AP PHYSICS 1

Kinematics

2016 EDITION

Click on the following link or scan the QR code to complete the evaluation for the Study Session https://www.surveymonkey.com/r/S_SSS

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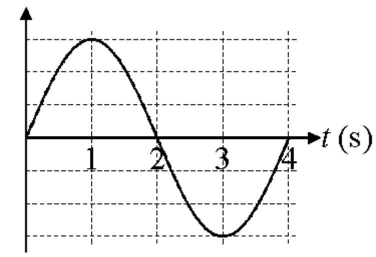
Pre-Assessment

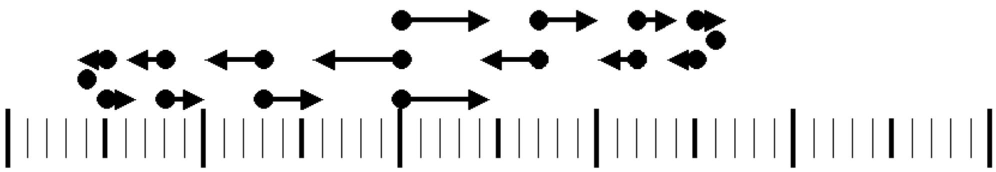
P1. Consider the graph shown, which represents the motion of an object traveling along a straight-line path.



(a) Suppose the graph is a position vs. time graph.

i. During which intervals of time is the object slowing down? Explain.

ii. Sketch a motion diagram representing the motion of this object. (*This one is done for you as an example.*)



(b) Suppose the graph is a velocity vs. time graph.

i. During which intervals of time is the object slowing down? Explain.

ii. Sketch a motion diagram representing the motion of this object.

(c) Suppose the graph is an acceleration vs. time graph, and the object is initially at rest.

i. During which intervals of time is the object slowing down? Explain.

ii. Sketch a motion diagram representing the motion of this object.

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Quantities of motion:

Name	Description	Type	Units	Symbol
Distance	The length of the path taken by an object	scalar	meters	d
Displacement	The straight-line length from an object's initial to final position along with direction	vector	meters	x or y
Speed	The length of the path traveled by an object in one second	scalar	m/s	v
Velocity	Ratio of displacement traveled to time interval during which the travel takes place	vector	m/s	$\mathbf{v}$
Acceleration	the number of m/s that an object's velocity changes each second	Vector	m/s^2	$\mathbf{a}$

Instantaneous vs. Average:

"Average" represents a change measured over an interval that is long enough that it could be measured by a stopwatch. If you measure the displacement of a car while it accelerates from rest and the time it takes to speed up, and divide these, you get average velocity. If you measure the change in the car's velocity while it speeds up and divide by the interval of time the car sped up, then you get average acceleration.

"Instantaneous" represents the rate at which a quantity changes at a specific moment in time. Changes in time used to measure instantaneous quantities are very short—much shorter than a human can use a stopwatch to measure. Photogates and video analysis allow the measurement of instantaneous quantities because they can measure very small length of time.

- As the car accelerates, if you take a video of the car, measure the distance it travels from one video frame to the next, and the time between frames, you can get instantaneous velocity.
- As the car accelerates, if you measure the increase in velocity from one frame to the next, and the time between frames, you can get instantaneous acceleration.

Constant Acceleration Motion Equations:

The equations of motion follow the same pattern (What you have after) = (What you had before) + (What you gained in between)

Position vs. Time Equation: $x = x_0 + v_0 t + \frac{1}{2}at^2$

$$\underbrace{x}_{\text{The position you have after}} = \underbrace{x_0}_{\text{The position you had before}} + \underbrace{v_0 t}_{\text{The position you gained by having a starting velocity}} + \underbrace{\tfrac{1}{2}at^2}_{\text{The position you gained by having an acceleration}}$$

Velocity vs. Time Equation: $v = v_0 + at$

$$\underbrace{v}_{\text{The velocity you have after}} = \underbrace{v_0}_{\text{The velocity you had before}} + \underbrace{at}_{\text{The velocity you gained by having an acceleration}}$$

The "No-Time" Equation: $v^2 = v_0{}^2 + 2a\Delta x$

$$\underbrace{v^2}_{\text{The squared-velocity you have after}} = \underbrace{v_0{}^2}_{\text{The squared-velocity you had before}} + \underbrace{2a\Delta x}_{\text{The squared-velocity you gained by accelerating through a distance}}$$

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Constant accelerations: You can use the above equations for any of these situations

- Free-fall or projectile motion
- Object on a straight incline
- Any situation where the forces applied are constant in time

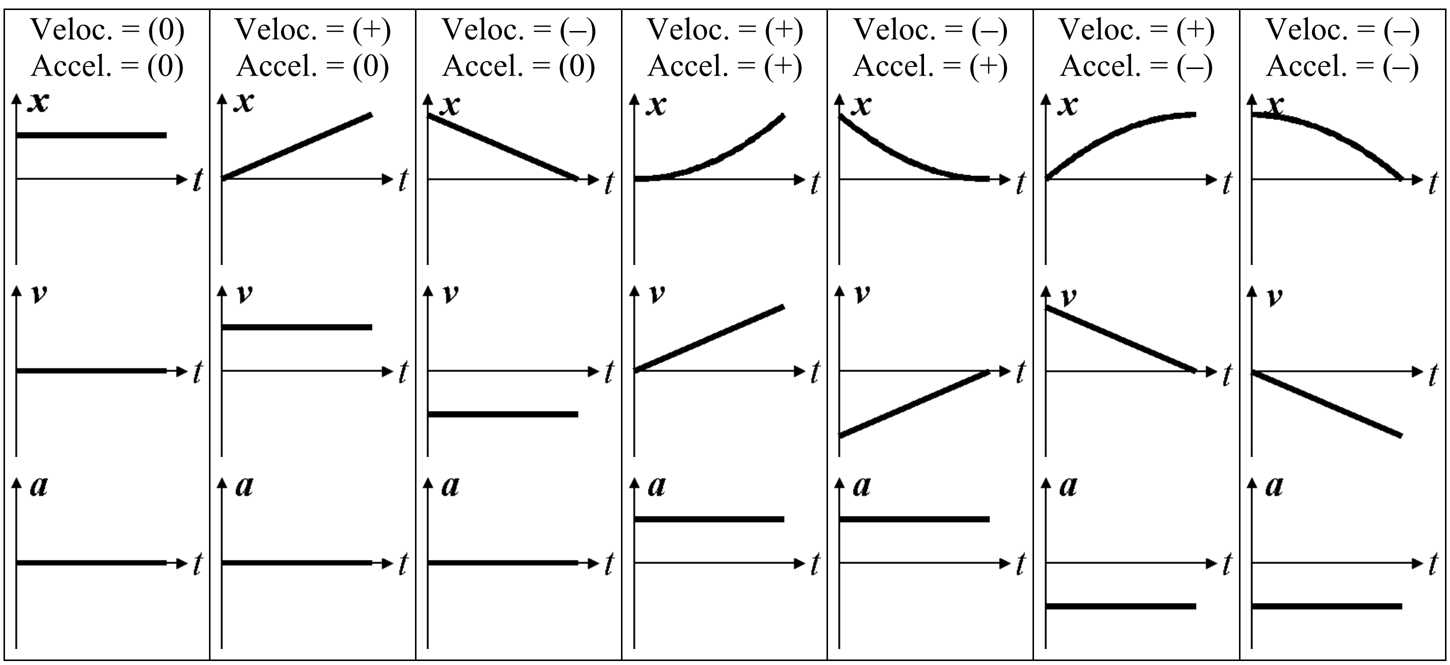
Non-constant accelerations: Do NOT use the above equations for any of these situations

- Anything where a spring or elastic acts on an object (non-constant force)
- Circular motion (acceleration is changing direction to point toward the center of the circle)
- Objects on a curved incline

<u>Graphs:</u>

- The slope of a position vs. time graph is velocity.
- The slope of a velocity vs. time graph is acceleration.
- The area under a velocity vs. time graph is **change** in position.
- The area under an acceleration vs. time graph is **change** in velocity.

Seven Example Motions and Their Motion Graphs



Patterns to Recognize from Above:

- If velocity is positive, x vs. t has positive slope. If velocity is negative, x vs. t has negative slope.
- If acceleration is zero, x vs. t is a line and v vs. t is specifically a horizontal line.
- If acceleration is positive, x vs. t is part of an upward-opening (“up like a cup”) parabola.
- If acceleration is negative, x vs. t is part of an downward-opening (“down like a frown”) parabola.
- If acceleration is positive, v vs. t has positive slope.
- If acceleration is negative, v vs. t has negative slope.

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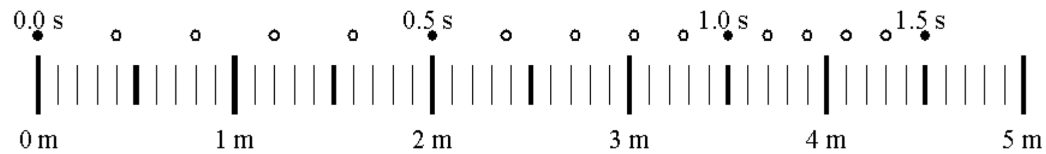
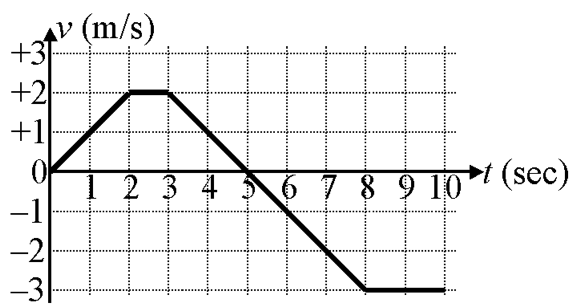
Multiple-Choice Questions



M1. The diagram above represents the motion of an object that travels to the right in a straight line path. Each dot represents the position of the object at 0.1 s intervals; black dots are labeled with the times at which the object was at that position. Which of the following best estimates the instantaneous speed of the object at time = 1.5 seconds?

(A) $\dfrac{0.2 \text{ meters}}{1.5 \text{ seconds}}$ (B) $\dfrac{0.2 \text{ meters}}{0.1 \text{ seconds}}$ (C) $\dfrac{4.5 \text{ meters}}{1.5 \text{ seconds}}$ (D) $\dfrac{4.5 \text{ meters}}{0.1 \text{ seconds}}$



M2. A person walking along a straight line moves such that her velocity as a function of time can be represented by the graph above. At what time does the person have the same position as she had at time $t = 0$?

(A) At $t = 5$ s
(B) During the interval 5 s $< t <$ 8 s
(C) At $t = 8$ s
(D) During the interval $t >$ 8 s

M3. A toy car is initially at rest and travels a straight-line distance of 16 meters in T seconds. Starting at time $t = 0$, the car has a uniform acceleration of 2 m/s^2 until it reaches a speed of 4 m/s. The car then continues with this velocity time $t = T$. What is the value of T?

(A) 4 s
(B) 5 s
(C) 8 s
(D) 12 s

M4. A student performs an experiment to determine whether an object released from rest truly exhibits free-fall motion. The student takes data of distance d that the object has fallen at various times t after the object is released. If the object does exhibit free-fall motion, which of these graphs will be a line?

(A) d vs. t
(B) d vs. t^2
(C) d^2 vs. t
(D) d^2 vs. t^2

M5. A car starting from rest accelerates for T seconds with constant acceleration a, traveling a distance D and reaching a speed v. After another T seconds have passed, the car is now a distance $3D$ from its initial position. What did the car do during the second T-second interval of time?

(A) The car continued accelerating forward with constant acceleration a.
(B) The car ceased to accelerate and continued forward with constant velocity v.
(C) The car slowed down with a backward acceleration $-a$ until it stopped.
(D) None of these things can account for the car's final position.

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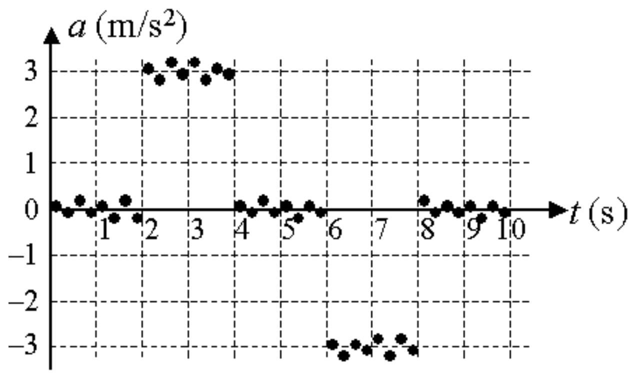
M6. A student conducts an investigation into the motion of a car that accelerates from rest on a straight, level roadway. A driver operating the car causes the car to speed up from rest at time $t = 0$ and the student makes measurements of the distance traveled and the speed of the car every second. What experimental evidence would support the conclusion that the car's acceleration is uniform? **Select two answers.**

(A) All objects released from rest at the same time fall together.
(B) The distance fallen is proportional to the square of the falling time.
(C) A graph of velocity vs. time is linear.
(D) Objects speed up as they free-fall.

Free-Response Questions

F1. An elevator is on the 20th floor of a 40-floor building. At time $t = 0$, the elevator is at rest and the doors have just finished closing. A student on the elevator has a smartphone with an app that can measure vertical acceleration. The student takes data for the 10 seconds starting at time $t = 0$; the acceleration data is shown in the graph on the right. Let positive values represent upward acceleration.



(a) Qualitatively and quantitatively describe the motion of the elevator at the following times.

i. Time $t = 5$ seconds

ii. Time $t = 10$ seconds

(b) At time $t = 10$ seconds, is the elevator above, below, or at its initial position? Explain your reasoning.

(c) On the grids below, draw graphs representing the velocity v and height y of the elevator as functions of time during the 10-second interval. Assume that the initial height of the elevator is $y = y_0$. Be sure that your graphs have proper shapes and slopes during the appropriate times.

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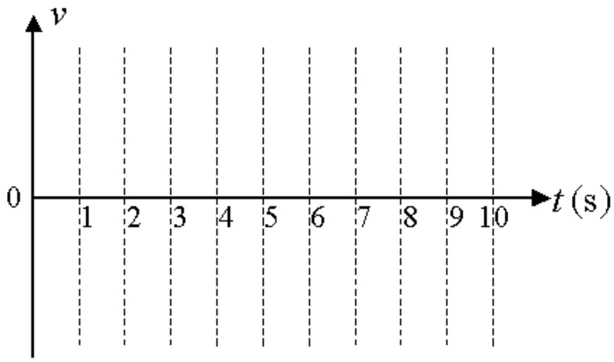

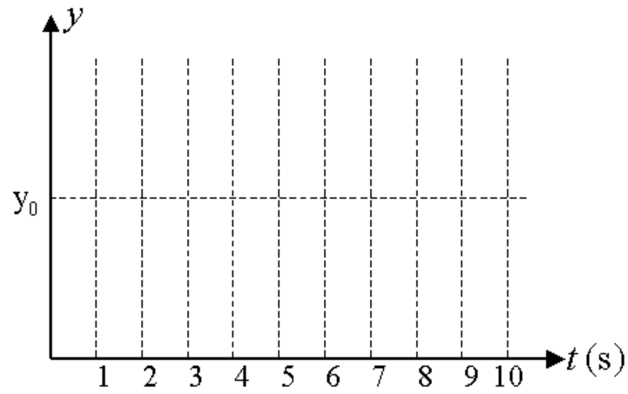

F2. Two students obtain a yo-yo. One of them fully winds the yo-yo, fixes the free end to a hook, and releases the yo-yo so that is falls and spins. The students observe that the yo-yo's speed increases as the yo-yo falls. Each of the students state a hypothesis about the motion of the yo-yo as it unwinds and falls:

Student *A*: "I think that the yo-yo falls with constant acceleration."
Student *B*: "Well the yo-yo is falling, so the yo-yo is obviously exhibiting free-fall motion."

(a) In the space below, outline a procedure that the students could follow in order to make the measurements necessary to experimentally test their two hypotheses. Explain how commonly-available equipment will be used to make measurements. Draw and label a diagram of the experimental setup.

(b) Suppose that student *A*'s hypothesis is correct, but student *B*'s hypothesis is incorrect.

i. In the space below, create an example graph or table representing the measurements that would have been taken during the procedure in part (a) and that reflects student *A*'s correctness and student *B*'s incorrectness.

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ii. Explain in words how the representation you created in part (b)-i shows that student *A* is correct and student *B* is incorrect.

(c) State a modification that can be made to the original procedure that would yield measurements that would validate both student *A*'s hypothesis and student *B*'s hypothesis.

(d) The students exchange their yo-yo for a small, dense sphere attached to a string. Write a procedure whereby the students can show the transformation of gravitational potential energy into kinetic energy. Explain how commonly-available equipment will be used to make measurements and how measurements will be used to determine that gravitational potential energy became kinetic energy. Draw and label a diagram of the experimental setup.

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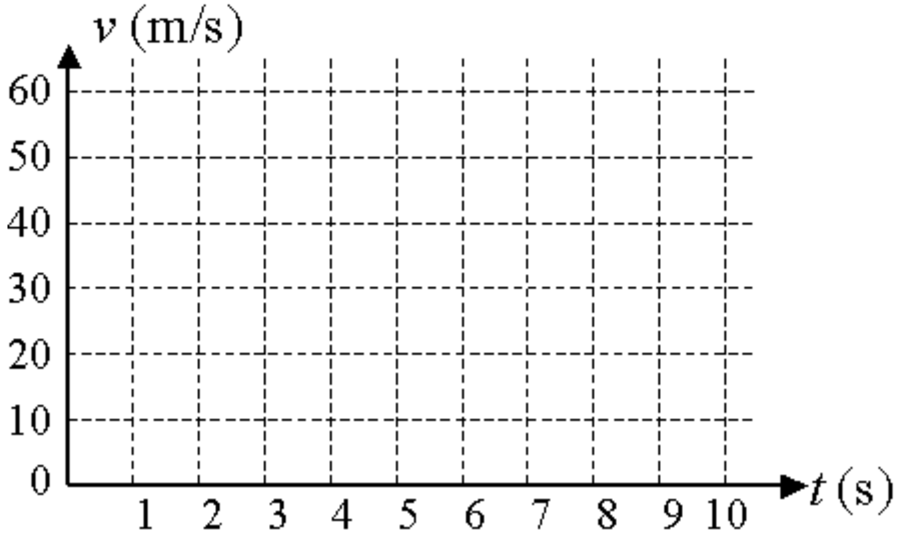
F3. A new model of sports car is being tested on a long, straight, horizontal roadway. The car is initially at rest at position $x = 0$. At time $t = 0$, the car begins to speed up with a constant acceleration of 6 m/s^2. The car has this constant acceleration for 5 seconds.

(a) At time $t = 5$ seconds, the car is at position $x = D$. Calculate the value of D.

(b) On the grid below, draw the velocity of the car as a function of time for the first five seconds of the car's motion.



At time $t = 10$ seconds, the car is at position $x = 2D$. Three students each suggest what motion the car could have had between $t = 5$ s and $t = 10$ s that would account for this fact.

___ Student A: The car slows down with the same magnitude acceleration that it had during the first 5 seconds.
___ Student B: The car continues to speed up with the same acceleration that it had during the first 5 seconds.
___ Student C: The car ceases to accelerate and simply has a constant velocity between $t = 5$ s and $t = 10$ s.

(c) Mark the blank next to the student whose suggestion correctly explains why the car is at position $x = 2D$ at time $t = 10$ seconds. On the grid in part (b), complete the graph by drawing the car's velocity during the interval $t = 5$ s to $t = 10$ s consistent with the motion suggested by the student that you marked.

(d) Use your graph to explain your selection of student.

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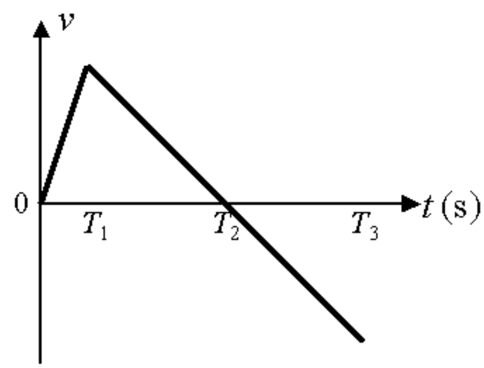
F4. A model rocket initially at rest at ground level is launched upward starting at time $t = 0$. The rocket has an upward acceleration as long as its engine is firing, but once the engine stops firing, the rocket is in free-fall until is reaches the ground again. The rocket's motion is purely vertical.

The graph to the right shows the velocity of the rocket as a function of time, where positive values represent upward velocity. The graph is NOT to scale, which means that the times T_1, T_2, and T_3 marked on the horizontal axis are NOT necessarily equally spaced apart.



(a) Explain what the rocket is doing at time $t = T_2$ seconds.

(b) i. Which is greater: the greatest upward speed reached by the rocket, or the greatest downward speed?

___ Greatest upward speed ___ Greatest downward speed ___ Both are equal

ii. Which is greater: the time the rocket spends moving upward, or the time spent moving downward?

___ Time moving upward ___ Time moving downward ___ Both are equal

iii. Explain your previous two answers in a well-reasoned, organized paragraph. Cite appropriate physical principles and use the graph shown above or construct one of your own.

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