

How Accurate is Your Watch?

by

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How Accurate is Your Watch?

What kind of equipment do you use for telling time?

Many people use a cheap watch or clock, with two or three hands, and make short-term observations (hours or minutes) by reading the hands. Others use quartz-controlled devices, with LED display, and boast of the split-second accuracy. I have in my laboratory a nano-second timer. With this instrument I can measure units of time much smaller than a millionth of a second. I use it to measure the speed at which shock waves travel through small pieces of rock; the elapsed time may be only 20 or 30 nano-seconds (billionths of a second).

But all of this equipment -- watches, clocks, timers -- only approximates the measurement of time. In the case of an electric clock, for example, if I plug it into the house current, I have only the degree of accuracy that is provided by the electricity: presumably 60 cycles per second, in the U.S., but this in turn is controlled by another piece of equipment somewhere, and I do not know that it is accurate.

We have three basic units of time, and two of them are spelled out by our planet. Some people have referred to the earth as "the clock on which we live," and this statement contains a lot of truth. But it is an uncertain

clock.

Our longest unit is one year. It is the amount of time required for the earth to complete one circle in its trip around the sun. The configuration of the stars is the sign-post that we use to tell us when we have gotten back to the starting point. This works very well for short intervals, such as a human lifetime; but not all the stars are travelling in the same direction or at the same speed, and therefore at some future date the sign-post will be quite different. For the time being, we have no basic unit of time measure any longer than the year. We assume that the year is constant in length, and therefore that we can use multiples (such as decades and centuries) without any major error.

Our intermediate unit is the day. This is the amount of time needed for the earth to make one revolution on its own axis. The word "day" has many valid definitions, some of them spanning intervals as long as 100 years and more. An example: "In the day of the Pharaohs, there were no automobiles." How long was that day?

For our purposes, the day is defined as being 24 hours. When we use the word "day" to mean weeks, months, or years, as in the example just given, or to mean a short period of time such as a working day of eight, or perhaps seven, hours, we are using very loose definitions. As a precise unit of time, a day is 24 hours long, neither

more nor less. It is then convenient to sub-divide that day, following tradition, into 24 hours of 60 minutes each, with one minute containing 60 seconds. From this point of view we see that a second is $1/86,400$ of a day. Therefore a second is a derived unit, as is a minute.

We have assumed that the year is constant in length. We are not able to make the same assumption about the day. In fact, we have a great deal of evidence to show that the day is slowly changing its value. The change, fortunately for our watches and clocks, is slow enough that it doesn't bother us any, but it is nevertheless real, and it gradually adds up to important numbers.

A day is one revolution of the earth on its own axis. But the earth is slowing down as it revolves. Because of the gravitational pull exerted by the sun and its planets, each rotating body is slowed until it reaches a lower limit. The moon has gone completely through this history, and now rotates on its axis only once during the time interval in which it circles the earth. The earth has not yet finished this evolution, but the planet Mercury has. Mercury, like the moon, always presents the same face to its primary. One specific side of the moon always looks down on earth; only when men travelled around the moon could they discover what the other side looks like. And one specific side of Mercury always

faces the sun. One side is always heated to the maximum, and the other side, always in the shadow, has the cold of empty space.

As the earth continues to slow down, it will eventually reach the condition where it rotates on its axis only once in one turn around the sun. That is, one face will always look toward the sun, and the other side will be in perpetual shadow. If the earth is slowing down, now, and is headed toward synchronous rotation and revolution, then it must have been spinning much faster in the past. This means that the day cannot be constant in length.

The rotation of our planet has changes which consist of two parts. One part is very regular, and is the long term deceleration mentioned above. The other part is quite irregular, and involves events when the rotation slows down suddenly, and other events when it speeds up, suddenly. We think that this erratic behavior is caused by motions deep within the earth, probably within the core. However, they appear to offset each other, and so we are left with long-term, highly regular slowing.

The rate at which the spin decelerates is two seconds per day every 100,000 years. You don't need to make a correction on your watch for such a slow change. But over the vast expanse of geological time, two seconds every 100,000 years is a big change. This is 20 seconds every million years, and 20,000 seconds every billion years.

20,000 seconds is 333 minutes, or 5.555 hours. That is, the earth is now slowing down, in its rotation, at the rate of 5.555 hours every billion years. This indicates that the day, one billion years ago, was 5.555 hours shorter than it is now: a day having only 18.445 of our modern hours in it. And farther back into time, the day was shorter still. 4 billion years ago, the day appears to have been about 2 hours long.

Certain fossil corals, collected from Devonian age rocks, have daily growth lines (the change from sunlight to dark, and back) and annual growth bands (the change from warm weather, to cold, and back). In the Devonian period, there were 400 days per year. Today, the year contains 8766 hours. This number, divided by 400, gives 21.9 hours (modern hours) in the Devonian day. If we spread this change over all the time that has elapsed since the Devonian, we obtain a slowing rate of 2 seconds every 100,000 years. This is the same rate that we got from modern astronomical observations. Because we got it in two totally different ways, we think it is reasonably dependable. But look what else we have acquired: the day may be our intermediate unit of time but it is not a constant unit.

We have now developed a series of ideas which, taken together, constitute a kind of "history of the day." During that long interval of some 15 to 25 billion of

years, after the universe had been created, but before there was any sun or earth, the "day", as a unit of time measure, did not exist. In the earliest part of solar system history, before the earth was organized as a coherent planetary mass, having a defined orbit and a defined period of rotation on its own axis, the "day" still did not exist. Only when the earth settled down to a steady rotation on its own axis did the "day" first appear. Since that moment, the "day" has been growing longer. This growth has been relatively steady for the most recent half-billion or billion years, and may have been steady for a much longer interval of time, but there is also the possibility that, in some part of its early history, the "day" was changed abruptly and spectacularly.

Our smallest unit of time is one vibration of a specific atom. I have skipped over the second, which is merely a subdivision of a day, and have gone to modern atomic time. An atomic clock, using the vibration of hydrogen atoms, can measure time so precisely that it can maintain an accuracy of one second every fifty million years. The basic unit of time here is smaller than a billionth of a second. Because this is such a small unit, it is convenient to express the results in conventional seconds. Therefore, the second has been re-defined, in terms of atomic time. This is an important advance,

because our earth is, after all, not a very reliable time piece.

We have mentioned astronomic time, having basic units of one year and one day. We have also mentioned atomic time, having a basic unit much smaller than a second. There is also radioactivity time, which has many units, no one of which can be shown to be basic; this has led to the practice of translating time measurements, by radioactivity methods, into years. That is, atomic time is translated into seconds, which are related to days; and radioactivity time is translated into years. These translations are made as of right now. At some future date, as the length of the day changes, an adjustment will have to be made between atomic time and the day, but this problem does not concern us at the moment. We do not foresee any difficulty in relating radioactivity time to the astronomic year. That relationship was established in 1950 and should hold throughout the future.

There are dozens of methods of measuring radioactivity time. All of them depend on the spontaneous decay of the nuclei of radioactive elements. These decay rates are among the best data points in science, because they do not vary in any way that can be detected. Therefore radioactivity dates obtained from a single planet, or a single planetary neighborhood, provided constant, consistent data. The popular fallacy that decay rates are, or may be

variable, is completely without foundation of any kind.

We now have three categories of time: astronomic, atomic and radioactivity. Astronomic time has two units (year; day). We observe that the day is slowly getting longer. Therefore the two units of astronomic time have a changing relationship. Atomic time is highly precise, but it can be used only to measure the present; it is of no value for the past. Radioactivity time can be used only to measure the past; it is of little value for the present. For long intervals of time in the past, radioactivity measurements, expressed in units of years, offer the best procedure. But the overall system is very complicated, and it contains one variable item, the day, which is, conceptually, the weakest part of the structure.

Lets pause for a moment and extract something of immediate benefit from all of this. We can draw three important conclusions.

1. The day (with its subdivisions), and the year, are limited to the earth. An observer on Mars, for example, could keep this same kind of time only if he were able to keep in close touch with the Earth. For the observer limited to working from the surface of Mars, the day is presently 24 hours 37.4 minutes long (Earth time), and the year is 687 days long (Earth time). Each planet has its own year, and its own day, and in almost every case, the rotation is slowing down. On Mercury, the

slowing down process has been completed, and the year is one day long. All of this information tells us that the units of astronomic time are highly local, and largely temporary: they are good only for "here" and "now."

2. The units of time vary, as time passes, in several different ways. The slowing of earth rotation was mentioned earlier.

3. Therefore modern units of time cannot be used, in time and space, wherever we wish to use them, and certainly not in the early history of the solar system.

If we have no good, useful, constant universal measure of time, what must we do? From a practical, day-to-day standpoint, we will continue to use the watches, clocks, sun-dials, or whatever, that we have been using all along. But when we think about origins of the system, we must keep clearly in mind that words like "day" and "year" do not mean anything except in terms of right here and right now. How long was a year, or a day, when the universe was created? This is a meaningless question. The Bible says that a day with the Lord is like a thousand years (Ps. 90:4, II Pet. 3:8). I take this to mean that we really have no feel for it. From a scientific point of view, we can say that we have no conception of it, because we do not know anything about absolute, unchanging units of time.

Is this confusing enough? Days and years are convenient, but they are only local and temporary. If you

could communicate with someone in the vicinity of a distant star, you would find that you could not talk about time at all; your time values, and his, have nothing in common.

We can measure time, one way or another, as indicated above, but in order to do this, we must have a measuring device of some kind, located in time and space, such as a clock placed on the surface of the Earth Now. If we don't have a suitable measuring device, we are reduced to dealing with subjective time. Subjective time is not the same as any of the three categories listed above, and, in fact, cannot be measured. A good understanding of subjective time can be gained, however. Consider two people, in the same room, for the same program. One of them enjoys it, and the other is bored to distraction. Neither has watch or clock. After it is over, ask them how long the program lasted. One might say, "It seemed like only four or five minutes." And the other might say, "It seemed more like four or five hours."

I once fell a short distance, during a hiking trip in the Rockies. An observer having no personal interest in the event might say that it happened so fast that he couldn't even time it. As the main participant, however, I felt sure that it took about four hours. That is subjective time. It cannot be measured. It is, nevertheless, very important, and enters into our perception of many

events. It confuses our accounts and distorts our memories. It may give insight into attitudes and reactions, but even careful statements of subjective time must not be understood to represent any unit of measure.

Once we strip away the confusion caused by subjective time, we still have a major problem. It is instinctive to think that surely, at the bottom of the tangle, there must be a single, simple basic unit which we can use as an absolute. Unfortunately, we have no hint as to what it might be.

In 1972 an important time experiment was reported in the scientific literature. In this experiment, the investigator made two round-the-world trips on commercial aircraft. One was taken toward the east, and one toward the west. That is, one trip was taken with the rotation of the earth, and the other trip was taken opposite to the rotation of the earth. Six atomic clocks were carried along. On the eastward trip, these clocks lost an average of 59 nanoseconds. A second contains one billion nanoseconds, so 59 nanoseconds is really not a very large error. However, for an atomic clock, it is serious. Furthermore, on the westbound trip, the average error was a gain of 273 nanoseconds. The important thing here is the relationship between the type of error, and the relative speed of travel. What we appear to be seeing here is a demonstration of the theoretical concept (due to Einstein) that the passage of time depends, in some very real way,

on the velocity of the instrument.

Now everything in the universe is moving. The earth moves as it turns on its axis; at the equator it has a speed of about 1,650 Km per hour. It also moves in its orbit, covering more than 107,000 Km per hour, or about 30 Km per second. The entire solar system has a velocity within our part of the spiral structure of the galaxy. The galaxy itself is turning, and in addition is moving at high velocity through space. Many other stars have velocities much higher than our own. Apparently time is a function of the velocity of the instrument, and the velocity depends on the location within the universe. This is in addition to the complications mentioned previously. Therefore even atomic time does not provide a universal constant unit.

According to the best available theory, time speeds up in a weaker gravity field, and slows down in a stronger gravity field. But the gravity field is not uniform throughout the universe. This last observation adds still another complicating factor.

We measure time, here and now, with very great precision. We obtain, by radiometric means, the duration of time (using modern, local units) since some important geologic event. But we cannot extrapolate our time into the ancient past, or into distant space.

It is very disconcerting to have to face the fact that

time apparently contains no universal absolutes, other than it passes, and that in a single direction.

In the light of all of the complications and uncertainties, what can we really say about time, other than that we measure it locally and are aware of at least some of the difficulties? I think that several observations are in order; I want to list seven of them.

1. God created it. There is no verse, that I know, that makes this specific statement, but I believe that it is part of his creation, and part of his design.

2. The statement that "evening and morning were the first day" must mean that God was marking out time in some way, and that the very flexible word "day" would be used, even though this unit was totally meaningless at that moment, well before the sun had been created. That is, "time passes," and in the absence of a standardized unit (one that is still good in 1981), the word "day" will be used to mean "whatever unit is convenient for God to use" in his attempt to communicate with us. It definitely cannot mean what it means now.

3. Time does not apply to us the same way that it applies to God. Perhaps it does not apply to God at all; or, perhaps, it applies to him but only in a limited way.

4. For us, time moves inexorably. We cannot slow it, and we cannot speed it. Only in "subjective time" can we change the rate at which it passes; and a nearby clock

shows us clearly that this is subjective only. This does not mean that the rate of passage of time is a constant; we do not know that. It merely means that we cannot control it. Can God control it? The answer to that question depends on what you choose to believe.

5. Time is allocated to us in quantities which we cannot measure in advance. On the other hand, time is not issued to God in a limited quantity. The concept of eternity, so frequently used in the Bible, is basically a statement that God has access to unlimited time. But we can neither increase nor decrease the amount allocated to us, except in the sense that we do, or do not, taken certain precautions. Jesus said that no one, by taking thought, can add anything to his life span (Mt. 6:27). In many translations this is given as "stature," but "life span" is a good translation, and I believe it is preferable here. Not very many of us would like to add, say 18 inches, to our heights, but quite a few would like to add perhaps 18 years to our lives. No matter how hard we think about it -- and this must include prayer -- we cannot increase the maximum length of life presently available to us.

Furthermore, this lack of information about the timing of future events, such as one's own death, must be extended to other future events also. The rich fool, in the parable told by Jesus, misjudged by a factor of

several thousand, and perhaps more than 5,000. He looked over his achievements with satisfaction, and then told himself that he had many years left to enjoy all the material things he had accumulated. But actually he had less than 24 hours. Each one of us always lives on the brink of physical termination. We may estimate, based on observations that we are able to make, but the estimates are -- commonly -- wrong. In my mother's family of 10 children one sister was particularly frail, whereas all of the others were obviously robust. This year, only the frail sister is still alive, and celebrates her 103 birthday.

Basically we have no information at all about the amount of time allocated, except in a few trivial cases, such as watching a person fall from the top of a 100 story building. We can control -- to a large extent -- the quality of our activities during the time available, but we have, other than the ability to take certain precautionary measures, no control over the quantity.

The dichotomy -- quality vs. quantity -- is a very interesting one. Which would you rather have? \$100 of genuine U.S. currency, or one million dollars of play money? A real home, and the small house in which it is located, or a sketch of a large and impressive mansion? I think most of us would choose quality rather than quantity. Isn't it interesting that God has given us

control over the quality, but not over the quantity, of time that we have available?

6. God expects an accounting of where and how and why we use the time that he has allocated to us. This accounting can be done, in some small measure, here and now; and each thoughtful Christian should undertake this exercise from time to time. But the primary accounting will be done later. Some of us have a mental picture of a judgment, in which each person will be called to stand before the Great Judge; and a bailiff (perhaps an angel) will read from a book, in which all of the brownie points, and all of the demerits, have been recorded. Let us, however, take one more step past this simplistic image. There is no book, except you yourself; you yourself are the record that is being kept for reading on that day. And there is no bailiff, except you yourself; you yourself will be called to be ready to read that record, with all of its flaws, not the way you will wish that they were written down, but the way they were actually recorded. You will be surprised to learn that some of the things that you were proud of, as victories, were actually defeats, but at that moment you will recognize them for what they were, for there will be no falsehood in the record as it is presented. But there will also be no reading, for each one will know, instantly, what kind of accounting he must be prepared to give. Fortunately, we

can preview this procedure today, and we can examine carefully the quality of time in our own lives.

We do not have to wait until we are finally allowed to glimpse the full majesty of God. Perhaps you would like to think that each of us has been given a bucket, the size of which is determined by the time that God has given us as a maximum allotment. Some people will be told that they are "on stage next," in that day, and they will take one look at the garbage that fills their buckets, and sneak away before they ever see the full panoply. To them the light will be harsh and glaring, and they will seek another place, where the contents of the bucket will look relatively good. Some people have already decided, here in this life, that they will examine the possibilities in each moment, and that they will fill the bucket with those thoughts and attitudes and deeds that will look good, then, for the reason that they were forged to meet God's standards, by means of his grace.

7. God is the creator and master of space and of time. This must mean, among other things, that he can move freely in the four-dimensional framework of space and time. He is not constrained by space, time or energy (but we must not interpret this statement to mean that he is capricious). God himself must be able to see all of time at one moment. I also believe that he can move

freely through time, or, perhaps better, that he can be present simultaneously at all moments in time, or perhaps best of all, that he is present simultaneously at all moments of time. A statement such as this should be a source of a great deal of awe, on our parts, but it also contains another matter of great importance: at the moment of death, a soul can be carried through time, by the hand of God, to some other moment, without using up any time. That is, when Stephen died, he could be carried by God, instantly -- without delay of any kind -- to the resurrection. No purgatory, no imprisonment, no way-station, no waiting room, no eternity of sleep.

Surely a soul -- not a body -- does not sleep, and Paul's language on the matter must be figurative. Sleep is a biological function, despite the fact that many Christians try to make it a spiritual function. What does the wide-awake soul do after death? The answer to this question, for many theologians, has been "purgatory," or "Paradise short of heaven" or some similar answer. But God is the creator, owner and director of time, and I believe that he can transport his child from the death experience, instantly, to the resurrection experience.

I do not wish to use Stephen's vision as evidence of this thought. The vision which one sees, at death, may be a mental construct, rather than any other kind of perception. I have been very close to death, myself,

and I know something about the mental constructs which one creates then, and I do not wish to use them as proof for a point of view about time, other than subjective time. I base my argument upon the simple assumption that God is free to move through, to occupy, to overstep, time.

The title of this talk has something to do with the precision of your watch, or your clock. It isn't very precise. It is good enough for us to use in our daily business, but it has no long-term precision worth talking about. Even the clock on which we live, our planet Earth, does not keep time very well. Perhaps it marks the year accurately, but it definitely provides us with a changing day. Fortunately, precision in a time-piece is of little importance outside of scientific research. Most of us do not use a watch to tell what time it is; we use it to tell what time it isn't, and for this we don't need great precision.

But time is more important than the measurement of time. It moves inexorably, it apparently varies in rate from one part of the universe to another, it cannot be reversed, and each of us has an unknown allocation of it. As we think about time, we get into concepts that are more important than mere time-keeping, and that may give us some insight into how God operates. This insight can be included in what we might call "the doctrine of

time." This doctrine is not stated explicitly in the Bible, but is implicit in much that is given to us in the Bible.

The most important thing we can say about time is that God has given to us the privilege of controlling -- not the quantity -- but the quality of time.

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