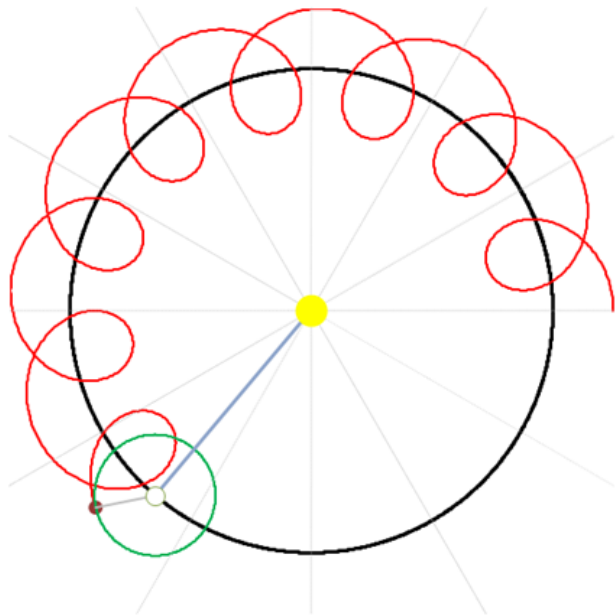
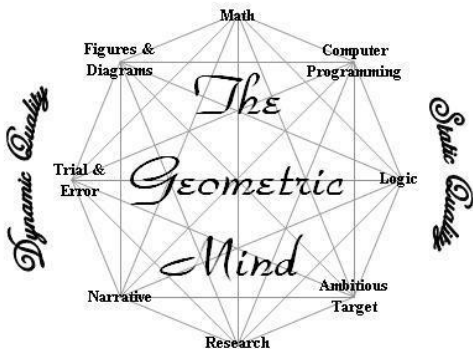


THE GEOMETRIC MIND SERIES  
an *auto*SOCRATIC QUICK-START publication

# *From an Apple to the Planets*

Newton, Gravity, and Planetary Motion





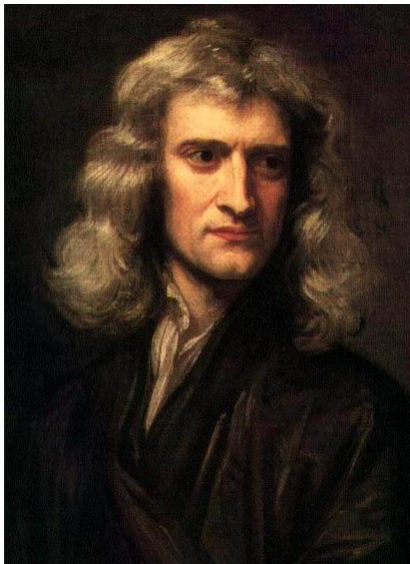
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## *A Simple Observation*

An apple fell from the tree. The moon is not falling. *Why not?*



**ISAAC NEWTON**

**1642 – 1727**

# NEWTON'S APPLE

## An Interesting Astronomical Story

Isaac Newton was sitting on the ground when an apple fell from a tree, (maybe) hitting him on the head.

Newton looked up in the sky and saw the moon, NOT falling to earth.

Newton wondered: "Why do some things fall to earth, but others do not"?

The moon doesn't just sit there - it orbits the earth.

The speed of the orbiting moon must be responsible for it not falling to earth.

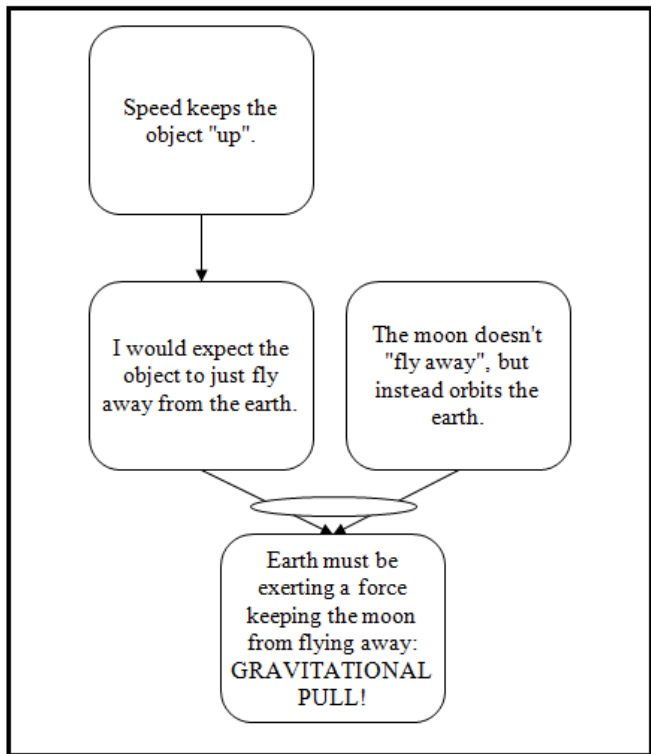
If speed alone was at work, the moon would fly away!



Of course, the moon orbits the earth.

# SPEED IS THE KEY

But where does "attraction" come from?



# UNIVERSAL GRAVITATION

## Newton's Famous Law

The earth exerts a force - a gravitational pull - on the moon.

If the moon were twice as big as the earth, likely we'd be pulled towards the moon!

The "pulling force" depends on the mass of the the objects in question.

All planets, stars, etc., are masses like the earth.

All bodies exert a pull on each other:  
**THE LAW OF UNIVERSAL GRAVITATION.**

# A FEW EXAMPLES

## Planetary Systems

If there are no other forces acting, and these bodies are completely stationary, and if Newton is right about the Law of Universal Gravitation is correct, then where will these planets meet?

Set 1  
2 Bodies



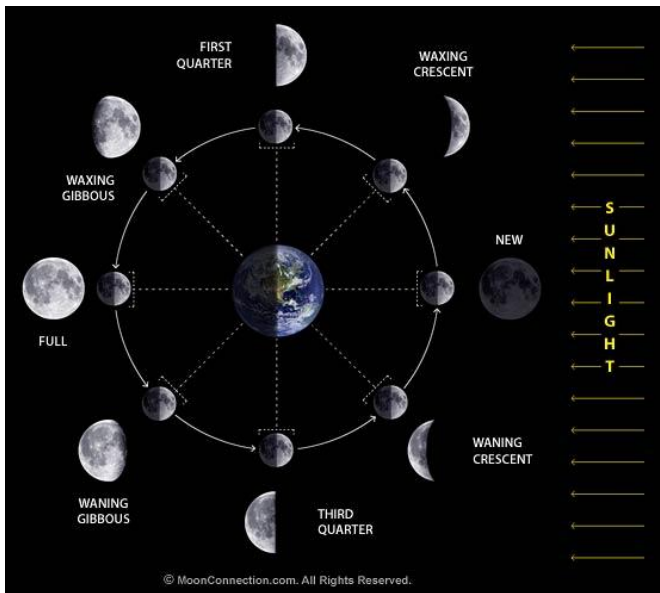
Set 2  
2 Bodies



Set 3  
3 Bodies







## *Exploring the Lunar Orbit*

Since we're talking about the moon and orbits, *what is the lunar orbit?* The *earth's* orbit, of course, is about 365.25 days. How long does it

take for the *moon* to go around the *earth*? A little research tells me: about 27.3 days.

Another way to think about this is: what's the number of days between full moons? Let's see:

<u>Day</u>	<u>Time</u>	<u>Approximate Difference</u>
January 26th	11:38 PM	
February 25th	3:26 PM	30.0
March 27th	5:27 AM	30.0
April 25th	3:57 PM	28.0
May 25th	12:25 AM	31.0
June 23rd	7:32 AM	29.0
July 22nd	2:16 PM	29.0
August 20th	9:45 PM	29.0
September 19th	7:13 AM	30.0
October 18th	7:38 PM	29.0
November 17th	10:16 AM	30.0
December 17th	4:28 AM	30.0
<b>Average Days Between Full Moons</b>		<b>29.5</b>

*What's this? 29.5? Why is there a difference?*

# THE LUNAR ORBIT

What is going on?

A full moon is when the earth is inbetween the sun and the moon.

When the moon returns to this same position, it has gone around the earth one time.

The data shows the average orbit time for the moon is 29.5 days.

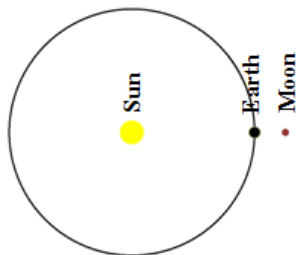
My research shows the average orbit time is 27.3 days.

**I don't understand what "lunar orbit" means!**

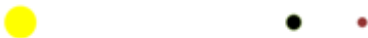
# THE LUNAR ORBIT

## *What is Going on?*

Let's just model it. Here's a "solar system", with just the sun, the earth, and the moon:



Since I'm going to just look at one moon orbit, let's strip away some of the detail above:



# MONITORING THE MOON AS IT ORBITS THE EARTH

**Orbit Time:  $\frac{1}{4}$  of 27.3 days.**

This puts the moon  $\frac{1}{4}$  of the way around the earth:



**Orbit Time:  $\frac{1}{2}$  of 27.3 days.**

This puts the moon  $\frac{1}{2}$  of the way around the earth:



**Orbit Time:  $\frac{3}{4}$  of 27.3 days.**

This puts the moon  $\frac{3}{4}$  of the way around the earth:



**Orbit Time: 27.3 days.**

This puts the moon all the way around the earth:



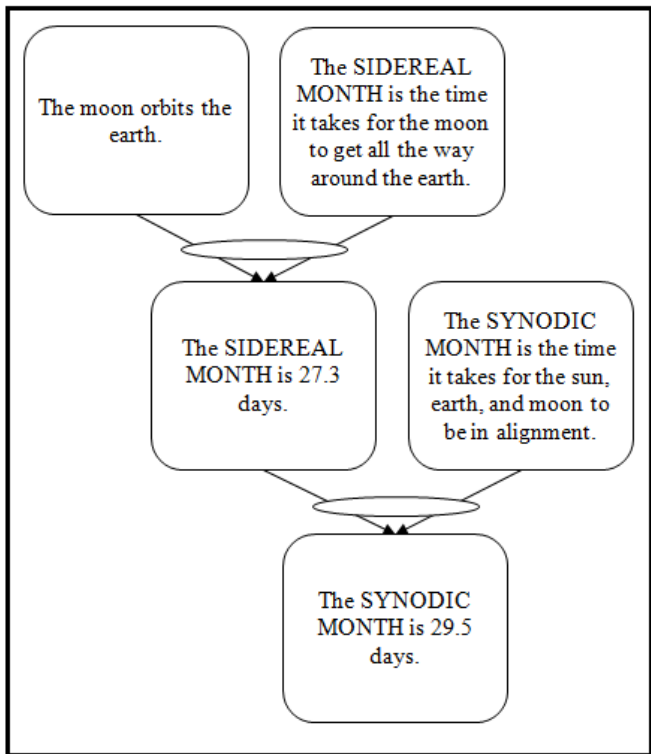
## THE PROBLEM

And now I see the problem. Yes, the moon has made one “complete trip” around the earth. However, the earth has now moved itself as it rotates around the sun! Therefore, the sun, earth, and moon are not in alignment. When are they in alignment? We know that: 29.5 days!



# LUNAR MONTHS

There ARE Two of Them After All!





# *Solar System Designs*

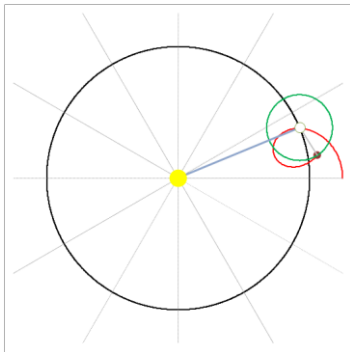
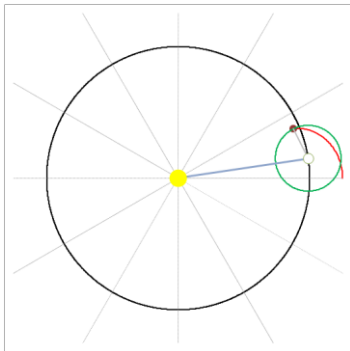
## *Let's Continue the Analysis*

Above, we've looked at the moon going around the earth just once. What happens if we trace the moon's path over several years?

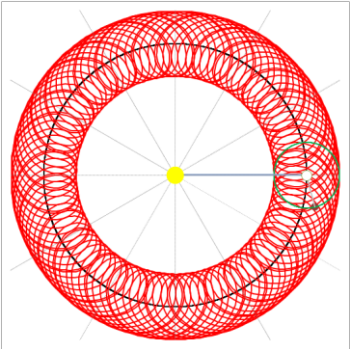
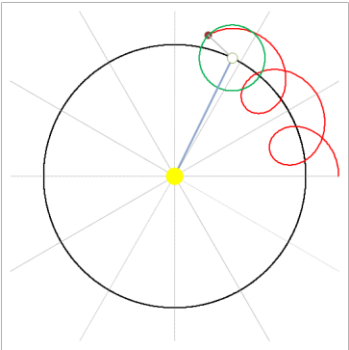
Another thing to keep in mind: in this model, we've got a certain radius for the earth's orbit, and one for the moon. The earth's is approximately 200 units, and the moon 50 units. This was for the sake of demonstration. The real relationship is much different than this. We'll talk about this shortly.

# Tracing the Path of the Moon About the Earth

Through one orbit

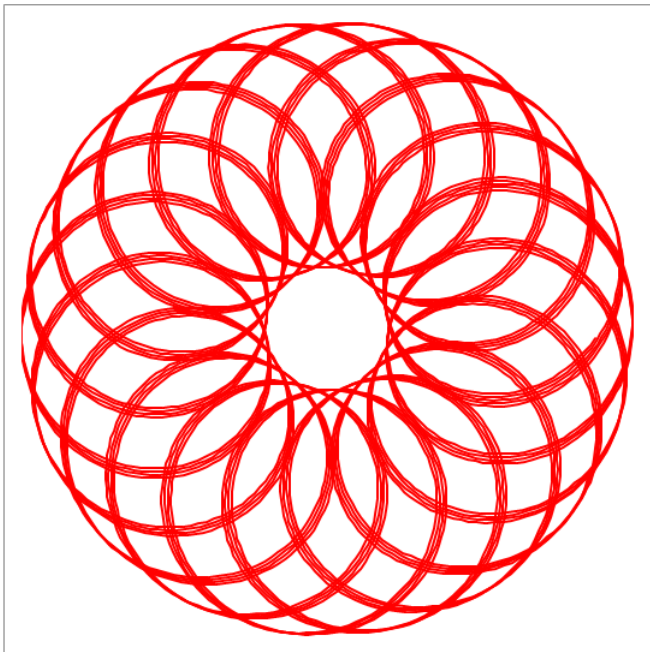


# Tracing the Path of the Moon About the Earth Through Several – and then Hundreds – of orbits

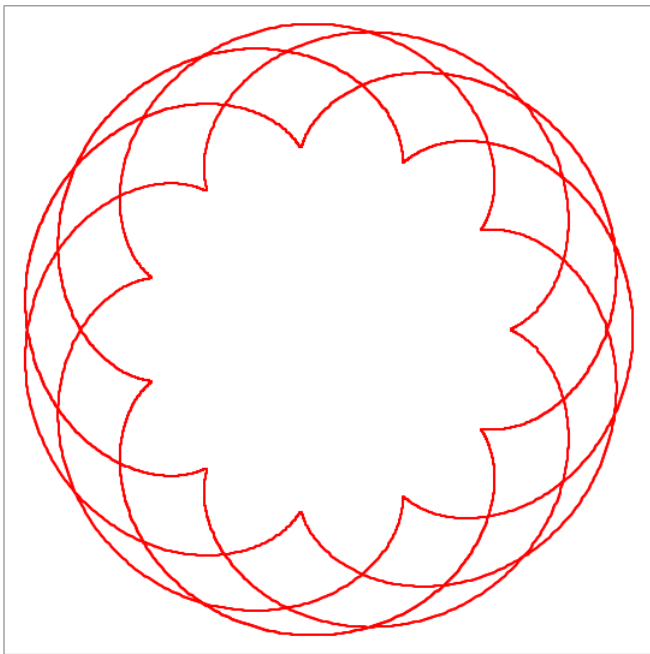


# DIFFERENT PARAMETERS

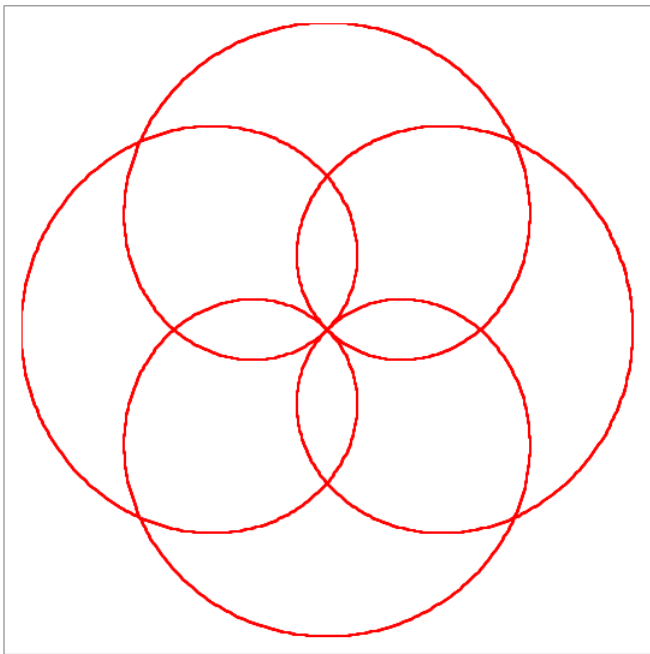
	<u>Earth</u>	<u>Moon</u>
Orbit (Radius)	150	100
Orbit (Days)	360	19



	<u>Earth</u>	<u>Moon</u>
Orbit (Radius)	200	50
Orbit (Days)	150	40



	<u>Earth</u>	<u>Moon</u>
Orbit (Radius)	125	125
Orbit (Days)	275	55





# THE GEOMETRIC MIND

# PROBLEMS

The following three problems each have a CHECK  
(to make sure you've done the problem right).

Once you've confirmed you've done the problem  
right, there's a KEY. The key is necessary to  
unlock the next installment.



**Key1**



**Key2**



**Key3**



# PROBLEM 1

	<u>Average Distance of Earth from Sun (miles)</u>	<u>Average Distance of Moon from Earth (miles)</u>	
Actual	93,000,000	240,000	
Model	200	50	incorrect scale
Model	200	<input type="text"/>	correct scale

.

Check Key 1

## PROBLEM 2

	<u>Sidereal Month</u>	<u>Synodic Month</u>
Actual	27.3	29.5
Theoretical	45.0	

.  **3**  
Key 2 Check

### PROBLEM 3

The model assumed the earth goes around the sun every 365.25 days. That's not exactly right. Actually, it's 365 days, 5 hours, 49 minutes, and 12 seconds. What's the difference? (Hint – convert the fractional part to seconds).

About	3	6	5	.	2	5	0	0
Exact	3	6	5	.				
				.			7	

Check Key3



THE GEOMETRIC MIND

# CONCEPT CARD

## **Look for the Exception**

Things fall. Wait a minute. The moon isn't falling. Why not? To every rule, there's an exception, and in explaining that exception is a wealth of information!

# LUNAR MONTHS

There ARE Two of Them After All!

The moon orbits the earth.

The SIDEREAL MONTH is the time it takes for the moon to get all the way around the earth.

The SIDEREAL MONTH is 27.3 days.

The SYNODIC MONTH is the time it takes for the sun, earth, and moon to be in alignment.

The SYNODIC MONTH is 29.5 days.



