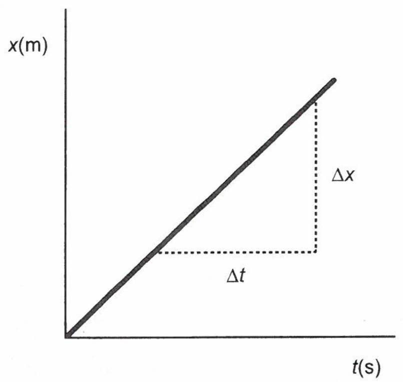
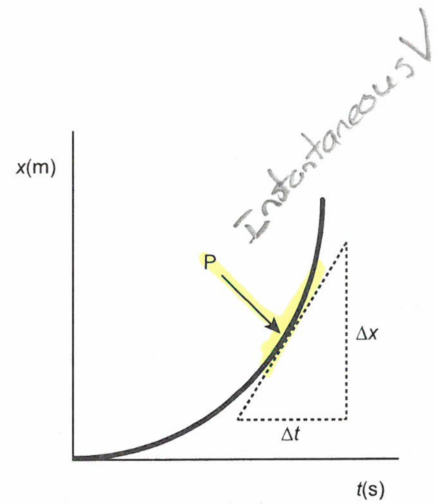
CONSTANT VELOCITY

Consider the position vs. time graphs shown:





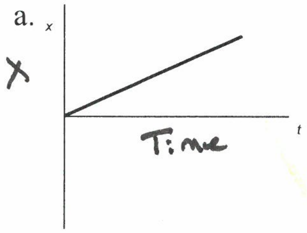
- The slope of the graph on the left is $\frac{\Delta x}{\Delta t}$, and is therefore velocity.
- The curved graph on the right indicates that the slope is changing. The slope of the curved graph is still velocity even though the velocity is changing, indicating the object is accelerating.
- The **instantaneous velocity** at any point on the graph (such as point P) can be found by drawing a tangent line at the point and finding the slope of the tangent line.
- The slope of a position-time graph is the same as the value (height) of velocity-time graph. Consequently, the value of a velocity-time graph is the same as the slope of a position-time graph.

EXERCISE 1. POSITION VS. TIME GRAPHS

Qualitatively describe the motion depicted in the following position vs. time graphs:

Hint: · Starts where?
· Direction?
· Type of Velocity

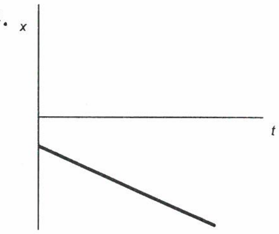
a.



+1
Object starts at origin
+1
& moves in Positive direction
with Constant Velocity
+1

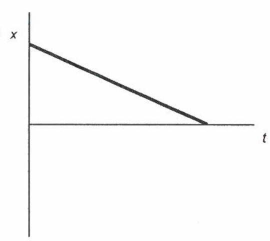
3pts

c.



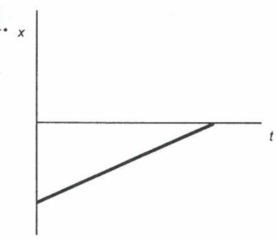
+1
+1 · Objects starts to the left of the origin (negative, + is Right)
+1 · moves in Negative direction
" · moves with Constant velocity

b.



· object starts to Right of the origin
· moves in the Negative direction
· moves with constant Velocity, ending at the origin

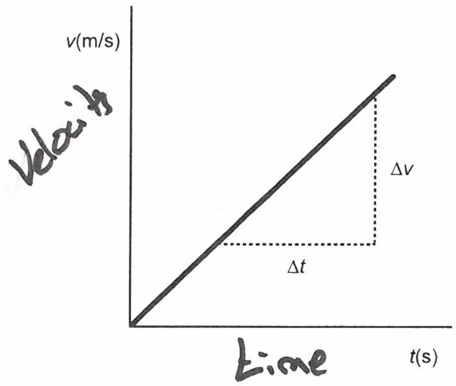
d.

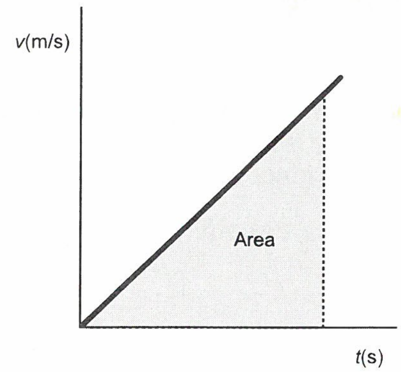


· Object starts to the left of the origin
· moves in positive direction
· Constant Velocity, ending @ origin

CONSTANT VELOCITY

Consider the velocity vs. time graphs shown:



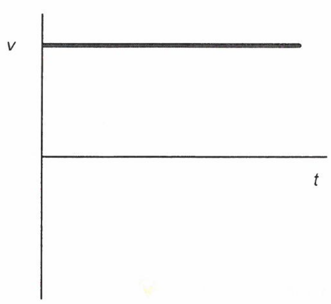


- The slope of the velocity vs. time graph on the left is $\frac{\Delta v}{\Delta t}$, and is therefore acceleration.
- The area under the velocity vs. time graph on the right has units of $\frac{\text{m}}{\text{s}} \times \text{s} = \text{m}$, and is therefore displacement.
- The slope of a velocity-time graph is the same as the value of an acceleration graph. Consequently, the value of an acceleration-time graph is the same as the slope of a velocity-time graph.

EXERCISE 2. VELOCITY VS. TIME GRAPHS

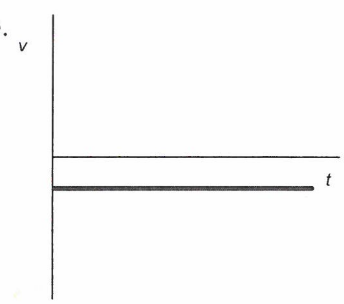
Qualitatively describe the motion depicted in the following velocity vs. time graphs:

a.



object moves to the Right at a Constant Speed

b.



object moves to the Left at a constant Speed

QUANTITATIVE APPROACH

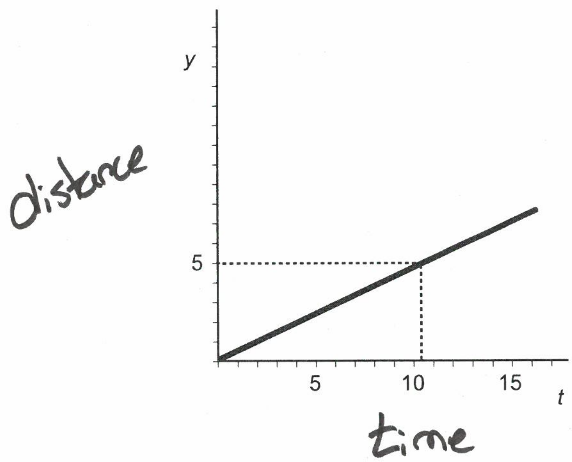
- The next step is to calculate the slope of a position vs. time graph, and understand that the value obtained is the average velocity. When the velocity is constant, the average velocity over any time interval is equal to the instantaneous velocity at any time.
- The area under the curve of a velocity vs. time graph is the **displacement**.
  - When displacement is plotted on the y-axis and time is plotted on the x-axis, the curve is a straight line.
  - Happiness is a straight line because once you have a straight line, you now have an equation:

$$y = mx + b$$

← y intercept

↑ slope

where m is the slope and b is the y-intercept. The slope is the change in y divided by the change in x (otherwise known as "the rise over the run").



- Because we are graphing displacement on the y-axis, the change in y is simply the change in displacement, or Δy. We have Δt for the x-axis, so the slope is

$$m = \frac{\Delta y}{\Delta x} = \frac{\Delta y}{\Delta t}$$

Slope or Rise/Run Really $\frac{\Delta x}{\Delta t}$ = Velocity

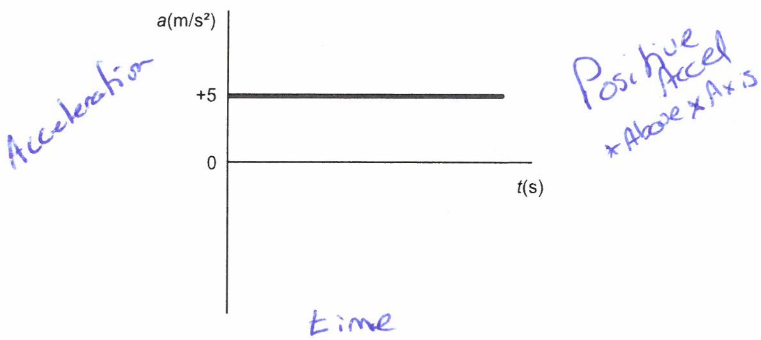
But $\frac{\Delta y}{\Delta t}$ is the velocity v, therefore the slope of the position vs. time graph is the velocity.

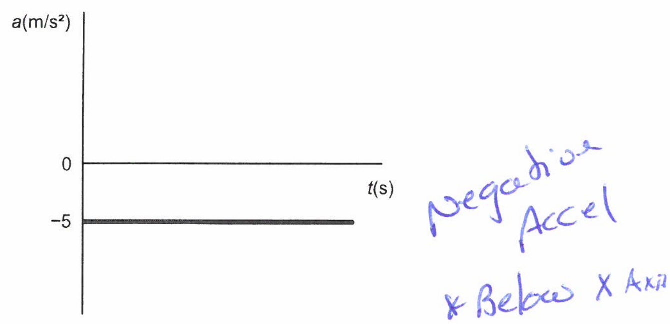
  - Example: What is the velocity of the object whose motion is depicted in the previous graph?

$$m = \frac{\Delta y}{\Delta x} = \frac{5\text{ m} - 0}{10.4\text{ s} - 0} = 0.48\text{ m/s}$$

ACCELERATED MOTION

- Because the AP Physics 1 exam generally deals with constant acceleration, any graph of acceleration vs. time on the exam would likely be a straight horizontal line:





  - This graph on the left tells us that the acceleration of this object is positive.
  - If the object were accelerating negatively, the horizontal line would be below the time axis, as shown in the graph on the right.

- If an object is undergoing a constant acceleration, we can analyze the motion and come up with several equations that will describe the motion. Start with the equation for acceleration:

$$a = \frac{v - v_0}{t - t_0}$$

Let $t_i = 0$, $v_0 = 0$:

$$a = \frac{v - v_0}{t}$$

$$v = v_0 + at$$

- So here are the kinematic motion equations. These will be provided to you on the AP Physics 1 exam. The following table shows their form on the test equation sheet.

KINEMATIC MOTION EQUATIONS	
$v_x = v_{x0} + a_x t$	v as a function of time
$x = x_0 + v_{x_0} t + \frac{1}{2} a_x t^2$	x as a function of time
$v_x^2 = v_{x_0}^2 + 2a_x (x - x_0)$	x as a function of velocity

AP TYPE QUESTION 1

You are asked to experimentally determine the acceleration of a skier traveling down a snow-covered hill of uniform slope as accurately as possible. Which combination of equipment and equation would be most useful in your experimental design?

a. Tape measure, stopwatch, $x = x_0 + v_{x_0} t + \frac{1}{2} a_x t^2$ - only one that measures time & Distance

b. Photogates, stopwatch, $v_x^2 = v_{x_0}^2 + 2a_x(x - x_0)$ Photogates measure time, same as Stopwatch

c. Radar gun, tape measure, $v_x = v_{x_0} + a_x t$ Rader gun - Instaneous speed only

d. Photogates, radar gun, $v = \frac{v_{x_0} - v_x}{2}$

Answer:

use tape measure to measure Distance, Skier Travels

use Stopwatch to measure time to Record time to travel Distance

$X = \cancel{X_0}^{0} + \cancel{V_{x0}}^{0} t + \frac{1}{2} a t^2$ $X_0 = 0$

$V_x = 0$

$X = \frac{1}{2} a t^2$

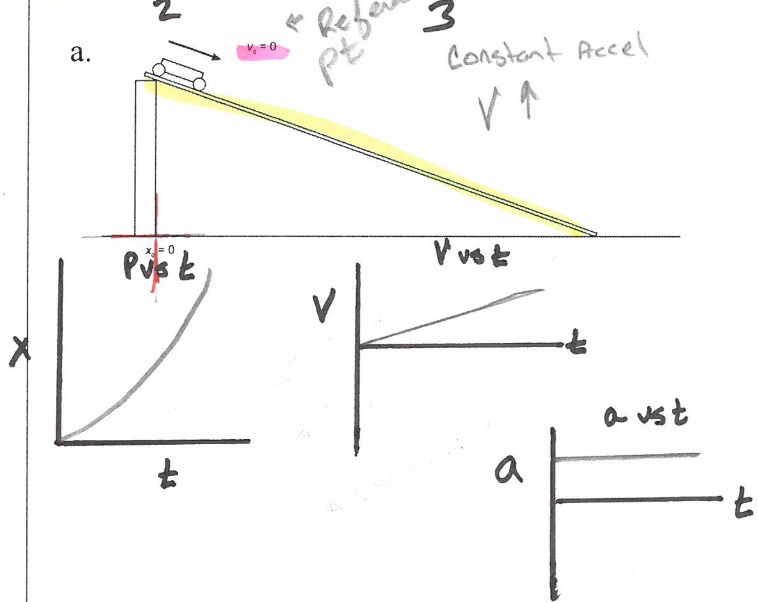
$a = \frac{2X}{t^2}$

Key

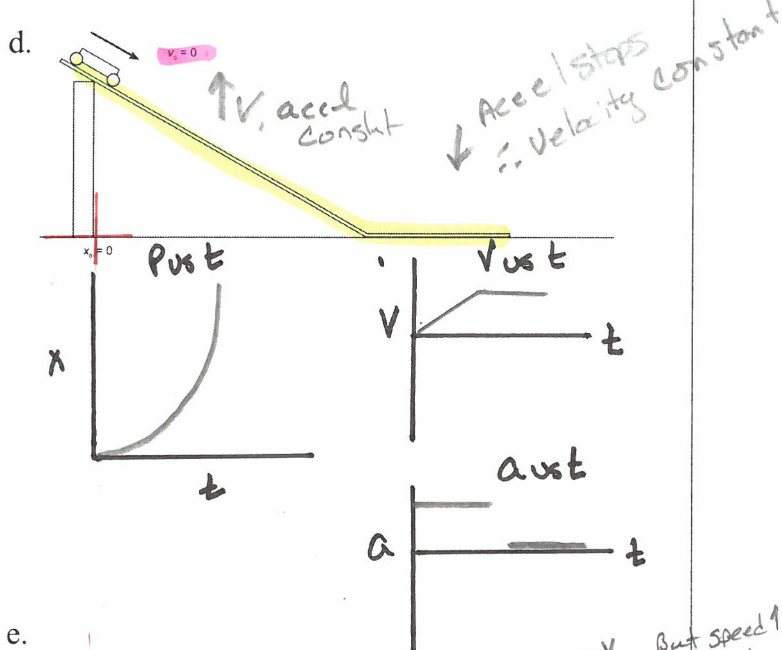
EXERCISE 3. ACCELERATED MOTION

A cart is rolling along a series of level and inclined tracks. Draw qualitative graphs of position vs. time, velocity vs. time, and acceleration vs. time.

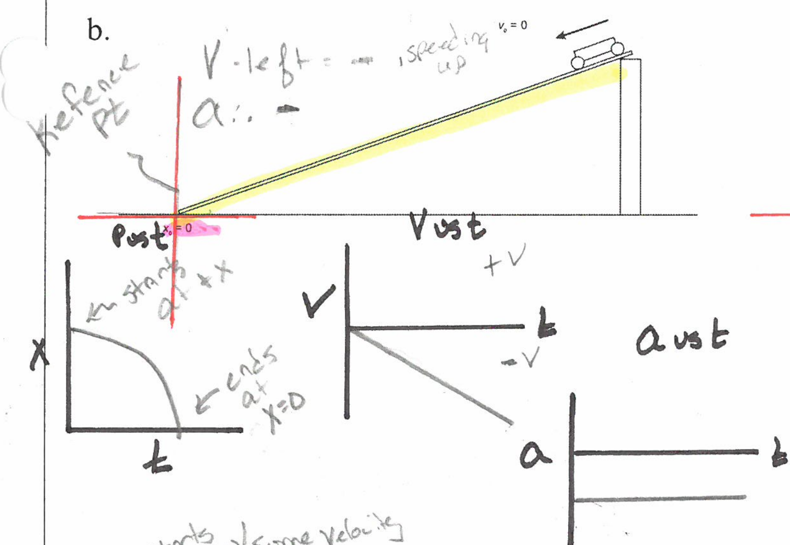
a.



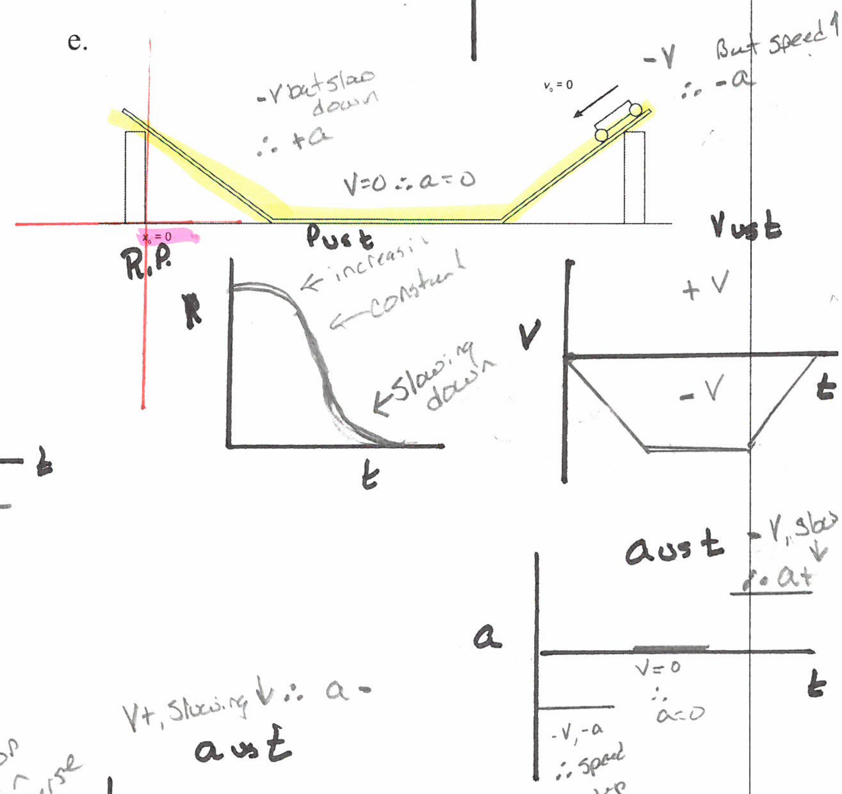
d.



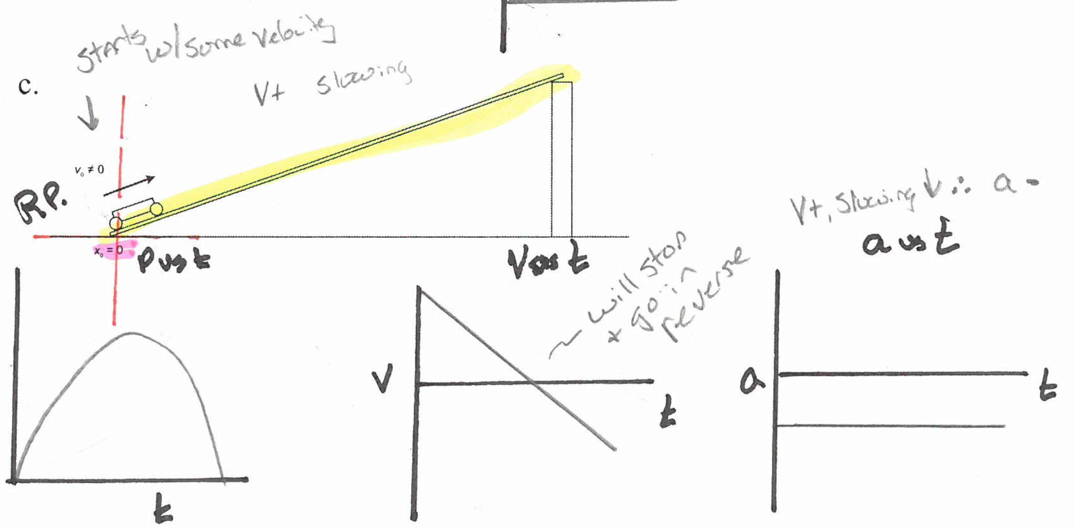
b.



e.



c.

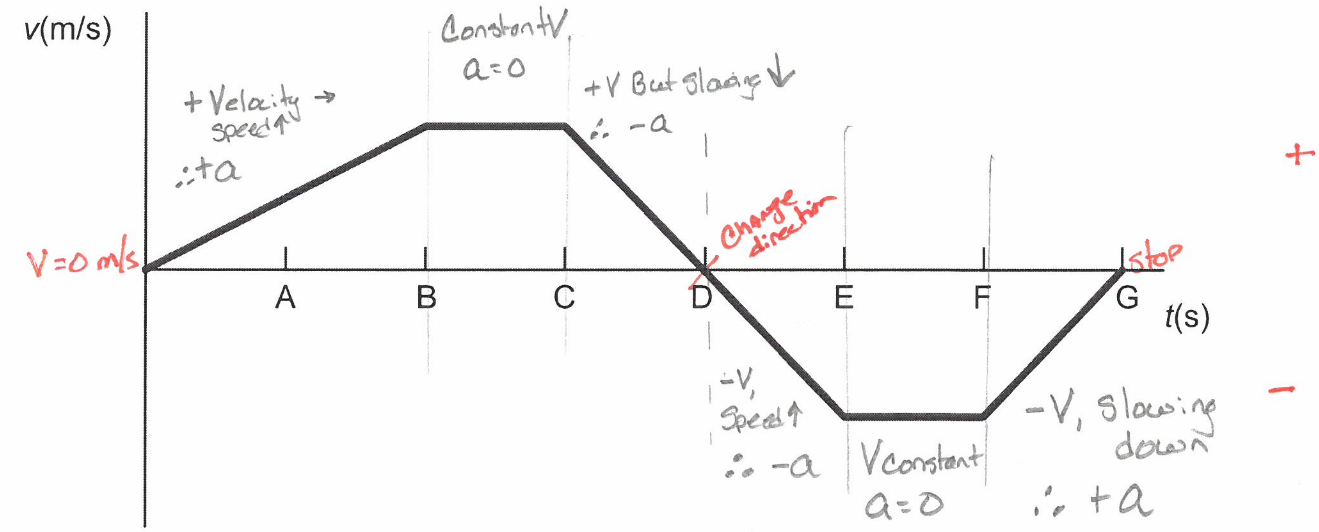


NTERPRETING GRAPHS

Key

EXERCISE 4. INTERPRETING GRAPHS

Qualitatively describe the motion of an object at the different time intervals depicted in the following velocity vs. time graph:



Remember

1st is V + or - direction

2nd slowing up or down?

3rd

+V +a } speed ↑
-V -a }

+V -a } speed ↓
-V +a }

A - B object speeding up, +a

B-C object constant Velocity, ∴ a=0

C-D object slowing down, ∴ -a

D-E object speeding up, away from R.P., - direction, ∴ -a

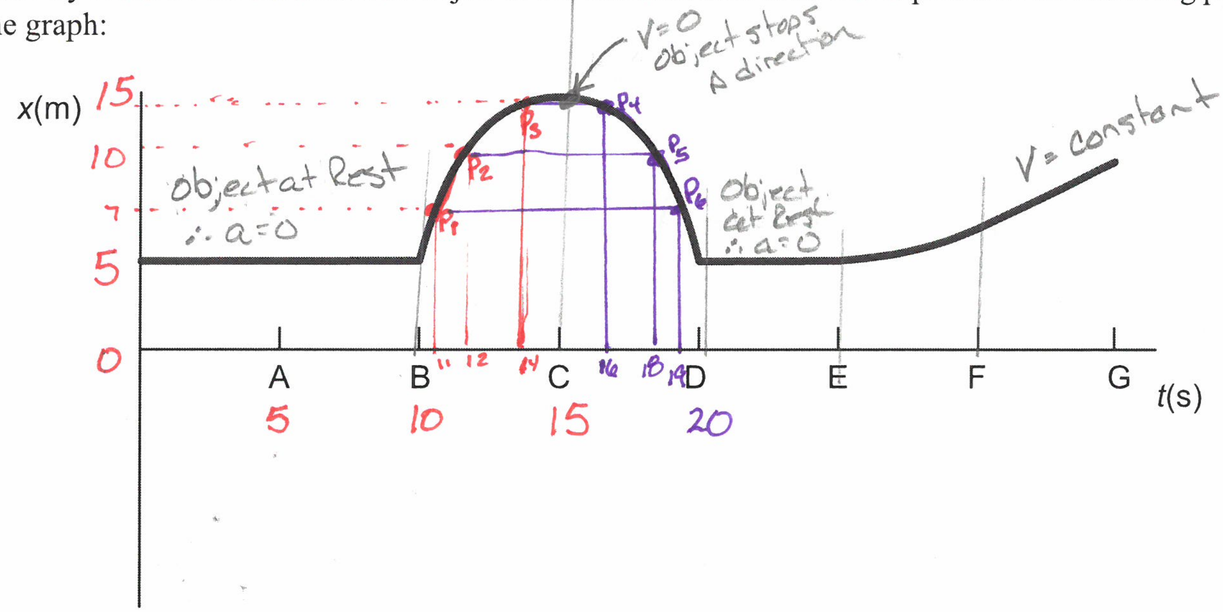
E-F object constant Velocity, ∴ a=0

F-G object slowing down, -direction, ∴ +a

Key

EXERCISE 5. INTERPRETING GRAPHS

Qualitatively describe the motion of an object at the different time intervals depicted in the following position vs. time graph:



A-B object at Rest

B-C object slowing down, accel Negative

Proof $P_2 - P_1$

$V_1 = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i} = \frac{10m - 7m}{12s - 11s} = 3 m/s$

$V_2 = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i} = \frac{15m - 10m}{14s - 12s} = \frac{5m}{2s} = 2.5 m/s$ ($P_3 - P_2$)

+V slowing down (to Ø) ∴ −a

C-D object speeding up in − direction

−V ∴ −a Proof

$V_3 = \frac{x_f - x_i}{t_f - t_i} = \frac{10m - 15m}{18s - 16s} = \frac{-5m}{2s} = -2.5 m/s$

$V_4 = \frac{P_6 - P_5}{t_6 - t_5} = \frac{7m - 10m}{19s - 18s} = \frac{-3m}{1s} = -3 m/s$

D-E object at Rest

E-F object speeding up, +a

F-G object moving w/ + Constant Velocity

Key

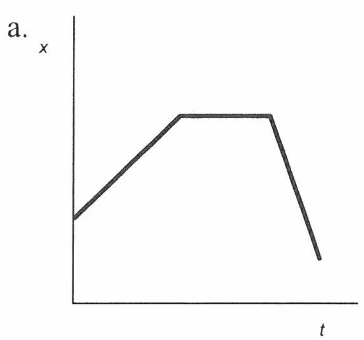
QUANTITATIVE APPROACH

- The quantitative approach includes the following calculations:
  - The slope of the tangent of a position vs. time graph defines instantaneous velocity.
  - The slope of the velocity vs. time graph is the average acceleration.
  - The area under the velocity vs. time graph is the displacement.
  - The area under the acceleration vs. time graph is the change in velocity.

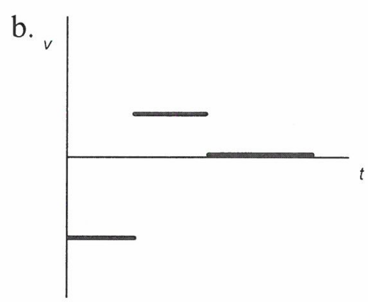
EXERCISE 6. QUANTITATIVE APPROACH

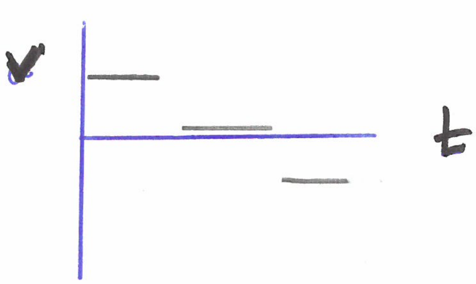
In concise, coherent statements describe the motion depicted by Graph (a) and Graph (b). Sketch a velocity vs. time graph for Graph (a) and a position vs. time graph for Graph (b).

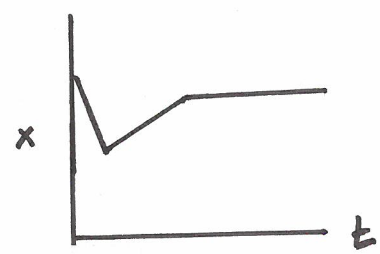
a.



b.





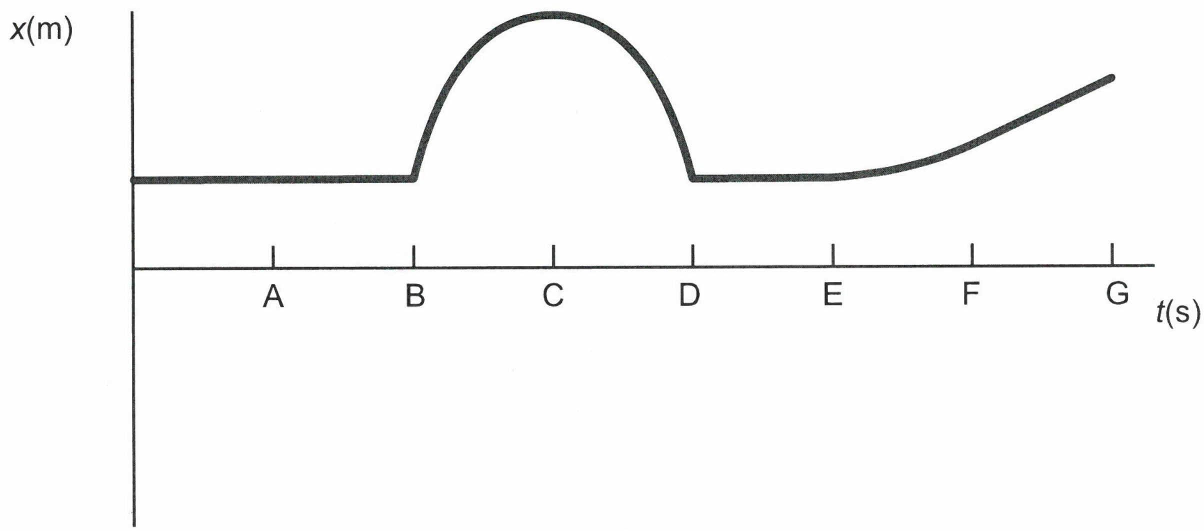


(a)
- object starts at Right of origin
- moves Right at Constant Velocity
- Stands still
- Then moves Left at faster Constant Velocity

(b)
- object moves left at Constant V
- Then moves Right, But slower Constant V
- Then Stands Still

EXERCISE 5. INTERPRETING GRAPHS

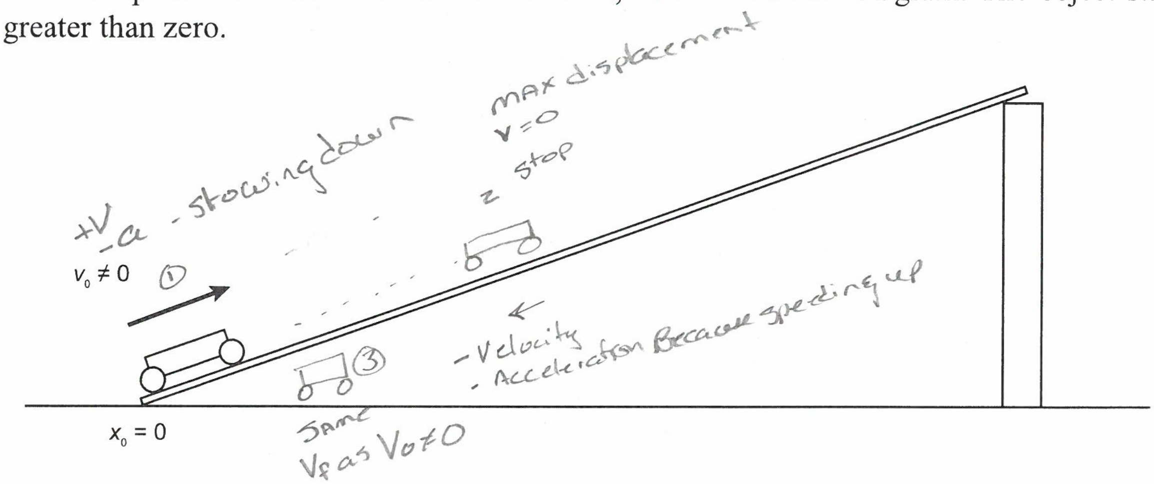
Qualitatively describe the motion of an object at the different time intervals depicted in the following position vs. time graph:



Key

AP TYPE QUESTION 2

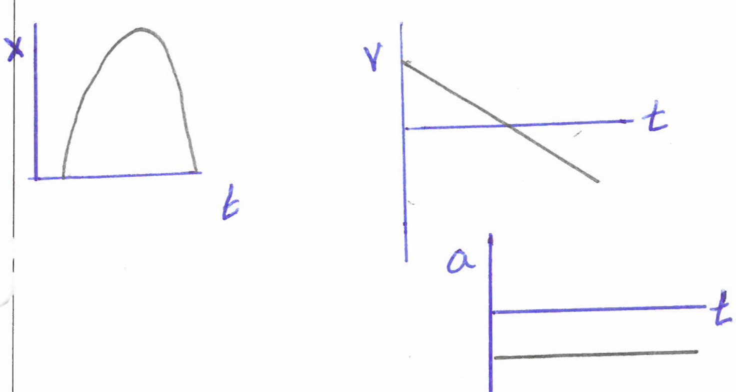
An object slides up and then down a frictionless track, as shown in the diagram. The object starts with a velocity greater than zero.



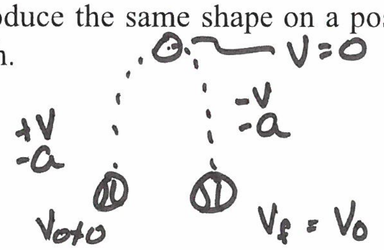
a. In a clear, concise paragraph describe the motion of the object. Assume direction up plane is positive

The Velocity of the object starts at a high Intial value. It slows down at constant Rate, until it reaches it highest point. At This point V=0. object changes direction, and Accelerates down inclined plane, increasing its speed at constant rate, unit it returns to origin with the ~~spee~~ same speed it start at.

b. Sketch the corresponding position vs. time graph, velocity vs. time graph, and the corresponding acceleration vs. time graph.



c. Qualitatively describe another type of motion that would produce the same shape on a position vs. time graph.

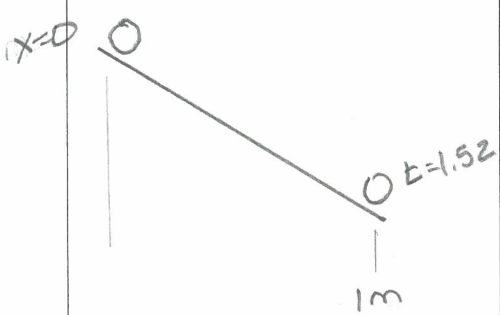


A Ball Thrown up, would have an initial Velocity (+) and have a -a till it Reached its Max height, were V=0 & The Ball change directions with an -a, -V until it reaches the orgin with the Same Velocity it start with

Key

AP TYPE QUESTION 2 (CONTINUED)

d. When the object gets to the top of the ramp, a student measures the time it takes for the object to travel various displacements down the ramp using a stopwatch. Three consecutive trials are measured and the data is recorded as shown. Describe qualitatively and quantitatively how the student could determine the acceleration of the object.



x | t

Displacement (m)	Average Time (s)
0	0
0.2	0.68
0.4	0.98
0.6	1.18
0.8	1.38
1	1.52

quantitatively using Kinematic eqn

$x = x_0 + v_0 t + \frac{1}{2}at^2$ at start ($x_0 = 0$, $v_0 = 0$)

or could have taken slope of velocity vs time graph

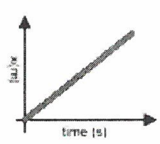
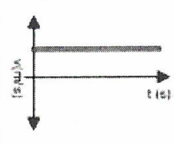
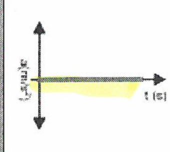
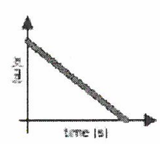
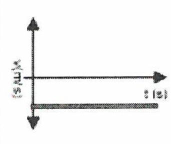
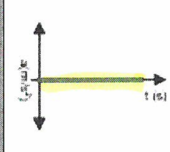
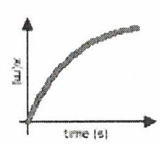
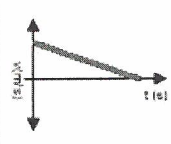
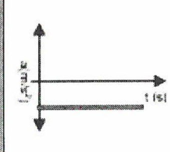
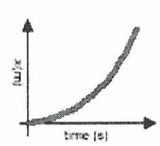
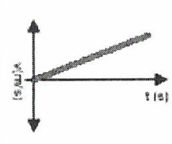
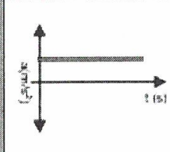
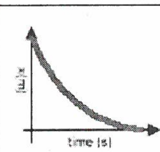
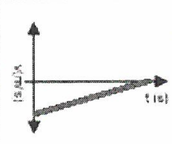
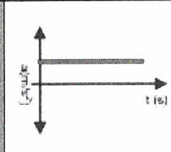
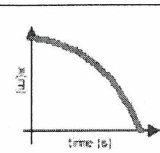
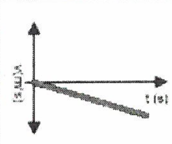
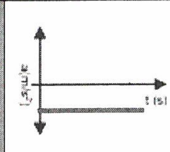
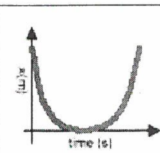
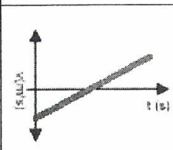
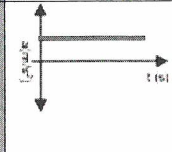
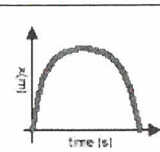
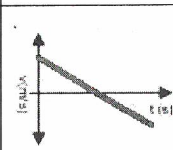
$x = \frac{1}{2}at^2$

$a = \frac{2x}{t^2} = \frac{2(1m)}{(1.52s)^2}$

$a = 0.87 m/s^2$

SUMMARY OF MOTION INTERPRETATION

Graph of Motion Interpretation

Scenario *R.P. means Reference Point, i.e. the motion detector.*	**Position vs. Time Graph** *Draw the shape of the graph.*	**Slope is....** Sign (+, – or zero)	**Slope is....** Constant	**Slope is....** Changing – Both: Increasing	**Slope is....** Changing – Both: Decreasing	**Velocity vs. Time Graph** *Draw the shape of the graph*	**Slope is....** Sign (+, – or zero)	**Slope is....** Constant	**Slope is....** Changing – Both: Increasing	**Slope is....** Changing – Both: Decreasing	**Acceleration vs. Time Graph** *Draw the shape of the graph*	**NET FORCE** (+, - or zero)
Traveling AWAY from the R.P. at a CONSTANT RATE. (constant velocity)		*Positive*	*Constant*				*Positive*	*Constant*				
Traveling TOWARDS the R.P. at a CONSTANT RATE. (constant velocity)		*Negative*	*Constant*				*Negative*	*Constant*				
Traveling AWAY from the R.P. at a DECREASING RATE. (slowing down)		*Positive*			*Decreasing*		*Positive*	*Constant*				
Traveling AWAY from the R.P. at a INCREASING RATE. (speeding up)		*Positive*		*Increasing*			*Positive*	*Constant*				
Traveling TOWARDS the R.P. at a DECREASING RATE. (slowing down)		*Negative*			*Decreasing*		*Negative*	*Constant*				
Traveling TOWARDS the R.P. at a INCREASING RATE (speeding up)		*Negative*		*Increasing*			*Negative*	*Constant*				
Traveling TOWARDS then AWAY from the R.P. at a CHANGING RATE		*Neg. → Pos.*		*Increasing*	*Decreasing then*		*Constant*					
Traveling AWAY then TOWARDS the R.P. at a CHANGING RATE		*Pos. → Neg.*		*Increasing*	*Decreasing then*		*Constant*