S.J.B.

A. M. D. G.

BULLETIN

of the

American Association of Jesuit Scientists

(Eastern Section)

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LOYOLA COLLEGE

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CONTENTS

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SCIENCE AND PHILOSOPHY

THE PHILOSOPHY OF MATHEMATICS

REV. EDWARD C. PHILLIPS, S. J.

Two articles have recently appeared which are of special interest to scientists and philosophers, and a brief exposition of their contents is here given for the benefit of the readers of the Bulletin, with the suggestion that the original articles themselves be read at leisure.

In "A Rational Basis for Mathematical Physics"*, Mr. Eiten deals with the *prima facie* incompatibility of the very terms describing the science of "Mathematical Physics": for Physics deals with material objects viewed from the point of view of sensible qualities and motions, whilst Mathematics deals with quantity alone divorced from all physical qualities and from any strict motion.

With St. Thomas as his guide the writer bases the reconciliation of these apparently mutually exclusive sciences on the doctrine of abstraction. He notes that the effort to justify the blending of Mathematics, which is such a highly abstract science, with Physics which deals with the actual physical properties of bodies, especially from the standpoint of energy and motion, "has led to solutions widely different in themselves. . . . they are solutions derived at least in some cases, it would seem, either from a faulty philosophy, or from a faulty application of philosophical principles, or from an erroneous knowledge of the various modes of abstraction which latter . . . seems to be the crux of the difficulty," (page 418). He therefore goes into considerable detail as to the proper understanding of the process and results of abstraction as applied to mathematics and physics. Following always the lead of St. Thomas, he shows that in general there are three degrees of abstraction to be considered: the first degree is found in the physical sciences, which prescind from the particular qualities of the individual material body and also from some of the qualities common to all bodies, and focus attention *chiefly upon the quality of motion in material bodies in general.* "Mathematics on the other hand (is) defined as the science which deals with the purely quantified aspect of material being. . . . . . it penetrates one degree further (than the physical sciences) in abstraction, for it does not consider material objects under the aspect of perceptible qualities and movements." (P. 423) Such a body, namely one stripped of its perceptible qualities and other external manifestations, evidently

* A Rational Basis for Mathematical Physics, by Robert Eiten, S.J., A.B., in THOUGHT, Vol. XIII, September, 1938, pp. 416-432.

cannot be cognised by any sense faculty but only by the intellect. Mathematics then deals with '*materia intelligibilis*' as opposed to '*materia sensibilis*'; its subject-matter is an *ens rationis*: but since the basis of mathematical abstraction is a reality, Mathematics retains its hold on the real. There is a still further degree of abstraction, by which we can take the subject-matter of Mathematics, i.e., *quantified* being, and prescind even from the *quantity*, thus leaving simply *being*, the '*ens*' of the philosophers: this is the highest form of abstraction, beyond which it is impossible to go, and forms the primary subject-matter of Metaphysics.

Now how does this doctrine of abstraction help us to reconcile the mixture of two sciences, Physics and Mathematics, which seem mutually exclusive? The answer of St. Thomas, outlined seven centuries earlier by Aristotle is that the more abstract a science is the greater is its applicability to other sciences. We may therefore say that as Mathematics is more abstract than Physics it can deal in a superior way with the principles and data of Physics; and again as Metaphysics is more abstract than Mathematics, it in its turn can deal with and judge the principles of Mathematics. We close this brief analysis of Mr. Eiten's article by reproducing, in part, his main quotation from St. Thomas*, which we hope may induce others to read further the text of the Angelic Doctor's masterly treatment of this very modern subject:

"In compounds the elements and their properties are not destroyed, although they function differently as is clear from the behaviour of the ordinary qualities and movements of the elements which are found in the compounds. However, those things which are proper to the compounds, are not found in the elements. So likewise the more abstract and fundamental the subject-matter of any science is, the greater on the other hand is the applicability of its principles to other sciences. Thus the principles of mathematics may be used in the physical sciences, but not conversely. Wherefore physics is built upon the foundations of mathematics, but not mathematics upon those of physics, as is explained in Aristotle's Third Book on the Heavens. As a result of this, in the physical and mathematical world, there are found three divisions of sciences. Some of them are purely physical considering as they do the ordinary properties of purely material objects, as the sciences of physics, agronomy, etc. Others however are of a purely mathematical character, limiting their subject-matter to abstract quantity, as we have in the case of geometry which deals with magnitudes, and of arithmetic which treats of numbers. Again there are others, such as spherical and celestial mechanics, which being *intermediate sciences* (mathematical physics), apply the principles of mathematics to the physical world. In the other article*

* St. Thomas, In Lib. Boethii De Trinitate, A. 5, Art. 3, ad 6. Cf. also ad 7.

* Petrus Hoenen, S.J.; De Philosophia scholastica cognitionis geometricae; in the Gregorianum, Vol. XIX (1938), pp. 498-514.

Fr. Hoenen, Professor of Cosmology in the Faculty of Philosophy of the Gregorian University, undertakes a summary exposition of an allied question, namely the nature of our primary concepts and judgments in the field of Geometry and the manner in which these may be rationally derived from the data supplied by our sense perception of material objects. As he notes in the introductory paragraphs, he initiates in this article a development of the doctrine set forth in Aristotle's *Analytica Posteriora*, and it would be profitable to our Logicians and Mathematicians to examine that pioneer work along with St. Thomas' Commentary on it, both of which may be found in the Angelic Doctor's *Opera Omnia.*

In the Analytica Posteriora, Aristotle treats of the *nature of science* in general, i.e. of any systematic body of truths known with certitude as propositions derived by means of strict demonstration from first principles and from primary concepts and judgements endowed with certitude and universality, i.e., with necessary truth. Aristotle throughout his work frequently uses geometry to illustrate his conclusions, using it as an example par excellence of a "science", since, as noted by St. Thomas, mathematics enjoy a quasi-priviledged position "propter certissimum (eorum) modum demonstrationis." The general principles and conclusions set forth by Aristotle are here applied by Fr. Hoenen to geometry itself taken not merely as an example but as one of the principle objects of his consideration. This examination of geometry in its turn leads to some results of importance in the philosophical field of epistemology. In any such study it is the duty of the scientist to determine which are the primary concepts and propositions forming the basis of the particular science under consideration, which here is geometry; it belongs then to the philosopher, i.e. the epistemologist,† to pass judgment on these in regard to their validity, certitude and sufficiency as the foundation on which a complete scientific (geometric) structure may be built.

The present-day importance of such an examination derives from the fact that a number (if not all) modern theories concerning the origin and nature of mathematical concepts tend to overturn the conviction of all past centuries as to the preeminent certitude, universality and exactitude of geometry.

Two main problems present themselves (of which however only the second is studied in the present paper of Fr. Hoenen):

> First problem.—The propositions of the mathematical sciences have always been looked upon as absolutely certain, i.e. expressions of *necessary truths*. But these propositions are derived by logical processes from certain primary concepts and judgments which in their turn depend upon our sense perceptions of the

† Cf. St. Thomas' stand on this point given above in the fifth paragraph ("Now how does . . . ") of the present article.

Where the reading of even the Latin translation may present difficulties to one who has been for a long time out of touch with such studies, help can be had from an English translation: In the Oxford edition of *The Works of Aristotle* translated into English under the editorship of Professor W. D. Ross, the Analytica will be found in Vol. I, Oxford, Clarendon Press, 1928.)

material world about us. Now all data of sense perception are in themselves, i.e. as know directly through the senses, only *contingent facts*. How then do the judgments or propositions derived from such contingent data possess absolute certitude or necessary truth?

Second problem.—The propositions of geometry besides being certain and universal are also *exact*. But the data of sense perception (through the activity of either the external senses or the imagination) are of their nature *inexact*. A few illustrations will make the meaning clearer: Geometry deals with points with absolutely no extension—we can see only extended objects of *small dimensions*, and we can imagine still smaller objects, but still they have some extension; and the same for lines, sensible or imaginable lines are relatively long and very thin bodies; geometric lines are neither broad nor thin, they simply have no second dimension. Again, geometry states that the three medians of a triangle meet in a single point, that all points of a circle are absolutely exactly equidistant from a single interior point, etc.: it is quite impossible to verify or to perceive these properties by means of the senses, even when helped by the most exact fulfilment of delicate instruments.

How then are we to explain the *exactitude of geometrical proportions* which are derived from data *devoid of exactness?*

Note. The problem of *exactness* does not arise in elementary arithmetic, because this deals with numbers and the senses supply exact data in this regard; we can see and distinguish with our senses two objects from three or four, etc.

This problem of geometric exactitude as derived from inexact data has been treated by many modern writers (chiefly scientists), and unfortunately some of these, even Einstein, endeavor to get rid of the problem—instead of solving it—by claiming that "pure mathematics" is a "pure invention of the human mind". They fail however to explain how it happens that such 'pure invention' agrees so well with objective material facts.

Those authors who admit the validity or objective truth of geometrical science, endeavor to solve the problem of exactitude by substituting for sense perception and intuition of the material world, some other basis for our geometrically exact concepts and judgments; and these attempts may be divided into two general classes:

One consists in basing geometry, not on sense perception of extended objects but upon the "arithmetical continuum" which in turn is itself based ultimately on our intuitively exact sense perception of natural numbers, i.e. the series of positive integers, 1, 2, 3, . . . etc.

The other takes its start from the critical examination of Euclid's Fifth Postulate, i.e. the Parallel Postulate.

The first method dispenses with our sense perception of extended objects and our intuitive deduction or abstraction therefrom of the geometrical continuum; but in doing so it calls in question the validity of such intuition or abstraction which had always been held as valid by both mathematicians and philosophers; moreover some of these authors not only call this validity into doubt but state that we now have clear cases in which this intuition leads us positively into error. If this be so there arises evidently a very serious epistemological difficulty: for the judgments or propositions of classical geometry were always looked upon as possessing strict metaphysical certitude. And to add to our difficulties there are some mathematicians even of the first order (as e.g. Weyl, Brouwer, O. Holder) who assert that even this new method of the arithmetical continuum as applied to geometry is invalid; and so whilst trying to avoid the Scylla of error we are in danger of being engulfed by the Charybdis of skepticism, unless we can uphold the fundamental validity of the classical geometry.

The second method, that of the critical treatment of the Parallel Postulate has led to the development of non-Euclidean Geometries; these, derived by substituting for the Parallel Postulate some contrary postulate, are in contradiction to many of the propositions of Euclid and to each other, but each one of them is self-consistent. This does not mean that objective certitude and necessary truth is denied to any one of these systems; each one of them is held to be true, but none of them is admitted to be exclusively true. Granting that there may be different systems of geometry—just as we may have under one genus different species each of which is exclusive of the others whilst all equally possess intrinsic possibility—the Epistemologist is still faced with the problem of explaining how in the supposition of different geometries, it was possible that for centuries the Euclidean geometry was universally considered as the only true and necessary one.

No complete or final solution of the various problems outlined above is here indicated by the author: his purpose in the present article was to clearly set forth the origin and general nature of the Problems with which one must deal in endeavor to construct the "Philosophia Cognitionis Geometricae". We hope that he will complete this construction in succeeding articles.

The author notes however that the critical attitude towards the classical geometry has not been barren, but has included much truly constructive criticism. It has led to the development of a new department of science, a part of Logic called "Axiomatics". It views each system of geometry as a self-consistent and necessary deduction from some chosen system of "axioms"; if we designate these by the letters A, B, C, ... N, and the geometrical body of propositions or conclusions by the letters P, Q, R, . . . etc., then the given system of geometry, say the Euclidean Geometry, will be of the nature of an enormously extended and complex conditional statement: "A,B,C, . . . N, are true, then P,Q,R, . . . etc., are true."

But evidently if such a geometry is to have more than mere conditional meaning, and value the chosen system of "axioms" must be such that each axiom is intrinsically possible and that all are so related that the entire complexus of possible conclusions logically implied in the fundamental system will be self-consistent. This latter condition—that there be no contradiction between any of the implied propositions—requires that methods be devised to show not only the absence of contradiction between any *actually* deduced propositions, but the absence of such contradiction between any propositions whatsoever, though still unknown to us, which it is logically possible to deduce from the axioms. Such methods have been developed and form a precious addition to the scienc of "deductive logic" and a valuable enlargement of Aristotle's exposition of the same in his *Analytica Posteriora.*

Surely this fruitful field of investigation should not be left, as it has been up to the present, almost exclusively to the mathematicians; it should be the object of interested consideration and of industrious cultivation by the scholastic philosopher as well.

INDETERMINISM AND FREE WILL

Rev. Joseph P. Kelly, S. J.

Science has found an argument for the free will of men. This statement and others similar to it have frequently appeared in scientific writings of a certain type. Their authors are not likely to be honored with the Nobel Prize. The reactions to these statements have been curious and interesting. Some people are quite startled by it, because in the last century science denied the possibility of free will. Now comes this "about face" and once more it is permitted to mention human freedom in scientific circles. Why this change of position? Some others have been overcome with indignation because the scientist has invaded the sacred precincts of philosophy. They ask by what right does science enter this field. They criticize the scientific opinions with the "trip-hammer of metaphysics", and point out with some justice, that the empirical conclusions of science are no guarantee for philosophical speculation. Perhaps this philosophical stand is fully justified. We will not try to justify nor condemn it, but simply discuss the problem from another point of view. Suppose we accept, for the moment, the validity of the principles of science, and admit the experimental method of science to be the proper one, then let us now examine the various logical steps that have led some scientists into the problem of free will. We begin with a fundamental principle of science.

THE PRINCIPLE OF PHYSICAL DETERMINISM

No one will deny that Physical Determinism has been one of the most fundamental principles of the natural sciences. In his investigations of Nature, the scientist has depended absolutely on it. It has been his guide; without it, organized science was impossible. Such was the position of the scientist in the evolution of Classical Physics.

Physical Determinism was called Physical Causation. The terms became inter-changeable in science. "Ten years ago practically every physicist of repute was or believed himself to be a determinist, at any rate so far as inorganic phenomena are concerned. He believed that he had come across a scheme of strict causality regulating the sequence of phenomena. It was considered to be the primary aim of science to fit as much of the universe as possible into such a scheme; so that, as a working principle, if not a philosophical conviction, the causal scheme was always held applicable in default of overwhelming evidence to the contrary. In fact, the methods, definitions and conceptions of physical science were so much bound up with the hypothesis of strict causality that the limits if any, of the scheme of causal laws were looked upon as the ultimate limits of physical science." 1. (Eddington, "New Pathways of Science." p. 72). All scientists would subscribe to this declaration. The term "determinism" denoted a characteristic of the universe, in which all the component parts were fixed and determined. Each element was definitely composed, had in itself a fixed activity and when placed in certain conditions would be followed inevitably by a definite phenomenon (or effect). Under this scheme, the scientific concept of the universe was that of an immense, machine-like organization. Left to itself, without outside interference, nature followed a "prescribed" course according to what were called "iron-clad laws". The "invariable sequence" of natural phenomena was the immediate consequence of the principle of Physical Determinism. Laplace has given us the classical enunciation of this concept. 2. [c.f. Jesuit Science Bulletin, Dec. 1935. p. 52]. Determinism enabled the scientist to accomplish a double purpose: first, to classify and correlate events of nature and thus formulate the rules of natural activity; secondly,—and more important for our question—it furnished a legitimate basis for foretelling a future state or phenomenon. Thus, the astronomer knowing the position, motion and direction of sun, moon and earth, can predict accurately the future eclipses of the sun and moon. Likewise, the chemist familiar with certain chemical elements, e.g., sodium and chlorine, could tell us in advance what compound would result from their composition and what qualities would be found in this compound. The fixity or determinateness of nature proclaimed that as things happened in the past, so they will in the future, other things being equal. This notion of scientific prediction soon gained a position of paramount importance. It became almost the "experimentum crucis" of a physical theory. Let any scientist propose an hypothesis and according to it, predict certain events, if these predictions agree with experimental results, the hypothesis will find a ready acceptance among the scientists. If, on the contrary, there is disagreement, between prediction and experimental data, the theory will receive scant attention. Predictability in science was fully warranted on the principle of Physical Determinism.

THE BREAKDOWN OF DETERMINISM

As long as the scientist was dealing with large-sized bodies, determinism and prediction were found applicable with a very high degree of approximation. It was sufficiently high to be called a practical certainty. With the discovery of minute entities, such as electrons, protons, etc., various theories were proposed to explain the composition of large bodies in terms of these elemental particles. Bohr in his atomic model pictured very beautifully the atom after the manner of a miniature solar system; a central nucleus, made up of protons and electrons, with a resultant positive charge, and the electrons, negatively charged, moving about the nucleus somewhat analogously to the motions of the planets about the sun. 3. [This Bohr model has been changed considerably in more recent times]. At first, the scientists naturally supposed that the activity of these minute particles could be explained according to the ordinary laws of Classical Physics. Hence, if one could know accurately a present position and velocity of an electron, its future status could be predicted with accuracy. But here precisely the scientist found himself face to face with a serious difficulty. These tiny beings apparently did not "obey the laws". Planck's Quantum Theory introduced a new element, a new concept of energy, and then Quantum Mechanics was developed. 4. [To attempt an explanation of the Quantum Theory would take us outside the purpose of our essay. The standard text-books will furnish any desired information on this topic]. Working according to this theory, Heisenberg showed that we can measure with a high degree of accuracy the position of the electron only by sacrificing accuracy in the measure of its velocity and vice versa. In other words we cannot measure accurately the simultaneous position and velocity of the electron. If one of these measures is certain, the other will necessarily be uncertain. This is commonly called the Heisenberg Uncertainty Principle. The consequences were startling to say the least. For it placed the scientific world in a very anomalous situation. Having labored most successfully for more than two centuries and having erected a magnificent structure of science on the Principle of Determinism, the scientists suddenly find that this very basic principle of science cannot be applied to the fundamental components of physical bodies. Determinism apparently reigns in the order of large sized-bodies but the contrary principle of Indeterminism seems to prevail among the sub-atomics, the electrons, etc. It was a crisis indeed nor has science yet found a satisfactory solution for the problem. In some quarters, among the Determinists, it is believed that science is passing through a transient phase in the evolution of science. On this basis, Planck and Einstein have faith in the ultimate triumph of deterministic causality. On the other hand, the Indeterminists see the doom of causality and determinism. Though Eddington stands among the latter, he warns us not to confuse the issue.

He does not believe that the point in question is the proof or disproof of determinism but whether the future progress of science is to be based on the Principle of Determinism or the Principle of Indeterminism. For, the Heisenberg enunciation has attacked the foundation stone of physical science. Whereas, in former times the universe was conceived in terms of a mechanistically determined system and scientific investigation and interpretation followed this general concept, now Heisenberg and the Indeterminists predicate an *intrinsic indeterminism* in nature Evidently the two notions cannot stand together. If Heisenberg has the truth on his side, the scientist is now deprived of his very useful and successful tool of predictability. For, "to calculate from any momentary position and velocity of all particles their future behavior exactly, is impossible because of the premise, namely, the exact knowledge of the momentary position and velocity, is fundamentally impossible." 5. [Thought, Vol. X. No. 4 March 1936. p. 583. Dr. Herzfeld here details what would happen if one were to attempt the ideal experiment for measuring the simultaneous position and velocity of an electron.]

If we analyze this state of affairs we will note that much of the concern of the scientists is due to the impossibility of accurate prediction. Now, according to their opinion this does not mean *merely* a lack of knowledge on our part. For, in this case, they might discover some remedy for this defect. The problem is rooted in the very nature of things, *viewed in the light of scientific principles.* The words are underscored advisedly. For if we look at the question in itself, we can easily distinguish between the objective manner in which a natural body acts according to its intrinsic nature, and our knowledge and interpretation of this process. The distinction is important for a clear understanding of our problem. "It is sometimes stated, in view of the above remarks (the Heisenberg Uncertainty Principle) that the behaviour of the atom is not causal; such a statement is at least very misleading. The law of causality (Physical Determinism) says in its application to physical processes, that we can specify the conditions of a material particle at some future time, if we know it at an earlier time. In the above instance, we never know the conditions at any one time so that we cannot express them at any other time. This only means that we cannot apply this principle (of causality) in these circumstances. Even if we were sure that we could never be able to express these states or conditions exactly, yet there is a great difference between whether the causality process can be proved or whether a process happens according to the law of casuality." 6. [Wulf, "Modern Physics" p. 463. Brackets ours.] The distinction between the causal process in itself and the scientific proof of it must be realized. The method of science is only one approach to reality. There are others equally valid. Because a causal process cannot be proved *scientifically* or experimentally does not invalidate other proofs of causality. It means that the scientist cannot apply the principle in this instance, that is in the *light of his scientific principles*. To put this in other terms, the denial of causality in science is a logical conclusion for the scientist and consistent with his own principles, prescinding for the moment from any philosophical considerations.

I will try to justify this assertion, "Physics is a science of measurement" 7. [Planck. "The Universe in the Light of Modern Physics" p. 7.] Further, Planck asserts that, "an event is causally conditioned if it can be predicted with accuracy." 8. ["Causality in Nature," c.f. "Science for a New World". Crowther. p. 347.] Now in the evolution of the physical sciences, predictability has become the *sole* criterion for Determinism or Physical Causality. The knowledge necessary for exact prediction is measurement knowledge and hence depends on the possibility of measuring the momentary state of a material particle. For the scientists "ex professo" have limited themselves to such knowledge of observable properties as can be derived through a process of measure. Thus, Heisenberg, Planck and Bridgman. It follows logically that wherever it is impossible to measure a physical body, prediction of any future state of that same body becomes impossible. When predictability fails through the impossibility of measure, the scientist has lost the *one* criterion, by which he can prove the deterministic or causal process in Nature. Hence, *in the light of his principles*, he is logically compelled to take his stand in the Principle of Indeterminism. We need not here quarrel with the scientists for limiting their field of investigation to the "observables and measureables", nor to point out that by doing so they have raised certain impassable barriers to progress. This definite limitation of scientific knowledge, depending as it does on measuring processes, is a problem to be solved by the scientist. Since he has accepted it *in principle* we can only examine the present situation in the light of these fundamentals.

The crux of the uncertainty problem seems to be the fact that there is no physical apparatus capable of measuring the simultaneous position and velocity of the electron, without at the same time upsetting the conditions we are trying to measure. Of course, we realize that in a great many other instances the process of measurement will in some way interfere with the things to be measured. For example, if we wish to measure the thermal state of a quantity of hot water, we place a thermometer in it, and after a short interval read the thermometer. But that does not tell us exactly the heat of the water. If the thermometer were colder than the water, a small amount of heat would be taken away from the water; and thus a "disturbance" would have been created by the measuring process. Our reading on the thermometer is that of a "modified" state of the water, not of the original state. True, in cases of this type we can easily make corrections and arrive at a proper solution of the problem.

But the solution is not so easy in the question of the electron. In our ideal experiment for determining (or measuring) the simultaneous position and velocity of the electron, in view of predicting a future state, a part of our measuring apparatus will consist of a photon of light. When it falls on the electron to illuminate it, so that we may see it, it causes the electron to recoil, to move away. This is according to the general principle that waves of any kind will exert a pressure on the object reflecting them. We might use the analogy of the billiard balls. When a moving ball collides with one at rest, the latter will be moved. We justify this analogy on the assertion of Dr. Compton that when light falls on an electron the process should be regarded as though there were a collision between two particles. Since the photon of light falling on the electron "pushes" it out of place, we can only say that we know where it *was* but not where it *is*. It has escaped our vision. This would seem to mean that any attempt to obtain measurement knowledge in this instance becomes impossible, because the very physical instruments of measure cause such a disturbance as to defeat our purpose. We cannot know the instantaneous position and velocity of the electron at any time because we cannot measure it, and therefore we cannot predict any future state. Thus we have no criterion for knowing a causal or deterministic process in the electron. Therefore, says the scientist, we have no longer Determinism but Indeterminism. Planck summarized the situation: "This much we can safely affirm; the elementary quantum of action sets an objective insuperable limit to the sensitiveness of the physical measuring apparatus at our disposal, which will prevent us forever from a completely causal understanding of the minutest physical processes in themselves." 9. (Planck. op. cit. ult. p. 362.) Hence the scientist has been lead into the Uncertainty Principle because he has no physical measuring apparatus to apply to the sub-atomic order, which will not at the same time create such an interference with the conditions to be measured, as to render the measure of these conditions impossible.

THE FREE WILL ASPECT OF THE PROBLEM

As has been indicated, there has been some speculation on the implications of the Heisenberg Principle regarding the doctrine of Free Will. It was quite natural. The Deterministic concept of the world embraced many human actions, as well as those of other material orders. Man is subject, e.g., to laws of gravity, motion, chemical change, etc. Nevertheless, it has always been recognized in science that certain human actions did not fit into the class of determined and predictable events. In spite of any scientific tendency to make the Principle of Physical Determinism all-inclusive, there have always been dissenting voices to this opinion, and that, on purely scientific grounds. How far this principle was to be extended to the order of conscious activity was a disputed point and left to the individual scientist to decide for himself. At the same time, it was rather disconcerting, in science, to have to recognize that there was one small field—the free will actions of man—which seemingly defied Determinism and forbade its universal acceptance. In every other camp of natural physical action the principle "worked" with very notable success. However, looking at the universe as a whole, there existed side by side Determinism and Indeterminism. It was scientifically intolerable.

The Uncertainty Principle offers an "escape from the horns". For since the free actions of man are unpredictable and in principle indetermined (antecedently) they can now be classified under the Heisenberg principle which proclaims everything undetermined, at least in principle.

The Heisenberg pronouncement opens up the way to a universal scheme of things which include living and non-living, free and non-free activities, *but only under that aspect in which they are considered indetermined and unpredictable*. Hence the admission of the possibility of free will *under this aspect* is no longer in open conflict with science. This classification may prove itself satisfactory to those who believe that no observable natural activity should escape the ambit of some scientific principle. But in the last analysis the fact that man has a free choice in certain of his actions, that these are anteriorly indetermined, does not depend on the validity or the invalidity of the Heisenberg Uncertainty Principle. In human liberty, the notion of "invariable sequence" in the scientific sense is an evident contradiction. The question of the free will is not a scientific problem. It is outside the scope of the physical sciences; it is not a phenomenon to be explained by a process of measure nor subject to scientific experimental methods. Centuries before the birth of what we call Modern Science, the freedom of the human will was adequately discussed and proved.

One final point in conclusion, and in this I am leaning on authority,—the authority of scientists. Among some of the more eminent men of science, there is the definite opinion that the Uncertainty Principle does not solve the free will problem, despite the amount of ink that has been spilled in the discussion of it. The following citations are pertinent:

"It has been suggested that the new outlook will remove the well known philosophical conflict between the doctrine of free will and determinism, and it has been welcomed by many for that reason. I would personally offer a most strenuous opposition to any such idea. The question is a philosophical one, outside the region of thought of physics and I cannot see that the physical theory provides any loophole." 10. [Darwin, "New Conceptions of Matter", p. 118.]

"The Indeterminist is sometimes said to postulate "something like" free will in the individual atoms. *Something like* is conveniently vague . . . But it is suggested that we postulate psychological characters in the individual atom of the kind which appear in our minds as human free will, I deny this altogether. We do not discard one rash generalization only to fall into another equally rash." [Eddington op. cit. p. 86. (Italics ours).]

Other opinions, C.f. Jeans, "New Background of Science", p. 283. Einstein in "Where is Science Going," by Planck. p. 210.

CHEMISTRY

GENERAL CHEMISTRY VISUALIZED

FRANK J. DAILEY, S.J.

After a discussion of the educative value and necessity of lecture demonstration experiments and taking into consideration the pros and cons of conducting a class in College General Inorganic Chemistry with the aid of lecture demonstration, the paper read at the recent Jesuit Science convention at Holy Cross College treated the question of selecting suitable experiments for lecture demonstration.

A description of some of the experiments which may be used for lecture demonstration will serve both as a good example of what we mean by suitable lecture demonstration experiments and may be of some value in the lecture hall.

While attending the Summer School at Fordham University, I had the pleasure of assisting Dr. Conway perform many such experiments before the class. And if we may take as a norm of their suitability and aptness the favorable reception these experiments met with on the part of the class, I think we need go no further in our search for lecture experiments. The experiments and methods of demonstration described in this paper are those used by Dr. Conway in conducting his classes at Fordham. To the Dr., therefore, I am indebted for permission to use them.

In following an average college text, say McPherson and Henderson's "A Course In General Chemistry", the student is introduced to a consideration of the metric system, energy, the varieties of matter, chemical reactions, the Atomic Theory and so forth. In the plethora of equations and symbols, the student is apt to suffer mental confusion unless he is given some clear concepts of what it is all about by the aid of lecture experiments. Conceded that this is difficult matter to demonstrate, yet some of the fundamental notions contained there can be demonstrated.

Dr. Conway illustrates, for example, the fundamental units of the metric system, say the cubic centimeter, by throwing a pair of small dice on the table. The liter is demonstrated by a large, square, wooden block. By comparing the relative sizes of the small pair of dice and the large block, the student gets some idea of the difference between a cubic centimeter and a liter.

The Atomic Theory and the divisibility of matter is illustrated before the class as follows: A gram of potassium permanganate is dissolved in water. This purplish, red solution is placed in a liter volumetric flask and filled to the mark. The class is given the opportunity of seeing the dark color of each drop. Ten milliliters of this liter are measured out and made up to a liter in a second flask and this is placed beside the first flask. The second flask is lighter in color than the first one, yet on the assumption that there are 25 drops to a ml, there are about 25,000 drops in the first liter. After dilution of 1 to 100, the solution contains about 2,500,000 drops, yet each drop still displays a deep rose color. Repeating the dilution a third time with 50 mls from the second flask, we bring the number of drops up to 50,000,000. Yet each drop still displays a faint rose color. This experiment gives the student some concept of the innumerable number of molecules in a milliliter. It shows one gram of material divided into 50,000,000 parts.

Oxygen is usually considered early in the course and some basic principles can be demonstrated, for example, spontaneous combustion. Dr. Conway places a mixture of ammonium chloride and ammonium nitrate with a layer of zinc dust sprinkled on top in a sand bath. The mere addition of a few drops of water causes spontaneous combustion to take place with the evolution of flames and considerable smoke.

He shows the speed of oxidation is influenced by the amount of surface exposed to the oxygen by means of a dust explosion.

Kindling point was demonstrated by starting a fire with a thermometer bulb. A small watch glass full of carbon bisulfide is placed on the demonstration table and a thermometer bulb is carefully heated in a bunsen flame to about 240° C. Then merely holding the hot bulb close to the carbon bisulfide does not cause it to ignite. Reheating to 250° C, however, does cause the carbon bisulfide to ignite, much to the surprise of the class.

The effect of the concentration of oxygen on the speed of oxidation can be illustrated by means of an oxy-acetylene blow torch. The flame of which melted the handle of an iron file placed in it.

When discussing ozone as an allotropic form of oxygen and to demonstrate allotropic forms in general, Dr. Conway placed two sealed glass tubes into a beaker of boiling water. One contained cuprous iodo mercurate, normally red, the other silver iodo mercurate normally yellow. Upon immersion in the boiling water, the former turned from red to black; the latter from yellow to orange within a few seconds. Cooling under tap water, almost instantly restored the original colors.

Hydrogen is the next topic treated by the author. Some of the lecture experiments taken in connection with this gas are as follows: For example the lightness and explosive nature of hydrogen are shown by Dr. Conway in this simple manner. The class is shown a large toy balloon in the shape of the Graf Zeppelin, which is filled with hydrogen. It is prevented from rising by being tied to the end of a meter stick. After showing the class that it can rise, the Dr. seems to accidentally bring the balloon near a bunsen flame. A tremendous explosion takes place, for the balloon contained one-third of oxygen.

Occlusion is illustrated by means of moth balls. In a solution of sodium chloride of just sufficient concentration to allow moth balls to sink to the bottom is placed in a large glass tube and hydrogen is slowly bubbled in at the bottom. The hydrogen sticks to the moth balls, causing them to rise to the surface. Upon tapping the moth balls with a glass stirring rod, the hydrogen is knocked off and the balls sink again, only to pick up more hydrogen and rise to the surface.

The student is next confronted with the gas laws. Here again, he may be assisted in gaining clearer concepts of these laws by suitable experiments. Atmospheric and vapor pressure was demonstrated by making five barometers right before the class, i.e. by filling five long glass tubes with mercury and inverting them in a dish of mercury. Keeping one as a norm, the demonstrator inserted a drop of water, alcohol, ether, and a small crystal of copper sulfate under each one respectively. In every case the mercury column fell and the fall was proportional to the amount of vapor pressure.

Air pressure was shown by the old parlor trick of pulling a hard boiled egg, minus the shell, into the neck of a milk bottle. A lighted match is placed in the milk bottle and the egg is inserted in the neck of the bottle. As the match burns it consumes the oxygen in the bottle, thus causing a difference of pressure, which the atmosphere overcomes by forcing the egg into the bottle.

Graham's law is exemplified by allowing a stream of hydrogen to diffuse into a porous cup, thereby creating pressure, which in turn forces an electrolyte to make an electric current light an electric bulb.

The relation of vapor pressure and boiling point was demonstrated by the familiar experiment of boiling and freezing the same water under low pressure.

The reason for bringing equilibrium into the definition of freezing point, was shown by super cooling a large bottle of glacial acetic acid.

When the subject of water was brought up, its peculiar density change was demonstrated by using Hoope's apparatus, which is a peculiar set up resembling an erlenmeyer flask and an old fashioned beer tumbler. The water is cooled at the top with a slush of carbon dioxide and alcohol. A thermometer at the top and bottom when read, after definite time intervals, show how circulation stops when the temperature reaches four degrees.

The electrolysis of water was carried out in a large Hoffmann apparatus so that even the more remote students could see what happened.

The action of sodium, potassium, and calcium on water and magnesium wire on steam was demonstrated before the class.

A spectacular experiment was then carried out in the following way. A heavy cast iron bomb was filled with water and then exploded by placing it in a freezing mixture of carbon dioxide dry ice and ether.

The nature of a catalytic agent was shown by placing a piece of pure zinc in pure dilute sulphuric acid. No reaction took place. Upon inserting a piece of platinum foil and allowing the zinc to come into contact with it, hydrogen was immediately liberated.

Carbon dioxide dry ice was made before the class by allowing the gas to escape from a large tank into a small chamois bag. And the density of carbon dioxide was demonstrated by carrying a pail of the gas and pouring it down an inclined trough of lighted candles. The candles were extinguished at once.

In connection with the chapter on the atmosphere and by way of review, Dr. Conway performs a series of experiments which we may term chemical magic. Their unusual character helps to fix them in the mind of the class, thereby bringing home to the students many of the fundamental principles that they have studied in previous chapters. We shall describe a few of these experiments.

When the class is seated and the lights have been extinguished, they are amazed to see the Dr. put a towel into a beaker and draw it forth glowing with a purplish light. Upon wringing the towel out, this strange liquid runs down the demonstrator's hands and onto the desk, still displaying this brilliant purple light, so strong that the lecture desk and the demonstrator's face are clearly discernible. The class is then reminded that this is an oxidation in which light energy instead of heat energy was given off. The towel was soaked in a solution of 3-aminopathalhydrazide, sodium hydroxide and hydrogen peroxide. Upon placing it in a dilute solution of potassium ferricyanide, the 3-aminopathalhydrazide was oxidized, emitting light energy.

The class is not a little surprised to see the doctor place a piece of burning cotton in his hands, hold it for several minutes and then place it in a hat without damage either to himself or the hat. They are told that the cotton had been soaked with a solution of carbon bisulfide and carbon tetrachloride. The dense fumes of the carbon bisulfide prevented the flames from doing any damage.

The great solubility of hydrogen chloride gas was shown with a hydrogen chloride fountain.

A low kindling point is shown by breaking a small tube of zinc ethyl. It takes fire on exposure to air.

The heat of solution was demonstrated by placing equal amounts of water and ammonium nitrate in a beaker and reading the temperature as it went down. The class was told that the ammonium nitrate required heat to go into solution, hence it took it from the water, causing the fall in temperature. The beaker being previously placed on a wet board is quickly frozen to it, proving the production of a low temperature.

A chemical hot water bottle was illustrated by means of a supersaturated solution of sodium acetate. The solid sodium acetate was melted before class and merely rubbing the stopper caused the sodium acetate to come out of solution, with the liberation of much heat.

A time reaction was carried out to show the law of molecular concentration. A clear solution of potassium iodate was added to a clear solution of sodium sulphite. After the lapse of 40 seconds, the solution suddenly turned blue. Repeating with half concentration, a double time was required. Thus showing how the speed of a reaction is proportional to the number of available molecules. Likewise a 75 second time reaction was performed by placing 50 cc's of sodium arsenite, 75 cc's of hydrogen chloride, 50 cc's of sodium thiosulfate in 400 cc's of water. At the end of the alloted time, the clear solution suddenly turned yellow.

A series of experiments are performed with liquid air in connection with the above mentioned.

Some cranberries are placed in a beaker of liquid air. Merely throwing them on the ground causes them to break into a million pieces. A carnation dipped into the same beaker was so brittle that merely touching it, caused it to break into innumerable pieces. The brittleness was due to the fact that the water in the petals was frozen solid. A rubber ball and piece of rubber tubing exhibited the same brittle nature when dipped into the liquid air. They broke like a piece of glass when dropped on the floor. The class received quite a laugh when a frankfurter behaved in the same manner.

A whistle attached to a glass tube connected to the large container of liquid air began to blow, when the stop cock was opened. A toy balloon was inflated, due to the expansion of the liquid air.

During the demonstration, two gold fish are kept in a beaker of water on the desk. Dipping one of the fish in the beaker of liquid air for a few seconds causes it to become solidly frozen. Upon inserting it back in the water again, it came back to life in a few minutes and started to swim again, as if nothing had happened to it. Keeping the other gold fish in the liquid air a few seconds longer rendered it so brittle, that a mere flick of the finger broke it in half.

A lead bell is shown to the class, which gave no sound when struck with a metal bar. However, after it had been placed in the liquid air for a few minutes, it sounded like an ordinary bell when struck with the metal bar.

A piece of heavy solder wire in the form of a coil, which displayed no elasticity, became very elastic when placed in the liquid air. An ordinary handkerchief was saturated with liquid air. Upon holding it in the air dense clouds formed around the handkerchief and in a few seconds it was perfectly dry.

A wet rag was twisted into the form of a rope and dipped into a beaker of liquid air. After a few minutes, it was frozen so solidly in the form of a hook that it was capable of supporting a ten pound weight.

A tea pot was made to boil by filling it with liquid air and placing it on a block of dry ice functioning as a stove. The white fumes escaping from the tea pot resembled real steam.

A mercury hammer was made by filling a small wooden match box with mercury and placing it in liquid air for several minutes. Upon removal from the liquid air and breaking the wooden box, a "real" hammer was produced capable of many functions of a metalic hammer.

An egg was fried by placing a small frying pan, filled with liquid air on a block of dry ice. Shortly after breaking a raw egg in the frying pan, the albumin froze into a solid white mass, having all the appearances of a real fried egg.

Ethyl alcohol was frozen into a solid mass, by placing a sealed test tube of it into a beaker of liquid air.

The climax of the experiments came with the production of snow. Dr. Conway poured several liters of liquid air into a pail of dry ice and water. Dense white clouds of fine particles issued from the pail and fell to the floor, averaging a depth of several feet and covering the entire floor space in the vicinity of the lecture desk.

In order to bring into repute the divine character of the bible in general and the new testament in particular, the Russian government has set her chemists to work. The miracles contained in the new testament have been the special object of their attack. For Our Divine Lord Himself called the people's attention to them as a proof of the divine character of His mission. In front of large crowds of working people, the Russian chemists claim to reproduce these miracles, hoping thereby, to cast into disrepute their divine character.

In concluding this paper, we shall consider a few of these so-called Russian miracles which Dr. Conway exposes before his class.

The first of these is the changing of water into wine at the Marriage Feast at Cana. Nine or ten clean 500 cc beakers are placed on the lecture table when the class enters the lecture room. About 300 cc's of tap water is placed into the first beaker and the water is poured from beaker to beaker until all have been covered. As the water enters each beaker, it changes from water to wine, wine to water, etc., at the will of the demonstrator. The Russians claim this is a reproduction of Our Lord's miracle at Cana. This fraudulent claim is repudiated by showing the class that the first beaker contained a few drops of phenolphthalein, the next beaker contained a drop of sodium hydroxide, which naturally turned the water a red wine color. The next beaker had two drops of hydrochloric acid of the same concentration as the sodium hydroxide, which restored the water color. The next beaker had three drops of sodium hydroxide which again turned the water to wine and so forth.

The Russian claim of reproducing the miracle of the Holy Sepulcher at Jerusalem is repudiated by bringing to class, just as the lecture is about to begin, a candle stick containing three candles. While the demonstrator is busy explaining some other point one candle suddenly lights, without anyone being near it. Then to the class' amazement a second, then a third. The class is let into the secret by being told that each candle wick is covered with a solution of white phosphorus and carbon bisulfide, which is applied just before the class is to begin. When the carbon bisulfide evaporates, the phosphorous takes fire, igniting the wick.

The miracle of the flaming characters on the wall, by which King Nebuchadrezzar was warned is next reproduced and exposed. A large piece of cardboard is concealed behind the lecture desk. When the class is seated, the lights are extinguished and when the class room is in darkness, the class is amazed to see the flaming characters, "Mene, Mene, Tekel, Upharsim" appear in the air. The trick is exposed to the class by showing them the cardboard, which the demonstrator held in his hands, while the class room was in darkness. The chemistry is the same as above. The characters were written with a solution of white phosphorous dissolved in carbon bisulfide. When the carbon bisulfide evaporated, the phosphorous was ignited.

The Russians in their attempt to better the miracle of the changing of water to wine, change water to milk. Two beakers containing clear solutions are placed beside a quart milk bottle. Upon placing the contents of one beaker in the milk bottle, followed by the second, a quart of milk is produced. The class is reminded that when solutions of barium chloride and sodium sulfate are placed together, a milky like solution of barium sulfate is produced, which settles out on standing.

The miracle of the Offering Fire at the dedication of Solomon's Temple is next demonstrated and exposed. The class sees a large bowl of excelsior over which the Dr. makes some mysterious signs and movements. Suddenly without touching the bowl or its contents, the excelsior takes fire and burns with a bright flame. The exposition is as follows: Under the excelsior is a paste of potassium permanganate and concentrated sulphuric acid. During the mysterious movements over the bowl, the Dr. surreptitously drops some alcohol on the side of the bowl from some cotton concealed in his hand. The alcohol sets the paste on fire, which in turn fires the excelsior.

The miracle of the divine picture. A large piece of white cloth is suspended from the top of the blackboard. By merely spraying the cloth with a flit gun, any desired picture can be reproduced in color. The cloth is prepared, by simply projecting any desired holy picture on the cloth and tracing its outline with soft pencil. The picture is then painted on the cloth in a suitable color scheme with solutions of cadmium sulfate, bismuth oxychlorate, manganous chloride, and lead aceate all of which are colorless. Upon spraying the cloth with ammonium polysulfide, the colors are reproduced by the formation of the corresponding sulfides.

Mysterious writings of any desired character can be reproduced by spraying a cloth, previously impregnated with lead acetate, with ammonium polysulfide from a flit gun.

Miracle of the vanishing cross. A large "silver" cross is immersed in a beaker of boiling water, over which a towel is placed. After making some mysterious movements over the beaker and towel to consume time, the towel is removed and the cross has vanished. The class is reminded that Wood's fusible metal, of which substance the cross is made, melts in boiling water, hence its disappearance.

Miracle of the healing of wounds. In concluding this series of experiments, Dr. Conway exposes one of the tricks that the Soviets' attempt to palm off on the people as a genuine explanation of the miraculous healing power of Our Lord. Affecting a serious mien, the Dr. bares his arm to the elbow and then proceeds to sterlize a large butcher knife in a "solution of iodine". After washing his arm with a "solution of alcohol", as an antiseptic, he draws the knife across his arm. The class is horrified to see an ugly, bloody streak appear and the blood run down his arm. A second later the wound is healed by merely wiping his arm with a clean towel. The pseudo-miracle is explained as follows: The so-called iodine solution was ferric chloride, and the alcohol was nothing but a solution of ammonium sulfo-cyanate. The so-called blood is ferric sulfo-cyanate caused by the reaction of ferric chloride on ammonium sulfo-cyanate.

A LABORATORY MACHINE-SHOP

Rev. Joseph J. Sullivan, S.J.

As one goes through the routine of the laboratory year after year, there are odd pieces of apparatus he comes across now and then which he finds he can make economically. Take for instance, "A Sodium Light Burner", such as is described by Fales and Morrell, J. A. C. S. *43*, p. 1629 (1921). This consists of a small, square transite chimney inside which is slung on a silica bearing a small, porous, alundum crucible. This porous crucible is to be filled with sodium chloride, which in the heat of the bunsen burner, melts, oozes through the pores of the crucible, and affords a source of brilliant, steady sodium light. This, we know is a very necessary part of our equipment for spectroscopic and polarimetric experiments. You can buy a "Sodium Light" which may be plugged into any electric light source.

But, it is costly. The above light we found we could make for almost the effort in making it. The difficult job is to cut the transite. This we did with our "Glass cutting wheel". This is a Norton product (Worcester, Mass.), and is catalogued by them as "3790 ROR 2G". It is 1/16 inch in cutting edge and 6 inches in diameter. The axial hole depends on the size shaft on which you are going to use it. 3/8 inch is standard for this size. Next we had to bore a hole for the silica bearing. Our set of "Stell bits" served this purpose as it has served many other purposes before. To bore the holes in the alundum crucible for the silica bearing,—a delicate step,—we must mix patience with the deft application of a rat-tail file.

The Glass-cutting Wheel has been extremely useful on many occasions. It is one certain way of getting straight edges on glass tubing, burette caps, test-tube lips and the like. It is also handy in tapering the dropping-end of a Hempel column. As we made quite a few of these latter at our glass-blowing table, the finish of the dropping-end was a requisite in turning out a column to specifications.

Norton also makes a glass-grinding wheel which is helpful in finishing off a chipped edge. It is similar to the above—same catalogue numbers—except that it is 1/8 inch thick, and will, of course stand side-pressure, which the cutting wheel will not. A necessary part of the glass-cutting and -grinding equipment is a metal housing, or a housing made of any substantial material for that matter. The glass-cutting wheels must be kept wet with plenty of water continuously while in operation, and unless they are properly housed in, the surroundings are deluged. Our "housing" was put together from a gallon oil can—rectangular in shape—and here we add a few more tools—namely, a soldering iron, solder and flux.

I don't imagine there is any need to speak of ordinary tools like hammers, a good saw, wood bits and brace, a variety of screw drivers, assorted pliers, and a collection of nails, screws, bolts and nuts of standard sizes. These one accumulates as time goes on. But, the important thing is to have them in their proper place—to be able to put your hand on them when you want them.

What I want to speak of particularly, though, is our new lathe. We wanted it first for turning glass of different sizes before the blast lamp so as to make a symmetrical and respectable flare. Thistle tubes are a cinch if flared in the lathe. And U tubes can be given a beautiful beaded finish if, while being turned in the lathe, they are heated in the blast-lamp and worked with a beading tool. At first then we were interested in a lathe because we were "glass-conscious". Now, we have become used to it, and we like it for many other reasons. Our lathe is an Atlas Precision Screw-cutting Lathe, with a 36 inch bed. It will turn anywhere from 28 to 2072 revolutions per minute, which gives plenty of flexibility in that direction. It is very inexpensive considering what it will do. And it will do many laboratory jobs which one would have to have done outside—at the expense of money and, what is sometimes more important, time.

At first, we wanted to taper some carbon rods which we use as flaring tools in glass-blowing. We had about a dozen of different sizes and were able to cut them into any desired taper. Then, we wanted to make a Kundt Tube—which is usually part of the Physics Laboratory equipment—but which we wanted for study of Specific Heats of gases in advanced Physical Chemistry. If you look over the diagram in any Supply House Catalogue, you can see there are several metal parts which would be difficult to buy—as such. But, you can turn them out on the lathe almost as fast as you could send to town for them—supposing they had them in town.

Recently, we wanted to make some pulleys. And we made them. Any size, and in a few minutes. Then, we wanted shafts to hold the pulleys. Metal shafts of the correct diameter and length. Our lathe turned them out for us exactly as required.

In most laboratories there is a scrap-box, the accumulation of flotsam and jetsam from many experiments that failed—or that left a residue of broken parts if they worked. Here you will find ground-glass stoppers and stop-cocks by the dozen. And often we are tempted to throw them out. And your lathe will turn them for you—axially—and at as slow a speed as you want. And, if you have the proper abrasive you can grind and finish new stopcocks from old ones.

As new problems come up, the machine-shop grows to meet them. Wood chisels for wood-turning, center rests and all the jargon of the wood-turner likewise become part of one's vocabulary. Then we progressively acquire a small plane, a level, a grinding unit for sharpening our tools, an adjustible vise, wood clamps—and we now learn some of the mysteries of glue. And speaking of glue, it is well to try out some of the new adhesives, like Du Pont Household Cement, Metallex (sometimes called Liquid Solder), etc.

It would be ideal, of course, to have all our tools in one place, in one room, which we could boast of as our "Machine Shop". But, we have no room we can label that way. Ours is a scattered machine-shop—scattered, but orderly. The big thing, after all, is to have the tools. But, it is equally important to know where to find them, and how to use them.

PHOTOGRAPHY

PHOTOGRAPHIC NOTES. PART III

REV. JOHN A. BROSNAN, S.J.

Part I, Bulletin Vol. XV, p. 171
Part II, Bulletin Vol. XVI, p. 72

In the preceding sections of these notes we have spoken of the making of negatives for slide production. These negatives may be large, simple or "compound" (a group of small ones) or slide-size negatives.

To work with the large negative set it in a frame parallel to the camera front (gelatine side towards the lens) and facing a uniform white surface, sky or artificial lighting. Proper setting of the camera will give the necessary reduction to slide size. Carefully center and square the reduced image on the ground glass. Place the slide plate in the holder and continue as in negative making. Different exposures may be given to separate parts of the same negative with the aid of appropriate masks. Unless one has a special kit for 3¼" by 4" plates some guide should be placed in the holder to insure centering of the slide. The time of exposure and the softness of the resulting positive may be controlled by the use of "stops" in the lens. Camera reduction of large negatives, especially scenic, gives beautifully soft slides with delicate detail.

Contact printing from small negatives is quicker, and for line work better than camera reduction. Let us now suppose that many slides are to be made from a number of negatives by *contact printing*. If the negatives have been properly spotted, blocked out and intensified (if necessary), they should be sorted in groups,—weak, medium and strong; all members of one group requiring practically the same exposure. Remembering of course to use the proper lantern plate with each group, "slow" for the weak, "normal" for the medium and "soft" (fast) for the strong.

If the subject is not well centered and accurately squared on the slide, the resultant positive will not be fit for projection. This adjustment of slide-plate to subject can be done more easily in daylight than in the gloom of the red lantern. Therefore, select the right-size, true-cut mat for each plate; place the mat on the gelatin side of the negative and square it up carefully with the subject. Then laying the negative, glass slide down, on a flat surface, without disturbing the setting of the mat, make, on the gelatin film, two scratches or ink-marks touching each of two adjacent edges of the mat. Remove the mat and placing on the negative, a 'cover-blass' so that its adjacent edges coincide with the coordinating marks, cut two scratches full length of the cover glass sides. Thus you have a simple way of "registering" the sensitive plate in the dark room; make its adjacent edges coincide with the scratched lines on the negative and there will be no worry about spacing or angles.

In the dark room we need a 4" by 5" tray, five or six ounces of developer (same as for negatives), a 4" by 5" shallow printing frame, snugly fitted with a flat flawless plate of glass, and most important of all, the proper exposure light. Most of the failures in slide-making (flatness and fog) may be traced to a strong uncontrollable exposure light. An old-fashioned small flat-wicked Kerosene lamp meets all the ordinary requirements. Its variations in light efficiency, being connected with the size of the flame, are more easily estimated and remembered than the changes in intensity of the glow of the Mazda lamp. Place the negative, face up, on the glass of the printing frame, lay on it the sensitive plate face down and square it with the adjusting lines: holding frame and plates on the table, set in the hinged back and clamp it down without moving the negative and overlying plate. During these maneuvers be very careful not to rub the sensitive side of the lantern plate, on the negative, as all friction marks are likely to develop in proportion to their harshness.

Light the lamp and make the exposure. The Hammer Yellow Label lantern plate is uniformly good and will give satisfactory results with almost any negative. With this plate and an oil lamp having a one-inch wide flat wick set to give a half inch flame, hold the printing frame about two feet from the light and expose (good negatives) for twenty seconds; for weak negatives, lower the light, double the distance and double the exposure. An oil lamp is more flexible than an electric bulb, and its low intensity reduces the chances of exposure error. The sodium hydroxide-hydroquinone developer recommended for negatives works very well with lantern plates, producing the necessary contrast with clear lights. While developing the exposed plate, keep the tray in shadow till the operation is nearly finished; then it may be moved into the full red light; the film is less sensitive when wet than when dry. A hand magnifier, 3 inches in diameter, will aid the eye to detect the approach of injurious fog. As soon as the developing is finished, place the plate in running water and leave it there until you have the next plate completely ready for exposure. This interval will allow time for the removal of the absorbed developer and will help to avoid "stains". Then transfer the washed plate to a clean "Hypo" solution (hardened), negative strength, and when it is thoroughly fixed change to the washing tray and leave it there of 15 or 20 minutes. With these precautions there will be no need of a "clearing" solution. Too long an immersion in a "hardened" fixing bath will interfere with good slide coloring. When the plates are washed, set them to dry on a rack in a dustless room. If the finished slides are weak or lacking in contrast, remove them; do not try intensification, the results will be poor and the life of the slide will be much shortened.

Selecting the proper grade of lantern plate to fit the negative and using the slow exposure light even the beginner will find it a little hard to make a poor slide. The appearance of the slide on the screen may be spoiled by its framing and consequently suitable mats should be employed. If the subject is approximately round in outline, do not use a circular mat; in general, the round-cornered parallel-sided openings are to be preferred. Avoid the freak shapes, stars, leaves, etc. Elliptical openings should be used only in exceptional cases. Above all, do not attempt to make mats; rough lines and incorrect angles are too prominent when magnified, and they catch the eye to the injury of the slide proper. If a mat of right size cannot be found, one of the stock sizes may be nicely fitted to the subject with a little ingenuity; but do not try to reduce the opening by pasting binding strips over it. The paper of which the mat is made, should be examined or tested carefully. One kind, a smooth (not glossy) thin dead black paper is extremely hygroscopic. If mats of this type are used, when the slide is bound up and put in the lantern for projection, the heat from even a 500 watt lamp will drive the retained water from the mat as vapor to condense, in the mat opening, on cover glass and film, forming a dark cloud of changing shape on the screen and disappearing only when the slide becomes too hot to hold liquid water. When the slide cools down, the water vapor finds a resting place in the mat until the next projection and so on "da capo". The only remedy is not to use this kind of mat—you cannot change its thirsty disposition. It is good practice in every case after the mat has been fastened to the slide, to heat the slide and cover glass before binding up. It may be useful for those who have no camera at hand to know a simple way of making, photographically, slides of diagrams, formulas or anything that may be set down in a comparatively small space with the aid of pen and ink.

Place a No. 1 mat (opening about three inches square) on a piece of clean white bond or eggshell paper, same size as full mat. Trace lightly in pencil the opening of the mat and in this space draw in good black ink (Higgin's) the diagram to be reproduced. When the ink is dry, rub out the pencil marks, place the drawing face up on the glass of the printing frame, and in the dark room, set on it a lantern plate, sensitive side down. Clamp the back and expose to the lamp light. On developing, the diagram will appear clean cut and clear on a black ground. This may be used as a slide with "chalk and blackboard" effect. Or when it has dried, expose it as a negative the same way, and the lines will come out perfectly black and defined on a clear background.

Now we come to slide-coloring. This may be slightly complicated, e.g., reproducing by hand the natural colors of botanical, animal or geological specimens. Or it may be very simple, a few lines to mark divisions on a map or to call attention to some title or explanatory word on the slide. One would naturally select a pen for this latter work, but without a very delicate touch and great care the slide may be ruined. It is better to use a fine brush, whose point is much less rigid than the pen point, and which will, with a little practice, give just as fine a line without the danger of cutting the film. A few words, then, about the brushes, colors and their application. Since few brushes are needed and since they will last a long time, buy the best. One will need at least two each of Winsor & Newton's Numbers 0, 1 and 2 sable brushes; the larger ones (for broad work) corresponding to Number 6 of the aristocratic type, may be camel hair, or more commonly squirrel's hair, or any even cheap brush that does not shed its locks. Do not take brushes with quill handles or oil-color brushes for ordinary slide coloring; the stiff bristles would cut the film. It will be more economical, though not neat, not to clean the brushes after use; leave them to dry with a load of color, and clean them only just before the next using. The moth larvae will eat off the tips of a clean brush, and with the tip gone, the brush is useless. The colors, water-soluble and transparent, are all coal-tar derivatives, sold as Egyptian, Japanese, Miracle, etc. The Eastman Company offers a good collection in book form, and these may be supplemented by a few "stains", e.g., Safranine, Congo Red, Bismarck Brown, Gentian Violet. Most red inks are different Eosine solutions, of good tint, but some of them will soften the gelatin and ruin the slide.

The slide best adapted to color should be soft, clear, with detail in the shadows, not harsh. Prepare the stand and magnifying glass already described in the notes on "Retouching and Blocking Out", and on its upper right hand corner fasten a piece of filter paper (to take off excess color from the brush). Have a tumbler of water on the right hand side (supposing the colorist to be 'dexterous'), and a china color-tray with 8 or 10 cavities and a cover. The makers of the color books advise the beginner to cut off a piece of the color sheet and put it in a little water, moving it about until the color is dissolved. The better way is to have some water in the cavities, wet the brush and remove some color from the sheet and stir it in the water, repeating the process till the desired strength is obtained. What is not used will dry up and the residue is merely wetted and used again with very little loss. Some of the colors must be handled with care. Do not use Methyl Green—it fades too quickly; Congo Red may be applied strong for lines, but not for surfaces—it smears. Some yellows and greens give blotchy effects if concentrated solutions be used, but the "meanest" colors to manipulate are the violets, Methyl and Gentian; always begin with a weak solution and go over the surface again and again, and continue with patience, remembering not to work a surface too long while it is wet; and try not to do any coloring on a hot damp day.

Areas should be colored fully to the edge and not over, or the work will be too sloppy to stand much screen enlargement. And when the slide is colored and bound up, keep in mind the fact that most of the coal tar colors, especially the more brilliant ones, (the azo-dyes), will hold their tones longer in the dark; so do not leave laboriously-colored slides lying about uncovered to be bleached by direct or diffused sunlight.

Color Record: If a "biological" slide is to be tinted, the colors to be chosen should be imitative, not decorative. Practically all specimens, moths, butterflies, larvae, leaves, flowers—lose much of their color after collection; and if the slide is not made soon and with the specimen, unchanged and near by, the results will often be "imaginary". Unless one has an exceptional color memory not merely for the basic color, but also for tints, a record of the colors and their location should be kept for reference. As soon as a negative is made and dried, write on the margin (gelatin side) in ink, the date, title, etc., for example, "Sour Gum Leaf, October 30, 1937; see Color Book, page 17.

In the Color book, an ordinary note-book (7" x 9") used for this purpose only, make a "topographical" sketch of the subject, same point of view as the negative, and add notes; for example, on Page 17:—

The name of the color, Safranine, Bismarck Brown, etc., may help to suggest the exact shade of red or brown. In some cases it may be necessary to place a small "dash" of the correct tint in the color book on the sketch. With the aid of these color notes, the slide may be finished at leisure, though the best results are to be gained when the object is resting near the coloring stand during the process.

In one of the preceding notes we suggested the use of dark backgrounds for some subjects. If, for example, we wish to photograph a white flower, we should use a gray ground which would show weil both flower and leaves. If the flowers have large petals (magnolia), the shades in the petals are grayish and are lost by want of contrast with the ground. The slide will be much improved by tinting not only flowers and leaves, but also the background. Select a color that harmonizes with the subject's tints but is not found in it.

Good background colors, those that cover easily, are safranine, some eosines, flesh color, yellow, orange and some greens. Using a small brush, work in the ground color as close as possible to the outline of the subject, and then with the large brush fill in the rest rapidly. In all cases use dilute solutions, and the required strength may be more easily and uniformly attained by successive applications than by one "dose" of a strong color, and besides, the ground should not be prominent in color.

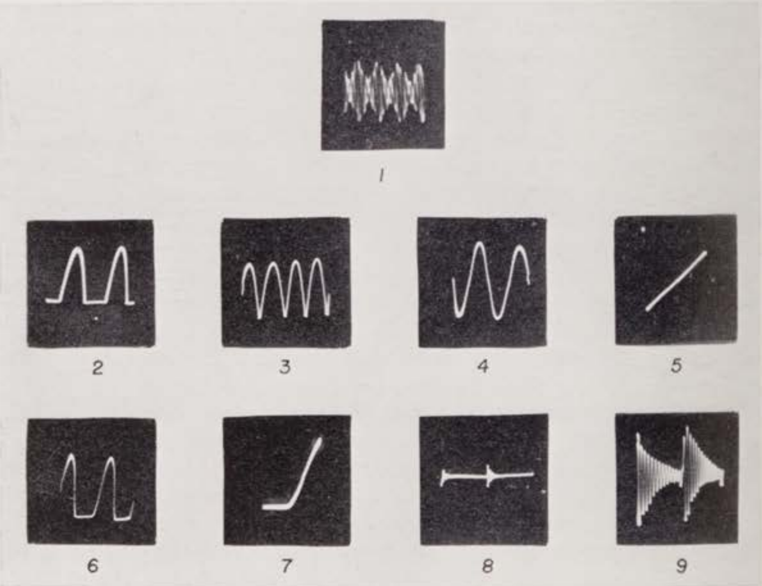
The next and last section of these notes will explain natural-color photography, old methods and new, some for the scientific laboratory only, some for "the man in the street" all rather expensive.

PHYSICS

DEMONSTRATIONS WITH THE CATHODE-RAY OSCILLOGRAPH

JOHN J. FITZGERALD, S.J.

We begin this effort by disclaiming any pretense of erudition or unusual information. The sole reason for describing these demonstrations, suitable for lecture work, is the hope that others reading this account may be stimulated to submit additional applications of the oscillograph with the result that these pages may eventually contain a varied and helpful series of visual teaching aids using that extremely flexible friend of the pedagogue—the Cathode-Ray Oscillograph.



1. Radio Carrier Waves and Modulation.

Most text books in their treatment of Radio show diagrams of undamped constant-carrier and amplitude modulated radio waves.

Fig. 1 shows a method of producing these patterns on the oscillograph. An alternating source of e.m.f. is substituted for the battery ordinarily used with carbon button microphones (a single or double button microphone may be used). The frequency of the alternating source should be high enough to permit a number of waves to appear when

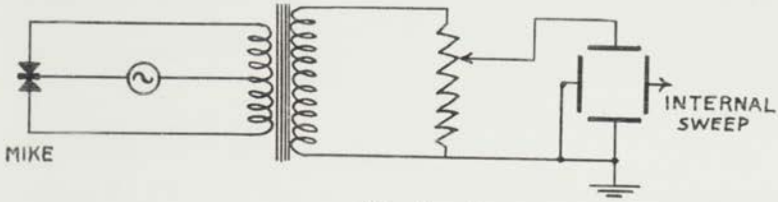


Fig. 1

the sweep is set to ¼ the modulating frequency. We have found that the output of an 1,000 cycle electric tuning fork (preferably filtered) is suitable. With the tuning fork providing an a.c. voltage on the vertical deflection plates and the sweep set at ¼ the modulating frequency, a pattern is obtained which may well serve to illustrate the undamped, unmodulated carrier wave. When the modulating sound impinges on the microphone the amplitude modulated pattern Plate I is produced. The modulating source will depend on the sensitivity of the microphone. With one microphone a heavy tuning fork mounted on a resonance box was sufficient; with another, an open organ pipe, blown directly at the microphone, was necessary. The organ pipe was used in obtaining Plate 1.

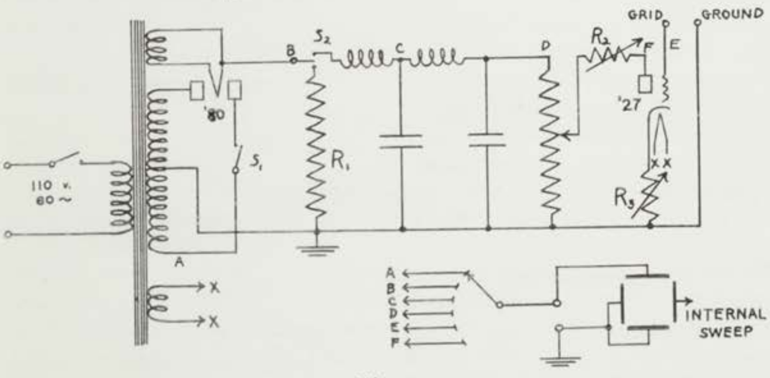


Fig. 2

2. Vacuum Tube Rectification—Filtering.

Fig. 2 shows the circuit used in this and the following demonstration. Choke and filter values are not given since the actual values used were dictated by our collection of 'parts'. A sufficient treatment of filter design can be found in The Radio Amateur's Handbook, s.v.

Power Supply—Filters. If the circuit is constructed with open wiring, it might be better to operate the rectifier at a lower plate voltage than is ordinarily used. The connections a — f are brought out singly by means of a non-shorting selector switch to one of a pair of binding posts (the other post is common—the 'chassis ground') and thence to the vertical deflection plates of the oscillograph. In obtaining the following patterns one terminal of the vertical deflection plates remains connected to the circuit ground which is common to all the potentials used.

a.c. input pattern—connection at 'a'

half-wave rectification—connection at 'b', S_2 closed through R_1, S_1 open. Plate 2.

full-wave rectification—as above, but with S_1 closed. Plate 3.

fiiltered pattern—connection at 'c' or 'd', S_2 closed through filter. Increasing the oscillograph amplification shows the presence and relative magnitude of the ripple voltages at 'c' and 'd'.

Note: If the oscillograph amplifiers are used the rectified patterns will be inverted when the positive filter lead is connected to the high oscillograph post. With the circuit shown no harm will be done by inverting the leads in this and the following demonstration IF the leads are changed back before the characteristic curves (cf. Demonstration 3) are produced.

3. Vacuum Tube Amplification, Plate Detection.

Connect a low voltage a.c. signal source between grid and ground in the circuit of Fig. 2. (We used a General Radio 'Variac') The grid may be connected to the high horizontal post of the oscillograph now, or when wanted. As in the previous demonstration, the circuit ground remains connected to one of the vertical deflection plates throughout the demonstration.

grid voltage—connection at 'e'

plate voltage—connection at 'f'

By varying the biasing resistor R_3, plate load resistor R_2 or the 'B' voltage potentiometer the triode can be operated as an amplifier or as a plate detector. If the grid has been connected to the horizontal deflection plate, switching the oscillograph from internal sweep to horizontal amplification or horizontal direct, as the case may be, produces characteristic curve corresponding to the particular operation of the tube. Plates 4 and 5 show the amplifier plate curve and corresponding characteristic curve; Plates 6 and 7 detector plate curve and its characteristic.

4. Vacuum Tube Oscillator—Tuned Grid Circuit.

For simplicity we represent this circuit as in Fig. 3. As a matter of fact the connections were made to the circuit of Fig. 2. An audio transformer was used since our purpose was served by low frequency oscillations. If the tube refuses to oscillate, reverse one pair of coil leads. Plate 9 shows regeneration of the waves of Plate 8. Further regeneration causes the tube to 'spill over' into oscillations. The above circuit is, however, self-starting i.e. grid excitation is not required for oscillation. Varying R_3, R_2 or plate voltage (cf. Fig. 2) varies the frequency of oscillation—with the transformer[1] we used from about 1,000 cycles per second to a few cycles. However,

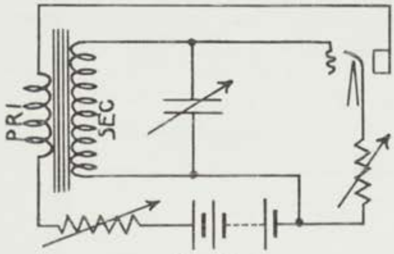


Fig. 3

for sine-wave form, it is necessary to change the frequency by varying C. Hence, the range is limited by that of C. Best results were obtained when we set C to minimum capacitance raised the frequency of sine-wave oscillations as much as possible by increasing bias (R_3 Fig. 2) and then tuned by varying C.

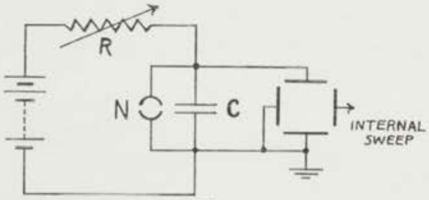


Fig. 4

5. Condenser Charging Curve.

Make connections as in Fig. 4[2] or use the voltage developed across R for the oscillograph potential. The small neon glow lamp N connected across the condenser will 'instantly' discharge the condenser when the potential reaches the necessary value. The frequency with which the charging process repeats itself depends on the resistance used, i.e. for a given battery voltage, resistance values higher than the optimum value decrease the frequency of repetition; lower values cause the lamp to conduct continuously or, at least, aperiodically. The following values, given for the fastest repetition obtained, are for a lamp that conducted at about 65 volts:

70 volts applied—260,000 ohms.
80 volts applied—400,000 ohms.
130 volts applied—2 megohms.

[1] Type 231 A Amplifying Transformer General Radio Co.
[2] W. C. Bosch, Am. Phys. Teacher, vol. 4, No. 2 (1936) p. 82, 83.

The demonstrator may find it helpful to use a variable resistance and/or variable voltage. Due, no doubt to some peculiarity of construction the polarity of our neon lamp was important.

Either the charging voltage or charging current may be illustrated. If the positive terminal of the condenser is connected to the high binding post of the oscillograph, the current curve is produced. Reversing leads shows the charging voltage. That, for purposes of illustration, such a reflection is valid, may be seen from an inspection of the equations for 'i' and 'e'. We found that the best wave form was obtained for direct leads when the resistance was in the positive line; for reversed leads when the resistance was in the negative line.

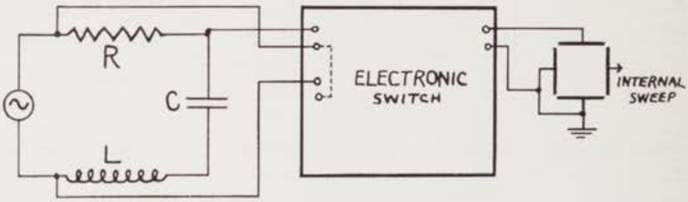


Fig. 5

6. Alternating Current Series Circuit—Resonance.

The advance or lag of current in an a.c. circuit containing inductance, capacitance and resistance in series with the source of e.m.f. is easily demonstrated by the Circuit of Fig. 5. If the L C value for 60 cycles is obtainable, an ordinary incandescent lamp can be used for R. The phase shifting is easily demonstrated if the inductance can be varied over a considerable range by the movement of an iron core. Without the Electronic Switch the phase shift can be demonstrated in terms of Lissajou's figures. Attention is called to the possibility of dangerously high voltages across L and C at resonance.

$$E_1 = 2\,\mathrm{pi}\,f\,L\,I; \qquad E_2 = \frac{I}{2\,\mathrm{pi}\,f\,C}$$

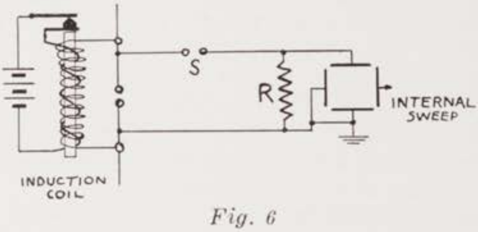


Fig. 6

7. Damped Oscillations.

The oscillatory nature of a spark discharge may be shown with the circuit of Fig. 6. L is the common battery-operated induction coil. S_1 is the spark gap of the induction coil and is not used, i.e. it is made much wider than S_2 so that the discharge must occur across S_2. The potential developed across R is applied to the vertical deflection plates of the oscillograph. We have found that about 3,000 ohms and a millimetre spark gap worked well.

The pictures for this article were taken with a Graflex camera using Eastman Kodak Panchromatic Super XX (their fastest film) 3¼ x 4¼ inches in size; stop f 4.5; time, ½ - 1 second. The film image is about 1 inch square (3 inch Oscillograph screen, green trace).

THE ABSOLUTE VALUE OF GRAVITY IN THE UNITED STATES

JAMES J. DEVLIN, S.J.

The gravity constant is of such frequent occurence in the various branches of physics that it has become one of the most important constants in this field of science. And yet in the current text books there is little mention made of a definite absolute value in the United States if such a thing exists and certainly there is no definite information on the methods of determining such a value and its reliability.

In the "Journal of Research" of the National Bureau of Standards for December 1936, there appeared a paper on the "The Value of Gravity at Washington", by Paul R. Heyl and Guy S. Cook, which furnishes just this information. The work of determining the absolute value of the gravity constant was undertaken by the Bureau of Standards at the request of the Coast and Geodetic Survey in order that their base station might have a reliable value for the gravity constant.

Up until the time of this work the value of g accepted for Washington was 980.112. This value was determined by G. R. Putnam in 1900 by relative comparisons with the Potsdam station. Another value of 980.117 was obtained later on from the Ottawa station which in turn rested on the absolute value of Potsdam. Then Dr. F. A. Vening Meinesz, of Holland, determined the value 980.121 for Washington with his gravity-at-sea apparatus. And finally in 1933 Lt. Brown of Coast and Geodetic Survey made a new direct connection with Potsdam which turned out to be 980.118. These various determinations left some doubt as to the correct value and furthermore at best the value at Washington was a relative one.

The determination of an absolute value for this as for most any constant of fundamental importance in physics is no easy task and this accounts for the wide use of relative values. The reversible pendulum method is still considered the best method in this work and was the one adopted by the Bureau of Standards. The great care taken to obtain reliable and precise measurements for the length of the pendulum are described at length in the above cited paper. The type of pendulum adopted was a fused silica tube which approximated a simple rod with two points on opposite ends of the rod about which the pendulum could swing with equal periods. The reason for the choice of silica was to render the uncertainty of the temperature correction as negligible as possible. The various sources of error in this type of measurement were all taken into consideration including the error arising from the flexibility of the pendulum. The fact that Helmert had taken this error into consideration in directing the determination at Potsdam in 1898 was chiefly responsible for the international acceptance of the Potsdam value as the absolute. The technical difficulties encountered in the experiment and the methods used to overcome them can be read in the article cited.

The value accepted by the Bureau of Standards is $g = 980.08$ cm. sec.$^{-2} \pm 0.003$ average departure. This value is the result of 70 single determinations of g and is the mean of the 7 best values. It differs by two parts in a thousand from the value given by Lt. Brown for Washington as a result of his direct connection with Potsdam. The precision claimed for this latter value is likewise $\pm$ 0,003. However this is a least square possible error and represents a greater departure from the mean value, than the value given in the report of Heyl and Cook.

A work of this nature is of considerable importance and naturally has far reaching results. For the research physicist and the geophysist it means that the value of g at the various gravity substations of the Geodetic Survey must be corrected in precise work. But the work on isostasy performed by geophysicists is little affected as they are more interested in gravity anomalies and consequently the relative differences in the value of g serves the purpose for them. Thus all the work of Vening Meinesz in the submarine determinations throughout the Caribean Sea area is as valuable as ever.

For the college professor in physics it is important to know that we have an absolute value of gravity in this country. And apropos of productive scholarship it would make a very interesting and instructive exercise for a college student of physics to study the research paper and report on the many possible sources of error in the pendulum determination of gravity, the effect of these errors on the ultimate determination of the constant and the methods in measuring these effects. The list of the sources of error itself will be startling to the student and impress upon him the need of caution and study in any experiment that demands precise results. Such a study might be encouraged in connection with the Kater Pendulum experiment which seems to offer so much difficulty in determining a reasonably accurate value of gravity.

SEISMOLOGY

AN ATTEMPT TO HARMONIZE THE SEISMOLOGICAL AND GEOLOGICAL ASPECTS OF DEEP FOCUS QUAKES

REV. J. JOSEPH LYNCH, S.J.

Two decades ago it was taken for granted that earthquakes occurred in the rigid crust of the earth and not far below the surface. Of late years, seismological evidence has indicated that some quakes have their origin as far down in the earth as 500 miles or more. It is hard to picture the geological mechanism of a quake at such a depth. From the large amplitude of the shear waves in these quakes we must conclude that considerable shear energy is released. It is very hard to imagine the resistance to distortion or twist that this shear energy implies, in a region where under any isostatic picture more or less plastic conditions must exist.

In view of this difficulty, Jeffreys and others are now prepared to attribute finite strength in the earth to a depth of 700 kms. or more. Before thus rejecting the orthodox Geological view of the earth's interior, the present paper suggests another possibility—namely that in the so-called deep focus quakes, the quake or fracture actually occurs comparatively near the surface, but that a real image of it is formed some hundred miles down, and it is from this focal point that the seismologist's waves start. The first question that arises on such a hypothesis is—does the seismologist then receive waves both from the quake and from its image or only from its image?

Clearly waves must be emitted from such a near surface fracture, but there are two reasons why perhaps they are not recorded. It is not at all uncommon for the first impulse of a compressional wave on a seismograph record to be preceded by some ten or twelve seconds, by an emergence. As its name implies, an emergence is a gradual beginning. If we can actually identify it 10 or 12 seconds before an impulse, it may well be that the very beginning of the emergence too faint to be identified, arrives many seconds earlier still. Hence the first possibility is that at the quake itself, the energy is spread over such a wide area that the waves emitted unless brought to a focus possess too little energy to make a perceptible record.

The other possibility is that the seismologist receives waves only from the real image of the hypocenter and not even feeble ones from the hypocenter itself. In this case we should have to postulate that the waves from the hypocenter were screened from the observing stations. The nature of this screening brings us to the question of how such a real image could be formed. The two possibilities would seem to be by reflection as in a concave or parabolic mirror or by refraction as by a converging lens.

The reflection possibility, is more easily pictured. If we adopt Airy's view of mountain roots it is easy to picture the roots as forming a vast parabolic basin which would act as a mirror with the reflecting surface the denser material in which the mountain may be considered as floating. If we take the Himalayas or the Hindu Kush mountains where the quakes which occur are consistently of the same depth of focus, about 200 kms., the mountain roots would have to form a parabolic mirror extending this depth into the isostatic level and in length and width extending roughly the length and width of the mountain range.

Zezawa in Japan has deduced that reflection and transmission of earthquake waves at a discontinuity are a function of wave-length—the longer waves being reflected, the shorter ones transmitted. For the waves from such quakes to be screened, we should therefore have to postulate a wavelength sufficiently long for total internal reflection at the inner surface of the parabolic mirror. Such a parabolic mirror, formed by sufficiently deep roots of a mountain range such as the Himalayas could conceivably account for a real image of a surface fracture such as we have pictured—but the mountain roots would have to be deeper than previously imagined and the notably short period of the compression waves of deep focus quakes might offer difficulty in total reflection on the basis of Zezawa's work.

The other alternative would seem to be that the real image is formed by a convex lens formed by the rock formation at the base of such a mountain range. It is not at all difficult to imagine the formation of such a rock lens. If we hold the density of the mountain structure to be less than that of neighboring sub-oceanic structures, we can conceive this lesser density to be the result of stretching or expansion of a formerly more compact material. If we consider a crustal prism or block in the earth's surface to be so expanded both upwards and downwards, as if pulled at the two ends, it is not hard to picture the expansion as taking place in such a way that the expansion or stretching would be greater, the further we get from the base of the prism and hence that the base of the prism, as a result of the double stretching both upwards and downwards should form a convex lens of slightly greater density than that of the upper and lower portions of the double prism. Granted the existence of such a convex lens of rock, it is easy to picture a fracture above it producing a real image some distance below it. The fracture would of course have to occur sufficiently above the lens to permit of a real image being found.

Since it would be difficult to imagine a fracture of wide area being brought to anything like a point focus such as the hypocenter of deep focus quakes seems to be, the failure of a station to record waves both from the fracture and its image would not have to be explained entirely by saying that the waves from the fracture are screened. For land quakes, such as those occurring in the Hindu Kush mountains, this would mean that the fracture would occur above sea level and hence only those rays brought to a focus below would be recorded—those traveling direct from the fracture would strike the side of the mountain and give rise to but very feeble surface waves. For sea quakes, i.e. quakes with their origin in sub-oceanic areas we should have to postulate a screening effect by internal reflection. This in turn would require such fractures to occur in the base of sub-oceanic elevations. On the whole this refraction image seems much less likely than the reflection one previously mentioned.

In conclusion, it must be emphasized that there is no evidence so far adduced to show that such image foci actually exist—but on the other hand there seems to be no evidence to show that they cannot exist. Their existence is suggested as a possible alternative to overthrowing the existing geological picture of an earth with a rigid outer structure extending only some 60 or 70 miles. One step toward testing the theory however, is being made. Records of deep focus quakes are being carefully scanned for evidence of phases earlier than the regular P phases. Naturally one would not expect perfect screening of waves from an extended fracture and if there are two such hypocenters, a real one and its image, one should expect at least occasionally to pick up waves from each. At the time of writing this work has only just started and hence we can offer no results—other than to suggest the hypothesis.

THE NORTH EASTERN SEISMOLOGICAL ASSOCIATION

Edward S. Powers, S.J.

During the past year united effort has been brought to bear on the study of short period seismic disturbances in New England. The immediate purpose being to facilitate the work of locating epicentral distances of local and near quakes and of distinguishing these quakes from the artificial disturbances caused by quarry blasts, railroad trains, etc. The number and distribution of Seismological Observatories in the district afford ample opportunity for any such work.

There are at present within New England six stations operating short period instruments of high sensitivity of the Benioff pendulum type seismometer. Fordham University in New York, Williams College, Williamstown, Mass., University of Vermont at Burlington and the Dominion Observatory, Ottawa, Canada, each operate a vertical component of this type seismometer. Three components of the same type are in operation at both Harvard University and Weston College. Instruments of longer period are in use at the Seven Falls and Halifax stations, under control of the Dominion Observatory; and the Massachusetts Institute of Technology's station at Machias as well as a private station at Portland, Maine, conducted with the cooperation of Harvard University, operate instruments of longer period and less sensitivity than the Benioff type.

A glance at this list of stations makes it apparent that the New England district included in this discussion is not exactly the

Fig. 1

same as that usually considered as the New England Maritime Province. However, the boundaries of the included area have been determined more by location of stations and the sensitivity of the instruments in use than by the geographical considerations and, for the present purpose, all of the area shown on the map in Fig. I may be considered as belonging to New England.

The records of those stations operating the Benioff instruments show a daily array of short period disturbances. Such disturbances may be due to any one of several causes and it often happens that an isolated station has great difficulty in distinguishing between local quakes, quarry blasts, the disturbances caused by railroad trains and body waves of teleseisms, especially if the latter happen to be of the deep focus type. In many cases, it is only by comparing the seismograms recorded at different stations that it becomes possible to recognize a particular type of disturbance.

It was to meet these difficulties that, at a meeting held last May, the directors of the various observatories decided to form an association of the New England stations. The aim of the association was to establish some central station where the data gathered from the entire district could be coordinated and the disturbances labelled according to their true nature. At present, this association, called the North Eastern Seismological Association—usually abbreviated to NESA—has its central station at Weston.

When a short period distrubance is recorded at any of the member stations, the distinguishable phases and the times of their arrival together with a possible interpretation are put down on a form post card and sent immediately to Weston. Here the various data are compiled, a comparison is made between the readings received from the different stations and, in many cases, the comparison affords easy recognition of the type disturbance. It is labelled, therefore, as "quarry blast", "local quake", or "teleseismic phase" as the case may be. This information is then published every two weeks in the NESA bulletin and mailed to all those interested.

The entire work of editing the bulletin is done here at Weston by Father Linehan and two Theologians, Messrs. J. Devlin and L. Langguth. The financial burden, however, does not rest on us but is taken care of from two separate sources; the United States Coast and Geodetic Survey furnishes the form post cards which, being considered as government mail, can be sent post free; the Dominion Observatory, Canada, Dept. of Mines and Resources supplies the paper and stencils. This latter organization also volunteered to take over the work of mimeographing the bulletin after it has been edited at Weston.

In locating epicentral distances, the travel times used are those compiled by Dr. L. D. Leet of the Harvard Observatory. These tables were described in the Bulletin of the Seismological Society for January, 1938. They were drawn up in 1937 especially for local quakes in New England; the data being determined from well timed quarry blasts set off throughout the district and their reception at the Harvard, Weston and Williamstown stations. In their published form, Dr. Leet carried the tables to a little less than 200 km., but, since then, extrapolation has shown them to fit greater distances out to 1500 km.

Since the inauguration of the Association, thirteen copies of the

NESA bulletin have been published listing 140 local quakes. During the interval from the second week of June, 1938, to the end of October, the bulletin shows recordings of ninety five local quakes. All were recorded at two or more stations. While many of them gave no possibility of accurate distance determination and some few others were recorded by only two stations and in such a manner as to allow too long an intersection of arc distances to make a definite determination practical, still the remaining number, twenty-three in all, have been determined with satisfactory accuracy. They are shown on the map in Fig. 2 represented by open circles. The closed triangles rep-

Fig. 2

resent epicenters determined by Harvard during the period extending from May 1935, to June 1938. The apparent small number of quakes before 1938 (there are only thirteen recorded on the map), may be accounted for by the fact that the Harvard epicenters were determined before the inception of the other stations in this area.

Ones first natural impulse in looking at a map of this kind is an attempt to correlate the seismic data with that of other phenomena in nature. However, seismologists feel that it is not yet time to make any such correlation here. The regional investigation has not been carried out so thoroughly or for a sufficient length of time to warrant any statement as to the relative seismicity of the various sections in New England or of the relation between quakes and the geological structure of the area.

A seismic map of the United States listing earthquakes from the earliest times to the close of 1937 was recently published by Capt. Heck in Bulletin No. 609 of the United States Coast and Geodetic Survey. A comparison between the number and location of New England quakes listed on that map and those recorded by NESA does not show exact similarities. For example, where a great number of the NESA epicenters are off shore, his are on land. This is not strange when we consider that most of the older quakes were determined by personal observations and therefore nearly all of those occurring off shore would be missed. Then too, non-instrumental observation of seismic activity is necessarily confined to those quakes which were of sufficient intensity to be felt generally by people within the disturbed region. Consequently Capt. Heck's map includes only quakes of intensity V and higher on the Rossi-Forel scale while those of NESA are mostly under V.

On comparing the NESA epicenters with those determined by Harvard it is found that repetition occurs in only two places, near New York City and near Morrisburg, Ontario. Some are altogether new as far as is known. Only two definite clusters appear on our map, one north of New York City and another to the south of this city. A lack of a sufficient number of gravity stations north of Massachusetts prevents correlation comparisons with this phenomenon.

Two of the quakes recorded during the past year merit special mention; the one near Lowell, Mass., and the one near Bangor, Maine.

A quake that occurred on June 23, just west of Lowell, Mass., in the township of West Chelmsford, has proven very interesting partly as it is the first that we have history of in this exact area and again, for the clarity of the instrumental recording. It was possible to obtain an arcual intersection less than a quarter of a mile diameter from the records of the Williams, Harvard and Weston stations. The aximuth-distance determinations from the Weston records and those of Harvard, used independently gave a point which ultimately was found to be in the area of highest intensity. Isoseismal lines were drawn from post card reports resulting in an elliptical figure about five miles long for the greatest intensity, about IV. The intersection of the Weston, Williams and Harvard arcs was on the southern end of this ellipse. Unfortunately, there is no station north of the area.

The quake near Bangor, Maine, on August 22, occurred at about 7:58 A. M., Eastern Daylight Time. Personal reports, therefore, were quite numerous. The area was canvassed by mail by the Coast and Geodetic Survey. Mr. R. L. Arringdale, Director of the Portland station, conducted a very extensive survey of the region about the city of Bangor. His greatest intensity circles concentrated near Orrington, and the distance arcs from Ottawa, Fordham, Williams, Harvard and Weston intersect about five miles west of the town center.

In summary, it can be said that the outcome of the past months' study in this area has been quite satisfactory. The data gathered from the exact interpretation of the records of local quakes and quarry blasts may prove very valuable in further work on the geological structure, especially the surface layers, of New England. The formation of the Association has proven to be of great help to the member stations individually.

The clarity and numerous registrations of local disturbances has justified the choice of Benioff instruments. The close coincidence of instrumental determinations and personal observations has proven the adequacy of the Travel Times used, even where they had to be extrapolated to greater distances. Need is felt, however, for one or more stations in Maine, and one in eastern Connecticut or Rhode Island.

THE EARTH

DANIEL LINEHAN, S.J.

While our knowledge of the earth's structure and composition is rapidly progressing, it has by no means reached the stage where we may classify it as finished business, or that any further research would be mere elaboration on the nicety of details. Theories on this subject have been many, and we may expect many more, and each model that comes forth gives us a better grasp on the interpretation of the phenomena that science uncovers.

Osmond Fisher pictured this earth as a mass of mobile lava covered with a very thin crust. Later Lord Kelvin and George Darwin discovered that such a model would not account for the high rigidity against tidal stresses and accordingly Kelvin thought of an earth with solidity even to the core, allowing for some interstitial spaces of liquid. Chamberlain followed with a similar structure though he differed with Kelvin in explaining the earth's birth. While the former demanded a liquid mass that had cooled to a solid, the latter liked to think of it as an accumulation of crystals and molecules. If liquid was present in the earth, according to Chamberlain, it was due to the compression of the piled up masses. Within the last two score years or so, geophysical experiments and measurements have brought forth many new facts to conjure with. The homogeneous structures mentioned above have given way to a layered earth. Seismological determinations have demanded this.

With a layered earth established we still find room for arguments concerning the composition and dimensions of each layer. Some demand a solid asthenosphere, or subcrustal layer, beneath the lithosphere, or crust. Some think this is necessary to account for the passage of seismic shear waves, while others suggest a liquid, or, at least, a plastic zone to account for the bending of the earth's crust under the load of glaciers. Many other apparently contrasting phenomena must also be explained away.

Dr. Reginald A. Daly, of Harvard University, has recently developed an earth model, that contains parts of older theories and some new ideas of his own. While Dr. Daly would be the last to call his explanation certain or final, he has brought together the findings of all branches of geophysics, and demonstrates quite well that many of the difficulties may yet be answered by laboratory experiments.

For a complete explanation of Dr. Daly's model, I would refer one to any of his books on this subject, and would recommend especially an article by him in the American Journal of Science, June, 1938. Briefly, Daly's earth consists of a thin crust floating on a vitreous substratum. Considering isostasy as an undeniable fact he explains the height and densities of continents and mountains as held up by roots from the crust and anti-roots from the substratum. The ocean beds are lower, due to their greater density. The surface of the asthenosphere comes to a height of about 80 km. below sea level beneath the ocean beds; it reaches a height of about 60 km. below sea level under the continents; while the anti-roots under mountains penetrate a bit higher. Geologically, Daly's crust would have granite in the upper part, gabbroic rocks below this with perhaps some crystallized basalt, and all floating on the vitreous basalt, or asthenosphere.

Difficulties against a vitreous asthenosphere come from a consideration of seismic shear waves. We realize that such waves do not pass through a medium in liquid state and if the medium should even be in a plastic stage the passage would be greatly hindered. Dr. J. M. Ide has found that the velocity of vibrations is little effected by the rise in temperature of a glass. Even to the point where "Pyrex" was so heated as to be ready to flow the waves maintained their velocity with little change. Such conditions could exist in the asthenosphere to give a region of little or no strength. This would allow for such distortions as accompany disturbances of long period, as tidal disturbances or glacial loads, and still permit the transmission of seismic waves that are found in the higher frequency spectrum. We must remember that rigidity and strength are not synonomous.

Daly has taken the data of seismologists to prove the existence of the centrosphere, or core. This has been quite evident from the disappearance of certain waves on records according to increasing distance from the earthquake focus. These waves have been eclipsed by some body within the earth only to reappear at greater distances after refraction from the body. Reflections from this core have also been identified. One interested in the picture produced by seismologists concerning the various reflecting and refracting layers at various depths can find a most excellent treatise on the subject in Fr. Macelwane's book listed below.

Daly's explanation of surface features of the earth, and the relative position of sub-surface materials require that this planet as a whole and in its various portions be in a state of equilibrium. Such a qualification is termed isostasy.

Isostasy has been both the goal and the goat of different schools in geophysics. We might call its first proponent Fr. Boscovitch, S.J., as he was the first to explain compensation in topographic features. Pierre Bouger had difficulty attempting to correlate the attractive forces of the Andes Mountains with the pull of the earth's center of gravity on his plumb line. Bouger expected that this great mass of rock above the earth's surface would exert a greater attraction than he actually measured. Fr. Boscovitch, using Bouger's figures, computed the amount of rock that must also exist below to compensate for the great topographic features above the surface. Isostasists have taken measurements the world over and although the number of stations are not entirely satisfactory, all agree that the crust, for the greater part, is in equilibrium and that no undue stresses are evident.

There are two areas that appear out of adjustment. A section in California and that part of India south of the Himalayas. Peninsular India, especially, shows gravity measurements that spell great excesses and deficiencies of rock within the crust, an amount that frightens the geodeist and geophysicist with the suggestion that the crust there might not be able to stand the strain of the great load placed upon it. Peninsular India seems to be out of isostatic adjustment, and several results might follow. It might be that the crust there is far stronger than in the rest of the world, though for no apparent reason! Isostasy might not exist for India, although it does for the rest of the world! We might expect that isostatic adjustment will take place in the near future, but if it does so, the effect will be cataclysmic! Or, we might find that our formula for the earth is incorrect, which would account for the large gravity anomalies and the extent they cover in this region.

The formula for the earth usually employed considers that the polar diameter is shorter than the equatorial diameter, but it considers the equatorial diameter as constant. Can it be that this latter diameter varies from place to place? Heiskanen amongst others firmly believes so, and in his 1938 formula for the earth (this has not yet been published) imagines that the longer diameter emerges about 25° West of Greenwich. Using this formula we find that the values for gravity will change in India, the extent of one-signed anomaly areas is decreased and the great stresses hitherto imagined are lessened to a reasonable degree. Likewise, California, at the other end of this short axis is brought into better adjustment. The large positive anomalies that Vening-Meinesz found in the Mid Atlantic are also done away with by the application of this new formula. Although such an earth figure accounts for many difficulties, will it stand the other tests, such as rotational inertia, precession of longitude, etc.? Daly's earth model fits in quite well with this formula of Heiskanen.

A great amount of research has yet to be done in geophysics, especially in the field of gravity, seismometry, volcanology and laboratory approximations of conditions in nature. The number of gravity stations must be increased to obtain sufficient data, but to date the methods have been slow and cumbersome. It is with great anxiety that geophysicists the world over await the outcome of Fr. Lejay's, S.J., work. Fr. Lejay's recent expedition to the Philippines was mentioned in the last issue of the Bulletin. His newly developed instruments and methods are expected to multiply stations many times. The field of seismology needs expansion with more stations and with instruments of greater sensitivity. A region such as the West Indies, for example, with its great negative gravity anomaly arc that runs from eastern Cuba around the Lesser Antilles, must be examined by high sensitivity seismic instruments. We have no data at present of a satisfactory nature concerning the possibility of mechanical motion along the arc, and this is due to lack of stations in the region.

These demonstrate but a few of the opportunities for research in a tremendously wide but extremely interesting field. The student needs, of course, a good training in geology as well as his physics and mathematics. It has been found out that specialists in each of these fields will ultimately have to enter the conflict for final determinations.

Suggestions for reading on the subject of the Earth's structure and composition.

Daly, R. A. "Architecture of the Earth", 1938, D. Appleton-Century, Co.

" "Igneous Rocks and the Depths of the Earth", McGraw-Hill Book Co., 1933.

" "Our Mobile Earth", Charles Scribner's Sons, 1926.

" "The Strength of the Earth's Outer Shells", American Journal of Science, Vol. XXXV, June 1938, pp. 401-425.

Fisher, Rev. Osmond, "Physics of the Earth's Crust", Macmillan & Co., 1881.

Jeffreys, Harold, "The Earth", Macmillan Co., 1929.

Macelwane, J. B. (S.J.), "Theoretical Seismology", John Wiley & Sons, 1936. (Especially Chapter VIII).

HISTORY

RICCI'S SCIENTIFIC CONTRIBUTION TO CHINA

A Study of the scientific attainments of the Jesuit astronomer at the Court of Peking

In the later Middle Ages it was through Islam that the Greek tradition in the exact sciences passed to Western Europe and to the Far East. While Europe had to content itself with such authors as Pliny or Boetius or Cassiodrous, the Arabs were in direct touch with the pure tradition of the Greeks. Euclid and Ptolemy and, above all, Aristotle were theirs; and if they had not the intellectual exuberance of their masters, still they preserved intact their intellectual inheritance, they cultivated it, and even in some important points developed and perfected it. They were lucid teachers, clear exponents, and in admirable text-books they made it easy for the intelligent student to acquire the knowledge they had to impart.

From the 10th. to the 12th. century a brilliant civilization had developed in Western Islam, and with this civilization Europe came in contact in Spain and in Sicily and along the French and Italian Rivieras. In Toledo and Salerno and Barcelona and Segovia and Palermo the Western European went to school with the Arabs and the Jews. Through the labours of scholars such as the Italians, Plato of Tivoli, Gerard of Cremona, Burgundio and Leonard of Pisa; Sicilian Greeks such as Henry Aristippus and Eugenius the Emir; Spaniards like Gundissalinus, Hugh of Santalla, and Mark of Toledo; Englishmen, such as Adelard of Bath, Robert of Chester, Daniel of Morley and Alfred of Sereshel; a Scot, the famous Michael; a Slav, Hermann of Carinthia; and a Fleming, Rudolf of Bruges, Greek science, enriched by the Arabs, became the common property of the West. Gerard of Cremona, who worked at Toledo till his death in 1187, with the aid of the Arabic-speaking Christian, Galippus, translated no less than seventy-four different works of Greeks and Arabs, and on his death the main tradition of Greek and Arab learing, both philosophical and scientific, had become accessible to the West: Archimedes, Euclid, Ptolemy, the Arabic mathematicians and astronomers, Galen, Avicenna, Al Farabi, Ibn Gebirol,—but above all Aristotle, who was to dominate the science of the West as he had already dominated the scientific tradition of the Greeks and the Arabs.

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* Bernard, Henri, S.J.: Matteo Ricci's Scientific Contribution to China. Translated by E. C. Werner. Henri Vetch, Peiping. 1935 pp. 108 $6.

MOSLEM LEARNING IN CHINA

But while the West was entering into the knowledge of Greek science through the Arabs, the Far East was not unaffected by the Moslem civilization which stretched from Spain to Afghanistan. Yeh-lu Ch'uts'ai, who had established a school at Peking, accompanied Genghis Khan to Persia, and in 1210 borrowed from the Uighurs their calendar in order to adapt it to the Mongol Empire. The Mongol dynasty of the Yüan in China favoured and promoted not merely an interchange of merchandise but of ideas, and the thirteenth century stands out as one of striking scientific development. Prior to that time China had been as backward, or even more backward, than the West in the exact sciences. In Arithmetic, for instance, the most ambitious among the learned confined themselves to explaining the Chiu-chang suan-shu, a method of calculation which had disappeared with the Burning of the Books in 213 B.C., and had been laboriously reconstructed by the scholars of the following centuries. But under Moslem influence there was a striking advance in mathematics and astronomy. The new advance reached its culmination in Kuo Shou-ching (1231-1316), who seems to have been an engineer and mathematician of genius. He constructed scientific instruments which Fr. Ricci, almost three hundred years later, saw at Nanking and at Peking and which filled him with surprise and admiration, for "he had seen nothing better in Europe." Even at the present day there may be seen in the lower court of the Central Observatory at Peking instruments dating from the Mongol dynasty, which, when compared with the splendid instruments near by constructed by Fr. Verbiest, are eloquent witnesses of the relative perfection which Chinese astronomy attained for one short period under Moslem influence.

RETURN TO OLD LEARNING

The new learning however experienced very different fortunes in the East and in the West. In the West it was assimiliated, becoming part of the general body of knowledge. It was as a seed sown in congenial soil, destined to become a great tree whose growth and vast ramifications are not yet determined. But it was quite otherwise in the Far East. In China it was an importation, and it remained an importation, and when the Mongols were driven out in 1368 by the native dynasty of the Mings, science fell with them. Ephemerides calculated according to the ancient Chinese rules were immediately substituted for the Yüan calendar. When the Emperor, in 1374, ordered some hundreds of Persian manuscripts found in the Palace Library to be translated into Chinese, the translators found that they could not understand the technical expressions and the scientific demonstrations, and so they contented themselves with transcribing the tables of practical astronomy, all the rest, including books on the theory of the planets and on mathematics, disappearing in the course of the years. Chinese arithmetic was reduced to the use of the abacus, their geometry to practical measurements. In the educational programme drawn up by the founder of the Mings mathematics had their place, but they consisted in solving problems from the Chiu-chang suan-shu. Ignoring the contribution of the Moslems, China reverted to the rudimentary arithmetic of the 3rd. century B.C.

It may cause surprise that in an Empire where learning was in such high esteem no one was found to devote himself to the study and the advancement of the sciences. But it must be borne in mind that while position and honour and wealth were open to the learned, learning must be understood in the traditional Chinese sense. The learned were those who had studied the canonical books, history, the laws, and morality, and who knew how to write with ease in the polite style. The abstract sciences profited nothing, and with such a handicap it is little wonder that they did not progress.

THE SCIENCE THAT RICCI KNEW

It was to such a China that Fr. Ricci came bringing with him his share of the scientific knowledge of the West. It was the science of the second half of the sixteenth century, a science which had advanced little beyond the science of the Greeks. The methods of Arithmetic had been simplified, Euclid was generally known, the elementary properties of Conic Sections and the simplest propositions of Trigonometry were understood, Algebra was still seeking for a suitable notation. In Statics a chapter had been written on parallel forces based on the principle enunciated by Archimedes: When two equal masses are suspended from a rigid beam at equal distances from the point of support they are in equilibrium. But the problem of the resultant of forces acting on a point had been solved only in the particular case of two rectangular forces. Dynamics as a science did not exist, and the false notion that the velocity of falling bodies was proportional to their masses still prevailed. In Astronomy the system of Ptolemy still held almost undisputed sway, though as observations multiplied the explanation of the motion of the planets by epicycles and eccentrics was becoming increasingly difficult. In Optics the laws of reflection were known, and the most elementary problems concerning rays reflected by spherical surfaces could be solved. In Hydrostatics the principle of Archimedes concerning floating bodies summed up the common knowledge.

Such was the science that Ricci knew. Born in 1552 at Macerata, he studied the humanities there in the Jesuit college for seven years. In 1568 he went to Rome where he studied law for three years till he entered the Society of Jesus on the 15th. August, 1571. From September 1572 to May 1578 he attended the courses of Philosophy and Theology in the Roman College, and there he came under the influence of Clavius. Clavius was an excellent teacher and his text-books became famous. He probably did more than any other German scholar of the sixteenth century to extend the knowledge of mathematics, even if he did little to extend its boundaries. In the Society of Jesus, and so also in the Roman College, mathematics and the sciences were studied in conjunction with Philosophy. The course which Ricci followed seems to have been: In the second year of Philosophy the first four books of Euclid during four months approximately, Practical Arithmetic one month and a half, Sphere two months and a half, Geography two months, and during the remainder of the year, Books V and VI of Euclid. In the third year of Philosophy: Astrolabe two months, Theory of the Planets four months, Perspective three months, during the remainder of the time, clocks and the ecclesiastical calendar. Ricci had a clear and active and a remarkable retentive memory and being interested in the sciences he brought away from the Roman College a good knowledge of the course, and probably something more. He was besides a good clock-maker, a competent architect, a correct draughtsman, and an expert mechanician.

RICCI IN CHINA

In 1582 Ricci arrived in China, landing at Macao on the 7th. August. The following year he established himself at Shiuhing where he remained for six years. In 1589 he left Shiuhing and went to Shiuchow. After five and a half years in Shiuchow, he spent three years in Nanchang. In the beginning of 1599 he established himself in Nanking, but within eighteen months he was on his way to Peking which he entered on the 24th January, 1601, and here he remained until his death in 1610.

Ricci was, in all, twenty-seven years in China, and during that time he gradually introduced to the Empire the science which had first come to it, as it had come to Europe, from out the great Moslem civilization of the later Middle Ages, and which was now to return to them from out the West. Ricci restored to China what it had lost of science when the Mongol dynasty was driven out.

During his six years stay in Shiuhing Ricci discovered no one capable of understanding the science he was so ready to impart. He taught his Christians the method of calculating their calendar, but it was merely by rule of thumb without any understanding of the principles on which the calculation was based. In Shiuchow, however, he met one who was richly to repay him for the time and trouble he took to instruct him. This was Ch'ü T'ai-su, a thoughtful and cultivated scholar. He came to Ricci hoping to get some tips on Alchemy and he remained with him for a year. He was a keen student, protracting his studies into the night. In place of calculation with the abacus Ricci taught him to count with pen and paper using Arabic numbers. He initiated him into the theory of fractions, into problems on the Rule of Three, progressions, extraction of square roots—almost all of which was to be found in the ancient Chinese treatises but which had been forgotten by the scholars of the sixteenth century. Besides Arithmetic, Ricci explained to him the Sphere of Fr. Clavius and the first book of Euclid. He taught him how to construct instruments and to measure heights and distances. What Ricci taught him in the common language Ch'ü T'ai-su translated into elegant Chinese, thus creating a scientific terminology which, in the course of time, supplanted almost completely the terms used by the ancient scholars. He also constructed many instruments, sextants, spheres, astrolabes, compasses, in wood or copper, many even in silver. In future, wherever Ricci was to go he was to find the way already prepared for him by Ch'ü T'ai-su, who constituted himself the herald of Ricci to the learned circles of China.

RICCI'S PUPILS

In Nanchang three pupils come to Ricci, two of them disciples of a famous scholar named Li Hsin-chai, the third sent to him by his master, who lived some three or four days journey from Nanking and occupied himself in trying to introduce a little method into Chinese mathematics. This third pupil had managed by himself to understand the first book of Euclid in Ch'ü T'ai-su's translation and was very anxious to learn more, but unfortunately Ricci had not the time to teach him. On his returning to his master, the old man published some very important books in which he reproduced many of the mathematical and moral teachings of Ricci. During this time, with the help of his pupils, Ricci constructed dials of various forms, spheres, terrestial globes, geometrical quadrants.

When after seventeen years of patient endeavour Ricci at length succeeded in establishing himself in Peking, his name was already famous and his reputation established. Besides Ch'ü T'ai-su two other distinguished scholars were to work for its increase, Li Wo-ts'un, later known as Doctor Leo, and the very remarkable Paul Hsü Kuang-ch'i. Li Wo-ts'un was drawn to Ricci through his interest in map-making. He constantly urged Ricci to republish his map of the world in an enlarged edition. The final edition appeared in 1601 and astronomy occupied a large part of it. These astronomical notes were for the most part extracts from Fr. Clavius' commentary on the Sphere of John Hollywood, but Ricci had reduced many of the distances to Chinese measure; thus the radius of the Earth is given as 14,318.9 li. Li Wo-ts'un had all the people in his palace occupied in constructing instruments, such as the sun-dials described by Clavius in his treatise, and a very fine astrolabe. Whenever business called him to the Capital he became a student of Ricci's, and when back in Hangchow he kept a constant correspondence with his master. He published quite a collection of scientific works, both mathematical and astronomical.

Paul Hsü Kuang-ch'i, the most remarkable of Ricci's converts, translated under Ricci's guidance the first six books of Euclid. This translation was published towards the end of 1607 and excited great curiosity in the intellectual circles of Peking; but "it was admired rather than understood." It served henceforth as a foundation for the teaching of Ricci and Paul Hsü who both recruited some pupils, thus little by little building up in the very heart of China a centre of scientific culture. Here, probably for the first time, Ricci explained the complicated system of epicycles and eccentrics by which the West still sought to explain the phenomena of the heavens.

It was in this work of teaching, and publishing scientific works, and revising works already published that death suddenly came to Ricci on May 11th. 1610. Before his death Ricci had already initiated four or five ardent disciples in the sciences of the West, he had, through translations, made the most important notions and results of these sciences accessible to the learned Chinese world, he had aroused in learned circles a desire to reform Chinese Astronomy, and he had made the name of Clavius familiar in the Far East. But his scientific contribution did not cease with his death. He was the inspiration urging Paul Hsü and Li Wo-Ts'un to push on to the completion of the work, the encouragement supporting his distinguished successor in the perilous mission of Peking. Is it too much to say that Fr. Ricci did for China in the beginning of the 17th. century what Yeh-lu Ch'u-ts'ai had done in the 13th., or what the great translators of Greek and Arabic works did for Western Europe in the later Middle Ages?

T. BYRNE, S.J.

NEWS ITEMS

GEORGETOWN UNIVERSITY. Physics Department

Meeting of the American Association of Physics Teachers

The District of Columbia and environs Chapter of the AAPT held its first all-day session at Georgetown University on April 1st. Arrangements for the meeting were made by Father Sohon, Father Love and Dr. F. I. Brady, Executive Officer of the Physics Department. A very attractive program was arranged which included papers by members and guests, a trip through the Laboratories and Museum, and an open-house at the Seismological Observatory. Lunch and dinner were served in the Maguire Dining Hall. In the opinion of all the meeting was a complete success and many of the lab and museum pieces designed by Father Kolkmeyer and built by Mr. Spriegel were greatly admired.

The following institutions were represented:

American University, D. C.
Baltimore City College
Catholic University
Georgetown University
George Washington University
Goucher College
Hood College
Juniata College
St. John's College, Annapolis
Trinity College
United States Naval Academy
Central High School, D. C.
Damascus High School
Forest Park High School, Baltimore
Hagerstown High School
Loyola High School
McKinley High School, D. C.
Roosevelt High School, D. C.
St. John's College, D. C.
Woodrow Wilson High School, D. C.
University of Maryland
Western Maryland
Woodstock College

The following members of the AAJS attended:

Father Kelley
Father O'Conor
Father Sohon
Mr. Cohalan
Mr. Neuner

MORNING SESSION

ADDRESS BY THE PRESIDENT OF THE CHAPTER
THOMAS B. BROWN

1. **Demonstration of 400 MC Oscillator**
   Thomas B. Brown, George Washington University.

2. **Melde's Apparatus Stroboscopically Illuminated**
George D. Rock, Catholic University.

3. **Measuring the Ability of High School Pupils to Apply Physics Principles**
W. A. Kilgore, Central High School, Washington, D. C.

4. **One Methed of Meeting Individual Differences in High School Physics**
G. Koehl, McKinley High School, Washington, D. C.

5. **Comparison of Teaching of Physics on College Level in the United States and Europe**
E. Teller, George Washington University.

6. **The Laboratory in the Arts Course**
Francis I. Brady, Georgetown University.

7. **Comparison of I. Q. and Achievement in High School Physics and Mathematics**
Richard L. Feldman, Roosevelt High School, Washington, D. C.

LUNCHEON

Between the luncheon and the afternoon session, and between the afternoon session and dinner, exhibits by the American Instrument Co., Spencer, and Bausch and Lomb, were on display in the laboratory. The Physics Museum was open at the same times.

AFTERNOON SESSION

8. **A Units Chart**
Glenn F. Rouse, American University.

9. **The Problem of Interesting More Students in Physics**
Viola P. Barton, Goucher College

10. **Modern Laboratory Course**
F. L. Talbot, Catholic University.

11. **Pre-Course Tests in College Physics**
R. J. Seeger, George Washington University.

12. **Ultrasonics as a Teaching Aid**
F. E. Fox, Catholic University.

13. **Demonstrations With the Stroboscope**
John S. O'Conor, S.J., Woodstock College.

14. **Weighing Air Without Balance or Vacuum Pump**
Ralph B. Kennard, Wilson Teachers College.

15. **Common Misconceptions Regarding the Effect of High Frequency Currents on the Body**
H. M. O'Bryan, Georgetown University.

Tour of the Seismological Observatory. Before the tour, the Director, Frederick W. Sohon, S.J., spoke briefly of the seismographs.

HOLY CROSS COLLEGE. Physics Department

Holy Cross Physics Department is now outfitted with complex X-ray and fluoroscopic facilities. The equipment was in regular hospital use until a year ago, and when supplanted by a more modern type was obtained for this department through the kind efforts of Dr. Francis Butler of Worcester. In the complicated wiring of the unit and its precise calibration, the physicists in the department were assisted by the college electrician as well as two outsiders. Mr. Arthur Martin the electrician is well known to all Holy Cross men of the past two decades. Mr. Fred Gallant, the X-ray technician at the Worcester City Hospital, has been connected with X-ray work since the World War. Mr. R. B. Whitman is the New England representative of the G. E. X-ray Corporation. These three gave freely of their time and skill, showing as much interest in the projects as if they were members of the department.

Eventually it is our hope to use the equipment for precise physical work, at present its use is confined to demonstration work as part of the Pre-Medical course. Though secondary, this seems to be an important and universally neglected phase of a Pre-Medical Physics course. According to Mr. Gallant, the average graduate of a Medical School is completely ignorant of the Physics of the X-ray, unaware of the sources of danger both to himself and to the patient.

On Thursday evenings during lent, the Scientific Society of Holy Cross, under the direction of the Physics Department ran a series of Scientific Moving Pictures. The purpose was as much psychological as scientific; lent being the time chosen because in a boarding school that season is the hardest of the whole school year, and any break from the regular order is welcome and helpful. The pictures were shown in Kimball Auditorium, the programs lasting approximately for one hour. Attendance varied from a maximum of two hundred to a minimum of fifty, and seemed to be a function of the state of student depression rather than of the quality of the pictures. All the details of program-making and the multiple correspondence involved was handled by Mr. Paul Thompson, S.J. Pictures were obtained from General Motors, General Electric, Ford Motor, Chevrolet and Hemphill Diesel School. The pictures are standard and for the most part I believe known to the various science departments; three however deserve comment, two adversely and one with favor. Two pictures from General Electric on Crystal structure sound fine in the descriptive circular, but in fact are a waste of time. They are mentioned here to prevent others from being disappointed as we were. Worthy of praise is "Color Harmony" a twelve minute picture destributed by Chevrolet. Not only is it an aid to teachers of Physics and Biology but Philosophy teachers also would find it to their advantage to have their students see this picture.

LOYOLA COLLEGE, Baltimore, Maryland.
Chemistry Department

At the spring-meeting of the American Chemical Society, held in Baltimore, April 3 to 7, Father Richard B. Schmitt read a paper before the members of the Microchemistry Division, entitled: "The Microdetermination of Active Hydrogen by the Soltys Method."

On March 14, Dr. Hugh S. Taylor, Chairman of the Chemistry Department of Princeton University, lectured to the members of the Loyola Chemists' Club on the topic: "The Conception of Speed in Chemical Processes."

The final meeting of the present scholastic year of the Chemists' Club was held on Tuesday, March 28. Dr. A. A. Benedetti Pichler, Professor of Chemistry of New York University presented an illustrated lecture on: "Some Applications of Micro Inorganic Analysis." Several demonstrations with the micro-projector made the lecture most interesting and instructive.

WOODSTOCK COLLEGE. Physics Department

At the annual meeting of The American Physical Society on April 29, a paper was read by Father John S. O'Conor. The abstract follows:

An Electron Lens Type of β-Ray Spectrometer.. C. Witcher, E. Haggstrom, J. S. O'Conor and J. R. Dunning, Columbia University.—A β-ray spectrometer has been constructed utilizing the lens action of a long solenoid, 152 cm long, 25 cm diameter. The radioactive source and the G. M. counter for detecting the β-rays are located 86 cm apart on the axis of the solenoid. A baffle system consisting of aluminum disks and rings is interposed between source and counter to restrict within specifiable limits the dimensions of the helical paths which electrons may traverse in passing from source to counter. The magnetic field of the solenoid is homogeneous within approximately 1.0 percent over the region between source and counter, and its maximum value under present operating conditions is 1200 gauss, corresponding to a β-ray energy of 5.0 Mev. There appear to be four major advantages inherent in a spectrometer of this form. (1) The relatively great distance between source and counter greatly reduces background from gamma-rays. (2) The total thickness of absorbing material in the electron path consists solely of the counter window, which may be made as thin as one or two microns. (3) Theory indicates, and preliminary experimental results verify, that a better combination of intensity and resolution can be obtained with this type of instrument than with the conventional type. (4) Sources in the form of disks 2.0 cm in diameter may be used.

LECTURES: Fr. John Brosnan's popularity as a lecturer has not waned. Recently he lectured before the Maryland Natural History

Society on "Volcanoes of the World." He is scheduled to give another lecture to the same society on April 22nd. on the subject "Three-flowers." At the invitation of Dr. Frank Thone, Fr. Brosnan will lecture before the Biological Society of Washington on April 29th at the Cosmos Club. His subject will be "Moths, Butterflies and their Larvae." Fr. John O'Conor recently spoke to the scholastics at Wernerville on Modern Developments in Physics. On the evening of March 14th Fr. C. A. Berger spoke before the Cytological Seminar of Johns Hopkins on "Cell Size in Relation to Growth and Differentiation."

Due to the illness of Prof. Egerton of Loyola College, Baltimore, Fr. C. A. Berger has undertaken to give the lectures in General Biology at that institution for the remainder of the term.

WESTON COLLEGE. Seismological Observatory

Bulletin No. 17 of the North Eastern Seismological Association carried a supplement pertaining to a group of quakes recorded by all the Benioff stations of the Northeastern area. These quakes appeared in groups of three a few minutes apart. After some study at the Central Station (Weston College), the groups of phases resolved themselves into a single quake of $20°$-$30°$ distance. Stations much nearer to the determined epicenters bore no evidence of these quakes until word finally came through from the U. S. Coast and Geodetic Station at Porto Rico gave some readings. One of these was felt at Caguas, Porto Rico. All of the epicenters determined were near and about the West Indies.

Progress may be reported concerning the installation of portable seismic equipment in the recently acquired panel truck. Fr. James Connolly has constructed a new type amplifier following the suggestions of Dr. Gager of the Boston College Physics Department. In use this amplifier has picked up a man's footsteps at about 200 yards distance. Several projects are awaiting the completion of this installation. The major one being a seismic survey of a basin like structure near Bellows Falls, Vt. Several requests in the near vicinity have been made to determine the depth of bed rock beneath the glacial till.

Physics Department

Professor Enrico of Rome, recent recipient of the Nobel Prize for his achievement in Nuclear Physics, was a guest of the Italian Historical Society of Boston on February 18 at a reception at the Copley Plaza Hotel. The Commonwealth, city and various educational institutions were represented. Fathers M. J. Ahearn, H. M. Brock and D. Linehan represented Weston College. Professor Fermi, who is at present at Columbia University, gave an interesting address.

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INDEX TO VOLUME XVI, 1938-1939

EIGHTEENTH ANNUAL MEETING

of the

AMERICAN ASSOCIATION

of

JESUIT SCIENTISTS

Fordham University
August 17 and 18, 1939