

# The Coriolis Force is a System of Accountancy for Real Forces

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*Abstract.* In 1835 Gaspard-Gustave Coriolis drew attention to a mathematical term of the form  $2m\mathbf{v}\times\boldsymbol{\omega}$  that arises in connection with rotation. Many years later, this term was named the 'Coriolis Force' in his honour. Coriolis was working in the context of water-wheels and he was attempting to analyze the dynamics from the perspective of a rotating frame of reference. He drew the conclusion that the force which was later to bear his name, and which he himself referred to as the 'compound centrifugal force', is a supplementary force which appears in a rotating frame of reference. But he left the matter unqualified in some key respects and hence he paved the way for the Coriolis force to be wrongly interpreted as being merely an illusion that is observed from rotating frames of reference, and which is seen as the right angle deflection of a particle that is moving in any direction relative to the plane of the rotating frame. This is unfortunately the interpretation which prevails to this day. This article, for the sake of consistency, will continue to use the term Coriolis force for any force that satisfies the term  $2m\mathbf{v}\times\boldsymbol{\omega}$ , but will seek to establish the nature of any real physical forces that satisfy this term. It will be shown that real forces do exist which give rise to this formula, but that the direction of the velocity term is strictly defined, and not free to rotate like a weather cock, as Coriolis himself seemed to believe.

## Cyclones

I. The Earth's atmosphere co-rotates with the Earth's rotation. This absolute rotational motion produces an inertial effect in the atmosphere. When a region of low pressure arises, wind blows inwards towards the centre of the low pressure region. If it were not for the rotation of the Earth, we would have a purely radial phenomenon. But the inertial effect in the atmosphere due to the Earth's rotation causes the depression to be a cyclonic spiral effect.

The deflection of the wind in a cyclone, that gives rise to the spiral pattern, is traditionally attributed to the Coriolis force as per the understanding of Gaspard-Gustave Coriolis [1], but in actual fact this cannot be so. The cyclonic behaviour in a cyclone is a real effect that is observable from outer space. It cannot therefore be attributed to a force which is defined as an illusion that is observed from a rotating frame of reference.

The inertial effect does indeed give rise to forces of the form  $2m\mathbf{v}\times\boldsymbol{\omega}$ . But such inertial forces require a degree of qualification. First of all, in the case of the cyclonic deflection, the velocity term,  $\mathbf{v}$ , strictly refers to the radial velocity. And secondly, the  $\boldsymbol{\omega}$  term strictly refers to the absolute rotation of the element in question. And thirdly, we can have a different Coriolis force in relation to radial motion towards any origin that we care to choose. There will be a Coriolis force relative to the centre of the Earth's rotation, and there will be a different Coriolis force relative to the centre of the cyclone, each of which constitute an aspect of one singular real effect. The inertial Coriolis force is merely a way of quantifying a particular aspect of the very real inertial effect, and this manner of quantification is purely relative to the chosen origin.

The cause of the cyclonic effect in a cyclone is, at least in part, the real inertial effect due to the absolute co-rotation of the atmosphere. But it is not the entire cause. If we were to have a state of affairs in which inertia were the only factor, then we could not observe any effect relative to the inertial frame of reference, and hence we could not observe such an inertial effect from outer space.

There is in fact another force at work as well. There is the dragging force that causes the co-rotation of the atmosphere. If this dragging force were by chance strong enough to produce total rigid co-rotation, then the cyclone would reduce to a purely radial effect as in the stationary case. We would have no sideways deflection of the

wind within the depression. Yet in relation to the Earth centred rotation, in such a scenario we would still have an observable Coriolis force acting on north-south motion, due to the fact that the entire depression would be rotating with the rotation of the Earth. And in this case, the Coriolis force in question would be caused by a combination of two real effects. These two effects are (1) the inertial effect, and (2) the dragging forces.

As it is, the dragging forces are not strong enough to cause total rigid co-rotation, and so a sideways deflection of the inward wind occurs. And just as in the case of total co-rotation, the spiral cyclonic effect is caused by a combination of the same two real effects. Together, these two real effects cause the cyclonic behaviour in the oceans and the atmosphere when the dragging forces are not strong enough to cause total rigid co-rotation.

The Coriolis force is merely an incidental quantification of either of these two real effects or their combination, in relation to any chosen origin, and in cyclones it refers to the transverse deflection of a radial motion. It often arises in connection with the conservation of angular momentum, as is the case in both planetary orbits and in cyclones. Similarly, we can define an axial Coriolis force as being the axial deflection of a transverse motion. The axial Coriolis force is easily observed when a pivoted spinning gyroscope precesses rather than topples under gravity, but this observation is totally denied in modern physics for the reason that the cause is unknown. For the cause of Coriolis force see "Inertia and the Electric Sea" [2], and "Lenz's Law" [3], and for the cause of the axial Coriolis force in particular, see "The Cause of Coriolis Force" [4].

## Roundabouts

II. When a person tries to move on a rotating roundabout, they will experience a toppling effect. This is commonly attributed to the Coriolis force as per Coriolis. In actual fact, the person who is co-rotating on the roundabout will indeed have an inertial effect due to that motion, and any radial motion towards the centre of rotation will also involve a transverse motion relative to the inertial frame. The inertial effect will hence give rise to a Coriolis force relative to the centre of the roundabout. When the person is stationary on the roundabout, friction will be causing the associated dragging force, and the person will have established a balance. When the person moves, a new dragging force will be required in order to counteract the Coriolis force and hence keep the person's internal relative motion co-rotating. This dragging force, caused by friction at the feet, will cause a torque that will trip the person up. Without the existence of friction as a dragging force, this scenario could not exist.

If the person who is co-rotating on the roundabout observes an aeroplane flying overhead in a straight line relative to the inertial frame of reference, the path of the aeroplane will appear to be rotating. No Coriolis force is involved in this illusion.

## Conclusion

III. The modern concept of Coriolis force as being merely an illusion that is observed from a rotating frame of reference is unacceptable. Viewing any detached motion from a rotating frame of reference merely has the effect of superimposing a circular motion on top of the already existing motion. This circular illusion is not the effect that is catered for by the term  $2m\mathbf{v} \times \boldsymbol{\omega}$  which we will still nevertheless refer to as the Coriolis force for the sake of consistency. The Coriolis force

is in fact any real perpendicular deflection of either a radial motion into the transverse direction, or of a transverse motion into the axial direction, that arises in connection with absolute rotation. Coriolis force is real, and of course it then follows that the cause of Coriolis force is real. But it should be further clarified that the Coriolis force is merely the quantification of one aspect of a real effect, as measured relative to any arbitrarily chosen origin, and as such the Coriolis force is also a relative quantity. The Coriolis force is in fact an accountancy system in polar or cylindrical coordinates that describes aspects of inertia and other real forces. The cause of the real physical effects that cause the Coriolis force are in turn dealt with in more detail in the papers listed below in the reference section.

## References

[1] Coriolis, Gaspard-Gustave, "Sur les équations du mouvement relatif des systèmes de corps", J. de L'Ecole Royale Polytechnique, 24<sup>th</sup> cahier, p142 (1835)

[2] Tombe, F.D., "Inertia and the Electric Sea" (2009)  
<http://wbabin.net/science/tombe61.pdf>

[3] Tombe, F.D., "Lenz's Law" (2009)  
<http://wbabin.net/science/tombe54.pdf>

[4] Tombe, F.D., "The Cause of Coriolis Force" (2008)  
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