# An Alternative to Mach's Principle.

Abstract
Mach argued that since the acceleration of a body can only be measured relative to other bodies, then the inertia of masses is somehow due to the presence of distant matter in the universe.
Here an alternative is put forward...that the acceleration (of one part of a body) can be measured relative to other parts. Inertia is thus considered to be due to the force needed to compress (or stretch) a body undergoing acceleration.

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## 1. A circular argument?

In this section it is argued that there is another reference frame which can be used to measure the acceleration of a body – the frame of the body itself. It is shown that the force needed to accelerate a body of mass m is equal to the force needed to compress it, as it accelerates.

Imagine we accelerate a mass in the shape of a cuboid, by pushing from one side. (The mathematical details are not too important, they are only to illustrate the point).

For a cuboid of length L, cross sectional area A, speed of sound c , the time taken for a pulse to travel from front to back is L/c and the compression is 0.5*a*(L/c)^2. Where a is the acceleration.

The required force to compress the mass is thus E*A* (0.5*a*(L/c)^2)/L. Which is 0.5* E*a*Volume/c^2 , where E is Youngs modulus.

Since c = sqrt(E/2*density) , and mass = density*volume, the force required to compress the object we are accelerating reduces to F = ma, where m is the mass.

So is the force required to accelerate the object, due to inertia, or due to the force needed to compress the object?

Is this a circular argument?
If inertia did not exist, then the side of the body pushed would accelerate infinitely fast....so it could be argued that atomic particles must have inertia of their own. However the argument can be repeated at the atomic level......Is the mass of a proton (for example) due to the force needed to compress (or stretch) the proton as it accelerates? The argument can be repeated infinitely many times and at no scale can it be proved that inertia must exist ....i.e. it can always be argued that resistance to acceleration could be due to the force needed to compress objects.

We can argue for example that the proton could be made up of many smaller charges, both positive and negative, which become polarised in the presence of an accelerating force, which is another charged object.

So, to conclude this section....We cannot be sure, in principle, that inertia is due to the presence of distant matter as Mach suggested...there is another reference frame which can be used to define the acceleration of a body – the frame of the body itself.
In the next section the relevance of this to gravitation is discussed.

## 2. Gravity.

When Einstein developed General Relativity he initially expected Mach's principle to be incorporated within it. It wasn't however, and he later came to doubt Mach's principle.

What of inertia of bodies in a gravitational field?

It is well known that bodies of different inertial masses accelerate equally when falling under the influence of gravity. Is this fact compatible with the suggestion that compression (or stretching) is responsible for inertia?

Yes it is, because the gravitational field acts throughout the whole body, there is no compression or stretching and therefore objects of different inertial masses (under other forces) can accelerate equally in a gravitational field.

An inertial reference frame can be defined as the reference frame in which the total potential energy stored in a body (due to the presence of stretches or compressions) is minimum. This definition allows a freely falling frame in a gravitational field to be regarded as inertial, and so is compatible with General Relativity.

## 3. Newton's Bucket

Newton once argued that because water rotating in a bucket took on a curved shape, the water 'knew' it was rotating due to its motion relative to absolute space.

Mach then argued that this absolute space didn't exist and the rotation must be due to the waters motion relative to the distant stars.

Let's imagine 3 masses linked in an equilateral triangle, by 3 springs. If we hold one mass and accelerate the system by pulling on one mass, the triangle would deform into an isosceles triangle. Does the system know to do this because of its motion relative to the distant stars? No, it does it because we pulled only one mass, which then pulls the others.

If we hold one mass and turn in a circle, the isosceles triangle still occurs, due to the same effect.

Now for Newton's bucket and water, different parts of the water accelerate differently to each other. Water near the centre has almost zero acceleration and at a larger radius a=w^2*r where r is the radius and w is the angular velocity.

So again, we need not assume distant matter causes the curvature of the water. It is caused by compressions in the water, caused by a force from the side of the bucket (inward towards the centre), and because of differences in the compressing forces throughout the water, the curved shape appears.

If we dropped the 3 masses in a gravitational field, the shape would be equilateral. (even though the system would be accelerating relative to distant stars).

So it seems better that the acceleration of any part of a body is defined relative to other parts. Inertia can, in principle, be due the forces necessary to compress or stretch a body when it accelerates. This suggestion is put forward as an alternative to Mach's principle.