Simulating a Fundamental Particle

Phase 1 Requirements

Simulating a Fundamental Particle

Initial Conditions | Runtime | Validation

Objective

To simulate a micro-sized universe, the motion of its components and the formation of the first particle, which is likely to be the neutrino.

Validation Criteria

The following should be validated in this phase of the project:

1. Formation of longitudinal traveling and standing waves
2. Formation of the neutrino particle
3. Formation of the antineutrino particle
4. Detection of electric waves and calculation of constructive and destructive interference

Custom Simulator vs Blender Add-On

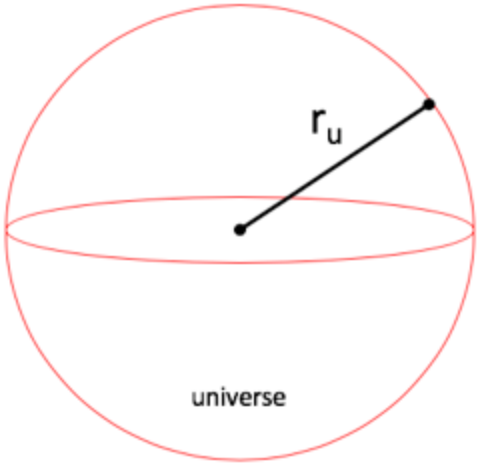
These requirements are intended for developers building a custom simulation. The Quantum Microscope for Blender Add-On was developed using these requirements but were adjusted for scale and Blender's capabilities. The modifications for Blender are found at the end of each section (Initial Conditions, Runtime and Validation). A list of suggested improvements for the Add-On are found in the source code and their ReadMe files.

Initial Conditions

The initial state of the universe is assumed to consist of a physical structure, referred to here as the *spacetime lattice* or sometimes simply as *aether*. The proposed lattice includes components that may be displaced from their position in the lattice, but will return to their initial position (equilibrium). Their displacement is simple, harmonic motion described over time with a sine wave function. These initial conditions are similar to air molecules being displaced to create sound waves, but in this case, it occurs at the Planck level with aether components referred to as *granules*.

1.1 Universe Size

For the first phase, the initial simulated size of the universe should be spherical with a radius around 1×10^{-16} meters. To simulate visually for the human eye, and for the purpose of calculations, a scaling factor can be applied (e.g. 1 meter = 1×10^{-16} meters). If a scaling factor is used, it needs to be applied consistently across any distances in these requirements.



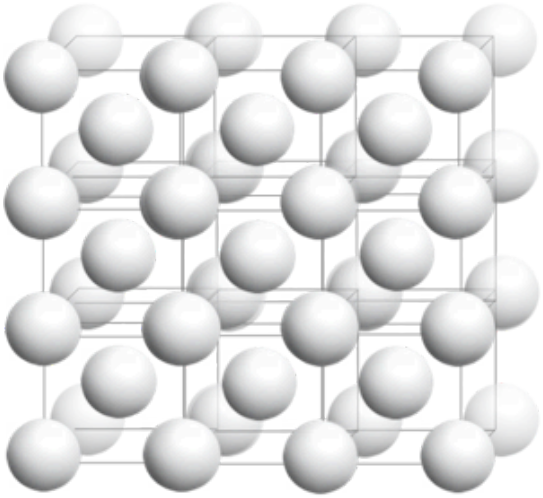
$$r_u = 1 \times 10^{-16} \text{ (m)}$$

Why? *The radius of the universe needs to be large enough to create a neutrino (10^{-17}), but as it gets larger, more computations are required. For the first phase it can be small enough to create a neutrino.*

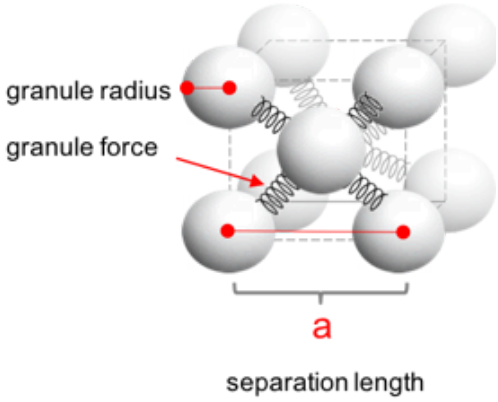
1.2 Granule Properties

The simulated universe should contain two types of aether particles: granules (white) and wave centers (blue). A wave center is possibly a high-density unit cell of granules, but for the purpose of the simulation, it should be built as a separate type of particle.

The structure of the universe should be a lattice with repeating cells. A cubic unit cell is proposed for the repeating cells in the structure. In this structure, springs are used to illustrate the interaction between the center granule and its surrounding granules as the forces between these components can be shown to be represented classically by a spring-mass system. This lattice should extend from one edge of the universe to the other. Similar to water molecules that are displaced and return to equilibrium for water waves, or air molecules for sound waves, granules move within the lattice and return to equilibrium.



Spacetime Lattice



Unit Cell

Granule Spacing

The initial separation length between granules at the edges of a unit cell (distance a) should be adjustable between 10^{-35} and 10^{-17} meters. This will have an effect on the total number of granules in the simulation. As a reminder, a scaling factor may be applied for this spacing, and for all distances in these requirements, as long as it is consistent with the factor chosen in the previous step for the size of the universe.

Why this structure and spacing? *The separation length is expected to be roughly five times the size of Planck length (10^{-35}) due to the relationship with Avogadro's number. However, this would create a significant number of unit cells to compute in a simulation. The separation length can be reduced to minimize the number of unit cells, but it will need to be smaller than the longitudinal wavelength, which is why 10^{-17} meters is the smallest it can be simulated to form waves.*

Granule Size

A granule is spherical with a radius (r_g) that should be adjusted according to the unit cell separation length (a) from above, according to the following equation, where e is Euler's number (2.7183).

$$r_g = \frac{a}{2e}$$

Why this size? *The radius is expected to be Planck length (10^{-35}), but due to the change in unit cell size for a computer simulation, granule radius should be adjust proportionally. See relationship of Planck length to Euler's number here. By modifying the unit cell separation length (a) as an additional scaling control to reduce the number of granules required for calculations, the granule's size is automatically scaled to adjust.*

Granule Mass

The mass of each granule should be adjusted according to the unit cell separation length (a) from above, according to the following equation, where ϱ is the density constant (3.86×10^{22} kg/m^3). An additional scaling parameter may be used for granule mass as long as this equation is maintained for future calculations using granule mass (e.g. 1 kg = 10^{-60} kg).

$$m_g = \frac{1}{2}\rho a^3$$

Why this mass? *The mass of each granule should account for a very high density, matching the Planck mass properties in a hydrogen sphere, as explained here.*

Granule Spring Constant

Granule motion is harmonic, eventually returning to equilibrium after being displaced. Some equations for forces and energy may be modeled based on a spring-mass system for this harmonic motion. The separation force is first determined and then a spring constant based on distance. The separation force (F_g) defaults to the Coulomb constant (9×10^9 newtons), but may be adjusted.

The spring constant (k_g) is force (F_g) over distance (r). For example, the spring constant between two granules at the edges of the unit cell, with separation distance a, is $k_g=F_g/a$.

$$k_g = \frac{F_g}{r}$$

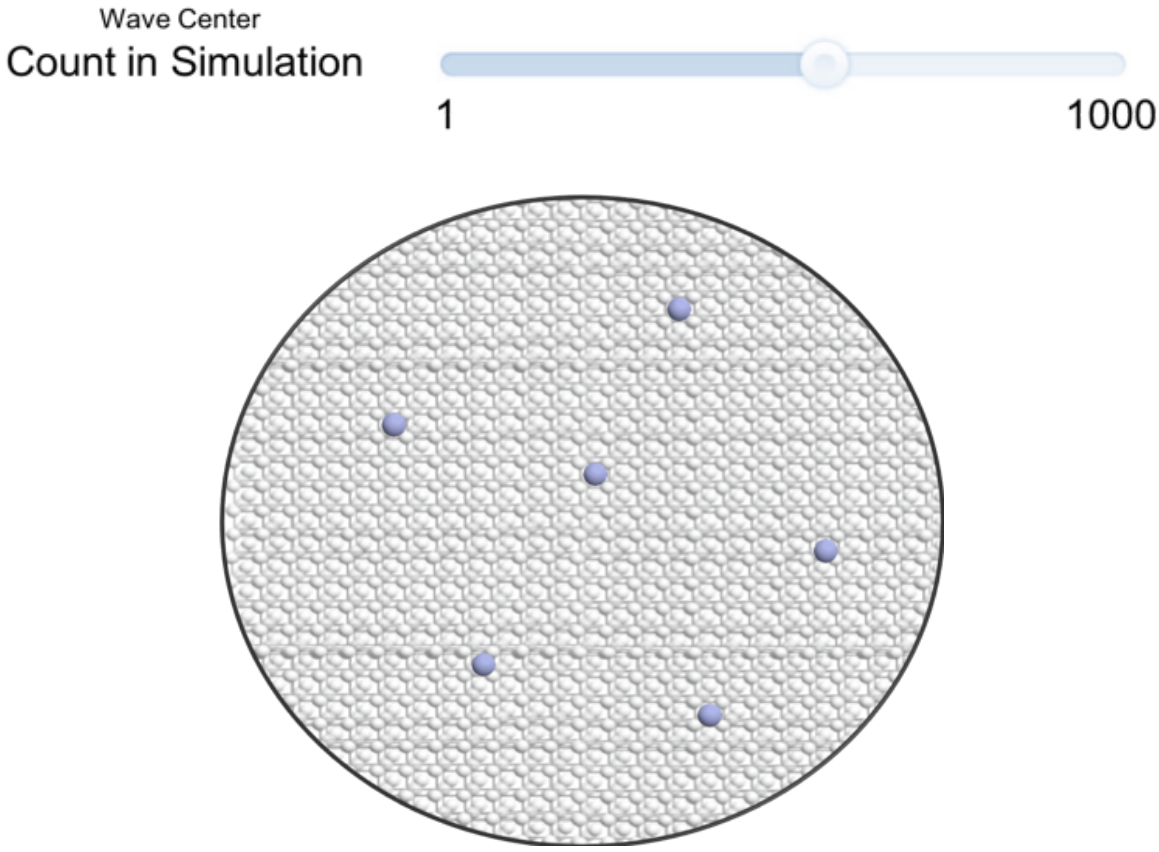
Why this spring constant? *The spring constant can be used for simplified calculations of energies and forces, as explained here. The value perfectly matches the Coulomb constant, but assuming granules are scaled in size and mass for the simulation, the force and spring constant will need to be adjusted accordingly.*

1.3 Wave Center Properties

The center of wave motion creating standing waves is the wave center. It is possible that the wave center is a high-density unit cell of granules, coinciding at the center of converging waves. For the purpose of the simulation, wave centers are inserted with a special property to ensure wave reflections.

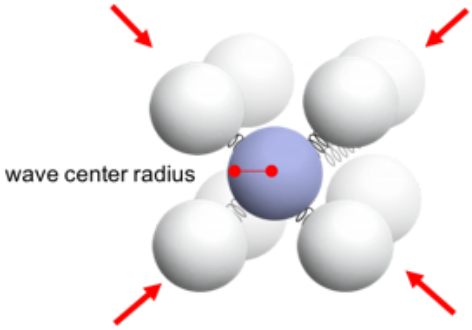
Number of Wave Centers

The number of wave centers that will be randomly placed into the simulation is chosen before the program starts. Only two wave centers are required for phase one, but it may be adjustable from 1 to 1000 (later phases should not require more than one thousand).

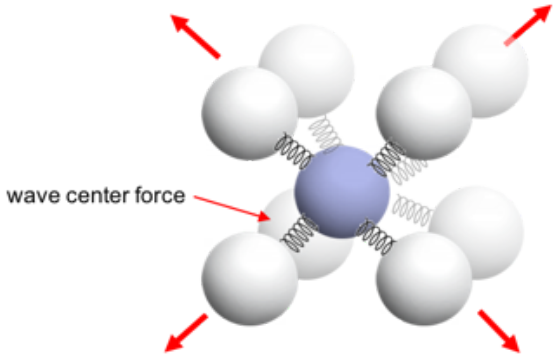


Wave Center Size and Mass

A wave center may be a granule or a collection of granules in a unit cell. For the purpose of the simulation, the same size and mass of a granule may be used for the wave center.



Unit Cell



Unit Cell

Wave Center Placement

The initial placement of each wave center is random before the simulation begins. A unit cell is randomly selected and the wave center replaces the center granule in the unit cell (see above figure).

Wave Center Spring Constant

The wave center separation force (F_w) defaults to the same value selected for the granule separation force (F_g). When the value is changed for F_g, the F_w value should adjust to be the same force value. However, the F_w value may be changed to be different from F_g. This is because the wave center separation force may need to be increased to cause reflections and standing waves.

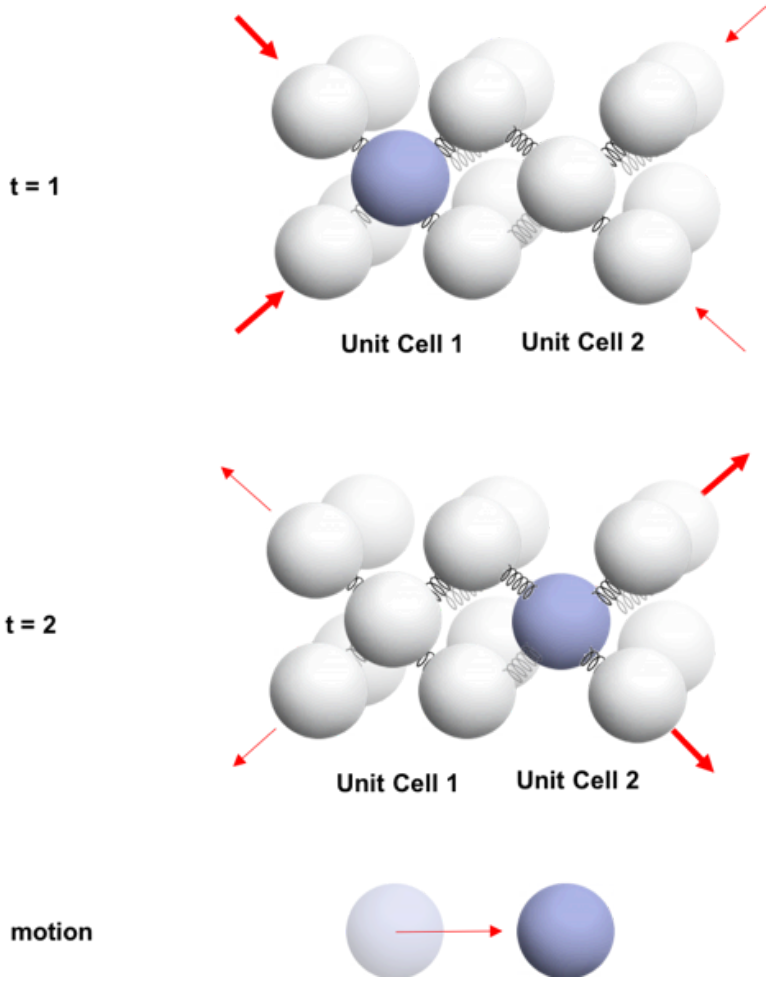
The spring constant for the wave center becomes:

$$k_w = \frac{F_w}{r}$$

Why this spring constant? *It is unknown if the wave center has different properties than a granule, but to create a simulation of standing waves, increasing the force should allow reflections to create standing waves. This simulates the possibility that the wave center is a high-density unit cell, whereby the separation force and spring constant should be greater than a typical unit cell.*

Wave Center Motion

Wave centers have the freedom to move throughout the spacetime lattice. They will eventually form particles, which can move throughout space. However, it may be the perception of a wave center moving throughout the lattice by changing the unit cell in which the wave center is located. For example, in the following illustration the wave center is located at the center of Unit Cell 1, at time t=1. There is a greater force from granules on one side of the unit cell (illustrated by thicker arrows on its left in the illustration). This causes the wave center to move to the adjacent unit cell, which is Unit Cell 2, at time t=2. The properties of the wave center are transferred to the center granule of Unit Cell 2 to accomplish this motion. This has the perceived motion of the wave center moving throughout the lattice.



Why this motion? *Particle creation and all forces are all dependent on a single rule – wave centers move to minimize wave amplitude (or force or energy which are related to amplitude).*

1.4 Spacetime Properties

The following properties describe longitudinal waves traveling in spacetime, which will be injected at the edges of the simulated universe at a given amplitude (A) and frequency (f), illustrated in Section 1.5.

Wave Amplitude

Granules are displaced in the longitudinal direction (A_l) a total of two times wave amplitude (amplitude is displacement from equilibrium, so peak-to-peak displacement is 2x). The initial amplitude is 9×10^{-19} meters but is adjustable and should be scaled if other distance properties in the simulation are scaled. This is the expected displacement when reaching a wave center, and it is unknown if this is the amplitude at the edges of the simulated universe, so this default property may be significantly adjusted to achieve results.

Why this amplitude? *The displacement at the wave center matches half the Planck charge, as explained here. Planck charge is likely peak-to-peak displacement and amplitude is half the value for equilibrium-to-peak. This is expected near the wave center, so it is possible this value needs adjusting when applied at the universe edge.*

Wave Frequency

Granules are displaced at the edges with a default longitudinal frequency (f_l) of 1×10^{25} Hz. This frequency is too high to visualize in a simulation so it is only used for calculations. See next section (Simulation Frequency) for the frequency to use in the simulation.

Frequency is composed of two components: 1) wave speed and 2) wavelength. The wave speed is the speed of light constant (c) at 3 x 10^8 meters per second. This value should remain constant if the wave frequency is adjusted for the simulation. The default longitudinal wavelength (l_l) is 2.85 x 10^{-17} meters. This value should change if frequency is adjusted according to the following equation:

$$f_l = \frac{c}{\lambda_l}$$

Why this frequency? *The speed of light is a known constant, so it is longitudinal wavelength that need to be explained, found here.*

Simulation Frequency

The simulation frequency is not used in calculations. To visualize the formation of waves in a simulation, the frequency needs to be something the human eye can detect. This is the frequency at which waves will appear to move in the simulation.

Blender Add-On Modifications

The Quantum Microscope Add-On for Blender uses these requirements with the following modifications:

1. The universe size is scalable by the user and can be shown in 1D, 2D or 3D views (size and dimensions affects performance).

2. The granule size (radius) is set to 0.2 meters and becomes the baseline distance for scaling in this phase.
3. Blender's wave modifier is used in the simulation, so spring-mass systems are not set. Although a generic Blender force is set to a value of 1.
4. A default wave amplitude of 2 meters is set but is adjustable by the user.
5. A default wavelength of 2 meters is set, and wave speed is adjustable by the user to control frequency.

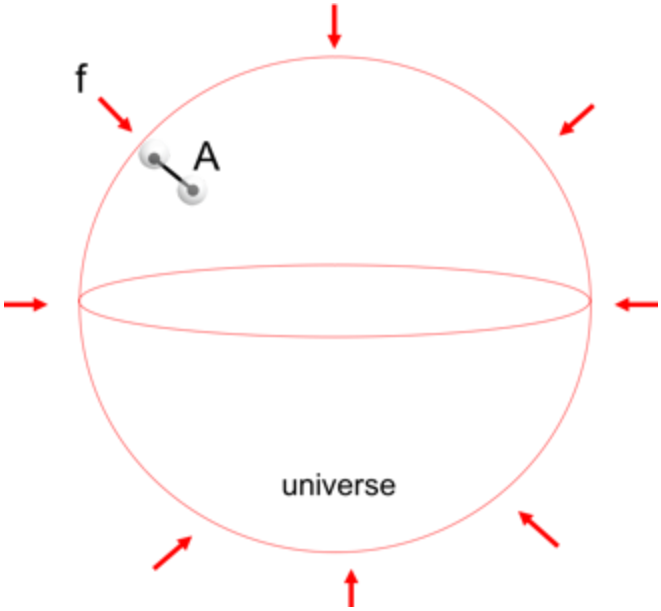
The issues with using Blender's wave modifier are documented in the ReadMe file.

Runtime

The program begins when the user chooses to begin and runs until a desired time. Energy is injected into the simulated universe.

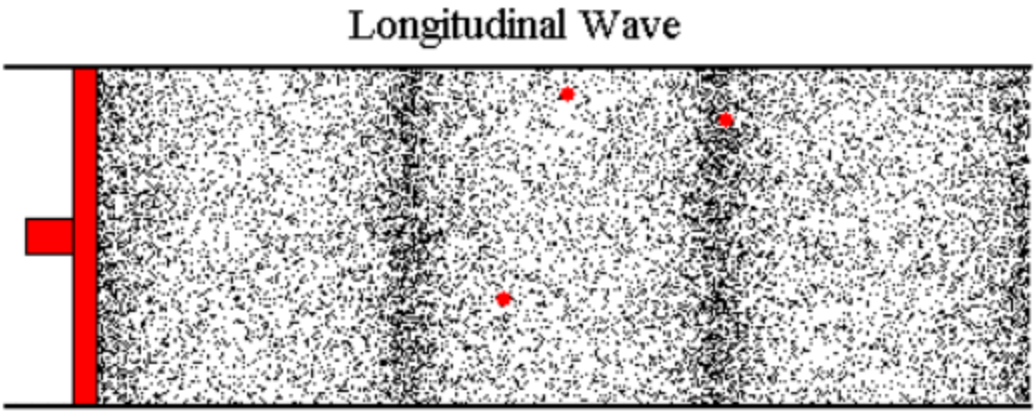
1.5 Energy Injection

During runtime, energy is continuously injected into the universe at the edges of the sphere, defined as the displacement of granules from equilibrium (their wave motion). For purpose of illustration, only one granule is shown. It would be expected that *all granules at the edge of the simulated universe* would move at the same amplitude (A_I) and frequency (f_I) defined in the previous settings.



Energy injected into universe at edges, frequency (fl) and amplitude (A_l)

An example of longitudinal displacement at the simulated universe edge (red color).



Example Edge of Universe (1D view) expanding and contracting to form waves

When granules reach the edge of the simulated universe (outwards), its energy should be allowed to escape as if it were to continue beyond the edge and that the universe continues beyond the simulation boundary.

1.6 Physics of Motion

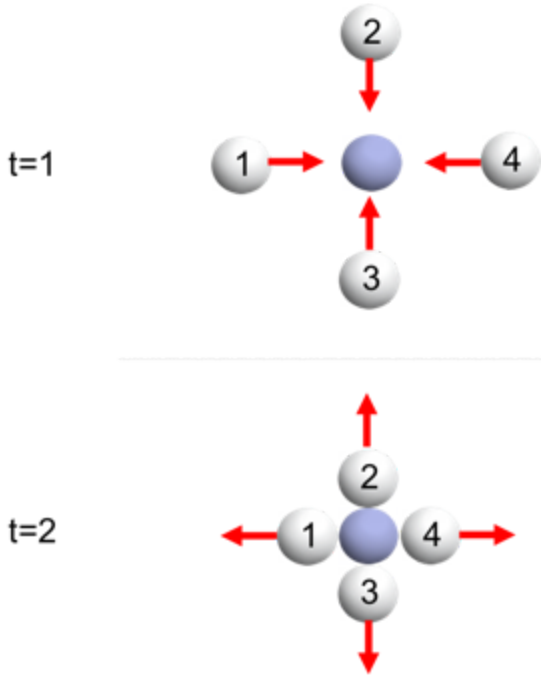
The motion of individual granules and the transfer of energy should follow classical mechanics. The physics of such motion is left open to the developer to choose a suitable method. Wave properties and spring-mass properties are available in the initial conditions to be chosen as methods, and both should be equal as explained here. The physics of sound waves is suggested due to similarities of longitudinal displacement from equilibrium. Whichever method is chosen, the following requirements must be met:

Granule Motion

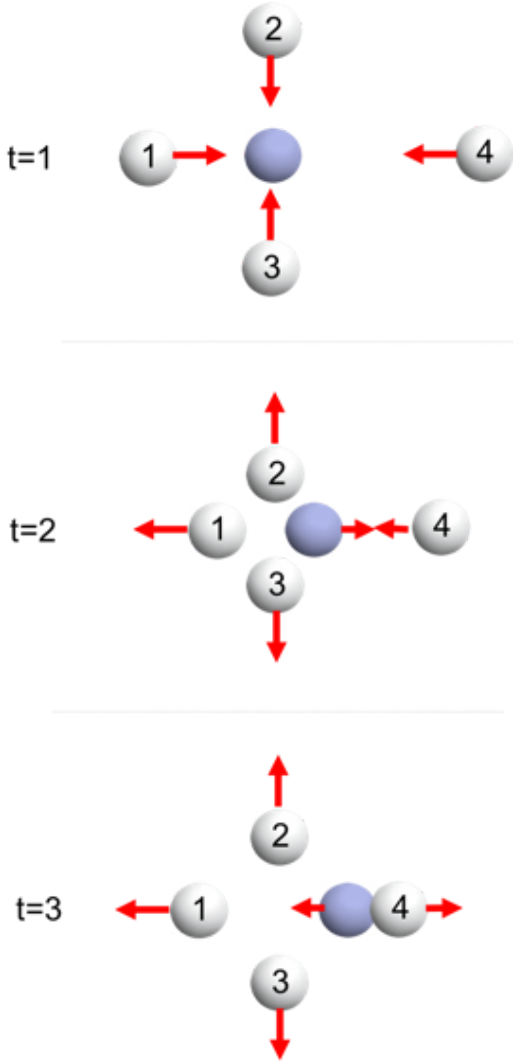
- When a granule is displaced from equilibrium, it follows simple, harmonic motion.
- When a granule collides with another granule, it is an elastic collision. The total energy should always be conserved.
- A granule may collide with multiple granules, before returning to equilibrium, such as the following illustration.

Wave Center Collision

- When granules reach a wave center *simultaneously* from all directions (as illustrated in the next figure), granule motion should be reversed and “reflected” from the wave center. Total energy should again be conserved.



- When granules reach a wave center from all directions, but *do not simultaneously* reach the center at the same time, or do not have equivalent energy from all directions, there will be motion of the wave center. Total energy is conserved but now also considers motion of the wave center. The properties of the wave center may be copied to the adjacent unit cell to describe wave center motion, as described earlier in Section 1.3.



Blender Add-On Modifications

The Quantum Microscope Add-On for Blender allows this runtime execution with the following modifications:

1. Wave patterns are created, allowing the user to see 1D, 2D and 3D views of both longitudinal waves and transverse.
2. There is an appearance of a reflection from a wave center which is animated.

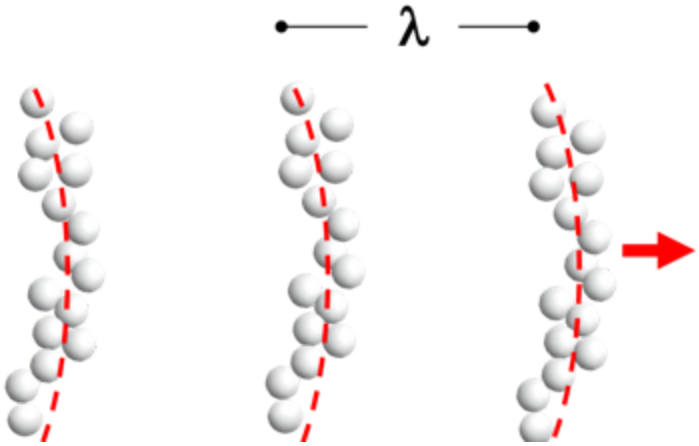
The main issue with using Blender's wave modifier is the lack of control to reflect granules off wave centers. This leads to a number of issues, summarized in the validation section.

Validation

The following should be validated during the simulation.

1.7 Formation of Traveling Waves

The motion of granules should form longitudinal traveling waves with a constant wavelength.



Traveling waves

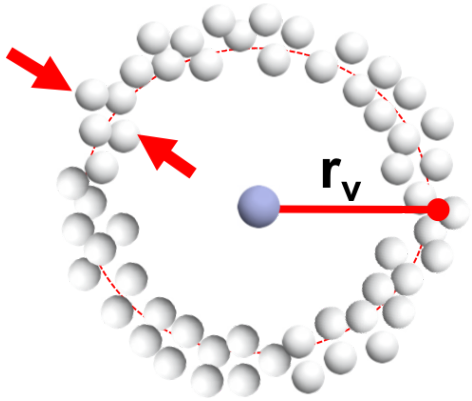
Validation

Visual confirmation of wave formation in the simulation. *The simulated frequency (wavelength and speed) will be different than the actual frequency used in calculations.*

1.8 Formation of Standing Waves

Once waves have formed, when these "wavelets" of granules reach a wave center from all sides, the reflection of granules should create a longitudinal standing wave – as new incoming waves of the same frequency meet outgoing waves. The properties of a standing wave should be recognized as zero net propagation of energy (i.e. stored energy). The sum

of all energy of the incoming waves (granule energy) should be equal to the sum of all energy of the outgoing waves.

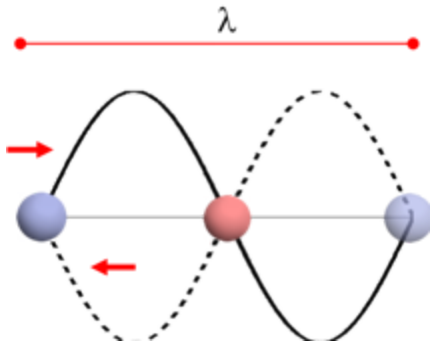


Standing waves (2D view)

Validation

A wave center is chosen in the simulation as the center point. From this center, the displacement of granules as waves into the center (in-wave) and waves reflected from the center (out-wave) are charted over time.

A standing wave should appear to a defined distance (r) from the wave center. For the neutrino, this distance **(r_v)** should be one wavelength (**λ**) and there should be two nodes per wavelength as illustrated below. This becomes the particle and antiparticle that will be seen in constructive/destructive wave interference.

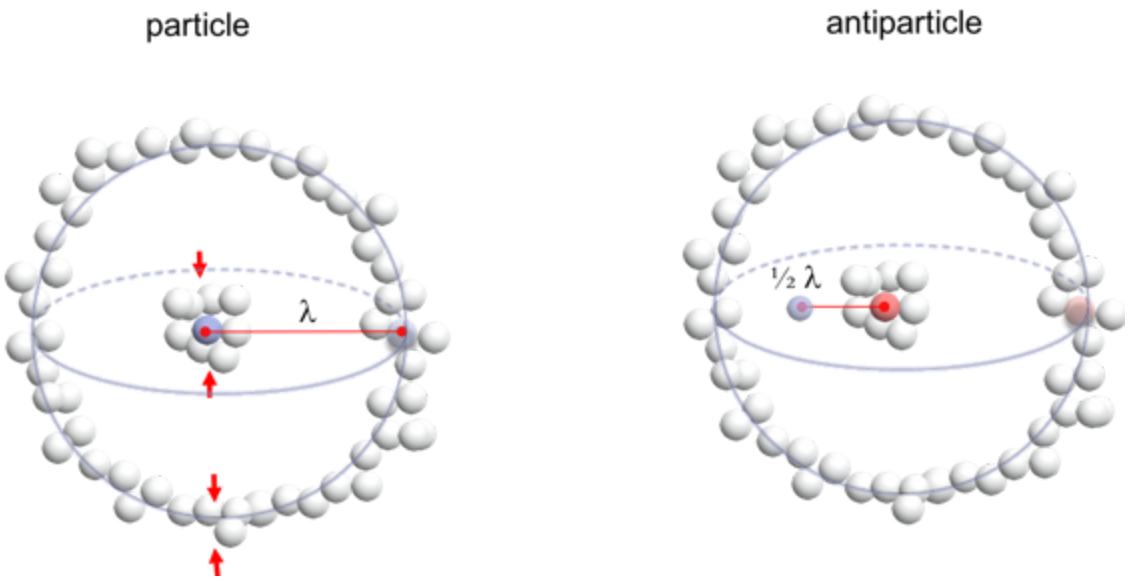


Standing wave nodes

Validate: $r_v \approx 3 \times 10^{-17}$ meters.

1.9 Neutrino and Antineutrino

At this step of the simulation, the first particle (fundamental particle) should be apparent. A particle's radius is its standing wave boundary. Beyond this radius, waves are traveling as in-wave energy and out-wave energy are not equal. Within the radius, standing wave energy is stored energy, which defines the particle's energy. The neutrino is a particle with one wave center. Its antiparticle, the antineutrino, is a particle with one wave center located on the opposite node of a standing wave, causing destructive wave interference.



Neutrino and antineutrino creation from standing waves

Validation

For each wave center in the simulation, the energy within its standing wave radius (r_v) is calculated and shown as the output. The following wave constants can be used to calculate energy:

- r_v – neutrino radius from previous step calculation
- ϱ – density from initial conditions
- c – speed of light from initial conditions

- A_l – longitudinal amplitude from initial conditions
- λ_l – longitudinal wavelength from initial conditions

The energy equation is based on frequency and amplitude squared, in a given volume of known density:

$$E_v = \rho V_v (f_v A_v)^2$$

Where volume is spherical, based on the calculated standing wave radius:

$$V_v = \frac{4}{3}\pi r_v^3$$

Where frequency is based on speed and wavelength:

$$f_v = \frac{c}{\lambda_l}$$

Where amplitude expands in three-dimensions, declining at the square of each wavelength:

$$A_v = \frac{A_l^3}{\lambda_l^2}$$

Validate: $E_v \approx 3.8 \times 10^{-19}$ joules (kg m^2/s^2)

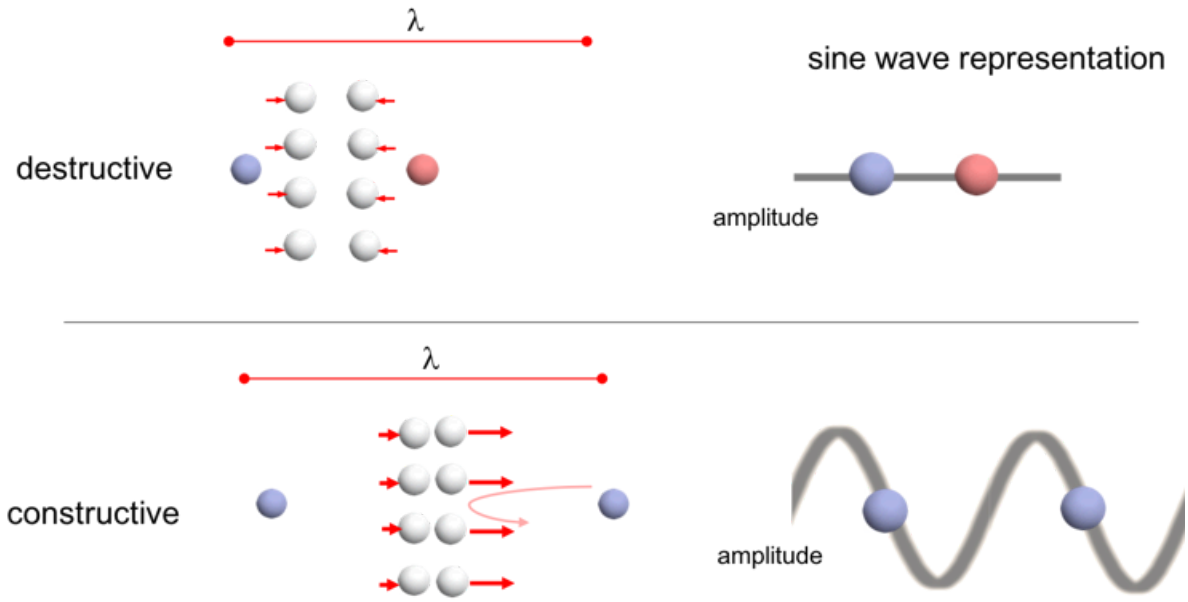
Note: this is roughly 2.4 electron volts, which is slightly higher than the proposed mass of the neutrino.

1.10 Wave Interference

Once wave centers align at standing wave nodes within wavelengths, two types of wave interference should start to appear – constructive and destructive. This is dependent on the position of the wave center on the node and the granules that are reflected from the wave center as explained below.

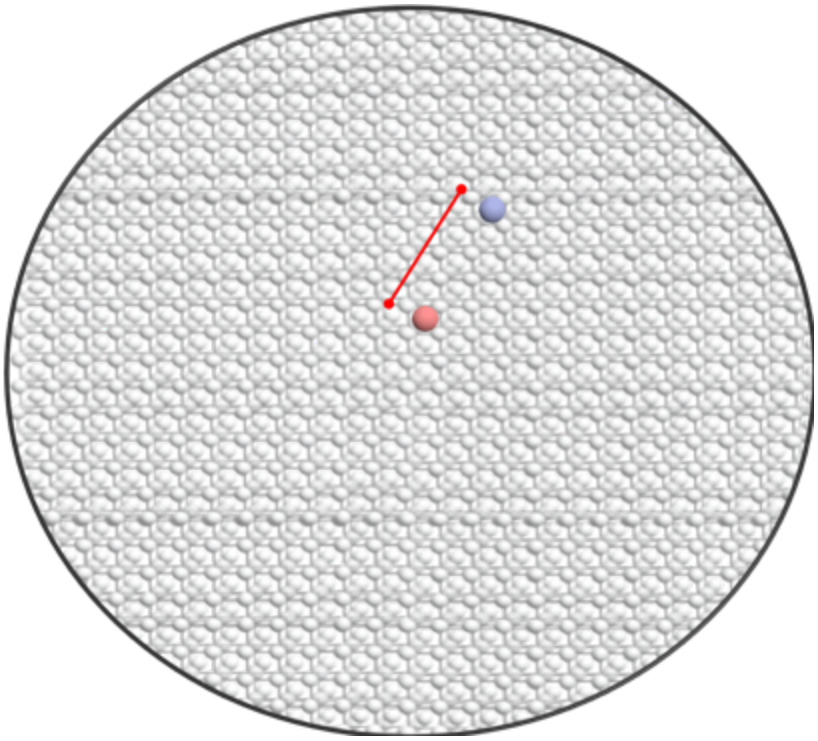
Constructive and Destructive Wave Interference

- Destructive wave interference should result from the collisions of granules that are reflected from wave centers placed on two different nodes within a wavelength (illustrated in the next figure as blue and red wave centers).
- Constructive wave interference should result from collisions of granules that are reflected from wave centers placed on the same node (illustrated as two blue wave centers).



Validation

Select two wave centers in the simulation and graph the displacement (amplitude) of granules in the vector between the two wave centers (Graph #1).



Select a vector in a different direction on one of the wave centers (e.g. perpendicular to direction between two wave centers) and graph the displacement amplitude of granules (Graph #2). There should be an amplitude difference between Graph #1 and Graph #2, showing that there is constructive or destructive wave interference.

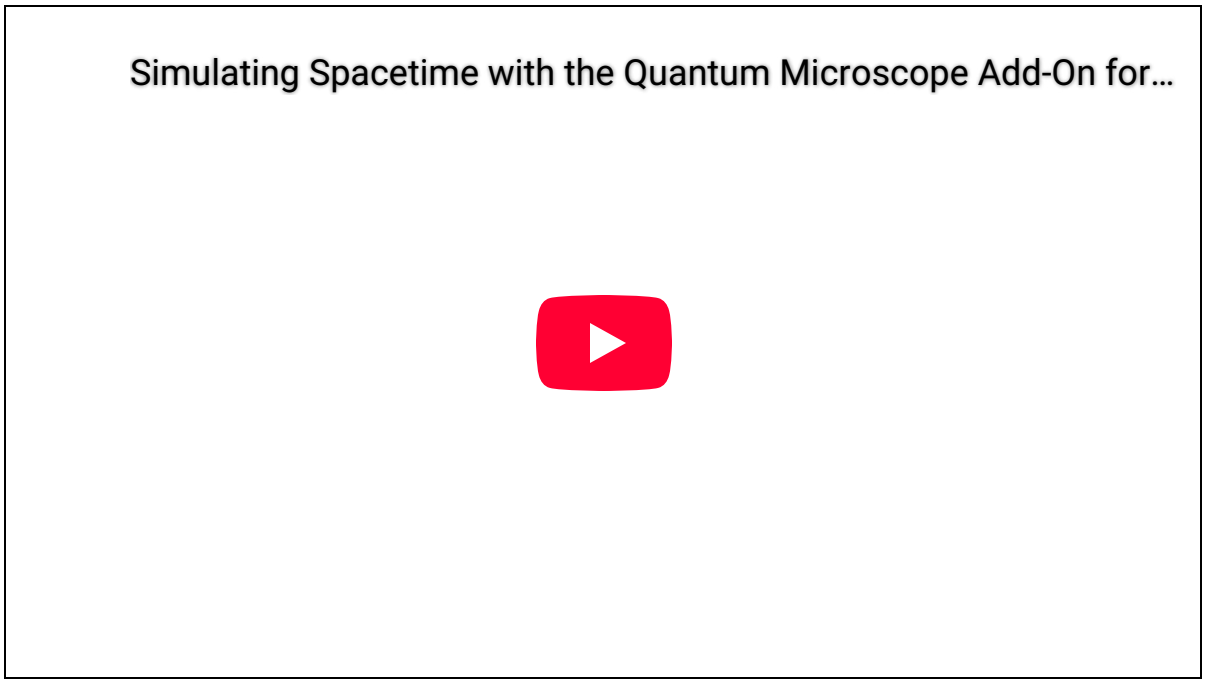
When destructive wave interference is found between two particles, the antineutrino is validated.

Blender Add-On Validation

The Quantum Microscope Add-On for Blender has issues with validating:

1. Standing waves. Due to the issue documented in the requirements for wave center reflections, standing waves are not produced naturally.
2. Neutrino energy. Due to issue that standing waves are not generated, energy within this volume cannot be calculated correctly.
3. Constructive wave interference. Although wave interference patterns are simulated, Blender's wave modifier does not appear to be doing accurate wave interference.

Video Summary



Previous: Quantum Microscope **Next: Simulating Standalone Particles**