Name:_____

Answer Sheet for AP Physics 1: Algebra-Based

Practice Exam, Section I

No.	Answer
1	
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No.	Answer	
21		
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35		
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131		
132		
133		
134		

AP® Physics 1: Algebra-Based Exam

SECTION I: Multiple Choice

2019

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

At a Glance

Total Time
1 hour and 30 minutes
Number of Questions
40
Percent of Total Score
50%
Writing Instrument
Pencil required
Electronic Device
Calculator allowed

Instructions

Section I of this exam contains 40 multiple-choice questions. Pages containing equations and other information are also printed in this booklet. Calculators, rulers, and straightedges may be used in this section.

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.

Because this section offers only four answer options for each question, do not mark the (E) answer circle for any question. If you change an answer, be sure that the previous mark is erased completely.

For questions 1 through 36, select the single best answer choice for each question. After you have decided which of the choices is best, completely fill in the corresponding circle on the answer sheet. Here is a sample question and answer.

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

For questions 131 through 134, select the two best answer choices for each question. After you have decided which two choices are best, completely fill in the two corresponding circles on the answer sheet. Here is a sample question and answer.

Sample Question	Sample Answer
New York 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 of the multiple-choice questions.

Your total score on Section I is based only on the number of questions answered correctly. Points are not deducted for incorrect answers or unanswered questions.

Form I
Form Code 4PBP4-S

83

AP® PHYSICS 1 TABLE OF INFORMATION

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

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

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

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

The following conventions are used in this exam.

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

AP® PHYSICS 1 EQUATIONS

MECHANICS

$v_x = v_{x0} + a_x t$

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

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

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

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

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

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

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

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

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

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

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

$\omega = \omega_0 + \alpha t$

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

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

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

$L = I\omega$

$\Delta L = \tau \Delta t$

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

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

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

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

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

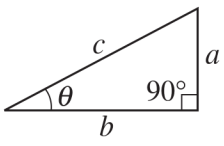
Rectangular solid
$V = \ell w h$

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



PHYSICS 1

Section I

Time—1 hour and 30 minutes

40 Questions

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

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

1. A 4 kg object moving to the left collides with and sticks to a 3 kg object moving to the right. Which of the following is true of the motion of the combined objects immediately after the collision?

   (A) They must be moving to the left.
   (B) They must be moving to the right.
   (C) They must be at rest.
   (D) The motion cannot be determined without knowing the speeds of the objects before the collision.

2. A brother and sister are standing next to each other at rest on a surface of frictionless ice. The brother's mass is exactly twice that of his sister's. The sister suddenly pushes her brother. As a result, the sister moves with kinetic energy K. What is the resulting kinetic energy of the brother?

   (A) $4K$
   (B) $2K$
   (C) $K/2$
   (D) $K/4$

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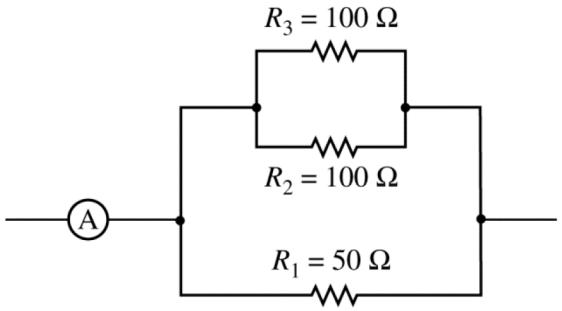
3. At time $t = 0$, a cart is at $x = 10$ m and has a velocity of 3 m/s in the $-x$-direction. The cart has a constant acceleration in the $+x$-direction with magnitude $3\ \text{m/s}^2 < a < 6\ \text{m/s}^2$. Which of the following gives the possible range of the position of the cart at $t = 1$ s?

(A) $4\ \text{m} < x < 5.5\ \text{m}$
(B) $8.5\ \text{m} < x < 10\ \text{m}$
(C) $11.5\ \text{m} < x < 13\ \text{m}$
(D) $14.5\ \text{m} < x < 16\ \text{m}$



4. The figure above shows part of a circuit containing three resistors and an ammeter. A steady current flows through the ammeter. Resistors R_1, R_2, and R_3 have currents I_1, I_2, and I_3, respectively. Which of the following expressions correctly relates the three currents?

(A) $I_1 > (I_2 = I_3)$
(B) $(I_2 = I_3) > I_1$
(C) $I_1 = I_2 = I_3$
(D) The relationship cannot be determined without information about the rest of the circuit.

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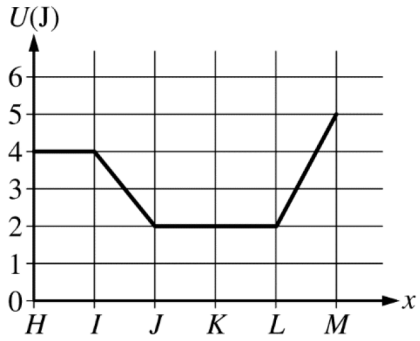
Questions 5-7 refer to the following material.



The graph above shows the potential energy U of a system as one object in the system moves along the x-axis and the rest of the system does not move. Six evenly-spaced points along the x-axis are labeled. At point H, the object is moving in the positive x-direction and the mechanical energy of the system is 5.0 J. As the object moves, no energy enters or leaves the system.

5. In which segment does the net force exerted on the object have the greatest magnitude?

(A) *HI*
(B) *IJ*
(C) *JL*
(D) *LM*

6. What is the kinetic energy of the object at point K ?

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

7. Which of the following describes the magnitude of the momentum of the object in the first two straight-line segments shown in the graph as the object moves from point H to point J ?

	HI	*IJ*
(A)	Zero	Increasing
(B)	Zero	Decreasing
(C)	Constant but nonzero	Increasing
(D)	Constant but nonzero	Decreasing

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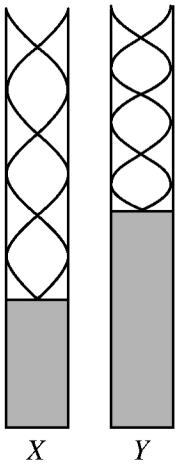

8. The figure above represents standing wave patterns in two identical tubes. The tubes contain different amounts of water, and the standing waves are produced by holding a vibrating tuning fork near the top of each tube. Is the frequency of the tuning fork the same for tubes *X* and *Y*, and why or why not?

(A) No, because one frequency cannot create multiple standing wave patterns of different total lengths.

(B) No, because the wavelengths of the patterns are different, so the frequencies must be different.

(C) Yes, because the patterns have the same number of nodes and antinodes.

(D) Yes, because the tubes are identical, so the same frequency can produce a standing wave in both.

Item 9 was not scored.

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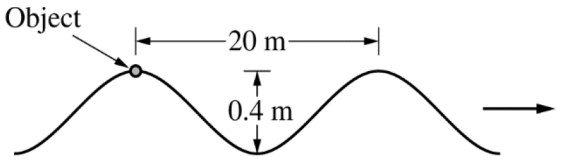
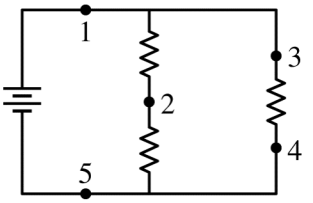


Note: Figure not drawn to scale.

10. The figure above shows a water wave traveling to the right. The horizontal distance between two adjacent crests of the wave is 20 m. At the instant shown, an object floating on the surface of the water is at its maximum height. At a time 2 s later, the floating object has moved a vertical distance of 0.4 m to its lowest position. The speed of the wave is most nearly

(A) 0.1 m/s
(B) 0.2 m/s
(C) 5 m/s
(D) 10 m/s



11. To test the hypothesis that all electrons entering a resistor also leave the resistor, ammeters could be placed in the above circuit at points

(A) 1 and 2
(B) 1 and 5
(C) 2 and 4
(D) 3 and 5

12. A toy doll and a toy robot are standing on a frictionless surface facing each other. The doll has a mass of 0.20 kg, and the robot has a mass of 0.30 kg. The robot pushes on the doll with a force of 0.30 N. The magnitude of the acceleration of the robot is

(A) zero
(B) 0.60 m/s^2
(C) 1.0 m/s^2
(D) 1.5 m/s^2

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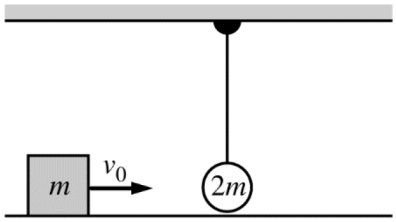

13. A block of mass m travels with speed v_0 to the right on a horizontal surface with negligible friction toward a sphere of mass $2m$ hanging at rest from a light cord, as shown above. The block collides elastically with the sphere. Which of the following correctly describes the speed and direction of the block and the speed of the sphere a short time after the collision?

	Speed and Direction of Block	Speed of Sphere
(A)	$v_0/3$ to the left	Slightly less than $2v_0/3$
(B)	$v_0/3$ to the right	Slightly less than $2v_0/3$
(C)	Zero	Slightly less than v_0
(D)	v_0 to the left	Zero

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GO ON TO THE NEXT PAGE.

14. A block of mass m slides along a frictionless surface with kinetic energy K_i. It collides with a block of mass $3m$ that is initially at rest, and the two blocks stick together and slide with total kinetic energy K_f. What is the ratio $K_f : K_i$?

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

Questions 15-16 refer to the following material.

A meteoroid is in a circular orbit 600 km above the surface of a distant planet. The planet has the same mass as Earth but has a radius that is 90% of Earth's (where Earth's radius is approximately 6370 km).

15. The acceleration of the meteoroid due to the gravitational force exerted by the planet is most nearly

(A) 9 m/s^2 toward the center of the planet
(B) 9 m/s^2 in the direction of the meteoroid's motion
(C) 10 m/s^2 toward the center of the planet
(D) 10 m/s^2 in the direction of the meteoroid's motion

16. Does the planet exert a torque on the meteoroid with respect to the center of mass of the planet? Why or why not?

(A) Yes, because the planet exerts a centripetal force on the meteoroid.
(B) Yes, because the meteoroid's direction of motion is constantly changing.
(C) No, because the force exerted by the planet on the meteoroid has a negligible magnitude.
(D) No, because the planet exerts a force on the meteoroid parallel to its position vector relative to the center of mass of the planet.

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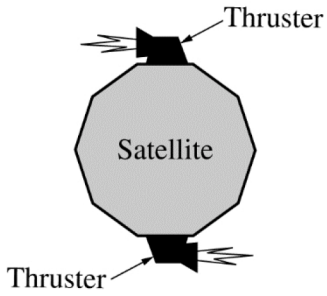

17. A satellite in a circular orbit around Earth is initially not rotating with respect to its center of mass. Two identical thrusters on opposite sides of the satellite fire in opposite directions over the same 10-minute time interval, as shown above, and then turn off. How does the firing of the thrusters affect the mechanical energy of the satellite-Earth system and the shape of the satellite's orbit, if at all?

	Mechanical Energy of Satellite-Earth System	Shape of Orbit
(A)	No effect	No effect
(B)	No effect	Would change
(C)	Increases	No effect
(D)	Increases	Would change

18. A point charge of magnitude $2q$ exerts an electrostatic force of magnitude F on a point charge of magnitude q that is a distance R away. What is the magnitude of the force that the $2q$ point charge exerts on a point charge of magnitude $3q$ that is a distance $R/5$ away?

(A) $15F$
(B) $30F$
(C) $75F$
(D) $150F$

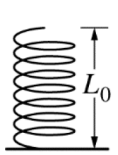

Figure 1

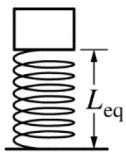

Figure 2

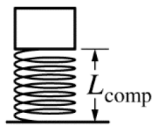

Figure 3

19. A vertical spring has unstretched length L_0, as shown in Figure 1. A block is attached to the top of the spring and slowly lowered until it is at rest and the spring has length Leg, as shown in Figure 2. The block is then pushed down until the spring is compressed to length L_{comp}, as shown in Figure 3, and then released. After release, at what height will the kinetic energy of the block be maximum?

(A) L_0
(B) L_{eq}
(C) L_{comp}
(D) $\left(L_{eq} + L_{comp}\right)/2$

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GO ON TO THE NEXT PAGE.

Cart Mass (kg)	Applied Force (N)	Time Force is Exerted (s)	Final Momentum (kg•m/s)	Final Kinetic Energy (J)
1	5	2	10	50
2	5	2	10	

20. Two frictionless lab carts start from rest and are pushed along a level surface by a constant force. Students measure the magnitude and duration of the force on each cart, as shown in the partially completed data table above, and calculate final kinetic energy and momentum. Which cart has a greater kinetic energy at the end of the push?

(A) The 1 kg cart
(B) The 2 kg cart
(C) Both carts have the same amount of kinetic energy.
(D) The relationship cannot be determined without knowing the distance each cart moved as the force was being applied.

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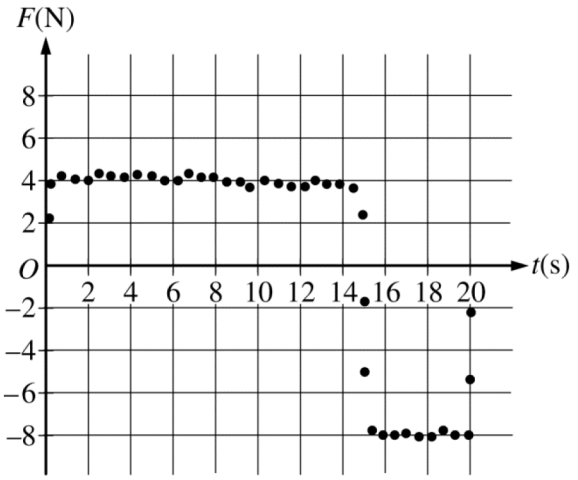
GO ON TO THE NEXT PAGE.

21. A simple pendulum consists of a sphere tied to the end of a string of negligible mass. The sphere is pulled back until the string is horizontal and then released from rest. Assume gravitational potential energy is zero when the sphere is at its lowest point. What angle will the string make with the horizontal when the kinetic energy and the potential energy of the sphere-Earth system are equal?

(A) Greater than 45°
(B) Equal to 45°
(C) Less than 45°
(D) It cannot be determined without knowing the mass of the sphere.



22. A stationary cart attached to a force gauge is on a straight, horizontal, frictionless track. A student uses the force gauge to move the cart, and the gauge produces the graph of force as a function of time shown above. How does the momentum of the cart change during the time interval 0 s to 20 s?

(A) The momentum increases in magnitude during the entire time interval.
(B) The momentum decreases in magnitude during the entire time interval.
(C) The momentum increases in magnitude at first, then decreases and reverses direction.
(D) The momentum increases in magnitude at first, then decreases without reversing direction.

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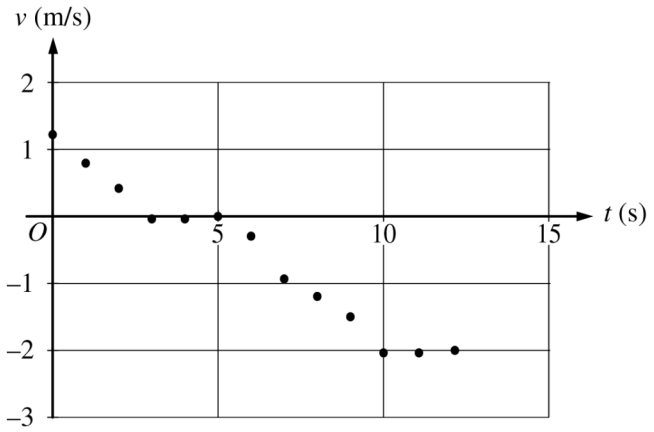

23. An engineer measures the velocity v of a remote-controlled cart on a straight track at regular time intervals. The data are shown in the graph above. During which of the following time intervals did the cart return to its position at time $t = 0$ s?

(A) $3 \text{ s} \le t < 5 \text{ s}$
(B) $5 \text{ s} \le t < 7 \text{ s}$
(C) $7 \text{ s} \le t < 10 \text{ s}$
(D) $10 \text{ s} \le t < 12 \text{ s}$

24. A guitar string with length 0.80 m resonates at a fundamental frequency of 320 Hz. A person presses on the string so that its effective length is reduced to 0.65 m, but the tension in the string does not change. The fundamental frequency of the 0.65 m string is most nearly

(A) 260 Hz
(B) 320 Hz
(C) 390 Hz
(D) 530 Hz

25. A student produces several standing waves on a string by adjusting the frequency of vibration at one end of the string. The student measures the wavelength λ and frequency f for each standing wave produced. Which of the following procedures and calculations will allow the student to determine the wave speed on the string?

(A) Graph λ as a function of $1/f$. The slope of the line is equal to the wave speed.
(B) Graph i as a function off. The slope of the line is equal to the wave speed.
(C) Graph λ as a function of $1/f$. The area under the line is equal to the wave speed.
(D) Graph λ as a function of f. The area under the line is equal to the wave speed.

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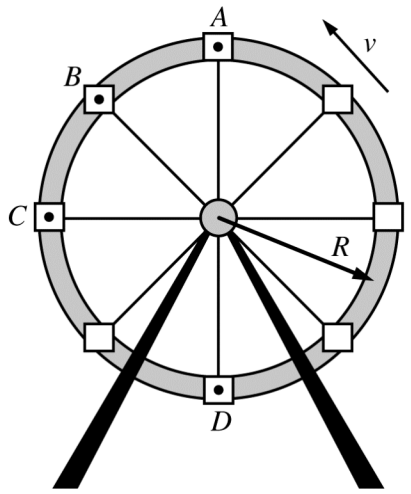
GO ON TO THE NEXT PAGE.

Questions 26-28 refer to the following material.



An amusement park ride consists of a large vertical wheel of radius R that rotates counterclockwise on a horizontal axis through its center, as shown above. The cars on the wheel move at a constant speed v. Points A and D represent the position of a car at the highest and lowest point of the ride, respectively. A person of weight F_g sits upright on a seat in one of the cars. As the seat passes point A, the seat exerts a normal force with magnitude $0.8F_g$ on the person. While passing point A, the person releases a small rock of mass m, which falls to the ground without hitting anything.

26. Which of the following best describes the passenger's linear and angular velocity while passing point A ?

	Linear velocity	Angular velocity
(A)	Constant	Changing
(B)	Constant	Constant
(C)	Changing	Changing
(D)	Changing	Constant

27. What is the normal force exerted on the rider when passing point D ?

(A) $0.2F_g$

(B) $0.8F_g$

(C) $1.0F_g$

(D) $1.2F_g$

28. The kinetic energy of the rock when it is at the same height as point D is most nearly

(A) $\frac{1}{2}mv^2$

(B) $\frac{1}{2}2mgR$

(C) $\frac{1}{2}4mgR$

(D) $\frac{1}{2}m\left(v^2 + 4gR\right)$

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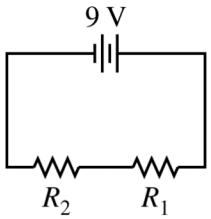
29. A negatively charged rod is placed in a small container filled with air that is electrically neutral. The container is then sealed. Fifteen seconds later, measurements reveal that the air inside the container has a net negative charge. What is the primary reason that the air becomes negatively charged?

(A) The extra electrons on the rod repel each other and therefore move away from the rod into the air.

(B) When air molecules bounce off the rod, negative charge transfers from the rod to some of those molecules.

(C) The electric force of the rod induces the air molecules near the rod to become negative, even if those molecules never touch the rod.

(D) When air molecules bounce off the rod, the rod's charge stays the same, but the rod exerts a force on the molecules that causes some of them to become negative.



30. The circuit shown above consists of a 9 V battery connected in series to two resistors. The potential difference across resistor R_1 is measured to be 3 V. Which of the following indicates the potential difference across resistor R_2 and explains why it has that value?

(A) 3 V, because the current through both resistors is the same

(B) 3 V, because the potential difference across resistors in series is always the same

(C) 6 V, because each coulomb of charge passing through the resistors loses 9 J of potential energy

(D) 6 V, because one-third of the current is used up in R_1, leaving two-thirds of the current to travel through R_2

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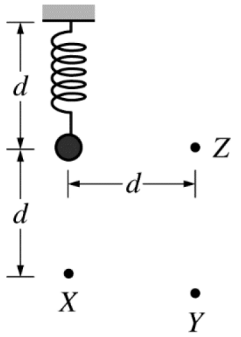

31. An object hangs in equilibrium from a spring, as shown above. The object is then displaced to one of the labeled points X, Y, or Z. Which of the following correctly ranks the elastic potential energy U stored in the spring when the object is at each of the three positions?

(A) $U_Z > (U_X = U_Y)$

(B) $U_Y > (U_X = U_Z)$

(C) $U_Y > U_X > U_Z$

(D) $U_Y > U_Z > U_X$

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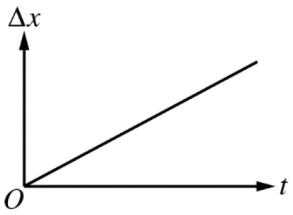
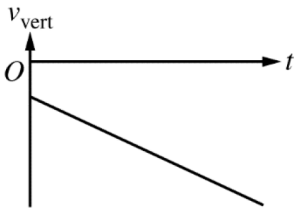
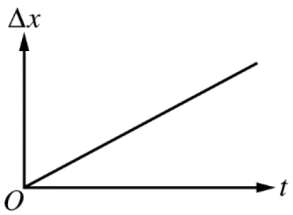
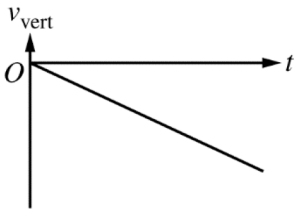
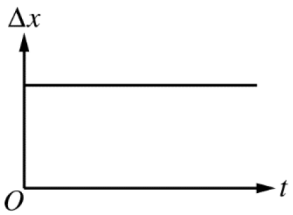
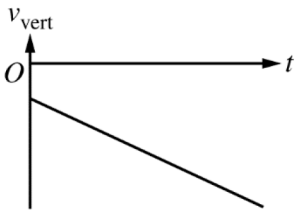
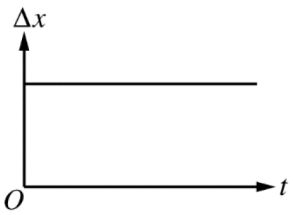
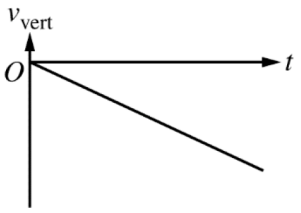
32. At time $t = 0$, a projectile is launched from the top of a cliff at an angle of 30 degrees below the horizontal. Which of the following pairs of graphs best represents the horizontal displacement Δx and the vertical velocity component v_{vert} of the projectile as a function of time t ?

	Horizontal Displacement	Vertical Velocity Component
(A)		
(B)		
(C)		
(D)		

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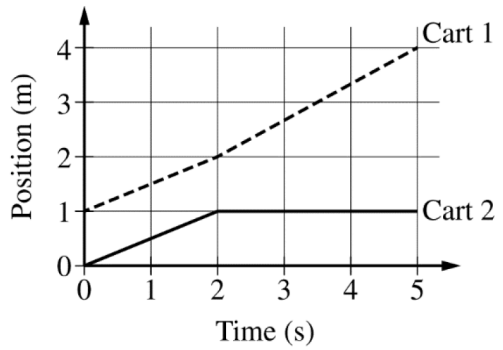

33. The graph above represents the position of two identical carts on a straight horizontal track as a function of time. Which of the following statements about the magnitude of the momentum of the two-cart system's center of mass, Pcom: is true?

(A) p_{com} is constant from $t = 0$ s to $t = 5$ s.

(B) p_{com} is smaller after $t = 2$ s than it is before $t = 2$ s.

(C) p_{com} is larger after $t = 2$ s than it is before $t = 2$ s.

(D) p_{com} increases at a constant rate from $t = 0$ s to $t = 5$ s.

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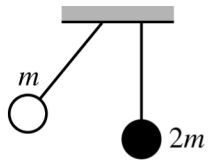
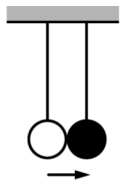


Before Release



Immediately
After Collision

34. Sphere 1 of mass m and sphere 2 of mass $2m$ hang from light strings. Sphere 1 is pulled back, as shown above, and released from rest. Sphere 1 has kinetic energy K_i immediately before colliding with sphere 2. The two spheres stick together and move horizontally for an instant after the collision. During the collision, what is the change in the kinetic energy ΔK of the two-sphere system?

(A) 0
(B) $-K_i/3$
(C) $-K_i/2$
(D) $-2K_i/3$

35. A wheel with radius 0.33 m and rotational inertia $2.0\ \text{kg}\cdot\text{m}^2$ spins on an axle with an initial angular speed of $3.0\ \text{rad/s}$. Friction in the axle exerts a torque on the wheel, causing the wheel to stop after 6.0 s. The average torque exerted on the wheel as it slows down has magnitude

(A) 0.50 N•m
(B) 1.0 N•m
(C) 2.0 N•m
(D) 3.0 N•m

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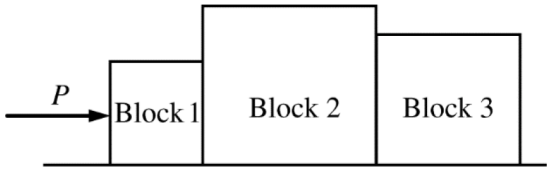
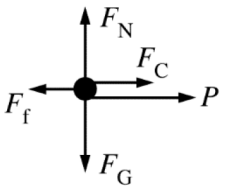
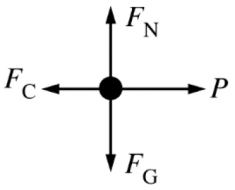


36. Three blocks are pushed along a rough surface by a force with magnitude P, as shown above. F_C is the magnitude of the contact force between blocks 2 and 3, and F_f, F_N, and F_G are the magnitudes of the friction, normal, and gravitational forces on block 3, respectively. Which of the following is a correct free-body diagram for block 3 ?

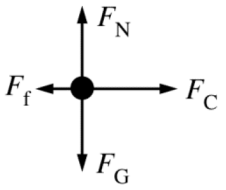
(A)



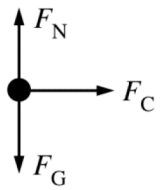
(B)



(C)



(D)



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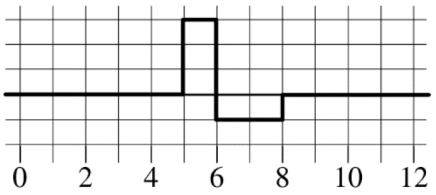
Directions: For each of the questions or incomplete statements below, two of the suggested answers will be correct. For each of these questions, you must select both correct choices to earn credit. No partial credit will be earned if only one correct choice is selected. Select the two that are best in each case and then fill in the corresponding circles that begin with number 131 on the answer sheet.

131. A block slides down an inclined plane in a classroom. Which of the following pieces of information are needed to determine whether the velocity of the block will be constant? Select two answers.

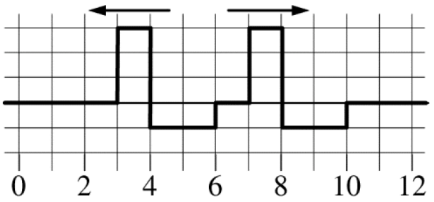
(A) The mass of the block
(B) The angle of the inclined plane
(C) The acceleration due to gravity in the classroom
(D) The coefficient of kinetic friction between the block and the inclined plane

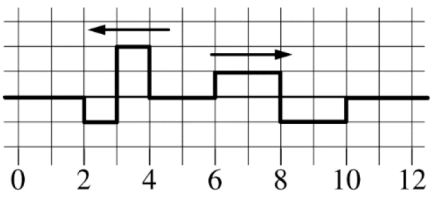
132. A test car and its driver, with a combined mass of 600 kg, are moving along a straight, horizontal track when a malfunction causes the tires to stop rotating. The car skids to a halt with constant acceleration, leaving skid marks on the road during the whole time it skids. Which two of the following measurements, taken together, would allow engineers to find the total mechanical energy dissipated during the skid? Select two answers.

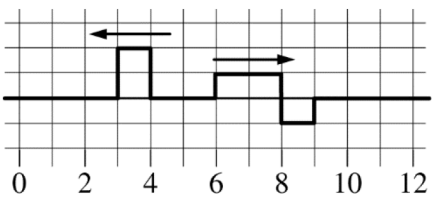
(A) The length of the skid marks
(B) The contact area of each tire with the track
(C) The coefficient of static friction between the tires and the track
(D) The coefficient of kinetic friction between the tires and the track

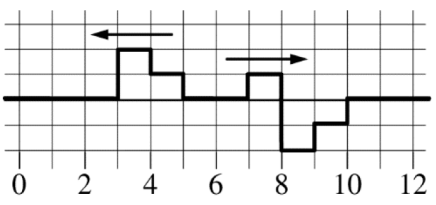


133. The figure above shows the result when two rectangular wave pulses overlap. If the pulses are moving at a rate of 1 tick mark per second, which of the following are possible graphs of the waves 2 s later? Select two answers.

(A)


(B)


(C)


(D)


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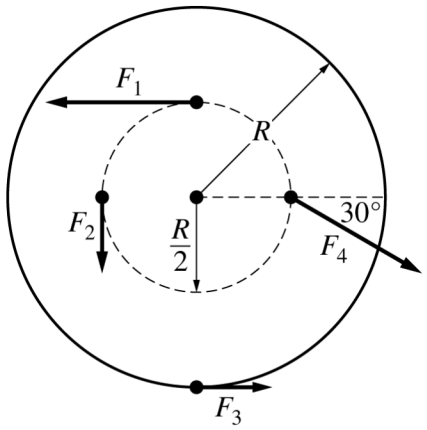

134. Four forces are exerted on a disk of radius R that is free to spin about its center, as shown above. The magnitudes are proportional to the length of the force vectors, where $F_1 = F_4$, $F_2 = F_3$, and $F_1 = 2F_2$. Which two forces combine to exert zero net torque on the disk? Select two answers.

(A) F_1
(B) F_2
(C) F_3
(D) F_4

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AP® Physics 1: Algebra-Based Exam

SECTION II: Free Response

2019

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

At a Glance

Total Time
1 hour and 30 minutes
Number of Questions
5
Percent of Total Score
50%
Writing Instrument
Either pencil or pen with black or dark blue ink
Electronic Device
Calculator allowed
Suggested Time
Approximately 25 minutes each for questions 2 and 3 and 13 minutes each for questions 1, 4, and 5
Weight
Approximate weights:
Questions 2 and 3: 26% each
Questions 1, 4, and 5: 16% each

IMPORTANT Identification Information

PLEASE PRINT WITH PEN:

1. First two letters of your last name ☐☐
   First letter of your first name ☐
2. Date of birth
   ☐☐ Month ☐☐ Day ☐☐☐☐ Year
3. Six-digit school code
   ☐☐☐☐☐☐
4. Unless I check the box below, I grant the College Board the unlimited right to use, reproduce, and publish my free-response materials, both written and oral, for educational research and instructional purposes. My name and the name of my school will not be used in any way in connection with my free-response materials. I understand that I am free to mark "No" with no effect on my score or its reporting.
   No, I do not grant the College Board these rights. ☐

Instructions

The questions for Section II are printed in this booklet. You may use any blank space in the booklet for scratch work, but you must write your answers in the spaces provided for each answer. A table of information and lists of equations that may be helpful are in the booklet. Calculators, rulers, and straightedges may be used in this section.

All final numerical answers should include appropriate units. Credit for your work depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should show your work for each part in the space provided after that part. If you need more space, be sure to clearly indicate where you continue your work. Credit will be awarded only for work that is clearly designated as the solution to a specific part of a question. Credit also depends on the quality of your solutions and explanations, so you should show your work.

Write clearly and legibly. Cross out any errors you make; erased or crossed-out work will not be scored. You may lose credit for incorrect work that is not crossed out.

Manage your time carefully. You may proceed freely from one question to the next. You may review your responses if you finish before the end of the exam is announced.

Form I
Form Code 4PBP4-S

83

AP® PHYSICS 1 TABLE OF INFORMATION

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

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

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

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

The following conventions are used in this exam.

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

AP® PHYSICS 1 EQUATIONS

MECHANICS

$v_x = v_{x0} + a_x t$

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

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

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

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

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

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

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

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

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

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

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

$\omega = \omega_0 + \alpha t$

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

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

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

$L = I\omega$

$\Delta L = \tau \Delta t$

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

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

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

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

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

$\Delta U_g = mg \Delta y$

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

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

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

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

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

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

ELECTRICITY

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

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

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

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

$P = I \Delta V$

$R_s = \sum_i R_i$

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

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

WAVES

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

f = frequency
v = speed
λ = wavelength

GEOMETRY AND TRIGONOMETRY

Rectangle
$A = bh$

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

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

Rectangular solid
$V = \ell w h$

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

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

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

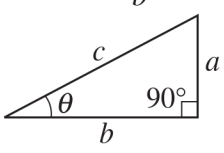
Right triangle

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

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

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

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



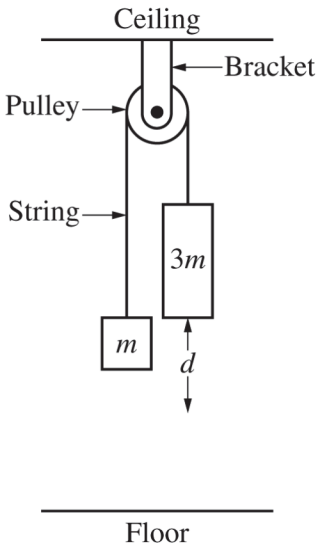
PHYSICS 1

Section II

Time—1 hour and 30 minutes

5 Questions

Directions: Questions 1, 4, and 5 are short free-response questions that require about 13 minutes each to answer and are worth 7 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



1. (7 points, suggested time 13 minutes)

   Two blocks, with masses m and $3m$, are attached to the ends of a string with negligible mass that passes over a pulley, as shown above. The pulley has negligible mass and friction and is attached to the ceiling by a bracket. The blocks are simultaneously released from rest.

   (a) Derive an equation for the speed v of the block of mass $3m$ after it falls a distance d in terms of m, d, and physical constants, as appropriate.

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(b) Determine the work done by the string on the two-block system as each block moves a distance d.

(c) The acceleration of the center of mass of the blocks-string-pulley system has magnitude acom. Briefly explain, in terms of any external forces acting on the system, why acom is less than g.

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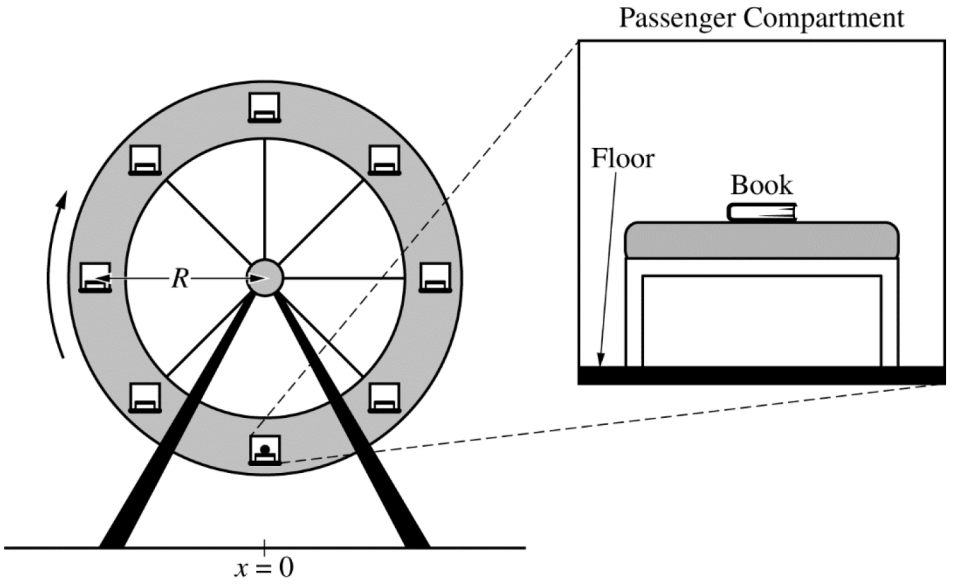
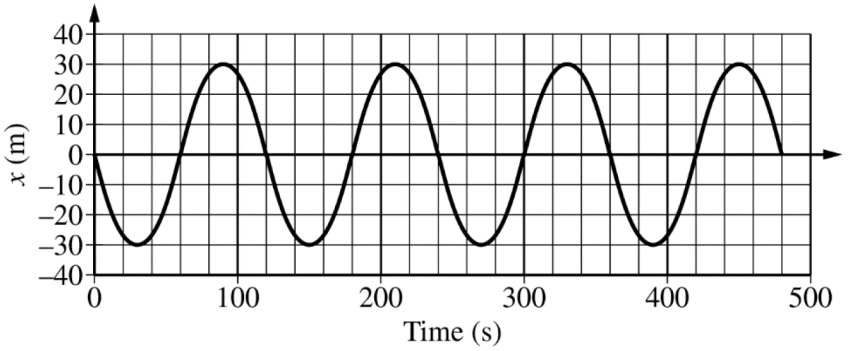


2. (12 points, suggested time 25 minutes)

A passenger compartment of a rotating amusement park ride contains a bench on which a book of mass m_b is placed, as indicated by the dot in the left figure above. The compartment moves with a constant angular speed about the center of the ride along a circular path of radius R. The bench remains horizontal throughout the compartment's motion. The right figure above shows a magnified view of the compartment.

The graph below shows the horizontal (x) component of the book's position as a function of time, where the $+x$-direction is to the right.



(a)

i. Determine the period of revolution of the book.

ii. Calculate the tangential speed v, (not the angular speed) of the book.

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(b)

i. On the dot below, which represents the book, draw and label the forces (not components) that act on the book at the lowest point of its circular path. Each force must be represented by a distinct arrow starting on, and pointing away from, the dot.



ii. At the lowest point of the circular path, the book is moving only in the horizontal direction. In what direction, if any, is the net vertical force on the book?

____ Up ____ Down -No direction, since the net vertical force is equal to zero

Without deriving any equations, briefly explain your reasoning in terms of the book's motion.

(c) Derive an algebraic equation for the vertical force that the bench exerts on the book at the lowest point of the circular path in terms of the book's mass m_b, tangential speed v_b, radius R of the path, and physical constants, as appropriate. Do not substitute any numerical values for variables or physical constants.

(d) At the lowest point of the circular path, is the force that the bench exerts on the book greater than, less than, or equal to the weight of the book?

____ Greater than ____ Less than ____ Equal to

Briefly explain how your answers in (b)ii and (c) support your selection.

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3. (12 points, suggested time 25 minutes)

A company selling a type of spring makes the following claim: "The elastic potential energy that the spring is capable of storing for a given compression distance does not decrease, even after the spring compresses and/or stretches hundreds of times." The students in a physics class have decided to test the company's claim.

(a)

i. State a basic physics principle or law the students could use in designing an experiment to test the company's claim.

ii. Using the principle or law stated in part (a)i, determine an equation for the elastic potential energy stored in the spring in terms of quantities that can be obtained from measurements made with equipment usually found in a school physics laboratory.

(b) Design an experimental procedure the students could use to collect the data needed to test the company's claim. 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 and the equipment used to measure them. 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

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(b) Continued

Describe the overall procedure to be used, referring to the table. Provide enough detail so 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) Explain how the students should analyze the data to determine whether the company's claim is true, i.e., whether the energy stored by the spring for a given compression distance does not decrease after the spring has compressed and/or stretched hundreds of times.

Question 3 continues on the next page.

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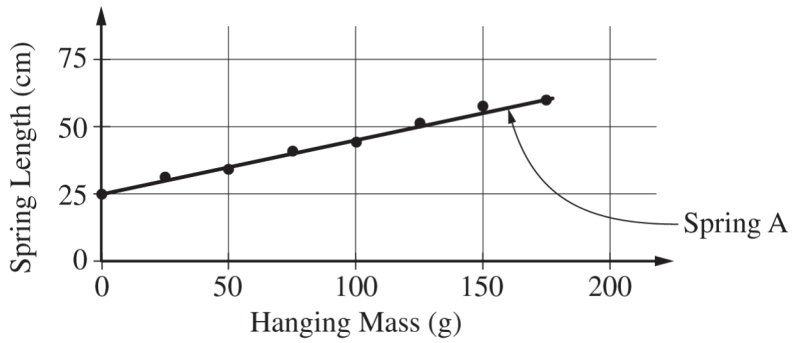
(d) The students also investigate two springs, spring A and spring B, made by another company. The students hang spring A vertically, attaching blocks of various known masses from the bottom end of the spring and measuring the total length of the spring for each block. The students graph the spring length as a function of hanging mass and draw the line of best fit, as shown below.



i. The students follow the same procedure using spring B, which has the same equilibrium length as spring A but stores more energy than spring A for a given displacement. On the graph above, sketch what the line of best fit could look like for the data obtained using spring B.

ii. The students attach a 100 g block to spring B and let it hang at rest. The students pull the block down by 1 cm, release it, and measure the time interval Δt for one oscillation. The students then repeat the procedure, but pull the block down by 2 cm instead of 1 cm. For which initial displacement, if either, is Δt greater?

____ Δt is greater for the 1 cm displacement.

____ Δt is greater for the 2 cm displacement.

____ Δt is the same in both cases.

Briefly explain your reasoning.

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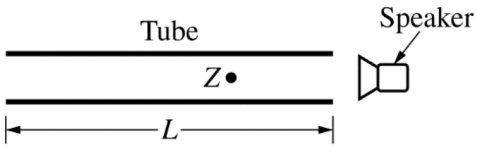


Note: Figure not drawn to scale.

4. (7 points, suggested time 13 minutes)

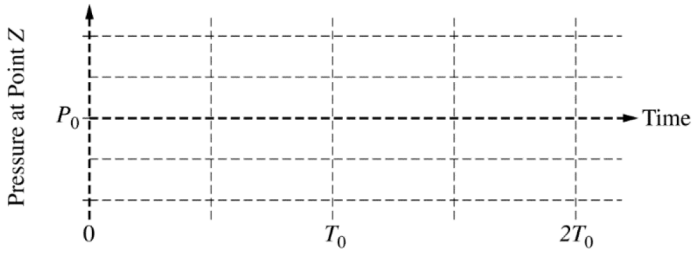
A speaker is placed near a narrow tube of length $L = 0.30$ m, open at both ends, as shown above. The speaker emits a sound of known frequency, which can be varied. A student slowly increases the frequency of the emitted sound waves, without changing the amplitude, until the fundamental frequency fo inside the tube is reached and standing waves are produced (fundamental resonance). The speed of sound in air is 340 m/s.

(a)

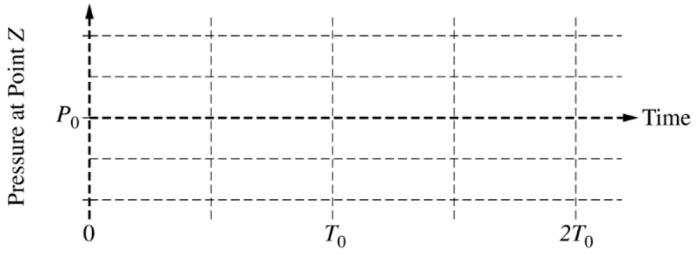
i. Calculate the period To of the sound waves at the fundamental resonance.

ii. For the fundamental resonance, consider the air pressure at point Z inside the tube. On the axes below, sketch the air pressure at point Z as a function of time. At time $t = 0$, the pressure at point Z is P_0, which is the atmospheric pressure.

Note: Do any scratch (practice) work on the grid at the bottom of the page. Only the sketch made on the grid immediately below will be graded.



The grid below is provided for scratch work only. Sketches made below will not be graded.



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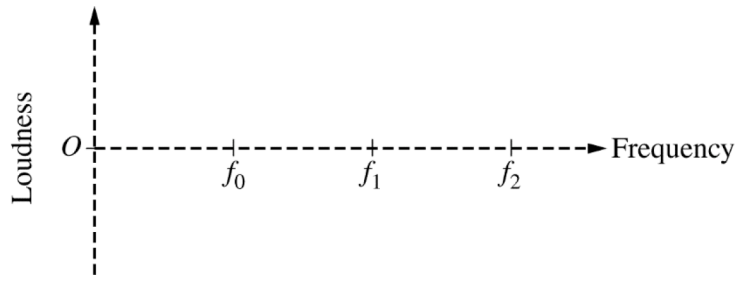
(b) The student continues to slowly increase the frequency of the sound waves emitted by the speaker without making any other changes to the setup. The student hears additional resonances at two higher frequencies, f_1 and f_2.

On the axes below, sketch the loudness of the sound (sound volume) heard by the student as a function of the frequency generated by the speaker for the range of frequencies shown on the horizontal axis. The fundamental frequency is f_0.



(c) The temperature of the air in the tube is increased. As the temperature increases, the speed of sound in the air increases. (Assume the size of the tube does not change). Does the tube's fundamental frequency increase, decrease, or stay the same?

____ Increase ____ Decrease ____ Stay the same

Briefly explain your reasoning.

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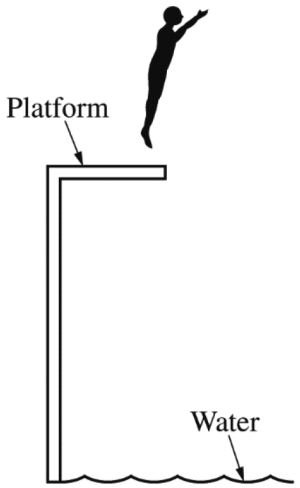

Figure 1

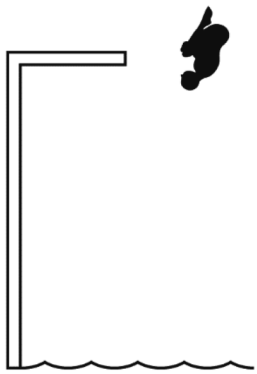

Figure 2

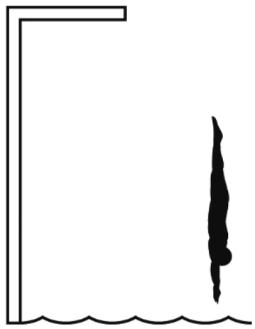

Figure 3

5. (7 points, suggested time 13 minutes)

The figures above show three stages of a dive performed by an athlete. During the dive, the athlete completes several rotations in midair while traveling from the platform to the surface of the water. Figure 1 shows the athlete just after jumping off the platform. Figure 2 shows the athlete rotating in midair. Figure 3 shows the athlete about to enter the water.

(a) In a clear, coherent paragraph-length response that may also contain figures and/or equations, explain why the athlete's angular speed increases between Figure 1 and Figure 2 but decreases between Figure 2 and Figure 3.

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(b) Is the rotational kinetic energy $K_{2,\text{rot}}$ of the athlete in Figure 2 greater than, less than, or equal to the rotational kinetic energy $K_{1,\text{rot}}$ of the athlete in Figure 1 ?

____ $K_{2,\text{rot}} > K_{1,\text{rot}}$ ____ $K_{2,\text{rot}} < K_{1,\text{rot}}$ ____ $K_{2,\text{rot}} = K_{1,\text{rot}}$

Briefly explain your answer.

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STOP

END OF EXAM

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