AP® PHYSICS 1 TABLE OF INFORMATION

CONSTANTS AND CONVERSION FACTORS	
Proton mass, $m_p = 1.67 \times 10^{-27}$ kg	Electron charge magnitude, $e = 1.60 \times 10^{-19}$ C
Neutron mass, $m_n = 1.67 \times 10^{-27}$ kg	Coulomb's law constant, $k = 1/4\pi\varepsilon_0 = 9.0 \times 10^{9}$ N·m^2/C^2
Electron mass, $m_e = 9.11 \times 10^{-31}$ kg	Universal gravitational constant, $G = 6.67 \times 10^{-11}$ m^3/kg·s^2
Speed of light, $c = 3.00 \times 10^{8}$ m/s	Acceleration due to gravity at Earth's surface, $g = 9.8$ m/s^2

UNIT SYMBOLS	meter,	m	kelvin,	K	watt,	W	degree Celsius, °C
	kilogram,	kg	hertz,	Hz	coulomb,	C	
	second,	s	newton,	N	volt,	V	
	ampere,	A	joule,	J	ohm,	Ω	

PREFIXES		
Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES							
θ	0°	30°	37°	45°	53°	60°	90°
$\sin\theta$	0	$1/2$	$3/5$	$\sqrt{2}/2$	$4/5$	$\sqrt{3}/2$	1
$\cos\theta$	1	$\sqrt{3}/2$	$4/5$	$\sqrt{2}/2$	$3/5$	$1/2$	0
$\tan\theta$	0	$\sqrt{3}/3$	$3/4$	1	$4/3$	$\sqrt{3}$	∞

The following conventions are used in this exam.

I. The frame of reference of any problem is assumed to be inertial unless otherwise stated.
II. Assume air resistance is negligible unless otherwise stated.
III. In all situations, positive work is defined as work done on a system.
IV. The direction of current is conventional current: the direction in which positive charge would drift.
V. Assume all batteries and meters are ideal unless otherwise stated.

AP® PHYSICS 1 EQUATIONS

MECHANICS

$v_x = v_{x0} + a_x t$

$x = x_0 + v_{x0} t + \frac{1}{2} a_x t^2$

$v_x^2 = v_{x0}^2 + 2a_x (x - x_0)$

$\vec{a} = \frac{\sum \vec{F}}{m} = \frac{\vec{F}_{net}}{m}$

$|\vec{F}_f| \le \mu |\vec{F}_n|$

$a_c = \frac{v^2}{r}$

$\vec{p} = m\vec{v}$

$\Delta \vec{p} = \vec{F} \Delta t$

$K = \frac{1}{2} m v^2$

$\Delta E = W = F_{||} d = F d \cos\theta$

$P = \frac{\Delta E}{\Delta t}$

$\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2$

$\omega = \omega_0 + \alpha t$

$x = A\cos(2\pi f t)$

$\vec{\alpha} = \frac{\sum \vec{\tau}}{I} = \frac{\vec{\tau}_{net}}{I}$

$\tau = r_\perp F = rF \sin\theta$

$L = I\omega$

$\Delta L = \tau \Delta t$

$K = \frac{1}{2} I \omega^2$

$|\vec{F}_s| = k|\vec{x}|$

$U_s = \frac{1}{2} k x^2$

$\rho = \frac{m}{V}$

a = acceleration
A = amplitude
d = distance
E = energy
f = frequency
F = force
I = rotational inertia
K = kinetic energy
k = spring constant
L = angular momentum
ℓ = length
m = mass
P = power
p = momentum
r = radius or separation
T = period
t = time
U = potential energy
V = volume
v = speed
W = work done on a system
x = position
y = height
α = angular acceleration
μ = coefficient of friction
θ = angle
ρ = density
τ = torque
ω = angular speed

$\Delta U_g = mg\Delta y$

$T = \frac{2\pi}{\omega} = \frac{1}{f}$

$T_s = 2\pi\sqrt{\frac{m}{k}}$

$T_p = 2\pi\sqrt{\frac{\ell}{g}}$

$|\vec{F}_g| = G\frac{m_1 m_2}{r^2}$

$\vec{g} = \frac{\vec{F}_g}{m}$

$U_G = -\frac{G m_1 m_2}{r}$

ELECTRICITY

$|\vec{F}_E| = k\left|\frac{q_1 q_2}{r^2}\right|$

$I = \frac{\Delta q}{\Delta t}$

$R = \frac{\rho \ell}{A}$

$I = \frac{\Delta V}{R}$

$P = I\,\Delta V$

$R_s = \sum_i R_i$

$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$

A = area
F = force
I = current
ℓ = length
P = power
q = charge
R = resistance
r = separation
t = time
V = electric potential
ρ = resistivity

WAVES

$\lambda = \frac{v}{f}$

f = frequency
v = speed
λ = wavelength

GEOMETRY AND TRIGONOMETRY

Rectangle
$A = bh$

Triangle
$A = \frac{1}{2} bh$

Circle
$A = \pi r^2$
$C = 2\pi r$

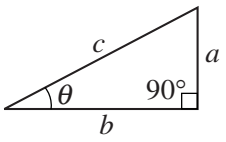
Rectangular solid
$V = \ell w h$

Cylinder
$V = \pi r^2 \ell$
$S = 2\pi r \ell + 2\pi r^2$

Sphere
$V = \frac{4}{3}\pi r^3$
$S = 4\pi r^2$

A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius

Right triangle
$c^2 = a^2 + b^2$
$\sin\theta = \frac{a}{c}$
$\cos\theta = \frac{b}{c}$
$\tan\theta = \frac{a}{b}$

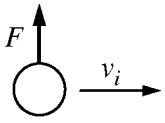


PHYSICS 1
Section I
50 Questions
Time—90 minutes

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

Directions: Each of the questions or incomplete statements below is followed by four suggested answers or completions. Select the one that is best in each case and then enter the appropriate letter in the corresponding space on the answer sheet.

1. An object is moving to the right with speed v_i when a force of magnitude F is exerted on it. In which of the following situations is the object's direction of motion changing and kinetic energy decreasing at the instant shown?

(A)


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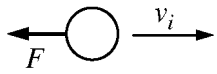

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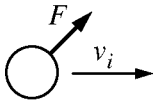

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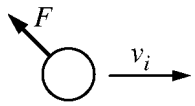

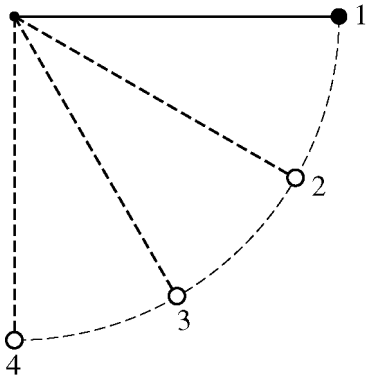

2. A ball is suspended by a lightweight string, as shown in the figure above. The ball is displaced to position 1 and released. The four labeled positions are evenly spaced along the arc of the ball's motion. Between which adjacent pairs of positions is the change in kinetic energy of the ball greatest?

(A) 1 and 2
(B) 2 and 3
(C) 3 and 4
(D) The change is the same for all adjacent pairs.

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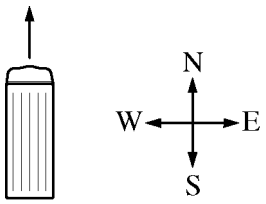
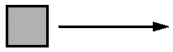
3. A newly discovered planet is found to have density $\frac{2}{3}\rho_E$ and radius $2R_E$, where ρ_E and R_E are the density and radius of Earth, respectively. The surface gravitational field of the planet is most nearly

(A) 1.7 N/kg
(B) 3.3 N/kg
(C) 6.7 N/kg
(D) 13 N/kg



4. A bus is initially traveling north at a constant speed, as shown in the figure above. As the bus starts to make a left turn without changing speed, a passenger notices that a box on the floor starts sliding toward the right side of the bus. Which of the following top views of the box, when correctly labeled, would best represent all of the horizontal forces exerted on the box as it starts sliding?

(A)


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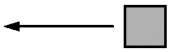
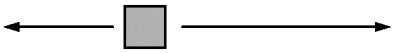


(C)


(D)


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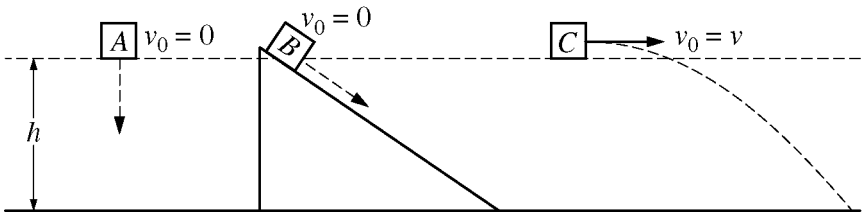
Questions 5-6 refer to the following material.



Three identical blocks each take a different path from a height h to the ground. Block A is released from rest and falls vertically. Block B is released from rest and slides down a frictionless incline. Block C is projected horizontally with an initial speed v.

5. Which block takes the longest time to reach the ground?

   (A) A
   (B) B
   (C) C
   (D) The blocks take the same time to reach the ground.

6. Which block has the greatest speed just before hitting the ground?

   (A) A
   (B) B
   (C) C
   (D) The blocks reach the ground with the same speed.

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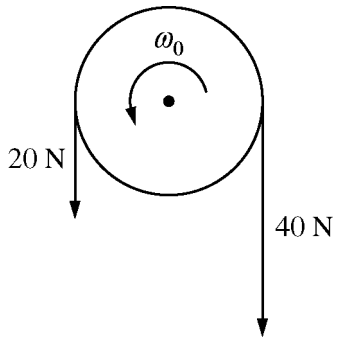
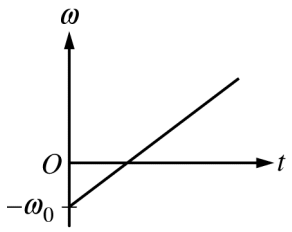
7. A ball is dropped from rest and falls to the floor. The initial gravitational potential energy of the ball-Earth-floor system is 10 J. The ball then bounces back up to a height where the gravitational potential energy is 7 J. What was the mechanical energy of the ball-Earth-floor system the instant the ball left the floor?

(A) 0 J
(B) 3 J
(C) 7 J
(D) 10 J



8. A disk is initially rotating counterclockwise around a fixed axis with angular speed ω_0.

At time $t = 0$, the two forces shown in the figure above are exerted on the disk. If counterclockwise is positive, which of the following could show the angular velocity of the disk as a function of time?

(A)


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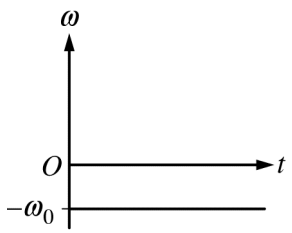

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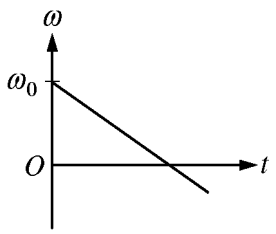

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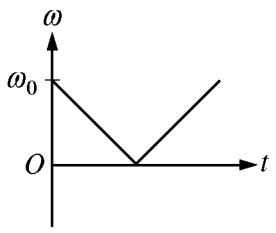

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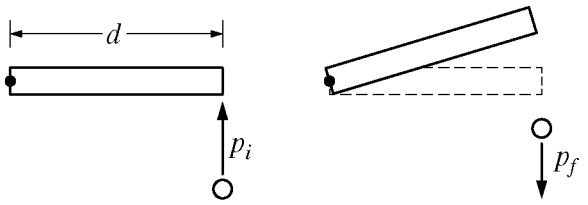
9. A 50.0 N box is at rest on a horizontal surface. The coefficient of static friction between the box and the surface is 0.50, and the coefficient of kinetic friction is 0.30. A horizontal 20.0 N force is then exerted on the box. The magnitude of the acceleration of the box is most nearly

(A) $0\ \text{m/s}^2$

(B) $0.5\ \text{m/s}^2$

(C) $1.0\ \text{m/s}^2$

(D) $4.0\ \text{m/s}^2$



Top View

10. A thin rod of length d on a frictionless surface is pivoted about one end, as shown above, and can rotate freely. The rod is at rest when it is struck by a sphere with linear momentum of magnitude p_i perpendicular to the rod. The sphere rebounds along its original line of motion with momentum of magnitude p_f. What is the magnitude of the angular momentum of the rod immediately after the collision?

(A) $p_f - p_i$

(B) $p_f + p_i$

(C) $\left(p_f - p_i\right)d$

(D) $\left(p_f + p_i\right)d$

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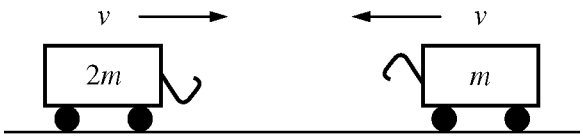
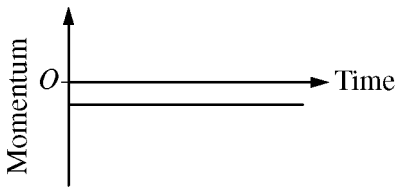
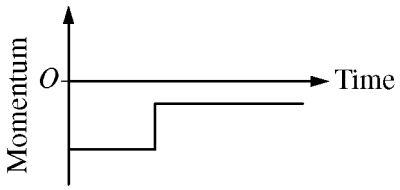
11. A spacecraft is placed in a circular orbit around a planet with mass 6.4×10^{23} kg . The spacecraft orbits at a height of 4.5×10^{7} m above the planet's surface. What additional information is needed to calculate the speed of the spacecraft in the orbit?

(A) No additional information
(B) The planet's radius only
(C) The spacecraft's mass only
(D) Both the planet's radius and the spacecraft's mass



12. Two carts, of mass $2m$ and m, approach each other head-on with the same speed v, as shown in the figure above. When the carts collide, they hook together. Assuming positive momentum is to the right, which of the following best represents the momentum of the cart of mass m as a function of time before and after the collision?

(A)


(B)


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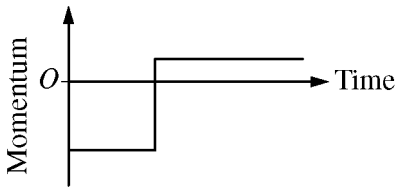

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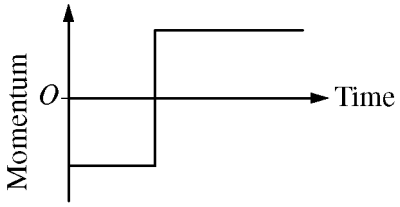

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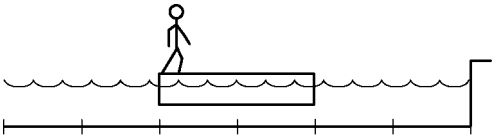
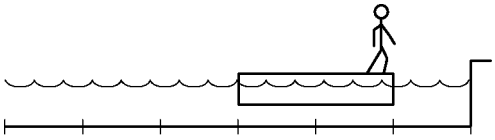


13. A student stands at one end of a raft floating in a pool with equally spaced marks along the bottom, as shown above. The student and the raft have the same mass. The student walks to the opposite end of the raft. Which of the following best shows the final locations of the raft and student relative to the marks at the bottom of the pool? Assume that there is no drag force between the raft and the water.

(A)



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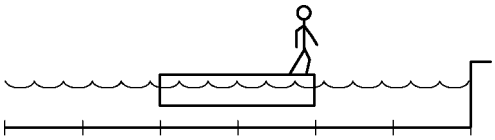

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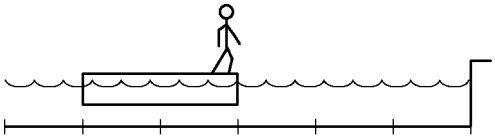

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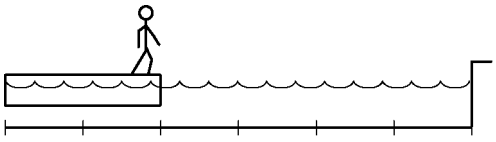

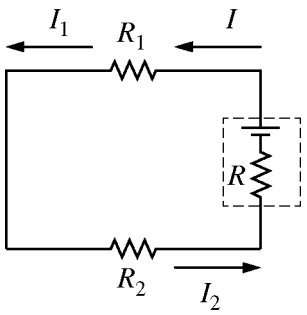

14. A circuit is designed with two resistors, $R_1 = 200\ \Omega$ and $R_2 = 400\ \Omega$, and a battery with internal resistance $R = 10\ \Omega$, as shown above. What is the relationship between the three labeled currents?

(A) $I_1 + I_2 = I$
(B) $I > I_1 > I_2$
(C) $I_2 > I_1 > I$
(D) $I_1 = I_2 = I$

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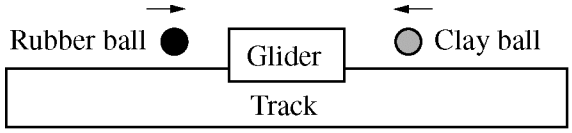
15. When two charged, massive objects are placed a distance r apart, the gravitational force between them has magnitude F. When the distance between the objects is increased to $2r$, the magnitude of the gravitational force between them becomes $F/4$. Did the electrostatic force between the objects also decrease to one fourth its initial magnitude as a result of the change in position, and why?

(A) No, because the gravitational constant is much smaller than the electrostatic constant.
(B) No, because the gravitational force is only attractive, and the electrostatic force can also be repulsive.
(C) Yes, because both forces have the same $1/r^2$ dependence.
(D) Yes, because the gravitational force always equals the electrostatic force at any given distance.



16. A clay ball and a rubber ball of the same mass are moving toward a glider that is at rest on a frictionless air track. The balls have the same speed, with the rubber ball moving toward the right and the clay ball moving toward the left, as shown above. The balls strike the glider at the same time. The clay ball sticks to the glider, and the rubber ball bounces off it. Which of the following indicates the direction of motion of the glider after the collisions and explains why it moves in that direction?

(A) The glider moves to the right because the magnitude of the change in momentum of the rubber ball is greater than the magnitude of the change in momentum of the clay ball.
(B) The glider moves to the right because the collision with the rubber ball is elastic and conserves energy.
(C) The glider moves to the left because the clay ball has more inertia when it sticks to the glider than the rubber ball does when it bounces off.
(D) The glider moves to the left because the clay ball exerts a force on the glider for a longer time than the rubber ball does.

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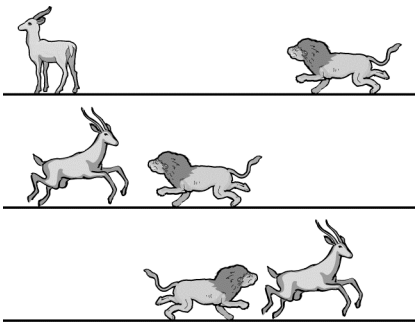
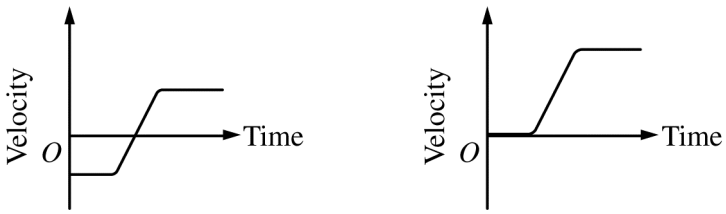
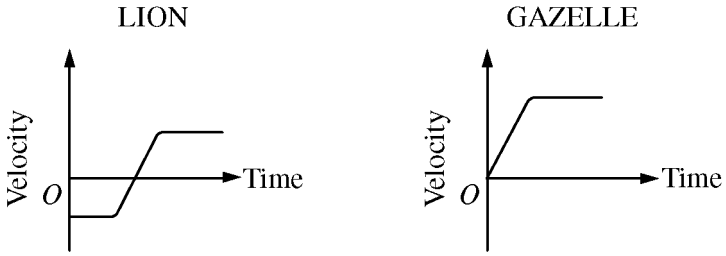


17. A lion is running at constant speed toward a gazelle that is standing still, as shown in the top figure above. After several seconds, the gazelle notices the lion and accelerates directly toward him, hoping to pass the lion and force him to reverse direction. As the gazelle accelerates toward and past the lion, the lion changes direction and accelerates in pursuit of the gazelle. The lion and the gazelle eventually each reach constant but different speeds. Which of the following sets of graphs shows a reasonable representation of the velocities of the lion and the gazelle as functions of time?

(A)



(B)



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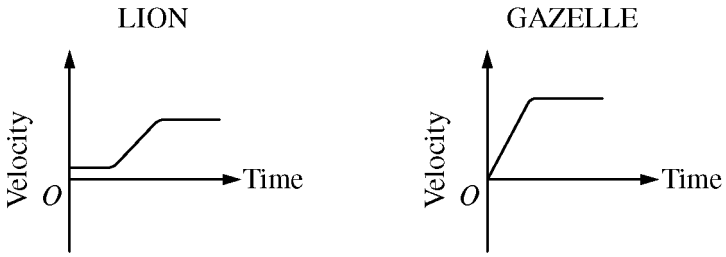

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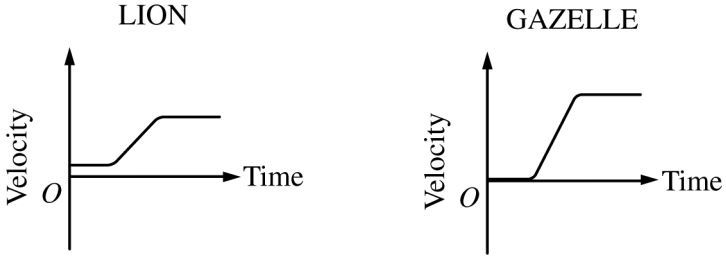

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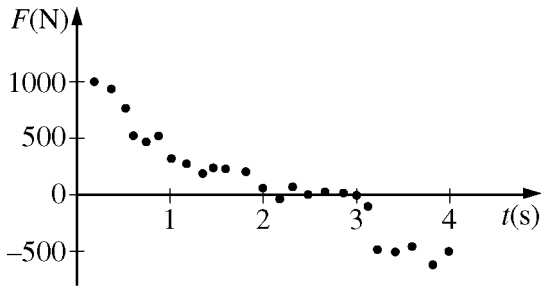

18. A spacecraft of mass 4000 kg is traveling in a straight line in the positive direction. Engines can be fired so that the force exerted on the spacecraft is in the positive or negative direction. The graph above shows data for the force during one interval. Which of the following is the best estimate of the net change in the speed of the spacecraft from time $t = 0$ to time $t = 4$ s ?

(A) +0.4 m/s
(B) +0.1 m/s
(C) –0.1 m/s
(D) –0.4 m/s

19. A rocket is continuously firing its engines as it accelerates away from Earth. For the first kilometer of its ascent, the mass of fuel ejected is small compared to the mass of the rocket. For this distance, which of the following indicates the changes, if any, in the kinetic energy of the rocket, the gravitational potential energy of the Earth-rocket system, and the mechanical energy of the Earth-rocket system?

	Rocket Kinetic Energy	System Gravitational Potential Energy	System Mechanical Energy
(A)	Increasing	Increasing	Increasing
(B)	Increasing	Increasing	Constant
(C)	Increasing	Decreasing	Decreasing
(D)	Decreasing	Increasing	Constant

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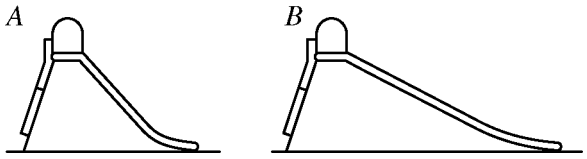
20. Block 1 is attached to a spring and oscillates on a horizontal frictionless surface. When block 1 is at a point of maximum displacement, block 2 is placed on top of it from directly above without interrupting the oscillation, and the two blocks stick together. How do the maximum kinetic energy and period of oscillation with both blocks compare to those of block 1 alone?

	Maximum Kinetic Energy	Period
(A)	Smaller	Smaller
(B)	Smaller	Greater
(C)	The same	Smaller
(D)	The same	Greater



21. A child slides from rest down slides *A* and *B* shown above. The slides are the same height, and the coefficient of friction between the slides and the child is the same. Which of the following compares the change ΔK in the kinetic energy of the child and the change ΔU in the potential energy of the child-Earth system for the two slides?

(A) $\Delta K_A = \Delta K_B$; $\Delta U_A = \Delta U_B$
(B) $\Delta K_A < \Delta K_B$; $\Delta U_A > \Delta U_B$
(C) $\Delta K_A > \Delta K_B$; $\Delta U_A = \Delta U_B$
(D) $\Delta K_A > \Delta K_B$; $\Delta U_A > \Delta U_B$

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Questions 22-24 refer to the following material.

A student is observing an object of unknown mass that is oscillating horizontally at the end of an ideal spring. The student measures the object's period of oscillation with a stopwatch.

22. The student wishes to determine the spring constant of the spring using the measurements of the period of oscillation. Which of the following pieces of equipment would provide another measured quantity that is sufficient information to complete the determination of the spring constant?

    (A) Meterstick
    (B) Motion sensor
    (C) Balance
    (D) Photogate

23. Using a number of measurements, the student determines the following.

Spring constant	85 N/m
Mass of object	0.50 kg
Amplitude of oscillation	0.30 m
Maximum speed of object	3.9 m/s

    The total energy of the object-spring system is most nearly

    (A) 0.98 J
    (B) 3.8 J
    (C) 7.6 J
    (D) 12.8 J

24. While the object is continuously oscillating, the student determines the maximum speed of the object during two oscillations. The first speed is 3.5 m/s and the second speed is 2.7 m/s . Which of the following could account for the decrease in the object's maximum kinetic energy?

    (A) Energy was transferred from the object to the spring, which increased the maximum potential energy of the spring.
    (B) Energy was transferred from the spring to the object, which decreased the maximum potential energy of the spring.
    (C) As energy was transferred back and forth between the object and the spring, a greater average share of the energy became potential energy of the spring.
    (D) The object-spring system lost energy to its surroundings.

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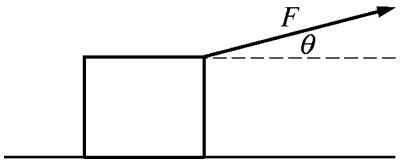
Questions 25-26 refer to the following material.



A crate is on a horizontal frictionless surface. A force of magnitude F is exerted on the crate at an angle θ to the horizontal, as shown in the figure above, causing the crate to slide to the right. The surface exerts a normal force of magnitude F_N on the crate. As the crate slides a distance d, it gains an amount of kinetic energy ΔK. While F is kept constant, the angle θ is now doubled but is still less than $90°$. Assume the crate remains in contact with the surface.

25. How does the new normal force exerted on the crate compare to F_N?

(A) The new normal force is greater than F_N.
(B) The new normal force is less than F_N.
(C) The new normal force is equal to F_N.
(D) The new normal force is greater or less than F_N depending on the value of θ.

26. As the crate slides a distance d, how does the new gain in kinetic energy compare to ΔK?

(A) The new gain is greater than ΔK.
(B) The new gain is less than ΔK.
(C) The new gain is equal to ΔK.
(D) The new gain is greater or less than ΔK depending on the value of θ.

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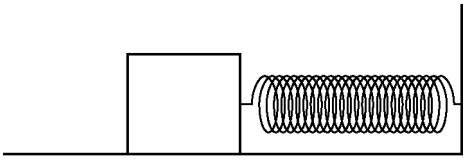
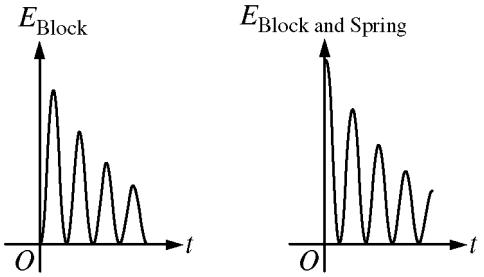
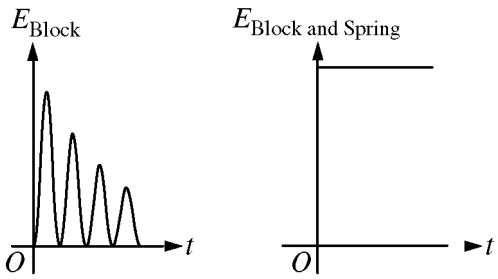


27. A block on a level surface is attached to one end of a spring, as shown in the figure above. The other end of the spring is attached to a wall. There is friction between the block and the surface. A person displaces the block from its equilibrium position and releases it. Which of the following shows the mechanical energy E as a function of time t for the system that includes only the block and the system that includes the block and spring?

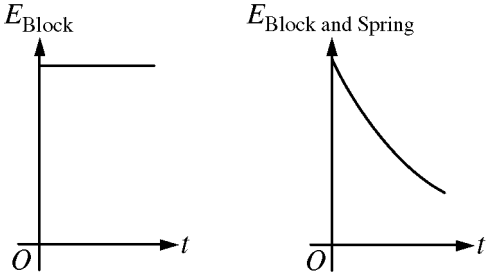
(A)



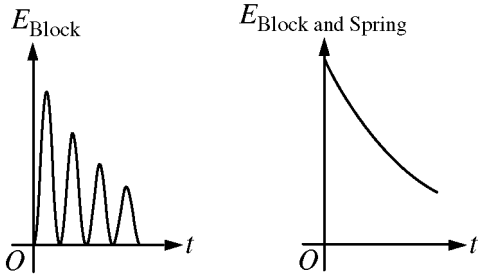
(B)



(C)



(D)



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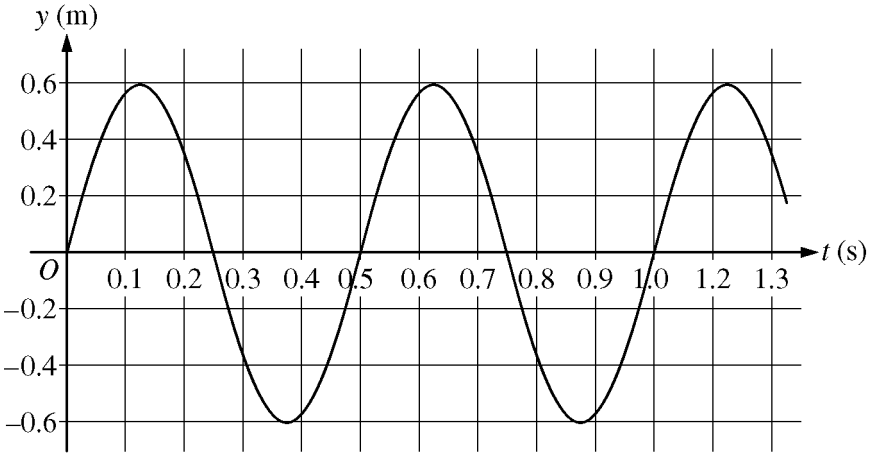

28. A transverse wave is traveling on a string. The graph above shows position as a function of time for a point on the string. If the frequency of the wave is doubled, what is the new average speed of the point?

(A) 0 m/s
(B) 2.4 m/s
(C) 4.8 m/s
(D) 9.6 m/s

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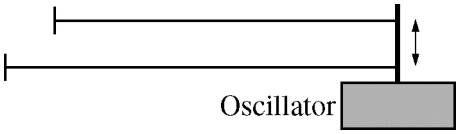
29. Alan and Beverly are on opposite sides of a large room when Alan says something to Beverly. Beverly does not hear him, so Alan repeats the message louder and Beverly now hears it. Which of the following could be different about the second sound wave compared to the first that allows Beverly to hear it?

(A) The second wave travels to Beverly more quickly, so less energy is dissipated by the time the wave reaches her.
(B) The second wave reflects more off the walls of the room.
(C) The air molecules disturbed by the second wave undergo a greater displacement from their equilibrium positions.
(D) The air molecules disturbed by the second wave are, on average, more closely spaced.



30. Two strings differing only in length are attached to the same oscillator, as shown in the figure above. Both are fixed at the other end and are under the same tension. The oscillator creates a transverse wave and is adjusted to the lowest frequency that creates a standing wave on the shorter string. Which of the following explains why there will not be a standing wave on the longer string?

(A) The waves travel at slightly different speeds on the two strings.
(B) An oscillator frequency that results in a standing wave on a string of one length cannot result in a standing wave on a string with a different length.
(C) The amplitude of the wave does not match the boundary conditions for strings of different length at the same time.
(D) The wavelength associated with the given frequency does not match the boundary conditions set by the length of the longer string.

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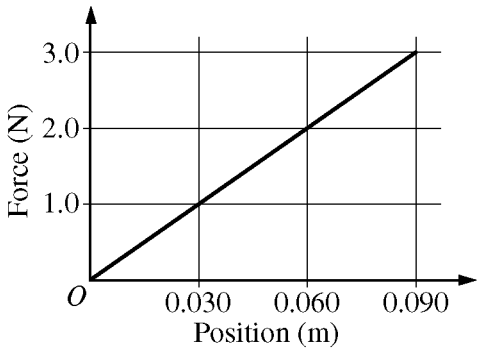
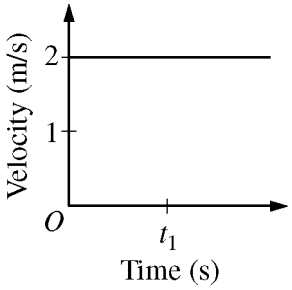


31. The figure above shows the net force exerted on an object as a function of the position of the object. The object starts from rest at position $x = 0$ m and acquires a speed of 3.0 m/s after traveling a distance of 0.090 m. What is the mass of the object?

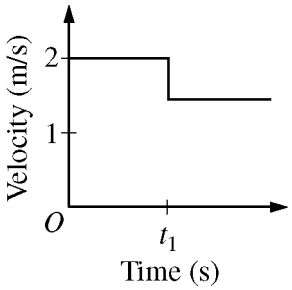
(A) 0.015 kg
(B) 0.030 kg
(C) 0.045 kg
(D) 0.060 kg

32. Two identical carts are free to move along a straight frictionless track. At time t_1, cart *X* is moving at 2.0 m/s when it collides with and sticks to cart *Y*, which is initially at rest. Which of the following graphs best shows the velocity of cart *X* before and after the collision?

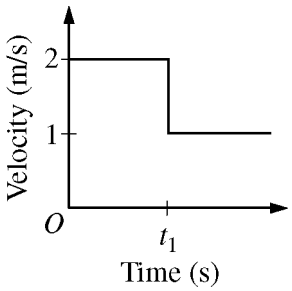
(A)



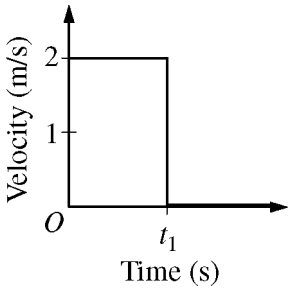
(B)



(C)



(D)



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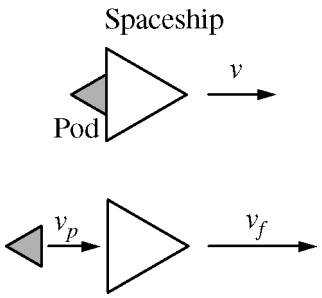


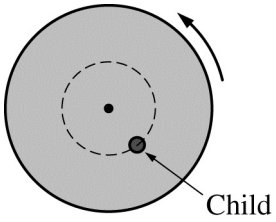
33. A spaceship and its shuttle pod are traveling to the right in a straight line with speed v, as shown in the top figure above. The mass of the pod is m, and the mass of the spaceship is $6m$. The pod is launched, and afterward the pod is moving to the right with speed v_p and the spaceship is moving to the right with speed v_f, where $v_f > v$, as shown in the bottom figure. Which of the following is true of the speed v_c of the center of mass of the system after the pod is launched?

(A) $v_c = v_f$

(B) $v < v_c < v_f$

(C) $v_c < v$

(D) $v_c = v$



Top View

34. The diagram above shows a top view of a child of mass M on a circular platform of mass $5M$ that is rotating counterclockwise. Assume the platform rotates without friction. Which of the following describes an action by the child that will result in an increase in the total angular momentum of the child-platform system?

(A) The child moves toward the center of the platform.

(B) The child moves away from the center of the platform.

(C) The child moves along a circle concentric with the platform (dashed line shown) opposite the direction of the platform's rotation.

(D) None of the actions described will change the total angular momentum of the child-platform system.

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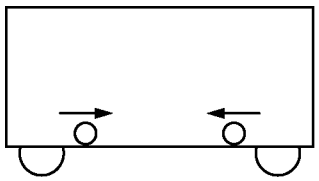

35. A train is traveling east with constant speed v_t.

Two identical spheres are rolling on the floor of one train car. In the frame of reference of the train, the spheres are moving directly toward each other at one instant with the same speed v_p parallel to the train's motion, as shown in the figure above. What is the velocity of the center of mass of the spheres in the frame of reference of the train and in the frame of reference of a person standing at rest alongside the train?

	Train	Person
(A)	Zero	Zero
(B)	Zero	v_t east
(C)	v_t east	$v_p + v_t$ east
(D)	$v_p + v_t$ east	Zero

36. A satellite that is a spinning cylinder has initial rotational inertia I_0 and angular velocity ω_0.

Solar panels unfold from the satellite and are extended outward. The satellite then has rotational inertia $I_f = aI_0$ and angular velocity $\omega_f = b\omega_0$, where a and b are constants. Which of the following is true about the constants a and b ?

(A) $a = 1$ and $b = 1$
(B) $a > 1$ and $b < 1$
(C) $a > 1$ and $b = 1$
(D) $a < 1$ and $b < 1$

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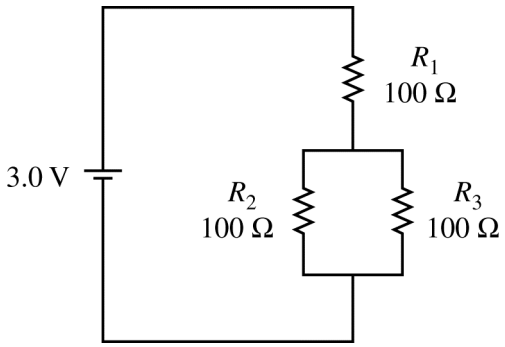


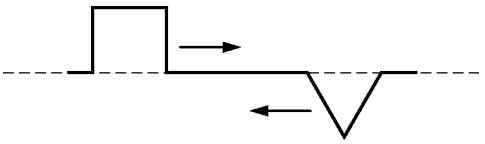
37. When the circuit shown above is set up, the potential difference across the battery is 3.0 V. By how much will the magnitude of the potential difference across R_2 change when R_3 is removed and its branch is left open?

(A) The magnitude of the potential difference across R_2 does not change.

(B) The magnitude of the potential difference across R_2 decreases by 0.5 V.

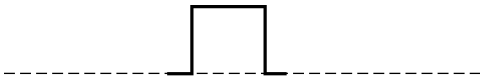
(C) The magnitude of the potential difference across R_2 increases by 0.5 V.

(D) The magnitude of the potential difference across R_2 increases by 1.0 V.

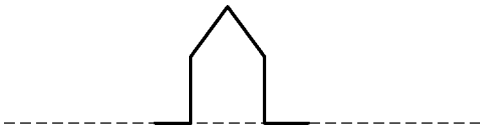


38. Two wave pulses are propagating along a straight line toward each other as shown above. Which of the following is the resultant when the centers of the pulses align?

(A)



(B)



(C)

(D)

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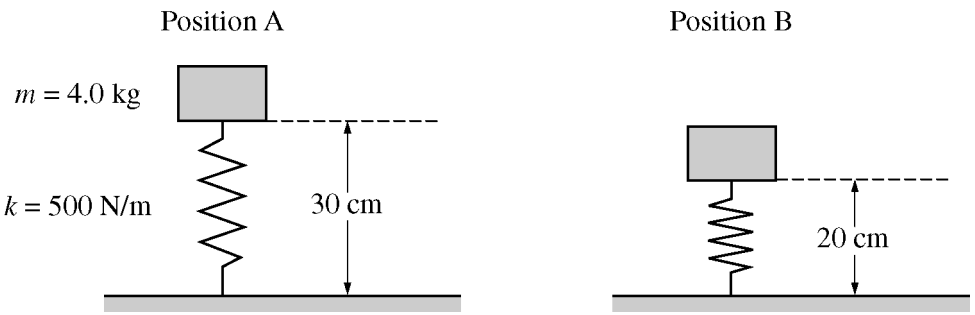

39. A person holds a 4.0 kg block at position A shown above on the left, in contact with an uncompressed vertical spring with a spring constant of 500 N/m. The person gently lowers the block from rest at position A to rest at position B. Which of the following describes the change in the energy of the block-spring-Earth system as a result of the block being lowered?

(A) The energy decreases by approximately 1.5 J.
(B) The energy decreases by approximately 2.5 J.
(C) The energy increases by approximately 4.0 J.
(D) The energy of the system does not change.

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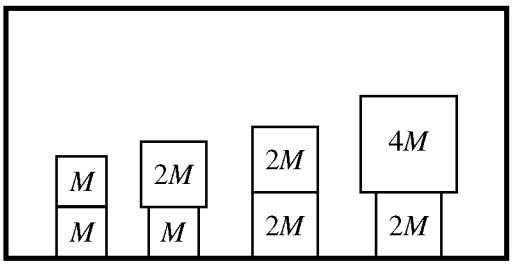
Questions 40-42 refer to the following material.

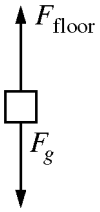


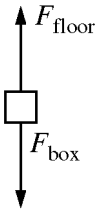
The stacks of boxes shown in the figure above are inside an elevator that is moving upward. The masses of the boxes are given in terms of the mass M of the lightest box.

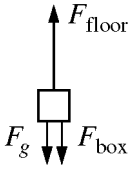
40. How does the magnitude of the force exerted by the top box on the bottom box compare with the magnitude of the force exerted by the bottom box on the top box for each of the stacks?

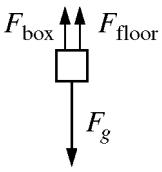
(A) The two magnitudes are always equal in each of the stacks.
(B) The two magnitudes are always different in each of the stacks.
(C) The two magnitudes are equal when the boxes have equal mass and different when the boxes have different masses.
(D) The two magnitudes are equal when the elevator is moving at constant speed and different when it is accelerating.

41. Assume the elevator is moving at constant speed, and consider the bottom box in the stack that has two boxes of mass $2M$. Let F_{floor} be the force exerted by the floor on the box, F_g be the force exerted by gravity on the box, and F_{box} be the force exerted by the top box on the bottom box. Which of the following best represents the forces exerted on the bottom box?

(A) 

(B) 

(C) 

(D) 

42. Assume the elevator has upward acceleration a, and consider the stack that has two boxes of mass M. What is the magnitude of the force exerted on the top box by the bottom box?

(A) Mg
(B) Ma
(C) $M(a - g)$
(D) $M(a + g)$

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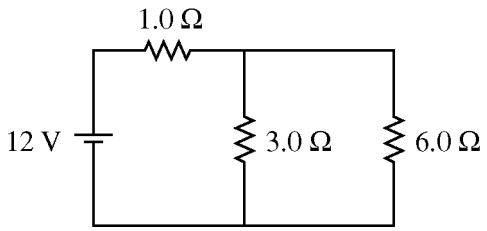
43. A researcher is analyzing data from a high-energy particle collision. The result of the analysis gives a value of $8.8 \times 10^{-19}\,\text{C} \pm 0.1 \times 10^{-19}\,\text{C}$ for the charge of one of the emitted particles. Should the researcher accept the value?

(A) Yes, it is a perfectly acceptable value.
(B) No, because the value is much bigger than the elementary charge.
(C) No, because the value is not an integer multiple of the elementary charge.
(D) No, because the uncertainty is more than 1% of the value.



44. The current through the 3 Ω resistor in the circuit shown above is most nearly

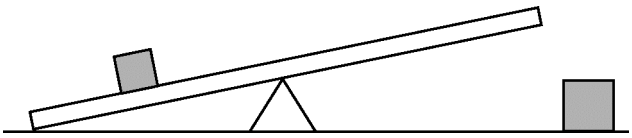
(A) 1.3 A
(B) 2.7 A
(C) 3.0 A
(D) 4.0 A

45. A student wants to determine the speed of sound at an elevation of one mile. To do this the student performs an experiment to determine the resonance frequencies of a tube that is closed at one end. The student takes measurements every day for a week and gets different results on different days. Which of the following experiments would help the student determine the reason for the different results?

(A) Repeating the experiment on several 10°C days and several 20°C days
(B) Repeating the experiment using a longer tube
(C) Repeating the experiment using a wider range of frequencies of sound
(D) Repeating the original experiment for an additional week

GO ON TO THE NEXT PAGE.

Directions: For each of the questions or incomplete statements below, two of the suggested answers will be correct. For each of these questions, you must select both correct choices to earn credit. No partial credit will be earned if only one correct choice is selected. Select the two that are best in each case and then enter both of the appropriate letters in the corresponding space on the answer sheet.



46. A uniform plank is placed with a pivot at its center. A block is placed on the plank to the left of the pivot, as shown in the figure above. A student is asked to place a second block of greater mass on the plank so it will balance when horizontal. Which of the following quantities are needed to determine where the second block should be placed? Select two answers.

    (A) The mass of the plank
    (B) The mass of each block
    (C) The length of the plank
    (D) The distance from the pivot to the left block

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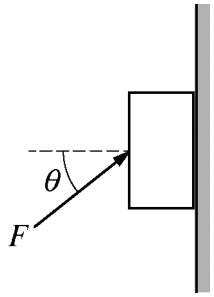

47. A block is held at rest against a wall by a force of magnitude F exerted at an angle θ from the horizontal, as shown in the figure above. Let $\vec{F}_g$ be the gravitational force exerted by Earth on the block, $\vec{F}_N$ be the normal force exerted by the wall on the block, and $\vec{F}_f$ be the frictional force exerted by the wall on the block. Which of the following statements about the magnitudes of the forces on the block must be true? Select two answers.

(A) $F = F_g / \sin\theta$

(B) $F\cos\theta = F_N$

(C) $F\sin\theta = F_g \pm F_f$

(D) $F = F_g + F_N \pm F_f$

48. Some students have determined the gravitational mass of an object and want to compare it to the object's inertial mass. Procedures that would allow them to accomplish this include which of the following? Select two answers.

(A) Hanging the object vertically from a spring scale and recording the scale reading

(B) Placing the object on one side of a double pan balance, adding objects of known mass to the other side until the masses are balanced, and recording the amount of mass added

(C) Attaching the object to a spring of known spring constant, allowing it to oscillate horizontally on a nearly frictionless surface, and measuring the period

(D) Attaching the object to a force sensor, using the sensor to pull the object across a nearly frictionless horizontal surface, and measuring the acceleration

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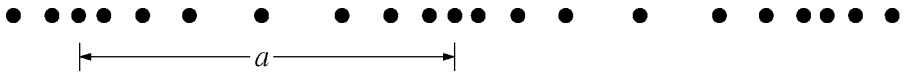
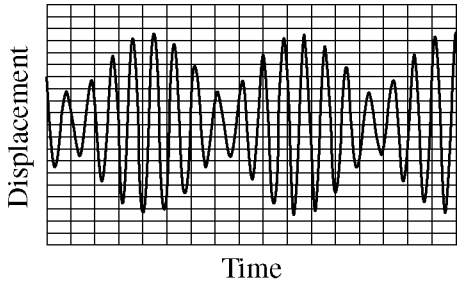


49. The figure above shows a representation of a wave traveling in a uniform medium at a particular instant. Correct statements about the wave include which of the following? Select two answers.

(A) It is a longitudinal wave.
(B) Distance *a* is the wavelength.
(C) The number of dots per unit length is the frequency.
(D) The largest distance between two successive dots is the amplitude.



50. A geologist is using a sensor to record waves in a layer of rock and is viewing them on a monitor screen. At one moment the monitor shows the signal above. If the signal is created by just two traveling waves, what can be concluded from the signal about the waves when they reach the sensor? Select two answers.

(A) The waves have different frequencies.
(B) The waves have different amplitudes.
(C) The waves are traveling in opposite directions.
(D) The waves are traveling at different speeds.

S T O P

END OF SECTION I

**IF YOU FINISH BEFORE TIME IS CALLED,
YOU MAY CHECK YOUR WORK ON THIS SECTION.**

DO NOT GO ON TO SECTION II UNTIL YOU ARE TOLD TO DO SO.