the general science journal

What is π?

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Historically, *pi* is the numerical relationship between the diameter and circumference of a circle. It is a geometric constant. What do we mean by geometric? Operationally, geometry is the study of drawn figures. The ancients actually drew their figures on paper (and some of us still do). All the concepts of geometry applied to these figures. A line was a drawn line. A circle was a drawn circle. Of course geometry soon invented some other postulates to help with the mathematics. A point was defined as having no extension, a line was defined as having no width, and so on. But the equations were still understood to apply to the figures. Geometry was always only partially abstract.

In this context, *pi* was assumed to be a dimensionless constant. It transformed one length to another. This is clear from the basic equation: $C = 2\pi r$. You can see that *pi* takes us from one length to another and therefore we must assume it is dimensionless.

What I will show in this paper is that this assumption is false. I will show that *pi* is not dimensionless. It is not dimensionless for the basic reason that the circumference is not a length. Nor is it a distance.

It is true that in one sense the circumference is a length. In common everyday language, a circle describes a certain length. We can make a circle with a piece of string and then straighten it out and measure it. But in straightening out the string we have applied a pretty complex action to it. The straight string and the curved string aren't physically or mathematically equivalent. As we know, mathematics is a more precise language, or should be. It turns out that by being a bit more precise than anyone has ever bothered to be before, we can solve some of the mystery of *pi* and of the circle.

Let us study the operation of drawing or physically describing a circle. When you draw a circle your pencil always has some velocity. This is because time is always a consideration in any real event. Drawing a circle is a real event, not an abstract event. In fact, any possible circle must take time into consideration. This is true of orbits, bugs walking in circles, whirlwinds, and so on. When we apply mathematics to any of these situations, we must take time into account. That is why we find accelerations in all circular motion, the most famous of which is the centripetal acceleration. Centripetal acceleration can be due to gravity or to some other force, but in *any* circular motion there will always be a centripetal acceleration. This has been known for many centuries.

Geometry dismisses time as a consideration. Geometry is understood to be taking place at a sort of imaginary instant. For instance, when we are given or shown a radius, we do not consider that it took some time to draw that radius. We do not ask if the radius was drawn at a constant velocity or if the pencil was accelerating when it was drawn. We don't ask because we really don't care. It doesn't seem pertinent. It seems quite intuitive to just postulate a radius, draw it, and then begin asking questions *after* that.

It turns out that this nonchalance is a mistake. It is a mistake because by ignoring time we have ignored many important subtleties of the problem of circular motion and of circle geometry.

As a simple example of this, when we draw a circle on a Cartesian graph, we make an entirely different set of assumptions than the ones above, although few have seemed to notice this. You would think you could draw a Cartesian graph anywhere you wanted and it wouldn't make any theoretical difference to the geometry. You could draw a graph on the wall, on the floor, on any flat surface. You would think all you are doing is making things a bit easier on yourself as an artist and a geometer. Just as the old artists would square off their paper in order to make drawing a head easier, a geometer squares off a section of the world in order to create a tidy little sub-world where things can be put in order.

But all this is completely false. Drawing the graph changes everything. If you draw a circle without a graph, then you can say to yourself that the line (that is now the circumference of the circle) is a length. As a length, it can have only one dimension. A length is a one-dimensional variable, right? Perhaps you can see where I am going with this, and you say, "Wait, a circle curves, so we must have two dimensions, at least. We must have an x and a y dimension." Yes, at the least we must have that. You saw this because you began to think in terms of the Cartesian graph and you could see in your head that the curve implied both x and y dimensions. Very good. But you are not halfway there yet. Take the circle and actually put it into a Cartesian graph. What you find is that the curve is now an acceleration. In fact, any curve is an acceleration in a two-dimensional graph. We all learned this in high school, although I don't think it sunk far in for most of us.

That line that represents a circumference is taking on dimensions very fast now. At first we thought it was just a length. Then we saw that it required two dimensions. Now we can see that it is an acceleration. What next?

Unfortunately, there is more. The Cartesian graph we have put it into to show it is an acceleration is still just an x, y graph. We still don't have a time variable. A circle is a planar object, existing in a plane, but in the real world a curve on a plane cannot be created without time passing. A two-dimensional object requires three dimensions for its creation, just as a three-dimensional object requires four dimensions for its creation. You cannot draw or walk or describe a figure in a three-dimensional universe without taking time into consideration. Figures require motion and motion requires time.

All this is clear I hope. Nothing esoteric about it, although it may be a bit shocking to be reminded of it. Many readers will think I am talking only to young or naïve people when I say that this problem has remained obscure. But I am talking to everyone, the most brilliant scientists and mathematicians included. You young readers may find it amusing to see what famous scientists still do everyday with circular motion. Here is an equation that is used everyday, right now, by the smartest people alive:

$$v = C/t = 2\pi r/t$$

where v is the orbital velocity, C is the circumference and t is the period of the orbit. Newton used this equation. Einstein used this equation. Feynman used this equation. Every famous person you can think of used and is still using this equation. But it is an error of gigantic proportions. First of all, we have a curved velocity, which is impossible by definition. You cannot describe a curve with a velocity. Next, look at the form. We have C in the place of x, as if C is a simple distance. I have just shown that C is not a simple distance. There is no way to express C with just an x-dimension. In fact, as I have just shown, C is three-dimensional, if you include time. This equation is including time, as you can see by the denominator. You cannot have a t in the denominator and claim you are ignoring time. You cannot put a curve over a time and have it come out to be a simple velocity. Velocity is defined as x/ t. The variable x is one-dimensional and therefore cannot curve.

Now let us return to the geometric circle. All the equations of geometry are created by assuming that time is not a factor. You can't really just ignore time, so what the geometry does is assume that all underlying time intervals are equal. What does that mean, specifically? Well, it must mean that all the lines are understood to have been drawn with the same velocity. We can ignore the velocity since we *define* it as equivalent. What does *that* mean?

It means that the radius is a velocity itself. Go back to the Cartesian graph and you will remember that any straight line in the graph is a constant velocity. You know, the slope, the intercept, all that? Well, our radius is somewhat like that. Instead of writing r, we should write r/t. The radius is r/t. When we start comparing r to the circumference, we have to assume that the circumference is drawn with the same velocity. If we are going to ignore it later, as the geometry does, we have to assume that it is equal. So let's do that.

Axiom 1: the velocity of the radius is equal to the velocity of the circumference.

However, I have just shown that the circumference curves. Therefore it cannot be a velocity. How do we assign a velocity to the circumference? We have to assign it to the tangential component of the circumference, which is a straight line like the radius.

It helps some to think of it this way: say you are in a tiny spaceship at the center of the circle. You are instructed to fly at a thousand miles per hour for one hour, then turn left at a 90^o angle and keep going, not pausing or changing your velocity. You will say, "I need some method for calculating velocity. What if the background changes in some weird way after I make the left turn?" I answer, "Just measure internally. Meaning, use your onboard clock and check your engine's rpm. Whatever the rpm's were as you were going a thousand miles per hour along the first straight line, keep them there after you turn left." You do as I say and after exactly one hour you come to a rosebush and a sign that says, "left here." Miraculously you make the sharp turn without slowing down at all. After some time you come to the rosebush again and you think, "Is that the same rosebush? What is going on?" What is going on is that I turned on a big magnet as soon as you got to the rosebush. My magnet and I, sitting at the center of the circle, are causing you to circle us.

According to this set-up, your velocity out to the rosebush would be r/t. You were instructed to keep this velocity, by a method that would guarantee it was kept. Therefore your *tangential* velocity is also r/t. **You do not have an orbital velocity, since there is no such thing as an orbital velocity. Velocities do not curve.** What you have is a sort of orbital acceleration. It is a vector addition of your tangential velocity and the centripetal acceleration I have applied to you with my magnet.

Now, the question is, what centripetal acceleration must I apply to you with my magnet to keep you moving in a circle? Surprisingly, the answer is always the same. It doesn't matter what your speed is going out to the rosebush or how long it takes you to get there or how far away the rosebush is. As long as you keep your speed the same before and after you turn, the acceleration I must apply to you with my magnet is. . . . π.

That's right, π is a centripetal acceleration. Geometry ignores this by just erasing all time variables in its equations. It defines all underlying time as equal. What this means is that all straight lines in the drawing are understood to be drawn at the same velocity, so that everywhere you have a velocity, you can simply turn it into a distance. Everywhere you have a v, you can erase the t in the denominator and you end up with an x. This makes the radius just a distance.

The problem is that geometry also erases the t^2 in the denominators of any and all accelerations. This makes them look like distances, too. But they aren't distances. Most importantly, the circumference is not a distance, as I have shown. So let's correct the basic equation, expanding it with all the dimensions labelled.

$C = 2 \pi r$

$C\ (m^2/s^3) = 2\ \pi\ (m/s^2)\ r\ (m/s)$
If we want to do like the geometry and treat the radius as just a distance, then we can multiply through by the time, which gives us:
$C\ (m^2/s^2) = 2\ \pi\ (m/s^2)\ r\ (m)$

Therefore, if the radius is taken to be a distance, then π must be a velocity and the circumference has the dimensions of a velocity squared. [In this case we may call π the instantaneous centripetal velocity. If the radius is just a distance, then we are doing geometry, not a full analysis including all time changes. By current theory, this would tend to turn all our accelerations into instantaneous velocities. If we do this we match current orbital theory, which also finds an instantaneous centripetal velocity. Actually, current theory often continues to call it an acceleration, even at an instant, but this is a technical subtlety that is beyond the scope of this paper. Suffice it to say that there is no such thing as an instant. All variables exist only over intervals, so that if the radius is taken to be a distance, then *pi* must be a velocity over the ultimate, very small, interval.*]

This last equation is very interesting for this reason. Look at its form. It mirrors the current form of the basic orbital equation $a = v^2/r$. See the parallels between these two equations:
$C = 2\ \pi\ r$
$v^2 = ar$
I have just shown that π is the centripetal motion and that C has the dimensions of a velocity squared. Except for the 2 it is the same equation.

Which takes us to my paper at http://milesmathis.com . In that paper I showed that Newton and all historical derivations of the equation are flawed. The equation should be $a = v^2/2r$! This means that I now have geometric confirmation of my new equation. **The two equations are really the same equation.**

Written out in full, the orbital equation should read:
$a = x^2/t^3//2r/t$
If we simplify by multiplying the right side by t/t, then we get
$a = x^2/t^2//2r = v^2/2r$

We can call that last velocity variable an orbital velocity if we want, but I would strongly advise against it. In this simplified equation the numerator has the *form* of a velocity squared, but it is not a velocity by any meaning of the word. We would be much smarter not to simplify the equation. We should leave it like this:

$$a = \frac{x^2/t^3}{2r/t}$$

This will remind us that the numerator is not really a velocity squared and that v is not an orbital velocity by the current definition. That is, it is not equal to $2\ \pi\ r/t$.

Pi only applies if the tangential velocity is equal to r/t. But in orbits and most physical problems, this will not be true. The centripetal acceleration and the tangential velocity are independent motions. They are not necessarily related, much less equal. That is why we don't find the value of *pi* for the acceleration in gravitational fields. In these cases, given the equation:

$$a = \frac{x^2/t^3}{2r/t}$$

$x \neq r$

Therefore $a \neq \pi$

$x^2/t^2 \neq 2\pi r/t$

$a \neq 2\pi^2 r/t^2$

As I showed in my other paper, the correct equation is

$a = \sqrt{v_o^2 + r^2}) - r$

Where v_o is the tangential velocity.

If we let $v_o = x/t$

$a = \sqrt{[(x^2/t^2) + (r^2/t^2)]} - r/t$

$a^2 + 2ar/t = x^2/t^2$

$r/t = (x^2/2at^2) – a/2$

$2r = at^2$

$r/t = (x^2/4r) – a/2$

$a = (x^2/2r) – 2r/t$

Since the wrong equation has been used throughout history and is still being used, this must once again compromise our calculated values for orbital "velocity". For instance, if we calculate an orbital velocity for a satellite using the equation $a = v^2/r$, we must either get the wrong number for a or for v.

The reason our current values mostly work in calculations is that they are at least consistent. We make the same mistake in all calculations (and always have)—this makes it possible to compare one calculation to another and find correct proportions. This allows us to put satellites in successful orbits despite using faulty math and equations. Our engineers have gotten very good at making any necessary corrections to equations, since they are much practiced at it. If one equation doesn't work, they just use another, or tweek the old equation until it does work.

To be even more specific, $a = v^2/r$ works in experiment because $v = 2\pi r/t$ works in experiment. The equation $v = 2\pi r/t$ is a very useful number to us even though it does not really express the orbital velocity, or any velocity. It is more useful to us than the actual orbital velocity or the actual tangential velocity, both of which aren't really that interesting in experiment except as theoretical numbers. The number $2\pi r/t$ is a number we can use, and if we mislabel it as a velocity, well, who cares as long as we mislabel it the same way throughout the centuries?

Engineers aren't paid or trained to care about such things, but theoretical scientists understand that such mistakes ultimately lead to ruin. In the short term they may lead to simple engineering failures, which is bad enough. But in the long term they always lead to theoretical dead-ends, since a sloppy equation is the surest of all possible ways to stop scientific progress. A correct equation is almost infinitely expandable, since its impedance is zero. Future scientists can develop it in all possible directions. But a false or imprecise equation can halt this development indefinitely, as we have ample proof. Mislabelling variables is not a semantic or metaphysical failure. Is it failure of science itself.

Summation

We have discovered several important things.
1) *Pi* is a centripetal acceleration and has the dimensions of acceleration.
2) The circumference of any circle has the dimensions m^2/s^3, if written out in full.
3) If the radius is treated as a distance, then the circumference has the dimensions m^2/s^2.
4) *Pi* is not applicable to orbits or most other physical circles, since the tangential velocity is not equal to the radial velocity. **There is no *pi* in the sky.**
5) In orbits and all other circular motion $v \neq 2\pi r/t$. Something may equal $2\pi r/t$, but it isn't a velocity.
6) There is no such thing as orbital velocity. There is only tangential velocity. The curve described by an orbit is not a distance, nor is it a velocity. It has the dimensions m^2/s^3, just like the circumference.

I would like to thank Mike Newman, a reader who suggested to me in an email that *pi* might be an acceleration. This led me to compare the circumference equation to the orbital equation and discover their equality. This probably would not have occurred to me if I had not already proved that $a = v^2/2r$ in another paper.