Advanced Placement Examination

PHYSICS 1

SECTION I

TABLE OF INFORMATION

CONSTANTS AND CONVERSION FACTORS

Proton mass,	$m_p = 1.67 \times 10^{-27}$ kg
Neutron mass,	$m_n = 1.67 \times 10^{-27}$ kg
Electron mass,	$m_e = 9.11 \times 10^{-31}$ kg
Electron charge magitude,	$e = 1.60 \times 10^{-19}$ C
Universal gravitational constant,	$G = 6.67 \times 10^{-11}$ $m^3/kg \cdot s^2$

PREFIXES

Factor	Prefix	Symbol
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

UNITS

Name	Symbol
meter	m
kilogram	kg
second	s
ampere	A
joule	J
watt	W
coulomb	C
volt	V
ohm	Ω

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES

θ	$\sin\theta$	$\cos\theta$	$\tan\theta$
0°	0	1	0
30°	1/2	$\sqrt{3}/2$	$\sqrt{3}/3$
37°	3/5	4/5	3/4
45°	$\sqrt{2}/2$	$\sqrt{2}/2$	1
53°	4/5	3/5	4/3
60°	$\sqrt{3}/2$	1/2	$\sqrt{3}$
90°	1	0	∞

The following conventions are used in this examination.

I. Unless otherwise stated, the frame of reference of any problem is assumed to be inertial.

II. The direction of any electric current is the direction of flow of positive charge (conventional current).

III. For any isolated electric charge, the electric potential is defined as zero at an infinite distance from the charge.

IV. For mechanics and thermodynamics equations, *W* represents the work done on a system.

GO ON TO THE NEXT PAGE.

AP PHYSICS 1

SECTION I

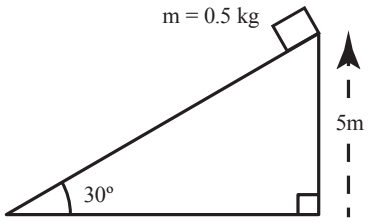
Note: To simplify calculations, you may use $g = 10$ m/s^2 in all problems.

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. What happens to the force of gravitational attraction between two small objects if the mass of each object is doubled and the distance between their centers is doubled?

   (A) It is doubled.
   (B) It is quadrupled.
   (C) It is halved.
   (D) It remains the same.

Questions 2-4 refer to the following figure:



2. If the surface of the incline is frictionless, how long will the block take to reach the bottom if it was released from rest at the top?

   (A) 0.5 s
   (B) 1.0 s
   (C) 1.4 s
   (D) 2.0 s

3. If the surface of the incline is frictionless, with what speed will the block reach the bottom if it was released from rest at the top?

   (A) 8 m/s
   (B) 10 m/s
   (C) 14 m/s
   (D) 18 m/s

4. If the coefficient of friction between the block and the incline is 0.4, how much work is done by the normal force on the block as it slides down the full length of the incline?

   (A) 0 J
   (B) 2.0 J
   (C) 4.0 J
   (D) 4.9 J

5. Two satellites are in circular orbit around the Earth. The distance from Satellite 1 to Earth's center is r_1, and the distance from Satellite 2 to the Earth's center is r_2, what is the speed of Satellite 2?

   (A) $v_1\sqrt{r_2/r_1}$

   (B) $v_1\sqrt{r_1/r_2}$

   (C) $v_1\left(\frac{r_2}{r_1}\right)$

   (D) $v_1\left(\frac{r_1}{r_2}\right)^2$

6. A simple harmonic oscillator has a frequency of 2.5 Hz and an amplitude of 0.05 m. What is the period of the oscillations?

   (A) 0.4 s
   (B) 0.2 s
   (C) 8 s
   (D) 20 s

7. Sound waves travel at 350 m/s through warm air and at 3500 m/s through brass. What happens to the wavelength of a 700 Hz acoustic wave as it enters brass from warm air?

   (A) It decreases by a factor of 20.
   (B) It decreases by a factor of 10.
   (C) It increases by a factor of 10.
   (D) The wavelength remains unchanged.

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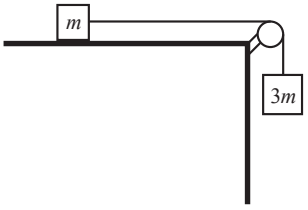
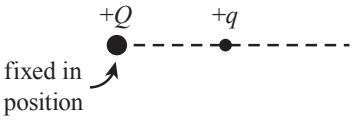


8. In the figure above, the coefficient of sliding friction between the small block and the tabletop is 0.2. If the pulley is frictionless and massless, what will be the acceleration of the blocks once they are released from rest?

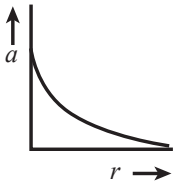
   (A) 0.5 *g*
   (B) 0.6 *g*
   (C) 0.7 *g*
   (D) 0.8 *g*

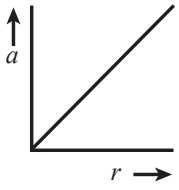
9. Two people, one of mass 100 kg and the other of mass 50 kg, stand facing each other on an ice-covered (essentially frictionless) pond. If the heavier person pushes on the lighter one with a force **F**, then

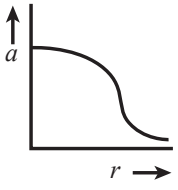
   (A) the force felt by the heavier person is (–1/2) **F**
   (B) the force felt by the person is –2 **F**
   (C) the magnitude of the acceleration of the lighter person will be half of the magnitude of the acceleration of the heavier person
   (D) the magnitude of the acceleration of the lighter person will be twice the magnitude of the acceleration of the heavier person

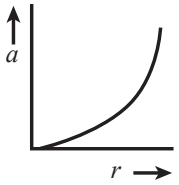


10. The figure above shows two positively charged particles. The $+Q$ charge is fixed in position, and the $+q$ charge is brought close to $+Q$ and released from rest. Which of the following graphs best depicts the acceleration of the $+q$ charge as a function of its distance r from $+Q$?

(A)


(C)


(B)


(D)


11. A spring of force constant 800 N/m is hung from a ceiling. A block of mass 4.0 kg is hung from its lower end and allowed to come to rest. How far will the block stretch the spring?

    (A) 0.50 cm
    (B) 1.0 cm
    (C) 3.2 cm
    (D) 5.0 cm

12. A crane lifts a shipping crate that weighs 5000 N at a constant speed of 4 m/s. At what rate is this crane doing work on the crate?

    (A) 2000 W
    (B) 4000 W
    (C) 10,000 W
    (D) 20,000 W

13. An astronaut lands on a planet whose mass and radius are each twice that of Earth. If the astronaut weights 800 N on Earth, how much will he weigh on this planet?

    (A) 200 N
    (B) 400 N
    (C) 800 N
    (D) 1600 N

14. An object of mass 5 kg is acted upon by exactly four forces, each of magnitude 10 N. Which of the following could NOT be the resulting acceleration of the object?

    (A) 0 m/s^2
    (B) 4 m/s^2
    (C) 8 m/s^2
    (D) 10 m/s^2

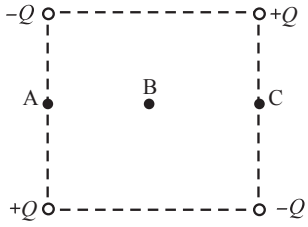
15. A rope stretched between two fixed points can support transverse standing waves. What is the ratio of the sixth harmonic frequency to the third harmonic frequency?

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

GO ON TO THE NEXT PAGE.

16. How much current does a 60 W light bulb draw if it operates at a voltage of 120 V?

(A) 0.25 A
(B) 0.5 A
(C) 2 A
(D) 4 A

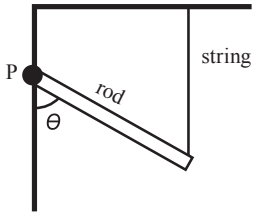


17. The figure above shows a plane diagram. The figure shows four point charges arranged at the corners of a square with point B as its center. A positive charge would experience no net force if it were placed at which of the three points shown in the figure

(A) A only
(B) B only
(C) C only
(D) A, B, or C

18. A beam of monochromatic light entering a glass window pane the air will experience a change in

(A) frequency and wavelength
(B) frequency and speed
(C) speed and wavelength
(D) speed only



19. If the rod in the figure above is uniform and has mass m, what is the tension in the supporting string? The rod is free to rotate about point P.

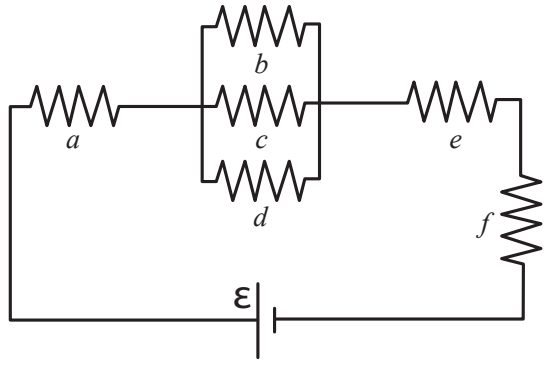
(A) $\frac{1}{2}mg\sin\theta$

(B) $mg\sin\theta$

(C) $\frac{1}{2}mg\cos\theta$

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

Questions 20-21 refer to the circuit shown below:



20. If each of the resistors in the circuit has a resistance of 3 Ω, what must be the emf of the battery if the circuit draws a total current of 3 A?

(A) 0.3 V
(B) 10 V
(C) 30 V
(D) 54 V

21. Which of the following relates P_b, the rate at which energy is dissipated by resistor b, and P_e, the rate at which energy is dissipated by resistor e?

(A) $P_b = 3P_e$
(B) $P_b = 9P_e$
(C) $P_e = 3P_b$
(D) $P_e = 9P_b$

22. In which of the following situations involving a source of sound and a detector of the sound is it possible that there is NO perceived Doppler shift?

(A) The source travels toward the stationary detector.
(B) The detector travels toward the stationary source.
(C) Both the source and detector travel in the same direction.
(D) Both the source and detector travel in opposite directions, with the source and detector moving away from each other.

23. If L, M, and T denote the dimensions of length, mass, and time, respectively, what are the dimensions of power?

(A) L^2M / T^2
(B) M^2L / T^2
(C) L^2M / T^3
(D) ML^2 / T^3

GO ON TO THE NEXT PAGE.

24. 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) $\sqrt{2GMm / R}$

25. At a distance of 20 m from a source of sound, the sound level is 40 dB. If the observer backs up to a distance of 40 m from the source, what will the sound level be? (Assume no absorption nor reflection of sound).

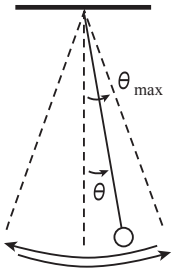
(A) 14 dB
(B) 20 dB
(C) 28 dB
(D) 34 dB

26. An electric dipole consists of a pair of equal but opposite point charges of magnitude 4.0 nC separated by a distance of 2.0 m. What is the electric field strength at the point midway between the charges?

(A) 0
(B) 9.0×10^4 N/C
(C) 1.8×10^5 N/C
(D) 7.2×10^5 N/C

27. A projectile is launched with an initial velocity of magnitude a at an angle β to the horizontal. Find its maximum vertical displacement, ignoring effects due to the air.

(A) $(a^2 \sin 2\beta) / (2g)$
(B) $(a^2 \sin^2 \beta) / (2g)$
(C) $(a^2 \sin 2\beta) / g$
(D) $(a^2 \sin^2 \beta) / g$



28. A simple pendulum executes simple harmonic motion as it swings through small angles of oscillation. If θ_{max} denotes the amplitude of the oscillations, which of the following statements is true?

(A) When $\theta = 0$, the tangential acceleration is 0.
(B) When $\theta = \theta_{max}$, the tangential acceleration is 0.
(C) When $\theta = 0$, the speed is 0.
(D) When $\theta = 0$, the restoring force is maximized.

29. Wire Y is made of the same material but has twice the diameter and half the length of Wire X. If Wire X has a resistance of R then Wire Y would have a resistance of

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

30. Two traveling waves of equal frequency, one of amplitude 4 cm and the other of amplitude 6 cm, superimpose in a single medium. Which of the following best describes the displacement, D, of the resultant wave?

(A) $2 \text{ cm} \leq D \leq 10 \text{ cm}$
(B) $D = 5$ cm
(C) $D = 10$ cm
(D) $10 \text{ cm} \leq D \leq 12 \text{ cm}$

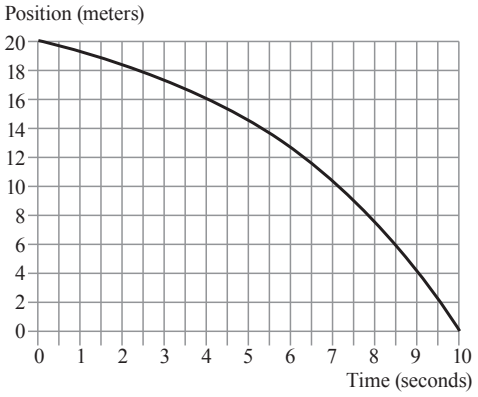
31. A uniform bar is lying on a flat table. Besides the gravitational and normal forces (which cancel), the bar is acted upon by two other forces, $\mathbf{F}_1$ and $\mathbf{F}_2$, which are parallel to the surface of the table. If the net force on the rod is zero, then which one of the following is true?

(A) The net torque on the bar must also be zero.
(B) The bar can accelerate translationally if $\mathbf{F}_1$ and $\mathbf{F}_2$ are not applied at the same point.
(C) The net torque will be zero if $\mathbf{F}_1$ and $\mathbf{F}_2$ are applied at the same point.
(D) The bar cannot accelerate translationally or rotationally.

GO ON TO THE NEXT PAGE.

32. An elevator has a mass of 500 kg. It may safely carry an additional mass of 1000 kg and accelerate upward at 2 m/s^2. What is the tension in the cable under these maximum conditions?

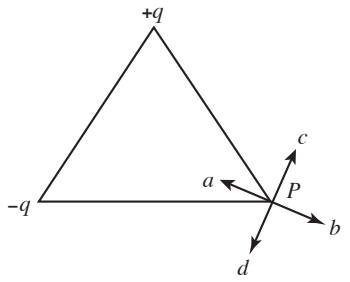
(A) 4,900 N
(B) 9,800 N
(C) 14,700 N
(D) 18,000 N



33. In the graph above, the instantaneous velocity at 9 seconds is closest to

(A) $\frac{4}{9}$ m/s
(B) $-\frac{4}{9}$ m/s
(C) $\frac{11}{4}$ m/s
(D) $-\frac{11}{4}$ m/s

Questions 34-35 refer to the following figure:

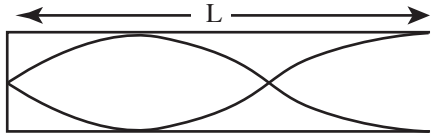


34. Two charges are placed as shown at the vertices of an equilateral triangle. What is the direction of the electric field at point P?

(A) a
(B) b
(C) c
(D) d

35. If a charge of $+q$ is placed at point P, the electric field at point P would

(A) increase by $\frac{1}{3}$
(B) increase by $\frac{1}{2}$
(C) decrease by $\frac{1}{3}$
(D) remain the same



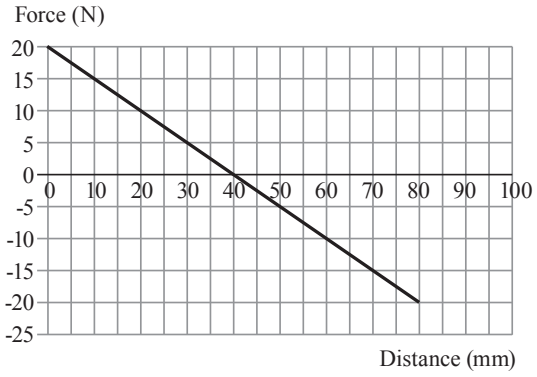
36. A tube with one end closed and one end open resonates for a wave with wavelength λ_a as shown. The next shorter wavelength at which resonance will occur is λ_b. The ratio of these two wavelengths λ_a / λ_b is

(A) $\frac{1}{4}$
(B) $\frac{1}{3}$
(C) $\frac{3}{5}$
(D) $\frac{5}{3}$

GO ON TO THE NEXT PAGE.

Questions 37-38 refer to the following graph.

A spring stretches 4.0 cm when a 0.2 kg mass is hung from it. The mass is lifted up four cm and dropped. The following graph represents the net force acting on a spring as it falls 8 cm from top to bottom.



Net Force versus Distance

37. What is the net work done as the mass falls from 0 to 8 cm?

(A) 80 J
(B) 20 J
(C) 0 J
(D) –5 J

38. What is the maximum velocity of the mass?

(A) 0.4 m/s
(B) 0.8 m/s
(C) 1.41 m/s
(D) 2 m/s

39. An alarm whose frequency is 400 Hz is dropped out of a third-floor window. The student who drops it measures the frequency with a very sensitive oscilloscope. The measured frequency

(A) appears higher than 400 Hz and the frequency increase as it falls
(B) appears higher than 400 Hz and the frequency decreases as it falls
(C) appears lower than 400 Hz and the frequency decreases as it falls
(D) appears lower than 400 Hz and the frequency increases as it falls

40. A small cart of mass M is initially at rest. It collides elastically with a large cart of mass $4M$ and velocity v. The large cart loses half its kinetic energy to the little cart. The little cart now has a velocity of

(A) $1.41v$
(B) v
(C) $2v$
(D) $4v$

Questions 41-42 refer to the following setup.

A stopper of mass M is tied to a string of length R and swings around horizontally in uniform circular motion with a velocity of v when acted on by a force of F.

41. What is the period of the stopper?

(A) $\sqrt{\frac{4\pi^2 MR}{F}}$
(B) $\sqrt{\frac{MR}{4\pi^2 F}}$
(C) $\sqrt{\frac{4\pi^2}{FMR}}$
(D) $\sqrt{\frac{4\pi^2 R}{MF}}$

42. What is the power developed by the force?

(A) FR
(B) Fv
(C) Mv^2
(D) 0

43. Two objects, A and B, have equal charge and equal mass. Neither body is in motion because the gravitational and electrostatic forces between them are equal. If the mass of Object A is halved, equilibrium will be maintained if

(A) the charge on Object A were doubled.
(B) the charge on Object B were halved.
(C) the charge on Object B were doubled.
(D) the mass on Object B were halved.

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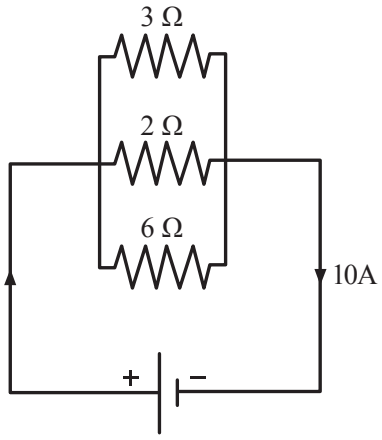


44. For the circuit shown above, what is the voltage of the battery (assuming the battery has no internal resistance)?

(A) 1 V
(B) 5 V
(C) 10 V
(D) 50 V

45. Which of the following changes to a circuit will always bring about an increase in the current?

(A) Increased voltage and increased resistance
(B) Decreased voltage and decreased resistance
(C) Increased voltage and decreased resistance
(D) Decreased voltage and increased resistance

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. If the acceleration of an object is not zero, then which of the following could be constant? Select two answers.

(A) Speed
(B) Linear momentum
(C) Kinetic energy
(D) Velocity

47. A lightweight toy car crashes head-on into a heavier toy truck. Which of the following statements is true as a result of the collision? Select two answers.

(A) The car will experience a greater impulse than the truck.
(B) The car will experience a greater change in momentum than the truck.
(C) The magnitude of the acceleration experienced by the car will be greater than that experience by the truck.
(D) The total momentum in the collision will be conserved.

48. A musician plucks a string on an acoustic guitar. Standing waves will most likely occur in which of the following media? Select two answers.

(A) The guitar string
(B) The air surrounding the guitar
(C) The air inside the guitar
(D) The ground beneath the musician

49. A mass on a spring and a simple pendulum undergo simple harmonic motion. There is no friction present for the mass on the string. Which of the following statements are true? Select two answers.

(A) Mechanical energy is constant.
(B) The momentum of the mass is constant.
(C) The period of the mass is constant.
(D) The restoring force is constant.

50. The electric field strength in a vacuum at a point at a distance from a source charge is NOT dependent on which of the following? Select two answers.

(A) Another charge placed at that point
(B) The magnitude of the source charge
(C) The distance from the soure charge
(D) The sign of the source charge

END OF SECTION I

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.

GO ON TO THE NEXT PAGE.

ADVANCED PLACEMENT PHYSICS 1 EQUATIONS

NEWTONIAN MECHANICS

$v = v_0 + at$

$x = x_0 + v_0 t + \frac{1}{2}at^2$

$v^2 = v_0{}^2 + 2a(x - x_0)$

$\sum \mathbf{F} = \mathbf{F}_{net} = m\mathbf{a}$

$F_{fric} \leq \mu N$

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

$\tau = rF \sin \theta$

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

$\mathbf{J} = \mathbf{F}\Delta t = \Delta \mathbf{p}$

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

$\Delta U_g = mgh$

$W = F\Delta r \cos \theta$

$P_{avg} = \frac{W}{\Delta t}$

$P = Fv \cos \theta$

$\mathbf{F}_s = -k\mathbf{x}$

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

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

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

$T = \frac{1}{f}$

$F_G = -\frac{Gm_1m_2}{r^2}$

$U_G = -\frac{Gm_1m_2}{r}$

a = acceleration
F = force
f = frequency
h = height
J = impulse
K = kinetic energy
k = spring constant
ℓ = length
m = mass
N = normal force
P = power
p = momentum
r = radius or distance
T = time
t = time
U = potential energy
v = velocity or speed
W = work done on a system
x = position
μ = coefficient of friction
θ = angle
τ = torque

ELECTRICITY AND MAGNETISM

$F = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$

$\mathbf{E} = \frac{\mathbf{F}}{q}$

$I_{avg} = \frac{\Delta Q}{\Delta t}$

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

$V = IR$

$P = IV$

$R_s = \sum_i R_i$

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

A = area
B = magnetic field
C = capacitance
d = distance
E = electric field
$\mathcal{E}$ = emf
F = force
I = current
ℓ = length
P = power
Q = charge
q = point charge
R = resistance
r = distance
t = time
U = potential (stored) energy
V = electric potential or potential difference
v = velocity or speed
ρ = resistivity
θ = angle
ϕ_m = magnetic flux

GO ON TO THE NEXT PAGE.

ADVANCED PLACEMENT PHYSICS 1 EQUATIONS

GEOMETRY AND TRIGONOMETRY

Rectangle

$A = bh$

Triangle

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

Circle

$A = \pi r^2$

$C = 2\pi r$

Parallelepiped

$V = \ell wh$

Cylinder

$V = \pi r^2 \ell$

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

Sphere

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

$S = 4\pi r^2$

Right Triangle

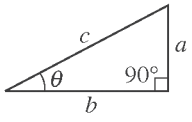
$a^2 + b^2 = c^2$

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

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

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

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



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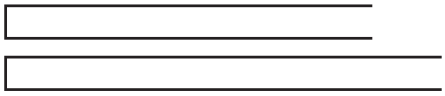
AP PHYSICS 1

SECTION II

Directions: Question 1, 2, and 3 are short free-response question that require about 13 minutes to answer and are worth 8 points. Questions 4 and 5 are long free-response questions that require about 25 minutes each to answer and are worth 13 points each. Show your work for each part in the space provided after that part.

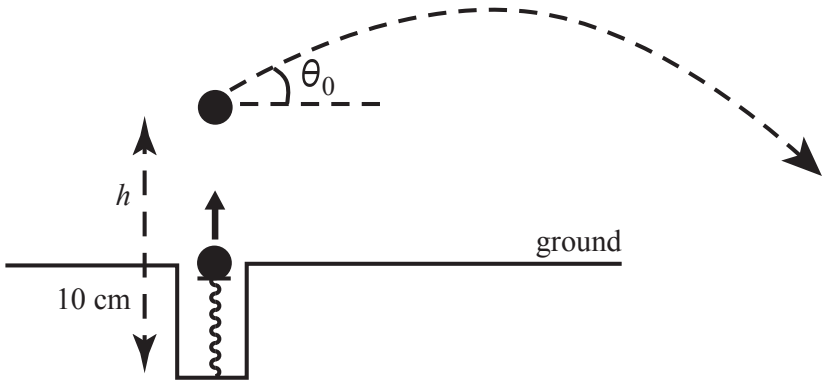


1. In the figure above, two tubes that are identical except for their slightly different lengths are set in front of a speaker with the open side of the tubes facing the speaker. The speaker is a variable frequency generator and is set to produce a note of very low frequency. The frequency is then slowly increased to produce resonance in the tubes. During the experiment, it is observed that at first only one of the tube resonates at a time. When the speaker begins to produce very high frequencies, there are times when both tubes resonate.

   Explain in a clear coherent argument why there are some high frequencies, but no low frequencies, at which both tubes resonate. You may include diagrams and/or equations as part of your explanation.

GO ON TO THE NEXT PAGE.

2. A light spring of natural length 10 cm with force constant $k = 500$ N/m is embedded vertically in the ground. A ball of mass $m = 0.15$ kg is placed on top of the spring, which is compressed 8.0 cm; when released, the spring pushes the ball. When the ball reaches ground level, it leaves its light supporting platform and continues vertically upward. When it reaches the top of its path, a batter strikes the ball at an angle θ_0 to the horizontal. Ignore air resistance.



(a) Find the height h at which the batter strikes the ball.

(b) If the batter gives the ball an initial velocity of 30 m/s with $\theta_0 = 0$ by striking the ball with an impact time of 4 ms, determine:

(i) the average force exerted on the ball by the bat.

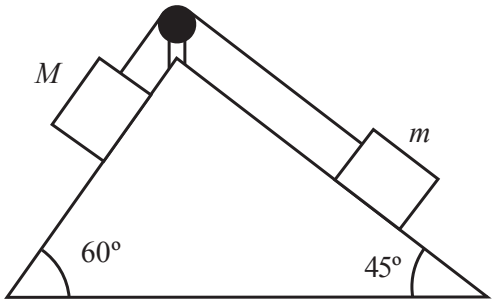
(ii) how long the ball is in flight after it has been hit.

(iii) how far the ball travels horizontally.

(c) If the ball failed to release from the platform, with what frequency would it oscillate?

GO ON TO THE NEXT PAGE.

3. The figure below shows two boxes attached by a light cord that runs over a frictionless peg. The mass of the block on the 60° incline is $M = 8$ kg, and the mass of the block on the 45° incline is $m = 2$ kg.



Assume that both inclined surfaces are frictionless for parts (a), (b), and (c).

(a) Find the acceleration of the blocks once they are released from rest.

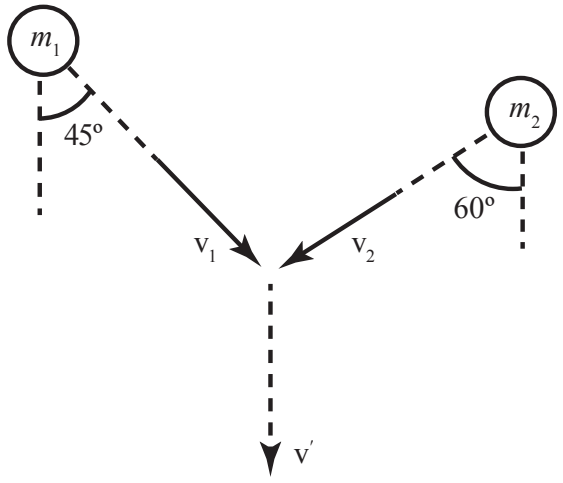
(b) What is the total force exerted by the cord on the peg?

(c) If block M is released from rest at a height of $H = 1.5$ m above the bottom of the triangle, find its speed when it reaches the bottom

(d) Answer the question posed in part (a) assuming that the coefficient of sliding friction between the blocks and the inclined surfaces is 0.2.

GO ON TO THE NEXT PAGE.

4. The figure below is a view from above of two clay balls moving toward each other on a frictionless surface. They collide perfectly inelastically at the indicated point and are observed to then move in the direction indicated by the post-collision velocity, **v**′. The masses are m_1 = 200 g and m_2 = 100 g, and the speed of m_2 just before impact is v_1 = 6.0 m/s.



(a) What is v_2?

(b) What is **v**′, the common speed of the clay balls immediately after the collision?

(c) How much kinetic energy was lost as a result of the collision?

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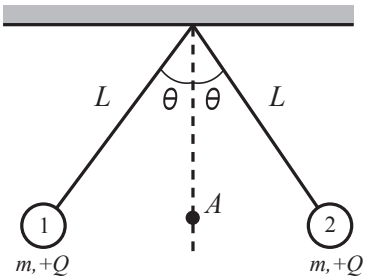
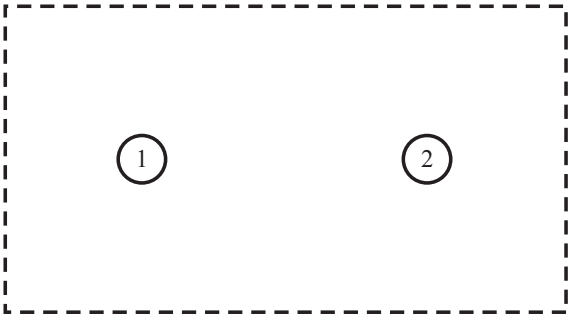
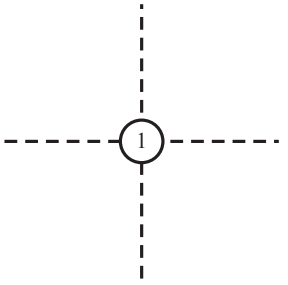


5. Two small objects, labeled 1 and 2 in the diagram above are each suspended in equilibrium from a string of length L and form an angle θ to the normal. Each object has a mass of m and a charge of $+Q$. The strings have negligible mass, are insulated, and are electrically neutral.

(a) On the following diagram, sketch the net electric field due to the two objects in the region enclosed by the dashed lines.



(b) On the following diagram of object 1, draw and label vectors to represent the forces on the object.



(c) In terms of m, L, Q, θ, and fundamental constants, derive an equation that shows the tension T in the left-hand string.

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