ENGINEERING EDUCATION

IN THE

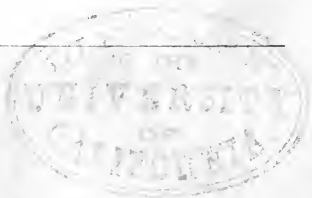
BRITISH DOMINIONS.

COMPILED FROM OFFICIAL SOURCES,

WITH REGULATIONS OF

The Institution of Civil Engineers

AS TO THE ADMISSION OF STUDENTS.



LONDON:

Published by the Institution,

25, GREAT GEORGE STREET, WESTMINSTER, S.W.

[TELEGRAMS, "INSTITUTION, LONDON." TELEPHONE, "3051."]

1891.

In 1870 *The Council of The Institution of Civil Engineers issued a volume entitled "The Education and Status of Civil Engineers in the United Kingdom and in Foreign Countries;" but since that time, this subject of Engineering Education has acquired much increased importance in consequence of the great success and large extension of the Student Class, and the consequent larger demand for preliminary education for the profession.*

The Council felt it their duty to draw up, with much care and consideration, a set of Regulations for the Admission of persons into this class, and as these have been found, by experience, to work well, they are now republished for general circulation.

The Regulations have expressly had reference to a preliminary course of education. The work of 1870 *contained information as to the Educational Institutions in Great Britain and Ireland, where instruction was given bearing on the profession of Civil Engineering; but during the time that has elapsed since that date, the number of these Institutions has so much increased that it is now necessary to issue an amended list, which is given in Appendix A. Further details may be obtained by applying to the Institutions themselves.*

In Appendix B are added some remarks on the general subject, which are considered worthy of attention.

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WALES.

SCOTLAND.

IRELAND.

INDIA.

CANADA.

AUSTRALIA.

APPENDIX B.

REGULATIONS OF THE COUNCIL AS TO THE PRELIMINARY EDUCATION OF CANDIDATES SEEKING ADMISSION AS STUDENTS.

1. On and after June 1, 1889, no person shall be admitted as a Student unless he shall produce evidence of a competent knowledge of the subjects of General Education specified in the following List:—

(1) English Grammar and Composition;

(2) Elements of Mathematics, comprising (*a*) Arithmetic, including Vulgar and Decimal Fractions, (*b*) Algebra, including Quadratic Equations, with one unknown quantity, (*c*) Geometry, including the first three books of Euclid, with easy questions on the subject-matter of the same;

(3) Elementary Mechanics of Solids and Fluids, comprising the Elements of Statics, Dynamics, and Hydrostatics.

(4) Two of the following optional subjects:—

(*a*) Latin, (*b*) Greek, (*c*) French, German, Italian, or any other Modern Language, (*d*) Logic, (*e*) Chemistry, Geology, Botany, or any other branch of Physical Science.

2. The evidence required in the above regulation shall be furnished by Certificates to show either—

(A) That the Candidate has obtained any one of the Educational Distinctions named in Schedule No. I.; or

(B) That the Candidate has attended classes in any of the Public Educational Establishments, mentioned in Appendix A, on any of the qualifying subjects, and has acquired a competent knowledge of the same; or

(C) That the Candidate has passed one or more examinations, in any of the qualifying subjects, by any of the recognized Public Examining Bodies mentioned in Schedule No. II.

The Certificates mentioned in (B) and (C) must, in the aggregate, include all the qualifying subjects named in Regulation No. I.

3. The Council may from time to time extend, alter, or otherwise amend the Schedules Nos. I. and II., and Appendix A.

4. The Council reserve to themselves power to accept special qualifications of practical work in lieu of certain educational qualifications; or to waive any of the above-named requirements under special circumstances as they may think advisable.

SCHEDULE No. I.

EDUCATIONAL DISTINCTIONS WHICH OF THEMSELVES IMPLY SUFFICIENT QUALIFICATION.

Any degree in Arts, or Science, or Engineering, in any University in the British Empire.
Matriculation in the University of London.
Matriculation in the Engineering Department of King's College, London.
Matriculation in the Engineering Department of University College, London.
Matriculation in the Central Institution of the City and Guilds of London Technical Institute.
Election as a "Whitworth Scholar."

SCHEDULE No. II.

LIST OF PUBLIC EXAMINING BODIES AND EXAMINATIONS RECOGNIZED BY THE COUNCIL.

UNIVERSITY OF OXFORD:—
Moderations.
Responsions.
Senior and Junior Local.

UNIVERSITY OF CAMBRIDGE:—
Previous Examination.
Higher, Senior and Junior Local.

OXFORD AND CAMBRIDGE SCHOOLS' EXAMINATION BOARD:—
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UNIVERSITY OF DURHAM:—
Examination for Certificate of Proficiency.
Examination for Students at the end of their first year.

VICTORIA UNIVERSITY:—
Preliminary Examination.

UNIVERSITY OF EDINBURGH:—
Preliminary Examination for Graduation in Science.
Senior and Junior Local.

UNIVERSITY OF ABERDEEN:—
Senior and Junior Local.

UNIVERSITY OF GLASGOW:—
Senior and Junior Local.

UNIVERSITY OF ST. ANDREW'S:—
Senior and Junior Local.
Scotch Education Department Leaving Certificate.

UNIVERSITY OF DUBLIN:—
General Examination at end of Senior Freshman year.
Public Entrance Examination.

ROYAL UNIVERSITY OF IRELAND :—
Matriculation Examination.

QUEEN'S COLLEGE, BELFAST :—
Matriculation Examination.

QUEEN'S COLLEGE, CORK :—
Matriculation Examination.

QUEEN'S COLLEGE, GALWAY :—
Matriculation Examination.

INTERMEDIATE EDUCATION BOARD OF IRELAND :—
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ST. DAVID'S COLLEGE, LAMPETER :—
Responsions Examination.

COLLEGE OF PRECEPTORS :—
Examinations for First Class Certificate, or Second Class Certificate of First or Second Division.

THE SCIENCE AND ART DEPARTMENT'S EXAMINATIONS.

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UNIVERSITY OF MADRAS :—
Entrance Examination.

UNIVERSITY OF BOMBAY :—
Entrance Examination.

UNIVERSITY OF MCGILL COLLEGE, MONTREAL :—
Matriculation Examination.

UNIVERSITY OF BISHOP'S COLLEGE, MONTREAL :—
Matriculation Examination.

UNIVERSITY OF TORONTO :—
Matriculation Examination.

UNIVERSITY OF TRINITY COLLEGE, TORONTO :—
Matriculation Examination.

UNIVERSITY OF QUEEN'S COLLEGE, KINGSTON, CANADA :—
Matriculation Examination.

UNIVERSITY OF VICTORIA COLLEGE, UPPER CANADA :—
Matriculation Examination.

UNIVERSITY OF MANITOBA :—
Previous Examination.

UNIVERSITY OF FREDERICTON, NEW BRUNSWICK :—
Matriculation Examination.

UNIVERSITY OF KING'S COLLEGE, NOVA SCOTIA :—
Responsions.
Matriculation Examination.

UNIVERSITY OF HALIFAX, NOVA SCOTIA :—
Matriculation Examination.

DALHOUSIE COLLEGE AND UNIVERSITY, HALIFAX, NOVA SCOTIA :—
Matriculation and Sessional Examinations.

UNIVERSITY OF MELBOURNE :—
Matriculation Examination.

UNIVERSITY OF SYDNEY :—
Matriculation Examination.

UNIVERSITY OF ADELAIDE :—
Matriculation Examination.

TASMANIAN COUNCIL OF EDUCATION :—
Examination for the Degree of Associate of Arts.

UNIVERSITY OF THE CAPE OF GOOD HOPE :—
Examination for a Degree in Arts.
Matriculation Examination.

UNIVERSITY OF OTAGO :—
Preliminary Examination.

UNIVERSITY OF NEW ZEALAND :—
Entrance Examination.

CHRIST'S COLLEGE, CANTERBURY, NEW ZEALAND :—
Voluntary Examinations.

CODRINGTON COLLEGE, BARBADOS :—
English Examination for Students of two years' standing.

APPENDIX A.

PARTICULARS OF EDUCATIONAL ESTABLISHMENTS IN THE BRITISH DOMINIONS WHERE INSTRUCTION IS GIVEN BEARING ON THE PROFESSION OF CIVIL ENGINEERING.

METROPOLITAN.

UNIVERSITY COLLEGE, LONDON.

This College, founded in 1828 as the "University of London," and subsequently incorporated by Royal Charter under its present title, is one of those in which the scientific education bearing on Engineering has been most fully studied and provided for.

It has three Faculties, devoted respectively to *Arts and Laws*, to *Science*, and to *Medicine*. It is only with the second of these that we have here to do.

The general scientific curricula comprehend—

Mathematics, in all grades and forms.
Applied Mathematics and Mechanics.
Physics, theoretical and experimental.
Chemistry, theoretical and experimental.
Geology and Mineralogy.
Botany.
Zoology.

As well as Physiology, Comparative Anatomy, Political Economy, the Philosophy of Mind, Logic, &c.

Included in this Faculty also, is a special department, called

Applied Science and Technology.

This department is intended to provide for students wishing to devote themselves to Engineering, Architecture, Applied Chemistry in any of its branches, and any other manufacturing or commercial pursuit, requiring a systematic training in the application of scientific principles to industrial purposes.

As in all other departments of this College, there is an unrestricted admission of students, without previous examination, to any class or classes they may select.

Curricula have been arranged for the different objects, so as to give the greatest opportunity of benefit to the student, and if he has sufficient time at his disposal, it is in most cases advisable that one or other of these should be attended.

The Engineering Branch.

The following remarks are placed at the head of the Syllabus in the College Calendar, and they are important, to prevent misunderstanding as to the scope of the instruction given—

'This Department includes Lectures, Drawing Classes, and Practical Work, the details of which are given below.

It should be understood, however, that none of this work can render unnecessary a pupilage, or its equivalent, in the actual practice of the profession. Such a pupilage is the only available means by which a student can obtain a sufficiently thorough knowledge of the practical details of his future work.

But the training given in the College will be found to be of value not only directly, but also by enabling those who have gone through it to take fuller advantage of the opportunities afforded during a professional pupilage.

The complete curricula for a student intending to become an Engineer, usually extend over three sessions. For the convenience of those who are unable to devote more than two sessions to their College work, an alternative curriculum, extending over two sessions, is also arranged. A very large number of students, under this plan, spend only two years at the College. In some instances a year of apprenticeship is taken between the two years of College work, the remainder of the apprenticeship coming after the second year.

The curricula include not only instruction in Applied Science, but also such preliminary instruction in Pure Science (especially in Mathematics, Physics, and Chemistry), as a student ought to have before proceeding to study its applications. The study of modern languages is not included in any of them; but a remark is made that their importance to the student is exceedingly great, and that, therefore, it may be often advisable that some time should be given to them.

The principal classes comprised in the complete course are described as follows :—

FIRST YEAR.

Mathematics, Junior.
Graphics, Junior.
Mechanics.
Surveying.
Experimental Physics.
Graphics, Drawing.
Economic Geology.

SECOND YEAR.

Engineering, Junior.
Machine Design and Drawing, Junior.
Mathematics, Senior.
Graphics, Senior.
Practical Physics.
Electrical Technology.
Chemistry.

THIRD YEAR.

Engineering, Senior.
Machine Designs and Drawing, Senior.
Engineering Laboratory.
Mathematics, Senior.
Physics, Senior.
Civil Engineering, or Electrical Technology.

The Junior Engineering Class comprises the manufacture of iron and steel; the strength of materials and simple structures; the theory of machines; and the elementary theory of the steam-engine and boiler.

The Senior Class treats of the kinetics of machinery; friction and efficiency; advanced theory of the steam-engine; air- and gas-engines; dynamometers and brakes; the testing of engines; marine engineering, the propulsion and resistances of vessels; locomotives, simple and compound.

The Drawing Classes form, as far as possible, a progressive course of Engineering Design, in which the students apply practically the instruction they receive. They include working-drawings of detailed parts; the graphic delineation of stresses, and ultimately the complete design of simple structures and machines.

The Engineering Laboratory, established in 1878, is a special feature in this College, and is thus described—

It is intended to provide systematic instruction to Students and young Engineers in the experimental methods which serve for determining the numerical data employed in engineering calculations, and also for familiarizing them with the strength and other physical properties of the chief materials used in construction.

The importance of such instruction is twofold. In the first place, the exact value of any numerical results derived from experiment, and the limits within which they may be safely trusted, can be rightly estimated only by those who have some practical and personal acquaintance with experimental processes of the kind employed in obtaining these results. In the second place, engineers are continually called on to deal with questions in regard to which some essential data are altogether wanting, and they are therefore very often compelled to make special experiments for their own guidance. It is obvious, however, that in such cases the probability of their obtaining accurate and trustworthy results will be

much greater if their previous training has made them practically acquainted with the art of experimenting and with the methods that had been successfully adopted by others in dealing with analogous questions.

The practical training given in the Engineering Laboratories is also specially arranged to give Students as intimate an acquaintance as possible with the working of engines under widely-differing conditions, economical and uneconomical, and generally with the manner in which experiments in matters relating to engineering science are carried on.

The Laboratory contains testing-machines of various kinds and powers; a steam-engine and a gas-engine, both fitted for testing purposes, and the machine-tools necessary for the making of apparatus, &c.

The Constructive Engineering Classes comprise—

Railways, their design, construction, and working, and the details of all their provisions and apparatus.
Roads and Tramways.
Rivers, Canals, Docks, and Harbours.
Water, Gas, and Sewage works, &c.

Visits to engineering works in or near London, are arranged from time to time.

Surveying Classes with practical field-work are held in the summer term.

The Electrical Technology Class comprises:—

The Elements of the Theory of Dynamos of various types.
Principles of Electric Light Installation.
Electric Motors, &c.

A Certificate of Matriculation is given by examination, at entrance, or after a certain portion of the course; and this is followed by a General Certificate of Engineering after more mature progress, which is endorsed for Honours in cases of special merit.

Two scholarships are given annually on the result of class examinations.

KING'S COLLEGE, LONDON.

This College was established by Royal Charter in 1829, as: "A College in which instruction in the doctrines and duties of Christianity, as taught by the Church of England, should be for ever combined with other branches of useful education."

The instruction is conducted "in twelve distinct but mutually related Departments"; namely—

The Theological Department.
The Department of General Literature.

The Department of Science.
The Department of Engineering and Applied Sciences.
The Medical Department.
The Department of Public Health.
The Department for Ladies.
The Evening Classes.
Technical Instruction.
The School of Art.
The Civil Service Department.
The School.

Students who attend the full prescribed course of study in their respective departments, are termed *Matriculated Students*, and are subject to certain general rules. But there is no Matriculation Examination, and entrance, either to the full courses or to portions of them, is open to all.

The Science Department comprises all the usual subjects.

The DEPARTMENT of ENGINEERING and APPLIED SCIENCES, has for its professed object to provide a system of general education of a practical character for young men who are to be engaged in professional employments, such as Surveying and Civil Engineering, Telegraphy, Building Construction and Architecture, Mechanical Engineering and the higher branches of Manufacturing Art, or in commercial and agricultural pursuits, or who wish to prepare for the Whitworth Scholarship Examination, or for entrance into the Engineering Department of the Royal Navy, or for Civil Engineering Appointments in India.

The ordinary engineering course occupies three years, and forms an appropriate introduction to that kind of instruction which can only be obtained within the walls of the manufactory, or by actually taking part in the labours of the surveyor, the engineer, or the architect.

Museums, containing mechanical and physical apparatus, chemical and industrial products, valuable collections of models and specimens, &c., illustrating the subjects taught, are open to the students.

A Testing machine (given by the Clothworkers Company) is employed for instructing the Students in the strength of materials used in engineering and architectural structures.

The following are the subjects of the different Lectures given in this department:

Divinity.
Mathematics.
Natural Philosophy (mechanics and physics, and physical laboratory).
Architecture and Building Construction.
Mechanical Engineering and the Workshop.

Civil Engineering.
Drawing (geometrical, architectural, and engineering).
Chemistry (theoretical, practical, and analytical).
Mineralogy.
Geology.
Photography.
Electrical Engineering.
Metallurgy.
The Workshop.

The course on *Mechanical Engineering* extends over three years.

During the first and second years the lectures deal with the methods of measurement, the mechanics of machinery, and the strength of materials, tension, compression, bending, shear, torsion, simple structures, riveted joints, alternating, repeated, and sudden loads. Theory of machines and analysis of mechanisms, including the theory of the steam-engine and boiler simply treated.

Occasional demonstrations will be given on the twenty-five-ton testing machine.

In the third year the students proceed to the more advanced study of the theory of the steam-engine and boiler, heat-engines in general, hot-air and gas-engines. Friction and efficiency of machines, with the methods of testing them. Valves and valve-gears, governors, twisting-moment in crank shafts, theory of propulsion and the resistance of ships, and screw-propellers. Other special subjects will be treated according to the requirements of students.

Engineering Laboratory and Workshops.—The workshop course for first-year students is so arranged as to give a preliminary knowledge of the use of tools, methods of adjustment, limits of accuracy obtainable in practice, &c.

In the second year students begin upon experimental work in the engineering laboratory. While in the machine shop they will be for the most part engaged in making and preparing apparatus and test specimens for their future use in the laboratory.

The course on *Civil Engineering* also extends over three years, as follows :—

During the first year :—The application of practical geometry to the purposes of a surveyor and engineer; surveying instruments, surveying of different kinds and by different methods, levelling, plan drawing, flying levels for roads, railways, and other works, with observations as to geology, strata, streams, springs, subsoil, &c., plotting sections and cross sections.

The practical instruction in the field consists in carrying out a chain survey explanatory of the usual difficulties that are met

with in practice. The various instruments which have been described in the lectures are used in the field.

During the second year the course deals both in the lecture room and in the field with extended surveying operations. Surveys of towns by theodolite, surveys for railways, roads, canals, &c., plane trigonometry applied to surveying purposes, spherical excess, trigonometrical determination of heights and distances, measuring distances from a primary base, taking out quantities of cuttings and embankments, setting out curves, contour levelling, trial levels for roads, railways and other works, and the observations to be recorded as to strata, streams, springs, woods, &c.

In the third year the course deals both in the lecture room and in the field with surveying in its application to the various branches of civil engineering practice, and includes setting out work, selecting routes for roads and railways, contouring and laying out land for building, irrigation, and other purposes, dialling for mining operations, tunnelling, measuring and observing currents, hydraulic surveying, bridges, calculation of strains, railways, tramways, land reclamation, foreshore protection, land draining, sewerage of towns and villages, water supply, floods prevention, improving navigable channels, training walls, docks, harbours, and piers.

The students of this year accompany the Professor to inspect various works in course of execution in the Metropolis.

Building Construction and Architecture:—This course is intended to furnish to second-year students a knowledge of the elementary practice of building construction and architecture, and of the application of the principles of mechanics to construction.

A short course of lectures is also given upon architectural design and history of the art.

Electrical Engineering:—After two years passed in the engineering department of the college in obtaining the general training that is necessary to enable students to successfully follow electrical engineering, they are admitted to the special course of lectures and laboratory work.

The laboratory will be open throughout the week for advanced students, whose preparation must qualify them for conducting original researches under advice and direction of the Professor.

The laboratory contains steam-engine and boiler, direct and alternate current dynamos of latest design, large resistances, and is thoroughly equipped with instruments of newest construction. It is fitted with a large set of accumulators, and students are enabled to study every branch of electrical engineering.

The prizes and certificates given in this subject depend partly on a written, and partly on a practical examination, and the syllabus for the course is as follows:—

Construction and use of standard cells.
Ballistic galvanometer.
Quantitative experiments on the magnetic qualities of iron, and electro-magnetic induction.
Dynamo and motor design, electrical and mechanical.
The direct current machine, as motor and generator.
The alternate current machine, as motor and generator.
Electrometer.
Dynamometer and brake experiments.
Wattmeters.
Arc lamps, projectors.
Efficiency tests with boiler, steam-engine, and dynamos.
Transformers.
Voltameters.
Electrical measurements.
Details of installation work, leads, switchboard, fuses, &c.
Central stations.
Underground and overhead cables.
Accumulators.

THE ROYAL COLLEGE OF SCIENCE, LONDON, WITH WHICH IS INCORPORATED THE SCHOOL OF MINES.

Although this institution does not profess to give special instruction directly in Engineering, yet the classes contain so many subjects bearing upon it that they may fairly be noticed as elements of Engineering Education.

The Royal College of Science at South Kensington is supported by the State to supply systematic instruction, in the various branches of Physical Science, to students of all classes. The instruction is arranged in such a manner as to give the students a thorough training in the general principles of science, followed by advanced instruction in one or more special branches.

The Royal School of Mines has a more special interest to Engineers. It is incorporated with the Royal College of Science, and Mining Students obtain their general scientific training in the latter-named establishment; but separate Classes are formed especially for the subjects more intimately bearing on Mining operations.

The prospectus of this latter establishment contains the following statement:—

The principal object of the Institution is to discipline the students thoroughly in the principles of those sciences upon which the operations of the miner and metallurgist depend. Of course nothing but experience in the mine and in the laboratory can confer the skill and tact requisite for the practical conduct of these operations; but, on the other hand, it is only by an acquaintance with scientific principles that the beginner can profit by that experience, and improve upon the processes of his predecessors.

The Science College gives general instruction, by Lectures and Laboratory work, in—

Mathematics.
Mechanics.
Physics.
Chemistry.
Astronomy.
Zoology.
Botany.
Drawing.
Mine Surveying.
Agricultural Science.
Geology.

The Mining branch adds theoretical and practical instruction in—

Determinative Mineralogy.
Metallurgy.
Assaying.
Mining operations.

Examinations are held, and an Associateship is granted on proper qualification, as are also many Exhibitions, Scholarships, Medals, and Prizes.

THE CITY AND GUILDS OF LONDON INSTITUTE FOR THE ADVANCEMENT OF TECHNICAL EDUCATION.

This Institution is so important, in its educational character, and so extensive in its scope, that a brief account of its origin and development will not be out of place here.

Some thirteen or fourteen years ago, certain of the Livery Companies of London, recognizing the altered conditions of apprenticeship, were moved by the desire to devote a part of the funds which had been bequeathed to them, and which had accumulated in their hands, to the general improvement, by means of technical education, of the industries of the country, or of the special trades with which they severally were associated.

Many of the Companies separately had previously, by means of occasional lectures, by prizes, by exhibitions, and by other agencies, endeavoured to promote the interests of their several trades; but it was generally felt that these isolated efforts of individual companies, although productive of some good results, were not calculated to exert that beneficial influence on the education of the industrial classes of the country which might follow from their united action.

Accordingly, some time before the question of technical education was as prominently before the public as it now is, a suggestion was thrown out that the Livery Companies of London might do well to combine for the purpose of developing a general scheme of technical instruction, adapted to the requirements of all classes of persons engaged in productive industry.

This idea took practical shape at the beginning of 1877, when, at a meeting of the representatives of several of the principal Companies, a Committee was formed for the purpose of preparing a scheme for a national system of Technical Education.

The Committee placed themselves at once in communication with a number of gentlemen distinguished for their scientific ability, as well as for their knowledge of the educational wants and requirements of the industrial classes of the country, and obtained from them a set of valuable reports on the best means of giving effect to their object. These having been duly considered, the Committee prepared the outlines of a scheme, which they submitted to the representatives of the several Livery Companies who had joined the Association.

This scheme provided for the foundation in London of a Central Institution for higher Technical Instruction; for the establishment of, or for assistance to, trade schools; for the conduct of examinations in technology; and for the subsidizing of other institutions in London or in the provinces, having cognate objects. All these intentions have been amply carried out, and are still in action.

This scheme was approved, and a Provisional Association of the Companies was constituted to commence proceedings. The prospects appeared favourable, and as the work was clearly likely to develop in more than one direction, and to increase in magnitude and importance, in the spring of 1880 the Institute was permanently established and registered under the title given at the head of this description; and shortly afterwards it received an important recognition in the acceptance, by H.R.H. the Prince of Wales, of the Presidency. The Chairmanship of the Council was accepted by the Right Hon. the Earl of Selborne (then Lord Chancellor), and that of the Executive Committee by

Sir Frederick Bramwell, Bart., F.R.S., M. Inst. C.E., who has always been one of the most earnest and active promoters of the movement.

The Royal Commission, appointed in 1881 to inquire into Technical Instruction, stated in their Report, three years later, 'No organization like that of the Science and Art Department, and of the City and Guilds of London Institute, exists in any continental country; and the absence of such organization has been lamented by many competent persons with whom we came in contact."

The most important feature in this scheme was the establishment of a Central Institution, in which instruction should be given with the general object of pointing out the application of different branches of science to various manufacturing industries. Specially the instruction was to be adapted to the requirements of (1) those who intended to become technical teachers; (2) those who were preparing to enter Engineers' or Architects' offices, or manufacturing works; and (3), those who wished to study the scientific principles underlying the particular branches of industry in which they were engaged. In 1879 the Institute acquired, from Her Majesty's Commissioners of the Exhibition of 1851, the use of a valuable plot of ground; and in July 1881 the foundation of the building was laid by the Prince of Wales. It was opened on the 25th of June, 1884, also by the Prince, who had then graciously accepted the post of President of the Institute.

The Institute has at present two teaching establishments: the one already mentioned, at South Kensington, called the *Central Institution,* and the other, called the *Technical College,* in Finsbury.

Central Institution, South Kensington.

The special object of this Institution is stated to be—

To give to London a college for the higher technical education, in which advanced instruction shall be provided in those kinds of knowledge which bear upon the different branches of industry, whether manufactures or arts.

The main purpose of the instruction given is to point out the application of the different branches of science to various manufacturing industries.

There are three complete courses of instruction specially arranged for students who intend to enter Engineering, Electrical, or Chemical Industries. Students who desire to go through a complete course, and to take the diploma of the Institute, have to pass an entrance or Matriculation examination in Mathe-

matics, Engineering Drawing, Chemistry, and Physics. A complete course of instruction occupies three years, except in the case of students who already possess knowledge enough to join the second year's course. The first year's course is the same for all students, and is intended to give a sound and thorough preparation for the technical studies of the second and third years. A large proportion of time is given to instruction in Mathematics and Mechanics, and in the other departments the instruction is elementary and preparatory to more advanced work. By the end of the first year a student elects to join the Engineering, the Physical, or the Chemical department, with a view of being educated specially as a Civil or Mechanical Engineer, an Electrical Engineer, or a Chemical Engineer; but studies in all four departments continue during the second year. During the third year a student spends the whole of his time in the department he has elected to join, with the exception only that some advanced Mathematical instruction is given to Engineering and Physical students. Besides regular matriculated students, persons who have knowledge enough to follow the instruction are admitted when there is room in the classes to any courses they may select, or to do work in the laboratories.

Department of Mechanics and Mathematics.

The chief object of this course is to give the student a thorough knowledge of those principles of mechanics of which he will make use in Physics or Engineering. A certain amount of pure mathematics is required, and is included in the course. For Engineering or Physical students the course extends over the three years.

First Year
- Mensuration of Areas and Volumes.
- Statics and Graphical Statics.
- Projective Geometry.
- Perspective.
- Trigonometry.

Second Year
- Vector Calculus.
- Kinematics of a Point.
- Differential and Integral Calculus.
- Kinetics.
- Statics and Hydrostatics.
- Theory of Equations.

Third Year
- Higher Geometry.
- Definite Integrals.
- Differential Equations.
- Partial Differential Equations with Applications to Physics.
- Higher Dynamics.
- Mathematical Theory of Electricity and Magnetism.

A laboratory of Mechanics is attached to the Mathematical Department, in which students experiment on the laws of dynamics and the determination of physical constants, and are made acquainted with measuring and calculating instruments such as planimeters and integrators. The students also construct various models, illustrating geometrical theorems and models of surfaces which are of importance in practical application.

Engineering Department.

The instruction in this department is divided into: (1.) A course of Lectures on Applied Mechanics, and Descriptive Engineering, with exercises worked in Class. (2.) A Drawing Office course, extending from elementary instruction in drawing to the designing of complete machines and structures. (3.) A Workshop course, in which instruction is given in Carpentry, Chipping and Filing, Smithwork, and the use of Machine Tools. (4.) A Laboratory course, in which experiments are made on the strength of iron, steel, cement, and other materials on a large scale, on the fuel consumption and efficiency of boilers, on the action of steam in a steam-engine in different conditions of working, on hydraulics, and on other subjects interesting to engineers. (5.) A Surveying course, including instruction in the use and adjustment of instruments, plotting, and field work.

During the *First Year* students intending to become Civil or Mechanical Engineers attend only the Workshop and Drawing Office course, the remainder of their time being given to Mathematics, Physics, and Chemistry.

In the *Second Year*, while the subsidiary instruction is continued, they attend Lectures on—

The Kinematics of Machines.
The Dynamics of Machines.
The Strength of Materials.
Hydraulics and Hydraulic Motors.

In the *Third Year*, in addition to advanced Mathematical instruction, the Lecture course embraces—

The Strength and Stability of Structures.
The more advanced parts of the theory of the Resistance of Materials.
The Theory of the Steam-Engine and Gas-Engines.

There are also Lectures on some parts of Descriptive Engineering such as Water Supply, Bridge Construction, Valve Gears, &c.

During this year the students spend one day per week making investigations in the Engineering Laboratory. They also take the course of instruction in Surveying, and they give about one day per week to designing machines and structures.

The workshops are well supplied with machine tools. The Engineering Laboratory, which has been partly described in Professor Kennedy's Paper on Engineering Laboratories, is one of the completest in the country. It is provided with a 100-ton testing-machine, an engine and boiler specially arranged for researches on the action of steam, and many smaller testing machines and measuring and other subsidiary appliances.

The Physical Department.

The Physical department is chiefly devoted to Electrical Technology. Physical students take the same course of instruction in Engineering and Mathematics during the first and second year as Engineering students, and in the third year devote their time chiefly to the applications of Electricity. The course of instruction in Physics consists of Lectures and of practical work in the laboratories. There are three electrical research laboratories; a Dynamo room, and Laboratories for Heat, Optics, Magnetism, and Acoustics. The first year's course of Physics begins with the discussion of the accurate commercial measurement of Electric Currents, Difference of Potential, Resistance, &c. The remainder of the session is taken up with the Laws of Heat, Sound and Light. Laboratory work goes on from the first, concurrently with the Lecture instruction. In the second year, the course of instruction in Electrical Technology embraces the following subjects—

Laws of Electro-Magnetism and Induction, and their application in Direct and Alternate-Current Dynamos and Motors.
Governing Dynamos for Constant Current or Potential.
Designing Dynamos.
Mechanical Measurement of Power of Dynamos. Efficiency of Dynamos.
Electric Lamps, Arc and Incandescent.
Accumulators. Transformers.
Distribution of Electricity.
Absolute System of Electrical and Magnetic Units.
Construction of Submarine Cables.

During the third year the more advanced parts of these subjects are taken up, and the students are encouraged to carry out some original research work. In addition, they test

the power and efficiency of Alternate Current Dynamos and Transformers, design and construct Electrical Apparatus, and Electrical Installations, practise Jointing and Laying of Leads, and the duties likely to be required of them at electrical works. The lecture course includes the designing of Dynamos to produce prearranged results ; the Laws of Propagation of an Electrical Disturbance in a Submarine Cable ; the Effects of Self and Mutual Induction. There is also a lecture course on Optics and Sound, with special reference to their electrical applications.

Chemical Department.

The course of instruction in Chemistry is similarly arranged to those for other subjects. In the first and second years Chemical students take Engineering and Physics along with their Chemical work, and in the third year undertake Independent Chemical Investigations, and attend Lectures on Crystallography, on various branches of Physico-Chemical Inquiry and of Applied Chemistry. The aim is to prepare students for the higher posts in those industries in which Chemical knowledge is important.

The Technical College, Finsbury.

During the time the Central Institution was building, the development of other parts of the general scheme was not suffered to remain in abeyance.

In order that a commencement might be made in the provision of Technical instruction for artizans and others, the Committee of the Institute, in the autumn of 1879, established some courses of Lectures and Laboratory instruction in Physics and in Chemistry in their application to different industries.

These classes were temporarily carried on in some schoolrooms in the city. It was soon found that they supplied a distinct want, and that for their fuller development a specially-adapted building would be necessary ; and this was the origin of the Finsbury College, Leonard Street, City Road, E.C., which was opened in 1883.

The operations of this College are divided into two distinct portions—*Day Classes* for those who are able to devote one, two, or three years to systematic technical education, attended by about 185 students ; and *Evening Classes*, attended by about 1,100 students, for those who are engaged in industrial or commercial occupations in the daytime, and who desire to receive supplementary instruction in the application of science

and art to the trades and manufactures in which they are concerned.

The College embraces the following departments:—

Mechanical Engineering and Applied Mathematics.
Electrical Engineering and Applied Physics.
Industrial and Technical Chemistry.
Applied Art (evening only).

The courses in these departments are full and complete, consisting of Lectures, Class Lessons, Laboratory Work, Drawing Office and Workshop Practice. There are five Electrical Laboratories; the mechanical laboratory, the drawing offices, and the pattern-shop and fitting-shop have lately been enlarged.

In the departments of Mechanical Engineering and Applied Mathematics, of Electrical Engineering and Applied Physics, the complete course of instruction extends over a period of two years; but students may remain longer. The complete course in the department of Applied Chemistry extends over three years.

The Evening Classes are largely attended by students from fourteen to forty years of age, the great majority of them being employed during the day in workshops or factories. There is an Evening Trades' Class Department, comprising classes in Plumbing, Sheet Metal Work, Builders' Quantities, Brick Cutting and Bricklaying, Carpentry and Joinery, Cabinet-making, and Practical Geometry.

THE ROYAL INDIAN ENGINEERING COLLEGE, COOPER'S HILL, STAINES.

This is one of the most important and complete of the modern establishments for Engineering Education, and it will be interesting to give, not only a description of its present arrangements, but also a brief notice of its origin and history, which throw light on the past state of Engineering Education in this country.

The institution was founded by the Secretary of State for India in 1871.

Some thirty years previously the Indian Government had awakened to the fact that there had been great neglect of Public Works in India, and that in this respect there was a

painful contrast between the results of our rule, and the vast remains still to be seen all over India and Ceylon, of great works and monumental constructions, due to the ancient native Monarchies of the country.

The obligations of the State in this respect began to obtain recognition about the year 1842, in which year the great Ganges Canal was projected, and the trunk road from Calcutta to the North West was set in progress. In 1849 the Punjab was annexed, which led to extensive works. A further impetus was given generally; and in 1854 the control of Public Works had attained so much importance that it was made a separate Department. From that time the outlay on public works continually increased, and in 1870 it had amounted to above seven millions annually; all this being exclusive of the railways, which were private undertakings. The Staff in 1870 comprised about 900 engineers, forming almost as large a body as the covenanted Civil Service.

Originally these engineers consisted wholly of military officers, but the wants soon outgrew this source, and about 1845 the civil element was first introduced. In 1847 the College at Roorkee was established, and began to send out a small number of young engineers, which was afterwards increased from other educational establishments in India, chiefly for training native subordinates.

These means of supply proving still inadequate, it became necessary to draw upon the Civil Engineering profession in England, and a beginning was made in 1854, when Lord Stanley sent out a few English engineers of experience, some of whom proved very valuable acquisitions to the service.

In 1859, after the mutiny, further requisitions were made, but the plan of sending out experienced men was found open to considerable objections. In the first place, such persons were under considerable disadvantages, being of mature age, unaccustomed to such a climate, and unacquainted with the language and usages of the country; and secondly, the introduction at intervals of new experienced engineers caused considerable difficulties in regard to the arrangement of the staff in the country. It was accordingly decided that the department should thenceforward be recruited at the bottom, by the annual appointment of a certain number of young men, who had received a reasonable preliminary education, and had gained some amount of practical experience.

It was supposed that among the large number of young men who were continually being trained for the profession of Engineering, many properly qualified persons might be found who

would be tempted to go out for the liberal life-provision offered by Indian Service, and it was determined to offer these appointments for public competition.

Accordingly examinations were instituted periodically, under the direction of the India Office, and subject to the following conditions :—

The candidates were to be not exceeding twenty-four years of age, and must have already passed three years either entirely with a practising engineer, or partly thus and partly in studying engineering in a school or college recognized for this purpose.

The subjects of examination included (1) Branches of preliminary education, such as Arithmetic, Mensuration, Trigonometry, Algebra, Euclid, and subjects in Mechanical Science; (2) Competence in Drawing and Surveying; (3) Questions in various branches of Practical Engineering, competency in any one sufficing for qualification.

These examinations were continued every year from 1859 to 1870, but the results were very unsatisfactory, so few of the candidates proving qualified. The examination was not strict, but superficial as it was, it was too severe for the candidates offering themselves; and although the standard was practically lowered from time to time, in the later years only about one-third of the appointments could be given away. General Chesney, in reporting to the India Office on this failure, made the following remarks, which (though the state of matters has now much changed) are historically interesting as exemplifying the state of Engineering Education at that time :—

The present mode of training an engineer, where a young man pays a fee to a civil or mechanical engineer for permission to work in an office or workshop, and pick up such crumbs of knowledge as fall in his way, is not education, and the cases must be very rare where persons, after undergoing such a training, will be found to pass an examination involving any knowledge of the principles of mathematics or theoretical mechanics. They usually take no knowledge of that subject into the office, and gain none there.

On this ground, therefore, the bulk of the candidates who had really practical qualifications, failed from ignorance of the principles of the work they were called on to do. When this was found out there arose a reaction, to push forward theoretical qualifications, and a supply of cramming schools, generally of very inferior character, sprang up to prepare young men for the examination. General Chesney said :—

The training of the bulk of the candidates who come forward usually consists in attending some school or college which professes to teach engineering, and then completing the requirements of the competition by spending a year with a civil engineer. It is for this last requirement

that the services of crammers have been found necessary, for the leading civil engineers will not take pupils for a single year. Besides, civil engineers in practice do not profess to teach pupils systematically; they leave them to train themselves, and the young men coming up to these examinations are thus driven to a class of persons who lay themselves out specially for this task, who have no professional practice, and whose qualifications are limited to being able to teach a little drawing and surveying. But since it is open to any person to style himself a Civil Engineer, and to take pupils, the year passed in this way qualifies for the competition.

In this difficulty it became the duty of the Indian Government, in the interests of the public service, to take special means to obtain, for those who entered the Indian Engineering Service, that scientific education which it appeared so difficult to obtain among the ordinary junior ranks of the profession.

With this view they determined to found an Engineering College near London, where a number of young men, admitted by open competition as the most promising on intellectual grounds, should be given, under competent professors, the most complete technical education that a college course could afford.

After this they were to be sent for a time to gain practical experience under a professional engineer, and then were to go out as assistants on the works in India, where, as their qualifications became more matured, they were to be gradually promoted to more responsible service.

The College was opened in 1871. There was no lack of promising candidates for admission; the proposed plan of training was fully carried out, and the result was that about forty well-qualified recruits were sent out from the College annually to take service on the Public Service in India, where their work fully justified the system under which they were educated and chosen.

This had gone on for seven years, when, in 1878, the Indian Government, from imperative financial reasons, found it necessary to curtail largely the expenditure on public works, and, as a consequence, to diminish the annual supply of Assistant Engineers by about one-half.

The continued maintenance of the College under these new circumstances became a financial question, which remained unsettled for two or three years. The Government and the authorities of the College took the wise step of asking the advice and assistance of some professional Civil Engineers, among whom were Sir John Fowler and the late Sir William Siemens, who had both taken special interest in Engineering education.

These gentlemen advised that, in addition to the students

who might be selected for the Indian Service, the facilities of the College should be thrown open to the public, and that such changes should be made in its constitution and curriculum as would make it attractive to students who, while able to afford the expensive education, were willing to look for a professional career elsewhere than in the service of the Indian Government.[1] A confident opinion was expressed that if this course were adopted, the vacancies left in the College by the altered policy would be filled by students of the class mentioned.

These changes, after being well considered, were carried out in 1883. The expectations regarding them have been fully justified, and now, at the beginning of every annual session, the College receives candidates for its appointments and diplomas up to the limits of its accommodation.

The curriculum at this College is very complete.

Admission to it is entirely open to all comers who conform to the regulations, about fifty students being admitted annually in September.

Candidates must be between the ages of 17 and 21; they must produce evidence that they are of good moral character, and they must have received a good general education; in addition to which they must have such a proficiency in elementary mathematics as will enable them to follow the College course with advantage.

The admission examination to test this is not competitive and includes:—

(*a*) English composition, to the extent of being able to write grammatically, and with correct spelling, in a neat and legible hand. The general education is tested by an examination in some classical or modern language, as well as in history or geography.

(*b*) Elementary Mathematics, comprising:—

Arithmetic.
Elementary Algebra.
Geometry (the first four and sixth books of Euclid).
Elementary Mensuration.
" Plane Trigonometry.
The use of Logarithms.

In the event of there being more qualified candidates for admission than the College can receive, the preference is given according to dates of application.

The whole or any portion of the entrance examination may be dispensed with if the candidate produces a University diploma, or other equivalent certificate of a recognized examining body.

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[1] See "The Life of Sir William Siemens," by W. Pole. London. 1888.

The course of education occupies three years, and is of a mixed character, comprising partly advancement in general scientific attainments, partly instruction in regard to the nature of engineering practice, drawing and surveying being thoroughly taught, and, especially under the head of "Applied Mechanics," the established theories of various branches of engineering.

The following description will illustrate this :—

First Year.

Descriptive Engineering.
Geometrical and Engineering Drawing.
Surveying (partly in the field).
Freehand Drawing.
Chemistry, and Chemical Laboratory.
Physics.
Mathematics (plane analytical geometry, elements of the calculus, statics, kinematics, and the elements of kinetics).
Geology
Elements of Architecture.
French or German.
Workshop.

Second Year.

Engineering and Applied Mechanics.
Geometrical and Engineering Drawing.
Surveying.
Chemistry.
Physics and Physical Laboratory.
Mathematics.
Geology.
Elements of Architecture.
French, or German, or Freehand Drawing (Alternative).

Third Year.

Engineering and Applied Mechanics.
Accounts.
Estimating.
Mechanical Laboratory (testing, &c.).
Photography.

During this year also, in addition to the class instruction, the students are employed in making a complete detailed survey in the field, with plans, estimate of quantities, &c., for a project for two or three miles of railway, road, or canal. They have also to work out three complete and detailed designs, the subjects being chosen from building construction and both civil and mechanical engineering.

Some of the subjects named are wholly or partially optional or alternative, the students being encouraged to pursue more particularly those branches of study for which they may show special aptitude.

There are also special courses for Telegraph Engineering and for Forestry to train selected candidates for those departments of the Indian Administration.

The proficiency of the students is tested by frequent periodical examinations, and by assigning values to the practical work executed during the course.

Superior attainments are attested by special diplomas.

A final examination is held at the end of each separate course, with the assistance of special examiners not connected with the College.

The Secretary of State for India offers annually a number of appointments, in the Indian Public Works Department, for competition among the students of the College, who are eligible in the order of standing after the final examination. Those so appointed have, after leaving the College, to go through a course of practical engineering (usually for one year) under a professional engineer. The cost of this is paid by the Government, and the student receives pay during the time.

In the case of students who are not so appointed, the College authorities endeavour, on the students' application, to arrange for placing them as pupils with professional Engineers of standing, at moderate rates of premium, payable by the students.

The staff of the College comprises 18 professors, lecturers, and demonstrators, not including those engaged exclusively in the department of Forestry.

THE ROYAL NAVAL COLLEGE, GREENWICH.

This Institution is intended chiefly for the high class instruction of Officers of the Navy; but private students are also admitted.

It has a very extensive general curriculum, which it is unnecessary to particularize here. The branches bearing on engineering subjects are—

Mechanical and Physical Science.
Naval Architecture.
Marine Engineering.

CRYSTAL PALACE SCHOOL OF PRACTICAL ENGINEERING.

This School, established in 1872, has for its purpose to give thoroughly practical instruction, duly worked out as to details, which may serve as the proper basis for a calculated course of after practice, and be in fact a first step in the professional career. "The leading object," it is said in the prospectus, "is to prepare students, by systematic practical instruction, for professional articles; so that on entering an Engineer's office or works, the pupil may at once be useful to his principal, and enabled to take advantage of the opportunities for learning open to him, because he has mastered the elementary details of the profession."

The curriculum has in other ways a more extended application, theoretical as well as practical.

The first year is devoted to Mechanical Engineering, and comprises instruction in—

Mechanical drawing—making drawings of machinery and constructions, including setting out quantities and estimates, and calculating the strength of materials.

Pattern-making—preparing patterns or models of engines and machinery.

Foundry work—moulding, and making castings.

Smith's work—working iron and making forgings.

Fitting shop work, the use of tools, and fitting and erecting engines and machinery.

The second year's course is devoted to Civil Engineering, comprising—

General surveying and levelling, including whatever is necessary for public works, such as railways, or docks, and the preparation of plans and estimates for Parliament, &c.; going on to specifications and working plans; calculations, &c., in detail of iron bridges and other structures; the investigation of great engineering works in progress, and the general application of principles to practice.

Further instruction is also given in regard to electric work, and to marine engineering.

There is also a "Colonial Section" of practical education and information, designed especially for persons going to the colonies or abroad, as explorers or settlers.

Examinations are held at the end of each term, by engineers not connected with the school.

PROVINCIAL, ENGLAND.

UNIVERSITY OF OXFORD.

The Millard Laboratory was opened by Trinity College in 1886, and in 1888 was enlarged by the addition of adjoining rooms lent by St. John's College. For the last two years it has been supported by the University from the Common University Fund.

The object of the course of instruction is to place before students those fundamental principles on which Mechanical and Electrical Engineering, as well as certain branches of Physics, are based, and without which the manual training of a workshop appears to be incomplete. The principal training is in the experimental methods by which the constants most frequently employed in Mechanical and Electrical Engineering are determined; modern graphic methods are largely used. Mechanical work and fitting is taught only so far as is necessary to show how machine and other tools are used, and processes of construction conducted, and the practical work in this branch of engineering is confined to the production of surface plates (by Sir J. Whitworth's method), and those parts of machines which present no very great difficulty in construction, though they require close and accurate work.

The view taken by Professor Kennedy, F.R.S., in a paper on "The Use and Equipment of Engineering Laboratories,"[1] describes the lines on which, as far as possible, the instruction in the Millard Laboratory has been conducted. The training recommended by the Professor appears to provide exactly what is wanted in order to supply that part of a student's education which in all probability he will not be likely to get either before or after going into "works" or entering upon the business of life. It may be as well to mention some of the different classes of students in the Universities to whom a training, such as has been mentioned, may be of value. They are as follows:—

Men who are going to be Engineers or Architects, and wish to receive some training in the first principles of their subject.

Men who do not take up the work with a view to a profession, but wish to use close and accurate observation of natural phenomena as a mental cultivator.

Medical students, who are required to pass a preliminary examination in Mechanics and Physics.

[1] Minutes of Proceedings, vol. lxxxviii. p. 1, reprinted in Appendix B.

Law students, who wish to acquire a knowledge of technical terms and scientific principles, such as are involved in patent and other cases.

A considerable number of men from each of these branches of study have now gone through courses of instruction in the Laboratory.

The Laboratory consists of:—

(*a*) A Lecture Room furnished with apparatus for illustrating the principles of Mechanics and Hydrostatics, and provided with a supply of electricity from both dynamos and accumulators, and an electric projection lantern.

(*b*) An Experimental Room, in which experiments involving the use of complicated apparatus can be done. This room contains a standard clock with electrical attachments, a chronograph, testing machines, and various forms of measuring instruments. Instruments for determining the velocity of flow of liquids.

(*c*) An Engine Room, which contains a steam-engine and boiler, gas-engine, three dynamos, transmission and turbine dynamometers. The steam-engine and boiler are fitted with the apparatus necessary for testing their efficiency.

(*d*) A Machine Room, containing two Whitworth lathes, one lathe with micrometer dividing head by Cook and Sons, York, and other light lathes, together with drilling, planing, and milling machines, and a full supply of engineers' hand tools.

(*e*) An Instrument Room, devoted to electrical testing, and containing galvanometers, electrometers and other electric measuring instruments, and various forms of incandescent and arc lamps, and photometric apparatus.

(*f*) A Book Room, containing books of reference, apparatus used for drawing and machine construction, planimeters and integrating instruments.

Lectures on Applied Mathematics and Graphic Methods, and certain branches of Physics which bear on engineering work, are given throughout the University terms.

UNIVERSITY OF CAMBRIDGE.

The University of Cambridge includes a Department of Engineering which is under the charge of the Professor of Applied Mechanics and Mechanism. The Professor is assisted by two demonstrators.

The work of the department comprises (1) Lectures, (2) Drawing-office instruction, (3) Laboratory instruction and research (4) Instruction in workshop practice, (5) Practical instruction in field-work.

(1) *The Lectures* cover the portions of the Theory of Engineering usually studied in a university course, namely: Applied Mechanics; the Strength of Materials; the theory of the Strength and Stiffness of Structures; Graphic Statics; the theory of Heat-engines and the working of Steam-engines and Gas-engines; the Production and Distribution of Power; the Kinematics and Dynamics of Machines; Hydraulics; Electro-technics, including the design of Dynamo-electric machines, Electric Lighting, and the Electric Transmission of Power.

(2) *Drawing Office.*—Lectures are given on Plane and Descriptive Geometry and on Machine Design, and on the application of graphic methods in the solution of engineering problems. The pupils are practised in sketching machines from measurement and in making working drawings, and gain some experience in the ordinary work of an Engineer's office.

(3) *Laboratory.*—The pupils make an experimental study of problems in statics and kinetics, also of the strength and elasticity of iron, steel, timber, and other materials of construction; the deflection of beams; the strength of columns; the torsion of shafts; the friction of sliding pieces, of journals, and of belts or pulleys; the efficiency of transmitting mechanism; the discharge of water through orifices and over notches; the accuracy of pressure gauges, indicator springs, &c.; the working and efficiency of the steam-engine and gas-engine.

There is an experimental steam-engine adapted to be run under various conditions, as to expansion, condensation, jacketing, superheating, &c., and very fully provided with means of measuring the heat supplied, the heat rejected, the work done, the dryness of the steam throughout its passage through the engine, the mechanical efficiency, and other points of practical and theoretical interest.

The laboratory is further provided with appliances for experimental work in practical electricity—dynamo, storage battery, and a variety of instruments for measurement, including a series of Sir William Thomson's new current balance.

(4) *The Workshops* are furnished with lathes, planing, shaping, and slotting machines, forge, and other appliances necessary to give pupils a general acquaintance with the processes of metal working and wood working. A staff of skilled workmen is employed to give instruction in each branch.

Although the workshops have been arranged on a considerable

scale the use of them is by no means intended to take the place of pupilage in a larger establishment. It will, however, be found to form a valuable preparation for that, enabling the pupil to learn the lessons which the larger establishment has to teach him in a much shorter time than he would otherwise take. The workshops also form an almost indispensable adjunct to the laboratory; further, they are taken advantage of by many members of the University who do not intend to become Engineers.

(5) *Instruction in Field-work* is given by lectures and by practice in the field. The pupils are taught to adjust the instruments, to perform the usual operations with chain, compass, sextant and theodolite, to set out curves, to keep the field book, and to draw plans of the surveys they have made.

The department includes a museum which contains, with other things, the collection of kinematic models prepared by the late Professor Willis. The buildings of the department adjoin the Cavendish (physical) and the Chemical Laboratories of the University. The department is open to Members of any of the Colleges, and to Non-Collegiate Students of the University.

OWENS COLLEGE, MANCHESTER.

This College was founded in 1851, under the will of Mr. John Owens, merchant, of Manchester, and was reconstituted and incorporated by Act of Parliament in 1871.

There are four departments, the first of which, allotted to "Arts, Science, and Law," comprehends (in addition to Professorships in classics, history, &c.) Professorships or Lectureships in Pure Mathematics; Applied Mathematics, Physics, Chemistry (Organic and Technological), Metallurgy, Mineralogy, and Geology.

There is also in the same faculty a "Beyer Professorship of Civil and Mechanical Engineering, and Geometrical and Mechanical Drawing," which was founded in 1868.

The first year's course in this comprises—

Measuring Instruments.
Plain Geodesy or Surveying.
Levelling.
Underground Surveying.
Setting out.
Hydrography.
Quantities and Estimating.

Hydraulic Surveying.
Earth-work.
Masonry.
Timber-work.
Foundations, &c.

The second year's course contains—

Theory of Concrete Forces.
Theory of Simple Structures.
Strength of Materials.
Mechanical Connexion, or Kinematics of Machinery.

The third year's course is devoted to—

Dynamics of Machinery.
The Theory and Construction of Machines.
Hydraulics and Hydraulic Machinery.
Steam and the Steam-Engine.

Visits are made, when circumstances permit, to inspect some of the most important engineering and manufacturing works in Manchester and the neighbourhood.

There is also an *Engineering Laboratory* attached to this College. By this is to be understood something essentially distinct from a workshop, the objects sought being to enable students to practise those methods of measurement of quantities, whatever their nature, which belong to the work of the Engineer.

It is pointed out that the making of tests, in particular, for materials and machines, and the reduction of their results, have become a most important part of the Engineer's work. The training for this is especially scientific, and can best be acquired in a laboratory worked in connexion with a course of scientific study. On the other hand, the laboratory work, by familiarising the student with practical mechanics in their higher developments, and by furnishing actual examples, will give to his scientific training a reality, the want of which has hitherto been greatly felt.

A course of instruction in laboratory work and drawing is arranged in connexion with the Engineering Lectures.

There is a class for *Practical Surveying*, to be carried on in convenient localities not too far from the College.

A *Geometrical and Mechanical* drawing course, of combined lectures and practical studies, is also arranged.

This College is affiliated to the "Victoria University, Manchester," which was founded by Royal Charter in 1880. Among the degrees granted there is that of "Bachelor of Science," which may be taken in five branches: Mathematics, Engineering, Experimental Science, Biology, and Geology.

Certificates in Engineering are awarded somewhat similar to that for the B.Sc. degree of the Victoria University.

MANCHESTER TECHNICAL SCHOOL.

In this Institution there are *Departments of Science and Technology*, which include classes for day and evening students in the Theory and Practice of Electrical and Mechanical Engineering and in Building Construction.

UNIVERSITY COLLEGE, LIVERPOOL.

The work of this College commenced in 1882, its object being in the words of the charter—

To provide such instruction in all the branches of a liberal education as may enable residents in the City of Liverpool and the neighbourhood thereof to qualify for Degrees in Arts, Science, and other subjects at any of the Universities granting degrees to non-resident Students, and at the same time to give such technical instruction as may be of immediate service in professional and commercial life.

In 1884 the College became incorporated in the Victoria University (the Owens College, Manchester, being then the other incorporated College, the Yorkshire College, Leeds, having since become incorporated). The College can thus prepare students for its own University degrees in Arts, Science, Law, and Medicine, both ordinary and honours degrees in Engineering being included in the Science faculty.

The Department of Engineering was organized in October, 1885, and since October, 1889, its work has been carried on in the block of buildings known as the Walker Engineering Laboratories (after Sir Andrew B. Walker, Bart., by whom they were built and equipped).

The training given is regarded as either preliminary to, or supplementary of, a pupilage under some Engineer, or apprenticeship with some Engineering firm.

Courses of instruction are arranged as follows:—

First Year.—Engineering, Drawing, and Design, Descriptive Geometry, Surveying, Workshop Instruction, Mathematics, Mechanics, and Physics.
Second Year.—Engineering, Drawing and Design, Descriptive Geometry, Laboratory Work, Surveying, Mathematics, Chemistry, and Physics.
Third Year.—Engineering Design, Laboratory Work, Mathematics, Physics.

The above courses are arranged so as to make it possible for students to take the work of the 1st and 2nd terms only, and enter some Engineering works during the summer (viz. from April to October).

The actual subjects taught under the head of Engineering are as follows :—

First Year.

1*st Term.* Measurements and Units.
Laws of Force and Motion, and the Dynamics of Machines.
The principle of Work and its applications.
The Nature and Laws of Friction.
Modulus of Machines.
Graphic Statics.

2*nd Term.* Hydro-Mechanics.
Stability of Walls, &c.
Motions of Fluids.
Flow in Pipes and Channels.
Resistance of Ships.
Pumps.
Pneumatics.

3*rd Term.* Brickwork, Stones, Cements, Masonry.
Foundations, Piles, Cofferdams.
Common Roads.
Railways and their appurtenances.
Bridge Construction.
Canals, Streams, and Rivers.
Marine Engineering—Piers, Harbours, Docks.
Waterworks.
Drainage and Irrigation.

Second Year.

1*st Term.* Machines and Mechanism of various kinds.

2*nd Term.* Prime Movers of various kinds.

3*rd Term.* Advanced Bridge Construction.

Third Year.

1*st Term.* Theory of Simple and Complex Structures.

2*nd Term.* Kinematics and Dynamics of Machines.

3*rd Term.* Advanced Theory of the Steam-Engine and other prime movers, Thermo-Dynamics.

Under the head of Engineering Drawing and Design is included in the first year—

A general description of materials used in machine construction, their strength, properties, and behaviour under the action of loads. The testing of materials. Simple problems in connection with forces acting in parts of structures and machines. The strength and form of riveted joints. The dimensions and strength of bolts, nuts, keys, and cotters. The strength and construction of pipes and cylinders.

And in the second year—

The effect of live loads. The theory and practical calculations required in dealing with the transmission of power by various means, such as by shafting, toothed friction, and screw gearing. The strength and form of

the essential parts of machinery. The form and dimensions of valves, and design of valve gears. The design of complete machines and the preparation of working drawings.

A College certificate in Engineering is awarded independently of the Victoria University degrees, and for this certificate the foregoing courses prepare students.

There is a summer vacation course in workshop practice and laboratory work.

Different courses of evening lectures in Engineering subjects suitable respectively for artisans and for professional men are given annually.

A special Engineering Prospectus is issued by the College.

YORKSHIRE COLLEGE, LEEDS.

This College was established in 1873, with the following objects—

To found, endow, and maintain, in the County of York, a College or Colleges, and by means thereof and by means of lectures to be delivered in any towns or places in that county, or by such other means as the Association may think proper, to promote the education of persons of both sexes, and in particular to provide instruction in such sciences and arts as are applicable or ancillary to the manufacturing, mining, engineering, and agricultural industries of the county of York, and in ancient and modern languages, history and literature, medicine, surgery, law, logic, moral philosophy, and any other subjects of University or College teaching, and in such other branches of education as shall from time to time be directed by the governing body.

The distinguishing feature of this College is the dual character of its work; equal importance being attached to the training of young men who are intended for professions and trades, and to the preparation of others for University degrees in the various faculties of science, arts, and medicine. In the former department there are classes and elaborately-equipped workshops and laboratories, dealing specially with the following subjects—

Engineering (Civil, Mechanical, Electrical and Mining).
Physics.
Coal Mining and Colliery Management.
Textile Industries.
Dyeing and Printing Textile Fabrics.
Leather Industries.
Agriculture.
Freehand and Geometrical Drawing.
Book-keeping, Shorthand and Commercial Business.
Practical Chemistry, &c.

In the *Department of Engineering*, the instruction extends over three sessions, and comprises Lectures on engineering principles and practice, geometrical and technical drawing, demonstrations and practice in the engineering laboratory, and visits to engineering works, and to manufactories.

There is also an Elementary Engineering Class, conveying instruction on simple principles, and as far as possible suitable for students who enter with little or no previous mathematical knowledge.

The Yorkshire College, with Owens College, Manchester, and University College, Liverpool, constitute the Victoria University.

BRADFORD TECHNICAL COLLEGE.

There is an Engineering department at this institution, and regular courses are given in Civil, Mechanical, and Electrical Engineering, which are stated to afford a sound theoretical and practical education to students.

It is intended that whilst preparatory to entering an Engineer's office or works, the general training shall be of such a nature as to be directly and immediately useful in business after the college courses are completed.

THE DURHAM COLLEGE OF SCIENCE, NEWCASTLE-UPON-TYNE.

This College is intended to "Represent the Faculties of Science and Engineering in the University of Durham, and thus to constitute an important portion of the University of the North of England."

It aims at supplying the higher educational needs of the whole of the district of which Newcastle is the commercial capital.

Complete courses of instruction have been organised in Mechanical and Marine Engineering, Naval Architecture, Mining Engineering, Electrical Engineering, and applied Chemistry.

The college possesses complete chemical and physical laboratories with special facilities for the study of technical electricity; a new metallurgical laboratory will be opened in October, 1891, and arrangements are being made for the immediate erection of the George Stephenson Engineering Laboratory.

THE MASON SCIENCE COLLEGE, BIRMINGHAM.

This Institution, founded by Sir Josiah Mason on the 23rd February 1875, was opened in 1880.

There are two Faculties, viz., of *Arts* and *Science* respectively.

The latter contains all the usual subjects, and comprises also a *Department of Civil, Mechanical, and Electrical Engineering.*

Like most other courses of this nature, it extends over three years, and its nature may be gathered from the following extracts from the calendar.

It will be seen that the plan of instruction is: Firstly, to describe the *facts* of engineering, *i.e.*, the tools, machinery, and methods used by engineers; secondly, to develop theoretical engineering science as based on these facts; and thirdly, to apply the scientific knowledge of facts and theory to practical problems in engineering design.

The whole of the teaching in the classes is practical and technical in its aim, no theory being introduced except such as has a direct bearing on the problems of professional practice, and no theories being taught until the facts upon which they are based have been fully explained.

The practical work in the drawing, exercise, and laboratory classes is designed to give familiarity with the processes, calculations, and materials used in engineering establishments and in surveying. In this laboratory the student makes experimental investigations of the properties of tools, machines, and materials, such as he can have no opportunity of making during an apprenticeship at work.

College study cannot, however, supersede the desirability of a formal or informal apprenticeship; but this apprenticeship may be shortened by two or three years if the student follows the engineering course offered in Mason College.

Certificates and Diplomas are given during the course and at its close.

Besides the ordinary entrance, and First and Second Year's Scholarships, the values of which range from £20 to £30, a "Tangye" Technical Scholarship in Engineering, of the value of £30, is annually awarded. There is also a £150 scholarship offered yearly to students in Technical Science by the Commissioners of the Exhibition of 1851.

UNIVERSITY COLLEGE, BRISTOL.

This College was established in 1876. It has classes of the ordinary kind, and includes a *Department of Engineering and the Constructive Professions.*

It is stated in the Calendar, that—

The instruction in this department is designed to afford a thorough scientific education to students intending to become Engineers, or to enter any of the allied professions, and to supplement the ordinary professional training by systematic technical teaching.

The "Course for Students intending to become Civil Engineers or Surveyors," has been arranged to extend over two years; but special arrangements will be made for students who may deem it advisable to remain for a third year.

There is also a "Course of Mechanical Engineering," a "Course of Electrical Engineering," and a "short Course of General Engineering," the latter being intended to meet the requirements of draughtsmen and others who cannot spare time to follow out any of the complete courses.

The subjects included are of the usual character.

There is a Mechanical Laboratory in which material is tested for commercial purposes.

UNIVERSITY COLLEGE, NOTTINGHAM.

This Institution was established in 1881. In addition to the subjects of ordinary education it contains many commercial and technical classes.

Complete courses of instruction, extending over three years, are arranged for boys who have just left school, and intend to become Civil, Mechanical, Electrical, and Mining Engineers. The object of each complete course of study in the workshop, lecture room, laboratory, and drawing office, is to give the students such a scientific and technical training, directly bearing upon industrial work, as will fit them to enter the factory or workshop with a thorough grip of the principles underlying their work. Advanced students will be permitted to join the middle or senior courses, if in the judgment of the Professor they are properly qualified. The workshops at present comprise two pattern maker's and carpenter's shops, a foundry, a smithy, a fitting, turning, and erecting shop, and a dynamo shed, containing a three-light Brush machine, a Ferranti dynamo, and Siemens exciter. Students receive instruction in Mathematics, Mechanics, Engineering, Mechanical Drawing, Physics, Chemistry, and Metallurgy, including laboratory work, and are trained in the use of tools under skilled instructors in the workshops. Advanced students have also experience during the summer term in the works of several engineering firms in town, including the Waterworks of the Corporation of Nottingham. There will also be demonstrations in surveying, levelling, testing the strength of material, engine trials, and general installation work.

The course of instruction is the same for all students during the first year. The subjects of the second year's course are

also the same for those intending to become Mechanical and Electrical Engineers. In the third year they specialise according to the particular branch of Engineering they intend to follow. Electrical Engineering students take charge of the electric lighting of the College for a week at a time in turn throughout the winter and spring. These students are allowed to look after the dynamo and the arc lamps, and make the necessary measurements of power and light. Special facilities are afforded for testing the experimental dynamo driven by the Atkinson cycle gas engine. Instruction is given in the management and methods of testing dynamo-electric machines and electro-motors, accumulators, arc and incandescent lamps.

Arrangements will be made for students to visit and inspect works in progress as well as factories and workshops, and when possible they will be encouraged and aided in making original investigation.

FIRTH COLLEGE, SHEFFIELD.

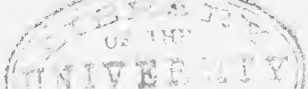
This Institution was founded in 1879 by Mr. Mark Firth, an eminent steel manufacturer. Originally intended as a Hall and Lecture-room, in which the Cambridge Extension Lectures could be given, its scope soon became enlarged so as to fill the position of a local University College for Sheffield.

The aim of the Firth College is to provide for the people of Sheffield and the district the means of higher literary and scientific education by University methods of teaching. Its doors are open to all, without distinction of sex or class, who are over seventeen years of age, though the limit of age may be lowered in exceptional cases. It forms one of the series of local University Colleges which have been founded, chiefly within the last decade, to spread the advantages of University education throughout the kingdom, and to attract and develop all the best intellects, wherever they may happen to appear. Amongst their chief functions may be mentioned:—

(1) The provision of higher education, by University methods, for students above ordinary school age in the large towns, such provision including laboratories and appliances for practical work in the experimental sciences.

(2) The means of teaching the applications of pure science to the technical operations carried on in their districts.

(3) Placing the means of higher education within reach of all, whose business or work would otherwise prevent it, through evening classes and laboratory work.



To which may be added (4), the means of original research in science or its applications.

SHEFFIELD TECHNICAL SCHOOL.

This was established in 1880 as a branch of Firth College, Sheffield, but is now separate, and is managed by a committee of the Corporation, with representatives of Firth College. It is maintained under the Local Taxation Act of 1890. The work of the institution is divided into three departments:—I. The Junior Day Department; II. The Senior Day Department, including (i.) the engineering section, and (ii.) the metallurgical section; III. The Evening Department, comprising, amongst others, special sections of engineering, metallurgy, mining, and building.

The complete course in Mechanical Engineering extends over three years, and includes, in addition to the lectures, work in the laboratories and in the workshops and drawing offices. The laboratory appliances include a 50-HP. steam-engine, a 4-HP. gas-engine, a 50-ton Buckton testing machine, and a hydraulic force pump and accumulator. There are also a machine and fitting shop, a wood-work shop, a smith's shop, and a foundry. The drawing office accommodates eighty students working at one time.

The lectures on Mathematics, Mechanics, Physics, and Chemistry to senior day students are given at Firth College by the respective professors. A student passing in the first class in the annual examination at the end of his course is awarded a diploma as an Associate of the Technical School.

Associated courses in Engineering, Metallurgy, Electrical Engineering, and Coal Mining, are given by Firth College to those students who have gone through a specified three years' course, and have passed the required examination.

THE HARTLEY INSTITUTION, SOUTHAMPTON.

This Institution was founded, in 1862, by the bequest of Mr. H. R. Hartley, "To promote the study and advancement of the Sciences of Natural History, Astronomy, Antiquities, Classical and Oriental Literature, and the Fine Arts, in the Town of Southampton."

An Engineering Department forms part of the educational

scheme. In this department students intended for the engineering professions receive a course of instruction in Pure and Applied Mathematics, Geometrical, and Engineering Drawing, and Mechanical, Physical, and Chemical Sciences. Physical and chemical laboratories are provided, and a mechanical laboratory will shortly be built. Practical surveying and levelling are taught in the field.

WALES.

UNIVERSITY COLLEGE OF SOUTH WALES AND MONMOUTHSHIRE.

The ninth session of this College begins on October 5th, 1891, and ends on Friday, July 24th, 1892.

The Department of Engineering already comprises the scientific sides of the most important branches of engineering, and it is hoped that the authorities of the College may be in a position at no distant date to appoint a separate lecturer or professor of mining and metallurgy.

The ordinary engineering course extends over three years, the first two of which are to be devoted to the study of Drawing of all kinds, and the principles of Applied Mechanics and Mechanical Design. In their third or last year students will be encouraged to specialize in particular branches.

The plans for the new engineering buildings which have recently been adopted are of the most complete character. Amongst other accommodation for the department they include a lecture room, drawing office, laboratory, machine shop, engine and dynamo room, and boiler house. The equipment of the laboratory and machine shop will be of the highest degree of excellence.

SCOTLAND.

UNIVERSITY OF GLASGOW.

This is one of the oldest Universities in Great Britain, having been founded by Pope Nicholas V. in 1450.

In addition to the usual instruction in Mathematics, Natural Philosophy, Chemistry, &c., a special Chair of *Civil Engineering and Mechanics* was founded by Queen Victoria in 1840.

The classes are arranged as follows :—

COURSE I.—*The Materials of Construction and the Elements of Applied Mechanics.*—The lectures will treat of the origin, preparation, properties and uses of the chief constructive materials, especially of cast-iron, wrought-iron, and steel, brass and other alloys, timber, building stones, cements and concrete, and of the more elementary principles of mechanics in their application to problems connected with engineering structures and machines.

COURSE II.—*Surveying, Levelling, and Setting-out of Works.*—Surveying with the chain and with angular instruments; levelling; the optical and mechanical principles, tests, and adjustments of surveying and levelling instruments; setting-out of works, especially setting-out of railways; mensuration of areas of land and of volumes in earthworks, etc. The lectures will treat for the most part of those portions of the subject which are not readily learned in ordinary field and office practice.

COURSE III.—*Prime Movers and the Mechanics of Machinery.*—The lectures will treat of the theory of steam and gas engines, the structural details of boilers and engines, the mechanics of machinery, the elements of machine design, the transmission of power, and friction and lubrication in machines.

COURSE IV.—*Higher Applied Mechanics and Hydraulics.*—The lectures will treat of the strength and elasticity of materials, the strength and stiffness of beams, girders, columns, framed structures, &c. Hydraulics and hydraulic appliances, including the gauging of water, the flow of water in pipes, and the principles of water wheels, turbines, and centrifugal pumps.

Engineering Drawing and Calculations.—The work of the classes will comprise lectures and practice in civil and mechanical engineering drawing, descriptive geometry, and graphical statics, and special times will be set apart for the performance of graphical work and calculations in connection with the lecture courses.

Attached to the syllabus are the following remarks :—

The courses of the professor of engineering extend throughout the winter session, that is, from the beginning of November till the end of April. They comprise lectures on Engineering Principles and Practice, instruction in Geometrical Drawing and in Engineering Drawing and Calculations, and visits to Engineering Works and Manufactories.

These courses are designed primarily to suit students who intend to devote themselves to Civil, Mechanical, Electrical or Mining Engineering, but the work of the classes will be found of direct practical utility to Architects and to men who are engaged in any occupations connected with manufactures.

The work of the classes is not intended in any way to supersede the usual requirements of pupilage or apprenticeship in engineering, but to enable the Engineer to gain such a knowledge of the principles underlying his profession or trade as he cannot acquire by only working in the office, in the field, or in the workshop. The classes may be attended either before or after pupilage or apprenticeship, or concurrently therewith.

Tl ere is also a Professorship of Naval Architecture, including

Marine Engineering, which was founded by the widow of Mr. John Elder in 1883.

The curriculum comprises Junior and Senior Courses of Lectures on Naval Architecture and Marine Engineering and Junior and Senior Courses of Instruction in Ship-drawing and Calculations.

This University grants, after due examination, the degree of B.Sc. in Engineering Science, and the degree of D.Sc. is granted on terms set forth in the University Calendar; Certificates of Proficiency in Engineering Science are also given.

Curricula for the B.Sc. Degree.

There are four alternative courses for the degree of B.Sc. in Engineering:—(*a*) Civil Engineering; (*b*) Chemical and Mining Engineering; (*c*) Mechanical and Electrical Engineering; (*d*) Naval Architecture and Marine Engineering.

The courses of study are as follows:—

(*a*) *Civil Engineering.*

1. Mathematics.
2. Natural Philosophy.
3. Chemistry.
4. Geology.
5. Geodesy.
6. Practical Chemistry, or Physical Laboratory, with a practical examination in the work of whichever is chosen.
7. Engineering Classes I., II., IV.
8. Engineering Drawing and Calculations.

(*b*) *Chemical and Mining Engineering.*

1. Mathematics.
2. Natural Philosophy.
3. Chemistry.
4. Geology and Mineralogy.
5. Chemical Laboratory.
6. Engineering Classes I., II., III., and IV.
7. Engineering Drawing and Calculations.

(*c*) *Mechanical and Electrical Engineering.*

1. Mathematics.
2. Natural Philosophy.
3. Chemistry.
4. Geology, or Geodesy, or Practical Chemistry.
5. Physical Laboratory.
6. Engineering Classes I., III., and IV.
7. Naval Architecture, Junior.
8. Engineering Drawing and Calculations.

(*d*) *Naval Architecture and Marine Engineering.*

1. Mathematics.
2. Natural Philosophy.
3. Chemistry.

4. Chemical or Physical Laboratory, with a practical examination in the work of whichever is chosen.
5. Engineering Class III. or IV.
6. Naval Architecture, including Marine Engineering.
7. Ship Drawing and Calculations.

The following notes were published by Professor D. J. Macquorn Rankine, in 1865.

1. *Preliminary Education.*

Of the ordinary branches of elementary education *arithmetic* is of special importance to the student of Engineering; and he ought to be familiar in particular with the most rapid ways of performing calculations consistently with accuracy.

It is desirable that he should be well instructed in engineering and mechanical drawing as part of his preliminary education; but he may, if necessary, obtain that instruction during the intervals of an University course.*

It is also desirable, *if possible*, that the elementary parts of mathematics, such as plane geometry, plane trigonometry, and algebra as far as quadratic equations, should form part of his preliminary education, as thereby time and labour will be saved during his University course.

2. *University Course.*

The course of study and examination adopted by the University of Glasgow is described in the Glasgow University Calendar.

In drawing up that course the University have had in view to avoid altogether any competition with the offices of civil engineers, or the workshops of mechanical engineers, or any interference with the usual practice of pupilage or apprenticeship; and they have accordingly adopted a system which is capable of working in harmony with that of pupilage or apprenticeship, by supplying the student with that scientific knowledge which he cannot well acquire in an office or workshop, and avoiding any pretension to give him that skill in the conduct of actual business which is to be gained by practice alone.

The University course may be gone through either before, during, or after the term of pupilage or apprenticeship, according to convenience. An arrangement which is sometimes found to answer well is to devote the winter to academic study, and the summer to the practice of engineering. A student who is not a candidate for a certificate in engineering science may attend as few or as many classes as he thinks fit.

UNIVERSITY OF EDINBURGH.

In this University, founded in 1583, there are four Faculties: Arts, Divinity, Law, and Medicine. The usual science subjects are at present comprised within the Faculty of Arts, in which there is also a Department of Engineering established in 1868.

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* As stated above, instruction in drawing now forms part of the University curriculum.

I. *Class of Systematic Engineering.*—The object of this course is to show the practical application of science to various branches of Engineering. The complete series of lectures forms a two-years' course of instruction.

The following are the Synopses of the Lecture courses given, in alternate years, during the winter Session:—

I.

Principles of statics; couples; moments of forces; parallel and inclined forces; centre of gravity; moments of inertia; friction.
Equilibrium and stability of frames.
Strength of materials.
Applications of mechanical principles to combined structures, especially to roofs and bridges.
Earthwork and masonry; retaining walls and masonry arches.
Principles of kinetics; Newton's laws of motion; conservation and transformation of energy.
Application of the principles of kinetics to prime movers, especially to the steam-engine.
Theory of heat engines.
Practical applications of electricity.

II.

Principles of statics; couples; moments of forces; parallel and inclined forces; centre of gravity; moments of inertia; friction.
Hydrostatics.
Principles of Kinematics; Newton's Laws of Motion; Conservation and Transformation of Energy.
Hydrokinetics.
Arrangement and construction of waterworks for the supply of towns.
Drainage, ventilation, warming, and sanitary requirements.
Water-wheels, pumps, and turbines.
Mill-work and gearing; spur and bevil-wheels.
Efficiency of various modes of transmitting power.
Locomotives.
Elements of machine design.

Engineering works and factories are visited by the class, under the guidance of the Professor.

II. *Class of Geometrical, Mechanical, and Architectural Drawing.*—Instruction is given in the elements of Geometrical Drawing, the making of figured sketches from actual measurements, and subsequently in the design and preparation of Working Drawings for Structures and Machines.

All students are recommended to take the classes in Engineering and Drawing together.

The class in Drawing may also be attended with advantage by those who propose in subsequent years to attend the class of Engineering, as it is of great importance that students should be able to readily understand mechanical diagrams, and

to apply the graphic methods of calculation frequently employed by Engineers.

III. *Additional Courses.*—Short courses of Lectures on special subjects, and of an advanced character, are given from time to time.

IV. *Tutorial Class.*—A Tutorial Class, at which the questions proposed in a Weekly Exercise paper are discussed and explained, is held each week.

V. *The Fulton Laboratory of Mechanical Engineering* in which practical instruction is given in the processes employed by the engineer in the experimental determination of the physical and economical constants of materials, machines, electrical appliances, and prime movers, is open to students during the Session.

VI. *Engineering Field-Work.*—A course of Theoretical and Practical Instruction in Surveying, Levelling, Setting Out, and Calculation of Quantities, is given during the Summer Session.

The course consists of Lectures, and of Practical Work, as undertaken in the field and in the office, and occupies the whole of each day for about three weeks. The number of hours during which instruction is given is thus made to correspond to an ordinary course extending over a much longer period.

VII. A special course of instruction in Sanitary Engineering and Practical Sanitation, consisting of Lectures, Demonstrations, and Drawing, suitable for candidates for Degrees or Diplomas in Public Health, is given during each winter session.

The University grants the Degrees of *Bachelor* and *Doctor of Science*, both of which may be taken in the Department of Engineering.

The following course of study is recommended :—

First Year.—Mathematics (First Class), Geometrical Drawing, Chemistry, Engineering Field-Work, Geology (Summer Session).

Second Year.—Mathematics (Second Class). Natural Philosophy, Engineering, Drawing.

Third Year.—Natural Philosophy (Advanced Class), Engineering, Drawing.

If the student is sufficiently well prepared, some modification of the foregoing may be found desirable.

HERIOT-WATT COLLEGE, EDINBURGH.

This Institution was founded in 1821 by Mr. Leonard Horner, F.R.S. In 1851 it took the name of the *Watt Institution and School of Art*, and in 1885 the present title was adopted

when it was placed under the management of George Heriot's Trust, and was substantially endowed by the Trust. In 1886–88 the College was rebuilt and fully equipped with all apparatus and appliances for Technical Instruction.

The *Technical Department* includes classes for Mathematics, Physics, and Chemistry, and the Natural Sciences, as well as for Engineering and the Constructive Arts.

The Engineering course extends over two years, and consists of lectures, exercises, and demonstrations in the laboratories.

THE GLASGOW AND WEST OF SCOTLAND TECHNICAL COLLEGE.

This was founded in 1886, according to a scheme framed by the Educational Endowments Act, whereby several educational institutions, namely, Anderson College, the Young Chair of Technical Chemistry, the College of Science and Arts, Allan Glen's Institution, and the Atkinson Institution, were fused together and placed under the management of one governing body.

The main objects of the amalgamated establishment are declared to be—to afford a suitable education to those who wish to qualify themselves for following an industrial profession or trade, and to train teachers for technical schools.

With this object, regular courses of instruction have been organized, for which the Diploma of the College is granted, in the following departments—

Civil Engineering.
Mechanical Engineering.
Naval Architecture.
Electrical Engineering.
Architecture.
Chemical Engineering.
Metallurgy.
Mining Engineering and Mining.
Agriculture.
Mathematics and Physics.
Chemistry.

The subjects of instruction in the first year are the same for all the courses; and are—

Natural Philosophy.
Mathematics.
Chemistry.
Drawing.
Workshop or Laboratory.

Candidates who have completed this course and passed the special examination at the end of the Session, should then select the Department in which they purpose taking their Diploma, and they will follow, during the second and third years, the courses corresponding thereto.

In their second and third years Engineering Students attend the higher classes in Mathematics, Natural Philosophy, and Drawing; also a course of lectures on Applied Mechanics (including the Elements of Construction), and lastly, courses of lectures with Office and Laboratory or Workshop Training in the department of study selected. Besides the examination in the subjects of the first year's course, candidates have to pass an examination in either French or German, and in either Logic, English Literature, or Political Economy, before they can be admitted to the final examination in the main subject of the department, which is partly written and oral, and partly practical.

The course for Civil Engineering comprises Lectures on (A) Roads and Railways; (B) Hydraulics; (C) Roofs and Bridges; (D) Engineering Geodesy.

That for Mechanical Engineering, treats first of the materials used, then of their manipulation, and lastly of Mechanical Design.

In the course for Electrical Engineering instruction is given in the method of testing the College Engine, Dynamos, Storage-Cells, &c.

Regular courses of instruction have also been organized in connection with the evening classes of the College, for apprentices and others engaged in daily work. For these courses junior and senior certificates are granted in the above and other departments of study.

Special prominence is given to Laboratory work, in Physics, in Chemistry, in Engineering, in Metallurgy, and in other courses where it can be introduced with advantage.

UNIVERSITY COLLEGE, DUNDEE.

This College was established nine years ago, and now forms part of the St. Andrews University. It is chiefly devoted to the modern sciences, and comprises a special Department of Engineering in which the lecture-hall, drawing office, and laboratory have been fitted up with modern appliances, and every requisite for experiment and research. The regular professorial lectures, and the work of the laboratory classes, are directed to a study of the theory and practice of both Civil and

Mechanical Engineering; while in the drawing office students are exercised daily in the practice of engineering drawing, in which instruction is given by an assistant lecturer. In the laboratory students join with the professor or the demonstrator in making practical experiments on the strength of materials, their elasticity, and other mechanical properties, the coefficients of hydraulic discharge, and in testing the efficiency of the gas-engine and the steam-engine under various conditions. The present equipment of the laboratory includes a Wicksteed testing machine, testing up to 50 tons in tension compression, shearing, and bending, with autographic recording apparatus for drawing diagrams of strain and stress; an experimental steam-engine, working up to 75 indicated HP., and arranged to work simple or compound, with or without a condenser, and with either surface or jet condensation; a high-pressure tubular boiler; a gas-engine working up to about 10 HP.; a set of machine tools; a mercury column for measuring pressure up to 250 lbs. per square inch, and for testing the accuracy of pressure gauges and indicators; a cement-testing machine; and a large number of minor appliances for testing and experimental work, in addition to dynamo electric machines and the apparatus of the Electrical Engineering Laboratory.

During the winter term a special course of evening lectures is given, in addition to the regular day classes, upon some branch or branches of Engineering. During the summer term of each alternate session, a few weeks are devoted to a course of lectures and field-exercises in surveying, levelling, and the setting out of engineering works. The field-work is therefore included in a two-years' course, but attendance during three years on the engineering and other science classes at Dundee is recommended as qualifying for the degree of B.Sc. in Engineering granted by St. Andrews University.

As regards the allied sciences, the college at Dundee comprises independent departments (with fully equipped laboratories) in chemistry, mathematics, and natural philosophy, including mechanics, kinetics, hydrostatics, physical optics, thermo-dynamics, magnetism, and electricity. The subject of electrical engineering is taken in connection with this department. The College session begins on October 13th.

IRELAND.

DUBLIN UNIVERSITY (TRINITY COLLEGE).

The ordinary Science subjects bearing on Engineering are well represented in this College; and there are, in addition, four special technical or "Professional" Schools, viz., for Divinity, Law, Medicine and Surgery, and Engineering.

The latter is thus described in the Calendar—

The School of Engineering was established in the year 1842 for the purpose of affording to such students as intend becoming Civil Engineers systematic instruction in those branches of knowledge, an intimate acquaintance with which is most useful to the Engineer in the practice of his profession.

While keeping this object in view, it has been deemed advisable to require that the student, during his Course in the School, should be a member of Trinity College, and subject to its regular discipline. He can thus at the same time avail himself of the advantages of a general University education, either as resident within the College or otherwise.

It should be observed that the school only professes to give instruction in those branches of science which are the foundation of engineering practice, and which are daily becoming more important with the increasing application of science to engineering. No College instruction can dispense with the practical training that is acquired in the routine of actual work, but it gives a greater value and a speedier comprehension of the experience thus obtained.

Admission to the School of Engineering is obtained by passing an entrance examination in Elementary Mathematics.

The Professional Course continues for three years, during which instruction is given, partly by Lectures and partly in Laboratories, and in the Field; being arranged thus—

First Year (*Junior Class*).

Mathematics.
Mechanics.
Experimental Physics.
Chemistry.
Drawing and Practical Geometry.

Second Year (*Middle Class*).

Practical Mechanics.
Theory of the Steam-Engine.
Applied Physics, Elements of Electrical Engineering.
Chemistry (Analyses of Ores, Minerals, &c.).
Elementary Geology.
Drawing and Office work.
Levelling, Surveying, and General Engineering.

Third Year (*Senior Class*).

Mineralogy, Geology, and Mining.
Drawing and Office work.
Levelling, Surveying, and General Engineering.

On concluding the senior year of his course, the student, after passing the final examination, will be entitled to receive a "Licence in Engineering" granted by this University.

If he has also graduated in Arts he will be entitled to proceed to the degree of "Bachelor in Engineering."

And after having been actually engaged upon engineering works for three years, he will be entitled to proceed to the degree of "Master in Engineering."

Honours are further awarded for special merit.

THE ROYAL COLLEGE OF SCIENCE FOR IRELAND, DUBLIN.

This establishment is under the Department of Science and Art, South Kensington, and is said in the Prospectus to supply—

As far as practicable, a complete course of instruction in Science applicable to the Industrial Arts, especially those which may be classed broadly under the heads of Mining, Engineering, and Manufactures.

The course of instruction for students desirous of obtaining the Diploma of Associate extends over three years.

In the first year the instruction is general, comprising—

Mathematics and Mechanics.
Descriptive Geometry.
Geometrical Drawing.
Theoretical Physics.
„ Chemistry.

In the second and third years the instruction is specialized under the heads of *Mining, Engineering,* and *Manufactures.*

In the Engineering Division the second year contains—

Drawing.
Mathematics and Mechanics.
Practical Physics.
„ Chemistry.
Mineralogy, Botany, and Zoology.

The third year comprises—

Applied Mechanics and Hydrodynamics.
Mechanism and Thermodynamics.
Mechanical Drawing, Engineering, and Surveying.
Geology and Palæontology.

Programmes and directories can be had from the Secretary on application.

QUEEN'S COLLEGE, CORK.

This College, founded in 1845, has, in addition to the ordinary Scientific courses, a "School of Engineering," of the same character as those in other educational institutions.

The course usually consists of—

First Session.

Mathematics (First Course).
Chemistry.
Modern Languages.
Geometrical Drawing.
Office Work.
Experimental Physics.

Second Session.

Mathematics (Second Course).
Mathematical Physics.
Mineralogy, Geology, &c.
Physical Geography.
Civil Engineering.
Office Work.
Field Work.

Third Session.

Mathematical Physics.
Civil and Mechanical Engineering.
Office Work.
Field Work.
Engineering Excursions.

Students can also, if they wish to do so, attend a course of Practical Chemistry in the Laboratory and of instruction in the use of tools under a carpenter in the workshop, to which will be shortly added a smith's forge. They may also attend the course delivered by the lecturer on Architecture. The school is furnished with a Cement-testing apparatus by Adge, a Thurston Testing machine, and a 30-ton Wicksteed Testing machine with automatic recorder.

There is also a *Colonial Department* with a course of two sessions, for the instruction of those who are about to settle in new countries.

A certificate of having passed through the above course satisfactorily is granted by the College Council, and the students may obtain, after due examination, in the Royal University of Ireland—

A Diploma in Engineering; or
The Degree of Bachelor of Engineering; or
The Degree of Master in Engineering.

QUEEN'S COLLEGE, BELFAST.

This College, founded in 1845, has a "School of Engineering," of a similar nature to that in the Queen's College, Cork.

It is also similarly affiliated to the Royal University of Ireland, where the same degrees may be taken.

QUEEN'S COLLEGE, GALWAY.

A similar description will also apply to this College.

INDIA.

UNIVERSITY OF BOMBAY.

Bombay was the first place where an attempt was made to give a systematic education to intelligent young men of native Indian extraction, with the object of fitting them to act as assistants on the public engineering works of the country.

A College had existed for many years, called the "Elphinstone Institution," where education was given to the natives in literature and science generally. The instruction was conveyed entirely in the English language, the pupils being only those who had already received a good elementary education. This College answered so well, and the young men showed such aptitude for scientific pursuits, that in 1843 the Government, who were just at that time beginning to think of exercising more activity in regard to the public works of the country, determined to try

the experiment of educating some of the pupils as engineering assistants upon them.

With this view, they directed the home authorities to find and send out a suitable person to undertake the educational duty; the matter was referred to the Institution of Civil Engineers in London, and on their recommendation one of their members, Mr. William Pole, was appointed to the post.

He went out in 1844; formed a class of young men, selected carefully from the most advanced pupils of the college, and gave them a course of three years' instruction, theoretical and practical. And although the subject was so strange to the pupils, and the general idea of College instruction in it was so new and undeveloped, the experiment was very successful. The class made, during their study, surveys having reference to the preparatory idea of the introduction of railways into the West of India, and at the end of their course, most of them entered, as proposed, into the public employ, and proved useful servants.

Mr. Pole was obliged by ill-health to leave India in 1847; but the work was continued, and its success led, at that date, to the formation of a special establishment for the same purpose under the Calcutta Government, at Roorkee, in the North-West Provinces. In 1854, the Bombay Engineering School was also placed on an independent footing, and removed to Poona.

A few years later the whole subject of education had acquired such magnitude, that it was determined to rearrange it in a more systematic manner, and in 1857 a University was founded in each of the three Presidencies, to which the whole of the Colleges and Schools of the district were affiliated, the Engineering Colleges among the number.

The University of Bombay embraces four Faculties: Arts, Law, Medicine, and Civil Engineering; and in the latter are granted the degrees of Licentiate and Master of Civil Engineering.

The instruction for this subject is given at

The Poona Civil Engineering College.

This arose out of the School already mentioned; its object being to educate subordinates, chiefly natives of India, for the Public Works.

There are four Departments: the highest being a full education for the University degrees; the three others (as in Roorkee) for inferior grades.

Workshops are attached to the College, where the students receive practical instruction, and where work of various kinds is executed for the Government and the public.

UNIVERSITY OF CALCUTTA.

This was incorporated by Act of Parliament in 1857.

There are four Faculties: Arts, Law, Medicine, and Engineering.

In the latter it grants degrees as—

Licentiate in Engineering;
Bachelor in Engineering, and
Master in Civil Engineering.

A large number of teaching institutions are affiliated to this University, in many of which scientific subjects are taught; but there are two affiliated colleges specially devoted to the Engineering faculty, namely—

The Thomason College, and
The Government Engineering College.

The following particulars will explain the nature of these:—

The Thomason Civil Engineering College, Roorkee, North-West Provinces.

This establishment was founded in 1847, by the Government of India.

It is designed to give Theoretical and Practical Instruction in Civil Engineering to "Statutory Natives of India" (either of English or Indian extraction), with a view to their employment on the Public Works of the country, according to their several qualifications, and the requirements of the Service.

There are three classes of Students, viz.—

The Engineer class.
The Upper Subordinate class.
The Lower Subordinate class.

Engineer Class.

Candidates for this must be between 18 and 22 years of age, and are selected by competition in an entrance

examination, which comprises languages, physical science, history, mathematics, and drawing.

The course of study extends over two years, and comprises ten separate subjects, namely—

Elementary Pure Mathematics.
Mechanics and Conic Sections.
Higher Pure Mathematics.
Applied Mechanics.
Civil Engineering.
Drawing.
Surveying.
Experimental Science.
Hindustani.
Physique and Sports.

There is also a tour of inspection of engineering works, when opportunity offers.

Students who have satisfactorily completed their course, are given Certificates as Assistant Engineers, and a number of appointments, on the Engineer branch of the Public Works, are annually guaranteed to properly qualified men; in addition to these, certain subordinate positions are given as prizes.

Upper Subordinate Class.

This is intended for Non-Commissioned Officers of good character, to be recommended by their Commanding Officers.

They are educated with a view to appointments on the Upper Subordinate Branch of the Public Works Department, as overseers.

The Course of Study extends over two years, and includes—

Mathematics.
Civil Engineering.
Drawing.
Surveying.
Hindustani.
English.
Physique and Sports.

Lower Subordinate Class.

This is intended for young men between the ages of 18 and 22, who are trained to be sub-overseers.

The course is a year and a half, and includes—

Mathematics.
Civil Engineering.
Drawing.
Surveying.
English.
Physique.

THE GOVERNMENT ENGINEERING COLLEGE, SÍBPUR.

This College was opened in 1880, and is under the control of the Director of Public Instruction, Bengal.

All classes of the community are admitted, and the courses are adapted to the requirements of—

General Engineers.

Mechanical Engineers.

Foremen, mechanics, and apprentices.

Pupils for the two higher classes have first to pass the University Entrance Examination; then they have to study four years in a theoretical course at the College, and a fifth year on practical work.

UNIVERSITY OF MADRAS.

This Institution is much like the two others.

There is only one Degree in Engineering given, that of Bachelor.

The instruction in this subject is given in the

COLLEGE OF ENGINEERING, MADRAS;

the curriculum of which follows pretty nearly the plan of those already described.

CANADA.

UNIVERSITY OF TORONTO.

In 1827 a charter was granted for a University at this place, under the designation of King's College. At a later period it was extended, combining "The University of Toronto" and "University College."

The University confers degrees in the Faculties of Law, Medicine, and Arts, and in Civil Engineering, the latter being called "The Degree of C.E."

The educational course is complete, in Science and Arts, comprising all the usual subjects.

Attached to this Institution is a—

School of Practical Science.

This was established in 1877. The students enjoy full advantage of the instruction given by the Professors and Lecturers in all departments of Science, and in addition, the School of Science includes courses of Engineering and Applied Chemistry.

Students are enabled to prosecute professionally—

Engineering.
Assaying and Mining Geology.
Analytical and applied Chemistry.

According to the Prospectus:—

The instruction in Engineering is designed to give the student a thorough knowledge of the scientific principles of the Profession, and also to afford such practical training in drawing and surveying as will make him immediately useful in the office and field.

'The establishment of a Diploma for special qualification in Assaying and Mining Geology,' apart from the knowledge of these subjects incidental to the course of mining engineering, is called for by the necessity which exists for the development of the mineral wealth of the province. Students who pass through the course necessary to obtain this diploma will have acquired the knowledge requisite for inspecting and surveying mineral lands, as well as the ability to report accurately on the composition and value of economic minerals generally.

Certificates in Surveying will be granted after due examination, which will have the effect of shortening the ordinary period of apprenticeship to a land surveyor, by the length of time covered by such certificates—one, two, or three sessions, as the case may be.

Students intending to become Mechanical Engineers will enter as special students, and receive instruction in the principles of mechanism, the theory of machines and drawing, together with such work in the civil engineering course as may be suitable for their purpose.

Students intending to become Electrical Engineers are admitted as special students, and will receive instruction in drawing, mechanical engineering, and electricity. The physical laboratory is furnished with a good collection of electrical instruments; and a separate room will be set apart for experimental work in this department. Special attention will be given to the subject of electrical testing. In connection with the physical laboratory there is a workshop, the power being given by a 4 HP. gas-engine.

Students who intend to pursue Architecture as a profession are advised to take, if possible, the regular course in civil engineering, as the instruction given in this course in the subjects of drawing, colouring, principles of construction (carpentry, masonry, and ironwork), strength, and other properties of building materials, flow of water and air, theory of heat, &c., will be as useful to them as to civil engineers. They may enter as special students if they please.

The Engineering course is arranged to occupy three years.

There are special courses adapted to Mechanical Engineering, Electrical Engineering, and Architecture.

There is another Canadian Educational Institution, "The University of Trinity College, Toronto," but it makes no special reference to Engineering.

McGILL COLLEGE AND UNIVERSITY, MONTREAL.

This was founded under a bequest of the Hon. James McGill, and was erected into a University by a Royal Charter in 1821, amended in 1852.

The University grants Degrees, the Scientific ones being—

Bachelor of Applied Science.
Master of Engineering.
Master of Applied Science.

Several Colleges and Schools are affiliated to the University, but the most important instruction is given in the "McGill College."

There are five Faculties, namely, Arts, Applied Science, Medicine, Law, Comparative Medicine, and Veterinary Science.

The Faculty of Applied Science is designed—

To afford a complete preliminary training of a practical as well as theoretical nature, to such students as are preparing to enter any of the various branches of the profession of Engineering and Surveying, or are destined to be engaged in Assaying, Practical Chemistry, and the higher forms of Manufacturing Art.

Five distinct departments of study are established, viz.:—

Civil Engineering and Surveying.
Electrical Engineering.
Mechanical Engineering.
Mining Engineering.
Practical Chemistry.

The study for each of these extends over four years, and is specially adapted to the prospective pursuits of the student.

The Lectures are comprehensive and complete, referring to subjects of the usual kind.

THE UNIVERSITY OF KING'S COLLEGE, WINDSOR, NOVA SCOTIA.

This College was founded A.D. 1789, by an act of the Provincial Legislature, chiefly through the exertions of the first Bishop of Nova Scotia, Dr. Charles Inglis. A Royal Charter in 1802 conferred on it the privileges of a University.

It confers Degrees in Arts, Divinity, Law, Science and Engineering.

The *School of Engineering* was added in 1871.

The course is described to be—

Framed with a view of giving the student a sound and thorough training in Mathematics, pure and applied, a comprehensive knowledge of Engineering and Applied Science, together with such practical experience in work connected with the profession of a Civil Engineer as it is within the scope of the University to afford.

The course of instruction extends in most cases over four years, and includes the usual subjects.

"Dalhousie College and University," Halifax, though an important educational establishment, appears to make no special reference to Engineering.

AUSTRALIA.

UNIVERSITY OF SYDNEY.

The University of Sydney was incorporated by the Colonial Legislature in 1850, for "The advancement of religion and morality, and the promotion of useful knowledge." There are four Faculties: Arts, Law, Medicine, and Science.

The latter includes a *Department of Engineering.* The study occupies three years, and comprises Lectures on the usual subjects.

Degrees are given in General Science, and specially in various branches of Engineering.

UNIVERSITY OF MELBOURNE.

This was incorporated by Act of Parliament in 1853.

In addition to the ordinary scientific topics of education, there are Lectures on special Engineering subjects; and the University confers the Degrees of Bachelor and Master of Civil Engineering. The course of study occupies four years, and the candidate is required to produce before completing his fourth year a certificate of having been engaged during twelve months in acquiring a practical knowledge of Engineering under an Engineer or Architect in charge of works, or of mining under a competent Mining Surveyor or Manager.

ADELAIDE UNIVERSITY.

This was founded by an Act of Incorporation in 1874.

There are Faculties of Arts, Science, Law, and Medicine.

There are "Engineering Scholarships," but there appears at present to be no special instruction in Engineering.

THE UNIVERSITY OF NEW ZEALAND.

This was established by Act of Parliament in 1870, and has power to confer degrees in Arts, Law, Science, Medicine, Music, and such other departments of knowledge, except Theology, as the Senate shall from time to time determine.

The University will be prepared in 1892 to issue certificates to students who have gone through a course of study at the School of Engineering and Technical Science at the Canterbury College, or at any other school or college of which the Senate may hereafter approve.

The course of study requisite for certificates in Engineering is to be on the standard of the course in the Canterbury College Engineering School, in Mathematics, Mechanics, Technical Science, Engineering, Surveying, &c.

Further information will be given at the session of Senate to be held in February, 1892.

APPENDIX B.

OPINIONS AND SUGGESTIONS ON ENGINEERING EDUCATION.

In the work published by the Institution in 1870, there were given some "Suggestions offered to the Council," and also some "Extracts from published documents," bearing on the subject of Engineering Education.

Many of these have no longer any force, in consequence of the changes that have taken place in the general views and practice. But there are some which are still valuable, as applying to the subject generally in all stages and at all times, and it may be worth while to repeat them here. Some remarks of a later date are also added:—

Report of the Society of Arts on Technical Education.

(No date; probably about 1865.)

The Committee came to a resolution, "That technical instruction should not, as a rule, be given in separate professional institutions, but in institutions established for general education."

They said:—

What is required is that students should enter on their pupilage as well instructed as foreign students enter the special schools of the Continent. This can be effected by existing colleges, if these institutions are willing to organize special courses of study, and found new chairs for professors of certain special applications of science.

This has now largely been done. The further views of the Committee are explained in the following extracts:—

When existing colleges have organized the proposed courses of study, and when the new schools, leading to those colleges, or giving analogous preparation for the scientific professions, have been established, it will be necessary that the proficiency of the students and the efficiency of the teaching should be tested by methodical examinations; and, in order that students should be induced, by a tangible reward, to present themselves well prepared for these examinations, it is desirable that diplomas or certificates should be granted for approved excellence. There would be serious objections to the granting of diplomas to civil engineers, architects, &c., if these diplomas were supposed to certify that, after a merely scholastic education, the students were ready to practise their professions, but there are no objections to certificates which simply attest that the student has attained such proficiency in his theoretical studies that he is fitted to enter on a practical pupilage with advantage to himself and his employer. The certificates will also be a valuable recommendation in early professional life, if they are granted with discretion. They might either

be granted by some one public examining body in each profession, or by the various colleges where the higher studies are carried on. The Committee prefer the latter plan, as less likely to lead to one monotonous system of teaching; but they feel that certain guarantees must be taken, lest a sort of Dutch auction should occur, in which the inferior schools and colleges would bid for pupils by granting certificates for smaller and smaller acquirements. Such conduct would no doubt bring its own remedy in time, but, to avoid the occurrence of the evil, the Committee consider that the examinations at each school and college should be conducted with the assistance of two independent examiners, one appointed by the Government and one by the leading professional institute belonging to the profession with which the examination was connected. These two examiners should also report on the proficiency of the students at the various institutions, and would thus perform the office of inspectors, without subjecting the professors of the higher colleges to any degrading supervision.

After this good scientific instruction, tested by examination, comes the pupilage in all cases, and after the pupilage it is desirable that voluntary public examinations should be held, with the view of testing whether the young men have really profited by their pupilage. This examination, which should be partly practical and partly theoretical, might be conducted by similar boards of examiners to those specified above; and diplomas, which would then express real proficiency in the several professions, should only be granted to young men of undoubted merit. Severe examinations of this type are conducted at Carlsruhe and other large polytechnic schools on the Continent.

The above recommendations are an expansion and explanation of the resolutions:—"That it is desirable that the higher scientific instruction should be tested by public examination, and that the proficiency of persons who pass these examinations should be certified by diploma;" and "That the preparation for the businesses considered by the Committee is not sufficient until due scientific instruction has been followed by practical pupilage in efficient works."

When, however, a methodical course of study has been rendered possible for each profession, and examinations have been instituted for testing the proficiency of students, it will at first be difficult to fill the classes of the new schools, and to induce young men in any numbers to present themselves for examination. It is incumbent on all those who really believe in scientific teaching to prove their faith by giving a practical value to the certificates obtained by students. This can be done only by the employers of labour, who must at first act on faith only. Hitherto no class of young Englishmen, trained in the manner proposed, has existed. In order to induce the rising students to follow this methodical training, they must see that the few who take that course do find employment more readily than those who do not. The employers of scientific labour can give an enormous impulse to scientific training by showing a real preference for young men who have passed through the courses of study recommended. Thus engineers and architects ought to receive pupils more readily who are well trained; they might reduce their premiums for such pupils; they should grant free pupilships as rewards for very successful public examinations; they might give privileges in their professional institutes to the holders of diplomas. The Committee "recommend employers of labour and others in the habit of taking pupils, apprentices, and clerks, to give the preference as far as possible to those adducing evidence of the possession of adequate instruction in the sciences applicable respectively to their professions or occupations."

Presidential Address of Mr. (now Sir) John Fowler, Bart., 9th January, 1866.[1]

From the many excellent remarks on Engineering Education contained in this address, the following may be quoted as bearing on the subject generally:—

With respect to the special preparation of young men, between the ages of fourteen and seventeen or eighteen, several of the largest and best proprietary schools and colleges in this country have special classes and departments for the study of the applied sciences; and thence well-prepared pupils are annually sent out to commence their career with engineers, architects, and surveyors; but still the character of this special preparation, in its theoretical branches, is not considered quite equal to that of France or Germany for the Civil Engineer.

It is true that nearly all continental nations have an advantage over this country in the power which the nature of their government gives them of concentrating, in one recognised official school for the preparation of Civil Engineers, all the best available talent of their country.

This plan does not exist in our country, and on the whole we rejoice that it does not; neither does the inducement of Government employment form the chief stimulus to our exertion, for which we are also thankful; but at the same time no good reason can exist why the opportunities of acquiring theoretical preparation in this country should be inferior to those of the Continent: and I have the confident hope, from the anxiety which is now manifested to increase the ranks of our profession, and the desire to have the best possible preparation for it, that even in the theoretical branches we shall shortly have to acknowledge no inferiority to any other nation. In the practical branches we are admittedly superior.

In drawing attention, however, to a comparison between our own and other countries, let me be guarded against the possibility of being understood to suggest that this theoretical equality ought to be obtained by any sacrifice whatever of our undoubted great practical knowledge; indeed, on the contrary, I think that the attention to the greater opportunities which young Engineers in this country enjoy, by reason of the number and character of our new public works, than is attainable in other countries, should be constantly encouraged to the utmost possible extent, and that our old superiority as practical Engineers should be ever maintained.

Extracts from a Lecture on "The Education of Civil and Mechanical Engineers," Inaugural Address Delivered in the University of Edinburgh, 3 November, 1868, by Professor Fleeming Jenkin, F.R.SS. L. & E.

Describing the system of education in England, the Author says:—

Young men, at the age of about eighteen, enter the office of a civil engineer. Usually few questions are asked as to previous training.

[1] Minutes of Proceedings Inst. C.E., vol. xxv. p. 203.

Etiquette requires the engineer to show a certain reluctance to receive the pupil, and, in fact, the ordinary pupil is a sort of nuisance in an office, only tolerated in consideration of the fee which accompanies him. From personal experience I can declare, that most pupils are so ignorant of algebra, that they are not only incapable of working out a result for themselves, but actually cannot apply the simple formulæ which are given in engineers' pocket-books. The calculation of the solid contents of a wall is often beyond their powers. Their arithmetic is very shaky, and a knowledge of physics, chemistry, geology, or the higher mathematics is wonderfully rare. The men have too often chosen the profession from an idea that it is pleasant, and because, forsooth, it is guarded by no preliminary examination. Not even a pass-examination is required, and the ignorance of some pupils, especially in mechanical workshops, must be experienced before it can be believed. They really seem to think that a little turn for making toy-models shows a bent for mechanical engineering such as will justify them in expecting success.

These young men during three years have the run of the office or workshop, and if they are intelligent, towards the end of their pupilage often have opportunities of seeing actual work in the field, or of designing some parts of actual machinery, and of assisting in the erection of more or less important works. No one teaches them anything; but they have the opportunity of seeing how some actual work is done; they see just how much mathematics is absolutely required, and they pick it up. They see how workmen are managed, and learn their habits; they are brought into contact with the exact class of work which they will have to perform, and they know that unless soon they are competent to do this work, they will not have a chance of employment. The one point for them is, to convince their masters that they are useful, and hence, notwithstanding their ignorance at starting, the neglect in which they are left during their pupilage, the absence for opportunities for improving their theoretical acquirements, many of them do become useful men.

We ought to form some idea of what the work of a Civil Engineer is :—

As a civil engineer, the young man is called upon to design small works, such as bridges or culverts, according to some well-established type—little originality is wanted, and just so much theory as will allow him to make safely the slight modifications required to meet each case; he superintends the execution of work by contractors, and must know good from bad work when he sees it; he must have such a knowledge of mensuration as will allow him to certify exactly the quantities of work done by the contractor. He must be able to survey on occasion, to level with great rapidity and accuracy, and to set out work in the field. He must have such a knowledge of the world as will enable him to deal pleasantly and firmly with workmen, contractors, and proprietors on whose land the works are being constructed. Above all, he must be a thoroughly honourable man, wholly above suspicion of taking bribes from contractors, of cooking his work, of concealing any blunders he may make, or of absenting himself from his duties.

Colleges cannot teach young men all these things, and my own experience has confirmed the conclusion, that a gentlemanly man of fair education and intelligence, after working as a pupil for three years in a civil engineer's office, is, for subordinate positions as a civil engineer, a more useful man than the pupil of a foreign school.

For a mechanical engineer the case is different. The younger men in

factories have to design machinery frequently of one type, but nevertheless varying so much from year to year, that a sound knowledge of mathematics, mechanics, and physics, is of the greatest importance to them; consequently as draughtsmen or designers we find foreigners employed all over the country. And *à priori* I would rather engage a foreigner to carry out my ideas in designing a new machine than a young Englishman of equal standing, especially as most of the foreigners complete their education by working in a shop for a short period.

As they rise in their professions, engineers are called upon to display higher and somewhat different qualities. The civil engineer may be called upon really to design great works and novel works; and here Englishmen feel sadly the want of a sound theoretical training. But even in the higher walks of the profession, design and invention are required much less than is usually supposed. The leading engineer must be a man of good business habits, able to advise the directors of great companies prudently as to the probable cost and revenue of proposed works. He must have the head of a lawyer in drawing up specifications and revising contracts. He must be able to choose his subordinates wisely, and keep them in good discipline. In a word, he must be a man of great *Common Sense*.

As a mechanical engineer, or as a contracting engineer, a knowledge of trade, a keen eye for economy in details, and a thorough practical knowledge of the properties of the materials he employs, must be added to the above list of talents; and when we reflect how very few of the above qualities can be taught at colleges, we understand how it is possible that our engineers should justly take a high rank in the estimation of the world.

You will long since have anticipated my conclusion,—that *there is no reason for abandoning our system of apprenticeship or pupilage to substitute for it the foreign plan of large special colleges*, even if we could hope to create colleges of equal merit with those formed abroad.

But this conclusion, instead of leading us to sit down wrapped comfortably in a veil of blinding self-conceit, ought rather to urge us to work with the greater vigour at removing the acknowledged defects of the British plan. We have not to construct the whole edifice anew, we have only to put on the cornice-stone.

Our defect is the want of a good knowledge of the theories affecting our practice.

It must be admitted that of this knowledge we possess far less than is necessary. By dint of sheer hard thinking and repeated trials we somehow do solve most problems; and the plan of Brindley, who used to go to bed when he was posed, and think steadily for a day or two, is by no means a bad one. But our success costs a vast expenditure of money and of brain which could be turned to better purpose if we knew how to calculate the results to be expected from a given combination with some certainty beforehand. And not only does our ignorance cause much wealth to be wasted by the community on useless trials, but it prevents the trial of many new schemes, because the engineers or managers to whom they are submitted feel that they have no means of judging beforehand of the probability of success, so they, wisely in their generation, think they had better stick to the old plans, and in nine cases out of ten they are right; but the rejection of the tenth case is a dead loss to themselves and to the country.

How much theory, as it is called, does the engineer want to enable him to judge soundly and design correctly? Certainly much less than is given abroad.

I have no doubt that the *engineering student of average ability might acquire a sufficient knowledge of theory before his apprenticeship begins, or during its course.* The very entrance-examinations required by the foreign colleges are a proof of this. These examinations are passed by young men of seventeen, eighteen, nineteen, and if our pupils could enter on their apprenticeship as well educated as the foreigners when they enter their special schools, I am convinced that the British would in every respect be far superior to the foreign system. Our engineers would then start in life with a good knowledge of algebra, trigonometry, mensuration, drawing, the elements of physics and chemistry. The few who had the turn for higher mathematics could pursue their studies in after life, but all would be saved the weary time now lost in offices by zealous men trying vainly to understand the simplest formulæ, and gradually picking up through practice the power of mensuration, and of representing ordinary geometrical forms by mechanical drawing. In addition, it would clearly be of great advantage that they should, before being brought in contact with practical work, have had their attention drawn to the manner in which all these branches of knowledge are applied to the solution of practical problems. The manner in which estimates are made, specifications drawn, and contracts framed, can be indicated by special examples. Above all, it is possible to inculcate the true principles of economy upon the mind of the student, who should never forget that the object of the engineer is not to display his ingenuity by the production of ingenious devices, but to use his judgment and invention so as continually to endeavour to increase production at a diminished cost.

Mr. Jenkin also, in a letter to the Secretary of the Institution, adds the following observations:—It is out of the question that any college training should replace the system of apprenticeship; but it is most desirable that pupils should enter offices better prepared than at present, and that they should continue their theoretical studies during their apprenticeship.

We do not require special institutions or any large number of technical chairs but rather . . . the practical recognition of the value of scientific training by engineers who take pupils; and by admitting as pupils only those students who have passed certain recognised examinations.

From "Systematic Technical Education for the English People." By the late John Scott Russell, F.R.S. 1869.

The following extracts will illustrate the Author's views bearing on the Education of Engineers:—

Page 79.—I will now come to the practical matters which show directly the results of a technical education in the production of one of its chief objects—the creation of wealth. It is notorious that those foreign railways which have been made by themselves in the educated countries of Germany and Switzerland have been made far cheaper than those constructed by us in England; it is known that they have been made by pupils of the industrial schools and technical colleges of these countries, and I know many of their distinguished men who take pride in saying that they owe their

positions entirely to their technical schools. I find everywhere throughout their work marks of that method, order, symmetry, and absence of waste which arise from plans well thought out, the judicious application of principles, conscientious parsimony, and a high feeling of professional responsibility. In the accurate cutting of their slopes and embankments, in the careful design and thoughtful execution of their beautiful but economical stonemasonry, in the self-denying economy of their large span bridges, the experienced traveller can read as he travels the work of a superiorly educated class of men; and when we come down to details, to the construction of permanent way, arrangements of signals, points, and sidings, and the endless details of stations, we everywhere feel that we are in the hands of men who have spared no pains, and who have applied high professional skill to minute details. It is well known that many years before we would follow their example, the engineers of the German railways had introduced a system of constructing and of uniting to each other the iron rails of the permanent way, which made them cheaper, more durable and safe than those employed in England. Happily for our national reputation it was an Irishman who invented it, though its advantages had first to be appreciated in Germany before we would follow the example.

It is remarked by every traveller that the works of their railway stations are, when compared with ours, much more beautiful, convenient, and fit, both within and without; the construction of their trains, the proportions of their carriages, the fitness, convenience, and comfort of their internal arrangements, all tell to the disadvantage of ours, and the one thing in which our railways excel theirs is in high speed. Theirs, on the other hand, are economical in capital and high in revenue.

Page 199.— . . . *What Technical Education should we give to the Mechanical Engineer or Machinist?*—From the days of James Watt and Arkwright until now, comprehending the whole of the present century, the mechanical engineer or machinist has formed one of the most important classes of this country, and has conferred on it immeasurable benefit. It was the mechanical engineer and the manufacturer who, together, during the early part of the present century, while the whole of Europe was overrun by the curse of war, created wealth in this country so rapidly, as to enable her to struggle through a burden of expenditure to which there has been no parallel, and to come out of it prosperous and wealthy.

There are no occupations or trades concerning which there could be so little difference of opinion as to the practical importance of special technical education, as this class of mechanical engineer and machinist. Philosophers have defined man as the tool-using animal; but if the man of this century were defined, the "engine-maker" and "machine-user" would be his leading characteristic: it is the triumph of human nature in our time, that it has achieved the understanding of the forces of nature so completely, that whatever material service we wish to perform, we can always discover some elementary force in nature, willing to lend us its aid to conquer our difficulty, provided we will study its nature sufficiently to direct it into the way in which it can best serve our end. The steam-hammer of Nasmyth, and the steel ingots of Krupp, are symbols of the powerful yet plastic forces man wields, in his gigantic shape-compelling processes of manufacture. We may sum up the duties of a man of this craft by saying, that there is scarcely a process now performed by animal or man, which our engineers or machinists of the next generation may not be called upon to perform better and quicker by machines of their own creation.

Of the engineer and machinist it is therefore very easy to indicate the course of instruction; unluckily, much easier to indicate than to accomplish. He must master all the known powers of material nature: heat and cold; weight and impulse; matter in all conditions—liquid, solid, and gaseous; standing or running, condensed or rare, adamantine or plastic—all must be seen through and comprehended, by the master of modern mechanics. The same laws which govern the machinery of the heavens, he has to apply to the machinery of the earth; and the same exquisite mechanism which the Creator has used in the structure of his animals, the modern mechanician has to apply in the construction of his microcosms. The modern mechanician, who would be equal to his work, must be prepared to shape a tool and frame an engine for the execution of tasks which were never even dreamt of by the older mechanicians.

. . . *What Technic Education should we give the Civil Engineer?*—The great public works of a civilised country have always demanded and generally received from its Government, earnest solicitude and forethought. In France, the civil engineers are the *élite* of the nation; the most distinguished pupils in the colleges throughout the country are promoted into the central technic institution of France in Paris; and out of this again, a selection is made of the most talented for the "corps de génie maritime;" for the "corps de génie militaire;" and for the "corps de génie civil," or "ponts et chaussées."

By the great public works of a country so much is gained or lost to the public well-being, that the most liberal measures are justified, if they succeed in providing for its service the profoundest knowledge, the most brilliant talent, and the highest skill. In the time of the Romans, Europe was covered with those wonderful roads which have been perpetuated to the present day, and are marvels of conception and execution. The correction of rivers and supply of waters to great cities, the drainage of marshes and the irrigation of plains, have developed the industry and created the wealth of populous countries; and it has depended almost entirely on the wisdom or folly of modern Governments, in the selection of their engineering systems, whether those great engines of commerce, the modern railways, have been given to a country at small cost, on a wise system of development, with gain at once to the capitalist, to the trader, and the Government. Where Governments have been wise, the railways have been well selected, cheaply made, economically and profitably worked. Where they have been reckless, ignorant, unwise, railways have been made at great cost, extravagantly worked, dear to the public, and unprofitable to the capitalist.

When it is considered that the telegraphs which now work the commerce of the world; the great lines of steam-ships which unite its most civilised portions; the railways which everywhere connect the populous centres of empires; the water supply; roads; ports and harbours; the direction, training and permanence of our navigable rivers—are all works involving enormous cost, involving the highest national interests, and requiring consummate knowledge and skill, it is plain that we may judge of the wisdom of a nation by the foresight and forethought it bestows upon the rearing, training, and selection of this *corps d'élite* or *corps de génie*; and it is therefore self-evident that, in a technical university, the pupils of this section must find a prominent place. For England especially, with her wide-spread dominions, it is evident that the youthful engineer should be prepared to find a sphere of usefulness in any quarter of the globe, and to carry with him a mastery of all the resources of modern science and skill.

From the Presidential Address of Mr. Thomas Hawksley, 9 January, 1872.[1]

On the subject of professional education I wish to say a few words, and I would address them rather to each one of the 200 Students of this Institution who may happen to be now present than to the Members who have acquired and who have usefully employed that peculiar knowledge by which they are severally known and distinguished.

To the Students, then, I would say:—1st. Of all things, don't attempt too much. 2nd. Keep up and augment your knowledge of mathematics and the applied sciences, especially of those sciences which are most needed in that walk of the profession which you have selected for your own path; but again, I say, do not attempt too high a flight, for if you do you will never become a practical man. 3rd. Do not let your French grow rusty, and acquire German, if your leisure and aptitude are sufficient for the purpose, because your future avocations may be in countries in which these languages are either habitually spoken or are in considerable use. 4th. Acquire in the office, and by the study of esteemed works, a knowledge of form and design. 5th. But bearing in mind that you will never become a practical Engineer on theory alone, take every opportunity which presents itself of becoming apt in surveying and levelling, and in the methods employed in the setting out of works; learn the uses and applications of tools; make yourselves able to distinguish a good material from a bad material, good workmanship from bad workmanship, sound ground from treacherous ground, good puddle from bad puddle, good mortar from bad mortar, and a good workman from a bad workman. This knowledge is not to be obtained in a school, a college, or an office, and cannot be learnt from books. 6th. Make yourselves acquainted with every description of plant, and all the appliances and contrivances which an experienced contractor employs for the purpose of rendering a paper design into a substantial construction. 7th. Keep brief treatises on geology and chemistry always at hand, for some acquaintance with these sciences cognate to Engineering is, in the present day, almost essential. 8th. Practise as much as possible the art of mental computation, for this will give you the means of almost intuitively arriving at determinations on questions of cost, and of at once seizing on the best of several alternative plans or methods. 9th. Be not afraid of soiling your hands or dirtying your boots, but be in every other respect—in thought, feeling, and conduct—a gentleman.

From the Presidential Address of Mr. J. F. Bateman, 15 January, 1878.[2]

Much of this was devoted to the subject of Engineering Education. He makes many references to, and quotations from the volume on this subject published in 1870. The following passages may be extracted here:—

Page 5.—There is considerable individuality in the practice of most of our members. Circumstances to a great extent control our operations.

[1] Minutes of Proceedings Inst. C.E., vol. xxxiii. p. 333.
[2] *Ibid.*, vol. lii. p. 2.

Early engagements or opportunities do much towards fixing a man's future career. Some men have been principally engaged in the construction of railways, others in hydraulic engineering, many in mechanical construction. Some have devoted their energies to the development of the electric telegraph; others to gas-lighting, to armour-plating, to naval architecture, or to artillery; while not a few may be considered as purely scientific men, investigating the strength of materials, the laws of motion, the phenomena of light and heat, and the thousand other questions which have a bearing on practical engineering.

It is, in fact, the combination of theory and practice which makes the successful engineer. Engineering is but the embodiment of practical wisdom,—"the conjunction," as Bacon calls it, "of contemplation and action."

It was thought, combined with practice, which enabled Watt to perfect his invention of the steam engine, now little more than one hundred years ago. It was thought and practice which, in the hands of George Stephenson, led to the successful application of the locomotive engine. Thought and practice produced the electric telegraph. Indeed, though practical wisdom may be said to be the parent of almost all successful undertakings, it is especially due to the combination of sound theory with successful practice, and to the practical wisdom which is the result, that engineering owes its present high position, and has been able to contribute so largely to the material prosperity of the world. It is not, however, material prosperity only to which the engineer may lay claim. His works have carried civilisation into the most remote and barbarous regions. The steam engine, in its various applications, has knitted together the most distant nations; it has brought ignorance into contact with knowledge, heathenism with Christianity, and has extended the blessings of civilisation to every quarter of the globe.

Page 8.— . . . Still there can be little doubt, on a review of the whole question, that our young engineers are not always prepared by preliminary education as well as they might be, for their subsequent acquisition of practical knowledge. It is not because there are not institutions in this country where such knowledge can be obtained, but rather from a general laxity in the views of parents and guardians upon technical education. Special qualifications, and some of a very high order, are required to ensure success in our profession, and many young men enter it as pupils without these qualifications.

From a Paper on "The Use and Equipment of Engineering Laboratories," by Professor Alex. B. W. Kennedy, read before the Institution December 21, 1886:[1]—

He believed that it was essential for a young engineer to obtain his practical training, in the ordinary sense of the expression, in a workshop. But the practical training of a workshop is incomplete even on its own ground, and there appeared to be plenty of room for practical teaching such as might fairly fall within the scope of a scientific institution, and which should at the same time supplement and complete workshop experience without overlapping it. In an ordinary pupilage a young

[1] Minutes of Proceedings Inst. C.E., vol. lxxxviii. p. 1.

engineer does not have much opportunity of studying such things as the physical properties of the iron and steel which he has to deal with, nor the strength of those materials, nor the efficiency of the machines he uses, nor the relative economy of the different types of engines, nor the evaporative power of boilers. These things, however, are only types of many others about which it is essential, not only that he should know something, but that he should form some definite working opinion. But they are all matters very closely analogous to those already treated in laboratory work in physics and chemistry. They involve simply the making of accurate measurements in the branches of physical science most closely related to engineering. Moreover they are useful to the student not only for their own sakes, but also as teaching the art of making experiments—or it may be simply called the art of accurate measuring—in matters relating to engineering science. They are, to a wonderful extent, suited to set the student free from the thraldom of the engineering pocket-book (making "every man his own Molesworth," as it has been put), by helping him to determine for himself, or at least to see practically how other people have determined, all the principal engineering constants, from the tenacity of wrought-iron to the calorific value of coal, or the discharge-coefficient of an orifice. Further, a healthy scepticism of uncritical generalisations, or of uninvestigated facts, is fostered by nothing so surely as by a personal and practical knowledge of what accurate experiments really are. From all these and other considerations it appeared to the Author that the kind of practical work which has been alluded to could be nowhere better given than at those educational institutions which endeavoured to teach young engineers the scientific basis of their profession, and following up this idea he gave in some detail, on the occasion to which he has alluded, a description of the function and work of an engineering laboratory.

LONDON: PRINTED BY WILLIAM CLOWES AND SONS, LIMITED, STAMFORD STREET AND CHARING CROSS.