From *Notre-Dame* to Norton Dome: Collapse and Reconstruction of a Cathedral of Determinism.

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Abstract

The Norton Dome is a beautiful problem in theoretical physics that is supposed to challenge the principles of causality, inertia and determinism in Newtonian mechanics. A static undeformable ball at the top of a dome of a given shape seems to move spontaneously at a certain moment, without the help of any external net force. We try to show here that the perfect rotational symmetry of the problem has not been taken into account as it should be in its solving. In this approach, we distinguish between trajectory study plan and real trajectory plan: the section of the dome in which the object will evolve or not isn't the result of a free choice or a probability but the pure consequence of physics. The differential equations of motion integrated over the entire dome precisely tell us that, if it moves, the ball should take all directions, which brings us back to a basic logical contradiction not with determinism or completeness of Newtonian theory, but between the solutions themselves: under penalty of ubiquity of the ball, its stable rest at the top remains the only known true solution to the Norton problem.

1. **Presentation of the problem.**

As early as the 19th century, scientists discussed the validity of Newtonian determinism, which had been elevated to sacred dogma a century earlier by Laplacianism [i]. They revealed multiple solutions to certain differential equations arising from the fundamental principle of dynamics, whereas determinism dictated one and only one behavior of a moving body in a force field based on given initial conditions. In the midst of the rise of spiritualism, mathematical objects in turn began to levitate or slide on their own, free wills awoke in matter, and 'phantom actions' were reported at the very heart of the austere rationalism of classical physics. Even the traditional distinction between cause and effect was no longer a given.

However, the fires and blows struck against the cathedral of determinism by these few poltergeists of science were considered anecdotal. "Abnormal" solutions only appeared in situations that are themselves "exotic", imaginary forces or infinite systems of masses pushed to the extreme...until a 2003 article by John Norton [ii] where he presents the entirely credible case of indeterminism of a ball in equilibrium placed at the top of a dome of well-defined shape in a most banal gravity field:

> While exotic theories like quantum mechanics and general relativity violate our common expectations of causation and determinism, one routinely assumes that ordinary Newtonian mechanics will violate these expectations only in extreme circumstances if at all. That is not so. Even quite simple Newtonian systems can harbor uncaused events and ones for which the theory cannot even supply probabilities. Because of such systems, ordinary Newtonian mechanics cannot license a principle or law of causality. Here is an example of such a system fully in accord with Newtonian mechanics. It is a mass that remains at rest in a physical environment that is completely unchanging for an arbitrary amount of time—a day, a month, an eon. Then, without any external intervention or any change in the physical environment, the mass spontaneously moves off in an arbitrary direction, with the theory supplying no probabilities for the time or direction of the motion.

In the following, we will say indistinctly particle, mass, ball, object…to speak about the unit mass point. First, J. Norton classifies the notion of causality into what he calls "folk science". To support his thesis, he presents us with this dome:

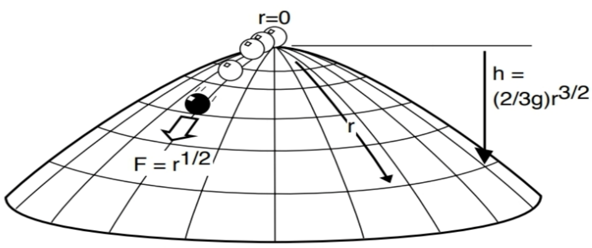


Figure 1a. Mass sliding on a dome

> A point-like unit mass slides frictionlessly over the surface under the action of gravity. The gravitational force can only accelerate the mass along the surface. At any point, the magnitude of the gravitational force tangential to the surface is $F = d(gh)/dr = r^{1/2}$ and is directed radially outward. There is no tangential force at r=0. That is, on the surface the mass experiences a net outward directed force field of magnitude $r^{1/2}$. Newton's second law, F=ma, applied to the mass on the surface, sets the radial acceleration d^2r/dt^2 equal to the magnitude of the force field:
>
> (1) $d^2r/dt^2 = r^{1/2}$
>
> If the mass is initially located at rest at the apex r = 0, then there is one obvious solution of Newton's second law for all times t:
>
> (2) $r(t) = 0$

He then deduces an infinity of possible solutions: the mass seems capable of moving without cause in any direction and at an arbitrary instant. More precisely, a unitary point mass, initially at perfect rest, will slide without friction, delivered to the sole force of its tangential weight, along the wall of a dome of equation :

$$h = \left(\frac{2}{3g}\right) r^{3/2}$$

In the polar coordinate system attached to the point, the weight vector **P** has the following components:

$$P_r = g\sin\theta$$

$$P_\theta = g\cos\theta$$

where **θ** is the angle between the tangent to the dome at a given point and the horizontal **x**. We then obtain the following relations:

$$\sin\theta = \frac{dh}{dr} \qquad P_r = \sqrt{r}$$

$$\frac{dh}{dr} = \sqrt{r}/g \qquad P_\theta = \sqrt{g^2 - r} = -R$$

from which we deduce the dynamic equation of the point identified by its curvilinear coordinate **r**:

$$\frac{d^2r}{dt^2} = \sqrt{r}$$

The reaction **R** of the support, directed along the normal to the tangent vector, in turn verifies the equation and the inequality :

$$\frac{1}{\sqrt{r(g^2 - r)}}\left(\frac{dr}{dt}\right)^2 = \sqrt{g^2 - r} - R$$

$$R \geqslant 0$$

The 2nd condition allows the mass to remain in contact with its support. It is clear that **r** is positive and must remain less than g^2, but the mass takes off as soon as its speed exceeds a certain critical value depending on **r** :

$$v_{crit}(r=0)=0$$

$$v_{crit}(r>0)=\sqrt[4]{r}\sqrt{g^2\cdot r}$$

We then obtain two types of solutions to our differential equations. One is the classical solution of rest for all **t** of the mass at the top :

$$\forall t,\ r(t)=0$$

The other new family of solutions that Norton derives is the following :

$$\forall T\geqslant 0,\quad \begin{cases} t<T: & r(t)=0 \\ t\geq T: & r(t)=\frac{1}{144}(t-T)^4 \end{cases}$$

In other words, at any instant **T**, the ball at rest, in perfect equilibrium between its weight and the reaction of the support (therefore a zero net force), leaves its summit and begins to slide without any added physical intervention. There is an apparent violation of causality (no reason for the movement) and of the principle of inertia according to which any mass at rest or in uniform rectilinear translation perseveres in its state as long as no external net force acts on it.

Another issue is how such a breaking of symmetry (a random trajectory starting from the top) can occur in such a perfectly symmetrical problem ? Newtonian mechanics should respect the famous principle of symmetry…In reality, as we will see, the latter also applies to problems with multiple solutions when these are superimposed. This is the case for Norton's possible dynamical solutions around the axis.

But the fact that **T** is arbitrary also implies a contradiction with determinism: the same initial state seems to lead to an infinity of possible trajectories. According to Norton, indeterminism is declared but the principle of inertia would be safe because no force is exerted on the ball at the « excitation time » **t=T** and outside there is no first instant where the movement would not be accompanied by a force.

This idea would be questionable in itself if we consider that the force (colinear to acceleration) "precedes" the velocity and position of the movement. Indeed, by deriving the position **r(t)** repeatedly with respect to time, a constant appears at the *4th* derivative:

$$\frac{dr}{dt}=\frac{1}{36}(t-T)^3 \qquad \frac{d^3r}{dt^3}=\frac{1}{6}(t-T) \qquad \frac{d^4r}{dt^4}=\frac{1}{6}$$

$$\frac{d^2r}{dt^2}=\frac{1}{12}(t-T)^2$$

While everything else is at rest, something seems to be brewing at the level of the "acceleration" of the net force at **t=T** (called the *jounce*), which will "then" impact (in the reverse order of successive integrations) the force itself, then the speed and finally the position from the following instant $\mathbf{T^+} = \mathbf{T + dT}$. We find ourselves in a weird situation where the principle of inertia would be never violated "ponctually" (at any instant **t**) but always "globally" (between two instants **T** and $\mathbf{T^+ > T}$), since no external net force, apart from the two forces in equilibrium at the initial time, acts on the system at rest, nor later when it starts. It is not certain that this last formulation is not in real contradiction with the definition of the inertia principle or one of its consequences.

In fact, the principle of inertia considers in a sense as « internal » the forces exerted on the initial system in equilibrium (rest or pseudo-equilibrium), to be distinguished from the « external » forces of which it speaks that would disturb this system at a later time. In the case of the dome, knowing that no force other than the actions of the weight and the support on the object intervenes at any moment of the experiment, the movement is only a result of the « internal » forces of the initial moment, without any external disturbance, hence its spontaneous nature by definition.

In this sense there is indeed a contradiction between the spontaneous solution of the Norton dome and the principle of inertia. But knowing that both come from the resolution of Newtonian equations, it then becomes difficult to say which one should be dismissed as unphysical, or at least contrary to the physical formalism used. We would need a sort of impartial arbiter, outside of strict Newtonian physics, to decide between them - we will look for it further in classical logic...

The Norton's dome would be in our view more remarkable for its spectacular and unprecedented violation of the inertia principle than for its indeterminism (the latter not being rare in problems like those of the three-body type).

Besides, Norton has also be criticized for forcibly 'agglutinating' heterogeneous solutions with different initial conditions (the lasting rest of the ball where all the quantities are zero up to time **T**, and its movement from a pseudo-rest at **T** where the acceleration of the force would be equal to *1/6*), which would be contrary to good practice in physics [iii]. However, this counter-argument does not quite hold up if we limit ourselves to the case **T=0**: we then have only one type of solution, only one set of initial conditions, although the paradox persists. We will see that the truth may lie elsewhere.

2. Taking into account the rotational symmetry.

The crucial moment when geometry is mentioned in Norton's article is in the following passage:

> Two distinct features of this spontaneous excitation require mention.
>
> *No cause.* No cause determines when the mass will spontaneously accelerate or the direction of its motion. The physical conditions on the dome are the same for all times t prior to the moment of excitation, t=T, and are the same in all directions on the surface.
>
> *No probabilities.* One might think that at least some probabilistic notion of causation can be preserved in so far as we can assign probabilities to the various possible outcomes. Nothing in the Newtonian physics requires us to assign the probabilities, but we might choose to try to add them for our own conceptual comfort. It can be done as far as the *direction* of the spontaneous motion is concerned. The symmetry of the surface about the apex makes it quite natural for us to add a probability distribution that assigns equal probability to all directions. The complication is that there is no comparable way for us to assign probabilities for the *time* of the spontaneous excitation that respect the physical symmetries of solutions (3). Those solutions treat all candidate excitation times T equally. A probability distribution that tries to make each candidate time equally likely cannot be proper—that is, it cannot assign unit probability to the union of all disjoint outcomes.[7] Or one that is proper can only be defined by inventing extra physical properties, not given by the physical description of the dome and mass, Newton's laws and the laws of gravitation, and grafting them unnaturally onto the physical system.[8]

We will discuss this postulate according to which the physical direction of the mobile's trajectory could be modeled by a uniform probability law of the type $\mathbf{dP = d\varphi/360°}$, with $\boldsymbol{\varphi}$ the angle of rotation around the vertical axis **h**. Of course, nothing prevents choosing a study section in the sense of a work plan (e.g. a profile view of the dome) to apply the laws of physics and predict the direction that the ball will follow at the top, hence the real section of its evolution. But these two types of direction, one (free) for the study of the problem, the other (imposed) that the laws of motion dictate to us, must not be confused: it is unjustified here to freely assign a direction (certain or probable) to the mobile since it is up to physics to say so. The latter is full of examples (electromagnetism, inertial forces in an accelerated frame, Coriolis forces, etc.) where the direction followed by the object does not belong to the work plan.

Yet we find this confusion between physical direction and study direction recurrently in the literature related to the dome by reading that the mass at rest begins to slide spontaneously from the summit in an "any direction". In the problem that concerns us, Norton himself obtained two types of possible physical solutions for each study section/plan/direction:

1) Stable rest for all **t**,

2) Rest until **t < T**, then "acausal" movement (at time **T**) *in the same direction*.

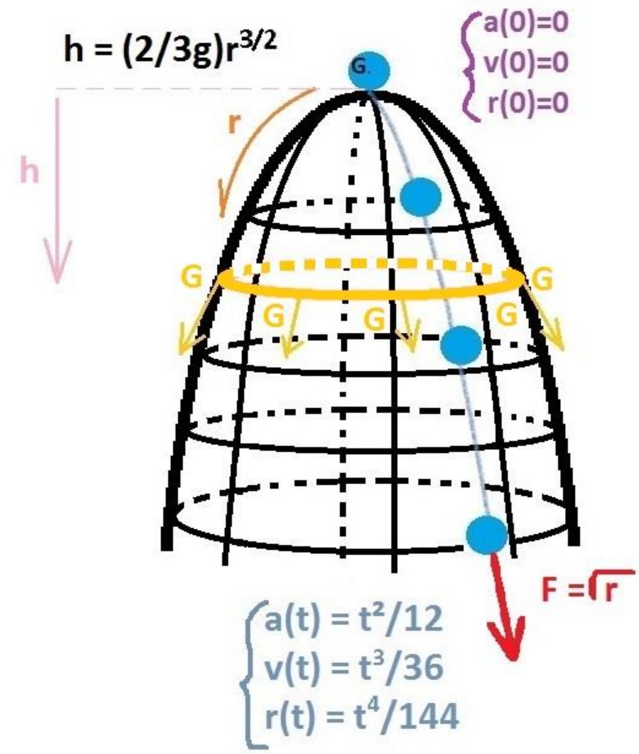
It is to this "binary" rule of the game that we will have to limit ourselves. For each of the directions around the vertical axis, nothing in the Newtonian physics of the dome indicates the possibility for the object to behave differently, let alone follow the direction of our wishes. For the physical analysis, intuition guides us to a section of the dome. On the chosen half-profile of study, all the forces in play – including the zero initial conditions – are coplanar : the fundamental principle of dynamics then implies that any possible movement of the mass will take place exclusively on this common plane, that of the study. The same reasoning being valid for any section around the axis of rotation of the dome, physics leads to a single possible conclusion : the ubiquity of the mobile particle on the dome.

Now, if we crudely count all the study directions to reconstruct the dome by revolution around the **h** axis, what do we obtain in terms of the kinematics of the mobile? An infinity of trajectories covering more or less the dome, some always remaining at the top, others starting at distinct or non-distinct times **T** (an infinite "excitation time" **T** being equivalent to the resting state of the particle). From the point of view of the cylindrical or rotational geometry of the dome, all these trajectories or states of rest are carried out simultaneously by the mass.

This panorama offers us a space of extremely heterogeneous kinematic possibilities, unless we accept the principle of symmetry, known as Curie's: *when certain causes produce certain effects, the effects have at least the symmetry of the causes.* In the case of multiple solutions to the problem, the « effects » are to be taken in the sense of superposition of all possible solutions.

Here - which avoids entering into the debate on the relevance of the concept of causality - the causes are to be understood simply as a combination of the geometry of the problem and forces in play at the initial moment (in this case, a dome, gravity and the reaction of the support), and the effects as the future evolution of the system. Their perfect symmetry of rotation implies the perfect symmetry of the trajectories of the mobile around **h**.

At this point, there are only two main solutions on the whole dome: either the mass at the top remains at rest indefinitely, or it takes all directions at once to slide spontaneously along the wall at the same time **T** following the same law of motion according to a perfect choreography (the centers of gravity **G** forming a uniform ring descending the dome at the same speed) :



Yet, on the one hand, Norton's set of possible solutions around the rotation axis (whose juxtaposition covers exactly the entire dome) respect the principle of symmetry as much as the set of contradictory solutions. On the other hand, invoking the principle of symmetry is not necessary to reveal the whole contradiction above of the evolutions of a mass supposed to move without cause.

To summarize all the cases, the particle does not suffer from manifest indeterminism in time but from hidden ubiquity in space: if it does not go "nowhere", then it goes "everywhere" - and vice versa. We have every good reason to eliminate the last solution, at least out of respect for the classical principle of non-contradiction, valid even in quantum mechanics, which prohibits the same point from following several simultaneous trajectories (there is also a violation of the principle of conservation of total energy which becomes infinite with an infinity of masses in motion, etc. but we will not discuss it). No conflict with Newtonian formalism, the principle of inertia, or that of sufficient reason, no incompleteness of physics, are necessary here: the particle must remain at rest, unless we endow it with a mystical or paranormal property of ubiquity, where its localizations contradict each other.

Let's test mathematically this view on a particular section, namely a complete profile of the dome. In order not to impose the movement of the particle on the left or right side, we'll let the curvilinear coordinate take negative values, calling it **s** (zero-valued variable at the top). A polar coordinate system **(u_r, u_Θ)** adapted to this relative coordinate **s** is chosen. The dome's curve will have equation:

$$h = (2/3g)|S|^{3/2}$$

We can then easily verify the new equation of motion on this complete dome profile:

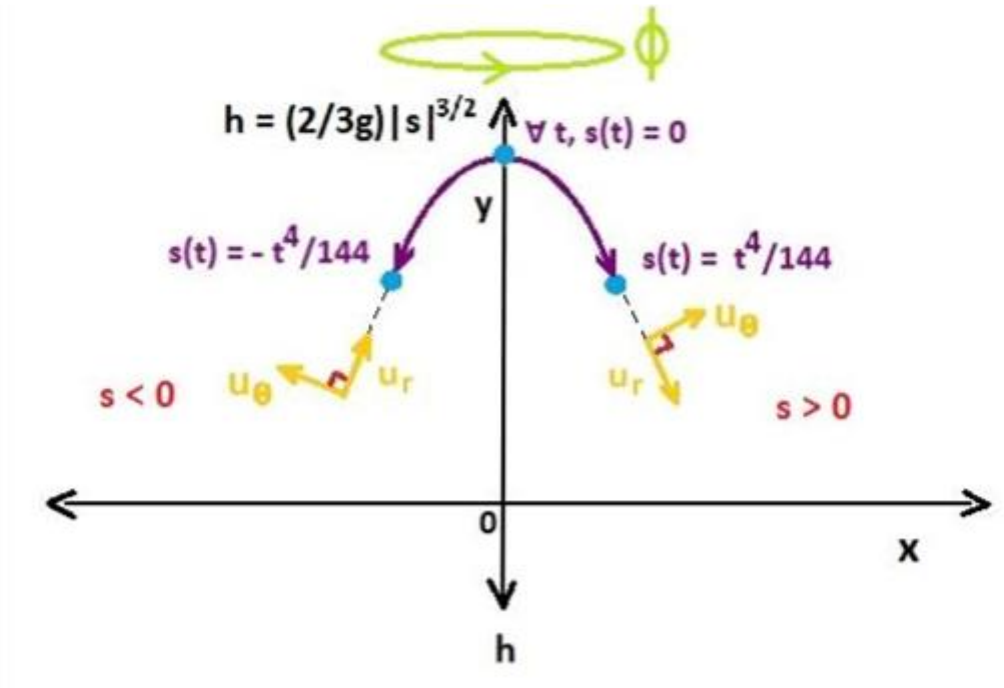
$$\frac{d^2|S|}{dt^2} = \sqrt{|S|}$$

We deduce the following solutions:

$$\forall T \geq 0, \quad \begin{cases} t < T: & S(t) = 0 \\ t \geq T: & |S(t)| = \frac{1}{144}(t-T)^4 \end{cases}$$

$$\Rightarrow \begin{cases} S(t) = \frac{1}{144}(t-T)^4 \\ S(t) = -\frac{1}{144}(t-T)^4 \end{cases}$$

This different approach involves now the absolute value of **s**. This is convenient so as not to prejudge the physical direction that the mobile will take. The parametric representation in time of these solutions clearly shows us the displacement of mass on both sides of the dome at once:



Over this entire dome study section, it is confirmed that Newtonian physics obeys the principle of symmetry in the strong sense of a ubiquity of the particle and not of the multiplicity of solutions. Norton's solution for $\mathbf{s \geq 0}$ is only a window that hides the global view of the entire solution **s** and its contradictions over the dome profile.

In the current solutions for **|s|**, there is no probability or arbitrary choice between the two directions: it is merely a contradiction. Furthermore, this contradiction is repeated all around the axis making all

Norton solutions contradictory: we see that clearly by posing our curvilinear abscissa as a function of both time and rotation angle **φ**, i.e. **s = s(t, φ)** – solving the differential equation above gives identical results.

At no time is it a question of the particle moving towards a section other than the study section, no transverse force appears in the dynamic balance : the differential equations do not describe a possible trajectory of the ball on the study plane but its only possible trajectory on the dome. However, all study planes say paradoxically the same thing.

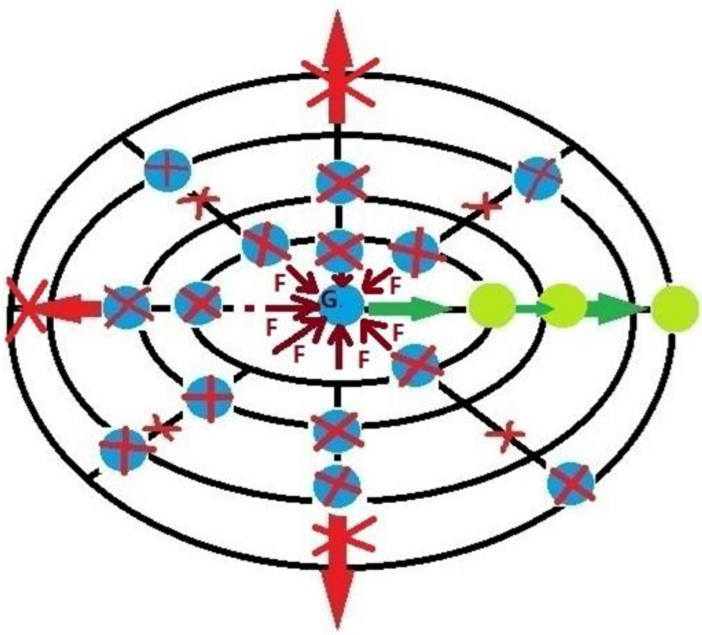
Besides, by deriving the double-direction solutions **|s|**, we find all the quantities zero at **t=T**, except both:

$$d^4 s/dt^4 = 1/6$$
$$d^4 s/dt^4 = -1/6$$

Now, the « dissociative » nature of the ball appears from its very initial state...

3. Physical Solution

Can we remedy this inconsistency of the solutions to the dome problem? Yes, provided at least that we destroy the initial symmetry of the problem, since this rotating geometry (the shape of the dome and the state of rest of the mass) itself creates the paradox. By applying symmetrical forces of the same intensity all around the particle, except in the desired direction of motion, all the forces cancel each other out in pairs except for one: the particle is allowed to move physically in a precise direction and no longer spontaneously, but with the help of an initial net force. All other contradictory trajectories should thus be eliminated:



One could also wonder if it would not be enough to cut the dome like a cherry cake, replacing the additional forces with "vacuum" to stop the particle... Except that then nothing would prevent Norton-type acausal solutions (with non-zero initial "reactivity" but undetectable in acceleration, speed and position) from "making the latter move by itself" in other directions to regain its magical ubiquity.

Here, we should perhaps clarify a little more the case of a simple half-profile: one can always see it as a complete asymmetrical profile, with a half-profile on the right (the dome) and a half-profile on the left, for example the ball at rest at **t=0** (**x_0=0**, **h_0=0**) on a platform overlooking a vertical precipice in a gravity field. We then solve the fundamental principle of dynamics on each side, wondering what global physical movement the ball would follow on this half-plane of study.

On the right, solutions would be the ball starting to spontaneously descend the wall of the dome at any time (Norton's solutions), or the ball staying permanently at rest.

On the left, even assuming that there is no acausal motion towards the precipice, the fundamental principle gives:

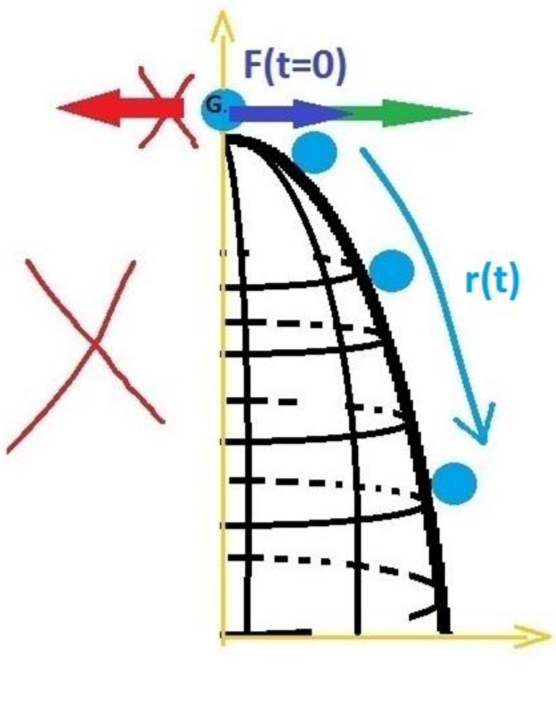
- On the **x** axis : $d^2x(t)/dt^2 = 0$, then after integration : $x(t) = 0$
- On the **h** axis : $d^2h(t)/dt^2 = g$, then after integration : $h(t) = gt^2/2$

It appears that on the right side the only solution compatible with our initial rest conditions would be : $x(t) = 0$ and $h(t) = 0$ for all **t** (stable rest at the apex because the mass cannot fall into the precipice).

Now, by bringing together these two behaviors on both sides for the same ball, the paradox still arises that the object would start towards the right but would remain at rest at the same time. Thus it seems that even by eliminating the possibility of a solution of acausal motion to the left, even without any mention of the Curie symmetric principle, the fact of successively considering the half profile seen from the right, then seen from the left would still give rise to contradictory displacement solutions.

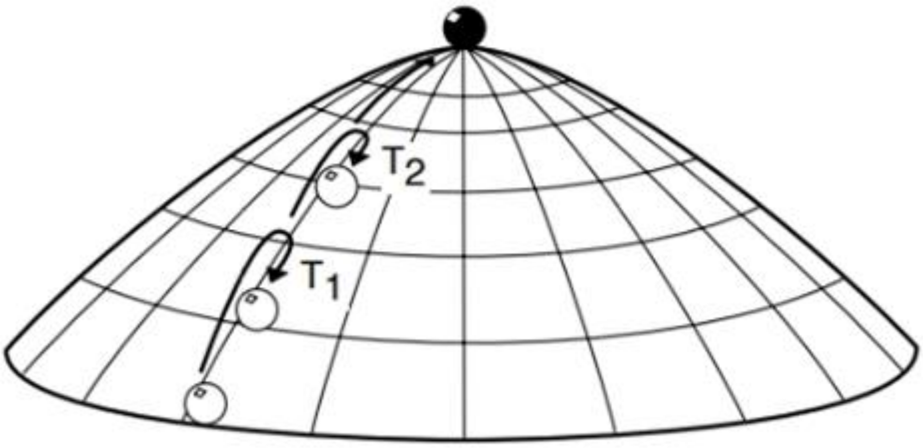
Moreover this approach demonstrates more the validity of the principle of symmetry for the dome (as a consequence of the Newtonian formalism) than it supposes it (see *section 2*). Taking into account the symmetry of the dome teaches us that for a particle in acausal motion everything can change according to the space to be studied. Considering only a half-profile of the dome would not allow those contradictions inherent in spontaneous physical behavior to disappear.

The possibility of a precipice on the other side of the half-dome must be eliminated and replaced by a directed force to prevent the ball from remaining at rest or falling into the void. On a half-profile of the dome (which is the pattern to rotate to restore the complete dome), we get for **T=0**:



This initial force **F(t=0)** could be for example the reaction of a wall against which the mass would be placed. It acts as a non-zero jerk force. This time, the symmetry is broken, the ball will have only one direction to follow.

Let's mention that Norton proposes another way to obtain his "acausal solutions": he asks to consider a mobile starting from the bottom of the dome to which we would impart an energy or initial speed sufficiently calibrated to hoist it exactly to the top. If we reverse the movement we would find, by the well-known principle of time invariance of Newtonian differential equations, the spontaneous sliding movement of the mass in question:



However, as we saw above, this would be forgetting that the solution obtained by time inversion is not the only trajectory starting from static conditions but, after analysis of the rotational symmetry of the problem, one among an infinity of simultaneous trajectories covering the surface of the dome. Certainly, only one trajectory starting from the top will arrive at the bottom with the velocity vector in the exact opposite direction to that of the initial projection experiment but, without this arbitrary "final condition", nothing will forces the static particle at the top to take this one direction rather than another (an infinity of others...).

Finally, we would be curious to have an idea of the physical solution with non-zero initial force $\mathbf{F_0}$ in a certain direction. Here we set **T=0**. A detailed study of the Norton dome problem[iv] shows that if the mass is not at zero speed at the top for **t=0**, it will detach from the wall at the slightest movement. Then applying $\mathbf{F_0}$, what will happen at time $\mathbf{t_1 = \Delta t}$ close to **t=0**? To ensure the adhesion of the mass, the following inequality must be verified (see section 1):

$t = t_1:$

$<$

$$\frac{1}{\sqrt{r}}\left(\frac{dr}{dt}\right)^2 < (g^2 - r)$$

Limited developments in the neighborhood of zero give us:

$$a(0) = \left.\frac{d^2 r}{dt^2}\right)_{t=0} = F_0$$

$$t \to 0 :$$

$$\Downarrow$$

$$v(t_1) = \left(\frac{dr}{dt}\right)_0 + \Delta t \left.\frac{d^2 r}{dt^2}\right)_0$$

Hence :

$$a(t_1) = \left.\frac{d^2 r}{dt^2}\right)_{t_1} = \sqrt{r_1} = \Delta t \sqrt{\frac{F_0}{2}}$$

$$v(t_1) = \left.\frac{dr}{dt}\right)_{t_1} = F_0 \Delta t$$

$$r(t_1) = r(0) + \Delta t \left.\frac{dr}{dt}\right)_0 + \frac{1}{2} \Delta t^2 \left.\frac{d^2 r}{dt^2}\right)_0$$

$$r(t_1) = \frac{1}{2} F_0 \Delta t^2$$

For $\mathbf{t_1 = \Delta t}$ sufficiently small, we then observe that $\mathbf{(dr/dt)^2/\sqrt{r}}$ is indeed bounded above by $\mathbf{g^2 - r}$, which verifies the sliding condition at least up to $\mathbf{t_1 > 0}$.

Conclusions

In this recent – and necessarily imperfect work (we heard about the Norton problem in January 2025[v]), is proposed the idea that only the stable rest solution of the ball at the top of Norton dome respected the spherical symmetry of this problem and thus – narrowly ? – avoided the logical contradiction with itself. It is not a secret indeterminism that one would discover in the holy of holies of Newtonian physics, nor its incompleteness, but the existence of inconsistent solutions to eliminate, in the sense of classical logic, from the solving of motion differential equations *over the whole dome*, rather than just one particular half-profile.

One can even consider the generalization of this approach to other physical paradoxes, like those brought to light since the 19th century, where a particle at rest in a symmetrical environment (rotational, axial, translational, etc. in one or more dimensions) starts moving spontaneously. Maybe scientists should care more about possible contradictions than about indeterminism or incompleteness, since the latter could be less serious than any structural inconsistency in Newtonian theory, which also endangers all theories built on it (fluid mechanics, electromagnetism, special relativity…).

Thousands of years of practice in engineering and construction have proven to man that mechanics was a safe bet, well before its royal theorization by Arab science and then Western scholars. The elevation of a cathedral like Notre-Dame de Paris would probably not have been possible in the Middle Ages if its static elements suddenly started to move by themselves, without any apparent causality, or if fires broke out spontaneously. Its overall safety can nonetheless still be threatened by the most 'benign' actions, as we know it today…

The same is true of the sovereign edifice of Newtonian deterministic doctrine, patiently built since the 17th century. Norton's Dome, like a competing and proud vault of indeterminism, symbolizes the fury and effectiveness of the blows that can be dealt to it. Indeed one can wonder why classical physics only eliminates this kind of "acausal" solutions indirectly, namely by considering the dome in its entirety: on a simple asymmetrical half-profile of the dome one really only sees "fire".

Then, the successive destructions and re-edifications of the "sacred cathedral" of Newtonian determinism do not guarantee the durability of its character: with each repair, its original charm is lost a little more. And one cannot say for how long this architecture, constantly renovated, tested, patched up...will resist before its final self-collapse.

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[i] Marij van Strien, *The Norton dome and the nineteenth Century foundations of determinism*, Journal for General Philosophy of Science, 45(1), April 2014, pp. 167, https://www.researchgate.net/publication/271399217_The_Norton_Dome_and_the_Nineteenth_Century_Foundations_of_Determinism

[ii] Norton, John D. (2003), *Causation as Folk Science,* Philosophers' Imprint Vol. 3, No. 4, http://www.philosophersimprint.org/003004/; Also : *The Dome : An Unexpectedly Simple Failure of Determinism,* Symposium « The Vagaries of Determinism and Indeterminism », PSA 2006 : Philosophy of Science Association Biennial Conference, Vancouver, November 2006.

[iii] Gruff Davies, *Newtonian physics IS deterministic (sorry Norton)* : https://blog.gruffdavies.com/2017/12/24/newtonian-physics-is-deterministic-sorry-norton/, 2017

[iv] Malament, David (2007) *Norton's Slippery Slope* : https://philsci-archive.pitt.edu/id/eprint/319

[v] *The Dome's Paradox : A Loophole in Newton's Laws*, J. Tan-Holmes : https://youtu.be/EjZB81jCGj4?feature=shared, December 26, 2024.