

1

The velocity of an object is given by the equation $v_1(t) = (-6 \text{ m/s}^2)t$. The velocity of a second object is given by $v_2(t) = (+3 \text{ m/s}^2)t$. Both objects start from rest, and after a time t the displacements of the first object and the second object are Δx_1 and Δx_2 , respectively. What is the ratio $\Delta x_2/\Delta x_1$?

(A) -2

(B) -1

(C) $-\frac{1}{2}$

(D) $\frac{1}{2}$

(E) 2

2

At $t = 0$ sphere 1 is dropped from a height h above the ground. At the same instant, sphere 2 is launched from the ground vertically upward with a speed v_0 . At what time t do the spheres pass each other?

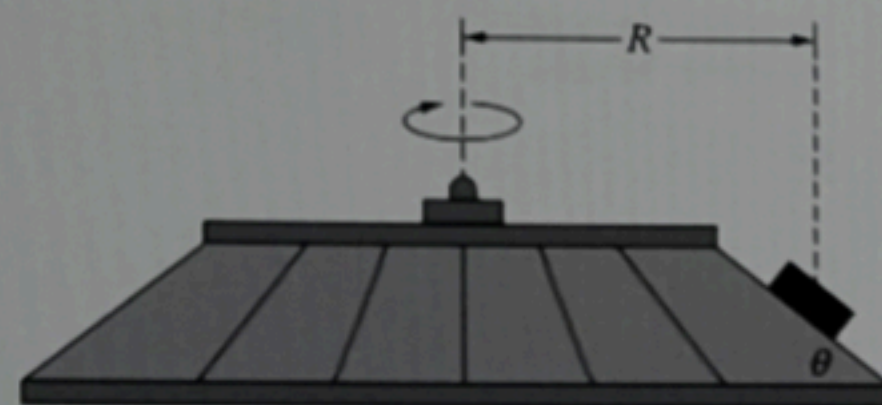
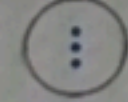
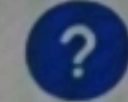
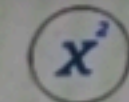
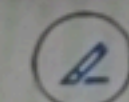
(A) $\frac{h^2}{v_0^2}$

(B) $\frac{2h}{v_0}$

(C) $\sqrt{\frac{h}{v_0}}$

(D) $\frac{h}{v_0}$

(E) $\frac{h}{2v_0}$



3

A block of mass m is on a rotating platform that is inclined at an angle θ to the horizontal, as shown. The block moves at constant speed v , and the horizontal distance between the axis of rotation and the block is R . The magnitude of the normal force on the block is F_N , and the force of friction exerted by the platform on the block is F_f . Which of the following equations correctly relates the speed of the block to the forces on it?

(A) $F_f - mg \sin \theta = \frac{mv^2}{R}$

(B) $F_f \cos \theta - F_N \sin \theta = \frac{mv^2}{R}$

(C) $mg \cos \theta - F_N = \frac{mv^2}{R}$

(D) $F_f \cos \theta - mg \sin \theta - F_N \cos \theta = \frac{mv^2}{R}$

(E) $F_f \sin \theta + F_N \cos \theta = \frac{mv^2}{R}$

4

An object with rotational inertia of $0.5 \text{ kg}\cdot\text{m}^2$ rotates about a fixed axis with an angular position given by $\theta(t) = At^3 + Bt$, where $A = 5.0 \text{ rad/s}^3$ and $B = 25 \text{ rad/s}$. The angular momentum of the object at 3 seconds is

(A) $45 \text{ kg}\cdot\text{m}^2/\text{s}$

(B) $80 \text{ kg}\cdot\text{m}^2/\text{s}$

(C) $160 \text{ kg}\cdot\text{m}^2/\text{s}$

(D) $320 \text{ kg}\cdot\text{m}^2/\text{s}$

(E) $6400 \text{ kg}\cdot\text{m}^2/\text{s}$

5

A disk with a radius of 2.0 m is fixed in place and rotates about its center. The disk starts from rest and accelerates at a constant rate, rotating 8 times in the first second. What is the angular velocity of the disk at the end of the first second?

(A) 4.0 rad/s

(B) 8.0 rad/s

(C) 8.0π rad/s

(D) 16π rad/s

(E) 32π rad/s

6

The mass of a distant planet is $\frac{3}{8}$ of the mass of Earth, and the radius of the planet is $\frac{1}{2}$ of the radius of Earth. What is the weight of a 6 kg object on the surface of that planet?

(A) 10 N

(B) 40 N

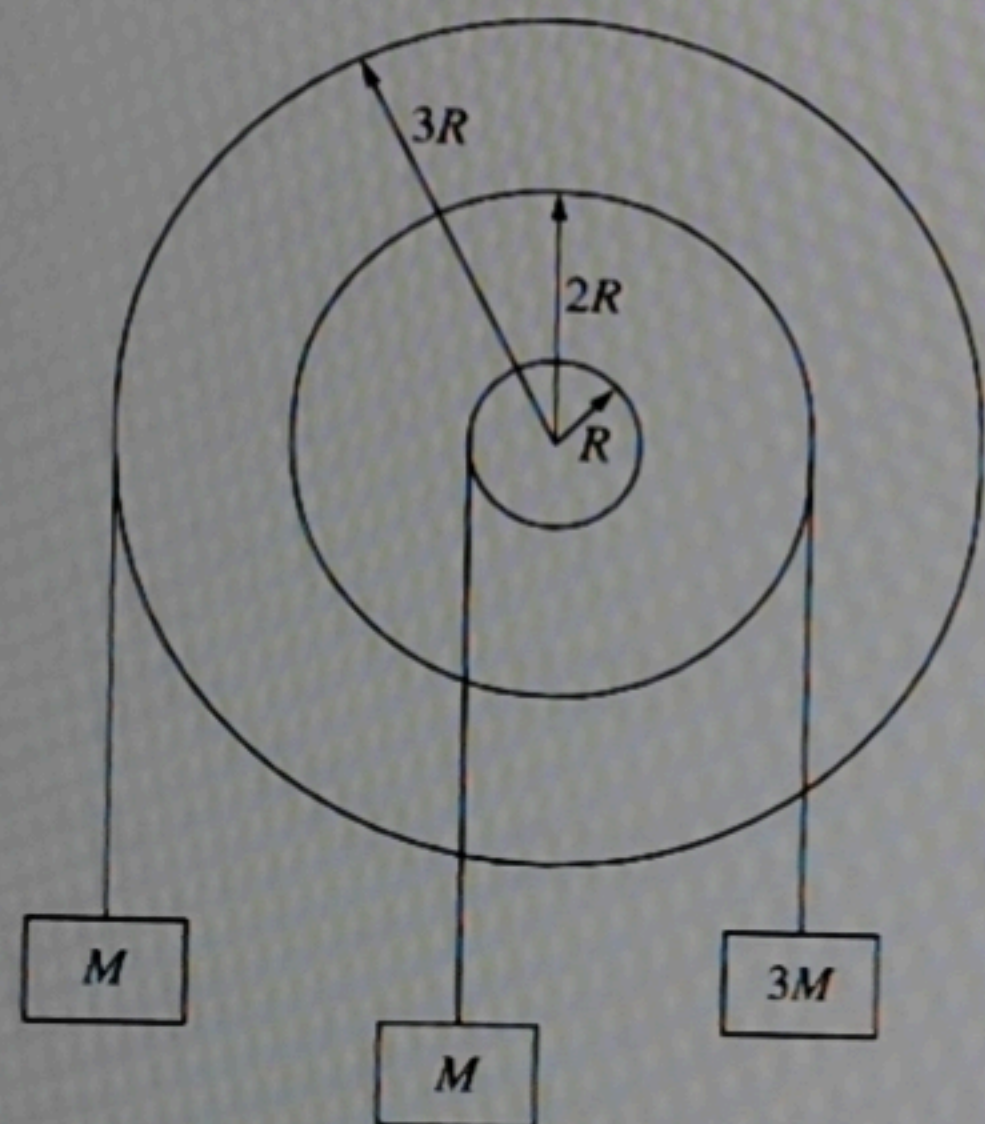
(C) 60 N

(D) 90 N

(E) 360 N

A solid uniform disk is rotating about an axis through its center of mass at an angular speed of ω_0 and has an angular momentum magnitude of L_0 . Which of the following actions would increase the magnitude of the angular momentum to $4L_0$?

- (A) Reduce the disk's mass to $\frac{1}{4}$ and rotate at a speed of ω_0 .
- (B) Increase the disk's mass by 4 times and rotate at a speed of ω_0 .
- (C) Increase the disk's angular speed to $2\omega_0$ and reduce the disk's mass by half.
- (D) Increase the disk's radius by $\sqrt{2}$ and rotate at a speed of ω_0 .
- (E) Reduce the disk's radius to $\frac{1}{\sqrt{2}}$ and rotate at a speed of $2\omega_0$.



8

A pulley system consists of three stacked discs of radius R , $2R$, and $3R$ and pivots about its center as shown. A mass M is hung from the pulley of radius R , a mass $3M$ is hung from the pulley of radius $2R$, and a mass M is hung from the pulley of radius $3R$. Which of the following statements is correct?

- (A) The pulley remains in equilibrium because the net torque on the pulley system is zero.
- (B) The pulley will rotate in a clockwise direction because the net torque on the pulley system is $10MgR$ in the clockwise direction.
- (C) The pulley will rotate in a clockwise direction because the net torque on the pulley system is $2MgR$ in the clockwise direction.
- (D) The pulley will rotate in a counterclockwise direction because the net torque on the pulley system is $2MgR$ in the counterclockwise direction.
- (E) The pulley will rotate in a counterclockwise direction because the net torque on the pulley system is $10MgR$ in the counterclockwise direction.

A pendulum located on Earth's surface has a period of T_E . The same pendulum is then put on a planet that has triple the mass as that of Earth and triple the radius as that of Earth. Which of the following correctly compares the period of the pendulum on the planet to T_E ?

- (A) The period would be smaller because the difference in the mass of the planet affects the period more than the difference in its radius does.
- (B) The period would be greater because the difference in the mass of the planet affects the period more than the difference in its radius does.
- (C) The period would remain the same because the difference in the mass of the planet affects the period the same amount as the difference in its radius does.
- (D) The period would be smaller because the difference in the radius of the planet affects the period more than the difference in its mass does.
- (E) The period would be greater because the difference in the radius of the planet affects the period more than the difference in its mass does.

The force exerted on a moving object is given by $F(x) = -A \sin(Bx)$, where $A = 5.28 \text{ N}$ and $B = \frac{1}{9} \text{ m}^{-1}$. The work done by the force as the object's position changes from $x = 0$ to $x = 9\pi$ meters is most nearly

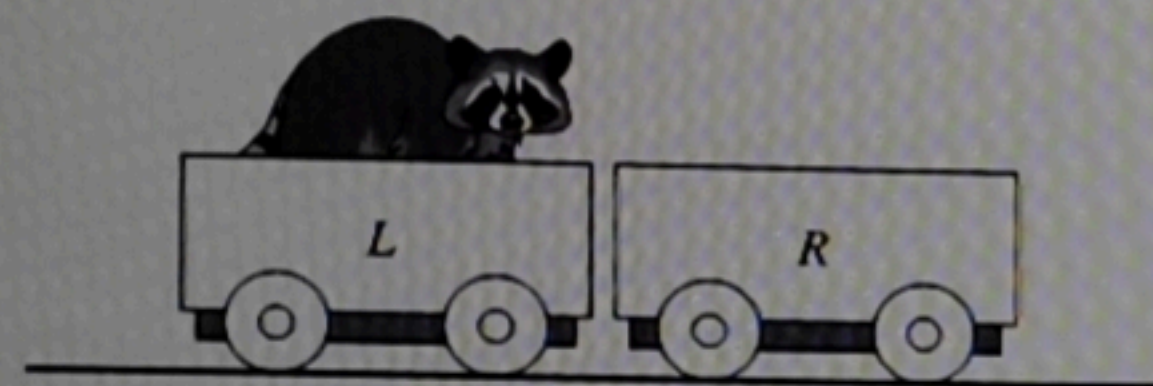
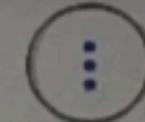
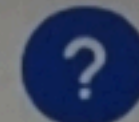
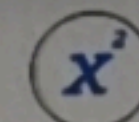
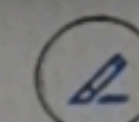
(A) 0.0 J

(B) -0.1 J

(C) -10.7 J

(D) -47.5 J

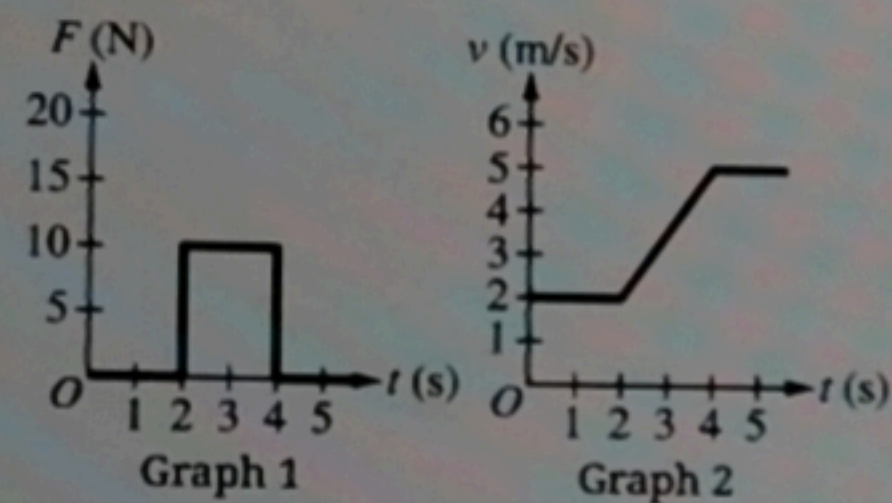
(E) -95.0 J



11

Two identical carts, each with mass 20 kg , are at rest on a horizontal surface. The carts can roll with negligible friction. A raccoon with mass 5.0 kg sits in the left cart, as shown. The raccoon jumps to the right with horizontal velocity of $+2.0\text{ m/s}$ relative to the ground into the right cart. After the raccoon lands in the cart, what is the velocity of the left cart as seen by an observer in the right cart?

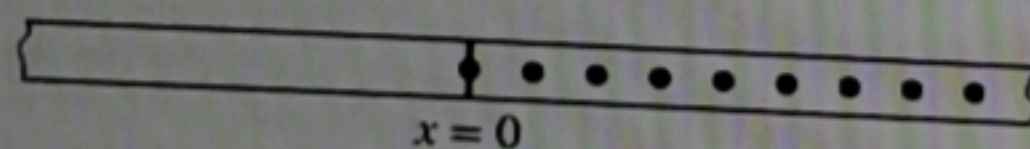
- (A) 0 m/s
- (B) -0.1 m/s
- (C) 0.4 m/s
- (D) -0.5 m/s
- (E) -0.9 m/s



12

Graph 1 shows the net force F exerted on an object as a function of time t . Graph 2 shows the velocity v of that object as a function of time t . What is the impulse J delivered to the object between $t = 0$ and $t = 5$ s, and what is the mass m of the object?

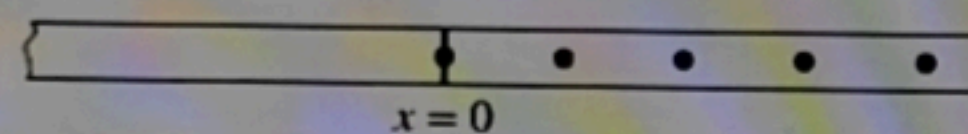
- (A) $J = 10 \text{ N}\cdot\text{s}$ and $m = \frac{20}{3} \text{ kg}$
- (B) $J = 10 \text{ N}\cdot\text{s}$ and $m = \frac{16}{3} \text{ kg}$
- (C) $J = 20 \text{ N}\cdot\text{s}$ and $m = \frac{20}{3} \text{ kg}$
- (D) $J = 20 \text{ N}\cdot\text{s}$ and $m = \frac{40}{3} \text{ kg}$
- (E) $J = 5 \text{ N}\cdot\text{s}$ and $m = \frac{40}{3} \text{ kg}$



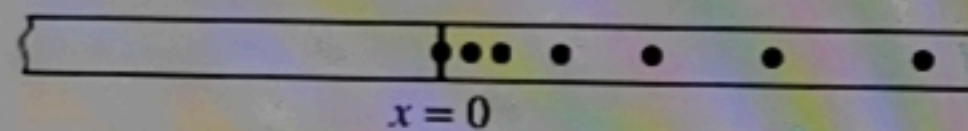
13

The position of an object is marked at regular time intervals on a thin strip of paper, as shown in the figure. The position of the object can be modeled by the general equation $x = A + Bt + Ct^2$, where A , B , and C are constants with appropriate units. The positive direction is to the right. If the motion of the object is changed such that the value of A is increased, which of the following could represent the position of the object over time?

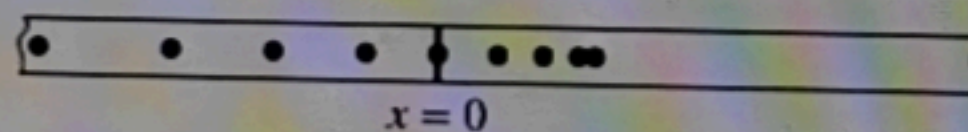
(A)



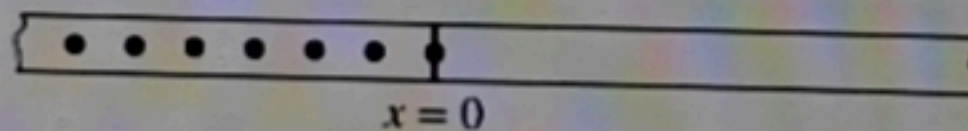
(B)



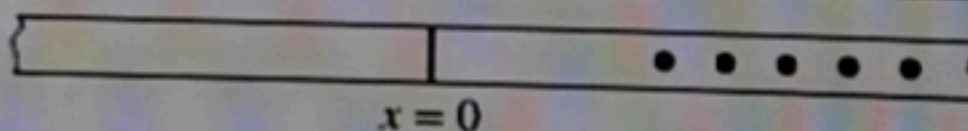
(C)

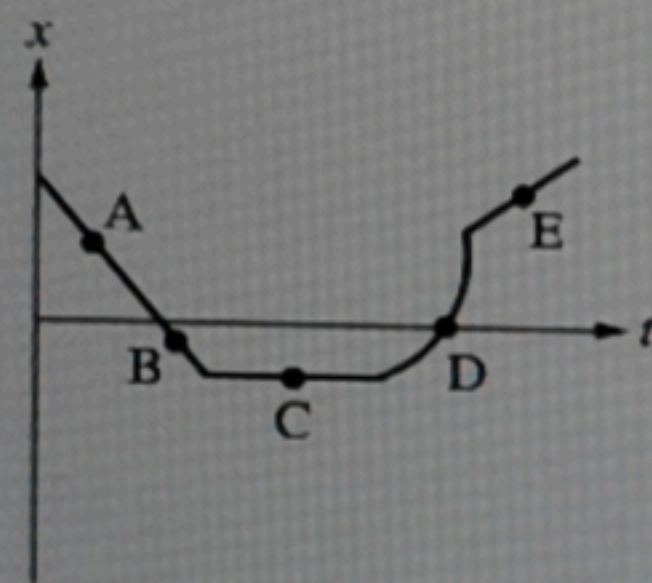


(D)



(E)





14

The graph represents the position of an object as a function of time as it moves along the x -axis. At which point is the object accelerating?

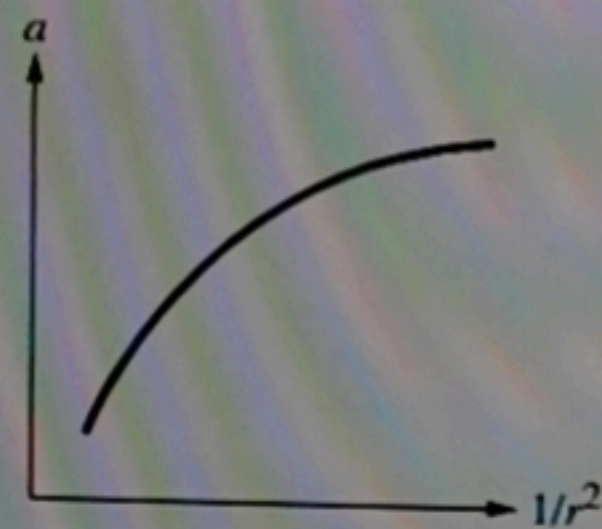
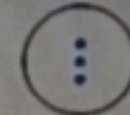
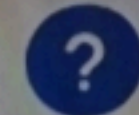
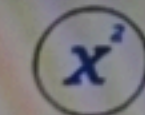
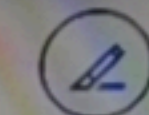
(A) Point A

(B) Point B

(C) Point C

(D) Point D

(E) Point E

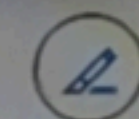


The figure shows the magnitude of the acceleration a for a spacecraft approaching a planet from far away as a function of the inverse square of the spacecraft's distance from the center of the planet, $\frac{1}{r^2}$.

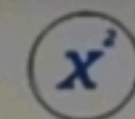
15

Which of the following best explains the shape of the figure?

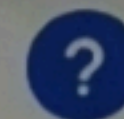
- (A) The spacecraft's engines exert a force on the spacecraft toward the planet as the spacecraft approaches the planet.
- (B) The spacecraft's engines exert a force on the spacecraft away from the planet as the spacecraft approaches the planet.
- (C) The force of gravity exerted on the spacecraft is constant as it approaches the planet.
- (D) The magnitude of the net force on the spacecraft decreases as it approaches the planet.
- (E) The spacecraft is in free fall as it approaches the planet.



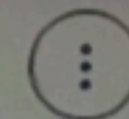
Annotate



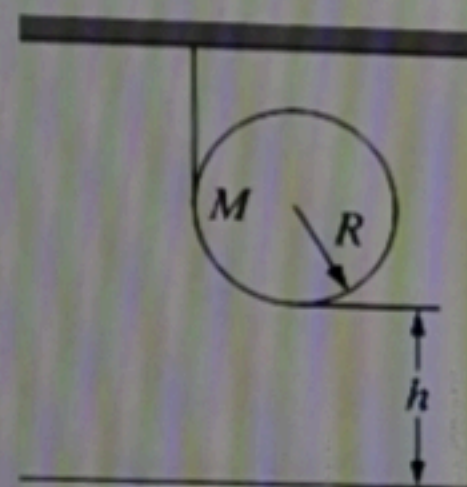
Reference



Help



More



16

A solid cylinder of mass M and radius R is attached to the ceiling by a cord that is wrapped tightly around the cylinder. The cylinder starts at rest at a vertical distance of h above the horizontal floor. The cylinder begins to fall and its motion is completely in the vertical direction. The cord does not slip relative to the cylinder as it unwinds. What is the rotational energy of the cylinder at the instant it reaches the floor? The rotational inertia of a cylinder around its center is $MR^2/2$.

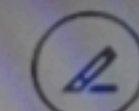
(A) $\frac{Mgh}{4}$

(B) $\frac{Mgh}{3}$

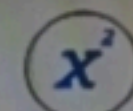
(C) $\frac{Mgh}{2}$

(D) $\frac{3Mgh}{4}$

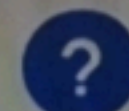
(E) Mgh



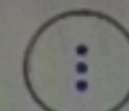
Annotate



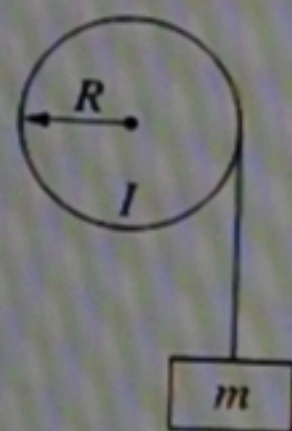
Reference



Help



More



17

An object of mass m is attached to a cord wrapped around a pulley of rotational inertia I and radius R , as shown. The object is released, and the pulley rotates without friction about an axis through its center. As the object falls, the tension in the cord is

(A) $mg \left(\frac{I}{I+mR^2} \right)$

(B) $mg \left(\frac{I+mR^2}{I} \right)$

(C) $mg \left(\frac{I}{mR^2} \right)$

(D) mg

(E) $\frac{1}{2}mg$

A block is attached to a spring on a smooth horizontal surface. The block is compressed on the spring and then released. The position of the block is given by $x(t) = A \cos(Bt + C)$, where A , B , and C are all constants with appropriate units. What is the expression for the acceleration a of the block at time $t = 0$?

(A) $AB^2 \cos(C)$

(B) $-AB^2 \cos(C)$

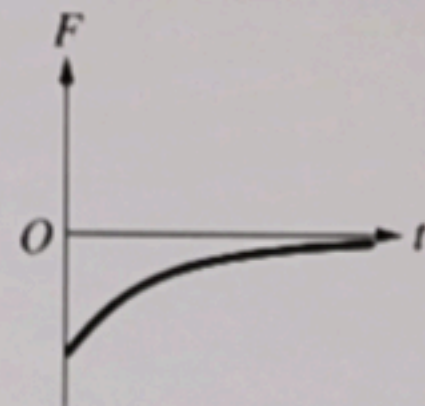
(C) $\frac{-A}{B^2} \cos(C)$

(D) $\frac{-A}{B} \cos(C)$

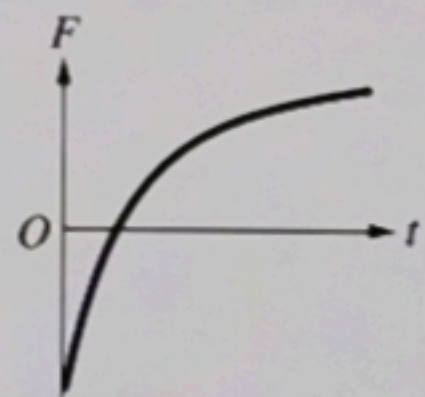
(E) $-A \cos(C)$

A large sphere is dropped from the top of a tall building. Assuming air resistance is **not** negligible, which of the following best shows the graph of the net force F exerted on the sphere as a function of time t during the time the sphere falls toward the ground? Assume up to be the positive direction.

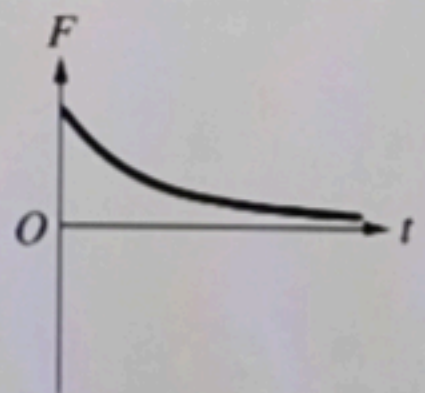
(A)



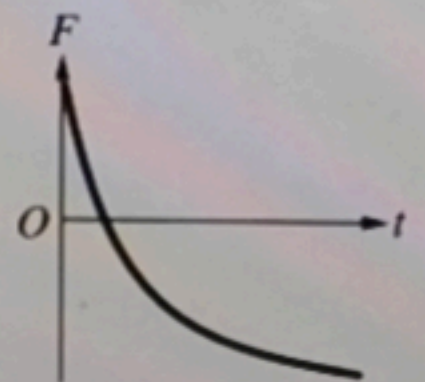
(B)



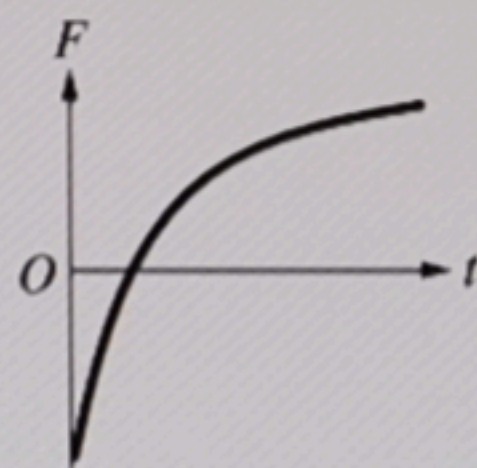
(C)



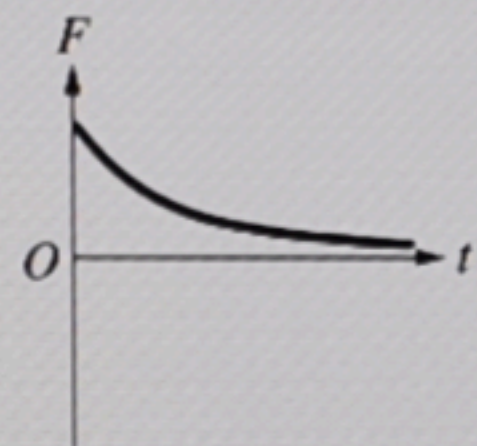
(D)



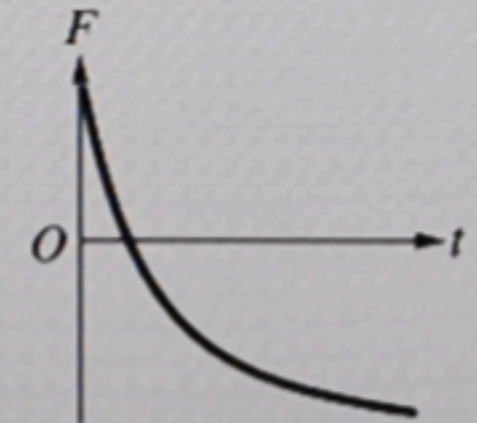
(B)



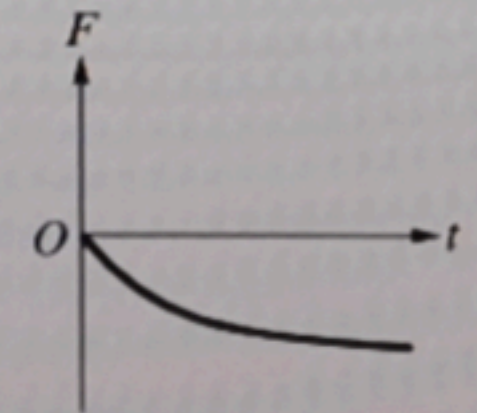
(C)



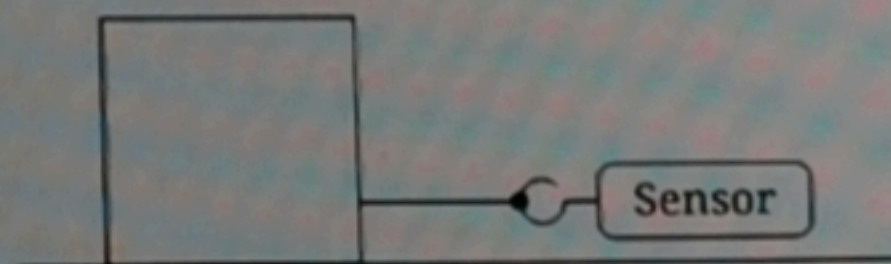
(D)



(E)



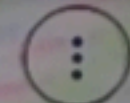
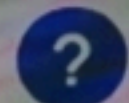
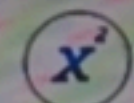
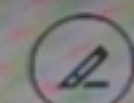
Directions ▾



20

A string is attached to a block placed on a horizontal surface. A student uses a force sensor to measure the force exerted toward the right on the block, as shown in the diagram. Which of the following best describes the circumstance(s) under which the force value measured by the sensor is equal to the magnitude of the friction force exerted by the surface on the block?

- (A) Any circumstance, regardless of the state of motion
- (B) Only if the block moves with constant acceleration
- (C) Only if the block is stationary
- (D) Only if the block is moving with constant nonzero speed
- (E) If the block is either moving with constant nonzero speed or the block is stationary



Questions 21 through 22 refer to the information below.

An object of mass 0.5 kg is given an initial velocity and then slides across a horizontal surface. The object experiences a resistive force that is a function of velocity. The velocity v of the object as a function of time t is given by $v(t) = \alpha e^{-\beta t}$, where $\alpha = 2 \text{ m/s}$ and $\beta = 3 \text{ s}^{-1}$.

21

As the velocity of the object approaches zero, the displacement of the object approaches

(A) $\frac{1}{3} \text{ m}$

(B) $\frac{2}{3} \text{ m}$

(C) 3 m

(D) 6 m

(E) infinity

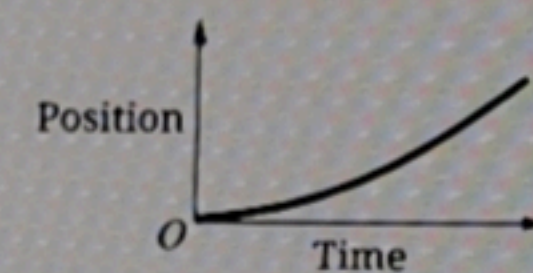
Questions 21 through 22 refer to the information below.

An object of mass 0.5 kg is given an initial velocity and then slides across a horizontal surface. The object experiences a resistive force that is a function of velocity. The velocity v of the object as a function of time t is given by $v(t) = \alpha e^{-\beta t}$, where $\alpha = 2 \text{ m/s}$ and $\beta = 3 \text{ s}^{-1}$.

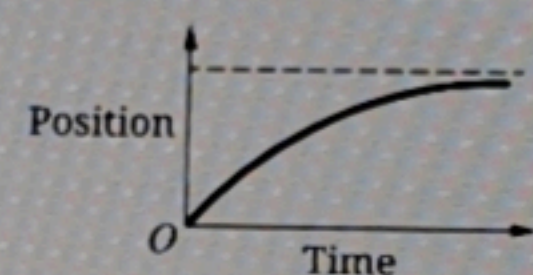
22

Assuming the object starts at position $x = 0$ at time $t = 0$, which of the following graphs best represents the position of the object as a function of time?

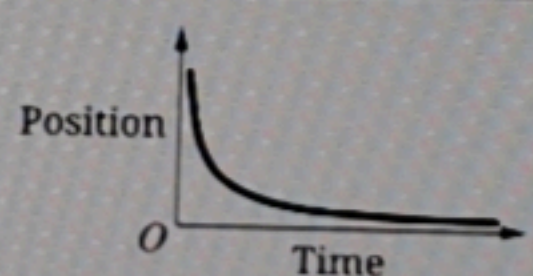
(A)



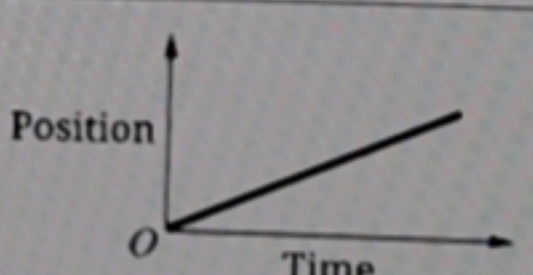
(B)



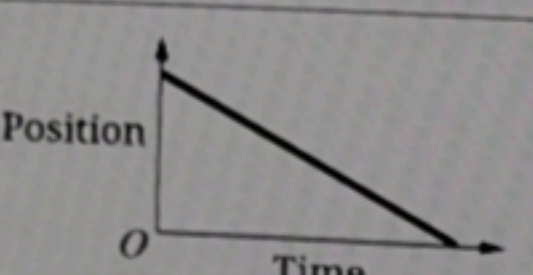
(C)

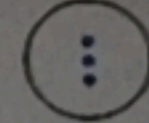
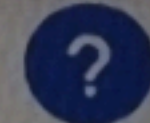
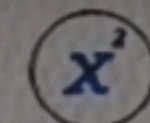
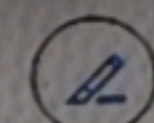


(D)

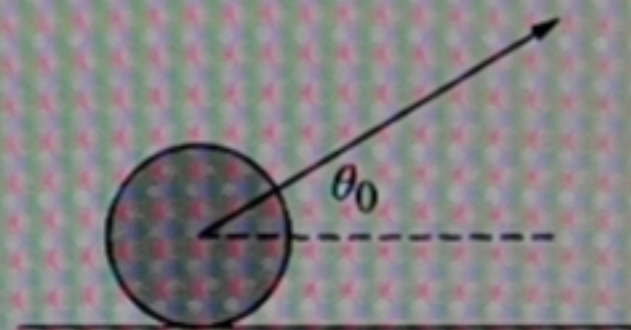


(E)





23



A ball is launched with speed v_0 at an angle θ_0 above the horizontal. At the top of its trajectory, the ball has a speed of $v_0/2$. What is the value of θ_0 ?

(A) 15°

(B) 30°

(C) 45°

(D) 60°

(E) 75°

A box with a mass of 5.2 kg is moving with a horizontal velocity given by $v(t) = At^2 - B$, where $A = 2.0 \text{ m/s}^3$ and $B = 3.5 \text{ m/s}$. This movement is due to a force exerted 20° above the x -axis. What is the force at time $t = 1.2 \text{ s}$?

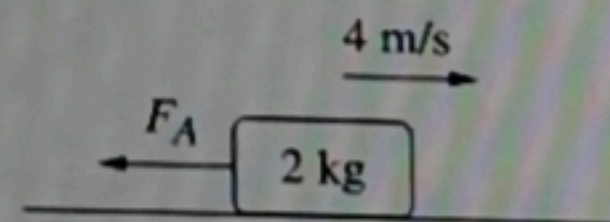
(A) 5.1 N

(B) 23.5 N

(C) 25.0 N

(D) 26.6 N

(E) 73.0 N



25

A block of mass 2 kg slides with an initial velocity of 4 m/s to the right on a frictionless horizontal surface. Starting at time $t = 0$, a force F_A is exerted to the left on the object, as shown. The magnitude of the force as a function of t is given by $F_A = \beta t^2$, where $\beta = 6 \text{ N/s}^2$. The magnitude and direction of the velocity of the object at $t = 2 \text{ s}$ is

(A)

Magnitude	Direction
22 m/s	To the left

(B)

Magnitude	Direction
16 m/s	To the right

(C)

Magnitude	Direction
12 m/s	To the right

(B)

Magnitude	Direction
16 m/s	To the right

(C)

Magnitude	Direction
12 m/s	To the right

(D)

Magnitude	Direction
12 m/s	To the left

(E)

Magnitude	Direction
4 m/s	To the left

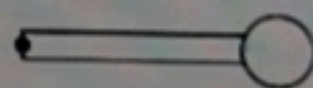
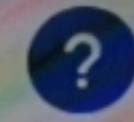
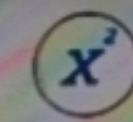
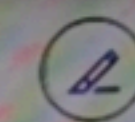


Figure 1

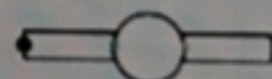


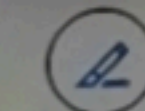
Figure 2

Note: Figures not drawn to scale.

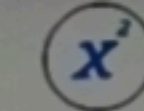
26

Two thin rods of negligible mass and different lengths are shown in the figures. A pivot point is at the left end of each rod. Two spheres of different masses are attached to the rods. Each rod is released from the position shown and allowed to swing about its pivot. Which rod will have the greatest initial angular acceleration when released?

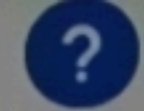
- ☐ (A) The rod with the sphere at the far end
- ☐ (B) The rod with the sphere in the middle
- ☐ (C) Both rods will have the same angular acceleration.
- ☐ (D) It cannot be determined without knowing the relative masses of the spheres.
- ☐ (E) It cannot be determined without knowing the relative lengths of the rods.



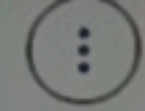
Annotate



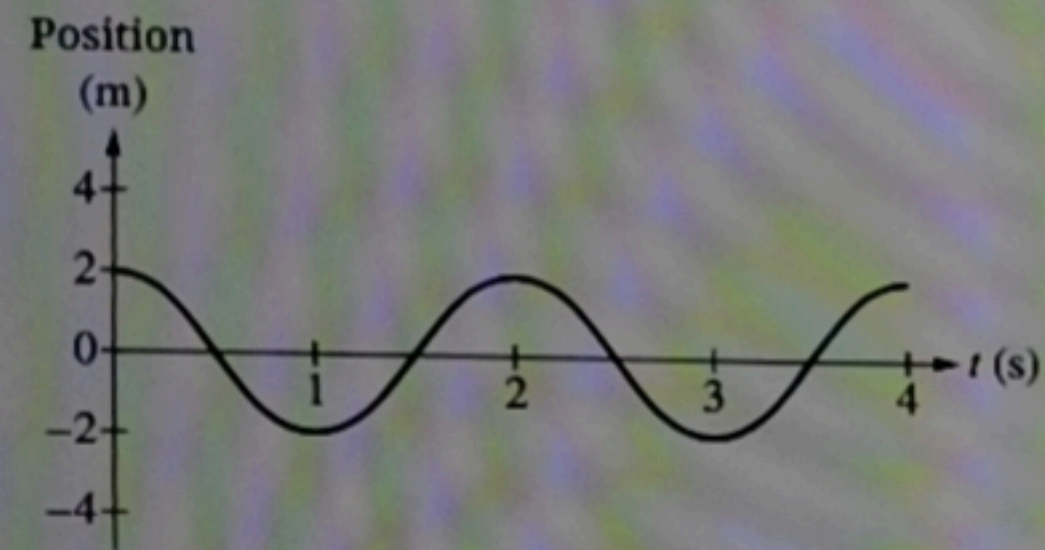
Reference



Help



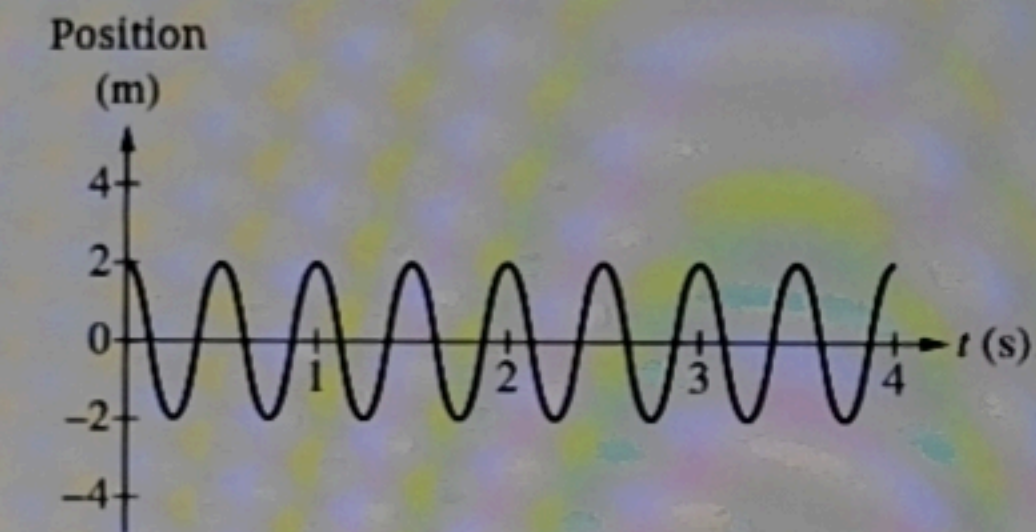
More



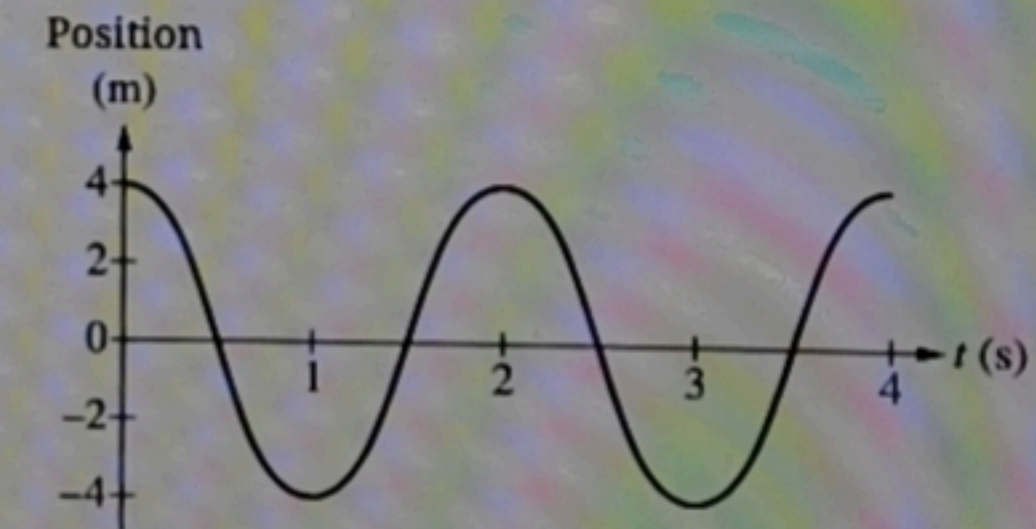
27

An object with mass m is attached to a horizontal spring of spring constant k and oscillates about its equilibrium position. The graph of the object's position x with respect to time t is shown. The object is then attached to a new horizontal spring of spring constant $\frac{1}{4}k$ and set into oscillation. Which of the following position-time graphs represents the new oscillatory motion of the mass?

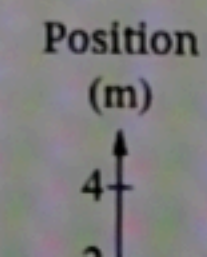
(A)

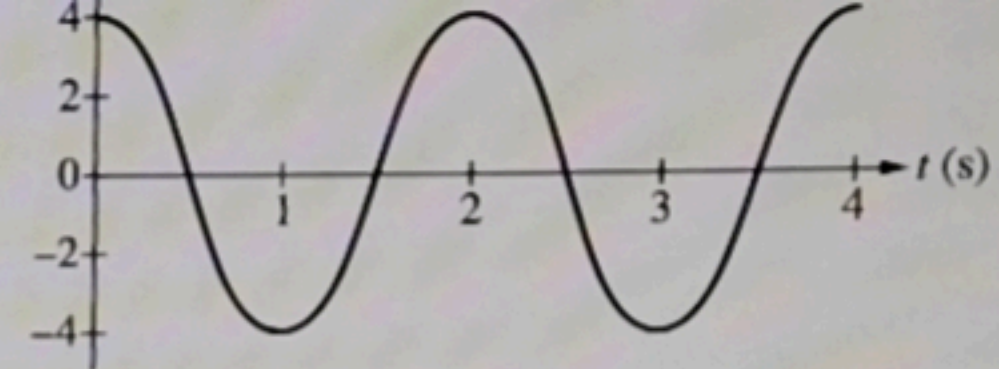
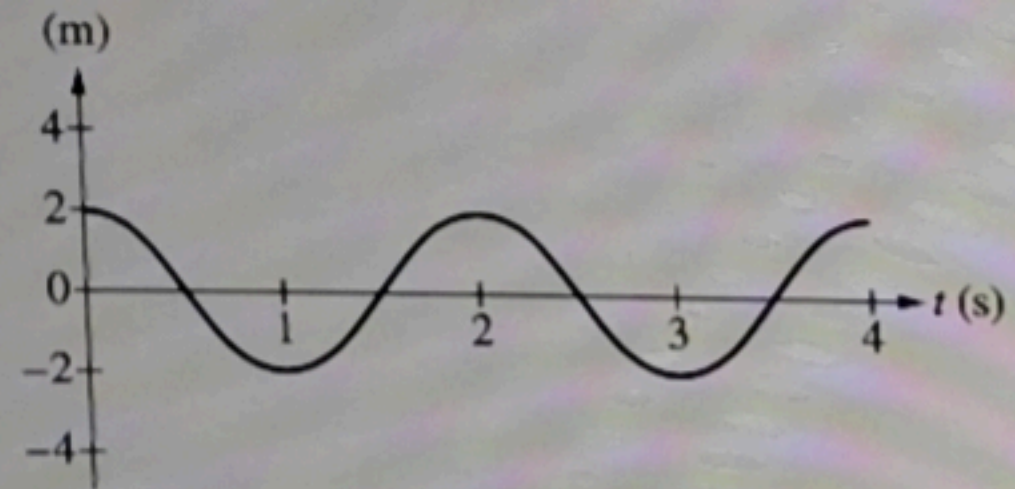


(B)

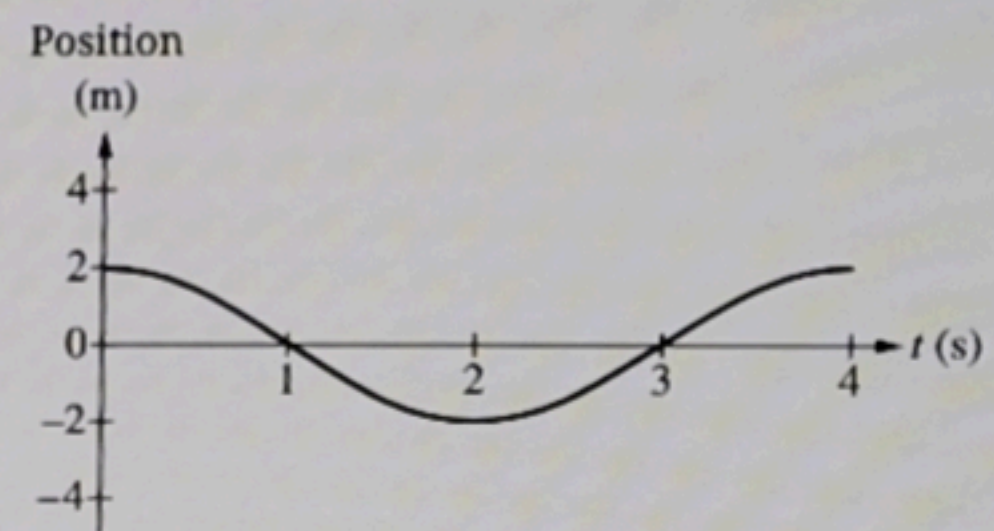


(C)

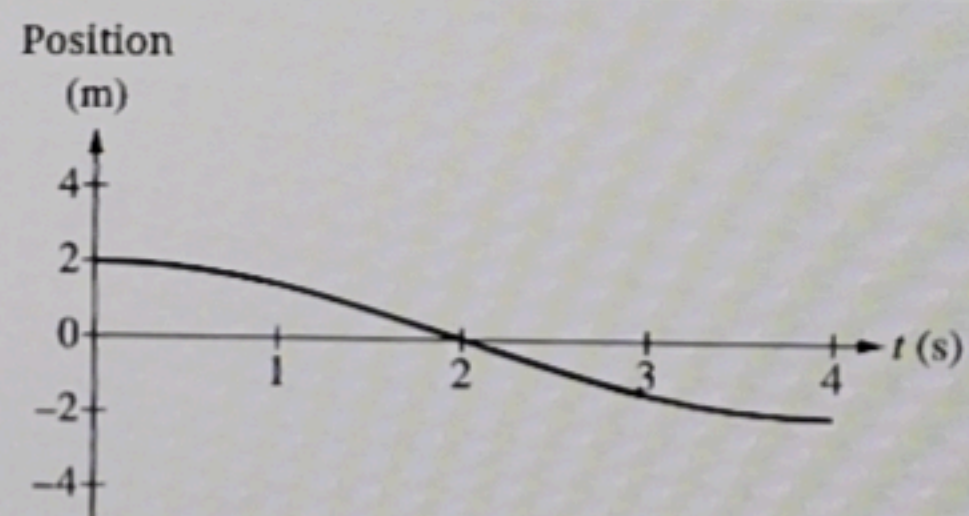




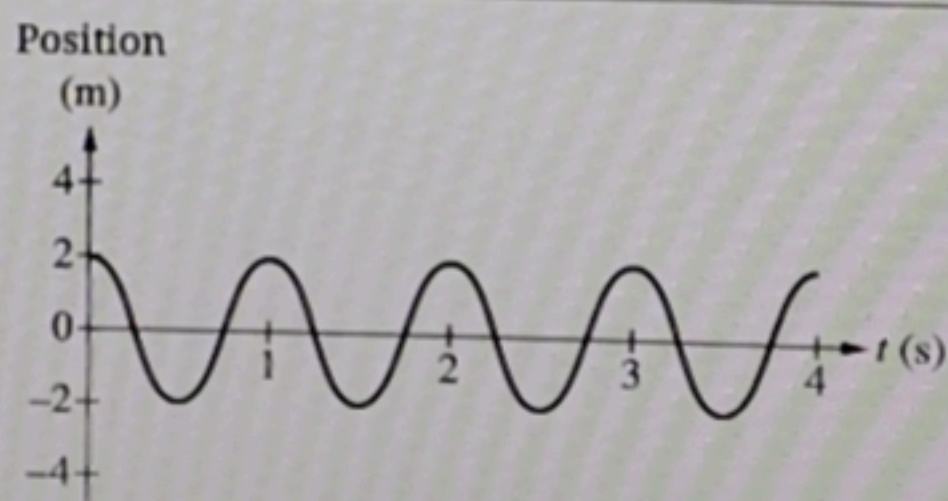
(C)

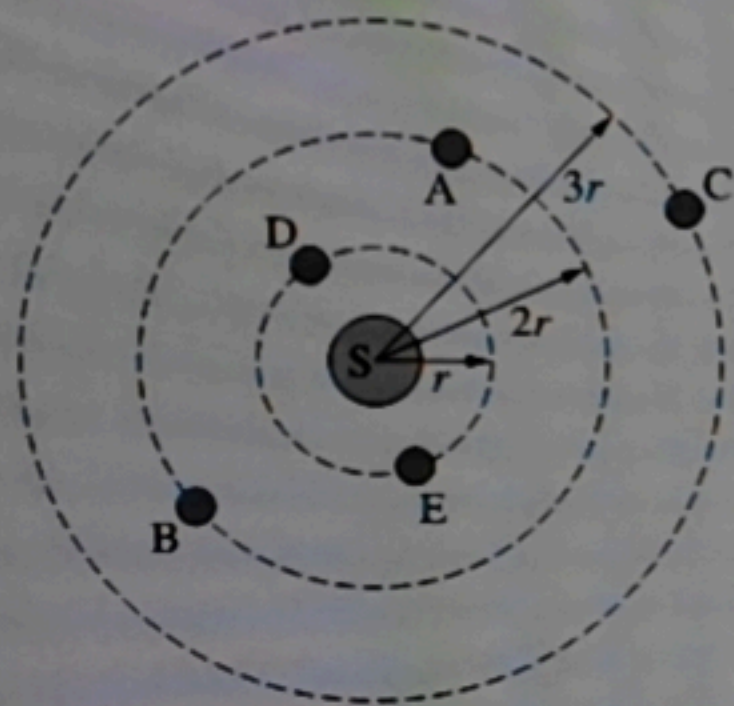
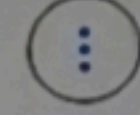
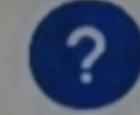
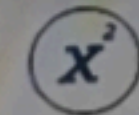
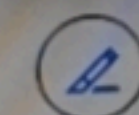


(D)



(E)





28

Planets are in stable circular orbits at various radii around Star S as shown in the figure. Planets C and D each have a mass of $5M$, Planets A and E each have a mass of $2M$, and Planet B has a mass of M . The mass of each planet is considerably less than the mass of the star. For which planet-star system is the absolute value of the total energy the greatest?

(A) System A-S

(B) System B-S

(C) System C-S

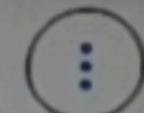
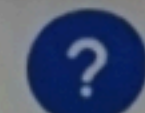
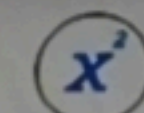
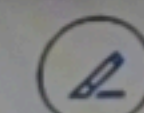
(D) System D-S

(E) System E-S

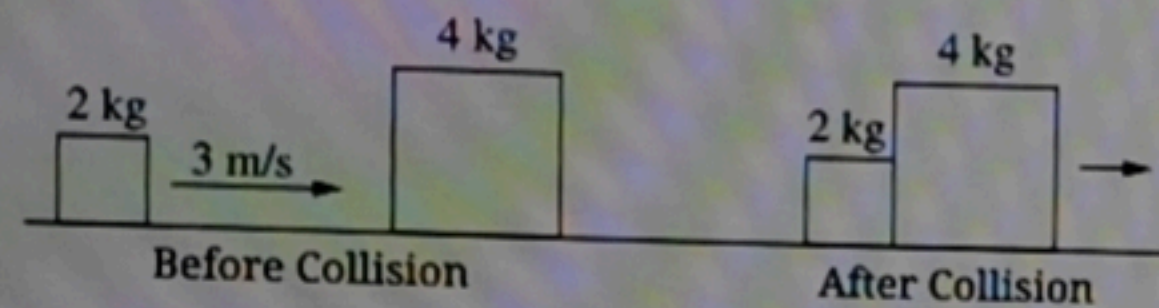
29

A block is sliding on a level horizontal surface with negligible friction. A force of magnitude F can be exerted in the directions indicated below. In which case will the absolute value of the work done on the block be the greatest? Assume that the force is applied over the same time interval in each case.

- (A) The direction of the force remains perpendicular to the direction in which the object is moving.
- (B) The direction of the force remains perpendicular to the **initial** direction in which the object is moving.
- (C) The direction of the force is opposite the direction in which the object is moving.
- (D) The direction of the force is in the direction in which the object is moving.
- (E) The direction of the force has components perpendicular to and parallel to the direction of motion.



Questions 30 through 31 refer to the diagram below.



A block with a mass of 2 kg is moving to the right on a horizontal table of negligible friction. The block moves with a speed of 3 m/s when it collides with a block of mass 4 kg that is at rest, as shown. After the collision, the two blocks stick together.

30

The change in kinetic energy of the two-block system is

(A) +6 J

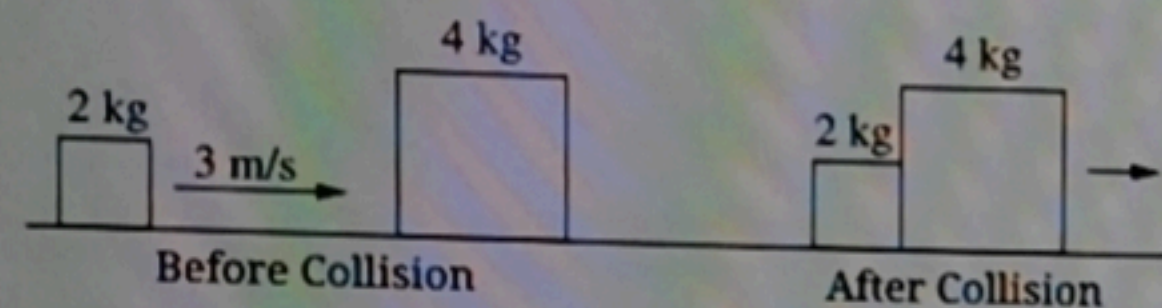
(B) +3 J

(C) 0

(D) -3 J

(E) -6 J

Questions 30 through 31 refer to the diagram below.

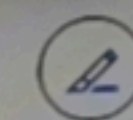


A block with a mass of 2 kg is moving to the right on a horizontal table of negligible friction. The block moves with a speed of 3 m/s when it collides with a block of mass 4 kg that is at rest, as shown. After the collision, the two blocks stick together.

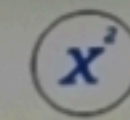
31

The change in momentum of the two-block system is

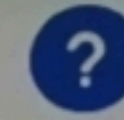
- (A) positive because kinetic energy is added to the system
- (B) positive because the larger block is accelerated to the right
- (C) zero because there is no net external force on the system
- (D) zero because the energy of the system is conserved
- (E) negative because the system loses kinetic energy



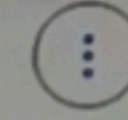
Annotate



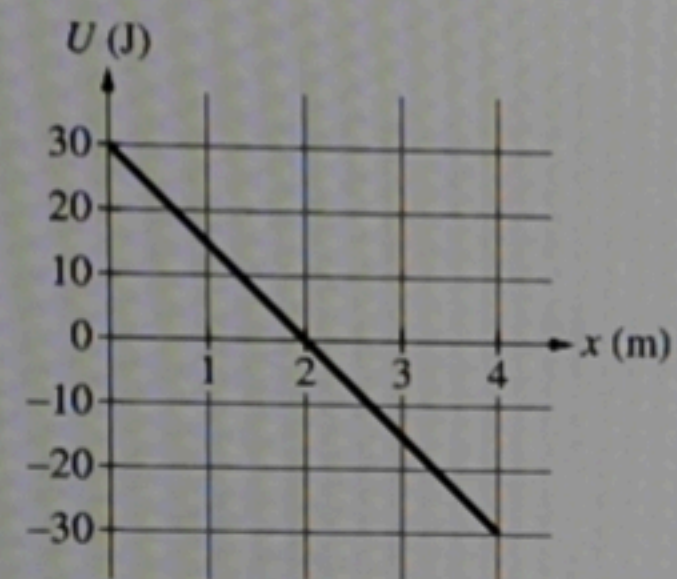
Reference



Help



More



32

Object A is fixed at the origin and exerts a conservative force on object B, which is free to move along the x -axis. The potential energy of the two-object system as a function of the location of object B is shown in the graph. Object B has a mass of 5.0 kg and moves in the positive direction. What is the acceleration of the object when its location is $x = 2.0 \text{ m}$?

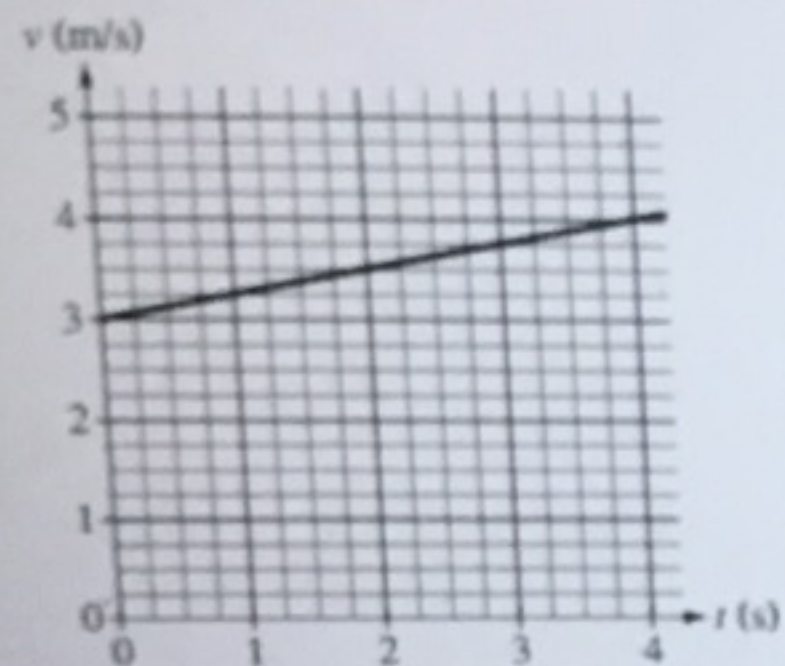
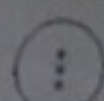
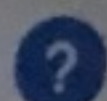
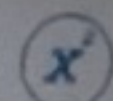
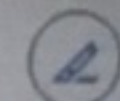
(A) -15 m/s^2

(B) -3.0 m/s^2

(C) 0.0 m/s^2

(D) 3.0 m/s^2

(E) 15 m/s^2



33

A 1.7 kg block is pushed by an unknown force. The graph shows the velocity v of the block as a function of time t . The work done on the block from time $t = 0.0$ s to $t = 4.0$ s is most nearly

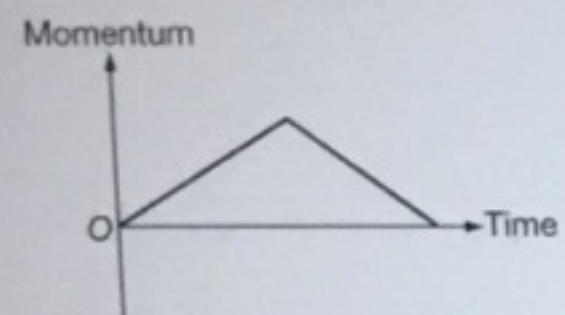
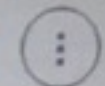
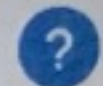
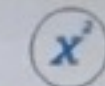
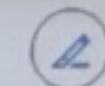
(A) 0.85 J

(B) 6.0 J

(C) 7.7 J

(D) 10.8 J

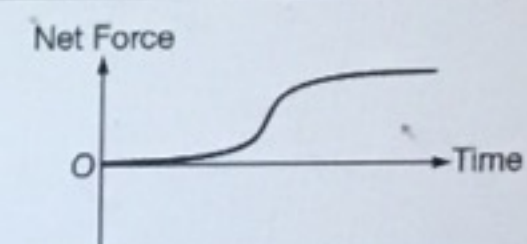
(E) 13.6 J



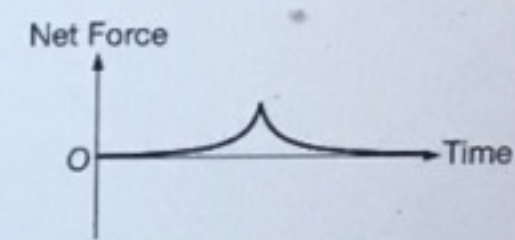
34

A block is moving along a level horizontal surface. The graph shows the momentum of the block as a function of time. Which of the following graphs best shows the net force on the block as a function of time?

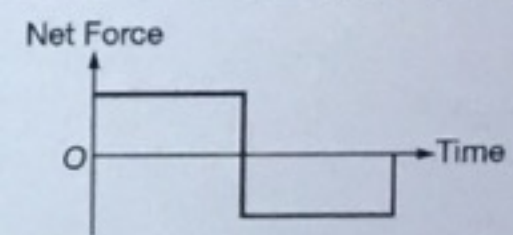
(A)



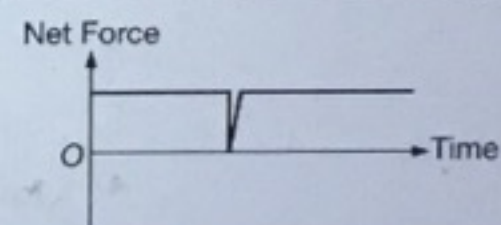
(B)



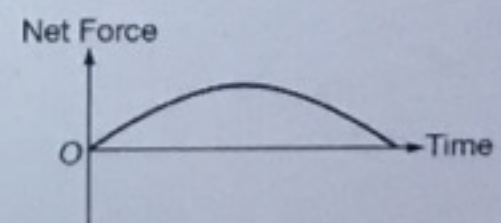
(C)



(D)

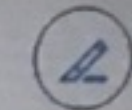


(E)

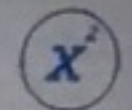


22:41

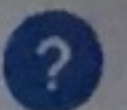
Hide



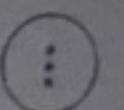
Annotate



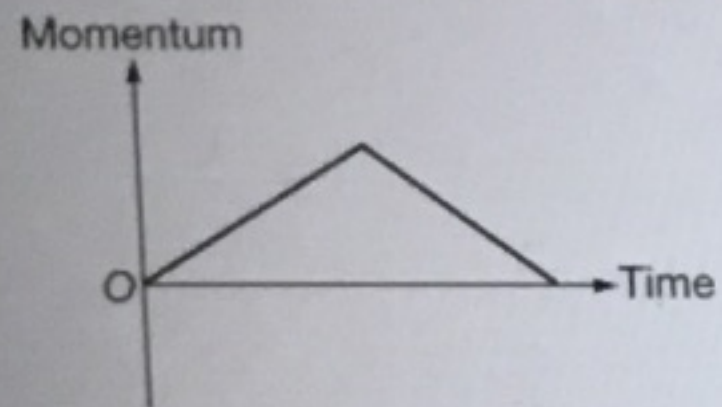
Reference



Help



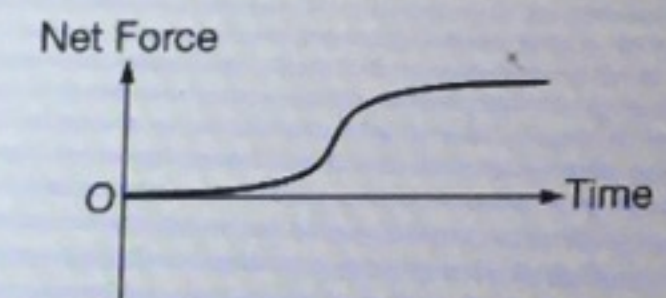
More



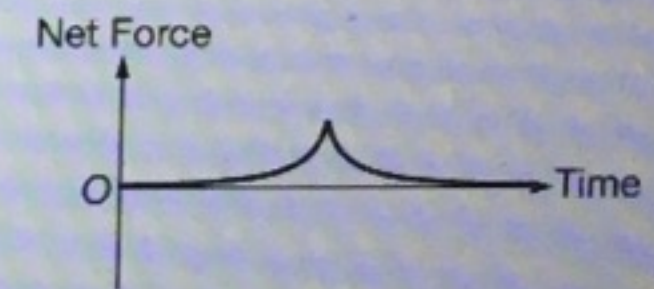
34

A block is moving along a level horizontal surface. The graph shows the momentum of the block as a function of time. Which of the following graphs best shows the net force on the block as a function of time?

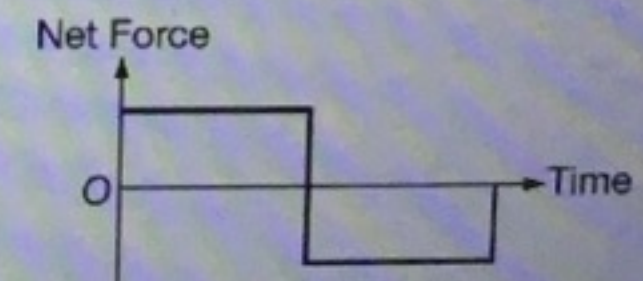
(A)



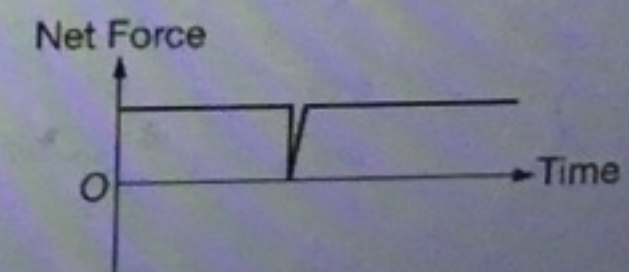
(B)



(C)

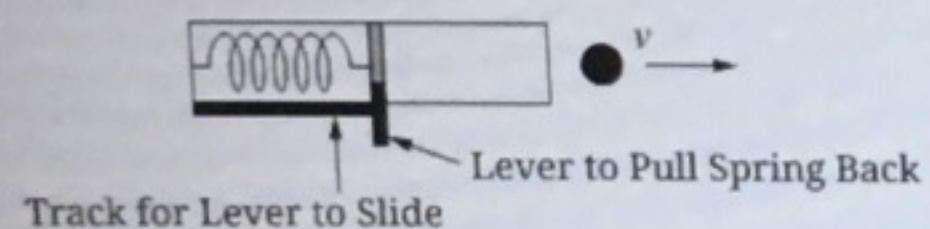
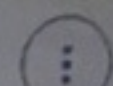
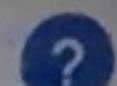
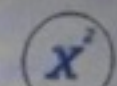
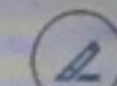


(D)



(E)

Net Force



35

Students are given a toy that launches small projectiles of unknown mass with a spring. The spring is completely enclosed in the toy and cannot be removed. The distance the launch lever is pulled back is equal to the compression of the spring. Is it possible for the students to determine the spring constant using only a meterstick?

- (A) Yes, they can determine the launch velocity from the maximum height and then determine kinetic energy if they launch the projectile vertically upward.
- (B) Yes, they can determine the gravitational potential energy of the projectile-Earth system at the maximum height if they launch the projectile vertically upward.
- (C) Yes, they can use the distance traveled to determine the launch velocity if they launch the projectile horizontally.
- (D) No, they cannot find the spring constant with the available equipment. The students also need to know the mass of the projectile to determine the spring constant.
- (E) No, they cannot find the spring constant with the available equipment. The students also need to know the time the projectile is in the air to determine the spring constant.