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Electromagnetism and the Rolling Wheel

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Abstract. A rolling wheel is driven forwards by virtue of the linear momentum in the upper half of the wheel. A closer examination of the forces involved will reveal the hand of the centrifugal force. The analysis also provides a visual aid to understanding the basic principles behind Ampère's Circuital Law and time-varying electromagnetic induction.

Ampère's Circuital Law

I. When a wheel rolls on a horizontal surface, the Coriolis force will act to give the wheel a gyroscopic stability. When we compare the horizontal translational aspect of the motion to electric current, and the rotational aspect to the rotating electron-positron dipoles in the magnetic field, then we can see that a rolling wheel is in fact a large-scale manifestation of Ampère's Circuital Law. The dipoles sit on the wire like wheels, and their rotation axes trace out solenoidal rings around the wire.

We have already seen in ***'The Cause of Coriolis Force'*** at,

http://www.wbabin.net/science/tombe55.pdf

This has been withdrawn and superseded by *"The Inertial Helicopter"* which can be found at,

https://www.researchgate.net/publication/315655279_The_Inertial_Helicopter

how a Coriolis force can only act on a rigid body where a centrifugal force already exists. Centrifugal force will of course exist in the rotating wheel.

It is common to split the kinetic energy in a rolling wheel into the translational component and the rotational component. As such we might then only associate the centrifugal force with the rotational component.

However, for every element of vertical motion in a horizontally rolling wheel, we will have a perpendicular deflection in the direction of the horizontal translational motion.

This perpendicular deflection requires a force, and there can only be two sources for this force. On the leeward side of the rolling wheel, where the perpendicular motion is upwards, this deflecting force will be supplied by centripetal tension. On the windward side where the vertical motion is downwards, the deflecting force will be supplied by centrifugal pressure. This component of the centrifugal force would have been involved in the rotational motion if the wheel had been spinning freely and not rolling. It is still however present in the system, but it is now involved in causing the linear translational motion. The same applies to the centripetal tension on the leeward side that was mentioned above. It would have been involved in the rotational motion if the wheel had been spinning freely and not rolling.

Time Varying Electromagnetic Induction

II. If we linearly accelerate a rolling wheel, this will in turn give rise to an angular acceleration. This situation corresponds to the increasing magnetic field strength that accompanies an increasing electric current. Work will need to be done against the increasing linear and rotational inertia as per Lenz's law.

If we have a spinning wheel and we place it on a horizontal frictional surface, the tangential impedance will angularly decelerate the wheel as per the $-\partial\mathbf{A}/\partial t$ force, where $\mathbf{A}$ is the tangential velocity. This angular deceleration will be accompanied by a linear rolling motion which corresponds to an induced electric current.

If a powered wheel sits on a frictional surface, the wheel will angularly accelerate. But it will not angularly accelerate as much as if it had been suspended in space with no friction. Some of the input energy will be converted instead into a translational rolling motion.

Work needs to be put in to overcome the rotational inertia and the mass of the wheel, or in the case of electromagnetism, to overcome the rotational inertia of the electron-positron dipoles and the mass of the electric current. Wherever angular acceleration is involved, Lenz's law is involved. Additional work will also need to be put in to overcome rolling friction in

the case of the wheel, and to overcome electrical resistance in the case of electric current.

In part IV of Maxwell's 1861 paper ***'On Physical Lines of Force'*** at,

http://vacuum-physics.com/Maxwell/maxwell_oplf.pdf

he said when remarking on the curl format of Ampère's Circuital Law (which is also seen in the time-varying aspect of electromagnetism that is described in the Maxwell-Faraday Law),

"It appears - - - - that the connexion between magnetism and electricity has the same mathematical form as that between certain pairs of phenomena, one of which has a linear *and the other a* rotatory *character"*