PART I

NOTES

Chapter I

(1) Mayme I. Logsdon: A Mathematician Explains, University of Chicago Press, Chicago, Ill., 1935, p. 158.

(2) University of Chicago Press, 1944, pp. 3 - 4.

(3) La Théorie Physique, (deuxième ed. Paris, Marcel Rivière & Cie., 1914, p. 158. Cf. also p. 166.

(4) The New Background of Science, Cambridge University Press, 1933, p. 296.

(5) Cf. Pierre Duhem: Le Système du Monde, Paris, Librairie Scientifique A. Hermann et Fils, 1916, I, pp. 136 - 139.

(6) Met. I, ch. 5; 985 b 23 - 986 a 10. Trans. by W.D. Ross.

(7) Cf. Roy Hack; God In Greek Philosophy To The Time of Socrates, Princeton University Press, 1931, pp. 47 ff.

(8) The Mysterious Universe, (second ed.) Cambridge University Press, 1937. p. 117. As we shall see later, there is a sense in which it is true to say that mathematics enters into physics from above: mathematics is the limit towards which matter is drawn. But Jeans has something quite different in mind here.

(9) Ibid, p. 122. Cf. also New Background of Science, pp. 296 - 297. It is interesting to note in passing that this view is vigorously contested by Eddington. Cf. The Philosophy of Physical Science, Cambridge U. Press, 1939 p. 137, etc. We shall consider Eddington's opinion later.

(10) Science and the Modern World, pp. 36, 47 - 48 Cf. Sir William Dampier: History of Science: Cambridge University Press, 1945, "In our own day, Aston with his integral atomic weights, Moseley with his atomic numbers, Planck with his quantum theory, and Einstein with his claim that physical facts such as gravitation are exhibitions of local space-time properties, are reviving ideas that, in older, cruder forms, appear in Pythagorean philosophy." - - p. 20.

(11) An Essay On Man, Yale University Press, 1944, pp. 210, 211, 214.

(12) Whitehead: Adventures of Ideas, Cambridge, University Press, 1933, pp. 194 - 196.

(13) De L'Explication dans les Sciences, Paris, Payot, 1927, p. 133.

(14) Op. cit. p. 101.

(15) Cf. St. Thom. In I Met. Lect 10, no. 143: "Unde et Plato tamquam eius auditor, recipiens Socratem, idest sequens, suscepit hoc ad inquirendum in rebus naturalibus, quasi in eis hoc posset evenire, ut universale in eis acciperetur de quo definitio traderetur, ita quod definitio non daretur de aliquo sensibilium, quia cum sensibilia sint semper 'transeuntantium,' idest transmutata, non potest alicuius eorum communis ratio assignari. Nam omnis ratio oportet quod sit omni et semper conveniat, et ita aliquam immutabilitatem requirit."

(16) Cf. Aristotle: I Met., ch. 6, 987 a 30. After discussing the position of the Pythagoreans he goes on to say: "After the systems we have named came the philosophy of Plato, which in most respects followed these thinkers, but had peculiarities that distinguished it from the philosophy of the Italians. For, having in his youth first become familiar with Cratylus and with Heraclitean doctrines (that all sensible things are ever in a state of flux and there is no knowledge about them), these views he held even in later years."

(17) I Met. ch. 6, 987 b 33 - 35.

(18) Philebus, 55, 56. Cf. Field: "Plato and Natural Science", in Philosophy, Vol. VIII, No. 30 p. 159.

(19) Substance and Function and Einstein's Theory of Relativity, Chicago, The Open Court Co., 1923, p. 134.

(20) A. E. Taylor: "Forms and Numbers", in Philosophical Studies, London, Macmillan and Co., 1934, pp. 149 - 150.

(21) I. Met. 993 a 30: Cf. St. Thom. I ct. 17, no. 259: "Sed Platonicis praetermittentibus huiusmodi causas facta sunt naturalia, ac si essent [illegible], dum principium et finem motus praetermittebant. Unde et dicebant

ebant Unde et dicebant

quod mathematica debent tractari non solum propter seipsa, sed aliorum gratia, idest naturaliu, inquan tum passiones mathematicorum sensibilibus attribuebant".

(22) "Number and spatial magnitudes cannot exist apart from things." Met. XIII, 1085 b 35.

(23) Procedures and Metaphysics, University of California Press, 1936, pp. 24 - 25; 27 - 28.

(24) Substance and Function and Einstein's Theory of Relativity, p. 135.

(25) Cf. pp. 40 ff.

(26) Pp. 184 - 186, 214 - 215, 217.

(27) Cf. F.S.C. Northrop: Science and First Principles, New York, The Macmillan Co., 1931. p. 16: "The third consequence of the mathematical theory is methodological in character. Since mathematical forms are not observed in nature, and, as Plato said, are suggested by, not contained in the world of observation, it follows that one cannot proceed, as did the physical theory of nature, from the facts of observation to one's scientific principles by the necessary relation of formal implication. The facts merely suggest the mathematical forms; they do not imply or contain them. Hence, as Plato maintained, the fundamental scientific method in this theory is the method of hypothesis. Since this method always commits the logical fallacy of affirming the consequent, Plato tries to introduce the dialectic, which is not the vicious thing its modern connotation suggests to certain minds, but the simple sound idea that all hypotheses must be traced to their common presuppositions and unified into a consistent deductive system. When we attempt to do this for psychology and epistemology as well as mathematics and astronomy, we find ourselves face to face with all the problems with which Plato wrestled in his Dialogues. To see the second movement of Greek science in the light of its bearing on first principles is to understand the philosophy of Plato. It was the mathematical and rational character of the inorganic universe that made an idealist in ancient times."

(28) Opus Majus, ed. Bridges, II, 173. Cited by Randall: The Making of the Modern Mind, Boston, Houghton Mifflin Co., 1940, p. 211.

(29) Cited by Weyl: Mind and Nature, Philadelphia, University of Pennsylvania Press, 1934. p. 50.

(30) Docta Ignorantia, I, 1.

(31) De Mente, Ch. VI.

(32) De Possest (Op. O., 259).

(33) Ernst Cassirer: "Giovanni Pico della Mirandola. A study in the History of the Renaissance", Journal of the History of Ideas, Vol. III, No. 3, p. 321. Cf. Cassirer's Individuum Und Kosmos in der Philosophie der Renaissance, Leipzig Teubner, 1927, pp. II, 15, etc.

(34) Cf. Frascanti, 85 - 88, 113. etc. Cited by Randall, op. cit. 221, 236.

(35) Cf. Dampier, op. cit. p. 115.

(36) Epitome Astronomiae Copernicae, p. 1

(37) Harm. Mundi, Lib IV, cap. 1.

(38) Cf. Strong, op.cit. Chapter VII: "Method and Metaphysics in Kepler".

(39) Ed. Nam. VIII, 613. Cited By Randall, op. cit. p. 237.

(40) Opere Complete di Galileo Galilei, Firenze, 1842, Vol. IV, p. 171. Cited by Burtt, op. cit. p. 64.

(41) Opere, IV, 333, Cited by Burtt, op. cit. p. 75.

(42) De L'Explication Dans Les Sciences, p. 134.

(43) Le Songe de Descartes, Paris, Editions L. A. Correa, 1938, p. 40.

(44) Descartes, Haldane and Ross ed. I, 13, 11.

(45) Lettre à Mersenne, ed. Cousin, T. VII, p. 121.

(46) Principia, II, 64.

(47) Principia, II, 4, 9.

(48) De Potentia, III, 1 ad 17.

(49) Cf. Regulae ad Directionem Ingenii, ed. Adam et Tannery, pp. 426 - 427.

(50) L'Expérience Humaine, Paris, 1928, p. 165. Cited by Meyerson: La Déduction Relativiste, Paris, Payot, 1925, p. 254.

(51) La Théorie Physique, pp. 169 - 170.

(52) Principia, IV, 199.

(53) Whitehead: Science and the Modern World, p. 69. It would be difficult to exaggerate the importance of the discovery of the calculus for the mathematical interpretation of the physical universe. Cf. Randall, op. cit. p. 258: "Such a method of measuring movement and continuous growth Newton discovered; he had arrived at the most potent instrument yet found for bringing the world into subjection to man. Since any regular motion, be it of a falling body, an electric current, or the cooling of a molten mass, can be represented by a curve, he had forged the tool by which to attack, not only the figures, but the processes of nature — the last link in the mathematical interpretation of the world. By its means a Lagrange in the eighteenth or a Clerk-Maxwell in the nineteenth century could bring all measurable phenomena into the unified world of mathematics, and calculate, predict, and control light, heat, magnetism and electricity."

(54) Op. cit. 255.

(55) Cited by Burtt, op. cit., pp. 204 - 205.

(56) The Limitations of Science, New York, The Viking Press 1935, p. 6.

(57) Science and Human Experience, London, Williams and Norgate, Ltd., 1931, p. 38.

(58) The Philosophy of Physical Science, pp. 188 - 189.

(59) Prolégomènes à toute Métaphysique Future, trad. J. Gibelin, dans "Bibliothèque des Textes Philosophiques", 1ère partie, pr. 10, pp. 44 - 45.

(60) Cited by Meyerson De L'Explication dans les Sciences, p. 458.

(61) Throughout this study the phrase "classical physics" refers to Newtonian physics and not to the physics of the Greeks.

(62) The Mysterious Universe, pp. 111 ff.

(63) Some authors have attempted to press this continuity to the extent of seeing in the distinctive achievements of recent physics the realization of the main trends in the history of mathematical physics. Cf. Juvet: La Structure Des Nouvelles Théories Physiques, Paris, Alcan, 1933, p. 177: "Les Nombres de Pythagore, les idées de Platon, la mathématique universelle de Descartes, la caractéristique de Leibnix sont de belles anticipations metaphysiques que la nouvelle philosophie naturelle fondée sur les travaux d'Einstein, de De Broglie, d'Heisenberg, la mathématique moderne créée par Galois, Lie, Cartan, Weyl confirment et précisent avec l'aide de la méthode axiomatique d'Hilbert. Les Nombres et les Idées sont les groupes, le symbolisme des axiomes, c'est la Caractéristique Leibnizienne, et les succès sans fin de la mathématique, qui ne se justifient que par la cohérence créée grâce à l'emploi des groupes, font du rêve de Descartes la réalité d'aujourd'hui." We believe that the true nature of the continuity between contemporary mathematical physics and the past is something quite different from what is indicated here by Juvet.

(64) Introduction à l'étude de la Médecine Expérimentale, pp. 94 - 95.

(65) The Logic of Modern Physics, New York, The Macmillan Co., 1932, p. 61. Cf. Woodbridge: An Essay on Nature, New York, Columbia University Press, 1940, p. 124.

(66) The Method of Theoretical Physics, Oxford, Clarendon Press, 1933, pp. 11 - 13. Cf. The World as I See it, pp. 32 - 34.

(67) The Mysterious Universe, p. 113.

(68) Op. cit. p. 121. Cf. "The Mathematical Aspect of the Universe," by the same author in Philosophy, Vol. VII, No. 25, pp. 3 - 14. It is not immediately evident how this doctrine of Jeans fits in with what he says in Physics

and Philosophy: "The same is true of all the discoveries of the pure mathematician: they are universal in the sense that they would be true in any world, and so cannot tell us anything about the special properties of this particular world." — Cambridge University Press, 1943, p. 49.

(69) Op. cit. p. 62.

(70) Op. cit. p. 176.

(71) "Mathematics For The Doctor in The Million," in Philosophy of Science, Jan. 1944, Vol. II, No. 1. pp. 48 - 49. Cf. also Lenard: Great Men of Science, New York, The Macmillan Co., 1933, pp. 220 - 222.

(72) The Principles of Quantum Mechanics, Oxford Press, 1935, Preface, p. vii.

(73) p. 157.

(74) Cf. also New Pathways in Science, Cambridge University Press, 1935, Ch. XII.

(75) Cf. Dantzig: Aspects of Science, New York, The Macmillan Co., 1937, p. 74.

(76) An Essay on Man, New Haven, Yale University Press, 1944, pp. 211 - 212. This position is developed at great length in his Philosophie der symbolischen Formen, and in Substance and Function.

(77) Since a number of historians have seen fit to consider the doctrine of St. Thomas as a perversion of the philosophy of Aristotle, it is worth while noting perhaps that we consider Thomism to be in the strictest peripatetic tradition. It would take us too far afield, however, to attempt to establish this point here.

(78) Our Knowledge of the External World, p. 240.

(79) Op. cit. p. 40. Cf. Randall, op. cit. p. 236.

(80) Cf. Science and the Modern World, pp. 15 - 16: "But for science something more is wanted than a general sense of the order of things. It needs but a sentence to point out how the habit of definite exact thought was implanted in the European mind by the long dominance of scholastic logic and scholastic divinity. The habit remained after the philosophy had been repudiated, the priceless habit of looking for an exact point and sticking to it when found. Galileo owes more to Aristotle than appears on the surface of his Dialogues; he owes him his clear head and his analytic mind. I do not think, however, that I have even yet brought out the greatest contribution of medievalism to the formation of the scientific movement. I mean the inexpugnable belief that every detailed occurrence can be correlated with its antecedents in a perfectly definite manner, exemplifying general principles. . . My explanation is that the faith in the possibility of science, generated antecedently to the development of modern scientific theory, is an unconscious derivation from mediaeval theology."

(81) Paris, Librairie Félix Alcan, (4e ed.) 1932, p. 40.

(82) Paris, Librairie Félix Alcan, 1931, p. 149. Cf. ibid. 695; De L'Explication dans les Sciences. pp. 489, 528, etc., etc.

(83) "Physique Ancienne et Physique Moderne: Leurs Conceptions de l'Intelligible", in Travaux du IXe Congrès International de Philosophie, V, Partie II., Paris, Hermann et Cie, 1937, pp. 197 - 198.

(84) Science and the Modern World, pp. 36 - 37. Cf. Adventures of Ideas: Aristotle's Logic "entirely leaves out of account the interconnections between real things. . . (It) remains an interconnected world of real things unintelligible. The universe is shivered into a multitude of disconnected substantial things. . .But substantial thing cannot call unto substantial thing. . .But the Platonic doctrine of the interweaving of harmony with mathematical relations has been triumphantly vindicated. The Aristotelian classifications based upon qualitative predicates have a very restricted application apart from the introduction of mathematical formulae. Indeed, Aristotelian Logic, by its neglect of mathematical notions, has done almost as much harm as good for the advancement of science. We can never get away from the questions: How much — In what proportions — and, In what pattern of arrangement with other things." — pp. 169 - 170, 196.

(85) Philosophy and History, Oxford, Clarendon Press, 1936, pp. 61 ff.

(86) p. 71 - 72.

(87) . 75.

(88) In Philosophie et Sciences, (Journées d'Etudes de la Société Thomiste, Louvain, 1935), Les Editions du Cerf, Juvisy.

(89) In Philosophie et Sciences, pp. 26 - 28.

(90) "La Conception Scolastique de la Physique," in Philosophie et Sciences, pp. 48 - 49.

(90a) Ibid. pp. 55 - 56.

(91) Cited by Meyer: Physics and Reality, New Haven, Yale University Press, 1940, p. 119. Cf. Strong: op. cit. pp. 161 - 162: "Galileo treats Aristotle in The Two New Sciences as a predecessor in the inquiry into problems of vacuum, infinity, and continuity, and mechanics. He introduces principles advanced by Aristotle in order to agree as well as disagree with them. In the earlier work, The Two Great Systems of the World, Galileo presents a more impatient Salviati and a Simplicio who is less of a student and more of a controversialist than in the later treatise. The "Peripatetics" receive the brunt of an attack launched against those who will not receive the evidence of the telescope and the demonstrations of mathematics; but this is not done to convict Aristotle, since Galileo believes that he should have changed his opinion in the light of the new evidence. In neither of his two major works does Galileo present an opposition between Platonic and Aristotelian metaphysics. Aristotle is rather presented in The Two New Sciences as more closely affiliated with mechanical questions than is Plato." In the preface to his Etudes Sur Leonardo da Vinci, Duhem shows that it is a mistake to believe that the science of Galileo is a victory of modern science over medieval philosophy. It is rather a victory of a mechanics that was born in Paris in the fourteenth century and based upon the critical treatment of doctrines derived from Aristotle and Averroes.

(92) "The Birth of Science among the Greeks," in Encyclopedia of Modern Knowledge, Edited by Sir John Harmerton, part 15, p. 1485.

(93) Cf. De Caelo, II, lect. 17, no. 2; I, 32, 1, ad 2.

(94) Op. cit., p. 74 (footnote).

(95) Ch. VIII, 1073 b 7 - 18.

(96) Loc. cit.

(97) Cf. St. Thom. lect. 9, No. 2566: "Quot autem sint motus planetarum, nos nunc dicemus ex quae circa haec mathematici dicunt, ut circa hanc ralderem attenti, ut aliqua pluralitas determinate concipiatur a nobis."

(98) Philosophical Essays for Alfred North Whitehead, Chapter I: The Mathematical Background and Content of Greek Philosophy, p. 39. Cf. A. E. Taylor: "Numbers and Forms" in Philosophical Studies.

(99) Op. cit. pp. 23 - 27.

(100) De L'Explication Dans Les Sciences, p. 174.

(101) 78 b 33 - 79 a 15.

(102) 193 b 23 - 194 a 10.

(103) That is to say, scientific in the Aristotelian sense of the term.

(104) Cf. Pet. III and XIII.

(105) The Nature of Physical Theory, New York, John Wiley and Sons, 1931, pp. 39 - 45.

(106) Cf. In II Phys, lect. 11, no. 3.

(107) This notion of the intrinsic incorruptibility of the heavenly bodies has, of course, been rejected by modern Thomists. But the question of the possible existence of such bodies still remains open.

(108) In this connection it is interesting to note that in some respects the physics of the medieval Scholastics was more mathematized than modern physics: "Les mêmes conceptions mathématiques se trahissent d'ailleurs dans le détail des théories particulières. C'est ainsi que la doctrine arithmétique classique des cordes vibrantes se complétait au moyen âge par une esthétique musicale entièrement fondée sur les nombres qui définissent les sons. Fait plus remarquable, des mêmes doctrines pythagoriciennes étaient mises en oeuvre dans les théories parallèles de la vue, du goût et de l'odorat. Le blanc, par exemple, était censé contenir le maximum possible

de lumière, le noir par contre le minimum (De Sensu, VII, 97 - 102, 104, 115. Cf. Ibid. 95, la doctrine qui fait du noir le minimum et non la privation). Toutes les autres couleurs résultaient ensuite d'un mélange en proportion définie de ces deux composantes simples (Ibid., 102) Pour les belles couleurs, dont on ajoutait mélancoliquement, qu'elles étaient aussi rares que les beaux accords musicaux, le rapport des composantes sera une fraction particulièrement simple, pour les vilaines un incommensurable (Ibid. 101, 104, avec la théorie mathématique aux 98 - 100) Les qualités perçues par le goût résultent pareillement d'un mélange en proportion définie de deux composantes simples le doux et l'amer. (De Sensu XI, 148). Et l'esthétique se faisant, cette fois gastronomie, on ajoute que les goûts agréables correspondent aux fractions simples, les mauvais goûts aux incommensurables. (Ibid. 149) Les odeurs, enfin, qui sont définies par les goûts auxquels elles sont conjugées, suivent la même loi. (De Sensu, XII, 174 - 176; XIII, 177 - 178) Et sur tous ces points la physique ancienne se montre manifestement beaucoup plus mathématisée que celle des modernes." R.P. Salman: "La Conception Scolastique de la Physique" in Philosophie et Sciences, pp. 46 - 47.

(109) We believe that M. Maritain has thrown some confusion upon this point: "Cet usage des principes mathématiques dans la connaissance de la nature peut ou bien rester accidentel et représenter un emprunt fait aux mathématiques par le naturalis, ou bien être essentiel à la science considérée, qui est alors proprement une scientia media; et il est clair que divers degrés de 'mathématisation' accidentelle doivent conduire progressivement de la science purement physique à la scientia media. La physico-mathématique des modernes réalise le type de la scientia media d'un façon parfaite. Au contraire nous pensons que l'usage des mathématiques en biologie par exemple ou en psychologie, n'arrivera jamais à subordonner typiquement ces disciplines aux règles d'explication mathématiques." Degrés du Savoir, p. 284 footnote.

(110) Cf. W.R. Thompson: Science and Common Sense, London, Longmans Green and Co., 1937, p. 29: "Eminent men of Science, indeed, maintain that the perfection of scientific synthesis depends on the extent to which it has resolved itself into mathematical concepts. There are, however, vast fields

of Science in which the data seem extremely refractory to mathematical interpretation; where we cannot conceive that they could by any process of distillation or boiling down, be reduced entirely to measurable elements. Science, in its present form, thus presents itself, not as a deliquescent and temporary construction melting to a dead level of mathematical material, but as a solid and ordered hierarchy of different kinds of knowledge: all true, all scientific, but diverse."

(111) "Réflexions sur le problème de l'indéterminisme" in Revue Thomiste, nov. - dec. 1937, p. 594.

(112) Le Cosmos (revised edition) p. 7.

(113) "Et c'est aussi en obéissant à cette même tendance éternelle de l'esprit humain que la chimie s'étonne de la diversité des substances et que cet étonnement, selon le témoignage autorisé de M. Job, constitue le point de départ de cette science tout entière." Meyerson: De l'Explication dans les Sciences, p. 181 - 182. Cf. also Essais, Paris, Librairie J. Vrin, 1936, p. 18 - 19.

(114) Cf. Cours de Philosophie Positive, Vol. II, 281; III, 29. Comte taught that the extensive use of mathematics in physics was simply an inexcusable prejudice. Cf. Cours de Politique Positive, 3e ed. IV, Appendice Général, pp. 1 - 3. It is also interesting to note that J.S. Mill considered the hope of applying mathematics to chemistry and physiology as something chimerical -- Cf. Meyerson: Du Cheminement de la Pensée, p. 190.

(115) Critique of Physics, London, Kegan Paul, Trench, Trubner and Co., 1931, p. 142.

(116) For a good summary discussion of this point see W.R. Thompson: Science and Common Sense, chapter VI.

(117) One of the simplest examples of how mathematical formulation may serve to throw light upon biological phenomena is indicated by W.R. Thompson in the following lines: "In the simplest cases, such as the cylindrical or spherical form, which we find in a multitude of organic formations, the mathematical formation is instantly made. It might seem, at first sight, that the

recognition of a raindrop or an Echinoderm egg as a sphere, or a plant stem as a cylinder, add nothing to our knowledge of these forms. But the recognition of a sphere, for example, implies the knowledge of its mathematical law, as expressed in the equations indicating the order between its quantities, such as $S = 4\ r2$ and $V = 4/3\ r3$. By the knowledge of the law of its quantities, these are reduced from multiplicity to unity so that the form of the sphere becomes intelligible and we have, in the formal order, a cognitio per causas. Furthermore, the mathematical definition of a sphere is the basis of a true deductive argument. Knowing that a cell is spherical, we know that it is something whose surface is smaller for the volume it encloses than any other possible figure: and we see also, looking at the matter from another angle, that it exemplifies the law according to which 'any system of bodies arranges itself in such a manner that the potential energy of the system is a minimum' (E. Edser, General Physics, 1915, p. 290)" -- Science and Common Sense, pp. 76 - 77.

(118) Cf. Thurston: Vectors of Mind, Chicago 1935; Spearman: The Abilities of Man, New York, 1928; Edgeworth: Mathematical Psychics, London 1881, etc.

(119) It is important to keep in mind that whenever intelligence is studied by any method of this kind, what is understood by intelligence can be known only operationally, that is to say, it can be defined only by a description of the concrete procedures of measurement by which the results have been arrived at.

(120) Introduction to Mathematics, The Home University Library, 1931, p. 223.

(121) The Physical Principle of Quantum Theory, Chicago University Press, 1930, p. 62.

(122) Pp. 4 - 7.

(123) L'Idée de Loi Naturelle dans la Science et la Philosophie, Paris, Librairie Philosophique J. Vrin, 1925, p. 136.

(124) Philosophical Aspects of Modern Science, New York, The Macmillan Co., 1932, p. 63.

(125) The Mysterious Universe, pp. 122 - 123.

(126) New Background of Science p. 298. Cf. also pp. 296 - 297. Cf. "The Mathematical Aspect of the Universe," in Philosophy, Vol. VII, p. 14.

Chapter II

(1) Cf. Thompson: An Introduction to Science, New York, Henry Holt and Co., 1911, Chapter IV.

(2) The Philosophy of Physics, London, George Allen and Unwin, 1936, p.81.

(3) The Three Reformers, London, Sheed and Ward, 1936, p. 84.

(4) Cf. Gilson: "L'Idée de l'unité du corps des sciences.. est inséparable, chronologiquement et logiquement, de l'extension de la méthode mathématique à la totalité du domaine de la connaissance." Discours de la méthode, Texte et Commentaire, Paris, 1925, p. 214.

(5) Cursus Phil. I, Q. XXVII, a. 1.

(6) Cf. Charles De Koninck: "La dialectique des limites comme critique de la raison", Laval Théologique et Philosophique, Vol. I, No.1, pp. 177 ff.

(7) Cf. III, 11, 6; Cf. also John of St. Thomas, Cur.Phil., I, Part II, Q. XXVII, a. 1. (Reiser ed. pp. 819 b and 824 b).

(8) Cf. Contra Gentes, III, Chap. 10.

(9) Cf. Henri Pichette: "Considérations sur quelques principes fondamentaux de la doctrine du spéculatif et du pratique", Laval Théologique et Philosophique, Vol. I, No. 1, pp. 52 ff.

(10) Cf. III De Anima, c. 10 433 a 10.

(11) II Met. I, 993 b 20; In Boet. de Trin., V, I, c.

(12) I - II, 57, 1, ad 1.

(13) I - II, 3, 5, ad 2.

(14) Cf. I, 14, 16.

(15) De Ver. III, 3, ad 4.

(16) De Veritate, I, 2, c.

(17) Cursus. Theol., I, disp. 2. a. 10, no. 18.

(18) Curs. Theol. I, disp. 2, a. 10, no. 5.

(19) In II Eth. lectio 12, no. 356. Cf. In III Sent. d. 23, q. 2, a. 3, sol. 2.

(20) Cf. S. Thomas, Comment. Polit., Prol.; De Ver., III, 3, c.

(21) Lect. 14, no. 8.

(22) Discours de la Méthode, Edition Hatier, Paris, p. 76.

(23) "Hypothesis" in Studies in the History and Method of Science, edited by Charles Singer, Oxford, 1921, Vol. II, pp. 489 - 491.

(24) London, M.C.L.C. Publishing Society, pp. 7 and 9.

(25) Language and Reality, London, George Allen & Unwin, 1939, p. 505.

(26) I, 1, 7.

(27) I - II, 46, 2; Cf. In VI Eth., lect. 5, no. 1145; St. Albert: Liber I Phys. I, cap. 5.

(28) Cf. Post. Anal. I, c. 2, 71 b 10.

(29) Cf. De Anima II; I 77, 3, etc.

(30) In Post Anal. I, lect. 41; De Trin. VI, etc.

(31) In De Generatione et Corruptione, Prolem.; Cf. III De Anima.

(32) In I, 1, 3, no. 3, 4, 5; Cf. also John of St. Thomas loc. cit. p. 819. and 860.

(33) This objective light must, of course, be distinguished from the interior light by which the cognitive potency is actualized.

(34) I, 1, 3.

(35) Cf. St. Thomas in Boeth. De Trin. V, 1.

(36) Cf. St. Thomas I, 14, 1; In De Anima II, lect. 24; De Veritate, II, 2, etc.

(37) Cf. In VI Eth. lect. 3, no. 1145 - 1149, etc.

(38) De Trin. V, 1; Cf. Post. Anal. I, lect. 41; In VI Met. lect. 1; I, 85, 1, ad 1 and 2; In De Sensu et Sensato, lect. 1, etc.

(39) In De Ente et Essentia, Prooem.

(40) In Boeth. De Trinitate, V, 3.

(41) "... proprium et determinatum rationem praedicati inferioris (non) accipiat." John of St. Thomas: Ars Logica, p. 31 a 22.

(42) Cf. John of St. Thomas, Curs. Phil. p. 265 a 30 - 35.

(43) V, 1.

(44) Cf. St. Thomas: I, 85, 1 ad 1; In VII Met.; De Trin. V, 2, etc. It is hardly necessary to point out that the student of nature uses individual observations and experiments, but only as a point of departure and as a means to arrive at the common sensible matter.

(45) Lest confusion arise, it must be pointed out that modern authors use the word "metaphysics" in a much broader sense than the traditional Thomistic acceptation of the term. It is now generally employed in such a way as to include philosophy of nature as well as metaphysics. We shall use the word in its strict Thomistic meaning.

(46) Cf. In I Phys. lect. 1; In VI Met. lect. 1; In XI Met. lect 4, etc.

(47) E.g. Maritain: Les Dégrés du Savoir, Paris, Desclée de Brower et Cie., 1932, pp. 77, 79, etc.

(48) De Subjecto Naturalis Philosophiae.

(49) Curs. Phil. II, q. I, a. 1.

(50) I, lect. 1.

(51) In Phys. I, lect. 1.

(52) Curs. Phil. I, 1. This point may give rise to a difficulty: a metaphysical definition (actus entis in potentia) seems to be employed in philosophy of nature. The answer is that the word potency has a different meaning when the definition is used in metaphysics and in philosophy of nature. In the latter case, it means the physical potency of matter. In the former it is considered in its general meaning as a principle of being. Every act of a being in potency is necessarily the act of a material thing, but while in reality there is identification, the aspect under which this reality is considered is different.

(53) "...ita quod ens mobile, licet complexionem nominum continent incomplexum tamen et per se unum quod quid est significat, sicut ens per se." De Subjecto Naturalis Philosophiae, Laval edition, 1939, pp. 9 and 10.

(54) "Ens mobile non sumitur complexe pro aggregato ex ente et mobilitate ut duobus, sed incomplexe pro quidditate, cui convenit mobilitas." Cursus Phil. II, q. I, a. 1.

(55) In IV Met. lect. 13, no. 683. Cf In III Met. lect. 3.

(56) Cf. In Boeth De Trin. V, 2; In VI Eth. lect. 3, etc.

(57) In VI Eth. lect. 1, no. 1123.

(58) In Anal. Post. I, lect. 16. Cf. I, 86, 3.

(59) In De Trin. V, 2.

(60) In VI Met. lect. 1.

(61) Cf. St. Thomas: In II Phys., lect. 3; In De Trinitate, V, 3.

(62) Cf. St. Thomas: In De Trinitate, V, 3.

(63) In Boeth. De Trin., VI, 2 Cf. De Coelo et Mundo, III.

(64) Cf. De Anima I.

(65) De Veritate XII, 3 ad 2.

(66) Curs. Phil. I, Pars I, q. 27, a. 1.

(67) E.g. II-II, 1, 1; I-II, 54, 2, ad 2; etc.

(68) E.g. In VI Met. lect. 1; In I Poster. Anal. lect. 41, etc.

(69) VI, lect. 1.

(70) Cf. e.g. L.M. Regis: "La Philosophie de la Nature: Quelques Apories", in Philosophie, Cahier I, Etudes et Recherches, Collège Dominicain, Ottawa, 1956.

(71) "La Physique Aristotélicienne et la Philosophie," in Philosophie et Sciences, pp. 25 - 26.

(72) Ibid. p. 24.

(73) It may be true that Aristotle himself never brought out this hierarchical structure as explicitly as St. Thomas. Yet the latter merely clarified what was already implicit in Aristotle's doctrine. That is why we see no point in Mansion's argument when he writes: "On ne voit donc pas ce qui justifie, en bonne doctrine aristotélicienne, l'abstraction mathématique entendue comme un degré special d'abstraction. Il faudrait pour cela que les notes quantitatives possèdassent vis-à-vis des autres notes auxquelles elles sont unies dans la réalité physique, une antériorité logique ou métaphysique, qu'Aristote n'a point cherché à établir. Les efforts faits dans ce sens par les scolastiques — Saint Thomas lui d'autres — ne peuvent pas entrer en ligne de compte pour formuler une appreciation concernant la position doctrinale du Stagirite lui-même." Ibid. p. 26.

(74) Ibid. 25.

(75) Ibid.p. 25.

(76) Ibid. p. 23 - 24.

(77) Ibid. p. 24.

(78) In De Trin., V, 3, ad 5.

(79) Ibid. p. 27 - 28.

(80) Loc. cit.

(81) Chap. 27, Trans. by C.R.C. Dure; McKeon edition: The Basic Works of Aristotle, New York, Random House, 1941, p. 155.

(82) Lectio 41, no. 5.

(83) La Théorie Physique, p. 167.

(84) Curs. Phil. II, Q. I, a. 2.

(85) Loc. cit.

(86) Meyerson makes it clear that the superior immateriality of arithmetic has been quite generally recognized. Cf. Du Cheminement de la Pensée, p. 308: "Telle était déjà l'idée de Gauss. 'Nous devons admettre humblement, écrivait-il à l'astronome Bessel, que, le nombre est uniquement le produit de notre esprit, l'espace, même au point de vue de notre esprit, constitue une réalité à laquelle nous ne pouvons a priori dicter complètement ses lois'. Dedekind, dans la préface de son fameux opuscule sur la nature du nombre a vivement insisté sur cette idée de l'autonomie de l'arithmétique à l'égard du réel. Le nombre est 'une création immédiate de l'esprit humain' et 'entièrement indépendant des concepts de temps et d'espace'; les nombres sont 'des créations libres de l'esprit humain, ils servent de moyen pour saisir plus aisément et avec plus de précision la diversité des choses' (Was sind und was sollen die Zahlen? 32 ed., Brunswick 1923, p. 111... "Mais Locke, déjà jugeait que 'le nombre est la plus simple et la plus universelle de toutes nos idées" (Essai Philosophique, II, Ch. XVI, no. 1), et Hume considérait la géométrie comme moins assurée que l'arithmétique et l'algèbre au point de vue de la valeur apodictique de ses affirmations. (Psychologie, tr. Renouvier et Pillon, Paris 1878, p. 98)".

(87) Cf. [illegible] Salmon: "La Conception Scholastique de la Physique", [illegible] Philosophie et Sciences, p. 37. "Ceux-ci (les

anciens) connaissaient bien des distinctions: les sciences et les arts, les arts libéraux et les arts serviles, les sciences pratiques et spéculatives, ces dernières diversifiées selon leur dégré d'abstraction; mais jamais dans aucun domaine, ils n'ont opposé une "science" à une "philosophie."

(88) Cf. Maritain: La Philosophie de la Nature: "Toutefois cette vérité capitale était payée chez les anciens, chez Aristote lui-même et chez les anciens scolastiques également, au prix d'une grave faute de précipitation intellectuelle. . . Pour l'optimisme des anciens, qui se portait très rapidement à des raisons d'être quelquefois très hypothétiques quand il s'agissait du détail des phénomènes, philosophie et sciences expérimentales étaient un seul et même savoir, et toutes les sciences du monde matériel étaient des subdivisions d'une seule et unique science spécifique qui s'appelait 'philosophia naturalis' . . . --p. 31.

(89) Cf. Réflexions Sur l'Intelligence, Les Dégrés du Savoir, La Philosophie de la Nature, Science et Sagesse, etc. Cf. also Yves Simon: "Maritain's Philosophy of the Sciences," in The Thomist, Vol. V. pp. 85 - 102.

(90) Art. cit. p. 95. (Italics ours)

(91) Curs. Phil. II, q. I, a. 2.

(92) Cf. In I Phys. lect. 1, nos. 6 - 8; De Sensu et Sensato, lect. 1, no. 2; De Generatione et Corruptione, Proem, In De Anima, lect. 1 no. 1; In Meteorolog. lect. 1; De Coelo et Mundo, lect. 1; etc.

(93) The full significance of this statement will be brought out in the next chapter which the question of subalternation will be studied in detail.

(94) In VI Met. lect. 1, no. 1147.

(95) Ibid. no. 1165.

(96) Ibid. no. 1149. Even on this point M. Maritain seems to be antiThomistic, for he writes: "Je note, entre parenthèses, que l'étude des premiers fondements ontologiques des mathématiques, la philosophie du nombre et du continu, rentre dans la sphère de la philosophie de la nature, car l'abstraction mathématique, ne portant pas de soi sur l'être réel, ne comporte pas de sagesse dans son ordre propre." — Dégrés du Savoir, p. 92-93. Cf. p. 345. Cf. also La Philosophie de la Nature, p. 91. It is difficult to see how the philosophy of mathematics, the problems of number and continuity fall within the sphere of philosophy of nature, which is the study of things in terms of mobility. Philosophy of nature is, indeed, a kind of wisdom within its own realm, in the sense that the general principles of mobile being which it studies give order to the entire study of natural things, but it is a wisdom only in terms of mobility. May not the source of Maritain's confusion be, at least in part, his substitution of sensible being for mobile being? The Philosophy of mathematics pertains to metaphysics not only for the reason given above, but also because, being wisdom, metaphysics has as one of its functions not only the critique of its own nature, but also of that of all the other sciences.

(97) Dégrés du Savoir, p. 352, footnote 1.

(98) Ibid. Cf. La Philosophie de la Nature, pp. 88.

(99) V, 1, ad 5.

(100) Art. cit., Cf. St. Thomas: In De Sensu et Sensato, lect. 1 no. 15.

(101) Cf. Les Dégrés du Savoir, pp. 77 ff., 94 - 95, 352, etc.

(102) After consistently assigning sensible being as the formal object of the study of nature throughout Les Dégrés du Savoir, M. Maritain notes in La Philosophie de la Nature, (p. 115) that as Cajetan explains in his opusculum, De Subjecto Naturalis Philosophiae, the expression ens sensibile is less apt than ens mobile. He still insists, however, that it is legitimate to assign ens sensibile as the formal object. For reasons indicated earlier in this chapter we feel that there is much more involved here than a question of aptness.

(103) "Maritain's Philosophy of the Sciences" in The Thomist, Vol. V, pp. 90 - 91.

(104) We prescind here from the important difference that the first definition in so far as it has to do with a living being, is based upon both internal and external experience, whereas experimental scientists with the exception of the experimental psychologists in some cases, have adopted the method of drawing only from external experience even when dealing with living beings. We shall return to this point in chapter VIII. For the moment it is sufficient to note that a difference in the sources of experience employed cannot, obviously, constitute a specific difference between sciences.

(105) In I Post. Anal. lect 16, no. 5.

(106) Art. cit. p. 94.

(107) Ibid. p. 92.

(108) Dégrés du Savoir pp. 74 - 75. Having made this admission he illogically holds that the experimental sciences come before the philosophy of nature in pedagogical order.

(109) Cf. Dégrés du Savoir, pp. 344 ff.

(110) La Philosophie de la Nature, pp. 91 - 92.

(111) The Sophist 219 a ff. Cf. Aristotle's criticism of this doctrine: Prior Anal. I, 31; Post. Anal. II, 5 and 13.

(112) Morceaux Choisis, pp. 44 - 47.

(113) In I Phys. lect. 1, no. 8.

(114) Cf. La Philosophie de la Nature, p. 83.

(115) Cf. Nos. 1147, 1151, 1165.

(116) Dégrés du Savoir, p. 77.

(117) Ibid. p. 351.

(118) Cf. Fulton J. Sheen: The Philosophy of Science, Milwaukee, The Bruce Publishing Co., 1934, pp. 164 - 189; Father Whittaker, O.P.: "The Position of Mathematics

in the Hierarchy of Speculative Science," in The Thomist, Vol. III, no. 3, p. 503.

(119) Cf. Cajetan: De Subjecto Naturalis Philosophiae, ed. Laval, pp. 19 - 20.

(120) Ibid., p. 91.

(121) 639 b 13 - 640 a 9.

(122) St. Thomas, lect. 15.

(123) Lect. 15, no. 5.

(124) De Part. An., loc. cit.

(125) Cf. Phys. II.

(126) In VI Met. lect. 1, no. 1149.

(127) Ibid. no. 1146. Cf. I, 46, 1 ad 3.

(128) We prescind here from the special case of man, whose future existence could have been demonstrated with apodictic necessity once given the existence of a material cosmos, for here the basis of demonstrability was something extrinsic.

(129) Cf. St. Th. In De Trinitate, VI, 1: Ex hoc autem quod consideratio naturalis est circa materiam a pluribus dependet, scilicet a considerationc materiae et formae, et dispositionum materialium et proprietatum quae consequuntur formam in materia. Ubicumque autem ad aliquid cognoscendum oportet considerare plura, est difficilior cognitio: unde in I Posteriorum dicitur, quod minus certa scientia est quae est ex additione, ut geometria ad arithmeticam. Ex hoc vero quod eius consideratio est circa res mobiles, et quae non uniformiter se habent eius cognitio est minus firma, quia eius demonstrationes. ut in majori parte sunt ex hoc, quod contingit aliquando aliter se habere: et ideo quando aliqua scientia magis appropinquat ad singularia, sicut operativae, ut medicina, alchimia, et moralis, minus possunt habere de certitudine propter multitudinem eorum quae considerande sunt in talibus scientiis, quae quodlibet si omittatur, frequenter erratur, et propter eorum variabilitatem.

(130) Cf. St. Thom. In I Eth. Nic. lect. 1.

(131) Cf. infra Chapter III, note

(132) The uniqueness of the method proper to each science does not, of course, exclude the possibility of a general treatise on scientific method, for logic, writes St. Thomas, "tradit communem modum procedendi in omnibus aliis scientiis. Modus autem proprius singularum scientiarum, in scientiis singulis circa principium tradi debet." (In II Met. lect. 5, no. 338) In view of this distinction of St. Thomas, the following assertion of Gilson is at best extremely ambiguous: "An Aristotelian discourse on method is. . . an impossibility; it is possible to speak only of a discourse on methods." (Op. cit. p. 71) Far from being an impossibility, a discourse on scientific method was actually written by Aristotle, namely the Posterior Analytics.

(133) VI, 2.

(134) La Philosophie de la Nature p. 24.

(135) Lect. 21.

(136) Ibid., no. 2.

(137) Ibid., no. 6.

(138) Lectio 22.

(139) Lectio 15.

(140) Ibid., no. 4.

(141) Du Cheminement de la Pensée, p. 481.

(142) No. 4.

(143) No. 4.

(144) Ibid., nos. 5 - 7.

Chapter III

(1) In maintaining that philosophy of mathematics is an intermediary science between the second and third degrees of abstraction, Father Whittaker has confused the kind of application just mentioned with true subalternation. Cf. "The Position of Mathematics in the Hierarchy of Speculative Science," in the Thomist, Vol. III, No. 3, p. 496.

(2) Cf. John of St. Thomas: Curs. Theol., I, q. 1, d. 2, a. 6.

(3) Cf. Gilson: L'Esprit de la Philosophie médiévale, Paris Librairie, J. Vrin, 1932, P. 4: "Alors que le rationaliste pur place la philosophie au sommet et l'identifie à la sagesse, le néo-scolastique la subalterne à la théologie, qui reste seule à mériter pleinement le nom de sagesse; mais pourquoi certains néo-scolastiques pensent-ils que même subalternée à la théologie, leur philosophie demeure identique en nature à celle qui ne reconnaît aucune sagesse au-dessus d'elle."

(4) Cf. Ars. Logica: P. I, Q. XXVI, a. 2.

(5) In De Trinitate, VI, 1.

(6) The ancient Thomists sometimes called this type of dependance subalternation secundum quid, but denied that it was subalternation simpliciter. Cf. John of St. Thomas, Curs. Phil. Ars. Logica P. II, q. XXVI, a. 2, pp. 798.

(7) Loc. cit. p. 796.

(8) V, 1, ad 5.

(9) Ibid.

(10) Loco. Cit. p 796 b 43. Philosophy for John of St. Thomas means the science of nature.

(11) Cf. Fulton Sheen: "Furthermore, the more developed the empirical sciences the better is the raw material upon which metaphysics may speculate to build a scientia media

or the Philosophy of Nature." The Philosophy of Science, p. 189. "Just as the science of mathematical physics is formed by the application of mathematics to physics, so too, the science of the philosophy of nature is formed by the application of the fundamental principles of metaphysics to the natural sciences." Ibid. 164. Cf. Whitaker: "The philosophy of nature is the intermediary science between the physical and metaphysical orders." Op. cit. p. 505.

(12) Cf. Annibaldus: In I Sent. dist. 1, q. 1, a. 1: "Primarum scientiarum proximum principium est intellectus, earum vero scientiarum, quae sua principia ab aliis supponunt, proximum principium est credulitas principiorum ab aliis suppositorum; primum vero earum principium est intellectus. Perficitur tamen certitudo istarum scientiarum cum per viam resolutionis in ipsum intellectum primorum principiorum perveniunt."

(13) John of St. Thomas, Curs. Theol. I, q. 1, d. 2, a. 6 p. 369 b.

(14) Curs. Theol. I, q. 1, d. 2, a. 5, p. 364 a.

(15) In I, 1, 2.

(16) Curs. Theol. I, q. 1, d. 2, a. 5, p. 364 a.

(17) Curs. Phil. Ars Logica, II, q. XXVI, a. 3. pp. 799 ff.

(18) De Veritate XIV, 9.

(19) De Veritate, XIV, 9, ad 3.

(20) Curs. Theol. loc. cit. p. 369.

(21) In De Trinitate, V, 3, ad 6.

(22) Cf. Vassily Pavlov: "Mathematics for the Doctor in the Million," in Philosophy of Science, Vol. II, no. 1, p. 48: "...an effort has been made...to a pretense of applying the concrete sciences to the abstract ones. It has gone to the extent of naming new hybrids in inverse order as physical mathematics, (compare Einsteins' physical geometry:)...biological mathematics, and the like... ...To this writer it still looks like the application of mathematics to biology rather than the reverse."

(23) I, lect. 5, no. 7.

(24) In De Trinitate, V, 3, ad 7.

(25) In I Post. Anal., lect. 25, no. 2.

(26) Ars. Logica, Pars II, q. XXVI, a. 2, p. 797.

(27) Ars. Logica, Pars II, q. XXVII, a. 1, p. 827.

(28) "La Conception Scolastique de la Physique" in Philosophie et Sciences, pp. 48 - 49.

(29) In I, 1, 2.

(30) Ars Logica, Pars II, q. XXVI, a 2, pp. 798 - 799.

(31) Lest this definition seem to exclude a posteriori knowledge by which we know things through their effects, it is necessary to note that the term "cause" in the definition refers to the cause of science.

(32) Ars Logica, loc. cit. p. 798 b.

(33) Cf. James A. McWilliams: "Idealism in Science," in The Modern Schoolman, Vol 14, p. 7: "These scientists are, in their turn, victims of the initial error of grounding their partial science on another partial science, on mathematics instead of metaphysics."

(34) Loc. cit. p. 799.

(35) In I Post. chap. 12.

(36) I Post. Anal. lect. 25. no. 4.

(37) I Post. Anal. ch. 13, no. 6.

(38) In II Phys. lect. 3, no. 8.

(39) Substance and Function, p. 117.

(40) Cf. Physique et Philosophie", in Philosophie et Sciences, p. 86: "Dès que nous entrons en physique, nous ne traitons que de rapports entre grandeurs. Mais la physique ne devient pas pour cela de la mathématique, et il n'y a ici aucune attraction d'une science moins noble par une science plus noble. C'est le donné initial qui impose cette forme

mathématique à la physique. Les relations entre grandeurs variables sont données implicitement quand ces grandeurs sont données; mais il faut les expliciter et les synthétiser." Cf. also p. 81: "Puis tout se traduit en nombres concrets. Les nombres fournis par les instruments ne sont pas des nombres abstraits ni des êtres de raison mathématiques; ce sont des nombres 'qualifiés par l'instrument qui les a fournis'. 7 volts et 7 dégrés ne sont pas la même chose parce que le premier s'obtient avec un voltmètre et le second avec un thermomètre".

(41) In I Post. Anal. lect. 25, no. 4.

(42) Phys. II, 2

(43) In De Trin., V, 3, ad 6.

(44) Curs. Phil., Vol. II, Q. I, a. 1.

(45) In II Phys., lect. 3, no. 8. Many modern authors hold that in this passage St. Thomas is guilty of misreading Aristotle. Maritain, for example, has this to say: "Ici j'ouvre une parenthèse d'ordre historique, Aristote, en réalité, n'a pas dit cela expressement, c'est saint Thomas qui l'a dit en s'appuyant sur un texte d'Aristote pour notre plus grand profit mal compris. Aristote, au livre II de la Physique, chap. 2, 194 a, 7, parle de la connaissance mathématique, et il parle des parties des mathématiques qui sont plus physiques que les autres, qui concernent d'avantage les choses physiques, c'est ce qu'il appelle Τὰ φυσικώτερα τῶν μαθημάτων, les traducteurs modernes traduisent à bon droit: "les parties les plus physiques des mathématiques". Saint Thomas, au contraire, dans sa troisième leçon sur le Livre II de la Physique, entend qu'il s'agit non pas des parties les plus physiques des mathématiques, mais de sciences plus physiques que mathématiques, magis naturales quam mathematicae." — La Philosophie de la Nature, p. 36. Cf. also Mansion, op. cit. p. 27. In spite of the fact that a superficial reading of the Greek phrase cited by Maritain might seem to favor his interpretation, we prefer to believe that St. Thomas' reading of Aristotle is correct. There are three reasons. First, the rendition of St. Thomas is not incompatible with the construction of the Greek phrase. Secondly, the Latin translation which Saint Thomas followed was that made by William of Moerbeke, and it is considered

by the most competent of modern critics as extremely accurate. Thirdly, the exactness of the version of St. Thomas is clear from the whole paragraph in which the disputed phrase appears, for in it Aristotle shows precisely that optics, for example, is more physical than mathematical. In order to bring out this last point we give here the whole paragraph in Greek, together with William of Moerbeke's translation:

Δηλοῖ δὲ καὶ τὰ φυσικώτερα
τῶν μαθημάτων, οἷον ὀπτικὴ
καὶ ἁρμονικὴ καὶ ἀστρολογία·
ἀνάπαλιν γάρ τρόπον τινὰ
ἔχουσι τῇ γεωμετρίᾳ. Ἀλλ' ἡ
μὲν γεωμετρία περὶ γραμμῆς
φυσικῆς σκοπεῖ, ἀλλ' οὐχ ᾗ
φυσική· ἡ δ' ὀπτικὴ μαθηματικὴν
μὲν γραμμήν, ἀλλ' οὐχὶ ᾗ
μαθηματική, ἀλλ' ᾗ φυσική.

"Demonstrant autem et quae magis physica sunt mathematica, ut perspectiva et harmonica et astrologia: e contrario enim quodammodo se habent ad geometriam. Geometria quidem enim physicam intendit lineam, sed non inquantum est physica: sed perspectiva quidem mathematicam lineam, sed non inquantum mathematica, sed inquantum est physica.

(46) II - II, 9, 2, ad 3.

(47) Curs. Phil. II, q. I, a. 1.

(48) Cf. Fulton Sheen: "Every science is constituted of a material and formal object. The material object is what is studied; the formal object is the aspect or the how it is studied. The new mathematical physics is, from the material point of view, a science of the real world, but it soon leaves that concrete, real world to manipulate it in terms of mathematical symbols." — The Philosophy of Science, p. 85.

(49) Op. cit. p. 88.

(50) On the Method of Theoretical Physics, p. 12. Cf. The World As I See It, by the same author, pp. 52 - 54.

(51) Ibid. p. 7.

(52) Op. cit. p. 173 footnote.

(53) Du Cheminement de la Pensée, p. 488. In spite of the great fame that Poyarnon has won for himself in the philosophy of science, and especially in the historical background of sciences, we find it necessary to remark that throughout his many writings he has consistently misinterpreted Aristotelianism and Thomism.

Chapter IV

(1) Lect. 1, no. 1.

(2) Cf. I Met. c. 2, 982 a 17.

(3) Cf. De Coelo et Mundo, Procemium; De Generatione et Corruptione, Procemium; De Meteorologicis, I; De Anima, I, lect. 1; De Sensu et Sensato, lect. 1; De Partibus Animalium, II, c. 1; De Generatione Animalium, I, c. 1, etc.

(4) Lectio 1, no. 2.

(5) It is worth while noting in this connection that the scholastic manuals which make the study of nature a part of metaphysics are perfectly logical in placing the study of general metaphysics before that of cosmology and psychology.

(6) Cf. Harold R. Smart: The Logic of Science, New York, D. Appelton and Co., 1931, p. 80.

(7) The Analysis of Matter, New York, Harcourt, Brace and Co., 1927, p. 150.

(8) Cf. Whitehead: Science and the Modern World, p. 41: "Nothing is more impressive than the fact that as mathematics withdrew increasingly into the upper regions of ever greater extremes of abstract thought, it returned back to earth with a corresponding growth of importance for the analysis of concrete fact. . .
The paradox is now fully established that the utmost abstractions are the true weapons with which to control our thought of concrete fact."

(9) Translation by H.F. Hardie and L.S. Gaye.

(10) Lect. 1, no. 6.

(11) Cf. St. Thom: In I Post. Anal. lect. 4, no. 10: "In omni enim generatione, quod est in potentia est prius tempore et posterius natura, quod autem est completum in actu est prius natura et posterius tempore. Cognitio autem generis est quasi potentialis in comparatione ad cognitionem speciei, in qua actu sciuntur omnia essentialia rei. Unde in generatione scientiae nostrae prius est cognoscere magis communia quam minus communia." Cf. John of St. Thom, Logica II, q. I, a. 1.

(12) I, lect. 1, no. 1.

(13) De Pot. III, 2, ad 2.

(14) pp. 128 - 129.

(15) "Que si, cependant, on considère les limites de ce qu'on entendait ainsi déduire, on s'aperçoit que Hegel est resté bien en deçà de son modèle. Aristote et ses sectateurs au moyen âge, nous l'avons vu à propos de Carsonide, limitaient sans doute la déduction à l'universel, mais ces universaux comprenaient tout ce qui constituait la science, puisque celle-ci ne peut traiter que du genre. Hegel ne déclare déductibles que certains aspects très généraux de la science, tout le reste étant issu de l'arbitraire, de la nature et justiciable seulement de savoir empirique. C'est qu'en dépit de toute son 'arrogance logique', la philosophie hégélienne est obligée de tenir compte de ce fait qu'un énorme acquis scientifique s'interpose entre elle et les derniers sectateurs de la physique péripatétique, et que cette évolution lui interdit de pousser sa régression au delà de certaines limites." pp. 476 - 477.

(16) No. 8.

(17) In II Phys., lect. 6, no. 5; De Trin. V, 4, 1ete.

(18) Méthodologie Scientifique, Laval, p. 26.

(19) Cf. for example Rey: "La Physique scolastique avait la prétention d'atteindre directement les propositions générales dont se déduisait le système complet de la nature. Contre cette prétention s'éleva la physique de la Renaissance." — La Théorie Physique, p. 344.

(20) De Partibus Animalium, Ch. 5. Transl. by Ogle.

(21) I, c. 2, 316 a 5 - 15.

(22) Cf. C. Singer: The Story of Living Things, pp. 9 - 44; "The Birth of Science Among the Greeks" in Sc. of Modern Knowledge, pp. 1415 - 1427.

(23) De Trin. VI, 2.

(24) The Philosophy of Physical Science, p. 10.

(25) Lect. 14, no. 8. Cf. In XII Met. lect. 12.

(26) Cf. Phys. II, lect. 2.

(27) Loc. cit. Cf. also page 133: "Ainsi le panlogisme péripatéticien et le panmathématisme et panpédantisme platonicien et moderne se rencontrent dans cette foi en la rationalité complète, et, partant, en la déductibilité de la nature."

(28) The Mysterious Universe, pp. 123 - 124.

(29) Cf. Spinoza: Ethics, Part I, Prop. XXIX: "Things could not have been produced by God in any other way or in any other order than the way and the order in which they have been produced."

(30) "None of even the relatively gross structures that the microscope has revealed was suspected to exist before it was seen." — Yves Delage. Cited by W.R. Thompson, Science and Common Sense, p. 45.

(31) Paul Valery. Cited by Louis De Broglie: Matière et Lumière, p. 318.

(32) Cf. Meyerson, Identité et Réalité, p. 368: "On ne peut mieux caractériser les traits distinctifs de cette méthode que ne l'a fait Paul Tannery: 'D'une part, tendance à s'attacher aux phénomènes tels que les sens les révèlent à l'observation superficielle et grossière, on peut même dire respect marqué pour les croyances vulgaires, du moment où elles ne sont pas visiblement erronnées; d'autre part, tendance à remonter le plus haut possible et le plus tôt possible dans la série des causes, mais cela par simple analyse du concept et sans aucun retour nouveau à l'expérience.' Les Principes de la science de la nature chez Aristote" in Congrès de Philosophie, 1900, Vol. IV, p. 214.

(33) Principia, III Pars, ch. 1. Cf. Lettre à Vorstius (1632) Ed. Adam et Tannery, t. I, p. 250: "Je suis devenu si

hardi que j'ose maintenant chercher la cause de la situation de chaque étoile fixe."

(34) Science et Hypothèse, p. 168.

(35) De Coelo, III, c. 7, 306 a 5 ff. Trans. by J.L. Stocks.

(36) De Coelo, I, c. 3, 270 b 10.

(37) Lect. 7, no. 6. Cf. lect. 3: "Unde hoc non est demonstratum sed suppositio quaedam."

(38) Ch. 12.

(39) Lect. 17, nos. 1 and 2.

(40) I q. 32, a. 1, ad.2. Cf. In I Meteor. lect. 11, no. 1: "Postquam Philosophus reprobant opiniones aliorum, hic incipit ponere opinionem propriam de comitia. Et primo ostendit modum certitudinis qui est in hac materia exquirendus. Et dicit quod de talibus quae sunt immanifeste sensui, non est exquirenda certa demonstratio et necessaria, sicut in mathematicis et in his quae subiacent sensui; sed sufficit per rationes demonstrare et ostendere causam ita quod quaestionem solvamus per aliquam solutionem possibilem, ex qua non sequatur aliquod inconveniens, per ea quae hic apparent secundum sensum. Unde hoc modo in proposito ad habendam causam est procedendum." Cf. also In XII Met. lect. 10, no. 2586., etc., etc.

(41) Cf. La Théorie Physique, pp. 54 ff.

(42) Prodromus Dissertationum Cosmographicarum, Continens Mysterium Cosmographicum, in Joannis Keplerl Astronomi Opera Omnia, t. K, p. 112 - 165 — Cited by Duhem, op. cit. p. 88.

(43) Op. cit. p. 89.

(44) Cf. Meyerson: De l'Explication dans les Sciences, p. 100: "Pour Comte, en effet, les lois découvertes, si elles atteignent un certain degré de généralité (comme, par exemple, la loi de Mariotte), doivent demeurer à tout jamais. Toute recherche ultérieure tendant à les ébranler, ou seulement à en modifier ou à en préciser le contenu, est jugée parfaitement oiseuse et doit être rigoureusement proscrite. C'est là un thème sur lequel Comte est revenu à maintes reprises et au sujet duquel il s'est exprimé avec

l'énergie la plus grande. Accumulant les termes de réprobation, il a déclaré 'incohérents ou stériles', procédant d'une 'curiosité toujours vaine et gravement perturbatrice', d'une 'puérile curiosité stimulée par une vaine ambition', les travaux où l'on se sert d'instruments de mesure trop précis; il a protesté hautement contre 'l'abus des recherches microscopiques et le crédit exagéré qu'on accorde trop souvent encore à un moyen d'investigation aussi équivoque.'"

(45) Posterior Analytics, I, c. 27, 87 a 30 ff. — Trans. by G.R.G. Mure.

(46) Cf. Meyerson: "L'irrationnel scientifique ressemble donc, à certains égards, à celui que, selons Renouvier, constituerait un acte de libre arbitre; il représente aussi dans un ordre de considérations tout différent il est vrai, un 'commencement absolu.'" De L'Explication dans les Sciences, p. 545.

(47) Cf. infra Ch. VI.

(48) Lect. 41, no. 3.

(49) Met. II, C. 1, 993 b 3. Trans. by W.D. Ross.

(50) Cf. St. Thomas, In De Trin. V, 1.

(51) Curs. Phil., I, p. 767 b 28 - 41.

(52) "Le Problème de l'indéterminisme" in L'Académie Canadienne Saint Thomas d'Aquin, Sixième Session, Québec, 1937, Extr. l'Action Catholique, p. 67.

(53) Curs. Phil, I, p. 200. Cf. p. 790.

(54) Cf. infra Chapter VI.

(55) Cf. John of St. Thomas: Logica p. 60.

(56) Cf. e.g. Bertrand Russell: "The general principles of science, such as the belief in the reign of law, and the belief that every event must have a cause, are as completely dependent upon the inductive principle as are the beliefs of daily life. All such general principles are believed

(70) Introduction to Meet Mr. Man Made of Man, pp. xi - xii. Cf. Dotterer: Philosophy by way of the Sciences: "If then, while including the descriptions arrived at by common sense within the class of genuine descriptions of reality we should deny this status to the results attained by scientific research, our attitude toward science would seem to imply the principle that the more pains we take in trying to discover the nature and structure of the natural world, the less likely we are to succeed in the attempt." New York, the Macmillan Co., 1929, p. 297.

(71) "Les Sciences expérimentales sont-elles distinctes de la philosophie de la nature?" in Culture, 1941, IV, p. 473.

(72) The Philosophy of Physical Science, p. 8.

(73) In Met. I, lect. 1. Cf. In I Sent. d. 38, q. 1, a. 5, c.

(74) Cf. Duhem: La Théorie Physique, p. 348: "Si donc l'interprétation théorique enlève aux résultats de l'expérience de Physique la certitude immédiate que possèdent les données de l'observation vulgaire, en revanche, c'est l'interprétation théorique qui permet à l'expérience scientifique de pénétrer bien plus avant que le sens commun dans l'analyse détaillée des phénomènes, d'en donner une description dont la précision dépasse de beaucoup l'exactitude du langage courant." Cf. also Pp. 346 - 347.

(75) An exception to this last statement is found in divine knowledge.

(76) De L'Explication dans les Sciences p. 214. Cf. Cheminement de la Pensée, p. 58.

(77) La Théorie Physique, p. 89. Cf. p. 407.

(78) Cf. Meyerson: Identité et Réalité, p. 20: "La loi qui régit l'action du levier n'envisage que le 'levier mathématique'; or, nous savons fort bien que nous ne rencontrerons jamais rien de pareil dans la nature. De même nous n'y rencontrerons jamais les 'gaz idéaux' de la physique ni les cristaux tels que nous les montrent les modèles cristallographiques. . . On connaît l'ensemble formidable de travaux auxquels il a dû se livrer pour obtenir de l'argent à peu près chimiquement pur; on sait

d'ailleurs qu'il avait choisi ce corps comme point de départ de ses déterminations parce qu'il lui paraissait offrir le plus de facilités, et l'on sait aussi que l'argent obtenu par lui n'était pas réellement pur, de sorte qu'il a fallu depuis rectifier les résultats auxquels il était parvenu. On peut voir, par cet exemple topique, combien le substrat même de la loi, le concept généralisé, est close de notre pensée." Cf. also De L'Explication dans les Sciences, pp 23, 26, etc.

(79) Substance and Function and Ein Theory of Relativity. p. 130.

(80) Preface to the second edition.

(81) Theoretical Biology, Introduction.

(82) "La seule science qui mérite proprement ce nom est celle dont la certitude est apodictique; la connaissance qui ne peut contenir d'une certitude empirique est ce qu'on n'appelle qu'improprement un savoir." un savoir théorique "ne mérite le nom de science de la nature que dans le cas où les lois de la nature qui en sont le fondement sont connues a priori et ne sont pas de simples lois de l'expérience." Kant: Premiers Principes Métaphysiques de la Science de la Nature, French transl. by Andler et Chavannes, Paris, 1902, p. 4. Cited by Meyerson: De L'Explication dans les Sciences, p. 458.

(83) Science et Hypothèse, p. 170. Cf. Whitehead: Process and Reality, p. 22: "Every scientific memoir in its record of the 'facts' is shot through and through with interpretation." And Schrodinger writes: "We cannot close the door to the entry of subjective factors in determining our scientific policy and in giving a definite direction to our line of further advance."—Science and the Human Temperament, New York, W. W. Norton and Co., 1935, p. 87.

(84) Pp. 39, 44, 53.

(85) Pierre Duhem is particularly eloquent on this point. He has shown with great penetration that what Bernard says is true of biological and medical science, applies with infinitely greater force to physics, in which the part

because mankind have found innumerable instances of their truth, and no instances of their falsehood. But this affords no evidence for their truth in the future unless the inductive principle is assumed." Problems of Philosophy, London, Thornton Butterworth, Ltd., 1912, p. 107.

(57) Cf. e.g. Mansion: "De ces données — encore incomplètes — il faudrait conclure: pour Aristote, la science —prise au sens moderne du mot ou dans un sens analogue — n'existe pas." Op. cit. p. 19.

(58) Cf. e.g. texts of Maritain considered in ch. II.

(59) Ch. 1, 642 a 5.

(60) Ch. 5, 645 a 5.

(61) Essay Concerning Human Understanding, IV, ch. 12 sect. 10.

(62) Cf. St. Thomas: In I Eth. lect. 4, no. 58:. . . Et quia nos rationicinando notitiam acquirimus, oportet quod procedamus ab his quae sunt magis nota nobis; et si quidem eadem sunt magis nota nobis et simpliciter, tunc ratio procedet a principiis, sicut in mathematicis. Si autem alia magis nota sint simpliciter, et alia quoad nos, tunc oportet a conventer procedere sicut in naturalibus et moralibus." Cf. also In I Poster. Anal. lect 4, no. 16. This is just one of the several points in which modern scholastics have made philosophy a kind of mathematics.

(63) Lect. 6, no. 10.

(64) Philosophy of Science p. 167.

(65) Cited by Thompson: Introduction to Science, pp. 124 - 125. Cf. also Cohen and Nagel: An Introduction to Logic and Scientific Method, New York, Harcourt, Brace, and Co., 1934, p. 149.

(66) Cf. Rey: La Théorie Physique: "La relativité des connaissances physico-chimiques leur permet de croire à côté de ces connaissances à des affirmations au sujet desquelles

la physique est incompetente. Elle ne leur permet pas d'en connaître l'objet." p. 367.

(67) Physics of the Twentieth Century, New York, The Philosophical Library, 1944, p. 142. Cf. Dingle: Through Science to Philosophy: "If, without violating the principles on which physics and biology have developed science can extend its correlations over the whole of experience it will become philosophy." p. 34. Cf. also Whitehead: Process and Reality, Cambridge University Press, 1929, pp. 12 - 13.

(68) La Philosophie de la Nature, p. 141. We believe that Maritain's error is at least partially due to the fact that he looks upon the whole of philosophy as pedagogically posterior to the experimental sciences. He writes: "Il y a, c'est bien sûr, une forte dépendance matérielle de la philosophie à l'égard des sciences. Tout d'abord, dans la hiérarchie des connaissances la philosophie est assez le terme culminant, et qui par suite vient pédagogiquement en dernier lieu. — Les Degrés Du Savoir, p. 101. In our opinion the correct pedagogical order of the speculative sciences is as follows: mathematics, philosophy of nature, the experimental sciences, metaphysics. We shall try to explain in chapter VI why mathematics is put in the first place: of all the speculative sciences it has the greatest harmony with the human mind. That is why there are child prodigies in mathematics and not in the other speculative sciences.

(69) The simplicity and commonness of the experience that is sufficient for philosophy of nature has led some authors to make of philosophy a kind of logic. Thus Professor Watson writes: "The student of philosophy already knows how to speak in the manner that is understood by his fellow in every-day affairs. When he begins philosophy, questions are asked which he can answer without learning new facts about the world...It must be the nature of philosophical problems that their solution does not have to await the becoming of facts. It must be irrelevant to philosophy what actually happens in the world. If this were not so how would philosophy differ from the sciences whose business is with facts." — Of Understanding Physics, Cambridge University Press, 1938, p. 6. cf. also p. 21.

that theory plays is so great. Cf. La Théorie Physique, pp. 278 - 278, et passim. "L'enseignement de la Physique par la méthode purement inductive, telle que l'a définie Newton, est une chimère. Celui qui prétend saisir cette chimère se leurre et leurre ses élèves. Il leur donne pour faits vus des faits simplement prevus; pour procédés réalisables, des expériences purement idéales; pour lois expérimentales, des propositions dont les termes ne peuvent sans contradiction, être pris comme exprimant des réalités. La Physique qu'il expose est une Physique fausse et falsifiée." p. 309.

(86) Du Cheminement de la Pensée, p. 468.

(87) Cf. Meyerson: "De plus, exposés dans hypothèses, les résultats experimentaux nous apparaissent comme quelque chose de définitif, d'achevé, sans que nous apercevions la voie qui y a mené, ni celle qui pourra nous conduire plus loin; car la science n'est pas baconienne, et l'expérience seule, sans le secours de l'hypothèse, ne saurait y mener bien loin. C'est ce qui fait que l'image de la science ou d'une partie de la science que l'on nous offre ainsi sera en quelque sorte statique, alors que la science se trouve en réalité dans un flux perpetuel et dynamique." — Identité et Réalité, p. 466.

(88) Where is Science Going? p. 97 Cf. Jeans: The New Background of Science, pp. 46 - 47.

(89) Du Cheminement de la Pensée, p. 45.

(90) Cf. Lindsay and Margenau: Foundations of Physics, New York, John Wiley and Sons, Inc., 1936, pp. 4 - 5.

(91) Cf. Cassirer: Nevertheless it would be a mistake to assume that exact science, owing to this characteristic feature of its concepts, withdraws more and more from the tasks offered by concrete empirical existence. Precisely in this apparent turning away from the reality of things, science is directed upon them in a new way." "They only go beyond the given in order to grasp the more sharply the systematic structural relations of the given." — Substance And Function and Einstein's Theory of Relativity, pp. 228 - 229, 128.

(92) Cf. Jules Tannery: Science et Philosophie, pp. 322 - 333: "Je pourrais bien ne pas parler de la masse puisque c'est une unité fondamentale et non une unité dérivée, mais je ne vois aucun inconvénient à ce qu'on définisse la masse d'un corps en décrivant la façon dont on fait une pésée (une double pésée, si l'on veut) au moyen d'une balance. Si l'on equilibre avec des grammes on dira que la masse en grammes est exprimée, ou encore, qu'on a pris le gramme pour unité de masse; c'est la même chose. Quant au 'gramme' il ne me viendrait nullement que les élèves pensassent au petit cylindre de cuivre que l'on sait, mais il est bien entendu que pour satisfaire tout le monde on parlera du morceau de platine irradié, etc... en n'oubliant pas, si l'on veut être dans le train, de dire que ce morceau de platine est déposé au pavillon de Bellevue, et non aux archives. Je sais bien qu'on tirera au cercle vicieux, . . "

(93) Cf. Eddington: The Philosophy of Physical Science, p. 70.

(94) Cf. Eddington: The Philosophy of Physical Science, p. 189: "Reference may also be made to another general philosophical system, namely logical positivism. Our insistence that physical quantities are to be defined in such a way that the assertions of physics admit of observational verification, may suggest an affinity with logical positivism. The meaning of a scientific statement is to be ascertained by reference to the steps which would be taken to verify it. This will be recognised as a tenet of logical positivism — only it is there extended to all statements. When it is limited as here to items of physical knowledge, it is in no sense a philosophical tenet; it is only a bringing into line of the language of theoretical and of experimental physics, so that we may not claim the support of observation for assertions which have no observational foundation. If it were a general characteristic of knowledge, it would not be so useful to us in discriminating physical knowledge from other kinds of knowledge. We are therefore not particularly predisposed to favour the more general assertion of logical positivism that the meaning of all non-tautological statements is to be ascertained in the same way, namely by reference to the procedure of verifying them."

(95) Pp. 1 - 4. Cf. The Nature of the Physical World, pp. 184 - 185: "Our knowledge of the external world cannot be divorced from the nature of the appliances with which we have obtained the knowledge. The truth of the law of gravitation cannot be regarded as subsisting apart from the experimental procedure by which we have ascertained its truth. The conception of frames of space and time, and of the non-emptiness of the world described as energy, momentum, etc., is bound up with the survey by gross appliances. When they can no longer be supported by such a survey, the conceptions melt away into meaninglessness." Et passim. For a detailed analysis of the meaning of operationalism and its implications cf. Percy Bridgman: The Logic of Modern Physics, New York, The Macmillan Co., 1932., and The Nature of Physical Theory. Princeton University Press, 1936.

(96) Méthodologie Scientifique, p. 16.

(97) Principles of the Quantum Theory, p. 3.

(98) Loc. cit.

(99) Cf. St. Thomas: "Sunt enim quidam, qui veritatem intelligibilem capere non possunt, nisi eis particulatim per singula explicetur. Et hoc quidem ex debilitate intellectus eorum contingit." I, 55, 3.

(100) Cf. Einstein: Introduction to Where is Science Going? p. 13: "In every important advance the physicist finds that the fundamental laws are simplified more and more as experimental research advances. He is astonished to notice how sublime order emerges from what appeared to be chaos." Cf. also Hermann Weyl: The Open World, p. 41: "The astonishing thing is not that there exist natural laws, but that the further the analysis proceeds, the finer the details, the finer the elements to which the phenomena are reduced, the simpler — and not the more complicated, as one would originally expect — the fundamental relations become and the more exactly do they describe the actual occurences."

(101) Physics, Bk. II

(102) Cf. Boutroux: De L'Idée de la Loi Naturelle dans la Science et dans la Philosophie, p. 42.: Les lois mécaniques ne peuvent donc être considérées comme réalisées telles quelles dans la nature des choses. Les concepts dont elles se composent deviennent intelligibles quand on a fait des êtres."

(103) Les Principes de la Physique, (adaptation of Physics, The Elements), Paris, Librairie Felix Alcan, 1929, p. 22.

(104) La Théorie Physique, p. 282.

(105) The Philosophy of Physical Science, pp. 66 - 67.

(106) Cf. Einstein and Infeld: Evolution of Physics, pp. 11 - 12 Eddington: The Nature of the Physical World, pp. 126 ff.

(107) For other examples cf. Duhem, op. cit. pp. 325 - 327.

(108) Cited by Duhem, op. cit. p. 318.

(109) The Nature of the Physical World, p. 254.

(110) L'Evolution des Idées en Physique, Paris, Flammarion, 1938, p. 286. Cf. Meyerson, De L'Explication, etc. p. 60.

(111) Cf. Louis De Broglie: Matière et Lumière, Paris, Editions Albin Michel, 1937, pp. 319 - 320.

(112) Cf. Einstein: The World as I See It, pp. 35 - 36: "The natural philosophers of those days were, on the contrary, most of them possessed with the idea that the fundamental concepts and postulates of physics were not in the logical sense free inventions of the human mind but could be deduced from experience by 'abstraction' — that is to say by logical means. A clear recognition of the erroneousness of this notion really only came with the general theory of relativity, which showed that one could take account of a wider range of empirical facts, and that too in a more satisfactory and complete manner, on a foundation quite different from the Newtonian. But quite apart from the question of the superiority of one or the other, the fictitious character of the fundamental principles is perfectly evident from the fact that we can point to two essentially different principles, both of which correspond with experience to a large extent; this proves at the same time that every attempt at a logical deduction

of the basic concepts and postulates of mechanics from elementary experiences is doomed to failure."

(113) Cf. Arist: I Anal. Post., 22: "Nam ab effectu qui a pluribus causis procedere potest, non potest una illarum concludi."

(114) Cf. Meyerson: "Une science privée de théorie apparaîtrait en quelque sorte comme entièrement achevée, statique, alors que la vraie science, nous le sentons, doit être en flux, evoluer, progresser. — De L'Explication, etc. p. 58.

(115) For an excellent example of how science advances by successive theoretical syntheses, see Louis de Broglie, Matière et Lumière, pp. 157 - 177.

(116) Cf. Duhem, op. cit. pp. 208 - 269; Rey, op. cit. p. 194, etc.

(117) Cf. Cassirer: "It is only owing to the fact that science abandons the attempt to give a direct, sensuous copy of reality, that science is able to represent this reality as a necessary connection of grounds and consequents. It is only through going beyond the circle of the given, that science creates the intellectual means of representing the given according to laws."—op. cit. pp. 164 - 165. Cf. p. 280.

(118) Cf. Petit, C.S.C.: Méthodologie Scientifique, p. 10: "Au-dessus du sujet, au delà de l'objet immédiat, la science se fonde sur le projet. Dans la pensée scientifique, la méditation de l'objet par le sujet prend toujours la forme du projet."

(119) L'Intellectualisme de St. Thomas d'Aquin, Paris, Beauchesne, 1924, p. 146.

(120) Cf. Curs. Phil. I, ed. Reiser, p. 86 a 18; 87 a 49 - b 23.

(121) Cf. St. Thomas: "A forma quae est in anima nostra procedit forma quae est in materia in artificialibus, in naturalibus autem e contrario." In Met. VII.

(122) V, 1, ad 3. In the context of this passage St. Thomas mentions explicitly only logic and mathematics, but from the examples he cites it is evident that he includes mathematical physics under mathematics.

(123) I, 93, 1.

(124) Cf. Goethe: "Hypotheses are the scaffolds which are erected in front of a building..." in Maxims and Reflections. Cited by Frank: Between Physics and Philosophy, p.53, Cf. also von Bexkull, loc. cit. p.x.

(125) Cf. e.g. Sir James Jeans: The New Background of Science: "The history of physical science in the twentieth century is one of a progressive emancipation from the purely human angle of vision." p.5. Cf.pp. 227 - 228.

(126) Op. Cit. p. 445.

(127) Cf. Niels Bohr: "The present day situation in physics brings forcefully home to us the old adage that we are actors as well as spectators of the grand drama of existence." Cited by Robins Gentzin: Aspects of Science, p. 135.

(128) Evolution Créatrice, pp.151, 101, 356. Cf. Matière et Mémoire, 3e Ed. Paris 1905, p.201.

(129) Les Principes de la Physique, p.166

(130) "L'Outillage Mental," in Encyclopedie Francaise, Paris 1937. Cited by Apple: Dialectics and Experimental Biology, p.20

(131) Cf. C. de Koninck: De La Primauté du Bien Commun Contre les Personnalistes, Editions de l'Université Laval, Québec, 1943, pp. 159 ff.

(132) Experience and Nature, pp. 357 - 358. Cf. also The Quest for Certainty, p. 252; "The doctrine that nature is inherently rational was a costly one. It entailed the idea that reason in man is an outside spectator of a rationality already complete in itself. It deprived reason in man of an active and creative office; its business was simply to copy, to re-present symbolically, to view a given rational structure. Ability to make a transcript

of this structure in mathematical formulas gives great delight to those who have the required ability. But it does nothing; it makes no difference in nature. In effect, it limits thought in man to retraversing in cognition a pattern fixed and complete in itself. The doctrine was both an effect of the traditional separation between knowledge and action and a factor in perpetuating it. It relegated practical making and doing to a secondary and relatively irrational realm."

(133) Onze Thèses sur Feuerbach, pp. 87, 95. Cf. Jean Langevin: "Sciences et Industrie" in A la lumière du Marxisme, p. 114: "La méthode expérimentale, est véritablement active, puisqu'elle consiste précisément à maîtriser ou à modifier les circonstances naturelles. C'est à elle, en premier lieu que s'applique la phrase de Goethe: 'Au commencement de tout, il y a l'action.'"

(134) Freedom Versus Organization, New York, 1934, p. 192. Nor was Hitler unaware of the essential meaning of Marxism, as the following passage clearly indicates: "Ce qui reste du marxisme, c'est la volonté de construction révolutionnaire, qui n'a plus besoin de s'appuyer sur des béquilles idéologiques et qui se forge un instrument de puissance implacable pour s'imposer aux masses populaires et au monde tout entier. D'une téléologie à base scientifique, il sort ainsi un vrai mouvement révolutionnaire, pourvu de tous les moyens nécessaires à la conquête du pouvoir. Et quel est le but de cette volonté révolutionnaire? Il n'y a pas de but précis. Rien qui soit fixé une fois pour toutes. Avez-vous tort de peine à comprendre cela? Nous sommes en mouvement. Voilà le mot qui dit tout...mais nous savons, nous qu'il n'y a pas d'état définitif, qu'il n'y a rien de durable, qu'il y a une évolution perpétuelle. Ce qui ne se transforme pas, c'est ce qui est mort. Le présent est déjà passé. Mais l'avenir est le fleuve inépuisable des possibilités infinies d'une création toujours nouvelle." in Hermann Rauschning: Hitler M'a Dit, pp. 211 - 214 -- Cited by C. De Koninck. Méthodologie scientifique, 1939, p. 7.

(135) Morceaux Choisis, p. 822.

(136) Cf. Poincaré: "C'est la commune façon qui est le but et l'action qui est le moyen." --Sciences et Hypothèses, p. 258.

(1) Physics and Philosophy, pp. 179, 181.

(2) The Mysterious Universe, pp. 138, 111. cf. The New Background of Science, p. 60.

(3) Cf. The Scientific Outlook, p. 88.

(4) Cf. Reg. II and III.

(5) New Pathways in Science, p. 24.

(6) Cf. John of St. Thomas, Ars. Logica, p. 639.

(7) I, lect. 20.

(8) Lect. 20, no. 574.

(9) Cf. St. Th. In Met VII, lect. 2, no. 1380: "Et quia posset aliqui videri, quod ex quo philosophus ponit omnes modos, quibus dicitur substantia, quod hoc sufficeret ad sciendum quid est substantia; ideo subjungit dicens, quod nunc dictum est quid sit substantia 'solum type', idest dictum est solum in universali, quod substantia est illud quod non dicitur de subjecto, sed de quo dicuntur alia; sed oportet non solum ita cognoscere substantiam et alias res, scilicet per definitionem universales et logicam: hoc enim non est sufficiens ad cognoscendum naturam rei, quia hoc ipsum quod assignatur pro definitione tali, est manifestum; Non enim huiusmodi definitione tanguntur principia rei, ex quibus cognitio rei dependet; sed tangitur aliqua communis conditio rei per quam talis notificatio datur."

(10) For other examples cf. Post. Anal. lect. 27, no. 7; lect. 33, nos. 1 - 2; lect. 38, no. 6.

(11) Cf. III Phys. lect. 8, nos. 1 - 4. When in this passage St. Thomas points out that the arguments of Aristotle for finiteness of bodies are purely dialectical because they proceed ex communibus, he does not mean common principles such as are found in the second type of dialectical reasoning, but principles that are commonly accepted and hence probable.

(12) Cf. St. Thomas lect. 2, nos. 24 - 28; cf. also St. Albert the Great; De Anima, I, tract. 1, cap. 7: "Physicus autem et dialecticus diffiniunt differenter unumquodque istorum quae dixiram esse animae opera et passiones. Si enim quaeriras quid est ira, intendentes de diffinitione quarere, dicet dialecticus quod est appetitus contrarii doloris, aut aliquid huiusmodi diffiens per intentiones communes formales, quae non sunt vera causa rei propria, sed intentiones communes inventae in pluribus et nulli propriae; et ideo diffinit per formam quae forma de se communis est, et non appropriatur ad esse rei nisi per proprium materiam uniuscuiusque rei. Physicus autem dicet quod ira ascensus vel ascensus et calefactio sanguinis circa cor, tangens propriam causam efficientem quae est ascensus et calefactio sanguinis, et propriam materiam quae est sanguis cordis bulliens, et subjectum quod est cor. Et horum quidem alius reddit materiam propriam scilicet physicus; alius autem reddit speciem et intentionem formae simplicem et communem quae est rei ratio communis. Hic enim considerat rationem sive intentionem communem rei, eo quod non descendit ad propria; ille autem considerat principia realia quae dant esse rei. Necessarium autem est quod ista realia principia sint in materia huiusmodi quae determinata et propria est, si erunt et habent esse in natura."

(13) Lect. 5, no. 9.

(14) Cf. Cajetan, in I, 17, 3, nos. 7 - 8.

(15) Cf. St. Thomas In I Sent. d. 38, q. 1, a. 5, c: "In istis causis effectus futuri non habent certitudinem absolutam, sed quandam, inquantum sunt magis determinatae causae ad unum quam ad aliud; et ideo per istas causas potest accipi scientia conjecturalis de futuris, quae tanto magis erit certa quanto causae sunt magis determinatae ad unum; sicut est cognitio medici de sanitate et morte futura, et judicium astrologi de pluviis et ventis futuris."

(16) Topics, I, 1, 100 b 21 - 23.

(17) 121 b 2 - 3.

(18) I, 1, 1355 a 14.

(19) Ibid.

(20) In I Top. c. XII, no. 4.

(21) In his Commentary on the Topics, St. Albert the Great brings out the meaning of probability and its connection with dialectics: "Probabilia autem sunt verisimilia. Dupliciter autem verisimilia: aut enim in se sunt verisimilia, eo quod ipsa habitudo praedicati ad subjectum verisimilis est, eo quod nec praedicatum est in subjecto per se, nec subjectum in praedicato per se, nec utrumque in utroque, nec praedicatum necessarium et essentialem inhaerentiam habet cum subjecto, sed verisimile est in signis non in causis necessariis acceptum. Aut quia necessariam habet inhaerentiam, sed non accipitur nisi per signum; et hoc est probabile secundum modum acceptionis, quamvis in se sit necessarium: sicut solem esse majorem terra (eo quod ubique unius quantitatis apparet) probabiliter acceptum est. Solem autem esse majorem terra per quantitatem diametri acceptum est necessarium et non probabile, secundum quod probabile et necessarium opponuntur. Probabile autem sic dictum verisimile est quod per suipsius veritatis figuram videtur omnibus aut pluribus aut sapientibus, et his sapientibus videtur omnibus aut pluribus aut maxime notis et probabilibus: ita quod sapientibus et his vel omnibus sapientibus vel pluribus vel maxime notis vel probabilibus, totum pro uno membro ponatur.
"Signa vero verisimilitudinis, aut occurrunt statim in superficie et in exterioribus rei quae accipit sensitiva potentia comparans sensata ad invicem: et si talia sunt signa, probabile est quod videtur omnibus, sicut nivem esse albam per hoc quod nix est parvae partes perspicui in parva conjuncti, in duius partibus undique lux diffunditur: hoc enim signum sensui est notum. Si autem signa indicium facientia de verisimilitudine sunt non in superficie, sed aliqualiter profundata, nec ad necessaria, sed nec in superficie extrinsecus manentia: tunc est id quod videtur pluribus: quia sensui aliquis miscent rationis, sicut quod stella in cauda minoris ursae sit polus, eo quod non deprehenditur eius singularis status: hoc enim rationis judicium sensui est [illegible]. Si autem signum

permistum
?

verisimilitudinis profundatur in essentialium et convertibilium causas quae sunt convertibilia sicut causae: tunc est quod videtur sapientibus, sicut est, quod luna moveatur in epiciclo: quia profundius et altius transit per umbram terrae: hoc enim non est causa sed signum.

"Ideo illud quod videtur sapientibus gradus habet, quia aut videtur omnibus, aut pluribus, aut maxime notis vel probabilibus. Quia signum convertibile cum causa, vel apparet mixtum sensui, et tunc videtur omnibus: vel in ipsis substantialibus profundatur, et tunc non videtur nisi probatis et probabilibus sapientibus vel medio est acceptum, et hoc dupliciter. Si enim plus est inclinatum ad sensum: tunc est quod videtur pluribus sapientibus. Si autem plus est profundatum ad necessaria essentialia et intellectualia: tunc est quod videtur maxime notis, qui ex potestate scientiae et artis hoc deprehendere noverunt. Hoc igitur est probabile, ex quo fit syllogismus dialecticus, quod tali et taliter diversificato deprehenditur signo. Haec est sententia communi Arabici: et sic scientia demonstrativi et etiam dialectici syllogismorum determinata est." — Lib. I, tract. I, Ch. 2.

(22) Indetermination in things may, of course, be a cause of the indetermination in the mind that is proper to opinion, as St. Thomas points out on numerous occasions, but this latter indetermination may also be had when things are objectively determined. Cf. De Veritate, XV, 2, ad 3: "Sunt autem quaedam in quibus non est possibile talem resolutionem facere ut perveniatur usque ad quod quid est, et hoc propter incertitudinem sui esse; sicut est in contingentibus in quantum contingentia sunt: unde talia non cognoscuntur per quod quid est, quod erat proprium obiectum intellectus, sed per alium modum scilicet per quasdam conjecturam de rebus illis de quibus plena certitudo haberi non potest. Unde ad hoc alia potentia requiritur. Et quia haec potentia non potest reducere rationis inquisitionem usque ad suum terminum quasi ad quietem, sed consistit in ipsa inquisitione quasi in motu, opinionem solummodo inducens de aliis quae inquirit; ideo quasi a termino suae operationis haec potentia ratiocinativum vel opinativum nominatur." Cf. also De Anima III, lect. 16.

(23) Cf. St. Albert the Great, In Perihermeneias, I, tract. II, c. 5, p. 495 b, Vives T. I.: "Sed attende quod licet nomen infinitum nihil ponat et nihil significet, non tamen est vox non-significativa ut britebaf: quia vox non-significativa non excitat intellectum ad aliquid de aliquo intelligendum, sed non-homo excitat ad intelligentiam de hoc quod est privatae qualitatis, quae tamen in rerum natura nihil est, quamvis sit in apprehensione: et hoc modo opinio est circa id quod est in apprehensione tantum. Et est si ille sicut quando dicimus innominabile, hoc nihil est, et tamen prout cadit in apprehensione per suum oppositum quod est nominabile, ad aliquid excitat intellectum."

(24) In I Post. Anal. lect. 1, no. 6. Cf. St. Albert, In I Physicorum, Tract. 1, cap. 5: "Hico autem quod omnis scientia quae habet principia sic procedit, et illa sola est vera scientia: quia est demonstrativa, et effectus solius demonstrationis est scire. Si autem ipsa non habeat verum nomen scientiae, tunc ipsa erit scientia topica dialecticae vel rehtoricae, et effectus eius non erit scientia, sed opinio. . . "

(25) Ars. Logica., II, Q. I, art. 5, pp. 278, 280.

(26) IV, lect. 4, nos. 576 - 577.

(27) The Philosophy of Physical Science, p. 1.

(28) Ars Logica, Pars I, p. 5.

(29) Ibid Pars II, p. 250.

(30) I, c. 12, 105 b 10.

(31) St. Thomas In I Poster. lect. 9, no. 4.

(32) Cf. I Post. Anal., lect. 5, nos. 7 - 8; lect. 19 nos. 4 - 5.

(33) H. Poincaré: La Science et l'Hypothèse, p. 245.

(34) In I Post. Anal. lect. 5, no. 4.

(35) I, lect. 21, no. 5.

(36) Cf. Top. Ch. 14.

(37) Matière et Lumière, p. 177. M. Jean Perrin writes: "Tout concept finit par perdre son utilité, sa signification même, quand on s'écarte de plus en plus des conditions expérimentales où il a été formulé."—Cited by Petit: Méthodologie Scientifique, p. 18.

(38) Philosophy by Way of the Sciences, p. 134.

(39) Op. cit. p. 66.

(40) When experimental science is made the only valid type of knowledge, and when it is applied to social and economic problems, it is easy to see that radical and revolutionary social doctrines are bound to be the result. Marxism is a proof of it.

(41) Top. I, tract. III, c. 1.

(42) The New Background of Science, pp. 46 - 47.

(43) Op. cit., preface p. x.

(44) Cf. I. Post. Anal. lect. 1; I Top., c. 2.

(45) Loc. cit. It must be noted in passing that the statement: "In nature everything is certain" is at best ambiguous. In relation to subjective probability it is true, but in relation to objective probability as defined above it is false.

(46) Op. cit. preface p. ix.

(47) Cf. for example, I De Generatione et Corruptione, c. 2, 316 a 5 - 15.

(48) Topics, I, c. 1.

(49) An Outline of Philosophy, p. 163.

(50) Mysticism and Logic, London, Allen & Unwin, 1927, p. 75.

Chapter VI

(1) Bertrand Russell: Mysticism and Logic, p. 91.

(2) It is worth noting that the Thomists are not the only ones who insist upon the essential relation between mathematics and quantity. A number of modern thinkers are beginning to realize that the only adequate solution for many of the problems concerning the nature of mathematics is a return to this traditional notion. Cf. Harold E. Smart: The Logic of Science, Chapter III.

(3) Cf. Burtt, op. cit. p. 43: "...the orthodox Aristotelian school minimized the importance of mathematics. Quantity was only one of the ten predicaments and not the most important."

(4) In Met. V, lect. 15, no. 983.

(5) Some modern Thomists erroneously make quantity a common sensible. Thus Maritain, who, after asserting that quantity precedes the whole sensible order says: "Elle (la quantité) est un 'sensible commun'." —Les Degrés du Savoir, p. 281.

(6) Cf. also I, 40, 3, c.

(7) De Trinitate, loc. cit.

(8) In I, V, 3, ad 4, no. 4.

(9) Op. cit.

(10) Loc. cit.

(11) Curs. Theol., Ia, Q.V and VI, disp. 6, art. 2.

(12) John of St. Thomas, loc. cit. no. 17.

(13) John of St. Thomas, loc. cit. no. 20.

(14) Science and the Modern World, p. 44. Earlier in the same work he writes: "Mathematics is thought moving in the sphere of complete abstraction from any particular instance of what it is talking about." This is perfectly true, but it does not bring out the par-

ticular character of mathematical abstraction, for the same statement could be made of other types of abstraction.

(15) The Nature of Physical Theory, p. 67.

(16) In Phys. II, lect. 3, no. 6.

(17) Substance and Function and Einstein's Theory of Relativity, pp. 19 - 20. Later in the same work (pp. 229 - 230, footnote) he writes: "The 'concrete universality' of the mathematical concepts has also incidentally been recognized and emphasized from the standpoint of Richert. 'The gap for conceptual knowledge between the universal and the particular,' says Lask in his work, Fichtes Idealismus unde die Geschichte, and the consequent irrationality is bridged in the mathematical view through the possibility of construction. The individual cases realizing the mathematical concept can be generated by the concept itself. From the concept of the circle, we can attain by construction the mathematical individuality of the particular circle, and thus go from the universal to the individual in its individuality... In mathematics, also, the intuitive object is an individual concrete and given object; but it is given a priori, not a posteriori like the material of sensation it is a logical unique, something individual, but at the same time capable of being construed a priori! We see here also that Richert's criticism would have taken another form if he had conceived the concepts of natural science decisively and from the beginning as products of constructive mathematical, rather than as results of 'abstractive' procedure. The insight once gained for mathematics would have had to be transferred to physics; for precisely here lies the real problem — that mathematics is no 'logical unique,' but that it progressively provides the 'special' natural sciences with its own characteristic form of concept. The form of mathematical 'deduction' is already contained in the form of physical 'induction', by which we grasp the empirically real, and thus the same method of mastery of the particular by the universal is achieved.

(18) I a, ... V and VI, disp. 6, art. 2 (... I, pp. ... - 536).

(19) Du Cheminement de la Pensée, p. 694.

(20) Loc. cit. no. 80.

(21) Physics and Philosophy, p. 16.

(22) III Met. Ch. 4.

(23) I, 5, 3, ad 4.

(24) Loc. cit. no. 89.

(25) Cf. In I Post. Anal. lect. 19, no. 6.

(26) I, 5, 4, ad 1.

(27) Met. XIII, ch. 3, 1078 b, 1 - 5.

(28) Pp. 130 - 131.

(29) P. 121.

(30) I, 85, 1, ad 2.

(31) In De Trin, V, 3, c.

(32) In De Anima III, lect. 8, no. 708. "Quaedam ergo sunt formae quae materiam requirunt sub determinata dispositione sensibilium qualitatum; et huiusmodi sunt omnes formae naturales; et ideirco naturalia considerant materiam sensibilem. Quaedam vero sunt formae, quae non exigunt materiam sub determinata dispositione sensibilium qualitatum, tamen requirunt materiam sub quantitate existentem: sicut triangulus, et quadratum, et huiusmodi: et haec dicuntur mathematica; et abstrahunt a materia sensibili, sed non a materia intelligibili, inquantum in intellectu remanet continua quantitas, abstracta a sensibili qualitate."

(33) In De Anima III, lect. 8, no. 714 - 715.

(34) Cf. In VIII Met. lect. 5, no. 1761.

(35) I Met. ... 6, 987 b 15.

(36) I, lect. 41, no. 5., Cf. De Veritate, II, 6, ad 1.

(37) Opera I, 31. Cited by Burtt: The Metaphysical Foundations of Physics, p. 57.

(38) Cf. II Met. lect. 5, no. 336; VI Eth., lect. 7, no. 1209; De Trin. VI, 1, etc.

(39) II Met., Ch. 1; St. Th. lect. 1, no. 281.

(40) In II Met., lect. 5, no. 336.

(41) Lect. 7, nos. 1209 - 1210.

(42) "Movet circa hoc quaestionem scilicet quare puer potest fieri mathematicus non autem potest fieri sapiens idest metaphysicus vel physicus, idest naturalis. Ad hoc respondet Philosophus, quia haec quidem, scilicet mathematicalia cognoscuntur per abstractionem a sensibilibus quorum est experientia; et ideo ad cognoscendum talia non requiritur temporis multitudo. Sed principia naturalia quae non sunt abstracta a sensibilibus, per experientiam considerantur, ad quam requiritur temporis multitudo. Quantum autem ad sapientiam, subjungit quod iuvenes sapientialia quidem scilicet metaphysicalia non credunt, idest non attingunt mente, licet dicant ore; sed circa mathematica non est inmanifestum eis quod quid est, quia rationes mathematicorum sunt rerum imaginabilium, sapientalia autem sunt pure intelligibilia. Juvenes autem facile capere possunt ea quae sub imaginatione cadunt. Sed ea illa quae excedunt sensum et imaginationem non attingunt recte, quia nondum habent intellectum exercitatum ad tales considerationes, tum propter paucitatem temporis, tum propter plurimas mutationes naturae." Ibid.

(43) In II Met., lect. 5, no. 334.

(44) Ibid no. 336.

(45) Cf. Gérard Petit, S.J.: Méthodologie scientifique, pp. 72, 78 etc.

(46) Cf. Timaeus 35 a.

(47) Cf. Meyerson: La Déduction Relativiste, p. 320: "Nous dirons donc que c'est parce que dans le spatial, l'esprit semble s'accorder parfaitement avec le réel que nous sommes embarrassés pour déterminer ce que nous devons attribuer à l'une ou l'autre source, et que nous pouvons, en fin de compte, selon des raisonnements qui s'appuient plus ou moins sur des expériences, modifier cette attribution."

(48) Du Cheminement de la Pensée, pp. 658 - 659.

(1) La Théorie Physique, pp. 15[illegible] - 159.

(2) Ibid.

(3) The Nature of the Physical World, pp. 251, 253.

(4) Saunderson, author of a treatise on optics, was blind from the first year of his life.

(5) The Philosophy of Physics, p. 16. Cf. also: Theoretical Physics, Columbia Univ., 1915, pp. 4 - 5.

(6) Cf. Optiks, Bk. I, Pt. II, 1931 ed., pp. 124 - 125.

(7) Leviathan, p. 3.

(8) Essay Concerning Human Understanding, Bk II, ch. 8 par. 9 ff.

(9) The Universe in the Light of Modern Physics, p. 14.

(10) Cf. Lindsay and Margenau: Foundations of Physics, p. 20; Norman R. Campbell: Physics - The Elements; Stebbing: Philosophy and the Physicists, p. 80; Bertrand Russell: The Scientific Outlook, p. 67, etc.

(11) Cf. Med. VI; Principia, IV, 198, 199. etc.

(12) Cf. I Phys, lect. 2, no. 7; II Phys, lect. 1, no. 8; VIII Phys., lect. 1, no. 3. etc.

(13) Dominique Salman: "La Conception Scolastique de la Physique," in Philosophie et Sciences, p. 54.

(14) Méthodologie Scientifique. Laval Univ. 1939, pp. 18 - 19.

(15) I, 27, 5, c.

(16) In De Anima III, lect. 2, nos. 592 - 593.

(17) In IV Met. lect. 12, no. 675.

(18) In De Anima II, lect. 10, no. 350.

(19) Science and the Modern World, p. 113.

(20) New Pathways in Science, p. 4.

(21) Met. IV, 5, 1010 b 33; Cf. Comment. of St. Th. lect. 14, no. 706; De Anima, III, lect. 2.

(22) The ambiguity of the word "physical" may give rise to some confusion on this point. We understand it here in its primitive meaning in which it signifies something pertaining to objective material nature. In the passage which we are about to quote from Eddington it has an entirely different meaning; it designates the world constructed by science. That is why there is no contradiction between Eddington's position and ours. "Writing this chapter on an autumn day, I feel myself in a familiar world whose most prominent characteristic is colour. There is no colour in the physical world. I think that that is the right way to put it. It is true that each colour is represented in the physical world by a number supposed to indicate the length of a wave of some kind. Similarly I am represented at the telephone exchange by a number indicating a hold in a switch-board; but it would not be correct to say that I inhabit the telephone exchange. To put it another way, there is nothing in the accepted description of the physical world which owes its acceptance to the fact that we have a sense of colour. Everything that we assert can be verified by a colour-blind person; and indeed most of our accurate knowledge has been ascertained through the medium of a colour-blind photograph plate." — New Pathways in Science, pp. 11 - 12.

(23) P. 158. Cf. Whitehead: The Concept of Nature, p. 29: "For natural philosophy everything perceived is in nature. We may not pick and choose. For us the red glow of the sunset should be as much part of nature as are the molecules and electric waves by which men of science would explain the phenomenon. It is for natural philosophy to analyze how these various elements of nature are connected".

(24) Dissertation of 1770.

(25) In IV Met., lect. 14, nos. 705 - 706. Cf. De Anima III, lect. 2, no. 596.

(26) Cf. I, 78, 3, ad 2.

(27) In V Met., lect. 15, no. 985.

(28) In I Met., lect. 2, nos. 5 - 6.

(29) Méthodologie Scientifique, pp. 19 - 20.

(30) Lect. 1, no. 6.

(31) Lect. 1, no. 6.

(32) Cf. I, 89, 2, ad 1.

(33) Cf. IV Phys., lect. 20, 22.

(34) In De Anima I, lect. 2.

(35) Cf. Planck: The Philosophy of Physics, p. 17: "Once the specific perceptions of the senses as fundamental concepts of physics had been eliminated from that science it was a logical step to substitute suitable measuring instruments for the organs of sense. The eye gave way to the photographic film, the ear to the vibrating membrane, and the skin to the thermometer. The introduction of self-registering apparatus further eliminated subjective sources of error. The essential characteristic of this development, however, did not consist in the introduction of new measuring instruments of steadily growing sensitiveness and exactitude: the essential point was that the assumption that measurement gave immediate information about the nature of a physical event — whence it followed that the events were independent of the instruments used for measuring them — now became the foundation of the theory of physics."

(36) Les Principes de la Physique, p. 16 - 18

(37) La Déduction Relativiste, p. 11. Cf. De L'explication dans les Sciences, p. 182: "Il est manifeste, en effet, qu'aucune propriété physique ne saurait nous apparaître comme réellement motivée par la raison suffisante, qu'au contraire toute qualité dont nous essaierons de doter la matière nous apparaîtra forcément comme une qualité occulte, seules les propriétés spatiales se révélant comme conformes aux exigences de notre esprit, comme réellement nécessaires. C'est donc que la matière véritablement rationnelle ne peut être au fond que de l'espace." Cf. also Rey: La Théorie Physique, p. 214.

(38) Sir James Jeans: The New Background of Science, 29 - 31. Cf. Dingle: Science and Human Experience, pp. 81 - 82: "Thus a colour-blind person may not be able to appreciate the full subtlety of Swinburne's observation: "Those eyes, the greenest of things blue, the bluest of things grey," but give him a spectroscope and he will discriminate colours by wave-lengths a million times as finely as the eye of the keenest artist. A deaf person cannot distinguish the horrors of modern dance music from the sonatas of Beethoven, but by the use of Lissajou's figures he can detect differences of pitch of which the ear of the most sensitive musician would be unconscious."

(39) Mind and Nature, p. 15.

(40) Identité et Realité, p. 398.

(41) Cf. Rey: "Pour Poincaré, comme pour le mécaniste, la matière du physicien implique une certaine homogénéité. Ce n'est pas l'homogénéité simple et absolue que la mathématique réclame de son objet, mais elle s'en rapproche indéfiniment comme vers sa limite naturelle. Cette marche vers l'homogénéité explique la possibilité pour la physique de prendre la forme mathématique." La Théorie Physique, p. 186. Cf. also pp. 263 - 265.

(42) This does not mean that quantity is strictly the subject or the root of the other accidents, but the medium by which they are rooted in the substance. "Accidens non potest per se esse subiectum accidentis, sed unum accidens per prius recipitur in substantia quam aliud, sicut quantitas quam qualitas." I, 77, 7, ad 2. "... subiectum recipit unum accidens alio mediante, sicut corpus recipit calorem mediante superficie, et sic unum accidens dicitur alteri inesse." I - II, 7, 1, ad 3.

(43) Cf. St. Thomas: "Ex velocitate et tarditate motuum contingit gravitas et acuitas in sonis." In X Met., lect. 2, no. 1948.

(44) I, 42, 1, ad 1; cf. I C. G. 43, etc.

(45) I, 11, ad 10.

(46) Cf. Meyerson: "C'est, encore une fois, l'accord entre la réalité et la mathématique, plus particulièrement, la géométrie, dont nous avons traité au chapitre précédent, en tant que fondement du panmathématisme. Mais ce que nous devons constater ici, où il s'agit de concepts du sens commun, c'est qu'il n'y a pas seulement accord, mais union, union immédiate et, au fond, indissoluble. Tout ce que notre perception nous présente comme réellement existant assume aussitôt la forme spatiale, et cette forme, nous ne pouvons l'en dépouiller sans atteindre par là l'existence elle-même. . . Existence et spatialité sont donc ici synonymes ou, du moins, inséparables, et c'est là encore un aspect de cette supériorité du panmathématisme en tant que conception métaphysique applicable à la science, que nous avons constatée." De L'Explication dans les Sciences, pp. 576 - 577.

(47) The Philosophy of Physical Science, p. 122.

(48) Eddington, op. cit. p. 124.

(49) Op. cit. pp. 123 - 125.

(50) P. 464. Cf. also Rey, Op. cit., pp. 214 - 215. Professor Dewey in the Quest For Certainty explains the significance and fruitfulness of this homogenization of nature from the point of view of instrumentalism: "Physical science disregards the qualitative heterogeneity of experienced objects so as to make them all members in one comprehensive homogeneous scheme, and hence capable of translation or conversion one into another. This homogeneity of subject-matter over a broad range of things which are as disparate from each other in direct experience as sound and colour, heat and light, friction and electricity, is the source of the wide and free control of events found in modern technology. Common-sense knowledge can connect things as sign and thing indicated here and there by isolated couples. But it cannot possibly join them all up together so that we can pass from any one to any other. The homogeneity of scientific objects through formulation in terms of relations of space, time and motion, is precisely the device which makes this indefinitely broad and flexible scheme of

transitions possible. The meaning which one event has is translatable into the meanings which others possess. Ideas of objects, formulated in terms of the relations and changes bear to one another, having common measures, institute broad, smooth highways by means of which we can travel from the thought of one part of nature to that of another. In idea at least, we can travel from any meaning —or relation —found anywhere in nature to the meaning to be expected anywhere else." In John Dewey's Philosophy by Ratner, p. 337.

(51) De L'Explication dans les Sciences, pp. 25 - 27.

(52) De L'Explication dans les Sciences, p. 14. Cf. La Déduction Relativiste, p. 256, etc.

(53) Matière et Lumière, p. 316.

(54) Cf. Boutroux: La Contingence des Lois de la Nature, p. 71: "Pour que la loi mécanique puisse être considérée comme la traduction de la loi physique proprement dite, il faut que l'équivalent existe, non seulement entre les deux ordres de faits, mais entre les deux ordres de rapports, entre l'enchaînement des faits physiques et l'enchaînement de leurs conditions mécaniques. Or cette seconde équivalence semble inintelligible parce que, tandis que la variable est homogène, l'élément qui doit en être la fonction est hétérogène."

(55) "C'est la qualité même, non seulement l'étendue où elle apparaît, qu'on réussit à mesurer."—La Pensée et la Quantité, Paris, Librairie Felix Alcan 1927. p. 54.

(56) "La quantité n'est rien d'original, pas plus matière, étendue ou durée, que grandeur purement logique; elle est une construction conceptuelle, fondée à la fois sur la diversité et l'homogénéité qualitative des contenus de pensée." Ibid. p. 379. "C'est la mesure qui crée la quantité."—p. 273.

(57) Cf. Sir James Jeans: Physics and Philosophy, p. 197.

(58) Cf. Benjamin: The Logical Structure of Science, p. 217:

"Now as a methodological postulate this can hardly be criticized. But as is often the case in science, a methodological postulate is given the status of a metaphysical judgment. The quantitative aspects of the world are soon looked upon as representative of its essential nature. To explain qualities is to explain them away. To understand them is to be convinced that they are mere appearances. To rationalize them is to construct a system in which they do not function at all as explicit elements. To talk about them is to talk about them vicariously. To grasp them is to realize that they cannot be grasped."

(59) Cf. Tannery, Science et Philosophie, p. 56.

(60) H. R. Thompson: Science and Common Sense, p. 69.

(61) "And so we have our schedule of pointer readings ready to make the descent. And if you still think that this substitution has taken away all reality from the problem, I am not sorry that you should have a foretaste of the difficulty in store for those who hold that exact science is all-sufficient for the description of the universe and that there is nothing in our experience which cannot be brought within its scope." Eddington: The Nature of the Physical World, p. 254.

(62) Curs. Phil. T. II, p. 764.

(63) Ramsperber, Philosophies of Science, New York, F. S. Crofts, 1942. p. 253.

(64) The Quest For Certainty, in John Dewey's Philosophy, by Ratner, pp. 336 - 341.

(65) Cf. Max Planck: The Philosophy of Physics: "The essential characteristic of this development, however, did not consist in the introduction of new measuring instruments of steadily growing sensitiveness and exactitude: the essential point was that the assumption that measurement gave immediate information about the nature of a physical event — whence it followed that the events were independent of the instruments used for measuring them — now became the foundation of the theory of physics. On this assumption a distinction must be made, whenever a

physical measurement takes place, between the objective and actual event, which takes place completely independently, and the process of measuring, which is occasioned by the event and renders it perceptible. Physics deals with the actual events, and its object is to discover the laws which these events obey." pp. 17 - 18.

(66) Planck: The Philosophy of Physics, p. 95.

(67) Ibid. p. 104.

(68) Eddington: Space, Time, and Gravitation, pp. 15, 31.

(69) Cf. Eddington: New Pathways in Science, pp. 12 - 13: "When we have eliminated all superfluous senses, what have we left? We can do without taste, smell, hearing, and even touch. We must keep our eyes — or rather one eye, for there is no need to use our faculty of stereoscopic vision. The eye need not have the power of measuring or graduating light and shade; I think it is sufficient if it can just discriminate two shades so as to detect whether an opaque object is in a certain position or not. . .
In 1915 Einstein made another raid on their sensory equipment. He removed all the retina of the eye except one small patch. The observer could no longer recognize form or extension in the external world, but he could tell whether two things were in apparent coincidence or not."

(70) Eddington: New Pathways in Science, pp. 2 - 3. Cf. The Philosophy of Physical Science, p. 77, etc. Cf. Bertrand Russell: The Analysis of Matter, p. 8: "All empirical evidence consists in the last analysis of perceptions; thus the world of physics must be, in some sense, continuous with the world of our perceptions, since it is the latter which supplies the evidence for the laws of physics."

(71) Pp. 69-70. Cf. Lenzen: "The qualitative phase of physics is an essential constituent of even the most highly developed system of physical theory, for the ultimate significance of physical concepts lies in their connection with immediate qualitative experience." — The Nature of Physical

Theory, p. 46.

(72) Introduction, viii.

(1) Curs. Phil. T. II, t. I, n. 1.

(2) L'Evolution Créatrice, p. 360.

(3) Cf. Planck: The Universe in the Light of Modern Physics: "The occasion of this development was that extreme refinement in measurement which is an essential condition of the progress of science." pp. 87 - 88. Cf. also pp. 58 - 60; 73 - 74.

(4) "Je crois que la prédominance de la physique est due principalement à sa méthode. Elle a l'avantage sur les autres sciences d'introduire la mesure le plus loin possible dans ses raisonnements. Tout le secret de sa valeur et de son influence est dans le fait qu'elle est la science de la mesure." — Les Principes de la Physique, p. 19.

(5) Cf. Eddington: Space, Time, and Gravitation, Prologue, p. 2: "Physicist: 'I really cannot tell you anything about it, if you will not let me make measurements of any kind. Measurement is my only means of finding out about nature. I am not a metaphysicist.'"

(6) In spite of the numerous criticisms that certain aspects of Eddington's position have evoked, we believe that his fundamental ideas on the relation between physics and measurement are quite correct, and that they represent an opinion that has become generally accepted in recent years, at least among those most competent to assess the true meaning of physical science. He himself writes: "I should like to make it clear that the limitation of the scope of physics to pointer readings and the like is not a philosophical craze of my own but is essentially the current scientific doctrine. It is the outcome of a tendency discernible far back in the last century but only formulated comprehensively with the advent of the relativity theory." — The Nature of the Physical World, p. 254.

(7) The Nature of the Physical World, pp. 252 - 258.

(8) Cf. Renoirte: "La Théorie Physique" in Revue Néo-Scolastique, Nov. 1923, p. 383: "Il convient, en effet, de ne

pas s'arrêter aux mots: les noms que l'on donne aux attributs étudiés en physique ont un rapport évident et immédiat avec des hypothèses sur la nature de ces attributs. L'expression 'longueur d'onde d'une lumière' a un sens obvie dans la théorie de l'ondulation et elle ne répondrait à rien dans la théorie de l'émission. Mais elle correspondra toujours à un procédé opératoire par lequel on trouve un nombre-mesure. Quoi qu'on imagine sur la nature de la matière, le procédé fera trouver le même nombre; on continuera sans doute à le représenter par λ, mais on préférera l'appeler autrement que 'ci-devant longueur d'onde.'"

(9) La Science et L'Hypothèse, p. 193.

(10) In X Met. lect. 2, no. 1938.

(11) Curs. Theol. Prima Pars, Q. X, disp. 9, a. 1 (Ed. Solesmes, p. 80 b).

(12) Cf. "Quarta Via", I, 2, 3, c.

(13) "Réflexions Sur Le Problème de l'Indéterminisme," in: Revue Thomiste, novembre-décembre, 1937, pp. 393 - 394.

(14) Met. X, Ch. 1.

(15) Ibid. no. 1938.

(16) Cf. John of St. Thomas. Cursus. Theol. loc. cit. p. 53 a.

(17) Ibid. no. 1938. Cf. In V Met. lect. 8, no. 872: "Ratio unius est in hoc, quod sit principium alicuius numeri. Quod ex hoc patet, quia unum est prima mensura numeri, quo omnis numerus mensuratur: mensura autem habet rationem principii, quia per mensuram res mensuratae cognoscuntur, res autem cognoscuntur per sua propria principia. Et ex hoc patet, quod unum est principium noti vel cognoscibilis circa quodlibet, et est in omnibus principium cognoscendi."

(18) Cf. Cajetan: Ens autem minime unum est, unum quidem est pro quanto non est in se divisum proportionaliter, minime vero est pro quanto tantum diversitatem formaler cum sua unitate

compatitur." De Ente et Essentia, cap. VI, edit. Laurent, p. 92, no. 58. Cf. St. Thomas In V Met. lect. 8, no. 875: "Sciendum est autem quod esse mensuram est propria ratio unius secundum quod est principium numeri. Hoc autem non est idem cum uno quod convertitur cum ente, ut in Quarto dictum est. Ratio enim illius unius in sola indivisione consistit: Huiusmodi autem unius in mensuratione."

(19) In X Met. lect. 2, no. 1945. Cf. John of St. Thomas, Curs. Theol., In Primam Partem, Q. X, disp. 9, a. 1, (ed. Solesmes, p. 49): "Perfectissimum seu magis indivisibile in uno genere, est mensura ceterorum: eo quod quanto est magis indivisibile, est magis certum: si quidem minus illi additur, vel aufertur; et sic quod est simplicius in aliquo genere deservit pro mensura, quia ad mensuram pertinet certificare de suo mensurato."

(20) Ibid., no. 1953.

(21) I - II, 91, 3, ad 3.

(22) In V Met. lect. 8. no. 875.

(23) "Et hoc maxime dicitur in quantitate, et inde derivatur ad alia genera ratio mensurae." Ibid. no. 1938.

(24) Ibid., nos. 1939 - 1940.

(25) Ibid., no. 1944.

(26) Ibid., no. 1945 - 1946.

(27) It is interesting to compare this doctrine of St. Thomas on the difference between the measurement of number and of magnitude with what has been written on the question by modern philosophers of science, particularly Sir Arthur Eddington: Cf. e.g. The Nature of the Physical World, p. 23: "Number (of discrete individuals) is absolute. It is the result of counting, and counting is an absolute operation. If two men count the number of people in this room and reach different results, one of them must be wrong. "The measurement of distance is not an

absolute operation. It is possible for two men to measure the same distance and reach different results, and yet neither of them be wrong."

(28) In Met. V. lect. 17, no. 1007.

(29) Ibid., 1035.

(30) In Post. Anal. I, lect. 36, no. 11.

(31) In De Coelo II, lect. 6, no. 4.

(32) Ibid.

(33) Phys. IV, lect. 19.

(34) Cf. Sir James Jeans: Physics and Philosophy, pp. 7 - 9

(35) Cf. St. Thomas loc. cit. no. 1950: "Non sensus non percipit differentiam valde parvorum, sed eorum differentia percipitur 'in rationibus', idest secundum diversas rationes proportionum quae ex diversis proportionibus numeralibus causantur.

(36) Cf. St. Thomas ibid. no. 1955: "....sicut mensura pedalis, quae quidem indivisibilis est proportione, sed non natura."

(37) Cf. also Bridgman: The Logic of Modern Physics, Chap. I.

(38) Cf. St. Thomas In V Met. lect. 15, no. 978: "Si esset longitudo infinita, non esset linea. Linea enim est longitudo mensurabilis. Et propter hoc in ratione lineae ponitur, quod eius extremitates sunt duo puncta."

(39) John of St. Thomas: Curs. Theol., loc. cit. p. 52 a. Cf. ibid. p. 92 a: "De ratione mensurae est quod sit notificativa quantitatis mensuratae ratione majoris uniformitatis suae: quia scilicet quantitas mensurati confusior vel inaequalior est, et reducta seu comparata ad uniformiorem et simpliciorem quantitatem notificatur et explicatur eius confusio."

(40) Curs. Theol. loc. cit. p. 49 b.

(41) Cf. Dekoninck, Méthodologie Scientifique, Laval, p. 61: "Alors que l'hypothèse du physicien classique définit l'étalon de mesure et sa fonction par rapport à une limite réelle il faut définir l'étalon par sa fonction. Alors que le physicien classique croyait s'assimiler l'univers en l'abordant de face, supposant tout droit devant lui la limite qu'il voulait atteindre, le physicien moderne avance à reculons, les yeux tournés vers l'ordre du monde, limite qu'il se précise à mesure qu'il recule."

(42) I - II, 97, 1. ad 2.

(43) John of St. Thomas, Curs. Theol. loc. cit. p. 50.

(44) In X Met., no. 1954. Cf. John of St. Thomas: Curs. Theol, loc. cit. p. 49. "Nihil enim mensuratur mensura propria et adaequata, nisi per aliquid quod est sui generis. Unde distinguuntur diversae mensurae secundum diversa genera; et perfectissima seu magis indivisibile in uno genere, est mensura eterorum: eo quod quanto est magis indivisibile, est magis certum."

(45) No. 1955.

(46) I, - II, 19, 4, ad 2.

(47) Cf. St. Thom., I, 5, 5, ad 2: "Objectio illa procedit de mensura proportionata hanc enim oportet esse homogeneam mensurato. Deus autem non est mensura proportionata alicui; dicitur tamen mensura omnium ex eo quod unumquodque tantum habet de esse, quantum ei appropinquat." Cf. Comm. of Cajetan, nos. 9 ff.

(48) Lect. 15, no. 978.

(49) Cf. De Ver. I, 1, 5, c.; II Sent., d. 2, q. 1, a. 2, ad 1.

(50) Curs. Theol. loc. cit. p. 50 a. Cf. Curs. Phil. T. II, I. I, q. 18, a. 5, ed. Reiser, pp. 381 - 382.

(51) Curs. Theol. loc. cit. p. 53 a.

(52) Curs. Theol. loc. cit. p. 57.

(53) John of St. Thomas: Curs. Phil. T. I, P. I, q. XVIII, a 3,

ed. Reiser p. 382.

(54) Cosmo. Theol. loc. cit. p. 92.

(55) Cf. e.g. R. Dalbiez: "Dimensions Absolues et Mesures Absolues" in Revue Thomiste, 1925, pp. 149 ff.

(56) V Met. Chap. 5, lect. 17.

(57) Ibid., no. 1003.

(58) Science and the Modern World, p. 37.

(59) Cf. Benjamin, The Logical Structure of Science, p. 326: "The fifth objection is the general incapacity of a quantitative system to represent dichotomous divisions, i.e. to handle two-value systems. Where qualities manifest themselves not by degrees, but by complete presence or complete absence, there can be no quantitative representation. Thus it is impossible to show quantitatively how two qualities may be at the same time similar because species of the same genus and yet contradictory because implying contradictory differentia."

(60) Cf. Eddington: "Distances are linkages whose intrinsic nature is inscrutable; we do not deny the inscrutability when we apply measure numbers to them — 2 yards, 5 miles etc. — as a kind of code of distinction." — The Nature of the Physical World, p. 81.

(61) New Pathways in Science, p. 224.

(62) "Le problème de l'Indéterminisme" in L'Academie Canadienne Saint-Thomas d'Aquin, 1935, p. 100.

(63) Substance and Function and the Theory of Relativity, p. 358.

(64) Critique de la Mésure, (Actualités Scientifiques et Industrielles Paris, Hermann and Cie, 1937, p. 10.

(65) New Pathways in Science, p. 229.

(66) Benezo, op. cit. p. 14. Cf. Frank: Between Physics and Philosophy, pp. 94 - 97.

(67) The Philosophy of Physics, p. 26.

(68) Physics and Philosophy, p. 142.

(69) Cf. "Réflexions sur le problème de l'indéterminisme," in Revue Thomiste, juillet-septembre, novembre-décembre, 1937; also: "Le Problème de l'indéterminisme." in Académie Canadienne Saint-Thomas d'Aquin, Sixième Session, 1938, Québec.

(70) This seems to be the opinion of Ostwald, for example: "When every magnitude appearing in the formula is itself measurable, then we are concerned with a lasting formula or with a law of nature; . . . if, on the contrary, magnitudes, which are not measurable, appear in the formula, then we are concerned with an hypothesis in mathmatical form, and the worm is in the fruit." — Vorlesungen uber Naturphilosophie, Leipzig, 1902, p. 215. Cited by Cassirer, Substance and Function, p. 141.

(71) Cf. Planck: Where is Science Going? pp. 92 - 93: "Every measurement first acquires its meaning for physical science through the significance which a theory gives it. Anybody who is familiar with a precision laboratory will agree that even the finest and most direct measurements — such as those of weight and current — have to be corrected (93) again and again before they can be employed for any practical purpose. It is obvious that these corrections cannot be suggested by the measurement process itself. They must first be discovered through the light which some theory or other throws upon the situation; that is to say, they must arise from an hypothesis." Cf. also p. 95.

(72) Substance and Function, pp. 357, 365.

(73) The Logic of Modern Physics, p. 10.

(74) Cf. Bridgman, The Logic of Modern Physics, pp. 9 - 25.

(75) Ibid., pp. 17 - 18.

(76) The Philosophy of Physical Science, p. 81.

(77) Eddington, The Philosophy of Physical Science, pp. 73 - 74.

(78) The Philosophy of Physics, p. 22.

(79) Cf. Lindsay, "Where is Physics Going?" in Scientific Monthly, Vol. 38, p. 246.

(80) Cf. Eddington, The Nature of the Physical World, p. 142 footnote.

(81) "Reflexions sur le Problème de l'indéterminisme." in Revue Thomiste, novembre-décembre, 1937. pp. 395 - 396.

(82) New Pathways in Science, pp. 224 - 225. Cf. The Mathematical Theory of Relativity, pp. 5 - 6. Cf. Max Planck: The Philosophy of Physics, pp. 95, 104.

(83) Cf. Lenzen, Procedures of Empirical Science, pp. 15 - 19, etc.

(84) Where is Science Going, p. 95.

(85) Matière et Lumière, p. 312.

(86) Cf. Eddington, Space, Time and Gravitation, p. 3 sqq.

(87) Cf. Renoirte, "La Critique Einsteinienne des Mesures d'Espace et de Temps," in Revue Néo-scolastique, 1924.

(88) Cf. Eddington: "It is perhaps not superfluous to add that no question arises as to whether the standard of length defined in this way is really constant at all times and places. The question implies that we have in mind some more ultimate standard (invested with 'reality') by which to define the delinquencies of the physical standard. The conception of physical quantities having to conform to some particular role allotted in advance in a vaguely imagined realm of reality, is not recognized in physical science; quantities such as length and time-extension are introduced solely for the purpose of succinct description of observational measurements actual or hypothetical." The Philosophy of Physical Science, p. 76.

(89) Space, Time, and Gravitation, p. 11.

(90) Space, Time and Gravitation, p. 12.

(1) The Universe in the Light of Modern Physics, p. 58.

(2) Cf. Renoirte: Eléments de Critique des Sciences et de Cosmologie, p. 135.

(3) Cf. Boutroux: L'Idée de Loi Naturelle p. 33.

(4) P. 120.

(5) Cf. Duhem: La Théorie Physique, pp. 349 - 269; Renoirte: "La Théorie Physique" in Revue Néo-scolastique, nov. 1923.

(6) Cf. Renoirte: Critique des Sciences et Cosmologie, p. 148.

(7) Cf. Géométrie und Erfahrung, Berlin, 1921.

(8) "La science ne se contente pas de formuler les lois d'expérience elle cherche bien plutôt à construire un système logique, reposant sur un minimum de prémisses et comprenant dans ses conséquences toutes les lois de la nature." — Einstein: La Théorie de la Relativité éd. Gauthier-Villars, Paris, 1921, p. 109.

(9) Op. cit. p. 26. In this connection it is interesting to note that in Le Système du Monde, Duhem claims that the Aristotelian doctrine of homocentric spheres was the first physical theory in the modern sense of the word: "Pour la première fois, en effet, dans la constitution de cette théorie, on vit le géomètre partir d'un certain nombre de principes simples qui lui étaient donnés d'ailleurs et, conformément à ces principes, construire un système mathématique hypothétique, retoucher, compliquer ce système jusqu'à ce qu'il sauvât avec une exactitude suffisante les apparences décrites par les observateurs.
"Lorsque l'observation eut fait connaître des phénomènes que tout système de sphères homocentriques était, à tout jamais, impuissant à sauver, les astronomes géomètres acceptèrent d'autres principes et, à l'aide de ces nouveaux principes, combinèrent de nouvelles hypothèses; mais la méthode qu'ils suivirent pour construire de nouveaux systèmes astronomiques ne différa pas de celle qui avait servi à édifier le système des sphères homocentriques." — I, p. 128.

(10) Substance and Function, etc. p. 135.

(11) Critique of Physics, p. 159.

(12) Cf. Eddington: "An ideal shines in front of us, far ahead perhaps but irresistible, that the whole of our knowledge of the physical world may be unified into a single science which will perhaps be expressed in terms of geometrical or quasi-geometrical conceptions. Why not? All the knowledge is derived from measurements made with various instruments. The instruments used in the different fields of inquiry are not fundamentally unlike. There is no reason to regard the partitions of the sciences made in the early states of human thought as irremovable."—The Nature of the Physical World, p. 137. Cf. also Einstein: The World As I See It, pp. 53 - 54.

(13) Op. cit., p. 84. Cf. also Garrigou-Lagrange: Le Sens Commun, La Philosophie de l'Être, p. 70: "Les sciences positives ne peuvent jamais que classer des faits généraux par des hypothèses provisoires (hypothèses représentatives et non explicatives]..."

(14) Cf. Dantzig: Aspects of Science, p. 231. "The continual use of such terms and phrases has finished by converting them into so many new patterns, and to the extent that they conjure up in the minds of the experts definite physical situations, these weird patterns fulfill their purpose as fully as did the classical mechanical models." Cf. Dirac: Quantum Mechanics, p. 10:"One may extend the meaning of the word 'picture' to include any way of looking at the fundamental laws which makes their self-consistency obvious. With this extension, one may acquire a picture of atomic phenomena by becoming familiar with the laws of the quantum theory."

(15) Cf. The Principles of Quantum Mechanics, by Dirac.

(16) The Nature of Physical Theory, p. 62.

(17) Cf. Shrodinger Science and the Human Temperament, p. 160. Cf. Dirac: The Principles of Quantum Mechanics pp. vi and 10.

(18) Op. cit. pp. 63 - 64.

(19) Cf. Eddington, The Nature of the Physical World, pp. 158

- 199: "In Bohr's semi-classical model of the hydrogen atom, there is an electron describing a circular or elliptic orbit. This is only a model; the real atom contains nothing of the sort. The real atom contains something which it has not entered into the mind of man to conceive, which has, however been described symbolically by Schrodinger." Cf. Urbain: Les Notions Fondamentales d'Élément Chimique et d'Atome. Paris, 1925, p. 114: "Cette hypothèse (de Bohr) est exceptionnellement grave. Elle est, en effet, en contradiction formelle avec les lois de l'électrodynamique. De ce chef, elle peut être qualifiée d'absurde. Si donc les théories étaient faites pour expliquer les phénomènes et donner ainsi à l'esprit la satisfaction de les comprendre, on aboutirait à ce résultat singulier qu'il faut recourir à l'absurde pour faire une théorie cohérente du monde. Mais, comme une pareille manière de voir est tout à fait inacceptable, on doit conclure que les théories n'admettent n'ont d'autre fin que de créer des modèles commodes. Toutes les hypothèses relatives a ces modèles sont acceptables, car, d'une part, le monde idéologique auquel ils appartiennent ne saurait être que conventionnellement astreint aux lois du monde sensible; d'autre part on ne saurait exiger des modèles que de schématiser des faits et de permettre à l'esprit de prévoir d'autres faits par les raisonnements relativement simples qu'ils peuvent suggérer." — Cited by Senoirte, Op. cit. p. 158.

(20) Pp. 189 ff.

(21) Ibid. Louis De Broglie has brought out the true relation between models and mathematics in physical theory: "Une autre conclusion s'impose à nous. Les représentations concrètes ont souvent aidé et aideront encore souvent les théoriciens dans leurs recherches, mais elle constituent en réalité la partie fragile et périssable des théories; ce qui subsiste ce sont les formes abstraites auxquelles ces représentations ont conduit. Fresnel était parvenu à l'équation des ondes en imaginant un éther élastique vibrant. Maxwell et ses continuateurs remplacent cet éther élastique par un éther électromagnétique déjà beaucoup moins concret. Einstein et les Relativistes abandonnent complètement l'idée d'éther et réduisent la vibration électromagnétique à n'être qu'une pure grandeur géométrique dirigée. La nouvelle Mécanique, enfin, ne peut pas encore attribuer une nature physique précise aux ondes qu'elle

envisage, et cela ne l'empêche nullement de se développer! "Le véritable but de la physique théorique paraît donc être de découvrir et d'étudier les formes mathématiques dans lesquelles les phénomènes physiques peuvent venir se loger. Assigner ce rôle à la Physique théorique, c'est sans doute faire participer cette science à la rigueur des Mathématiques, mais c'est aussi lui marquer ses limites: derrière l'harmonie que nous révèle la possibilité de couler les faits dans des moules analytiques se cache une Réalité dont l'essence nous demeure prodigieusement inconnue." Recueil d'exposés sur les Ondes et Corpuscules, Paris, 1930 pp. 24 - 25. Cited by Renoirte, op. cit. pp. 162 - 163.

(22) Rousseau: De La Méthode dans les Sciences, Paris, Alcan 42 éd., 1915, p. 124.

(23) Cited by Duhem, op. cit. p. 116.

(24) Science et Hypothèse, p. 174.

(25) Op. cit. pp. 60 - 61.

(26) "L'Oeuvre d'Einstein et l'Astronomie" in L'Astronomie, Juillet, 1931. Cited by Maritain: Les Degrés du Savoir, p. 205 footnote.

(27) Cf. Duhem: "En exigeant que les opérations mathématiques par lesquelles les postulats produisent leurs conséquences aient toujours un sens physique, on impose au géomètre d'insupportables entraves qui paralysent toutes ses démarches; avec H. Robin, il en vient jusqu'à rédouter l'emploi du calcul différentiel; en fait, s'il se piquait de satisfaire sans cesse et scrupuleusement à cette exigence, il ne pourrait presque plus développer aucun calcul; dès ses premiers pas, la déduction théorique se trouverait arrêtée. Une idée plus exacte de la méthode physique, une plus juste démarcation entre les propositions qui ont à se soumettre au contrôle des faits de celles qui en sont dispensées, rendront au géomètre toute sa liberté et lui permettront d'user, pour le plus grand développement des théories physiques, de toutes les ressources de l'Algèbre." op. cit. p. 316.

(28) Cf. Milhaud: Le Rationnel, p. 105: "Comment nier que la science tire le plus grand profit de notions fictives, invérifiables, de droit, dans leur nature, aux conditions

ordinaires de détermination des choses..., dans en mathématiques, chaque symbole nouveau introduit par généralisation précisément dans les cas où en vertu des conditions premières, il cesserait de rien représenter? Et ce ne sont pas seulement des notions fictives qui peuvent réussir, ce sont parfois des vues manifestement absurdes." Cited by Meyerson: Du Cheminement de la Pensée, p. 368. Cf. A. E. Thompson Science and Common Sense, p. 87. Obviously fictitious entities can serve an explanation only if the explanation be conceived as not being definitive, nor ontological nor proper. Cf. Meyerson: "Il nous semble aller en quelque sorte de soi que la véritable explication soit en même temps une explication réelle, par ce qu'il y a au-dessous du phénomène, par ce qui est. Seule, les habitants d'un asile d'aliénés, dit avec raison Hartmann, pourraient tenir des explications physiques à l'aide de concepts sciemment irréels."—De L'Explication dans les Sciences, p. 61. Cf. Whitehead: The Concept of Nature, pp. 44 - 46.

(29) Cf. Space, Time and Matter, [French ed.] p. 280.

(30) A.S. Eddington: The Nature of the Physical World, pp. 161-162 Cf. Cassirer: Substance and Function, p. 116.

(31) "The feeling that all the steps in a mathematical theory must have their counterpart in the physical system is the outgrowth, I think, of a certain mystical feeling about the mathematical construction of the physical world. Some sort of an idea like this has been flitting about in the background of the paraphernalia of the thinking of civilization at least since the days of Pythagoras, and every now and then, perhaps after some particularly striking mathematical success, it bursts forth again like a crop of mushrooms after a rain, as in the recent fervid exclamation of Jeans that 'God is a mathematician.'" — Op. cit. p. 67.

(32) Substance and Function, p. 116. (Italics ours)

(33) Cf. Prof. G. Castelnuovo: Scientia, Vol. XXXIII, pp. 169 - 190.

(34) The New Background of Science, pp. 60, 114, 136.

(35) Cassirer: Substance and Function, p. 156. Cf. Eddington:

We must seek a knowledge which is neither of actors nor of actions, out of which the actors and actions are a vehicle. The knowledge we can acquire is knowledge of structure or pattern contained in the actions." — New Pathways in Science, p. 256.

(36) I, 18, 1, ad 1.

(37) Physics II.

(38) Physics, III, 1.

(39) Cf. Phys, IV, lect. 1.

(40) Lect. 15.

(41) No. 985.

(42) V. 3.

(43) The Nature of Physical Theory, p. 73.

(44) Cf. Meyerson: "Nous avons vu qu'à l'origine le concept de la vitesse n'est qu'un rapport entre deux termes limités et que le mouvement apparaît comme un changement analogue au changement de couleur. Il n'en est plus ainsi pour nous; le mouvement nous apparaît comme un état, analogue par conséquent non au changement de couleur, mais à la couleur elle-même."—Identité et Réalité, p. 159.

(45) Space, Time, and Gravitation, p. 51.

(46) Cf. Phys. IV, lect. 20: "Non omne quod non movetur, quiescit; sed quiescens est privatum motu, quod tamen aptum natum est moveri."

(47) Cf. Eddington: The Nature of the Physical World, pp. 132 - 138.

(48) Cf. Alexander: Space and Reality, p. 91: "The world of your physics is finished before it begins — an accomplished work extended in time, a realm of established laws, natura naturata. . . Your world is the plane of actuality. Your laws relate actualities to one another. They are verified

by experience in a structure detected by the anonymous observer from the totality of phenomena. Its content is the behavior of classes and aggregates. So far as certain conditions prevail — and they do prevail in your large scale inorganic world—the plane of actuality is governed by your sort of physical laws. Hence your straight-line causality. But the plane of actuality is not the entire body of reality. Reality embraces both actuality and potentiality, the surface and the depth. . ."

(49) Regulae ad Directionem Ingenii, edit. Adam et Tannery, pp. 426 - 427.

(50) Cf. Bertrand Russell: Mysticism and Logic, pp. 80 - 94: "Weierstrass, by directly banishing from mathematics the use of infinitesimals, has at last shown that we live in an unchanging world, and that the arrow in its flight is truly at rest. . . As regards motion and change, we get similarly curious results. People used to think that when a thing changes, it must be in a state of change, and that when a thing moves, it is in a state of motion. This is now known to be a mistake...we may now indulge the comfortable belief that a body in motion is just as truly where it is as a body at rest. Motion consists merely in the fact that bodies are sometimes in one place and sometimes in another, and that they are at intermediate places at intermediate times. Only those who have waded through the Quagmire of philosophic speculation on this subject can realize what a liberation from antique prejudices is involved in this simple and straightforward commonplace."

(51) Cf. Principia, c. 37 and 39.

(52) I Sent. d. 19, q. 10, a. 4.

(53) Cf. e.g. Maritain: Théonas, p. 78: "Car le sens commun et la philosophie parlent du temps réel, d'une réalité physique qui est la durée de ce qui change; tandis qu'Einstein — de fait, si non d'intention — parle de tout autre chose, d'une entité mathématique qui est une variable dans une équation, et qui n'a que le nom de commun avec le temps."

(54) "You define motion. But this motion when measured by your own acting and being acted on does not move. To define motion you use time. But time as a dimension of your space of num-

here is extended and stands still. This time is not the living time you are familiar with, marching without rest and respite, turning future into past and ever generating and devouring yourselves and your present." — Hiezler: Physics and Reality, pp. 54 - 55.

(55) Cf. Eddington: "Objection has sometimes been felt to the relativity theory because its four-dimensional picture of the world seems to overlook the directed character of time. The objection is scarcely logical, for the theory is in this respect no better and no worse than its predecessors. The classical physicist has been using without misgiving a system of laws which do not recognize a directed time; he is shocked that the new picture should expose this so glaringly." —The Nature of the Physical World, pp. 68 - 69.

(56) The Principle of Relativity, p. 213.

(57) The Foundations of Physics, p. 76. Cf. Eddington: "So if the laws of Nature are indifferent as to the doing and undoing of an event, they must be indifferent as to a direction of time from past to future. That is their common feature, and it is seen at once when (as usual) the laws are formulated mathematically. There is no more distinction between past and future than between right and left. In algebraic symbolism, left is - x and right is x; past is - t and future is t." — The Nature of the Physical World, p. 66.

(58) Cf. Eddington, op. cit. Chapter IV and V.

(59) Lenzen: The Nature of Physical Theory, p. 75.

(60) Op. cit. p. 68.

(61) Substance and Function, pp. 449 - 450.

(62) "Cette vue de l'univers est ... la vue d'une intelligence qui serait capable d'embrasser d'un seul coup d'oeil le tout de l'espace et du temps. Mais les limitations de l'intellect humain résolvent ce tout privé de changement en ses aspects temporel et spatial, et le passé et l'avenir du monde physique ont le passé et l'avenir de l'intelligence qui le perçoit." — Cunningham: The Principle of Relativity,

Cambridge, 1914, p. 213 — Cited by Meyerson: La Déduction Relativiste, p. 101.

(63) Meyerson: La Déduction Relativiste, p. 102. As is well-known, Bergson has treated the problem of the spatialization of time at great length. We do not agree with many of his views on the problem, but at least he has effectively demonstrated that modern science has destroyed the true notion of time. Cf. Les Données Immédiates de la Conscience, Durée et Simultanéité, La Durée et le Nouveau, Matière et Mémoire, etc.

(64) Lect. 11, no. 1. Cf. In I Phys. lect. 1, no. 5.

(65) Ibid., lect. 10. no. 15.

(66) Ibid., lect. 11, no. 7.

(67) No. 14.

(68) Cf. Northrop: Whitehead's Philosophy of Science, p. 167, Cf. also Hiezler, op. cit. p. 42: "If I am not mistaken there is some confusion about causality. Many of you, it seems to me, mix up the principium rationis with the law of causality. Each ought to be kept distinct. The principium rationis binds reason and consequence. When you draw your conclusions in the realm of your mathematics you are inclined to call reason the thesis to start from — say, a given triangle having a right angle. From this you proceed to the Pythagorean proportion of the squares, speaking of consequence. In doing so you refer merely to the process of your thinking. You may also start from the squares and conclude that the angle is a right angle. Then reason and consequence exchange places."

(69) I, 44, 1, ad 3.

(70) "Ainsi, il est impossible d'en douter, la diversité dans l'espace constitue pour nous une énigme, un sujet d'étonnement d'essence sinon identique, du moins très semblable à celui que nous découvrons dans la diversité dans le temps, et dès lors nous ne pouvons échapper à cette conclusion que si nos raisonnements sont exacts, le but vers lequel tendent explication et théorie consiste réellement à remplacer ce monde infiniment divers qui nous entoure par de l'iden-

tique dans le temps et l'espace, lequel, évidemment, ne peut être que l'espace lui-même."—Meyerson, De L'Explication dans les Sciences, p. 186.

(71) In II Phys. lect. 5. no. 11. Cf. In I Phys. lect. 1, no. 5: "Nam materia est propter formam forma autem est ab agente propter finem."

(72) In III Met. lect. 4, no. 375.

(73) Essai sur les données immédiates de la conscience, Paris, 1906, 5e ed. p. 157.

(74) Cf. Lonzen: "Bodies and processes are represented by numbers or by symbols which may be represented by matrices. Hence the search for substance becomes the search for constants and invariants. There are functional relations between numbers. Thus the permanence, objectivity, and self-determination of substance are replaced by the constancy, invariance and functional relationship of numerical measures."—The Nature of Physical Theory, p. 277. Cf. Eddington: The Philosophy of Physical Science, pp. 129 - 130.

(75) Lect. 1, no. 5; lect. 14, no. 8.

(76) Space, Time, and Gravitation, p. 200.

(77) Meyerson Identité et Réalité, p. 285. Cf. La Déduction Relativiste, p. 256.

(78) Cf. Meyerson: Du Cheminement de la Pensée, p. 707: "N'y-a-t-il pas là, véritablement, sujet à l'émerveillement le plus profond? Comment, en s'écartant ainsi du réel concret, en le foulant aux pieds intentionnellement (l'expression ne semble certes pas trop forte dans ce cas particulier), le mathématicien a-t-il pu néanmoins rester aussi intimement en accord avec son rythme profond?"

(79) Cf. The Mysterious Universe, pp. 113 - 124.

(80) The Nature of Physical Theory, p. 67. Cf. Stebbing: Philosophy and the Physicists; p. 28 - 29: "Given this exclusion, then the sounds of a Beethoven sonata could be replaced by a series of curves or a set of mathematical formulae. By studying these formulae we might discover that Beethoven was a mathematician. We should not be able to discover that he was a musician because we have replaced the sounds by the mathematical expressions by means of which they could be mathematically but not musically described. To discover that musician we need further what Jeans would no doubt call musical concepts. But it then becomes impossible to maintain that the universe is God's mathematical thoughts or God thinking mathematically. "Perhaps the source of the confusions into which Jeans falls lies in the fact that he believes both that a mathematical description of a phenomenon can give complete knowledge of the phenomenon and also that the phenomenon is indeed an appearance of an unknown reality."

Chapter X

(1) Cf. e.g. The Nature of the Physical World, Introduction, et passim.

(2) A General Theory of Value, p. 406.

(3) Cf. Urban: Language and Reality, London, George Allen and Unwin, 1939, pp. 405.

(4) Cf. Urban, op. cit., p. 405: "From recent psychological literature I gather the following 'gem': 'My behaviour symbol relative to steaming foods may be a reacting of the salivary glands.' To say that the reaction of my salivary glands is a sign of the presence of food is entirely appropriate, but to call it a symbol is a linguistic distortion which is not only in itself inexcusable, but bars the way to any proper use of the concept of symbol."

(5) A Modern Introduction to Logic, p. 13.

(6) Process and Reality, p. 265. Ogden and Richards make symbolism coterminous with all uses of language with the exception of the emotive and the evocative.— The Meaning of Meaning, Chapter X. "A symbol," they tell us, "symbolizes an act of reference, that is, among its causes in the speaker, together no doubt with desires to record and communicate, and with attitudes towards hearers, are acts of referring. Thus a symbol becomes when uttered, in virtue of being so caused, a sign to a hearer of an act of reference."—p. 205.

(7) Cf. Delacroix: Le Langage et la Pensée, Paris, 1924, p. 560: "Toute pensée est symbolique." Cf. also Lambert: Organon, part II.

(8) III, d. 25, q. 1, a. 1.

(9) In this connection the term "name" includes the verb.

(10) In I Perih. lect. 4, no. 13.

(11) Lect. 1, no. 5.

(12) Cf. Introduction to Mathematical Philosophy, Macmillan, 1938, p. 18.

(13) Priora Analytica, I, tract. 7, c. 9 (Vivès-Borgnet, p. 472 b)

(14) Cf. John of St. Thomas: Curs. Phil. T. I, Pars II, q. III, a 2, pp. 515 ff.

(14a) Cf. In IV Met., lect. 12, no. 684.

(15) Mind and Nature, p. 38.

(16) We believe that J. Maritain has misconstrued Eddington's doctrine on this point: "M. Eddington paraît oublier ici que non seulement les mesures recueillies dans la nature par nos appareils nous livrent quelque chose de réel (qui peut sembler une 'ombre' au regard de notre univers familier, le philosophe cependant sait que ce sont autant de points d'émergence par où un aspect des choses existant en soi nous apparaît), mais encore que le premier degré ou le premier temps de conceptualisation, parfois très élaboré, où nous dégageons de ces mesures une description du comportement observable des choses nous met aussi en présence de réalités —je dis observables et mesurables, et prises précisément comme telles, — nous introduit dans un monde de faits, de causations observables et de structures observables que le physicien théoricien a tendance à tenir pour une simple matière offerte à son génie constructeur, mais dont le physicien de laboratoire n'est pas disposé à laisser méconnaître qu'ils font déjà authentiquement partie de la science physique elle-même. Ces faits peuvent être établis d'une manière plus ou moins certaine ou plus ou moins hypothétique, ils peuvent impliquer à un degré ou à un autre un achèvement idéal du réel par la raison, ils n'en ressortent pas moins à l'ordre de l'être réel. Des notions comme celle de la constitution des gaz par des molécules individuelles en agitation sans fin, ou de la structure réticulaire des cristaux, et une foule de notions semblables, doivent être tenues pour autre chose que des symboles, — je dis en tant même que traductions du mesurable et de l'observation, avant que l'effort théorique, en s'appliquant à approfondir leur signification et à découvrir, dans une explication complète, de quoi elles nous parlent, nous permette de comprendre qu'en dernière analyse nous ne savons

que symboliquement de quoi elles nous parlent. Mais c'est précisément ce second degré ou ce second temps de conceptualisation scientifique que M. Eddington a en vue; et là il serait téméraire de récuser son témoignage." — Les Etapes du Savoir, pp. 514 - 516.

(17) The Foundations of Physics, pp. 12 - 13.

(18) Pp. 250 - 251.

(19) Cf. H. Margenau: "Methodology of Modern Physics", in Philosophy of Science, Vol. II, Nos. 1 and 2 (Jan. and April, 1935.)

(20) Introduction to Science, p. 137.

(21) Substance and Function, p. 229.

(22) Cf. H. Margenau: "Metaphysical Elements in Physics", in Reviews of Modern Physics, Vol. 13, no. 3.

(23) The Universe Around Us, pp. 133 - 134.

(24) Cf. Eddington: "In short, the physicist draws up an elaborate plan of the atom and then proceeds critically to erase each detail in turn. What is left is the atom of modern physics. I want to explain that if the erasure is carefully carried out, our conception of the atom need not become entirely blank. There is not enough left to form a picture; but something is left for the mathematician to work on."— New Pathways in Science, p. 259.

(25) Some modern authors reserve the term "symbolism" to this perfect type that is provided by mathematics, and they describe the evolution of physics from the use of sensible and pseudo-sensible constructs to the use of pure mathematical signs as a progress from schematism to symbolism. See in this connection the writings of Ernst Cassirer.

(26) The New World Picture of Modern Physics, British Association for the Advancement of Science, Aberdeen, 1934.

(27) The Nature of the Physical World, Introduction.

(28) Cf. also Science, Religion, and Reality.

(29) The Nature of the Physical World, pp. 264, 280, 282.

(30) Eddington: The Philosophy of Physical Science, pp. 141 - 142.

(31) Book VII, Cf. Jeans: The Mysterious Universe, pp. 111 - 113.

(32) Eddington: The Nature of the Physical World, pp. 237 - 238 Cf. Riezler, Physics and Reality, p. 34.

(33) Cf. Eddington: Science and the Unseen World, p. 37.

(1) Cf. Eddington: New Pathways in Science, p. 315: "In Rossetti's poem the Blessed Damosel looked down from the golden balcony of Heaven across 'The void, as low as where this earth spins like a fretful midge.' Looking from the abode of truth, perfect truth alone can enter her mind. She must see the world as it really is..." Cf. The Mathematical Theory of Relativity, p. 1; The Nature of the Physical World, p. 225. Cf. also M. Brunschvicg, Le Progrès de la Conscience, 702: "Jamais n'est apparu aussi chimérique l'espoir que l'homme réussisse à forcer la barrière de l'expérience humaine et qu'une fois de l'autre côté il aperçoive les choses à la manière dont on suppose que Dieu les contemple dans son éternité". — Cited by Meyerson, Du Cheminement de la Pensée, p. 589.

(2) Cf. Eddington: The Philosophy of Physical Science, pp. 157 ff.

(3) Le Songe de Descartes, p. 63.

(4) Cf. Eddington: New Pathways in Science, p. 45: "We must concede therefore that 'the universe as it is conceived in modern physics' is not identical with what a philosopher would call 'the objective physical universe.' When we come to think of it there is no reason why it should be. The task of physical science is to disclose the scheme of the recurrences in the combined experience of conscious beings. We have seen that the universe which constitutes the solution of this problem must necessarily have the characteristics of regularity and externality; we said nothing about objectivity. And so it happens that the aim of science and the search for an objective universe follow the same road up to a certain point and then part company."

(5) Cf. Planck: The Universe in the Light of Modern Physics Pp. 11 - 12: "As soon as contact with reality has been lost, physical law ceases to be felt as the relation between a number of magnitudes which have been ascertained independently of one another, and becomes a mere definition by which one of these magnitudes is derived from the others. In this method there is a particular attraction, due to the fact that a physical magnitude can

be defined far more exactly by means of an equation than by means of measurement. But at the same time, this method amounts to a renunciation of the true meaning of magnitude; while it must also be remembered that confusion and misunderstanding result when the same name is retained in order to denote a changed meaning."

(6) Cf. Cohen: Reason and Nature, p. 277: "But this fails to explain why phenomena seem to occur as if the law of gravitation with its inverse squares were true, or why the properties of circular functions have proved most potent instruments for the discovery of important facts in almost all branches of physics. Doubtless equations are not vibrating strings; but is it not straining the dualistic dogma to assert that they have nothing in common with each other? Do not let us be misled by the terms 'expedient' or 'invention'. A map or a chart is an expedient or invention. Yet if it fairly represents its objects, is it not because certain relations between its parts are precisely those between corresponding parts of the objects represented? Cf. also "The Logic of Fictions," Journal of Philosophy, 1923, p. 447.

(7) Cf. de Sitter; Kosmos, p. 6.

(8) The Mathematical Theory of Relativity, p. 3.

(9) Eddington rightly objects to Professor Stebbing's contention that physicists are not concerned with chairs; "Physicists are not concerned with chairs! Are we really expected to take this sitting down? . . . Why is it that a Transport Company, wishing to improve its arrangements for seating, consults a physicist who is not concerned with the chairs we sit upon, instead of a philosopher who is?" The Philosophy of Physical Science, pp. 159 - 160.

(10) Cf. e.g. Eddington: The Nature of the Physical World, and The Philosophy of Physical Science.

(11) Cf. Jeans: The Mysterious Universe, pp. 70 - 71: "It may be well to state one or two [illegible] advance. It

is, in brief, that the ethers and their undulations the waves which form the universe, are in all probability fictitious. This is not to say that they have no existence at all: they exist in our minds, or we should not be discussing them; and something must exist outside our minds to put this or any other concept into our minds. To this something we may temporarily assign the name 'reality', and it is this reality which it is the object of science to study. But we shall find that this reality is something very different from what the scientist of fifty years ago meant by ether, undulations and waves, so much so that, judged by his standards and speaking his language for a moment, the ethers and their waves are not realities at all. And yet they are the most real things of which we have any knowledge or experience, and so are as real as anything possibly can be for us."

(12) New Pathways in Science, p. 315.

(13) New Pathways in Science, p. 26. (E.& O.E. means: errors and omissions excluded).

(14) Elsewhere Eddington writes: "We asked why the story teller should be believed when he talks about galvanometers, although he is untrustworthy when he talks of familiar objects. I think the answer is that the truth of the story is not the point in question; the physicist is concerned only with the scraps of cipher contained in it. The galvanometer is a device for leading the story into situations in which the underlying cipher becomes less baffling to interpret; it is not a bridle on the story teller's imagination.— New Pathways in Science, pp. 10 - 11.

(15) Op. cit. pp. 424 - 425.

(16) Cf. Duhem: La Théorie Physique, p. 509: "En un mot le physicien est forcé de reconnaître qu'il serait déraisonnable de travailler au progrès de la théorie physique si cette théorie n'était le reflet de plus en plus net et de plus en plus précis, d'une Métaphysique; la croyance en un ordre, transcendant à la Physique, est la seule raison d'être de la théorie physique."

(17) Cf. John Dewey: The Quest for Certainty, Chapter V.

(18) Cf. Urban, op. cit. p. 514: "There is, as we have seen no possible type of symbol which does not contain some element 'of fiction' (of the factitious, to use Descartes' terms), and which does not in some way and to some degree 'distort' reality. In the case of the aesthetic symbol the artist seeks to achieve deviations from reality in order, paradoxically, to represent reality better or to penetrate more deeply into it. In the case of the scientific symbol the scientist also deviates from the intuitive, phenomenal reality — in this case, however, to explain and ultimately to control reality and predict happenings."

(19) Cf. "De Valore Theoriarum Physicarum" in Acti Primi Congr. Thom. Roma, 1925, pp. 61 - 74; 269 - 275; "Inquisitiones criticae in Theoriam Atomicam Physico-chimicam Eiusque Valore Pro Philosophia Naturali" in Gregorianum, 1925: pp. 248 - 265; 1927: pp. 229 - 242; 1928: pp. 417 - 460.

(20) Cf. John of St. Thomas: Ars Logica, p. 681 b: "...non aliter signatum repraesentat quam prius se ut obiectum repraesentando, ulterius extendendo repraesentationem sui ad aliud in se virtualiter implicitum et contentum."

(21) In I, 55, 3, no. 13.

(22) Curs. Phil., Ars Logica, p. 692 b.

(23) Cf. John of St. Thomas, loc. cit. p. 647 a: "Ratio signi formaliter loquendo non consistit in relatione secundum dici, sed secundum esse."

(24) Cf. Eddington: The Mathematical Theory of Relativity, Introduction.

(25) Cf. Duhem: La Théorie Physique, p. 452: "Pourquoi donc le physicien peut-il, sans prêter à rire, affirmer que l'expérience découvrira une certaine loi parce que sa théorie réclame la réalité de cette loi, tandis que le

conchyliologist serait ridicule si la seule présence d'une case vide dans ses tiroirs, consacrés aux diverses couleurs du spectre, le menait à conclure qu'il y a des coquilles bleues dans l'Océan? C'est que visiblement, la classification de ce collectionneur est un système purement arbitraire, qui ne tient aucun compte des affinités réelles entre les divers groupes de mollusques; tandis qu'en la théorie du physicien, transparaît comme le réflet d'un ordre ontologique."

(26) Op. cit. pp. 265 - 266.

(27) Chapter 6, 1016 a 25, lect. 7, no. 865.

(28) Chapter 14, 224 a 2, lect. 23, no. 13. Cf. St. Albert the Great. Ibid., Tract. III.

(29) The Universe in the Light of Modern Physics, p. 13.

(30) Science et Hypothèse, p. 6 Cf. Jeans; New Background of Science, p. 51: "The layman sees Science, as it seems to him, forever changing her mind, hesitating, turning back on her tracks, and repudiating her earlier opinions. The scientist sees her ever progressing through a succession of theories, each of which covers more phenomena than the predecessor it displaced, towards the goal of a single theory which shall embrace all the phenomena of nature."

(31) La Théorie Physique, p. 53.

(32) Mind and Nature, p. 46.

(33) Eddington: The Nature of the Physical World, p. 353. Cf. Planck: The Philosophy of Physics, p. 31.

(34) For a study of this notion and its philosophical implications see Juvenal Lalor, O.F.M. "Notes on the Limit of a Variable" in Laval Théologique et Philosophique, Vol. I, Nos. 1 and 3.

(35) The Nature of the Physical World, pp. 352 - 353.

(36) Cf. Lalor, op. cit. No. 1. p. 143.

(37) Lalor, op. cit. p. 146.

(38) Where is Science Going?, p. 82. Cf. The Universe in the Light of Modern Physics, p. 15., The Philosophy of Physics, p. 51. cf. also De Broglie, op. cit. p. 319.

(39) Cf. Duhem: La Théorie Physique, p. 450.

(40) Cf. Planck: Where is Science Going?, p. 200, The Universe in the Light of Modern Physics, p. 57 - 58. Cf. also Eddington: Science and the Unseen World, p. 23: "We seek the truth; but if some voice told us that a few years would see the end of our journey, that the clouds of uncertainty would be dispersed, and that we should perceive the whole truth about the physical universe, the tidings would be by no means joyful. In science as in religion the truth shines ahead as a beacon showing us the path; we do not ask to attain it; it is better far that we be permitted to seek."

(41) Cf. Morceaux Choisis Sur le Marxisme, pp. 51, 52.

Chapter XII

(1) New Pathways in Science, p. 7.

(2) The Universe in the Light of Modern Physics, p. 15.

(3) The Nature of the Physical World, Introduction.

(4) Cf. "Interviews with Eminent Scientists" in The Observer, April 13, 1930 by J.W.N. Sullivan: "I found that not only Einstein, but also Planck and Schrodinger fully recognized the subjective element in science. Planck in particular...regards science as a constructed work of art, expressing a certain side of man's nature."

(5) Cf. Rey: La Théorie Physique, p. 350.

(6) Cf. Jeans: The New Background of Science, pp. 2 - 3; 67, etc.; Physics and Philosophy, pp. 143 - 144.

(7) The Evolution of Physics, p. 33.

(8) Du Cheminement de la Pensée, p. 654.

(9) Pp. 16 - 20.

(10) Cf. Ibid. p. 57.

(11) Pp. 108 - 112.

(12) In I Met. lect. 10. no. 158.

(13) "Réflexions sur le problème de l'indéterminisme" in Revue Thomiste, 1937, p. 396.

(14) Cf. Fulton Sheen: Philosophy of Science, p. 76: "The problem whether science has a real value is much like a modernization of the Scholastic dispute of whether an idea is an id quo or an id quod. In modern language this means, do mathematics have a relation to reality or are they only a mathematical symbol? The modern idealist would hold that scientific knowledge is "that which is known" instead of that "by which" reality is known. St. Thomas' criticism of the subjective theory of knowledge is therefore quite to the point."

(15) "We must therefore remember that not all our knowledge of the physical universe is comprised in knowledge of the laws of nature. The warning is not so superfluous as it seems. I have often found an impression that to explain away the laws of nature as wholly subjective is the same thing as to explain away the physical universe as wholly subjective. Such a view is altogether unfounded." Op. cit. p. 15. Cf. also pp. 104, 178, 217, etc.

(16) Cf. e.g. Du Cheminement de la Pensée.

(17) Cf. Meyerson: La Déduction Relativiste, pp. 134, 143.

(18) De L'Explication dans les Sciences, pp. 526 - 528.

(19) "La science est réaliste; mais nous savons cependant que d'explication en explication, elle ne peut aboutir qu'à l'accomisme, à la destruction de la réalité. Or, dans le relativisme, précisément parce qu'il constitue, une forme très avancée, très parfaite, de l'explication théorique, ces deux extrêmes de l'existence et de la non-existence se trouvent trop rapprochés l'une de l'autre. D'où une sorte de conflit douloureux dans la conscience du physicien." — Meyerson: La Déduction Relativiste, p. 205.

(20) De Sitter: Kosmos, p. 108.

(21) P. 104.

(22) Ibid., pp. 188 - 189.

(23) La Déduction Relativiste, pp. 209 - 210.

(24) Preface to the second edition (French version) p. 26.

(25) Cf. Eugene Lubin, op. cit.

(26) Cf. Tome I, p. 61 (French edition).

(27) Op. cit. pp. 61 - 62.

(28) Space, Time, and Gravitation, p. 201.

PART II

BIBLIOGRAPHY

1. Books

Alder, Mortimer : What Man Has Made of Man, New York, Longmans Green and Co., 1937.

Agar, William : The Dilemma of Science, New York, Sheed and Ward, 1941.

A La Lumière du Marxisme, Paris, Editions Sociales Internationales, 1937.

Aquinas, Thomas : Summa Theologica, Ed. Leonina, Romae Desclee et Socii, 1927.

———— Summa Contra Gentiles, Ed. Leonina, Romae, Formani et S. 1927.

———— In Posteriora Analytica, Ed. Leonina, Romae, Ex Typ. Polyglotta, S.C. de Propaganda Fidei, 1882.

———— In Libros Physicorum, Ed. Leonina, Romae, Ex. Typ. Polyglotta, S.C. de Propaganda Fidei, 1882.

———— In De Coelo et Mundo, Ed. Leonina, Romae, Ex Typ. Polyglotta, S.C. de Propaganda Fidei, 1882.

———— In De Generatione et Corruptione, Ed. Leonina, Romae, Ex Typ. Polyglotta, S.C. de Propaganda Fidei, 1882.

———— In De Meteorologicis, Ed. Leonina, Romae Ex. Typ. Polyglotta, S.C. De Propaganda Fidei, 1882.

———— In De Anima, Ed. Pirotta, Taurini, 1925.

———— In De Sensu et Sensato, Ed. Pirotta, Taurini, Marietti, 1925.

———— In Libros Metaphysicorum, Ed. Cathala, Taurini, Marietti, 1927.

———— In Libros Ethicorum, Ed. Pirotta, Taurini Marietti, 1934.

———— Quaestiones Disputatae De Veritate, Taurini, Marietti, 1925.

———— Quaestiones Disputatae De Potentia, Taurini, Marietti, 1924.

———— In De Trinitate Boetii, Paris, Lethielleux, 1927.

———— In Libros Sententiarum, Ed. Mandonnet, Paris, Lethielleux, 1929.

Aristotle: Analytica Posteriora, Trans. G.R.G. Mure, Ed. McKeon New York, Random House, 1941.

———— Topica, Ed. Sylvester Maurus.

———— Physica, Trans. R.P. Hardie and R.K. Gaye, Ed. McKeon, New York, Random House, 1941.

———— De Coelo, Trans. J.L. Stocks, Ed. McKeon, New York, Random House, 1941.

———— De Generatione et Corruptione, Trans. Joachim, Ed. McKeon, Random House, 1941.

———— De Anima, Trans. J.A. Smith, Ed. McKeon, New York, Random House, 1941.

———— Historia Animalium, Trans. Thompson, Ed. McKeon, New York, Random House, 1941.

———— De Partibus Animalium, Trans. Ogle, Ed. McKeon, New York, Random House, 1941

———— Metaphysics, Trans. Ross, Ed. McKeon, New York, Random House, 1941.

———— Ethica Nicomachea, Trans. Ross, Ed. McKeon, New York, Random House, 1941,

Benèse: Critique de la Mesure, (actualités Scientifiques et Industrielles) Paris, Herman et Cie, 1937.

Benjamin, A.C.: The Logical Structure of Science, London, Kegan Paul, Trench, Trubner and Co., 1936.

———— An Introduction to the Philosophy of Science, New York, The Macmillan Co., 1937.

Born, Max: Experiment and Theory in Physics, Cambridge University Press, 1943.

Boutroux, Emile: De l'Idée de Loi Naturelle dans la Science et la Philosophie, Paris, Librairie Philosophique J. Vrin, 1925.

Bridgman, Percy: The Logic of Modern Physics, New York, The Macmillan Company, 1932.

———— The Nature of Physical Theory, Princeton University Press, 1936.

Burtt, Edwin: The Metaphysical Foundations of Modern Physical Science, New York, Harcourt Brace, 1927.

Cajetan, Thomas: In Summam Theologicam, ed. Leonina, Rome, Ex. Typ. Polyglotta, 1888.

Campbell, Norman Robert: Les Principes de la Physique (translated and adapted in French by Mme. A.-L. Rebellier from the original: Physics, The Elements, Cambridge at the University Press, 1920) Paris, Librairie Felix Alcan, 1919.

Cassirer, Ernst: Substance and Function and Einstein's Theory of Relativity, Chicago, The Open Court Co. 1923.

———— Individuum und Kosmos in der Philosophie der Renaissance, Leipzig, Teubner, 1927.

———— An Essay on Man, New Haven, Yale University Press, 1944.

Cohen, Morris: Reason and Nature, New York, Harcourt Brace and Co., 1931.

———— An Introduction to Logic and Scientific Method (with Ernest Nagel), New York Harcourt, Brace and Co., 1934.

Conze, Edward: An Introduction to Dialectical Materialism, London, [illegible] Publishing Society.

Dampier, William: A History of Science (third ed.) Cambridge University Press, 1943.

Dantzig, Tobias: Number the Language of Science, New York, The Macmillan Co., 1933.

———— Aspects of Science, New York, The Macmillan Co., 1937.

De Broglie, Louis: Matière et Lumière, Paris, Editions Albin Michel, 1937.

———————— L'Avenir de la Science, Liège, Editions Soledi, 1941.

De Koninck, Charles: Le Cosmos, Quebec, 1936.

———————— Le Problème de l'Indéterminisme, (L'Académie Canadienne Saint-Thomas D'Aquin, Sixième Session), Québec, Typ. L'Action Catholique 1937.

———————— De La Primauté du Bien Commun, Editions de l'Université Laval, Québec, 1943.

———————— Méthodologie Scientifique, Québec, Université Laval.

Descartes, René: Discours de la Méthode (ed. Lemaire), Paris, Librairie A. Hatier,

De Sitter, W.: Kosmos, Cambridge, Mass., Harvard University Press, 1932.

Dewey, John: Experience and Nature, New York, W.W. Norton and Co. 1929.

Dingle, Herbert: Science and Human Experience, London, Williams and Norgate Ltd. 1951.

Dirac, P.A.M.: The Principles of Quantum Mechanics, Oxford, The Clarendon Press, second edition, 1935.

Dotterer, Ro. H.: Philosophy By Way of the Sciences, New York, The Macmillan Co., 1929.

Duhem, Pierre: La Théorie Physique, (Deuxième éd.) Paris, Marcel Rivière & Cie., 1914.

Eddington, Arthur: Space, Time, and Gravitation, Cambridge University Press, 1920.

———————— Science and the Unseen World, New York, The Macmillan Co., 1929.

———————— The Mathematical Theory of Relativity, 2nd. ed., Cambridge University Press, 1930.

———————— The Nature of the Physical World, Cambridge University Press, 1933.

———————— New Pathways in Science, Cambridge University Press, 1935.

———————— The Philosophy of Physical Science Cambridge University Press, 1939.

Einstein, Albert: On the Method of Theoretical Physics, Oxford, Clarendon Press, 1933.

———————— The World as I See It, New York, Covice Friede, 1934.

———————— The Evolution of Physics (with Leopold Infeld), New York, Simon and Schuster, 1938.

Frank, Philipp: Between Physics and Philosophy, Cambridge, Mass., Harvard University Press, 1941.

Hack, Roy K.: God in Greek Philosophy To the Time of Socrates, Princeton University Press, 1931.

Heisenberg, Werner: The Physical Principles of the Quantum Theory, Chicago University Press, 1930.

Hobson, E.W.: The Domain of Natural Science, New York, The Macmillan Co., 1923.

Infeld, Leopold: The Evolution of Physics (with Einstein) New York, Simon and Schuster, 1938.

Jeans, James: The Mysterious Universe (second edition) Cambridge University Press, 1937.

_____ The New Background of Science, Cambridge University Press, 1933.

_____ Physics and Philosophy, Cambridge University Press, 1943.

Joad, C.E.M.: Philosophical Aspects of Modern Science, New York, The Macmillan Co., 1938.

_____ Guide to Modern Thought, New York, Frederick A. Stokes, Co., 1933.

John of St. Thomas: Cursus Philosophicus, Ed. Reiser, Taurini, Marietti, 1930.

_____ Cursus Theologicus, Parisiis, Vives, 1884, (Vols. I - III, Ed. Solesmes, Parisiis, Desclee et Soc., 1937).

Jordan, Pascual: Physics of the Twentieth Century, New York, Philosophical Library, 1944.

Juvet, Gustave: La Structure des Nouvelles Theories Physiques, Paris, Librairie Felix Alcan, 1933.

Le Chatelier, Henri: De la Méthode dans les Sciences Experimentales, Paris, Dunod, 1936.

Lenard, Philipp: Great Men of Science, New York, The Macmillan Co. 1933.

Lenzen, Victor: The Nature of Physical Theory, New York, John Wiley and Sons, 1931.

_____ Procedures of Empirical Science, Chicago University Press, 1938.

Levy, Hyman: Modern Science, New York, Alfred A. Knopf, 1939.

Lewis, Gilbert: The Anatomy of Science, New Haven, Yale University Press, 1926.

Lindsay, Robert: Foundations of Physics, (with Henry Margenau) New York, John Wiley and Sons, Inc., 1936.

Logedon, Payne: A Mathematician Explains, Chicago University Press, 1936.

Margenau, Henri: Foundations of Physics (with Robert Lindsay), New York, John Wiley and Sons Inc. 1936.

Maritain, Jacques: Théonas, Paris, Nouvelle Librairie Nationale, 1921.

_____ Réflexions sur l'Intelligence et Sur Sa Vie Propre, Paris, Desclee, De Brouwer et Cie., (3e ed.) 1930.

_____ Le Songe de Descartes, Paris, Editions R.A. Correa, 1932.

_____ Les Degrés du Savoir, Paris, Desclée De Brouwer et Cie. 1932.

_____ La Philosophie de la Nature, Paris, Téqui.

Meyerson, Emile: Identité et Réalité, Paris, Librairie Felix Alcan, (4e ed.) 1932.

_____ La Déduction Relativiste, Paris, Payot, 1925.

_____ De l'Explication Dans Les Sciences, Paris, Payot, 1927.

_____ Du Cheminement de la Pensée, Paris, Librairie Felix Alcan, 1931.

_____ Essais, Paris, Librairie Philosophique J. Vrin, 1936.

Milliman, Robert: Time, Matter, and Values, North Carolina University Press, 1932.

_____ Electrons (-and -), Protons, Photons, Neutrons, and Cosmic Rays, Chicago University Press, 1936.

Moore, Louis: The Limitations of Science, London, Constable and Co., 1915.

Nagel Ernest: An Introduction to Logic and Scientific Method (with Morris Cohen), New York, Harcourt, Brace and Co., 1934.

Northrop, F.S.C.: Science and First Principles, New York, the Macmillan Co., 1931.

Otis, Louis: Les Théories de l'Evolution, Quebec, Laval Université, 1944.

Pearson, Karl: The Grammar of Science, (Everyman edition), London, J.M. Dent and Sons Ltd., 1937.

Petit, Gerard: Méthodologie Scientifique, Université de Montréal.

_____ La Philosophie de la Nature, Université de Montréal.

Philosophie et Sciences, (Journées d'Études de la Société Thomiste Louvain, 1935) Les éditions du Cerf, Juvisy.

Planck, Max: The Universe in the Light of Modern Physics (English translations of two books: Das Weltbild der Neuen Physik, and Physikalische Gesetzlichkeit im Lichte neurer Forschung) London, Allen and Unwin, Ltd., 1931.

_____ Where is Science Going?, New York, W.W. Norton and Co., 1932.

_____ The Philosophy of Physics, London, Allen and Unwin Ltd., 1936.

Poincaré, Henri: Science et Méthode, Paris, Ernest Flammarion, edition of 1927.

_____ Science et Hypothèse, Paris, Ernest Flammarion, edition of 1932.

Ramsperger, Albert: Philosophies of Science, New York, F.S. Crofts, 1942.

Randall, John: The Making of the Modern Mind, Boston, Houghton Mifflin Co., 1940.

Ratner, Joseph: Intelligence in the Modern World, New York, Random House, 1939.

Renoirte, Fernand: Eléments de Critique des Sciences et de Cosmologie, Louvain, 1945.

Rey, Abel: La Théorie de la Physique, Paris, Félix Alcan, 1907

Riezler, Kurt: Physics and Reality, New Haven, Yale University Press, 1940.

Ritchie, A.D.: Scientific Method, London, Kegan Paul, Trench, Trubner and Co., Ltd., 1923.

Rousselot, Pierre: L'Intellectualisme de Saint Thomas, Paris, Beauchesne, 1924.

Russell, Bertrand: The Problems of Philosophy, London, Thornton Butterworth Ltd., 1912.

_____ Mysticism and Logic, London, Allen and Unwin, 1917.

_____ An Outline of Philosophy, London, Allen and Unwin Ltd., 1927.

_____ The Analysis of Matter, New York, Harcourt, Brace and Co., 1927.

_____ Selected Papers, New York, Random House, 1927.

_____ The Scientific Outlook, London, Allen and Unwin Ltd., 1931.

Sagnet, Jules: La Révolution Philosophique et la Science, Paris Librairie Felix Alcan, 1924.

Schrodinger, Erwin: Science and the Human Temperament, New York, W.W. Norton and Co., 1935.

Sheen, Fulton: The Philosophy of Science, Milwaukee, The Bruce Publishing Co., 1934.

Hurt, Harold: The Logic of Science, New York, D. Appleton and Co., 1931.

Smith, Vincent E.: Philosophical Problems of Physics, Washington, Catholic University, 1943.

Speier, Albert: La Pensée et la Quantité, Paris, Librairie Félix Alcan, 1927.

Stebbing, L. Susan: Philosophy and the Physicists, London, Methuen and Co., 1937.

Sullivan, J.W.N.: The Limitations of Science, New York, The Viking Press, 1933.

_____ The Bases of Modern Science, Harmondsworth, Middlesex, England, Pelican edition, 1938.

Supple, J.M.: Dialectics and Experimental Biology, Quebec Université Laval, 1941.

Taylor, A.E.: Philosophical Studies, London, Macmillan and Co., 1934.

Tannery, Jules: Science et Philosophie, Paris, Félix Alcan 1924.

Tennant, F.R.: Philosophy of the Sciences, Cambridge University Press, 1932.

Thompson, J. Arthur: Introduction to Science, New York, Henry Holt and Co., 1911.

Thompson, J.M.: Science and Common Sense, London, Longmans Green and Co., 1937.

Urban, Wilbur: Language and Reality, London, George Allen & Unwin, 1939.

Watson, G.H.: On Understanding Physics, Cambridge University Press, 1938.

Weyl, Hermann: Mind and Nature, Philadelphia, University of Pennsylvania Press, 1934.

Whyte, L.L.: Critique of Physics, London, Kegan, Paul, Trench Trubner and Co., 1931.

Whitehead, Alfred: The Concept of Nature, Cambridge University Press, 1920.

———— Science and the Modern World, Cambridge University Press, 1926.

———— Process and Reality, Cambridge University Press, 1929.

———— An Introduction to Mathematics, The Home University Library, 1931.

———— Adventures of Ideas, Cambridge University Press, 1933.

Whitehead, Philosophical Essays For, New York, Longmans, Green and Co. 1936.

Whitehead, The Philosophy of, Evanston, Northwestern University Press, 1941.

Woodbridge, Frederick: An Essay on Nature, New York, Columbia University Press, 1940.

2. Articles

Ashton, John: "The Mathematicians and the Mysterious Universe", Thought, Vol. VI, pp. 258 - 274.

Babin, Eugène: "L'objet de l'intuition sensible selon Kant et l'objet de la physique mathématique", Laval Theologique et Philosophique, Vol. I, No. 1, pp. 168 - 176.

Bandas, R.G.: "Science and Philosophy", Proceedings of the American Catholic Philosophical Association, 1927.

Barton, A.: "Quelques problèmes recents de philosophie et des sciences", Revue Neoscolastique, Vol. XLII, pp. 5 ff.

Caldin, L.F.: "Modern Physics and Thomist Philosophy", The Thomist, Vol. II, pp. 208 - 225.

Campbell, Norman: "The errors of Sir Arthur Eddington", Journal of Philosophical Studies, Vol. VI.

Cassirer, Ernst: "Giovanni Pico della Mirandola. A Study in the History of The Renaissance", Journal of the History of Ideas, Vol. III Nos. 2 and 3.

Dalbiez, R.: "Dimensions Absolues et Mesures Absolues", Revue Thomiste, 1925, pp. 147ff.

De Bruyne, E.: "A propos de la définition et de la division des sciences", Revue Neoscolastique, Vol. XX, pp. 50 ff.

Dekoninck, Charles: "Reflexions sur le problème de l'indéterminisme", Revue Thomiste, 1937, juillet-septembre, et novembre-décembre.

_____: "Les sciences expérimentales sont-elles distinctes de la philosophie de la nature", Culture, Vol. IV, pp. 465 - 476.

_____: "La dialectique des limites comme critique de la raison", Laval Theologique et Philosophique Vol. I, No. 1, pp. 177 ff.

Dopp, Joseph: "Physique ancienne et physique moderne: leurs conceptions de l'intelligible", Travaux du IXe Congrès International de Philosophie, Vol. V, Partie II, 1937.

Eddington, A.S.: "Physics and Philosophy", Philosophy, Vol. VIII, no. 30.

Eiten, Robert: "A Rational Basis for Mathematical Physics", Thought, Vol. XIII, pp. 416 - 432.

Field, G.C.: "Plato and Natural Science", Philosophy, Vol. VIII, no. 30.

Geny, Paolo: "Metafisica ed Esperienza nella Cosmologia", Gregorianum, Vol. I, pp. 91 - 116.

Gill, Henry: "Facts and Fancies: Physics and Philosophy", Studies, Vol. XXXII, pp. 91 - 100.

Gilson, Etienne: "Concerning Christian Philosophy", Philosophy and History, Oxford, Clarendon Press, 1936, pp. 61 ff.

Herzfeld, Karl: "The Frontiers of Modern Physics and Philosophy", Proceedings of the American Catholic Philosophical Association, 1930.

Honnen, Petrus: "Inquisitiones Criticae in Theoriam Atomicam Physico-Chimicam Hodiernam Valorem Pro Philosophia Naturali", Gregorianum, Vol. [illegible], pp. 417 - 442.

_____: "In Quibus Deficiant Scientiaterum Methodus et Doctrina", Gregorianum, Vol. IX, pp. 443 - 460.

_____: "De Philosophia Scholastica Cognitionis Geometricae", Gregorianum, Vol XIX, pp. 498 - 514.

_____: "De Problemate Necessitatis Geometricae", Gregorianum, Vol. [illegible], pp. 19 - 54.

_____: "De Problemate Exactitudinis Geometricae", Gregorianum, Vol. IV, pp. 321 - 350.

Jeans, James: "The Mathematical Aspect of the Universe", Philosophy, Vol. VII, 1932, pp. 3 - 14.

Lalor, Juvenal: "Notes on the Limit of a Variable", Laval Theologique et Philosophique, Vol. I, no. 1, pp. 129 - 149.

Langrecht, Sterling: "Sense Qualities and Material Things", The Philosophical Review, Vol. [illegible], pp. 73 ff.

Lawler, G.: "The Influence of Descartes on Modern Science," Thomist, Vol. III, pp. 657 - 682.

Lawton, Hilary: "Physical Research and Metaphysical Reality" Thomist, Vol. II, pp. 458 - 476.

Lenzen, Victor: "Philosophy of Science", Twentieth Century Philosophy, Philosophical Library, New York, 1943, pp. 107 - 186.

Lindsay, R.B.: "Where is Physics Going?", Scientific Monthly, Vol. XXXVIII, pp. 240 - 250.

Mansion, Le Augustin: "La Physique Aristotélicienne et la Philosophie", Philosophie et Sciences, (Journées d'Etudes de la Société Thomiste, Louvain, 1935.

Marcenau, R.: "Metaphysical Elements in Physics", Reviews of Modern Physics, Vol. XIII, No. 3.

Martial: "La Théorie Kantienne de la Science", Revue Thomiste, 1925, pp. 144 ff.

Mc Williams, James: "Realism in Science", The Modern Schoolman, Vol. XVI

---: "Mathematics and Metaphysics in Science", New Scholasticism, Vol. XI, pp.338 ff.

O'Keefe, Thomas: "The Extent of Physical Knowledge", Modern Schoolman, Vol. XIV, pp.58 ff

Osgniach, Augustine: "Realism and the New Physical Theories", Proceedings of the American Catholic Philosophical Association, 1932.

Pavlov, Vassily: "Mathematics for the Doctor in the Million", Philosophy of Science, Vol. II, No.1 pp. 47 ff.

Peris, Anton: "The Frontiers of Philosophy and the Limitations of Science", Proceedings of the American Catholic Philosophical Association, 1933.

Pichette, Henri: "Considérations sur quelques principes fondamentaux de la doctrine du speculatif et du pratique", Laval Théologique et Philosophique, Vol. I, No.1, pp. 52 - 70.

Rampersaer, L.G.: "What is Scientific Knowledge?", Philosophy of Science, Vol. VI.

Regis, L.M.: "La Philosophie de la Nature: Quelques Apories", Philosophie, Cahier I, Etudes et Recherches, Collège Dominicain, Ottawa, 1956.

Renoirte, F.: "La Philosophie des sciences selon Maritain", Revue Néoscolastique de Philosophie, Vol.XXXV, pp. 96 ff.

---: "Physique et Philosophie", Philosophie et Sciences, (Journées d'Etudes de la Société Thomiste, Louvain, 1935).

Salman, Dominique: "La Conception Scolastique de la Physique", Philosophie et Sciences, (Journées d'Etudes de la Société Thomiste, Louvain, 1935.

Sheen, Fulton: "Philosophy and Science", New Scholasticism, Vol. VII, pp. 109 ff.

Simon, Yves: "Maritain's Philosophy of the Sciences", The Thomist, Vol. V, pp. 85 ff.

Simon, Yves: "La Science Moderne de la Nature et la Philosophie", Philosophie et Sciences, (Journées d'Etudes de la Société Thomiste, Louvain, 1935).

Swann, W.F.G.: "The Relation of Theory to Experiment in Physics", Reviews of Modern Physics, Vol. XIII, No.3.

Whittaker, John: "The Position of Mathematics in the Hierarchy of Speculative Sciences", The Thomist, Vol. III, No.3.