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# A Comparative Study of Certain Methods in General Science

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# A COMPARATIVE STUDY OF CERTAIN METHODS IN GENERAL SCIENCE

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Anthony J. Chalupsky

# INTRODUCTION

In this comparison of certain methods of teaching general science, it has been the author's purpose to state and interpret the facts as they were found, and to discover, if possible, whether or not these methods are uniformly effective, or whether some are more useful than others.

The investigation consists mainly of a comparison of three methods of visual instruction, and one non-visual or modified recitation method. The conduct of this investigation is limited to a period of five weeks, spent by the author in teaching four classes of elementary physical science I pupils at the South Omaha High School. In each class was applied one of the methods of approach under investigation.

The conditions under which this study was conducted may be described as ideal, because the various persons with whom contact was made were willing to cooperate to the fullest extent of their time and ability.

With the ready permission of Principal Marrs and Mr. L. E. Smith, head of the science department of the school, these four classes were put entirely in charge of the author, as regards the teaching procedures used in this experiment.

In view of the fact that the investigation was carried on as an experiment, the author will follow the generally accepted form of compiling his study.

The experimenter planned to employ intelligence test scores in comparing the capacity of the different classes in rate of learning. Investigation showed, however, that intelligence tests had not been administered previously to these classes: opportunity to administer intelligence tests during the experiment did not seem to be in harmony with conditions under which permission to carry on the experiment was granted.

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# Chapter I

# HISTORICAL BACKGROUND OF THE METHODS INVOLVED IN THIS STUDY

## 1. The Recitation Method

One of the principles of procedure which might be regarded as universal at the time of the origin of the recitation system, was the identification of schooling with textbook learning. Going to school meant reciting from a textbook and learning was identified with reproducing for the teacher what the book contained.

Prior to the nineteenth century, instruction in both the elementary and grammar schools was prevailingly individual. The pupil of that period was left to shift for himself, while the master whittled quills. When the master was finally ready to receive him, the pupil walked to the bench and often in a sing song manner, recited the task that had been his lot to study. He then resumed his seat while another pupil repeated the procedure. At their seats the pupils dreamed, dozed, or perhaps studied, while the master was busy with the individual before him. Learning ended when the pupil finished reciting. A good memory was considered a premium in those days .

This method was used with little or no variation for a half century. In 1855, Grimshaw wrote in an educational journal of the day, that he "deplored the time wasted by the old-fashioned and false method of teaching individuals instead of classes."[1]

Educators of the time were being jostled awake, presumably by economic forces and so they evolved recitation by groups. Incidentally those economic forces were the invention of steel pens and blackboards. The steel pen precluded the necessity of a whittling master and inducted a master who was able to give more of his attention to his pupils. The blackboard was the means of gathering the pupils of the same stage of progress and presenting new material to them as a unit.

The pen and the blackboard were thus the primary inducers of group recitation but it was Joseph Lancaster and his co-workers who brought group recitation at this time to a more nearly perfect state. Lancaster and his fellows evolved what was known as "The Monitor System." It was under this system that procedure in the classroom was brought to the highly mechanized similarity of the German goose-step. The room and the pupils were the breath of precision. The atmosphere in

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1 V. T. Thayer, Passing of the Recitation, D. C. Heath and Co. 1928 p. 2

the room was one of click, shuffle, clatter, click. The pupils were given numbers to facilitate taking of the roll call.

The actual learning process was so highly mechanized that in arithmetic the monitor had only examples and a key. They were all he needed. The monitor, or master would read the entire problem, following it to its conclusion, and the pupils, hanging on his very words would follow the procedure as read, with their pencils.

This monitorial system was so highly mechanized that in the light of modern reason, it seems stultifying and absurd. A characterization of the system would be, " much rhyme but no reason."

"In spite of all these things teachers are more heavily obligated than they usually appreciate. Were we to discuss adequately the contributions of the monitorial system, we should indicate not only the fact that it gave to the recitation system the structural outlines which it still retains, but it laid as well the basis for a free public education with professionally trained teachers. Under no other method could universal and free education have been envisaged; the expense would have seemed prohibitive. Thus in 1819 there were ten monitorial schools in Philadelphia, each with one teacher in charge and an average of 284 pupils per teacher. As late as 1834 in the same city the average number of pupils per teacher was 218. The monitorial system alone made it economically feasible to undertake the public education of children."

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1 V. T. Thayer, Passing of the Recitation, D. C. Heath and Co. 1928 p.6

The Pestalozzian system in this country dates from 1860 and it was first introduced in Oswego, New York.

Changes are seldom radical and so the Pestalozzian method was but a modification of earlier methods especially of the Lancaster. It goes back to individualism again, starting with the experiences of the pupils and leading them to a systematic knowledge by a careful direction of the learning activity on part of the teacher. Of course, books were now being somewhat replaced by actual experiences of the children. Arithmetic was learned less by "rhyme than reason". The danger in this was that the teacher was rutted. His routine, once established, never varied. To quote Dr. Mossman in part, "It made very slight provision for pupil initiative. It assumed teacher dictation of every step in the learning process."[1]

Finally, Herbart added his hoop to strengthen group instruction methods. Perhaps his greatest addition was the adding of social sciences in the curriculum. The stressed points were "virtue" and "citizenship". He held moral development as the ultimate aim of education.

Herbart unlike Pestalozzi, stressed teacher activity but he still set the activities of children into distinct molds. His five steps in learning illustrate the point.

1. Preparation 2. Presentation 3. Comparison and abstraction 4. Generalization 5. Application.

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1 Dr. Lois Coffey Mossman, Changing Conceptions Relative to Planning of Lessons, 1924 p. 4

But the developments since Lancaster have led to little more than the pouring of new wine into old bottles, since we have not fundamentally reconstructed the recitation system which Lancaster had devised a little more than a century ago.

## 2. Visual Instruction Method

The need for scientific scrutiny of that group of new methods or devices which go by the name of visual education is apparent on every hand. The commercial world discovered long ago that one of the most effective and universal means of appeal is through pictures, charts, and diagrams. In any issue of one of our national periodicals, in which the most successful advertisers of this country concentrate their efforts, the percentage of space given over to pictrues and other non-verbal media of communication is quite high. Advertising experts have learned, through continued and carefully studied experience, that pictures and diagrams pay. They have learned that it is essential to reduce the reading material to a minimum so that more space may be given to non-verbal material; that pictures attract attention where printed words will not; that the message they wish to convey can be most economically delivered through drawings and pictures; and that the impressions produced by these means tend to be more permanent.

"There is something strange and unusual about visual education. It is an organized department of instruction which is based, not upon subject-matter, but upon a method of presentation. This method has as its essential feature the fact that it belongs to one of the senses. Such a situation is without parallel.

We may get at the fundamental cause of the unusual situation in which visual education finds itself by glancing at its history. Visual education, in broad sense of the term, is, of course, not new. Models, maps, diagrams, pictures, all have been used for generations. Teachers of the various school subjects have developed materials and forms of visual presentation to be used in traching their subjects. Geography and nature study have employed an abundance of such materials. There is now a strong movement toward the centralization of these materials, and with this centralization has gone an agitation for the enlargement of the scope of their use.

A number of conditions have combined to produce centralization. One is the development of elaborate museums in place of the small collections of models in individual school buildings. A second condition favoring the centralization of visual education is the development of the extension service of the state universities. This service has emphasized agricultural education, but has also included general public education. A third factor is the organization of large companies which manufacture for use in the school the material equipment for visual education. This equipment may consist of models, charts, projection apparatus, or material to be projected."[1]

The eye is the most retentive as well as the most observant of human sense organs. With many of the lower animals other senses are predominant, the sense of smell in some, hearing with others, but in man, sight is ascendant among his faculties. While oral methods may have been the first used by man in the transference of ideas, although there is authority for asserting that even here the visual was first, it is certain that visual images were used in the dim ages of antiquity to convey information and even to teach. The sand was used as a blackboard in the open-air village schools of ancient India. Mankind today is learning from drawings and paintings discovered in ancient caves in France and Spain, the types of animals familiar to men of paleolithic times, who lived five or ten thousand years before the dawn of recorded history.

The earliest records are picture records. The purpose of these records was to inform, and to educate. It is now generally

1 Frank N. Freeman, Visual Education, Uni. of Chicago Press 1924 pp. 3-5

believed that the cavemen drew pictures on their walls not as a means of ornamentation but primarily to impart facts, or to issue warnings. Certainly their purpose was to convey ideas.

Egyptian hieroglyphics mark the transition between picture writing and the early alphabets of the ancients. Pictures are and always have been primarily a means of conveying information and are in form, antecedent, and in purpose essentially educational.

In studying the history of education we see that educational theory in modern times has followed three distinct lines. The humanists relied for purpose of school training on the study of good authors with their records of human experience. The realists believed that teaching the child from books was secondary in importance to bringing him into direct contact with nature and reality. The naturalists maintained that the child can be prepared for life only by living.

Foremost among the realists was John Amos Comenius (1592-1671), who gave the world the first illustrated textbook, in his Orbis Pictus or The World Illustrated.

Comenius believed that the child could not learn through words alone. He, therefore, appealed to the eye and the mind of the pupil through the skill of the artist. Words were clarified and made impressive by pictures or by the thing itself when possible. His World Illustrated became the most popular schoolbook in Europe and held that place for nearly a century.

Pestalozzi (1746-1827) and Rousseau (1712-1778), representing the naturalist school, taught that the child should learn life by living and preached a "return to nature." Froebel (1782-1852), who put Pestalozzi's theories into practice, believed in developing the senses of sight and touch and employed visual aids in his famous kindergarten.

One of the greatest impulses given visual education has been afforded by the British Museum. Art galleries and museums are, in a sense, merely visual aids. The sculpture of ancient Greece and the paintings of medieval Italy were visual aids to education, religious and civil. People have made collections of paintings, statues, minerals, of birds and butterflies, because of their special interest in these objects, or because they wanted to see, to study, to observe these things at their leisure and enable others to do so. The British Museum, which was opened to the public in 1759 and contains printed books manuscripts, prints and drawings, antiquities of many nations and people, coins and medals, and biological and geological exhibits, is the largest and the oldest existing of these storehouses of knowledge, and has long been a most prominent and potent factor in the promotion of visual education.

To Comenius, however, belongs the distinction of introducing visual education to the modern world. He may properly be called the father of visual education. And may we not name as the grandfather the teacher who first drew pictures in the sands of India and as the great grandfather the paleolithic man who first began to build a picture language on stone before the dawn of recorded history?

It is apparent that visual aids are fully as old as education itself. The picture has grown steadily as an aid in teaching, from the time when earliest man carved his first crude drawings in stone until the art of photography and cheap reproduction made pictures accessible to all.

An even hundred years ago the photographic art began. In 1822 the first permanent photographs were secured by a Frenchman named Niepce. As early as 1802 a process by which records could be made by the action of light was discovered by a certain Tom Wedgewood, but no method of fixing it was then known. Photography, considered a recent art, is a centenarian, and visual education is much older.

Out of the photograph quickly grew the stereoscope and the lantern slide, and all three have found a prominent and lasting place in the world's educational systems. Blackboard drawings, illustrations in testbooks, graphs, maps, charts, photographs, stereoscopes and the stereopticon have long since become intimately interwoven in the fabric of pedagogy. Without a doubt the introduction of the stereopticon slide into the educational may be attributed to the efforts of the Chautauqua lecturers of a few years past, who for the most part were educators. After using this medium as a form of instruction in their lectures, they were quick to realize its significance for the educational world and hence introduced it in some of their schools. The Visual Instruction Division of the New York State Department of Education announced that in 1922 it was circulating something over a half million slides, besides numerous photographic prints.

Now has come a new form of illustration, ushered in with the twentieth century, an art made up of all the methods of picturization which have gone before, an art which adapts itself naturally and basically to instructional use. This new form of picturization is the motion picture. It combines the principles of the photograph and the lantern slide with the earlier arts of drawing, and has added to them the semblance of motion. As a result we have a composite which seem destined largely to revolutionize illustrative pedagogy.

It must be borne in mind that while education has been developing for several centuries, the motion picture has been available for education only for the past few years. It is logical to assume that Comenius and Froebel would have eagerly seized upon the motion picture as an aid to education if it had been available to them. Motion pictures have disclosed a whole new world for observation and study. They have brought the miracles and wonders of nature to the pupil, have shown him the microscopic life of the ocean, life in the arctic and antarctic regions, how a plant unfolds, how a caterpiller becomes a butterfly, and many of the long hidden musteries and secrets of Mother Earth.

It is most significant, however, that Muybridge's experiments, which mark the real beginning of motion pictures, were scientific in character and results. The first use of motion pictures, by the founder of the art, was in education. Moreover, for many years Muybridge's experiments were conducted at the University of Pennsylvania with funds appropriated by the University as a contribution to the advancement of science and education. Taking up the work practically where Muybridge left off, Dr. Marey also devoted his experiments solely to the attainment and demonstration of scientific facts. Dr. Marey was an eminent French scientist, a member of the Institute and of the Academy of Medicine, Professor at the College of France, and Director of the Physiological Station, where most of his experiments in pictured motion were conducted.

Educators and men ~~of~~ science have instinctively turned to motion pictures for aid in teaching and demonstration. Continually, though spasmodically, the educational use of the motion picture has been evolving slowly. Some educators have made excessive claims for the motion picture as the coming panacea for all of education's shortcomings, destined to eliminate textbooks and teachers.

The production of educational films has started, and sufficent progress has been made in this direction to point the way.

## Chapter II

## METHODS OF PROCEDURE

This investigation consists largely of a comparison of three forms or methods of visual instruction and one non-visual or modified recitation method. The experiment covers a period of five weeks, spent in teaching four classes of Elementary [illegible] High [illegible]. With the permission of Principal Marrs and Mr. L. E. Smith, head of the science department of the school, the classes were put at the disposal of the author, as regards methods of instruction employed.

### Types of Methods Used in the Study

We may first consider the types of presentation or methods which were compared with one another in the experiments of this study. In all of the procedures, the material or subject matter in the classes which were compared was duplicated as exactly as possible. For example, if a sketch was to be compared with a lantern slide, the sketches were so drawn as to duplicate, as near as possible, the pictures which were shown on the screen. A number of experiments were likewise performed from time to time to illustrate certain laws or forces. These too were duplicated identically in each and every one of the four classes, so as to maintain a uniformity of instruction of material and secure a correspondingly uniform and reliable result.

On the whole the sketches were made directly from specially prepared slides, made by Mr. Smith, or gathered from sources closely related to the materials depicted by them. In all of the methods involved, the explanations and lectures followed along closely similar lines and the discussions as well were similar. Facts obtained directly from the slides and sketches by the classes using them, were presented orally to the non-visual or modified recitation method class.

The unit taught in all of the four classes was based on the following ideas. It began with a description of ancient and modern befiefs as to the shapes of the earth and the extent of the universe and lead up to the motions of the earth and the effects of these motions on seasons and time. It ended in a study of inertia, centrifugal force, and a thorough explanation of the laws of gravitation.

The slides employed in teaching this unit, (as well as in all of the units in the two courses in Elementary Physical Science) have been prepared by Mr. Smith, who has selected his materials from different sources, and who may appropriately be called a pioneer in the field of visual education in this part of the country.

Upon questioning Mr. Smith as to how he chanced to adopt this type of procedure and continued to experiment along this line, the author was told, "that it was at first due to a desire to save time ordinarily spent in laborously drawing sketches on the board, only to have the next class come along and erase them, before the explanation of the sketch had been completed. Secondly that it was a tremendous interest stimulator, as it appealed to the students, and lastly that it secured rather remarkable results, and coule be kept in step with scientific progress."

1. The Sketch Method of Visual Instruction

In as far as we have been able to ascertain, the sketch method of instruction is an original departure from the strictly orthodox slide or film forms of visual teaching. It was suggested by the slide method, and considered from the standpoint of utility for the teacher, who has a desire to try out the visual method, and offers an economical substitute for the rather expensive slides and projection apparatus. This method of approach consisted of sketches, hand drawn or cut by the author on mimeograph stencils.[1] These were mimeographed by Miss Sieberling's typewriting classes in quanitities large enough to supply the demand. These mimeographed sketch sheets were passed out to members of the class, and each sketch was individually explained and lectured upon by the author. The following day a review of the sketches was in order, and if possible a discussion started. The sketches were explained in the same manner as the slides employed in the other methods. Upon completion of the study of

1 See appendix C

one sheet of sketches, another was passed out, and the procedure repeated. The sketches used in this method comprise well over a hundred in number, drawn on eleven separate 8½ by 14 inch stencils.[1]

This method was applied to the first period general science class, made up of forty-six students, for the greater part Freshman A boys and girls.

## 2. The Modified Recitation Method

Since textbooks are not used by any of the Elementary Science classes of South High School, the author was confronted by the problem of supplying some form of textual material to be used in the recitation form of instruction. This obstacle was overcome be literally writing a textbook. In it the subject matter needed to convey the information given by the visual methods was selected from a number of reliable sources.[2] The information thus found was then put in as understandable a form as possible. The material was written into the form of a story, and as nearly as possible put in the words of pupil experience. From this material stencils were cut, and the information issued in form of a nineteen page 8½x14 mimeographed test.

This type of procedure is referred to as the modified recitation, because its application was varied slightly from that usually adopted by the adherents of the traditional recitation method. With them it is the text book first and always, a type

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1 See appendix C.
2 See appendix D

of education that concerns itself with teaching the book instead of the children being taught.

The method was not a strict recitation plan, because the author neither depended solely upon the textbook, nor offered it as the one and only basis of instruction. The students were expected to get the explanations and the view point of the text, while the teacher concerned himself in his lectures with slightly different viewpoints, obtained from other sources, all aimed at the common goal of obtaining a better measure of understanding. This is an aim common to each of the methods involved in this investigation. The pupils, however, were questioned both upon the content of text and the gist of the classroom discussion and lecture. At the completion of each phase or sub-unit in this method, as well as in the other three, an attempt was made to get a summary review of the materials, as a basis for the next day's work.

This modified recitation method was applied to the second period class which consisted of thirty-seven students of approximately the same grade as those in the other three classes.

### 3. The Slide Plus Collateral Reading Method of Visual Instruction

This method simply makes use of Mr. Smith's slides and lantern or projector as a basis of instruction. The slides arranged in the proper sequence, and numbering 68 in all, were flashed or projected upon the screen, and as simple and comprehensive an explanation as possible was given of the principle that the slide depicted. The number of slides averaged approximately five per day. The first few nimutes of each day were spent in a review of the slides covered the day before, and in engineering, if possible, a discussion. Following Mr. Smith's principle of interest arousal, questions intended to arouse the curiosity and provoke original thought discussions were put to the class, previous to the explanation of certain meaningful slides.

The collateral reading provided for this type of instruction is the same as that which was used as the basis or text in the modified recitation method. This text, or collateral reading, as has been stated before, was arranged so as to give as direct and simple as possible an explanation of materials which the slides and sketches illustrated. Questions regarding both the collateral reading and the slide discussions were put to the class. This method was used in the third period class, which consisted of fifty pupils.

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### 4. The Straight Visual Method

This type of approach is identical with the method described in the preceeding discussion, save that the collateral reading was not furnished to this group. This straight visual method of instruction was applied to the tenth period class, a group of forty-nine pupils, of approximately the same ability as those serving as the subjects for the three previously described procedures.

### 5. Tests and Testing Procedure

In planning this study the author was at once confronted by the perplexing problem of obtaining a satisfactory instrument of measurement. A number of standard general science tests were examined, but proved unsatisfactory, because the material covered by Mr. Smith's slides is very extensive, and because his slides are in a seemingly continous state of modification. New slides are being made and old out-dated ones being discarded, thus keeping in step with the ever new and changing concepts of modern science. His course may be very fittingly described as a contemporary course in General Science.

In preparing the test, the author compiled a list of 210 points, selected from the materials incorporated in the unit under consideration. The difficulty of securing a standard test which would be applicable to a more or less contemporary course of this kind can readily be percieved from the fact that, upon examining closely four well known Standard general science tests, the author was able to select from them but five of the total of 210 points used that actually fitted the type of unit that was to be taught.

Of these 210 points, the 105 points were incorporated in the pretest, while the remaining 105 even ones were used in the final examination. To determine the extent of the knowledge already possessed by the students, the pretest was given to each of the four classes, on the first day marking the beginning of the experiment. The final examination was given on the last day of the investigation. From the differences between the pretest and final test scores the relative degrees of improvement of the four classes were calculated. The tests were scored on the basis of 105 points, to make allowance for the possibility of guessing a 2 point deduction in the true and false sections.

Brief semi-weekly tests were also given to each class, so as to keep a close check on their study activities. These tests were based partly upon a series of fact question test sheets, compiled by Mr. Smith, from the sketches, text and slides, that had been discussed.

### 6. Construction and Validation of the Tests

As has been stated above, the tests were constructed and scored on a basis of 105 points each. The tests were of the objective battery type.

The author bases his claim to validity upon the fact that the tests were based entirely and solely upon the content material used in teaching this general science unit. Moreover the tests were thoroughly examined and checked by Mr. Smith for irrevalency and ambiguity of statement, and as an additional check as to possible inclusion of irrevalent material, the test was given to two Elementary Physical Science II classes, which had but recently completed a study of the material incorporated in these tests.[1]

1 See appendix D.

# Chapter III

## OBSERVATIONS AND RESULTS OF INVESTIGATION

In this chapter the author will briefly summarize the findings and observations of this experimental attempt to compare and if possible, discover the most preferable type of the four different methods involved in the teaching of general science.

### Results

The results of this investigation are shown in diagrams 1 to 6, and in tables I and II. An examination of diagrams 1 to 4, which show the frequency distribution of pretest and final examination scores, as made by each of the four methods compared, brings out the following facts, obtained from the class using the sketch method. Upon its examination it will be noted that the score range of the pretest was 0-70, with the greatest number of the cases grouped between 16-40. Going from this to the final test distribution, we find that the score range has changed to 16-94, with 14, or 35 percent of the cases being 60 or above in score, as shown in table II, and that the scores have moved forward slightly, with the greatest frequency of cases being distributed between the scores of 16-75.

Turning to diagram 2, we find the greatest frequency of distribution of scores to be between 6-41, and the range to be 0-55. In the final test we find that the range has widened, extending from 25-96, and that the greatest uniform frequency of distribution is to be found between 46-91. In this class, taught by the modified recitation method, it was found, as illustrated in table II, that 20 students, or 55.6% of the entire class made a score of 60 or above in the final examination.

In diagram 3, we find the pretest range to be 22.5, with the frequency of score distribution being rather uniformly grouped between the 1-41 section of the scale. In the final examination represented by diagram 3, illustrating frequency distribution of scores as achieved by the slide plus collateral reading method, we find the score range to now extend from 22-99, with the majority of cases being distributed between 26-61. From table II we can find that 18 have made a score of 60 or above, consisting of 40.9% of the class.

Diagram 4 shows the frequency distribution of test scores as achieved by the fourth or straight visual method of instruction. Upon examining this diagram, we find the pretest range to be 9-60, with a very pronounced distribution of scores along the 1 to 36 section of the graph. The final test graph reveals a 3 division split as regards the score distributions between the 21-40, 46-65, and the 76-90 sections of the scale respectively. The range of scores as may be observed is now 11-90.

An examination of diagram 5, which is a graphic comparison of the pretest and final means of each of the methods involved, it may be readily seen that the means of the final of methods 1 and 3 are practically the same, but that the method 1 mean is higher in the pretest than that of method 3, indicating a somewhat greater gain in achievement during the course of the experiment. Method 2, as is evident from the diagram 6, stands out as having achieved the greatest improvement. Its pretest is practically the same as 1, a trifle more than 3, and less than 4, but its final mean tops the list. Comparing 3 with 4 we find the balance to be slightly in favor of 3 with the advance in mean by 2 and 4 being very similar.

Diagram 6 is a complete graphic illustrative comparison of the standard deviations of the pretest and final test, away from their respective means. It may readily be percieved that this diagram brings out the same interpretation as regards the relative achievements of the four methods of instruction used in this study. i.e.- Recitation gained 34 points in comparison to smaller gains made by the other three methods, thus again indicating, that it is slightly superior to the others.

In order to demonstrate that the difference existing between the methods employed is a true one, the author has computed by means of Garrett's formulae 18 and 19, and table 14,[1] the chances in a hundred that the difference of the methods when compared with each other is a true one. The results of these computations may be found in table 2.[2] From this table it may readily be seen, that in all of the comparisons in which method 2 takes part, that the chances are all above 94 out each one hundred, illustrating that the difference existing in each case is a true one. Thus indicating that the possibilities are high as regards the true superiority of the modified recitation, over the other methods employed.

The result of this investigation may surprise the reader as much as it did the author, who had entertained preconceived notions as to the superiority of the visual approaches, but was amazed to find that the tests disclosed the modified recitation to be somewhat superior. From these results and from carefully observing the classes involved, the author has taken the liberty of inferring that these tests, as well as any other tests, cannot measure all of the contributions that the slides and visual methods make. This is based on the fact it has been observed pupils responded more readily and frequently, and displayed

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1 Garrett, Henry   Statistics in Psychology and Education
Longmans Green & Co. 1926, pp. 121,127,129

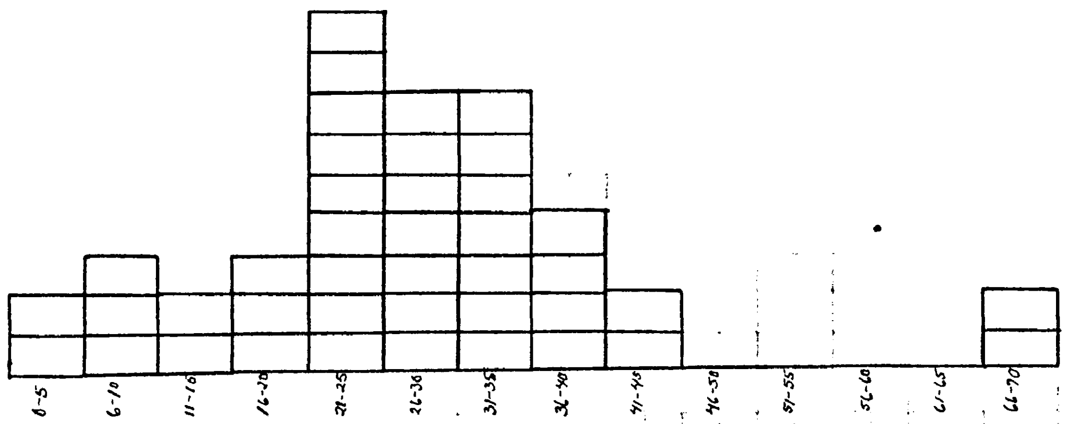
2 See table 2

more initiative as regards discussion, yet showed up considerably lower in tests, than did those working with modified recitation.

This superiority of the recitation method may in part be due to the fact that the majority of the students concerned had recently come from the elementary schools, where this method is still prevalent, and secondly, perhaps, it may be due in some degree to the fact that the text was not emphasized, and too many opposing viewpoints were presented in the lectures and discussions. Another possibility exists that the modified recitation proved somewhat superior, due to excessive verbalization since lectures and tests were verbal.

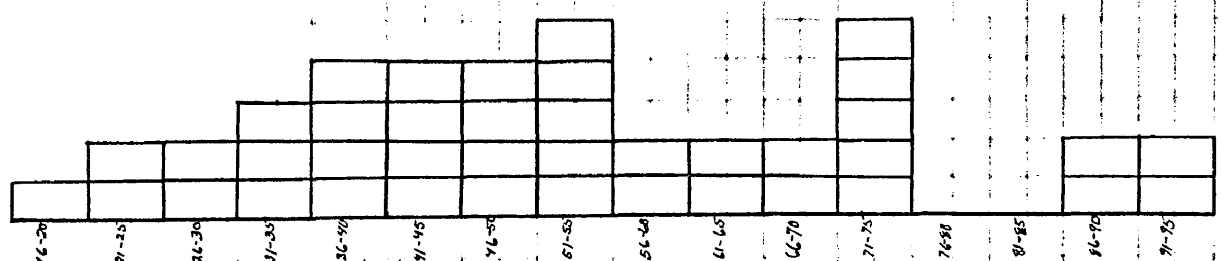
METHOD 1

Pretest



Mean -- 25.75
Median-- 25.7
Range -- 0-70
S. D. -- 12.05

Final test

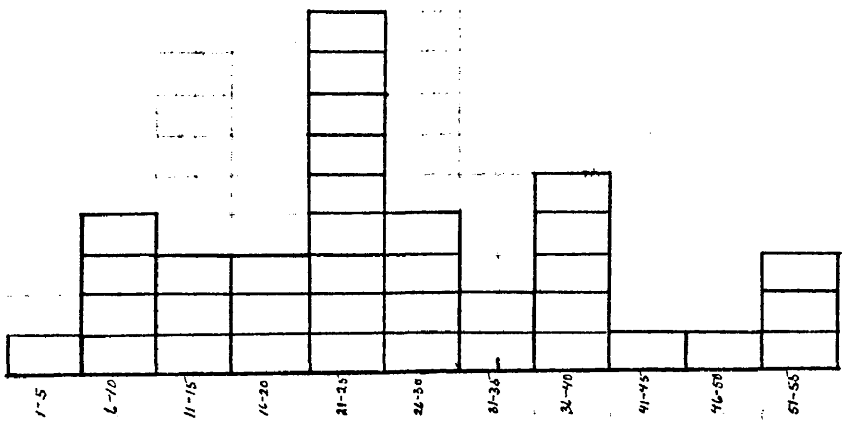


Mean -- 52.
Median-- 48.75
Range -- 16-94
S. D. -- 19.8

Diagram 1. Graph showing frequency distribution of pretest and final examination scores, as made by the class using method 1, or the mimeographed sketch method of visual instruction. (Each block in diagram represents one student.)

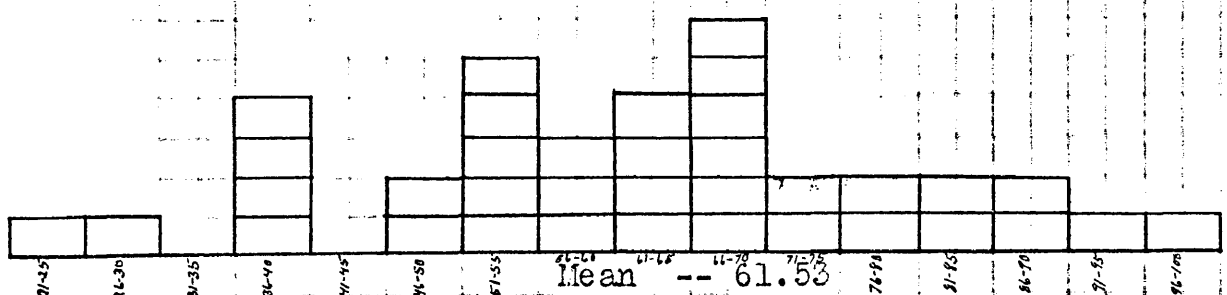
METHOD 2

Pretest




Mean -- 25.97
Median-- 23.8
Range -- 0-53
S. D. -- 13.30

Final Test

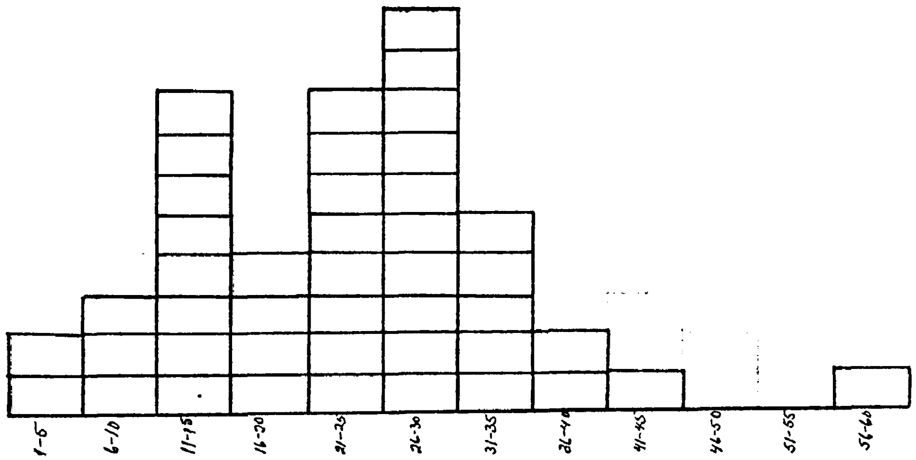



Mean -- 61.53
Median-- 65.53
Range -- 25-96
S. D. -- 15.8

Diagram 2. Graph showing frequency distribution of pretest and final examination scores, as made by the class using method 2, or the modified recitation method of instruction. (Each block in diagram represents one student.)

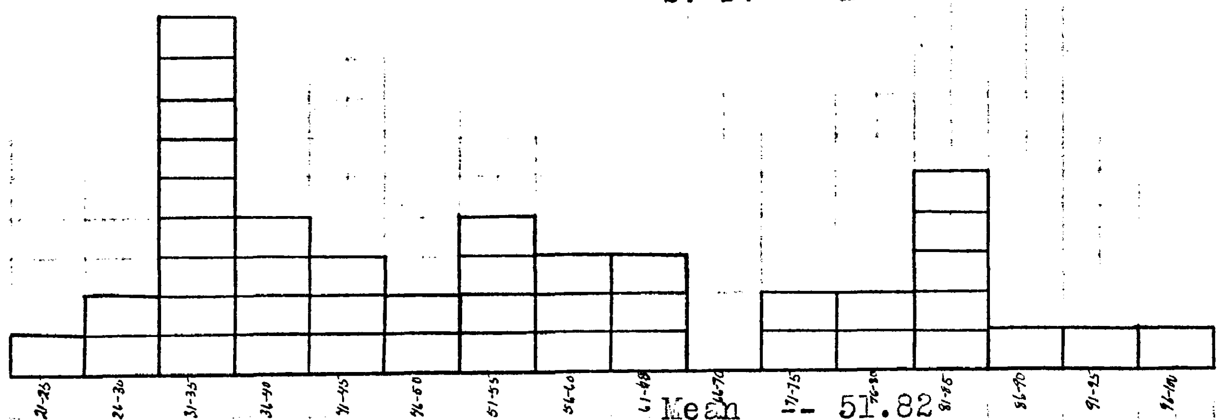
METHOD 3

Pretest




Mean -- 22.50
Median-- 23.1
Range -- 1-58
S. D. -- 10.8

Final Test

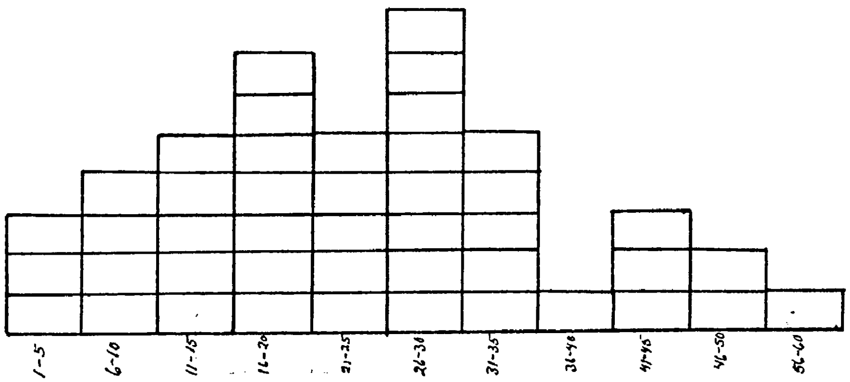


Mean -- 51.82
Median-- 57.25
Range -- 22-99
S. D. -- 17.18

DIAGRAM 3. Graph showing frequency distribution of pretest and final examination score, as made by the class using method 3, or the slide plus collateral reading method of visual instruction.

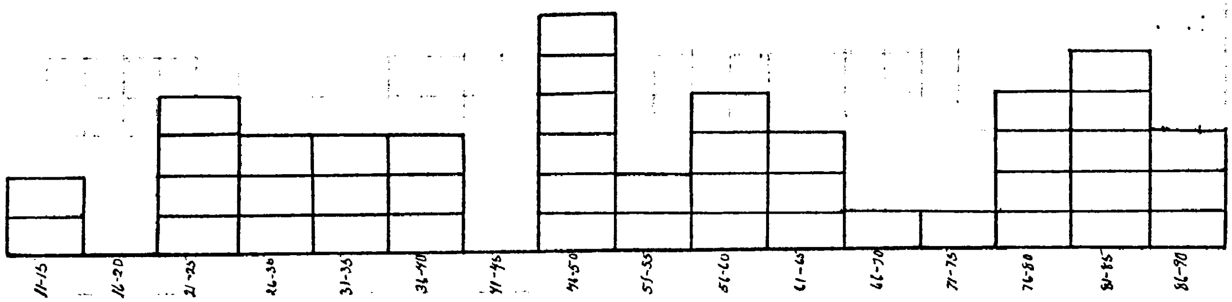
METHOD 4

Pretest




Mean -- 28.43
Median-- 28.
Range -- 9-60
S. D. -- 12.5

Final Test




Mean -- 53.18
Median-- 52.50
Range -- 11-90
S. D. -- 22.5

Diagram 4. Graph showing frequency distribution of pretest and final examination scores, as made by the class using method 4, or the slide only method of visual instruction. (Each block in diagram represents one student.)

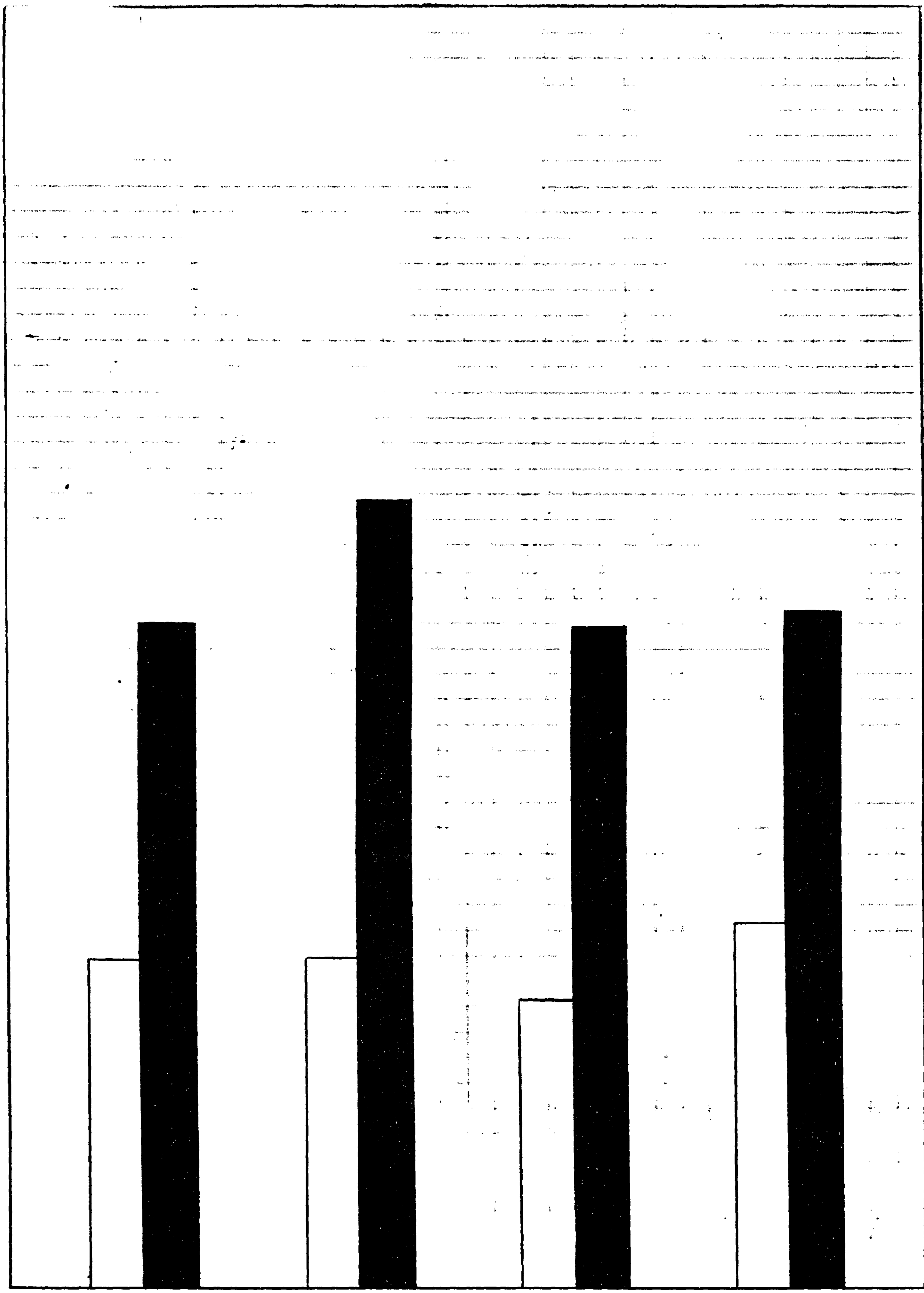



Diagram 5. A comparison of the means of the various methods involved, showing advances made in the means between pretest, (white bar) and final test (black bar).

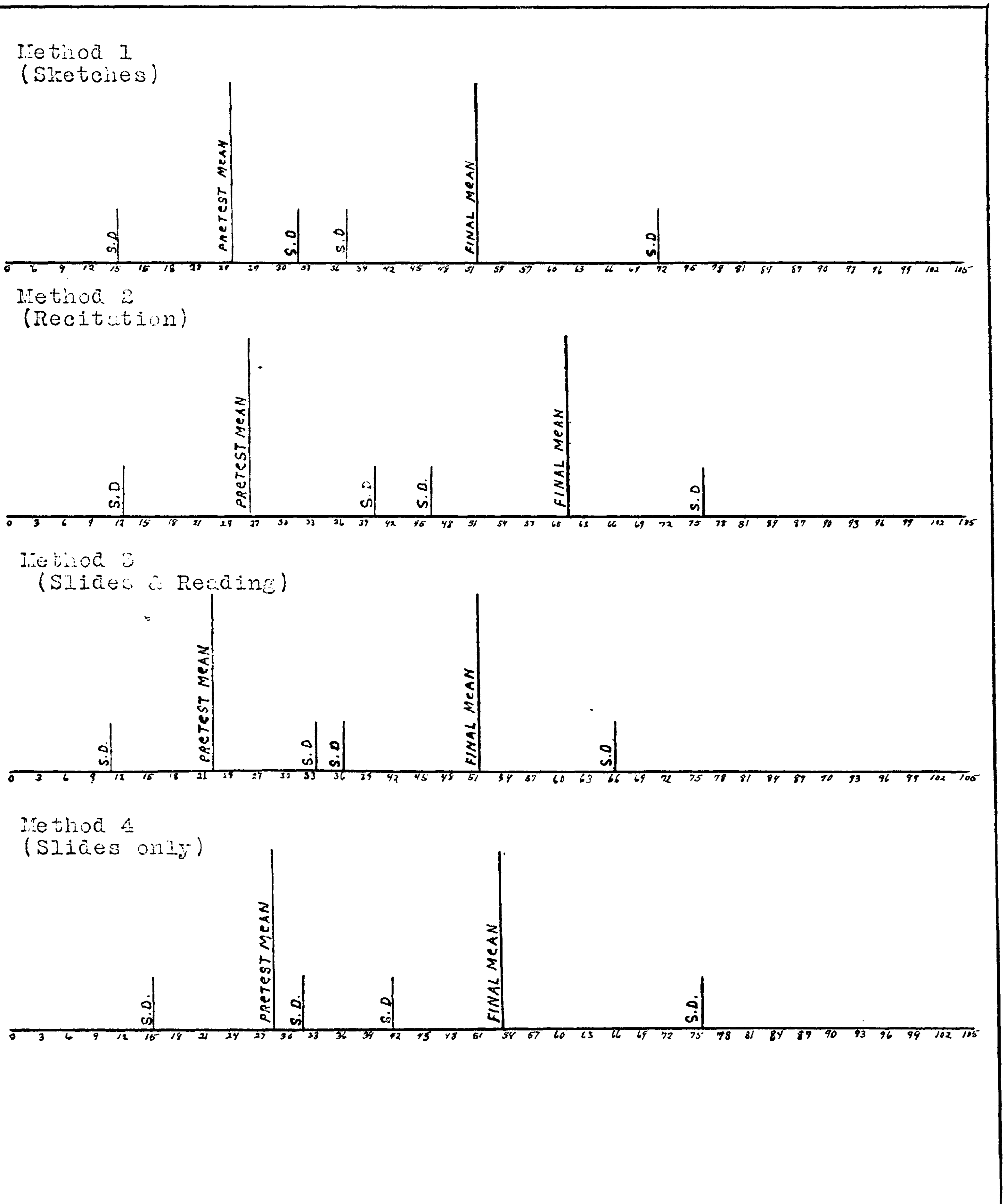



Diagram 6. A comparison of each method's pretest and final examination standard deviations, (S.D.), showing their relative distances from their respective means.

| METHODS COMPARED | CHANCES IN A HUNDRED |
|---|---|
| 1 and 3 | 50. |
| 1 and 2 | 94.4 |
| 1 and 4 | 60. |
| 2 and 3 | 99.5 |
| 2 and 4 | 99. |
| 3 and 4 | 62. |

Table 1. Showing the chances in a hundred that the differences obtained in the comparison of the methods is a true one, in so far as the tests applied have been able to determine.

| METHOD | PERCENT above 60 | PERCENT 45-60 | PERCENT 0-44 |
|---|---|---|---|
| 1. Sketch | 35. | 30. | 35. |
| 2. Recitation | 55.6 | 30.5 | 30.99 |
| 3. Slides & Reading | 40.90 | 20.46 | 38.65 |
| 4. Slides Only | 43.18 | 22.78 | 34.14 |

Table 2. Giving the percentages of the students making scores above or below a certain point.

# Chapter IV

# GENERAL CONCLUSIONS AND RECOMMENDATIONS

The results of the experiment justify the following inferences and recommendations.

## Conclusions

1. That as indicated by the test results, both the lecture and the study of the printed text yield as much information as does the visual method of instruction.

2. That the beginning teacher may make profitable use of the recitation method, provided that he is ambitious enough to present the subject matter in ways best suited to the individual groups of students, and teaches the pupils how to organize and summarize the material, and does not adhere too slavishly to the textbook. He should leave it to the student to get the text viewpoint, and should present the same material from several sources, thus giving a more varied and interesting point of view.

## Recommendations

The methods of teaching and the teaching materials used should be varied, in order to utilize such methods and materials as are best suited in each instance to accomplish the purpose of efficient instruction.

During a given class period, show only the slides on a single theme or on related themes.

The results obtained in various phases of the visual method are relatively uniform. However, it is recommended with this method, since the results of this experiment point slightly in that direction, that some collateral reading be required or given in conjunction with this method.

It is the author's firm belief that much better results could have been obtained in respect to the visual sketch procedure, had the sketches been arranged with but one to the page, since too many illustrations on one sheet seem to have a distracting influence.

An opinion is also offered in respect to another form of visual procedure, that the author has in mind, and intends to put to test at his earliest opportunity. Both slides and sketches might be furnished to the same class. The inference is that this method would bring better results than the other methods did. This conclusion is based on the reaction of a number of the students of both the sketch and slide plus collateral reading methods, who expressed to the author their liking for this type of method, in the following phrase, "We like the drawing better than the slides, because we cannot take the slides home with us to study."

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| | |
|---|---|
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# APPENDIX A

## LISTS OF INDIVIDUAL PUPIL SCORES

## TABLE I

| Pupil | Pretest Scores | Final Scores |
|---|---|---|
| A-1 | 37 | 72 |
| A-2 | 8 | 34 |
| A-3 | 17 | 42 |
| A-4 | 37 | 74 |
| A-5 | 35 | 54 |
| A-6 | 34 | [illegible] |
| A-7 | 5 | 33 |
| A-8 | [illegible] | 37 |
| A-9 | 27 | [illegible] |
| A-10 | 31 | 25 |
| A-11 | 44 | 37 |
| A-12 | 53 | 70 |
| A-13 | 70 | 88 |
| A-14 | 50 | 73 |
| A-15 | 3 | 50 |
| A-16 | 54 | 45 |
| A-17 | 10 | 58 |
| A-18 | 31 | 55 |
| A-19 | 50 | 91 |
| A-20 | 29 | 47 |
| A-21 | 32 | 51 |
| A-22 | 58 | 52 |
| A-23 | 45 | 60 |
| A-24 | 31 | 47 |
| A-25 | 14 | 16 |
| A-26 | 25 | 58 |
| A-27 | 31 | 40 |
| A-28 | 19 | 71 |
| A-29 | 22 | 55 |
| A-30 | 15 | 40 |
| A-31 | 25 | 47 |
| A-32 | 35 | 50 |
| A-33 | 29 | 70 |
| A-34 | 36 | 42 |
| A-35 | 19 | 59 |
| A-36 | 27 | 41 |
| A-37 | 21 | 72 |
| A-38 | 22 | 61 |
| A-39 | 28 | 65 |
| A-40 | 23 | 94 |

A list of individual pupil scores, as achieved by class employing the sketch method of visual instruction.

METHOD II

| Pupil | Pretest Scores | Final Scores |
|---|---|---|
| B-1 | 0 | 25 |
| B-2 | 25 | 38 |
| B-3 | 31 | 77 |
| B-4 | 25 | 65 |
| B-5 | 23 | 51 |
| B-6 | 23 | 64 |
| B-7 | 21 | 61 |
| B-8 | 36 | 83 |
| B-9 | 29 | 96 |
| B-10 | 38 | 71 |
| B-11 | 48 | 29 |
| B-12 | 51 | 39 |
| B-13 | 15 | 72 |
| B-14 | 37 | 86 |
| B-15 | 8 | 36 |
| B-16 | 25 | 70 |
| B-17 | 18 | 43 |
| B-18 | 14 | 46 |
| B-19 | 25 | 69 |
| B-20 | 52 | 91 |
| B-21 | 9 | 53 |
| B-22 | 24 | 85 |
| B-23 | 40 | 59 |
| B-24 | 14 | 36 |
| B-25 | 22 | 56 |
| B-26 | 26 | 53 |
| B-27 | 40 | 77 |
| B-28 | 43 | 70 |
| B-29 | 31 | 70 |
| B-30 | 10 | 62 |
| B-31 | 29 | 67 |
| B-32 | 17 | 57 |
| B-33 | 19 | 55 |
| B-34 | 53 | 55 |
| B-35 | 28 | 70 |

A list of individual pupil scores, as achieved by class, employing the modified recitation method of instruction.

# METHOD III

| Pupil | Pretest Scores | Final Scores |
|---|---|---|
| C-1 | 23 | 33 |
| C-2 | 32 | 65 |
| C-3 | 32 | 90 |
| C-4 | 30 | 83 |
| C-5 | 35 | 58 |
| C-6 | 22 | 31 |
| C-7 | 36 | 63 |
| C-8 | 28 | 53 |
| C-9 | 1 | 34 |
| C-10 | 1 | 85 |
| C-11 | 15 | 61 |
| C-12 | 24 | 44 |
| C-13 | 8 | 55 |
| C-14 | 17 | 71 |
| C-15 | 26 | 32 |
| C-16 | 26 | 27 |
| C-17 | 15 | 41 |
| C-18 | 30 | 33 |
| C-19 | 34 | 70 |
| C-20 | 26 | 78 |
| C-21 | 13 | 50 |
| C-22 | 14 | 53 |
| C-23 | 8 | 32 |
| C-24 | 14 | 81 |
| C-25 | 42 | 83 |
| C-26 | 38 | 99 |
| C-27 | 58 | 95 |
| C-28 | 8 | 81 |
| C-29 | 24 | 36 |
| C-30 | 17 | 22 |
| C-31 | 23 | 48 |
| C-32 | 13 | 33 |
| C-33 | 15 | 32 |
| C-34 | 23 | 37 |
| C-35 | 17 | 30 |
| C-36 | 27 | 80 |
| C-37 | 35 | 72 |
| C-38 | 26 | 36 |
| C-39 | 24 | 79 |
| C-40 | 16 | 45 |
| C-41 | 22 | 39 |
| C-42 | 30 | 60 |
| C-43 | 29 | 33 |
| C-44 | 12 | 51 |

A list of individual pupil scores as achieved by class employing the slide plus collateral method.

## METHOD IV

| Pupil | Pretest Scores | Final Scores |
|---|---|---|
| D-1 | 14 | 48 |
| D-2 | 39 | 80 |
| D-3 | 48 | 79 |
| D-4 | 27 | 26 |
| D-5 | 33 | 76 |
| D-6 | 39 | 90 |
| D-7 | 33 | 83 |
| D-8 | 16 | 25 |
| D-9 | 49 | 85 |
| D-10 | 39 | 51 |
| D-11 | 30 | 62 |
| D-12 | 24 | 34 |
| D-13 | 60 | 82 |
| D-14 | 34 | 82 |
| D-15 | 52 | 83 |
| D-16 | 13 | 11 |
| D-17 | 10 | 49 |
| D-18 | 9 | 27 |
| D-19 | 21 | 15 |
| D-20 | 15 | 50 |
| D-21 | 34 | 40 |
| D-22 | 38 | 47 |
| D-23 | 35 | 60 |
| D-24 | 35 | 36 |
| D-25 | 22 | 68 |
| D-26 | 10 | 39 |
| D-27 | 32 | 22 |
| D-28 | 11 | 25 |
| D-29 | 23 | 59 |
| D-30 | 24 | 57 |
| D-31 | 22 | 32 |
| D-32 | 22 | 34 |
| D-33 | 43 | 35 |
| D-34 | 18 | 36 |
| D-35 | 16 | 24 |
| D-36 | 20 | 27 |
| D-37 | 40 | 86 |
| D-38 | 39 | 72 |
| D-39 | 17 | 46 |
| D-40 | 32 | 61 |
| D-41 | 29 | 60 |
| D-42 | 47 | 90 |
| D-43 | 26 | 64 |
| D-44 | 54 | 77 |

A list of individual pupil scores, as achieved by class employing the straight visual method of instruction.

# APPENDIX B

## TEXT COMPILED BY AUTHOR
## FOR THE MODIFIED RECITATION METHOD

# CHAPTER 1

# ANCIENT AND MODERN NOTIONS AS TO THE SHAPE OF THE EARTH

The earth as we know it and as common sense and science teaches us, is a sphere like the other planets of our solar system, and many experiments have been devised and performed which prove that this is so. An interesting way to see that it is round, consult an almanac for the time of the next eclipse of the moon visible to you and watch for it. When this occurs you will see that the edge of the shadow of the earth that it cast on the moon is round. Another proof of the roundness of the earth as devised by the Greek philosopher, Aristotle, which we may try even today, is to watch a ship come in. First we see only the smoke, then we see the top of the mast, as if the ship were climbing up the side of a hill. Finally it is over the circle, sailing clear on the top of the ball.

EARLY IDEAS ABOUT THE EARTH---- Long before the world was thought to be round, the Vedic priests believed it was a great flat surface supported by twelve great pillars, and virtuous persons were sacrificed to the gods to keep these pillars from collapsing. However, the earth was originally conceived as a great flatland of infinite depth, which supported the heavens. Later when men began to round the Capes in ships, they imagined the earth as floating in a universal ocean of unknown extent, and from this it was but a short step to the conception of the earth as bounded by a circle with roots reaching downard.

Anaximander a Greek of the 6th century B.C. concluded that the earth was a cylinder, whose diameter was three times its height, which floated in the center of the vault of heaven. Only its upper face was inhabited, of which the northern half was Europe and the southern half was Libia or Africa, and Asia.

A little later Plato evolved his cubical earth, holding that the cube with its six faces, being the most perfect of forms, should be the form of the dwelling place of man.

Long before the Western world had begun to measure toward the spheroid form, the ancient East had imagined a spherical earth with great mountains to the north and south. Here again in this conception of the earth, the earth is again held upright by a majestic pillar or the worlds axis. Now they thought in hemispheres, and mostly in northern hemispheres. The northern half of the earth came to be, therefore, a great mountain, rising out of the equatorial ocean, and carried in imagination to the clouds and beyond them, to the dwelling place of the gods themselves. Where the southern hemisphere was located, it in turn also was a great mountain, inverted, however, connecting the earth with the home of the demons below. These mountains of the world connecting the heavens and the places below with the earth, and serving as the axis around which the heavenly bodies revolved, was an early Hindu notion.

A later Hindu conception was of the earth as a large half shell or disc. The Hindus represented this circular as resting on the backs of four great elephants, symbolizing the four elements, or winds; these rested on the back of a great turtle swimming in a sea of milk, which symbolized variously strength, endurance, patience, creation, or eternity.

The Chaldeans thought the earth was an enclosed chamber surrounded by water.

The Greeks believed the earth a great disc floating in the sea.

The Chinese believed the earth a great square and their country the greatest circle within the square.

While the Ancient Egyptians thought the earth was a great box, rectangular in form, the stars hanging from cables or ropes and the sky was considered a rigid ceiling, and the above mentioned suspended stars, were thought to be lamps, and the sun was considered a disc of fire travelling around on a boat in a river.

The Eskimos believed the center of the earth was a nice, warm heaven where good peopgle go, and the sky a terrifically cold place where the wicked froze forever.

Another very ancient idea of the earth, which reached the western world not more than 1500 years ago, is the universal egg, floating in ether, sometimes on its side, sometimes erect. Edrisi, an Arabian geographer of the eleventh century A.D. considered this egg or earth, to be half plunged in water, that is the unknown part or hemisphere was submerged. The venerable Bede, of the 8th century explains this idea as follows: "The earth is an element placed in the middle of the world, as the yolk in the middle of an egg; around it is the water, like the white of the egg which surrounds the yolk. Outside of that is the air, like the membrane of the egg; and around all is the fire which closes it in as the shell does. The portion which is exposed to the torrid action of the air is burnt by the sun and is uninhabitable; its two extremities are too cold to be inhabited, bu the portion that lies in the temperate region of the atmosphere is habitable. The ocean which surrounds it by its waves as far as the horizon, divids it into two parts, the upper of which is inhabited by us, while the lower is inhabited by our antipodes; though not one of them can come to us, nor one of us to them."

On a "tomato shaped" form Ptolemy, in the 2nd century stretched his maps of the world. The poles were in the middle of a great plateau. With this form as his working model , Apianus, in 1520 made his famous "cardiform projection" nd this it obtained his heart-shaped map, supporting the revival by the middle ages of the old fancy that the earth is "the heart of God."

The cardiform earth map bears a curious, far off resemblance to the earth of Columbus. For it is one of the little ironies of life that the man who more than any other popularized the notion that the earth was "shaped like a ball," himself believed it was shaped like a pear. We find this in his letters, and in the writings of his contemporaries. For he privately affirmed that the earth was pear shaped. The old hemisphere, the eastern half runs true to the spherical form on which he had staked his all. But the new hemisphere, the western world he was to unroll, rose to a loftly mountain at the equator. "The mountain of the world" had moved, that is, from north to west. Columbus compared his earths figure to that of a nearly round pear.

Dante's earth, a century earlier, had too its mountain, "the mountain of purgatory," but it was placed more than 30 degrees below the equator. "The City of Jerusalem," or "Zion" stands with this mountain in such wise on the earth that both have a single horizon and diverse hemispheres.

More recent ideas about the shape of the earth -- Gueer and often fantastic notions concerning the shape or form of the earth cannot be confined to the beliefs of the ancients and the middle ages alone. For a little over a hundred years ago, in St. Louis, in 1819 to be exact, Capt. John Cleves Symmes issued the first details of which has come to be known as the Symmes Theory of concentric circles. In 1833 and again in 1824 he petitioned the congress of the United States, asking for two vessels whereby to enter, if he might, the interior of the earth.

According to the Symmes Theory, the earth, and all stars, consist of a collection of spheres, more or less solid, concentric with each other, and more or less open at their poles; each sphere reported from its neighbors by space rich in aerial elastic fluid. The planet called earth is composed of at least 5 concentric spheres, all habitable as well upon the concave as the convex surface. The north polar opening would be about 4,000 miles in diameter, the southern 6,000. The theory of Symmes may well be termed the open hole theory of the earth.

Little less than a century later, Marshall Gardner at Aurora, Illinois, in 1913, published "A Journey to the Earth's Interior," giving his theory of a hallow earth, open at the poles, with, however, one shell 800 miles thick, and with an interior sun. He gives this single shell a "Center of Gravity" that allows for a concave surface probably the reverse of the outer as regards the distribution of land and water. The polar openings are estimated as 1,400 miles in diameter, which allows the imagined voyagor sufficient "curve" for rounding the great capes of water, or "the lips of the world."

William L. Green in 1875 worked out, with the aid of a "model crystal" a inverted Tetrohedron or pyramid with its sides depressed and its four corners thereby slightly raised. His hypothesis is that during the process of the earth's cooling, and because of what he calls "the tetrohedral collapse of the earth's crust in the southern hemisphere," the assumed spheroid form of the earth tends to develope into a tetrohedron

## CHAPTER 2

You may or may not know it, but the first astronomers were boys. At least they were the first to gaze wonder eyed at the stars and want to know about t hem. These youngsters were the shepherds of old, and they had to watch over the argili and musmow, which were, after the wolf, the first animals to be tamed by the earliest of the primitive races, and kept them from straying away or being killed by other animals.

In the course of time the wolf became the dog and the argili and musmow became the sheep for the latter were the first wool bearing animals, and as the half-savage boys herded them they taught their wolf-dogs to run off intruders, later on, how to round up their charges.

As these pre-historic boys watched over their herds, they observed that when the great fiery ball, which we now call the sun, went down on one side of the place where they sky and the land seemed to meet, dusk came on, and then darkness, and soon bright points of light, which are the stars, appeared all over they sky. Then as they gazed at these bright points thru the long watches of the night, they saw them gradually move across the bowl of they sky, and as some sank from sight, others rose on the opposite side until the sun came up and put them all to flight.

At night there were other things that appeared in the sky, some of which filled them with fear, one of them, however, they were not at all afraid of, though it did make things around them look dreadfully scary; this was a great ball of mellow light as large as the sun - sometimes larger - and since named the moon.

The two things which especially frightened them at night were those balls of fire which shot across the skies and which we call meteors, and secondly the appearance at rare intervals of another ball of fire, much larger than any meteor, with a huge blasing tail, that did not shoot and disappear, but which stayed in one place in the sky night after night. Oh! I tell you these meteors and comets were terrible objects to a boy with just a little more sense than a monkey, herding sheep alone, on a great plane.

And when these boys returned to their elders in the morning they would the most wonderful tales about what they had seen during the night, then the grown-ups would get interested in the starry heavens and do a little star gazing on their own account. In just the same way that the boy "Radio fans" of today have interested their fathers and mothers in wireless, so in this respect the world is not very different now from what it was when this human race was young.

Where the First Star Gazing took Place ----- And when and where do you suppose all this happened? It took place more than 10,000 years ago on what is called the Iranian Plateau, a great expanse of land in the country that is now Persia. It was here that the first human race lived, and from here, from time to time, members of it journeyed forth to India and China, and Chaldea and Egypt. These were the ancestors of the present races of these and all the other countries.

Not only was the great plateau the firth place of nations, but it was also the cradle of civilization. This is the reason that all the old races know about the stars, and as the chief occupation of the boys and men was to tend sheep, they became more and more versed in astronomical lore. Then they began to till the soil and to sail the seas, and they put their knowledge of the heavenly bodies to practical use and so learned more about them. The best of the earlier astronomers were the Chaldeans and the Babylonians, probably because they lived closer to the Ironian Plateau where astronomy had its origin. The Babylonians are credited with inventing the Sun Dial. They are also responsible for the rise of astrology, which falsely supposes that the stars influence the destinies of human beings, and curiously enough there are some today that still believe it.

The Beginning of Real Astronomy ----- Thales, who lived about 600 B.C., and was the chief of the Seven wise men of Greece, may be considered to be the father of real astronomy. It was he that first measured the height of the pyramids of Egypt by the shadows they cast, who taught that the earth is round, that the fixed stars shine by their own light, and that the moon shines by the reflected light of the sun. His greatest achievement was his prediction of an eclipse of the sun, and it is said that this took place when a battle was being fought between the Medes and the Lydians and that it ended the war and made peace between them.

Next came the great Hipparchus, another Greek astronomer who lived about 150 B.C. It was he who first found the true length of the year, discovered the procession of the equinoxes, and the revolutions and motions of the planets, and finally on seeing a new star in the sky he concluded to make a catalogue of all those visible, but this only included 1080 stars. He also invented trignometry.

The man who did the most to upset the true astronomy that Hipparchus and those before him built up was Ptolemy. He was and Egyptian who lived in the 2nd century after Christ, and he divised a complicated system to explain the motions of the heavenly bodies; in a word, he fixed the Earth as the center of the universe, with the sun, moon and planets revolving around it every 24 hours, while the fixed stars were carried round them all in the same length of time by a great sphere. This idea was the accepted one for the next 1500 years.

The Astronomy of Today----- It was Copernicus, a Polish astronomer who lived in 1500, who overthrew the system of Ptolemy, and following him about a hundred years later came Galileo who left not the shadow of a doubt on which to hang the Egyptian's system. Copernicus could not see how the distant fixed stars could possibly move fast enough to revolve around the earth every day.

So he concluded that the sun was the center, not of the universe but of our solar system, that the earth was a planet like Mars and Jupiter and Venus, that all of these revolved around the sun, while the moon revolved around the earth and finally, that the distant stars were fixed, that is they did not revolve around either the earth or sun. But while Copernicus knew that the planets revolved around the sun, he believed their orbits were circular in shape.

Then in 1600 came Tycho Brahe (pronounced Brah) a Danish astronomer who made many observations with a large sextant, the telescope had not yet been invented. Johann Kepler, a German mathematician, worked with Tycho, and after the latter death, discovered that the orbits of the planets were not circles but eclipses. He then formulated three great laws, called Kepler's laws, and with these it was easy to explain all the shortcomings of the Copernican system.

The discovery of the Telescope ----- At the same time that Kepler was working out his laws, there lived a man as famous in science as Columbus is famous in discovery. His name was Galileo Galilei and he was the first to look at the stars through a telesco e. Because Galileo was such a great scientist he is often given the credit for having invented the telescope, but it is a matter of history that it was discovered by a boy.

It came about in this way. In the city of Amsterdam, Holland, there lived a spectacle-grinder named Lippershey and he had a boy working for him as a helper. This boy, whose name was not recorded, which is a sane, was one day looking through various lenses at objects down the streets. Finally he held two lenses in a line before his eye, and looked at a church some distance away. A wonderful change had taken place, for the church seemed to be very much nearer than it was before, and he could easily see the details of it, which without the aid of the lenses were invisible. He had discovered thetelescope.

What Galileo Saw.-------In due time the news of the discovery of the telescope by Lippershye's boy reached Galileo and he forthwith constructed a telescope which had a magnifying power of 32 times. His obervation with this instrument soon startled the world for he announced that there were mountains on the moon, that Jupiter has four moons, that Venus has phaces like our moon, that the sun has spots on it, and many other strange things that had been unknown up to his time.

A new interest had been given to astronomy by the telescope and Galileo's discoveries, and from that time on larger and ever larger telescopes were made until now there is one at Yerkes Observatory 40 inches in diameter.

## CHAPTER 3

## THE EARTH AND ITS UNIVERSE

What You May Expect To Fin In this Unit.-------We have just learned about some of the ideas which ancient and modern people have had regarding the shape of the earth. But the earth is merely like the house in which we live. There are other houses in the town, other towns in the state, other states in the country, other countries in the world we call the universe. All things in the universe are drifting in space, the extent of which no one has seen, whose depths no instrument has ever fathomed, whose substance is so thin that it can be compared with none of the materials we know on earth. Compared with space, even the partial vacuum in an electric-light bulb is thick and heavy. The universe is so vast that it is almost impossible for the human mind to imagine its size. Yet its immensity is not its most remarkable characteristic. More awe-inspiring than this, as we shall shortly learn, is the fact that everything in space moves with pefect order.

You may have noticed that some groups of stars appear to form particulr kinds of groups. The astronomer calls each of these groups a constellation. The ancients imagined that these constellations represented animals and people in the sky. They saw the Great Bear, the Little Bear, The Qeen and her chair (Cassiopia) Arion and many others.

Some of the stars seem to remain in about the same position with relation to one another, while others move about. The ancient people knew this and called the first fixed stars and the second morning stars, or "wanderers," because they seemed to be roaming about the heavens. We call the wanderers planets.

An understanding of how the movements of the earth, sun and stars are related has been one of mans great advances in knowledge. We know that the universe moves with an orderly precision greater than man is able to duplicate, even in the best laboratories We know the exact time of sunrise and sunset, the exact time of noon, the exact time when the sun is over the equator, and exactly when it is farthest north or farthest south. We know exactly when the next eclipse of the sun or eclipse of the moon will be. We even know when every eclipse for hundreds of years to come will occur. This unit is intended to help in the understanding of this orderly universe, of which our own earth is a very small part.

## CHAPTER 4

## THE SOLAR SYSTEM

In beginning our study of the universe it is well for us, since we are dwellers on the earth, to begin our study of the solar system, of which we are a part.

What "Solar System" means.----- Our solar system consists of our sun, a huge sphere, the diameter of which is about 866,400 miles, 108 times the diameter of the earth and nearly 300 times the diameter of the smallest planet, Mercury. It would take more than a million earths to equal the volume of the sun. Composed with its family of planets, the sun is overwhelmingly great. It contains nearly 99.9 percent of the mass of the entire solar system In the remaining 0.1 percent are included all the other members of the solar system and their moons, as well as the planetoids, meteors and other small bodies under control of the sun. Besides this sun the solar system likewise consists of the various kinds of heavenly bodies that revolve about it. These bodies are the 9 planets with their satellites (moons) the asteroids (Sometimes called planetoids) the meteors and meteorites, and the coments.

Each of these bodies follows an orbit, or path around the sun. These orbits are so exact and definite that after a few observations of a planet, or comet, the astronomers are able to compute the entire orbit of the body, and to determine with great accuracy where that body will be at any future date. Then paths or orbits are elliptical in shape.

The Planets.---- There are 9 known planets in our solar system They may be distinguished from the stars because (1) they shine with a steady light and (2) from night to night they change their position among the stars. We can see them because like the moon, they reflect the sunlight. These planets named in order of their distance from the sun, are Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto. All of the planets fall on definite orbits about the sun. All travel in their orbits from west to east. Mercury and Venus are the only planets which have not at least one satellite, or moon; the earth has 1, Mars 2; Jupiter 9; Saturn 10 and Uranus 4.

Mercury is not only the nearest planet to the sun, but it is also the smallest and swiftest moving.

Venus is often called the earth's twin, because it is almost as large as the earth.

The earth is about 8,000 miles in diameter and 25,000 miles round at the equator.

We have just learned that the earth has 8 companion planets that circle about the sun. All the planets move about the sun in the same direction. The following table presents the outstanding facts concerning the planets.

| Planet | Rotation on axis (Length of day) | Revolution around sun (Length of year) | Diameter (In miles) | Distance from sun (In Miles |
|---|---|---|---|---|
| Mercury | 88 da. | 88 days | 2765 | 36000000 |
| Venus | Uncertain | 225 days | 7700 | 67200000 |
| Earth | 24 hrs | 365 days | 7918 | 93000000 |
| Mars | 24 hr 37 min | 687 days | 4230 | 141000000 |
| Jupiter | 9 hr 55 min | 12 yr | 86500 | 483000000 |
| Saturn | 10 hr 14 min | 29½ yr | 73000 | 886000000 |
| Uranus | Uncertain | 84 yr | 31900 | 1782000000 |
| Neptune | Uncertain | 165 yr | 34900 | 2793000000 |
| Pluto | Uncertain | 248 yr | About the same as the earths | 3678000000 |

Besides the nine known planets, there are many smaller bodies under the Gravitative pull of the sun. These have up till now been about 940 planetoids or small planet-like bodies located, revolving about the sun between the Mars and Jupiter.

It will help you to get a mind picture of the solar system if you think of the sun as a ball 5 feet in diameter. On this same scale, then, Mercury would be represented by a tiny ball about 1/5 of an inch in diameter, over 200 feet from our five foot sun; Venus by a marble about 1/2 inch in diameter, nearly 380 feet away; the earth by another 5 inch marble over 500 feet away; Mars by a tiny ball about 3/10 of an inch in diameter, more than 800 ft. away; Jupiter by a ball half a foot in diameter over 1/2 mile away; Saturn by a 5 inch ball nearly a mile away; Uranus by a 2 inch ball nearly 2 miles away and Neptune by a ball 1-1/4 inches in diameter, over 3 miles away from the 5 foot sun, and Pluto by a 5 inch marble about 5 miles away from our 5 foot sun.

The Solar System as marked by the orbit of the outermost planet, Pluto is very large in comparison with any distances that are common in our lives. It would take a bullet 750 years to travel across Pluto's orbit. For us who are accustomed to thinking of distances on the earth's surface, the size of our solar system staggers the imatination. With the Orbit of Pluto as its outer edge, our solar system is approximately 8,000,000,000 miles across.

Using a common type of locomotives, familiar to us here on earth a train for instance travelling at a speed of 70 miles per hour, it would take that train 166 days to each the moon, 5055 years to reach neptune, 40 million years to the nearest star, 76 years to Mars; 177 years to the Sun; and 110 years to Mercury.

As we have said before, the sun and earth move thru the universe and if we were to observe 2 stars nightly, they would seem to be farther and farther apart due to the fact that the angle of our vision is increased, due to the fact that the earth has moved closer to the position of these fixed stars.

In measuring the enormous distances to the various planets the astronomers use what is known as the base line and angle method. A known line is drawn between two points of observation, then by use of micrometers on their telescopes the astronomer measures the angles from their point of observation to the point to be observed on the planet or star whose distance is in question, and then by the use of the Trigmetric junctions, he is able to determine the unknown distance by simply knowing the length of the base line and its adjacent angles. These methods of measurements are readily compared to the way a surveyor uses his transit to measure distance or width of an unapproachable object. It is likewise analagous to the gunfinder used by the gunners on Uncle Sam's big warhips. They consist of a single eye piece, with two rather widely separated objective lenses, with focusing cross hairs, and by so focusing the range finder until the hairs cross in the objective lenses the correct range is found. Since the true distance of an object is determined by the angle of they eyes and the size of an object.

Men Have Always Studied the Sky --- The earliest men must have studied the heavens. Since so much of their safety and welfare depended upon their being able to observe and interpret the positions of the heavenly bodies, primitive man came to regard the heavens with awe and superstition. Little by little, as men became civilized, they began to organize their scanty knowledge of the heavens into a rude sort of science. This was not a true sdence but a mixture of a little astronomy with a great deal of superstition and fancy, and it was called astrology.

Astronomy Grew Out of Astrology --- The science of astronomy owes much to the early astrologers. In their study of they skys for omens or signs bearing upon human affairs they discovered and confirmed many scientific facts. Thus astronomy slowly developed out of astrology.

It is surprising how much early astronomers learned when we remember that they had to make all their observations with the naked eye. The telescope was invented only a bout 300 years ago, and the spectroscope is a very recent invention. By means of the telescope and other marvelous instruments, astronomers have been able to measure the distance to various stars, to find out the nature and weight of the earth, the sun, and other heavenly bodies, and to determine much about the conditions which exist on the different planets.

Stars Larger and Smaller Tan our Sun --- The astronomers have also learned that the stars vary greatly in size. There are stars which are no larger than the planets of the solar system. Our sun is more than a million times larger than the earth, yet it is hardly a medium sized sun. Betelguese, the beautiful orange-red star in Orion, has about 27 million times the volume of our sun, and red Antares may be a still larger sun. Antares is less dense than the best vacuum which we can make in the Physics laboratory; but some of the smallest stars are so dense that a cubic inch of their substance would weigh tons. Thus it would take a powerful derrick to left a lump the size of a golf bll; and a railroad flat car could hardly hold up the weight of a lump the size of a man's doubled fists.

The Milky Way Made Up of Billions of Stars.---- When we look at the sky on a clear night when the moon is not shining, we see a broad band of dim light stretching across the heavens. We call this band of light the Milky Way or Galaxy. When we examine the Galaxy with a small telescope, we find that the dim light is really the light of separate stars so close together that we cannot see them as separate stars with the naked eye. Our small telescope reveals several hundred thousand stars in the Galaxy; with the greatest modern telescope (that on Mt. Wilson, Cal.) more than a billion may be photographed.

Astronomers believe that there are probably innumerable suns in our Galaxy which even the monster telescope does not r reveal, because their light is too dim or because they are dark. Doubtless hundred of thousands more would be revealed by more poerful telescopes. Astronomers know that our sun is merely one of the smaller stars in the Galaxy. If the whole Galaxy could be seen at once, it would be found to be an enormous swarm of suns grouped together somewhat in the shape of a watchcase. All these suns are moving in response to the gravitational attraction of other stars in the group. They are travelling in various directions like a swarm of insects, at the average rate of about half a billion miles a year. They are so far away that from year to year we can observe no changes in their positions, in fact, if we could have seen the sky at the time of Christ it would have looked almost exactly as it does now.

Many Galaxies in the Heavens -- The Galaxy which we see in the sky is brighter than other portions of the heavens, because we are looking through that part of it which is greatest in extent and where the stars are thickest. Moreover, these stars are not close together, as they seem to be. They are in fact thousands of luminous cloudy patches called nebulae scattered through the heavens. Many of these are distant galaxys containing billions of suns. Some of these galaxys are probably smaller than ours and others even larger.

The Milky Way is estimated as having a depth of 50,000 light years at its widest part, and 10,000 light years at its narrowest, and is about 300,000 light years long.

Astronomers have never yet found any evidence which would lead them to believe that any other star besides our own sun is surrounded by a group of planets. Because we have no way yet of discovering any of these planets if they do exist, because if a planet as great as Jupiter, the largest in our solar system, circled around the nearest star beyond our sun, it could not be seen with the most powerful telescope.

Our Earth of Small Importance in the Heavens-- Our earth seems to us vast and important. However, it is just a tiny speck in comparison with our sun, which is only a medium-sized star and one of perhaps 10 billion in the Galaxy, and there are hundreds of thousands of other galaxes, or star systems, scattered through space with the distances that separate them so great that our minds fail to comprehend them. We are forced to realize that our earth and ourselves and even our solar system are so small as to be of little importance. Yet we can be proud of the fact that, small as we are, the minds of our scientists have been able to invent instruments which have enabled them to explore these vast heavens and tell us with assurance about so many marvels that the heavens contain.

The Instruments of an Observatory:---- The three chief instruments that are used by the practical astronomer are the equatorial telescope, the observatory clock, and the transit instrument. Necessary adjuncts to these are the micrometer, the spectrosco e, the camera and chronograph.

The Equatorial Telescope--Big telescopes for astronomical work are usually housed in a dome having a slit in it that reaches from the top to the bottom, and it is through this opening that the light from the heavenly object passes into the objective of the telescope. The dome is provided with machinery with which it can be revolved so that the slit can be made to face the object that is to be observed; the floor of the dome where the telescope is mounted is in some large observatories raised and lowered by machinery to suit the convenience of the observer.

The telescope itself consists of three chief parts, and these are the principal, or polar axis, which is parallel with the axis of the Earth; at right angles to the polar axis is the declination axis, and on this is mounted the telescope, set at ri ht angles to it. Both of these axis are fitted with graduated circles, the first of which is the right ascension circle, and this shows the position of the stars in hours, minutes, and seconds, and the other is the declination circle, which shows the position of them in degrees, minutes and seconds.

The telesco e needs only to be turned from east to west and at a speed which corresponds to that of the earth rotating on its axis to keep it pointing to a given star. To do this automatically a driving clock, which is usually placed inside of the supporting pier of the telescope, turns the polar axis according to sideral time (star time) from east to west, when the telescope will follow the apparent motion of the star.

The Observatory Clock.-- The precision time-keeping clock that is used for astronomical work must not be confused with the driving-clock of the telesco c. The observatory clock is a fine one driven by weights having a pendulum encagement. It is made as accurately as the clock-makers skill can do so. All this is necessary, for the astronomical calculations are based on the time it keeps. Different from an ordinary clock, the dial is divided into 24 hours, hence its hour hand makes only 1 complete revolution in 24 hours. It is regulated to deep Sideral time.

The Transit Instrument:--- It is with the tranit instrument that the astronomer get the exact time to set the observatory clock by. This instrument consists of a telescope rigidly mounted on a horizontal axis, and this swings in bearings set in a line due east and west hence the telescope can be swung in a north and south line only, and this is exactly on the meridian. At the point where the eye piece and the object-glass come to a focus in the telescope there are a number of spider threads, and 5 of these in the middle in the horizonal plane. Now when the observer sees the star he is looking at pass across the certical spider threads, and it crosses the horizontal one, he knows that the star is crossing the meridian, and this is called its transit; at this instant he presses a key that closes an electric circuit which is connected with a chronograph. In this way he is able to set the clock every 24 hours or oftener if he wishes to.

The Micrometer-- A micrometer is an instrument used on telescopes for measuring very small angular distances of or between heavenly bodies, as those of double stars.

The Spectroscope-- The astronomical spectrosco e is a specially made instrument that is fitted to the eye-end of the telescope. The chief use of the spectroscope is to find out what the elements are of which the Sun and other stars are made. It has been found that most of the lines in the solar spectrum can be identified with the spectra of the elements of which the Earth is made.

In 1869 Sir Normen Lockyer, a noted British astronomer while examining the Sun with a spectroscope discovered a gas which was not known to exist on Earth, and as he believed it to belong to the Sun alone he called it Helium from the Greek word helios which means Sun. Later Sir Wm. Ramsey found it in Clevise a rare earth mineral. And since then it has been found in large quantities along with natural in Kansas. This further shows that all the elements we have on earth also go to make up the Sun.

## CHAPTER 5

## METHODS OF MEASURING STELLAR DISTANCE

## BY LIGHT YEARS.

The size of our solar system is so great that we cannot comprehend it, yet it occupies only an exceedingly small part of the space which the astronomers have explored. In fact, between our sun and the next nearest star there would be room for several thousand solar systems as large as ours. Vast as this distance is, the astronomers have been able to measure the distance to other stars which are no less than 20,000 times as far away from our sun as is the nearest star.

The solar system as marked b y the orbit of the outermost planet Pluto, is very large in comparison with any distances that are common in our lives. It would take a bullet about 750 years to travel across Pluto's orbit. For us who are accustomed to thinking of distances on the earth's surface, the size of our solar system staggers the imagination.

With the orbit of Pluto as its outer edge, our solar system is approximately 8,000,000,000 miles across. Yet compared with the distance of the earth from the nearest star outside of the solar system, Proxima Centauri, it is a relatively small and compact group of heavenly bodies. Compared with the milky way, its size becomes an almost insignificant speck.

We can get an idea of the enormous distances which astronomers have measured another way. Since astronomical distances are so great they are measured by the time consumed by light in travelling from one place to another. Light travels approximately 186,300 (more exactly (186,285) miles each second. The distance over which light can travel in one year is called a light year. The light year may very appropriately be called the astronomers yard stick. The cluster of Hercules is so distant that light given out by it at the time of the birth of Christ will not reach us until after the year 34,0000. A suggestion of these tremendous distances, which are measured by the speed of light, can be had when we realize that light travels fast enough to circle the earth at the Equator 7 times during one beat of the human heart. Light crosses the solar system from the sun to Pluto in about 6 hours, a relatively short time, which when compared with the time taken for light to reach us from Hercules shows us how relatively small the solar system is. The approximate length of time required by light to reach us from some of the near stars and star groups follow:

| | | | | | | |
|---|---|---|---|---|---|---|
| Sun .......................8 min. | | | Capella ........ 43 | light | y |
| Proxima Centauri .........4.27 | light | year | Ursa Major (all)70 | " | " |
| Alpha Centauri .........4.31 | " | " | Betelgeuse.....192 | " | " |
| Sirius ..................8.7 | " | " | Pleides........326 | " | " |
| Altair ..................16. | " | " | Antares........362 | " | " |
| Vega.....................26. | " | " | North Star.....466 | " | " |

Compared with some other much larger stars, our sun seems small. Antares, the brilliant star in the constellation of Scorpius, is 325 times as large as the sun. Many millions of stars are visible to the powerful eyes of astronomy. It takes the light from our sun about 8 min. to reach the earth. It takes over 4 hours for light to come from Neptune to earth. It takes over 4 years for light to travel tous from the star nearest to our sun. The light that we are now receiving from the Pole Star srted about 40 years ago, and there are stars so far away that the light by which we now observe them started from them nearly a 100,000 years ago. For all that we know, some of these distant stars may no longer exist as stars. If they had been destroyed, however, we should have no way of knowing this for thousands of years because the light which we left them before they were destroyed would still be coming to the earth.

A phorograph taken of the heavens by means of a telescope, would reveal veritable clouds of stars which are not visible to the naked eye. Were it possible for a dweller on one of the remote stars, to observe events on earth, he would be greeted with a prehistoric picture of our earth, with its dinosaurs, peterodactyls etc., each fighting for existance in the great battle of survival of the fittest.

The light year or astronomers yardstick is approximately 6 trillion miles in length. Travelling at the speed of light it would take 1½ sec. to reach the moon; 4 min. to Mars and 8 min. to the sun. Using a scale of 93,000,000 miles to the inch, it would still be difficult to show the distance of the remote stars. To include a star 200,000,000 L.Y. distant it would require a map that would be 200,000,000 miles wide. It woud reach to the sun and back with 14,000,000 miles to spare.

THE SWIFTEST THINGS ON EARTH-----A shell travels 975 yds., per sec. or 2,000 miles per hr. A man walks a mile in 6½ min, or 9.24 mi. per hr. A Bamboo tree grows 27/10,000,000 yd. per sec. A snail moves 93/10 yd. per sec. A man runs a mile in 4½ sec. or 13.3 mi. per hr. The earth speeds around the sun 65,533 mi. per hr. The fastest moving thing on earth is the cannon ball and the slowest is the tree growth or the growing thumb nail on the human hand. Our fastest speed cannot compare with light.

## CHAPTER 6.

## ANCIENT & MODERN METHODS OF MEASURING TIME.

The first measure of time was had when mankind discovered that the day and night were divided into two parts by the rising and the setting of the Sun. The sun is the world's greatest timepiece. The walls of the cliff were the face of the cliff dweller's clock, while the moving shadow was the hand that told time.

The cliff dweller had the walls of the cliff on which to mark the progress of the shadows. The herdsman or the tent dweller on the plains must measure time by the shadow cast by a tree or stone. Some day which was a wonderful day in the history of any tribe where it happened, a man who was more clever and more systematic than his fellows, set up a pole where there was no tree or rock and put a stone to mark for all succeeding days the point where the shadow fell when the sun was highest in the heavens. That was the first time that a man went beyond the provision which nature had made for him and deliberately of his own choice set out to divide his days by a regular measure. If a stone is used for the shadow at noonday, why not one for early morning, and one for mid0afternoon? In a circle of stones, with a stick to throw a shadow, the clock face with its marking of the hours was born. The sundial was the forerunner by many hundreds of years of the clock.

Time, except in big sections like morning, noon and afternoon, mattered as little to the savage man living with his family in a cave as it would to a Robinson Crusoe cast up on a desert island. When men began to come together in villages and towns and to plan their lives together, it was convenient to have a system with shorter periods. So the fact of the sundial was marked with lines at regular spaces to indicate regular intervals of time.

EARLY THE RECORDS---The very earliest records of time telling come from a wonderful peo le the Babylonians. Their priests devised theZodiac chart, ith its twelve divisions. Here we see for the first time t e use of the figure twelve, on which our whole system of time keeping is built. The Babylonians figured out a year as having twelve moons or months. They divided day and night into twelve hours each, making a day of 24 hours. Then they divided the hour into 60 minutes, and finally th minute into 60 seconds. It was not by chance that they hit on these figures of 12 and 24 and 60. No smaller number than sixty can be divided into so many other numbers as sixty. If you look at your clock or watch you can see how simple it is to divide its face into 5-minute periods, and also into quarter-hours and half hours. We owe a great deal to these ancient "Magi," who gave us our time scheme in twelves.

Sundials of one kind and another were the most common timepieces all through the Middle Ages, and have lasted to our own day. "Gnomons' they were sometimes called, from the Latin name for the pointer on the dial casting the shadow, which was thought of almo t as a person, "the on e who knows." But the trouble with the "gnomon" was it did not always know. "I count but sunny hours," reads the inscription on an ancient dial. On rainy days or in dull seasons, and at night, the sundial was of no more use than any other piece of metal. The "gnomon" was the servant of its master the sun. When the sun disappeared, how was a man to time his life and keep his appointments? "The "gnomon" could not answer, but the "water thief" could.

THE WATER THIEF--- Commonly known as water clock, its invention is attributed to the Chinese. It was first made in the form of a jar containing certain amounts of water, with a tine hole from which water was allowed to escape. Time periods were measured by the time it took for the jar to empty itself. At irst they were not self running machines someone had to pour the water, later wheels were put in the water clock. It had float which controlled a pointer similar to our clock hands, and resembled our modern clocks.

However, the water thief had its disadvantages, for the water froze or being dirty, changed the rate of speed of the escaping water. So the hour-glass with its sand and 2 funnel-shaped bowls took its place. It was used until Galileo by chance discovered and formulated the laws of the pendulum. Christians Huyghens the Dutch astronomer made use ofthis discovery and made the pendulum clock. With its even swing back and forth, always at the same rate, it could regulate the speed at which the machinery turned and keep the clock going at an even rate.

The next great improvement was to substitute for the heavy weight a coiled spring, which would gradually unwind. The unwinding of the spring gave the motive power, which had been supplied earlier by water falling or weights dropping. This made a small clock or a watch possible.

With the recent coming of clocks and watches for everyone's use, the modern age in which we live really begins. Our whole world is run by time-pieces. Schools and factories, trains, shops and homes, are all managed on a system of time keeping, by which every man's life fits closely into other lives. Without clocks and watches the modern world could hardly run. It has been well said, "The Middle Ages made clocks and watches;

and clocks and watches make the A e in which we live.

Back in the days of the middle ages when so many wonderful things were being found out, people began to think that they could do anything if they only knew how. So all through the Middle Ages we find some worker possessed by the impossible idea that he might start a machine going that would never stop, a perpetual motion machine.

We of the 20th century, who have learned more of the laws of matter, force and enegery, know this to be impossible. However, by harnessing nature to do our work for us; we can make something that will keep going long after we are gone. For instance:

A CLOCK TO GO YEARS-- A scientist has made a clock which is run by the action of radium as it breaks up. Radium takes the place of weights or the coiled spring. The radium atom has been "wound up" for us by nature; it is slowly "unwinding" or going to pieces. Radium in that clock is harnessed to the works. The clock has not had to be wound in all the years since the radium was set in it. Radium holds itself together in somewhat the way in which a coiled spring stays coiled. But this spring unwinds slowly; and the radium breaks u very slowly. If the radium keeps on "unwinding" year by year at the same slow rate, and no accident occurs, like fire or earthquake, at the place where the clock stands, the clock will go 2,00 years. If it stops, the trouble will be that man's machinery in the clock has w rn out or got disc nnected. The radium will not stop doing its part.

However when or after clocks were invented, it was found that the sun was not a good ti e keeper and so it was found necessary to add or subtract from the sundial.

THE EQUATION OF TIME:--- This term means the difference between apparent time and mean time. Since apparent time is sun, or solar time, which you get with a sun-dial, and mean time is clock ti e, the former is nearly always a little faster or little slower than the latter.

SUMMARY: DIVISIONS OF TIME AND ATTEMPTS TO MEASURE THE YEAR-- The word day comes from an ancient word meaning "to shine." The Greeks measured their day from sunrise to sunset, the Romans measured their day from midnight to midnight, the Babylonians from sunrise to sunrise. The day was the first measure of time.

Since the day is a short unit of time a longer was suggested by the changes of the moon. Beginning with the New Moon and waning to full moon then gradually waning to new moon, the time from new moon (29½ days) was called a month or moonth.

The next measurement of ti e, the year, was suggested by the seasons. People noticed that there was a period of heat and cold, a ti e when trees put forth their buds and a time when all nature seemed to die. The time from one Spring to another was found to be 12 moons and came to be known as the year. 12 x 29½ = 354 days, in the year.

The ancients did not know that the seasons and hence the year is due to the movement of the earth around the sun, the time as we now know being 365 days, 6 hours and 49 minutes. Since the year of 12 moons or 354 days as accepted by the ancients, was shorter than the true year it was not long until the spring months would come while it was still cold or winter. To overcome this the Jews put in an extra month 7 times in 18 years making their average year 365 days 11 hrs.

The Greeks added 3 months in 8 years making an average of 365 days, 1 hr. 26 min. The Romans had a year of 10 months beginning with March, then they added 2 months making a year of 355 days. To make up for the shortage, days were added in a confusing manner so the Roman dictator, Julius Caesar, ordered that the year 45 B.C. should consist of 445 days, and that future years should have 365 days, 6 hours, which is 11 min. longer than the true year. The small amount made a difference of 10 days in a few 100 years. In 1582 Pope Gregory ordered that 10 days be left out and the day after the 4th of October was called the 15th. The change was made in England in 1751 when eleven days were dropped causing much discontent. Since our present year is a little too long it was arranged that instead of every 4th year, leap year, the years which end in 00 as 1700, 1800 should not be leap years. This leaves our calender short about 3 hours, 20 minutes in every 100 years.

## CHAPTER 7

## RELATION OF MOTIONS OF EARTH TO TIME

The orbits in which the planets revolve around their central luminary or sun are in strictness eclipses, or slightly flattened circles. But the flattening is so slight that the eye would not notice it without measurement. The sun is not in the center of the ellipse but in a focus, which in some cases is displaced from the center by an amount that they eye can readily perceive. No two orbits of the planets lie exactly in the same plane. That is if we regard any one orbit as horizontal, all the others will be tipped by small amounts, toward one side. Astronomers find it convenient to take the orbit of the earth, or the ecliptic, as the horizontal or standard one. The angle by which an orbit is tipped from the plane of the ecliptic is called its inclination.

KEPLERS LAWS--The motions of the planets in their orbits take place in accordance with certain laws laid down by Kepler the German astronomer, and therefore known as Kepler's laws. The first of these is: The orbits of the planets are ellipses, of which the sun is in one focus. The second law is; that the nearer the planet to the sun the faster it moves. With more mathematical exactness, the areas swept over by the line joining the planet and sun in equal times are all equal. The third law is that the cubes of the mean distances of the planets from the sun are proportional to the squares of their times of revolution. This law requires some illustration. Suppose one planet to be 4 times as far away from the sun as another. It will then take it 8 times as long going around it. This number is reached by taking the cube of 4, which is 64 ( 4 x 4 x 4 = 64) and then extracting the square root, which is 8.

HOW TIME IS HAD AND MEASURED:--- Since the earth makes one complete turn on her axis in 23 hours and 56 minutes and one complete revolution around the sun in 365½ days, it would seem to be an easy matter to measure the length of a day and a year by these standards, but such, however, is not at all the case.

WHAT SUN OR SOLAR TIME IS:-- The chief kinds of time we use are Sun, or Solar time, and Star or Sidereal time. A day when measured by Sun time is called a solar day or more properly an apparent solar day, because it is the earth that turns around on its axis and not the Sun that turns around the earth. We get our Sun, or Solar time by noting when the sun crosses the Meridian.

When the center of the sun is exacrly on the meridian, it is at its highest altitude, so it is half way between the time it rises and the time sets, so we call this point noon. Now a day measured by the sun is the time between 2 successive noons, such a day is 4 minutes longer than one that is measured by Star time, you will see why later on.

The length of a day measured by sun time, varies for 2 chief reasons, because the orbit of the earth is tilted slightly out of the plane of her equator, and the speed of the earth as she travels around her orbit varies in different parts of it. These factors make each solar day of the year a little different length, depending on the part of her orbit she is in. The ideal kind of time is to have every day of the year equal in length, when clocks were invented this was a necessity. The different lengths of all the days of the year were taken, added up and the average length was found to be 24 hours, so every day is that long without regard to the sun.

STAR OR SIDEREAL TIME: Astronomers get their time from the stars, and the length of a day obtained by star time is 4 minutes shorter than that obtained by sun time. Star, or sideral time is found by observing a star as it crosses the meridian twice in succession and the time between the two transits, is said to be a day.

The reason a solar day is 4 min. longer than a sidereal day, is because the sun apparently travels around the earth every year, whereas the stars remain fixed in their positions. The earth turns on its axis toward the east and this is also the direction the sun apparently moves. By the time the former has made one complete turn, the latter has moved nearly 1 degree, equal to 4 min., and the earth must turn thaT much further around in order to catch up with the sun.

The Equation of Time:-- This term means the difference between apparent time and mean time. Apparent time is sun time, gotten from a sun-dial and mean time is clock time.

STANDARD TIME:-- To prevent the confusion that true local time gives rise to when trains are running east and west, or the other way about, the system of standard time was invented. This was first put into effect when the International Meridian Congress was held in Washington in 1884, and it was agreed that Meridian and Greenwich, England, was to be the 0 or prime Meridian, and the earth was to be divided into 24 standard meridians, hence each of these represents 15% of longitude.

The clocks at any place within 7½ degrees east and west of these meridians are set with the time of the Meridian. In this way the time, not only all over the U/S but all over the whole world agrees with that of Greenwich in minutes and seconds, but it changes in hours by whole numbers.

## CHAPTER 8

## EARLY IDEAS REGARDING THE SEASONS

Primitive people did not know enough astronomy to enable them to invent an accurate calendar. Of course, they noted the regular return of full moon and the succession of the seasons. Thus, the Indians would locate some event by saying that it had occurred "three moons" before, or they would give the age of a child as "two summers."

Long before men became civilized, however, they noted that the length of daylight changed from moon to moon. They came to know that daylight lasted longer than the darkness during the warmer period, or summer, and that the darkness lasted longer than the daylight during the colder period, or winter. They were unable, of course, to account for these phenomena and consequently invented strange and interesting myths to explain the longer and shorter days.

WHY WE HAVE THE SEASONS: --- It is only within the last few hundred years that the astronomers have known that the seasons are due to the fact that the earth's axis titls at an angle of 23½ degrees from the perpendicular to the plane of its orbit.

If the earth's axis were vertical to the plane of its orbit (that is, if the earth's axis did not tilt) there would be no "lon est" and "shortest" days in the year; there would be no seasons, because the direct rays of the sun would always strike the equator; every spot on the earth would then have t twelve hours of daylight and twelve hours of darkness every day in the year.

If the earth's axis were inclined at an angle of 45 degrees to the plane of its orbit, the seasonal changes would be more pronounced. Winter would be colder, summer hotter, and there would be no temperate zones.

Since the earth's axis tilts away from the perpendicular to the plane of its orbit, there are only two days in the year, March 21 and September 22, when its axis is not tilted either toward the sun or away from it. On these two days the direct rays of the sun fall on the equator, with the result that every spot on the earth has twelve hours of daylight and twelve hours of darkness. For this reason March 21 is called the Spring equinox or vernal equinox, and September 22 the fall equinox or autumnal equinox.

As the earth travels round its orbit after March 21, the upper end of its axis points more directly toward the sun from day to day. The direct rays of the sun, therefore, strike farther and farther north of the equator. On June 22 the earth has reached the point in its orbit where its axis points most directly toward the sun. Since the axis tilts at an angle of 23½ degrees, the direct rays of the sun now strike 23½ degrees above the equator. The sunlight reaches 23½ degrees beyond the north pole, throwing all the artic circle into the sunlight while all the antartcic circle is in darkness. This date is called the summer solstice. The imaginary circle round the earth, 23½ degrees north of the equator, where the direct rays of the sun fall on June 22, is called the tropic of Cancer. On June 22, every spot on the earth north of the tropic of Cancer has more than twelve hours of sunlight.

As the earth continues round its orbit its axis gradually points less directly toward the sun. Day by day the direct rays of the sun move south from the tropic of Cancer, until on September 22, when the earth's axis is pointing neither toward nor away from the sun, the direct rays of the sun rest again on the equator.

The earth travels on. The northern end of its axis now tilts slightly away from the sun. The direct rays of the sun leave the equator and continue to travel gradually further south, until on December 22, they have reached their most southern point. On this date the northern end of the earth's axis tilts directly away from the sun. The Sun's direct rays now strike the earth 23½ degrees wouth of the equator, drawing round the earth an imaginary circle called the tropic of Capricorn. All the antartic circle is now in sunlight and all the arctic circle is in darkness. Every spot on the earth south of the tropic of Capricorn on December 22, (date of the winter solstice) has more than twelve hours of daylight and fewer than twelve hours of darkness. In Argentina and South Africa, therefore, people have summer when we are having winter. Thus their seasons are always the reverse of ours.

As the earth continues in its orbit the direct rays of the sun gradually travel north toward the equator and the tropic of Cancer, and the seasons are repeated.

The imaginary circles drawn on the earth by the Sun's rays during the year mark the boundaries of the zones. Thus the direct rays of the sun pass back and forth across the torrid zone, between the tropics of Cancer and Capricorn. The arctic and antarctic circles include all the places on the earth which at some time in the year can have more than twenty four hours of continuous daylight or darkness. Places in the temperate zones have the direct rays of the sun and never have twenty-four hours of daylight or darkness at a time.

## CHAPTER 9

## WHY IS SUMMER WARMER THAN WINTER

The earth's orbit is not quite a perfect circle but is slightly elliptical. The sun, moreover, is not exactly in the center of it. Fig. shows this last fact, but shows the sun to be much farther away from the center of the earth's orbit than is actually the case. But the figure shows us also a surprising fact. We who live in the north-temperate zone are actually further from the sun during our summer than during the winter. How, then, can our summers be warmer than our winters? There are two reasons: (1) We actually receive more light and heat from the sun during the summer, because the sun's rays strike more directly down upon us than in winter; (2) the sun is pouring down upon us its heat and light from so many more hours every day during the summer than during the winter.

If the earth always kept the same side toward the sun, like Mercury, the time of day at any spot would always be having either unchanged daylight or unchanging darkness, year after year and century after century. But the earth does rotate, and this rotation causes sunrise, noon, sunset, and night.

HOW WE COUNT THE HOURS:-- For convenience both in locating places on the earth and in reckoning time, the equator is divided into exactly three hundred sixty parts called degrees. Each degree is further divided into sixty minutes, and each minute into sixty seconds. These minutes and seconds are parts of a circle, not minutes and seconds of time. Imaginary lines are drawn on the earth, which run north and south through the degrees, minutes and seconds, and end at the poles. These imaginary lines are called meridians of longitude.

The meridian of longitude which passes through Greenwich is called the zero meridian or prime meridian. Since there are exactly twenty-four hours in a day, the earth rotates one twenty-fourth of 360 degrees, or 15 degrees in one hour; so the meridians every 15 degrees apart, starting at the prime meridian, are called hour circles, because each of these twenty-four hour circles has sunrise exactly one hour later than the hour circle east of it.

SUN TIME:--- The exact hour of the day at any point on the earth is the "sun time." Noon at any place is the exact second in the day when the sun is nearest overhead. All points on the same meridian are having noon at the same instant. At that instant it is afternoon at all places east of that meridian, and forenoon at all places west.

Thus because Portland, Oregon, may know before 2 P.M. the results of a World's Series baseball game which did not begin in New York until 2;30 P.M. of the same date.

STANDARD OR RAILROAD TIME:-- If we tried to keep our watches exactly correct by sun time we should have to be putting them ahead whenever we went a few miles east and back whenever we went west. If each zone covered only one minute of solar time there would be 228 different times in the U.S. You would have to reset your watch every eleven miles east or west. Standard time at Omaha is 23 min. 50.2 seconds faster than mean solar time. A day on earth lasts 48 hours, that is 48 hours pass before the beginning of a day at one point on earth reaches its end at the other extreme portion of the earth. To avoid confusion and bother the civilized nations in 1884 established standard time. According to this plan time belts about fifteen degrees wide were established round the earth with each of the hour circles in the middle of the time belt.

The United States is marked off into four of these belts, each roughly fifteen degrees across. For convenience every place within any time belt has the same standard time. Thus New York and Pittsburgh have the same standard time, though Pittsburgh's sun time is considerably later than New York's. Chicago's standard time is exactly one hour slower than New Yrk's and Pittsburgh's. If you were travelling from Chicago to New York you would have to put your watch ahead only once, and that would be when you crossed into the Eastern Standard time belt. As we travel east the time becomes later by one hour for each 15 degrees of longtitude. Process is reversed going west. There are twenty-four of these hour zones in the world.

DAYLIGHT SAVING:--- Many of you know that the city you live in has "city time" is "daylight-saving time." More than one hundred and fifty years ago Benjamin Franklin suggested the idea of daylight saving. It is only within the last few years, however, that daylight saving has been established in various parts of this country. The purpose of daylight saving is to start the working day an hour earlier so that we can be through with the day's work and ready for recreation while there is still considerable daylight left. Thus in summer there is time for baseball, swimming, and other recreations between dinner and dark. To accomplish this some places keep the clocks one hour ahead of the standard time all the year round; in others thetime is put one hour ahead of standard time in April and is set back again one hour in October.

Many of the ancient civilized peoples established calendars of their own to keep track of their historic dates. There was the Egyptian calendar, the Hebrew calendar, Chinese calendar, Mohammedan calendar and others. No two of these began with the same year, because each people began its own calendar with some important date in its own history. All these calendars were more or less inexact because their astronomers did not have accurate instruments with which to make their astronomical measurements. In the first century before Christ, Julius Caesar established the Julian calendar, making every year 365¼ days long. In the sixteenth century Pope Gregory XIII established the Gregorian calendar, which was more accurate than the Julian calendar. The Gregorian calendar was not adopted in England until nearly two centuries later, however, and it has been adopted in Greece and Russia only within very recent years. It is now used in this country and in most of the civilized world, but by no means in all of it.

Lately it has been proposed by Mr. Moses B. Cotswerht, a Canadian, that the calendar again be changed throughout the civilized world. With this "International Fixed Calendar" the year will consist of thirteen months of twenty-eight days each, making 364 days. The thirteenth month will be added between June and July and will probably be called Sol.. Every year and every month will begin on Sunday, and thus every date will come on the same day of the week every year. All national holidays will be set on Mondays to allow the working people two successvie free days. The three-hundred-and sixty-fifth day will be "Yearday" between Saturday, December 28, and Sunday, January 1. The extra day in leap years will similarly be June 29, between Saturday, June 28th and Sunday, Sol. 1. Easter will always be the same Sunday in April.

It is thought that everybody will derive some benefit from the new calendar, though those will gain the greatest advantages who are engaged in commerce and business. It will be easier to plan the monthly expenses both of business firms and of households when all the months are of the same length and have the same number of Saturdays.

LOCATING PLACES ON THE EARTH:-- The meridians of longitude not only serve to determine the time but also help to determine the exact location of every place on the earth. They enable us to know how many degrees east or west of London any place is. But if we are going to locate a place exactly we must also know how many degrees north or south of the equator it is. For this purpose, with the equator as a starting line, imaginary circles called parallels of latitude are marked off on the earth in the same manner as the meridians of longitude, but running east and west round the eart h. Places north of the equator are said to be in "north latitude;" those south of the equator, in "south latitude." Thus the north pole is 90 degrees north latitude, and the south pole 90 degrees south latitude. The longitude of the north and south poles is zero.

## CHAPTER 10

## PROPERTIES & EFFECTS OF INERTIA

Sir Isaac Newton in his studies of gravitation and moving bodies has given the fundamental laws under which motion takes place. The first of these has to do with a property of matter which scientists call inertia. If one stubs his toe against a stone it is quite apparent that there is a tendency for the stone to remain at rest. Likewise if an individual is standing on a street car which starts with a sudden jerk, his head and shoulders are thrown back while his feet are carried forward by the car. Evidently there is a tendency for a body to remain at rest. If a coin is placed on a calling card and the card supported on the tip of the finger, the card may be suddently jerked away, leaving the coil at rest on the finger tip. It is this tendency of a resting body to resist motion that is called inertia.

If a body is in motion, it has a tendency to remain in motion. Thus, if a baseball is thrown, it is necessary for some force to act on the ball to stop its motion or change its direction of motion. The ball has a tendency to continue in the same direction in which it was thrown. A person standing on a rapidly moving stre t car which is brought to a sudden stop will be thrown forward violenty. Again there is evidence that a body tends to continue in its direction of motion. This tendency for moving bodies to continue in motion in the same direction is also called inertia.

Sir Newton summarized these facts in the first law of motion. Everybody which is at rest has a tendency to remain at rest, and evey moving body has a tendency to remain in motion without change in speed or direction. This tendency of a body to remain at rest, or in the same direction of motion can be overcome only by the application of some external force.

The reason that work is often hard to perform is because the force applied usually meets with resistance. In doing mechanical work we meet with three causes for resistance; inertia, wei ht and friction.

INERTIA:--The resistance due to inertia can be seen everywhere. If you have ever "stalled" in an automobile you realize how a body at rest tends to remain at rest. It requires a strong push from outside or the force of the starting motor, to move the car. The explanation is, of course, that the inertia of the car must be overcome, as well as the friction of the bearings and of the wheels to the ball would send the ball on and on, if it were not for the friction of the air and the force of gravity.

OTHER KINDS OF FORCES:-- The kind of a force that makes a body move in a curved path, as when you tie a stone to a string and whirl it in a circle,,is called centripetal force, and the reaction against this force by the moving body, which is due to the resistance offered to it by its being turned out of a straight line, and this is caused by its inertia is called centrifugal force. Both forces are the result of the same stress, hence are equal and opposite and if the string should break both forces will instantly disappear. Due to rotation of the earth, the Mississippi river flows up hill one mile from Lake Itaska to the Gulf of Mexico.

EVERYTHING LOSES WEIGHT AT EQUATOR: -- Earth bulges at the equator and is flattened at the poles, the distance from the north pole to the center being about 13½ miles less than distance from equator to the center. The pull of gravitation is less at greater distances, and so a balance with one pan at the north pole and the other at the equator, would show that of two equal masses, the one at the equator would weight less than the one at the north pole.

CRADLE OF DEEP TO ROCK SHIPS NO MORE:--Due to Gyroscopes working on same principle as toy top, due to power of its terrific speed remains in position and counteracts effect of sea rolls..

FOUCAULT'S PENDULUM:-- One of the few convincing proofs that the earth rotates is given by the Foucault pendulum. At 8 o'clock in the morning, a 125# ball hung by a 95 ft. steel wire is started oscillating along 8-8 line. A dial fastened to the floor rotates with it and at 6 in, the evening the pendulum is swinging along the 6-6 line. From the angle between these lines and the time required for the pendulum to rotate through the angle, the latitude of the place can be determined.

Our earth bulges about 4 mi. at the equator and is flattened about 9 mi. at the poles, due to rotation speed of earth, which at equator is 1039 M.P.H. If earth were standing still, the globe no doubt would have been a perfect sphere. If the earth were to make a complete revolution in 1.41 hr., the bulge would become so great that objects at the equator would begin to fly off, in fact the earth would begin to break up.

ENORMOUS POWER IN UNIVERSE:-- It woule require a man 10,00 miles tall, using energy equivalent to the poor of 200,000,000,000,000,000 average automobile engines one whole year to stop our world spinning and this energy is only a small part of the inconceivable power of the sun and the other celestial bodies.

# CHAPTER 11

## GRAVITATION AS IT AFFECTS WEIGHTS, TIDES AND OFFSETS CENTRIFUGAL FORCE IN THE UNIVERSE

THE LAW OF GRAVITATION:-- Nobody knows the exact nature of the mighty forces which keep the earth and all other heavenly bodies in motion. We do know that the direction of movement is controlled by what Sir Isaac Newton over 250 years ago called gravity. He discovered the universal law of gravitation, by chance one day when he happened to see an aple fall from a tree. This set him to thinking out the reason as to why a body falls, and he came to the conclusion that a body falls because the earth attracts it, and also that every body in space has an attraction for every other body, regardless of how small or lrge it may be. This attraction between bodies implies that there must be a force acting on them, and this we call the force of gravitation, or just gravitation for short. Then this great scientist asked himself if the earth did not have the same sort of attraction for the moon, and the sun for the earth and its sister planets. After many years Newton developed mathematical proof for his ideas. We speak of the weight of a body. Weight is the measure of the attractive force of the earth. If there were no attractive force, there would be no gravity, nothing would have weight.

In its final form, Newton's law of gravitation states, that the force of this mutual attraction between all bodies varicus in direct proportion as the product of their sizes, and in universe proportion as the square of the distance between them. This means that the more substance two bodies possess, the more attraction they have for each other. As the distance between the two bodies increases, the attraction lessens. If the distance is doubles, the attraction is lessened to 1/4 of its former force. If the distance is triples, there is but one-ninth of the original attraction; if quadrupled, but one-sixteenth and so on. From this you will see that what actually takes place when an aplle, or other bodies, fall, is that it moves toward the earth and the earth moves toward it until they meet. The reason that the apply apparently moves through all the distance and the earth does not move at all is becausethe former is so very small when compared with the size of the latter.

When ever you push or pull some object, you expect a force upon it. Gravity is the force which tends to pull all objects toward the center of the earth; in fact, a force is a push or a pull.

Canvendish, the English scientist, in 1798, made an apparatus by which he was actually able to measure the force of attraction, or gravitation, between two bodies. This consisted of two small balls mounted on the ends of a light crossbar, which in turn was suspended by a fine silver wire at its center. Two large balls of lead, that weighed 80 pounds a piece, were suspended near each of the above mentioned small balls, each large ball near and on opposite sides of the small balls, so that the gravitational force would make the bar turn in the same direction. To prevent air currents from acting on the moving elements the apparatus was enclosed in a box, in one end of which was a glass window and in the other a telescope. The movements of the bar showed that there was an actual attraction between the small and the large ball.

To prove that every body in space attracts every other body Prof. Maskelyne, an Astronomer Royal of Great Britian, made the following experiment more than 50 years ago. He suspended a metal weight from a horizontal support so that it hung freely over a steep, precipitous rock in the Schichallion Mountains in Scotland, and going to a convenient position he saw that the weight did not hang vertically like an ordinary plumb line but was attracted to one side instead.

Hence that which we call gravity is simply the attraction for each other of the earth and of bodies that are on or near its surface, and what we call weight is the amount of the attraction of gravitation between the earth and bodies on or near its surface. The direction of gravity is always vertical, that is, directly toward the center of the earth. Whatever has been said about gravitation or gravity does not in the least indicate what the nature of the attraction is, but Newton, who first worked out the laws that govern its action, believed it to be a force, while Einstein does not think so. Gravitation is, then, simply a word that is used to mean a certain kind of attraction without telling you anything about it, just as a horse means a certain kind of four legged animal without telling you anything about it.

THE EINSTEIN THEORY:-- The Einstein Theory of Relativity, or the Einstein Theory as it is called for short, consists of a number of new ideas about space and time and motion that were worked up into definite laws by Dr. Albert Einstein of the Kaiser Wilhelm Academy for Research at Berlin.

Briefly, these ideas are that all things were relative one to another; that everything in the universe is in motion; that all experiments have failed to show the presence of an either, since nothing is fixed in nature, there is no absolute standard by which a body in motion can be measured; that light is the only thing whose speed is always the same under all conditions; that gravitation bends a ray of leight out of its course; that space and time must be taken together and not separately; that time can be considered as the 4th dimension; and, finally -- and this is a hard one -- that gravitation is not a force at all, as Newton thought it was, and has since been taught, but that it is caused by the curvature of space-time.

Now just as Newton when he saw the apple fall from a tree, formed his theory and law of gravitation, so in the same way Einstein when he saw a man fall from a building formed his theory and law of gravitation. The man who fell landed on a soft spot and so lived to tell Einstein how he felt in his drop to the earth. He said that he was falling to the earth, but instead it seemd as if the earth had jumped up until it met him. [illegible] is not a force at all which pulls bodies together as magnetic andelectric forces do, but that it is the effect of difform motion, which is opposite to uniform motion and means any quick, jerking movement. To illustrate difform motion, suppose you have a fly buzzing in the center of a bottle which is suspended by a string. Now if you give the bottle a quick pull to one side, the other side will strike the fly and he will have the same sensation as if he fell and struck the earth. In the same way, but on a larger scale, if a boy is suspended in a big box, and the box is suddently jerked to one side he will strike the other side, and have exactly the same sensation as if he had fallen and struck the earth; that is, the sensation he experienced would be exactly the same as though he had been acted on by gravitation when there was no gravitation at all. It is on this principle of difform motion that Einstein has worked out his theory and mathematical formulas of gravitation, and those give results that coincide very closely with those of Newton, the chief difference between them being that the former is more accurate than the latter.

While gravity tends to keep the solar system together, the planets move about the sun so rapidly that they expect a large centrifugal force, (away from the center,) which tends to throw them away from the sun. Thus the attractive forces of the planets and the sun operate in opposition to the centrifugal force of the planets. Each planet takes an orbit which will make these two opposite forces equal.

OTHER KINDS OF FORCE:-- The kind of a force that makes a body move in a curved path, as when you tie a stone to a string and whirl it in a circle, is called centripetal force, and the reaction against this force by the moving body, which is due to the resistance offered to it by its being turned out of a straight line, and this is caused by its inertia, is called centrifugal force. Both forces are the result of the same stress; and hence are equal and opposite, and if the string should break both forces will instantly disappear.

As regards weight and gravitation, a man weighing 150 lbs. on earth would collapse on the sun, borne down by his increased weight of two tons, however on the surface of Antares he would register no more than 1 or 2 lbs; on the heaviest, most weighty B-type star he would weigh 8 tons. But on the little companion of Sirius, that densest of all stars, his weight would be 4,000 tons, equal to that of a block of iron 26 feet long, 26 feet high.

At the center of the earth a 150 pound man would weigh nothing, half way to center 75 pounds. Could he ascend in a balloon 3,000 miles he would weigh 37 pounds, and at 12,000 miles but 16 pounds; and at 239,000 miles he would weigh 2/3 of an ounce. On the moon he would weigh 25 pounds.

TIDES ON EARTH, MOON, SUN:-- There is but little early record of the tides among the Greeks, Romans or Hebrews, and no reference occurs in the old or new testament. Perhaps this is due to the fact that these people lived on the shores of the Mediterranean where the tide is very small and received little attention by these people. However, Herodotus, 435 B.C. decribed a tide in an arm of the Red Sea, and Pytheas of Massilia, 325 B.C; who navigated to the British Isles, noted the relation of the tide to the moon. Most early explanations were based on some fanciful notion. Some early philosophers believed the earth an animal and the tide due to the animal breathing, drinking or spouting of the water. Some explained it as the pulse beat.

Pleny's Natural History 77 A.D. exemplifies the knowledge of tides at that time. "All the seas are purified at full moon, some also at stated periods. "Aristotle adds that no animal dies except when the tide is ebbing. The observation has often been made on the ocean of Gaul, but it has only been found true with respect to man. In conclusion he says: "Hence we may conjecture that the moon is not unjestly regarded the Star of Life. That it is that which replenished the earth; when she approaches it, she fills all bodies, while, when she recedes, she empties them. Shell fish grow with her increase. Also the blood of man is increased or decreased in proportion to the quantity of her light. Also the leaves and vegitables feel her influence, her power penetrating all." In the 13th century we find the following explanation: "As for the flow of certain seas at the time of the rising of the moon, it is supposed that at the bottom of such seas there are solid rocks andhard stones, and that when the moon rises over the surface of such seas, its penetrating rays reach these rocks and stones which are at the bottom, and are then reflected back thence; and the waters are heated and rarefied and seek an ampler space and roll inwaves toward the seashore and so it continues as long as the moon shines in mid-heaven. But when she begins to decline, the boiling of the ocean ceases, and the particles cool and become dense and return to their state of rest, and the currents run according to their want. This goes on until the moon reaches the western horizon, when the flow begins again, as it did when the moon was in the eastern horizon.

With the growth of knowledge we find the tide ascribed to the discharge of rivers into the sea, to great whirlpool near Norway which for 6 hours absorbs the water then for 6 hours disgorges it. In the same time Scalinger supposed that it was the coast of America that obstructed the general motion of the sea and reverberated. As late as 1650 some explained that it is, "The occult quality" or sympathy whereby the moon attracts all moist bodies. While Galileo thought it was preposterous to think the moon caused tides. In 1687 Newton showed that the tide was a natural consequence of the law of gravitation.

TIDES: Those who live near the ocean know that the water edge keeps changing its place. They know that the water line moves gradully farther toward the land for about 6 hours, then slowly farther out for the next 6 hours. This movement of the water is called the tide. In some places the water line may be more than a quarter of a mile farther in at high tide than at low tide.

The moon is the chief cause of the tides, though the sun also is a less important cause. The gravitational attraction of the earth and the moon tend to pull the two bodies together, and cnetrifugal force tends to throw them apart out of their orbits. These 2 forces exactly balance each other at the center of the earth and the moon, so that they neither fall together nor fly apart. There is also centrifugal force at the earth's surface due to its rotation. On the tion is stronger than the centrifugal force due to rotation, on the side of the earth furthest from the moon the centrifugal force is stronger than the gravitational attraction. The result is that these two forces tend to make the earth bulge on the side nearest the moon and on the side opposite the moon. The solid earth is too rigid to bulge, but the water is not. Consequently there are two bulges of water under the and opposite sides of the earth. As the earth rotates these bulges follow the moon as two large waves. The result is that places on the ocean shore have a high tide in between two high tides. Because the moon revolves in its orbit while the earth is rotating, these tidal waves do not travel around the earth in exactly 24 hours, but take 2 4 hours and 52 minutes. Hence each place on the ocean shore has 1 high tide and one low tide every 12 hours and 26 minutes.

At new moon and full moon when the sun and the moon are in the same straight line, the high tides are highest and the low tides are lowest. These new-moon and full-moon tides are called spring tides, though the name has nothing whatever to do with the seasons. At the first and third quarter, when the sun and moon are exerting their gravitational attractions in opposite directions on the oceans, the high tides and low ties are smaller than at any other time durin the month. These small tides are called neap tides. The gravity of the moon is suficient to raise waters of the ocean a slight amount. As the earth rotates on its axis, the "hump" in the ocean moves toward the west. As this "hump" reaches the seashore, some ofthe water is dragged part way up the shore, only to return again to the ocean after the earth has turned a little bit farther. This coming in and going out of the waters is known as the tides. If the sun is on the same side of the earth as the moon, the high tides are higher than usual. Tides occur every 12 hours and 26 minutes, instead of every 12 hours because the moon moves in the course of a day.

The tides are of great importance to ocean travel since large vessels can enter and leave many of the ports only at high tides. The tides are also important to various fishing industries, particularly the gathering of oysters, clams and other shell fish along the shore. And these tides seem also to be of possible future source of useful energy.

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## APPENDIX C

DRAWINGS MADE BY AUTHOR

FOR THE USE OF THE SKETCH METHOD

## APPENDIX D

TESTS DEVISED TO MEASURE THE RESULTS

OF THE PROCEDURES USED

PART I

# 'ANCIENT + MODERN IDEAS AS TO THE SHAPE OF THE EARTH'

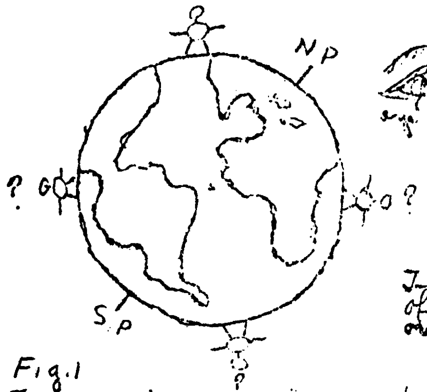
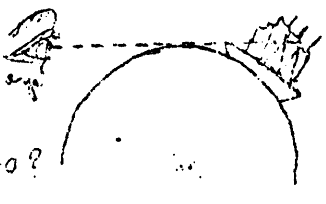



Fig. 1
The world as we know it is spherical




Aristotle's proof:
The disappearance of a ship sailing over the horizon

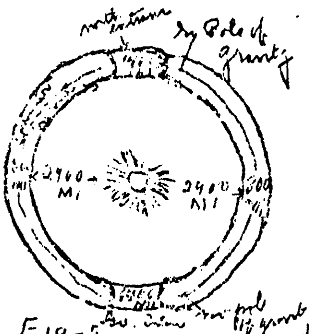



Fig-5
Gardner's earth, a hollow sphere

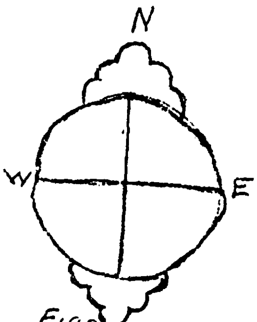



Fig 8
The antipodal polar mountains of ancient Hindu belief

The earth floating on a universal ocean
Fig-2

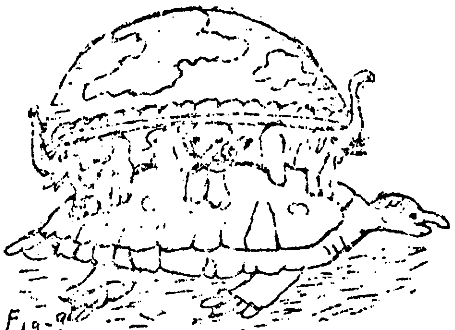


Fig-9
The Hindu earth as a shell supported by 4 elephants standing on a turtle's back swimming in a sea of milk

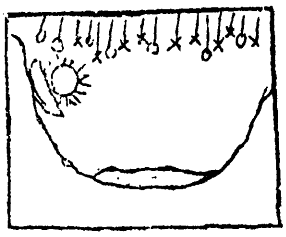


Fig-10 - The egyptian's earth, a nearly rectangular box, with a solid ceiling from which the stars or lamps were hung by ropes, while the Sun was a ball of fire travelling across the sky in a boat

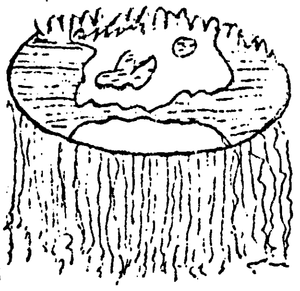


Fig-3
The earth with Roots


Fig-10
The earth a universal egg floating in the ether. idea prominent about the eight century

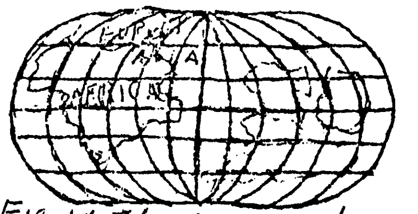



Fig-11 The tomato-shaped earth of Ptolemy

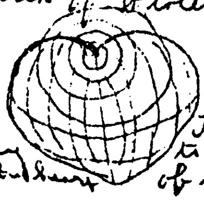


Fig-12 The earth
ascending to middle ages
into darkness of God

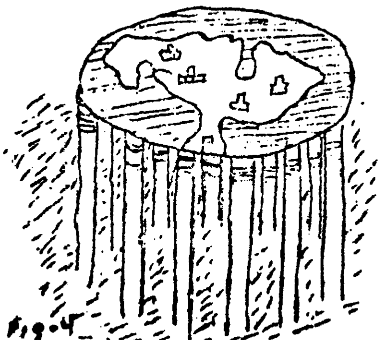


Fig-4
The earth supported on 13 pillars - Vedic priests idea. Humans sacrificed

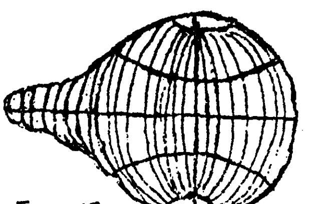


Fig-13
The pear-shaped earth of Columbus

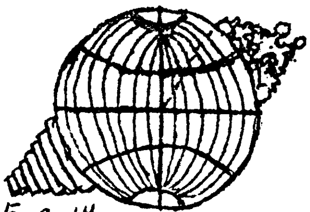


Fig-14
Dante's earth with its mount of purgatory & Jerusalem balancing it exactly on the other side

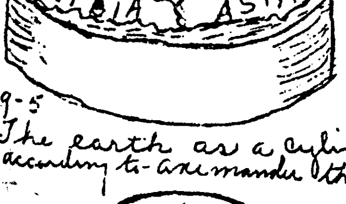



Fig-5
The earth as a cylinder according to Anaximander the Greek

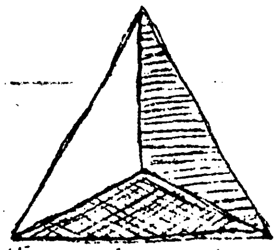


Fig-15 according to Green about 1875 the earth is a tetrahedron

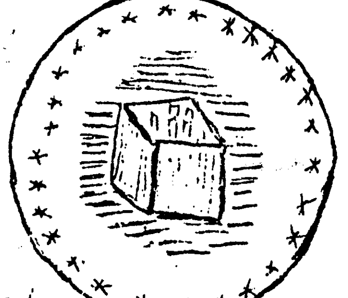


Fig. 6
The earth as a Cube according to Plato - because Cube the most perfect of forms

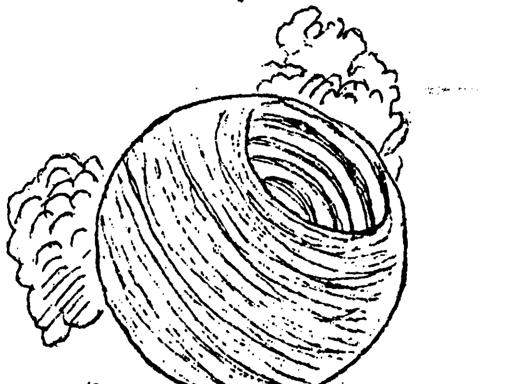


Fig 15 The 5 concentric circles or holes in the earth theory of Capt. Symmes

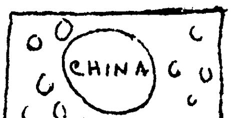



Fig 16 The earth of Chinese was great square with China biggest square Oval within the square

Eskimos believed center of earth warm heaven where good people go, sky cold place where the wicked froze forever

# PART II
# THE BEGINNING OF ASTRONOMY

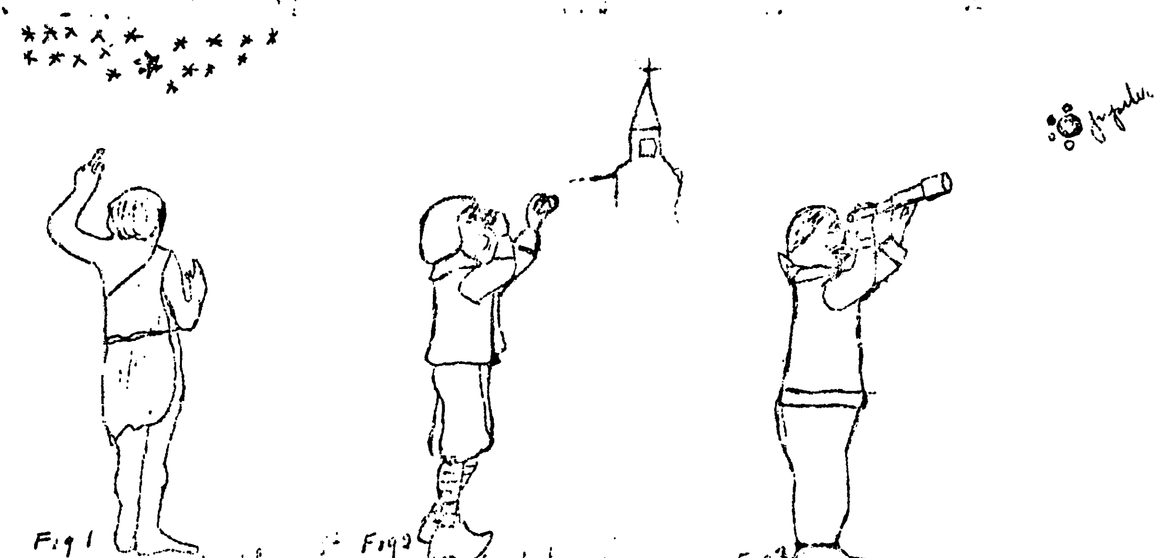



Fig 1 Prehistoric shepherd boys [illegible] Chaldea [illegible] Persia were the [illegible] to be first star-gazers

Fig 2 Lippershey, a boy in Amsterdam Holland discovers the telescope

Fig 3 Galileo heard of the discovery, constructs a telescope + discovers the 4 moons of Jupiter

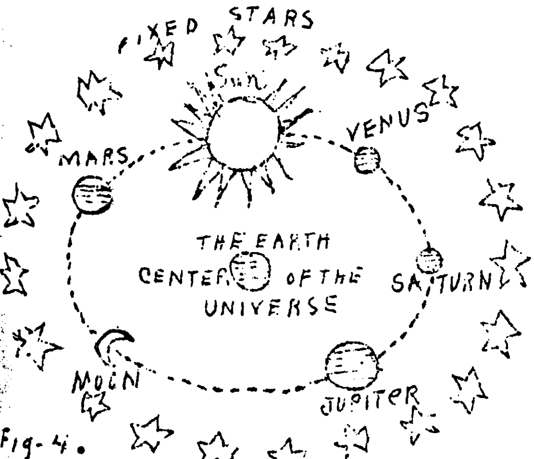



Fig-4. The Ancients idea of Universe, as worked out by the Egyptian astronomer Ptolemy about the second Century A.D. Theory was accepted for 1500 yrs

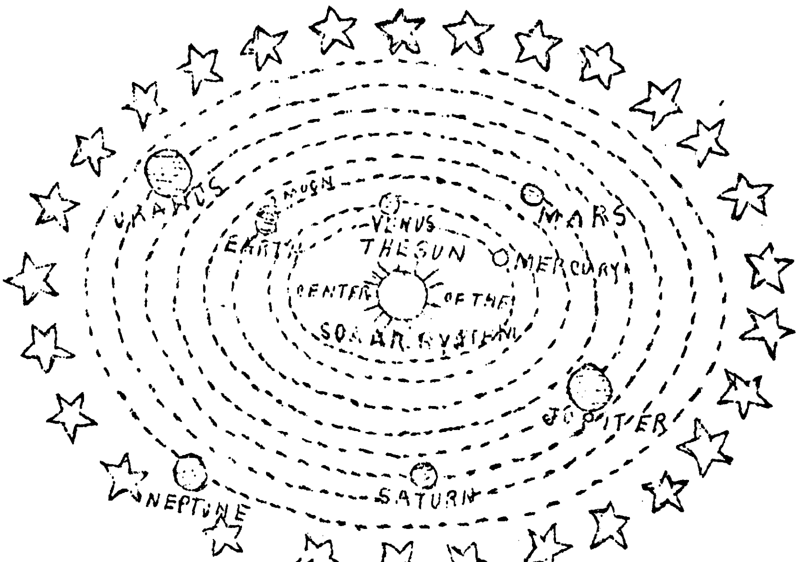



Fig-5 The modern theory of the universe as first suggested by the Polish astronomer, Copernicus about 1500 A.D.

## THE SOLAR SYSTEM

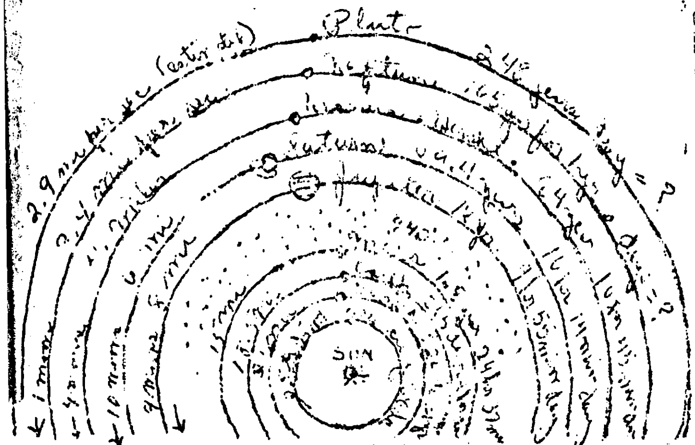


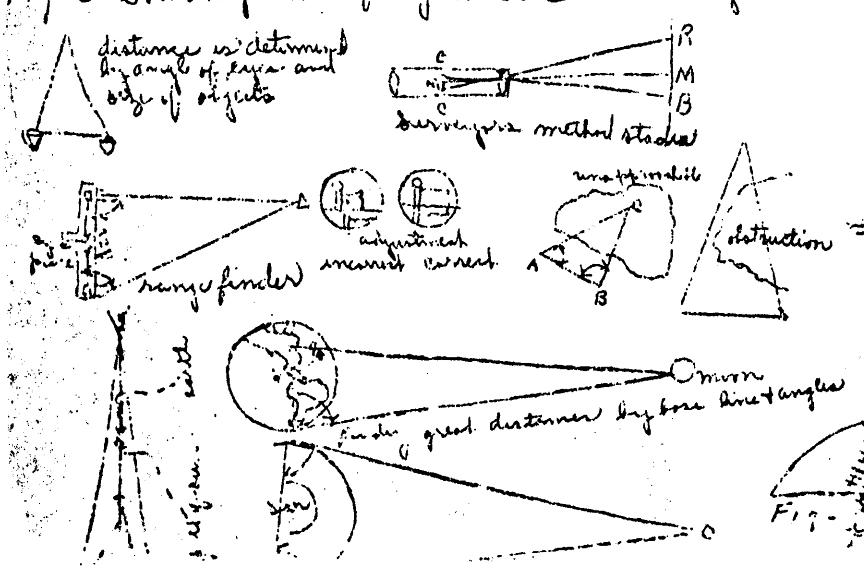

Fig-6 Solar system of Copernicus

| Name | Diameter | Weight rel. to earth | Vol. |
|---|---|---|---|
| Sun | 864,392 | 332,390 | 1,301,000 |
| Moon | 2,160 | .012 | .02 |
| Mercury | 3,004 | .045 | .06 |
| Venus | 7,825 | .817 | .92 |
| Earth | 7,918 | 1.000 | 1.00 |
| Mars | 4,216 | .106 | .15 |
| asteroids | 57,455 | very small | |
| Jupiter | 88,392 | 314.5 | 1300 |
| Saturn | 74,163 | 94.07 | 760 |
| Uranus | 30,878 | 14.40 | 65 |
| Neptune | 32,932 | 16.72 | 85 |
| Pluto | about same as earth | unknown | |

| | Dia | Per. of rev. |
|---|---|---|
| Earth. | 2160 | 27da |
| 1 moon | | 1hr |
| Mars | | |
| 1 Phobos | 10? | 7hr 39 min |
| 2. Deimos | 10? | 1 da 6 hr |
| Jupiter 9 moons | | hr. min |
| I | 100? | 11. 57 |
| II | 2452 | 30. 6 |
| III | 2045 | 85 |
| IV | 3558 | 7da. 3hr |
| V | 3345 | 16da. 16hr |
| VI | small | 270da |
| VII | very small | 780 |
| VIII | | |
| IX | 20 | 3 yr. |

| | Dia | Per. of Rev. |
|---|---|---|
| Saturn | | |
| 10 moons | | |
| 1 Mimas | 600 | [illegible] |
| 2 Enceladus | 800 | 1 - 8 |
| 3 Tethys | 1200 | 1 - 12 |
| 4 Dione | 1100 | 2 - 17 |
| 5 Rhea | 1500 | 4 - 12 |
| 6 Titan | 3000 | 15 - 21 |
| 7 Hyperion | 500 | 21 - 6 |
| 8 Japetus | 2000 | 79 - 7 |
| 9 Phoebe | 200 | 546 |
| 10 Themis | ? | 5 - 3 |
| Uranus | | |
| Ariel | 500 | 2 - 12 |
| Umbriel | 400 | 4 - 3 |
| Titania | [illegible] | 8 - 16 |
| Oberon | [illegible] | 13 - 11 |

Fig-7 = extensive information on solar system



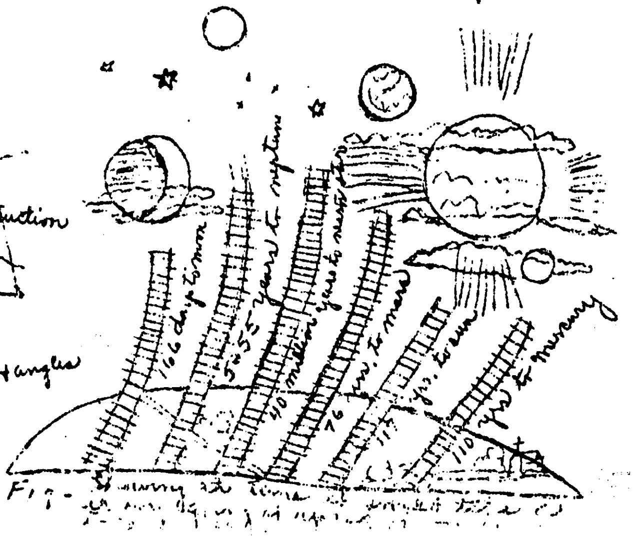



Fig 8

# THE UNIVERSE

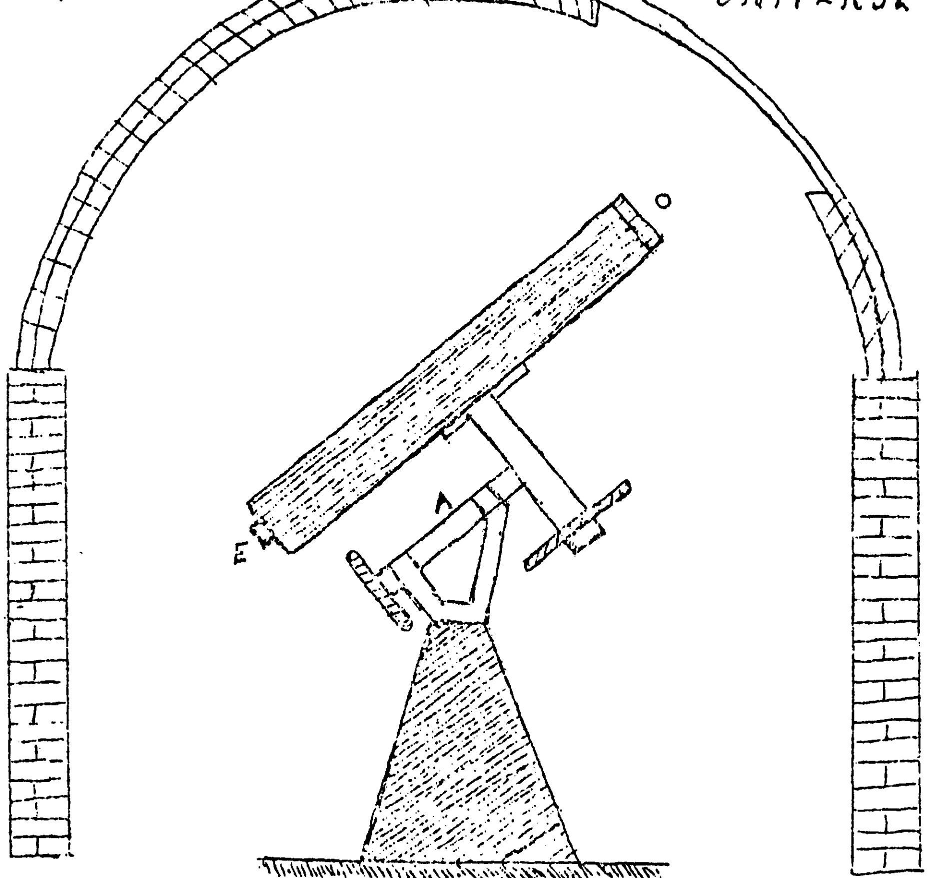



Fig 1 - Equatorial telescope as housed in observatory

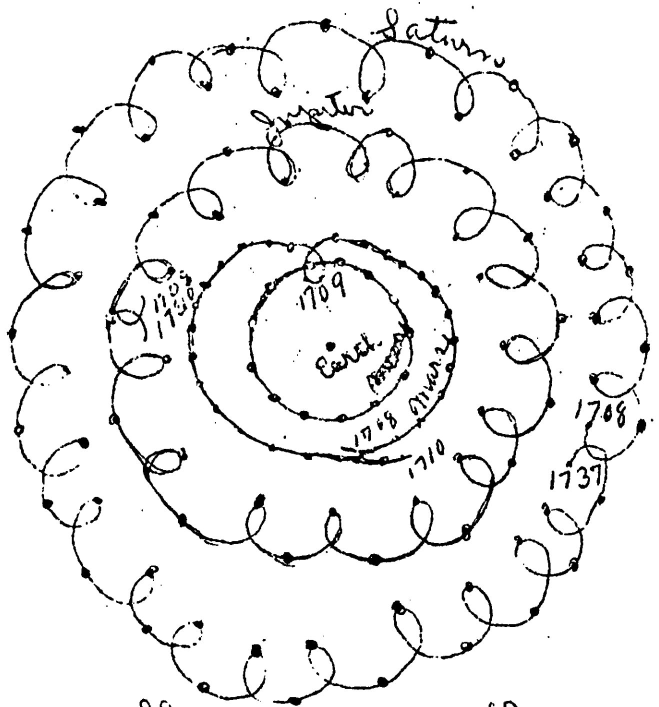



Fig-2 Showing the paths of Saturn Jupiter & mars around the earth

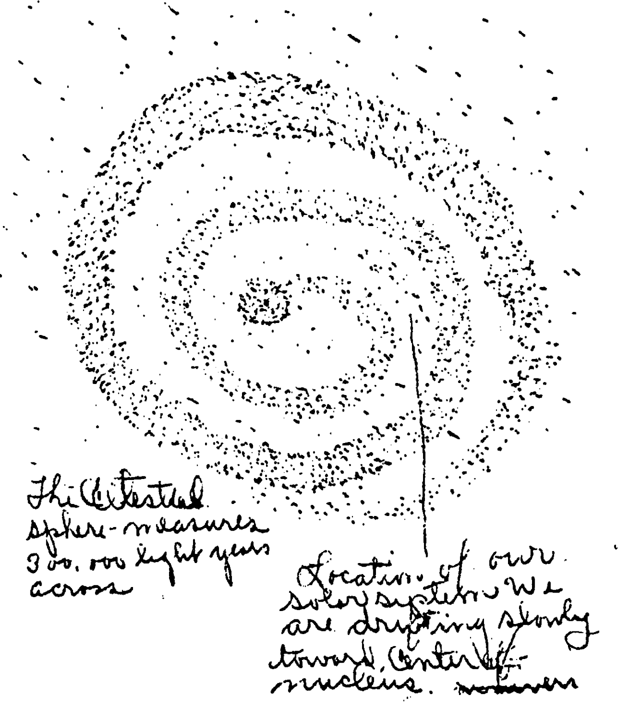



Fig-4- Latest conception of Universe
Our universe seems to be in form of a sphere. With a great Nebula & the milky way forming its equator. Most of stars and all systems with it seems to be a double spiral with nucleus at center. Our own system is now located ½ between outer limits of milky Way & this great Center nucleus

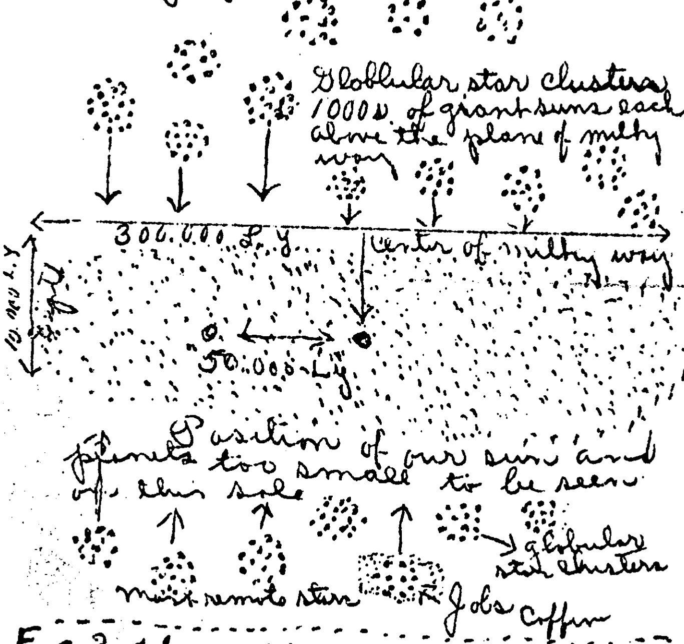
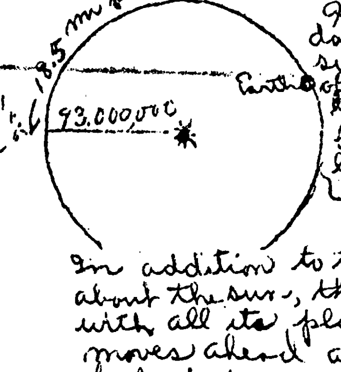



Fig 3 The milky way or galaxy as seen from edge. The present estimate of stars is 500 million in our own stellar universe




How far do we travel a day? Make plans for your summer vacation millions of miles from here. Enjoy your present scenery because you will never live to see it again."

To show distance travelled
Earth travel 18.5 mi per sec in its orbit Find the distance travelled per day

In addition to the motion about the sun, the sun with all its planets moves ahead at the rate of about 1.000.000 miles per day

| | |
|---|---|
| 18.5 | 266400 |
| 60 | 133200 |
| 111.00 | 1.598.400 mi per day due to motion of Earth in orbit |
| 60 | |
| 6600 | |
| 24 | |

# PART II

# METHODS OF MEASURING STELLAR DISTANCES BY LIGHT YEARS

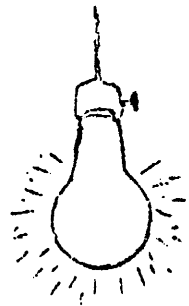
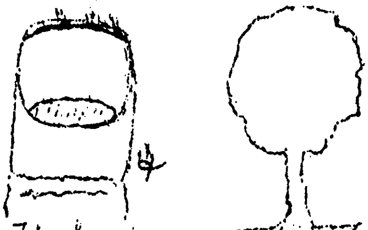


Fig-1 Light travels at the rate of 186,000 mi. per sec.



The human thumb nail — The growing tree

Fig 2-3 The slowest things that move on earth

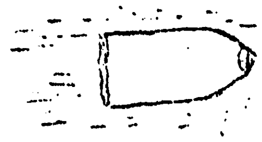


Fig-4 The fastest moving thing on earth. A shell travels at a speed of 2000 mi per hour

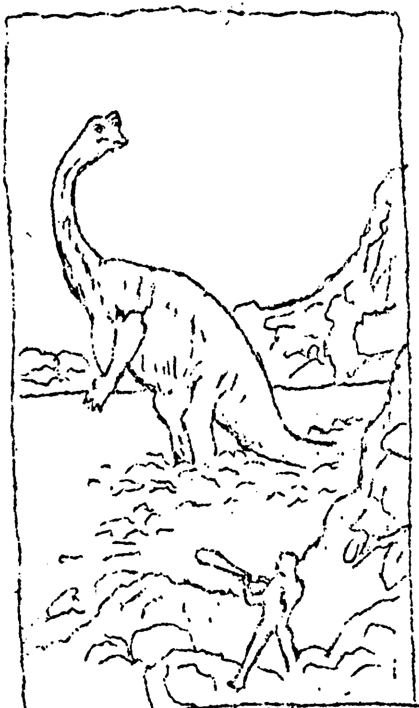


Fig-5 Standing on one of the most distant stars, an observer would see our earth with its gigantic dinosaurs etc, as it was 19,000,000 years ago. Although his vision has been travelling at a rate of 186.000 miles per second.

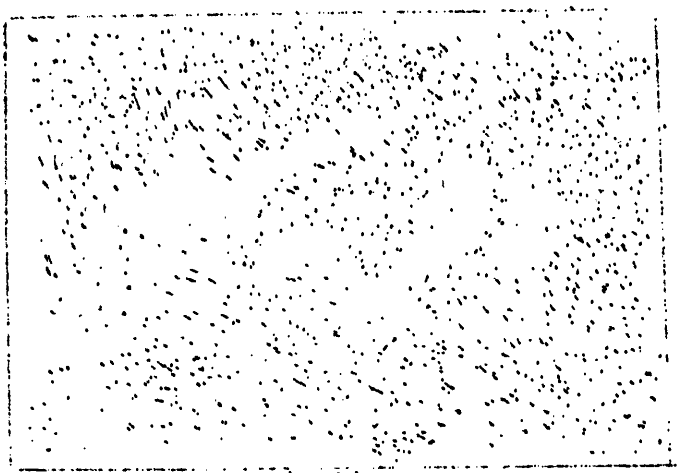
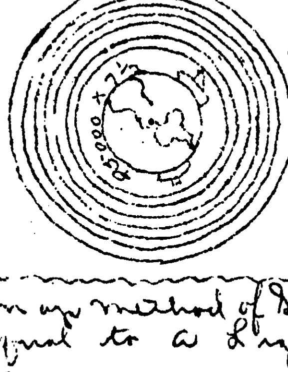


Fig-6 - Veritable clouds of stars. Not a single star in this sketch is visible to the naked eye, yet every tiny dot is the image of a world that wrote its image and superscription on a photographic plate.

## THE LIGHT YEAR THE YARDSTICK FOR STELLAR DISTANCE




A ship going at the speed of light would encircle the earth approximately 7½ times in 1 second.

Using a scale of 93.000.000 mi = 1 in it would still be difficult to show the distance to the remote stars.

To include a star 200.000.000 light years distant, would require a map that would be 200.000.000 miles wide. It would reach to the sun + back with 14.000.000 mi over.

A way method of Showing Distance Equal to a Light Year

Reduce the scale of the universe 6 trillion times. Then the sun is 1/100 inch in diameter. The earth 1 in distant would be microscopic in size 1/10.000 in. Neptune would be 5 feet distant

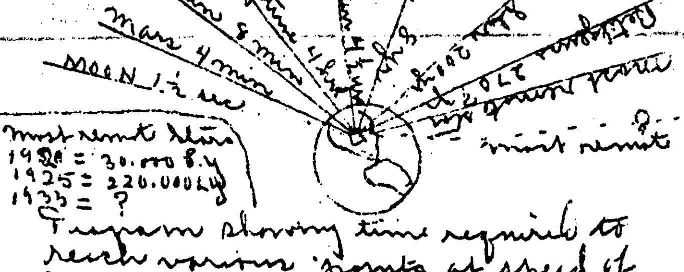
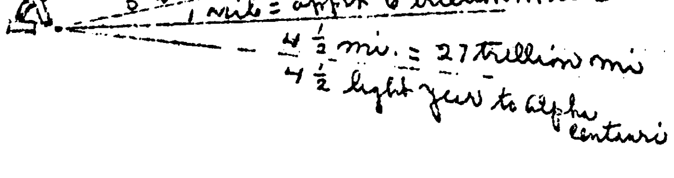



Diagram showing time required to reach various points at speed of light

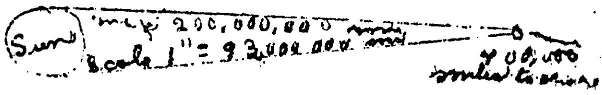



The number of miles in a light year. Speed of light = 186.000 mi per sec.

186.000 × 60 × 60 × 24

× 365 = 5.865,996,000,000 mi per yr.

Or light year is approximately 6 trillion miles. 6,000,000,000,000 miles



# NCIENT & MODERN METHODS OF MEASURING TIME

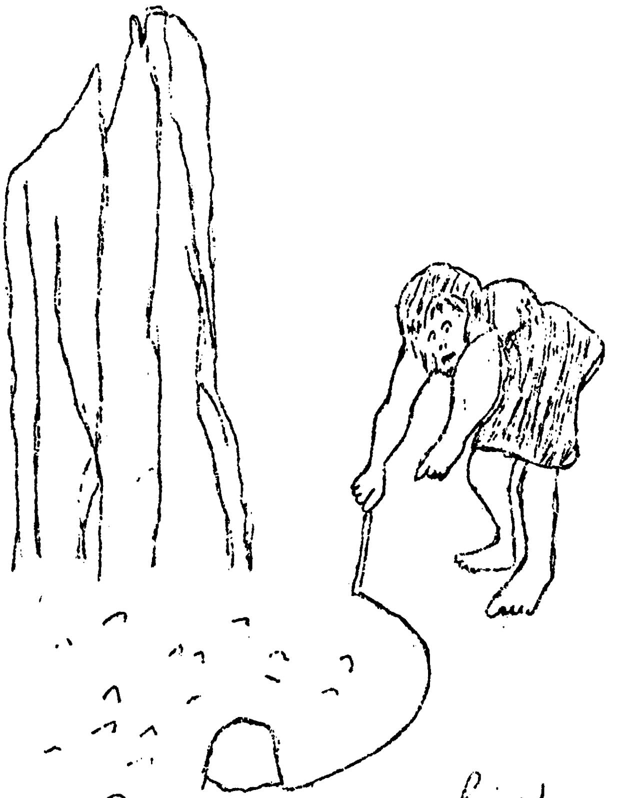


Fig-1 Prymitive man first measured time by the moving shadow, as cast by sun near rock or tree. The first primitive form of sun dial.

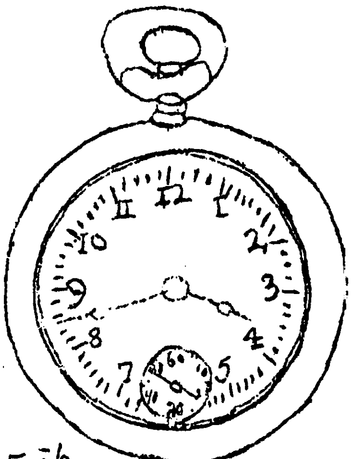




Fig 6 One of our modern spring wound time-pieces.

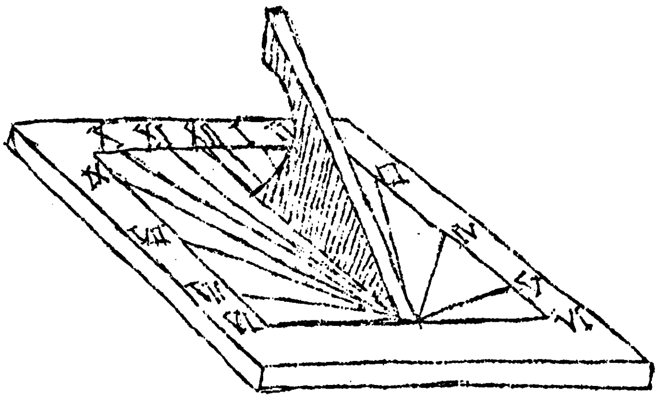


Fig-2 The Sundial a popular time piece even up till time of middle ages.

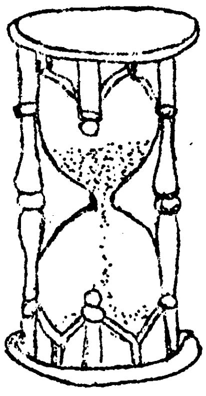


Fig 5 The hourglass supplants the sundial. Because of night & cloudy days.

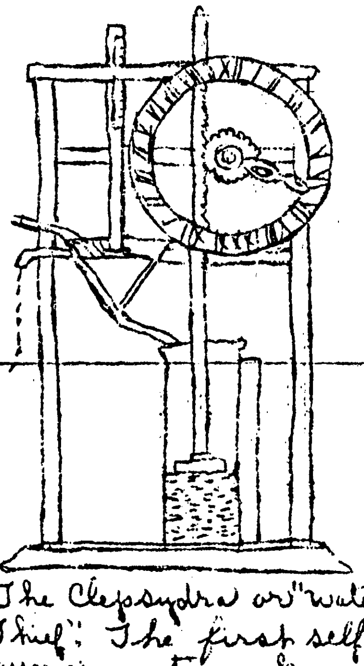


Fig 3 The Clepsydra or "water Thief". The first self-running, time-keeping machine in the worlds history

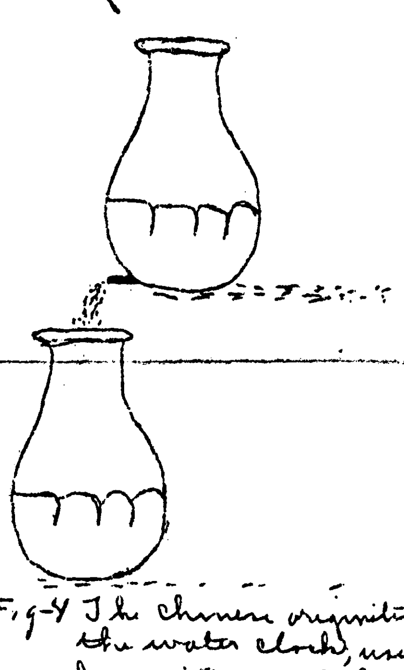


Fig-4 The Chinese originated the water clock, used Jar with small hole near bottom and thus measured time intervals thereby.

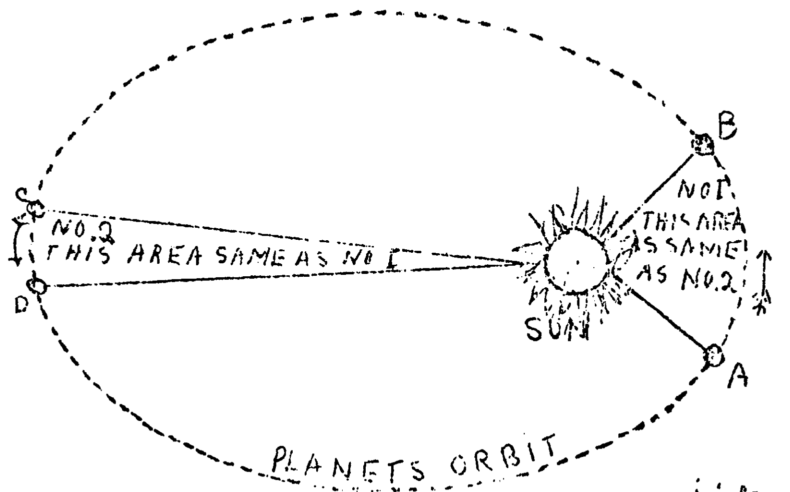



Fig-1 The changing pace of Earth round its orbit. This diagram illustrates one of Keplers Laws: A line drawn from the sun to the earth takes the same time to pass over the area No. 1 as it does to pass over the equal area No. 2, the motion of the earth being swifter between A + B than between C and D.

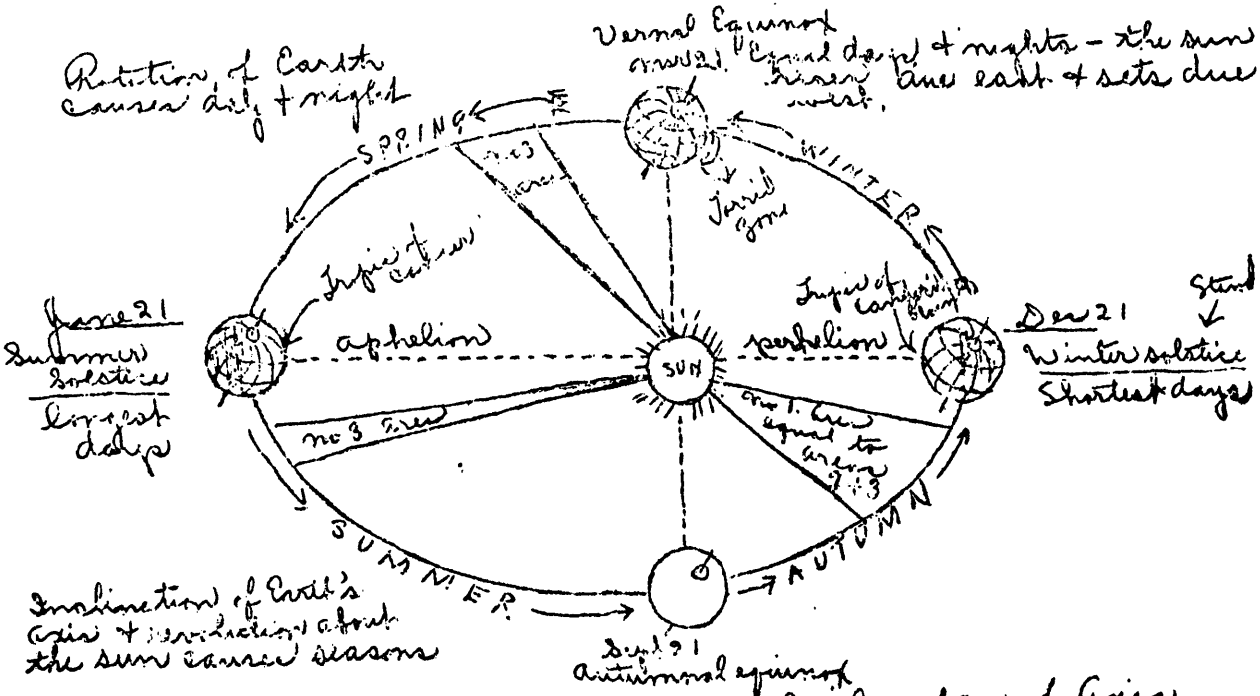



Fig 2 - The earth's orbit - Inclination of Axis, Seasons + time

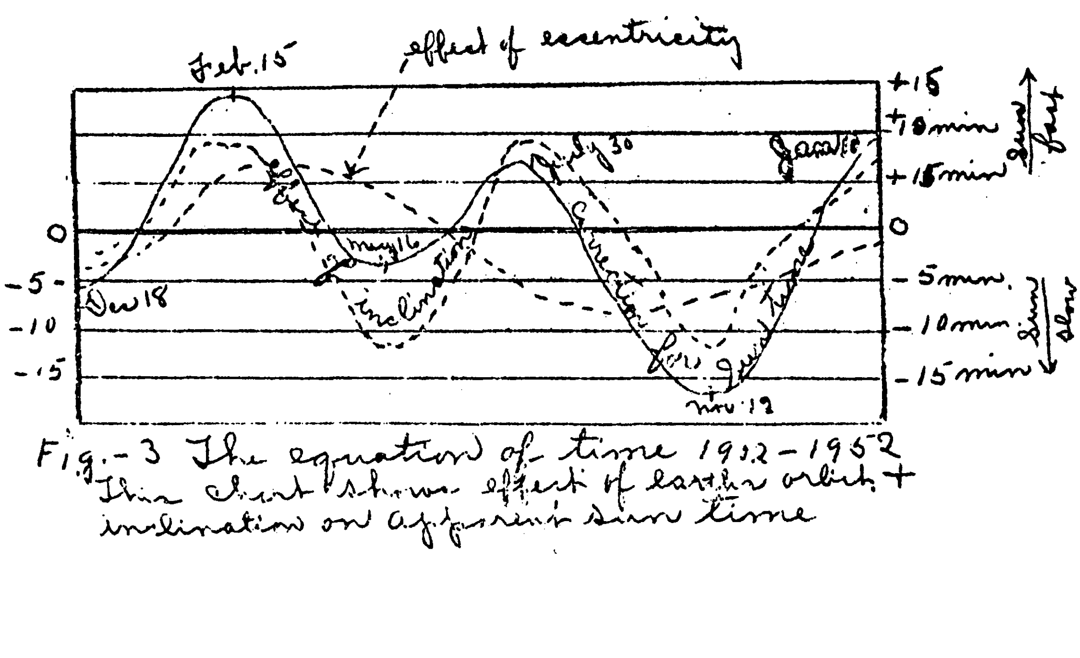



Fig.-3 The equation of time 1932-1952 This chart shows effect of earths orbit + inclination on apparent sun time

# THE DIVISIONS OF TIME

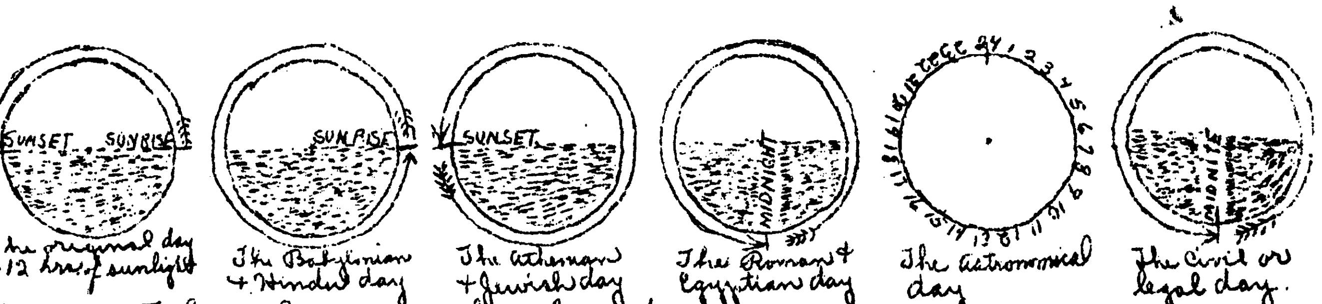



Fig. 1 The Length of the day.

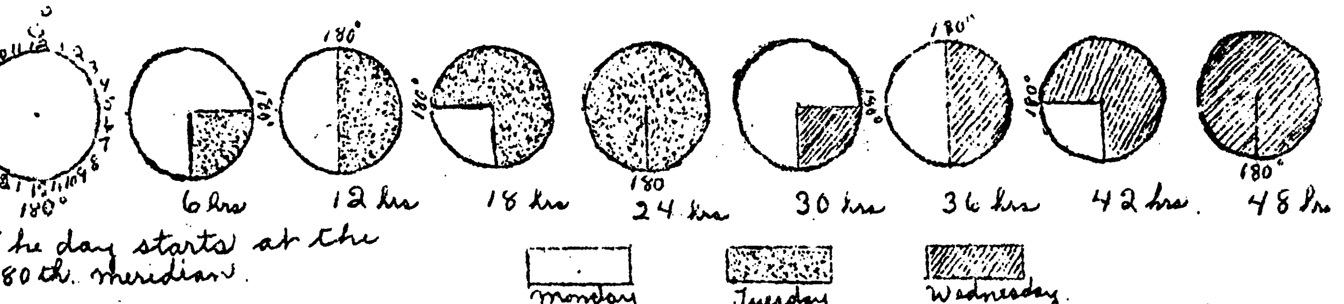



Fig. 2 - How zones are reckoned east and west from Greenwich. Going west gains time, east loses it

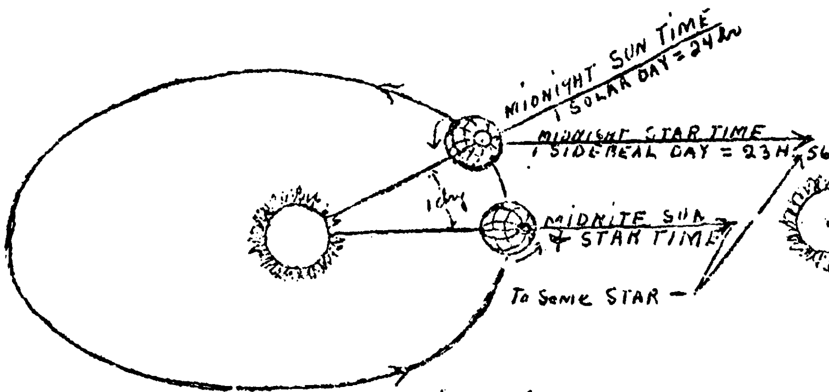



Fig-3 Different measures of a day

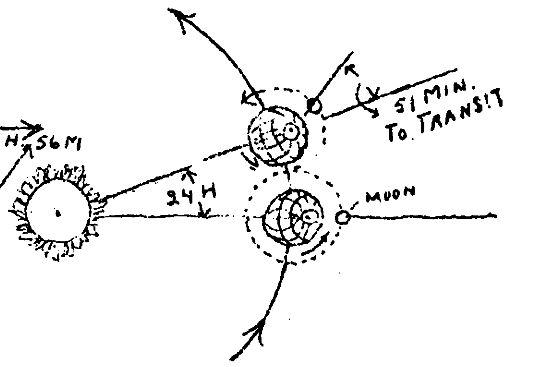
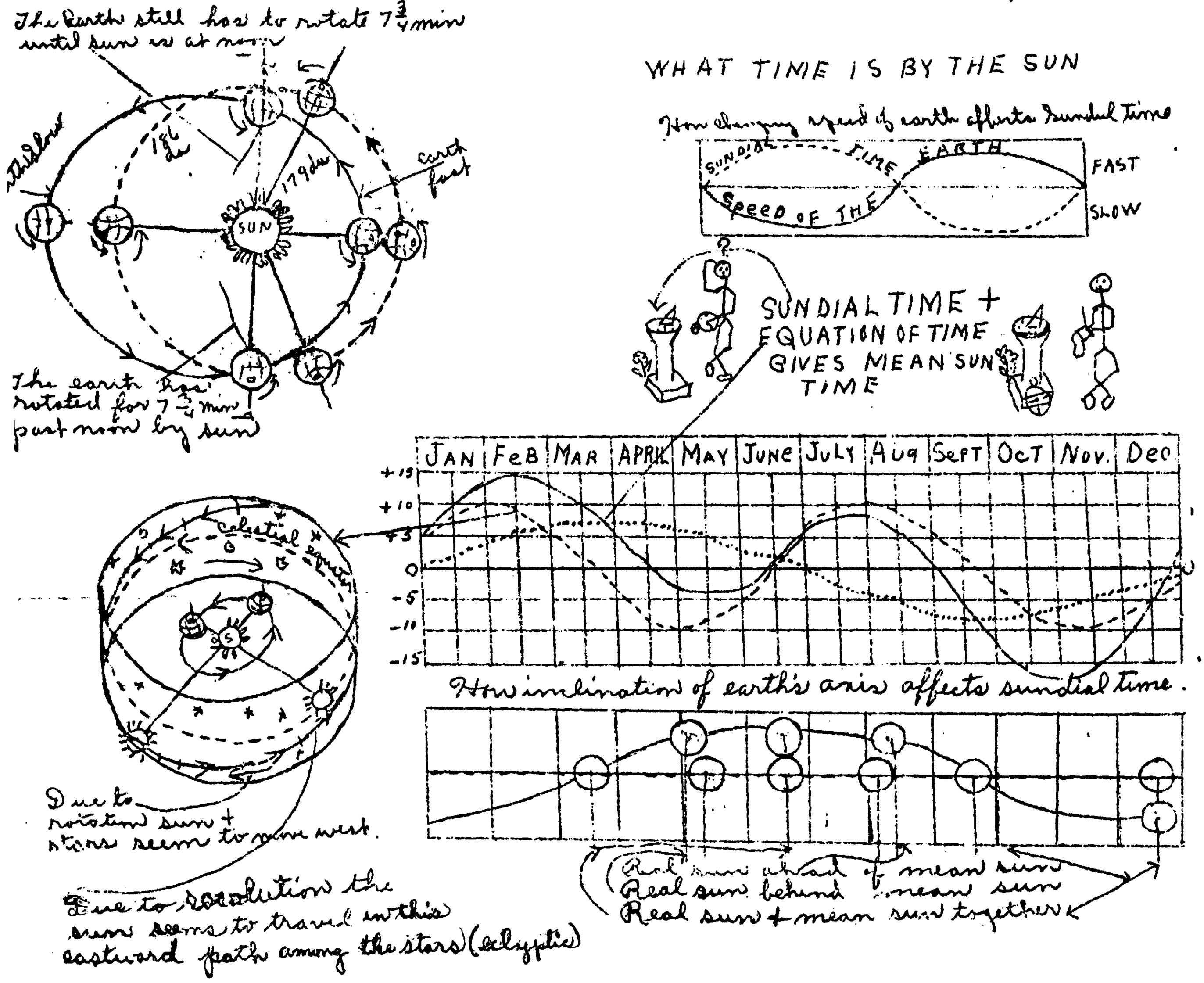
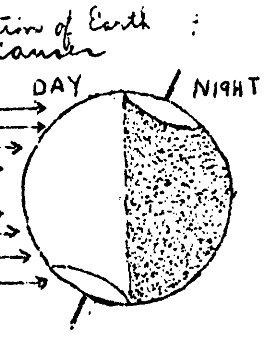


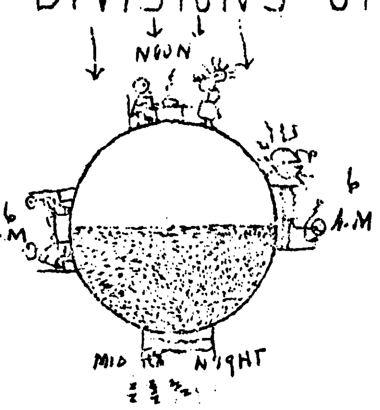

Fig-4 - One lunar day = 24 H. 51 MIN. (average)

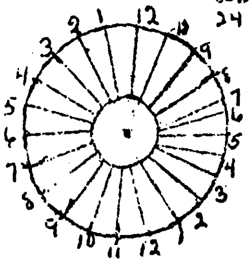
WHAT TIME IS BY THE SUN



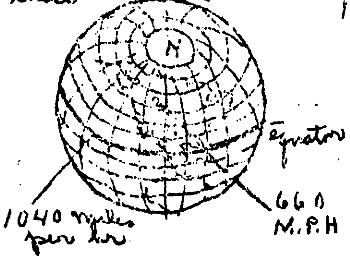
# THE DIVISIONS OF TIME

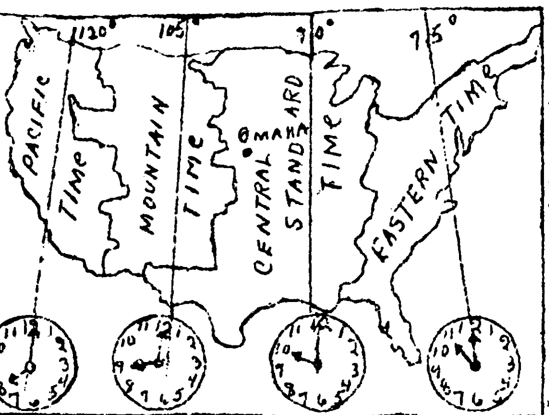


As we travel East the time becomes later by 1 hr. for each 15° of Longitude. Whereas it goes a... as you go west. There are 24 of these hrs. ... around world



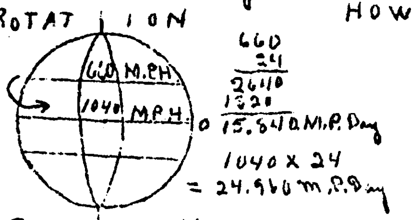

Standard time at Omaha is 23 M 50.2 sec. faster than mean Solar time

Fig-5 STANDARD TIME BELTS OF U.S. Each time zone extends about 7½° east & west of its meridian and covers 1 hr. The past boundaries were originally set by R.R. for own convenience and these have since been confirmed by the states.

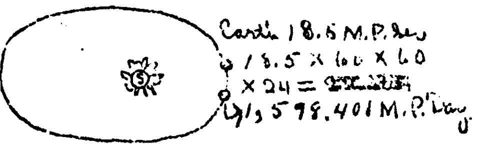
Fig-6 HOW MANY TIME ZONES IF EACH COVERED ONE MINUTE? If each zone covered only one minute of solar time, there would be 228 different times in U.S. You would have to reset your watch every eleven miles east or west.

HOW DO WE TRAVEL

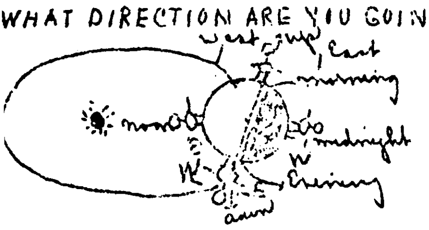
ROTATION

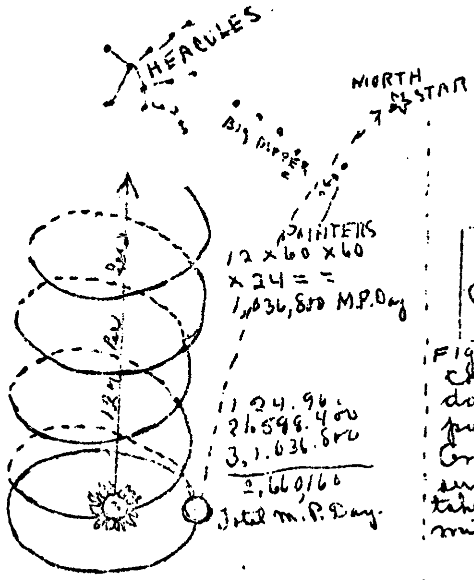



REVOLUTION




WHAT DIRECTION ARE YOU GOING



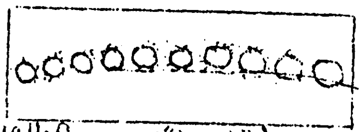
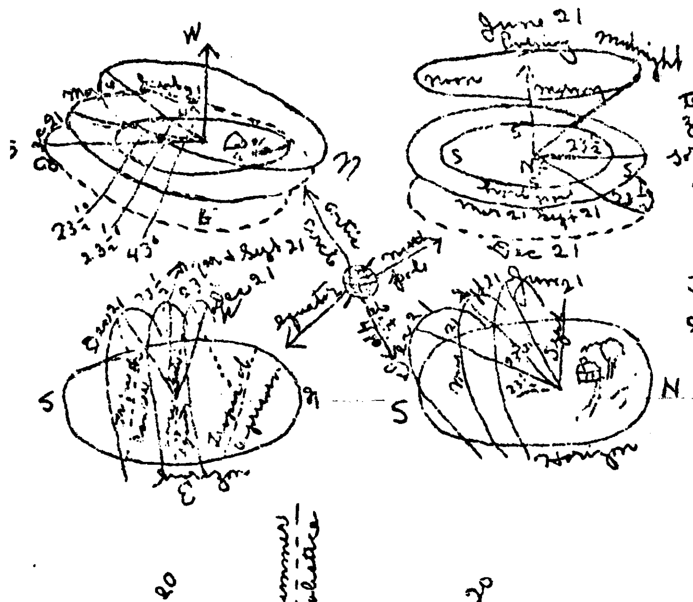
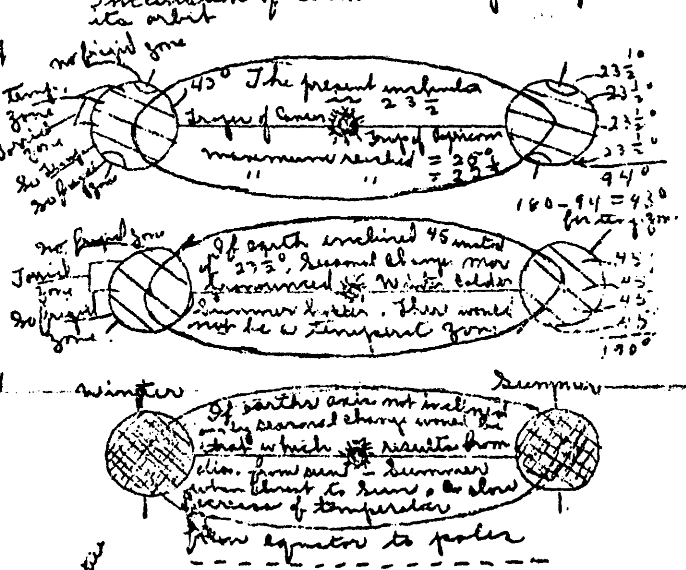



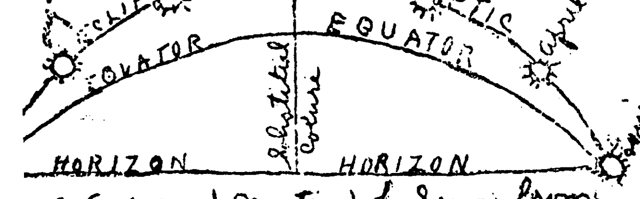
Fig 11. Camera "sees" Sun's course on the shortest day in the year from a point in the Arctic Circle. Only 2 hours passed from sunrise to sunset. Snaps taken on same plate at 12 minute intervals

APPARENT PATH OF SUN A DIFFERENT LATITUDES




Inclination of Earth's Axis to plane of its orbit




-19 Apparent Motion of Sun from March till Sept.

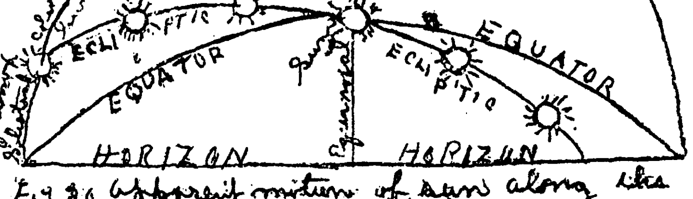



Fig 20 Apparent motion of sun along the ecliptic during Spring and Summer

# PROPERTIES + EFFECTS OF INERTIA

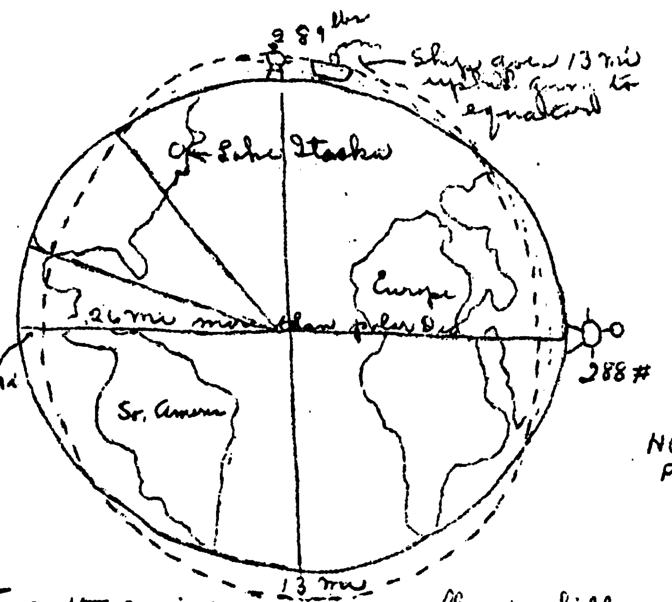



Fig-1 Mississippi River flows uphill one mile in going to the gulf.

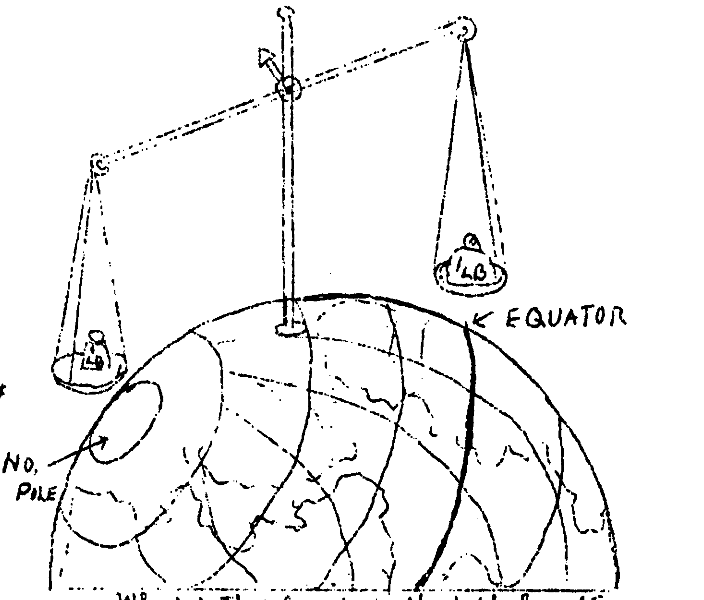
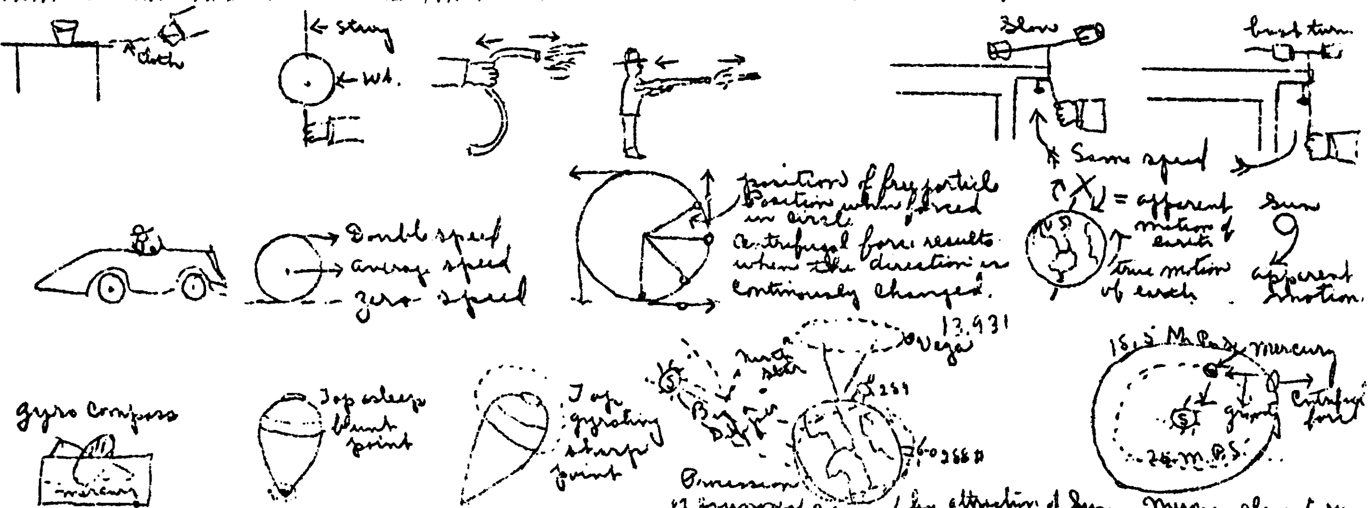



Fig-2 Why everything loses weight at the Equator. The earth bulges at equator and is flattened at the poles, dist. from N.P. to center 13½ Mi less than dis. from E to center. Pull of Gravity less at greater Dis. so balance shows that mass at Equator has less than the one at N.Pol.

INERTIA - THAT PROPERTY OF ALL THINGS CAUSING RESISTENCE IN STARTING, STOP + CHANGE SPEED ETC.




Precession of equinox caused by attraction of Sun + Moon for Equatorial Bulge

Mercury close to sun requires more Cent force to balance gravity

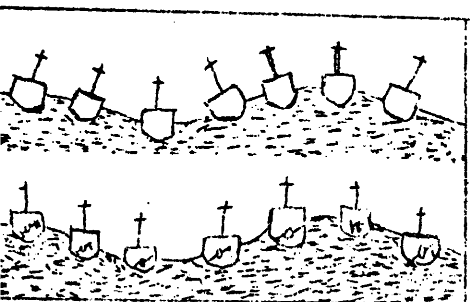


Fig-18 Cradle of Deep to Rock ships no more? Due to gyroscope

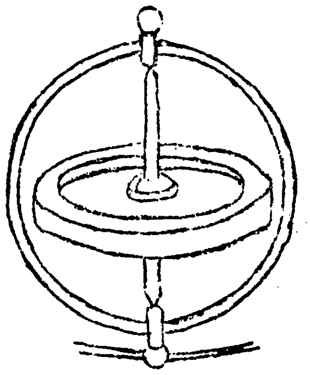


Fig-17 The Gyroscope

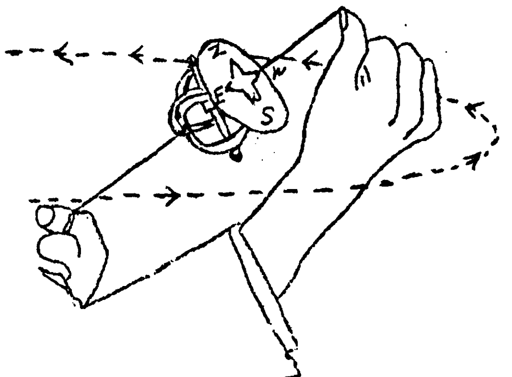


Fig-16 Gyro or Spinning Compass

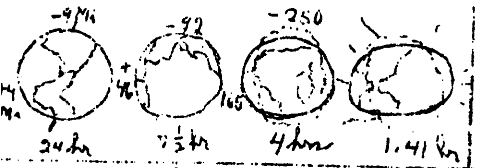



Fig-19 - Effect of various speeds of rotation on shape of earth

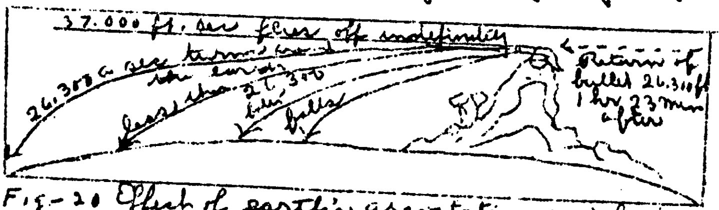



Fig-20 Effect of earth's gravitation on bodies of different velocities

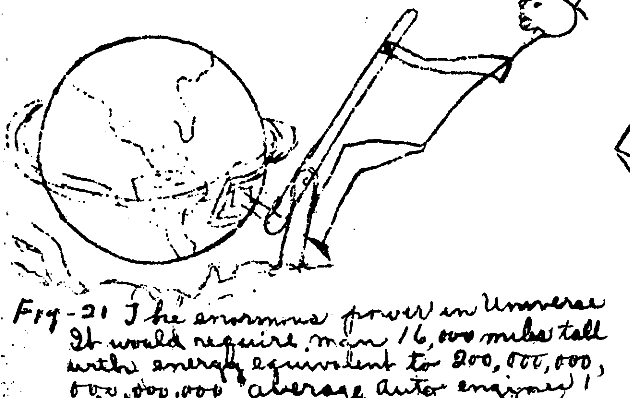


Fig-21 The enormous power in Universe. It would require man 16,000 miles tall with energy equivalent to 200,000,000,000,000,000 average auto engines 1 whole year to stop our world spinning + this energy only small part of the inconceivable power of sun + other celestial bodies

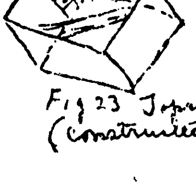


Fig 23 Topsy Turvy House (Constructed on an angle)

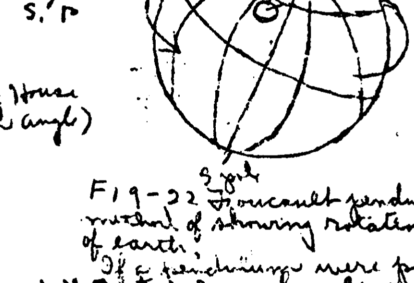
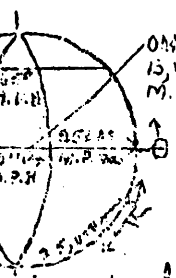



Fig-22 Foucault pendulum method of showing rotation of earth. If a pendulum were placed at N.P. its plane of vibration would seem to make 1 complete Rev. per 24 hrs. In reality the pendulum keeps the same plane while the earth turns under it




... speed of ... surface

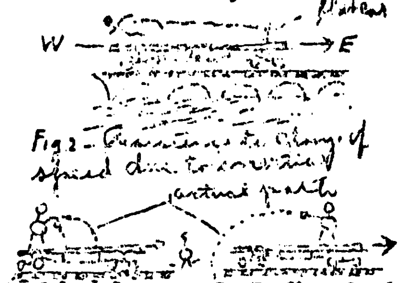



Fig 2 – ... change of speed due to ...

Fig-3 – Path of ... with respect to car and earth

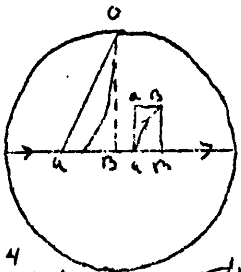
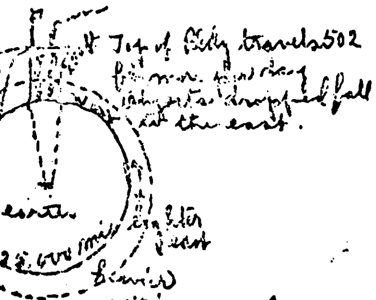


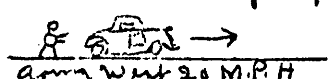

Fig-4 Winds, rivers, trains moving south are forced to the west. Things moving north are forced east.




Top of building moves faster ... yet it does not get ahead.

Einstein says, all motion is relative. We measure motion by comparison, of trees, cars, people etc.

E.g.




But earth turns east at 1040 M.P.H. leaving a speed of 1020 M.P.H.

However earth going around the sun must sometimes travel west 66,000 M.P.H but the sun takes the planets thru space. Even the universe may have motion relative to other universes.


Fig 5 Illustrating Einstein's theory

Sir Isaac Newton sees an apple fall.

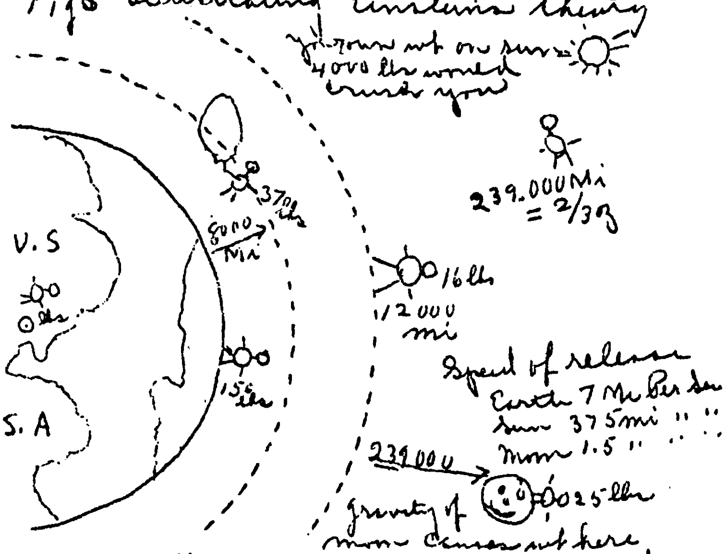
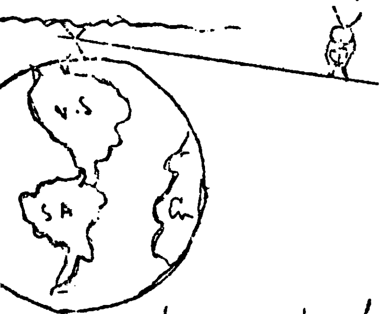



Fig 8. Effects of gravitation at various heights




Archimedes originator of mechanics or science said give me a fulcrum on which to rest I will move the earth

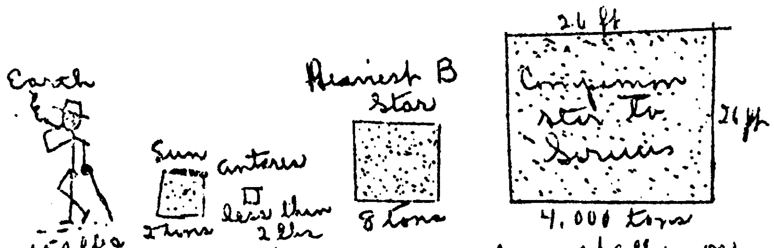



Fig-10 – A man weighing 150# on earth would collapse on the sun, crushed by his wt of 2 tons, on the surface of antares he would weigh no more than 2 lbs. On heaviest B star would weigh 8 tons. But on little companion to sirius densest star his wt would be 4,000 tons, equal to 26 ft of iron block

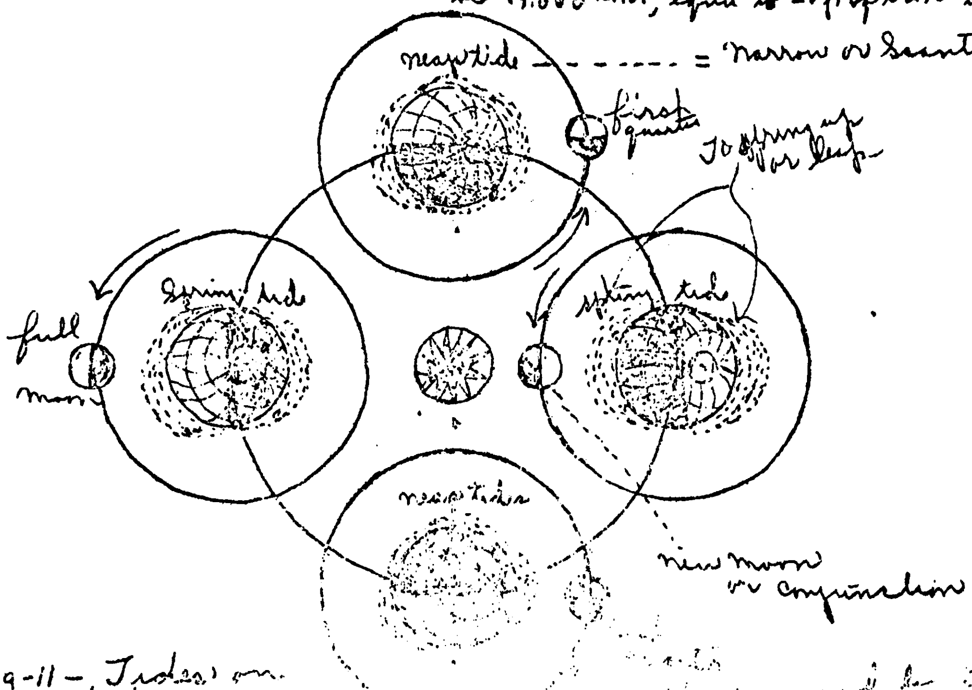
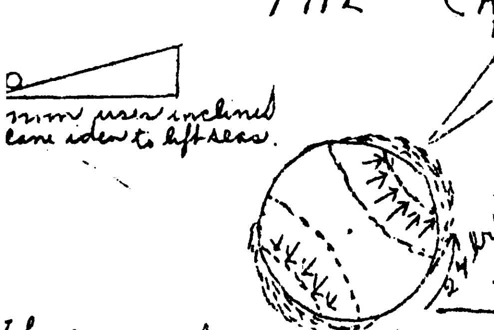



Fig-11 – Tides ... of the moon ... caused by gravity

# THE CAUSES OF TIDES



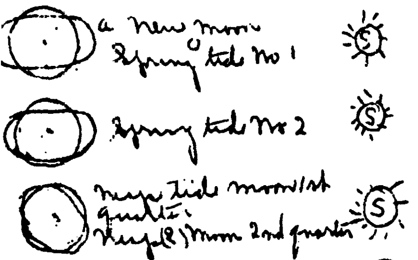

O Moon no tides because there is no rotation. If moon had an ocean + did rotate the tides would be 1000 ft high. Some writers claim that the moon's low temperature is due in part to the lack of tidal forces, constantly kneading the moon + causing heat

The energy of rotation of the earth furnishes the energy for tides. ...0,000 H.P. developed in Bay of Fundy at high tide. The tremendous rotational energy [of t]he earth can be appreciated when it is realized that it takes 6,000,000 years to slow ... 1 min. The gravitational forces of the sun + moon continually compress and [stre]tch the earth. This kneading action, some writers believe is responsible for [eart]hquakes, volcanoes, hot springs, internal heat of earth, some trade winds + ocean [cur]rents. Not all of the energy is expended on the earth. Part is used to pull the moon [becaus]e the earth turns faster than the moon. This increase of speed on the moon causes [i]t to move farther from the earth. Some think that perhaps the moon was at one [tim]e much closer to a part of the earth.

Since the sun rotates once in 25 da, 8 hr. this tends to increase the speed [of] revolution of the earth making the earth move farther away from the sun [du]e to tidal friction on the sun caused by the planets when in line [w]hich occurs about every 11 yrs, some writers say, this causes sun spots. And some ... say that in this way the earth gives more heat to the sun than it receives [in] light and heat rays.

## Tides – Earth Moon Sun

Newton first showed that tides were a natural consequence [of the] moon's gravitational forces on the ocean.

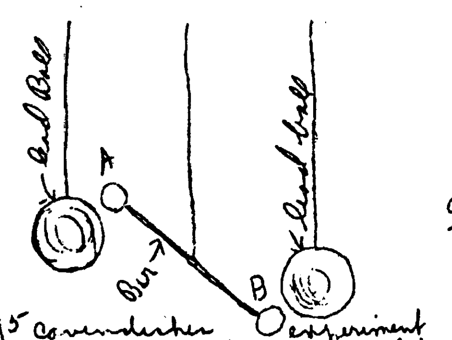




**Data**

| | | |
|---|---|---|
| average or mean tide | = | 4.7 ft |
| Spring tide 20% greater | = | 5.6 ft |
| Neap tide 20% less | = | 3.8 ft |
| Perigean (closest moon) 23% | = | 5.8 ft |
| Apogean (farthest moon) 20% | = | 3.8 ft |

Explanation of Tides – The moon attracts the water on the near side (a) not lifting but pulling side waters up incline of earth's surface to make the tide (a) + the earth being closer than water, B is pulled away allowing water to pile up at this point. A complete explanation must take Centrifugal force into account.

Facts. – The moon's pull is 1/10,000,000 as strong as the earth's pull of gravity. A 50,000 ton steamer would weigh 15 lbs. less at the new moon. Power of Venus is 1/10,000 as strong as moon. Jupiter 1/410,000,000 as strong. The great wt. of the sun would make it 26,000,000 times the strength of the moon, but its distance 389³ makes the force 58,000,000 times weaker so that the moon is 2¼ times strong as sun.




...5 Cavendish's experiment showing attraction between small bodies

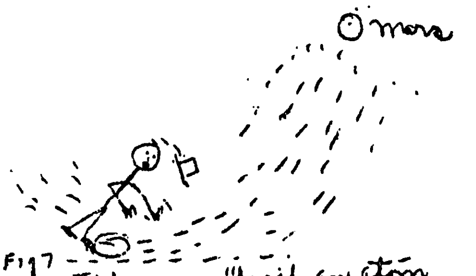



Fig 7 A scientist says, "jiggle an atom here + every other atom in universe jiggles somewhere something. Stub your toe here on earth and mars feels it and later on earth responds to the reaction of mars.

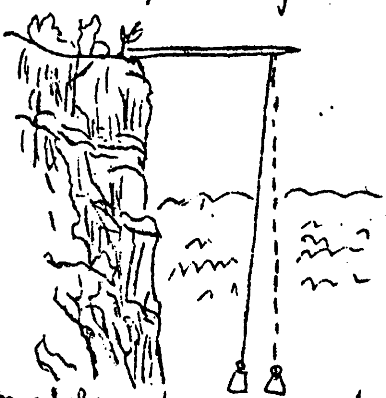


Fig 6 Maskelyne's experiment showing attraction of mountains on small bodies

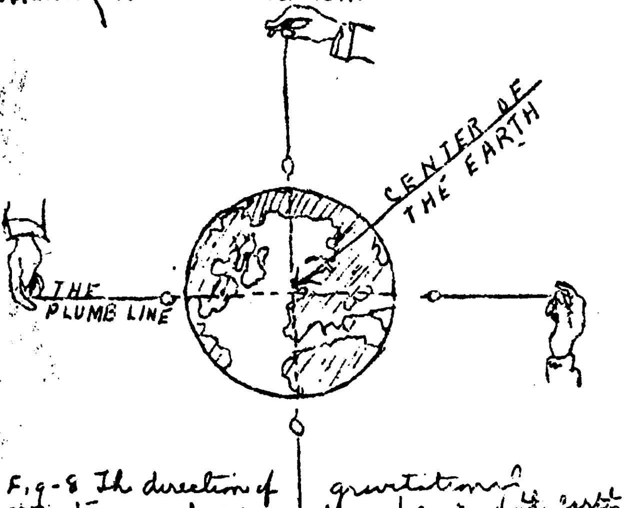



Fig-8 The direction of attraction is always gravitational toward center of the earth

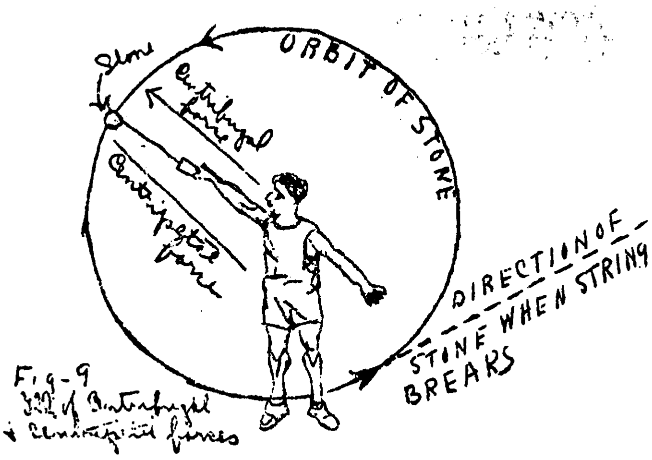



Fig-9 ... of Centrifugal + Centripetal forces

# PRE I TEST

Indicate to which item in Col. I each item in Col. II belongs by placing the numbers preceding the items in Col. II in front of the proper items in Col. I.

| | | |
|---|---|---|
| _____ | Mercury | 1. The center of the solar system is the |
| _____ | Gravity | 2. The nearest neighbor to the earth is the |
| _____ | Sun | 3. The number of known planets travelling about the sun. |
| _____ | Nine | 4. The most recently discovered planet |
| _____ | equator | 5. The planet that moves about the sun in the least time. |
| _____ | Julius Caesar | 6. The length of a day on earth, in hours, is |
| _____ | Columbus | 7. The place on the earth where you would weigh the least. |
| _____ | Twenty-four | 8. That force which keeps the planets from flying into space. |
| _____ | Moon | 9. Into how many standard times is the world divided? |
| _____ | Pluto | 10. The man who about 45 A.D. decreed the year to be 365 days long with each fourth year being 366, or a leap year, was |
| _____ | Forty-eight | 11. The man that believed the earth was pear shaped was |

## II

Below are a number of statements of which some are true and some are false. If in your opinion, the statement is true, place a "+" before it. If it is false, place an "0" before it.

___ 1. The Greeks thought that the earth was a floating disc in the sea.

___ 2. The shape of the world today is known to be a tetrahedron.

___ 3. The direction toward the center of the earth is down.

___ 4. The people living on the underside of the earth stand with their heads hanging down.

___ 5. Mars was the Greek god of love.

___ 6. It is the stars instead of the planets that twinkle.

___ 7. The moon revolves about the earth.

___ 8. The light coming from moons and planets is reflected sunlight.

___ 9. Tides are caused by the gravitational effects of the moon.

___ 10. The path of the earth about the sun is called the orbit.

___ 11. Shooting stars become incandescent because of heat caused by friction.

___ 12. The approximate diameter of the earth is about 8,000 miles.

___ 13. The Chinese believed the world a great square and their country the greatest circle in the square.

___ 14. Stellar distances (the distance to the stars) are relatively small.

___ 15. There are four standard time belts in the United States.

___ 16. Time cannot be determined from the stars.

___ 17. The word day comes from an ancient word meaning darkness.

___ 18. The month as a unit of time was suggested by the changes of the moon.

___ 19. The standard of time is the revolution of the earth.

___ 20. Ordinary time must be adjusted to darkness, that is, to the hours between sunset and sunrise.

___ 21. Time as determined by the sun is called sidereal time.

___ 22. The sun is the only star in our solar system.

___ 23. Most of the sun is supposed to be in a solid state.

___ 24. The earth and its people are travelling through space at a speed 50 times that of a canon ball.

___ 25. The revolution of the earth causes night and day.

___ 26. If the sky were packed full of moons, their combined light would be about one sixth that of the sun.

___ 27. In our yearly trips around the sun, we travel about 1,500,000 per day.

___ 28. We call that property of all matter which resists starting, stopping, or changing speed or direction, constant acceleration

___ 29. A ship in going from the pole to the equator travels about thirteen miles up hill.

___ 30. The equator is the place where you would weigh the most.

___ 31. The Mississippi river rises one mile in going from Lake Itaska to the Gulf of Mexico.

___ 32. If the speed of the earth's rotation was increased 17 times, a person would possess no weight at the equator.

___ 33. Electricity is the force which causes weight.

___ 34. Small objects possess greater gravitational attraction than do large ones.

___ 35. A 150 pound man would weigh 25 pounds on the moon.

___ 36. The sun produces the largest tides on earth.

___ 37. The falling tide is called the flood tide.

___ 38. The energy of the tides over the world is wasted in friction, which tends to retard the rotation of the earth.

___ 39. A screen against gravity has recently been discovered.

___ 40. The sun exerts a greater gravitational pull on Mercury than it does on the earth.

___ 41. We must set our watches ahead as we go westward across the country.

___ 42. We have never seen all of the moon.

III

Fill in the blanks with the correct word:

1. The __________ were the people that believed the center of the earth was a nice warm heaven and the sky a cold place where the wicked freeze forever.

2. The Greek word for planet meant _________.

3. The planets were named after _________.

4. The world as we know it today is _________ in shape.

5. The _________ revolves around the earth.

6. _________ is the name given to small worlds or asteroids.

7. The sun and all the planets advance through the universe abcut _____ _________ miles per day.

8. At present the earth's axis is inclined at an angle of _________ degrees to its orbit.

9. In going west from Omaha on the Union Pacific, the time changes at _________________.

10. There are _________ standard time belts in the United States.

11. The cave man measured time by means of the moving _________.

12. Before clocks were invented men told time by the _________ at night and the _________ in the daytime. A ______ ______ helped to make the daytime measurement more exact.

13. The compass which has a spinning wheel to point the way instead of a needle is called a _________ compass. The wheel of this compass floats in _________.

14. The force which arises where there is a constant change of direction as moving in a circle is called _________ force.

15. We can locate the position of a place on the earth by giving its _________ and _________.

16. _________ is the force which causes weight.

17. ____ _______ _________ explained gravitation by explaining that there was attraction between all things.

18. The falling tide is called the _________ tide.

19. The astronomers by knowing the distance of the sun and its gravitational pull, are able to calculate its _________.

20. The _________ produces the highest tides on earth.

21. The solar system consists of the _________, _________, and _________.

## IV

Place the number of the correct statement in the blank before question numeral.

____ 1. The people that believed the earth was an enclosed chamber surrounded by water were the 1. Greeks, 2. Chinese, 3. Chaldeans, 4. Hindus, 5. Eskimos.

____ 2. The country in which star gazing is supposed to have originated was 1. Persia, 2. India, 3. France, 4. Spain, 5. U.S., 6. Denmark.

____ 3. The approximate diameter of the earth is 1. 8,000 mi., 2. 10,000 mi., 3. 1,000,000 mi., 4. 20,000 mi., 5. 12,000.

____ 4. The number of times light would be able to go around the world in a second, provided it travelled in a curved line, is 1. 20, 2. 7½, 3. 1, 4. 3, 5. 9, 6. 12.

____ 5. The path of a heavenly body is called its 1. circumference, 2. orbit, 3. inclination, 4. radius, 5. equator, 6. latitude, 7. declination.

____ 6. The passage of the moon between the sun and earth is called, 1. eclipse of sun, 2. eclipse of moon, 3. eclipse of earth, 4. full moon, 5. third quarter, 6. autumnal equinox.

____ 7. The largest of the planets is 1. Venus, 2. Saturn, 3. Mars, 4. Jupiter, 5. Uranus, 6. Pluto.

____ 8. The density of a solid is usually compared with that of 1. air, 2. hydrogen, 3. water, 4. lead, 5. oxygen, 6. wood.

____ 9. The distance above sea level is called 1. longitude, 2. rotation, 3. altitude, 4. latitude, 5. revolution, 6. declination, 7. inclination.

____ 10. The law of gravitation was discovered by 1. Archimedes, 2. Galileo, 3. Copernicus, 4. Aristotle, 5. Newton, 6. Marconi, 7. Edison.

____ 11. "Shooting stars" are properly called 1. planets, 2. suns, 3. nebulae, 4. asteroids, 5. comets, 6. meteors.

____ 12. When two objects are moved apart the attraction between them 1. remains the same, 2. grows less, 3. increases.

____ 13. The highest tides on earth are found in or on 1. Bay of Funday, 2. California, 3. Pacific coast, 4. Florida.

____ 14. A man as he is travelling east finds as he passes from one time belt to the next that his watch is 1. one hour slow, 2. one hour fast, 3. has stopped, 4. 10 min. slow, 5. 30 min. fast.

____ 15. The man said to be the true originator of mechanics as a science was 1. Edison, 2. Archimedes, 3. Ford, 4. Darwin.

## V

Select and check the correct statement.

1. The man who was supposed to have saved himself from the Indians by his knowledge of an eclipse was __Columbus, __Buffalo Bill, __Captain John Smith __Daniel Boone.

2. The kind of tide that results when the sun and moon are pulling at right angles is __ ebb tide, __ neap tide, __rising tide.

3. The date on which the sun in its southern journey rises due east and sets due west and the day and night are equal the world over is about the __21st of June, __ 21st of September, __21st of December, __21st of March.

4. The special name applied to the moon is __planetoid, __satellite, __asteroid, __meteor.

5. Since rivers or trains moving south have the property of inertia and resist a change of speed, the bank or rail which should wear the most is the __east rail, __west rail, __north rail, __south.

6. In our yearly trip around the sun, the distance we cover each day is about __1,500,000 mi., __100,000 mi., __1,000,000 mi., __500,000 mi., __ 50,000 mi.

7. As boy or girl scouts we learn to tell the time by means of the __compass, __sun and stars, __moon, __clouds, __chronometer __watch.

8. The maximum angle at which the earth's axis can be inclined to its orbit is __$23\frac{1}{2}$ degrees, __15 degrees, __25 degrees, __50 degrees, __10 degrees.

9. The man that discovered that the earth revolves around the sun __Copernicus, __Aristotle, __Edison, __Haley, __Ptolemy.

10. The man that offered as proof that the world was round, the fact that a ship going out to sea can be seen to gradually drop down over the horizon was __Columbus, __Aristotle, __Davey Jones, __Priestly, __Galileo.

Final I Examination

Indicate to which item in Col. I each item in Col. II belongs by placing the numbers preceding the items in Col.II in front of the proper items in Col. I.

| | |
|---|---|
| _____ Eight | 1. The Egyptian astronomer that taught , the sun moon and stars move around the earth. |
| _____ Kepler | 2. The Polish astronomer about 1500 A.D. who that the sun was the center of rotation |
| _____ Sun | 3. The number of minutes required for light to reach the earth from the sun |
| _____ Rotation | 4. The man that first used the telescope and discovered the four large moons of Jupiter |
| _____ Nebulaé | 5. The man of modern times, within last 100 years, that proposed the open hole theory of the earth |
| _____ Revolution | 6. The name given to huge clouds of stars dust is |
| _____ Copernicus | 7. That motion of the earth which causes day and night |
| _____ Galileo | 8. That motion of the earth which gives us the year |
| _____ Symmes | 9. The light of the moon comes from the |
| _____ Ptolemy | 10. Man that stated that the orbits of the planets were not circles but elipses was |

II

Below are a number of statements of which some are true and some are false. If in your opinion, the statement is true, place a "x" before it. If it is false, place an "O" before it.

____ 1. The stars are closer to the earth than the planets.

____ 2. The Ancient egyptians thought the earth a great box--the stars hung from ropes and the sun a disc of fire carried on a boat in a river.

____ 3. There are twelve known planets in our solar system.

____ 4. The planets were named after animals.

____ 5. Star gazing was supposed to have originated in Persia.

____ 6. The direction away from the center of the earth is up.

____ 7. Jupiter is closer to the sun than the planet Mars.

____ 8. The moon is the center of the solar system.

____ 9. Human beings could not live on the moon because its temperature is higher than that of the sun.

____10. Jupiter is the smallest planet of the solar system.

____11. The nearest neighbor to the earth is the moon.

____12. Mercury has two moons.

____13. The microscope is used to study light from the heavenly bodies.

____14. Jupiter is a planetoid.

____15. Omaha is located in the mountain time standard time belt.

____16. The year as a unit of time was suggested by the seasons.

____17. The "day" was the first measure of time.

____18. Primitive man used a sundial to tell time by.

___19. The scientific time, time used by astronomers, differs at various points on the earth.

___20. As the earth turns from west to east and as London is east of New York, the sun sets in London while New York is enjoying daylight.

___21. We have been in this part of the universe before.

___22. The true fixed stars are really suns like our own Sun.

___23. The full moon is always visible in the daytime when it is above the horizon and not hidden by the clouds.

___24. The planets farthest from the sun have the greatest speed.

___25. Rotation must be added to the revolution of the earth to produce the seasons.

___26. The diameter of the earth is greater than that of Jupiter.

___27. There is no motion at the poles of the earth.

___28. Centrifugal force is the cause of the equitorial bulge.

___29. Inertia forces the Mississippi river to run uphill.

___30. Considering centrifugal force, the place on the earth's surface where you would weigh the least is at the poles.

___31. If the speed of rotation of the earth was increased 17 times the days would be 1 hour, 25 minutes in length.

___32. If the speed of rotation of the earth were increased the equatorial bulge would get smaller in size.

___33. The sun is a perfect time piece and indicates exact time all the year round.

___34. Von Guerike explained gravitation by saying, "that there was attraction between all things".

___35. A person would lose weight by going up in an aeroplane.

___36. The rising tide is called the ebb tide.

___37 The sun and moon combined produce the spring tide.

___38. The earth is kept from flying into space by the force of gravity.

___39. A steel cable 3,000 miles in diameter would be required to provide a substitute for the sun's gravitational attraction.

___40. The earth's axis of rotation is inclined to the plane of its orbit.

___41. Gravity has but little effect on birds in flight.

___42. The year does not equal an exact number of days.

## III

Fill in the blanks with the correct word.

1. The ________ believed the world was a flat disc held up by four great elephants which stood on the back of a turtle swimming in an ocean of milk.

2. The direction toward the center of the earth is ________.

3. The ________ are closer to the earth than the ________.

4. There are ____ large planets in our solar system.

III ( cont.)

5. It takes ___ _____ for light to reach the earth from the sun.

. The _____ _____ is the astronomers yardstick.

. __________ must be added to rotation of the earth to give seasons.

. The sun crosses the equator coming north on the twenty-first of _____ and marks the beginning of _____.

. The time taken from the stars is called ________ time.

. The ________ measured their day from midnight to midnight.

. Time in Omaha is expressed in terms of ________ ________ time.

. The way of dividing time into hours, minutes and seconds was invented by the ancient __________ astronomers.

. A ________ may be used to keep a ship from rolling in a heavy sea.

. It takes the earth a _____ to go entirely around the sun and come back to the same place in its _____.

. The term used to denote the force opposed to centrifugal force in a rapidly revolving wheel is, __________ force.

. The water clock was first invented or used by the ________.

7. Ones weight due to the attraction of the earth at the distance of the moon would be about ____ ______.

3. We call that property of all matter which resists starting, stopping or changing speed or direction ________.

9. The planet upon which the sun exerts the greatest gravitational pull is ________.

. The planets in order of their distance from the sun are; (a) ______ (b) ________, (c) ________, (d) ________, (e) ________, (f) ________ (g) ________, (h) ________, (i) ________.

IV

Place the number of the correct statement in the blank before question numeral.

___ 1. The man who in recent times proposed that the world was a tetrahedron in shape was 1. Symmes, 2. Einstein, 3. Newton, 4. Green, 5. Franklyn.

___ 2. The present known number of small worlds or planetoids is 1. 10,000, 2. 3000, 3. 940, 4. 365, 5. 150, 6. 1,000,000.

___ 3. The speed of light is, 1. 60 mi. per hr; 2. 1250 mi. per hr; 3. 186,000 mi. per sec.; 4. 50,000 mi. per sec.; 5. 10,000 mi. per hr.; 6. 1,000,000 mi. per hr.

___ 4. Galileo invented the 1. printing press, 2. cotton gin, 3. microscope, 4. telescope, 5. dynamo, 6. camera, 6. steamboat.

___ 5. Distance east and west around the earth is called, 1. longitude, 2. altitude, 3. rotation, 4. inclination, 5. latitude, 6. revolution.

___ 6. The resistance a body offers to being set in motion is called 1. momentum, 2. friction, 3. cohesion, 4. erosion, 5. voltage, 6. inertia, 7. fusion.

___ 7. The earth rotates on its axis once in (1) 12 hrs. (2) 24 hrs. (3) 7 days (4) 31 days (5) 3 months (6) 365$\frac{1}{4}$ days (7) 4 years.

___ 8. The smallest of the planets is 1. mercury, 2. Venus, 3. Mars, 4. Jupiter, 5. Saturn, 6. Uranus, 7. Earth.

___ 9. The instrument used to analyze the light of the stars in order to find of what elements they are composed of is called

___10. What direction would the Mississippi river flow if the earth stopped its rotation 1. north, 2. south, 3. east, 4. west.

___11. A 150 lb. man would weigh on the companion star to Serius about 1. 25 lbs. 3. 4000 tons, 4. 50 tons 5. 180 lbs.

___12. The man who said, "Give me a fulcrum on which to rest my bar and I will move the earth," was, 1. Aristotle, 2. Newton, 3. Archimedes, 4. Einstein, 5. Gallvani, 6. Samaon, 7. Atlas.

___13. Going at the speed of light the time necessary for a projectle to reach the sun would be (1) 8 min. (2) 6 hrs. (3) 1 year, (4) 6 months, (5) 9 months.

V

Select and check the correct statement.

1. About what is the speed of rotation of Mercury ___25-35 miles per per sec. ___ 18½ miles per sec. ___ 10 to 20 miles per sec. ___40 to 50 miles per sec.

2. The planet upon which the sun exerts the least gravitational pull, ___ Venus, ___ Mercury, ___ Pluto, ___ Uranus, ___ Jupiter, ___ Mars, ___ Neptune.

3. The name given to the date of September 21, ___ vernal equinox, ___ hunter's moon, ___ autumnal equinox, ___ harvest moon.

4. The early scientist that thought it was absurd to believe that the moon caused the tides, ___Aristotle, ___Copernicus, ___Archimedes. ___Galileo, ___ Newton.

5. Since rivers or trains moving north likewise have the property of inertia and resist a change of speed, the rail or bank which should wear the most is the, ___ east rail, ___ west rail, ___ north rail, ___south rail.

6. In a year light travels about, ___ million miles,___ three trillion, miles, ___ 6 million miles, ___ 6 trillion miles, ___ two billion miles.

7. The closest true star to the earth is the, ___ moon, ___ sun, ___ planet Mars, ___ Serius, ___ north star, ___ pole star.

8. In our journey about the sun, the speed of the earth per second is about, ___ 18½ miles, ___ 60 miles, ___ 25 miles, ___ 27 miles, ___ 150 miles.

9. The distance of a place from the center line around the earth, the equator, is called its ___ inclination, ___ longitude, ___ latitude, ___ rotation, ___ altitude.

10. The scientific name for the comparison of the weight of a substance with that of the same volume of water is called, ___ density, ___ chemical composition, ___ specific gravity, ___ volumetric analysis.