What is Mass?

by Mark A. Newstead and Stephen C. Newstead

email: mark.newstead@alumni.lboro.ac.uk

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In this paper we investigate the connection between energy and mass. From this we propose that mass is "generated" when a volume of space contains a sufficient amount of localised energy. We then show how this definition explains various phenomena, for example why mass increases with velocity.

1 Introduction

Mass has always been thought of as an intrinsic property of matter. This is especially true in Newtonian mechanics where it represents the amount of inertia a body has, as well as being proportional to the body's gravitational field strength [1, 6]. Although relativity showed us that mass and energy are equivalent to one another [2, 4], we still consider these two properties as separate entities, in most situations. This maybe due to the fact that in everyday situations the mass of an object does not change [2, 4]. In this paper though we will investigate the connection between mass and energy and propose a definition for mass, which will explain its equivalence to energy.

2 What is Mass?

We know from relativity [2, 4] that mass and energy are equivalent to one another. This equivalence, for a stationary particle, is given by

$$E = mc^2, \quad (1)$$

where E is the energy, m is the mass and c is the speed of light (in a vacuum). However we still consider particles to have mass, whilst energy (e.g.

electromagnetic waves or photons) is massless. We propose though that mass is "generated" when a volume of space contains a sufficient amount of localised energy (i.e. mass is just a dense form of energy). By localised energy, we mean that each "piece" or "unit" of energy is always within a certain distance from the centre of the energy or mass. For example if we take a sphere, as our imaginary container, then all the localised energy would always be contained within that sphere, even if the sphere was moving. Moreover the smaller the volume for the same amount of energy or the more energy for the same volume, the greater the mass (in the same way as increasing density, increases the mass for a given volume). Also we propose that the original localised energy defines the volume of the sphere, such that any extra energy added (e.g. kinetic) is always contained within this sphere and does not increase its volume. Hence our definition of mass is very similar to an electrical capacitor, as both can hold a large amount of energy in one place and then release it quickly, given the correct circumstances.

We note that our definition of mass includes a volume, whereas for example equation (1) does not include any distance or volume. The reason for this apparent discrepancy, is that mathematically we always consider the centre of mass and not its distribution. Thus all bodies (e.g. the Sun, the Earth, neutrons, protons, electrons, etc.) are converted into point particles (i.e. something with zero dimensions), which have mass equal to that of the body and located at the body's centre of mass [1, 6]. Hence from our description of mass, it would be a particle located at its centre of mass (in the case of our imaginary sphere the particle would exist at its centre).

Additionally, since kinetic energy is related to velocity [1, 2, 4, 6] then the faster a particle is moving the more kinetic energy it has. Moreover as this energy is related to the particle, it must be contained within its localised energy, as proposed above. This in turn increases the amount of energy within that volume. Hence by our definition this would increase the mass of the particle, which correlates with relativity [2, 4].

Furthermore, we previously proposed [9, 10] that the mass of an electromagnetic wave varies with its speed. This variation is such that, the mass of the wave is zero when it is travelling at the speed of light (i.e. in a vacuum). However its mass monotonically increases the slower the wave travels, (i.e. it has mass when passing through a medium or impacts some matter). This would correlate with our proposal of what mass is, since the slower the wave travels, the shorter its wavelength [5]. Hence as the wave slows down its total energy is contained within a smaller volume, "generating" mass. Moreover, we note that this "generation" of mass is consistent, independent of the waves frequency or energy. This follows since the energy of a wave is inversely proportional to its wavelength [12, 5] and thus the higher the energy, the less time it takes for the whole wave to pass a particular point in spacetime. Therefore as relativity states that gravity travels at the speed of light [2, 4], this implies that it takes both time and energy to bend spacetime. Hence when any electromagnetic wave is travelling at the speed of light, it has insufficient energy and time to bend spacetime and thus has no mass. However, the moment the wave slows down its energy is contained over a shorter distance and thus it becomes sufficient to bend spacetime, i.e. to have mass. This also implies that a low frequency wave could have more mass than a high frequency wave, assuming the lower frequency wave was travelling sufficiently slower than the high frequency wave. An example of this would be a high frequency wave travelling through a vacuum tube and thus having no mass. Whilst at the same time a low frequency wave was travelling through a parallel tube containing a different medium, e.g. air or water, then it would have mass, which by definition would be greater than that of the high frequency wave. Moreover, this change of mass with energy density would also hold true for subatomic particles. For example we know that a down quark (of mass 4.1 to 5.8 MeV/c^2) decays into an up quark (of mass 1.7 to 3.3 MeV/c^2) and a W^- boson (of mass 80.4 GeV/c^2) [7, 11, 3]. In this case the W^- boson must be physically smaller than the down quark, since it originated there, but it has significantly more mass. However this is acceptable from our proposal, as the constituting energy of the W^- boson is contained within a much smaller volume, giving it more mass that either of the down or up quarks. Hence this implies that mass and physical size are independent of each other for both particles and waves.

3 Conclusions

In this paper we investigated the relationship between energy and mass. In particular we proposed that mass is obtained (or "generated") when a volume of space contains a sufficient amount of localised energy. This localised energy is what forms the body with mass (e.g. an electron) and thus moves with it. Moreover this localised energy defines the radius of the body and hence any extra energy the body gains (e.g. kinetic) is added within this radius. From this definition of mass we explained why it would increase with velocity, which correlates with relativity [2, 4]. We also explained why the distribution of mass or energy is generally not considered when dealing with bodies of mass, since they are always converted to point particles [1, 6]. We then went on to correlate this definition of mass, with our previous proposal that the mass of an electromagnetic wave varies with speed [9, 10]. This variation is such that, the mass of the wave is zero when it is travelling at the speed of light and a maximum when it impacts something and stops. Lastly we showed that mass and physical size of waves and subatomic particles are independent of each other, since the constituting energy can be contained within different volumes. For example when a down quark decays it ejects a W^- boson [7, 11, 3]. This W^- boson is much heavier, but since it came from the down quark must be smaller. Hence from our definition of mass, this implies that the constituting energy of the W^- boson is contained within a smaller volume, giving it more mass than the down quark it came from.

Overall therefore this paper explains how mass is generated and why there is an equivalence between it and energy.

4 Further Work

This concept of mass being "generated" by energy would give credence to the idea that matter consists of energy, in the form of electromagnetic waves. Work on this concept of joining matter and electromagnetic waves has already been done in "The Atom Uncovered" [8].

References

[1] S. Chandrasekhar. *Newton's Principia for the common reader*. Oxford University Press, April 2003.

[2] A. Einstein and R. W. Lawson. *Relativity: The Special and General Theory*. Dover Publications, March 2001.

[3] K. Nakamura et al. (Particle Data Group). Quarks. *JPG*, 37.

[4] M. P. Hobson, G. Efetathiou, and A. N. Lasenby. *General relativity: an introduction for physicists*. Cambridge University Press, Feb 2006.

[5] I. Kenyon. *The Light Fantastic A Modern Introduction to Classical and Quantum Optics*. Oxford University Press, 2008.

[6] J. M. Knudsen and P. G. Hjorth. *Elements of Newtonian mechanics: including nonlinear dynamics*, volume 3. Springer, June 2000.

[7] L. M. Lederman and D. Teresi. *The God Particle: If the Universe Is the Answer, What Is the Question?* Mariner Books, 2006.

[8] M. A. Newstead and S. C. Newstead. *The Atom Uncovered*. Baldr Limited, 2010.

[9] M. A. Newstead and S. C. Newstead. *Gravity and Electromagnetic Waves*. Baldr Limited, 2010.

[10] M. A. Newstead and S. C. Newstead. Mass of an electromagnetic wave. *viXra*, 2011.

[11] P. Watkins. *Story of the W and Z*. Cambridge University Press, 1986.

[12] F. Wilczek. The universe is a strange place. *International Journal of Modern Physics A*, November 2005.

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