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Formulation of General Relativity without Losing Physical Insight

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Abstract: *The paper aims to elaborate General Relativity based on the principle of time dilation & length contraction happened between two relatively stationary reference frames in a gravitational field. The paper firstly, establishes a factor of General Relativity, γ_G for time dilation & length contraction; such factor is similar to the Lorentz factor,γ in Special Relativity. The strength of time dilation & length contraction in gravity field depends on the factor, γ_G and the radius distance from a point mass. This means the length of a ruler is shortened when it is moving radially away from a point mass; whereas the clock ticks faster if it is positioned radially away from the point mass. The equation of gravitational acceleration can then be derived with the help of the said factor, γ_G. With the derived equation, the graph of gravitational acceleration versus radius distance from a point mass can then be plotted. By aligning with the title of this paper, the author explained the Lorentz transformation of Special Relativity too by emphasizing physical insight. Thus, readers shall find the formulation of General Relativity lies within a same framework with Special Relativity and does not involve heavy mathematical tools, but is still rigorous and does not lose physical insight. After the formulation of General Relativity, the deflection of a light beam in a gravitational field can be explained by the increased of energy of the light beam occurred only at the radial component of momentum of the light beam that points towards the point mass, whereas the tangential component of momentum remains constant. Finally, the space-time invariant is explained and found to be valid in both Special Relativity & General Relativity.*

Keywords: general relativity, Einstein, gravity

INTRODUCTION

Einstein formulated General Relativity **[1]** by using Advanced Mathematics; this leads to the possibility of losing physical insight for most of the readers. Since Einstein had published his work, many scholars subsequently published books in General Relativity, claimed as foundational or the first book for beginners, such as “General Relativity’ **[2]** and “Gravitation” **[3].** These two books, one is a mini book, while the other is the bulky one. However**,** none of them can avoid using tensor calculus as their tool to formulate general relativity. It is obvious that tensor calculus is a graduate-level mathematics which

appeared not popular & mastered by many undergraduate particular from engineering disciplines. As a result of such heavy mathematics, General Relativity becomes impossible to teach in the high school level, even for the introductory level. This is because the field equation & equation of motion **[4]** of General Relativity are both in tensor form.
Field equation,

$$R_{\mu v} - \frac{1}{2} g_{\mu v} R = \frac{8\pi G}{c^4} T_{\mu v} \quad (1)$$

In which,
$R_{\mu v}$ = Ricci curvature tensor
$g_{\mu v}$ = Metric tensor
R= Ricci scalar
$R_{\mu v} - \frac{1}{2} g_{\mu v} R = G_{\mu v}$, Einstein tensor

$T_{\mu v}$ = Stress-energy-momentum tensor
$\frac{8\pi G}{c^4}$ = Einstein constant of proportionality

Equation of motion,

$$\frac{d^2 x^\mu}{d\tau^2} + \Gamma^\mu_{\alpha\beta} \frac{dx^\alpha}{d\tau} \frac{dx^\beta}{d\tau} = 0 \quad (2)$$

In which,
τ = proper time
x^μ= space-time coordinates of the particle path
$\Gamma^\mu_{\alpha\beta}$= Cristopher symbol or connection coefficient

Till now it is no doubt why Newton's Gravitation **[5]** still dominates the high school textbook, although it cannot explain the well-known phenomenon, which is the deflection of light beams near massive object. This paper aims to formulate General relativity in a simple & logical manner without heavy mathematical tools based on the principle proposed in the paper titled "Map of Physics under Yin Yang Theory." **[6]**

Methodology

The underlying principle of General Relativity described in the paper**[6]:** "..*General Relativity is actually an extension of Special Relativity. Simply put, there is only one more variable been added. Refer to Special Relativity, there is one unit interval of space when light moves one unit interval of time; there is one unit interval of time when light moves one unit interval of space. According to General Relativity, the size of the unit interval of space-time is different in two relatively stationary coordinate systems …*" **.**
Details elaboration shall as follows,

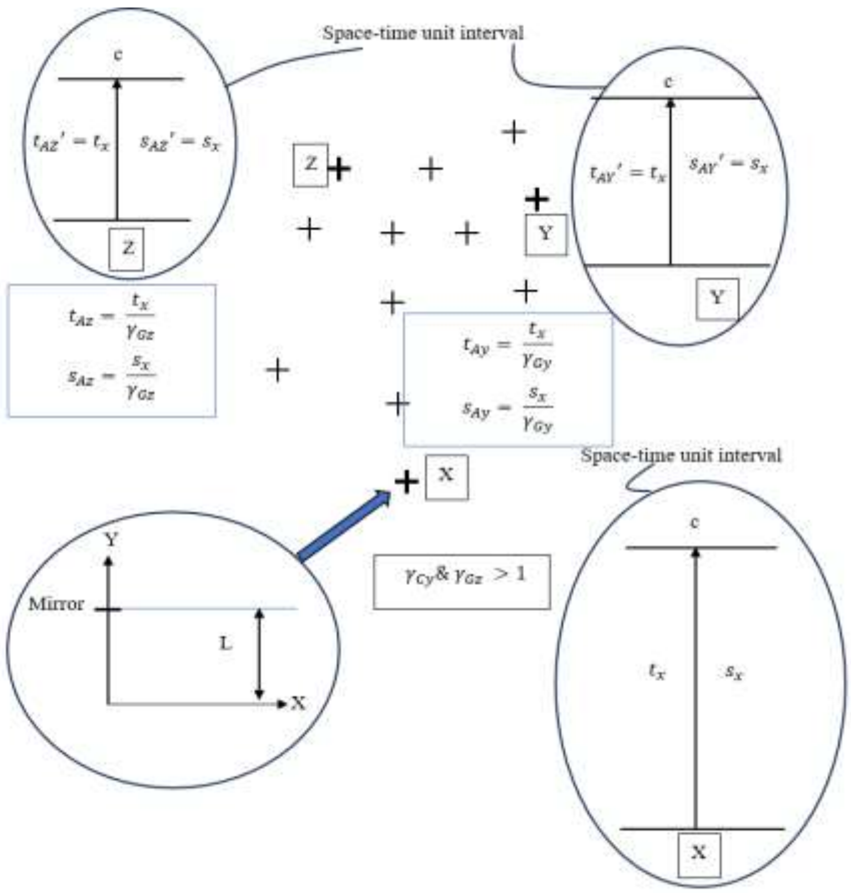

Figure 1: Time dilation & length contraction in between relative stationary reference frames

Refer to **Figure 1.** Initially, there are three observers, A, B & C, located at point X, each with a mirror at a unit distance L along the y-axis. When each of the observers, A, B & C sends a beam of light in the direction of the y-axis, the light will be reflected to the origin after hitting the mirror. Observers A, B, C all measure the equal length of the space-time. This means,

$interval\ of\ space, L = s_x$ are equal for all observers
$interval\ of\ time, T = t_x$ are equal for all observers.

Now observer B, together with his mirror, moves to point Y; observer C, together with his mirror, moves to point Z. Both observers maintain the unit distance L of the mirror relative to themselves. When the observer B & C at points Y & Z send a beam of light to their mirror respectively, both of them measure the space-time as still equal to s_x & t_x. As the unit interval are contracted at Y & Z (their rulers are shorten as described by Feynman **[7]**) compare to X; the observer B & C at Y & Z are having clock ticks faster thus more counts than observer A at X as the light beams emitted by them are having shorter distance to travel compare to emitted light beam by observer A at X. For the observer A at point X, he shall measure the space-time of the light beam emitted by observer B & C at points Y& Z, aren't equal to s_x & t_x.Instead, he shall measure,

$$interval\ of\ space\ at\ point\ Y, s_{Ay} = \frac{s_{AY}{}'}{\gamma_{Gy}} = \frac{s_x}{\gamma_{Gy}} \quad (3)$$

$$interval\ of\ space\ at\ point\ Z, s_{Az} = \frac{s_{AZ}{}'}{\gamma_{Gz}} = \frac{s_x}{\gamma_{Gz}} \quad (4)$$

$$interval\ of\ time\ at\ point\ Y, t_{Ay} = \frac{t_{AY}{}'}{\gamma_{Gy}} = \frac{t_x}{\gamma_{Gy}} \quad (5)$$

$$interval\ of\ time\ at\ point\ Z, t_{Az} = \frac{t_{Az}{}'}{\gamma_{Gz}} = \frac{t_x}{\gamma_{Gz}} \quad (6)$$

In which,
γ_{Gy} & γ_{Gz} are dimensionless factors of General Relativity with a value greater than 1.
$t_{Az}{}'$ & $t_{AY}{}'$ are time intervals measured by observer at points Y &Z.
$s_{AY}{}'$ & $s_{AZ}{}'$are space intervals measured by observer at points Y &Z.
General relativity simply means length of unit intervals are different at points within a space. From above, an observer of a freefall spaceship under the effect of general relativity cannot know himself is moving or stationary without looking out of the window, while for a reference frame on the surface of earth shall see that it is accelerating (Einstein Equivalent Principle) as the spaceship is moving from one point to another with different lengths of unit intervals of space-time.

Freefall at Gravity Field of a Point Mass, M

Let,
T_n , length of time unit interval at point n times marked from point mass measured by the stationary observer at point mass.
s_n = length of space unit interval at point n times marked from point mass measured by the stationary observer at point mass.
L_n = distance traveled by freefall particle at point n measured by stationary observer at point mass.
n = number of times ruler marked when radially out from the point mass
$n\gamma_G$ = factor of General Relativity at point ruler n times marked
T_0 , length of unit interval of time is equal to 1×10^{-8} s at point mass
s_0 , length of unit interval of space/ruler is equal to 2.99792458 m at point mass
L_0=distance traveled by freefall particle at point 0 measured by stationary observer at point mass.
Speed of light, $c = 299792458$ ms^{-1}

From (3),

$$s_1 = \frac{s_0}{1\gamma_G}$$

$$s_2 = \frac{s_0}{2\gamma_G}$$

$$s_3 = \frac{s_0}{3\gamma_G}$$

$$s_n = \frac{s_0}{n\gamma_G} \quad (7)$$

The space-time unit interval length is shortened as radial out from a point mass, M. The radius distance, R from point mass, M, which is under the effect of General Relativity measured by an observer at point mass,

$$Radius\ distance, R = s_0 + \sum_{n=1}^{k} \frac{s_0}{n\gamma_G} = s_0 + \frac{s_0}{1\gamma_G} + \frac{s_0}{2\gamma_G} + \frac{s_0}{3\gamma_G} \dots \frac{s_0}{k\gamma_G} \quad (8)$$

From (5),

$$T_1 = \frac{T_0}{1\gamma_G}$$

$$T_2 = \frac{T_0}{2\gamma_G}$$

$$T_3 = \frac{T_0}{3\gamma_G}$$

$$T_n = \frac{T_0}{n\gamma_G} \quad (9)$$

Derivation of Gravity Acceleration, $\vec{g}$

From (9),

$$T_n = \frac{T_n{}'}{n\gamma_G}$$

In which $T_n{}'$ is the time-unit interval length measured at the freefall particle's local reference frame,

$$T_n{}' = T_0$$

$$acceleration, \vec{g} = \frac{\Delta\,\vec{v}}{\Delta t}$$

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$$\Delta t = T_n$$

$$\vec{g}= \frac{(\vec{v}_n - \vec{v}_{n-1})}{T_n} \quad (10)$$

Freefall particle distance traveled measured at local reference frame,

$$L_n{}' = L_0$$

From (7),

$$L_n = \frac{L_n{}'}{n\gamma_G}$$

$$velocity, \vec{v}_n = \frac{L_n}{T_0}$$

Substitute $\frac{L_n}{T_0}$ into (10)

$$\vec{g}= \frac{(\frac{L_{n-1}}{T_0} - \frac{L_n}{T_0})}{T_n}$$

$$\vec{g}= (L_{n-1} - L_n)\frac{1}{T_0 T_n} \ (11)$$

The direction of $\vec{g}$ is on the radial line of point mass, M and towards the point mass.

Finding Velocity & Acceleration
Free fall can be discussed graphically using **Figure 2**,

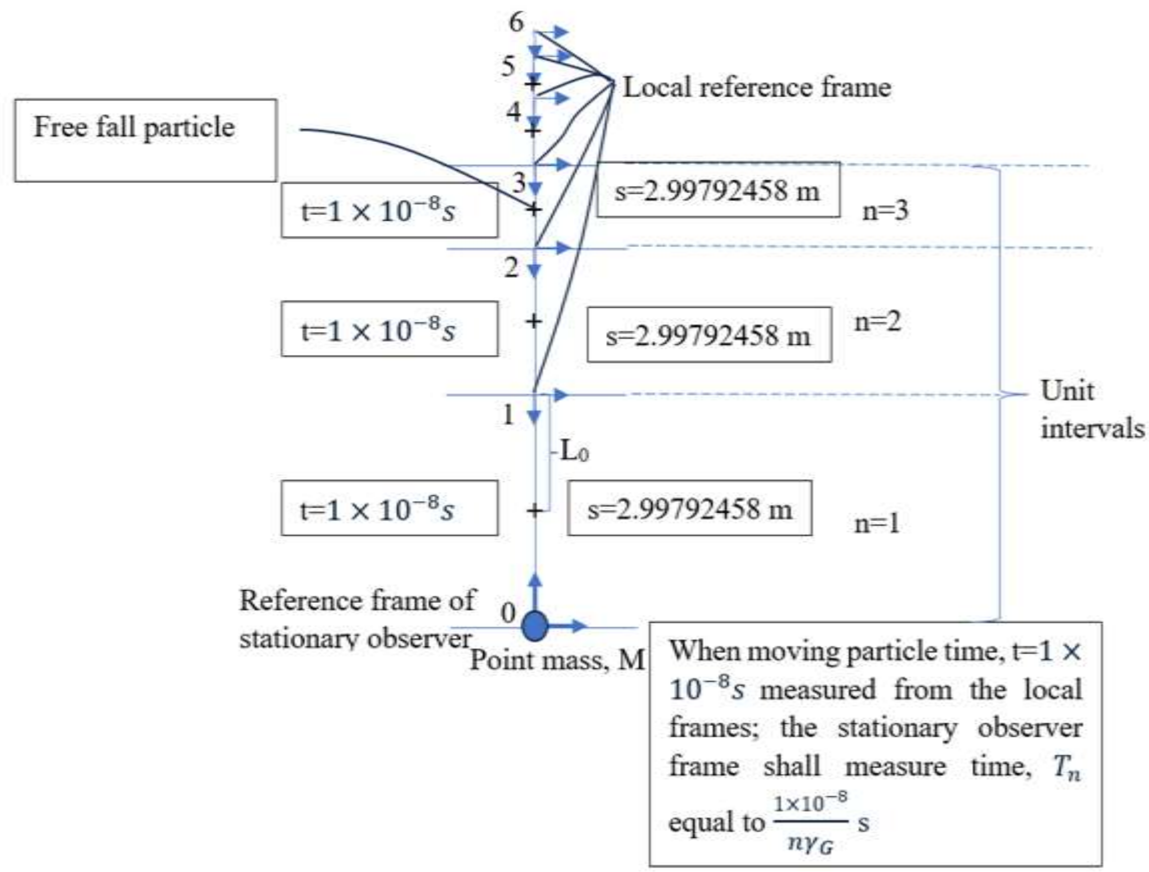

Figure 2: Free fall particle

Let,
γ_G =2
L_n, freefall particle distance traveled at point n
L_0, freefall particle distance traveled = $\frac{s_0}{2}$ at point 0~1

Thus, for the stationary observer at point 0,

Particle velocity at point 0~1,

$$velocity,\vec{v}_0=\frac{L_0}{T_0}$$

$$\frac{\frac{2.99792458}{2}}{1\times10^{-8}}=149{,}896{,}229\text{ms}^{-1}$$

Particle velocity at point 1~2,

$$L_1 = \frac{L_0}{1\gamma_G}$$

$$L_1 = \frac{1.49896229}{1(2)}$$

$$= 0.749481145\text{m}$$

$$velocity, \vec{v}_1 = \frac{L_1}{T_0}$$

$$\frac{0.74948114.5}{1 \times 10^{-8}} = 74{,}948{,}114\text{ms}^{-1}$$

Particle velocity at point 2~3,

$$L_2 = \frac{L_0}{2\gamma_G}$$

$$= \frac{1.49896229}{4}$$

$$= 0.3747405725\text{m}$$

$$velocity, \vec{v}_2 = \frac{L_2}{T_0}$$

$$\frac{0.37474057.25}{1 \times 10^{-8}} = 37{,}474{,}057\text{ms}^{-1}$$

Particle velocity at point 3~4,

$$L_3 = \frac{L_0}{3\gamma_G}$$

$$= \frac{1.49896229}{6}$$

$$= 0.2498270483\text{m}$$

$$velocity, \vec{v}_3 = \frac{L_3}{T_0}$$

$$\frac{0.2498270483}{1 \times 10^{-8}} = 24{,}982{,}704 \text{ ms}^{-1}$$

Particle velocity at point 4~5,

$$L_4 = \frac{L_0}{4\gamma_G}$$

$$= \frac{1.49896229}{8}$$

$$= 0.18737028625\text{m}$$

$$velocity, \vec{v}_4 = \frac{L_4}{T_0}$$

$$\frac{0.18737028625}{1 \times 10^{-8}} = 18{,}737{,}028\text{ms}^{-1}$$

Particle velocity at point 5~6,

$$L_5 = \frac{1.49896229}{5\gamma_G}$$

$$= \frac{1.49896229}{10}$$

$$= 0.149896229m$$

$$velocity, \vec{v}_5 = \frac{L_5}{T_0}$$

$$= \frac{0.149896229}{1 \times 10^{-8}} = 14{,}989{,}622\text{ms}^{-1}$$

The measured acceleration by the reference frame of stationary observer shall be the change of velocity of freefall particle from one unit interval to another.

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The time-unit interval measured by the local reference frame of the freefall particle,

$$T_n{}' = T_n n\gamma_G$$

$$T_n = \frac{T_n{}'}{n\gamma_G}$$

$$acceleration, \vec{g} = \frac{\Delta\,\vec{v}}{\Delta t}$$

$$\Delta t = T_n$$

When the particle moves through the points 4,5,6;

$$T_5 = \frac{1 \times 10^{-8}}{5\gamma_G}$$

$$T_5 = \frac{1 \times 10^{-8}}{10}$$

$$acceleration, \vec{g} = \frac{(18{,}737{,}028 - 14{,}989{,}622)}{1 \times 10^{-9}}$$

$$\vec{g} = 3.747406 \times 10^{15}\mathrm{ms}^{-2}$$

Verify by (11)

$$\vec{g} = (L_4 - L_5)\frac{1 \times 10^{8}}{T_5}$$

$$= (0.18737028625 - 0.149896229)\frac{1 \times 10^{8}}{1 \times 10^{-9}}$$

$$= 3.747406 \times 10^{15}\mathrm{ms}^{-2}$$

When the particle moves through the points 3,4,5;

$$T_4 = \frac{1 \times 10^{-8}}{4\gamma_G}$$

$$T_4 = \frac{1\times10^{-8}}{8}$$

$$accerelation, \vec{g} = \frac{(24{,}982{,}704 - 18{,}737{,}028)}{1.25\times10^{-9}}$$

$$\vec{g} = 4.9965409\times10^{15}\mathrm{ms}^{-2}$$

Verify by (11)

$$\vec{g} = (L_3 - L_4)\frac{1\times10^{8}}{T_4}$$

$$= (0.24982704 - 0.18737028625)\frac{1\times10^{8}}{1.25\times10^{-9}} = 4.99654\times10^{15}\mathrm{ms}^{-2}$$

When the particle moves through the points 2,3,4;

$$T_3 = \frac{1\times10^{-8}}{3\gamma_G}$$

$$T_3 = \frac{1\times10^{-8}}{6}$$

$$accerelation, \vec{g} = \frac{(37{,}474{,}057 - 24{,}982{,}704)}{1.667\times10^{-9}}$$

$$\vec{g} = 7.4933131\times10^{15}\mathrm{ms}^{-2}$$

Verify by (11)

$$\vec{g} = (L_2 - L_3)\frac{1\times10^{8}}{T_3}$$

$$= (0.37474057 - 0.24982704)\frac{1\times10^{8}}{1.667\times10^{-9}} = 7.4933131\times10^{15}\mathrm{ms}^{-2}$$

When the particle moves through the points 1,2,3;

$$T_2 = \frac{1\times10^{-8}}{2\gamma_G}$$

$$T_2 = \frac{1 \times 10^{-8}}{4}$$

$$accerelation, \vec{g} = \frac{(74{,}948{,}114 - 37{,}474{,}057)}{2.5 \times 10^{-9}}$$

$$\vec{g} = 1.4989623 \times 10^{16} \mathrm{ms}^{-2}$$

Verify by (11)

$$\vec{g} = (L_1 - L_2)\frac{1 \times 10^{8}}{T_2}$$

$$= (0.74948114 - 0.37474057)\frac{1 \times 10^{8}}{\frac{1 \times 10^{-8}}{4}}$$

$$= 1.4989623 \times 10^{16}\ \mathrm{ms}^{-2}$$

When the particle moves through the points 0,1,2;

$$T_1 = \frac{1 \times 10^{-8}}{1\gamma_G}$$

$$T_1 = \frac{1 \times 10^{-8}}{2}$$

$$accerelation, \vec{g} = \frac{(149{,}896{,}229 - 74{,}948{,}114)}{0.5 \times 10^{-8}}$$

$$\vec{g} = 1.4989623 \times 10^{16} \mathrm{ms}^{-2}$$

Verify by (11)

$$\vec{g} = (L_0 - L_1)\frac{1 \times 10^{8}}{T_1}$$

$$= (1.49896229 - 0.74948114)\frac{1 \times 10^{8}}{0.5 \times 10^{-8}} = 1.4989623 \times 10^{16} \mathrm{ms}^{-2}$$

Graph for Acceleration $\vec{g}$ versus Radius Distance

Refer **Figure 3** for the graph of gravity acceleration. $\vec{g}$ versus radius distance from point mass, M. The table of value of $\vec{g}$ for n from 1 to 100 shall be in the Appendix section.

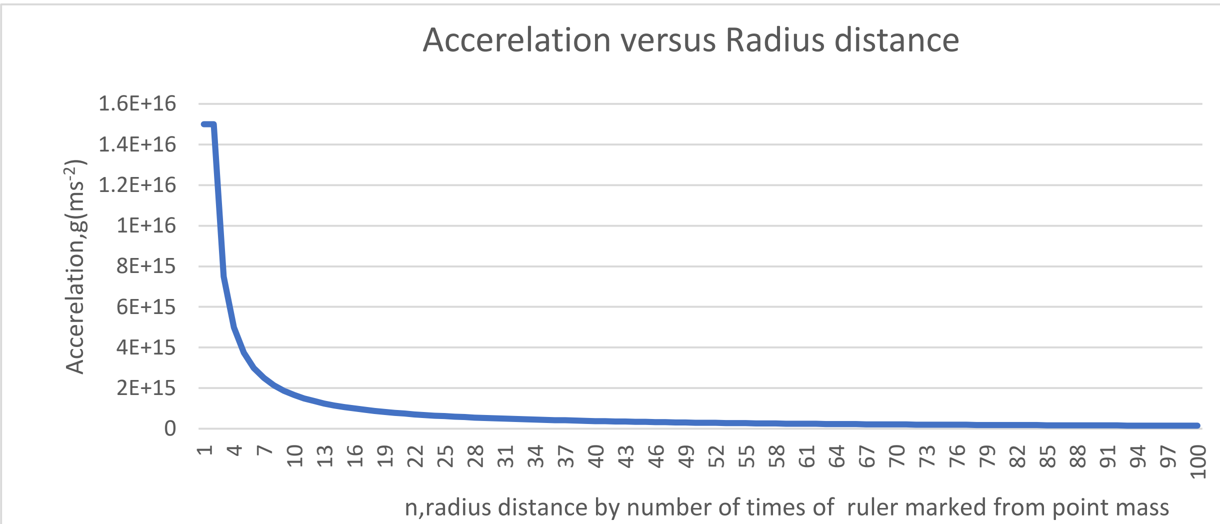

Figure 3: Graph of acceleration versus radius distance

Finding γ_G of Earth

At the surface of earth, $\vec{g}= 9.81ms^{-2}$

Substitute $\vec{g}= 9.81ms^{-2}$ & $L_1 = 0m$ into (11)

$$9.81 = (L_0 - 0)\frac{1}{T_0T_1}$$

$$9.81= (L_0)\frac{1}{T_0T_1}$$

Set up an experiment to get L_0, then can calculate T_1 , as $T_1 = \frac{T_1'}{1\gamma_G} = \frac{T_0}{\gamma_G}$;then γ_G can be calculated.

Finding Earth's gravitational constant, G_G of General Relativity

Mass of earth, $M = 5.9722 \times 10^{24}kg$

$$\gamma_G \alpha M$$
$$\gamma_G = G_G M$$
$$\gamma_G = G_G 5.9722 \times 10^{24}$$

$$G_G = \frac{\gamma_G}{5.9722 \times 10^{24}} \quad (12)$$

Deflection of light in General Relativity

The deflection of light beam **[8]** occurs in gravity field as shown in **Figure 4.**

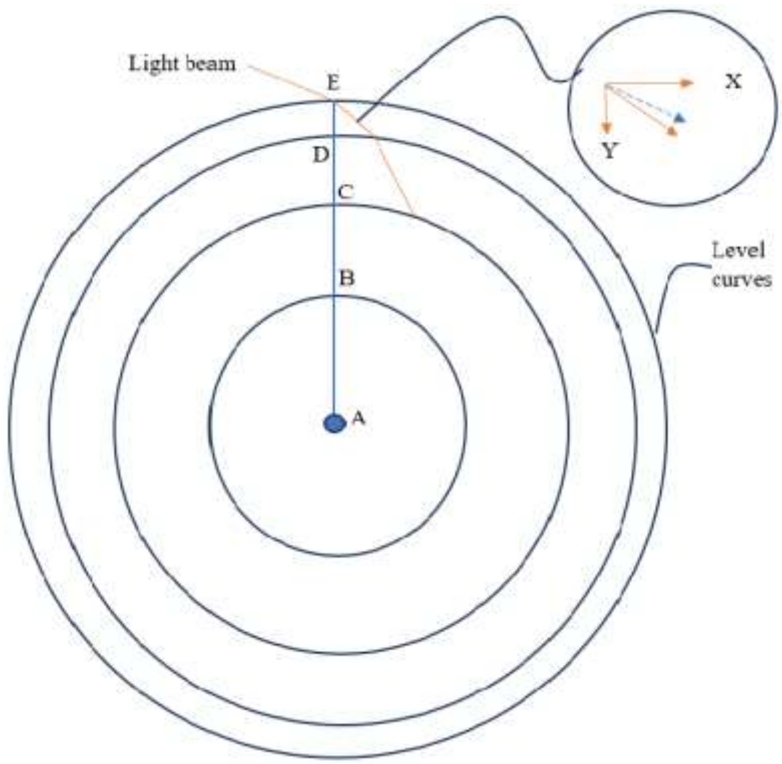

Figure 4: Deflection of the light beam

The photon moves from point E to point D is deflected from the original path (blue line). As momentum, $\vec{p}$ of a photon can be resolved in X-Y direction and related to energy, E by E= $\vec{p}\ c$, its' associated X-Y component energy can be calculated. The path of the photon is deflected because the Y component energy, E of the photon, increases due to gravitational pull, whereas the X component of energy remains unchanged.

Space-time Invariant, ds^2

Under effect of General Relativity, the energy, E, hence the potential, Θ; time, T; space, L; are not invariant when changing the observer (reference frame) to point at other levels. The concept of an invariant interval, ds **[9]**is introduced for this reason. Space-time invariant, ds^2 is the difference between $(cdt)^2$ and the spatial displacement interval of an event, dS^2.Space-time invariant, ds^2 is an invariant in which all observers in relative stationary (General Relativity) or in relative uniform motion (Special Relativity) have an equal value.

$$ds^2 = (cdt)^2 - dS^2 \quad (13)$$

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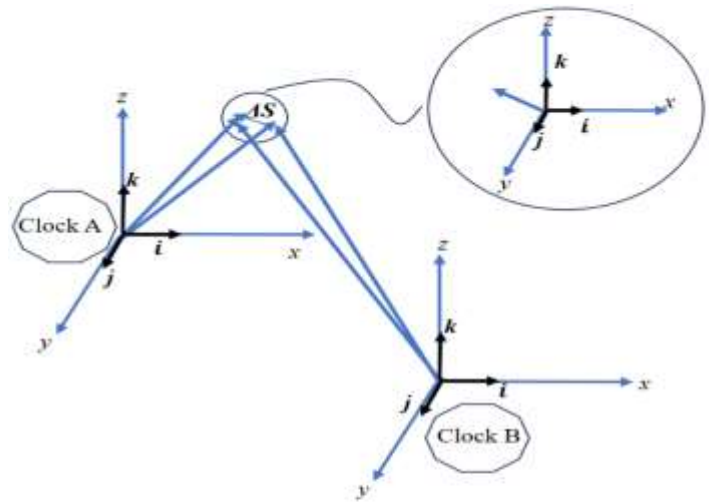

Figure 5: $(cdt)^2{}_A - dS^2{}_A = (cdt)^2{}_B - dS^2{}_B$

Refer to **Figure 5**, for an event observed in two different frame, time & spatial displacement of the event measured by their clock & ruler might be different depend on whether both observers and the event are in the gravity field or they are having relative motion to each other. From above, spatial space of general relativity is no longer Euclidean space but still 3-dimensional space means the space unit interval length is changing from a point to other point measured by observer in a stationary reference frame, and having a clock tick faster or slower compare to other points' clock.

Discussion on Lorentz Transformation Equations

Lorentz transformation **[10]** equations applicable to Minkowski space, that is resulted from the time dilation & length contraction of Special Relativity. As from figure 6,7 of the paper "Map of physics under Yin Yang theory" **[6]**, the light clocks in both stationary and moving frame are emitting beams in Y axis direction. For the moving frame move at velocity u relative to the stationary frame along the x-axis, and origins coincide at t=t'=0, the Lorentz transformation is stated,

$$y' = y \quad (14)$$

$$z' = z \quad (15)$$

In which,
y' & z' are length in Y&Z axis of moving frame
y & z are length in Y & Z axis of stationary frame

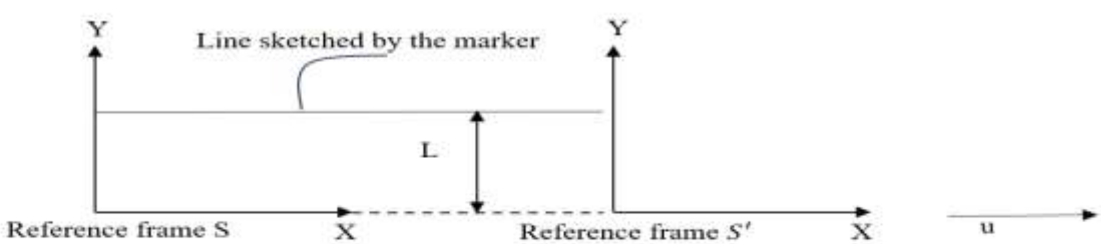

Figure 6: Line sketched distance equal to L

Refer to **Figure 6** to explore why (14) & (15) must be true. Let there are two reference frames S & S', originally at the same origin; there is a marker pen on the reference frame S' at a distance L from the origin in Y direction. Then the reference frame S' moves at a uniform speed, u along X-axis. Thus, the marker pen shall draw a line as it is moving. The observer S shall measure the vertical distance of the line to its x axis is always equal to L, whereas the observer at moving frame still measured the marker pen is in distance L from its origin. Thus, for a line slanted at an angle to the x-axis in the moving reference frame S'**.** The length contraction only happens on its x-component.
The other two Lorentz transformation equations,

$$x' = \frac{x-ut}{\sqrt{1-\frac{u^2}{c^2}}} \quad (16)$$

$$t' = \frac{t-\frac{ux}{c^2}}{\sqrt{1-\frac{u^2}{c^2}}} \quad (17)$$

(16) simply is the rearrangement of the equation $x = x'\sqrt{1-\frac{u^2}{c^2}} + ut$

(17) is the outcome of manipulation on the equation $x = x'\sqrt{1-\frac{u^2}{c^2}} + ut$ by substituting x' with $x\sqrt{1-\frac{u^2}{c^2}} - ut'$, as demonstrated by Michel van Biezen **[11]**.

CONCLUSION

General Relativity can be formulated without the prerequisite of heavy mathematics tool such as tensor & Riemannian geometry. Similar to the Lorentz factor, γ in Special Relativity, the factor of General Relativity, γ_G is contributed to the time dilation & length contraction in General relativity. Newton's law of universal gravitation can then be replaced by General Relativity in high school textbooks as it is an outdated law that does not account for the light beam deflection near a massive object.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

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Appendix

Table 1: Computation of gravity acceleration for n from 1 to 100

$$\vec{g} = (L_{n-1} - L_n)\frac{1}{T_0 T_n}$$

$L_{(n-1)}$ (m)	L_n (m)	$L_{(n-1)}-L_n$ (m)	T_n (s)	T_0 (s)	g(ms^{-2})	n
1.49896229	0.749481145	0.749481145	5E-09	1E-08	1.499E+16	1
0.749481145	0.374740573	0.374740573	2.5E-09	1E-08	1.499E+16	2
0.374740573	0.249827048	0.124913524	1.6667E-09	1E-08	7.4948E+15	3
0.249827048	0.187370286	0.062456762	1.25E-09	1E-08	4.9965E+15	4
0.187370286	0.149896229	0.037474057	1E-09	1E-08	3.7474E+15	5
0.149896229	0.124913524	0.024982705	8.3333E-10	1E-08	2.9979E+15	6
0.124913524	0.107068735	0.017844789	7.1429E-10	1E-08	2.4983E+15	7
0.107068735	0.093685143	0.013383592	6.25E-10	1E-08	2.1414E+15	8
0.093685143	0.083275683	0.01040946	5.5556E-10	1E-08	1.8737E+15	9

0.083275683	0.074948115	0.008327568	5E-10	1E-08	1.6655E+15	10
0.074948115	0.06813465	0.006813465	4.5455E-10	1E-08	1.499E+15	11
0.06813465	0.062456762	0.005677887	4.1667E-10	1E-08	1.3627E+15	12
0.062456762	0.057652396	0.004804366	3.8462E-10	1E-08	1.2491E+15	13
0.057652396	0.053534368	0.004118028	3.5714E-10	1E-08	1.153E+15	14
0.053534368	0.04996541	0.003568958	3.3333E-10	1E-08	1.0707E+15	15
0.04996541	0.046842572	0.003122838	3.125E-10	1E-08	9.9931E+14	16
0.046842572	0.044087126	0.002755445	2.9412E-10	1E-08	9.3685E+14	17
0.044087126	0.041637841	0.002449285	2.7778E-10	1E-08	8.8174E+14	18
0.041637841	0.039446376	0.002191465	2.6316E-10	1E-08	8.3276E+14	19
0.039446376	0.037474057	0.001972319	2.5E-10	1E-08	7.8893E+14	20
0.037474057	0.035689578	0.001784479	2.381E-10	1E-08	7.4948E+14	21
0.035689578	0.034067325	0.001622254	2.2727E-10	1E-08	7.1379E+14	22
0.034067325	0.032586137	0.001481188	2.1739E-10	1E-08	6.8135E+14	23
0.032586137	0.031228381	0.001357756	2.0833E-10	1E-08	6.5172E+14	24
0.031228381	0.029979246	0.001249135	2E-10	1E-08	6.2457E+14	25
0.029979246	0.028826198	0.001153048	1.9231E-10	1E-08	5.9958E+14	26
0.028826198	0.027758561	0.001067637	1.8519E-10	1E-08	5.7652E+14	27
0.027758561	0.026767184	0.000991377	1.7857E-10	1E-08	5.5517E+14	28
0.026767184	0.025844177	0.000923006	1.7241E-10	1E-08	5.3534E+14	29
0.025844177	0.024982705	0.000861473	1.6667E-10	1E-08	5.1688E+14	30

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0.024982705	0.024176811	0.000805894	1.6129E-10	1E-08	4.9965E+14	31
0.024176811	0.023421286	0.000755525	1.5625E-10	1E-08	4.8354E+14	32
0.023421286	0.02271155	0.000709736	1.5152E-10	1E-08	4.6843E+14	33
0.02271155	0.022043563	0.000667987	1.4706E-10	1E-08	4.5423E+14	34
0.022043563	0.021413747	0.000629816	1.4286E-10	1E-08	4.4087E+14	35
0.021413747	0.020818921	0.000594826	1.3889E-10	1E-08	4.2827E+14	36
0.020818921	0.020256247	0.000562674	1.3514E-10	1E-08	4.1638E+14	37
0.020256247	0.019723188	0.000533059	1.3158E-10	1E-08	4.0512E+14	38
0.019723188	0.019217465	0.000505723	1.2821E-10	1E-08	3.9446E+14	39
0.019217465	0.018737029	0.000480437	1.25E-10	1E-08	3.8435E+14	40
0.018737029	0.018280028	0.000457001	1.2195E-10	1E-08	3.7474E+14	41
0.018280028	0.017844789	0.000435239	1.1905E-10	1E-08	3.656E+14	42
0.017844789	0.017429794	0.000414995	1.1628E-10	1E-08	3.569E+14	43
0.017429794	0.017033662	0.000396132	1.1364E-10	1E-08	3.486E+14	44
0.017033662	0.016655137	0.000378526	1.1111E-10	1E-08	3.4067E+14	45
0.016655137	0.016293068	0.000362068	1.087E-10	1E-08	3.331E+14	46
0.016293068	0.015946407	0.000346661	1.0638E-10	1E-08	3.2586E+14	47
0.015946407	0.015614191	0.000332217	1.0417E-10	1E-08	3.1893E+14	48
0.015614191	0.015295534	0.000318657	1.0204E-10	1E-08	3.1228E+14	49
0.015295534	0.014989623	0.000305911	1E-10	1E-08	3.0591E+14	50

0.014989623	0.014695709	0.000293914	9.8039E-11	1E-08	2.9979E+14	51
0.014695709	0.014413099	0.00028261	9.6154E-11	1E-08	2.9391E+14	52
0.014413099	0.014141154	0.000271945	9.434E-11	1E-08	2.8826E+14	53
0.014141154	0.01387928	0.000261873	9.2593E-11	1E-08	2.8282E+14	54
0.01387928	0.01362693	0.000252351	9.0909E-11	1E-08	2.7759E+14	55
0.01362693	0.013383592	0.000243338	8.9286E-11	1E-08	2.7254E+14	56
0.013383592	0.013148792	0.0002348	8.7719E-11	1E-08	2.6767E+14	57
0.013148792	0.012922089	0.000226703	8.6207E-11	1E-08	2.6298E+14	58
0.012922089	0.01270307	0.000219018	8.4746E-11	1E-08	2.5844E+14	59
0.01270307	0.012491352	0.000211718	8.3333E-11	1E-08	2.5406E+14	60
0.012491352	0.012286576	0.000204776	8.1967E-11	1E-08	2.4983E+14	61
0.012286576	0.012088406	0.000198171	8.0645E-11	1E-08	2.4573E+14	62
0.012088406	0.011896526	0.000191879	7.9365E-11	1E-08	2.4177E+14	63
0.011896526	0.011710643	0.000185883	7.8125E-11	1E-08	2.3793E+14	64
0.011710643	0.011530479	0.000180164	7.6923E-11	1E-08	2.3421E+14	65
0.011530479	0.011355775	0.000174704	7.5758E-11	1E-08	2.3061E+14	66
0.011355775	0.011186286	0.000169489	7.4627E-11	1E-08	2.2712E+14	67
0.011186286	0.011021782	0.000164504	7.3529E-11	1E-08	2.2373E+14	68
0.011021782	0.010862046	0.000159736	7.2464E-11	1E-08	2.2044E+14	69

0.010862046	0.010706874	0.000155172	7.1429E-11	1E-08	2.1724E+14	70
0.010706874	0.010556072	0.000150801	7.0423E-11	1E-08	2.1414E+14	71
0.010556072	0.01040946	0.000146612	6.9444E-11	1E-08	2.1112E+14	72
0.01040946	0.010266865	0.000142595	6.8493E-11	1E-08	2.0819E+14	73
0.010266865	0.010128124	0.000138741	6.7568E-11	1E-08	2.0534E+14	74
0.010128124	0.009993082	0.000135042	6.6667E-11	1E-08	2.0256E+14	75
0.009993082	0.009861594	0.000131488	6.5789E-11	1E-08	1.9986E+14	76
0.009861594	0.009733521	0.000128073	6.4935E-11	1E-08	1.9723E+14	77
0.009733521	0.009608733	0.000124789	6.4103E-11	1E-08	1.9467E+14	78
0.009608733	0.009487103	0.00012163	6.3291E-11	1E-08	1.9217E+14	79
0.009487103	0.009368514	0.000118589	6.25E-11	1E-08	1.8974E+14	80
0.009368514	0.009252854	0.000115661	6.1728E-11	1E-08	1.8737E+14	81
0.009252854	0.009140014	0.00011284	6.0976E-11	1E-08	1.8506E+14	82
0.009140014	0.009029893	0.000110121	6.0241E-11	1E-08	1.828E+14	83
0.009029893	0.008922395	0.000107499	5.9524E-11	1E-08	1.806E+14	84
0.008922395	0.008817425	0.000104969	5.8824E-11	1E-08	1.7845E+14	85
0.008817425	0.008714897	0.000102528	5.814E-11	1E-08	1.7635E+14	86
0.008714897	0.008614726	0.000100171	5.7471E-11	1E-08	1.743E+14	87
0.008614726	0.008516831	9.78946E-05	5.6818E-11	1E-08	1.7229E+14	88
0.008516831	0.008421136	9.56947E-05	5.618E-11	1E-08	1.7034E+14	89

0.008421136	0.008327568	9.35682E-05	5.5556E-11	1E-08	1.6842E+14	90
0.008327568	0.008236057	9.15117E-05	5.4945E-11	1E-08	1.6655E+14	91
0.008236057	0.008146534	8.95224E-05	5.4348E-11	1E-08	1.6472E+14	92
0.008146534	0.008058937	8.75971E-05	5.3763E-11	1E-08	1.6293E+14	93
0.008058937	0.007973204	8.57334E-05	5.3191E-11	1E-08	1.6118E+14	94
0.007973204	0.007889275	8.39285E-05	5.2632E-11	1E-08	1.5946E+14	95
0.007889275	0.007807095	8.218E-05	5.2083E-11	1E-08	1.5779E+14	96
0.007807095	0.00772661	8.04855E-05	5.1546E-11	1E-08	1.5614E+14	97
0.00772661	0.007647767	7.8843E-05	5.102E-11	1E-08	1.5453E+14	98
0.007647767	0.007570517	7.72502E-05	5.0505E-11	1E-08	1.5296E+14	99
0.007570517	0.007494811	7.57052E-05	5E-11	1E-08	1.5141E+14	100