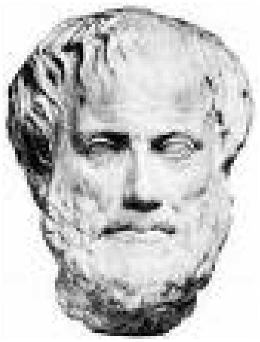
PHYSICISTS TIME-LINE

Classical Period 500 BC	Middle Ages 400 AD	Renaissance Ages 1300	Classical Physics 1700 -1900 EM	Thermo
Aristotle (c. 300 BC)	Al-Fazari (735-806)	Copernicus (1473-1543)	Franklin (1706 – 1790)	Carnot (1796-1832)
Ptolomy (c. 200 AD)	Al-khwarizmi (850-926)	Kepler (1571-1630)	Coulomb (1736 – 1806)	Kelvin (1824 – 907)
	Ibn Sina, (965-1039)	Galileo (1564-1642)	Faraday (1791 – 1867)	Boltzmann (1844 -1906)
	Ibn Al-Haitham (980-1037)	Newton (1642-1727)	Maxwell (1831 – 1879)	

Modern Physics 1900 - PRESENT

1- SCIENTISTS FROM THE CLASSICAL PERIOD



Aristotle

(384- 322 BC)

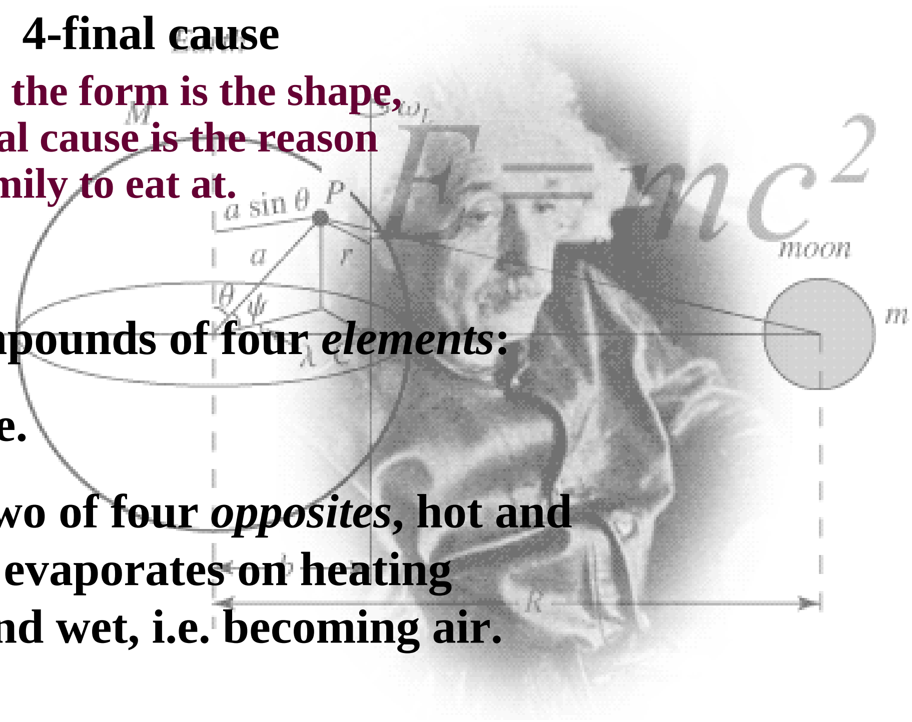
Aristotle was the most famous philosopher and scientist in ancient Greece. He was a student of the famous philosopher Plato and a tutor of Alexander of Macedonia.

❑ CAUSES

Aristotle practiced detailed observation of plants and animals. His study of nature was a search for “causes”. He stated that any object had four *features*:

1-matter 2- form 3-moving cause 4-final cause

For example, for a table, the matter is wood, the form is the shape, the moving cause is the carpenter and the final cause is the reason the table was made in the first place, for a family to eat at.



❑ ELEMENTS

Aristotle assumed all substances to be compounds of four *elements*:

1- earth 2- water 3- air 4- fire.

Each of these has to be a combination of two of four *opposites*, hot and cold, and wet and dry. for example, water evaporates on heating because it goes from cold and wet to hot and wet, i.e. becoming air.

❑ MOTION:

➢ WHY THINGS MOVE?

- **For Aristotle, motion of the animal was fulfilling his "nature", just as the growth fulfilled the nature of the animal.**

- **The motion of any non-living objects could be understood by postulating that: *elements tend to seek their natural place* in the order of things.**

According to Aristotle, Earth's place was at the bottom; water rested on the earth; air on top of that, and flames rose toward the stars, which were of fire.

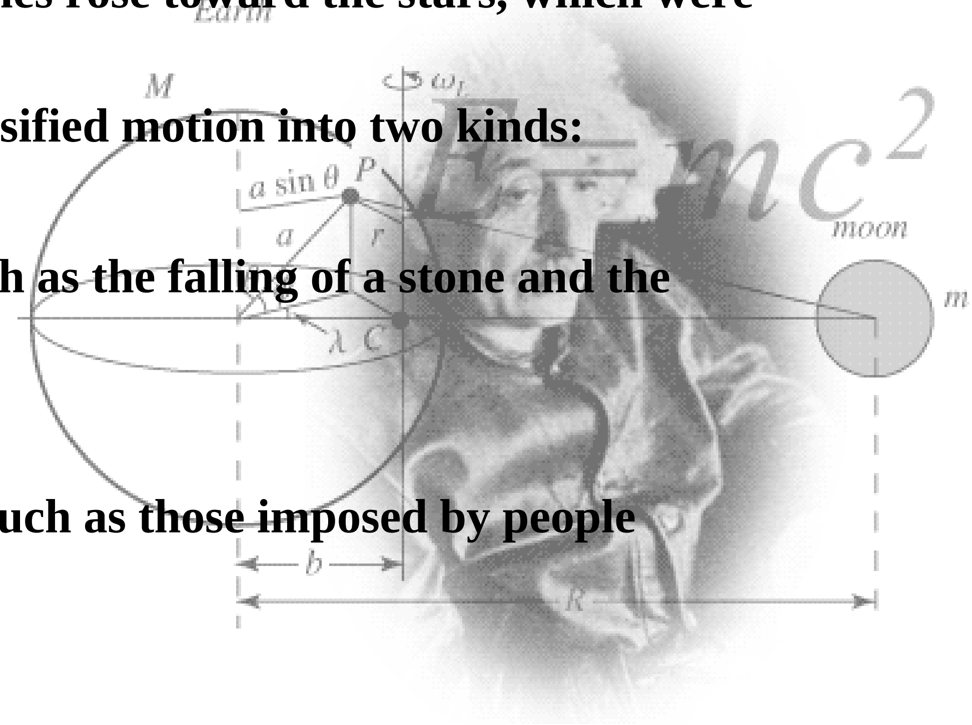
➢ TYPES OF MOTION: **Aristotle classified motion into two kinds:**

***1- natural motion* :**

Which is occurred without force, such as the falling of a stone and the motion of sun & moon.

***2- unnatural (violent) motion*:**

Which requires *push* or *pull* forces, such as those imposed by people or animals.

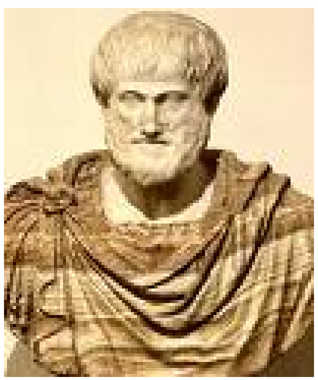


❑ PLANETARY DYNAMICS

▪ **The idea that inanimate objects move to seek their natural place clearly cannot be applied to the planets, whose motion is apparently composed of circles.**

▪ **Aristotle, therefore, postulated that the heavenly bodies (stars, moon and planets) were not made up of the four elements:** *earth, water, air and fire*, **but of a fifth, different, element called *aither*, whose natural motion was circular.**

▪ **He postulated that the Earth is at rest and it is fixed at the center of the Universe.**



❑ ARISTOTLE'S ACHIEVEMENTS

▪ **Aristotle's philosophy laid out an approach to the investigation of all natural phenomena.**

▪ **He expressed the old understanding of motion on Earth and in the Heavens with the Earth at the center of the Universe.**

▪ **He stated that Heavens (Stars, Sun, moon and planets) are governed by laws different than Earthly objects. Proposed that heavenly bodies are "by their nature" in motion whereas earthly objects are "by their nature" at rest.**

Ptolemy

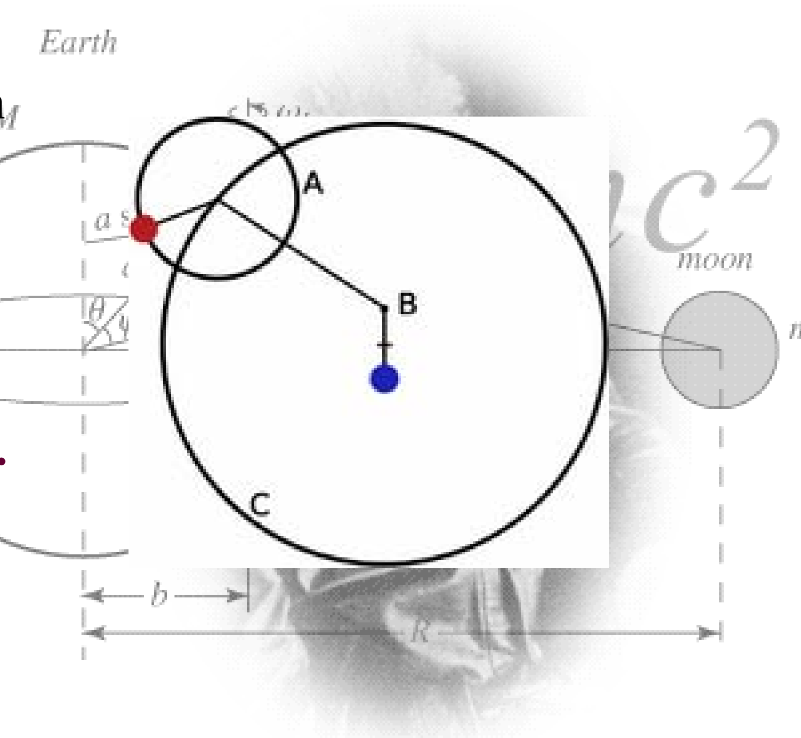
(87- 150 AD)

Ptolemy was a Greek astronomer and geographer lived in Alexandria in Egypt .

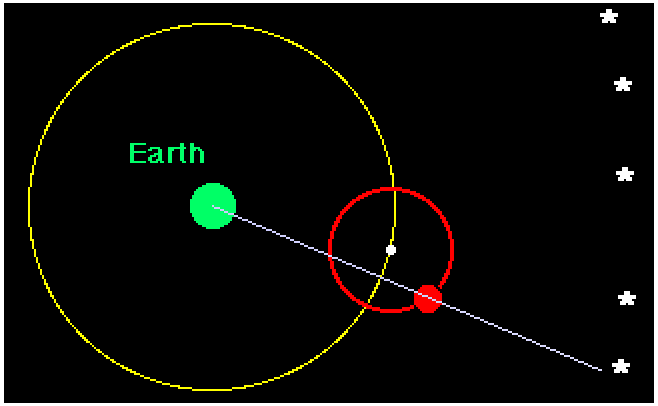
He developed a ***geocentric model*** for planetary motion based on circles and ***epicycles*** with the Earth at the center.

❑ PTOLEMAIC SYSTEM.

In the Ptolemaic system, the planets are assumed to move in a small circle, called an ***epicycle*** **(A)**, which in turn moves along a larger circle called a ***deferent*** **(C)**. Both circles rotate counterclockwise and are roughly parallel to the Earth's plane of orbit.
The epicycle rotated on the deferent with uniform motion, not with respect to the center, but with respect to the off-center point called the ***equant*** **(B) .**
The *deferent* was a circle centered around a point halfway between the *equant* and the earth.



❑ PTOLEMAIC SYSTEM.



Ptolemy's system involved at least 80 epicycles to explain the motions of the Sun, the Moon, and the five planets known in his time. He believed the planets and sun to orbit the Earth in the order:

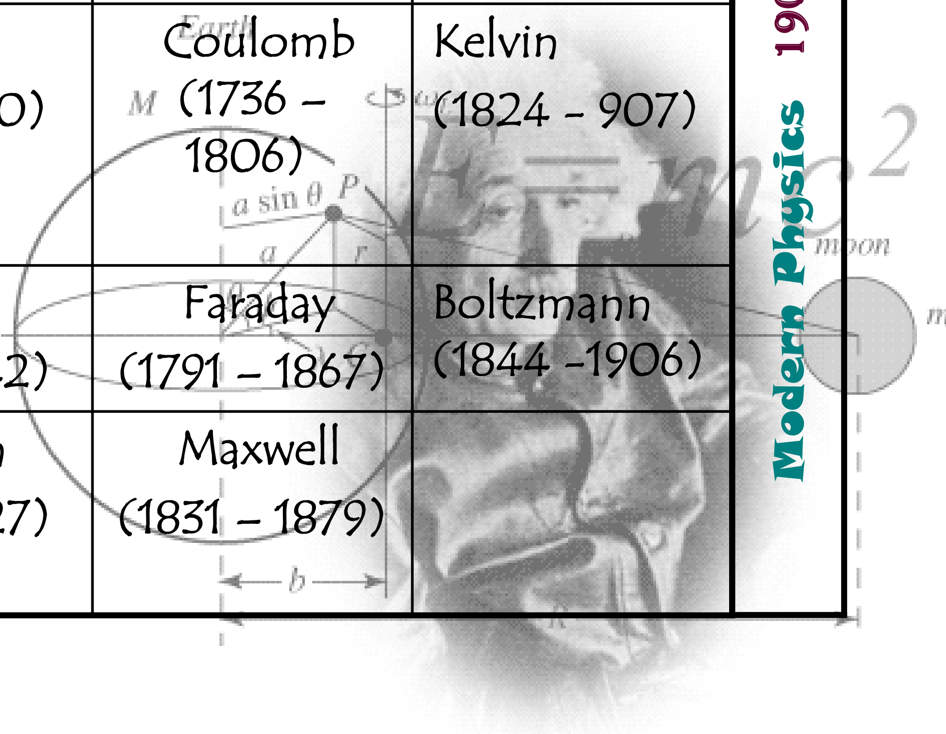
Mercury -Venus – Sun – Mars – Jupiter- Saturn

His book (***Almagest***)✍ contains a countless of information ranging from earth conceptions to sun, moon, and star movement as well as eclipses and a breakdown on the length of months. The Almagest also included a star catalog containing 48 groups, using the names we still use today.

✍ from Arabic *al-majusti*, the Arabic version of Ptolemy's astronomy book; *megistē* (*syntaxis*), literally, great (composition) or book.

PHYSICISTS TIME-LINE

Classical Period 500 BC	Middle Ages 400 AD	Renaissance Ages 1300	Classical Physics 1700 -1900 EM	Thermo-	Modern Physics 1900 - PRESENT
Aristotle (c. 300 BC)	Al-Fazari (735-806)	Copernicus (1473-1543)	Franklin (1706 – 1790)	Carnot (1796-1832)	
Ptolomy (c. 200 AD)	Al-khwarizmi (850-926)	Kepler (1571-1630)	Coulomb (1736 – 1806)	Kelvin (1824 – 907)	
	Ibn Sina, (965-1039)	Galileo (1564-1642)	Faraday (1791 – 1867)	Boltzmann (1844 -1906)	
	Ibn Al-Haitham (980-1037)	Newton (1642-1727)	Maxwell (1831 – 1879)		



2- SCIENTISTS FROM THE MIDDLE AGES

al-Fazari

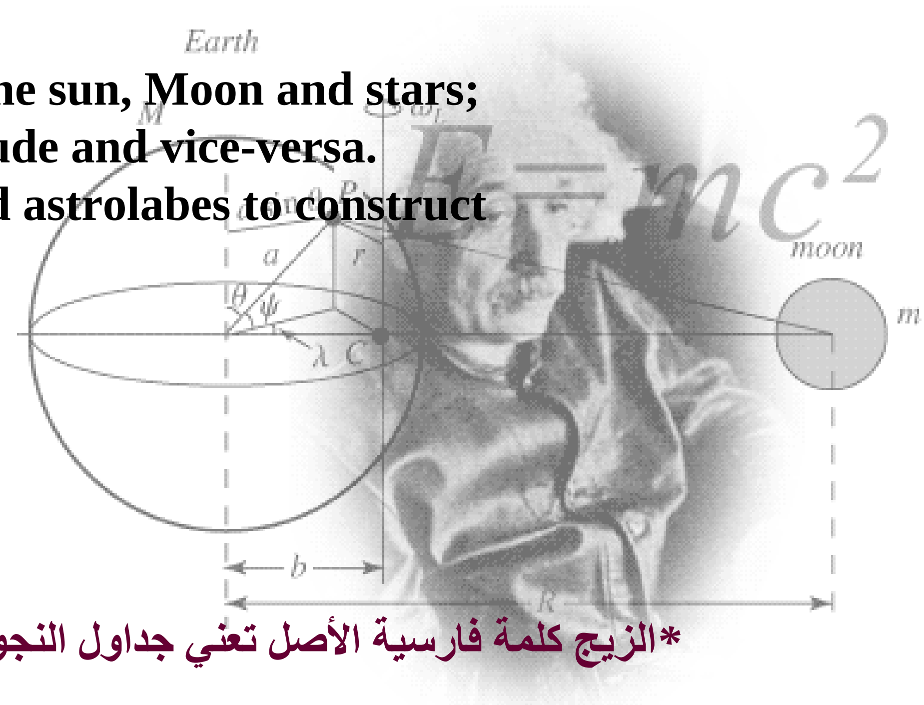
(735 -806 AD)

Abu abdallah Muhammad ibn Ibrahim al-Fazari was a Persian philosopher , mathemtician and astronomer.

Al-Fazari built the first astrolabe in the world.
The astrolabe is a historical astronomical instrument used until the invention of the sextant in the 18th century. It has many uses included:

- **locating and predicting the positions of the sun, Moon and stars;**
- **determining local time given local longitude and vice-versa.**
- **Astrologers of the European nations used astrolabes to construct horoscopes.**

The mathematical background of the astrolabe was established latter by Al-Battani in his book *Kitab az-Zij (920 AD).**



*الزيج كلمة فارسية الأصل تعني جداول النجوم السيارة

Al-khwarizmi

(780-850 AD)

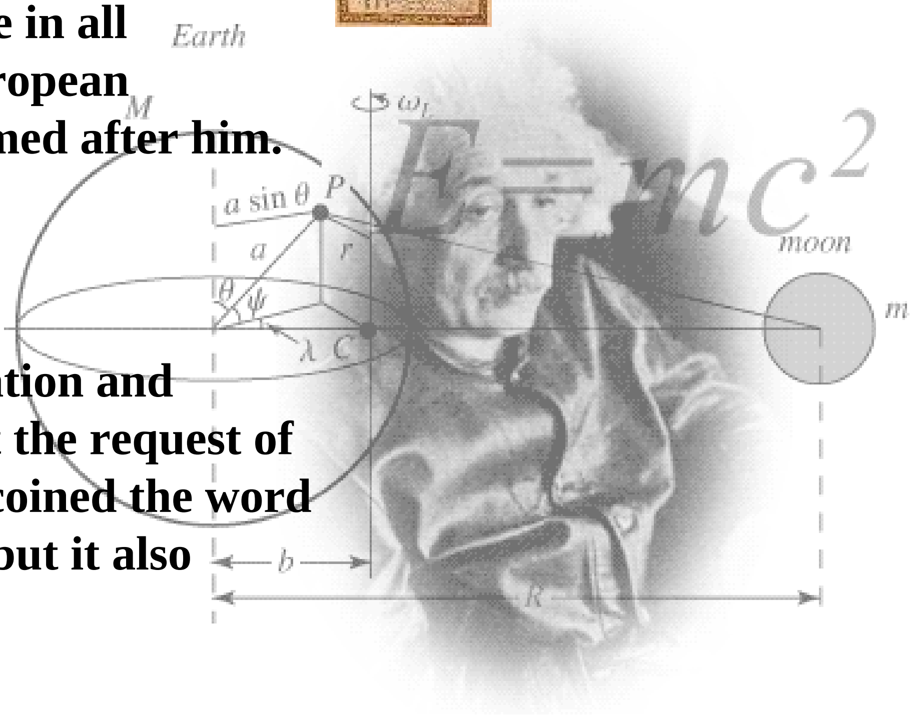
Al-Khawarizmi was one of the greatest Arab and world scholars whose works had a significant influence on mathematics and astronomy.

- ## SCIENTIFIC CONTRIBUTIONS

He was the first to have used the term of algebra. Up to now, algebra is known by its Arabic name in all European languages. All the terms in European languages ending by "algorithm" are named after him.

- ## MAJOR WORKS

Al-Jabr wa-al-Muqabilah, (Book on Integration and Equation) an unprecedented book wrote at the request of the Caliph al-Mamun. This book not only coined the word of algebra and gave it its present meaning but it also opened verily a new era in mathematics.



Ibn-Sina

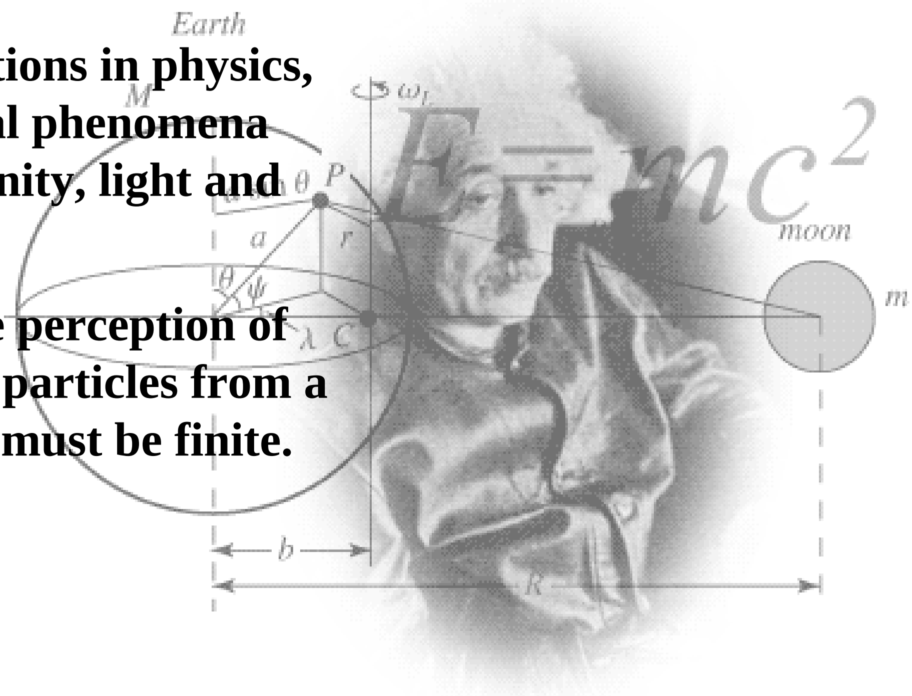
(980-1037 AD)

Ibn Sina is the most outstanding Muslim scientist and one of the world's most famous scholars. He became a reference in medicine, astronomy, mathematics and philosophy before reaching the age of 20 .

❑ SCIENTIFIC CONTRIBUTIONS

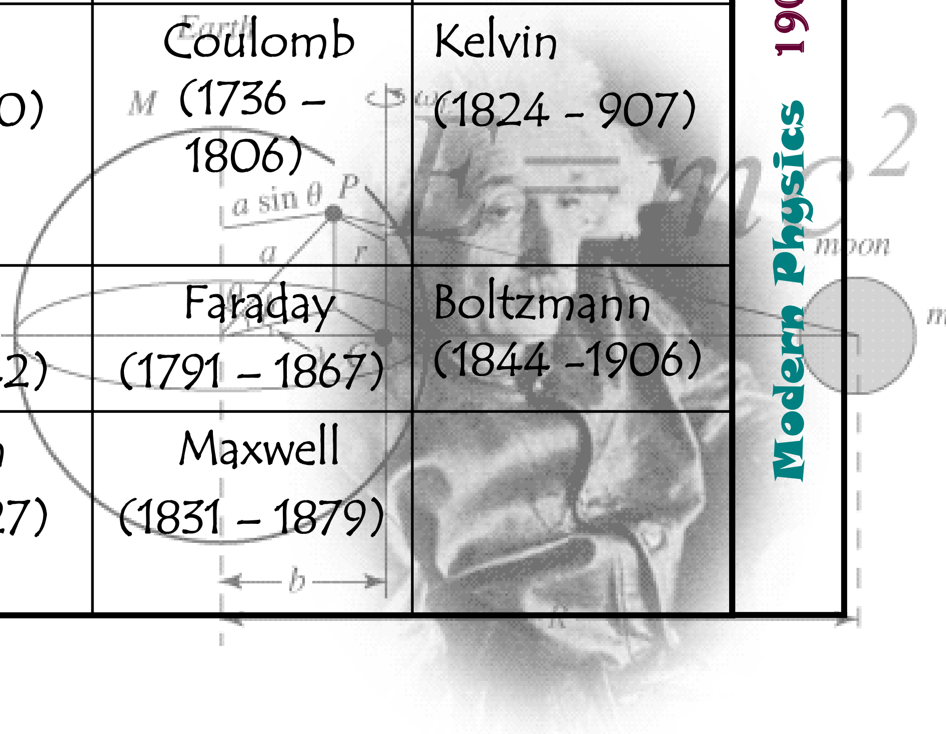
Ibn Sina made important contributions in physics, through the study of several natural phenomena such as motion, force, vacuum, infinity, light and heat.

He made the observation that if the perception of light is due to the emission of some particles from a luminous source, the speed of light must be finite.



PHYSICISTS TIME-LINE

Classical Period 500 BC	Middle Ages 400 AD	Renaissance Ages 1300	Classical Physics 1700 -1900 EM	Thermo-	Modern Physics 1900 - PRESENT
Aristotle (c. 300 BC)	Al-Fazari (735-806)	Copernicus (1473-1543)	Franklin (1706 – 1790)	Carnot (1796-1832)	
Ptolomy (c. 200 AD)	Al-khwarizmi (850-926)	Kepler (1571-1630)	Coulomb (1736 – 1806)	Kelvin (1824 – 907)	
	Ibn Sina, (965-1039)	Galileo (1564-1642)	Faraday (1791 – 1867)	Boltzmann (1844 -1906)	
	Ibn Al-Haitham (980-1037)	Newton (1642-1727)	Maxwell (1831 – 1879)		



2- SCIENTISTS FROM THE MIDDLE AGES

al-Fazari

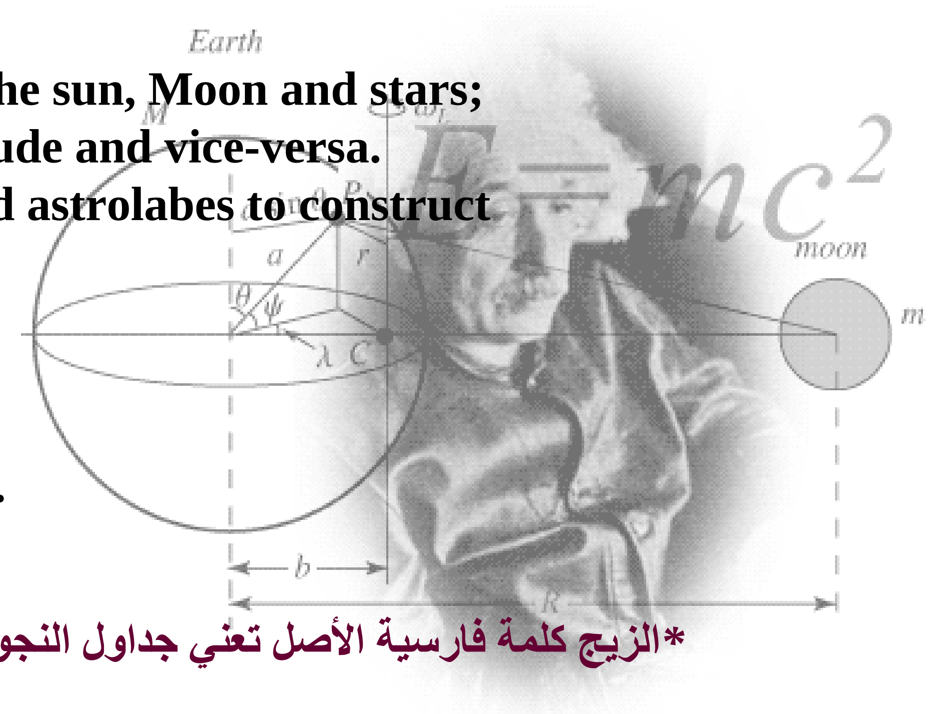
(735 -806 AD)

Abu abdallah Muhammad ibn Ibrahim al-Fazari was a Persian philosopher , mathemtician and astronomer.

Al-Fazari built the first astrolabe in the world.
The astrolabe is a historical astronomical instrument used until the invention of the sextant in the 18th century. It has many uses included:

- **locating and predicting the positions of the sun, Moon and stars;**
- **determining local time given local longitude and vice-versa.**
- **Astrologers of the European nations used astrolabes to construct horoscopes.**

The mathematical background of the astrolabe was established latter by Al-Battani in his book *Kitab az-Zij (920 AD).**



***الزيج كلمة فارسية الأصل تعني جداول النجوم السيارة**

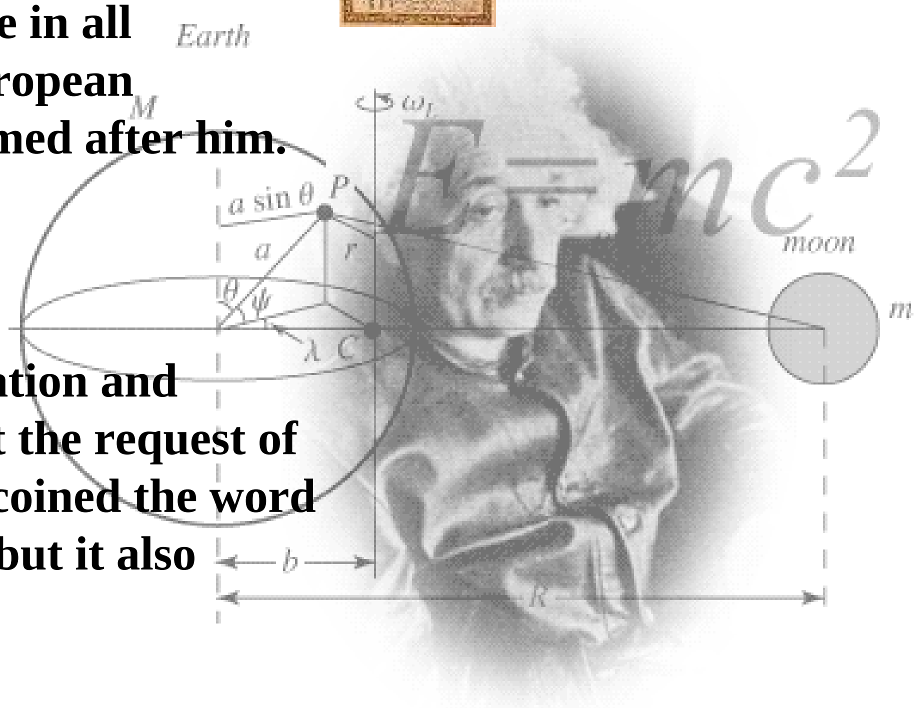
Al-khwarizmi

(780-850 AD)

Al-Khawarizmi was one of the greatest Arab and world scholars whose works had a significant influence on mathematics and astronomy.

❑ SCIENTIFIC CONTRIBUTIONS

He was the first to have used the term of algebra. Up to now, algebra is known by its Arabic name in all European languages. All the terms in European languages ending by "algorithm" are named after him.



❑ MAJOR WORKS

***Al-Jabr wa-al-Muqabilah*, (Book on Integration and Equation) an unprecedented book wrote at the request of the Caliph al-Mamun. This book not only coined the word of algebra and gave it its present meaning but it also opened verily a new era in mathematics.**

Ibn-Sina

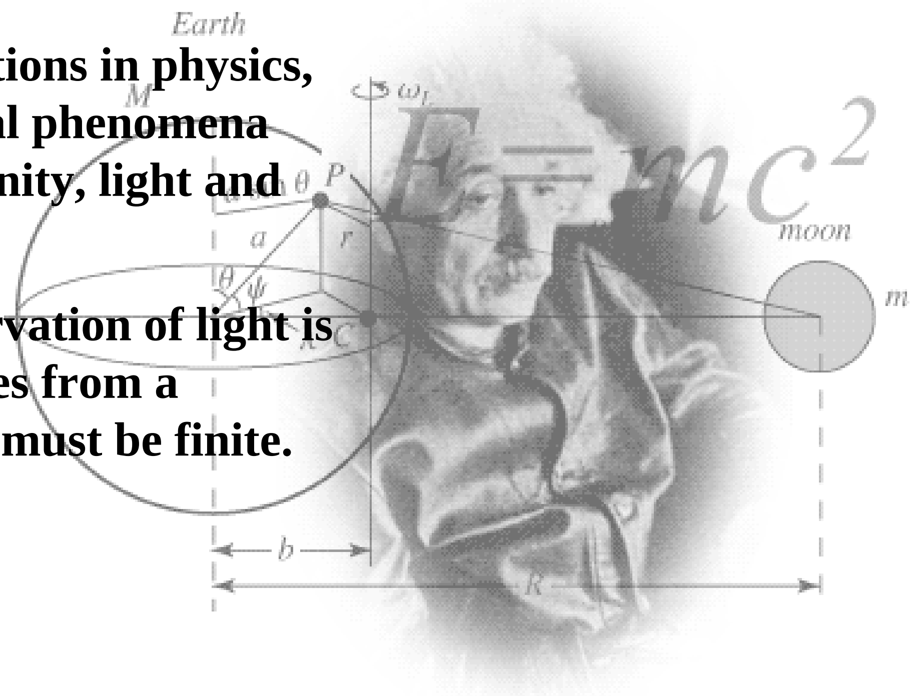
(980-1037 AD)

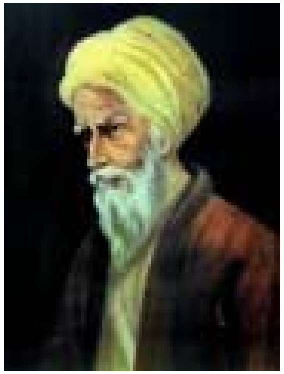
His name is Abu Ali Al-Husain Ibn Sina. He is the most outstanding Muslim scientist and one of the world's most famous scholars. He became a reference in medicine, astronomy, mathematics and philosophy before reaching the age of 20.

❑ SCIENTIFIC CONTRIBUTIONS

Ibn Sina made important contributions in physics, through the study of several natural phenomena such as motion, force, vacuum, infinity, light and heat.

He made a remark that if the observation of light is due to the emission of some particles from a luminous source, the speed of light must be finite.



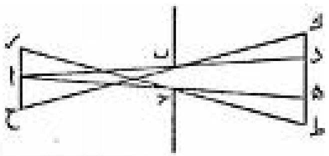


Ibn Al-Haitham

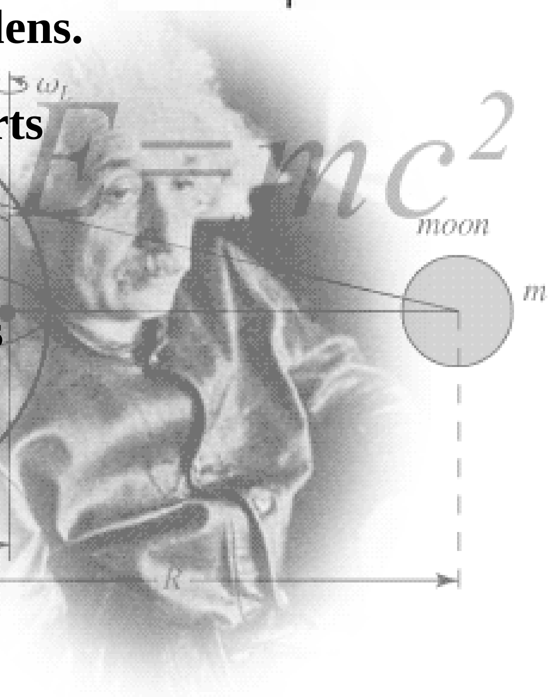
(965-1039 AD)

His full name is Abu Ali Hasan ibn Al-Haitham, known by Europeans as ‘Alhazen’. He is one of the most outstanding Arab scholars. He excelled in and contributed to the fields of optics, mathematics, natural science, medicine and philosophy.

❑ SCIENTIFIC CONTRIBUTIONS

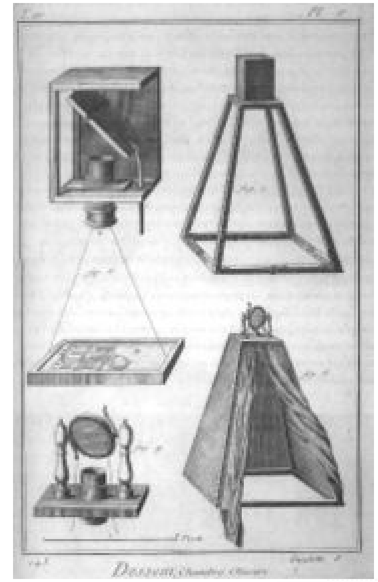


- **He was the first to conclude the magnifying property of a lens.**
- **He was also the first to describe accurately the various parts of the eye and gave them names that Western scientists adopted and translated into their languages.**
- **He reached the conclusion that vision originates from rays sent by an object to the eye. These rays are reflected on the retina and transmitted to the brain through the optic nerve, constituting the image of the object.**



- He also carried out the first experiments on the dispersion of light into its constituent colors. Thus, he introduced the experimental methodology before Francis Bacon (1561-1626).

- He gave the first accurate description of the Camera Obscura (*dark chamber*)

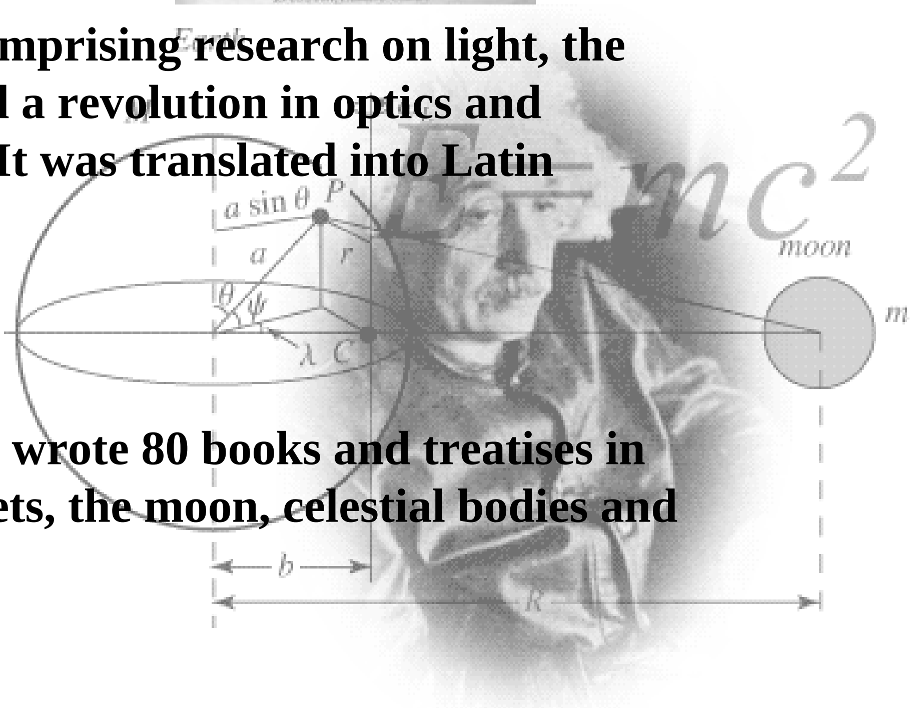


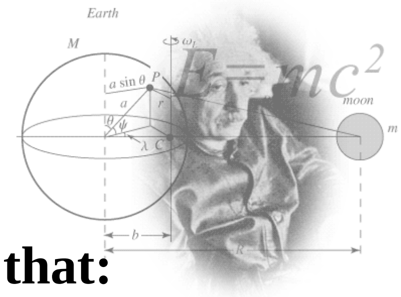
❑ MAJOR WORKS

-"**Kitab al-Manadhir**": a thesis on optics comprising research on light, the eye's anatomy and vision. This book created a revolution in optics and remained a reference for several centuries. It was translated into Latin several times in the Middle Ages.

- "**Hal Shokouk Euclid's**";
- "**Kitab al-Jamia fi Oussoul al-Hissab**";
- "**Kitab fi Tahlil al Massaïl Al-Handassia**."

It is worth mentioning that Ibn Al-Haitham wrote 80 books and treatises in astronomy, dealing with the motion of planets, the moon, celestial bodies and their dimensions.





THE HELIOCENTRIC MODEL

Introduction:

To anyone who stands and looks at the sky, it seems clear that:

- **The earth stays in one place while everything in the sky rises and sets or goes around once every day.**
- **The Sun makes a slower circle over the period of a year.**
- **The planets have similar motions, but they sometimes turn around and move in the reverse direction.**

As these motions became better understood, they required more and more complicated descriptions or "model".

Definition:

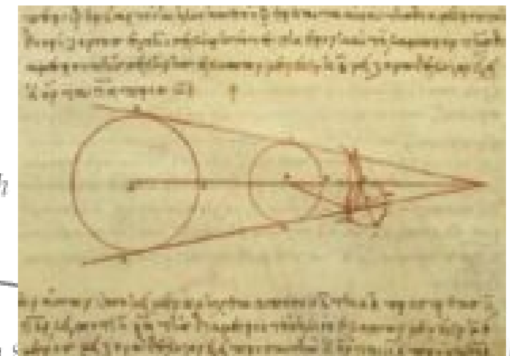
The *heliocentric model* is that places the Sun at the center of the Universe. It is opposed to *geocentric* which considers the earth at the center.

The word is derived from the Greek (*Helios* = "Sun" and *kentron* = "Centre").

DEVELOPMENT OF THE HELIOCENTRIC MODEL

1- Ancient Greece:

In (**270 BC**) the Greek astronomer **Aristarchus** calculated the size of the earth, and measured the size and distance of the Moon and Sun.



From his estimations, he concluded that the Sun is much larger than the Earth. Some people have suggested that paying attention to these numbers led **Aristarchus** to think that it made more sense for the Earth to be moving than for the huge Sun to be moving around it.

However, Aristarchus's original work on *heliocentrism* has not survived and is known only from others' accounts; it is uncertain whether these arguments were his own.

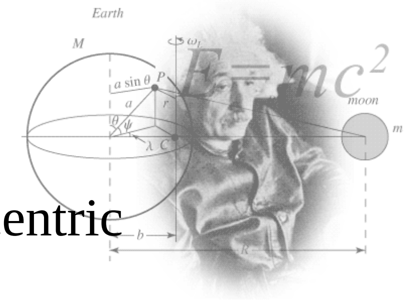
2- Medieval India:

In (**470-550**) the Indian astronomer **Aryabhata** suggested a *heliocentric model* in which the Earth was taken to be spinning on its axis and the periods of the planets were given with respect to a stationary Sun. and that the planets follow an *elliptical* orbit around the Sun.

He was also the first to discover that the light from the Moon and the planets was reflected from the Sun,

Arabic translations of ***Aryabhata's*** *work* were available from the 8th century, while Latin translations were available from the 13th century, 200 years before Copernicus. So it is possible that ***Aryabhata's*** work had an influence on Copernicus' ideas

3- Isalmic World:

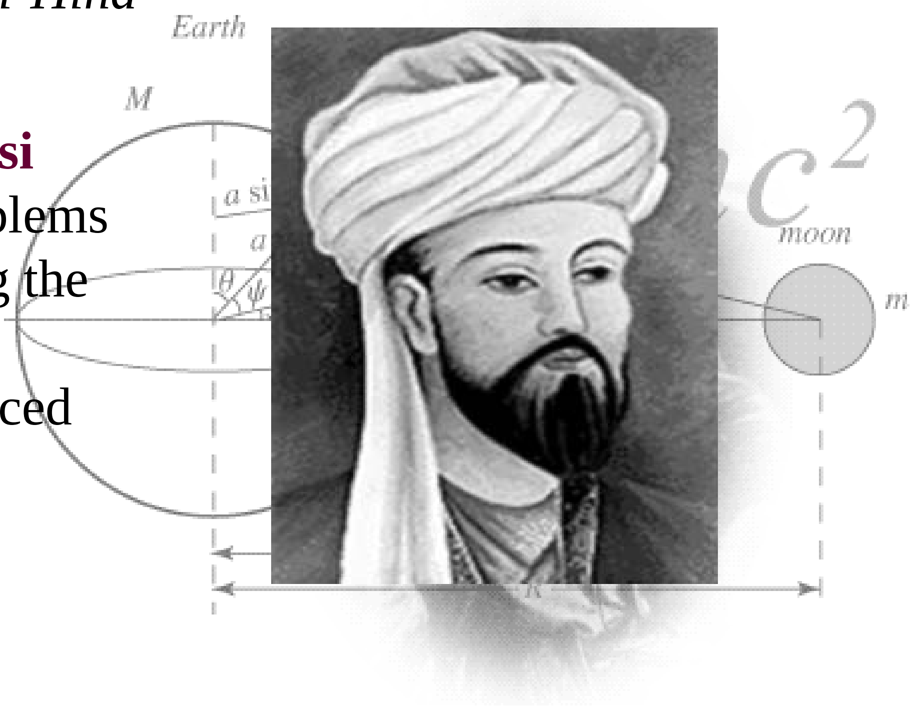


Although Muslims scholars never actually proposed a heliocentric model, some astronomers did criticize the geocentric model.

Ibn Al-Haitham (965-1039) wrote a comment on of Ptolemy's model: "Ptolemy assumed an arrangement that cannot exist".

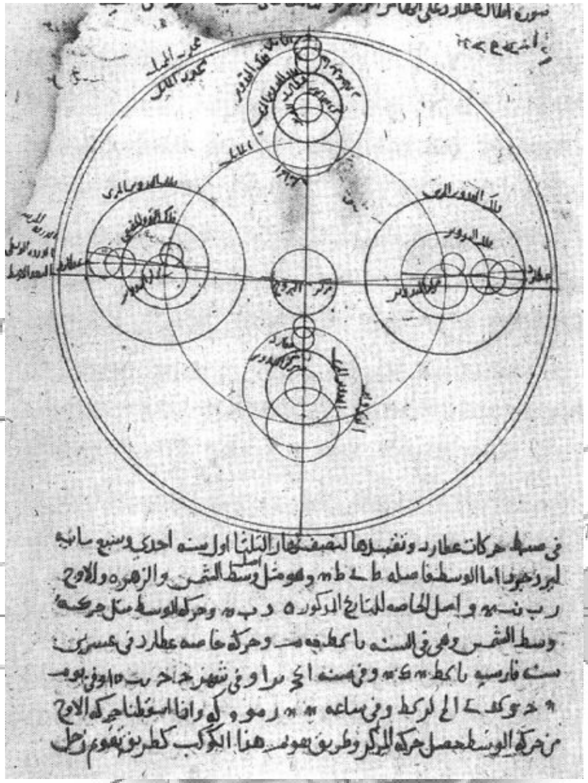
In 1030, **Al-Biruni** discussed the Indian heliocentric theories of Aryabhata, in his *Ta'rikh al-Hind*

The Persian scientist **Nasir al-Din Tusi** (1201-1274) resolved significant problems in the Ptolemaic system by developing the **Tusi-couple** as an alternative to the physically problematic *equant* introduced by Ptolemy.



3- Isalmic World:

The Muslim astronomer **Ibn al-Shatir** (1304-1375) in his book *Kitab Nihayat as-Sul fi Tashih al-Usul*, eliminated the need for an equant by introducing an extra epicycle. Ibn al-Shatir proposed a system that was only approximately geocentric, rather than exactly so. He showed trigonometrically that the Earth was not the exact center of the universe.



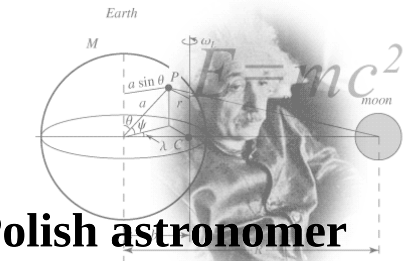
Ibn al-Shatir refinement was later used in the Copernican model, along with the **Tusi**-couple and **Urdi** lemma. Their theorems played an important role in the Copernican model of heliocentrism.

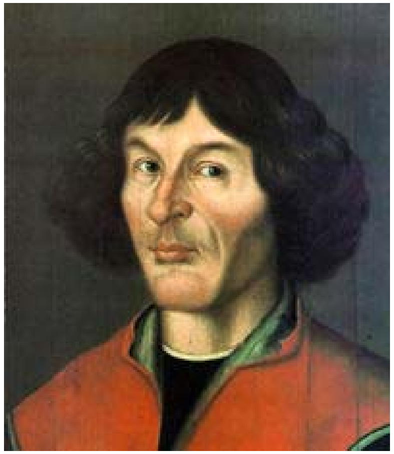
The Muslim astronomy was at the threshold of heliocentrism when the lead passed on to Europe.

PHYSICISTS TIME-LINE

Classical Period 500 BC	Middle Ages 400 AD	Renaissance Ages 1300	Classical Physics 1700 -1900 EM	Thermo-	Modern Physics 1900 - PRESENT
Aristotle (c. 300 BC)	Al-Fazari (735-806)	Copernicus (1473-1543)	Franklin (1706 – 1790)	Carnot (1796-1832)	
Ptolomy (c. 200 AD)	Al-khwarizmi (850-926)	Kepler (1571-1630)	Coulomb (1736 – 1806)	Kelvin (1824 – 907)	
	Ibn Sina, (965-1039)	Galileo (1564-1642)	Faraday (1791 – 1867)	Boltzmann (1844 -1906)	
	Ibn Al-Haitham (980-1037)	Newton (1642-1727)	Maxwell (1831 – 1879)		

3- SCIENTISTS FROM THE RENAISSANCE AGES





Copernicus
(1473-1543)

Nicolaus Copernicus was a Polish astronomer who adopted and announced the modern *heliocentric model* of the solar system .

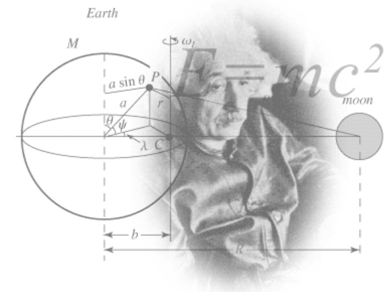
Although Greek, Indian and Muslim scientists had published heliocentric *hypotheses* centuries before Copernicus, he was the first to publish a *scientific theory* of heliocentrism.

He made his celestial observations from a tower situated on a wall around the cathedral, his observations were made by a "bare eye" hundred years before the invention of the telescope.
In 1530, Copernicus completed and gave to the world his great work, which asserted that:

the earth rotated on its axis once daily and traveled around the sun once yearly.

The pronunciation of the heliocentric theory by Copernicus marked the beginning of the scientific revolution.

This scientific theory that reflected so deeply on humanity was not welcomed by the church.



Copernicus's major theory was published in his book, (*On the Revolutions of the Celestial Spheres*), in the year of his death, 1543, though he had arrived at his theory several decades earlier.

In Copernicus's cosmology the sun is still (motionless) and it placed not at the centre of the universe, but close to the centre. He assumed as well that all motion was circular so, like Ptolemy, was forced into using epicycles.


NICOLAI
COPERNICI TO-
RINENSIS DE REVOLVTIONI-
bus orbium cœlestium,
Libri VI.

IN QVIBVS STELLARVM ET FI-
XARVM ET ERRATICARVM MOTVS, EX VETE-
ribus atq; recentibus obseruationibus, restituit hic autor.
Præterea tabulas expeditas luculentasq; addidit, ex qui-
bus eosdem motus ad quoduis tempus Mathe-
matum studiosus facillime calcu-
lare poterit.

ITEM, DE LIBRIS REVOLVTIONVM NICOLAI
Copernici Narratio prima, per M. Georgium Ioachi-
mum Rheticum ad D. Ioan. Schone-
rum scripta.

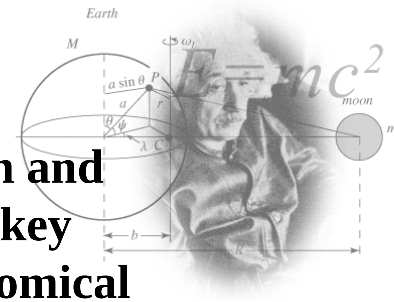
Cum Gratia & Priuilegio Cæs. Maiest.
BASILEAE, EX OFFICINA
HENRICPETRINA.

Could Copernicus have been influenced by the previous astronomers?

True motivation for Copernicus to adopt the heliocentric system is still a matter of debate.

Researchers concluded that since "no Latin translation has been found of any of their works or indeed of any work describing their models," it is unlikely. But because a lot of material remains still unexamined, it is not very improbable if such linkage came to light in the future.

Kepler
(1571-1630)



He was a German mathematician and astronomer who considered as a key figure in the 17th century astronomical revolution.

He was an assistant and successor to Tycho Brahe, the *Imperial mathematician*.

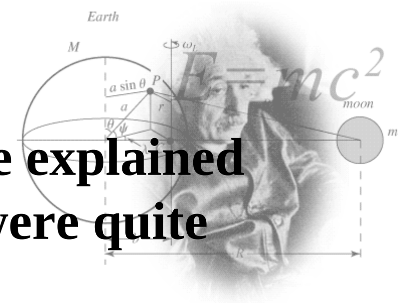
Kepler spent almost 10 years trying to determine the orbit of Mars from Tycho's data.

He was a Copernican from his twenties on, and was intended to bring some acceptance of the *heliocentric* concept.

Kepler rejected many ideas, such as circular orbits, because they did not fit Brahe's observations . He found the solution in two changes:

PATH: ellipses instead of circles
SPEED: not uniform - varies with the time of year

❑ KEPLER'S LAWS :



Kepler was convinced that the planetary system could be explained with simple mathematical relations. Those simple laws were quite radical ideas for his time.

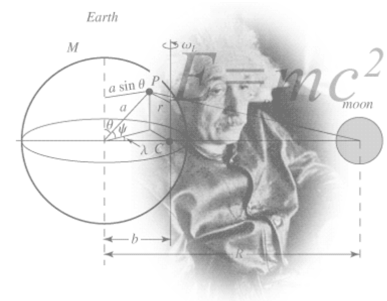
By trial and error, *Kepler* discovered three observed laws that accurately described the motions of all planets (not only Mars).

In 1609, Johannes Kepler finally published his first two laws of planetary motion in a book entitled *New Astronomy*.

In 1619, his third law was published in *The Harmonies of the World*.

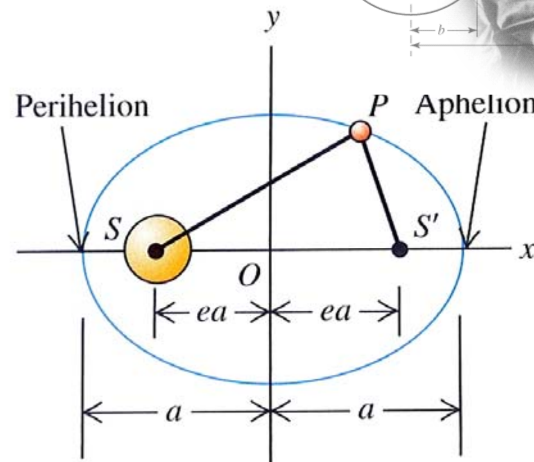
Two hundred years later, Newton discovered that each of Kepler's laws can be derived using Newton's laws of motion and the law of gravitation.

In fact, Kepler's laws provided one of the foundations of Newton’s theory of *universal gravitation.*



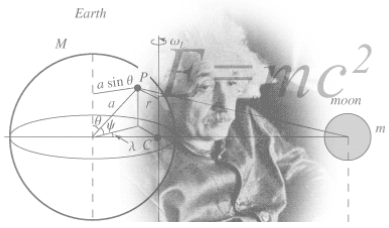
FIRST LAW: LAW OF ELLIPSES

Each planet moves in an elliptical orbit, with the sun at one focus of the ellipse.



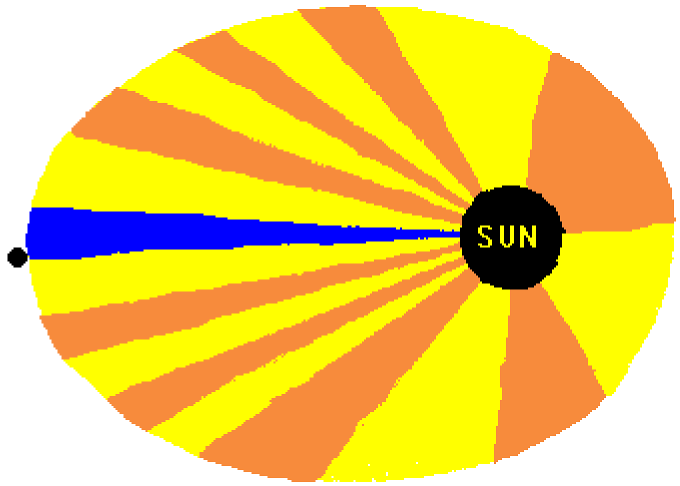
main properties of the ellipse:

- ❑ **The longest dimension *2a* is the major axis, with half-length *a* known as the *semi-major axis*.**
- ❑ ***S* and *S′* are the *foci* . The sun is at *S*, and the planet is at *S′***
- ❑ **The point in the planet's orbit closest to the sun is the *perihelion*, and the point most distant from the sun is the *aphelion*.**
- ❑ **The distance of each focus from the center of the ellipse is *ea*, where *e* is a dimensionless number between 0 and 1 called the *eccentricity*. If $e = 0$, the ellipse is a circle. The actual orbits of the planets are somewhat circular; their eccentricities range from 0.007 for Venus to 0.248 for Pluto. The earth's orbit has $e = 0.017$**



SECOND LAW: LAW OF EQUAL AREAS

A line from the sun to a given planet sweeps out equal areas in equal times.



In a small time interval *dt*, the line from the sun *S* to the planet *P* turns through an angle $d\theta$. The area swept out is the

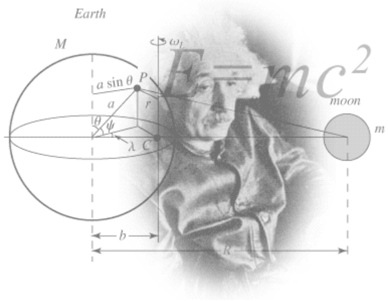
$$dA = \tfrac{1}{2} r^2 \, d\theta .$$

The rate at which area is swept out, *dA/dt*, is called the *sector velocity*:

$$\frac{dA}{dt} = \frac{1}{2} r^2 \frac{d\theta}{dt}$$

The real meaning of Kepler's second law is that the sector velocity has the same value at all points in the orbit. When the planet is close to the sun, *r* is small and $d\theta/dt$ is large; when the planet is far from the sun, *r* is large and $d\theta/dt$ is small.

Third Law: Harmonic Law



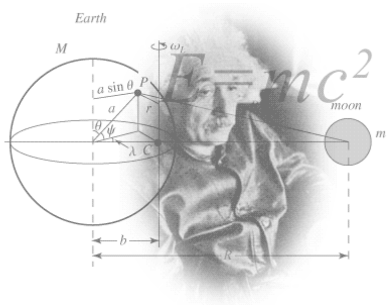
The ratio of the squares of the periods for two planets is equal to the ratio of the cubes of their semi-major axes.

This law can be expressed as;

$$\frac{T_1^2}{T_2^2} = \frac{a_1^3}{a_2^3} \;\Rightarrow\; \frac{T_1^2}{a_1^3} = cons.$$

convenient unit of measurement for periods is in Earth years, and a convenient unit of measurement for distances is the average separation of the Earth from the Sun, which is termed an *astronomical unit* and is abbreviated as AU.
If these units are used in Kepler's 3rd Law, the constant in the previous equation are numerically equal to unity and it may be written in the simple form:

$$\frac{T_{yrs}^{2}}{a_{AU}^{3}} = 1$$

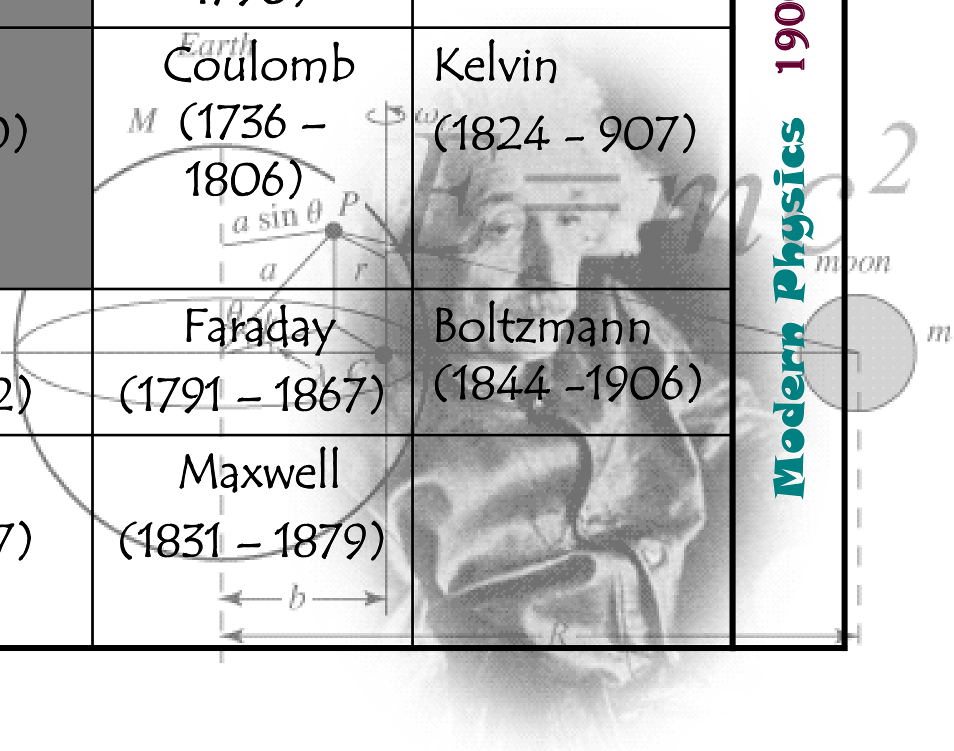


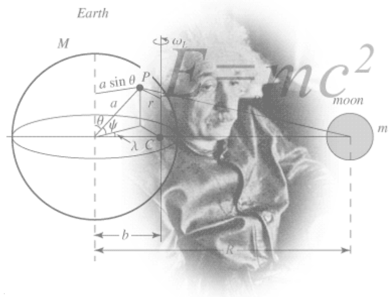
	a in AU	T in yrs	T²/a³
Mercury	0. 387	0. 241	1. 002
Venus	0. 723	0.615	1.001
Earth	1. 000	1.000	1.000
Mars	1. 524	1. 881	1. 000
Jupiter	5. 203	11. 862	0. 999
Saturn	9. 534	29.456	1.001

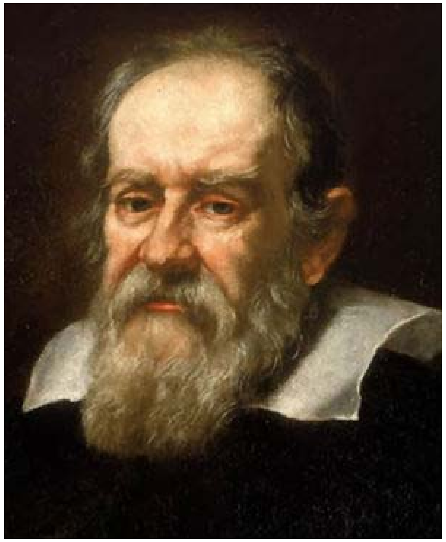
This Law (unlike the first two) ties together the motions of different planets.
Newton will explain why this works latter.

PHYSICISTS TIME-LINE

Classical Period 500 BC	Middle Ages 400 AD	Renaissance Ages 1300	Classical Physics 1700 -1900 EM	Thermo-	Modern Physics 1900 - PRESENT
Aristotle (c. 300 BC)	Al-Fazari (735-806)	Copernicus (1473-1543)	Franklin (1706 – 1790)	Carnot (1796-1832)	
Ptolomy (c. 200 AD)	Al-khwarizmi (850-926)	Kepler (1571-1630)	Coulomb (1736 – 1806)	Kelvin (1824 – 907)	
	Ibn Sina, (965-1039)	Galileo (1564-1642)	Faraday (1791 – 1867)	Boltzmann (1844 -1906)	
	Ibn Al-Haitham (980-1037)	Newton (1642-1727)	Maxwell (1831 – 1879)		







Galileo Galilei
(1564 –1642)

Galileo was an Italian physicist, astronomer, and philosopher. His achievements include the first systematic studies of uniformly accelerated motion, improvements to the telescope, and a variety of astronomical observations that supported the *heliocentric model*

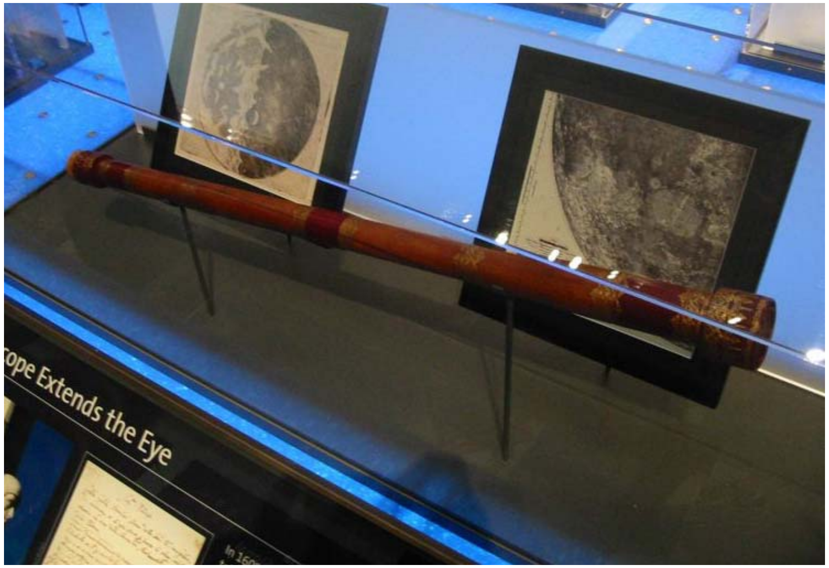
Galileo's support for the heliocentric theory got him into trouble with the Roman Catholic Church. In 1633 he was convicted with heresy and he was forced to retract his support of Copernicus.

In 1636 Galileo became blind (at the age of 72) and he died in 1642, the year Newton was born

CONTRIBUTIONS :

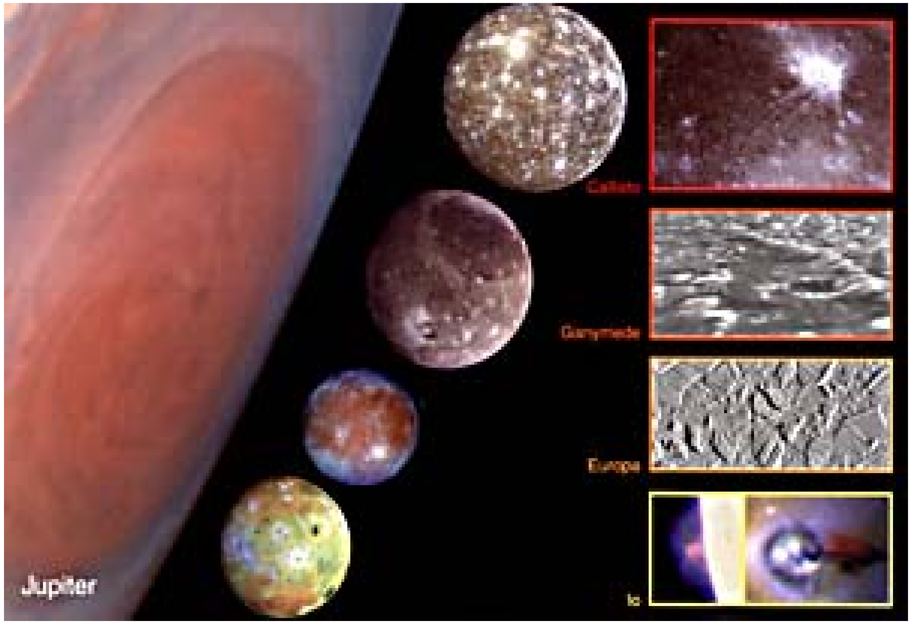
1- Astronomy

- Based only on sketchy descriptions of the *refracting telescope*, invented in Holland in **1608**, Galileo made, in the same year, one with about **3x** magnification, and later made others with up to about **32x** magnification .



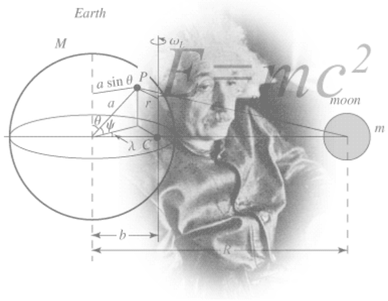
❍ In 1610 Galileo discovered the four moons of ***Jupiter***. He noted that the moons would appear and disappear periodically, so he concluded that they were orbiting the planet. The demonstration that a planet had smaller planets orbiting it was problematic for the widespread picture of the *geocentric model*

❍ Galileo opposed Kepler's hypothesis that the gravity of the moon is the origin of the tides. This was one major scientific error of Galileo.



2- Physics

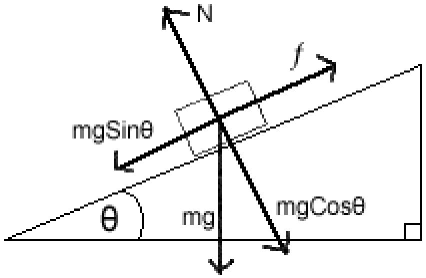
❍ Galileo worked theoretical and experimental on the motions of bodies. He was a pioneer in performing accurate experiments and insisting on a ***mathematical description*** of the laws of nature.



❍ Galileo was the first to demonstrate experiments involving rolling balls down *inclined planes*, which proved that:

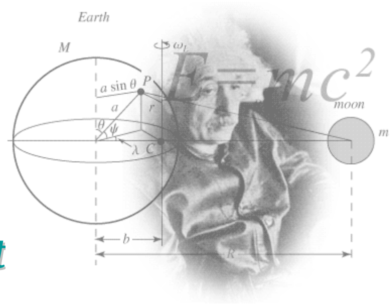
falling or rolling objects are accelerated independently of their mass.

NOTE: rolling is a slower version of falling, as long as the distribution of mass in the objects is the same.



Time	Total Distance Covered
1	1
2	1 + 3 = 4
3	1 + 3 + 5 = 9
4	1 + 3 + 5 + 7 = 16

Time	Total Distance Covered	Time Squared
1	1	$(1)^2 = 1$
2	4	$(2)^2 = 4$
3	9	$(3)^2 = 9$
4	16	$(4)^2 = 16$



❍ Galileo determined the correct mathematical law for acceleration. He stated that: ***the total distance covered, starting from rest, is proport square of the time.*** *Or*:

$$d \propto t^2$$

Equations for Constant Acceleration:

- **Acceleration:**

$$a = \Delta v / \Delta t$$

- **Velocity:**

$$\Delta v = a\ \Delta t$$

or $$v = v_0 + a\,(t - t_0)$$

if $v_0=0$ $$v = at$$

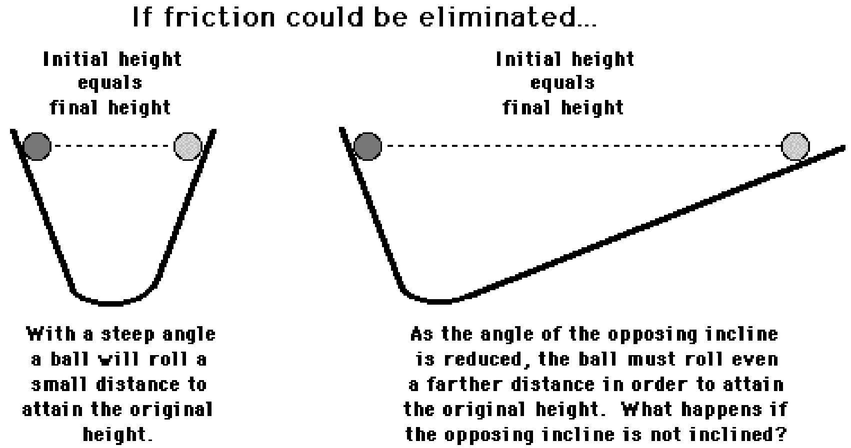
- **Distance:**

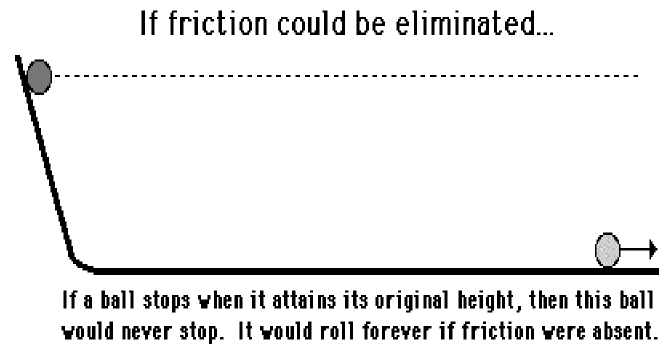
since velocity is changing

$$d = \text{avg velocity} \times \text{time}$$

$$d = (1/2\ at\ )\ t = 1/2\ at^2$$

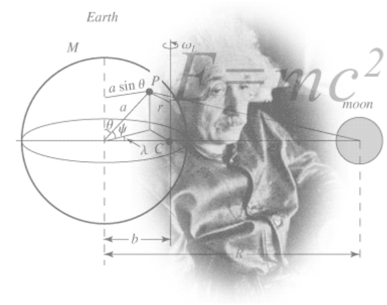
❍ He also introduced the concept of **Inertia** when he concluded that *objects retain their velocity unless a force—often friction—acts upon them*, refuting the generally accepted Aristotelian hypothesis that objects "naturally" slow down and stop unless a force acts upon them.





Galileo's Principle of Inertia stated:

"***A body moving on a level surface will continue in the same direction at constant speed unless disturbed***."



This principle was included into Newton's laws of motion (first law).

- Galileo also put forward the basic principle of relativity, known as **Galilean relativity**, which states that:

The classical laws of physics are the same in any system that is moving at a constant speed in a straight line.

Therefore there's no reason to expect to sense that the Earth is moving. There is no reason to say the earth is at rest!