

STATIC AND DYNAMIC PHYSICAL LAWS

Does the vector derivation by transforming a rotating base into a fixed one (called the 'Frenet base') provide the mathematical proof of the existence of the centrifugal force? That's what we're going to check!

Some useful information

- A system of reference is a set of benchmarks to measure the characteristics of the movement of a mass. There are two types of systems: the general reference to describe a real movement, and the limited reference to describe an apparent motion.

The Earth is the general reference adapted to the description of the movement of cars and all they contain (passengers, luggage) because, as the name implies, land vehicles move relative to the Earth. On the opposite, a car can only be a limited reference that does not allow other description than that of the movement of passengers and luggage. This distinction was detailed in a folder to read elsewhere (see ADILCA folders).

- A force is any cause capable to change the speed or the trajectory of a body. There are two types of forces: the real forces and imaginary forces.

The real forces act remotely or by contact, they are at the origin of the movement observed in a general reference. There are only two forces acting at a distance: the gravitational force and the electromagnetic force. By cons, there are a multitude of contact forces, including those governing the movement of land vehicles. These are exerted on the tires in contact with the ground and they are four in number (driving force, engine brake, braking force and guiding force).

The imaginary forces (also called apparent strengths, fictitious forces or pseudo-forces), are of a different nature: they are supposed to be exerted on the center of mass of a mass to explain apparent movement or balance but can only appear in a limited reference or in a static description. Physics knows only three imaginary forces: inertial force, centrifugal force and the Coriolis force.

From reality to fiction

What is the transformation of a rotating base into a fixed base?

Mathematics and physics are certainly complementary, but we must avoid aligning calculations without considering their real meaning. In this case, the passage of a rotating base into a fixed base is a transformation that ignores the real movement. It is a purely imaginary projection. In other words, the rotation base is then considered to be immobile, and it is then necessary to resort to imaginary forces to explain an apparent equilibrium.

The conditional

How to separate reality from fiction? Here is an example:

- Sentence 1: I won the lottery \$ 300 and my grandmother left me \$ 700, I have \$ 1,000.

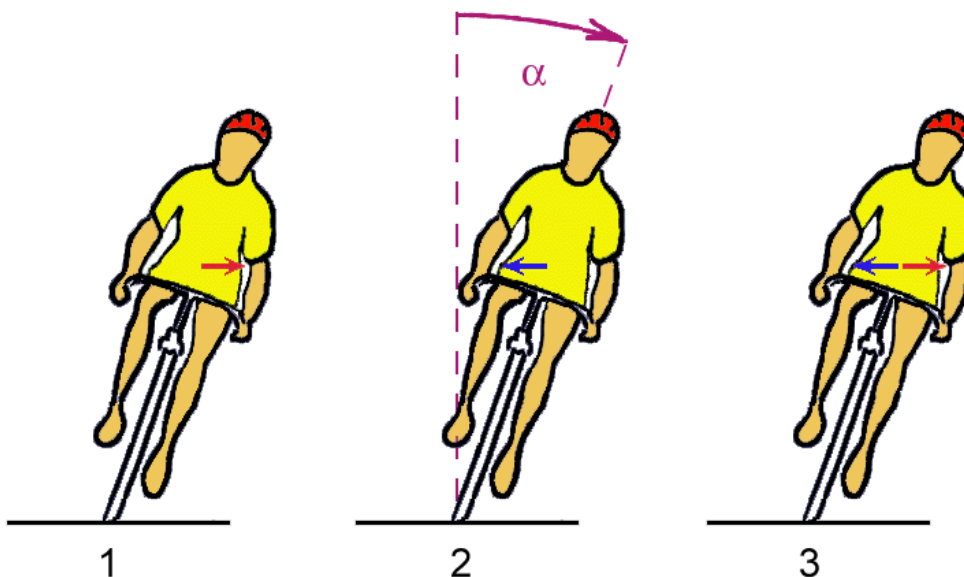
- Sentence 2: If I won the lottery \$ 300, and if my grandmother gave me \$ 700, I would have \$ 1,000.

We see that the two calculations are perfectly exact in both cases, with one difference, however: the money is real only in the first sentence, it is completely fictitious in the second sentence! These are the modes of conjugation that distinguish them, and there is no question of mixing them, neither from grammatical point of view nor from accounting point of view.

From dynamic to static

The same transformation is allowed as much in mathematics as in physics! Moving from a rotating base to a fixed base is like using this conditional, assuming here that the real movement is frozen. The first description is named 'dynamic', this is the real description. The second is called 'static', this is an imaginary description. But better than a thousand words, here is the example of the cyclist to illustrate this distinction.

Three drawings better than a long speech



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- Drawing 1: this is the real description, known as 'dynamic'. The rotating base is made of a cyclist on the bicycle. Concrete translation: the cyclist is moving and describes a circle. According to Newton's law, the cyclist was initially deviated from its straight path by a contact force F , unique and real, which causes the transverse acceleration of its center of mass, this is the guiding force (arrow red on the drawing 1). In reality this force is exerted in contact with the ground but, for better readability of the drawing, we 'transported' it to the rider's center of mass, that is one of the basic rules of vector calculus.

In this description, the proper relationship is:

$$\mathbf{F} = \mathbf{M} \mathbf{V}^2 / \mathbf{R}$$

A numerical example shows that if the mass of the rider is 100 kg (bicycle included, "g" = 10 m.s⁻²), the speed 10 meters per second, and the radius of its path 100 meters, the intensity of the guiding force is 100 newtons. Furthermore, an accurate measurement of the angle of the cyclist inclination relative to the vertical (from a photograph, for example) show us that, in these conditions, this angle is exactly equal to 5.7 degrees.

- Drawing 2: this is the imaginary description, called 'static'. The rotating base was converted to fixed base. Concrete translation: the cyclist is now motionless, he is no longer advancing. But it leans to one side! To prevent fall, the equilibrium condition requires the presence of a force \mathbf{F}' , commonly called 'centrifugal force' (blue arrow in the drawing 2).

This force is supposed to act on the cyclist's center of mass (if we neglect the mass of the bicycle). But that famous strength she really exist? No, because nobody has ever seen a cyclist, both motionless and able to stay balanced in such a position.

This force is called centrifugal force, that means 'distances from the center.' This term is it appropriate? Because the cyclist is motionless, there is neither trajectory, nor radius nor center. The correct name of this force is 'fictitious force', 'imaginary force' or 'pseudo-force'.

Another regrettable error: the relationships between quantities. Indeed, contrary to popular belief, the famous magic formula $\mathbf{F} = \mathbf{M} \mathbf{V}^2 / \mathbf{R}$ can never be applied to this description because the speed is always zero. An attempt to numerical application confirms it:

$$\forall \mathbf{M}, \forall \mathbf{R} \neq \mathbf{0}, \text{ pour } \mathbf{V} = \mathbf{0}, \mathbf{F} = \mathbf{M} \mathbf{V}^2 / \mathbf{R} = \mathbf{0} / \mathbf{R} = \mathbf{0} ! \dots$$

Here is this famous mathematical proof! And that's not all! What value to give to \mathbf{R} ? How measuring the trajectory radius of a motionless object? It is clear, clean and definitive: this formula does not work, it only leads to a dead end!

So how to calculate the intensity of centrifugal force? In truth, the only relationship that fits this description is the following:

$$F' = - P \cdot \tan \alpha$$

In this relation, P is the weight of the assembly and α its inclination angle relative to the vertical. Here, the [-] sign is decisive: it specifies the spatial orientation of this force that, obviously, should act on the opposite side of the tilt. We will see later why that sign is so important.

The digital implementation of this equation shows that for retaining a motionless cyclist with a mass of 100 kilograms (bicycle understood, "g" = 10 m.s⁻²) in a tilted position of 5.7 degrees from the vertical, he should have a force of absolute value 100 newtons.

A 100 newton force? What a curious coincidence! Or rather: what an extraordinary values correspondence, what marvelous precision of the physics, for chance and coincidences obviously do not have their place here!

These calculations show that, for an identical leaning angle, the guiding force (dynamic description) and the centrifugal force (static description) have the same intensity! Hence the confusion.

Beware! The accuracy of the calculation and the equality of the result do not prove the reality of the concept. Only one of these two forces is real, that is the guiding force. The other force is purely imaginary, we repeat, this is the centrifugal force.

And now, we will demonstrate that these two forces, and therefore the two descriptions which they relate, can neither complement nor mix!

- Drawing 3: it is a mixture of the two previous descriptions, a sort of fusion against nature intended to bring clear and definitive evidence that these two descriptions are totally incompatible.

In this description, the two forces coexist, but the vector calculation shows that these two forces of equal intensity but of opposite directions, cancel each other:

$$F + F' = 100 - 100 = 0 !$$

How to interpret this? A vector sum of zero means that everything happens then as if these two forces not acting: the cyclist is now released from all strength!

That is, if we reason in dynamics, the cyclist (who is moving) remains tilted but retains a straight path, he cannot describe any circular trajectory! And if we reason in statics, the cyclist (who is motionless) immediately falls, he cannot stay motionless and leaning at the same time!

This reasoning by contradiction must convince us that it is imperative to choose one of these two descriptions and forget the other! QED!

That is an absolute rule: never mix a rotating base and a fixed base, a dynamic description and a static description, the present and the conditional, reality and fiction!

Static or dynamic: the true definition!

The above brings us to these two definitions:

Is called a perfectly static description in which a moving base is considered motionless.

We call dynamic a real description of the movement and its causes.

Caution! Physics abhors mix of genres. We insist again on the formal and absolute prohibition to merge the two descriptions. Please note in passing a common mistake: confusion of the static and dynamic descriptions (see ADILCA files "*centrifugal force*" and "*inertial force*").

What misunderstandings, as setbacks, blunders for those, students or teachers who do not respect these precautions!

Centrifugal force: the true definition!

The distinction between statics and dynamics brings us to these two original and unpublished definitions of centrifugal force:

We call centrifugal force a transverse force that should be exerted on the center of mass of a motionless bicycle (we neglect the mass of the bicycle) to keep it in balance with the same leaning angle as that can be observed when describing a circular trajectory. This definition applies only in statics and is void if the bicycle is in motion.

For a car, this definition becomes:

We call centrifugal force a transverse force that should be exerted on the center of mass of a motionless car to create on tires and suspension a comparable effect to that which can be observed when the car is in motion and describes a circular trajectory. This definition, only valid in statics, lapses if the car is moving.

A purely imaginary force!

Emphasize the first requirement of this definition: the vehicle must be motionless. Then underline the hypothetical nature of this force, made clear by the use of the conditional '*force should be exercised*'... and finally, the technical impossibility to exercise directly any force to the center of mass of a mass.

Moreover, no one has ever seen with his own eyes such a force appear

spontaneously. We therefore deduce that the centrifugal force is an imaginary force. This is an apparent force, a fictitious or pseudo-force, i.e. a force that has no real existence.

The only force that really exists is exercised in contact with the ground, is the guiding force. It is the only force that deflects the initial straight path of land vehicles, and allows circular trajectories. There is no other force into play on this occasion!

Proof by the water bottle

How to distinguish a static description of a dynamic description? The experiment called 'water bottle' may be enough! This experience is to partially fill a plastic water bottle, preferably with syrup (mint, grenadine...) to color the content and then install the bottle flat across the handlebars or tank of a motorcycle.



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The experiment called 'water bottle' can reveal the true nature of the description. In dynamics, the liquid surface remains perpendicular to the motorcycle's plane of symmetry. In statics, the fluid falls on the side where the machine leans.

Then just go for a ride and observe the movements of the liquid during variations in trajectories: except brutal driving or shaking, the liquid surface is always perpendicular to the axis of symmetry of the motorcycle. It obviously would not be the case in statics!

This experience is very useful: when a teacher tries to draw some forces, ask him how will behave a liquid inside a bottle... You will know right away if the teacher reasons in statics, in dynamics, or if he is wrong!

What is the use of an imaginary description?

Beyond the controversy as fun as sterile, the real question to ask is rather this: why did physicists felt the need to invent imaginary descriptions? Reality is not enough?

Incidentally, this exercise of intellectual acrobatics, used by many teachers, constitutes a kind of 'donkeys bridge' intended to sort out the pseudo-scientific (those who confuse the pseudo-forces with the real forces!).

But the real explanation is not there. To the physicist, this intellectual construction is justified in the consistency of all descriptions, both theoretical and fictional they may be.

Thus Physics abhors a vacuum and physicist projects its rigorous logic everywhere, including in the abstract!

The fictitious forces are concepts that serve only to satisfy the need for coherence own theory. The fact remains that these forces are purely imaginary, they have no real existence. Pretend otherwise is fraud or incompetence.

Conclusion

The imposture is not the concept of centrifugal force! The only intellectual imposture is the confusion between reality and fiction, the present and the conditional, the dynamics and the statics. The only intellectual imposture is to believe or make believe that the centrifugal force trully exists!

Indeed, the least scientific and educational precaution is to always clearly specify the nature of the proposed description and to add that in the case of a static description, there can be only an imaginary description in which forces have no real existence. Then all description mixture is obviously prohibited.

Finally, the famous magic formula $F = MV^2 / R$ used almost everywhere indiscriminately can be applied only to a dynamic description, it can therefore express only one force: the guiding force. Spread the word!

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SOME RELATIONSHIPS BETWEEN QUANTITIES...

1. Guiding force

$$F = M \cdot V^2 / R$$

F: guiding force, expressed in **N**

M: mass, expressed in **kg**

V: speed, expressed in **m.s⁻¹**

R: radius of trajectory, expressed in **m**

consistency of the units: $F = \text{kg} \cdot (\text{m} \cdot \text{s}^{-1})^2 \cdot \text{m}^{-1} = \text{kg} \cdot (\text{m}^2 \cdot \text{s}^{-2}) \cdot \text{m}^{-1} = \text{kg} \cdot \text{m} \cdot \text{s}^{-2} = \text{N}$

Example: calculate the guiding force acting in contact with the ground and maintaining a bicycle + cyclist set of 100 kilograms (220 lb) on a circular trajectory of 100 meters radius (330 ft) at a speed of 10 meters per second (22.4 mph):

$$F = 100 \times 10^2 / 100 = 100 \times 100 / 100 = 100 \text{ N}$$

2. Lean angle

$$\text{Tangent } \alpha = F / P$$

α: lean angle, dimensionless;

F: guiding force, expressed in **N**

P: weight, expressed in **N**

consistency of the units: $\text{N} / \text{N} = \text{dimensionless}$

Example: calculate the lean angle when a 1,000 N bicycle + cyclist set describes a circular trajectory with a guiding force of 100 N:

$$\text{Tangent } \alpha = 100 / 1,000 = 0.1$$

$$\alpha = 5.7^\circ$$

3. Centrifugal force

$$F' = - P \cdot \text{tangent } \alpha$$

F': centrifugal force, expressed in **N**

P: weight, expressed in **N**

α: lean angle, dimensionless.

consistency of the units: $F' = \text{kg} \cdot \text{m} \cdot \text{s}^{-2}$

Example: calculate the centrifugal force that should be exerted on the center of mass of a motionless bicycle + cyclist set weighing 1,000 N, in order to maintain it in equilibrium despite a 5.7 degrees lean angle:

$$F' = - 1,000 \times \text{tangent } 5.7^\circ = - 1,000 \times 0.1 = - 100 \text{ N}$$

Note 1: this force is commonly referred to as "*centrifugal force*" which is an incorrect name since there is neither trajectory nor center (the bicycle + cyclist set remains motionless all the time). The scientific name of this force is: imaginary force, fictional force, pseudo-force, or inertial force.

Note 2: the sign [-] is mandatory, it specifies that the spatial orientation of this force is contrary to the logic of the movement.

Note 3: beware to misinterpretation, the numerical equality of results does not allow the interchangeability of descriptions, concepts or reasoning.

Note 4: the different calculations must be done in the order indicated. It is indeed impossible to directly calculate the centrifugal force without performing the intermediate calculations detailed above.

Note 5: any scientific approach is based on the same principle: from experiment, observations and *measurements* (here: measuring the mass of the set, its speed and the radius of its trajectory), to then allow *calculations* (here: calculation of a force and a lean angle), and finally lead to a *reasoning* (here: the concept of centrifugal force). This passage from the concrete to the abstract, from the real to the imaginary has often been short-circuited, hence the confusion and misunderstanding about the centrifugal force.

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