Kinematic in One Dimension

by

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P2.1g Solve problems involving average speed and constant acceleration in one dimension.

P2.2B Use the change of speed and elapsed time to calculate the average acceleration for linear motion.

Items:

1. The Five Kinematic Variables.

2. Equations Related to Uniform Motion.

3. Free-Fall.

Equations of Kinematics for Constant Acceleration

In this universe, most things are in constant motion, whether it be planets orbiting suns, electrons in atoms, or birds in the sky. Describing these motions mathematically is the first step toward understanding them.

Kinematics deals with the concepts that are needed to describe motion.

There are five kinematic variables related to motion with constant acceleration. They are:

    1. displacement, x

    2. acceleration (constant), a

    3. final velocity (at time t), v

    4. initial velocity, v_o

    5. elapsed time, t

There are 4 kinematic equations that relate the 5 variables and deal with motion.

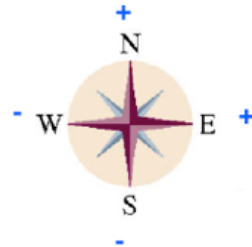| Kinematic Equations for Motion with Constant Acceleration |
| --- |
| $$v = v_o + at$$ |
| $$x = \tfrac{1}{2}\left(v_o + v\right)t$$ |
| $$v^2 = v_o^2 + 2ax$$ |
| $$x = v_o t + \tfrac{1}{2}at^2$$ |

Steps to solve kinematic problems:

1. Make a drawing.

2. Decide which directions are to be called positive (+) and negative (-).

3. Make a Data Table: Write down the values that are given for any of the five kinematic variables:

Data Table				
x	a	t	v_o	v

4. Verify that the information contains values for at least three of the five kinematic variables. Select the appropriate equation.

Example 1: **Jet taking off:** A jet is taking off from the deck of an aircraft carrier as shown in the figure below. Starting from rest, the jet is catapulted with a constant acceleration (a) of +31 m/s² (east direction) along a straight line and reaches a velocity (v) of +62 m/s. Find the displacement (x) of the jet.
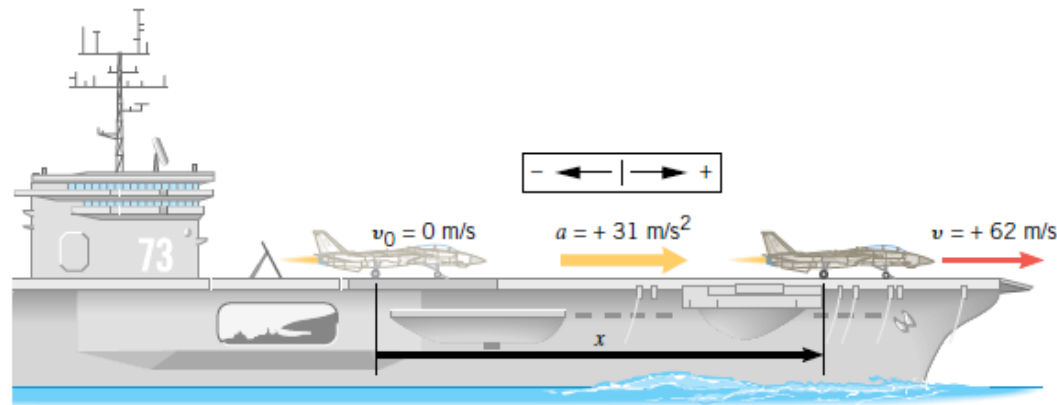
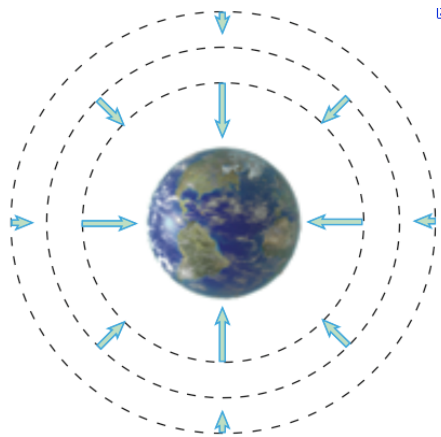| Jet Data				
x	a	v	v_0	t
?	+31 m/s²	+62 m/s	0 m/s	

$$x = \frac{v^2 - v_o^2}{2a} = \frac{(62\,\text{m/s})^2 - (0\,\text{m/s})^2}{2(31\,\text{m/s}^2)} = +62\,\text{m}$$

Free Falling Body

Earth is surrounded by a gravitational force field (blue- greenish vectors $\Rightarrow$, in the picture below). This means that every mass large or small feels a force pulling it towards its center.

In the absence of air resistance, all bodies at the same location above the Earth fall vertically with the same acceleration due to gravity.

This idealized motion is called **free-fall.**

Acceleration due to gravity (g)

The acceleration of a freely falling body is called the acceleration due to gravity.

The acceleration due to gravity is:

a) directed toward the center of the Earth,

b) has the symbol g

c) has the constant value of 9.80m/s^2.

**Acceleration due to gravity = a = g = 9.80m/s^2 or 32.2 ft/s^2**

In the absence of air resistance, all bodies at the same location above the Earth fall vertically with the same acceleration due to gravity **= a = g = 9.80m/s^2** Example is shown next.

Effect of air resistance on the speed of falling objects

The figure show the effect of air resistance on the speed of falling objects.

a) Air filled tube: In the presence of air resistance, the acceleration of the rock is greater than that of the paper. The effect of air resistance is responsible for the slower fall of the paper.

b) Evacuated tube: In the absence of air resistance, both the rock and the paper have the same acceleration due to gravity (g = 9.80m/s² or 32.2 ft/s²).

Air-filled
tube
(a)

Evacuated
tube
(b)
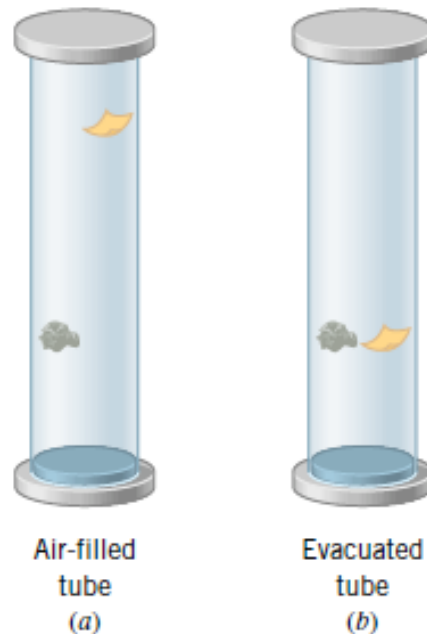
Example 2: A Falling Stone: A stone is dropped from the top of a tall building.

After t = 3.00s of free fall, what is the displacement y of the stone?

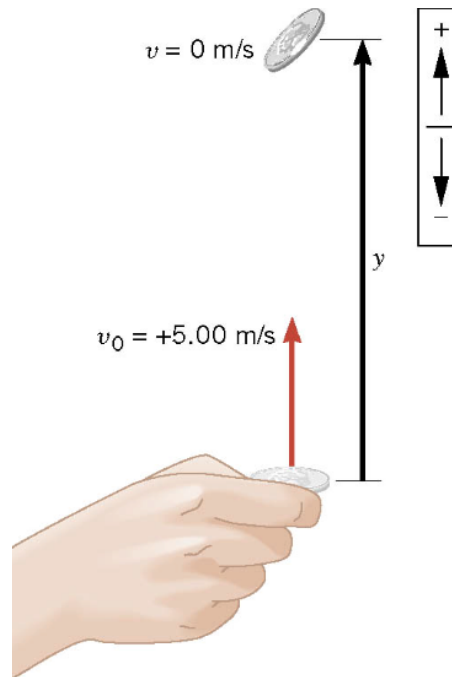Because it is a free fall, a = **-9.80m/s² (**negative because the up direction is +).

y	a	v	V_o	t
?	-9.80 m/s²		0 m/s	3.00 s
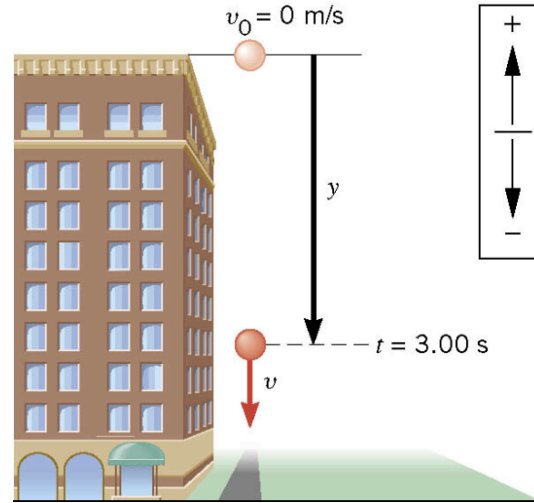
$y = v_o t + \frac{1}{2} a t^2$

$= (0\,\text{m/s})(3.00\,\text{s}) + \frac{1}{2}(-9.80\,\text{m/s}^2)(3.00\,\text{s})^2$

$= -44.1\,\text{m}$

Example 3: A Referee Tosses the Coin Up.

The referee tosses the coin up with an initial speed of 5.00m/s. In the absence of air resistance, what kinematic variables can you calculate?

$v = 0$ m/s

y

$v_0 = +5.00$ m/s

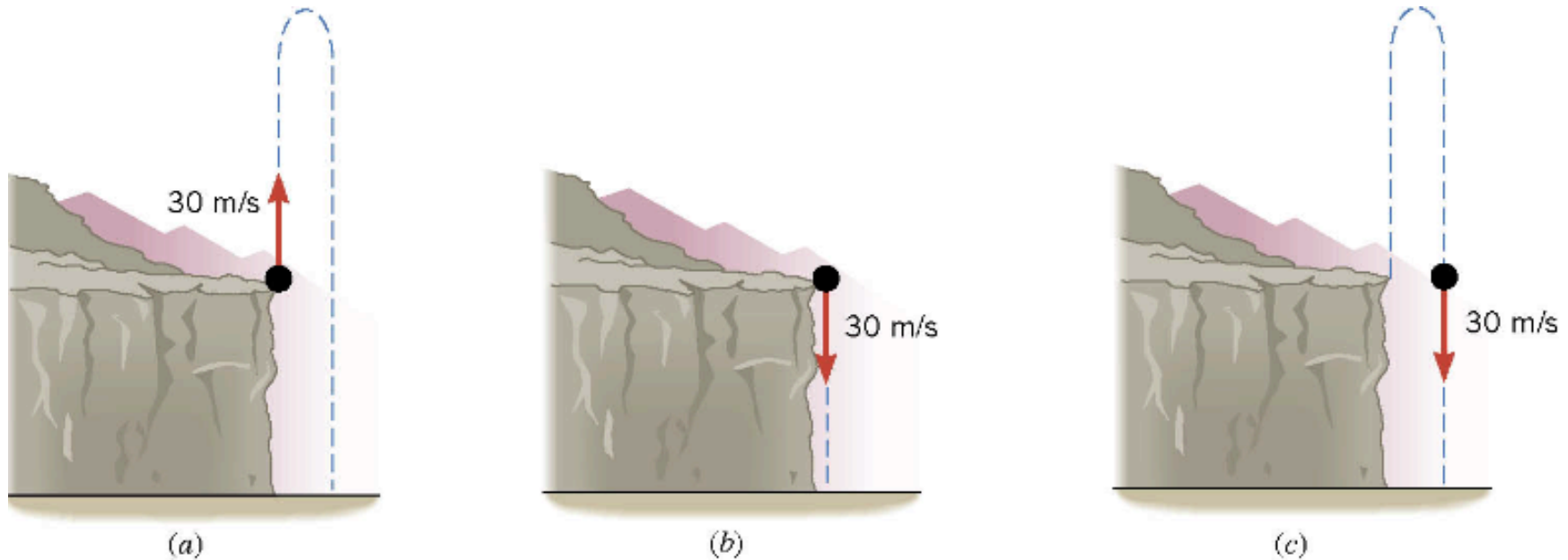| Data Table				
y	a	t	v_0	v

Example 4: *Speedboat with a Constant Acceleration;*

The speedboat below has a constant acceleration of +2.0 m/s². If the initial velocity of the boat is +6.0 m/s, what kinematic variables can you calculate after 8.0 seconds?

$t_0 = 0$ s

$a = +2.0$ m/s²

$v_0 = +6.0$ m/s

$t = 8.0$ s

v

x
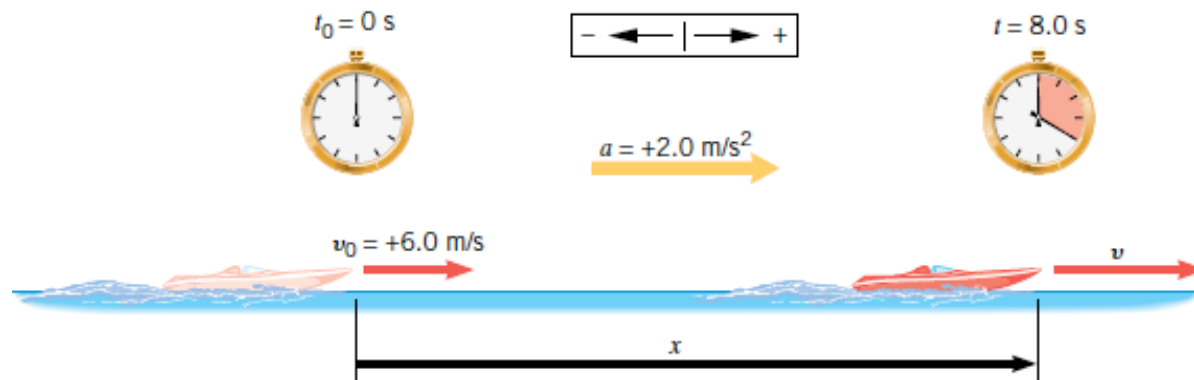
Data Table				
x	a	t	v_0	v

Example 5: *From the Edge of a Cliff, a Pellet is Fired from a Gun;*

(a)   (b)   (c)

Picture (a): From the edge of a cliff, a pellet is fired straight upward from a gun.

The pellet's initial speed is 30 m/s.

Picture (b): From the edge of a cliff, the pellet is fired straight downward with an

initial speed of 30 m/s.

Compare the speed of both pellets when they hit the water surface.

References:

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Physics 1200 Lecture Slides: Dr. Thomas Humanic, Professor of Physics, Ohio State University, *2013-2014 and Current. www.physics.ohio-state.edu/~humanic/*

2) Cutnell, J. D. & Johnson, K. W. (1998). *Cutnell & Johnson Physics, Fourth Edition*. New York: John Wiley & Sons, Inc.

The edition was dedicated to the memory of Stella Kupferberg, Director of the Photo Department:"We miss you, Stella, and shall always remember that a well-chosen photograph should speak for itself, without the need for a lengthy explanation"

3) Martindale, D. G. & Heath, R. W. & Konrad, W. W. & Macnaughton, R. R. & Carle, M. A. (1992). *Heath Physics.* Lexington: D.C. Heath and Company

4) Zitzewitz, P. W. (1999). *Glencoe Physics Principles and Problems*. New York: McGraw-Hill Companies, Inc.

5) Nada H. Saab (Saab-Ismail), (2010-2013) Westwood Cyber High School, Physics.

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