What Is Time?

Written in response to a class assignment involving the construction of audience, this essay comes in two versions: the first addresses readers with some knowledge of post-Newtonian physics; the second is for anyone who can tell time by a wrist watch or a clock tower and who enjoys reading magazine articles about perennially interesting subjects like time.

Version I

The nature of time has been an essential component of every theory since the beginning of physics. When he wrote down his three axioms of motion, Newton defined time implicitly with the statement, “Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external” (Wheeler 40). He set forth this definition so that he could apply his mathematical formalism and not worry that the quantity “t” in his equations might be affected by motion. This Newtonian concept of time as an absolute quantity was taken for granted throughout science, and indeed throughout society, for hundreds of years. However, as sometimes happens in physics, Newton assumed too much when he said that time is absolute.

Near the turn of the century, Einstein showed, in his theory of special relativity, that the concept of absolute time is without meaning, thus completely altering our conception of the nature of time. Measurements of time and space are intimately connected with motion; time intervals are dilated and space intervals contracted by a factor which depends upon the relative velocity between two given frames of reference. Moreover, if one carries Einstein’s reasoning beyond the simple ideas of time dilation and length contraction and through to its logical conclusion, one is forced to demote time from its status as an independent entity and to unify it with space. Time, then, becomes simply one dimension of a four-dimensional spacetime.
Einstein later formulated the theory of general relativity, which extends relativity to include non-uniform motion. To accomplish this feat, he discovered that it was necessary to allow for the possibility that spacetime is not flat, but curved, and that the curvature is determined by the strength of the gravitational field. One consequence of this reasoning is gravitational time dilation, that is, the phenomenon that time flows more slowly in the presence of a gravitational field than in the absence of one. Thus, not only is the flow of time not “without any relation to anything external,” but it also does not “flow equably” in different regions of the universe.

Today, general relativity is the accepted theory of gravity, and the concept of spacetime has become rooted in the minds of physicists. There are problems, however, when one attempts to combine general relativity with quantum mechanics. General relativity assumes that spacetime is continuous, that is, that spacetime intervals can be subdivided into arbitrarily small units. Quantum theory, on the other hand, predicts that at extremely small distances there will exist huge fluctuations in the energy density of “empty” space. These fluctuations would be large enough, in fact, to produce a non-trivial curvature of spacetime. Theoretical physicist John Wheeler and others (Wheeler 1201) have speculated that, at such extremely small distances, spacetime disintegrates into a “quantum foam,” in which virtual black holes are popping into and out of existence on an infinitesimally short time scale (speaking loosely, since our ordinary conception of time has very little meaning for such occurrences). In this realm, general relativity absolutely must be replaced by a quantum theory of gravity. To devise such a theory, it will probably be necessary to incorporate the discontinuity of spacetime, or to do away with spacetime altogether.

One candidate for a quantum theory of gravity is string theory, which proposes that the ultimate constituents of matter are not particles but tiny, one-dimensional extended objects called strings. String theory’s implications for the nature of time have not yet been sorted out, but there are indications that a complete theory of strings will not include space and time at a fundamental level; space and time will appear as quantities derived from the theory itself. In other words, string theorists hope to show that what we call spacetime is somehow made up of this mesh of strings extending throughout the universe. Physicists working in this area emphasize that, although string theory is highly speculative and not yet experimentally tested, it offers the best candidate yet for a
unified explanation of the universe (Green 183). If string theory lives up to the expectations of the theorists, it will imply that time is much more complicated, but also more interesting, than the simple “t” of Newton or the “tick” of a grandfather clock. With such speculations in the air, the possibility that physics could return to Newton’s universe (or even to Einstein’s) seems remote beyond question.

Version II

“Does anybody really know what time it is? Does anybody really care?” Chicago’s lyrics do not often provoke deep thoughts about the nature of the universe, but in this case, the questions are pretty good. Most people feel familiar with time; it takes sixty seconds to cook minute rice, and classes at Cornell last fifty minutes. What more is there to say?

A lot more, as it turns out. Physicists, the people whose business it is to worry about the things most people take for granted, have been thinking about the problem of time for quite a while. Back in the seventeenth century, Isaac Newton took the common-sense view: “Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external.” To Newton, time was just what it seemed to be—the regular tick of a clock. For three hundred years, this was the way everyone thought about time; there was nothing more to be said.

Then a young genius named Albert Einstein appeared on the scene and twisted the world up into knots with a radical idea, the theory of special relativity. According to this theory, which has passed every test physicists can devise, time is a lot weirder than Newton imagined, because its flow depends on how fast one travels. If you want to outlive everyone on Earth, all you have to do is climb into a spaceship, jet out into space, and travel around in a circle (at nearly the speed of light) for a few months. When you step out onto the landing pad, you may find, like the astronauts in Planet of the Apes, that centuries have passed in your absence.

Not content with his special theory of relativity, Einstein proceeded to work out the details of a general theory of relativity. This one did even stranger things to time. For one thing, it combined space and time into one thing called, imaginatively enough, “spacetime.” Since there are three directions in space (length, height, and width) and one
direction in time (tomorrow), this means that spacetime has four dimensions. Even worse, spacetime is curved! It’s probably impossible for three-dimensional creatures like us to visualize four-dimensional space, but general relativity does have measurable consequences. One consequence is that time flows faster on the top story of a high rise, where gravity is weaker, than it does in the basement. (Don’t think that you’ll get an edge on life by moving up one floor in your apartment building, though; the effect is measurable, but it’s so tiny that it takes atomic clocks to detect it at all.)

Beginning to feel a bit wary of your wristwatch? Worried that there could be something stranger even than general relativity? If you fret about such things, there remains cause for concern, because physicists of today think they might have chanced upon a theory to supersede even Einstein’s grand invention. The best candidate is called string theory, which, true to its name, postulates that everything in the universe can be understood in terms of strings vibrating in different ways and colliding with each other. In fact, the theorists hope to show that the universe itself, including space, time, and your wristwatch, is composed of strings. What this would mean is that, at some fundamental level, it is impossible to slice up time into shorter and shorter intervals. Time, according to this theory, would be made up of little pieces, tiny “bits” of time.

That’s an idea to set Newton spinning in his grave; it might even give Einstein’s imagination some twists. As for me, I’d just like to know if it can be sung to the tune of “Saturday in the Park.”

Works Cited
