The physical nature of the basic concepts of physics

9. Time [i]

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Abstract

One of the greatest mysteries of the present physics is the physical nature of 'time'.
In this paper the author demonstrates that the ageing of a composite, multi-particle system is a general expression for the loosening of the internal coherence of its basic particles, which is mathematically expressed as the increase of its entropy [ii].
In that way, the 'time' of a given particle system can be expressed by the relation between the increase of its entropy and the increase of the entropy of a particle system with a steady entropy increase, that is taken as a time standard or "clock".
It is thereby demonstrated that this definition of the 'time' leads in a self-evident way to the time dilation of high speed particle systems, which is demonstrated to be a real physical phenomenon. And this leads on its turn to Einstein's gravitational time dilation and to the time contraction with ageing.

1. The present time standard

The 'second' as a time unit, was first defined as a 1/24x60x60th of a mean solar day and is now replaced by the atomic standard of time, which corresponds to 9192631770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of a caesium-133 atom.
This definition defines the measurement of time in a very accurate way, but it doesn't answer the question whether time is a universal (Newton) or a material (Aristotle, Leibnitz) phenomenon.

2. The present contradictory concepts of time

2.1 The dual philosophical time concept

The first scientific considerations on the concept of 'time' were made by Aristotle, who came to the conclusion that time is a measure for the change of things, be it the change of their location or of their internal physical state like e.g. one's heartbeat, that is approximately 60 beats per minute and lies at the origin of the definition of the 'second'. It follows from

[i] Updated edition of the paper "Velocity, Mass and Time" of December 1991 by the same author.
[ii] See my paper on the physical nature of entropy.

Aristotle's view that time is a dynamic phenomenon so that without change, there is no time. This Aristotelian concept of 'time' was however questioned by Isaac Newton. Just like Aristotle, Newton based himself on the fact that time is related to 'change', but concluded that these changes take place in the framework of a universal 'clock', that hangs somewhere up in space and that proceeds at a constant rate, totally independent from Earthly changes. The German philosopher Gottfried Wilhelm Leibnitz rejected Newton's view, and supported Aristotle's view of time as a physical phenomenon that cannot be separated from the material world.

2.2 The dual nature of time

The cyclic nature of time comes naturally from our daily experiences of day and night following each other up, and of the seasons that periodically change our climate.
On the other hand, the fact that our children grow up while our parents grow old, has led to the 'the arrow of time', consisting of a 'present' that irreversibly changes, a 'past' that we remember, and a 'future' that we predict by means of time-reversible mathematical equations. And this predicting power of modern science in forecasting falling meteorites and upcoming diseases, is so extremely accurate that it has by far surpassed the predicting power of the classic Greek oracles.

2.3 The reversible time of theoretical physics

When we study the role of time in physics, it strikes us that there are many laws in which time plays an important role. In most of these laws, time is however nothing but a parameter that expresses the relationships between two physical concepts.
- One example is the equation "$t = l/v$" which expresses 'time' as the relationship between 'distance' and 'speed',
- Another example is the equation "$t = v/a$" which expresses 'time' as the relationship between 'speed' and 'acceleration'.

It is clear that in these relationships, time is considered as a multiplication factor that doesn't tell us anything about its physical nature.

On the other hand, the laws of physics are in principle reversible, so that all parts of time (past, present and future) are treated as if they were on a par with each other. In that way, the distinction between past, present and future, which is so important in our daily life, doesn't play any role in physics. According to Kenneth G. Denbigh [1] "*Physics tends to regard only those things which are constant and changeless … hence the great importance in physics of the various conservation principles associated with the notions of determinism and of symmetry*"!

3. The ambiguous nature of relativistic time

3.1 Time dilation in the Special Theory of Relativity

Newton's absolute view on 'time', as a universal clock hanging somewhere up in the universe, received a serious blow with the arrival of Einstein's theory of Relativity.

In 1892, on the basis of the Michelson-Morley experiment, Hendrik Lorentz (who was a leading adherent of Maxwell's electromagnetic theory) published a modification of the Galilean transformation in which, in addition to the transformation equation for the space coordinate ($x' = x - v_0 t$), he added a similar transformation equation for the time coordinate ($t' = t - v_0 x/c^2$). This led to a mathematical expression for the 'time dilation' of moving bodies:

$$\Delta t_v = \frac{\Delta t0}{\sqrt{1 - v^2/c^2}} = \gamma \Delta t_0$$

in which 'Δt_v' and 'Δt_0' represent the duration or the length of a unit time interval, respectively at a velocity 'v' and a velocity '0' [2] (see section 5 on 'time dilation').

In 1905 Albert Einstein published his paper "*On the Electrodynamics of Moving Bodies*" which later became known as the "*Special Theory of Relativity*". Einstein based his whole theory on two fundamental postulates:

- the relativity postulate, by which the laws of physics have the same form in all inertial frames of reference, and
- the postulate of the invariability of the speed of light in vacuum, by which the speed of light in vacuum is the same in all inertial frames of reference, regardless the relative states of motion of these frames

On the basis of these two postulates, Einstein came to a set of transformation equations, that led to Lorentz equations for the "time dilation" and the "length contraction".

In his book "Understanding Relativity" Stanley Goldberg underlines that there is however a fundamental difference between Einstein's and Lorentz's view on the time dilation [3]: "*Whereas Lorentz's interpretation of this phenomenon was to deny that it had a physical reality", .. "In the Einstein theory, time dilation is not a mathematical device. It is a genuine phenomenon because observers in different frames of reference will report that the clocks in frames of reference moving relative to them are slow*" and he writes further "*Given Einstein's analysis, this is not a statement about the physical nature of clocks, rather it is an artefact of how we measure*". This ambiguity about the physical or the observational nature of the time dilation, has however never been cleared out, as is demonstrated by the following examples about the "time dilation".

1. The textbook " Physics – Second Edition, Expanded" [4].
   "As measured by the clocks on the Earth, the clock on the spaceship runs slow. The time-dilation effect is symmetric: as measured by the clocks on the spaceship, a clock on the Earth runs slow by the same factor. (= relative)
   The slowing down of the rate of lapse of time applies to all physical processes. In accurate experiments performed at CERN, muons with a speed of 0,999c were found to have an average lifetime 29 times as large as that of muons at rest." (= absolute)

2. The textbook "Physics for Scientists and Engineers with Modern Physics – Third Edition" [5]:
   "Moving clocks are observed to run more slowly than clocks at rest do. It is not that the clocks are physically altered, rather time intervals that are observed in different inertial frames differ." (= observation)
   "The time dilation is a symmetric effect. (= relative)
   The time-dilation effect is real: We can produce experimental evidence with measurements of the half-lives of radioactive nuclei or unstable particles in motion." (= absolute)

3. The textbook "Modern Physics" [6]:
"Observers in S conclude that the clock in S' runs slow since that clock measures a smaller time interval between the two events." "In 2010 J. C.-W. Chou at NIST used precision optical clocks to detect the minuscule time dilation at a speed of only 10 m/s. These experimental result leave little basis for further debate as to whether traveling clocks lose time. They do." (= absolute)

4. The book "Relativity, Gravitation and Cosmology" [7]:
"Any inertial observer will find that time passes more slowly for any other inertial observer who is in relative motion. Both will be right because time is a relative quantity, not an absolute one." (= relative)

It is clear that these descriptions are ambiguous, not only because they contradict each other in subtle ways, but especially because they contradict themselves by underlining that these effects are relative and therefore fully symmetric, while claiming at the same time that they are real!
It is indeed a paradox that a relativistic velocity, of which the magnitude depends on an arbitrarily chosen reference frame, can have real, physical consequences, such as e.g. the time-dilation of the muon decay or the slower ageing of a fast moving twin brother (iii).
In the view of Kenneth G. Denbigh [8] there is however no doubt that the theory of relativity is a pure observation theory, in which: "*Observers at places such as P, will regard the clock P_0 as running slow relative to their own clocks. But this is of course a symmetrical effect, for the observer at P_0 will regard the clock at P, which is in relative motion, as running slow*".

From this we must conclude that, roughly a hundred years after its publication, the ambiguity about the physical nature of 'time' and the time-dilation has not yet been properly cleared out and that therefore the question remains whether time dilation is a genuine physical process or an observation phenomenon?

3.2 The ambiguous nature of gravitational time dilation

In Einstein's General Theory of Relativity, 'fields' are considered the 'substances' that constitute the fabric of the physical reality:
- The electromagnetic 'field' is the fabric of which light is made of, and it is at the same time, the origin of the forces that make electric motors run.
- According to the General Theory of Relativity, the gravitational 'field' is the fabric of spacetime and its stretching and bending is the cause of the gravitational acceleration of masses toward each other in that field.

According to Einstein's Theory of General Relativity, time slows down in the surroundings of massive bodies, such as the Earth, so that for a person who lives at sea level, time proceeds slower than for a person who lives up in the mountains. In the General Theory of Relativity, this phenomenon is considered as a consequence of the nature of space-time.
It is thereby important to notice that in General Relativity, this slower ageing is considered as a real, physical phenomenon that is linked to a physical location.

(iii) See section 2.3 "The ambiguity of the time dilation" of my paper Part 7 on the physical nature of velocity.

3.3 The absolute time dilation of fast moving muons

In 1936, Seth Neddermeyer observed muons at sea level! These muons, that have a lifetime of 2μs, arise more than 7000 meter above sea level and move at a velocity of 0,999c, which would mean that they can move over a distance of only 600 meter.
The reason why Seth Neddermeyer nevertheless observed them at sea level is that, because of their high speed, their lifetime has physically increased from 2μs to 30μs, so that they can in fact travel over 9000 meters instead of 600 meters!
It is as a result of this increased lifetime of high speed muons, which is completely opposite to the (symmetric) relativistic view, that in 1957 C. G. Darwin published his paper in Nature on the "Twin Paradox"! It must thereby be clear that this 'paradox' of Special Relativity has nothing to do with the acceleration of the twins, nor with any possible reunion of the twins. The paradox is created by the fact that a 'relativistic' speed can have a hard physical consequence, such as the increase of the lifetime of moving muons. In other words, the twin paradox is a paradox in the heart of Special Relativity, because Neddermeyer's observations demonstrate that their velocity is an absolute physical state of those particles, with the absolute consequence of more than a tenfold increase of their covered distance.

4. The physical nature of time

4.1 The irreversible nature of thermodynamic time

In theoretical physics all fundamental equations are reversible with regard to time.
There is however one law that is directly linked to time, without 'time' playing the role of an arbitrary parameter or a multiplication factor. That law is "the second law of thermodynamics" that makes a fundamental distinction between congruent motion (such as in the case of kinetic energy, electro-magnetic energy, and gravitational energy) and isotropic motion (such as thermal motion).

In my paper on the physical nature of entropy, I have demonstrated that with two heat sources at different temperatures, it is possible to produce congruent translational motion by means of an adiabatic expansion of the 'hot' particle system, which produces a (partial) rectification of the motions of these particles and increases in that way their amount of congruent velocity, while cooling their temperature down to that of the 'cold' source.
When left to themselves, the two heat sources at different temperatures will also come to an equilibrium at an average temperature, without however being able to produce congruent translational motion. In that case the whole particle system consisting of a hot and a cold part, will make an irreversible evolution, which is expressed by its entropy increase. This evolution of the temperatures difference between both reservoirs, can in that way be taken as a physical indicator (a clock) of the time (entropy) evolution of the whole system. (Fig 9.1)

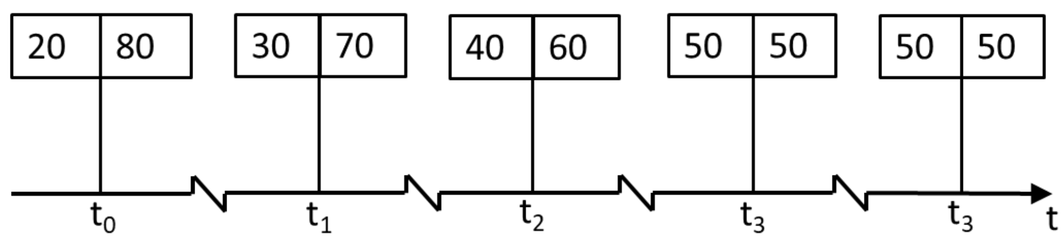

Fig. 9.1

This ‘clock’ isn’t however of much practical use because the evolution of the temperature is not linear. It demonstrates however that “time” has nothing to do with the motion of particles coming to a standstill, because according to the first law of thermodynamics, the (thermal) motion cannot disappear. It just means that ‘time’ exists as a function of the irreversible ageing of a given particle system, which is the gradual transformation of its internal congruent motion into isotropic motion. This irreversible ageing is mathematically expressed as the increase of the entropy of the particle system (iv) .
Every particle system or ‘body’, has its own rate of ageing, its own individual time progress. Even the clock complies with this definition, because when one winds up the spring of a clock, one diminishes the entropy of the spring (by doing work on it) which increases its potential energy. When the spring then slowly relaxes, its entropy increases. When the spring is completely relaxed, the entropy of the clock has reached a maximum and the clock system is physically ‘dead’ (until someone rewinds it). In that view the clock is just a device that is made to have a constant rate of ageing.
According to Kenneth G. Denbigh [9] “*the thermodynamic time concept is similar to the time concept of conscious awareness, in so far that it regards the sequence of events as irreversible. .. Here we have the familiar basis of the second law and of course the notion of irreversibility plays an important role in biology. .. Once something has happened it can never be made un-happened*”.

4.2 Time progress as the rate of entropy increase

In composite particle systems, existing velocity gradients between different subsystems are gradually equalized by the fortuitous internal collisions between these subsystems.
This phenomenon is known as the ‘decay’ or disintegration of instable ‘particles’, such as in the case for radioactive isotopes. The decay rate of such macroscopic particle systems determines their average lifetime and is therefore a measure for their ageing.
This rate of ageing is (like all rates) expressed with respect to ‘time’, in which ‘time’ is an arbitrarily chosen, steadily proceeding time indicator, or ‘clock’.
As pointed out in section 1, it is on the basis of this ‘time’ concept that the present definition of the ‘second’ is defined by the decay of a standard atomic clock, which corresponds to 9192631770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of a caesium-133 atom and which is in that way based on exactly the same phenomenon as the decay rate that we want to measure.

This means that the rate of ageing, or the "time-progress" of any composite system (an instable particle or a living body) can be expressed as the loosening, or the decay of its coherence, expressed in function of the decay of an object with a steady decay rate, that is therefore taken as a time standard, or ‘clock’.
This means that the concept of ‘time’ as a universal datum does not exist! Only the physical entropy increase of particle systems exists!
This may sound strange and one automatically poses the question: “change of the entropy, with respect to what?”. This question is however of exactly the same nature as the question: “time progress with respect to what?” of which the nonsensical nature is clear, since time is taken as a reference for all other changes.

(iv) See my paper Part 6 on the physical nature of entropy.

This allows me to conclude that the time progress or the 'ageing' of a particle system is the increase of the dispersion of the motions of its components, which is expressed as the increase of its 'entropy'.

5. Nelissen's dynamic entropy of isotropic dispersion

In the present physics, there are two definitions of entropy:

- Clausius' thermodynamic entropy of a particle system, which is a quantitative expression of the total number of particles with isotropic motion S = Q/T.
- Boltzmann's statistical entropy of a particle system, which is a mathematical expression of the spatial dispersion of the particles, of which the exact locations are not known and can only be estimated statistically S = k logW, and

In section 2.3.3 of my paper Part 6 on the physical nature of "Entropy", I have introduced a new dynamic expression of the entropy of a particle system, as the degree angular dispersion of the velocities of its basic particles. This new concept of entropy allowed me to demonstrate that the entropy of a particle system that consists of particles with an average velocity 'z' can be expressed by a complex number:
z = **v** + iq (Fig. 6.2)

- in which the real part is the congruent velocity '**v**' with which all particles move in unison in the x-direction, and
- in which the 'imaginary' velocity 'q' is the RMS-value of the isotropic thermal velocities of which the average speed is 'q_c':

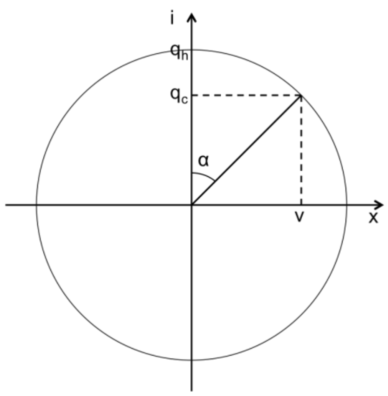

Fig. 9.2

The magnitude (modulus) of this complex number is: $z = \sqrt{v^2 + q^2}$
So that: $v^2 + q_c^2 = z^2$
or: $v^2/z^2 + q_c^2/z^2 = 1$
so that: $\sin^2\alpha + \cos^2\alpha = 1$

And this allowed me to introduce a new, dynamic concept of entropy, that expresses the degree of isotropy or randomness, of the angular distribution of the velocities:

$$S_d = q_c/q_h = \cos\alpha = \sqrt{1 - \frac{v^2}{qh^2}}$$

This dynamic entropy of the isotropic dispersion (S_d) of the of the velocities of the particles, varies between 0 and 1:

- For $\alpha = 0$: $S_d = \cos\alpha = 1$ and all the kinetic energy will be present under the form of thermal kinetic energy;
- For $\alpha = 90°$: $S_d = \cos\alpha = 0$ and all the kinetic energy will be present under the form of kinetic energy of bulk motion.

In that way, the entropy of isotropic dispersion of the velocities of its basic particles can be used as a direct mathematical expression of the second law of thermodynamics, which can be formulated as: "Without external influences, the degree of angular dispersion of an isolated particle system cannot diminish" (v), which basically means that in an isolated particle system, thermal motion cannot spontaneously transform in congruent motion.
This dynamic entropy in function of the degree of isotropy of the particle's motions has thereby the added advantage that it is valid for mechanical as well as thermodynamic systems, because it automatically leads to the equivalence between the second law of thermodynamics and Newton's first law of motion for multi-particle systems. In the case of 'bodies' considered as particle systems, Newton's first law says indeed that [10] "A particle system at rest remains at rest and a particle system in motion continues to move at a constant velocity" (unless acted upon by an external force).

6. The time dilation of fast moving particle systems

In section 4.4 "A new kinematic speed equation" of my paper on the physical nature of velocity, I have demonstrated that the variable velocity of mass particle system is a physical state of that system, that can be expressed by the degree of 'congruence' of the motions of its basic, massless components, moving at light speed: $v = c \sin\alpha$ (vi).
This allowed me to express the internal, isotropic velocity as $q = c \cos\alpha$.
So that: $v^2 + q^2 = c^2(\sin^2\alpha + \cos^2\alpha) = c^2$

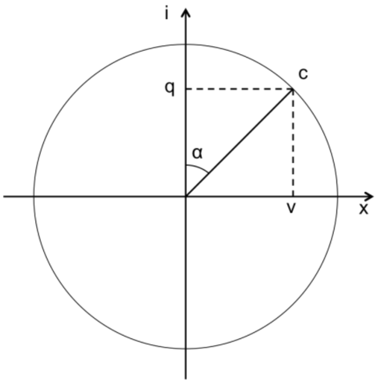

Fig. 9.3

In this case, the dynamic entropy of angular dispersion is:

$$S_d = q/c = \cos\alpha = \sqrt{1-\frac{v^2}{c^2}} = 1/\gamma$$

- This means that the variable speed "$v = c \sin\alpha$" of a mass particle system that consists of massless particles moving at the invariable speed of light, is a physical state of that system,

(v) It will allow me, in my paper about the physical nature of "Extent, Velocity and Length contraction", to develop Lorentz' equation for the length contraction of moving particle systems.
(vi) The nature or 'mass' will be analyzed in my paper on the physical nature of mass.

which represents the degree of congruence or rectification, of the velocities of its massless components.
- And it also means that the contour (and consequently the diameter) of the particle system is formed by the internal, repetitive isotropic motion "q = c cosα" of its basic, massless particles

In section 5 of my paper Part 8 on the physical nature of 'velocity' this has led to the conclusion that a moving particle system will suffer an anisotropic contraction in its direction of congruent motion, which is generally known as its "length contraction":

$l_v/l_0 = 1/\gamma = q/c = \cos\alpha = \sqrt{1 - sin^2\alpha} = \sqrt{1 - v^2/c^2}$

It follows from this, that while a particle system at rest has a time (entropy) increase of 1 unit ($t_0 = 1$), an identical particle system that moves at a velocity 'v' has a smaller entropy (time) increase of $t_v = \cos\alpha = \sqrt{1 - sin^2\alpha} = \sqrt{1 - v^2/c^2}$ so that: $\frac{tv}{t0} = \sqrt{1 - v^2/c^2}$

Because the time (entropy) progress 't' is inversely proportional to the length of a unit time (entropy) interval 'Δt', this means that: $\frac{\Delta tv}{\Delta t0} = \frac{1}{\sqrt{1 - v^2/c^2}}$

Which gives us the equation of the "time dilation" or time increase with increasing speed:

$$\Delta t_v = \frac{\Delta t0}{\sqrt{1 - v^2/c^2}}$$

In this equation, 'Δt_0' is the unit time interval at rest and 'Δt_v' is the unit time interval at a velocity 'v' so that: $\Delta t_v > \Delta t_0$.
This simply means that with an increasing speed, the amount of congruent translational motion in the given direction increases, so that its entropy and consequently its time progress, decreases proportionally with the degree of congruence of the motions of its basic particles.
It also means that the contour (and consequently the diameter) of the moving particle system that is formed by the internal, repetitive motion "q = c cosα" of its basic particles, will have contracted in its direction of congruent bulk motion.

From this we can conclude that, while a particle system that is at rest has aged one time unit, that same system when moving at a velocity 0.5c, will only have aged only 0.866 time units
Which allows us to conclude that:
- Particle systems that move at the absolute speed of light (e.g. photons) have no entropy increase and consequently no time in their direction of motion.
- Particle systems that don't move, the rate of their entropy increase and their time progress will have a maximum value for the local ageing conditions.

This definition of the "time-progress" of a particle system in function of its velocity gives a concrete, physical explanation for the so-called 'time dilation'.
In that way the so-called 'Twin Paradox of the Special Theory of Relativity [11] isn't a paradox at all, but is a fundamental characteristic of a moving particle system.

7. The physical nature of gravitational time dilation

A particle system with a mass 'm' that is initially at rest ($v_0 = 0$) at a large distance from a planet with mass M, falls towards that planet with an increasing speed.
The velocity 'v' of the falling particle system at any distance 'r' from the center of the planet,

can be deduced from the conservation of energy of the falling mass: $mv^2/2 = GMm/r$, so that: $v = \sqrt{2GM/r}$

This means that at any distance 'r' from the center of mass of the planet, the amount of congruent motion of the particle system has increased from $v_0 = 0$ to $v = \sqrt{2GM/r}$, so that it has received a time dilation: $\Delta t_v = \frac{\Delta t0}{\sqrt{1 - v^2/c^2}} = \frac{\Delta t0}{\sqrt{1 - 2GM/rc^2}} = \gamma t_0$

Which is the so-called 'relativistic' gravitational time dilation for a mass particle system in a gravitational potential energy field.
In my paper on the physical nature of potential energy fields, I have demonstrated that potential energy is a mathematical expression of the amount of internal, reversibly transferrable motion of its basic particles. In that way the increasing translational velocity of a falling mass is a caused by a gradual transformation of its internal congruent motion into congruent translational bulk motion.
This demonstrates the gravitational time dilation of a mass particle system that is located in a given point in a gravitational field is not any different from the time dilation of a high speed mass particle, because both particle systems have exactly the same amount of congruent translational motion. In other words, my development demonstrates that the gravitational time dilation is in fact not a special case, but that it is just an application of the time dilation of moving particle systems (vii).

8. The biological time contraction with age

It is generally known that one's proper time proceeds at different rates in different conditions and at different ages.

In section 5, I have demonstrated that my dynamic entropy of isotropic dispersion of a particle system expresses the degree of isotropy of the motions of its basic elements. Applied to the organs of a body, like e.g. the brain, this means that for a young person, the body is a perfect coherently working system and its degree of randomness or entropy is very low:

- the perfect brain transmits the signals directly from one location to another, without any noise or deviations
- ideas are stored unaltered, without loss of information
- the blood is transported through perfect blood vessels and veins, without loss of pressure

In that way, the body and the brain of a young person can be compared to that of a high speed particle system, of which the amount of congruent motion is very high (and its amount of random motion is negligible), which means that it has a unit time interval that is comparable to that of a high speed particle system:

$\Delta t_v = \frac{\Delta ts}{\sqrt{1 - \sin^2\alpha}}$ (In which sinα approaches 1).

It is that effect that makes that when on is young, one has a fast working metabolism, that makes it possible to do many tasks in a day and makes a summer vacation seem endless!
(This is not to be confused with the purely psychological time increase that one experiences as "time stands still" when one has a very boring experience, and as "time flies by" when one

(vii) This will be analyzed in my paper on the physical nature of gravitation.

has a great time.)

For an old person the body is kind of worn-out, so that:

- one has a slow metabolism which makes it takes a long time to get out of bed, to dress oneself and to finish breakfast, so that it becomes difficult to do more than a few simple tasks in a day. In that way, three months become just a number of days of standing up, washing, eating and going to sleep.
- the memory is worn-out so that stored information fades away and cannot be reached anymore
- And due to the reinforcing feedback effect of the entropy increase, the imperfections in the body of an old person, will multiply at an increasing speed, so that the bodily functions will work slower and one will eat slower, and one's digestion will work slower. One's brain will work slower, all your actions will become slower, so that in one day you can only do a few basic things, so that a summer will seem to pass faster and faster each year.

In that way, the body and the brain of a very old person can be compared with a particle system that is virtually at rest, which means that it has a unit time interval that is close to that of a particle system at rest 'Δt_0'.

$$\Delta t_v = \frac{\Delta ts}{\sqrt{1 - \sin^2\alpha}}$$ (In which sinα approaches zero).

And it is that effect that makes that for old people, time seems to pass faster and faster each year.

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