MAGIC NUMBERS

ARE THEY REALLY MAGIC AND CONSTANT OR DO THEY VARY?
Topics

• Speed of Light – Particle or Wave?
• Speed of Sound – Constant or Varies?
• Gravity – What is it and What Causes it to Vary?
• Time – Can it be Effected by Other Physical Forces?
• Four Dimensions in our Universe– But Is there one Universe or are there many?
• Age of the Oldest Star – Can it be older than the Universe?
• Conclusions
Speed of Light

- At first thought to be infinite
- Galileo in the 17th Century was the first to try to measure it.
  - Two people stood a certain distance apart and held lanterns
    - Covered the lantern and then released it
    - Second person uncovered his lantern when he saw it
    - Distance was too short to be measured
- Danish astronomer around 1676 determined that it was constant by using two moons of Jupiter.
  - Noticed when there were eclipses that the time was different dependent upon where they occurred in their orbit around the planet.
  - Established that the speed was constant
- First non-astronomical measurement was in 1849.
  - Shined light through a toothed wheel located a significant distance away
  - Found that the time varied with distance but was a constant
- 1920s American physicist Albert Michelson carried out his research in the mountains of Southern California using an eight-sided rotating mirror apparatus
- 1983 the speed of light in a vacuum that we use today: 299,792,458 meters per second (186,282 miles per second)

However

We now know that gravity effects light such that it is lensed around galaxies and under extreme gravity can be stopped entirely.

- The laws of quantum physics, which govern subatomic particles and all things very small, say that the vacuum of space is actually full of fundamental particles like quarks, called "virtual" particle and these particles effect the speed of light by 0.05 femtoseconds
- A femtosecond is a millionth of a billionth of a second
- A gravity effect on light speed occurs under tremendous gravitational forces in large stars. It is also affected by air and water and is somewhat slower.
Speed of Sound

Speed of sound \(a\) depends on the type of medium and the temperature of the medium.

\[
a = \sqrt{\gamma \cdot R \cdot T}
\]

\(\gamma\) = ratio of specific heats (1.4 for air at STP)

\(R\) = gas constant \((286 \text{ m}^2/\text{s}^2/\text{K}\) for air\)

\(T\) = absolute temperature \((273.15 + ^\circ\text{C})\)
Causes for Speed of Sound Variance

• Medium it travels through
  - Air is a gas, and a very important property of any gas is the speed of sound through the gas
  - All matter is made from atoms with the configuration of the atom (number of protons, number of neutrons ..) determining the kind of matter present (oxygen, lead, silver, neon ...)
  - An analysis based on conservation of mass and momentum shows that the speed of sound is equal to the square root of the ratio of specific heats $\lambda$ times the gas constant $R$ times the temperature $T$,

\[
a = \sqrt{\gamma \frac{R T}{\rho}}
\]

$\gamma$ = ratio of specific heats (1.4 for air at STP)
$R$ = gas constant (286 m²/s²/K for air)
$T$ = absolute temperature (273.15 + °C)
Scientists Have Built a Model for our Atmosphere

**Earth Atmosphere Model**
**Imperial Units**

**For \( h > 82345 \) (Upper Stratosphere)**
\[
T = -205.05 + 0.00164 \ h \\
p = 51.97 \times \left( \frac{T + 459.7}{389.98} \right)^{-11.388}
\]

**For \( 36152 < h < 82345 \) (Lower Stratosphere)**
\[
T = -70 \\
p = 473.1 \times e^{(1.73 - 0.000048 \ h)}
\]

**For \( h < 36152 \) (Troposphere)**
\[
T = 59 - 0.00356 \ h \\
p = 2116 \times \left( \frac{T + 459.7}{518.6} \right)^{5.256}
\]

\( \rho = \text{density (slugs/cu ft)} \)  
\( p = \text{pressure (lbs/sq ft)} \)  
\( \rho = \frac{p}{(1718 \times (T + 459.7))} \)  
\( T = \text{temperature (\(^{\circ}\)F)} \)  
\( h = \text{altitude (ft)} \)
Speed of Sound Varies with Temperature in Our Atmosphere

• If the molecules vibrate faster,
  – **Sound** waves can travel more quickly.
  – Therefore, the *speed of sound* at room temperature in *air* is 346 meters per second. This is faster than 331 meters per second, which is the *speed of sound* in *air* at freezing temperatures.
Graph Showing Speed Variance With Humidity on Earth
Speed of Sound for Mars

• From data acquired from the Mars Pathfinder probe. This gives sound on Mars a speed of **240 m/s**, much slower than the **332 m/s** on earth.

• Why?
  – Gas makeup is different on Mars so that effects the speed
  – The Atmosphere is thinner on Mars so that effects the speed
  – There is essentially no water in the atmosphere on Mars
Speed of Sound in Water and Solids

• Density is also a key to speed
  – Since water is more dense than air, then sound vibrations can move faster than they do in air.
  – Solids are more dense than water, then sound moves faster in solids
• Speed of sound in water at sea level and 20 degrees C is 1,484 Meters per second which is 4.3 times as fast as in air
• Speed of sound in an iron bar is 5,120 meters per second
• Bottom line is that density and temperature both effect the speed of sound
Two More Little Facts

• Why does sound pitch change with respect to a train whistle?
  – We are dealing with the speed of sound in air and if the train is moving toward you the sound is higher because the speed of sound is enhanced by the speed of the train and lower if the train is moving away because the sound is moving slower due to the train movement

• Why is there a 5 second rule for determining distance of a lightning strike?
  – Light travels in air, as we saw earlier, at approximately 186,000 miles per second such that you see the strike almost instantly on earth
  – Sound is only traveling at roughly 345 meters per second so this means that it takes about 5 seconds per mile
  – Bottom line is that sound travels slowly and light travels very quickly
Review
Sound in Review Continued
Gravity

• What is the speed of Gravity?
  – Believe it or not, this is one of the most severe differences between Newton’s and Einstein’s theories about Gravity. According to
  • Newton, you have two masses separated by a distance, and that determines the force. You take one of those masses away, and the force goes away. **Instantly**
Gravity

• The Theory of Relativity that Einstein proposes does not support the idea that gravity has no speed but is constant
  – First off, it isn’t mass, per se, that causes gravity
  – Rather, all forms of energy (including mass) affect the curvature of space
    • You can think of it similar to dropping a stone into water that produces waves
    • Waves that are produced travel at the speed of light
    • Using Einstein’s approach if the sun all of a sudden disappeared we would not be affected for about 8 minutes
    • Gravity is causing space to change its curvature all the time but is limited to the effect being done at the speed of light not instantly
    • The next slide shows why a discovery made in the last year is so important

• We now know that Theory of Relativity of Einstein is correct
How do we Know Who to Believe?
This Video Sums it Up.
• Wow! Wow! Wow
• Einstein’s Theory of Relativity is Real and all the elements are now accounted for
Time

- Time is the indefinite continued progress of existence and events that occur in apparently irreversible succession from the past through the present to the future
- Question one is a minute 60 seconds long and an hour always 60 minutes long and is it constant?
- Time in physics is what a clock reads
- This operational definition leaves aside the question whether there is something called time, apart from the counting activity just mentioned, that flows and that can be measured
- Originally the second was defined as 1/86,400 of the mean solar day, which is the year-average of the solar day
This is the Physical Representation of Time
Time is a Bit Unique but Not Really Constant
Dimensions of our Universe?

• Einstein’s Theory of Relativity is based upon 4 dimensions and they include X, Y, Z, and time.
  – His conclusion is based upon the particle theory of the Universe

• String Theory gives us many different numbers of dimensions to our understand of Universes
  – I know I have talked about this before so let us listen to Michio Kaku who sums it up beautifully
Kaku’s View of the Universe
Interstellar Example of Multiverse
Oldest Star
14.5 billion years (plus or minus 0.8 billion years),

Wait just a minute here!!!!
This is not Possible, right?

• Earlier estimates from observations dating back to 2000 placed the star as old 14.5 BY + or – 800 million years. Interesting since the Universe is 13.8 BY
• Hubble age estimates reduce the range of measurement uncertainty, so that the star's age overlaps with the universe's age
• This "Methuselah star," cataloged as HD 140283, has been known about for more than a century because of its fast motion across the sky
• Just passing through the solar neighborhood at a rocket-like speed of 800,000 miles per hour
• Also, the star has a higher than predicted oxygen-to-iron ratio and Berylium and Boron lowers the age
• The jury is still out
Conclusions

• Absolute numbers of most things are plus or minus something
• Interaction between different forces can cause a variance in behavior that sometimes is small but other times may be large
• There may be reasons to believe that our universe is not alone
• Science is still developing an understanding of forces in our universe, ages in our universe and whether there is only one universe or many
• It would appear that there are no absolutes that exist even though we sometimes wish there were
QUESTIONS?
Speed of Light