ADVANCED PLACEMENT 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,	$k = 1/4\pi\varepsilon_0 = 9.0 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$
Electron mass,	$m_e = 9.11 \times 10^{-31}$ kg	Universal gravitational constant,	$G = 6.67 \times 10^{-11}\ \text{m}^3/\text{kg}\cdot\text{s}^2$
Speed of light,	$c = 3.00 \times 10^8$ m/s	Acceleration due to gravity at Earth's surface,	$g = 9.8\ \text{m/s}^2$

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 <u>on</u> 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.

ADVANCED PLACEMENT PHYSICS 1 EQUATIONS

MECHANICS

$v_x = v_{x0} + a_x t$

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

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

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

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

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

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

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

$K = \frac{1}{2}mv^2$

$\Delta E = W = F_{\parallel}d = Fd\cos\theta$

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

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

$\omega = \omega_0 + \alpha t$

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

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

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

$L = I\omega$

$\Delta L = \tau\,\Delta t$

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

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

$U_s = \frac{1}{2}kx^2$

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

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

$\Delta U_g = mg\,\Delta y$

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

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

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

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

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

$U_G = -\frac{Gm_1 m_2}{r}$

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
$V = \ell wh$

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

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

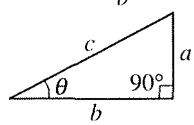
A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius

Right triangle
$c^2 = a^2 + b^2$

$\sin\theta = \frac{a}{c}$

$\cos\theta = \frac{b}{c}$

$\tan\theta = \frac{a}{b}$

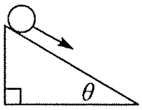


AP PHYSICS 1

SECTION I

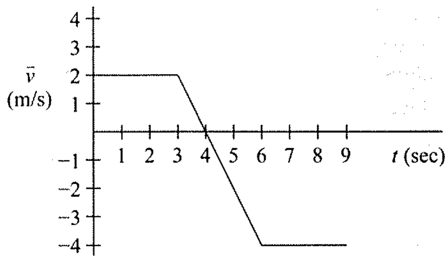
Note: To simplify calculations, you may use g = 10 m/s^2 in all problems.

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



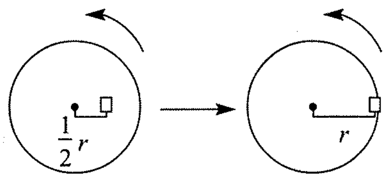
1. If a ball is rolling down an inclined plane without slipping, which force is responsible for exerting the torque that causes its rotation?

   (A) Normal force
   (B) Gravity
   (C) Kinetic friction
   (D) Static friction



2. The graph above shows the velocity of an object as a function of time. What is the net displacement of the object over the time shown?

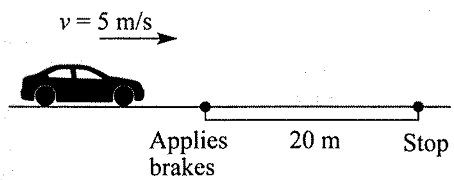
   (A) −23 m
   (B) −9 m
   (C) 9 m
   (D) 23 m



Top view

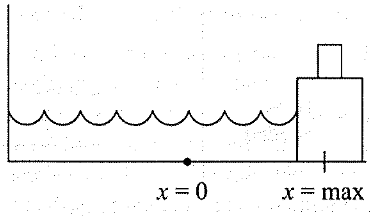
3. An object is resting on a platform that rotates at a constant speed. At first, it is a distance of half the platform's radius from the center. If the object is moved to the edge of the platform, what happens to the centripetal force that it experiences? Assume the platform continues rotating at the same speed.

   (A) Increases by a factor of 4
   (B) Increases by a factor of 2
   (C) Decreases by a factor of 2
   (D) Decreases by a factor of 4

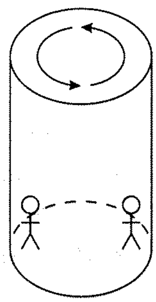


4. A car of mass 1000 kg is traveling at a speed of 5 m/s. The driver applies the brakes, generating a constant friction force, and skids for a distance of 20 m before coming to a complete stop. Given this information, what is the coefficient of friction between the car's tires and the ground?

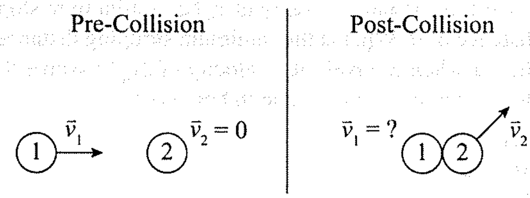
   (A) 0.25
   (B) 0.2
   (C) 0.125
   (D) 0.0625



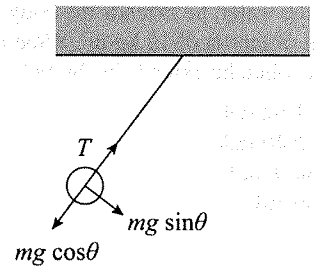
5. A spring-block system is oscillating without friction on a horizontal surface. If a second block of equal mass were placed on top of the original block at a time when the spring is at maximum compression, which of the following quantities would NOT be affected? Assume that the top block stays on the bottom block.
   (A) Frequency
   (B) Maximum speed
   (C) Amplitude
   (D) All of the above quantities would be affected.



6. A certain theme park ride involves people standing against the walls of a cylindrical room that rotates at a rapid pace, making them stick to the walls without needing support from the ground. Once the ride achieves its maximum speed, the floor drops out from under the riders, but the circular motion holds them in place. Which of the following factors could make this ride dangerous for some riders but not others?
   (A) The mass of the individuals
   (B) The coefficient of friction of their clothing in contact with the walls
   (C) Both of the above
   (D) None of the above



7. Two balls collide as shown above. Given the final direction of the second ball's motion after the collision, which of the following is a possible direction for the first ball to move after the collision?
   (A) $\nwarrow$
   (B) $\leftarrow$
   (C) $\rightarrow$
   (D) $\searrow$



8. As a pendulum swings back and forth, it is affected by two forces: gravity and tension in the string. Splitting gravity into component vectors, as shown above, produces $mg\sin\theta$ (the restoring force) and $mg\cos\theta$. Which of the following correctly describes the relationship between the magnitudes of tension in the string and $mg\cos\theta$?
   (A) Tension $>$ $mg\cos\theta$
   (B) Tension $=$ $mg\cos\theta$
   (C) Tension $<$ $mg\cos\theta$
   (D) The relationship depends on the position of the ball.

GO ON TO THE NEXT PAGE.

9. A car traveling at a velocity of v_0 has a minimum stopping distance of d. What is the minimum stopping distance of the car when it travels at a velocity of $2v_0$? Assume that the acceleration is the same in both cases.

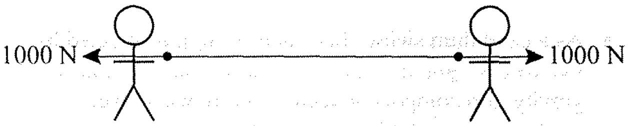
(A) $d/2$
(B) $2d$
(C) $4d$
(D) $8d$

10. A car accelerates from 0 to 25 m/s in 5 s. If the car's tires have a diameter of 70 cm, how many revolutions does a tire make during this acceleration?

(A) 14.2 revolutions
(B) 28.4 revolutions
(C) 89 revolutions
(D) 179 revolutions

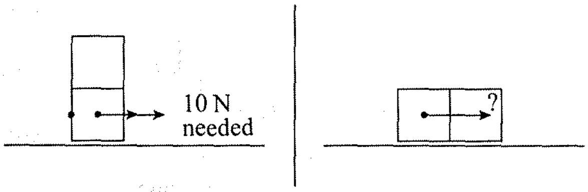
11. A diver rotates at a rate of 18 rad/s when his body is tucked and has a moment of inertia of 4.5 kg·m^2. Before he hits the water, he extends his body so that it has a moment of inertia of 15 kg·m^2. What is his body's rotation rate when he extends his body?

(A) 1.62 rad/s
(B) 5.40 rad/s
(C) 60.0 rad/s
(D) 200 rad/s



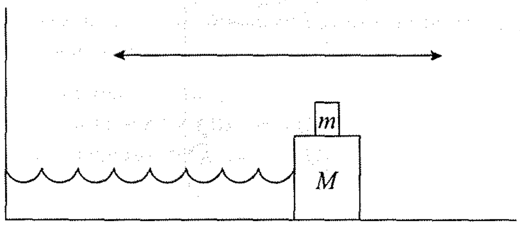
12. If two people pull with a force of 1000 N each on opposite ends of a rope and neither person moves, what is the magnitude of tension in the rope?

(A) 0 N
(B) 500 N
(C) 1000 N
(D) 2000 N



13. Two identical blocks are stacked on top of each other and placed on a table. To overcome the force of static friction, a force of 10 N is required. If the blocks were placed side by side and pushed as shown in the figure above, how much force would be required to move them?

(A) $\dfrac{10\sqrt{2}}{2}$ N
(B) 10 N
(C) $10\sqrt{2}$ N
(D) 20 N



14. A block of known mass M is connected to a horizontal spring that is sliding along a flat, frictionless surface. There is an additional block of known mass m resting on top of the first block. Which of the following quantities would NOT be needed to determine whether the top block will slide off the bottom block?

(A) The maximum coefficient of static friction between the blocks
(B) The amplitude of the system's motion
(C) The spring constant
(D) The period of the motion

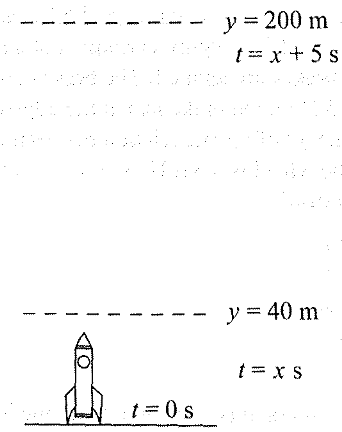
Questions 15–17 all refer to the following scenario.

A 35 kg child ziplines from rest on a platform 12 m high to the ground with negligible friction. In the last 8 m of the zipline, which is approximately horizontal, a braking mechanism applies a constant force opposing the motion to slow the child down so that she's traveling at 2.5 m/s when she finally lands on the safety padding at the end. The padding compresses for 1.5 s when the child lands on it and stops.

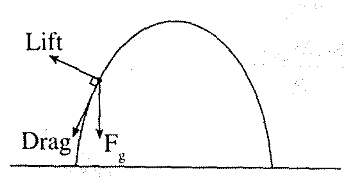
15. What is the magnitude of the force applied by the braking mechanism?
    (A) 350 N
    (B) 511 N
    (C) 525 N
    (D) 4090 N

16. What is the average force acting on the child as she comes to a stop on the safety padding?
    (A) 1.7 N
    (B) 58 N
    (C) 73 N
    (D) 150 N

17. If the height of the platform had been 15 m, by what factor would her maximum speed have increased?
    (A) $\frac{\sqrt{5}}{2}$
    (B) $\frac{5}{4}$
    (C) $\sqrt{\frac{5}{2}}$
    (D) $\frac{5}{2}$



18. A rocket is launched into the air. A few moments after liftoff, the rocket is 40 m above the ground. After another 5 s, the rocket is now 200 m off the ground. What is the average velocity of the rocket during this 5 s interval of the flight?
    (A) 16 m/s
    (B) 32 m/s
    (C) 48 m/s
    (D) 64 m/s

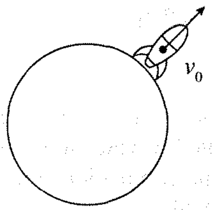


19. In projectile motion, an object experiences three forces: gravity, drag, and lift. These are depicted in the picture above. Given this information, how does lift affect the speed of a projectile?
    (A) It increases the speed.
    (B) It decreases the speed.
    (C) Its effect on speed varies.
    (D) It has no effect.

20. An object is launched from a cliff with a speed of 20 m/s at an angle of 30° above the horizontal. It lands on the ground below 5 s later. How high is the cliff? Assume air resistance is negligible.
    (A) 25 m
    (B) 50 m
    (C) 75 m
    (D) 125 m

21. A bicycle wheel with a diameter of 62.2 cm and a rotational inertia of 0.40 kg·m^2 is rotating at a rate of 8 rad/s when the brakes are applied. The brakes apply a normal force of 85 N on the brake pad at the edge of the wheel. The coefficient of kinetic friction between the brake pad and the wheel is 0.32. How long does it take for the bicycle to stop?
(A) 0.19 s
(B) 0.29 s
(C) 0.38 s
(D) 2.6 s

22. A rocket of mass m is launched with kinetic energy K_0 from the surface of the Earth. How much less kinetic energy does the rocket have at an altitude of two Earth radii in terms of the gravitational constant, G; the mass of the Earth, m_E; the radius of the Earth, R_E; and the mass of the rocket?
(A) $\dfrac{GM_Em}{2R_E}$
(B) $\dfrac{2GM_Em}{3R_E}$
(C) $\dfrac{3GM_Em}{4R_E}$
(D) $\dfrac{8GM_Em}{9R_E}$



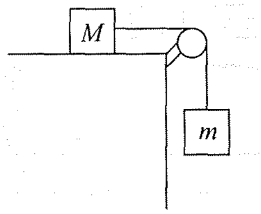
23. Escape velocity is defined as the minimum speed at which an object must be launched to "break free" from a massive body's gravitational pull. Which of the following principles could be used to derive this speed for a given planet?
(A) Conservation of Linear Momentum
(B) Newton's Third Law
(C) Conservation of Angular Momentum
(D) Conservation of Energy

24. What is the average power used to pitch a 0.142 kg baseball at 42 m/s, if it takes 0.3 s to accelerate it from rest?
(A) 251 W
(B) 417 W
(C) 501 W
(D) 835 W

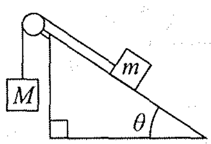
25. The muzzle velocity of a 0.003-kg paintball pellet is 90 m/s. If it takes 0.002 s for the pellet to be shot from the paintball gun, what is the average force of the recoil on the paintball gun?
(A) 24 N
(B) 60 N
(C) 68 N
(D) 135 N

26. A 40-kg box slides down an incline that is angled 30° above the horizontal. The box starts from rest at a height of 8 m, and the coefficient of kinetic friction is 0.2. What is the total work done on the box as it slides to the bottom of the incline?
(A) 1109 J
(B) 2091 J
(C) 3200 J
(D) 4309 J

27. A runner on a relay team starts running as her teammate approaches with the baton. Once she takes the baton, she accelerates at 2.4 m/s^2 for 2 s to reach a speed of 10 m/s. How far does she travel from the time she takes the baton to the time she reaches her top speed?
(A) 4.8 m
(B) 15.2 m
(C) 20.0 m
(D) 24.8 m



28. A block of mass M is at rest on a table. It is connected by a string and pulley system to a block of mass m hanging off the edge of the table. Assume the hanging mass is heavy enough to make the resting block move. Knowing the acceleration of the system and the mass of each block is sufficient to calculate all of the following quantities EXCEPT which one?
    (A) Net force on each block
    (B) Tension in the string
    (C) Coefficient of kinetic friction between the table and the block of mass M
    (D) The speed of the block of mass M when it reaches the edge of the table



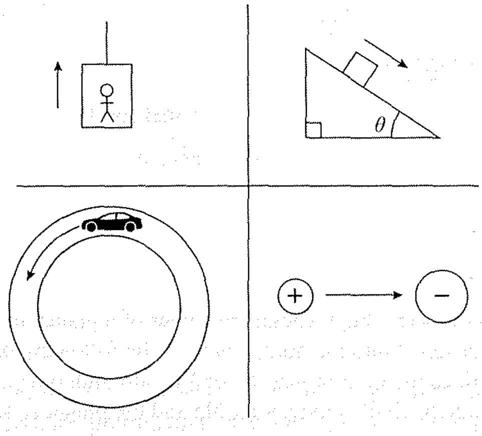
29. A block of mass m is connected by a string that runs over a frictionless pulley to a heavier block of mass M. The smaller block rests on an inclined plane of angle θ, and the larger block hangs over the edge, as shown above. In order to prevent the blocks from moving, the coefficient of static friction must be

    (A) $\dfrac{mg\sin\theta}{Mg - mg\cos\theta}$

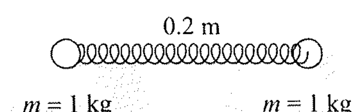
    (B) $\dfrac{Mg - mg\sin\theta}{Mg\cos\theta}$

    (C) $\dfrac{Mg - mg\sin\theta}{mg\cos\theta}$

    (D) $\dfrac{Mg - mg\cos\theta}{mg\sin\theta}$



30. Which of the following forces does not do work in its given situation?
    (A) Normal force, as a person goes up in an elevator
    (B) Frictional force, as a box slides down a ramp
    (C) Centripetal force, as a car drives around a circular track
    (D) Gravitational force, as a positive charge moves toward a negative charge



31. Two identical spheres of mass 1 kg are placed near each other. To keep the spheres apart, a light spring is placed between them. The spring has a natural length of 1.0 m. If equilibrium is achieved when the spheres are 0.2 m apart, what is the spring constant of the spring?
    (A) 4.17×10^{-10} N/m
    (B) 1.67×10^{-9} N/m
    (C) 2.09×10^{-9} N/m
    (D) 8.34×10^{-9} N/m

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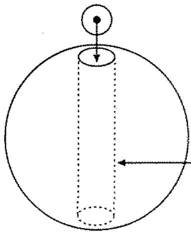
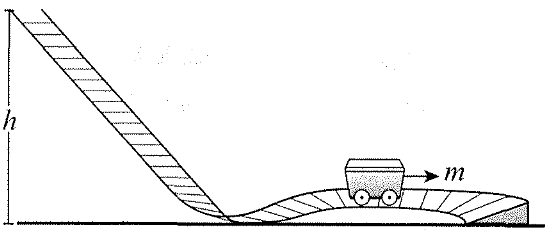


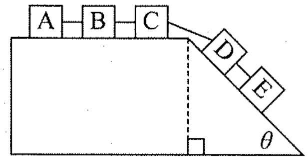
32. If a hole were dug through the center of a planet and a ball dropped into the hole, which of the following best describes the motion that the ball would undergo? Assume the ball is indestructible and the planet is a perfect sphere.

(A) It would continuously gain speed and eventually escape the gravitational pull of the planet.
(B) It would fall to the center of the planet and get stuck there because gravity is always pulling things toward the center of the planet.
(C) It would fall to the other end of the hole, come to a momentary stop, fall back to the starting location, and then repeat this back-and-forth motion indefinitely.
(D) None of the above is correct.



33. An empty mine car of mass m starts at rest at the top of a hill of height h above the ground, then rolls down the hill and into a horizontal semicircular banked turn of radius r. Ignoring rolling friction so that the only forces acting on the mine car are the normal force from the track and gravity, what is the magnitude of centripetal force on the car as it rounds the banked curve?

(A) mgh
(B) $2mgh/r$
(C) mgh/r
(D) $mgh/(2r)$



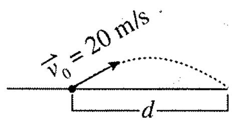
34. Five boxes are linked together, as shown above. If both the flat and slanted portions of the surface are frictionless, what will be the acceleration of the box marked B?

(A) $\frac{1}{5}g\sin\theta$

(B) $\frac{2}{5}g\sin\theta$

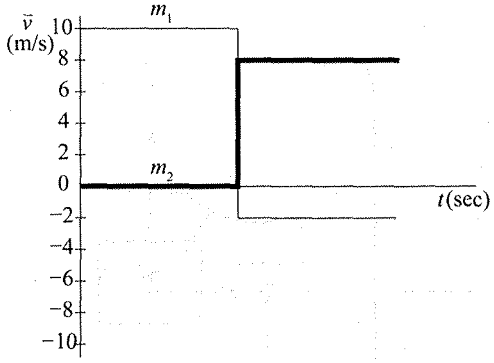
(C) $\frac{5}{7}g\sin\theta$

(D) $\frac{2}{5}g\cos\theta$



35. A soccer ball on a level field is kicked at an angle of 30 degrees above the horizontal with an initial speed of 20 m/s, as shown above. What is d, the distance from the spot of the kick to the spot where the ball lands? Ignore air resistance.

(A) $20\sqrt{3}$ m
(B) 40 m
(C) $40\sqrt{3}$ m
(D) 80 m



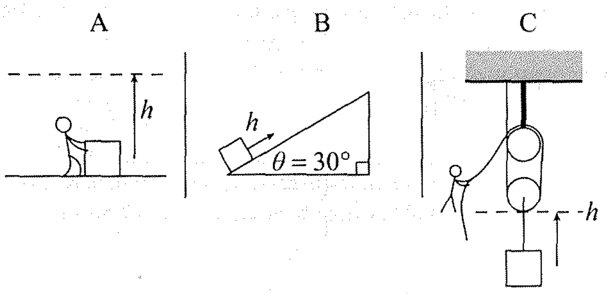
Questions 36–37 refer to the graph above.

36. Two objects of masses m_1 and m_2 undergo a collision. The graph above shows their velocities with respect to time both before and after the collision. If m_1 = 10 kg, then m_2 must be

(A) 5 kg
(B) 10 kg
(C) 15 kg
(D) 20 kg

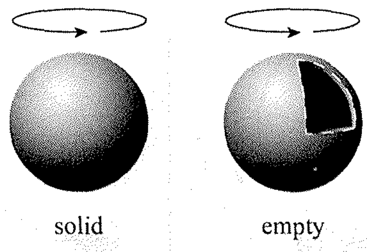
37. If the two objects have masses of m_1 = 4 kg and m_2 = 6 kg, what type of collision does the graph represent?

(A) Perfectly elastic
(B) Perfectly inelastic
(C) Neither of the above
(D) Cannot be determined



38. The diagrams above show a box of mass m being lifted from the ground up to a height of h via three different methods. In situation A, the box is simply lifted by a person. In B, it is pushed up a ramp with an incline angle of 30 degrees. In C, it is lifted by a pulley system. Assuming ideal conditions (no friction) for all of these situations, which of the following correctly ranks the amount of work required to lift the box in each case?

(A) A > B > C
(B) A > B = C
(C) C > B > A
(D) A = B = C



$$m_1 = m_2$$

$$\tau_1 = \tau_2$$

39. Two spheres of equal size and equal mass are rotated with an equal amount of torque. One of the spheres is solid with its mass evenly distributed throughout its volume, and the other is hollow with all of its mass concentrated at the edges. If both spheres start at rest, which one is rotating faster after 1 second?

(A) Solid sphere
(B) Hollow sphere
(C) They are rotating with the same angular velocity.
(D) Additional information is required to determine the relative rates of rotation.

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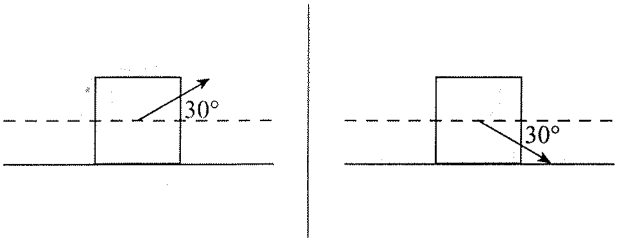
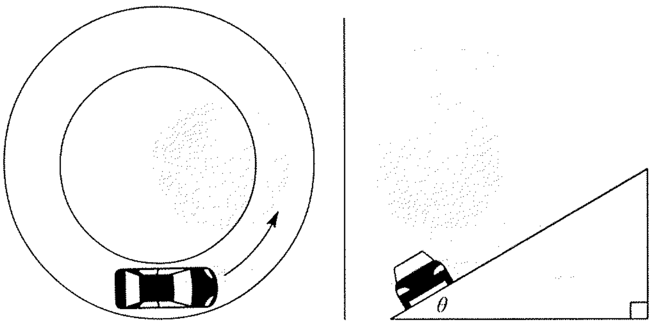


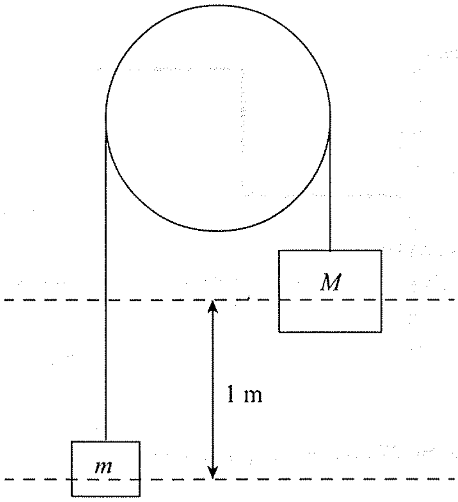
40. Pulling a block of mass m to the right by a connected string at an angle of 30° above the horizontal (as shown in the left picture) with a force equal to the block's weight produces a friction force F_{kf}. If the same block were to be pulled at an angle of 30° beneath the horizontal (as shown in the right picture), what would be the friction force? Assume that the applied force is enough to make the block move in both cases.

(A) $3F_{kf}$
(B) $2F_{kf}$
(C) $F_{kf}/2$
(D) $F_{kf}/3$



41. A car is traveling in a horizontal circle of radius r, on a frictionless banked turn, at a constant speed v. How does the magnitude of the normal force on the car compare with the car's weight?

(A) $F_N < F_g$
(B) $F_N = F_g$
(C) $F_N > F_g$
(D) The answer depends on the speed of the car, the radius of the turn, and the angle of the embankment.



42. The pulley above is both frictionless and massless, and the blocks are initially at rest. How long will it take for the two blocks to reach an equal height if block M of mass 15 kg starts 1 m above block m of mass 5 kg?

(A) $\sqrt{\frac{2}{5}}$ s
(B) $\sqrt{\frac{1}{5}}$ s
(C) $\sqrt{\frac{1}{20}}$ s
(D) $\frac{1}{5}$ s

43. A person pushes a 60 kg grocery cart, initially at rest, across a parking lot. He exerts a pushing force directed 20° below the horizontal. If the person pushes the cart with a force of 300 N for 5 m across horizontal ground and then releases the cart, the cart has a speed of 3 m/s. What is the work done by friction during this motion?

(A) −1230 J
(B) −1140 J
(C) 1140 J
(D) 1230 J

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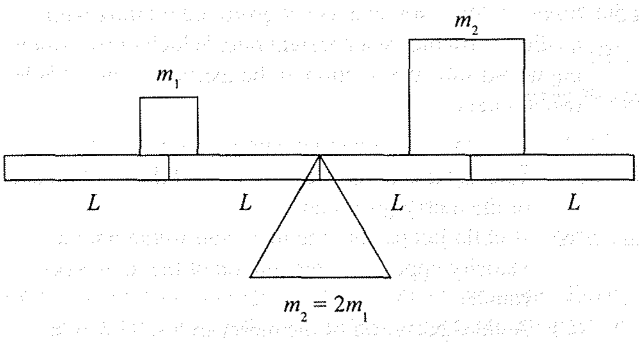
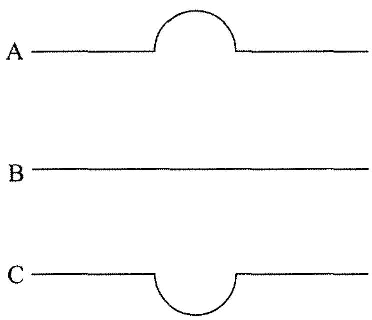


44. The system above is currently not balanced. Which of the following proposed changes would keep the system out of balance? Assume the plank has no mass of its own.

(A) Adding a mass equal to m_2 on the far left side and a mass equal to m_1 and on the far right side
(B) Stacking both masses directly on top of the fulcrum
(C) Moving the fulcrum a distance $L/3$ to the right
(D) Moving both masses a distance $L/3$ to the left

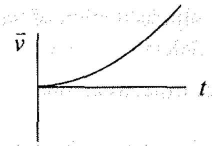


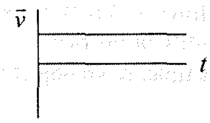
45. Three identical balls are rolled from left to right across the three tracks above with the same initial speed. Assuming the tracks all have negligible friction and the balls have enough initial speed to reach the ends of each track, which set correctly orders the average speed of the balls on the three tracks?

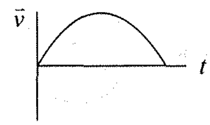
(A) A = B = C
(B) B > C > A
(C) C > B > A
(D) Cannot be determined

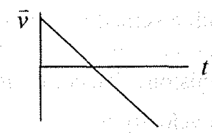
Directions: For each of the questions 46–50, <u>two</u> of the suggested answers will be correct. Select the two answers that are best in each case, and then fill in both of the corresponding circles on the answer sheet.

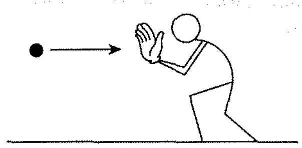
46. Which two velocity-versus-time graphs depict situations of uniformly accelerated motion? Select two answers.

(A) 

(B) 

(C) 

(D) 



47. A man is standing on a frictionless surface. A ball is thrown horizontally to him, and he catches it with his outstretched hand, as shown above. Which two of the following values will remain the same after the catch as they were before the catch? Select two answers.

(A) Angular momentum of the man-and-ball system
(B) Angular momentum of the ball about the man's center of mass
(C) Mechanical energy of the man-and-ball system
(D) Momentum of the man-and-ball system

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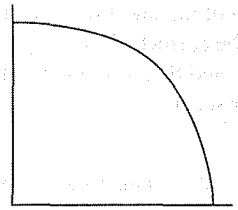
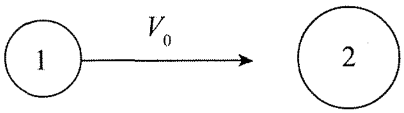


48. The graph above could be a representation of which two of the following situations? Select two answers.
    (A) Vertical position versus time, as an object falls with no air resistance
    (B) Kinetic energy versus time, as an object falls with no air resistance
    (C) Kinetic energy versus time, as a rocket flies at constant speed but steadily burns fuel
    (D) Potential energy versus time, as an object falls with no air resistance



49. Ball 1 rolls toward ball 2 with a velocity v_0. Ball 2 is initially at rest and has a greater mass than ball 1. What are possible outcomes of the collision? Select two answers.
    (A) Ball 1 rebounds with a velocity of $-v_0$.
    (B) Ball 1 and ball 2 have the same final velocity.
    (C) Ball 2 has a final velocity of v_0.
    (D) The final velocities of ball 1 and ball 2 are not parallel.

50. Some children are on a merry-go-round rotating with negligible friction at a constant rate. Which of the following would slow the rotation of the merry-go round? Select two answers.
    (A) A child jumps onto the merry-go-round with a velocity that points directly toward the rotation axis of the merry-go-round
    (B) A child jumps onto the merry-go-round with a velocity opposite to the motion of the merry-go-round
    (C) A child jumps off of the merry-go round with a velocity that points directly away from the rotation axis of the merry-go-round
    (D) A child jumps onto off of the merry-go-round with a velocity opposite to their instantaneous velocity before jumping

END OF SECTION I

DO NOT CONTINUE UNTIL INSTRUCTED TO DO SO.

AP PHYSICS 1

SECTION II

Free-Response Questions

Time—90 minutes

Percent of total grade—50

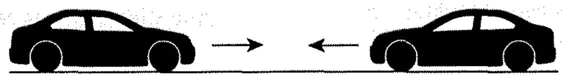
<u>General Instructions</u>

Use a separate piece of paper to answer these questions. Show your work. Be sure to write CLEARLY and LEGIBLY. If you make an error, you may save time by crossing it out rather than trying to erase it.

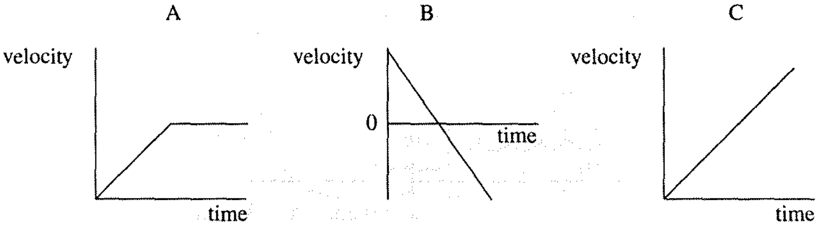
AP PHYSICS 1

SECTION II

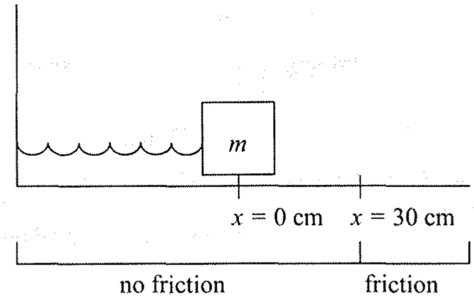
Directions: Questions 1–5 here are as follows: one experimental design question (worth 12 points), one quantitative/qualitative translation question (worth 12 points), one paragraph argument short-answer question (worth 7 points), and two additional short-answer questions (worth 7 points each). You have a total of 90 minutes to complete this section. Show your work for each part in the space provided after that part.



1. A car of known mass m_1 will collide with a second car of known mass m_2. The collision will be head on, and both cars will only move linearly both before and after the collision. In a clear, coherent, paragraph-length response, explain a method for determining whether the collision is perfectly elastic, perfectly inelastic, or neither. If the collision is perfectly inelastic, include at least one possible cause of energy loss.



2. Each of the three graphs above depicts the velocity of an object as a function of time. Each graph is of a different object, as labeled above. For each velocity graph, draw a displacement versus time graph and an acceleration versus time graph. Additionally, give an example of a situation that could produce each of the three graphs above.



3. In the diagram above, a spring-block system is oscillating on a flat horizontal surface. Part of the surface is frictionless, and part of the surface is frictional. The block starts at rest at position $x = 0$ cm. The block is then pushed to the left, compressing the spring, until it reaches the position $x = -50$ cm. After being pushed in, the block is released and allowed to move naturally.

(A) Draw a graph of the system's position as a function of time starting from the moment it is released, and explain your reasoning behind the graph you draw. Be sure to label important values on the graph.

(B) Given that the mass $m = 2$ kg and the spring constant $k = 100$ N/m, what is the magnitude of work done by the frictional surface?

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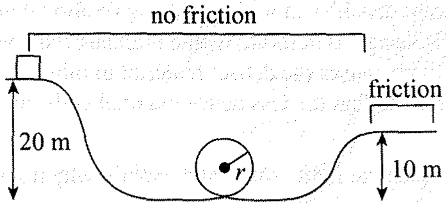


4. A roller coaster cart rides along the track shown above. The initial drop, the loop, and the ascending ramp are all frictionless. The flat portion of the track after the ascending ramp is frictional.

(A) How fast would the cart be moving just before it enters the loop?

(B) Would the normal force on the cart be greater just after entering the loop or at the peak of the loop? Explain why using relevant equations.

(C) What is the greatest possible radius for the loop that would allow the cart to still make it through?

(D) If the coefficient of static friction for the final segment of the track is 0.2, how long does the segment need to be to allow the cart to come to a complete stop due to friction alone?

5. Centrifuges separate materials of different densities in a sample using rotational motion. The samples are placed in centrifuge tubes that are placed in a rotor, which is designed to rotate with a high angular speed. As the rotor spins, the samples experience a large centripetal acceleration, which causes the denser material to migrate toward the outer part of the rotor. The denser material displaces the less dense material, so that the less dense material ends up toward the center of the rotor.

(A) Describe the motion of a dense particle in the rotor, and explain why it moves toward the outer part of the rotor.

(B) Although many centrifuges are designed to rotate at set angular speeds, it is the centripetal acceleration that determines the efficacy of the separation. If a rotor of radius r_1 rotating at an angular speed ω_1 results in a centripetal acceleration a_c for material at the outer portion of the rotor, what angular speed should be used to achieve the same acceleration with a rotor of radius r_2?

(C) The acceleration of a centrifuge is often reported as a multiple of the acceleration due to gravity. What angular speed would produce an acceleration of $1000g$ in a 20-cm radius rotor?

PRACTICE TEST 1: DIAGNOSTIC ANSWER KEY

Let's take a look at how you did on Practice Test 1. Follow the three-step process in the diagnostic answer key below and go read the explanations for any questions you got wrong, or you struggled with but got correct. Once you finish working through the answer key and the explanations, go to the next chapter to make your study plan.

STEP 1 » Check your answers and mark any correct answers with a ✔ in the appropriate column.

Section I: Multiple Choice

Q #	Ans.	✔	Chapter #, Title	Q #	Ans.	✔	Chapter #, Title
1	D		**10,** Torque	21	C		**10,** Rotational Inertia
2	B		**4,** Acceleration	22	B		**7,** Conservation of Mechanical Energy
3	B		**6,** Uniform Circular Motion	23	D		**7,** Conservation of Mechanical Energy
4	D		**5,** Friction	24	B		**7,** Power
5	C		**9,** Simple Harmonic Motion	25	D		**8,** Impulse
6	B		**6,** Uniform Circular Motion	26	B		**7,** Conservation of Energy with Nonconservative Forces
7	D		**8,** Conservation of Linear Momentum	27	B		**4,** Uniformly Accelerated Motion and the Big Five
8	D		**5,** Friction **6,** Uniform Circular Motion	28	D		**5,** Pulleys
9	C		**4,** Uniformly Accelerated Motion and the Big Five	29	C		**5,** Friction **5,** Pulleys
10	B		**10,** Rotational Motion	30	C		**7,** Work at an Angle
11	B		**10,** Rotational Motion	31	C		**6,** Newton's Law of Gravitation **9,** Simple Harmonic Motion
12	C		**5,** Newton's 1st Law	32	C		**6,** Newton's Law of Gravitation
13	B		**5,** Friction	33	B		**6,** Uniform Circular Motion **7,** Conservation of Mechanical Energy
14	D		**5,** Friction **9,** Simple Harmonic Motion	34	B		**5,** Pulleys
15	B		**7,** The Work–Energy Theorem	35	A		**4,** Projectile Motion
16	B		**8,** Impulse	36	C		**8,** Conservation of Linear Momentum
17	A		**7,** Conservation of Mechanical Energy	37	A		**8,** Collisions
18	B		**4,** Uniformly Accelerated Motion and the Big Five	38	D		**7,** Conservation of Energy with Nonconservative Forces
19	D		**4,** Projectile Motion	39	A		**10,** Rotational Inertia
20	C		**4,** Projectile Motion	40	A		**5,** Friction

ADVANCED PLACEMENT 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,	$k = 1/4\pi\varepsilon_0 = 9.0 \times 10^9 \ \text{N}\cdot\text{m}^2/\text{C}^2$
Electron mass,	$m_e = 9.11 \times 10^{-31}$ kg	Universal gravitational constant,	$G = 6.67 \times 10^{-11} \ \text{m}^3/\text{kg}\cdot\text{s}^2$
Speed of light,	$c = 3.00 \times 10^8$ m/s	Acceleration due to gravity at Earth's surface,	$g = 9.8 \ \text{m/s}^2$

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 <u>on</u> 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.

ADVANCED PLACEMENT PHYSICS 1 EQUATIONS

MECHANICS

$$v_x = v_{x0} + a_x t$$

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

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

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

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

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

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

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

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

$$\Delta E = W = F_{\parallel} d = Fd\cos\theta$$

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

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

$$\omega = \omega_0 + \alpha t$$

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

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

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

$$L = I\omega$$

$$\Delta L = \tau\,\Delta t$$

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

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

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

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

$$\Delta U_g = mg\,\Delta y$$

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

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

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

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

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

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

- 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

ELECTRICITY

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

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

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

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

$$P = I\,\Delta V$$

$$R_s = \sum_i R_i$$

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

- 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
$V = \ell wh$

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

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

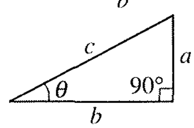
- A = area
- C = circumference
- V = volume
- S = surface area
- b = base
- h = height
- ℓ = length
- w = width
- r = radius

Right triangle
$c^2 = a^2 + b^2$

$\sin\theta = \frac{a}{c}$

$\cos\theta = \frac{b}{c}$

$\tan\theta = \frac{a}{b}$



GO ON TO THE NEXT PAGE.

Section I: Multiple Choice (Continued)						
.	✔	Chapter #, Title	Q #	Ans.	✔	Chapter #, Title
		6, Uniform Circular Motion	46	B, D		**4,** Acceleration
		5, Pulleys	47	A, D		**8,** Conservation of Linear Momentum **10,** Angular Momentum
		7, The Work–Energy Theorem	48	A, D		**4,** Free Fall **7,** Conservation of Mechanical Energy
		10, Equilibrium	49	B, D		**8,** Conservation of Linear Momentum
		7, Conservation of Mechanical Energy	50	A, B		**10,** Angular Momentum

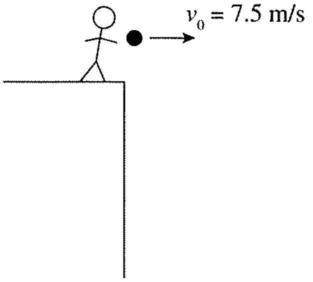
Section II: Free Response			
Q #	Ans.	✔	Chapter #, Chapter Title, Section Title
1	See Explanation		**8,** Momentum, Collisions
2	See Explanation		**4,** Kinematics, Acceleration
3(A)	See Explanation		**9,** Simple Harmonic Motion
3(B)	See Explanation		**7,** Energy, Conservation of Energy with Nonconservative Forces
4(A)	See Explanation		**7,** Energy, Conservation of Mechanical Energy
4(B)	See Explanation		**6,** Circular Motion and Gravitations, Uniform Circular Motion
4(C)	See Explanation		**7,** Energy, Conservation of Mechanical Energy
4(D)	See Explanation		**5,** Dynamics Friction **7,** Conservation of Energy with Nonconservative Forces
5(A)	See Explanation		**6,** Circular Motion and Gravitations, Uniform Circular Motion
5(B)	See Explanation		**6,** Circular Motion and Gravitations, Uniform Circular Motion **10,** Torque and Rotational Motion What is Angular Velocity?
5(C)	See Explanation		**6,** Circular Motion and Gravitations, Uniform Circular Motion **10,** Torque and Rotational Motion, What is Angular Velocity?

AP PHYSICS 1

SECTION I

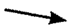
Note: To simplify calculations, you may use g = 10 m/s^2 in all problems.

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



1. An object is thrown horizontally to the right off a high cliff with an initial speed of 7.5 m/s. Which arrow best represents the direction of the object's velocity after 2 seconds? (Assume air resistance is negligible.)

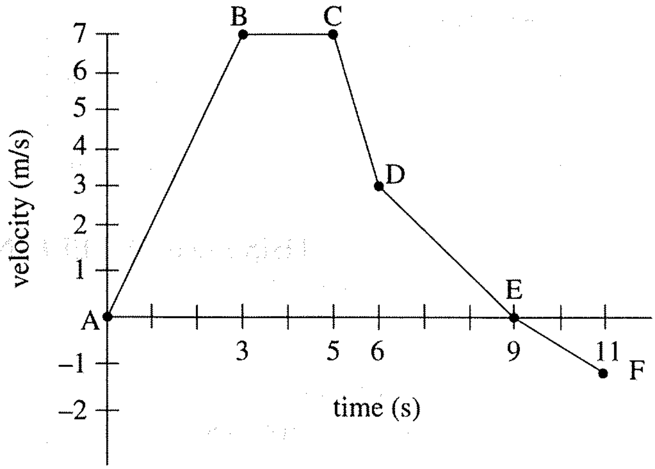
(A) 

(B) 

(C) 

(D) 

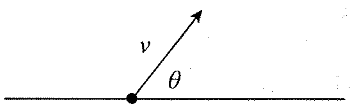
Questions 2–4 refer to the following figure:



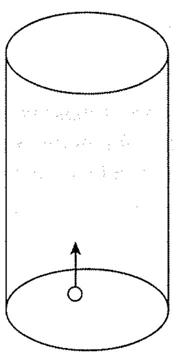
2. Rank the change in momentum for each segment from least (most negative) to greatest (most positive). Assume that the mass of the object remains constant.
   (A) BC, EF, DE, AB, CD
   (B) AB, CD, DE, EF, BC
   (C) BC, EF, DE, CD, AB
   (D) CD, DE, EF, BC, AB

3. During which segment is the magnitude of average acceleration greatest?
   (A) AB
   (B) BC
   (C) CD
   (D) DE

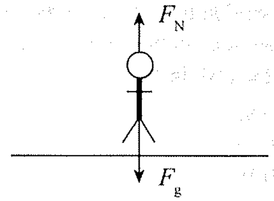
4. What is the total distance traveled by the object?
   (A) 32 m
   (B) 34 m
   (C) 35 m
   (D) 38 m



5. A ball is thrown with an initial velocity v at an angle θ above the ground. If the acceleration due to gravity is $-g$, which of the following is the correct expression of the time it takes for the ball to reach its highest point, y, from the ground?
   (A) $v^2 \sin \theta/g$
   (B) $-v \cos \theta/g$
   (C) $v \sin \theta/g$
   (D) $v^2 \cos \theta/g$

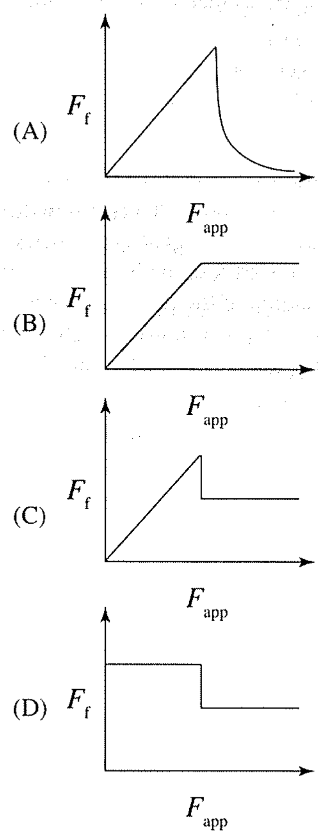


6. A bubble in a glass of water releases from rest at the bottom of the glass and rises at acceleration a to the surface in t seconds. How much farther does the bubble travel in its last second than in its first second? Assume that the journey takes longer than 2 seconds.
   (A) $a(t + 1\text{ s})^2$
   (B) $a(t - 1\text{ s})(1\text{ s})$
   (C) at^2
   (D) $a(t + 1\text{ s})(1\text{ s})$



7. A person standing on a horizontal floor is acted upon by two forces: the downward pull of gravity and the upward normal force of the floor. These two forces
   (A) have equal magnitudes and form an action/reaction pair
   (B) have equal magnitudes and do not form an action/reaction pair
   (C) have unequal magnitudes and form an action/reaction pair
   (D) have unequal magnitudes and do not form an action/reaction pair

8. Which of the following graphs best represents the force of friction on an object that starts at rest and eventually starts sliding across a level surface because of a linearly increasing horizontal force?



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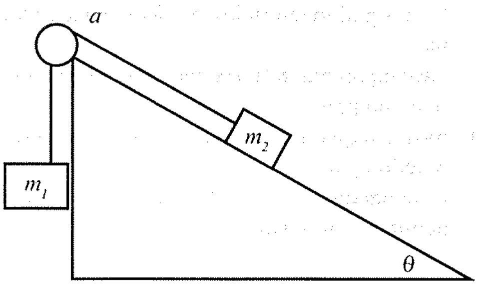
9. A crane lifts a 600 kg beam from the ground to a height of 20 m. How much power must the crane provide to accomplish this task in 4 s?

(A) 1,470 W
(B) 3,000 W
(C) 29,400 W
(D) 117,600 W

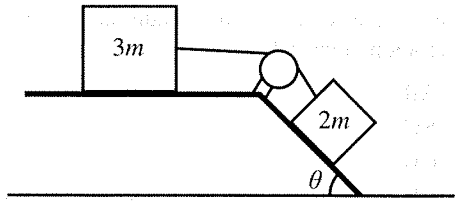


10. Consider the above configuration of two blocks of masses attached via a massless rope and pulley over a frictionless inclined plane. What is the acceleration of the blocks?

(A) $(m_2 - m_1)\, g/(m_1 + m_2)$
(B) $(m_2 \sin\theta - m_1)\, g/(m_1 + m_2)$
(C) $(m_2 \cos\theta - m_1)\, g/(m_1 + m_2)$
(D) g

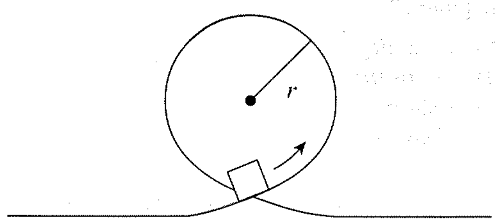
11. A child sits on a merry-go-round with a radius of 1.5 m. Her father exerts a force 120 N tangent to the merry-go-round at its outer edge to start rotating it from rest. If the combined moment of inertia of the merry-go-round and child is 250 kg·m^2, how long does it take for the merry-go-round to reach an angular velocity of 5 rad/s?

(A) 0.14 s
(B) 6.94 s
(C) 10.4 s
(D) 36.0 s



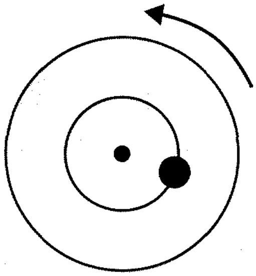
12. In the figure above, two blocks of mass $3m$ and $2m$ are attached together. The plane is frictionless and the pulley is frictionless and massless. The inclined portion of the plane creates an angle θ with the horizontal floor. What is the acceleration of the block $2m$ if both blocks are released from rest (gravity = g)?

(A) $2mg$
(B) $\left(\frac{2}{5}\right) g \sin\theta$
(C) $\left(\frac{2}{3}\right) g \sin\theta$
(D) $\left(\frac{3}{5}\right) g \sin\theta$



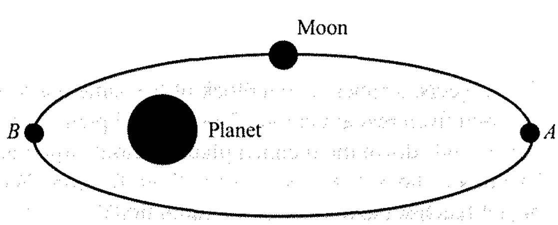
13. If a roller coaster cart of mass m was not attached to the track, it would still remain in contact with a track throughout a loop of radius r as long as

(A) $v \le \sqrt{rg}$
(B) $v \ge \sqrt{rg}$
(C) $v \le \sqrt{(rg/m)}$
(D) $v \ge \sqrt{(rg/m)}$



14. The diagram above shows a top view of an object of mass M on a circular platform of mass $2M$ that is rotating counterclockwise. Assume the platform rotates without friction. Which of the following best describes an action the object can take that will increase the angular speed of the entire system?

(A) The object moves toward the center of the platform, increasing the total angular momentum of the system.
(B) The object moves toward the center of the platform, decreasing the rotational inertia of the system.
(C) The object moves away from the center of the platform, increasing the total angular momentum of the system.
(D) The object moves away from the center of the platform, decreasing the rotational inertia of the system.



15. A moon has an elliptical orbit about the planet as shown above. The moon's mass is much smaller than the planet's. Which of the following quantities is/are (approximately) conserved as the moon moves from point A to point B?

I. The moon's mechanical energy

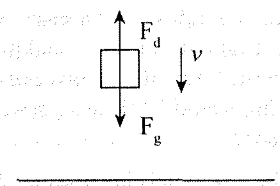
II. The moon's angular momentum

III. The moon's linear momentum

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

16. A sphere starts from rest atop a hill with a constant angle of inclination and is allowed to roll down the hill, without slipping. What force provides the torque that causes the sphere to rotate?

(A) Static friction
(B) Kinetic friction
(C) The normal force of the hill on the sphere
(D) Gravity



17. Which of the following correctly describes the motion of a real object in free fall? Assume that the object experiences drag force proportional to speed and that it strikes the ground before reaching terminal speed.

(A) It will fall with increasing speed and increasing acceleration.
(B) It will fall with increasing speed and decreasing acceleration.
(C) It will fall with decreasing speed and increasing acceleration.
(D) It will fall with decreasing speed and decreasing acceleration.

18. Which of the following concerning uniform circular motion is true?

(A) The centrifugal force is the action/reaction pair of the centripetal force.
(B) The centripetal acceleration and velocity point in the same direction.
(C) The velocity of the object in motion changes, whereas the acceleration of the object is constant.
(D) A satellite undergoing uniform circular motion is falling toward the center even though its path is circular.

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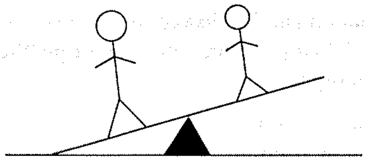


19. A girl of mass m and a boy of mass $2m$ are sitting on opposite sides of a lightweight seesaw with its fulcrum in the center. Right now, the boy and girl are equally far from the fulcrum, and it tilts in favor of the boy. Which of the following would NOT be a possible method to balance the seesaw?

(A) Move the boy to half his original distance from the fulcrum.
(B) Move the girl to double her original distance from the fulcrum.
(C) Allow a second girl of mass m to join the first.
(D) Move the fulcrum to half its original distance from the boy.

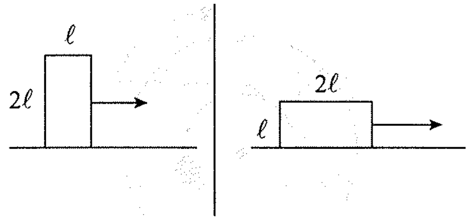
20. A satellite of mass m is in orbit at an altitude of one-third of Earth's radius, R_e. How much work must its thrusters do to put it in an orbit of one-half R_e? (G is the gravitational constant, and M is Earth's mass.)

(A) $\dfrac{GMm}{24R_e}$

(B) $\dfrac{GMm}{12R_e}$

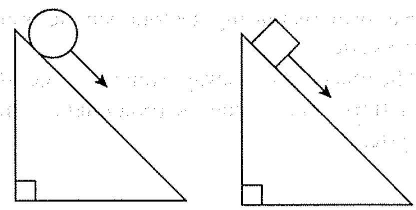
(C) $\dfrac{GMm}{8R_e}$

(D) $\dfrac{GMm}{2R_e}$



21. A wooden block experiences a frictional force, $\mathbf{F}_f$, as it slides across a table. If a block of the same material with half the height and twice the length was to slide across the table in the same direction, what would be the frictional force it experienced?

(A) $(1/2)\mathbf{F}_f$
(B) $\mathbf{F}_f$
(C) $2\mathbf{F}_f$
(D) $4\mathbf{F}_f$



22. Two objects, a sphere and a block of the same mass, are released from rest at the top of an inclined plane. The sphere rolls down the inclined plane without slipping. The block slides down the plane without friction. Which object reaches the bottom of the ramp first?

(A) The sphere, because it gains rotational kinetic energy, but the block does not
(B) The sphere, because it gains mechanical energy due to the torque exerted on it, but the block does not
(C) The block, because it does not lose mechanical energy due to friction, but the sphere does
(D) The block, because it does not gain rotational kinetic energy, but the sphere does

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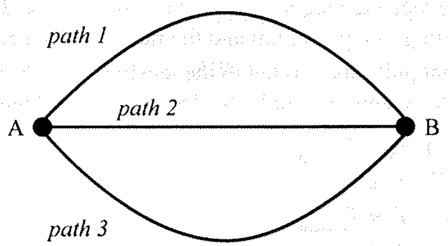
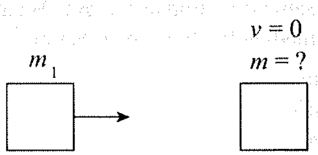


23. In the diagram above, each of the three frictionless tracks shown here contains an object of mass m. Each object starts at point A with the same initial horizontal velocity v_0, which in each case is sufficient to allow the object to reach the end of the track at point B. The masses remain in contact with the tracks throughout their motions, and the displacement A to B is the same in each case. Path 1 is directed up, path 2 horizontally, and path 3 down. The total length of paths1 and 3 are equal. If t_1, t_2, and t_3 are the total travel times between A and B for paths 1, 2, and 3, respectively, what is the relation among these times?

(A) $t_3 < t_2 < t_1$
(B) $t_2 < t_3 < t_1$
(C) $t_2 < t_1 = t_3$
(D) $t_2 = t_3 < t_1$

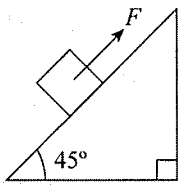


24. An object of mass m_1 experiences a linear, elastic collision with a stationary object of unknown mass. In addition to m_1, what is the minimum necessary information that would allow you to determine the mass of the second object?

(A) The final velocity of object 1
(B) The initial speed of object 1
(C) The final velocity of object 2
(D) Any 2 of the above values

25. A 60-kg snowboarder is riding down a hill at 15 m/s when he realizes that he's about to hit a 5-m dip in the terrain with a hill behind it. Friction from the snow does −6000 J of work on him before he slows to a stop. How high up the next hill, relative to the bottom of the dip, does he get before he stops?

(A) 1.3 m
(B) 6.3 m
(C) 16.5 m
(D) 26.7 m



26. A box of mass m is sitting on an incline of 45° and it requires an applied force F up the incline to get the box to begin to move. What is the maximum coefficient of static friction?

(A) $\left(\frac{\sqrt{2}F}{mg}\right) - 1$
(B) $\left(\frac{\sqrt{2}F}{mg}\right)$
(C) $\left(\frac{\sqrt{2}F}{mg}\right) + 1$
(D) $\left(\frac{2F}{mg}\right) - 1$

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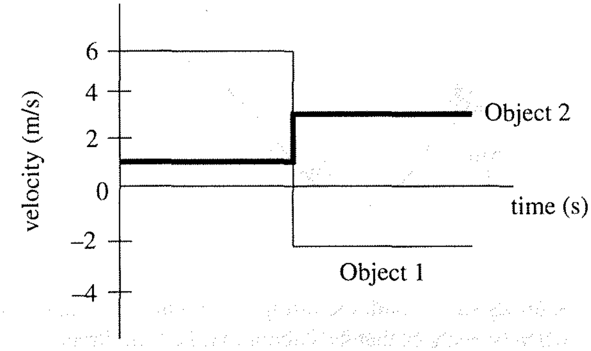
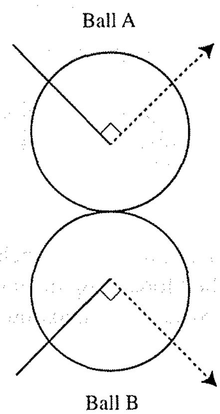


27. The graph above shows the velocities of two objects undergoing a head-on collision. Given that Object 2 has 4 times the mass of Object 1, which type of collision is it?

(A) Perfectly elastic
(B) Perfectly inelastic
(C) Inelastic
(D) Cannot be determined



28. The picture above depicts the collision of two balls of equal mass. Which arrow best indicates the direction of the impulse on Ball A from Ball B during the collision?

(A) 

(B) 

(C) 

(D) 

29. Which of the following best describes the relationship between the magnitude of the tension force, F_T, in the string of a pendulum and the radial component of gravity that pulls antiparallel to the tension, $F_{g,\text{ radial}}$? Assume that the pendulum is only displaced by a small amount.

(A) $F_T > F_{g,\text{ radial}}$
(B) $F_T \geq F_{g,\text{ radial}}$
(C) $F_T = F_{g,\text{ radial}}$
(D) $F_T \leq F_{g,\text{ radial}}$

30. A ball bounces straight up off the ground with an initial speed v_0. When the ball is at two-thirds of the maximum height in its trajectory, what is its speed?

(A) $\frac{1}{9}v_0$

(B) $\frac{1}{3}v_0$

(C) $\frac{\sqrt{3}}{3}v_0$

(D) $\frac{\sqrt{6}}{3}v_0$

31. A 5.0-kg bowling ball traveling at 7.0 m/s strikes a 1.6-kg bowling pin. After the collision, the bowling ball continues in the same direction at 5.2 m/s. What is the speed of the pin immediately after the collision?

(A) 1.8 m/s
(B) 5.3 m/s
(C) 5.6 m/s
(D) 8.3 m/s

32. A young girl at a waterpark rides down a waterslide with a height of h and slides from rest to speed v at the bottom of the slide. Then, she rides down a slide with a height of $2h$. If there is negligible friction on the slides, how fast is she going at the bottom of the second slide?

(A) $\frac{\sqrt{2}}{2}v$

(B) $\sqrt{2}\,v$

(C) $2v$

(D) $4v$

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33. A projectile at the peak of its flight has $\frac{1}{4}$ of its initial kinetic energy at launch. What was its launch angle?

Assume negligible air resistance.

(A) 30°
(B) 60°
(C) 76°
(D) 86°

34. The Gravitron is a carnival ride that looks like a large cylinder. People stand inside the cylinder against the wall as it begins to spin. Eventually, it is rotating fast enough that the floor can be removed without anyone falling. Given that the coefficient of friction between a person's clothing and the wall is μ, the tangential speed is v, and the radius of the ride is r, what is greatest mass that a person can be to safely go on this ride?

(A) $\mu v^2/(rg)$
(B) $r^2v^2/(\mu g)$
(C) $rg/(\mu v^2)$
(D) None of the above

35. The spring in the launcher of a pinball machine has a spring constant of 150 N/m. If the spring is compressed 3 cm, how fast can it launch a pinball with a mass of 0.08 kg?

(A) 1.30 m
(B) 1.69 m
(C) 1.84 m
(D) 13.0 m

36. A student is experimenting with a simple spring-block oscillator that has spring constant k and amplitude A. The block attached to the spring has a mass of M. If the student places a small block of mass m on top of the original block, which of the following is true?

(A) The small block is most likely to slide off when the original block is at maximum displacement from the equilibrium position but will not slide off as long as the coefficient of static friction between the blocks is greater than $kA/[(M + m)g]$.
(B) The small block is most likely to slide off when the original block is at the equilibrium position but will not slide off as long as the coefficient of static friction between the blocks is greater than $kA/[(M + m)g]$.
(C) The small block is most likely to slide off when the original block is at maximum displacement from the equilibrium position but will not slide off as long as the coefficient of static friction between the blocks is greater than $(M + m)g/(kA)$.
(D) The small block is most likely to slide off when the original block is at the equilibrium position but will not slide off as long as the coefficient of static friction between the blocks is greater than $(M + m)g/(kA)$.

37. A horse accelerates at a constant rate from rest to 15 m/s in 2.4 s. How far does the horse travel in that time?

(A) 6.3 m
(B) 18 m
(C) 36 m
(D) 43 m

38. A 62,000-kg maglev train traveling at 110 m/s brakes over a distance of 2,800 m on a horizontal track. What magnitude of force do its brakes exert?

(A) 122,000 N
(B) 134,000 N
(C) 244,000 N
(D) 268,000 N

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Questions 39–41 refer to the following scenario:

In a theater, a winch is used to lower a 75-kg performer in a harness down onto the stage below. The cable is wound around the drum of the winch that has a diameter of 15 cm.

39. What is the torque applied by the winch to lower the performer at a constant speed?
(A) 0 N·m
(B) 5.6 N·m
(C) 55 N·m
(D) 110 N·m

40. To lower the performer 12 m, how many revolutions does the drum rotate through?
(A) 12.7 revolutions
(B) 25.5 revolutions
(C) 80 revolutions
(D) 160 revolutions

41. During the last portion of the performer's descent, the drum undergoes 2.5 revolutions as the performer slows to a stop from a speed of 0.8 m/s. What is the magnitude of the angular acceleration of the drum during this period?
(A) 3.6 rad/s^2
(B) 5.7 rad/s^2
(C) 14 rad/s^2
(D) 23 rad/s^2

42. How much power does the engine of a 1300-kg car need to provide to accelerate the car from 0 to 25 m/s in 7 s at constant rate?
(A) 46,000 W
(B) 58,000 W
(C) 116,000 W
(D) 406,000 W

43. A box of mass m is pulled a distance d across a horizontal surface with a force of mg at an angle of 30° above the horizontal. If the coefficient of kinetic friction between the box and the surface is $\mu_k = \frac{1}{3}$, what is the total work done on the box?
(A) $\frac{mgd}{6}\left(\sqrt{3}+1\right)$
(B) $\frac{mgd}{6}\left(3\sqrt{3}-2\right)$
(C) $\frac{mgd}{6}\left(3\sqrt{3}-1\right)$
(D) $\frac{mgd}{6}\left(3\sqrt{3}+5\right)$

44. A tennis player hits a 60-g tennis ball that is approaching her at 32 m/s. Her racket is in contact with the ball for 5 ms, after which the ball leaves her racket traveling opposite to its initial direction at 36 m/s. If the ball's initial velocity was in the positive direction, what is the average force exerted on the ball by her racket?
(A) –816 N
(B) –48 N
(C) 48 N
(D) 816 N

45. An 85-g apple drops 9 m to the ground below. It hits the ground with a speed of 13 m/s. How much work is done by air resistance on the apple during its descent?
(A) –0.315 J
(B) –0.282 J
(C) 0.282 J
(D) 0.315 J

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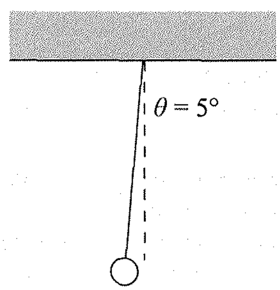
Directions: For each of the questions 46–50, two of the suggested answers will be correct. Select the two answers that are best in each case, and then fill in both of the corresponding circles on the answer sheet.

46. An object traveling at x m/s can stop at a distance d m with a maximum negative acceleration. If the car is traveling at $2x$ m/s, which of the following statements are true? Select two answers.
    (A) The stopping time is doubled.
    (B) The stopping time is quadrupled.
    (C) The stopping distance is doubled.
    (D) The stopping distance is quadrupled.



47. A ball with a 2 kg mass is attached to a massless 0.5 m string and becomes a simple pendulum when the string is pulled to an angle of $\theta = 5°$, allowing it to oscillate. Which of the following will change the period of the pendulum? Select two answers.
    (A) Replacing the mass with a 1 kg mass
    (B) Changing the initial extension of the pendulum to a 10° angle
    (C) Replacing the string with a 0.25 m string
    (D) Moving the pendulum to the surface of the Moon

48. In a billiards game, the 1 and 2 balls are at rest and in contact with one another. The cue ball then strikes the 1 ball in line with the 1 and 2 balls, resulting in the cue ball coming to rest, the 1 ball remaining motionless, and the 2 ball being shot off the end. Which of the following statements is true? Select two answers.
    (A) The cue ball exerts a force on the 2 ball.
    (B) The reaction force to the cue ball striking the 1 ball causes the motion of the 2 ball.
    (C) The force that acts on the 2 ball is equal in magnitude to the force the cue ball exerts on the 1 ball.
    (D) The reaction force to the cue ball striking the 1 ball stops the cue ball.

49. A warehouse worker uses a forklift to move a crate from the ground to an elevated shelf. Which of the following must be true of this process? Select two answers.
    (A) The mechanical energy of the crate is conserved.
    (B) Gravity does positive work on the crate.
    (C) The forklift transfers mechanical energy to the crate.
    (D) The total work done on the crate is zero.

50. A paintball hits a wall and sticks to it. Which of the following would decrease the impulse delivered to the wall by the paintball? Select two answers.
    (A) Adding padding to the wall
    (B) Reducing the speed of the paintball
    (C) Changing the material of the paintball so that it takes longer to deform and break open
    (D) Using paintballs that are the same size but less dense

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AP PHYSICS 1

SECTION II

Free-Response Questions

Time—90 minutes

Percent of total grade—50

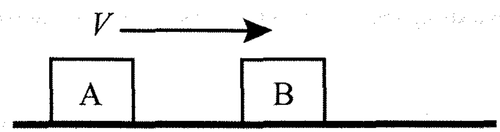
General Instructions

Use a separate piece of paper to answer these questions. Show your work. Be sure to write CLEARLY and LEGIBLY. If you make an error, you may save time by crossing it out rather than trying to erase it.

AP PHYSICS 1

SECTION II

Directions: Questions 1–5 here are as follows: one experimental design question (worth 12 points), one quantitative/qualitative translation question (worth 12 points), one paragraph argument short-answer question (worth 7 points), and two additional short-answer questions (worth 7 points each). You have a total of 90 minutes to complete this section. Show your work for each part in the space provided after that part.

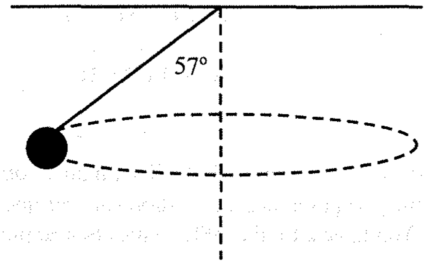


1. An experiment is conducted in which Block A with a mass of m_A is slid to the right across a frictionless table. Block A collides with Block B, which is initially at rest, of an unknown mass and sticks to it.

(A) Describe an experimental procedure that determines the velocities of the blocks before and after a collision. Include all the additional equipment you need. You may include a labeled diagram of your setup to help in your description. Indicate what measurements you would take and how you would take them. Include enough detail so that the experiment could be repeated with the procedure you provide.

(B) If Block A has a mass of 0.5 kg and starts off with a speed of 1.5 m/s and the experiment is repeated, the velocity of the blocks after they collide are recorded to be 0.25 m/s. What is the mass of Block B?

(C) How much kinetic energy was lost in this collision from part (B)?



2. A conical pendulum is hanging from a string that is 2.2 meters long. It makes a horizontal circle. The mass of the ball at the end of the string is 0.5 kg.

(A) Below, make a free-body diagram for the ball at the point shown in the above illustration. Label each force with an appropriate letter.

(B) Write out Newton's Second Law in both the x- and y-direction in terms used in your free-body diagram.

(C) Calculate the centripetal acceleration from your free-body diagram.

(D) What is the radius of the circle that the ball is traveling in?

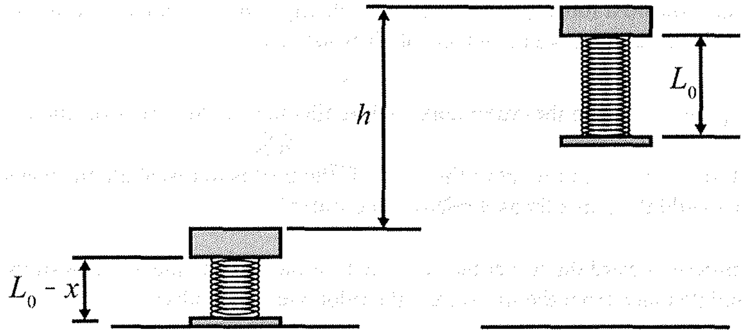
(E) What is the speed of the ball?

3. A fire-fighting airplane flies toward a forest fire at a constant velocity and elevation and drops water out of its tanks to douse the fire that is burning on flat terrain. Ignore the effects of air resistance.

(A) Explain why the pilot must open the water tanks before the plane is directly over the fire.

(B) It takes 8 s for all the water to drain out of the tanks. If the goal is to distribute the water over a distance of 600 m. How fast should the plane fly as it releases the water?

(C) The plane flies directly toward the fire at the speed determined in (B) and at an elevation of 150 m above the ground. At what horizontal distance from the fire should the pilot open his tanks?



4. An experiment is designed to calculate the spring constant k of a vertical spring for a jumping toy. The toy is compressed a distance of x from its natural length of L_0, as shown on the left in the diagram, and then released. When the toy is released, the top of the toy reaches a height of h in comparison to its previous height and the spring reaches its maximum extension. The experiment is repeated multiple times and replaced with different masses m attached to the spring. The spring itself has negligible mass.

(A) Derive an expression for the height h in terms of m, x, k, and any other constants provided in the formula sheet.

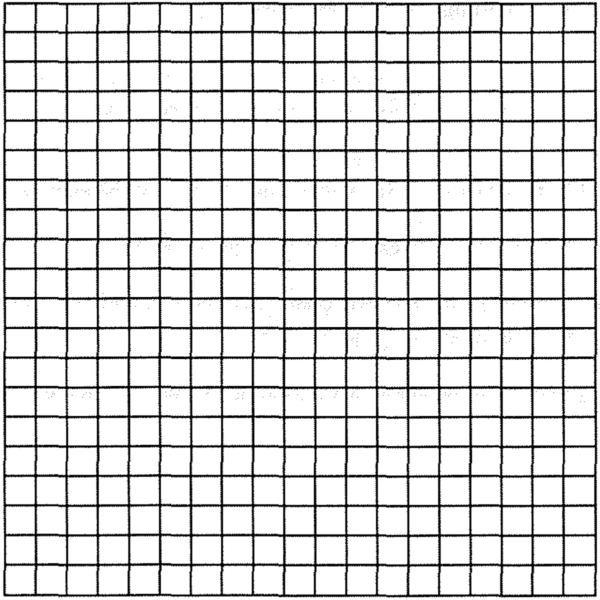
(B) To standardize the experiment, the compressed distance x is set to 0.020 m. The following table shows the data for different values of m.

	m **(kg)**	h **(m)**
	0.020	0.49
	0.030	0.34
	0.040	0.28
	0.050	0.19
	0.060	0.18

i. What quantities should be graphed so that the slope of a best-fit straight line through the data points can help us calculate the spring constant k?

ii. Fill in the blank column in the table above with calculated values. Also include a header with units.

(C) On the axes below, plot the data and draw the best-fit straight line. Label the axes and indicate scale.



(D) Using your best-fit line, calculate the numerical value of the spring constant.

(E) Describe an experimental procedure that determines the height h in the experiment, given that the toy is only momentarily at that maximum height. You may include a labeled diagram of your setup to help in your description.

5. Hydroelectric plants use flowing water to generate electricity. Water that is approximately motionless in a storage reservoir flows down through a height H to have speed of v_{in} as it encounters a turbine. The flowing water turns the turbine, which gen erates electricity. Water flowing away from the turbine has a speed v_{out}.

(A) If a volume V of water flows through a power plant in time t, determine the maximum power the plant could produc in terms of H, the density of water ρ, and any required physical constants.

(B) If $v_{out} = \frac{1}{2} v_{in}$, what is the efficiency e of this power plant, that is, of the energy available, what fraction is convertec to electrical energy? Assume that the energy lost by the water is converted completely to electrical energy.

(C) If 3 m^3 of water flows through this hydroelectric plant each second, and H = 180 m, how much electrical power is produced? (ρ = 1000 kg/m^3)

(D) If a home typically has a maximum power consumption of 55 kW, how many homes could his hydroelectric plant power?

PRACTICE TEST 2: DIAGNOSTIC ANSWER KEY

Let's take a look at how you did on Practice Test 2. Follow the three-step process in the diagnostic answer key below and go read the explanations for any questions you got wrong, or you struggled with but got correct. Be sure to compare your scores on Practice Test 1 with your scores on Practice Test 2.

STEP 1 » Check your answers and mark any correct answers with a ✔ in the appropriate column.

Section I: Multiple Choice							
Q #	**Ans.**	**✔**	**Chapter #, Title**	**Q #**	**Ans.**	**✔**	**Chapter #, Title**
1	C		**4,** Projectile Motion	21	B		**5,** Friction
2	D		**4,** Momentum	22	D		**7,** Conservation of Mechanical Energy **10,** Rotational Kinetic Energy
3	C		**4,** Acceleration	23	A		**7,** Conservation of Mechanical Energy
4	C		**4,** Acceleration	24	D		**8,** Collisions
5	C		**4,** Projectile Motion	25	B		**7,** Conservation of Energy with Nonconservative Forces
6	B		**4,** Uniformly Accelerated Motion and the Big Five	26	A		**5,** Friction **5,** Inclined Planes
7	B		**5,** Newton's 1st Law **5,** Newton's 3rd Law	27	A		**8,** Collisions
8	C		**5,** Friction	28	D		**8,** Impulse
9	C		**7,** Power	29	B		**9,** Pendulums
10	B		**5,** Pulleys **5,** Inclined Planes	30	C		**7,** Conservation of Mechanical Energy
11	B		**10,** Rotational Motion	31	C		**8,** Collisions
12	B		**5,** Pulleys **5,** Inclined Planes	32	B		**7,** Conservation of Mechanical Energy
13	B		**6,** Uniform Circular Motion	33	B		**4,** Projectile Motion **7,** Kinetic Energy
14	B		**10,** Angular Momentum	34	D		**5,** Friction **6,** Uniform Circular Motion
15	A		**7,** Conservation of Mechanical Energy **8,** Momentum **10,** Angular Momentum	35	A		**7,** Conservation of Mechanical Energy **9,** Simple Harmonic Motion
16	A		**10,** Torque	36	A		**5,** Friction **9,** Simple Harmonic Motion
17	B		**5,** Newton's 2nd Law	37	B		**4,** Uniformly Accelerated Motion and the Big Five
18	D		**6,** Uniform Circular Motion	38	B		**7,** The Work-Energy Theorem
19	D		**10,** Equilibrium	39	C		**10,** Torque
20	A		**7,** Conservation of Mechanical Energy	40	B		**10,** Rotational Motion

Section I: Multiple Choice (Continued)

Q #	Ans.	✔	Chapter #, Title	Q #	Ans.	✔	Chapter #, Title
41	A		**10,** Rotational Motion	46	A, D		**4,** Uniformly Accelerated Motion and the Big Five
42	B		**7,** The Work-Energy Theorem **7,** Power	47	C, D		**9,** Pendulums
43	C		**7,** Work	48	C, D		**5,** Newton's 3rd Law
44	A		**8,** Impulse	49	C, D		**7,** Energy
45	A		**7,** Conservation of Energy with Nonconservative Forces	50	B, D		**8,** Impulse

Section II: Free Response

Q #	Ans.	✔	Chapter #, Chapter Title, Section Title
1(A)	See Explanation		**8,** Collisions
1(B)	See Explanation		**8,** Collisions
1(C)	See Explanation		**7,** Kinetic Energy
2(A)	See Explanation		**5,** Dynamics: An Overall Strategy
2(B)	See Explanation		**5,** Newton's 2nd Law
2(C)	See Explanation		**5,** Newton's 2nd Law **6,** Uniform Circular Motion
2(D)	See Explanation		**6,** Uniform Circular Motion
2(E)	See Explanation		**6,** Uniform Circular Motion
3(A)	See Explanation		**4,** Projectile Motion
3(B)	See Explanation		**4,** Projectile Motion
3(C)	See Explanation		**4,** Projectile Motion
4(A)	See Explanation		**7,** Conservation of Mechanical Energy **9,** Simple Harmonic Motion
4(B)	See Explanation		**9,** Simple Harmonic Motion
4(C)	See Explanation		**9,** Simple Harmonic Motion
4(D)	See Explanation		**9,** Simple Harmonic Motion
4(E)	See Explanation		**4,** Uniformly Accelerated Motion and the Big Five
5(A)	See Explanation		**7,** Potential Energy **7,** Power
5(B)	See Explanation		**7,** Conservation of Energy with Nonconservative Forces
5(C)	See Explanation		**7,** Power
5(D)	See Explanation		**7,** Power

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

At a Glance

Total Time
90 minutes
Number of Questions
50
Percent of Total Grade
50%
Writing Instrument
Pen required

Instructions

Section I of this examination contains 50 multiple-choice questions. Fill in only the ovals for numbers 1 through 50 on your answer sheet.

CALCULATORS MAY BE USED ON BOTH SECTIONS OF THE AP PHYSICS 1 EXAM.

Indicate all of your answers to the multiple-choice questions on the answer sheet. No credit will be given for anything written in this exam booklet, but you may use the booklet for notes or scratch work. Please note that there are two types of multiple-choice questions: single-select and multi-select questions. After you have decided which of the suggested answers is best, completely fill in the corresponding oval(s) on the answer sheet. For single-select, you must give only one answer; for multi-select you must give BOTH answers in order to earn credit. If you change an answer, be sure that the previous mark is erased completely. Here is a sample question and answer.

Sample Question	Sample Answer
Chicago is a (A) state (B) city (C) country (D) continent	Ⓐ ● Ⓒ Ⓓ

Use your time effectively, working as quickly as you can without losing accuracy. Do not spend too much time on any one question. Go on to other questions and come back to the ones you have not answered if you have time. It is not expected that everyone will know the answers to all the multiple-choice questions.

About Guessing

Many candidates wonder whether or not to guess the answers to questions about which they are not certain. Multiple-choice scores are based on the number of questions answered correctly. Points are not deducted for incorrect answers, and no points are awarded for unanswered questions. Because points are not deducted for incorrect answers, you are encouraged to answer all multiple-choice questions. On any questions you do not know the answer to, you should eliminate as many choices as you can, and then select the best answer among the remaining choices.

ADVANCED PLACEMENT 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,	$k = 1/4\pi\varepsilon_0 = 9.0 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$
Electron mass,	$m_e = 9.11 \times 10^{-31}$ kg	Universal gravitational constant,	$G = 6.67 \times 10^{-11}\ \text{m}^3/\text{kg}\cdot\text{s}^2$
Speed of light,	$c = 3.00 \times 10^8$ m/s	Acceleration due to gravity at Earth's surface,	$g = 9.8\ \text{m/s}^2$

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 <u>on</u> 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.

GO ON TO THE NEXT PAGE.

ADVANCED PLACEMENT PHYSICS 1 EQUATIONS

MECHANICS

$v_x = v_{x0} + a_x t$

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

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

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

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

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

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

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

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

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

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

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

$\omega = \omega_0 + \alpha t$

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

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

$\tau = r_{\perp} F = r F \sin\theta$

$L = I\omega$

$\Delta L = \tau \Delta t$

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

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

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

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

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

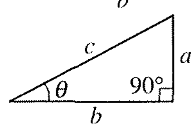
A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius

Right triangle
$c^2 = a^2 + b^2$

$\sin\theta = \frac{a}{c}$

$\cos\theta = \frac{b}{c}$

$\tan\theta = \frac{a}{b}$



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SECTION I

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

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

1. A section of a river flows with a velocity of 1 m/s due south. A kayaker who is able to propel her kayak at 1.5 m/s wishes to paddle directly east from one bank to the other. In what direction should she direct her kayak?

(A) 37° N of E
(B) 42° N of E
(C) 45° N of E
(D) 48° N of E

2. An object's initial velocity has components $v_{1x} = -1$ m/s and $v_{1y} = 4$ m/s. Its velocity 3 s later has components $v_{2x} = 4$ m/s and $v_{2y} = -2$ m/s. What is its average acceleration relative to the $+x$-axis during this time interval?

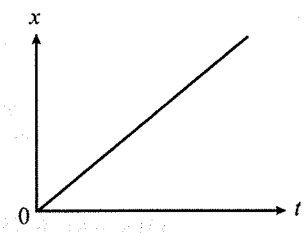
(A) 1.1 m/s^2 at −50.2°
(B) 1.1 m/s^2 at −39.8°
(C) 2.6 m/s^2 at −50.2°
(D) 2.6 m/s^2 at −39.8°

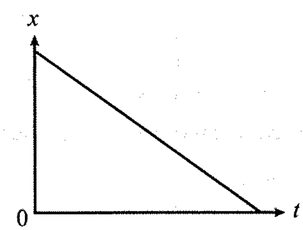
3. A student lives 1.2 km from school as the crow flies. On a particular day, it takes her 10 min to get from home to school. Which of the following must be true about this trip to school?

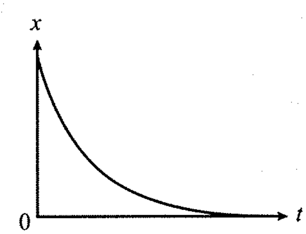
I. She traveled a distance of 1.2 km.
II. Her average speed was 2 m/s.
III. The magnitude of her average velocity was 2 m/s.

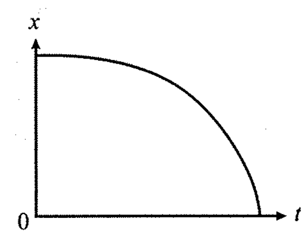
(A) I only
(B) II and III only
(C) III only
(D) I, II, and III

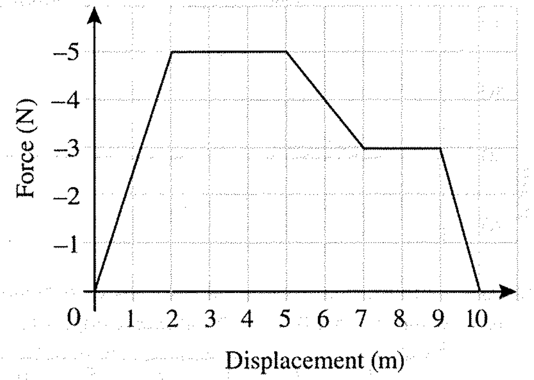
4. In which of the following position-versus-time graphs does the object in motion have a constant negative acceleration?

(A)


(B)


(C)


(D)


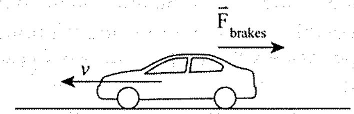


5. The graph above shows the magnitude of a variable force acting on an object moving in a straight line. The force acts in the same direction as the motion. How much work does the force do from $t = 0$ s to $t = 10$ s?
   (A) –3 J
   (B) 0 J
   (C) 29.5 J
   (D) 35.5 J

6. An airtanker is being used to fight a forest fire. It is flying with a ground speed of 85 m/s and maintaining an altitude of 300 m. If it is flying directly toward the fire, at what approximate horizontal distance from the fire should its tanks be open in order for the water dropped to land on the fire? Assume that the fire is relatively localized.
   (A) 230 m
   (B) 250 m
   (C) 660 m
   (D) 1,700 m

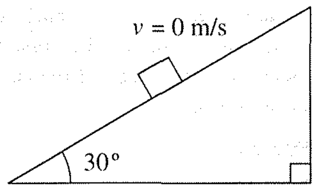
7. Two cannons are fired from a cliff at a height of 50 m from the ground. Cannonball A is fired horizontally with an initial velocity of 40 m/s. Cannonball B is fired at a launch angle of 60° with an initial velocity of 80 m/s. Which cannonball will have a greater magnitude of displacement after two seconds?
   (A) Cannonball A
   (B) Cannonball B
   (C) Both cannonballs will have the same displacement.
   (D) Cannot be determined

8. A car initially at rest accelerates linearly at a constant rate for eight seconds. If the total displacement of the car was 600 m, what was the speed of the car after the eight seconds of acceleration?
   (A) 50 m/s
   (B) 100 m/s
   (C) 150 m/s
   (D) 200 m/s



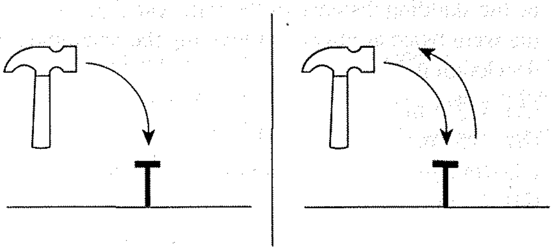
9. A car traveling at a speed of v_0 applies its brakes, skidding to a stop over a distance of x m. Assuming that the deceleration due to the brakes is constant, what would be the skidding distance of the same car if the braking were twice as effective (doubling the magnitude of deceleration)?
   (A) $0.25x$ m
   (B) $0.5x$ m
   (C) x m
   (D) $2x$ m

10. A student is pushing a 3-kg book across a table with a constant force of 30.0 N directed 10° below the horizontal. The coefficient of kinetic friction between the book and the table is 0.3. What is the magnitude of the force that the table exerts on the book during this motion?
   (A) 30.7 N
   (B) 37.0 N
   (C) 38.2 N
   (D) 45.0 N



11. A box with a mass of 2 kg is placed on an inclined plane that makes a 30° angle with the horizontal. What is the minimum possible coefficient of static friction (μ_s) between the box and the inclined plane if the box remains at rest?

    (A) 0.5
    (B) 0.58
    (C) 0.87
    (D) 1

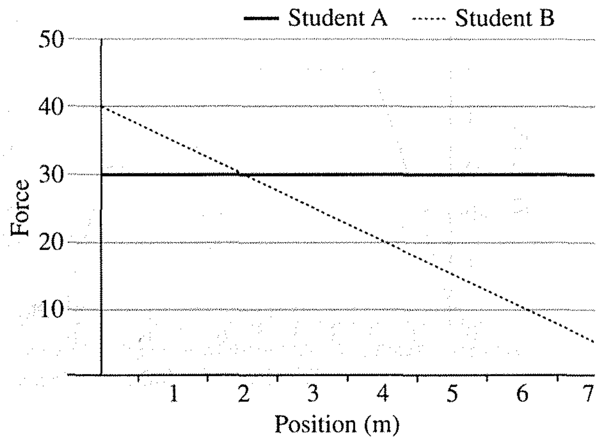


12. A construction worker strikes a nail with a hammer twice with the same initial velocity (v_0). The first time, the hammer comes to rest after hitting the nail. The second time, the hammer recoils after hitting the nail and bounces back toward the worker. Assuming the contact time in both strikes is the same, which strike imparts a greater impulse on the nail?

    (A) The first strike
    (B) The second strike
    (C) The nail experiences the same impulse in both strikes.
    (D) Cannot be determined

13. A box with a mass of 5 kg is sliding across a table at a speed of 2 m/s. The coefficient of kinetic friction between the box and table is $\mu = 0.25$. What is the minimum force that has to be applied on the box to maintain this speed?

    (A) 0 N
    (B) 10 N
    (C) 12.5 N
    (D) 25 N

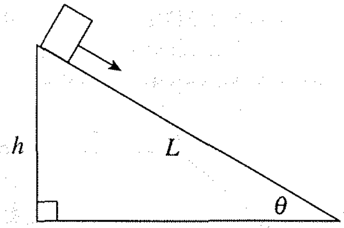


14. Two students each push a 30 kg box across the room. Student A applies a constant force of 30 N. Student B starts with a force of 40 N but gradually reduces the force due to fatigue. Given the force-versus-position graphs of the two students, at what position will both students have done the same amount of work?

    (A) 2 m
    (B) 3 m
    (C) 4 m
    (D) 5 m

15. A 2000 kg truck is initially traveling with a speed of 20 m/s. The driver applies the brakes and the truck slows to 10 m/s. How much work was done by the frictional force applied from the brakes?

    (A) −300,000 J
    (B) −100,000 J
    (C) 100,000 J
    (D) 300,000 J



16. A box of mass m slides down a frictionless inclined plane of length L and height h. If the box is initially at rest, what is the speed of the box halfway down the inclined plane?
    (A) $\sqrt{2gh}$
    (B) $\sqrt{gh}$
    (C) $\sqrt{\frac{gh}{2}}$
    (D) $\sqrt{\frac{gh}{4}}$

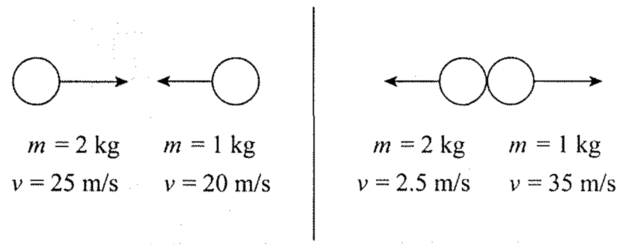
17. A car with a mass of 1000 kg experiences a frictional force of 3500 N while driving at a constant speed of a 15 m/s. What is the power output of the car's engine?
    (A) 3.5 kW
    (B) 5.25 kW
    (C) 35.0 kW
    (D) 52.5 kW

18. A student launched a small rocket with a mass of 50 kg into the air with an initial velocity of 10 m/s in the positive vertical direction. The student then turns on the secondary engines of the rocket to apply a constant upward force that increases the velocity of the rocket to 15 m/s. If the force provided by the secondary engines did 4,500 J of work, how much work did the force of gravity do on the rocket?
    (A) −625 J
    (B) −750 J
    (C) −1,250 J
    (D) −1,375 J

19. A student drops a 1 kg rock off a cliff with a height of 20 m. The rock lands on the ground and comes to rest in 0.25 seconds. What was the magnitude of the average force that the rock experienced while coming to rest?
    (A) 20 N
    (B) 40 N
    (C) 80 N
    (D) 160 N

20. A plutonium atom with a mass of 244 Da (daltons) is initially at rest. The atom suddenly undergoes alpha decay, emitting an alpha particle with a mass of 4 Da with a velocity of 45 m/s east. What is the velocity of the decay product with a mass of 240 Da?
    (A) 0.75 m/s west
    (B) 0.75 m/s east
    (C) 0.66 m/s west
    (D) 0.66 m/s east

21. A 2000-kg truck traveling due north at 40.0 m/s collides with a 1500-kg car. The vehicles lock bumpers after the collision, and skid due north for 8 m before coming to a stop. If the coefficient of kinetic friction between the vehicles and the horizontal ground is 0.3, what was the car's velocity before the collision.
    (A) 37.2 m/s north
    (B) 37.2 m/s south
    (C) 41.9 m/s north
    (D) 41.9 m/s south



22. A 2 kg ball traveling at 25 m/s collides head on with a 1 kg ball traveling at 20 m/s. After impact, both objects reverse direction with the 2 kg ball traveling at 2.5 m/s and the 1 kg ball traveling at 35 m/s. What type of collision occurred?
    (A) Inelastic
    (B) Perfectly inelastic
    (C) Elastic
    (D) Cannot be determined

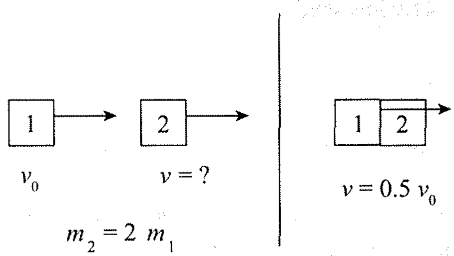
GO ON TO THE NEXT PAGE.

23. Which of the following statements is FALSE regarding perfectly inelastic collisions?

(A) The objects stick together after the collision.
(B) Momentum is conserved.
(C) If the two objects are of equal mass and collide head-on, they will exchange velocities.
(D) The maximum possible amount of kinetic energy is lost.

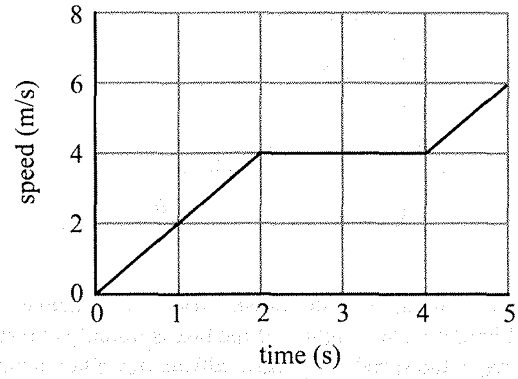
24. A 0.145 kg baseball is traveling at 40 m/s horizontally when it is struck by a baseball bat. The baseball leaves the bat at 50 m/s back in the direction it came from, but at an angle of 40° above the horizontal. What is the magnitude of the impulse imparted to the baseball?

(A) 1.45 N·s
(B) 4.66 N·s
(C) 12.3 N·s
(D) 13.1 N·s



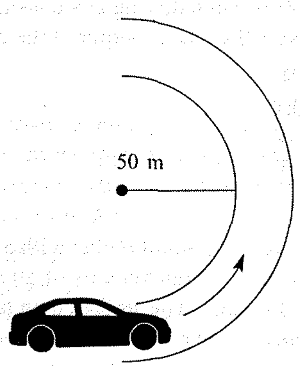
25. Object 1 travels with an initial speed of v_0 toward Object 2, which is traveling in the same direction as Object 1. Object 1 collides perfectly inelastically into Object 2, and the velocity after impact is $0.5v_0$. If Object 2 has twice the mass of Object 1, what must have been the initial speed of Object 2 (assuming no external forces)?

(A) $0.25v_0$
(B) $0.5v_0$
(C) $0.75v_0$
(D) v_0



26. A 2 kg object is tied to a machine with a 0.5 m long string. The machine whirls the object in a horizontal circle at various speeds according to the speed-versus-time graph above. What is the magnitude of the centripetal acceleration of the 2 kg object at $t = 3$ s?

(A) 0 m/s^2
(B) 8 m/s^2
(C) 16 m/s^2
(D) 32 m/s^2



27. A car is driving on a flat curve with a radius of 50 m. If the coefficient of friction between the ground and the car's tires is 0.8, what is the maximum speed of the car in order to make the curve without sliding?

(A) 8 m/s^2
(B) 12 m/s^2
(C) 16 m/s^2
(D) 20 m/s^2

GO ON TO THE NEXT PAGE.

28. A planetoid orbits a planet in a circular path at constant speed. The planet has a mass of 4×10^{20} kg and a radius of 1.6×10^5 m. What is the speed of the planetoid if it is 3.2×10^5 m above the surface of the planet?

(A) 72 m/s
(B) 193 m/s
(C) 236 m/s
(D) 439 m/s

29. The magnitude of the gravitational force between two objects is F. If the distance between the two objects is tripled and the mass of one of the objects is doubled, what is the new magnitude of the gravitational force between the two objects?

(A) $\frac{1}{9}F$

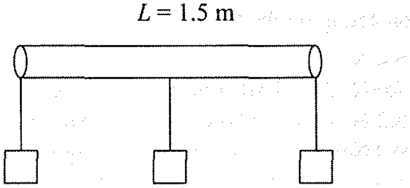
(B) $\frac{2}{9}F$

(C) $\frac{1}{6}F$

(D) $\frac{1}{4}F$

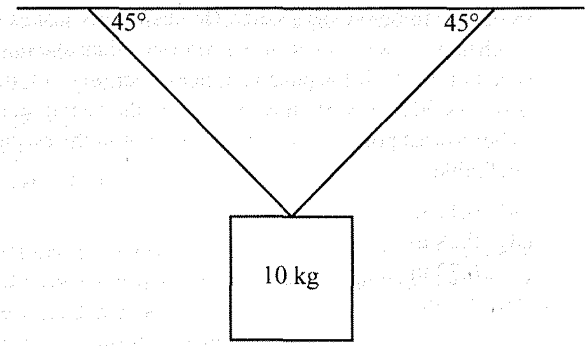
30. A mechanical wheel initially at rest on the floor begins rolling forward with an angular acceleration of 2π rad/s^2. If the wheel has a radius of 2 m, what distance does the wheel travel in 3 seconds?

(A) 4π m
(B) 6π m
(C) 16π m
(D) 18π m



31. Three masses are attached to a 1.5 m long massless bar. Mass 1 is 2 kg and is attached to the far left side of the bar. Mass 2 is 4 kg and is attached to the far right side of the bar. Mass 3 is 4 kg and is attached to the middle of the bar. At what distance from the far left side of the bar can a string be attached to hold the bar up horizontally?

(A) 0.3 m
(B) 0.6 m
(C) 0.9 m
(D) 1.2 m

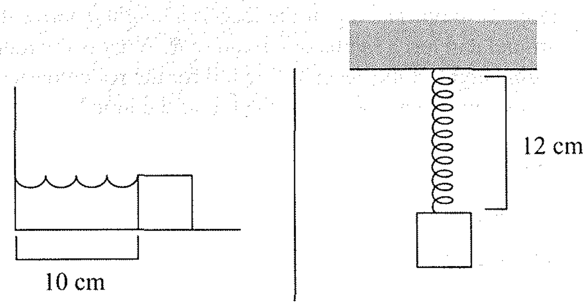


32. A 10 kg mass is attached to the ceiling with two strings (shown above). If the system is in static equilibrium, what is the tension in each of the strings?

(A) 50 N
(B) 70.7 N
(C) 100 N
(D) 141.4 N

33. A beginner skier is skiing slowly at 2 m/s and stops by gliding up a gentle slope. How high (vertically) above the bottom of the slope are they when they come to a stop? (Friction is negligible.)

(A) 0.10 m
(B) 0.20 m
(C) 0.41 m
(D) The answer cannot be determined without the angle of the slope.



34. A horizontal spring with a block attached to the end has a natural length of 10 cm. When the spring is attached to the ceiling, the spring is stretched 2 cm beyond its natural length at equilibrium. If the spring constant of the block is 50 N/m, what is the mass of the block?

(A) 0.01 kg
(B) 0.05 kg
(C) 0.1 kg
(D) 0.5 kg

GO ON TO THE NEXT PAGE.

35. A boy gives his 18-kg younger sister on a swing a quick push to help her swing higher. He pushes her just as she reaches the lowest point of her motion, when she has a speed of 3 m/s. If his push is in her direction of motion and does 50 J of work, how high does she swing relative to her lowest point? Assume that friction in the swing is negligible.

(A) 0.17 m
(B) 0.28 m
(C) 0.73 m
(D) 1.5 m

36. A block attached to an ideal spring undergoes simple harmonic motion about its equilibrium position ($x = 0$) with amplitude A. What fraction of the total energy is in the form of potential energy when the block is at position $x = \frac{1}{4}A$?

(A) $\frac{1}{16}$

(B) $\frac{1}{4}$

(C) $\frac{3}{4}$

(D) $\frac{15}{16}$

37. A rollercoaster rolls from rest at the top of an acceleration hill a height H above the ground then rolls through a loop-the-loop. The top of the loop is a height h above the ground and has a radius of curvature R. What is the minimum height of the accelerating hill for the rollercoaster to stay on the track above it at the top of the loop?

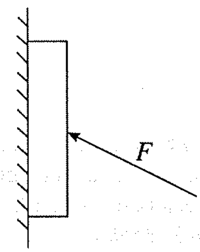
(A) $h + \frac{R}{2}$
(B) $h + R$
(C) $h + 2R$
(D) $\frac{R}{2}$

38. A pottery wheel with a rotational inertia of 7 kg·m^2 rotates at a constant rate of 30 rad/s. An artist accidentally drops a 2.5-kg ball of clay onto the pottery wheel 0.3 m from its axis of rotation. If no net external torque acts on the system, and the rotational inertia of the clay is $I = mr^2$, what is the angular speed of the wheel with the clay?

(A) 22.3 rad/s
(B) 29.1 rad/s
(C) 29.5 rad/s
(D) 31.0 rad/s

39. A toy train engine is connected to toy train car A followed by toy train car B. The engine pulls with a force of 0.60 N. Car A has a mass of 500 g and car B has a mass of 300 g. What is the tension in the connector between cars A and B?

(A) 0.23 N
(B) 0.36 N
(C) 0.38 N
(D) 0.60 N



40. While deciding where to hang a picture frame, a man holds the 1.3-kg frame against the wall by applying a force of 15 N at an angle of 25° above the horizontal. The coefficient of static friction is 0.6. What is the force of friction acting on the frame?

(A) 6.4 N
(B) 7.6 N
(C) 8.2 N
(D) 9.0 N

41. A salad spinner has an internal 0.15-m radius spinning basket that spins at 26 rad/s to remove water from salad greens. The basket has a rotational inertia of 0.1 kg·m^2. To stop the basket, a piece of rubber is pressed against the outer edge of the basket, slowing it through friction. If rubber is pressed into the outer edge with a force of 5 N, and the coefficient of kinetic friction between the rubber and the basket is 0.35, how long does it take for the basket to stop?

(A) 1.5 s
(B) 3.5 s
(C) 5.2 s
(D) 9.9 s

42. When walking on a slackline or tight rope, why is it helpful for people to hold their arms out to the side?

(A) It decreases the angular acceleration resulting from a torque on the body.
(B) It raises the location of the body's center of mass, reducing the lever arm for forces exerted at the feet.
(C) Having an arm to either side of the body balances the torques on the body.
(D) It minimizes the impact of air currents.

43. Masses m_1 and m_2 are connected by a thin sting that passes over a massless pulley. The system is released from rest. What is the tension in the string?

(A) $(m_1 + m_2)g$

(B) $(m_2 - m_1)g$

(C) $\dfrac{(m_2 - m_1)^2}{m_1 + m_2}g$

(D) $\dfrac{2m_1m_2}{m_1 + m_2}g$

44. Two runners start at the same trailhead. Runner A takes a steep trail while runner B takes a trail with a more moderate slope, but they both meet again at the top of the hill to rest. Which of the following correctly describes the relationship between the work done by runner A, W_A, and the work done by runner B, W_B.

(A) $W_A > W_B$
(B) $W_A = W_B$
(C) $W_A < W_B$
(D) The relationship cannot be determined from the given information.

45. A 60-kg woman in an elevator descends 8 m at a constant speed. How much work does the normal force do during this motion?

(A) –4700 J
(B) 0 J
(C) 480 J
(D) 4700 J

Directions: For each of the questions 46–50, two of the suggested answers will be correct. Select the two answers that are best in each case, and then fill in both of the corresponding circles on the answer sheet.

46. Which of the following describes a particle that is slowing down? Select two answers.

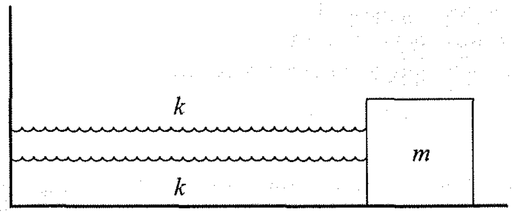
(A) A particle has a positive velocity and a positive acceleration.
(B) A particle has a positive velocity and a negative acceleration.
(C) A particle has a negative velocity and a positive acceleration.
(D) A particle has a negative velocity and a negative acceleration.

47. A box slides from rest at a given height down and off of a ramp. Which of the follow statements are true? Select two answers.

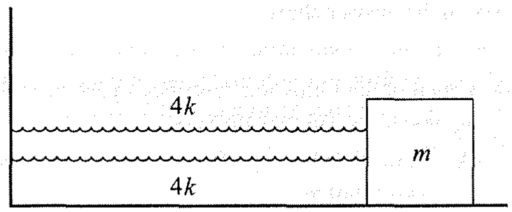
(A) One of the forces acting on the box does no work during the motion.
(B) The work done by gravity on the box depends on the incline angle of the ramp.
(C) The magnitude of the work done by friction on the box is greater than the work done by gravity.
(D) The total work done on the box depends on the incline angle of the ramp.

48. For which combination of springs will the effective spring constant be equal to $2k$? Select two answers.

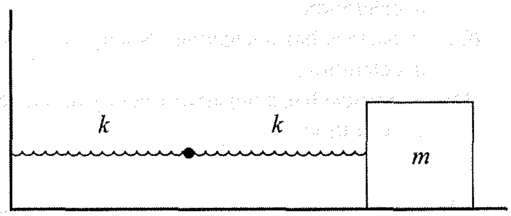
(A)



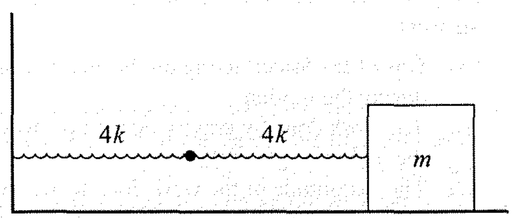
(B)



(C)



(D)



49. Which of the following must be true for an object at translational equilibrium? Select two answers.

(A) The kinetic energy of the object is 0.
(B) The net force on the object is 0.
(C) The acceleration of the object is 0.
(D) The net torque on the object is 0.

50. The biceps attach to the forearm close to the elbow joint. When lifting an object held in the hand without moving the elbow, the forearm has a constant angular speed. Which of the following is true? Select two answers.

(A) The forearm is in dynamic equilibrium.
(B) The biceps exert more force on the forearm than the object does.
(C) The net torque on the forearm does not change as the object is lifted.
(D) The object exerts an equal magnitude of torque on the forearm as the biceps do.

END OF SECTION I

DO NOT CONTINUE UNTIL INSTRUCTED TO DO SO.

AP PHYSICS 1

SECTION II

Free-Response Questions

Time—90 minutes

Percent of total grade—50

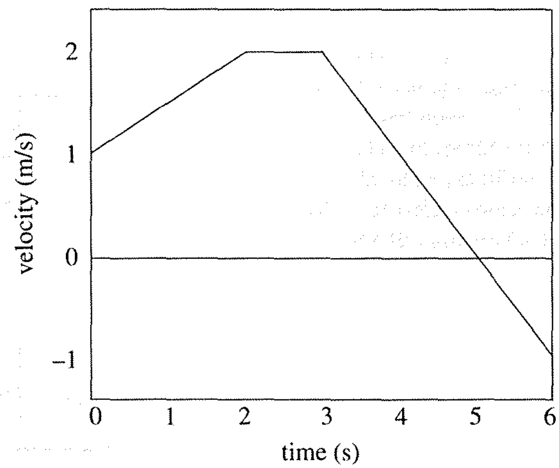
General Instructions

Use a separate piece of paper to answer these questions. Show your work. Be sure to write CLEARLY and LEGIBLY. If you make an error, you may save time by crossing it out rather than trying to erase it.

AP PHYSICS 1

SECTION II

Directions: Questions 1–5 here are as follows: one experimental design question (worth 12 points), one quantitative/qualitative translation question (worth 12 points), one paragraph argument short-answer question (worth 7 points), and two additional short-answer questions (worth 7 points each). You have a total of 90 minutes to complete this section. Show your work for each part in the space provided after that part.

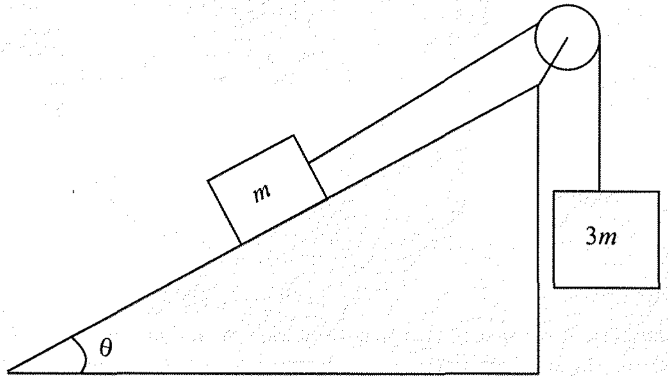


1. The motion of an object is given by the following velocity-versus-time graph.

(A) What is the displacement of the object from time $t = 0$ s to $t = 6$ s in the graph above?

(B) At what times is the speed of the object increasing?

(C) Make of a sketch of the object's position-versus-time graph during the time interval of $t = 0$ s to $t = 6$ s. Assume that the object begins at $x = 0$.



2. A small box of mass m is placed on an inclined plane with an angle of incline of θ. There is a coefficient of kinetic friction μ_k between the inclined plane and the small box. The small box is attached to a much heavier box of mass $3m$ by a pulley system, as shown above.

(A) Draw free-body diagrams of both masses, including all of the forces acting on each.

(B) Assuming a frictionless, massless pulley, determine the acceleration of the blocks once they are released from rest in terms of μ_k, g, and θ.

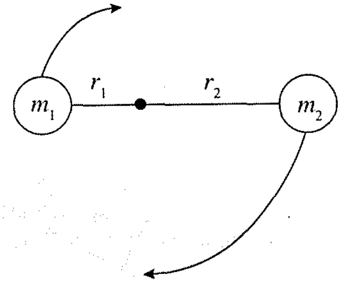
(C) If $\mu_k = 0.3$ and $\theta = 45°$, what distance is traveled by the blocks 3 s after being released from rest?

3. A 250-g volleyball is dropped from a height of 2 m. It bounces to a height of 1.8 m. Then, the volleyball is returned to a height 2 m, and a 60-g tennis ball is held centered, and slightly above the volleyball. Subsequently, the two are dropped simultaneously. The tennis ball collides with the volleyball just after the volleyball has bounced off of the ground. The volleyball continues up to a height of 0.3 m before returning to the ground again. (Neglect the effects of air resistance.)

(A) What percentage of its energy does the volleyball lose in its bounce? What happens to this lost energy?

(B) If it took 0.2 s for the volleyball to bounce, what was the average force on the ball during the bounce?

(C) How high does the tennis ball bounce?



4. A particular binary star system consists of two stars of masses m_1 and m_2 that orbit each other in circular orbits about the center of mass of the system. The star with mass m_1 is a distance r_1 from the center of mass and orbits with a speed of v_1, and the star with mass m_2 is a distance r_2 from the center of mass and orbits with a speed of v_2.

(A) Derive an equation for the mass m_1 in terms of v_2, r_1, r_2, and the gravitational constant, G.

(B) Derive an equation for the ratio m_1/m_2 in terms of v_1 and v_2.

(C) If the star of mass m_2 is four times faster than the star of mass m_1, and the total mass of the system is 10^{31} kg, what are m_1 and m_2?

5. Two spheres (one hollow, one solid) are placed side by side on an inclined plane and released at the same time. Both spheres roll down the inclined plane without slipping.

(A) Using a free-body diagram, explain what force provides the torque that allows the spheres to roll down the inclined plane.

(B) Which sphere reaches the bottom of the inclined plane first and why?

(C) How do the kinetic energies of the two spheres compare at the bottom of the inclined plane?

STOP

END OF EXAM

PRACTICE TEST 3: ANSWER KEY

1.	B	26.	D
2.	C	27.	D
3.	C	28.	C
4.	D	29.	B
5.	D	30.	D
6.	C	31.	C
7.	B	32.	B
8.	C	33.	B
9.	B	34.	C
10.	B	35.	C
11.	B	36.	A
12.	B	37.	A
13.	C	38.	B
14.	C	39.	A
15.	A	40.	A
16.	B	41.	D
17.	D	42.	A
18.	D	43.	D
19.	C	44.	B
20.	A	45.	A
21.	B	46.	B, C
22.	A	47.	A, D
23.	C	48.	A, D
24.	C	49.	B, C
25.	A	50.	B, C

ADVANCED PLACEMENT 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,	$k = 1/4\pi\varepsilon_0 = 9.0 \times 10^9\ \mathrm{N{\cdot}m^2/C^2}$
Electron mass,	$m_e = 9.11 \times 10^{-31}$ kg	Universal gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{m^3/kg{\cdot}s^2}$
Speed of light,	$c = 3.00 \times 10^8$ m/s	Acceleration due to gravity at Earth's surface,	$g = 9.8\ \mathrm{m/s^2}$

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 <u>on</u> 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.

ADVANCED PLACEMENT PHYSICS 1 EQUATIONS

MECHANICS

$$v_x = v_{x0} + a_x t$$

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

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

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

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

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

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

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

$$K = \frac{1}{2}mv^2$$

$$\Delta E = W = F_{\parallel}d = Fd\cos\theta$$

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

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

$$\omega = \omega_0 + \alpha t$$

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

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

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

$$L = I\omega$$

$$\Delta L = \tau\,\Delta t$$

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

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

$$U_s = \frac{1}{2}kx^2$$

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

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

$$\Delta U_g = mg\,\Delta y$$

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

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

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

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

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

$$U_G = -\frac{Gm_1 m_2}{r}$$

ELECTRICITY

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

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

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

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

$$P = I\,\Delta V$$

$$R_s = \sum_i R_i$$

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

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
$V = \ell wh$

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

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

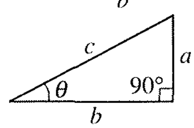
A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius

Right triangle
$c^2 = a^2 + b^2$

$\sin\theta = \frac{a}{c}$

$\cos\theta = \frac{b}{c}$

$\tan\theta = \frac{a}{b}$



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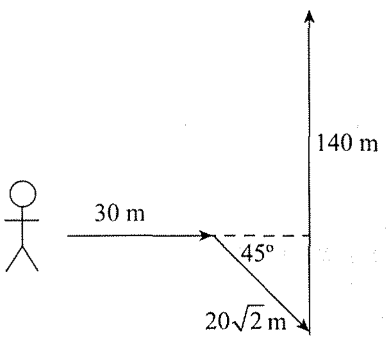
SECTION I

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

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

Questions 1–3 refer to the following scenario:

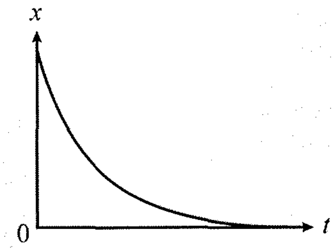


An explorer travels 30 m east, then $20\sqrt{2}$ m in a direction 45° south of east, and then 140 m north.

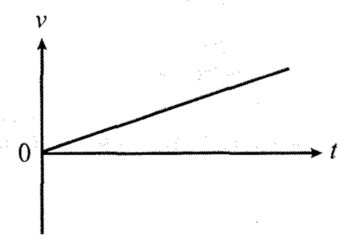
1. What is the distance traveled by the explorer?
   (A) 167.2 m
   (B) 169 m
   (C) 170 m
   (D) 198.2 m

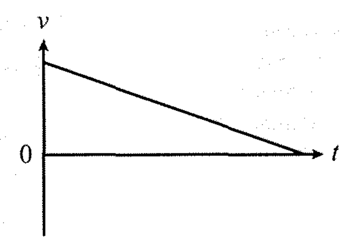
2. What is the displacement of the explorer?
   (A) 130 m
   (B) 169 m
   (C) 170 m
   (D) 215 m

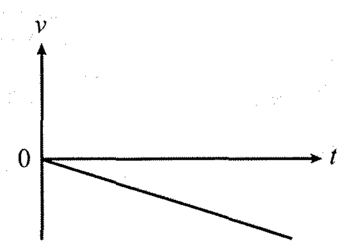
3. The explorer took 60 s, 130 s, and 70 s to travel the 30 m, $20\sqrt{2}$ m, and 140 m north distances, respectively. What is the average velocity of the explorer over the total distance traveled?
   (A) 0.50 m/s
   (B) 33.3 m/min
   (C) 0.76 m/s
   (D) 100 m/min

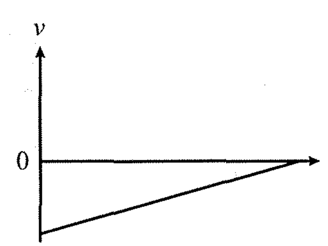


4. The graph above is the position-versus-time graph of an object. Which of the following is the velocity-versus-time graph of the object?

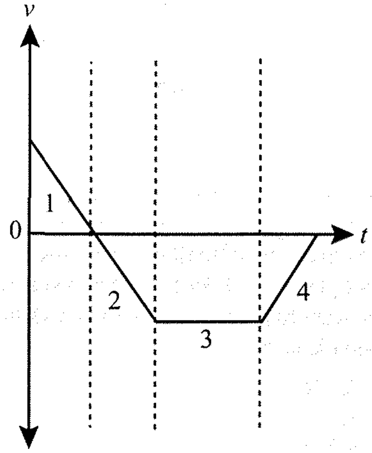
(A)


(B)


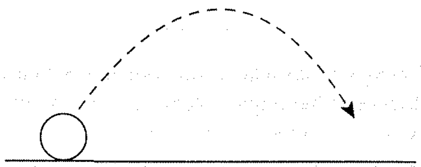
(C)


(D)


5. In which section of the following velocity-versus-time graph is the object slowing down and moving in the negative direction?

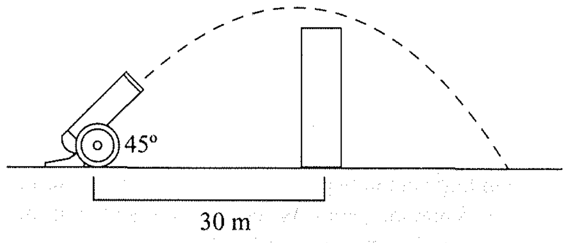


(A) Section 1
(B) Section 2
(C) Section 3
(D) Section 4



6. Which of the following is a true statement regarding the motion of projectiles?

(A) The velocity of projectiles is smallest at the apex of the trajectory.
(B) All projectiles have zero velocity at the apex of the trajectory.
(C) The acceleration of projectiles is greatest at the apex of the trajectory.
(D) Projectiles have maximum kinetic energy at the apex of the trajectory.



7. A cannonball is fired with an initial velocity of 20 m/s and a launch angle of 45° at a wall 30 m away. If the cannonball just barely clears the wall, what is the maximum height of the wall?

(A) 5.92 m
(B) 6.34 m
(C) 7.51 m
(D) 8.32 m

$v_0 = 0$ m/s

8. A car initially at rest accelerates linearly at a constant rate for 5 s. If the final speed of the car is 15 m/s, what was the displacement of the car?

(A) 20 m
(B) 37.5 m
(C) 75 m
(D) 150 m

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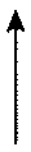
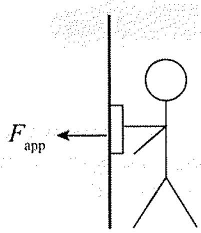
9. A standing person begins to run to the right, as shown above. While the person is speeding up, which of the following could be the direction of the (total) contact force that the ground exerts on his/her foot?

(A) 

(B) 

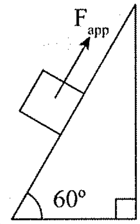
(C) 

(D) None of these are possible.



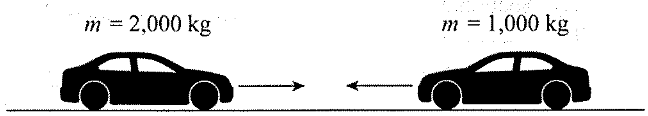
10. A student presses a 0.5 kg book against the wall. If the μ_s between the book and the wall is 0.2, what force must the student apply to hold the book in place?

(A) 0 N
(B) 15 N
(C) 25 N
(D) 35 N



11. A box with a mass of 10 kg is placed on an inclined plane that makes a 60° angle with the horizontal. The coefficient of static friction (μ_s) between the box and the inclined plane is 0.2. What force must be applied on the box in order to prevent the box from sliding down the inclined plane?

(A) 32.7 N
(B) 48.3 N
(C) 56.2 N
(D) 76.6 N



12. A 2,000 kg car has a head-on collision with a 1,000 kg car. How does the impact force on the heavier car compare with that on the smaller car?

(A) The heavier car experiences a greater impact force.
(B) The smaller car experiences a greater impact force.
(C) Both vehicles experience an impact force with the same magnitude.
(D) Cannot be determined

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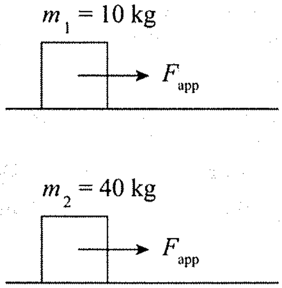
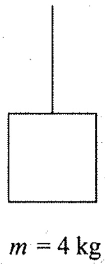


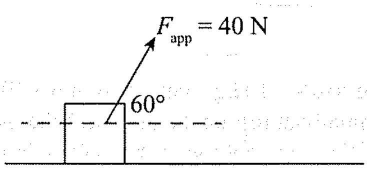
13. Two students push two different boxes across a frictionless floor. Both students exert a horizontal force of 50 N. If the first box has mass $m_1 = 10$ kg and the second box has mass $m_2 = 40$ kg, what is the value of a_1/a_2?

(A) 1/4
(B) 1/2
(C) 2
(D) 4



14. A 4 kg box is accelerated upwards by a string with a breaking strength of 80 N. What is the maximum upward acceleration that can be applied on the box without breaking the string?

(A) 2.5 m/s²
(B) 5.0 m/s²
(C) 7.5 m/s²
(D) 10 m/s²

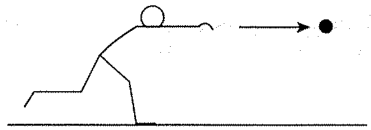


15. A worker moves a 30 kg box by pulling on it with a rope that makes a 60° angle with the horizontal. If the worker applies a force of 40 N and pulls the box over a distance of 20 m, how much work did the worker do?

(A) 100 J
(B) 200 J
(C) 400 J
(D) 800 J

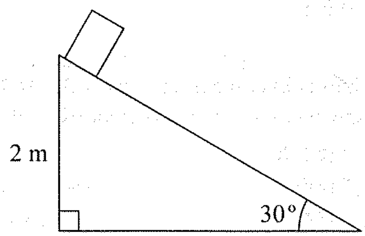
16. A 2 kg rock is dropped off a cliff with a height of 20 m. What is the speed of the rock at the bottom of the hill?

(A) 10 m/s
(B) 14 m/s
(C) 20 m/s
(D) 40 m/s



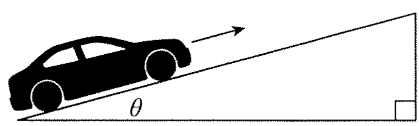
17. How much work is done by a pitcher to throw a 0.2 kg ball at a speed of 30 m/s?

(A) 3 J
(B) 9 J
(C) 30 J
(D) 90 J



18. A 10 kg block is placed at the top of an inclined plane with an angle of incline of 30° and $\mu_k = 0.1$. If the height of the inclined plane is 2 m, what is the kinetic energy of the block when it is halfway down the incline?

(A) 64 J
(B) 72 J
(C) 83 J
(D) 100 J



19. A car's engine must exert a force of 2,000 N to maintain a speed of 30 m/s up an incline. What is the power provided by the engine during this motion?

(A) 67 W
(B) 9,000 W
(C) 60,000 W
(D) 90,000 W

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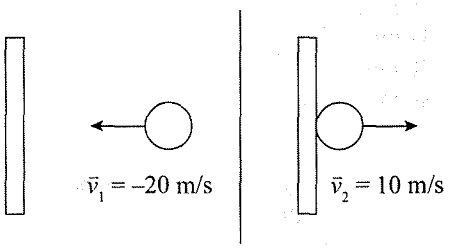
Questions 20–22 refer to the following scenario:

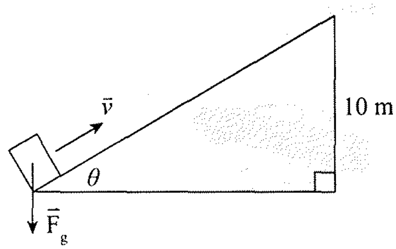


A 2 kg ball with a velocity of –20 m/s collides with the wall and bounces back with a velocity of 10 m/s.

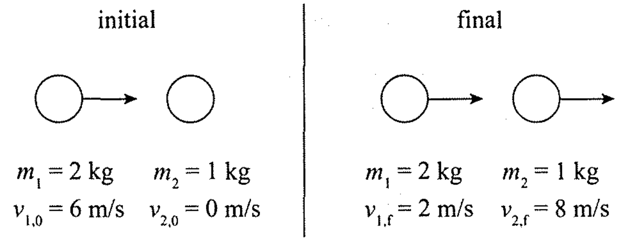
20. What is the impulse during the collision?
    (A) 10 N·s
    (B) 20 N·s
    (C) 30 N·s
    (D) 60 N·s

21. If the ball is in contact with the wall for 0.002 s, determine the average force experienced by the ball.
    (A) 3,000 N
    (B) 5,000 N
    (C) 30,000 N
    (D) 50,000 N

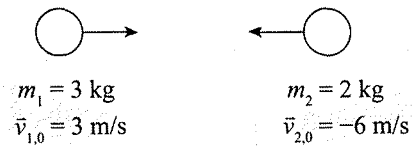
22. How much work did the wall do on the ball?
    (A) –300 J
    (B) –400 J
    (C) –750 J
    (D) –1,000 J



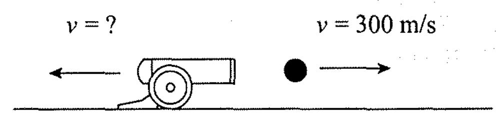
23. A student pushes a 6 kg box up an inclined plane with a height of 10 m. How much work does gravity do on the box during this process?
    (A) –1,200 J
    (B) –600 J
    (C) 600 J
    (D) 1,200 J



24. A 2 kg ball traveling to the right at 6 m/s collides head on with a 1 kg ball at rest. After impact, the 2 kg ball is traveling to the right at 2 m/s and the 1 kg ball is traveling to the right at 8 m/s. What type of collision occurred?
    (A) Inelastic
    (B) Perfectly inelastic
    (C) Elastic
    (D) Cannot be determined



25. A 3 kg mass with an initial velocity of +3 m/s has a perfectly inelastic collision with a 2 kg mass with an initial velocity of –6 m/s. What is the final velocity after impact?
    (A) –1.0 m/s
    (B) –0.6 m/s
    (C) 0.6 m/s
    (D) 1.0 m/s



26. A soldier loads a 10 kg cannonball into a 300 kg cannon that is initially at rest on the ground. What is the recoil speed of the cannon if the cannonball is fired with a horizontal velocity of 300 m/s ?
    (A) 5 m/s
    (B) 7.5 m/s
    (C) 10 m/s
    (D) 15 m/s

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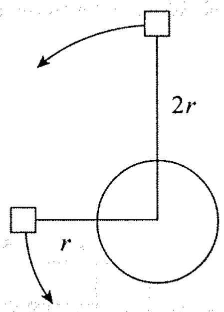
27. A student attaches a 1.5 kg mass to a 40 cm long string. The student then spins the mass in a horizontal circle with increasing speed. If the string snaps when the mass has a speed of 6 m/s, what is the breaking strength of the string?

(A) 22.5 N
(B) 135 N
(C) 240 N
(D) 360 N



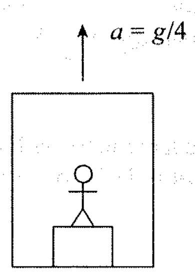
28. If the speed of a satellite orbiting the Earth at a distance r from the center of the Earth is v, what is the speed of a second satellite orbiting the Earth at a distance $2r$ from the center of the Earth?

(A) $2v$

(B) $\sqrt{2}v$

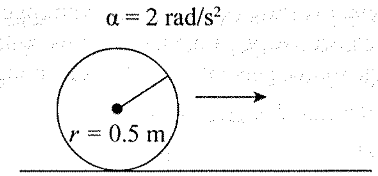
(C) $\frac{1}{\sqrt{2}}v$

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



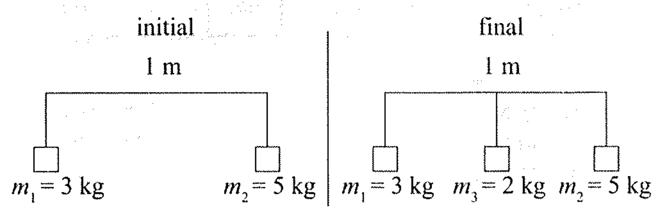
29. A 50 kg man stands on a scale that measures force in an elevator traveling up with an acceleration of $g/4$. What will the scale read?

(A) 375 N
(B) 500 N
(C) 575 N
(D) 625 N



30. A mechanical wheel initially at rest on the floor begins rolling forward with an angular acceleration of 2 rad/s². If the radius of the wheel is 0.5 m, what is the linear velocity of the wheel after 5 s?

(A) 0.5 m/s
(B) 1 m/s
(C) 5 m/s
(D) 10 m/s



31. Two masses are attached to a 1 m long massless bar. Mass 1 is 3 kg and is attached to the far left side of the bar. Mass 2 is 5 kg and is attached to the far right side of the bar. If a third mass that is 2 kg is added to the middle of the bar, how does the center of mass of the system change?

(A) The center of mass shifts to the left by 0.025 m.
(B) The center of mass shifts to the right by 0.025 m.
(C) The center of mass shifts to the left by 0.075 m.
(D) The center of mass shifts to the right by 0.075 m.

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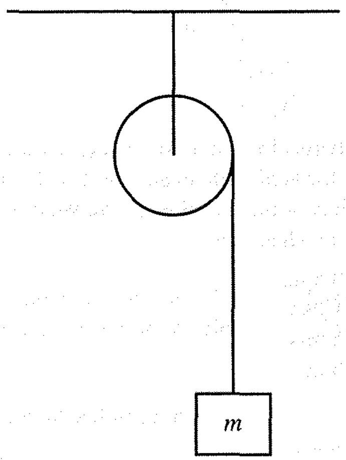
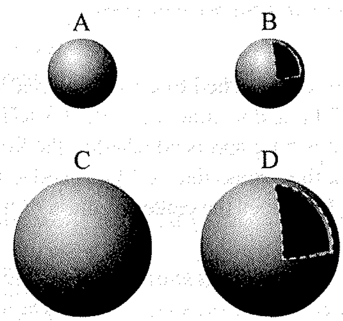
32. A 5 kg box is connected to a pulley with rope in the diagram shown below. If the radius of the pulley is 0.5 m, what is the torque generated by the box on the pulley?

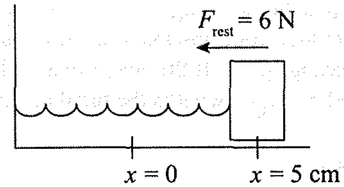


(A) 10 N·m
(B) 25 N·m
(C) 50 N·m
(D) 75 N·m



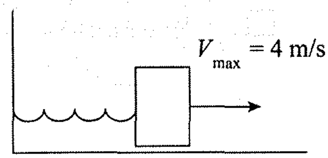
33. Which of the following objects has the greatest rotational inertia?

(A) A 1 kg solid ball with radius of 5 cm
(B) A 1 kg hollow ball with radius of 5 cm
(C) A 5 kg solid ball with radius of 5 cm
(D) A 5 kg hollow ball with radius 5 cm



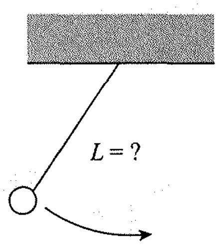
34. A horizontal spring is attached to a 5 kg block. When the block is pulled 5 cm to the right, the restoring force has a magnitude of 6 N. What is the frequency of the spring?

(A) 0.32 Hz
(B) 0.56 Hz
(C) 0.78 Hz
(D) 0.98 Hz



35. A 3 kg block is attached to a horizontal spring with a force constant of 10 N/m. If the maximum speed of the block is 4 m/s, what is the amplitude of the block?

(A) 0.55 m
(B) 1.1 m
(C) 2.2 m
(D) 4.4 m



36. A simple pendulum oscillates back and forth with a period of 2 s. What is the length of the string of the pendulum?

(A) 0.25 m
(B) 0.5 m
(C) 1 m
(D) 2 m

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37. An object of mass m is attached to a horizontal spring with spring constant k, oscillating on a frictionless horizontal surface with an amplitude A. What is the speed of the object when its displacement from its equilibrium position is $\frac{A}{2}$?

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

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

(C) $\frac{A}{2}\sqrt{\frac{3k}{m}}$

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

38. A planet forms from a cloud of gas and dust that collapses under gravity. Why does the planet rotate faster than the cloud of gas and dust it was formed from?

(A) As the cloud collapses, the gravitational forces between particles increase, causing more torque on the cloud.
(B) As the cloud collapses, the gravitational forces between particles increase, increasing the angular momentum of the system.
(C) As the cloud collapses, its rotational inertia decreases, so its angular velocity increases to conserve angular momentum.
(D) As the cloud collapses, its rotational inertia decreases, so torques acting on it result in higher angular acceleration.

39. An object (mass = m) above the surface of the Moon (mass = M) is dropped from an altitude h equal to the Moon's radius (R). What is the object's impact speed?

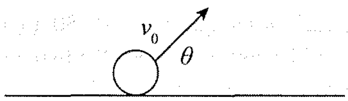
(A) $\sqrt{GM/R}$
(B) $\sqrt{GM/(2R)}$
(C) $\sqrt{2GM/R}$
(D) $\sqrt{2GMm/R}$

40. While loading identical boxes onto a truck, some boxes are lifted from ground level directly onto the truck, while others are pushed up a ramp with a somewhat rough surface. Which of the following MUST be true?

(A) The work required to push a box up the ramp is greater than the work required to lift a box onto the truck.
(B) The work required to push a box up the ramp less than the work required to lift a box onto the truck.
(C) The force required to push a box up the ramp is greater than the force required to lift a box onto the truck.
(D) The force required to push a box up the ramp is less than the force required to lift a box onto the truck.

41. A ball of mass m hangs on a string of length L. A child pushes the ball so that it starts to swing back-and-forth. When the string is at an angle θ from the vertical, what torque does gravity apply to this system?

(A) mgL
(B) $mgL \sin \theta$
(C) $mgL \cos \theta$
(D) $mgL(1 - \cos \theta)$



42. A projectile of mass m is fired into the air at some angle θ. If its launch velocity is v_0, which of the following expressions represents the object's kinetic energy at the peak of its motion?

(A) 0
(B) $(1/2)m(v_0 \sin \theta)^2$
(C) $(1/2)m(v_0 \cos \theta)^2$
(D) $(1/2)m[(v_0 \sin \theta)^2 + (v_0 \cos \theta)^2]$

43. A spider of mass m accelerates at a rate of a down a vertical strand of its web. What is the magnitude of tension in the strand?

(A) mg
(B) $m(g - a)$
(C) $m(a - g)$
(D) $m(g + a)$

44. An object slides from rest down a 10.0-m long, frictionless incline that is at 30° to the horizontal, then it skids to a stop on a rough horizontal surface over a distance of 12.5 m. What is the coefficient of kinetic friction between the object and the rough horizontal surface?

(A) 0.400
(B) 0.462
(C) 0.693
(D) 0.800

45. What is the power delivered by gravity as it pulls an object of mass m that is dropped from a height h down to the ground?

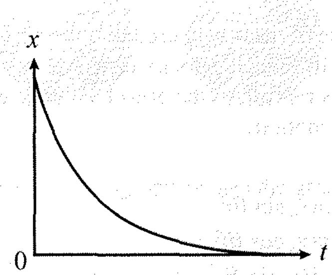
(A) mgh

(B) $\frac{mg^2}{2}$

(C) $\frac{m\sqrt{2g^3h}}{2}$

(D) $m\sqrt{2g^3h}$

Directions: For each of the questions 46–50, <u>two</u> of the suggested answers will be correct. Select the two answers that are best in each case, and then fill in both of the corresponding circles on the answer sheet.

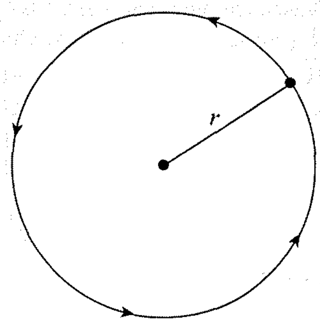


46. The graph above is the position-versus-time graph of an object. Which of the following is true regarding the motion of the object? Select two answers.

(A) The object is moving in the positive direction.
(B) The object is moving in the negative direction.
(C) The acceleration of the object is decreasing.
(D) The speed of the object is decreasing.

47. In which of the following scenarios is the total work done on the box equal to zero? Select two answers.

(A) A box is lifted from the floor and placed on a shelf.
(B) A box falls some distance to the ground.
(C) A box is pushed along the ground at a constant speed.
(D) A box slides along a horizontal surface, slowing from an initial speed to a stop.



48. Which of the following statements is true regarding an object undergoing uniform circular motion? Select two answers.

(A) The velocity of the object is constant.
(B) The centripetal force is always the net force acting in the plane of the circular path.
(C) The object must feel a force directed radially outward.
(D) The acceleration of the object must point toward center of the circle.

49. Which of the following is true regarding conservative forces? Select two answers.

(A) The work done by conservative forces is path dependent.
(B) The work done by conservative forces is path independent.
(C) Conservative forces depend only on the position of an object.
(D) When a conservative force does positive work on an object, its potential energy increases.

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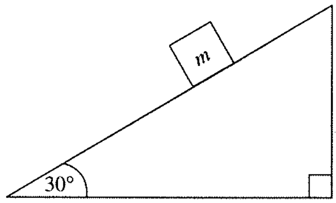
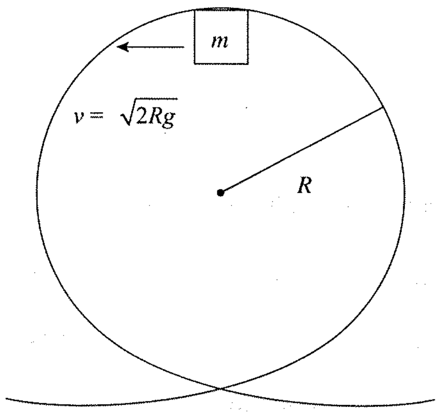
50. In which of the following scenarios is the normal force acting on the object equal to mg? Select two answers.

(A)



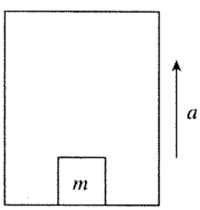
An object of mass m rests on an incline plane at an angle of 30°.

(B)



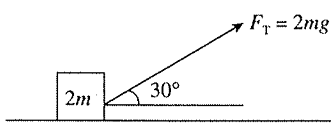
An object of mass m slides upside down on a curved track of radius R with a speed $v = \sqrt{2Rg}$.

(C)



An object of mass m rests on an elevator that accelerates upward.

(D)



An object of mass $2m$ is pulled along a horizontal surface by a tension force $F_T = 2mg$ at an angle of 30° above the horizontal.

END OF SECTION I

DO NOT CONTINUE UNTIL INSTRUCTED TO DO SO.

AP PHYSICS 1

SECTION II

Free-Response Questions

Time—90 minutes

Percent of total grade—50

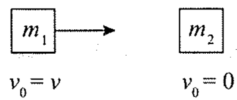
General Instructions

Use a separate piece of paper to answer these questions. Show your work. Be sure to write CLEARLY and LEGIBLY. If you make an error, you may save time by crossing it out rather than trying to erase it.

AP PHYSICS 1

SECTION II

Directions: Questions 1–5 here are as follows: one experimental design question (worth 12 points), one quantitative/qualitative translation question (worth 12 points), one paragraph argument short answer question (worth 7 points), and two additional short answer questions (worth 7 points each). You have a total of 90 minutes to complete this section. Show your work for each part in the space provided after that part.

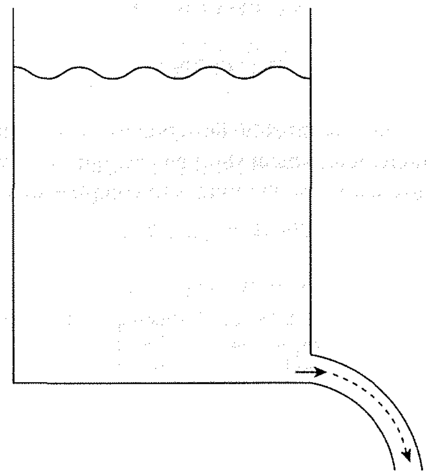


1. A mass m_1 traveling with an initial velocity of v has an elastic collision with a mass m_2 initially at rest.

(A) Determine the final velocity v_1 of m_1 in terms of m_1, m_2, and v.

(B) Determine the final velocity v_2 of m_2 in terms of m_1, m_2, and v.

(C) For what values of m_1 and m_2 would the final velocities of the two masses be in the same direction? The opposite direction?



2. A student observes water flowing out of a small hole at the bottom of a large tank (onto a floor with a drain). The water flows out of the hole horizontally.

The student hypothesizes that the water flowing out of the hole undergoes projectile motion, so that its range can be determined by the equations of projectile motion.

(A) The student plans to test the hypothesis by observing the water flowing out of the tank. They are able to open the top of the tank and refill it as needed.

i. State the basic physics principles or laws the student could use in designing an experiment to test the hypothesis.

ii. Design an experimental procedure to test whether or not the water undergoes projectile motion. Assume equipment usually found in a school physics laboratory is available. In the table below, list the quantities and associated symbols that would be measured in your experiment. Also list the equipment that would be used to measure each quantity. You do not need to fill in every row. If you need additional rows, you may add them to the space just below the table.

Quantity to be Measured	Symbol for Quantity	Equipment for Measurement

(B) Describe the overall procedure to be used to determine whether the range of the water is described by projectile motion, referring to the table. Provide enough detail so that another student could replicate the experiment, including any steps necessary to reduce experimental uncertainty. As needed, use the symbols defined in the table and/or include a simple diagram of the setup.

(C) Describe how the experimental data could be analyzed to confirm or disconfirm the hypothesis that the water's range can be calculated with the equations of projectile motion.

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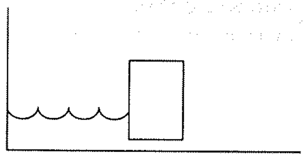


$m = 0.1$ kg

$k = 40$ N/m

3. A horizontal spring with a spring constant of 40 N/m is attached a 0.1 kg block.

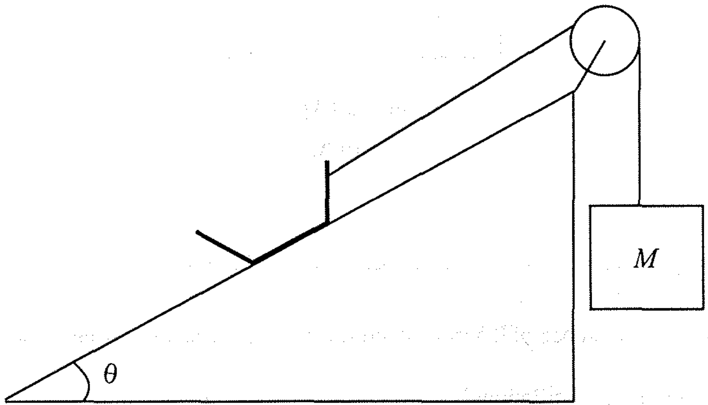
(A) If the block is pulled to a distance of 0.5 m from equilibrium and released, what is the maximum speed of the block?

(B) What is the frequency of the oscillations?

(C) If the spring were flipped vertically and attached to the ground with the block placed on top, how would the natural length of the spring change?

(D) How does the frequency of the oscillations of the vertical spring-block oscillator compare with the frequency when it was placed horizontally?

4. A massless tray is placed on an inclined plane with an angle of incline of θ. There is a coefficient of static friction μ_s between the inclined plane and the massless tray. The tray is attached to a box of mass M by the pulley system shown below.

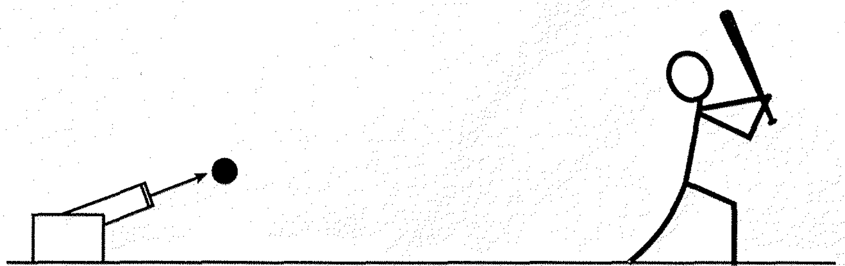


(A) If mass can be loaded onto the massless tray, how much mass m has to be loaded to stop the tray from being pulled up the inclined plane by M?

(B) How much mass m has to be loaded until the tray starts sliding down the inclined plane?

(C) If $\mu_k = 0.3$ and $\theta = 45°$, what is the acceleration of the massless tray if $m = 4M$?

5. A machine launches a 2 kg ball to the right with an initial velocity 16 m/s at an angle of 30° to a student standing 20 m away with a baseball bat.



(A) What height must the student swing the bat to hit the ball?

(B) What is the magnitude of the velocity of the ball just before impact?

(C) If the student hits the ball with an upward vertical velocity of 5 m/s and horizontal velocity of 12 m/s to the left, what are the horizontal and vertical components of the impulse of the ball from the collision?

(D) If the impact time with the bat was 0.05 s, what is the average force experienced by the ball during impact?

PRACTICE TEST 4: ANSWER KEY

1.	D	26.	C
2.	A	27.	B
3.	A	28.	C
4.	D	29.	D
5.	D	30.	C
6.	A	31.	A
7.	C	32.	B
8.	B	33.	D
9.	A	34.	C
10.	C	35.	C
11.	D	36.	C
12.	C	37.	C
13.	D	38.	C
14.	D	39.	A
15.	C	40.	A
16.	C	41.	B
17.	D	42.	C
18.	C	43.	B
19.	C	44.	A
20.	D	45.	C
21.	C	46.	B, D
22.	A	47.	A, C
23.	B	48.	B, D
24.	C	49.	B, C
25.	B	50.	B, D