

must reflect the flawless work of God, and that which he ordained us to do—which is, simply to admire and record.

KEPLER: It is widely known throughout all Europe that you excel, above all men, in these so-called art forms.

TYCHO: Therefore, I am *a god!* For he who is unable to live in society, or who has no need because he is sufficient unto himself, must be a god—as Aristotle has said.

KEPLER: Or a beast, as Aristotle has also said.

TYCHO: Is that Aristotle’s bad opinion?

KEPLER: Think about the root of these things. If one holds these instruments, and asks, “What are their uses?,” then one may come to a better understanding

of what prosperity is. We use them to further our knowledge of the world and the heavens, in order to increase our children’s well-being, do we not?

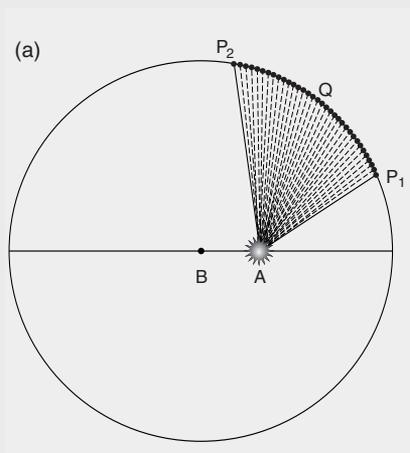
TYCHO: I don’t understand. To better our children’s well-being?

KEPLER: It is well known, today, that those awe-inspiring pyramids standing on the shore of the Nile, built by peoples so long ago, however beautiful, are meaningless to a civilization out of harmony. And by “out of harmony,” I signify the reckless disregard of human reason in seeking to further mankind. Man goes about the world seeking knowledge, and using that knowledge to better his surroundings, in order to live better and happier. If only we had a nation based on that today—a nation whose sole purpose was to perpetuate the happiness of men’s souls, by allowing them to participate in a process of making discoveries and implementing them to the benefit of themselves and their posterity. Today, war

## Kepler’s Physics of Non-Constant Change

Kepler’s revolution was, to derive the principles of planetary motion from physical principles, not mathematical ones. He conceived that the sun moved all the planets by a virtue (*power*) emanating from it, whose intensity diminished with distance. Thus, if the planet were moving in an orbit in which its distance from the sun varied, it would physically speed up and slow down as it moved around the sun.

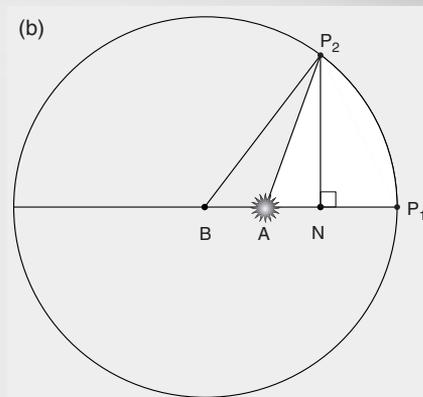
(a) The planet at  $P_1$  is closer to the sun  $A$ , than at  $P_2$ . Thus, as the planet moves from  $P_1$  to  $P_2$ , it is always slowing down. This



means that equal portions of the planet’s period do not correspond to equal distances along its orbital path. Kepler showed that these equal portions corresponded to equal areas swept out by a line connecting the planet to the sun.

(b) Kepler measured these areas. The area swept out as the planet

moves from  $P_1$  to  $P_2$  is the white area ( $P_1-P_2-A$ ). That area is measured by the portion of the circle,  $P_1-B-P_2$  minus the triangle  $P_2-B-A$ . The area of that triangle is the distance  $BA$  times the height  $P_2-N$ . But, the line  $P_2-N$ ,



as Nicolaus of Cusa showed, is incommensurable with the arc  $P_1-P_2$ . Thus, the principle of non-uniform planetary motion is dependent on magnitudes which are not susceptible of precise calculation. This gave rise to the famous “Kepler problem”: If Kepler knew where the planet had been, he could calculate what portion of the orbit (time) had elapsed. But, owing to the transcendental relationship between

and disease are all that nations seem to perpetuate.

TYCHO: Oh, Johannes! The young are easily deceived, because they are quick to hope. We make war, so that we may live in peace.

KEPLER: Where's the peace? Religious warfare has been raging since before my birth. In war, truth is the first casualty, our fathers the second.

TYCHO: Truth? We will never know truth.

KEPLER: So, even you don't think that man can know the truth, and that the truth sets men free?

TYCHO: Man can never and will never know the truth. All man can do is sharpen his eyes, so that he may better perceive that which is happening; but sadly, he will never know why it is happening. Do not look too much into the underlying causes of things; simply try to find a nice model that everyone can accept, which fits the description of what you see. And if at some time it no longer works, don't worry, just make whatever adjustments are needed to your system . . .

KEPLER: But . . .

TYCHO: . . . as long as it fits your observations, it will do just fine. Besides, you can never really know what is going on, especially up there in the heavens.

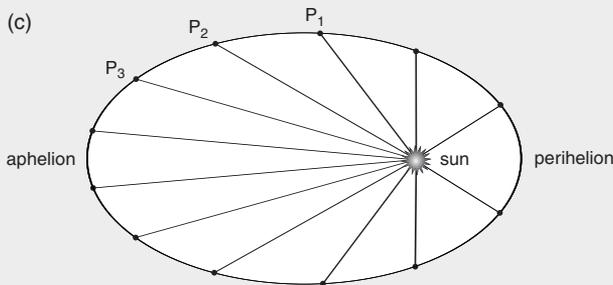
KEPLER: Take, for example, the observed motion of the planet Mars, god of war. See how he marches steadily across the sky, relative to the fixed stars behind him, in the same eastward direction as the rest of the planets and our moon. Yet, every two years he turns back westward, pausing for a brief moment before looping back eastward to resume his annual track. He certainly is a troublesome god, for not being able to proceed regularly along his perfectly circular orbit like this. [pause] The paradox leads me to wonder . . .

TYCHO: You and I can't solve that. All we can do is provide a model that best represents what is happening.

KEPLER: In other words, an *opinion* about what is happening?

TYCHO: Yes, an opinion.

KEPLER: Your beloved Hippocrates said, "There are, in fact, two things, science and opinion; the former begets knowledge, the latter ignorance." So, then, the question becomes, are we—but more specifically, you—a scientist at all?



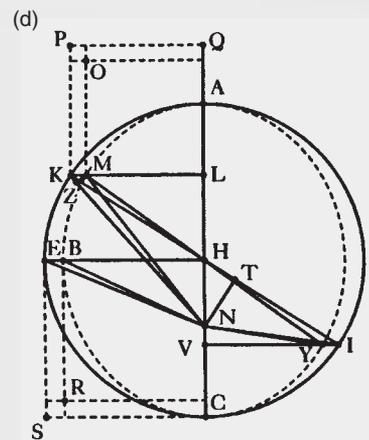
sun at an eccentric point. After comparing his results to the true observations, Kepler found he was 8' of arc off. It is a tribute to Kepler's

the line and curve, he could not precisely calculate where the planet would be when an equal amount of time would have elapsed. Kepler called on future geometers to solve this problem, which provoked Leibniz to develop the calculus.

(c) Kepler's initial discovery of the "equal areas, equal times" principle was developed under the assumption that the orbit was circular, with the

genius, that he saw that this small discrepancy was a matter of principle, not simply a minor error. He subsequently revised all his work, and discovered that the planetary orbits were ellipses with the sun at one focus.

(d) Kepler's diagram from *The New Astronomy*. The dotted curve is an ellipse. As you can see, this ellipse is very close to a circle, but as Cusa



had forecast in *On Learned Ignorance*, there is no perfectly circular motion in the created world.

—Bruce Director