but the friction between the ladder and the wall is negligible.

31. The magnitude of the normal force exerted by the floor on the ladder is

(A) W (B) $W \sin\theta$ (C) $W \cos\theta$ (D) $\frac{W}{2}\sin\theta$ (E) $\frac{W}{2}\cos\theta$

32. The magnitude of the friction force exerted on the ladder by the floor is

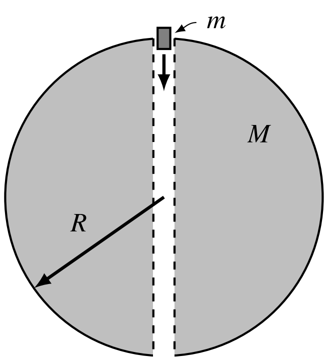
(A) $2W \tan\theta$ (B) W (C) $W \cot\theta$ (D) $\frac{W}{2}$ (E) $\frac{W}{2}\cot\theta$

33. An ideal spring with spring constant k is cut in half. What is the spring constant of either one of the two half springs?

(A) $\frac{k}{2}$ (B) $\sqrt{k}$ (C) k (D) k^2 (E) $2k$

34. A rocket has landed on Planet X, which has half the radius of Earth. An astronaut onboard the rocket weighs twice as much on Planet X as on Earth. If the escape velocity for the rocket taking off from Earth is v_0, then its escape velocity on Planet X is

(A) $2v_0$ (B) $\sqrt{2}v_0$ (C) v_0 (D) $v_0/2$ (E) $v_0/4$



35. Suppose that a hole is drilled through the center of Earth to the other side along its axis. A small object of mass m is dropped from rest into the hole at the surface of Earth, as shown above. If Earth is assumed to be a solid sphere of mass M and radius R and friction is assumed to be negligible, correct expressions for the kinetic energy of the mass as it passes Earth's center include which of the following ?

I. $\frac{1}{2}MgR$
II. $\frac{1}{2}mgR$
III. $\frac{GMm}{2R}$

(A) I only (B) II only (C) III only (D) I and III only (E) II and III only