The Scaling Theory XI: Newton’s Absolute Time and Length

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Abstract: The bases of the scaling theory which were dealt with in earlier sections are enhanced by more elementary, but profound, concepts emerging from a slightly modified Newtonian vision of space and time. It is shown here that if observations through light signals are ruled out the Newtonian view of absolute time and distance can be implemented in a specific measurable fashion, and that both absolutes must be interrelated, to give rise to what we shall still call “an absolute space”. The concept of a frame being at absolute rest can also be given a precise meaning. In part XIII we show that when observations through light signals are incorporated, the absolute space give way to what we call “a universal space” in which distance from an observer is defined through “optical length”. A universal space retains geometric distance and time in the original absolute space as absolute.

19.1. Newton’s Absolute Space and Time

In Newtonian mechanics, inertial frames as the sites in which the law of inertia holds, are conceived traditionally in a specific way which resembles, in some sense, the scaling theory view. Inertial frames in Newtonian mechanics stem their realization from Newton’s vision of absolute space and time stated in his Principia[18]:

“*Absolute space, in its own nature, without relation to any thing external, remains always similar and immovable…”*

“*Absolute, true and mathematical time, of itself and from its own nature, flows equably without relation to any thing external, and by another name is called duration; relative, and apparent common time is some sensible and external .. measure of duration by the means of motion, which is commonly used instead of true time, such as an hour, a day, …”*

Newton emphasized that one can only make measurements of space and time in terms of arbitrary given standards, or units[18]; and he identified the absolute space by the heliocentric frame, or as to say, by a rectangular Cartesian system $A \equiv CXYZ$ with its axes pointing permanently to some fixed stars and C is the center of mass of the solar system. Newton’s three laws of motion hold therefore against the background of absolute space, with the Euclidean nature of absolute space geometry is implicitly assumed. As far as the laws of motion are concerned, Newton’s followers realized that the frame of absolute space is not privileged to any inertial frame, which is a frame in a uniform translational motion relative to the frame of absolute space.

If S and s are two inertial frames, then time flows equably in S and s, and distance between two objects is the same in both frames at each instant of time. This implies that timers read the same durations and a rod has the same length in all inertial frames. The coordinates in S and s are related by the Galilean transformations. It is noted that the Newtonian conception of “absoluteness” is the same as the concept of “invariance”. Indeed, the absolute length of a rod means that the result obtained when measuring its length is independent of the state of the rod’s motion, or equivalently, the result obtained is the same when measuring this length from any inertial frame. Thus we may carry out a measurement of a rod’s length *conclusively within the frame S* and find the same result whether the rod is stationary or moving in S. Similar statement is applicable to time durations.

A “Newtonian” clock moving in S indicates the same instant of time as the stationary clock in S that is contiguous to it. The last sentence seems so ambiguous, since it pre-requires the frame S to be already synchronous, but Newton’s envisaged *a clock as an instrument that is in accord with a universal timer, set up by the configuration of the earth with respect to the distant universe*, with this timer is in use by every observer and not biased to any one. The latter issue will be expounded when we talk in (part XII) about a universal timer.

We point here to some basic differences between the scaling theory and Newtonian concepts of space and time, and later we show that, although the scaling theory mildly alter the Newtonian concepts, a well-defined sense of measurability is injected through these modified concepts.

(i)It was always perfectly clear what motion of a reference frame with respect to another meant, but what was not clear and needed elaboration is the concept of a frame *S* being at rest! At rest with respect to what? In the scaling theory one arbitrary frame *S* of the set of inertial frames that are translating uniformly relative to each other can be taken as the frame of fixed stars and considered stationary, while all other frames will be moving relative to *S*, and accordingly to the fixed stars. The absolute space is mapped to, or identified by, *S;* while any other frame will be moving in the absolute space.

(ii)In Newton’s treatment the rule of observation by light’s signals is absent all together.

(iii) From the geometric distance in a stationary frame *S* on which the absolute space is mapped, to be called later “a timed frame”, distance and time intervals in any other inertial frame *s* are induced such that the velocity of light is *c* within *s*.

We discuss in this part (XI) how far one can implement the traditional view of inertial frames in a measurable fashion when the effect of observation through light signals is not taken into account. In (part XIII) and onwards we consider the impact of observations through light signals on distance and time.

19.2. Global Time in an Inertial Frame - Synchronous Frames

Consider an arbitrary inertial frame $S \equiv OXYZ$. The coordinates system is assumed to be already calibrated using a given unit of length, say *LS*. The geometric distance between two points $A \in S$ and $B \in S$, or geometric length of a rod *AB* stationary in *S*, refer to the result L_{AB} obtained by laying the unit of length *SL* in *S* along the bar repeatedly from one end till reaching the other by multiples and fractions of *SL*. This can be done rationally and takes no time. If $R = R_g.LS$ is the geometric distance of the point *B* from *O* then the dimensionless quantity R_g is the radial coordinate of *B*. It is clear that the geometric distance between two points is independent of the instant (or instants) of time at which it is measured, and thus, immediately available whenever the frame of reference is endowed with a coordinate system, i.e., it is an already given data. In principle, light’s signals need not enter in coordination of *S*, which requires only geometric measurements using a given unit of length. If *b* is moving in *S*, then its distance from *O* depends on the instant of time at which the measurement is done.

The unit of time, though arbitrary, is chosen as the duration, say “second”, between two consecutive ticks (or readings) of identical clocks that run at synchrony with each other. *Contemplating in the last statement, we may be astounded by the fact that we really have defined nothing concerns the world outside the clocks.* Indeed, two nearby identical clocks stationary in *S*, count the same number of beats of a distant pulsar during a second, i.e. the same frequency.

Again, this tells us nothing more than that we can adopt, instead of a second, a new unit of time corresponding to the period of one pulsar's beat, while the ability of describing motion in S is still out of reach. In order that a unit of time, say a second, bears a meaning as far as motion in S is concerned, *it should be correlated to what can happen during "a second" in the outside world*, and more precisely, it should quantify the amount of the spatial displacement intrinsic to some *reference physical phenomenon*, such as the propagation of light from an arbitrary point in S, or be related to a free reference (spherical) body that is not translating in S but rotating about its axis. *A "second" must thus be corresponded with (and actually could be measured by) the distance traveled by light within S during the period of a second in the former case, and with the angle at which the reference body rotates relative to the remote universe in the latter. Time measurements therefore must be reduced to specific types of spatial measurements.*

Appealing to Galileo law of inertia we hope to have a way out of the empty definition of the "second" stated by the underlined statement above. Newton's first law, or law of inertia, asserts that in an inertial frame S a force-free body b can be in any state of motion that is characterized at each instant of time by the same vector velocity. This implies that although we already know that a free body moves at a constant vector velocity in S, this constant vector velocity has to be determined through measurements. The measurement of the velocity of a body requires the readings of two *synchronous clocks* at two distinct points of its trajectory, but this brings us to the issue of how to synchronize clocks at distinct points. We may suggest that clocks are synchronized at one point and then transported to all other points in S. Or we may instead use the uniform motion of the body b to synchronize clocks along its trajectory. This is carried out as follows: The observer O sets his clock when b passes by at $T = 0$ and informs (by any possible means) all observers $(R, \emptyset, \theta)$ to set their clocks (which are identical), when the body passes by, at $T = aR$, with a is an arbitrary given constant. This process synchronizes the clocks along the trajectory of b and defines a unit of time by the duration taken by b to travel $(1/a = v)$ of the unit of distance along its trajectory. To synchronize clocks for every $(\emptyset, \theta)$ we need beforehand a pulse of particles springing simultaneously from O in all directions with each particle having the same speed. Therefore, the described synchronization procedure acquires practicality only if a type of particles has the property that: it propagates invariably from its source O at a constant speed.

One way to materialize synchronization in a measurable meaning is to postulate that: *Light propagates rectilinearly within the stationary inertial frame S in all directions at a constant velocity c.* Now we can proceed with the Newtonian view and imagine that as soon as S is furnished with a system of coordinates, a system of synchronized timing is immediately established with respect to one timer, say $O \in S$. This means that, in the same way we envisage rationally the assignment of a triplet $(R, \emptyset, \theta)$ to each point B in S, we can also imagine that a timer can be placed at each point B which is *synchronized with $O \in S$ and runs uniformly* at the same rate as the master timer, and accordingly with all other timers. Indeed, due to the latter postulate a *global timing* in S can be practically established, with the notion of an "instant T_0" has a global meaning in S, in the sense that if an event takes place at $B_0(R_0, \emptyset_0, \theta_0)$ at T_0 then it will be detected at $B(R, \emptyset, \theta)$ through a light signal emanating from B_0 and arriving at B at the instant

(19.1) $$T = T_0 + \|\vec{R}_0 - \vec{R}\|/c.$$

Thus every S observer B assigns to the event of light's emission the same instant $T_0 = T - r/c$, where r is his spatial separation from B_0 and T is the time read at the clock B when light is received. It follows that the concept of time arrow -past, present, and future- has a global meaning in S, and any two or more S observers have the same temporal ordering of the events monitored by them. In particular, the notions of simultaneity and non-simultaneity are well-defined global concepts in S.

Having set up a global time in S, any S observer, say O, can determine the instant of occurrence of any event at any $B \in S$ just by knowing the distance $R = |\overrightarrow{BO}|$. In fact the time readings t_O by the observer O when he receives a light's pulse from the point $B(R, \emptyset, \theta)$ is sufficient to inform O that the pulse was emitted at $t_O - R/c$. Thus, for the observation process by O, all timers apart from his, are not necessary. Similarly, a light's message coded with the time reading t of a timer at an arbitrary point B is sufficient, when compared with the reception time t_O at O, to inform O of the distance $|BO| = R = c(t_O - t)$. If the unit of time in S is defined as the duration required by a light pulse to cross the unit distance (a given rod stationary in S) from one end to another, say 1 *meter*, we may designate the unit of time also by 1 meter, to mean the time required by a light's signal to cross this distance. In this system of units, the velocity $\vec{v} = \Delta\vec{R}/\Delta t$ is a dimensionless 3-vector, and the speed of light in vacuum is 1. Moreover, acceleration has the dimension of 1/meter, whereas mass and energy have the same unit, kilogram. Or we may instead conform to the modern definition of the unit of length- "meter"- as the distance travelled by light during $1/c$ seconds, in "*vacuum*". In this system of units, both time and distance intervals are measured in seconds, speed is dimensionless, acceleration by 1/second, mass and energy by kilogram. The difference between our definitions and the modern one is that ours are valid in a stationary inertial frame S (or timed inertial frame), since the velocity of light is assumed constant within S, while in the modern definition, the light's velocity is an absolute constant independent of the relative motion between the source and the observer. Moreover, the concept of distance is more primitive than the concept of time; indeed, we have reckoned in the previous paragraph that *time measurements must be reduced to spatial measurements.* Also, the modern definition hinges on the availability of synchronized clocks that remain so under displacement from a point to another, not to mention the possible effect of fields of force on these timers. Operationally, and as long as we are confined to the same inertial frame S (i.e. the source of light is stationary in S), the two definitions are of course equivalent.

We reiterate that Newton's global time was assumed to be readable at each point of space. The synchrony of all point-wise timers was partly circumvented through appealing to a universal timer formed by the fixed stars in the firmament. This seems to be a generalization of the approximately uniform global time set up in the region from which all our observations are conducted, namely the earth surface. The earth's global time is induced by the configuration of the firmament relative to the earth.

It is important to mention that synchronization in a uniformly rotating frame, or more accurately, in the part from which observations are conducted, can be achieved without appealing to light's signals. The existence of a global time in non-inertial frames motivates the following definition:

Synchronous frames: A frame s, not necessarily inertial, is said to be synchronous if it is endowed with a global time. In other words, the frame s can be furnished by a system of clocks that remain synchronous according to a specific criterion not requiring necessarily light signals.

19.3. Distance and Simultaneity by Contiguity

We proceed here to closely model the Newtonian conceptions of absolute space and time in a measurable way, but with observation through light signals is still discarded.

Imagine a train, consisting of n similar carriages, passing by a station pavement at a constant velocity $\vec{u} = u\vec{\imath}$. Assume that the pavement's frame $S \equiv X'OX$ is synchronous and s is a frame attached to the train. For simplicity we shall assume that both frames, S and s, are inertial. This assumption is certainly true for a short period of time. At an instant $T = 0$, as determined in the synchronous frame S, the train occupies the spatial interval $[0, L] \subset X'OX$ of the pavement; its rear o is at $O(X = 0)$ and its front b is at $B(X = L)$. According to the Newtonian concepts, the distance between two bodies at any instant of time is the same when measured from any inertial frame, and this comprises the length of a rigid rod which we naturally identify by the distance between its two ends. The length of a rod (or a unit of length), therefore, enjoys an *identity* that is the same in all inertial frames, and the length of the train is absolute in the sense that it's the same when stationary or moving at a constant velocity relative to S. Thus the Newtonian concept of absolute length is materialized in a measurable meaning just by granting a given unit of length an absolute identity. Indeed, if the length of each carriage is one unit of length, *SL*, then the length of the train when moving or stationary in S is $L = n.SL$. Because of the unit of length which is the length of one carriage is the same in S and s (i.e. it's invariant), the length of the train in s is also $L = n.SL$.

An important *consequence that follows from the absoluteness of length is the absoluteness of time.* Indeed, at the instant $T = 0$ in S at which the train *ob* occupied the interval $[O, B] \equiv [0, L] \subset X'OX$, the point $o \in s$ and $b \in s$ were contiguous to $O \in S$ and $B \in S$ respectively, and the length of the train *ob* was found to be equal to the length of a stationary train *OB* that happened to be had parked in the station *S*. Relative to the frame *s*, which can count itself stationary, the train *OB* is moving at velocity $-\vec{u} = -u\vec{\imath}$, and its length must be $L = n.SL$ because of its invariance. The frame s admits that the contiguity of $o \in s$ and $O \in S$ [or instead, b and B] signifies the same instant of time in both frames, and he has no objection to denote this instant as S did by $T = 0$, but he may doubt that the contiguity of b and B [the contiguity of o and O] took place at the instant of contiguity of o and O [b and B]. To eliminate this doubt we assume the contrary: (the contiguity of *o and O*) took place before (after) (the contiguity of *b and B*). In the first (second) case, *s* will find the length of *OB* less (greater) than *L*, which is a contradiction, since length is absolute. It follows therefore that if it was found at $T = 0$ in S that ($o \in s$ is contiguous to $O \in S$) and ($b \in s$ is contiguous to $B \in S$) then the same compound event takes place at the same instant in *s*, which we denote by $t = 0$. Since at the instant $T = 0$ in the synchronous frame S there corresponds to *every* point $B \in S$ a contiguous point $b \in s$, all clocks in s must read when o is contiguous to O the same instant of time $t = 0$. Therefore, when o and O are contiguous, we have

(19.3) $\quad X = x, Y = y, Z = z, T = t = 0 \; everywhere\ in\ S\ and\ s,$

with (X, Y, Z) and (x, y, z) are the coordinates of an arbitrary contiguous points $B \in S$ and $b \in s$ respectively.

Let's choose a unit of time ST in S equal to the period during which a carriage of the train *ob* that was initially exactly contiguous to one carriage of the train *OB* moves to become exactly contiguous to the next carriage of *OB*. As seen from *S*, and after a lapse of time ST, every carriage of *ob* occupies a spatial interval determined by the rear and the front of the next carriage in *OB*, except the last one which go beyond *OB*. Thus at $T = ST$ in S the train *ob* occupies the interval $[1, L + 1] \subset X'OX$ and such that every carriage of *ob* (apart from the last one) is exactly contiguous to a carriage of *OB*. The *new state of contiguity* corresponds to the displacement $SL = ST$ of each compartment. As it was proved in the previous paragraph, there corresponds to $T = ST$ in *S* an instant of time t in s at which the new state of contiguity is also realizable in *s*, and which results from displacing each carriage of *OB* by the same magnitude *SL* but in the opposite direction. But as determined in s, $SL = t$. Comparing the last two expressions of *SL* we get $t = ST$. Since *SL*, and accordingly *ST*, can be chosen arbitrarily, we permanently have $T = t$, or $T \equiv t$. Note that the new state of contiguity is envisaged in *s*, which considers itself stationary, as the train *OB* occupying the spatial interval $[-1, L - 1] \subset x'ox$.

Thus, accepting that length is absolute results in time flowing equably in *S* and *s*. Let's determine the coordinate of a carriage by the abscissa of its middle and assume that each train has an infinite number of infinitesimally small carriages extending indefinitely along both sides of the *X*-axis. We may envisage each carriage x of the train $s \equiv x'ox$ as a free body and apply the law of inertia in the frame $S \equiv X'OX$ (i.e. the pavement) to write

(19.4) $$X = x + T, Y = y, Z = z, T = t,$$

where both *x* and *X* refer to the coordinates in *S* of a carriage of the moving train $x'ox$ at the instants $T = 0$ and $T = T$ respectively. Or instead, we may conceive *x* as the coordinate of the carriage *x* relative to the train *s* and *X* is its coordinate relative to *S* at an instant *T*.

Or we may choose to consider the frame *s* stationary, in which case

(19.5) $$x = X - T, y = Y, z = Z, T = t,$$

where X is the coordinate in s of a carriage of the train $S \equiv X'OX$ at the instant $T = 0$ and *x* is its coordinate in *s* at an instant *T*.

To tackle the problem in its general formalism we consider an inertial frame *s* that is translating uniformly at a velocity $\vec{u}$ $(u > 0)$ relative to the inertial frame *S*. The following arguments are based on the assumption that length is frame independent (or invariant, or absolute).

-At an instant $T = 0$ there corresponds to each point $B \epsilon S$ a unique point $b \epsilon s$. If at $T = 0$ in *S*, (*o* is contiguous to *O*) and (*b* is contiguous to *B*), then by a similar proof to that presented earlier, these events are also simultaneous in *s*. The point $b \epsilon s$ is $arbitray\ with\ B \epsilon S$, and the set of all events of the form (*b* is contiguous to *B*) at $T = 0$ in *S* are simultaneous in *s*. This set of simultaneous events in *s* defines therefore an instant of time $t = 0$ in s. Thus there corresponds to each given arbitrary instant of time *T* in the synchronous frame *S* a unique instant of time *t* in *s*, which signifies the same instant of time in both frames. This implies in particular that simultaneity is absolute, in the sense that it is frame independent.

-An instant of time τin both frames is fully meaningful and may be identified by a unique state of simultaneous contiguity of the points of *s* and *S* as realized at that instant of time in the synchronous frame *S*. We restate that the frame *s* is synchronized through its state of contiguity with S at an arbitrary instant of time T in S. Since simultaneity by contiguity is valid for any two instant of time T and T' in S, the duration $\Delta T = T' - T$ is the same in both frames. The homogeneity of time follows from the homogeneity of the space and the law of inertia which dictates that $(\Delta X, 0,0) = (u, 0,0)\Delta T$.

- Since the frame s yields itself to synchrony by means of contiguity to the synchronous frame S, we may consider both frames as equivalent in terms of which is a hypothesis and which is a conclusion. In other words, it makes no difference to the result whether we start from S or from s as being synchronized by hypothesis and then conclude that other frame is also synchronized by means of contiguity. It follows that one system of synchronized clocks in one frame will be sufficient to determine time in both frames. Thus and regardless of his state of motion, any observer registers the time shown on the S-clock which is just contiguous to him. Of course, it makes no harm to imagine an additional s-system of clocks with each clock is always at synchrony with the S-clock that is contiguous to it, but this does enrich the case.

- The induction of time and distance in an inertial frame s through its state of contiguity with the synchronous frame S amounts operationally to the following: Assume that at T_0 as determined in S, the points $a \in s$ and $b \in s$ are contiguous to $A \in S$ and $B \in S$ respectively. Now

-We define geometric distance $d(a, b)$ between a and b in s by $D(A, B)$, where D is the geometric distance in S.

-We define the time reading at an every point $b \in s$ in s by the reading of the contiguous clock at $B \in S$.

19.4. The Galilean Transformations

Let $S \equiv OXYX$ be an inertial frame of fixed stars; which is the frame of the non-accelerating (=far from all matter) observer O that is not rotating relative to the fixed stars. This frame accommodates also all observers that are stationary in it. The frame S can be considered stationary and thus identifiable with the absolute space. The law of inertia then states that a free body b will move in S according to the equation

$$\vec{R}(T) = \vec{r} + \vec{u}(T - T_0), \tag{19.6}$$

with $\vec{u}$ is a constant vector and $\vec{r} = \vec{R}(T_0)$ is the initial position of the body at T_0. We may understood the last equation as defining a transformation from s to S (the Galilean transformations) if we imagine b as always stationary in an inertial frame s with origin o that coincides with O at the instant T_0. The relation (19.6) determines then the position $\vec{R}(T)$of the same body b in S at any instant of time in terms of its position $\vec{r}$ in s. The inverse relation

$$\vec{r}(T) = \vec{R} - \vec{u}(T - T_0), \tag{19.7}$$

which is a transformation from S to s with $\vec{R} = \vec{r}(T_0)$ is the position of a body B stationary in S and $\vec{r}(T)$ is its position in s at the instant T, should also be understood in terms of the law of inertia as describing a free body B moving at a constant velocity $-\vec{u}$ in s, with $\vec{R} = \vec{r}(T_0)$ is its initial position and $\vec{r}(T)$ is its position at an instant T.

If it happened and the bodies b and B were contiguous at $T = 0$, i.e. at the instant the two frames coincides, then $\vec{R}(T_0) = \vec{r}(T_0)$, and the relation (19.6) describes the motion of the body b in the stationary frame S, while (19.7) describes the motion of another body B in the stationary frame s.

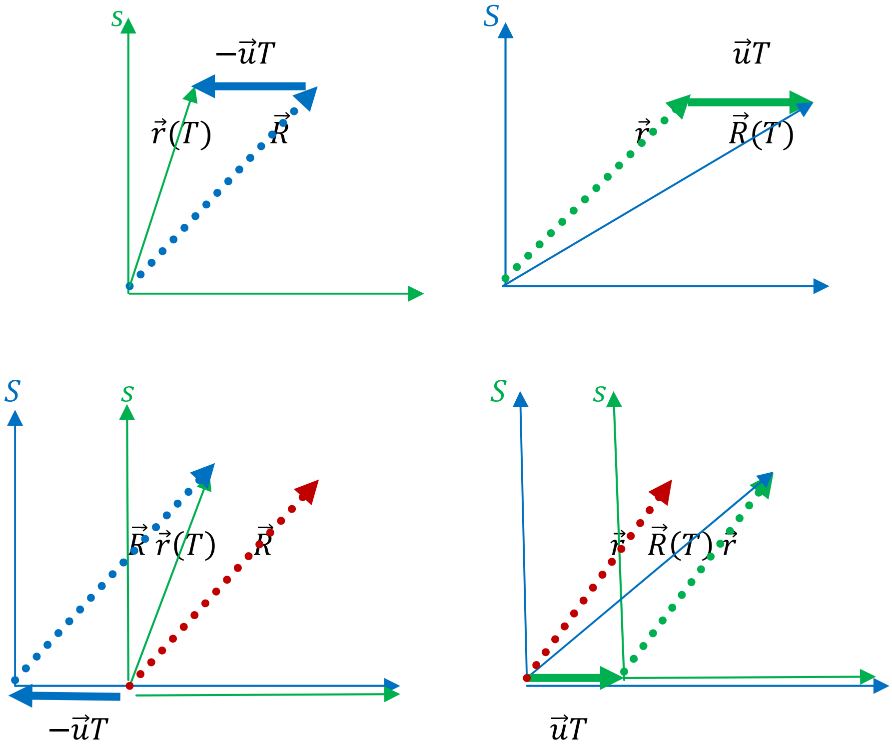

Fig.1. (top) the motion of a force-free body stationary in *S* (in *s*) as observed from *s* (from *S*). The dotted vectors represent the initial positions in *s* (in *S*) (bottom) motion of two contiguous free bodies with one body is stationary in each frame, as observed from *s* (from *S*). The red dotted vector is the initial position of the two bodies and the final position of the body which is at rest in the concerned frame.

In the Galilean transformations, the frames *S* and *s* are in essence observationally separated in the sense that direct observations through light's signals are either ruled out or assumed to have no effect on the results. Only local, or point–wise, readings of an event's characters (time and coordinates) from either frame are possible. Equivalently, one inertial frame is sufficient to describe motion, while the other frame can be dispensed with. Observers far from the event are imagined to be "rationally aware" of the characters of this event, or informed later of these characters through a light's message coded with these local readings.

It is important to note that accepting either inertial frame can be considered stationary while the other is moving, requires the existence of a third frame to which the state of being at rest is referred. The third frame is somehow close to Newton's conception of the absolute space; *it is the frame set up by a force-free non-rotating observe with respect to the fixed stars. Any given frame defined by the last statement is an inertial frame that can be identified by Newton's absolute space, and thus considered stationary, while all other inertial frames should then be considered moving with respect to this frame.* The last statement implies that no two inertial frames can be considered together stationary, with the understanding that the class of all inertial frames that are not moving relative to one given frame has been identified as one inertial frame. Contrary to the clarity of the concept of motion relative to a reference frame, the concept of an inertial frame being at rest is puzzling! *At rest with respect to what?* We have answered this question by identifying S by the frame of fixed stars, while demanding that every other inertial frame (i.e. every thing else) must be moving with respect to *S*. Note that the absolute space can accommodate only one inertial frame of fixed stars at a time.

19.5. Timed Inertial Frames

A timed frame is a stationary inertial frame (i.e. a frame of fixed stars) in which a global time has been set up using light's signals. The synchronization process is carried out in the familiar way, in which all clocks in S are synchronized with respect to a master clock at a point $O \in S$. A timed inertial frame therefore is a synchronous frame which is isotropic with respect to light propagation from sources stationary in *S*. As a result, the duration taken by light to travel along any fixed straight segment within *S* in one direction is the same as that taken in the opposite direction. The latter fact, which will be called the *strong Sagnac condition*, implies the "*literal*" *Sagnac condition*[23] which states that there is no time difference between the durations of any two closed trips enunciating from the same point and tracing the same path in opposite directions. While the literal Sagnac condition is *true in any inertial frame*, and may serve accordingly as a rapid practical criterion to single out inertial frames, the strong Sagnac condition, as it was see in (part X), is true only in a timed inertial frame *S*. If the inertial frame S is timed then the length and duration of a light trip within any other frame s that is translating uniformly relative to S is determined from its counter entities in *S* by the "scaling transformations".

The definition of a timed inertial frame is illuminated by the following comments:

- In a timed frame *S*, global time is compatible with geometric measurements. In fact, when we say that the length of a rod that is stationary in *S*, or the geometric distance between two points in *S*, is *L*, we mean that have we measured this length by a calibrated ruler, or by a light signal and two synchronized clocks, the two results will be L. In the second type of measurement, the length of the rod is $L = cT$, where T is the period taken by light to cross this rode from one end to another regardless of which end we choose as the initial point of the light signal. The phrase "*geometric measurement*" will be used for *spatial and time intervals measurements only in a timed inertial frame* employing length measurements or light signals, since both ways are equivalent. According to the way in which a global time is set up in a timed frame *S*, the strong Sagnac condition is automatically fulfilled in *S*.

-We may think ideally of a timed frame as any laboratory *S*, sufficiently far from all matter, and not rotating with respect to the remote universe. The unit of length - a meter - which serves to set up coordinates $OXYZ$ in the laboratory, serves also, when combined with the constancy of the speed of light within *S*, to define a unit of time and to synchronize all timers in *S*. The system of coordinates in the laboratory can be extend by the relation $c^2T^2 = X^2 + Y^2 + Z^2$. When the extended laboratory S is considered *stationary* (of course with respect to the remote universe) while all other frames are moving, *S* becomes a timed inertial frame.

- Starting from a timed inertial frame S a global time can be set up by contiguity in any other inertial frame s. Consequently *one system of clocks* in S (or in s) is sufficient to determine the duration and length of every light trip in any other inertial frame, or equivalently, it optical length and duration in *S*. The last statement implies that simultaneous events in *S* are also so in any other inertial frame. It is important however, to note that the frame *S* is an arbitrary inertial frame, in the sense that one should be able at any stage to view the other frame *s*, if inertial, as the timed inertial frame.

Summary

Upon slightly modifying the Newtonian vision of space and time, the Newtonian concepts of absoluteness of time and length can be retained and endowed with a measurable meaning. On adopting length as absolute, the modifications introduced and the emerging picture are summarized as follows:

-One arbitrary given inertial frame of fixed stars *S* is identified by the absolute space and every other inertial frame *s* is considered to be moving in this absolute space.

- *S* is is assumed homogeneous, and accordingly isotropic with respect to light propagation within *S*, or as to say that light propagates from any source $B \in S$ rectilinearly in all directions at a constant velocity *c*. Using this assumption, *S* can be furnished with a system of synchronized timers and possesses consequently a global time; it becomes thus a timed inertial frame.
- Distance and time in any other inertial frame *s* are induced from those in *S* by contiguity. As a result a given rod (or copies of such) serves as a unit of length in all inertial frames, and the system of clocks in *S* alone is sufficient to specify time at any location in any inertial frame; it is simply the reading of the contiguous *S*-clock. Simultaneity therefore is an absolute concept.

The scaling theory maintains the picture above fully. But moreover

-It determines the effect of the motion of a source of light on the travel time between this source and the observer.

- It privileges any inertial observer, but no more than one at a time, to consider his own inertial frame *S* stationary, and thus identifiable with the absolute space, while all other frames must be moving relative to his own frame.
- it relates the length (duration) of a light trip in *S*, i.e. its optical length (duration), to its geometric length (duration).