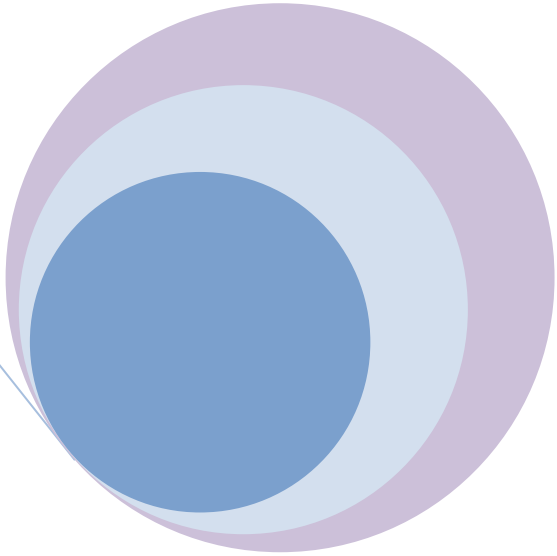
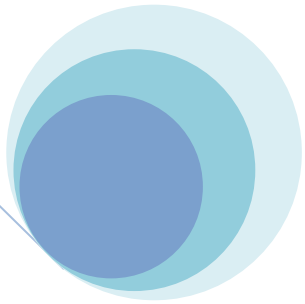


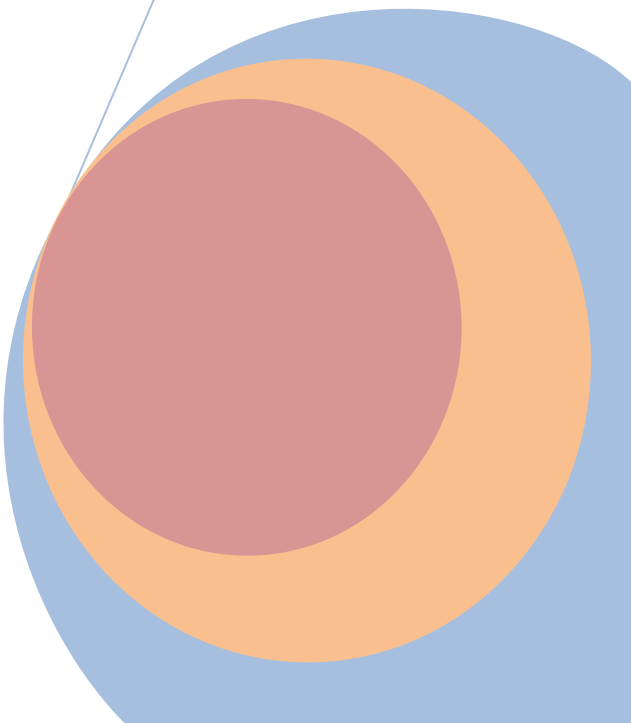


Touhou: A Scientific Interpretation

For fans, by a fan

Explore the world of Gensokyo, through the proposed physical conditions and calculations, which make fantasy just that bit closer to reality… just a bit.

Dylan Walsh
10/7/2014



Disclaimer

By no accounts is this a fully fledged thesis piece. This is merely a paper, written for the sole purpose of explaining concepts and presenting new ideas for the wider audience's consumption. All pictures, aside from those directly associated with the Touhou games and other fan based content, are my own. *Content within this paper may change with respect to time.*

Gensokyo: A Scientific Interpretation

In a nutshell, Gensokyo is a region of space-time in relation to planet Earth, somewhere in Japan (potentially near the Yatsugatake Mountains), which is physically bordered by the Great Hakurei Border. Such a border plays an active role in keeping any unwanted visitors (for the most part) from entering Gensokyo, by means of hidden technology. It was first created in 1885AD, as a means of stopping further tensions between indigenous humans and newly arriving youkai. The origins of the youkai are relatively unknown, but given how Gensokyo consists of routes which lead to entirely different regions of space-time (eg Former Hell, the Netherworld), which are not geographically notable on Earth, they could have very well have arrived from alternate realities. Such realities would likely comprise of civilisations of the sort, where technology could be available that allows travel between realities (going by the Everett's Many Worlds Interpretation).

The manipulation of dark energy could be a candidate for how youkai were able to engineer such routes between realities. Presently, dark energy stands as the course for why the observable universe today is continuing to expand, as the result of its ability to expand the fabric of space-time. The Big Rip Theory suggests that a significantly large enough energy density of this dark energy could cause rips to occur, holes/gaps in the fabric of space-time. However, given what little is known about dark energy in terms of experimental information, this cannot be absolutely known for sure.

A description for the way in which the border acts as a decent fence against outsiders, covers how outsiders become disorientated by some form of illusion in their journey into Gensokyo, to end up being turned around, to simply arrive back outside of the border (on off chances, sometimes outsiders do still make it in). This could be achieved with the use of chemical compounds delivered by nanites (potentially an alcohol of sorts) that could impair an outsider's senses and induce amnesia for the duration they remained on the border (i.e. "smash" trespassers). Only if the outsider made it off the border (most likely on the outside again) would the disorientating effects start to wear off.

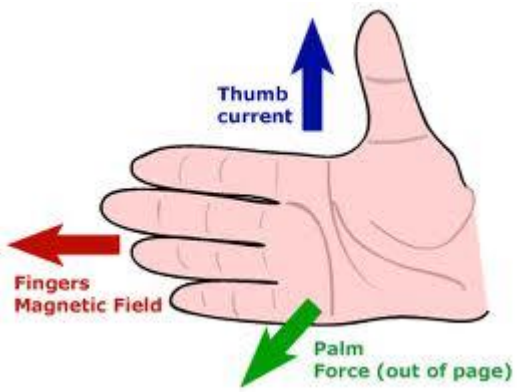
Now considering what's within Gensokyo, there are three conditions to consider:

1. The magnetic field passing through the Gensokyo region, is stronger than the magnetic field of Earth, emanating through connections from other realities.
2. Biological organisms within have the evolved mechanisms to utilise the stronger magnetic field, originating from other connected realities.
3. Highly advanced technology exists, originating from other connected realities (eg nanites, manipulation of dark energy).

These conditions, which all utilise the Everett's Many Worlds Interpretation of Quantum Mechanics (poses alternate realities), are what play into a classically known quirk of the Touhou-verse, with regards to unaided flight.

Unaided Flight Essentials

Iron fibers which are able to conduct electricity, are embedded into an inhabitant's skeletal structure (insulated, in the Amps range), which can be naturally occurring (under condition 2). With the presence of a strong uniform magnetic field (under condition 1) in relation to straight conducting fibers positioned using the right hand rule, you can generate what's called a Lorentz Force (the same force used to make loudspeakers work). Acquiring the iron fibers from a biological stand point, is done at birth and gradually maintained throughout an inhabitant's life (for youkai, humans would only achieve this through nanotechnology via condition 3). Using molecular structures similar to that of haemoglobin, the iron can be transported around the body of the inhabitant and extracted, without any unwanted oxidisation processes taking place.



To prevent problems in relation to Lenz's law, which effectively can counter balance against Lorentz Forces initially created by Electromagnetic Induction, a decent potential difference must be maintained across the fibers, to keep the current travelling in the correct direction in relation to the uniform magnetic field, to maintain the correct Lorentz Forces.

Maintaining this potential difference will require electrochemical signalling to take place. By setting up conversions of ATP into ADP on one end of an iron fiber, and vice-versa conversions of ADP back into ATP on the other end, this will generate the required voltage, and hence, the required direct current to pass through the fiber (ATP is regenerated from said current). This ultimately avoids the use of any fibers that are connected into a loop (to complete the circuit), which in places along the loop with current flowing, will create Lorentz Forces which will point in the wrong direction.

So then taking into account the average mass, bone mass and bone density of a typical female, the number of fibers of a given length, radius, and the drift velocity for flowing charge through the fibers (related to current), you can potentially generate a sufficient Lorentz Force to achieve lift, against the force of gravity.

A consequence of having the stated conditions in place, is that you could potentially generate your own electricity just by walking through this strengthened magnetic field, as a result of Electromagnetic Induction (the inducing of an electric current in a moving conductor [ie an iron fiber] through a uniform magnetic field). Biological safeguards would probably be in place to prevent accidental conduction of the fibers at the wrong time, most likely by keeping the circuit cut chemically. Discharging excess electricity could possibly be another (i.e. Danmaku).

Another consequence of having a stronger magnetic field, could explain why the technology available in Gensokyo on face value, appears fairly elementary in comparison to real life technologies. A strong magnetic field will typically screw up electronic devices (looking at Electromagnetic Induction again), hence the baser uses of technology. Though if they really wanted to, they could overcome this problem by simply surrounding any circuitry with a metal that has a high magnetic permeability (metals like Permalloy and Mu-metal), which can draw the strong magnetic fields surrounding any kind of circuitry, away from said circuitry, allowing circuits to function.

See Appendix A for calculations regarding flight
(see Appendix B, Stage 3 for the overall energy scheme)

Flandre's Physiology

With regard to the colourful iron wings attached to Flandre's back, it's likely that there's more metal that "anchors" into Flandre. This extra surface area of the anchored metal is probably connected to some form of skeletal structure, remnant of whatever original wings she may have once had (wing sockets of the sort). This wing skeletal structure is then what connects to any surrounding muscle tissue which Flandre can control, which in turn, ultimately control her wings.

Though the control Flandre would have over her wings would be pretty limited, unlike her sister who has the muscle and bones which extends throughout her bat-like wings. Flandre who clearly doesn't, would probably be only able to move her wings up and down, unable to contract/expand her wings. Think of this limited movement as a lever action, pivoted around her back.

In terms of how such artificial wings could've got there in the first place, in real life there are most certainly technologies available that allow for artificial attachments to skeletal structures. The exact process of fusing the artificial to skeletal is called Osseointegration. But hold on a second! Assuming Flandre lost her wings at a very early age, surrounding her date of birth of 1508 AD, there should have been no way for Flandre to have access to the required technology to perform the necessary Osseointegration (the first documented procedure of this on "Earth" was only done in 1952 AD).

This leaves one possibility in the view of Gensokyo's network to other alternate realities. The Scarlet Devil Mansion and its inhabitants arrived from an alternate reality in the approximate year of 2003 AD, from an alternate civilization present in an alternate reality, which was at least 450 years more advanced than us around 1508 AD (relatively speaking).

Sakuya's Ability: Manipulating the Perception of Time

Sakuya's ability is that of being able to slow down time or virtually stop time within her surroundings, usually for cleaning the mansion or the occasional fight. To do this, her ability must allow her to "speed up" time in her immediate surroundings, for the surroundings further afield to become slower/virtually stopped relative to Sakuya (such a speed up mechanism we'll arbitrarily assume works [something to do with the passage of gravitons maybe?]).

Examining a typical confrontation between Sakuya and Reimu, there arises interesting side effects to do with her time manipulation ability, which demonstrates how Sakuya isn't entirely immune from being defeated. If Sakuya were to move up to Reimu with her ability in play, there's the risk that Reimu could fall closer to Sakuya's closely sped up surroundings, which would allow Reimu to move at a similar speed to Sakuya, to stand a chance against her attacks. Now apply the second postulate of Special Relativity.

For the speed of light to remain constant for any inertial frame (ie any observer), if time slows down in Sakuya's further surroundings, distance must also contract for c to remain constant (c=x/t). So imagining we're using Sakuya's ability, from our perspective, everything around us would appear incredibly close to us, all contracted/squashed. During a fight in Sakuya's case, Reimu would actually look as though she was right in front of her, along with her knives.

Ultimately, it isn't that Sakuya can't walk up to Reimu to stab her due to some force resisting from her ability, it's simply because by an optical sense, Sakuya can't necessarily gauge how close she'll be to Reimu, to avoid Reimu being able to move at a speed closer to that of Sakuya's (this seems likely given how Sakuya's ability can range from being subtle to extreme). Hence why Sakuya is smart to just to keep her distance.

The exact degree towards how much of Sakuya's surroundings would be slowed by her ability, could be defined by the Inverse-Square Law (intensity inversely proportional to the distance squared). Notice how I say that Sakuya can "virtually" stop time, not completely. By the Inverse-Square Law, Sakuya's ability does fall off to a considerable degree with great distance, but the effect is still there at said great distances, just very weakly.

Regardless, Sakuya must have a lot of practice at not getting motion sick from the way the length contractions/expansions occur for every time she frequently actives/deactivates her ability respectively. As for her three blades (red, green, blue) which seem to multiply after initially being thrown, that could be put down to rapid nanite construction. Each initial blade could replicate on their own.

Danmaku

For this to work, it requires all the conditions as stated near the start of this paper to be present. In real life, trying to pass energy in the form of electricity through the air is a pretty difficult task. The air, filled with its many gas constituents, has to first be ionised with enough energy, to liberate electrons from the gasous molecules present. It is then the flow of these electrons which essentially make up the passage electricity through the air. But to even create an electrical arc for just 1 metre, 3,000,000 Volts is required, which isn't something any Gensokyo inhabitant let alone any human can generate and handle... Unless they had a bit of help. Cue the use of nanites, which could be used to create a potential difference, by locally ionising the air in a given region of 3D space, in the direction of the intended Danmaku bolt, utilising a concept we call the Townsend Effect (used in gas cathode lamps).

Effectively, the Townsend Effect is the mass cascade of electrons being liberated from gaseous molecules, with the aid of an electric field (a potential difference), which also constantly supplies more energy (in the form of work) to any liberated electrons. This extra energy supplied to the already liberated electrons, is then used to free even more electrons still bound to the gaseous molecules. Eventually though, electrons which had already been liberated, get recaptured by the previously ionised molecules, which in the process, releases a photon as the recaptured electron settles back into its ground state orbit, with respect to an atom's nucleus. It is then these released photons that provide the illumination we usually want in gas cathode lamps (which depending on the gases themselves and their electron orbits, will allow for certain photons to be given off that correspond to specific EM wavelengths in the visible range, like red with Neon gas).

Now back to Gensokyo. Let a Gensokyo inhabitant be the initial source of electrons to be dispersed into the air as our Danmaku bolt, with the aid of a potential difference created by nanites which produces the Townsend effect (replacing the typical electric field in gas cathode lamps) and hey presto, the initial electrons will now have enough energy to continue liberating more electrons from the gaseous molecules present in air, in a given trajectory towards whatever potential difference and target there may be (zap zap). With any electrons liberated, as stated with the Townsend Effect, liberated electrons will also return to previously ionised molecules to emit a photon of a specific EM wavelength. This could account for all the beautiful displays of visible light, emitted from Danmaku bolts.

In terms of how the particular displays can come about in terms of spell cards, the spell cards themselves could be comprised of the nanites which are programmed to respond to the user, to create the assorted formations in 3D space. The type of programming behind these nanites is indicative of the spell card type. The nanites communicate with one another (in the infrared range), conveying information about their proximities to each other. When the programmed distances concur for each and every surrounding nanite cluster, it is then that all the positioned nanites start to create the required potentials.

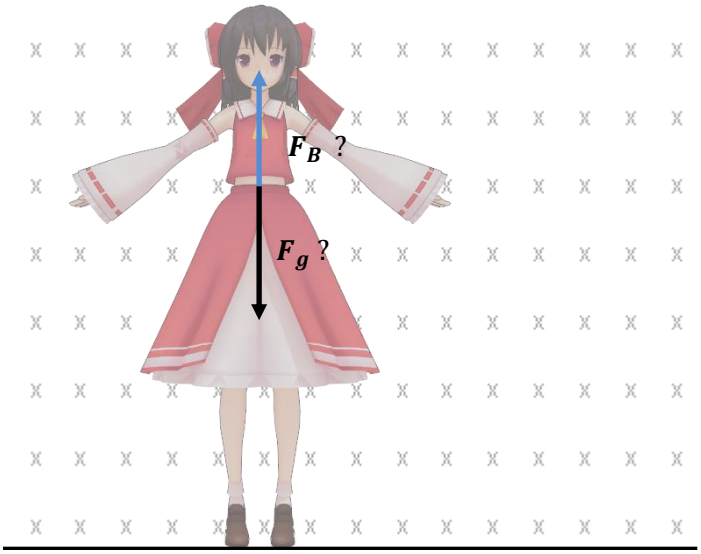
In terms of how the nanites actually operate, we'll assume the inventor of the nanites technology found a way to overcome the chaotic Brownian Motion of the particles in the air (for a very small machine close to the level of particles, manoeuvring could very well be like trying to walk against a tornado). At the same time, we'll also assume the inventor was able to find a way of utilising the Brownian Motion to generate power for the nanites, by means of a nanite sized, one way paddle-gear system (something like a wind turbine, only on a very small scale). To prevent any unwanted magnetic disturbances from the rest of Gensokyo, they are also shielded as well, again with metals like Permalloy and Mu-metal (electrical insulation is also in order). Then finally, with regards to being able to replenish lost electrons spent through Danmaku from a Gensokyo inhabitant, the excess electrons present within a Danmaku bolt could be collected by means of a capacitor, to store and shuttle the excess electrons back to where they had been first ejected (completing a dynamic circuit, some ATP may be used as a temporary replenishment of electrons).

See Appendix B for diagrams on Danmaku formation and the overall energy scheme.

See Appendix C for calculations regarding Danmaku ionisations!

Appendix A

Stage 1: The Situation



x: refers to direction of the magnetic field, travelling into the page.

$\vec{B}$ = 0.15T, *aided* by nanite clustering (see Stage 6)

Consider the average mass of a human female, being approximately 60kg.

Stage 2: What Do We Have To Work With?

i) Calculate the bone volume (V_B) available:
Sources say:

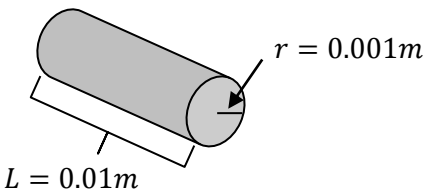
- Typical bone mass percentage for females = 12%
- Bone density = 1500kg/m^3

$$\therefore V_B = \frac{m}{\rho_{bone}}$$

$$= \frac{0.12 \times 60}{1500}$$

$$= 4.80 \times 10^{-3} m^3$$

ii) Consider the dimensions and calculate the volume (V_C) of a unit of our iron fibers.
Let:



$$\therefore V_C = L\pi r^2$$
$$= 0.01 \times \pi \times 0.001^2$$
$$\approx 3.14 \times 10^{-8} m^3$$

iii) Calculate the number of iron fibers (N) that can fit within the bone volume:

$$N = \frac{V_B}{V_C}$$

$$= \frac{4.80 \times 10^{-3}}{3.14 \times 10^{-8}}$$

$\approx 1.53 \times 10^5$ 1cm fibers which can fit within the volume of the bone available

For this particular flight scenario, we'll use $N_A = 1.50 \times 10^4$ fibers. The percentage of iron fibers present through the skeletal structure.

$$\therefore \frac{N_A}{N} \times 100 = \frac{1.50 \times 10^4}{1.53 \times 10^5} \times 100$$

$\approx \mathbf{9.8\%}$ **of Reimu's skeletal structure is made of iron.**

iv) Calculate the extra mass (m_{extra}) added by the iron fibers (m_{iron}), taking into account the amount of bone mass extruded to make up the required volume for the iron fibers (m_{bone}):

$$\begin{aligned} m_{extra} &= m_{iron} - m_{bone} \\ &= N_A V_C (\rho_{iron} - \rho_{bone}) \\ &= 1.50 \times 10^4 \times 3.14 \times 10^{-8} (7870 - 1500) \\ &= 3.0kg \end{aligned}$$

∴ Taking into account the human and extra masses, the force due to gravity is:

$$\begin{aligned} \overrightarrow{F_g} &= (m + m_{extra})\vec{a} \\ &= (60.0 + 3.0) \times 9.8 \\ &\approx \mathbf{617N} \end{aligned}$$

This is our target value of force we have to beat to achieve lift.

Note: Reimu's actual weight could be less, given that 60kg is only a female average.

Stage 3: Flight

i) Calculate the properties of the iron fibers, with regards to the electron density (n), cross-sectional area (A), and drift velocity (v_d).

$$n = \frac{A_{\#}\rho}{M}$$

$$= \frac{6.02 \times 10^{23} \times 7870}{0.055845}$$

$\approx 8.48 \times 10^{28}$ electrons/m^3

$$\begin{aligned} A &= \pi r^2 \\ &= \pi \times 0.001^2 \\ &\approx 3.14 \times 10^{-6} m^2 \end{aligned}$$

Assuming a current (I) of 30A. Charge of an electron (q) being 1.60×10^{-19}J.

$$v_d = \frac{\left(\frac{I}{A}\right)}{nq}$$

$$= \frac{\left(\frac{30}{3.14 \times 10^{-6}}\right)}{8.48 \times 10^{28} \times 1.60 \times 10^{-19}}$$

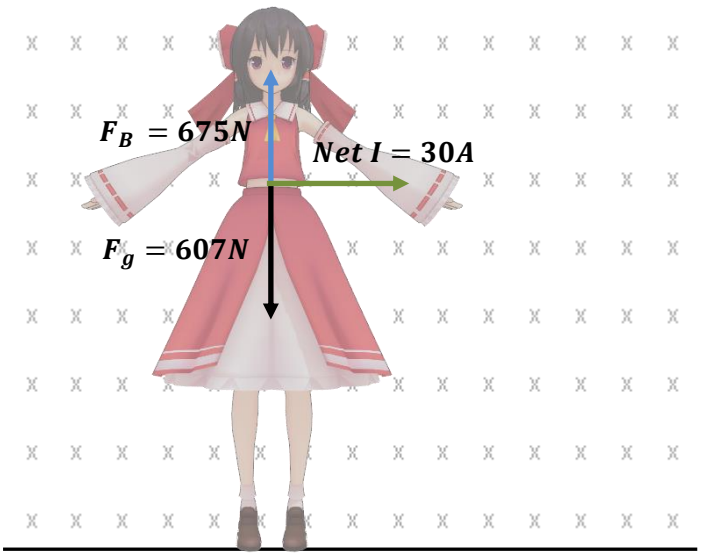
$$\approx 7.04 \times 10^{-4} m/s$$

ii) Consider the Lorentz force (F_B) generated by the N_A conducting iron fibers of length L, with current I, subject to a magnetic field (B = 0.15T):

$$\overrightarrow{F_B} = \vec{B}ILN_A$$
$$= 0.15 \times 30 \times 0.01 \times 1.50 \times 10^4$$
$$\approx \boldsymbol{675N}$$

Versus $\overrightarrow{F_g} = \boldsymbol{617N}$

A net force of **58N** is achieved in the upwards direction, flight is achievable!



$$\vec{a} = \frac{\vec{F}}{m}$$

$$= \frac{58}{63}$$

$\approx \boldsymbol{0.92 m/s^2}$ of acceleration upwards

This assumes that the conducting fibers are aligned perpendicular to the magnetic field direction and to the direction of the Lorentz force. This can be done by Reimu simply moving around any bodily appendages into the correct position, and having all the iron fibers naturally aligned in the skeletal structure horizontally.

Stage 4: Voltage and Power Requirements

i) Calculate the voltage required over 1cm of an iron fiber (ρ in calculation is resistivity [in this case, for iron], not to be confused with density):

$$V = IR$$

$$= I\frac{\rho L}{A}$$

$$= 30 \times \frac{9.71 \times 10^{-8} \times 0.01}{3.14 \times 10^{-6}}$$

$$\approx 9.28 \times 10^{-3} = \mathbf{9.28}\boldsymbol{mV}$$

In comparison to reaction potentials found in the human body (related to muscle systems), 9.28 millivolts is within a reasonable order of magnitude.

ii) Calculate the power requirement to maintain all N_A fibers at the calculated V and I:

$$P = VIN_A$$
$$= 9.28 \times 10^{-3} \times 30 \times 1.50 \times 10^{4}$$
$$\approx \mathbf{4.18} \times \mathbf{10^{3}}\boldsymbol{W}$$

Note: This amount of power is distributed throughout Reimu, per fiber:
$P=VI=9.28\times10^{-3} \times 30 = 0.28W$, less than a 1W LED.

From sources regarding ATP:

- The lowest amount of energy released in any ATP conversion to energy is $\Delta G = -30.5kJ/mol = -3.05 \times 10^{4}J/mol$. (The negative refers to energy released in an exothermic reaction).
- The molar mass of ATP (M_{ATP}) is 507.18g/mol.

So if we assume 0.25 moles (n) of ATP are needed to meet power requirements, that is:

$$P = n\Delta G$$
$$= 0.25 \times 3.05 \times 10^{4}$$
$$\approx 7.63 \times 10^{4}W$$

$$\therefore m_{ATP} = n \times M_{ATP}$$
$$= 0.25 \times 507.18$$
$$\approx \mathbf{127}\boldsymbol{g}\ \textbf{of ATP are required.}$$

The typical human has on average at any one time, 250g of ATP present, so Reimu is well within the clear with requiring this amount. 250g of ATP, or potentially, even more as a reserve (a total of say, 400g).

Stage 5: Heat Generated

i) Calculate the increase in temperature (ΔT) for Reimu's mass (m), for 30 seconds of flight (t), for an upward acceleration of $\vec{a} \approx 0.92 m/s^2$

Sources say:

- The average heat capacity of the human body (c) is 3.470 J/g °C.

Given the power required for $\vec{a} \approx 0.92 m/s^2$ is 4.18x10^3 W.

$$\Delta T = \frac{Qt}{cm}$$

$$= \frac{(4.18 \times 10^3) \times 30}{3.470 \times (6.0 \times 10^4)}$$

$\approx$ **$0.60°C$ bodily temperature increase over 30 seconds of flight.**

The human body operates normally between 36.5 to 37.5°C, so in terms of long term flight, this may not to be ideal.

However, this calculation assumes that the system (Reimu) has a constant acceleration and is perfectly insulated, whereby no heat is lost as work is being done, to generate the required Lorentz forces. The calculation therefore fails to take into account variables such as:

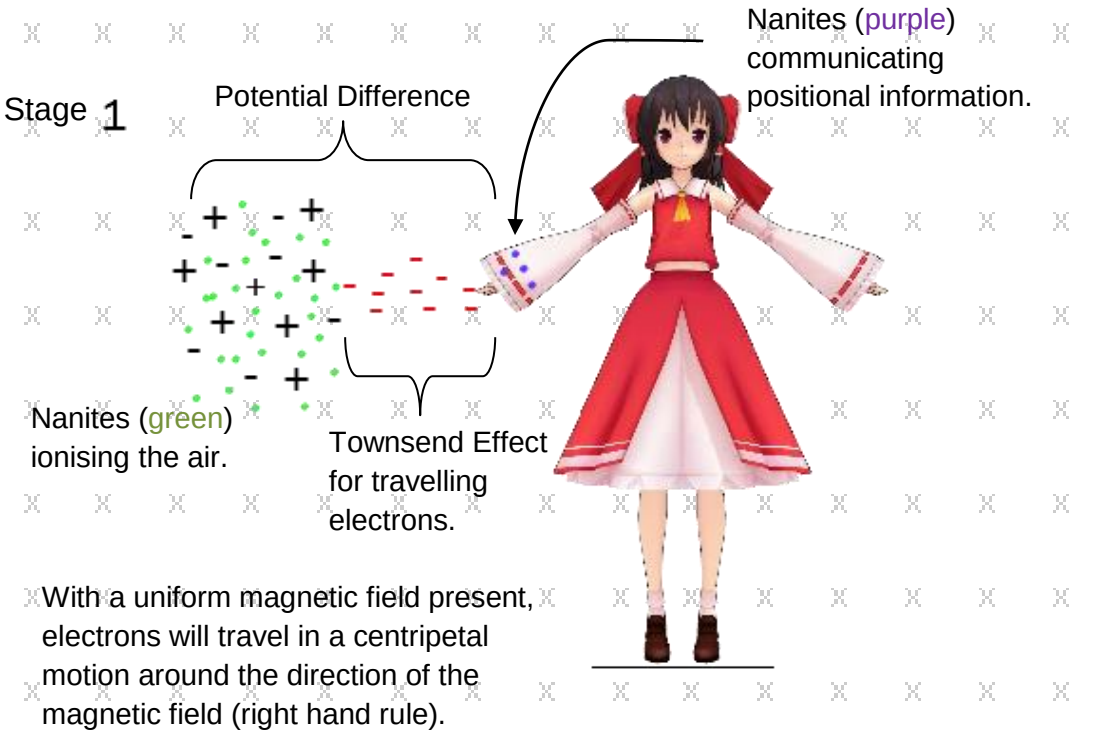
- The amount of heat actually produced when Reimu is trying to maintain or lose altitude (maintaining an altitude for 30 seconds gives a ΔT of approximately 0.55°C).
- The moving air cooling Reimu in flight.
- The normal or increased blood flow, that can move heat towards Reimu's outer extremities, for heat to be radiated away quicker through less body mass.
- Nanites by direct contact, could conduct heat directly away from Reimu (potentially using it as another as another power source).

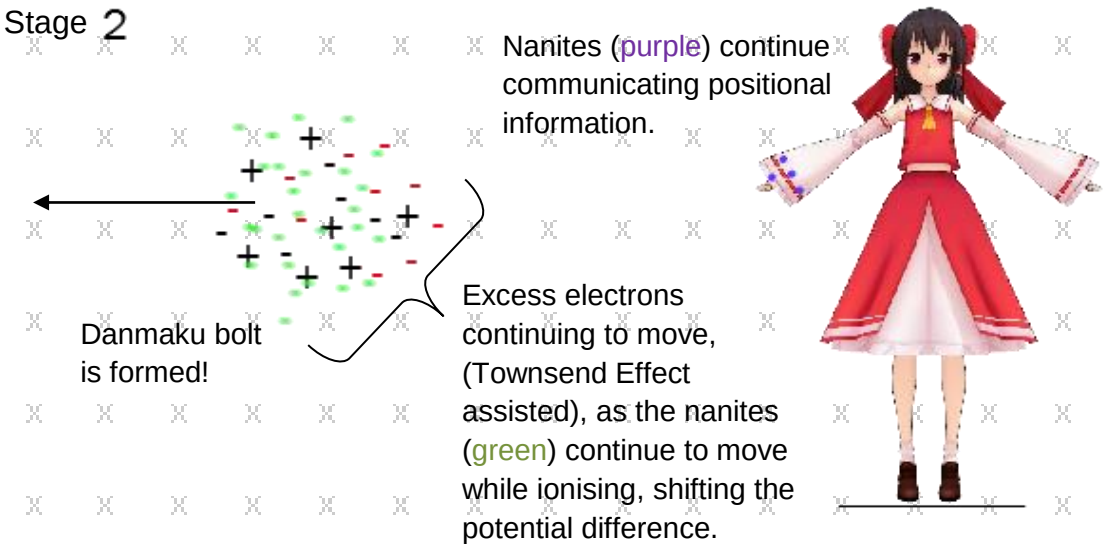
Stage 6: Aided Flight VS Unaided Flight: The Speculative Origins

Unaided flight, in terms of its early evolutionary origins with early youkai, would very much be simpler. Its primary uses by this time could've been for simply finding food, water and shelters and escaping predators, where briefly flying to higher ground or up a tree would've been incredibly useful, all while maintaining the benefits of having articulate hands (very important for tool making). Aspects of total unaided flight could still be present by the current time of Gensokyo (within sport perhaps??).

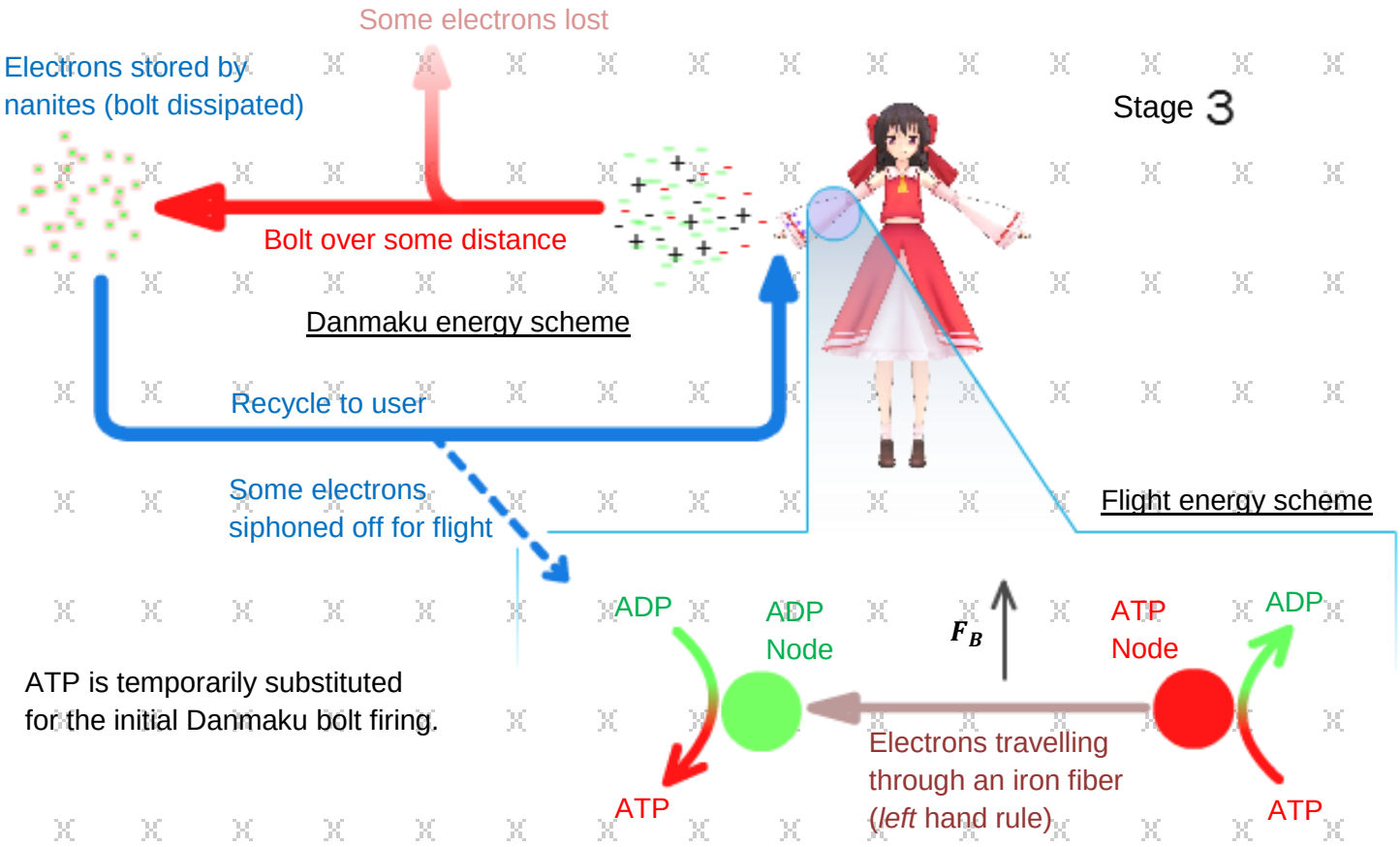
Aided flight on the other hand, most likely would be much closer to what is traditionally seen in Gensokyo, whereby longer flight and extra manoeuvrability can be achieved with the use of nanite clustering, to deflect and concentrate the magnetic field lines within Gensokyo (using metals like Permalloy and Mu-metal), through a flying inhabitant, in any uniform direction.

Appendix B





Overall energy scheme on the next page, with Stage 3.



Appendix C

i) Calculate the energy required to ionise the air (specifically gaseous oxygen in this case) and the energy (E) acquired with travelling electrons (travelling at the drift velocity v) by the uniform magnetic field (B) present:

- The 1st ionisation energy required is E_1 = 1313.9kJ/mol or 2.2×10^{-18}J/atomic oxygen.

This is our target ionisation energy.

ii) Consider the force due to the uniform magnetic field (F_B) and the corresponding centripetal force according to the left hand rule (F_C) (Note: The left hand rule applies for negative moving charge, the right hand rule applies for positive moving charge. By convention, currents within circuits rely on the flow of positive charge):

$$\overrightarrow{F_B} = \overrightarrow{F_C}$$

$$\vec{B}qv = \frac{mv^2}{r}$$

$$r = \frac{mv}{\vec{B}q}$$

$$= \frac{9.11 \times 10^{-31} \times 1.06 \times 10^{-3}}{0.02 \times 1.60 \times 10^{-19}}$$

$$\approx 3.02 \times 10^{-13} m$$

$$\therefore \overrightarrow{F_B} = Eq = \frac{mv^2}{r}$$

$$E = \frac{mv^2}{qr}$$

$$= \frac{9.11 \times 10^{-31} \times (1.06 \times 10^{-3})^2}{1.60 \times 10^{-19} \times 3.02 \times 10^{-13}}$$

$$= \mathbf{2.12 \times 10^{-5} J}$$

Versus $E_1 = \mathbf{2.2 \times 10^{-18} J}$

More than enough energy to ionise gaseous oxygen!

Note: This calculation is somewhat unnecessary, because ionisations in the air can still occur even in Earth magnetic fields, which are only about 3 orders of magnitude less then Gensokyo's magnetic field. More or less, this is just for thoroughness.

A nearby potential difference generated by the nanites ionising the air, is what's largely is going to be the difference between an awesome Danmaku display, and a normal human poking their finger in close proximity to someone else, only to spark them without nanites aiding.