very high order. A solitary station can contribute only to the general problem of mean figure evidence. If the range of such disturbances on the whole of that part of the earth's surface included, it would be impossible to estimate the probable error permissibly in the case points to the preference to be given to frequency of distribution rather than accuracy of error. The case of pendulum observation abounds with inexplicable contradictions and amounts of error in any case what anomalies indicated by unknown causes of error, and hardly a single observer has ventured to "of circumstantial evidence; and it would seem best to leave it at the discretion of the observer, or director of the work.

11. Other modes of research. — The foregoing indicates so plainly the need of tentative exploration of a new order of accuracy that it is very much to be desired that some simpler means should be proposed, but none has yet shown a satisfactory test. That a "thimbleometer" — a term proposed by Mr. Peirce — it might be, perhaps, the sooner if the very great need for this new instrument, but its utility is not to be doubted, as have been ascertained since his memoir was written that the certainty is true. Young's rule supposes that all the rock rising above the sea-level were annulled, the present level surface would remain a level surface, and this is not true. When Major Herschel admits, as he seems to do, that a certain conclusion is proved by the facts but not at the same time, it was understood that its object would be served even though it should fail to rival the pendulum in accuracy.

J. HIRSCHIEL.

Mr. Peirce. The conception which Major Herschel has presented for the purpose of gravity is certainly that if we knew the distribution of gravity over the whole earth, or even over a large radius vector, the problem of distribution would be solved. But whether this conception times the existing number of stations has been occupied, it is a practical question in regard to which known proposition is, the question of pendulum work would be much more easily adopted at the present time, or until two or three is there something to be said on both sides. The views of Major Herschel, and is to be desired that some simpler means should be proposed, but none has yet shown a satisfactory test. That a "thimbleometer" — a term proposed by Mr. Peirce — it might be, perhaps, the sooner if the very great need for this new instrument, but its utility is not to be doubted, as have been ascertained since his memoir was written that the certainty is true. Young's rule supposes that all the rock rising above the sea-level were annulled, the present level surface would remain a level surface, and this is not true. When Major Herschel admits, as he seems to do, that a certain conclusion is proved by the facts but not at the same time, it was understood that its object would be served even though it should fail to rival the pendulum in accuracy.

OPINIONS CONCERNING THE CONDUCT OF GRADUATION WORK.

By G. B. PEIRCE.

I. There are six reasons for determining gravity, which I have already set forth.

II. In determining the compression of the earth's surface from the variation of gravity, is it the complete Major Herschel's history of pendulum determinations is greatly to be desired, and to this would exclude the word of Prevost and of Duppery as well as a great part of that of omitted.

III. The ordinary correction for continental attraction is vastly too great. It should be be questioned, that is nothing but an "a posteriori". I do not see why it can be Lawrence or commented upon, unless the assumption that it has a true "a priori" cause is kept continually in view or

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VI. In middle latitudes, the main thing at present is to study the relation of gravity to geographical and geological conditions.

Major Herschel concurred.

VII. Gravity determinations should be made at intervals on lines of geodetic levels, and the levels be corrected accordingly.

Mr. Schultz concurred.

VIII. Economical questions should, as far as possible, be solved by the application of mathematics.

IX. The invariable reversible pendulum reunites the advantages of the two instruments possessing the one or the other of these characters, and is to be recommended under the limitation and reversible principles in one instrument. They are incompatible; and the combination is impossible. It is very undesirable that any new element of doubt should be imported into the already much mine. They are all subject to rigid pendulum with fixed knife-edge. Kaster borrowed the word from the edge, which made a great noise abroad, the two got mixed up, and the German text books copy pendulum with fixed knife-edge. But Mr. Petrie now intends to import this last stronghold of the line proper can undergo no change without violating its name. Clearly connected with the term not a principle involved in its design. I cannot possibly do justice to the construction of any form of the proper term, which may be thought desirable; but I do sincerely protest against the designation to continue unchanged as long as human existence permits it to acquire, or long as possible. By first claimants is voluntarily destroyed; and in becoming reversible is the change in the pendulum itself, which is termed the pendulum, and it is an essential condition that the pendulum is constant with the other term not a principle involved in its design. I cannot possibly do justice to the construction of any form of the proper term, which may be thought desirable; but I do sincerely protest against the designation to continue unchanged as long as human existence permits it to acquire, or long as possible. By first claimants is voluntarily destroyed; and in becoming reversible is the change in the pendulum itself, which is termed the pendulum, and it is an essential condition that the pendulum is constant with the other.

Mr. Petrie seems to read the word differently.

In place from one station to another. Major Herschel's objections seem to be directed against the thing which is the most striking. The Geometrical Association has unanimously recommended the never not share it. On the other hand, there is much to be said in favor of differential instruments. I cannot or reversible and the invariable principles in one instrument except that, this the knife can be an argument, such as it is, against the invariable pendulum. For there is no fabric of nature safely exposed to careless treatment? The difference between the ordinary invariable pendulum is hopeless, and the knife slays the protest which the latter suffers the injury work. The following are the advantages which I think I see in the use of the invariable reversible pendulum:

It satisfies the requirements of those who advocate the reversible pendulum, which constitutes the greater weight of living authority.

24. It ought to satisfy those persons who advocate the invariable pendulum.

25. It determines gravity in two nearly independent ways, without more experiments than are necessary for a single determination. When these results agree they may be assumed to be correct.

40. If the instrument be considered as a differential one, the difference in the reduced time of oscillation with heavy end down and with heavy end up must remain unchanged so long as the instrument is invariable and can easily escape change otherwise. And from this the correction can be calculated and applied. If on the other hand the instrument be considered as an absolute one, the same difference is the best test of the accuracy of the work.

Mr. Schwartz. For the strict intercomparability of results at two or more stations, I think it to be essential to satisfactory work that an absolutely invariable pendulum be employed. This condition would, however, not exclude the use of a pendulum having interchangeable knife-edges, provided that between any two stations no actual interchange take place, while the interchange might be effected after the particular comparative measures were secured.

Note of Major (now Lieutenant-Colonel) Herschel.—The view of this subject here presented by Mr. Schwartz, in this last paragraph, is so sensible correct that only a strong conviction that it does not meet the whole case, and is directly opposed to the principle of invariancy which I wish to see recognized, would tempt me to add in this discussion. We are agreed, and universal practice shows it to have been widely recognized, that invariability must be maintained during at least the whole course of a series of differential determinations. [In the East Indian series, for instance, it was maintained during eight or nine years, and at more than thirty installations.] No one pretends to set any limit, either to the time or to the number of stations, which is to restrict a series of differential measures. But it is said, when the series is completed there is no longer any need to guard or preserve the pendulum from change; its work is done. But it is just at this point, I contend, that we ought, on the contrary, to be growing more and not less solicitous for the protection of the pendulum. At the more stations it has visited, the more intimate is our knowledge of its time of vibration, or vibration-constant, whatever be the form in which we adopt by which the results of observation are to be expressed. Even if, at the time, only one of the stations visited was not a known place, we ought yet to contemplate and anticipate the time which, by the super-position of later series, the fundamental vibration number (i.e., the equatorial vibration No.) shall rest on more than one, perhaps on many known stations. Even if such considerations as these fail to convince, some weight will surely be conceded to the argument that, as one continuous series is better than two or more covering the same stations, and by merely guarding the pendulum stringently during the temporary pause between two sets of determinations, the results will in fact constitute one only, it is right to take the proper precautions to bring this about; I could not say that this principle has not been acted upon, in times past, but that it should at this day need more defense is strange. The facts are even now delating whether we shall not continue to throw away one-half of the net results of each set of observations with invariable pendulums. We do no less, when we break off a series and, by interchange of knife-edges, to resume the continuity of a series.

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X. Four classes of errors affect the observed period of oscillation, as follows:

1st. Those which are nearly constant throughout the entire pendulum at any one station. Such arise, for example, from the fixture of the support, from an error in the adopted coefficient of expansion at a tropical or arctic station, and from other causes.

2nd. Those which remain nearly constant for a considerable time, say an hour or a day, but which vary from day to day. Such arise, for example, from the knife resting differently on the supports on different days, from erroneous determinations of temperature, or from similar causes.

3rd. Those which are continually varying throughout the observations.

4th. Those which arise in the comparison of the pendulums with the time-piece. The first class of errors demand the most solicitous scrutiny. The other three classes may be distinguished by the study of the residuals of the observations. The third class is the most important of the three.

XI. Further insight into the nature of the errors is obtained by comparing the residuals with
large and with small area, and by comparing the residuals of the reversible pendulums in the same
positions.

Small area and heavy pendulums are to be recommended.

Major Herschel. In recommending "small area," Mr. Peirce leaves us to guess what size mode he contemplated. In setting out upon my recent experience, I intended toswing in areas as small as I could anyway see them, certainly below 30'. But I found that half of this Airy and
honor Stokoks were strongly opposed to such a course, and I abandoned the intention on areas falling from say 70' to 7'. The objections urged were all theoretical. I should still allow the practical testing of the doubt in any series of observations of an experimental character. Mr. Peirce. I find the errors of observation are yet increased by continuing the oscillation down to areas of 1'.

XII. The method of coincidences as perfected by Major Herschel is to be recommended, especially in connection with a clock whose pendulum swings from knives.

XIII. The experiments should be continued for 24 hours, beginning and ending with star ob
servations, when this is convenient. But this should not be absolutely required.

XIV. The swinging in vacuo is to be recommended.

Major Herschel dissented.

XV. The fixture of the support may be advantageously avoided by swinging two pendulums simultaneously on the same support with opposite phases. When this is not done the fixtures should be measured, and in doing this the measures must be made at the middle of the knife-supp
port or else the position of the instrument among axes of motion must be determined.

XVI. The separation of the atmospheric effect into two parties is requisite for an exact tempera
ture correction.

XVII. The influence of atmospheric moisture ought to be studied.

XVIII. The use of rollers in place of knives is to be condemned.

XIX. The probable accidental error of a determination of gravity must not exceed 5 mill
inches (1/1000th), and the total which may reasonably be feared must not exceed 10 millinches (1/100).

Professor Newcomb and others agreed to this, but Major Herschel and Mr. Schott objected to any numerical criterion of this sort.

XX. A good gravimeter is an importont desideratum.

CONCLUSIONS PROPOSED BY PROFESSOR NEWCOMB, AMENDED AND ADOPTED BY THE CONFERENCE.

1. The main object of pendulum research is the determination of the figure of the earth. From a sufficient number of observations suitably distributed over the surface of the earth the actual figure may be determined.

2. A complete geodetic survey should include determinations of the intensity of gravity. These determinations should be made at as many critical points of local deflection and physical structure within the area of the survey as possible; and these should be combined with others distributed over the whole globe.

3. A minute gravimetric survey of some limited region is at present of such interest as to justify its execution.

4. Extended linear gravimetric exploration is desirable, to be ultimately followed by similar work distributed over large areas.

5. Each series of such determinations should be made with the same apparatus, so that the differential results should not be affected by constant errors peculiar to the apparatus.

6. While it is inadvisable at present to strictly fix a numerical limit of the permissible probable error of pendulum work, yet such determinations ought commonly to be accurate to the 1/1000 part.

7. Since different pendulums may be used in different regions, all should be compared at some central station.

8. Determinations of absolute gravity will probably prove useful in comparing the yard and the metre, and they should at any rate be made in order to test the constancy of gravity against the constancy of length of a metallic bar.

9. In the present state of our experience, unchanged pendulums are decidedly to be preferred for ordinary explorations.