Free Fall

I. Free Fall

Free Fall is a special case of uniform (constant) acceleration where the acceleration is $9.8\ m/s^2$ toward the Earth.

A. Assumptions

1. **The body must be NEAR the Earth**. Quantitatively, this means that its height above the Earth must be small compared to the radius of the Earth so that it can't see the curvature of the Earth. We will look at this condition again when we study Newton's Universal Law of Gravitation and when we study Gauss' Law.

2. **Neglecting aerodynamics -** This means that we consider the pull of gravity to be the only "push" or "pull" on the body. We will look at this again when we study Newton's Laws.

B. Leonardo de Vinci

Leonardo de Vinci developed the first law of falling bodies as part of his work as a military engineer. Leonardo realized that a falling ball covered increasingly distance in each succeeding second. Leonardo was influenced by the prevailing concept that the laws of nature must obey the perfection of God. Thus, he proposed that God would only have used integers of distance.

Time (s)	Distance Traveled This Second	Total Distance Traveled
0	0	0
1	1	1
2	2	3
3	3	6
4	4	10

Although Leonardo's theory turned out to be wrong, it was a good approximation for falling bodies as long as the flight time was small. Thus, it found important application in Leonardo's day by predicting the flight of Italian projectiles with their limited range.

C. Galileo Galilee

Using Leonardo's ideas and performing experiments, Galileo developed a corrected law of falling bodies that is still used today. Galileo's work is similar to Leonardo's in some ways but he stated that after the ball started falling God **only used the Odd Integers** (see table below)

Time (s)	Distance Traveled This Second	Total Distance Traveled
0	0	0
1	1	1
2	3	4
3	5	9
4	7	16

We see that Galileo's work shows that the distance traveled by a ball dropped from rest is directly proportional to the square of the time.

$$\Delta x \propto t^2$$

D. Galileo's Falling Bodies and the Kinematic Equations

If we assume that the acceleration of a falling object is constant then the Kinematic equations that we developed previously must hold. Since our falling body starts with an initial velocity of zero, the Kinematic equation becomes

Comparing our Kinematics equation to Galileo's work, we see that the proportionality constant is half the acceleration due to gravity!!

Thus, we know that the **acceleration due to gravity for a falling body** is a **<u>CONSTANT</u>**!

Galileo did even more. He determined that everybody (rock, book, or you) has the same acceleration due to gravity!! All of his work is contained in the following statement of Galileo's Law of Falling Bodies.

Galileo's Law of Falling Bodies

<u>All</u> falling bodies accelerate <u>toward the center of Earth</u> <u>at 9.8 m/s^2</u>.

Read the law carefully, acceleration is not the same thing as moving (ie velocity)!!

E. Kinematics

Falling body problems are just a special case of constant acceleration problems! The Kinematic equations are valid and can be used to solve problems. In the case of falling bodies, you have additional information (the value of the acceleration)!

F. Useful Information

1. The vertical velocity of the object is _________________ at the

object's _____________________ _______________________________

2. You can **NOT** include the **interaction** between the **ball** and the **ground** when using the Kinematic equations since it **changes the acceleration** of the object (not constant)!!

Thus, the velocity of the ball is **NOT ZERO** at the **ground** if you are using the Kinematic equations.

3. The time that a ball rises is NOT necessarily equal to the time it takes to fall!! In order for the times to be the same, the ball must start and end at the same height.

Falling Body Example (Problem 2-33):

a) If a flea can jump straight up to a height of 0.440 m, what is its initial speed as it leaves the ground?

Solution:

Figure **Useful Equations**

Physics:

Given:

a)

b) How much time is it in the air?