1000 Mev. energies may possibly be reached. The Metropolitan-Vickers have under construction a 300 Mev. electron synchrotron and the Birmingham University a proton synchrotron.

Relativistic cyclotrons producing ions of energy more than 200 Mev. can be constructed if the problem of space and time variation of the magnetic field are solved satisfactorily. Arrangements are in progress to convert the 184-inch Berkeley cyclotron into a frequency modulated instrument (synchrotron cyclotron). It is expected that a dee voltage of only 50 kV. will be able to generate one micro-ampere of 200 Mev. deuterons.[4]

The *microtron* is an electron cyclotron where the particles are made to slip one cycle of phase in each circuit. A micro-wave resonator located near the edge of a uniform magnetic field gives rise to the necessary electric field. The use of a split magnet and several resonant cavities in series worked by a single power source is suggestd by Schwinger to compensate for the drift in the orbits. The short acceleration time of the electrons makes the radiation loss negligible and the large separation of the orbits facilitates the easy removal of the output beam. Electrons of 1000 Mev. energy can be produced if defocussing can be counteracted by proper shaping of the magnetic field or by the insertion of a loosely coupled parallel series of resonators.

The *linear resonance accelerator* uses an array of high Q resonators operated at a metre wave-length and pulsed simultaneously. When used for accelerating ions, a loosely coupled co-axial line, driven by a master oscillator and loaded suitably, may be employed to phase the system. Radiation losses are at a minimum and the equipment is inexpensive compared to the magnetic devices. A 450-metre long system may be needed to generate 300 Mev. electrons. The *linear wave guide accelerator* developed in the M.I.T. Radiation Laboratory consists of an array of tightly coupled resonators operated from a single oscillator. If difficulties connected with the accurate construction of wave guide sections to avoid the propagation of unwanted modes and the provision of an automatic tuning to overcome temperature and other variations are successfully tackled, it may be possible to speed up electrons to 1000 Mev. energy. A detailed discussion of the working and possibilities of the new devices is given by Schiff.[5]

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WHAT IS MASS?

By D. FERROLI, S.J., D.SC.

1. *Tentative Definition.*

In text-books which are very widely used, we find the mass of a body defined as "the quantity of matter it contains".

Matter is tentatively defined as "that which can be perceived by the senses" (*confr.* Loney, *Dynamics of a Particle*, pp. 4-5).

Hence, colour, sound, electricity, magnetism would presumably come under the *genus* "Matter". I wonder whether many would agree to this. Another definition is: "Matter is that which can be acted upon by, or exert force".

So matter would be both active and passive, under different circumstances. Could perhaps, matter, under its active aspect ("that which can exert force") be identified with energy?

The author in question is aware of the imperfection of his definition, for he adds: "Matter, like time and space, is a primary conception, and hence it is practically impossible to give it a precise definition".

2. *Mass under a triple aspect.*

As the student advances, he meets the concept of mass under three aspects:

(*a*) From the first fundamental equation of Dynamics: Force = Mass × Acceleration, one would deduce that mass is a *coefficient of inertia*, it is something passive, something which, in a way, tends to resist acceleration.

(*b*) In the second fundamental equation of Dynamics: Mass × Velocity = Acceleration × Time, the mass assumes a slightly different connotation; it is a *capacity of impulse*, it is something which contributes to the momentum of a body. The contribution, however, does not seem merely passive, but active, as a man who tries to stop a roller or a cricket ball, would experience.

(*c*) Finally in the equation of energy E = Half the mass by the square of velocity, the mass is a capacity of *kinetic energy*—not energy really, but something that can be energised, invested, so to say, with energy. The passive aspect of mass is again prominent.

3. *Mass in Relativistic Mechanics.*

In Relativistic Mechanics the above three definitions of mass do not give the same values. In fact, even before Einstein, one met in Higher Mechanics the Maupertuisian Mass, the Hamiltonian Mass and the Leibnitzian Mass.*

The present writer has dealt at length with their conceptual significance in his *Madras University Lectures* (March 1927), which were published by the University in 1929. Here it may be sufficient to point out that:

(*a*) If mass is a *coefficient of inertia* then it is necessary to consider two masses: *the longitudinal* mass, when the force is parallel to the velocity; and the *transversal mass*, when the force is

* Of which the Maupertuisian mass is the mean of the Hamiltonian and the Leibnitzian masses.

perpendicular to the direction of the velocity.

Both vary with the velocity, but according to different laws. They are equal when the velocity is zero.

(b) If mass is considered as *a coefficient of impulse*, then there is only the transversal mass, which is independent of the direction of the force.

4. *A Query.*

Now it may be asked: If a different direction of force leads to a different conception of mass, are the respective formulæ merely a result of different definitions of time and space, or do they point to a different and real configuration of the particles constituting the mass in question? For it is conceivable that a different configuration may afford a different reaction, according as the force is parallel, or perpendicular to the velocity. Now is the different configuration produced gradually or instantaneously? And if gradually, what would be the mass when the force is in a direction which is neither along, nor perpendicular to the direction of motion? A solution which is based on the parallelogram law seems unsuitable, for in Relativistic Mechanics, velocities are not compounded according to the parallelogram law.

5. *Classical Definition of Mass is discarded.*

It is clear, however, that the classical conception of mass, as a definite quantity of matter in a body, is thrown overboard. Similarly the idea is abandoned that mass is something which remains constant throughout all the transformations of matter; on the contrary, mass varies with the velocity of matter.

But one may reasonably ask the meaning of these words "mass varies with the velocity of matter", when matter has been emptied of what seemed to be its most fundamental attribute—that of mass and inertia. In fact, if mass varies, can we say that matter changes at all? Or, if it changes, what is it that remains constant throughout the change? For a change which is all change, without anything that really changes is difficult to conceive. Or have we, perhaps, to go back to Aristotle's *"prote ule"* which is the same throughout all changes, not being liable to "corruption and generation"?

6. *Is Matter also to go overboard?*

H. Poincare begins his most suggestive chapter on *"La fin de la matiere"* with the words: "L'une des découvertes les plus étonnantes que les physiciens aient annoncées, c' est que *la matiére n' existe pas*". And yet is there not a way of saving the existence of matter?

In the theory of the cathode corpuscles, *unchanging mass still leaves its traces* quite discernible, though it is almost nil in comparison with the electro-magnetic mass which is revealed by the phenomenon of *self-induction*. But in Einstein's conception an unchanging mass finds no place whatever. Again, the negative corpuscles, though apparently endowed with inertia, borrow it entirely from the æther, whilst, according to Einstein, the inertia of a moving body is inherent in the body, though it changes with *the directed* velocity of the body itself, and has nothing to do with the æther, for the æther, itself is done away with. According to Lorentz, matter has no existence, and what we call matter is but a hole in the æther. For M. Langévin, matter is only liquid æther, which has lost its properties. Matter in motion is not liquid æther moving through ordinary æther, but it is merely an extension or propagation of liquefaction, the æther gradually melting in one direction and solidifying in the direction opposite to the direction of motion. Hence moving matter would constantly lose its identity.

Einstein does away with these interesting suggestions; for him matter is but a mathematical function with the power of reaction on a fourfold geometrical variety, which may be called the *time-space* or the *chronotope*.

7. *The Kingdom of Nominalism.*

But is this modern tendency to change everything into mathematical formulæ a healthy one? Mathematicians think they simplify things. Rather than simplifying them, they etherialize them into the purest gossamer. In the XVI century a reaction set in against the *hair-splitting exaggerations of the later scholastics.* It was a healthy reaction: the reaction of Induction against exaggerated Deduction, the reaction of observation against abstractions, *the reaction of objective against* subjective science. Now abstractions have come back—no less insidious, because dressed in a mathematical garb, Nominalism seems again to have taken its seat among scientists. It is true that mathematics deals with *symbols*, but its symbols must be capable of some interpretation. Now, what is the interpretation to be given to *mass*? and if *mass* cannot be interpreted apart from matter, what is the interpretation to be given to *matter*? ... One does not want to be flippant, but *Punch's* joke seems appropriate: "What is matter? Never mind". "What is mind? No matter".

Or perhaps Bertrand Russell's paradox: "Mathematics is the science in which we do not know what we are talking about, and do not care whether what we say about it is true."

Science seems to have turned full circle. Descartes was satisfied with the truth of a statement only if it could be given a mathematical expression. Aristotle maintains that *"In mathematicis non est bonum"*. No good in mathematics ..... or is it in the mathematicians? .....