Re: Another Rotating Cylinder Problem − explain from moving frame view

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- *From*: sal <pragmatist@xxxxxxxxxx>
- *Date*: Wed, 19 Apr 2006 22:16:45 −0400

On Tue, 18 Apr 2006 14:07:07 +0000, David wrote:

> On 17 Apr 2006 13:10:24 −0700, "sal" <SpamMeHere@xxxxxxxxxx> wrote:
>
>> David wrote:
>>
>>> Can anyone explain this rotating disk problem from the point
>>> of
>>> view of a moving observer?
>>>
>>> In the rest frame let there be two rotating disks of diameter D
>>> perpendicular to the x axis. Let the distance between the
>>> disks
>>> be L. Let there be a rotating cylinder of the same diameter
>>> and
>>> length connecting these two disk. Let the disks be massive
>>> and
>>> made out of steel and let the cylinder be made out of wax.
>>> Let
>>> the cylinder and disks rotate at one revolution per second.
>>>
>>> Let there be a frame moving along the x axis relative to this
>>> rest
>>> frame with some V. Let L and V be such that simultaneous
>>> events
>>> measured in the moving frame at each disk (separation L) are
>>> measured as a half− second time interval in the rest frame. At
>>> time t0 as measured in the moving frame a thin straight wire
>>> is
>>> simultaneously attached to the two disks at the top position
>>> of
>>> each disk and along the top of the wax cylinder. This is a
>>> straight line in the moving frame, but spirals around the
>>> cylinder
>>> making a half revolution as viewed in the rest frame.

> Now very slowly the tension of this wire is increased − the
> wire
> is stretched. This means the wire is very slowly approaching
> a
> straight line as viewed in the rest frame. As the tension is
> increased this wire cuts through the wax cylinder. Eventually
> the
> wire becomes a straight line and any further stretching of the
> wire does not change its shape.
>
> As viewed in the moving frame the wire is a straight wire on
> the
> surface of the cylinder rotating with the cylinder before we
> start
> stretching the wire. Now as the wire is stretched the center
> point of this wire eventually touches the center of the
> rotating
> cylinder (the x−axis) as the wire slices through the wax. Can
> anyone explain as viewed in the moving frame why the
> center of
> this straight wire cuts the wax all the way through to x−axis
> as
> the wire is stretched?

You may not realize just how complex this problem is.

You are asking about the forces on and tension in a wire which is in motion, where the forces and tension are measured by a _stationary_ observer.

For starters, you need to at least think about how a stationary observer would even _measure_ the tension in a wire that's in motion. The measurement is surely not going to be the same as the value measured in the wire's rest frame −− but we need to go beyond that simple assertion of what it _won't_ be. What _will_ the tension be, as viewed from the stationary frame? And what does it even _mean_? Until you've determined how you can measure the tension within an object which is in motion, without having the measurement apparatus co−move with the object, you don't have a working definition for "tension" in a moving object.

The rotating lever paradox is difficult, and it involves just a couple of torques; what you've described here is even more complex than that.

So I would suggest backing up and taking a running start. Go back to a simpler problem, and work out an analytic solution to that. Then tackle the more complex problem.

As a general rule, what you need to do is begin by analyzing the problem completely in the most convenient frame−of−reference you can find. Typically, that's the center of mass frame.

Here's an example of a simpler problem, similar to something you've posted in the past; I'll just sketch it (I'm sure you can fill in the details): Start with a spinning rod with a (straight) stripe on it. Viewed in a moving frame the stripe looks like a spiral. In the center of mass frame, let the stripe "fall off" and fly away. Now, describe _exactly_ what appears to happen in the moving frame.

Post the answer. Working that through completely will help a lot with your later problems, I think.

Then take the problem you've posted here, but instead of pulling the wire through the wax, release it so it can fly off. Figure out what happens in the center of mass frame (this may prove harder than you expect, even though it's "just" Newtonian mechanics!). Then map that into the frame in which the cylinder is moving, and tell us what the moving observer would see.

Finally, figure out how to transform _tension_ and _force_ between frames. Figure out the tension and 4−force on the taught wire in the center of mass frame, and transform that to the moving frame. Tell us what you found: post the transformation equations.

The latter is going to be difficult but would be a very useful exercise for you to do, and is a prerequisite for solving the problem you actually posted.

Once you've done that, you can apply your transformations to the "straight" wire in the moving frame and see if you can correctly predict that it will cut through the wax.

I, personally, have no plan to do this for you :−) but I'd be more than happy to look at (and, if possible, help with) any attempt at a solution you can come up with.

> If you post an explanation, does the same explanation work when
> the straight wire is simultaneously attached as measured in the
> rest frame and then the wire is slowly stretched?

The rotating cylinder problem is easy to visualize. I don't need an extensive math explanation just some simple verbage.

<g> OK, then let me ask you a simple question about it.

Let's suppose the cylinder lies on the X axis.

So, if the wire runs straight from one disk to the other, we would say that it makes an angle of 0 degrees with the X axis.

If, on the other hand, it is in a circle around the cylinder −− not a spiral at all, just a single loop −− then it makes an angle of 90 degrees with the X axis.

_IF_ the wire is to appear _STRAIGHT_ in the moving frame, what's the _MAXIMUM_ angle it can make with the X axis?

Obviously, it can't cross the X axis at 90 degrees, since in that case it's just a circle, not a spiral. But can it cross the X axis at angles arbitrarily close to 90 degrees? In other words, can it form a really _tight_ spiral? Or is there some limit to the "tightness" of the spiral it can make, and still appear to be completely straight in the moving frame?

Please post your answer. :−)

Actually the problem of the spinning spiral is pretty cool, and I hope to have more to say about it later. The wax cylinder makes it more graphic but you don't really need it in order to have a very confusing problem −− the spiral of wire alone will do the job!

> Here's the same problem without using rotations.

No, no, let's stick with one problem at a time. Besides, the spiral problem is quite interesting all by itself, as I already said.

The acceleration on the spiral of wire is the real killer −− the problem below hasn't got that aspect to it (which certainly makes it easier to deal with).

> This version doesn't have the graphic visualizations of the rotating cylinder problem. I'll provide the simple physics verbage for the effect in the rest frame and perhaps you can provide the simple physics (or math) verbage in the moving frame which I will start.
>
> In the rest frame I have a long rectangular steel rod (like a long two by four) aligned on the x−axis. The two end surfaces of this

> rod are perpendicular to the x−axis. Perpendicular to the x−axis is a wide conveyer belt (as wide as the rod is long). The belt is moving with some low speed along the y−axis. Now I have a moving frame that has velocity V=0.866c along the x−axis with respect to this rest frame. At time t0 moving frame observesr simultaneously place all points of the rod on to the conveyer belt. The placement is parallel to the x−axis.
>
> Rest Frame View
>
> After the accelerations have stopped and the rod is moving at the same rate as the conveyer belt the rest frame observers note that the rod is no longer parallel to the x−axis. They say this occurred because one end of rod was placed on the conveyer belt before the other end (SR view). They also measure that the end surfaces of the rod are also no longer perpendicular to the x−axis. They note that the acceleration of the rod was so small that chemical bonds remained intact and the rod did not change shape.
>
> Moving Frame View Now what is the verbage the moving frame uses for the same events? Observers in the moving frame measure that long edges of the rod remains parallel to the x−axis. But they observe that the rod has changed shape. The end surfaces of the rod are no longer perpendicular to the x−axis, nor to the sides of the rod. What explanation is given by these observers to explain why the rod changed shape? That is what I'm trying to understand.

While I think about this one, you think about it too, and see if you can answer this simple question:

Given that the rod appears parallel to the X axis in the "moving" frame, what is the _maximum_ angle the rod can (appear to) make with the X axis in the "stationary" frame?

Can the rod appear to be arbitrarily close to an angle of 90 degrees with the axis, or is there some smaller upper bound on the angle?

It's the same question as in the spiral case, of course, and once again it points up the fact that just imagining the objects is insufficient to understand what's going on.

You should also think about ways you could answer _all_ questions about the rod's orientation and apparent shape. How would you go about it, if you _had_ to find the answer and nobody was here to work it out for you? Could you apply the Lorentz transforms in some way?

Please think about that and try to post a procedure for doing it.

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Nospam becomes physicsinsights to fix the email
I can be also contacted through http://www.physicsinsights.org

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