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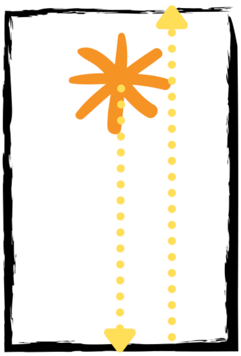
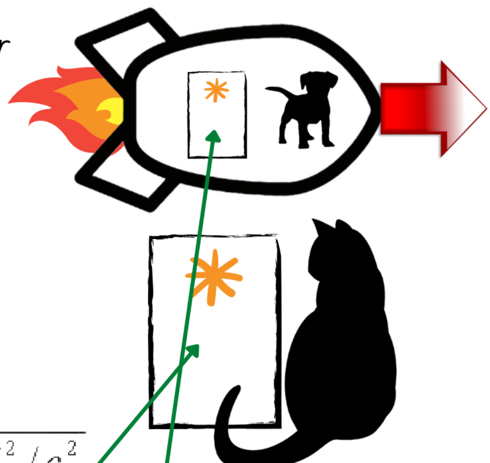
TIME DILATION



Imagine a clock as follows: A light source in a container moves up and down, and after each roundtrip you increment time by 1 unit.

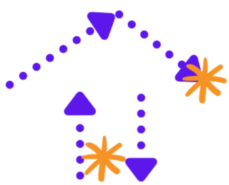
Now suppose you board a rocket ship and zoom past me with this clock, and I have a clock of my own, as depicted below



Because of your sideways motion, your light travels a longer distance than mine, shown below.

Naxxy's Clock:

My Clock:



$$t' = t\sqrt{1 - V^2 / c^2}$$

Where: t' = dilated time
t = stationary time
V = velocity
c = speed of light

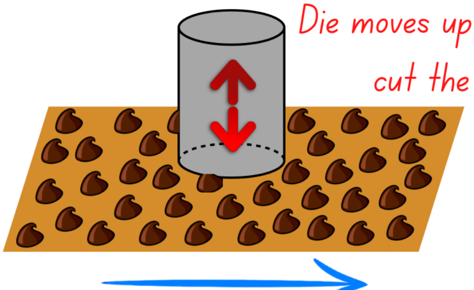
Since the speed of light is constant in all reference frames, Naxxy's 'roundtrips' must take more time. Thus, according to me on Earth, time actually ticks slower on your moving rocket! THIS IS NOT AN ILLUSION, IT IS REAL. However, we do not really notice this because time dilation doesn't become apparent until you move sufficiently close to the speed of light (relativistic speeds).

Relativistic Chocolate Chip Cookies P1

Now you know a bit about relativity, let's solve the following problem:

Problem:

Suppose we are trying to cut cookie doughs using an industrial cutter. That is, a cookie sheet moves along a conveyor belt at relativistic speeds (naturally), and the die (circular in shape in the factory's r.f), comes down and cuts the cookies from the sheet. It looks a little like this:



What is the shape of the cookies after the conveyer belt slows down to a stop? Are they circular, elliptical, square?

Paradox?

This is quite a tricky problem, because in the factories r.f., the cookies should come out in an oval shape, since although the die cuts circles, the cookie sheet is length contracted. It would seem that more of the cookie was cut in one direction, so the cookies are ellipses, stretched along the sheet!

However, in the cookie sheet's r.f., the die is elliptical perpendicular to the sheet, so the cookies would be stretched in the opposite direction to the cookies when viewed in the factory's r.f.!

How can this be possible? Is this some sort of paradox? Is relativity broken?!

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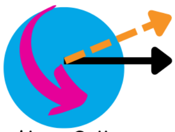
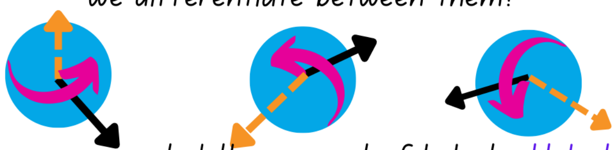
HELICITY

The previous page was slightly misleading. When we refer to spin-1/2 particles, like an electron, we are categorizing them by the magnitude of their spin. However, spin is actually a vector - a mathematical object that has both magnitude and direction. Now, consider a particle that has a spin in a certain direction, but it's momentum vector is pointing in another direction, like so:



The spin vector is denoted with an orange, dashed arrow, while the momentum vector is denoted with a black, solid one.

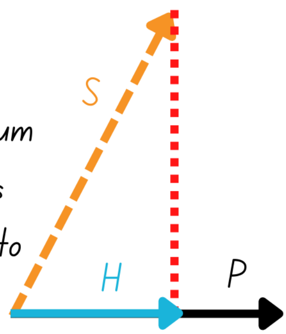
Consider the following arrangements of spin and momentum. How would we differentiate between them?



For this purpose, we created the concept of helicity. Helicity is defined to be the projection of the spin vector onto the momentum vector. What does a projection mean?

WOOF!

Exactly! Projecting the spin vector onto the momentum vector p is the same as taking the vector that has components in the direction of p of s. The diagram to the right to is there to help you understand it.



If H is positve (right-handed), then the direction of motion is equal to the direction of spin. Else, H is negative (left-handed).

Helicity is actually dependent on the reference frame through which the measurement of momentum is taken. What is the helicity of a massless particle? Well, massless particles travel at c, no matter the r.f. Thus, helicity for massless particles is actually constant!

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EXTRA DIMENSIONS?

WOOF?

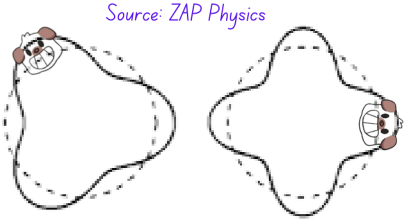
What's to say that the 'extra-dimensions' are relatively large? Great question! The answer is ... we don't really know! They might actually be very small, or Planck scale. There are different types of string theories that are currently suggesting the use of extra dimensions. For example, Bosonic String Theory, Superstring Theory, and M-Theory require 26, 10, and 11 extra dimensions to our 4-d spacetime respectively!

Naxxy, suppose you were a quantum particle moving along a circle. What is the best way to describe your position?

WOOF!

Right! The solution to the Schrodinger Equation yields a circular standing wave, where the peaks represent a higher probability of you being at that location, while the troughs represent a lower probability.

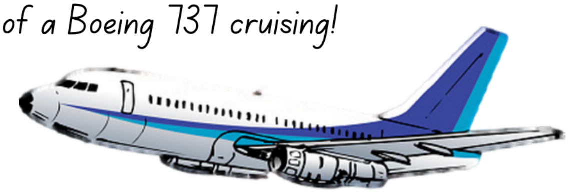
Source: ZAP Physics



If the radius of the circle is small enough, the amount of energy for Naxxy to access the next lowest energy level is huge! Thus, extra spacial dimensions may exist!

The caveat is that they need to extremely small. Let's consider the biggest particle accelerator ever built - the Large Hadron Collider (LHC). The LHC accelerates protons to about 7 miles short of the speed of light. Their KE is approximately equal to a flying mosquito. The technology required to be able to see the extra dimensions, however, needs to give protons the KE of a Boeing 737 cruising!

VS



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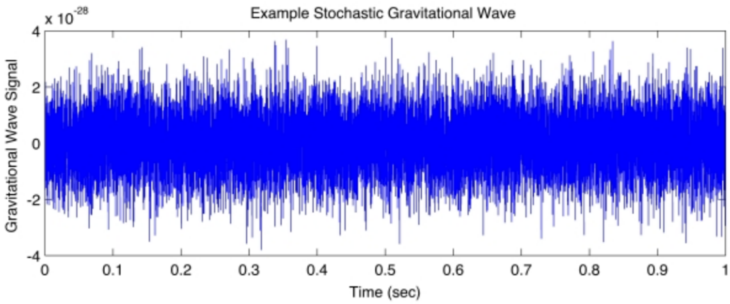
GRAVITATIONAL WAVES P4

STOCHASTIC

Astronomers hypothesize that the number of sources for continuous or binary inspiral gravitational waves is very few so that detectors like LIGO do not expect there to be multiple passing the Earth at the same time. However, we do know that there are tons of sources of small gravitational waves all across the universe, and that they are probably combined into a 'noisy' signal when detected at Earth. These combined waves make up a Stochastic Signal, since the waves can be analyzed statistically but cannot be predicted. Parts of this signal are believed to originate from the Big Bang itself!



Source: LIGO Collaboration

BURST

We don't really know what this type of gravitational wave looks like or how it is formed. Sometimes, physicists do not know enough about the physics of a system to know how to model the gravitational waves, and thus, we have named these burst gravitational waves. The search for burst gravitational waves is especially difficult because we really don't know what we are looking for! Detecting burst gravitational waves may reveal information that we have not yet discovered about the universe, which makes them highly important.