

Physics 2A

Chapter 2: Motion in One Dimension

“Whether you think you can or think you can’t, you’re usually right.” – Henry Ford

“It is our attitude at the beginning of a difficult task which, more than anything else, will affect its successful outcome.” – William James

“The first and most important step toward success is the feeling that we can succeed.”
Nelson Boswell

Reading: pages 31 - 58

Outline:

- ⇒ describing motion
 - representing position
 - representing velocity
 - from position to velocity (read on your own and covered in Lab 3)
- ⇒ uniform motion
- ⇒ instantaneous velocity (read on your own and covered in Lab 3)
- ⇒ acceleration
- ⇒ motion with constant acceleration
 - constant-acceleration equations
 - examples
- ⇒ solving one-dimensional motion problems (read on your own)
- ⇒ free fall
 - examples

Problem Solving

All constant-acceleration problems can be solved using the following three equations:

$$(v_x)_f = (v_x)_i + a_x \Delta t,$$

$$x_f = x_i + (v_x)_i \Delta t + \frac{1}{2} a_x (\Delta t)^2$$

$$(v_x)_f^2 = (v_x)_i^2 + 2a_x \Delta x.$$

Six quantities appear in these equations: x_i , x_f , $(v_x)_i$, $(v_x)_f$, a_x , and Δt . Note that if the motion is vertical instead of horizontal, then all of the equations are exactly the same except with x replaced with y .

Mathematically, a typical constant-acceleration problem involves identifying the known and unknown quantities, then solving one of the constant-acceleration equations for the unknown quantity. **You should use the Problem Solving Strategy listed on page 51 when doing constant-acceleration problems.**

It is often helpful in solving a constant-acceleration problem to fill in a table. For any problem, write numerical values next to given quantities and a question mark next to unknown quantity. There will usually be one equation that contains all of the known quantities and the unknown quantity.

Free-fall problems are exactly the same as other constant-acceleration problems for which the acceleration is given. The notation is different because we choose the y axis to be vertical, so the object moves along that axis rather than the x axis. You should realize that this is a superficial difference. The acceleration is always known (g , downward) and is usually not given explicitly in the problem statement. If up is defined as positive, then the acceleration due to gravity is $-g$ or -9.8 m/s^2 .

Quadratic equations.

You should be able to solve algebraic equations that are quadratic in the unknown.

If $At^2 + Bt + C = 0$, then

$$t = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

When the quantity under the radical sign does not vanish, there are two solutions. Always examine both to see what physical significance they have, then decide which is required to answer the particular problem you are working. If the quantity under the radical sign is negative, the solutions are complex numbers and probably have no physical significance for problems in this course. Check to be sure you have not made a mistake.

SUMMARY

The goal of Chapter 2 has been to describe and analyze linear motion.

GENERAL STRATEGIES

Problem-Solving Strategy

Our general problem-solving strategy has three parts:

PREPARE Set up the problem:

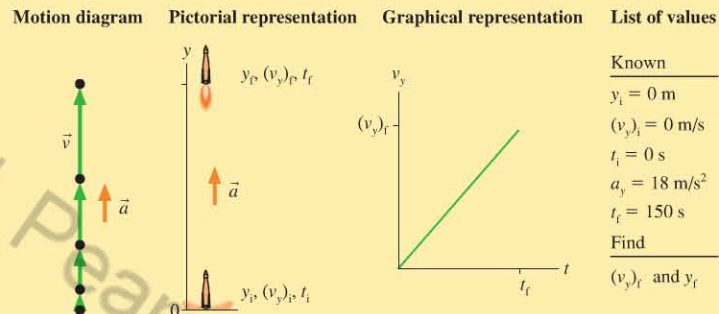
- Draw a picture.
- Collect necessary information.
- Do preliminary calculations.

SOLVE Do the necessary mathematics or reasoning.

ASSESS Check your answer to see if it is complete in all details and makes physical sense.

Visual Overview

A visual overview consists of several pieces that completely specify a problem. This may include any or all of the elements below:



IMPORTANT CONCEPTS

Velocity is the rate of change of position:

$$v_x = \frac{\Delta x}{\Delta t}$$

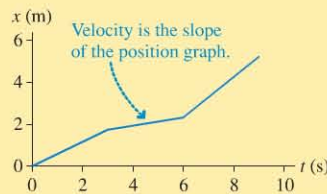
Acceleration is the rate of change of velocity:

$$a_x = \frac{\Delta v_x}{\Delta t}$$

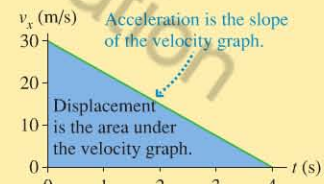
The units of acceleration are m/s^2 .

An object is speeding up if v_x and a_x have the same sign, slowing down if they have opposite signs.

A **position-versus-time graph** plots position on the vertical axis against time on the horizontal axis.



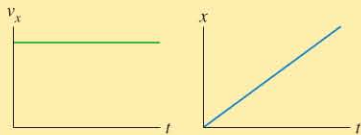
A **velocity-versus-time graph** plots velocity on the vertical axis against time on the horizontal axis.



APPLICATIONS

Uniform motion

An object in uniform motion has a constant velocity. Its velocity graph is a horizontal line; its position graph is linear.



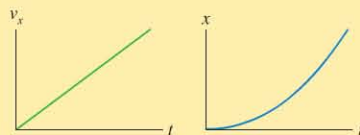
Kinematic equation for uniform motion:

$$x_f = x_i + v_x \Delta t$$

Uniform motion is a special case of constant-acceleration motion, with $a_x = 0$.

Motion with constant acceleration

An object with constant acceleration has a constantly changing velocity. Its velocity graph is linear; its position graph is a parabola.



Kinematic equations for motion with constant acceleration:

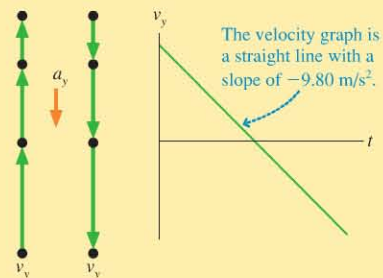
$$(v_x)_f = (v_x)_i + a_x \Delta t$$

$$x_f = x_i + (v_x)_i \Delta t + \frac{1}{2} a_x (\Delta t)^2$$

$$(v_x)_f^2 = (v_x)_i^2 + 2a_x \Delta x$$

Free fall

Free fall is a special case of constant-acceleration motion; the acceleration has magnitude $g = 9.80 \text{ m/s}^2$ and is always directed vertically downward whether an object is moving up or down.



Questions and Example Problems from Chapter 2

Question 1

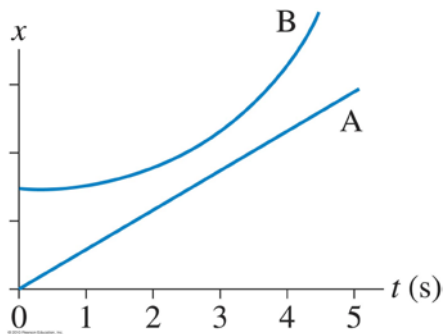
You are driving down the road at a constant speed. Another car going a bit faster catches up with you and passes you. Draw a position graph for both vehicles on the same set of axes, and note the point on the graph where the other vehicle passes you.

Question 2

The figure below shows the position versus-time graphs for two objects, A and B, that are moving along the same axis.

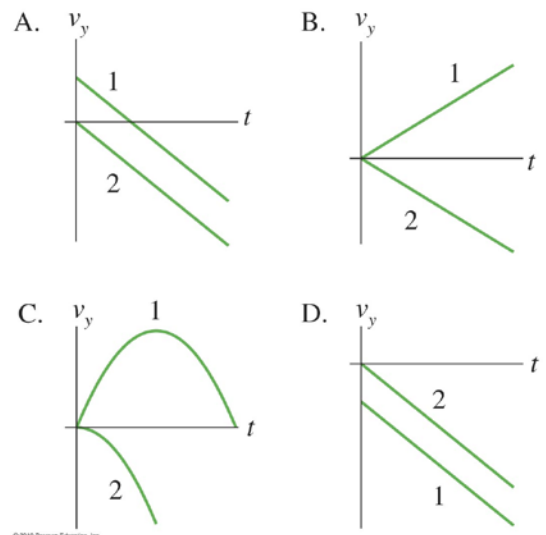
a) At the instant $t = 1$ s, is the speed of A greater than, less than, or equal to the speed of B? Explain.

b) Do objects A and B ever have the same speed? If so, at what time or times? Explain.



Questions 3

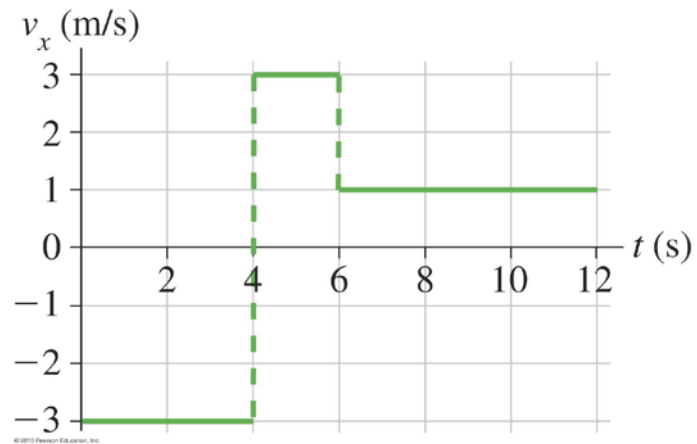
Ball 1 is thrown straight up in the air and, at the same instant, ball 2 is released from rest and allowed to fall. Which velocity graph in the figure to the right best represents the motion of the two balls?



Problem 1

For the velocity-versus-time graph of figure below:

- Draw the corresponding position-versus-time graph. Assume that $x = 0$ m at $t = 0$ s.
- What is the object's position at $t = 12$ s?
- Describe a moving object that could have these graphs.



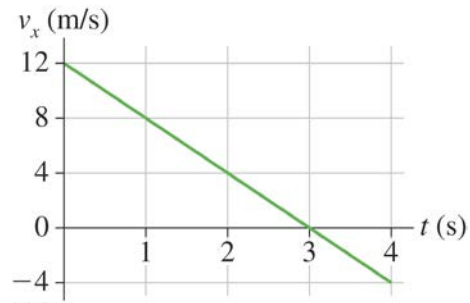
Problem 2

In a 5.00 km race, one runner runs at a steady 12.0 km/h and another runs at 14.5 km/h. How long does the faster runner have to wait at the finish line to see the slower runner cross?

Problem 3

A car starts from $x_i = 10$ m at $t_i = 0$ s and moves with the velocity graph shown in the figure below.

- What is the object's position at $t = 2$ s, 3 s, and 4 s?
- Does this car ever change direction? If so, at what time?



Problem 4

(a) What is the magnitude of the average acceleration of a skier who, starting from rest, reaches a speed of 8.0 m/s when going down a slope for 5.0 s? (b) How far does the skier travel in this time?

Problem 5

a) What constant acceleration, in SI units, must a car have to go from zero to 60 mph in 10 s?
b) What fraction of g is this?
c) How far has the car traveled when it reaches 60 mph? Give your answer both in SI units and in feet.

Problem 6

A light-rail train going from one station to the next on a straight section of track accelerates from rest at 1.1 m/s^2 for 20 s. It then proceeds at constant speed for 1100 m before slowing down at 2.2 m/s^2 until it stops at the station.

- a) What is the distance between the stations?
- b) How much time does it take the train to go between the stations?

Problem 7

Starting from rest, a speedboat accelerates at $+10.5 \text{ m/s}^2$ for a distance of 525 m. The engine is then turned off and the speedboat slows down at a rate of -5.00 m/s^2 . How long does it take for the speedboat to come to rest?

Problem 8

A drag racer, starting from rest, speeds up for 402 m with an acceleration of $+17.0 \text{ m/s}^2$. A parachute then opens, slowing the car down with an acceleration of -6.10 m/s^2 . How fast is the racer moving $3.50 \times 10^2 \text{ m}$ after the parachute opens?

Problem 9

At the beginning of a basketball game, a referee tosses the ball straight up with a speed of 4.6 m/s. A player cannot touch the ball until after it reaches its maximum height and begins to fall down. What is the minimum time that a player must wait before touching the ball?

Problem 10

An astronaut on a distant planet wants to determine its acceleration due to gravity. The astronaut throws a rock straight up with a velocity of +15.0 m/s and measures a time of 20.0 s before the rock returns to his hand. What is the acceleration (magnitude and direction) due to gravity on this planet?

Problem 11

A student standing on the ground throws a ball straight up. The ball leaves the student's hand with a speed of 15 m/s when the hand is 2.0 m above the ground. How long is the ball in the air before it hits the ground? (The student moves her hand out of the way.)

Problem 12

A 200 kg weather rocket is loaded with 100 kg of fuel and fired straight up. It accelerates upward at 30.0 m/s^2 for 30.0 s, then runs out of fuel. Ignore any air resistance effects.

- a) What is the rocket's maximum altitude?
- b) How long is the rocket in the air?
- c) Draw a velocity-versus-time graph for the rocket from liftoff until it hits the ground.