

Negative Mass: Science and Technology concept for UPSC Exam

Negative matter is matter whose mass is of opposite sign to the mass of regular matter. It is an imaginary type of matter which, if it existed, will have negative mass and negative energy.

Negative matter is a concept featured in the General Science section of the UPSC Syllabus.

Overview of Negative Mass

In physics negative mass is any matter whose mass is of opposite sign to the mass of normal matter. For example if an object weighs 5 kg, its negative mass will be -5 kg. As a result such an object with the resulting negative matter would break more than one or more energy conditions, while showing some strange properties, stemming from the ambiguity as to whether attraction should refer to force or the oppositely oriented acceleration for negative mass. It is used in certain speculative hypotheses, such as on the construction of traversable wormholes. Initially, the closest known real representative of such exotic matter is a region of negative pressure density produced by the Casimir effect.

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Concept of Negative Mass

In considering negative mass, it is important to consider which standard concepts of mass are negative. Ever since Isaac Newton first formulated his theory of gravity, there have been at least three conceptually distinct quantities called mass:

- Inertial mass – the mass m that appears in Newton's second law of motion, $F = m a$
- "Active" gravitational mass – the mass that produces a gravitational field that other masses respond to
- "Passive" gravitational mass – the mass that responds to an external gravitational field by accelerating.

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The law of conservation of momentum states that active and passive gravitational mass should be identical. Einstein's equivalence principle speculates that inertial mass must equal passive gravitational mass, and all experimental evidence to date has found these are, indeed, always the same.

Upon further examination of negative mass, it is assumed that the equivalence principle and conservation of momentum continue to apply, and therefore all three forms of mass are still the same, leading to the study of "negative mass". But the equivalence principle is simply an observational fact, and is not necessarily valid. If such a distinction is made, a "negative mass" can be of three kinds: whether the inertial mass is negative, the gravitational mass, or both.

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There have been many case studies regarding the analysis of negative mass, with non having addressed a fundamental question - what kind of energy and momentum would be necessary to describe non-singular negative mass? Indeed, the Schwarzschild solution for a negative mass parameter has a naked singularity at a fixed spatial position.

The question that immediately comes up is, would it not be possible to smooth out the singularity with some kind of negative mass density. The answer is yes, but not with energy and momentum that satisfies the dominant energy condition. This is because if the energy and momentum satisfies the dominant energy condition within a spacetime that is asymptotically flat, which would be the case of smoothing out the singular negative mass Schwarzschild solution, then it must satisfy the positive energy theorem, i.e. its ADM mass must be positive, which is of course not the case.

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Questions relating to Negative Mass

Why is there no negative mass?

The absence of negative mass is known in theoretical circles as the weak Energy condition. The weak energy condition states that for particles moving along valid trajectories, the distribution of mass-energy will always be positive at every point in spacetime.

Does dark matter have negative mass?

Dark matter may be an invisible material, but it exerts a gravitational force on surrounding matter that we can measure. Negative masses are a hypothetical form of matter that would have a type of negative gravity – repelling all other material around them

Can negative mass be created?

Under optimum conditions it is possible to create negative mass. For example scientists by cooling rubidium atoms to just a hair above absolute zero, created what is known as a Bose-Einstein condensate.

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