About Time

What is time?

To quote John Gribbin in the book “Q is for Quantum”. “Everybody knows what time is, but nobody can explain what it is.”

What Is proposed here is a physical explanation of time.

Physics is the study of the natural world with regards to the objects that make up the universe and the way these objects interact with each other. The motions of bodies such as the planets and projectiles were amongst the first studies that man had done on the physical world. The motion of planets and in particular the moon were observed to be cyclical, and the interval between each cycle to interpreted as a given period which is called time.

The cycle of the earth day and the smaller divisions of it into hours, minutes and seconds defined a standard for the duration at which one can measure a passage between two events. Clocks were invented to measure the passage from one event to another and took different forms in each age of human history and technological development.

A notion of ordered events leads to the conception of past, present and future, and a perception of a “flow” of time from past, to present, to future.

In conducting experiments and observation of projectile motion, and the motion of rolling balls on incline planes, Galileo, and in turn, Newton connected the motion of bodies to time elapsed as measured by a clock by creating the physical properties of velocity and acceleration. By using the invention of calculus, a mathematical description of an instantaneous physical property of velocity and acceleration was derived.

Instantaneous velocity, **v** is defined at a displacement point **p** from a reference point of origin **o**, as the limit of the change in displacement of **p**, divided by the change in duration or time elapsed between each measurement of displacement ∂t, as ∂t becomes infinitesimally close to zero. Mathematically is expressed as

$$\mathbf{v} = \lim_{\partial t \to 0} \frac{\partial \boldsymbol{p}}{\partial t} \qquad \text{ET 01}$$

Thus the relationship of the concept of time from this seed becomes incorporated into virtually all of mans description of the physical universe, where any change in the physical state of a body or system of bodies is concerned. But time is not a physical entity that can be seen or touched. It is a concept and a means of describing the order or events or processes that occur in the universe.

A description of time

To describe time, one must first give a description of a set of objects and their location or initial physical state in a space. If no change in any of these objects has occurred, it can be argued that no time has passed for this set of objects, and a condition of zero time exists for them as they have not had a change in the physical system that they exist in. If any one or more of these objects changes in any way, no matter how insignificant, then it can be argued that a physical event has occurred, and because of this, time has progressed. Extending this argument to the whole universe, the universe will experience a zero passage of time if every entity that makes up the universe does not change its physical state.

Thus a definition of time can be given as

Definition T1:

Time is the change of physical state of an entity or system of entities from physical state A to physical state B.

But then a question can be asked.

How can a duration or passage of time be measured or exist of an entity or system of entities that undergoes a change in its physical state?

That is, if the change in the physical state has no “observer” (ie an entity that can “see” or interact with the change in physical state), then how can there be a measurement of time?

It will argued that there cannot be a measurement of time here because there is nothing to compare a change in one physical system to another.

How can a non self interacting system be “aware” of a passage of time duration if it has nothing to compare a change of it physical state to?

A physical entity may change from state A to state B, and then from state B to state C, but it will not “know” which has the longer duration as no “observer” can exist within this system that has a “clock” to keep a record of the duration between events. Any “observer” within this system needs some kind of external “clock” (a system that changes from one physical state to another at a “constant” rate) that is independent or non interactive of events A, B or C to know that time has passed at a different duration for change of state A to B, and of B to C.

Eg: imagine an electron in a hydrogen atom changing from its ground orbital state (A) to that of another orbital state (B) after absorbing a photon. Then it undergoes a further change to orbital state (C) after another absorption of a photon. Any “observer” on this electron (ie the reference frame of the electron) would not “know” of any passage of time interval unless there is one or more intermediary steps between state A and state B, or between state B and state C. Such an “observer” would only “know” that time has passed since the electron is in a new physical state, not a concept of the duration of time.

Consider that an entity is considered to change its state in a consistent manner such that this change is considered as of a constant period of passage of time. Let this entity thus be a standard clock.

If there is some external “clock” that is at state X1 when the photon hits the electron, and is observed to be at state X2 when the electron is at state B then the passage of time is measured as X2-X1. If the external “clock” is at a physical state X3 when the photon hits the electron that is in state B, and is observed to be at state X6 when the electron is at state C then the passage of time is measured as X6-X3 and a difference in duration of the electron going from state A to B and from B to C is (X6-X3) - (X2 - X1). If X2-X1 = X3-X2 = Xn -Xn-1 = 1 unit time, have the difference of the duration of time of change of state between B to C and A to B being 3 - 1 = 2 units of time. That is, B to C is of longer time duration than A to B, and a concept of time duration can be understood in terms of using this “clock”.

This leads to the next question

Is there a minimum value of duration or time for a transition of some physical transition of some entity from one physical state A to another physical state B that can be used as a standard “clock” by which all passage of time can be measured by?

Assuming such a physical transition from state A to state B minimum time duration does exist, it could only be used as a measuring stick of time if it was periodic. If not, then a measurement of its time duration would not be possible as there would be nothing to compare it to. eg a second hand that only advances one second cannot be compared to a minute hand if that minute hand is the smallest duration of time that can be used as a time measuring stick. Ie if one cannot count how many seconds make up a minute, then how can one determine the time duration that one second is compared to a minute. A second would be known to be smaller than a minute, but not how much smaller.

Also, such a minimum physical transition time duration may suggest that it is the minimum permissible duration between physical states, and that no physical process can occur with a lower time duration. This minimum transition of time can be considered what is natures standard measurement of time, and is its clock which all other changes in physical states are to be compared to. Even if such a minimum time duration were not measurable.

This can lead to a new definition of the measurement of time.

Definition T2:

A measurement of time is the number of a standard metric intervals that it takes for one or more entities to change from one physical state into another physical state. The standard metric interval can be defined as the discovered minimum time for some entity to change from its given state A to another given state B compared to all other entity physical state transitions in the universe.

To conclude the above discussion.

If an entity or system of entities change from a physical state A to a physical state B in one single step, then a passage of time is detected, but not any perception of its duration. A duration of time passed is only perceived if some form of external “clock” can be observed that changes its state in a constant given manner that can be compared to the change in state of the entity/entities undergoing a physical transition. This also means that this “clock” must have a smaller or equal duration of the physical transition of physical state than that being measured.

A concept of time being quantized and of a minimum duration for any physical process to occur can be defined.

Local Time

In the universe that exists, the universe consists of what can be considered an infinite system of individual elementary entities, that has an infinite change in its state from one section of the universe to the other. The interactions between entities cause a change of physical states of those interacting entities in the universe, and hence the universe itself, including the processes in the human brain. The human brain has an ability to store memories of a past physical event and compare it to what is seen as current physical event or change of physical state of the surrounding universe. From this memory, a sense of continuity is perceived of the passage of time. This can lead to a perception is that time exists even when a change of state of the universe does not.

If a human brain and body has all the particles and sub-particles, energy exchanges etc remain in a single state down to the quantum level, then time does not pass for that human. The same can be said for any physical system including the universe. To perceive that time does pass when there is no change in physical state is incorrect for that entity or system of entities that undergoes no change in physical state. For an isolated entity or system of entities that undergoes no change of physical state, but exists within a larger system of entities surrounding that do have a change of physical state, then a perception of lost time can be argued to have occurred for that isolated entity or system of entities in human terms. Similar is the analogy of lost time when one sleeps. There is no perception of time is in the human brain while it is inactive. But when awaken, a passage of time has been perceived to have occurred.

In the physical world there is no such thing as lost time. For an isolated entity or system of entities, time progresses at a different rate when compared to entities or system of entities external to it.

That is, time or physical state progression of an entity or system of entities is a local, and not universal when considering an individual entity or system of entities within a lager universe. Taking the universe as a whole, the progression of time within it is lumpy and inconsistent from one region to another, right down to the quantum level.

That is, time is a local physical phenomenon for any entity or system of entities that has a change in the physical state from physical state **A1** to physical state **A2**.

Thus a new definition of time can be defined as given in definition T3.

Definition T3:

Time only exits between the change of state of a physical entity or system of entities from one physical state to the next. Time is only measurable in a relative sense between two or more mutually exclusive entities or systems of entities such that the change in the physical state of one physical entity or system is compared to another.

What this definition T3 means is that by comparing the changes in physical states between two or more entities or systems, each entity or system can act as a “clock” to every other entity or system.

Thus Time can be suspended, or slowed, or sped up for one physical system of entities when compared to another. This can be a system of entities that is part of a larger system. (eg an atom within a molecule) or two separate entities as part of the same larger system. Any change of physical state is independent of any other entity and the larger system they exist in, but one has a change of physical state while the other does not. As a result the one that changes its physical state experiences a time progression, while the other that undergoes no change in physical state does not.

To reiterate in a different form. If one entity E1 takes a greater number of standard metric time intervals (**Definition T2**) to change its physical state when compared to another, second identical entity E2 undergoing the exact same change of physical state, then entity E1 can be considered to have time slowed down, and time is sped up for E2. An “observer” independent of the entities E1 and E2 and is able to “see” and has its own “clock” to measure a progression of time, the changes in physical states of E1 and E2 would measure that E2 has changed its physical state before E1, and thus, time passes more slowly for E1.

E2 will “see” that it has time running faster than E1 as it has completed the physical transition whereas E1 has not,. E1 will not “know” that it has a slower time than E2 as when it has completed its transition from state A to state B, it will see that E2 is in state B but has no information to say when E2 reached state B. Simultaneously or prior to itself reaching state B. Neither would E2 be able to tell how long it took to reach state B from state A.

Only an “observer” that has an internal “clock” that runs “faster” than the transitions of state A to state B of entity E2 would be able to gauge which physical transition of E1 or E2 had occurred first. This “clock” would itself be a series of transitions of physical states that can be compared to that of E1 and E2. The “observer” is at sate O1 when the beginning of the transition of E1 and E2 from physical state A to B begins. At the “observers” physical state O2, E2 has completed its transition, and at the “observer” physical state O3, E1 has completed its transition. Only by been given information from this observer would each of E1 and E2 “know” when according to the observers clock measuring the changes in physical states they completed their transitions. The observer physical states O2 and O3 may have had many more transitions (eg ticks of the clock) of physical states between these, and “knowing” how many of these transitions had occurred, a standard “clock” can be defined for that “observer”.

If there are more of these “observers” also able to “see” and use their own clock to measure the changes in physical states of E1 and E2 from state A to sate B, then they may have a series of transitions of physical states that are different to observer O and observe these transitions of state that are inconsistent to observer O. Thus any standard “clock” to “measure” time must be the same exact physical transitions for all “observers”, which ideally would occur with the smallest transition of state compared to all other transition of state of any physical entity.

Note that in the above discussion, “observer” actually refers to a hypothetical situation where an entity or system of entities detects the physical states of entities E1 and E2, or has a means of detecting a change in the physical states of entities E1 and E2 at each step or change in its own physical state. This detection has a zero clock time delay between when E1 and E2 completing the transition from state A to state B and the “observer”, or that there is no difference in receiving a signal from E1 when it completes its transition to that of E2.

the word “see” refers to a signal being received from entity E1 and E2 that causes a detection or awareness of the state of E1 and E2 in every step or transition of its own physical states.

In Summary, local time is the change of physical state of an entity, or group of entities that is considered independent and a subset of a larger system, and that the duration of this change of physical state is also independent of any larger system.

Universal Time

If the universe were to be considered as a whole entity, and that the change in its physical state was just one atom transitioning from physical state A to another physical state B, then how can a measurement of time be made for this transition?

The simple answer based upon the argument for Local Time is that this is not possible. Time occurs, but can only be measured relative to some secondary physical entity that acts as a “clock”.

Now consider the universe as a whole where no entity within it changes its physical state. As determined by definitions T1, T2 and T3, time does not occur. Imagine that there is some hypothetical “observer” that can travel throughout the universe using as an origin some location in this universe. This “observer” can detect and know every physical state, and in turn, location of every entity within this frozen universe and records all this information. This “observer” traces its path back to the origin where it began its trek.

A definition needs to be given for the next phase of this hypothetical thought experiment, and that is a universal time step.

Definition T4: Universal Time Step

Within the universe as a whole, there is a minimum time interval that one, many or all physical entities can complete for a specific physical transition of state when compared to all other entities undergoing physical transitions. This minimum time interval for this physical transition compared to all others is called the universal time step or metric of universal time.

What this means is that the “observer” described in the paragraph above exists within this universal time step and can measure the progression of the universe in time against it. Also this “observer” does not interact with the universe in any way, which means the location that was chosen as a point of origin also does not change at any stage with respect to the universe as a whole at any point in time according to the “observers” time clock. To continue.

The universe advances one universal time step and the “observer” then repeats the procedure as stipulated above. ie The hypothetical “observer” travels throughout the universe from the specified origin previously defined. This “observer” detects every physical state and location of every entity within this frozen universe and records all this information. This “observer” traces its path back to the origin where it began its trek.

Now consider that this is repeated over and over again, giving a “history” of the universe in time and space. What is being described here is that the universe can be considered as a whole, a clock, of which the metric of the passage of time is definition T4. The universal time step.

That is, time can be considered as a quantum phenomenon if this concept of a universal time step exists.

Evidence that such a universal time step may exist is if the velocity of light is truly the maximum limit of the propagation of EM, gravitational and the strong and weak nuclear radiation or forces. Only by interacting with these forces does the physical state of an entity or system of entities change.

To find this universal time step, one clue may be the shortest EM wavelength (highest frequency) or the limit thereof. Propagating EM radiation can be considered as a change in physical state of the EM properties of space. The shortest wavelength may represent the shortest possible space in which a change in physical space can occur in, and in turn give the minimum, or indicate the order of magnitude of this universal time step.

If this universal time step does exist, would the universe actually run according to it as described above? If so, could it be determined if it does? This will not be answered here.

The description given above could be interpreted as the absolute time and space that Newton and others used to simplify the mathematical description of physical phenomenon rather than using a relative relationship of describing the universe. The merits or not of this will not be discussed, but the use of the description of the “observer” view above to illustrate a point, which is.

The universe must be considered that if frozen in time, a point of origin in time for the whole universe can be given and described. Consider this frozen universe as a snapshot or time slice of the “current“ state of the universe. By observing the universe by progressing it forward one universal time step at a time, a new way of viewing, and perhaps a greater understanding of the universe and the laws that govern it may be known.

However in reality, any observer in the universe such as ourselves cannot know this current state of the universe at any such given instant in time. This is because every entity or group of entities (including the whole universe) within this universe will only experience time if it changes its physical state. A change in physical state only occurs by interaction of an entity with one of the forces governing the universe. These forces can be considered to propagate from entities that have some kind of charge, eg electric, mass. This propagation itself can be considered as a change of the state of space. This propagation of the change of space reaches and interacts with another charged entity, changing its physical state and causing time to progress for that entity, and the universe as a whole. Thus the rate of this propagation is finite and infinitesimal compared to the universe as a whole.

What all this means is that a present change in the state of any entity in the universe, including the universe itself is a sum of previous field propagation from entities that themselves may not even exist in the frozen snapshot of the universe described above.

Thus time can only be progressed by the propagation of a force or field originating from a charged entity. This propagation, by current theory has a maximum velocity given by the speed of light. This implies the speed of light governs the rate of change of physical states of entities and their measurement. Einstein and others have shown in their theories how the measurement of time, and how observers in one reference frame is effected by their physical states in that reference frame, and having an interacting force influence its physical state from a source in another reference frame. The guiding principle is that the measurement of the speed of light is constant in all reference frames. This implies by the above argument that the change in physical state of any entity is also constant in all reference frames. If not, the laws of physics would be observed to change as the interactions between entities would become stronger or weaker in one reference frame when compared to existing in another.

This does not mean that an observer in one reference frame observes the same phenomenon in a different reference frame as being the same. eg the frequency of light in reference frame A can be observed to be different in another reference frame B if transmitted from reference frame A to B.(the Doppler effect). The theories of relativity give account of this. This is digressing and not in the scope of what is being discussed, so will go no further.

Implications

If a minimum period of transition from physical state A to state B for an entity , or universal time exists as defined in definition T4, then this would lead to physical equations involving time, such as that of velocity, being rewritten in such a manner as to take account of this universal time step. If the measurement of time is for a certain transition of state of an entity or system of entities, then any equation involving time describing that entity should be in regards to the measurement of time for that transition of state.

Eg when describing the motion of an entity, the minimum measured time (ϵ) it takes for that entity to move, the minimum permissible measured distance is the limit at which the time value should be taken to in any calculus calculation.

$$\text{eg} \quad \text{velocity } \mathbf{v} = \lim_{\partial t \to \epsilon} \frac{\partial \boldsymbol{p}}{\partial t} \qquad \text{ET 02}$$

Calculus is based on $\epsilon = 0$ for both differentiation and integration, and which simplifies differential and integral equations.

Adopting $\epsilon \neq 0$ may lead to more complicated mathematical equations, but would also be more accurate in describing the physical system. Using a time scale smaller than ϵ would result in errors if ∂t is of the same order of magnitude as ϵ. This is because the entity cannot have a transition of state occurring smaller than the time ϵ .This would be most notable on the quantum scale where measurements of ∂t is of the order of 10^{-12} seconds or less.

Consider this. If only one entity, say an electron, of the entire universe were to change its physical state, and hence undergo a progression in time, would the entire universe advance as well. By the definition T3 the universe as a whole would because this single electron is part of the universe, and being one part of the universe, which is a system of entities, only one entity needs to change its physical state for the progression of time for the whole to advance. But treated as a separate system of entities from this electron, this separated or sub universe would not progress in time relative to the electron that did.

What this means is that time is universal and local. Universal in that the whole progresses in time by needing only one entity to change its physical state for the whole to progress. Local in that any sub part of the whole progresses in time in a different step relative to any or all other sub parts of the whole.

Returning to the question. If this universal time step does exist, would the universe actually run according to it as described above?

If the reference frames in which physical phenomenon occur in can only be incremented by amounts such that they must obey some law involving this universal time step value, then perhaps.

Conclusion

In the discussion above in describing what time is, many references were made to the differences of comparable or relative rates of transitions of entities or systems of entities from the same physical state A to another physical state B. What is not mentioned is what would cause these differences. That is because an explanation of this phenomenon can be found in theories such as relativity. What has been discussed here is what time is and under what circumstances it can be measured, as well as some consequences of this interpretation.

The definition of what time is, is summarized by Definition T3

Time only exits between the change of state of a physical entity or system from one physical state to the next. Time is only measurable in a relative sense between two or more mutually exclusive entities or systems of entities such that the change in the physical state of one physical entity or system is compared to another.

One consideration that can be drawn from this discussion is that the progression of the universe, or any subset of it, can be considered as an iterative process, and that the universe is governed by the iteration of progressive steps from one state of the universe to the next in a feedback loop where a current physical state of the universe determines the processes that occur to progress to the physical state.

Time Travel

In all of physics and fiction, one of the most common themes of human desire and imagination connected to the perception of time is to be able to be transported to a location in time, either the far future or the distant past.

To be transported to the future is by the very nature of the world we humans exist in. What is desired is to do so instantaneously without aging. In the discussion of what time is and how to measure it as discussed above, and the definitions of time given, this is possible if that person wishing to time travel into the distant future can have his/her body physical state down to the atomic/molecular level ceasing to progress to the next physical state .The term for this is for the body to be in a form of temporal stasis. If a technology can be found to do this, or for a physical system that exists in the universe that can permit this, then this would be entirely possible. One is effectively, traveling at the velocity of light where theoretically, passage of time is zero.

What about time transportation into the past. To consider if this is possible, one must first consider what the consequences of doing this would involve. These are the physical consequences, not the philosophical human consequences touched upon in fiction or conjecture.

If any entity or system of entities (eg a human) where able to be transported into the past, what would be transported would be all that makes up that entity. ie mass, charge, energy, and space. All these quantities would be added to the past universe and subtracted from the universe from where that entity originated from. Without taking an equal sum of the quantities from the past to the present location of origin of the entity being transported to the past, would upset the balance of both time locations and all futures from each time location.

Without somehow performing this exchange, what would happen is that a past universe would have, say for one characteristic, have a greater mass. This would at first cause small insignificant deviations of that universe from whatever changes of state (ie time) it would have otherwise have progressed to. As the number of transitions of state progression occurs, (ie time increases) this may very likely result in greater and greater deviations.

This the leads to an unavoidable philosophical question. Does the act of sending something back into the past change the conditions of time from where it was sent back?

Assuming that it does, then the act of sending that entity back in time never occurred because the person never came to exist, or never performed the act sending the entity back in time with exactly the same conditions. Ie a paradox, and there are many of those littering the time machine landscape.

Now assume that it does not. The act of sending the entity back in time with exactly the same conditions will occur, subtracting mass from that time location and modifying the state of the universe at that time location into the future. This then says that the transition of state of the universe is set and cannot be changed. Every thought, action of every living or non living entity down to the quantum level is predetermined and unchangeable in all of the future sense of what we call time.

Another problem is information about the past universe so as that any time traveling entity would not end up in a period or part of the universe where conditions would not permit that entity to exist.

This is digressing and fanciful, but many believe that the universe can operate with some kind of future-past time connection. It is hoped that the case explained here touches on why this just simply cannot occur. There are many other examples that also illustrate why past time travel is just simply physically impossible.

Examples of hypothetical spacial constructions that may facilitate time travel can be found, but they never explain or give a credible argument as to how they could exist beyond the mathematical equations derived. Just because a mathematical model or equation says something can exist and act in a certain manner, does not mean it does without having empirical proof.

What seems to fascinate scientists and others about traveling into the past are the equations are derived and interpret as having terms that can be reversible in time. These equations should be interpreted as saying that a physical process that is time reversible means that an entity in a physical state A can change to a physical state B, and can also change from physical state B to physical state A. This be a natural self interacting process, or a forced process via external intervention.

A simple example to illustrate this point would be an electron of a hydrogen atom in a ground state A, absorbing a photon and progressing to an excited state B. Then this excited sate of the hydrogen atom can then progress to the ground sate C which is identical to state A.

Such a process is termed time reversal because it can never be known without being informed, the sequence these two processes in time. That is, the entity could have been in physical state B prior emitting a photon and progressing to A is just as valid as if it were in physical state A before absorbing a photon and progressing to B.

A more accurate description of one of these time reversible equations is that an entity or group of entities possess an inverse physical process as described for the hydrogen atom above. This inverse process does not reverse time or travel into the past as the name suggests, but rather both processes has a progression in state (and therefore time) which is also where the next progression of the surrounding universe physical state lies. ie travel into the future or rather next instant of the new current present.

Even if the entire universe is reversible and all of a sudden starts reverting to a prior existing state, it would still be progressing into the future, but the physical states it is progressing into will be a prior existing physical state. Any human brain that will progress separate to the entire universe, and observing this phenomenon may interpret is as a reversal of time. This would be incorrect as explained. A reversal of a physical process does not mean a progression in reversal of time and thus time traveling into the past.

This argument gives a case why there is no such thing as past time traveling or time reversal. Time is a concept based upon human experience. A physical explanation of time is that it is the progression of the physical state of the universe, in part and whole, from one physical state of being to the next. Thus the argument is also given that there is only one direction in human terms for the progression of time. ie into an unknown future.