on the specimens or not. This is not the arbitrary ruling of any local office, but the written decision from headquarters in Washington. Such being the case, exchange of specimens with foreign countries is practically prohibited; and this seems all the more absurd, we may even say contemptible, when it is known that Christmas cards, and several other articles not classed in any way as samples, are allowed to be sent at sample-rates; furthermore, that from several foreign countries, packages of specimens are allowed to be sent to the United States at the cheap rate. Under the circumstances, it may, perhaps, be asked whether our Canadian friends are not going too far in asking that specimens not exceeding in weight four pounds, nor exceeding twenty-four inches in length by twelve inches in width or depth, be sent at the rate of one cent for four ounces. To be sure, such an arrangement seems to be eminently proper; and all naturalists should unite in bringing the measure before the Lisbon convention. In any event, the present embargo on scientific exchanges, whether caused by the illiberal interpretation of the rules of the postal union by our post-office, or by any ambiguity in the rules themselves, should be removed.

LETTERS TO THE EDITOR.

**** Correspondents are requested to be as brief as possible. The writer's name is in all cases required as proof of good faith.*

Inertia.

As Mr. E. H. Hall (*Science*, vol. iii., No. 63, p. 482) referred to Maxwell, Thomson, and Tait, as *the* authorities in regard to the use of the word 'inertia,' it seems to me it would have been well for him to explain what Maxwell meant when, in reviewing Thomson and Tait's Natural philosophy, he said, —

"Again, at p. 222, the capacity of the student is called upon to accept the following statement: —

"'Matter has an innate power of resisting external influences, so that every body, as far as it can, remains at rest, or moves uniformly in a straight line.'

"Is it a fact that 'matter' has any power, either innate or acquired, of resisting external influences? Does not every force which acts on a body always produce exactly that change in the motion of the body by which its value, as a force, is reckoned? Is a cup of tea to be accused of having an innate power of resisting the sweetening influences of sugar, because it persistently refuses to turn sweet unless the sugar is actually put into it?" (*Nature*, vol. xx. p. 214).

Did Maxwell mean by these questions to deny the statement of Thomson and Tait?

S. T. MORELAND.

Lexington, Va., April 21.

The method of measuring the inertia of a body, proposed by Mr. Hall in No. 63 of *Science*, p. 483, is identical with a mode of measuring the mass of a body. Does he consider *inertia* as identical with *mass?* If not, wherein is the distinction? Whatever be the language describing it, or the ideas concerning it, Newton says it "differs nothing from the inactivity of the mass, but in our manner of conceiving it." Here *inertia* and *mass* are, by implication at least, not identical. W.

April 23.

The recent article by Mr. Hall on 'inertia' is especially to be deprecated, because it may lead many to regard the ideas relating to it as in some sense indefinite. The source of the whole difficulty is that the word has been used in two perfectly legitimate senses, — one qualitative, and the other quantitative. In the qualitative sense, it simply implies the truth of Newton's first law of motion: in the quantitative sense, it is mass, and nothing else. This double use of the word has been fully recognized for a generation by all accurate scientific thinkers; and, on account of this ambiguity, all careful writers and teachers have practically long since abandoned it. Above all, it ought to appear in no text-book, just because it has a double sense.

This statement as to the usage of careful teachers is directly opposed to that of Mr. Hall, who mentions Thomson and Tait, and *quotes* Maxwell in support of the position which he occupies. As no teacher is clearer in his presentation of elementary ideas, nor more precise in his choice of words for conveying them, than Maxwell, either my statement or Mr. Hall's quotation demands revision. That the latter alternative is the proper one, I shall prove by quoting the whole of the passage of which Mr. Hall quotes only a portion of one sentence: —

"In a rude age, before the invention of means for overcoming friction, the weight of bodies formed the chief obstacle to setting them in motion. It was only after some progress had been made in the art of throwing missiles, and in the use of wheel-carriages and floating vessels, that men's minds became practically impressed with the idea of mass as distinguished from weight. Accordingly, while almost all the metaphysicians who discussed the qualities of matter assigned a prominent place to weight among the primary qualities, few or none of them perceived that the sole unalterable property of matter is its *mass*. At the revival of science, this property was expressed by the phrase, 'the inertia of matter;' but while the men of science understood by this term the tendency of the body to persevere in its state of motion (or rest), and considered it a measurable quantity, those philosophers who were unacquainted with science understood inertia in its literal sense as a quality, — mere want of activity, or laziness.

"Even to this day, those who are not practically familiar with the free motion of large masses, though they all admit the truth of dynamical principles, yet feel little repugnance in accepting the theory known as Boscovich's, — that substances are composed of a system of points, which are mere centres of force, attracting or repelling each other. It is probable that many qualities of bodies might be explained on this supposition; but no arrangement of centres of force, however complicated, could account for the fact that a body requires a certain force to produce in it a certain change of motion, which fact we express by saying that the body has a certain measurable mass. No part of this mass can be due to the existence of the supposed centres of force.

"I therefore recommend to the student that he should impress his mind with the idea of mass by a few experiments, such as setting in motion a grindstone, or a well-balanced wheel, and then endeavoring to stop it; twirling a long pole, etc., till he comes to associate a set of acts and sensations with scientific doctrines of dynamics, and he will never afterwards be in any danger of loose ideas on these subjects. He should also read Faraday's essay on 'mental inertia,' which will impress him with the proper metaphorical use of the phrase to express, not laziness, but habitude" (Maxwell's Theory of heat, pp. 85, 86).

It will be observed that Maxwell, instead of calling a certain property of matter *inertia*, and defining it

quantitatively in accordance with Mr. Hall's statement, is very careful to *avoid* using the term, putting it between quotation-marks in the only place where it enters. In short, in so far as a somewhat careful inspection of the book from which the above quotation is made, of his admirable tract on Matter and motion, and of his treatise on Magnetism and electricity, warrants me, I make the assertion that Maxwell never uses the word 'inertia' in a quantitative sense. I am confident that the word does not enter into the elementary book on mechanics in any sense.

In connection with the last paragraph from Maxwell, I quote a sentence from Mr. Hall's article (the italics are mine): "Maxwell suggests certain simple experiments which the student may perform in order to become thoroughly acquainted with that property of matter which *he calls inertia*."

Mr. Hall asserts, also, that Thomson and Tait use 'inertia' in the same sense which he recommends. As Maxwell's employment of the term is so different from what we should suppose from the article in question, I had the curiosity to look into the usage of the other authors named. I find the following passage, which forms § 216 of Thomson and Tait's Natural philosophy, vol. i., part i., new edition: —

"Matter has an innate power of resisting external influences, so that every body, so far as it can, remains at rest, or moves uniformly in a straight line."

"This, the *inertia* of matter, is proportional to the quantity of matter in the body; and it follows that some *cause* is requisite to disturb a body's uniformity of motion, or to change its direction from the natural rectilinear path."

This confused definition offers a marked contrast to the clear and extended definition of mass contained in sections which precede it. It is confused, because it admits of a wholly logical but erroneous conclusion. According to the definition, if we double the quantity of matter in a body, we double the inertia of the matter present, and thus quadruple the inertia of the body. This is absurd. What is meant, but not written, is, that the inertia of a *body* is proportional to the quantity of matter in the body. Let us consider this amended form, and write I and M for inertia and quantity of matter (or mass) respectively: then the assertion is, that

$$I = MX,$$

where X is a function of any thing or every thing except mass. Now, experience shows us that I, however defined, does not depend upon time, position, temperature, electrification, or, in short, upon any change in physical condition. We must conclude, then, that

$$X = C, \text{ a constant, and}$$
$$I = C\,M.$$

The numerical value of the constant will, in any case, depend upon the system of units selected for measuring I and M: therefore we may so select the system, that C becomes equal to unity, whence

$$I = M.$$

Here we see a case where an unnecessary, and, as it seems from a casual inspection of the following portions of the work, unused term is introduced as a survival from the period of 'the revival of science.' Of course, the passage does no harm to those who are competent to read the work which contains it: nevertheless, Maxwell would not have used it.

It is worth noting, that Mr. Hall, in the last paragraph of his article, finally gives a definition of mass as a quantitative definition of inertia. Of course, this is the only quantitative notion which can be attached to it.

A passage in the article under discussion reads, "Text-books too frequently say, in such a connection, that 'masses of matter receive motion gradually, and surrender it gradually,' or that 'it requires time to impart motion to a body as a whole,' — statements from which the student is in danger of getting the idea, if indeed he gets any idea, that the *time* is required in order to draw things taut within the body, and get its particles to acting upon each other, somewhat as it takes time and a succession of jerks to take up the slack of a freight-train while it is being started." Unlike its writer, I should recommend the sentences within quotation-marks to the special attention of the student, and emphasize the fact that *time* is required to transmit motion from one part of a body to another by the statement, that, in physics, this time is known as the measure of the velocity of propagation of a wave of disturbance. Finally, if I used the illustration of the freight-train (not a bad one in its way), I should be careful to explain to the student that the jerks are due only to the fact that the train is not mechanically homogeneous.

Obviously, the discussion of the term 'inertia' is not of the slightest scientific importance at this stage of scientific development; but it is of enormous pedagogical importance that loose ideas should not be taught. I have been prompted to the above remarks by appeals from some, who, supposing they had definite notions of elementary mechanics, had been led into confusion by Mr. Hall's statements.

C. S. HASTINGS.

Baltimore, April 24.

In *Science*, No. 63, Mr. E. H. Hall makes an attempt to clear away the mistiness which he seems to have discovered in the use of the word 'inertia.' No word in the English language deserves more sympathy than this. It has been knocked about so constantly that it must long ago have given up all idea of being able to 'persevere in a state of rest.' Lately there have been many indications of an intention to put it on the retired list in the near future, and for the present to assign it to such duties as it may be capable of performing without injury to itself or others. But Mr. Hall inconsiderately orders it to the front, and insists on endowing it with a real vitality, which, in the opinion of the writer, renders it capable of doing a good deal of harm.

Much of the confusion in the use of the word 'inertia' has originated in the various interpretations of Newton's first law. It is indeed curious to see how many different versions of this celebrated statement may be found in a half-hour's search.

Thomson and Tait, the restorers of Newton, say, 'Every body *continues* in a state of rest,' etc. To this form of statement it is difficult to object in any way. It is a simple statement of a fact, the denial of which "is in contradiction to the only systems of doctrine about space and time which the human mind has been able to form" (Clerk Maxwell). This version of the first law is identical with that of Tait in his Recent advances.

But another translator uses the word 'perseveres' instead of 'continues,' — the rendering so wisely chosen by Thomson and Tait; for 'to persevere' means, by common consent, something more than 'to continue.' Webster says, 'To persevere is to continue, *in spite of discouragements*,' etc. In an excellent and modern treatise on physics, the law is written, 'Every body tends to persevere,' etc., in which, evidently, 'persevere' is used in the generic sense of 'continue,' but in the ordinary sense, to 'tend to

persevere,' is not wholly satisfactory. In one edition of the Principia which lies before me, I find the statement that 'every body . . . endeavors to persevere in its present state,' etc. Here, certainly, we begin to see some trace of Mr. Hall's 'inertia;' and I should not be surprised to meet with the statement, in full harmony with his views, that 'every body tries to endeavor to persevere,' etc.

The beginner in physics is certainly liable to be confused in his endeavor to grasp this idea, — the idea of the mysterious resistance which Mr. Hall illustrates in his string-pulling; but his confusion will be vastly increased when he comes to grapple with the proposition, that "we must distinguish very carefully between inertia itself, a property of matter, and the resistance which matter can exert in virtue of that property," comparing it, as Mr. Hall does, with that property in virtue of which a man can exert force, and the force which he may be actually exerting at any time; and particularly when he is told that the resistance which he has considered is not the body's inertia, but is *merely the manifestation of that property!*

The unquestionable tendency of all this is to cause the student to attribute to the word 'inertia' some occult meaning. Most teachers of physics have encountered this condition of things, and have found some trouble in ridding their pupils of it.

Now, a brief analysis of Mr. Hall's own statements will unveil the mystery. If he had tied his string to the ghost of a fifty-pound ball, the resistance offered would have been nothing; at least, we may so affirm, in the present state of our knowledge in regard to ghosts. But the string was tied to a *mass*, and when he pulled it, he learned, that, in order to do work, work must be done. In short, the word 'inertia,' when properly used, is synonymous with 'mass;' and it is so used by nearly if not quite all the first authorities. There is, therefore, nothing mysterious about it, and, I may add, scarcely any reason for its use at all.

Mr. Hall mentions Maxwell, and Thomson and Tait, as apparently sustaining him in his view of the matter, quoting to a limited extent from the first.

Thomson and Tait, in their Natural philosophy, although not affirming that matter 'endeavors to persevere,' etc., do say that "matter has an innate power of resisting external influences, so that every body, as far as it can, remains at rest, or moves uniformly in a straight line." And this innate power is called 'the inertia of matter.' It is declared to be proportional to the quantity of matter in the body, and is afterward used as synonymous with mass.

This assertion of the existence of an 'innate power' bears the stamp of high authority, and one ought to question it with fear and trembling. But there is no evidence, that I have been able to find, that its authors believed in it themselves; that is, in the sense in which many people undoubtedly understand it. I have always regarded it as an unfortunate expression, which was likely to leave an impression which was never intended.

Professor Rankine, who was not careless in the use of terms, uses 'inertia' as meaning 'mass.'

Maxwell is universally admitted to have been a man of rare insight into the nature of things; and, as he is quoted by Mr. Hall, it may be interesting to see, as far as may be, what his position was on the point in question. His earliest public expression of opinion, as far as I know, was in his paper, 'On the properties of matter,' prepared at the age of seventeen years for Sir William Hamilton. This concludes as follows: "and the impossibility of a body changing its state of motion or rest without external force is called inertia." The next, as far as I know, is found in the Theory of heat, quoted by Mr. Hall. But in beginning the quotation where he does, Mr. Hall, unintentionally no doubt, does Maxwell an injustice. The sentence preceding that quoted is a most important and necessary part of the whole statement [quoted in full by C. S. Hastings, above].

It will be observed that this gives a perfectly definite meaning to the phrase 'measurable quantity,' and one quite different from that which might be inferred from Mr. Hall's fragmentary quotation.

Later came that remarkable 'little book on a great subject,' the Matter and motion; and it is a curious fact, and worthy of note, that the word 'inertia' does not occur in this book, not even in its compound form of 'moment of inertia.' It can hardly be believed that this omission was any other than intentional. His opinion of the 'innate power' may be learned from his review of Thomson and Tait's Natural philosophy [same quotation as given in first letter, above].

T. C. MENDENHALL.

In his article (*Science*, April 18), Dr. Hall writes as follows: "Elementary text-books usually speak of inertia as a mere *inability*, — the inability of a body to set itself in motion, or to stop itself when in motion. This is an old use of the term, but certainly not the best use."

Right here, I am constrained to believe, is Dr. Hall's fundamental error or misconception. He mistakes inertia for mass, and, strangely enough, laboring under this illusion, makes Maxwell use the word 'inertia' where in the text will be found the word 'mass.' For example: Dr. Hall goes on to say that "Maxwell suggests certain simple experiments which the student may perform in order to become acquainted with that property of matter which he calls inertia." Now, by reference to the article referred to, the reader will find Maxwell's words to be exactly as follows: "I therefore recommend to the student, that he should impress his mind with the idea of mass by a few experiments, such as setting in motion a grindstone, or a well-balanced wheel, and then endeavoring to stop it," etc.

Dr. Hall says, "We are driven to the conclusion that matter possesses a property in virtue of which it *offers resistance* to an agency which is setting it in motion." If Maxwell regarded inertia as an entity, 'a measurable quantity,' is it not remarkable that he did not even once, so far as I am able to find, use it in his incomparable work on Matter and motion?

If, as Dr. Hall is forced to conclude, "matter possesses a property in virtue of which it offers resistance," *why does it not resist?* Has a mass of matter, free to move, ever been known to 'stand still'? Certainly not: the whole science of dynamics will be overturned when such an instance occurs. The illustration given by Dr. Hall verifies *our* position. The fact that his heavy weight 'is left slightly swinging,' shows that a large mass will *not* resist the slightest force. Of course, the velocity generated will depend on the time of application. The whole thing is contained in the equation, $v = \frac{ft}{m}$. If m is large, and f small, t must be large to make v considerable. Thus, in the case cited, there is an attempt to make v considerable in a short time (t): therefore f must be large; and it is easily made larger than the string can bear, when, of course, it breaks.

In his second illustration, in which 'a weak thread'

is 'pulled gently and steadily,' is the reason that the fifty-pound weight acquires a greater velocity, because the weight resists less (if so, then resistance is less than itself), or because the time of application is greater?

In elementary works on physics, the word 'inertia' should be seldom used, lest the pupil acquire the impression that inertia is an entity. Most exact writers, foremost among whom is J. Clerk Maxwell, carefully avoid the use of the word. But if Dr. Hall's quasi-definition, given in the last paragraph of the article under discussion, is to be accepted, then must the word necessarily become one of constant use. It is a pity that Maxwell has not given us a definition of 'an inertia unit.' We shall be pleased to have Dr. Hall supply the desideratum. A. P. GAGE.

In my article on 'Inertia' I was mainly concerned for the distinct recognition of a physical fact. My interest in the word 'inertia' was secondary. Professor Mendenhall and Mr. Gage appear to deny the reality of the 'resistance' of which I spoke in defining inertia. I said, "Matter possesses a property in virtue of which it offers resistance to an agency which *is setting* it in motion." Professor Mendenhall attempts to avoid the idea of a resistance in explaining the fact that force is required to set a body in motion, by speaking of the *work* done. The attempt seems to me entirely unsuccessful, unless he has some unusual definition of the word 'work.' According to Maxwell (Theory of heat, 4th ed., p. 87), 'work is done when resistance is overcome;' and, though he does not say that work is done *only* when resistance is overcome, no reader of Maxwell will deny that he meant that. This, by the way, is the only reply I need make to my critics' use of Maxwell's tea-and-sugar illustration; for certainly Maxwell considered setting a mass in motion to be doing work. With this I leave the question of physical fact, and come to that of the word or words used to denote that property which I have called 'inertia.'

In using the word 'inertia' as I did, I knew perfectly well that I assigned to it a meaning sometimes given to the word 'mass.' I knew that Maxwell, in the very passage of which I quoted a part, and of which Dr. Hastings has quoted the whole, used 'mass' as I have used 'inertia.' It was my belief, however, and it still is, that Maxwell, in that famous chapter, used 'mass' in two senses. He does use it as I have used 'inertia,' and in that case defines it as a '*property* of matter' (the italics are mine). Elsewhere in the same chapter he says, "What is really invariable is the *quantity of matter* in the body, or what is called in scientific language the *mass* of the body," etc. (the italics are mine).

As to Maxwell's use of the word 'inertia,' I was in error. I certainly spoke as if he gave undoubted sanction to the word in the sense in which I have used it. This I had no right to do, for he merely states what others have meant by this word. Any one, by reading the passage which Dr. Hastings has quoted from Maxwell, will see all the excuse I have to offer for my blunder.

Dr. Hastings admits that Thomson and Tait use the word 'inertia' to denote that property of matter for which I have used the same name; but he says that their statement is confused. This criticism is just; but it is irrelevant, unless Dr. Hastings means to imply that Thomson and Tait wrote 'inertia' where, in a clearer moment, they would have written 'mass.' Moreover, his commendation of their definition of the latter word might lead one to infer that Thomson and Tait use 'mass' as Maxwell does in the passage he has quoted. What, then, is their definition of 'mass'? It reads thus: '*The quantity of matter* in a body, or, as we now call it, the *mass* of a body," etc. (art. 208).

And now what is the practice of my critics in the use of the words 'inertia' and 'mass'? In the preface of Mr. Gage's Elements of physics, we read, "Dr. C. S. Hastings of Johns Hopkins university has read the larger portion in manuscript, and the remainder in proof-sheets." On p. 8 of this book I find, "By the *mass of a body* we understand *the quantity of matter in it*," and on p. 20, "The term *mass* is equivalent to the expression *quantity of matter*." Of course, the word 'mass' occurs in many other passages of the book; but I have discovered no case in which it appears to denote any thing but *quantity of matter*.

As to the use of 'inertia' in the same book, on p. 90 I find, "This inability is called *inertia*. Evidently the term ought never to be employed to denote a hindrance to motion or rest." But when we come to the subject of centrifugal force, p. 101, we read, "Centrifugal force has, in reality, no existence: the results that are commonly attributed to it are due entirely to the tendency of moving bodies to move in straight lines in consequence of their inertia."

Now, one of these results is the maintenance of the solar system. Why do not the planets, obeying the law of gravitation, fall into the sun? According to the teachings of this book, we must answer, "Simply because of their 'utter inability' to put themselves in motion, or to stop themselves, although this inability must never be understood as a 'hindrance to motion or rest.'" A little farther on in the book we read, it is true, that "to produce circular motion, the centripetal force must be increased . . . as the mass increases." 'Mass' enters here when the book speaks of numerical relations; but we see, that, when it attempts to *explain* 'centripetal force,' it appeals to 'inertia,' and says nothing whatever of 'mass.'

I think it not too much to claim that 'mass,' used to denote that property of matter which Thomson and Tait call 'inertia,' is comparatively rare, while one can hardly take up a book upon physics without finding 'mass' used in the sense of 'quantity of matter.' That an exceedingly intimate relation exists between inertia as I have defined it, and mass as commonly defined, I am well aware. Thomson and Tait's words are, "This, the *inertia* of matter, is proportional to the quantity of matter in the body." I should prefer to say, bodies of equal inertia (see the last paragraph of my article on 'Inertia') are assumed to contain equal quantities of matter. Quantity of matter, in this sense, is called 'mass.'

If it seems best to use 'mass' to denote also the property of matter which Maxwell undoubtedly does denote by it, let us so use it; and, by all means, let its double meaning be distinctly recognized in the elementary text-books. To me it seems far wiser, however, to use the two words, 'inertia' and 'mass,' substantially as Thomson and Tait use them, and to rigorously exclude from the text-books the comparatively useless 'inability' definition of inertia.

E. H. HALL.

Silk-culture in the colonies.

The term 'silk-balls' was doubtless employed at times to designate cocoons; but that is quite different from 'raw-silk' and 'raw-silk balls,' which, as we stated, might more appropriately apply to the twisted hanks of raw silk which are so doubled and