Free Fall

Manager: Katie Knowles, Notetaker: Rubin Ortega, Speaker: Mauricio Uribe, Equity Manager: Alex Du

After completing this worksheet, you will be able to:

- Analyze the kinematics of objects undergoing free-fall.
- Identify the limitations of the simplified free-fall model.
- Begin the development of a robust problem-solving strategy.

While completing this worksheet you will develop:

- Oral & Written Communication Skills (exchanging information with teams and presenting results to the class).
- Management Skills (managing time in-between team exchanges and class reports).
- Information Processing Skills (making deductions based on pictorial representations and extracting data from problem descriptions).
- Critical Thinking Skills (make predictions without the need to rely on calculations based on the data offered).

Model 1: Motion Diagram of an Object in Free Fall

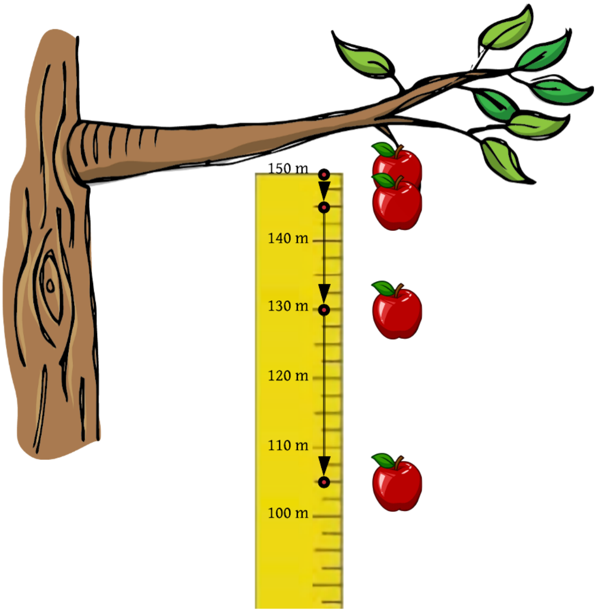

Figure 1: Motion Diagram of an apple falling from a very tall apple tree.

1) As a team, examine ***Model 1***, and fill out the table below.

Time				0s	1s	2s	3s
Apple's position				150	145m	130m	105m

2) Use your table from question (1) to finish the table below.

Time interval				0-1s	1-2s	2-3s
Apple's average velocity	-			-5m/s	-15m/s	25m/s

Send your Speaker to check your team's work to question (2) with a neighboring team before you continue.

3) From your table in question (2), discuss within your team what you can conclude about the **apple's acceleration**. What is the apple's acceleration? Does it change? Write your conclusions below.

The apple's acceleration is constant at around $-10 m/s^2$

Once your team agrees on a value of the apple's acceleration, have your Speaker report this [to th]e class.

4) Considering the pattern in question (2), predict what the **<u>average</u> velocity** will be for the time interval, and report it below.

-35 m/s

5) As a team, discuss the difference between **average** and **instantaneous** velocity. Complete the following table.

Time	0s	1s	2s	3s	4s
Apple's instantaneous velocity	0m/s	-10m/s	-20m/s	-30m/s	-40m/s

Send your Speaker to check your team's work to question (4) and (5) with a neighboring team before you continue.

6) Looking at your answer to question (5). How is the apple's velocity changing with time? Do you see any patterns? As a team, using the acceleration from question (3), construct a method to find the instantaneous velocity of the apple at

any time, *t*. Describe it below.

- The apple's velocity is decreasing at a constant rate (pattern is $-10 m/s^2$)

- The product of time and acceleration, when added to V_{is}, results in V_{fs}, the final velocity

We assign symbols for each variable we encounter. Below is a summary of some common variables used in kinematics.

Variable	Description
S_i	Initial position in the x or y direction.
S_f	Final position in the x or y direction.
V_{is}	Initial velocity in the x or y direction.
V_{fs}	Final velocity in the x or y direction.
$\Delta t = t_f - t_i$	The symbol delta (represents change. Therefore, is the change in time. This is equivalent to .
a_s	Acceleration in the x or y direction.

Information Box 1:

7) Which of the variables from ***Information Box 1*** do you use in your method from question (6)?

$V_{fs}, a_s, \Delta t, V_{is}$

8) Using the variables from ***Information Box 1***, build an equation describing your method of finding the apple's velocity from question (6).

$\boxed{V(t) = -10t}$ $\quad V_{fs} = a_s \cdot \Delta t + V_{is}$

Answer

Send your Speaker to check your team's answer to question (8) with a neighboring team before you continue.

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Once your team agrees on the answer to question (8), have your Speaker report your team's equation [to t]he class whiteboard.

9) Discuss in your team whether your equation from question (8) would be valid if the acceleration were not constant. Explain, in your own words, why or why not.

The equation would not work because the acceleration would now

When the acceleration of an object is constant, we can use the three following kinematic formulas:

Information Box 2:

In your team, consider the following worded problem statement of an apple falling from a tree:

"An apple initially hangs at rest from a tree branch 150 m above the ground. Suddenly, the apple falls from the tree and starts falling to the ground. Calculate the apple's velocity just before it hits the ground."

10) Together with your team, in the problem statement above, circle or highlight all the pieces of information you think are important.

11) Sometimes, not all numbers needed to solve a problem are given. From the problem statement above, what do you know about the **apple's initial velocity**?

$V_i = 0 m/s$

12) From the problem statement above, what do you know about the **apple's acceleration**? *Hint: Think about problems taking place on another planet, or with no gravity at all.*

$a = 9.8 m/s^2$

13) Review your answers to questions (10) – (12), and list each of the variables from ***Information Box 1*** as either a known or an unknown. Circle or highlight the one you are asked to find.

Knowns	Unknowns
V_i S_i	V_f
a, S_f	Δt

Send your Speaker to check your team's answer to question (13) with a neighboring team before you continue.

14) Based on the knowns and unknowns you wrote, which of the three kinematic formulas from ***Information Box 2*** would you use here? Write it below using your variables from question (13).

$V_f^2 = V_i^2 + 2a(S_f - S_i)$

15) Explain why you didn't choose one of the other two formulas.

We were only given 1 variable and we can't do any more without any additional known variables

Once your team has agreed on the best kinematic equation to use, have your Speaker report the decided upon equation from question (14) on the class whiteboard.

16) Use your answers to question (13) and (14) to solve the **worded problem statement**. Show your work in the box below.

$V_i = 0 m/s$

$a = -9.8 m/s^2$

$S_f = 0 m$

$S_i = 150 m$

$V_f^2 = V_i^2 + 2a(S_f - S_i)$

$V_f^2 = (0)^2 - 2(-9.8)(0 - 150)$

$V_f^2 = 0 - (-19.6(-150))$

$V_f^2 = -(2940)$

$\sqrt{V_f^2} = -\sqrt{2940}$

$V_f = -54.2 m/s$

Send your Speaker to check your team's answer to question (16) with a neighboring team before you continue.

17) Based on your work for question (16), and from looking at the kinematic equations in ***Information Box 2***, would you say an object's mass, size, and shape have any impact on its velocity during free fall? Briefly explain your answer.

None of the aforementioned properties affect freefall, as the force of gravity is independent from all other factors. This results in all objects falling at the same acceleration

18) Brainstorm with your team to find a real-life example that contradicts your answer to question (17) and write it below.

Feathers fall slower than a bowling ball

19) Based on your answer to question (18), what are we ignoring in free-fall problems?

This is caused by air resistance with the small hairs capturing air and uses it to push the feather against the gravitational pull.

Have your Speaker sign up with Dr. Morris to report your team's answer to question (18) and (19) to the class.

Are you finished? Considering volunteering to help other teams! Sign up with Dr. Morris.