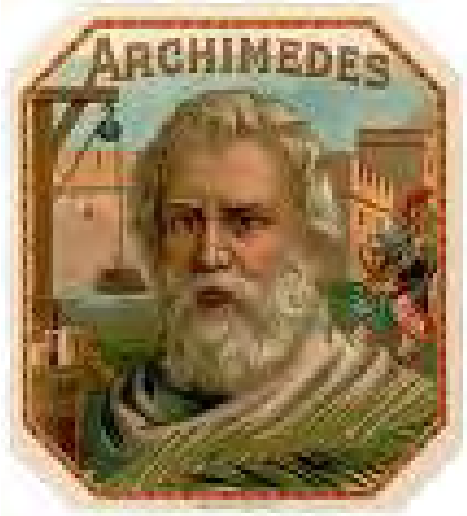
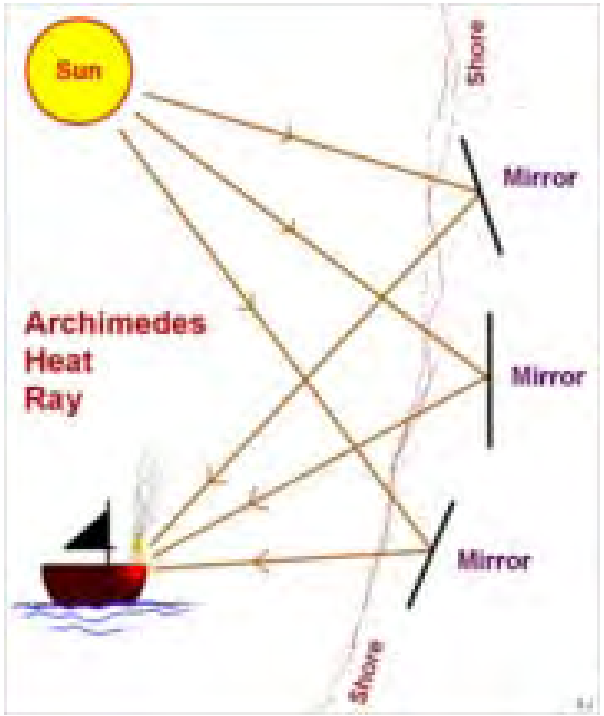
The History of

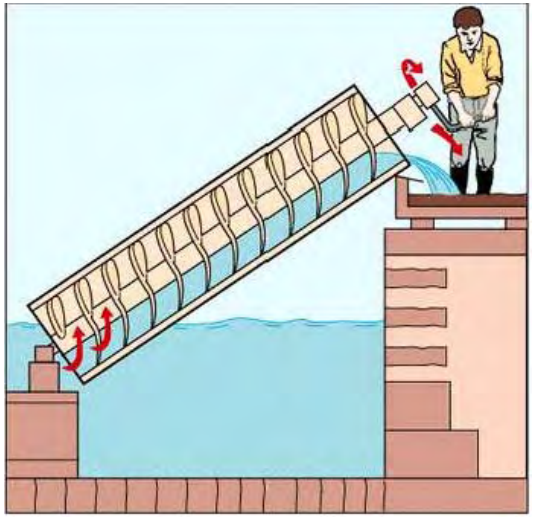
Density and Pressure



Archimedes

- Born in 287 BC in Syracuse, Italy
- Traveled to Alexandria during his youth – learned geometry and engineering
- Applied knowledge to construct war machines & other inventions:
  - Death ray
  - Spiral pump





Archimedes…

- The first to have the "idea" of density
- Never actually defined it as mass over volume
  - stated that an object with more mass per volume had a greater *weight*
- The famous problem: The King's Crown
  - King gave a goldsmith a brick of gold and asked him to make a crown
  - The King suspected that the crown was not made entirely of gold
  - He asked Archimedes to determine the amount of gold in the crown without altering it

Archimedes…

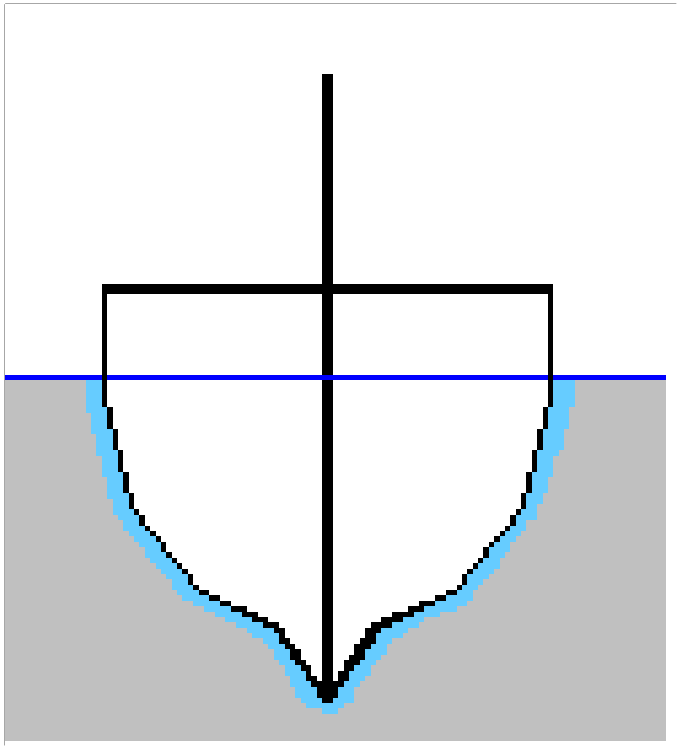
- Archimedes was a little perplexed and took a bath to relax and ponder the problem
- When he got in, he noticed the water level rose
  - Came to the conclusion that the volume of water displaced was equal to the volume of his body
- It dawned on him that he could do the same thing with the crown to determine the amount of gold in it
  - This is apparently when he jumped out of the tub and ran naked in the streets yelling “Eureka!”

Archimedes…

- He took two equal weights of gold and silver and compared the weights when they were submerged in water
- Then he compared the weights of the King's crown and a crown made of pure silver having the same dimensions, when they were submerged in water
- By comparing these results, he determined that the King's crown was not made of solid gold

Archimedes' Paradox...

- "…an object can float in water that has less volume than the object itself, if its average density is less than that of water."
  - There must be enough water to prevent the object from touching the bottom or sides



Archimedes' Paradox

- This is the principle behind massive ships being able to float
  - The ship is made of steel, but contains mostly air therefore the overall density of the ship is less than water
- If the hull is punctured (Titanic) water rushes in, which pushes the air out of the ship
  - As a result, the overall density becomes greater than water and the ship sinks

Archimedes' Paradox...

- An application of Archimedes' Paradox can be found in Scotland: The Falkirk Wheel
- It connects the Clyde Canal with the Union Canal which differ in height by 24 meters
- It consists of two main "tubs", one on either canal
  - The boats enter the tubs which lock in the water so the boats remain floating
  - The Falkirk Wheel rotates as the tubs stay horizontal moving the boat from the top of the lock to the bottom and vice versa
  - The whole process takes 15 minutes


welcome to

Archimedes' Paradox...

- From this paradox, we have learned that liquids or gases which are more dense sink below liquids or gases which are less dense

Archimedes…

- Killed in 212 BC during Second Punic War by a Roman Soldier
- Working on a math problem involving circles and didn't want to be disturbed
- Soldier killed him when he refused to go with him

Archimedes Tomb

- Tomb had inscription of his favorite math proof (a sphere inside a cylinder) and verses
- Discovered by Marcus Tullius Cicero in 75 BC

Evangelista Torricelli

- Born in Faenza, Italy on October 15, 1608.
- Eldest of three boys
- Sent to his uncle Brother Jacopo at an early age for proper education
- Went to a Jesuit College in 1624 for two years
- Taught by Benedetto Castelli and became his secretary


Goito
Mantua
VENETO
Gorgo
Chioggia
Microsoft
MapPoint
PADUA
VENEZIA
Gulf of Venice
Rovigo
Vrsar
Rovinj
MANTUA
Ostiglia
Selva
45°
A22
Case
Ocaro
Poggio Rusco
ROVIGO
Mirandola
Ferrara
FERRARA
Foci del Po
BRIJUNI
Carpi
Codigoro
Palata Pepoli
A1
Modena
San Giovanni
Comacchio
Adriatic Sea
Budrie
Riolo
Argenta
Bologna
Mediterranean Sea
44° 30'
Sassuolo
Ravenna
Lugo
EMILIA-ROMAGNA
MODENA
Vergato
Faenza
Cervia
BOLOGNA
Faidello
Fognano
Forlì
Cesena
Castiglione
dei Pepoli
Rimini
FIRENZE
Predappio
44°
Boveglio
Vicchio
San Marino
Corniolo
Prato
PISTOIA
Pesaro
Novafeltria
Galleno
Florence
FORLÌ
Lunano
Senigallia
Cetica
Falera
Empoli
Poppi
MARCHE
Ancona
TUSCANY
PESARO E URBINO
Polverigi
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11° 30'
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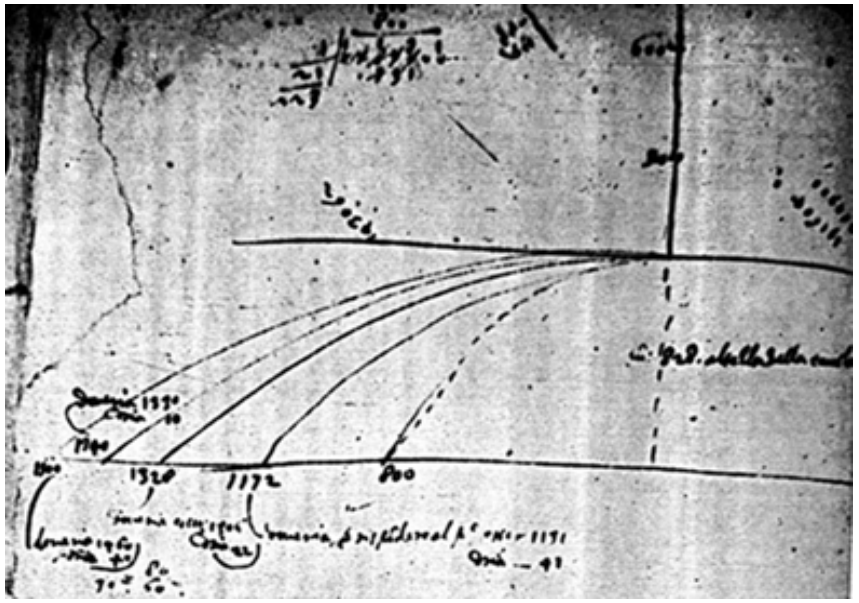
12° 30'
13°

Evangelista Torricelli

- Wrote to Galileo in 1632 in the absence of Castelli and informed him of his own achievements in math and that he agreed with the Copernican and Galilean theories
- However, with Galileo's trial in 1633, Torricelli decided to change his focus
- From 1633 to 1641

Torricelli finished "De motu gravium" which was a continuation on Galileo's work on the parabolic path of projectiles



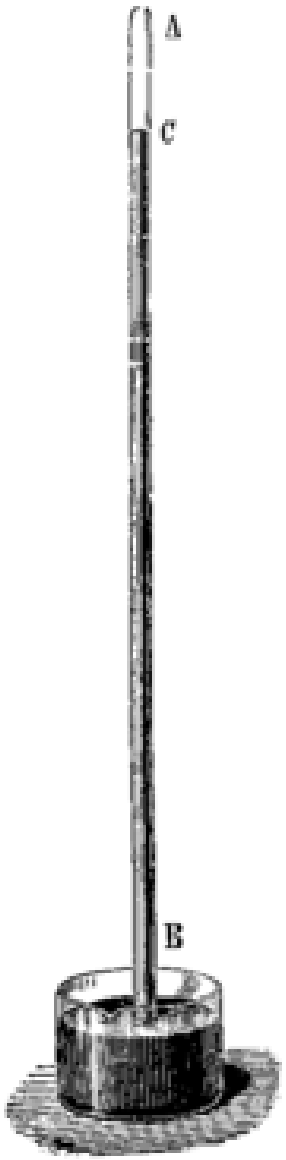
Torricelli…

- Castelli read it and suggested to Galileo that Torricelli become his assistant
- Torricelli went to live with Galileo in Arcetri on October 10th 1641, just 3 months before Galileo died
- Grand Duke Ferdinando II de'Medici chose Torricelli to take over Galileo's position as grand-ducal mathematician and Professor of Mathematics at the University of Pisa
- He stayed at the ducal palace in Florence until his death on October 25th, 1647 after catching typhoid fever

The University of Pisa

Torricelli…

- In 1643, Torricelli invented the first barometer
  - A barometer is a device used to measure the pressure of the atmosphere
- He filled a 1 meter long tube with mercury and quickly inverted it into a bowl also filled with mercury
  - The mercury in the tube decreased by ~24cm
  - He observed that the decrease of mercury fluctuated slightly but did not understand why



Torricelli…

- He concluded that the height of the mercury in the tube was caused by some force at the surface of the earth
- He was unable to describe this force in detail

“We live submerged at the bottom of an ocean of elementary air, which is known by incontestable experiments to have weight".

Blaise Pascal

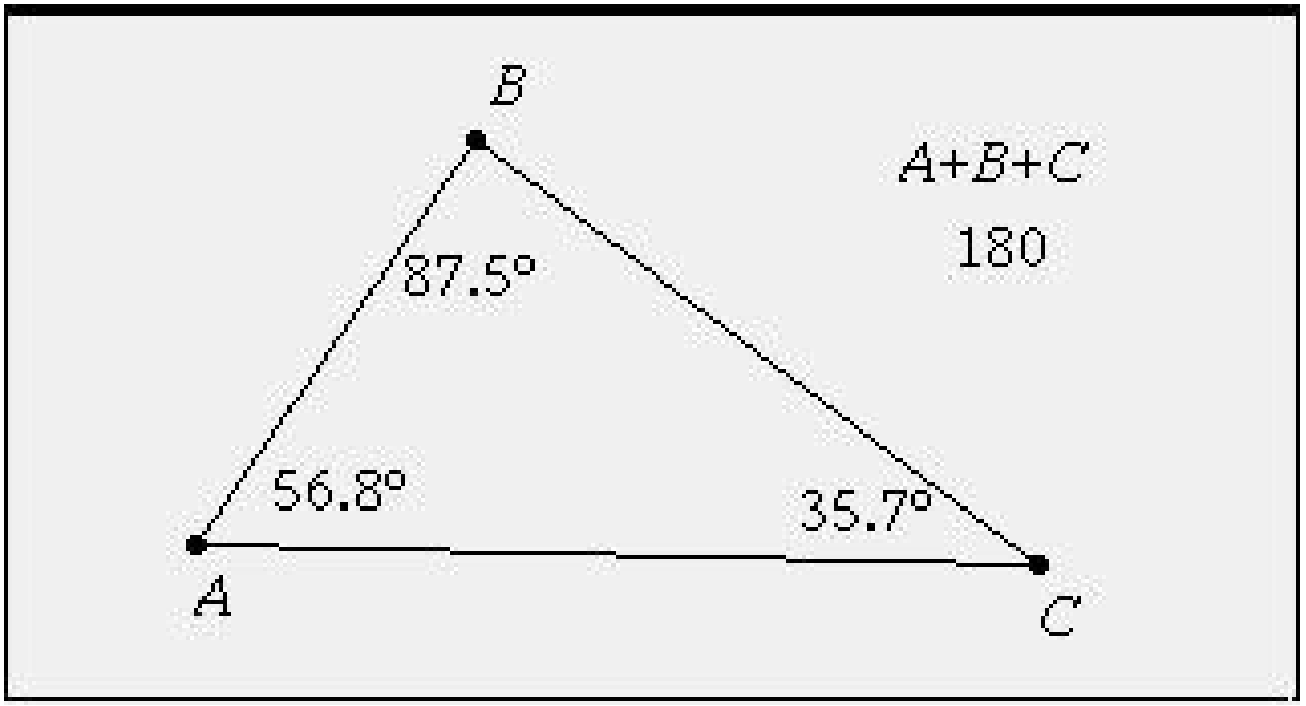
- Born on June 19, 1623 in Clermont-Ferrand, France
- Lost his mother at the age of three and lived with his father and 2 sisters
- Educated by his father, a judge interested in math and science

Pascal…


Lille
Amiens
Rouen
Caen
Reims
Epernay
Nancy
Strasbourg
PARIS
Versailles
St Malo
Brest
Chartres
Rennes
Colmar
Troyes
Angers
Nantes
Tours
Dijon
La Rochelle
Annecy
Clermont-Ferrand
Lyon
Aix-les-Bains
Chambery
Grenoble
Arcachon
Bordeaux
Avignon
Nimes
Aix-en-Provence
Nice
Monaco
Juan-les-Pins
Cannes
Toulon
Marseille
Montpellier
Toulouse
Carcassonne
Biarritz
Lourdes
Perpignan

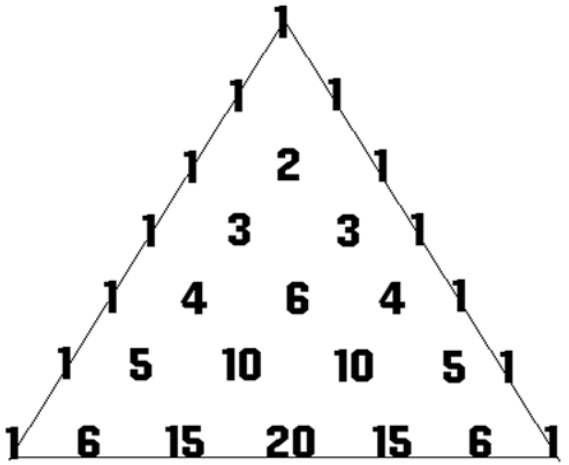
Pascal…

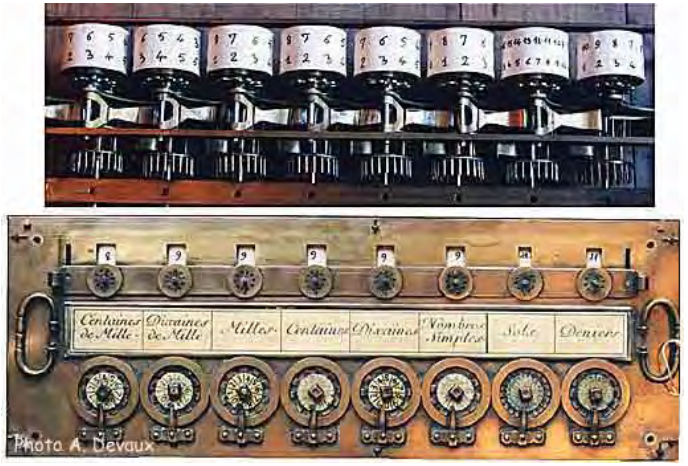
- When he was 12, he wrote out a proof on his wall in coal stating that the sum of all the angles in a triangle is equal to the sum of two right angles



Pascal…

- At 18, his father became a tax commissioner and he built the first calculator to help his father add and subtract all of the taxes owed and paid
- He also invented Pascal's Triangle and Pascal's Theorem





Pascal…

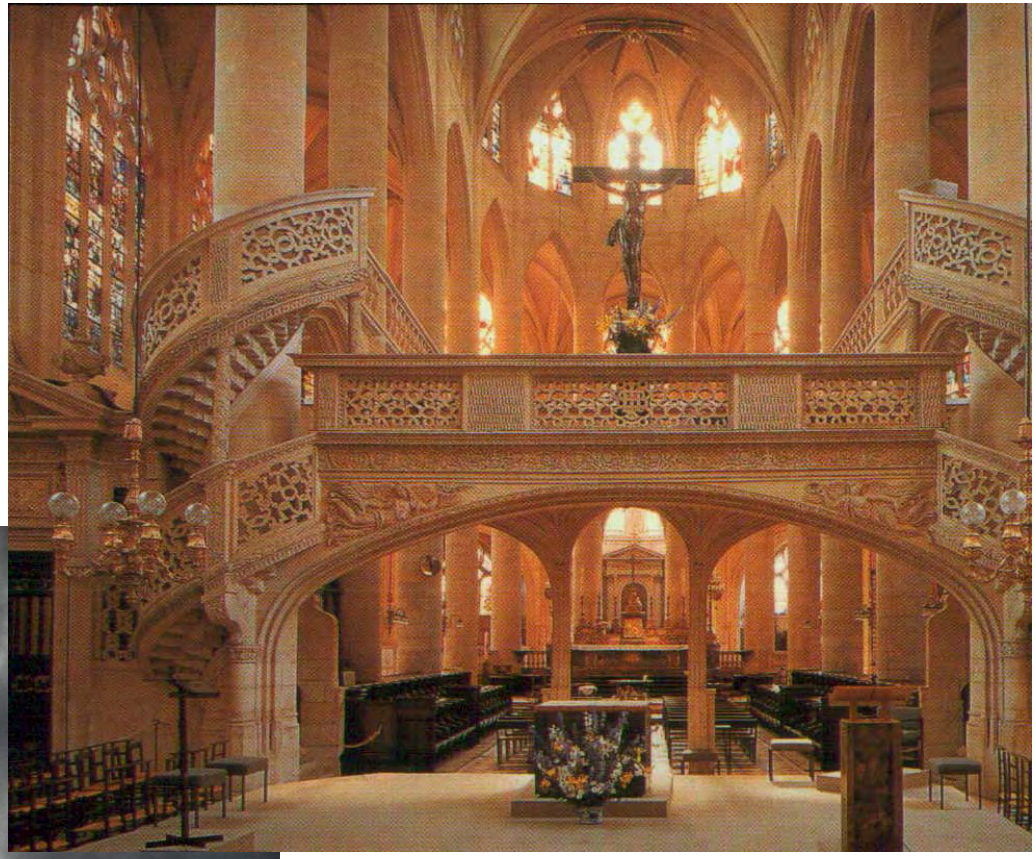
- In regards to Torricelli's barometer, Pascal was baffled by the unexplainable force described by Torricelli and set out to define it
- He predicted that the mercury would decrease at higher altitudes
  - Proved this in 1648 when he went to the top of Puy de Dome in France
  - He concluded that this was due to a change in pressure which acts uniformly in all directions and decreases with altitude
  - He defined this as Atmospheric Pressure
  - The pascal (Pa) was named in his honor

Pressure Units

	pascal (Pa)	bar (bar)	atmosphere (atm)	torr (Torr)	pound-force per square inch (psi)
1 Pa	≡ 1 N/m^2	10^{-5}	9.8692×10^{-6}	7.5006×10^{-3}	145.04×10^{-6}
1 bar	100,000	≡ 10^6 dyn/cm^2	0.98692	750.06	14.504
1 atm	101,325	1.01325	≡ 1 atm	760	14.696
1 torr	133.322	1.3332×10^{-3}	1.3158×10^{-3}	≡ 1 Torr; ≈ 1 mmHg	19.337×10^{-3}

Pascal…

- Became ill in 1659 but continued to write scientific papers
- Died on August 18, 1662 in Paris from tuberculosis and stomach cancer
- He was buried in St. Étienne du Mont, behind the Pantheon



Robert Boyle

- Born on January 25, 1627 in Lismore, Ireland at the Lismore Castle
- 14th child and 7th son of father Sir Richard Boyle

Boyle…

- When he was 3 he almost drowned when the horse he was riding on fell into a fast-moving stream
- At 7 years old, he was nearly crushed when his bedroom ceiling collapsed
- At 8, his mother passed away and he was sent to Eton College in England
- When he was 11, he was sent on a Grand Tour to France, Switzerland and Italy

Boyle…

- While in Florence, Italy, Galileo passed away which greatly influenced Boyle
- Returned to England at age 18 and dedicated his life to scientific studies
- Joined the “Invisible College” which became the Royal Society of London

Boyle…

- In 1662, Boyle published what is known as "Boyle's Law", which states:

"For a fixed amount of gas kept at a fixed temperature, P and V are inversely proportional (while one increases, the other decreases)."

- The mathematical equation is written as:

$$PV=k$$

Where P is the pressure, V is the volume and k is a constant describing the system

Boyle…

- Boyle's Law can also be used to predict the change in volume or pressure of a closed system where the temperature remains constant
- This can be expressed as follows

$$P_1V_1 = P_2V_2$$

- With the help of this we can predict the volume of a gas or liquid with a change in pressure
- Example: a cylinder compresses a gas to ½ times the original volume, so the pressure goes up by a factor of 2

Boyle…

- Boyle led a very secluded and lonely life
- In 1668 he went to live with his sister, Lady Ranelagh
- He was offered to be the President of the Royal Society in 1680 but declined because of his strong Christian beliefs
- His health deteriorated from 1689 until his death on December 30, 1691 in London, England
- He was buried at St. Martin-in-the-Fields

Henry Cavendish

- Born October 10, 1731 in Nice, France
- Mother died in 1733 after giving birth to his brother, Frederick
- Very wealthy family
- At 11 years old, became student at the Dr. Newcome's School in Hackney

Cavendish…

- In 1749 went to the University of Cambridge but left four years later without graduating
- Toured Europe for a few years with his brother then lived in Soho, London with his father until his father's death in 1783
- Cavendish became a millionaire through inheritances when he was 40 years old

Cavendish…

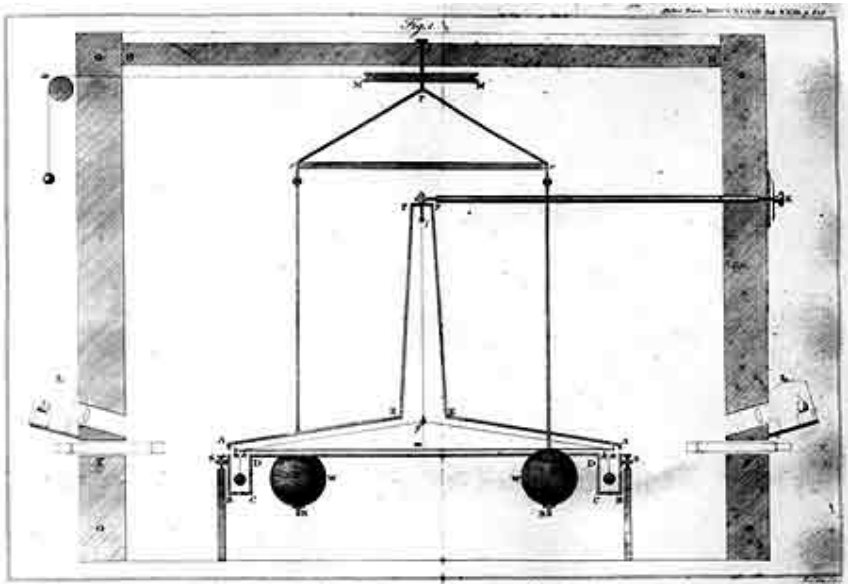
- Very quiet and isolated individual
- Painfully shy of women:
  - Communicated with his housekeepers through notes and had a back stairwell put in to avoid meeting them
- Only socializing was through the Royal Society where he dined with the other members prior to the weekly meetings

Cavendish…

- Because of shyness, he avoided publishing his work
- James Clerk Maxwell in 19th century read his papers and came upon discoveries Cavendish made that others had been given credit for like:
  - Ohm's Law
  - Richter's Law of Reciprocal Proportions
  - Charles's Law of Gases

Cavendish…

- In 1798, he was the first to successfully measure the density of Earth.
- He used a complicating device which consisted of a torsion balance which measured the gravitational attraction between two large lead balls.



Cavendish…

- These measurements were so precise, that even the slightest air movement would offset the results. He therefore constructed a 10’x10’ box with 2’ thick walls around the apparatus. He made his observations by looking through two small holes in the side.
- He concluded that the density of earth was 5.48 times that of water.

Cavendish…

- Another discovery by Cavendish was that of Hydrogen. (He called it “inflammable air”)
- He was able to produce and isolate hydrogen so that he may further study it.
- Not only did he discover that hydrogen was 11 times lighter than air, he also discovered that carbon dioxide was 1.47 times heavier than air.
- We now understand that some gases are heavier (denser) than others.

Cavendish…

- Died on February 24, 1810 after becoming sick
- Buried in Derby Cathedral in the United Kingdom

Jacques Charles

- Born on November 12, 1746 in Beaugency-sur-Loire, France
- He received an education as a young boy, yet it didn't include much math and science
- He worked at the Bureau of Finances in Paris during his late teens
- Changed his focus to science after hearing Benjamin Franklin speak in Paris

Charles…

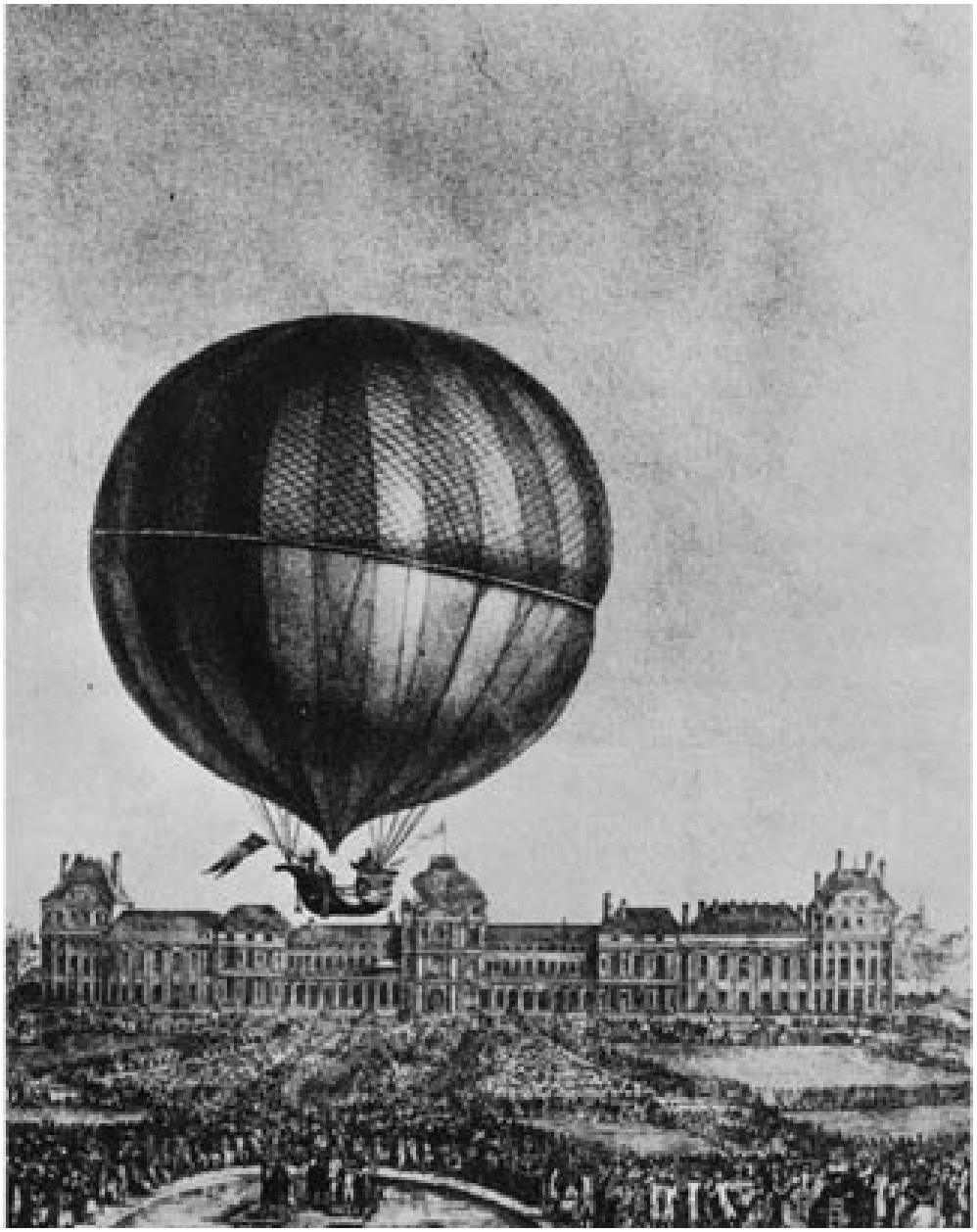
- In 1787, he came up with Charles's Law which relates temperature and volume when there is a constant pressure:

$$V_1/T_1=V_2/T_2$$

- When the pressure remains constant, the volume of a gas is directly proportional to the absolute temperature

Charles…

- He was the first person to use Hydrogen in an air balloon
- On August 27, 1783 he filled a balloon with hydrogen which sailed out of Paris
- It landed in the country side, and was immediately distroyed by terrified civilians.
- On December 1, 1783 he flew his newly constructed hydrogen balloon with Ainé Roberts in the first manned flight
- This happened only 10 days after the Montgolfier brothers' first manned hot-air balloon flight



Charles…

- On November 20, 1795 he was admitted to the Académie des Sciences
- In 1816, he became a physics proffessor at the Conservatoire des Arts et Métiers
- Jacques Charles married Julie-Francoise Bouchard des Herettes, and is not believed to have had any children
- He died on April 7, 1823 in Paris, France

Joseph Louis Gay-Lussac

- Born on December 6, 1778 in the village of Saint-Léonard-de-Noblat in France
- Was educated at home until 1794 when he attended the École Polytechnique in Paris
- Was a professor in chemistry and physics from 1808 to 1832

Gay-Lussac…

- The relationship between temperature and pressure was described by Joseph Louis Gay-Lussac in 1802
- He claimed that with an increase in temperature, identical volumes of gases expand uniformly
- Even though Jacques Charles described this property 15 years earlier, he neglected to publish his results
- This is basically Charles's Law, just rearranged

Gay-Lussac…

- His biggest accomplishment was in 1804 when he and Jean-Baptiste Biot flew to 23,000 feet in a hydrogen filled balloon to take samples of gases in the atmosphere
- It took another 50 years for the next person to accomplish the same feat

Gay-Lussac…

- He died on May 9, 1850 in Paris, France
- He is buried at the Père Lachaise Cemetery in Paris

Everyday Applications

- Thanks to the discoveries of these famous scientists, our standard of living has greatly improved:
  - Blood pressure
  - Weather predictions (Tornadoes in particular)
  - Airplane travel

Applications…

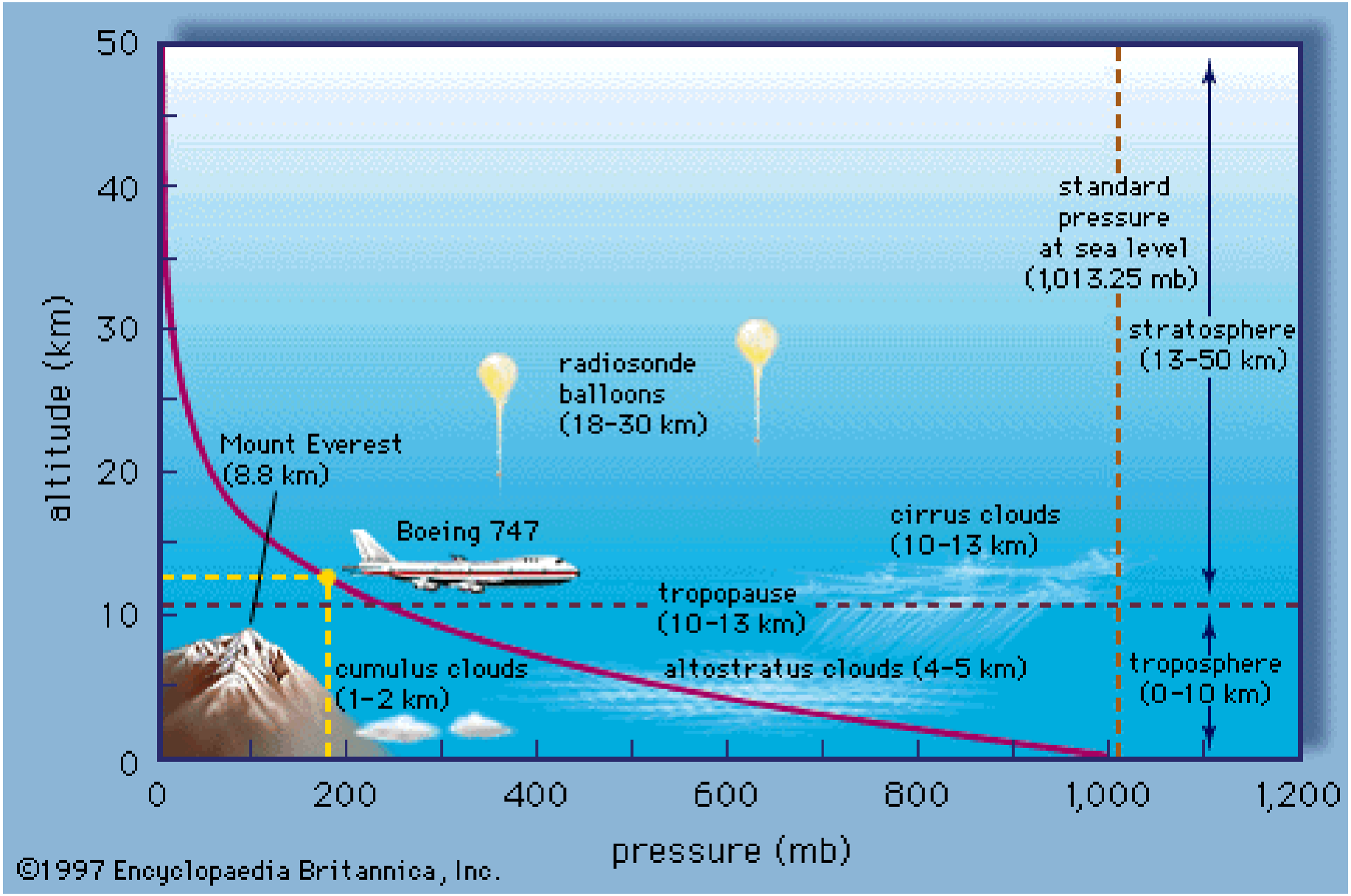
- Blood pressure:
  - The first time a human's blood pressure was measured was in 1847 which involved inserting catheters directly into the artery – not very appropriate for clinical use
  - Today we use more humane and practical methods which allow blood pressure to be measured without any insertion into the artery
  - As a result, serious health problems can be detected early on and addressed

Applications…

- Tornadoes:
  - Advancements in detecting atmospheric pressure changes has permitted meteorologists to predict different weather patterns, like tornadoes
  - They are able to give people an advanced notice when a tornado is approaching so that they may find shelter
  - As a result, more lives are saved

Applications…

- Airplane Travel:
  - As we know, pressure decreases with altitude, therefore airplane cabins must be pressurized in order to fly
  - The pressure inside the cabin must be similar to the pressure at the surface of the earth which relates to the amount of oxygen in the air
  - If it weren't pressurized, there wouldn't be enough oxygen for us to breath and we would lose consciousness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400
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800
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1,200
pressure (mb)
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pressure
at sea level
(1,013.25 mb)
stratosphere
(13–50 km)
troposphere
(0–10 km)
radiosonde
balloons
(18–30 km)
Mount Everest
(8.8 km)
Boeing 747
cirrus clouds
(10–13 km)
tropopause
(10–13 km)
cumulus clouds
(1–2 km)
altostratus clouds (4–5 km)
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