Ch. 2 1-Dimensional Motion

conceptual question #6,
problems # 2, 9, 15, 17, 29, 31, 37, 46, 54

Quantities

Scalars	Vectors
distance	displacement
speed	velocity
	acceleration

Definintion

Distance = how far apart two points in space are from each other (only has magnitude)

Displacement = the relative location of one point in space to another point. (involves direction)

Speed = how fast an object is traveling

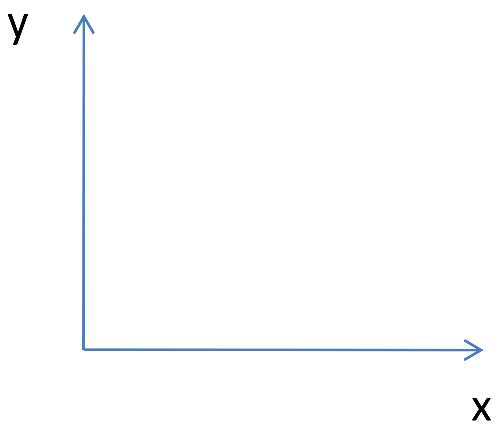
Velocity = how fast and in what direction an object is traveling

Acceleration = the changing of an objects velocity with time (this can include the velocity's direction)

for example keeping your speed constant but driving around a curve

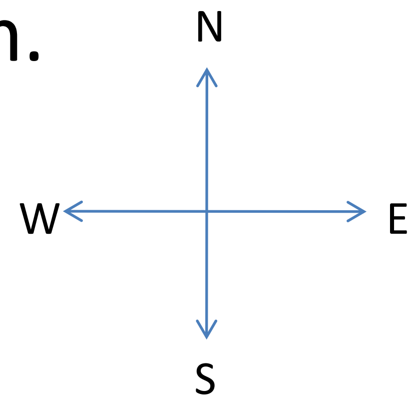
Coordinate systems

When setting up a coordinate system you can pick any direction to be positive.



For this coordinate system, x and y are positive in the right and up directions respectively.

The distance between A and B is 5 m.



The displacement of B with respect to A is 5 m to the right of A.

You could say that point B is 5 m east of point A.

Speed and Velocity

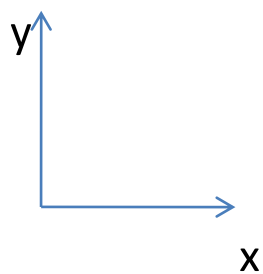
S   how fast an object is moving at that instant

S_{ave} = distance traveled/total time

V   how fast and in what direction an object is moving.

$\mathbf{V}_{\mathbf{ave}}$ = total displacement/total time

$\mathbf{V}_{\mathbf{ave}} = (\mathbf{x}_f - \mathbf{x}_i)/(t_f - t_i)$ or $\mathbf{V}_{\mathbf{ave}} = \Delta\mathbf{x}/\Delta t$



$\mathbf{V}_{\mathbf{ave}} = (18\text{ m} - 3\text{ m})/(12\text{ s} - 7\text{ s}) = 3\text{ m/s}$

For constant velocity:

$\mathbf{V}_{\mathbf{ave}} = (\mathbf{x}_f - \mathbf{x}_i)/(t_f - t_i)$ Becomes $\mathbf{V} = (\mathbf{x}_f - \mathbf{x}_i)/t$

Rearranging the equation gives:

$\mathbf{x} = \mathbf{x}_0 + \mathbf{v}*t$ for constant velocity

(I renamed x_f => x and x_i => x_o)

example

Estimate the average speed of an Apollo spacecraft in m/s if it took 5 days to reach the moon. The moon is 3.8×10^8 m from the Earth.

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1 day is 60 x 60 x 24 seconds or 86400 s

Lets round this to 100 000 s.

So 5 days is about 500 000 s.

Average Speed = distance/time

$$= 3.8 \times 10^8 \text{ m}/5 \times 10^5 \text{ s}$$

$$= 760 \text{ m/s}$$

Example in book says ~900 m/s. Difference is from rounding 86400 s to 100000 s.

Confused football player

A football player fields a kickoff at his own goal-line, runs to the edge of the opposite end-zone before turning around and running back. He is tackled at the same spot where he caught the ball. (He plays for Univ. of Tennessee)

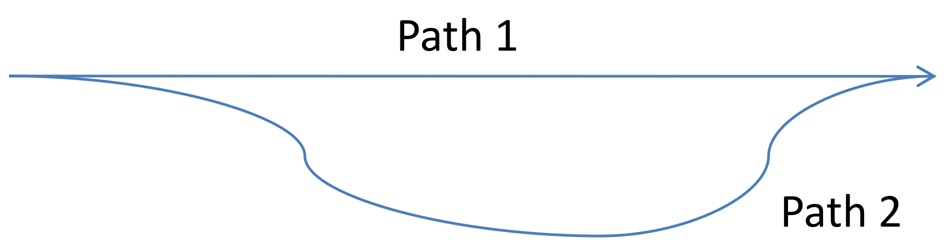
a) What is the players total distance traveled?
b) His displacement?
c) Average velocity?

Drag Race

Watching a drag race from overhead you see 2 cars taking 2 different paths from the same starting and end points. If they arrive at the end point at the same time:

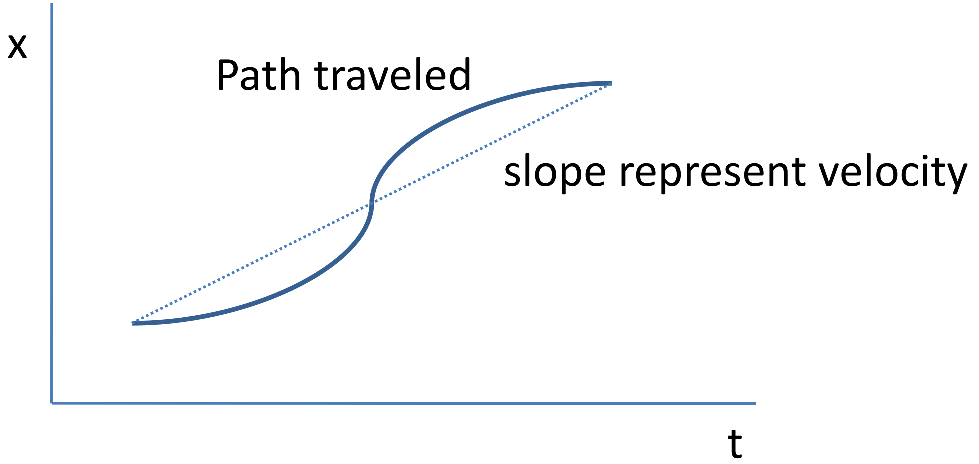
a) Do they have the same average velocity?

b) Do they have the same average speed?

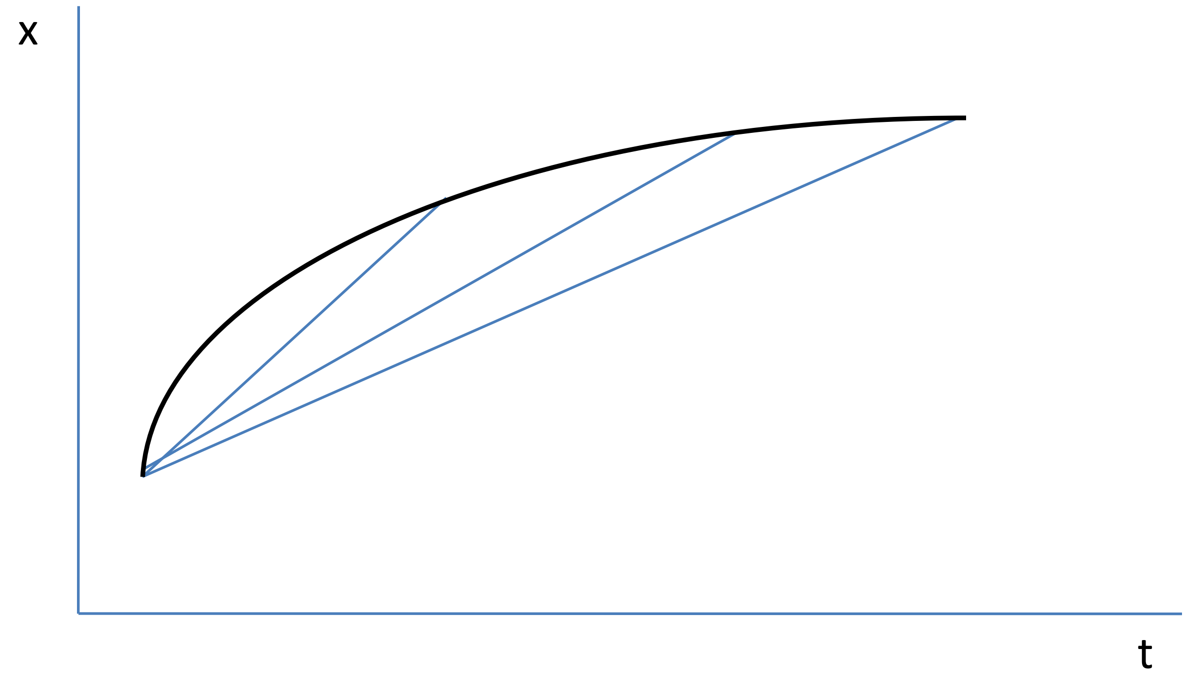


Graphical Representation of velocity

If you have a graph of position versus time. The slope of the line connecting two endpoints is the velocity.



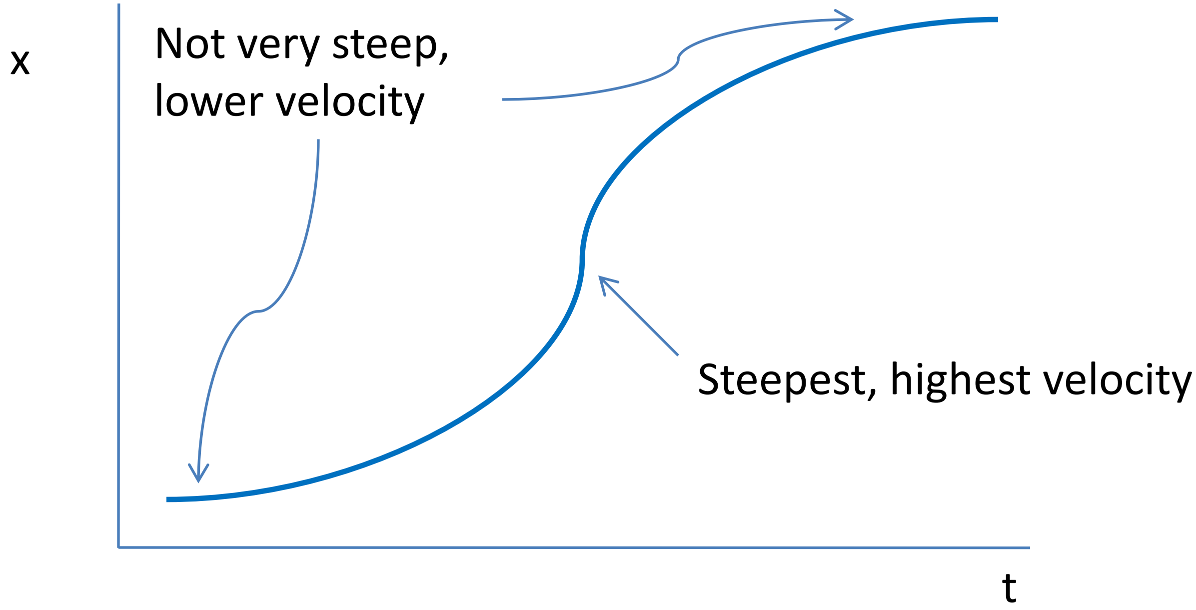
Graphical Representation of velocity



As the time separation is changed, the slope of the blue lines change. As the time interval approaches zero, the slope of the tangent line represents the instantaneous velocity.

Instantaneous Velocity

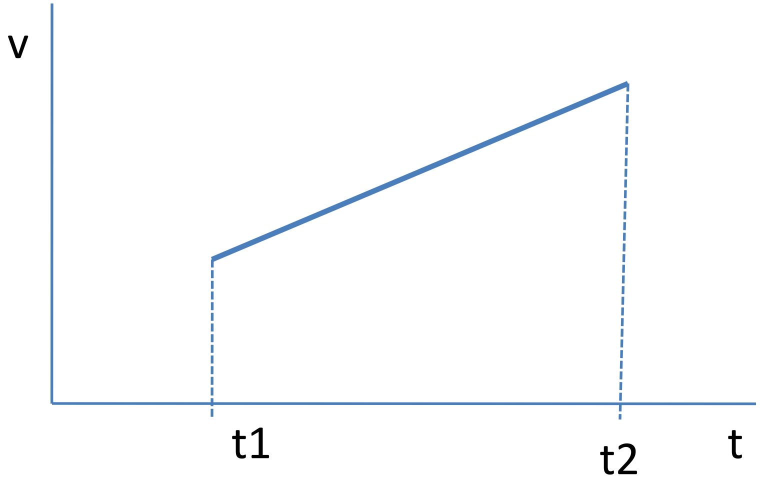
Determined by the slope of a line tangent to the position vs. time curve, at that instant.



Graphical Representation of velocity

If you have a graph of velocity versus time.

The are positive area under the curve represents the net displacement.



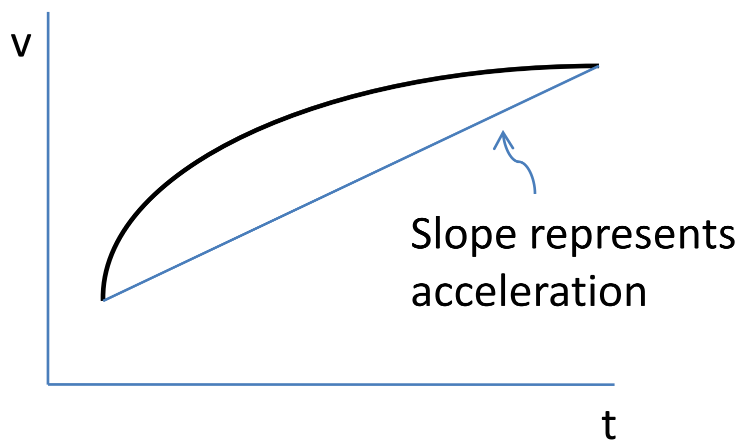
Acceleration

Defined as the time rate of change of the velocity.

Acceleration is a vector quantity.

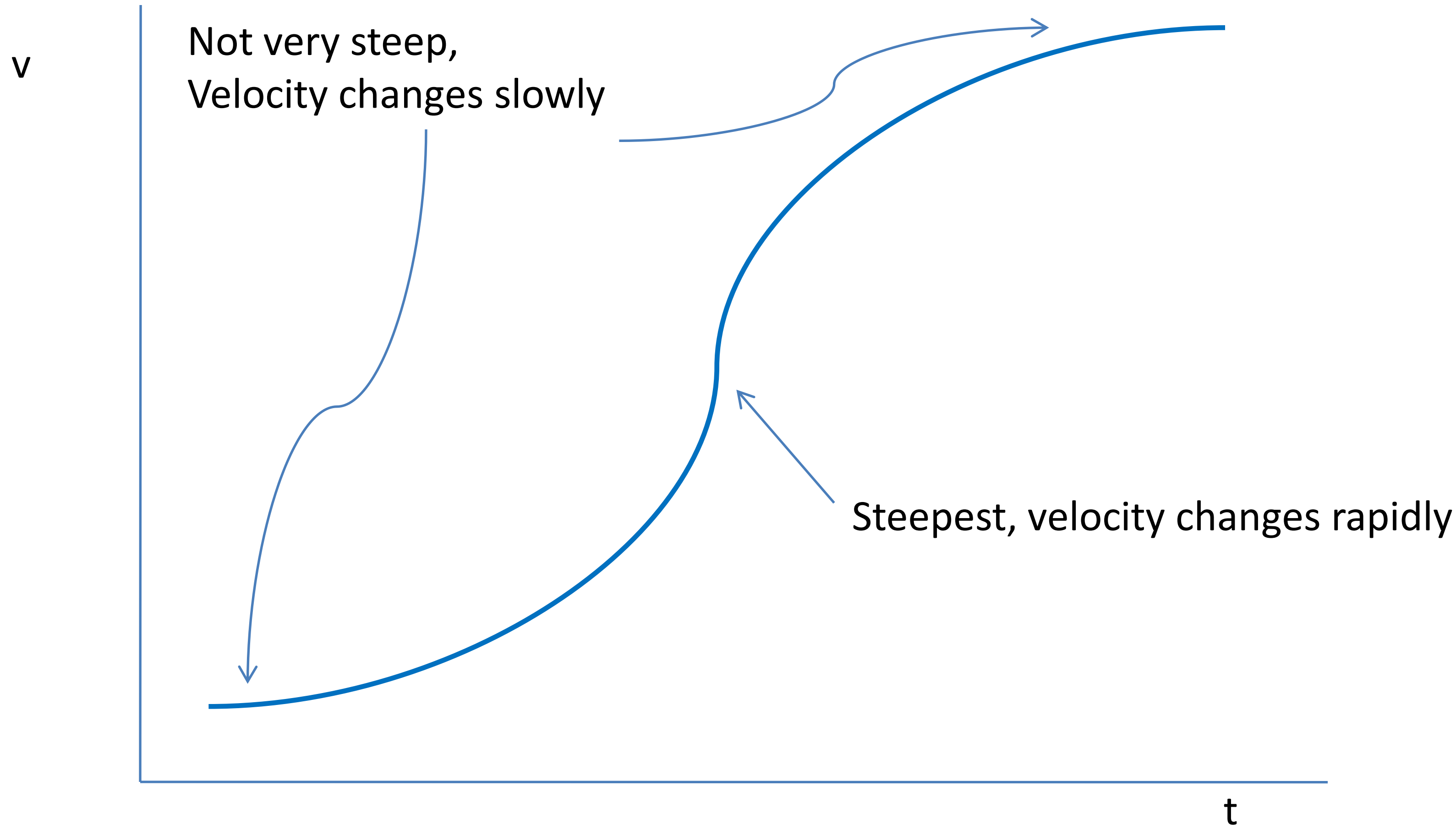
Can include the velocity's magnitude changing, the direction of the velocity changing, or both.

$\mathbf{a}_{ave} = (\mathbf{v}_f - \mathbf{v}_i)/(t_f - t_i)$ or $\mathbf{a}_{ave} = \Delta\mathbf{v}/\Delta t$

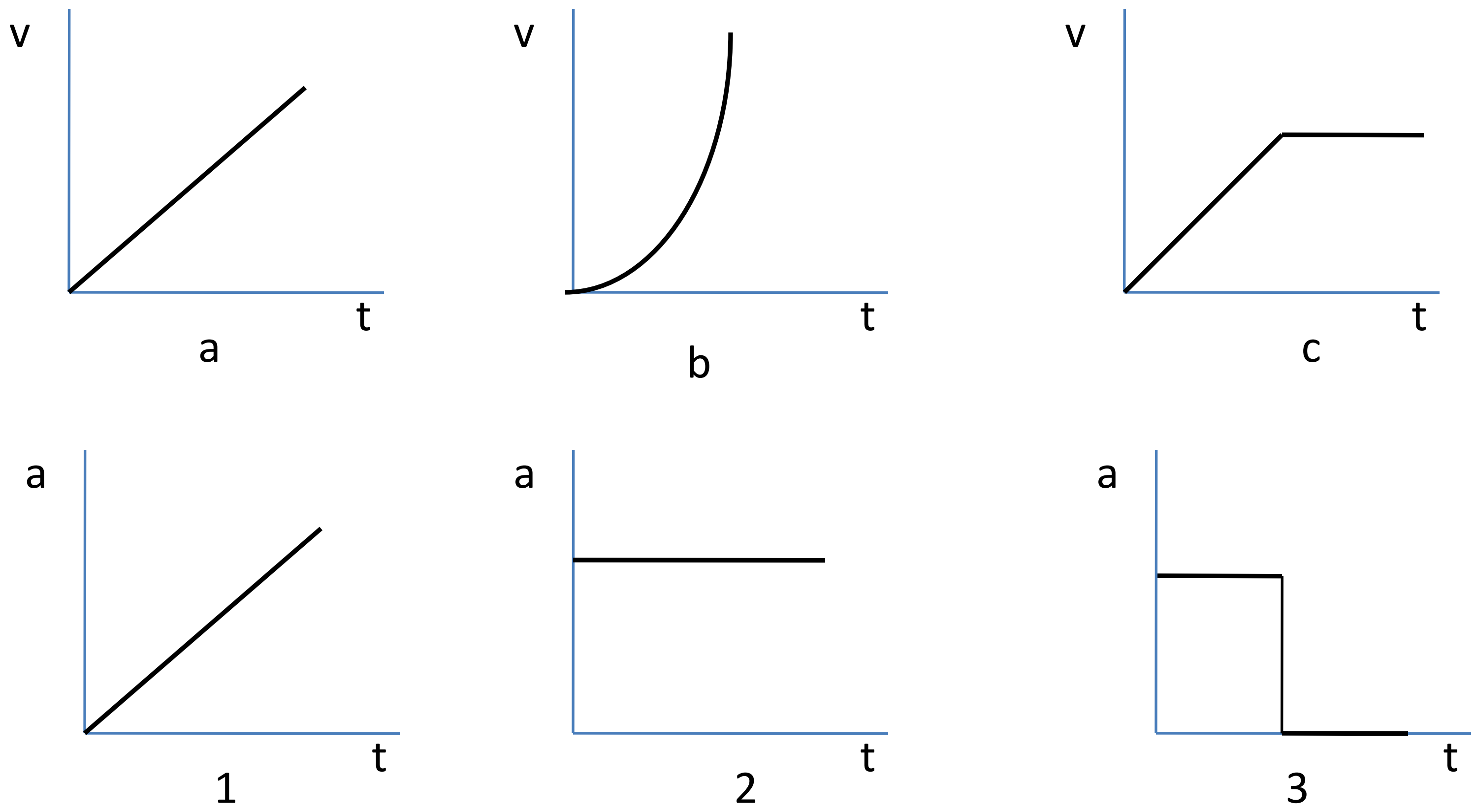


Again, as the time separation is changed, the slope of the blue line changes. As the time interval approaches zero, the slope of the tangent line represents the instantaneous acceleration.

Instantaneous Acceleration

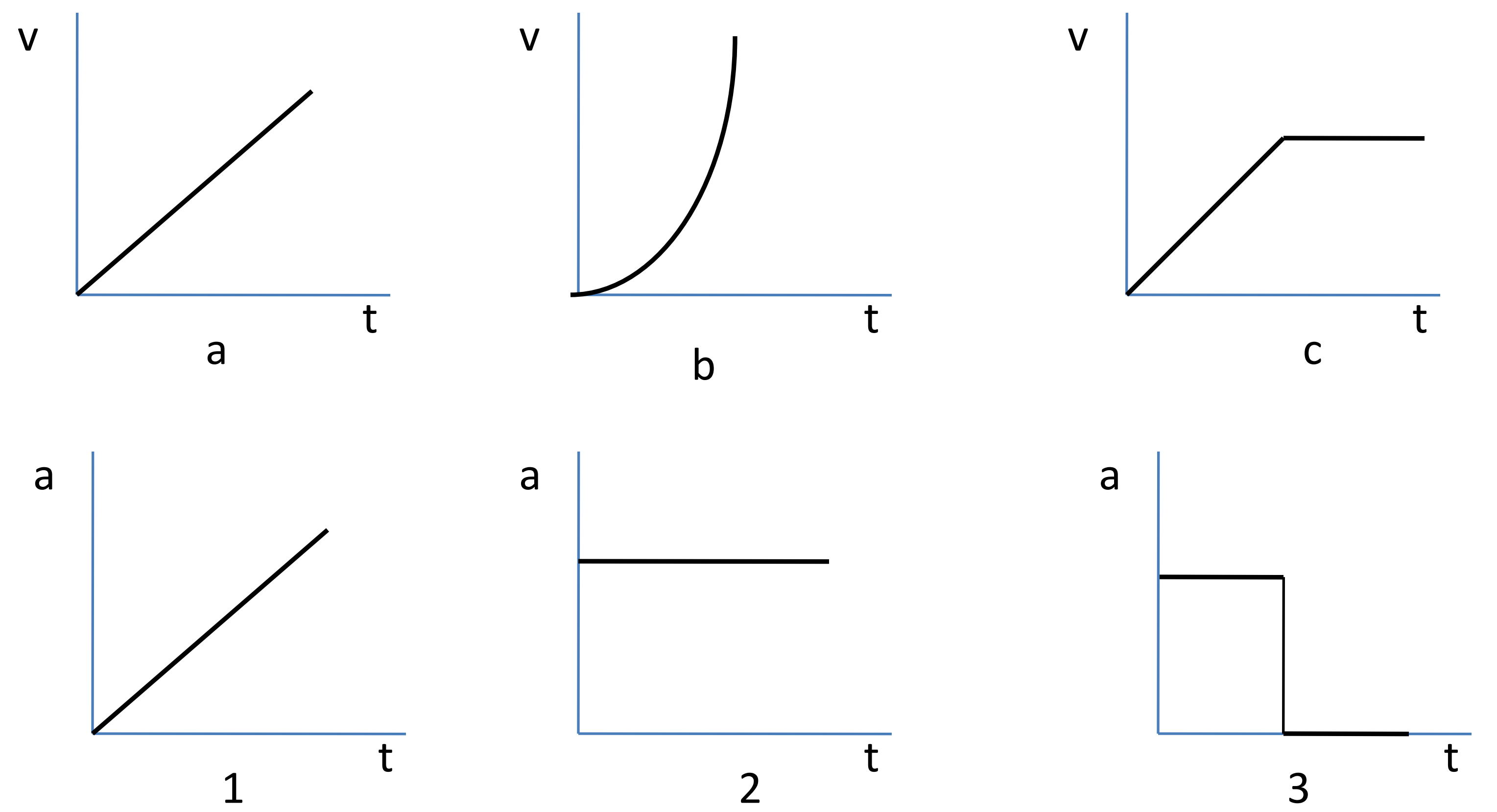


Match the velocity vs. time graph with the corresponding acceleration vs.time graph.



Match the velocity vs. time graph with the corresponding acceleration vs.time graph.

Answers: a-2 b-1 c-3



1-D Motion with Constant Acceleration

$\mathbf{a}_{ave} = (\mathbf{v}_f - \mathbf{v}_i)/(t_f - t_i)$ becomes $\mathbf{a} = (\mathbf{v}_f - \mathbf{v}_i)/t$

Rewrite as: $\mathbf{v} = \mathbf{v}_0 + \mathbf{a}*t$

$\mathbf{v}_{ave} = (\mathbf{v}_0 + \mathbf{v})/2$ when **a** is constant

Since $\Delta\mathbf{x} = \mathbf{v}_{ave}*t$, Then $\Delta\mathbf{x} = \frac{1}{2}(\mathbf{v}_0 + \mathbf{v})*t$

Combining: $\Delta\mathbf{x} = \frac{1}{2}(\mathbf{v}_0 + \mathbf{v})*t$ and $\mathbf{v} = \mathbf{v}_0 + \mathbf{a}*t$

We get: $\Delta\mathbf{x} = \frac{1}{2}(\mathbf{v}_0 + \mathbf{v}_0 + \mathbf{a}*t)*t$

or $\Delta\mathbf{x} = \mathbf{v}_0*t + \frac{1}{2}\mathbf{a}*t^2$

On page 36, by doing some more substituting, we can derive one more equation:

Using: $\Delta \mathbf{x} = \frac{1}{2}(\mathbf{v}_0+\mathbf{v})*t$ and $t = (\mathbf{v}-\mathbf{v}_0)/\mathbf{a}$

and doing some rearranging we get:

$$\mathbf{v}^2 = \mathbf{v}_0^2 + 2*\mathbf{a}*\Delta \mathbf{x}$$

3 very important equations
(found in table 2.4)

For constant acceleration:

Velocity as function of time

$\mathbf{v} = \mathbf{v}_0 + \mathbf{a} * t$

Displacement as a function of time

$\Delta \mathbf{x} = \mathbf{v}_0 * t + \frac{1}{2} \mathbf{a} * t^2$

Velocity as a function of displacement. Also called timeless equation.

$\mathbf{v}^2 = \mathbf{v}_0^2 + 2 * \mathbf{a} * \Delta \mathbf{x}$

Example 2.6 Runway length.

A plane lands with a speed of 160 mph and can decelerate at a rate of 10 mi/hr/s. If the plane moves with constant speed of 160 mph for 1.0 s after landing before applying the brakes, what is the total runway length needed to come to rest?

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First convert all quantities to SI units.

v_0 = 160 mph (1mph = 0.447 m/s) => 71.5 m/s

a = -10 mi/hr/s = -4.47 m/s^2 (negative because plane slows down in direction of motion)

Ex 2.6 cont.

For the 1.0 s the planes travels before applying brakes:

$\Delta x_{coasting} = \mathbf{v}_0 * t + \frac{1}{2} \mathbf{a} * t^2 = (71.5 \text{ m/s})(1.0 \text{ s}) + \frac{1}{2}(0)(1.0 \text{ s})^2 = 71.5 \text{ m}$

While braking to a stop:

Use $\mathbf{v}^2 = \mathbf{v}_0^2 + 2 * \mathbf{a} * \Delta \mathbf{x}$

$\Delta \mathbf{x}_{\mathbf{braking}} = (v^2 - v_0^2)/(2a) = (0 \text{ m/s} - (71.5 \text{ m/s}))^2/(2 * -4.47 \text{ m/s}^2)$

$\Delta \mathbf{x}_{\mathbf{braking}} = 572 \text{ m}$

Total length of runway is 71.5 m + 572 m = 644 m

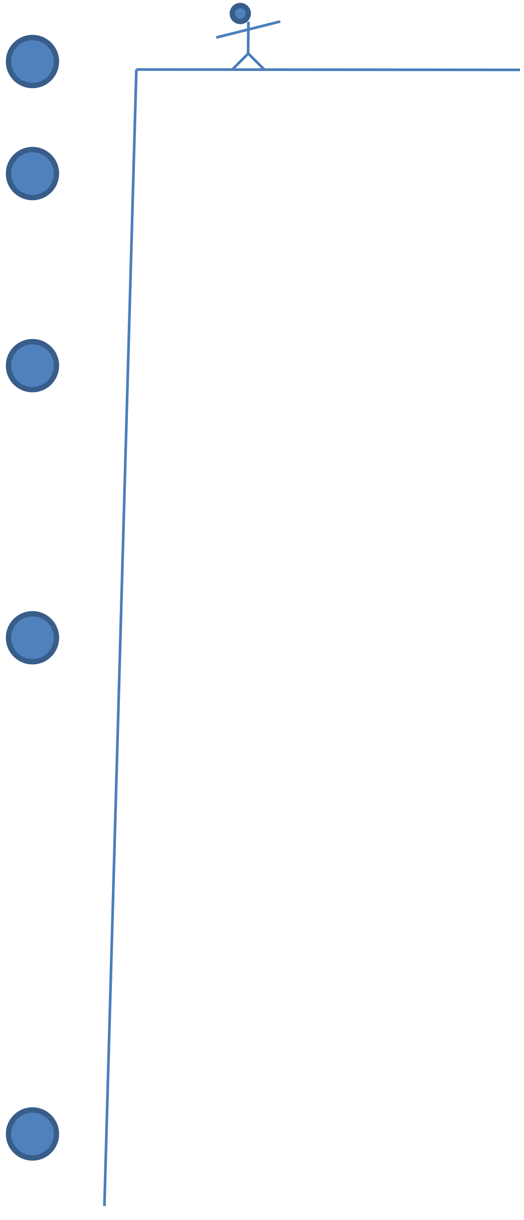
Free Falling Bodies

For free falling objects the acceleration is due to gravity; $a = g = 9.8\ m/s^2$ in the downward direction. (if the coordinate system states that up is positive, the gravity is negative)

For close estimates you can use $g = 10\ m/s^2$

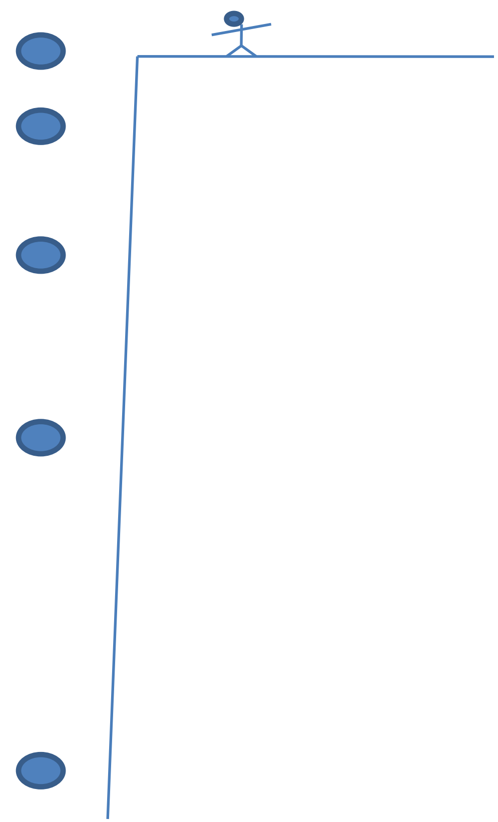
Suppose you dropped a ball from a high cliff. After each second interval, the magnitude of the ball's velocity increases by about 10 m/s.

Time (s)	Velocity (m/s)
0	0
1	10
2	20
3	30
4	40



Notice that in each 1 second time interval, the distance traveled increases.

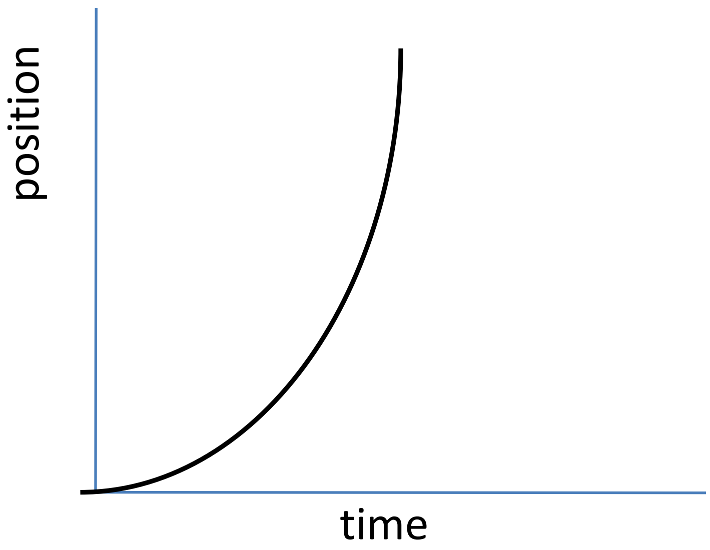
Time (s)	Velocity (m/s)
0	0
1	10
2	20
3	30
4	40



Remember the equation: $\Delta \mathbf{x} = \mathbf{v}_0 * t + ½\ \mathbf{a} * t^2$

The displacement as a function of time is quadratic.

If acceleration is constant, a graph of position vs. time will look like this:



Ballistic Rocket (Ex. 2.10)

A rocket moves straight upward, starting from rest with an acceleration of +29.4 m/s^2. It runs out of fuel after 4.0 s and continues upward to a maximum height before falling back to Earth.

a) Find the rocket's velocity and position after 4.0 s.
b) Find the maximum height the rocket reaches.
c) Find the velocity the instant the rocket hits the ground

Ballistic Rocket cont.

What we know:

Velocity at launch is zero. (Starting from rest)

Accelerates at +29.4 m/s^2 (Upward)

Time of acceleration is 4.0

While accelerating to find the velocity and position after 4.0 s, use:

$\mathbf{v} = \mathbf{v}_0 + \mathbf{a}*t$ and $\Delta \mathbf{x} = \mathbf{v}_0*t + ½\, \mathbf{a}*t^2$

Ballistic Rocket cont.

After 4.0 seconds:

$v = v_0 + a*t = 0m/s + (29.4\ m/s^2)(4.0\ s) = 118\ m/s$

$\Delta \mathbf{x} = \mathbf{v}_0 * t + ½\ \mathbf{a} * t^2 = (0m/s)(4.0\ s) + ½\ (29.4\ m/s^2)(4.0\ s)^2$

$\Delta x = 235\ m$

Next the rocket slows down until it reaches the maximum height.

Now:

$v_0 = +118\ m/s, \qquad a = g = -9.8\ m/s^2$

We also know that at the top, the velocity is zero to $v_f = 0m/s$.

Use : $\mathbf{v}^2 = \mathbf{v}_0^2 + 2*\mathbf{a}*\Delta \mathbf{x}$ to find Δx.

$\Delta x = (v^2 - v_0^2)/(2a) = (0\ m/s - (118\ m/s)^2/(2*-9.8\ m/s^2)$

$\Delta x = (v^2 - v_0^2)/(2a) = (0\ m/s - (118\ m/s)^2/(2 * -9.8\ m/s^2)$

$\Delta x = 710$ m, this is the distance the rocket continues to rise after Running out of fuel. To get the total height add the 235 m from Part a) for a total of 945 m. Notice that the book used a different Method to solve part b). They both work.

c) Find the rocket's velocity just as it hits the ground.

Rocket starts free falling from height of 945 m.

$a = g = -9.8\ m/s^2$ (downward)

The net displacement while falling is -945 m (downward)

I'll use the equation: $\mathbf{v}^2 = \mathbf{v}_0^2 + 2 * \mathbf{a} * \Delta \mathbf{x}$

$v^2 = (0\ m/s)^2 + 2(-9.8\ m/s^2)(-945\ m) = 18522\ (m/s)^2$

Taking the square root gives us v = 136 m/s.

What about the sign?? The velocity when it hits the ground is downward. All the other downward quantities in this problem were negative. The final velocity will be negative. (-136 m/s).