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A SUCCESSFUL ENGINEER:

BEING

HINTS TO YOUTHS INTENDING TO ADOPT

THE PROFESSION.

BY

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PREFACE.

THE education of a youth, to enable him to take his place among men in after life, is a matter of the utmost importance; and upon his undergoing such an education under a proper system when he is young, depends, to a great extent, the formation of his character, and, consequently, his future success in life. The system of commercial education is pretty well established, and, therefore, needs no comment. A scientific education, however, designed to fit its recipient for a professional life, can only be best imparted by a certain system or course of instruction; in short, the youth or student must have the right studies peculiar to the profession placed before him at the right time, so as to ensure a maximum and steady progress. This is especially the case in the education of students in engineering science. There have been many self-made engineers, and, although not possessing what may be called a Commercial, or English education, yet they have all been, in the science of their profession, educated men. It is true that many men have, without the aid of education of almost any sort when young, risen in maturer years to the greatest proficiency as engineers; but these have possessed an intuitive and strong love for their profession, and have only acquired that degree of proficiency by a system of self-directed education under many and great disadvantages. As every man does not possess such rare qualifications as those just mentioned, the experience of society shows that, to enable a man to become successful in his business, a knowledge of such must be acquired, and that as early in life as possible, this knowledge being imparted rather than self-directed. In the engineering profession the system of education is very varied, and is frequently imparted by illiterate and incompetent men; and there being always two ways of attempting to accomplish an object, a right and a wrong way, the natural consequence is that as many of these systems are wrong ones as others are right; so that many young men, after having gone through the routine of their engineering education, have just acquired so much knowledge as to enable them to perceive their ignorance, and that they have been misguided in their way to the proper acquisition of engineering knowledge. Take, for example, the case of a young man who has completed his course of a sound English education, and who has resolved, with the sanction and approval of his parents or guardians, that he will follow the profession of an engineer. A premium is accordingly paid to secure his admission to the works of a mechanical engineer, or, it may be, into the office of a civil engineer. He is so far privileged, and, as a pupil, the means of acquiring information are placed within his reach, or he gets in the shop the best of work; but as everything else depends on himself, it not unfrequently happens that, instead of being turned out an educated engineer, it is found that he has undervalued his profession and has been wasting his time, all of which might have been prevented by a proper system of discipline and education.

Enough, probably, has been said to show the importance of a good system; and this little volume, *therefore, is designed with a view, as far as possible, to point out what the author considers the proper course of instruction for those aspiring to become professional engineers.* Technicalities have, as far as possible, been avoided, and the style of information has been so far reduced to suit the intellectual capacity of a youth who may be supposed capable of considering what profession it will be expedient for him to follow. At the same time, the author recommends it to the consideration of parents and guardians who may decide for those under their charge.

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HOW TO BECOME A SUCCESSFUL ENGINEER.

INTRODUCTION.

ALMOST any man with the ordinary capacity for instruction can be taught to do certain things. For some of these, however, he may exhibit a greater aptitude than for others: it is therefore said of such a man that he has a particular talent for such and such a trade. All men are not alike endowed with natural talent and ability,—some possessing it in a very general way; others only in one particular channel; while many there are who may be said to possess scarcely any, and, to all appearance, have evidently "nothing in them." Now, as we believe that every man endowed with reason at all has "something in him," however latent the talent may be, it becomes young men, or their parents for them, earnestly to set about discovering, as far as possible, in what direction such talent lies, and this at as early a period in life as possible, so that, having well decided what course of study shall be adopted, it may be pursued with all sincerity and earnestness. This point considered, we shall assume that the young man, intended as a student in engineering, should have some little inclination for such a profession—at least no positive aversion to it; for we may say, if the latter should be the case, little hope could be entertained of the individual's success. We would therefore here warn parents, and others in charge, of forcing young men to follow a certain line of trade—a profession for which they may not only have no inclination, but a positive dislike. In nearly all cases the choice of a profession should originate with the young man himself, with the aid of the information and advice given him by his parents or guardians. Exceptions, however, there are, where the youth wants decision, or is of a fickle and unsettled nature, in which case the judgment of those in authority over him must be exercised; and where such fickleness exists, it must be subdued as much as possible by a rigid system of discipline and training.

During the last fifty years engineering has made most gigantic strides, and has now become a science of a very comprehensive character; so much so, indeed, that it has been separated into divisions having their various sections, and these in turn having as many branches. The original body of men assuming the title of engineers were those engaged in military affairs; and to distinguish another body in existence shortly after, who also professed engineering, the prefix "civil" was applied to the name of engineer. Thus there were only two classes of engineers, namely, civil and military engineers. Since then, engineering has widened out in the civil direction into two main sections—the one preserving the original name of civil engineers, the other that of mechanical engineers. The former body of men are principally engaged in designing large works, such as bridges, docks, canals, railways, and many other important works, and whether executed in various materials, such as iron, wood, or stone. These designs are carried out under such engineer's superintendence by contractors—as mechanical engineers, builders, and masons. Mechanical engineers are usually employed in carrying out the designs of civil engineers in large works executed in iron. They are also employed in designing and manufacturing general machinery, steam engines, and various other iron work.

Mechanical engineering is again subdivided into many detailed branches, differing only, however, in the requirements of the particular description of the work, the designing and execution of such work being carried out under one broad system. So vast is the subject of engineering, that in the mechanical department alone there are various branches, each singly affording a life-study for many engineers. The locomotive, marine, hydraulic, mining, and gas engineers, as also the general machinist and millwright, all find abundant matter for study and improvement in each of those branches to serve them for their lifetime, and to be handed down as a legacy to their ancestors, almost to the end of the material world.

We do not intend going into each branch already mentioned, but will simply confine our remarks to the two main sections, namely, Mechanical and Civil Engineering, as sufficiently illustrative of the system of training and instruction necessary for the successful practice of engineering, and which can be applied to any particular branch. Our remarks will be principally confined to the education of the Mechanical Engineer, as much of what is given in connection with this will be applicable to the education of the Civil Engineer.

CHAPTER I.

THE EDUCATION PRELIMINARY TO PRACTICE.

When boys and youths are first sent to school, their minds and inclinations are not sufficiently matured as to warrant their parents or friends in determining what profession they are likely, or in some measure naturally designed to follow; consequently they are sent to school, there to receive a sound English education, so as to develop their understanding, and thus give some evidence of their capabilities. This, then, we consider absolutely necessary to every individual, whatever his prospects or views of a profession, as a solid intellectual foundation upon which to raise the whole fabric of his professional knowledge.

Having received such an education, and the youth having reached that age when he is supposed to have somewhat definite views upon the choice of a profession, it is expedient that he should at once, with the assistance and advice of his friends, determine what the nature of such a profession shall be. Having done so, and such being that of an engineer, we shall humbly endeavour to point out that route which we think the shortest, and at the same time the surest, to a tolerable proficiency in the science of engineering. We do so, although modestly, yet at the same time with a certain amount of confidence, having travelled the road ourselves; and, looking back, we have seen with regret the roundabout way by which we have reached our destination, so to speak; and for want of proper direction and guidance have not unfrequently lost our way. There are two distinct divisions in the life of a young man designed to follow engineering. The first is his scholastic education, the second his professional apprenticeship or pupilage,—the former ending with his leaving school, the latter with his completing his term of apprenticeship, when he is supposed to merit the title of engineer.

We will therefore proceed first with the scholastic education of a young man desiring to qualify himself as a mechanical engineer; and in doing so we wish it to be distinctly understood that we only direct attention to those studies which we consider absolutely necessary. Others may be added, at the pleasure of the student or his friends, as necessary to his position or station in life. Of these they are the best judges. Certainly, a man can never know too much, provided he does not undertake more than he can accomplish with duty to his health and the learning of his business.

The English education which we have already mentioned, consists of a knowledge of the English language, geography, writing, arithmetic, and occasionally the rudiments of Latin.

The study of the English language being the primary one in an individual's life, it ought to be thoroughly accomplished, for upon a perfect knowledge of such depends the facility with which a man obtains his information in after life. Although we do not here intend to enumerate all the points in the acquisition of this knowledge, yet we would direct attention particularly to the following:—Grammar, spelling, choice of words, and arrangement of such in English composition,—as it must be remembered that engineers are not always confined to the workshop or drawing-office, but are frequently called upon to furnish information and give opinions to men of distinction and education, as also to frame and write reports; all of which, to be done in a professional manner, involves a sound knowledge of the English language.

The study of geography is also one of intense interest to the student in engineering, for in the present advanced state of the iron manufacture of Great Britain, it has become the main centre from which almost the whole world is supplied. It is therefore most essential that the student in engineering should also be conversant with the various inhabited parts of the globe. Of writing there is little to be said further than that it is necessary that a good and legible hand should be acquired, so that, besides the style peculiar to every individual, a distinct and unmistakable delineation of the letters and words of the English alphabet shall be obtained.

We now come to the most important branch of education to the young student in engineering, namely, arithmetic. An educated engineer, one who is conversant with the theory as well as the practice of his profession, and having in the course of his duties occasion to apply the former to the latter, is constantly making use of his arithmetic, and, as we shall afterwards notice, his mathematics. A shopkeeper or other clerk may have his ready-reckoner and other tables to facilitate his counting-house duties, so that his arithmetical powers may never be called upon to exercise themselves further than the act of running up a trade bill or subtracting from such a discount, which discount he finds from ready-made tables. Now all this, at the same time that it facilitates the duties of the counting-house, reduces the work of such clerks merely to the level of machines. This, however, is not the case in engineering, as no such ready-reckoner exists, nor, indeed, could exist, for the purpose of solving the problems and working the calculations required in the practice of engineering, so many and so varied are the forms and application of such calculations. In some cases tables do exist where the calculations are laborious, such as areas and circumferences of circles, weights of iron, etc., etc.; but no engineer ever thinks that in such tables he will find all he wishes, and therefore he looks upon them simply in the light of auxiliaries; nevertheless, he is, or should be, perfectly able to do without them. In acquiring a knowledge of arithmetic, the student should not so much learn the rules, etc., and be able simply to perform the different operations,—such as addition, subtraction, multiplication, division, proportion, square root, cube root, and fractions,—but should endeavour to master the principles upon which each operation is based; and in doing so he will impress them with much greater force upon his memory, besides being able to apply them with ease to any case. We would impress upon the student in engineering the necessity of making himself thoroughly conversant with the various branches of arithmetic, and in particular with the primary branches, such as addition, multiplication, and subtraction; also with the theory of decimal fractions, and their conversion to vulgar fractions, and *vice versa.* We may as well intimate here, to show the importance of decimal fractions to the engineer, that, owing to the accuracy with which his work must be calculated and designed, all such calculations are performed through the medium of decimals, when fractions are required at all; indeed, without them the engineer would be exposed to ceaseless labour. Vulgar fractions, again, are also much used, owing to our standard of measure and quantity precluding the direct application of decimals. Next in importance to the engineer is book-keeping; and although, in the strict sense of the term, it is not absolutely necessary, yet it is highly advisable that a knowledge of its principles should be possessed. We are sorry to say that this is a point of weakness in many engineers, and it not unfrequently happens that our greatest engineers are anything but great commercial men.

Coming now to Latin, this also is not absolutely necessary, unless so far as it facilitates the comprehension of the English language. It is, however, highly advisable, not only as an assistance to acquiring a thorough knowledge of our mother tongue, but also the more modern languages, which are of great importance to the engineer.

Having thus endeavoured to define what we mean by a good English education,—one, indeed, which we think useful to any individual, whether designed to follow engineering, or any other trade or profession,—we shall in the next chapter endeavour to direct attention to those points in the education of an individual which are more directly connected with engineering.

In addition to what has been said on the subject of general education of youth, the following will perhaps be suggestive as bearing upon the subject:—

Let any professional or business man who reads this say if the subject of his education was ever so considered, with reference to himself as an individual, so that it would bear upon and aid the interests of such profession or business to which he might have taken a liking. The truth is that our systems of education are not based upon philosophical principles. They pretend to take us in hand and prepare us for the battle of life which we have all to fight, and yet they ignore the fact that there is a battle-field at all; or, if the upholders of these educational systems do admit that it exists, they turn their back upon it, and invite the attention of their pupils—so-called—to the fields of Elysium, peopled with the gods and goddesses of yore, and invested with an interest of mythological traditions. Of course this is all very crotchety, and will be set down as utterly Gothic in taste and false in principle. But, patience; we do not now ignore, or ever have ignored, the immensely mental advantages obtained by a study of classic lore. Nor would we, like some, object, with an over-refinement of feeling which may approach to prudery, to the time given to impart to youth a knowledge of the intricate intrigues and the careless loves of heathen gods and goddesses; but what we insist upon as being eminently ridiculous in this present nineteenth century of ours is, that while our youth in our superior schools are taught all this, they are taught nothing more. It may be well—doubtless to many is very interesting—to trace the genealogy of a Jupiter, and to make faultless Greek or Latin verses; but as we have to live now-a-days in the midst of a keen and ever-restless competition, it behoves our youth to enter life with *some other* knowledge tacked to all this,—to come down, or be brought down, from the seventh heaven of heathen delights to a knowledge of the present world, "with all its pomps and vanities." Nor will they make Latin or Greek verses a whit the less elegant, or appreciate them the less, either, if they are able to write a good hand, reckon up an account, and have at least a general yet accurate notion of the principles of those arts and sciences which have contributed so much to the material wealth and power of this country. Many of the absurdities connected with our scholastic system, and which encumber it dreadfully, arise, we venture to think, from a mistaken notion of what education is. Judging from the details of the system, education would seem to be the art of cramming—just as if the mind was a bag into which so much could be stuffed. Now, the meaning of the word education—a meaning which, we regret to say, has been almost altogether overlooked in practice,—indicates a process the very reverse of this. It means simply "to lead out." Just as if we said to a pupil, "Look around! Everywhere the fruit of knowledge lies near and about you; but it cannot be seen without closely looking after it—'searching for it as for hid treasure.' Lead out, then, —*educe* the powers of your mind which God has given you, so that they will search out and grasp the secrets of knowledge, and, grasping them, assimilate them to you." Now, where the powers of the mind are brought thus to bear upon its education, or are drawn out or educed, the knowledge derived will be lastingly remembered, and will, moreover, be brought to bear directly upon the interests of the individual; whereas, if the system be adopted of the teacher himself picking from the stores of knowledge which he has, and forcing or cramming them into the memory, just as a man crams pigs into a hamper, then the pupil, having nothing in common with the subject—having no real mental interest in the matter—speedily forgets it all. His mind, in fact, is simply made to act as a receiver, the teacher caring little whether the matter so put into the receiver can be assimilated or not. A man may have his purse full of the purest gold, but if he cannot take anything out of it, or if none can be drawn out of it by him, he is as poor as ever. A crammed pupil is like a man who possesses a field in which a gold mine is, but who does not know of its existence. A pupil brought up on the eductive system is like a man to whom a field is offered at a low price, because its owner deems it worthless, but whose knowledge or mental powers are so cultivated that he knows it is priceless, because it contains diamonds within its bowels. The difference, then, between the two systems of education we have here alluded to will be, perhaps, more apparent if the teacher will consider how a man of intellectual attainments begins to study a subject new to him. He does not commence by cramming himself with facts; but he leads out his mental powers—educes all his capabilities to study at once facts and the principles which guide them. Why should we adopt a different method in the education of youth?

But while we insist upon the necessity to follow a rational system of education, so that our young men shall be taught, or rather led, to send out the powers of their mind, so that they will be able to range around and draw into themselves nutriment which they can assimilate and make practically useful to them in their daily life, there is another point which we no less deem essential to be remembered, and this is—the education of the *heart* must not be sacrificed to that of the *head*. While we remember the outward polish, let us not ever forget to keep up the healthy pith. Ornament is all very well in its place, but it has but a poor chance of being preserved if the core on which it rests is not sound. It is folly to paint a fresco which is fit to be admired for ages on a wall that will not last a week.

Some education is like the palace of snow which the Emperor of all the Russias built on the banks of the Neva; it will only dazzle the eyes of the beholder for a day or two, and its beauty will please no longer in the world. We have no hesitation in saying that a vast deal of the worthless folly which is at present so much deplored as existing amongst the young men and women (we beg their pardons, young gentlemen and ladies—misses even work in mills!) of the day is owing almost entirely to the erroneous system of education, —unfortunately we can find no other word for this, but education proper it is *not*,—under which they are brought up, and which turns out many of them in an utterly heartless condition. Their duty to themselves and to their neighbours, the value of thoughtfulness of others, of the hatefulness of selfishness, they seem to be utterly ignorant of; and the result is that they dream away a life, mere gilded butterflies, or dreary drones of the hive, with, by the way, a very well developed scorn for the labours of the bees thereof. Let the education of the heart and all its fine affections be attended to, but it must be persistently and consistently attended to. Its precepts must not be inculcated in the dry, drowsy sayings which, as they do not come *from* the heart of the teacher, will never reach to that of the pupil, but must be warm with the life-blood which makes its presence felt and understood. Such conditions as those we have here insisted upon are by no means unimportant. Taken up and acted upon, they will influence for good the rising man. For it must not be overlooked that the young engineer aspires to the time when he will no longer be a learner or a worker, but be a master, having men under him; and it is of the highest importance that he should be able to comport himself towards them as a man to men, the truest and the best relationship that can exist between master and man. By so acting, that mutual trust and sympathy will be engendered between them which will alone yield the sure foundation of a pleasurable or profitable intercourse between them. Intellect is indispensable; but intellect without heart, the aspiring engineer, who looks forward to the conduct of men, will find a barren and a purposeless gift. In the education, then, of the young engineer, let the teaching of the heart not be forgot amidst the tasks of the teacher of the intellect.

CHAPTER II.

SPECIAL EDUCATION.

ENGINEERING being in the strictest sense of the word essentially a scientific profession, and being made up of nearly all the sciences, it follows that the general tenor of the education of an individual intended for such a profession should be of a scientific nature. The sciences more immediately connected with engineering are Natural Philosophy, Mathematics, and Chemistry.

The science of Natural Philosophy treats principally of the known laws by which the material universe is governed, and the effects of such laws upon matter in general. Mathematical science is closely allied to that of Natural Philosophy, investigating the various relations of measurable quantity, and serving to analyse the effects of its various material laws. These two sciences may be said to contain the whole secret or theory of engineering. In Natural Philosophy the principal branches of study are as follows:—General and special properties of matter; force and motion, including force of gravity, centrifugal and molecular force; the elements of mechanics or machinery, including motive powers and agents; hydraulics, hydrostatics, pneumatics, acoustics, optics, heat, electricity, and galvanism. The foregoing branches in Natural Philosophy should be brought, each in their proper order, under the notice of the youth when at school, in a popular and elementary style, rather to make him acquainted with the laws of nature, and the most common results or examples, than the general application of such laws to material bodies. We do not here intend to notice each of those branches, but will simply recommend the youth at school, who has not before known anything of Natural Philosophy, to procure that excellent elementary work on "Natural Philosophy for Schools," by Dionysius Lardner, published by Walton and Maberly, London. This book is profusely illustrated with diagrams, showing the arrangement of apparatus for conducting most of the experiments, at the same time conveying, in clear and concise terms, a popular notion of the leading divisions of physical science. To a certain extent the taste for scientific inquiry is inherent in the young, but, for want of proper encouragement, frequently disappears with manhood; hence a very small portion of the community take delight in scientific pursuits. We are no advocates of popular science in connection with engineering; but in the case of the young the eye must be attracted in the first instance by illustration and experiment, so as to detract from the dryness which is so inseparably connected with the rudiments of general science. The teacher, therefore, need not despair because he may with apparent fruitlessness be performing experiments before his pupils, and yet they may not at the time comprehend such. A great matter is gained if the attention is arrested and curiosity excited, for then a taste is sure to be acquired for the study of science; and once create a taste for any particular study, and the possessor of such will be certain to progress, and that rapidly.

The study of Mathematics—a science of incalculable importance to the engineer—is, we fear, one in which but little progress is made at school when the pupil is young. This may, however, be to a certain extent due to the want of appreciation of this science on the part of teachers. Whether the pupil is intended to follow the profession of an engineer or not, the study of Mathematics is one of the utmost importance to the development of his intellectual faculties, and the formation of his character. The study of Mathematics may be said to cultivate chiefly the reasoning faculty, at the same time that it strengthens the memory and powers of perception, and also tends powerfully to promote a habit of undivided and unremitting attention, so indispensable to success in any pursuit. Little progress can be made in the study of this science at school, so that probably beyond the elementary portion of algebra, with the first book in Euclid's Elements of Geometry, is all which can be accomplished thoroughly. This to a great extent is owing to the difficulty of popularising this science, and so divesting it of a portion of its dry and uninteresting nature to the youth at school, whose tastes and inclinations are generally the very antipodes of Mathematics.

The science of Chemistry is one which, although not so closely allied to engineering, is yet of considerable importance, inasmuch as it treats of the various operations connected with the manufacture of iron and other metals, largely made use of by the engineer. To the youth at school it is also important, as, being by far the most attractive and interesting of the sciences, it is often the means of creating a strong desire for scientific knowledge in general, and also because it is the science of all others which is most easily popularised. At school, therefore, Chemistry should be among the first sciences brought under the notice of the youth intended to study other sciences of a more uninteresting nature in connection with engineering. A youth at school may perhaps exhibit considerable dulness and apparent stupidity, but these should be no data from which to anticipate his future talent. If, therefore, he be diligent and, generally speaking, studious, he fulfils what is required of him. Youths at school must and will have recreation. And this is both important and necessary, for success in study depends to a great extent on physical health, and this can best be preserved by a proper proportion of bodily exercise. The character of the exercise will to a great extent depend upon the tastes of the student. Popular recreations, such as boating, cricketing, etc., are beneficial to health, and therefore ought to be encouraged; but frequently the taste of the student, if at all mechanically inclined, will develop itself in working with tools, such as "sawing," "filing," "turning," etc. In this the youth intended for the profession of engineering should receive the greatest encouragement; for while it affords good physical and healthy enjoyment, it instructs the youth in the more rudimentary elements of mechanics and handicraft. It is not unfrequently that we may find youths at school dull and apparently stupid, but showing considerable taste for and aptitude in the handling of tools. This was fitly illustrated in the early life of Sir Isaac Newton, who though, comparatively speaking, a dull scholar, was yet most assiduous in the use of his hammer, saw, and hatchet, making models of carriages, machines, etc. All such recreations, and, indeed, any others of a scientific tendency, such as dabbling in chemicals and electrical apparatus, etc., etc., should receive the highest encouragement, provided, at the same time, that the youth in conducting such experiments is not reckless and unsettled. If such a disposition shows itself, it should be at once corrected, by insisting on one article being completed and thoroughly understood before undertaking any other. This is an imperfection peculiar to youth, and very liable to become worse by having the means of gratifying it with every novelty which presents itself. Such a fault should be carefully guarded against, it being much more easily checked at the school than in the office or shop; but this we shall have occasion to notice more fully hereafter.

Having so far noticed the studies which are necessary to a student intended for engineering while he is at school, we shall now endeavour to direct attention to his course after leaving school. We consider that the required proficiency in the branches we have already noticed, as far as they go at school, could be attained by any ordinary youth by the time he reached the age of thirteen, assuming that he was placed at school on his reaching the age of seven. Of course, a sharper boy will reach such a stage sooner than one who is very dull, but we think that such an age represents the average. Up to this point, then, the student has most of his information imparted to him, and, indeed, to use a mechanical expression, "hammered" into him, whether he will or no, by means of the "cane" and other punishments; therefore very little may be said to depend upon the youth himself, as long as he is under this strict discipline, due allowance being made for encouragement in the shape of rewards of prizes. After this period of the school-days of a youth, almost everything depends upon himself. He can read and write fluently and distinctly, and may have a rudimentary knowledge of the sciences connected with his profession. He has therefore the advantage which many of our ablest engineers have not had in starting, namely, a capital of sound information and knowledge, which, if properly directed, will enable him, with a little trouble, to acquire more.

The vital importance of making a good start in life cannot be overrated. The force of habit is tremendous, and can only be fully realised by the man who has been so unfortunate as to form a bad habit, and who collects all his power to overthrow such a habit: he only knows what the power of habit is. In short, habit may be said to be a second nature, and therefore every care should be bestowed upon the formation of good habits. Habits of thought and action are simply, and indeed imperceptibly, formed by a series of individual thoughts and acts, producing a peculiar desire, under the circumstances, to repeat such thought or action. Such is habit. The character of a young man is greatly strengthened and supported by the cultivation of good habits; for in the performance of such habits he will scarcely feel the exertion, and the oftener his actions are repeated the stronger they will become. Habits of industry, steady application, temperance, etc., are at first easily formed, and become in time so surely confirmed, that indolence, unsteadiness, and intemperance become hateful, and cannot be endured. How many men there are who have lived the bulk of their younger days in active and energetic labour, and who, having accumulated considerable wealth, imagine they can retire and enjoy themselves during the remainder of their life in peace and quietness! Such men only retire to discover the force of habit, and that they cannot exist without their usual amount of work. Indeed, it is a remarkable fact that many who persist in such a course, so opposite to what has been to them a confirmed habit, live a miserable life, and frequently die of actually having nothing to do.

The importance, therefore, of the formation of good and virtuous habits cannot be over-estimated. The formation of such habits depending, then, on the repetition of certain courses of conduct, it follows that the best period of life is that when we are young, and therefore have the world before us. It is also essential that the watchful care of parents and others in authority should be exercised over the youth about to enter on life, for, owing to the unfortunate perversity of human nature when left to itself, if there is a wrong way it is sure to be taken; and, besides, the formation of habit advances in so stealthy a manner, that the subject of such habits may not be aware of their existence until he has arrived at a period in life when he experiences to his cost some habitual weakness or disadvantage in his character, and which he in vain endeavours to undo. Since, then, the force of habit is constant, whatever be its nature or direction, and that its force is accelerated by frequent repetition of thought or action, it follows that the main and most important point in the life of a young man is to make a fair start, and in the proper direction; and such a commencement will generally hold within it the termination, and thus habit will, like a ball allowed to commence its descent upon a properly directed incline, become accelerated in its force, and not fail, having once fairly started, to reach its desired destination.

As we have already observed, everything, after a youth leaving school, depends upon himself; and we would add that, to do a youth justice, he should be distinctly informed that upon himself *only* would he have to depend; for it frequently happens that a young man's exertion on his own behalf is enfeebled in the same, and sometimes a greater, ratio that his prospects of assistance appear. And this, especially for a young man designed to follow the profession of an engineer, is most injurious, as it will render him faint-hearted and incapable of meeting and effectually baffling those difficulties which he is sure to meet in the up-hill battle of life. The habit of overcoming difficulties is one of the most valuable a man can possess, for it comprehends habits of perseverance, of hard working, and indefatigable industry. A man may not in every case come off victorious, but in the encounter he will increase and train his strength, while he will retire better disciplined and more skilled for a future effort. Besides, why should we be disheartened by failure, when it is the very forerunner of success, provided we possess the habit of indomitable perseverance? In no profession is there fitter illustrations of this than in engineering. Take, for instance, any machine, or, more to the point, the locomotive. Was it not through a series of the most apparently hopeless failures and baffling difficulties that Stephenson brought this wonderful machine to such perfection?—difficulties, indeed, which were beyond reasonable hope of being surmounted, considering the incorrigible prejudice of the people in those days against the introduction of such engines. Stephenson, however, well knew the advantages of having such difficulties to contend with; for his great object in directing his pupils was, not to make the path of knowledge too easy for them, but to lead them to think for themselves, and thus accustom themselves to overcome difficulties in the acquisition of knowledge, so that they might form the habit of boldly encountering and surmounting the difficulties of their after-life. It is a much more hopeful sign to see a young man standing up manfully against misfortune and repeated failures, attacking his object with renewed vigour and energy, and with the nobly-determined resolution not to be beat, than to see one set out in life with every advantageous assistance which is calculated to ensure success in his pursuit. The former will be emboldened by his meeting with and surmounting difficulties, and through his repeated failures will eventually be successful; while the chances are that the latter, having so many advantages and so much assistance from without, will become in himself weak and inactive in the pursuit of his profession, and when difficulties do occur, he will become intimidated at their very appearance. Now, in the pursuit of engineering this is most especially the case, and it therefore points out, as a proper school for training, that of difficulty and hardship. We have only to direct attention to the lives of our very greatest engineers, and we find that one and all of them, when starting in life, met and triumphed over a series of difficulties, the very surmounting of which made men of them. It must not be supposed, however, that because such a school of hardship is the proper one in which to train the youth destined to follow the profession of engineering, that hardship and difficulty are to be purposely thrown in his way. This would be certainly cruel treatment, for he will find quite enough of hardship and difficulty connected with acquiring a proper knowledge of his profession without having any additions thrown in his way. These even sometimes do occur from misfortune and other external sources, over which the young student may have no control; but we believe in all cases they are sent for his instruction by the supreme ordinance of our Great Parental Guardian, who knows us better far than we do ourselves, and who is certain in the end to cause all such misfortune to work together for our good. What is meant by this school of hardship is simply to allow the young student to help himself, placing within his reach,—*but no further*,—the means by which he may do so, and at the same time encouraging him to *think for himself* and *exert himself* in acquiring that knowledge which is to fit him for his profession.

That the young student in engineering may effectually overcome his difficulties, he must believe that he possesses the power to do so. If he does not believe this he will never try; and however much he may desire to remove such difficulties, unless such desire ripens into earnest purpose and effort, and an energetic attempt made, he will sink down in impotence and despair. No one knows what he can do until he has really and seriously *tried;* and as long as a young man sees the prospect of his difficulties being removed for him, there is slender chance of his doing his best. Therefore it is important that those in authority should be careful how they assist; for it is only when a thing *must* be done that it *will* be done, and then it is that necessity, "the mother of invention," will give birth to the means by which the difficulty is to be surmounted. Now, there are some characters possessing a considerable amount of confidence in their ability, before having had much to test it. This excess of confidence, which in some cases approaches to vanity, will soon get considerably shaken after having met with a few failures, and therefore such existing in a youth is rather an advantage than otherwise. In others, however, there exists a bashfulness and timidity which are apt to ripen into indecision and want of confidence. Such a character is one of the very worst which a young man can possess, especially in engineering; and unless the means are taken to counteract such when young,—such as bringing the young man out, instead of the too general notion that young men should be kept down,—such want of confidence and timidity will prove a great barrier to future advancement. Too much confidence renders a man vain and impudent, but, withal, is certainly better than none at all. In the former case the man has a chance of success, although he may frequently, by an excess of confidence, be led to undertake more than he can possibly perform. But in the latter case the man is hopeless, as with such a want of confidence he can never be prevailed upon to decisively undertake anything; therefore he has no chance of success whatever. "Faint heart never won fair lady" is a true and most applicable maxim—one, indeed, to be constantly remembered by a young man entering the profession of an engineer.

Before proceeding to other points connected with the education of the young engineer, it will be perhaps useful to give here, as supplementary to our own opinion on the subject of what we may call the *preliminary education* of the aspirant to engineering honours, that of Mr Scott Russell, than whom there is no higher authority. In an address delivered at the South Kensington Museum, this eminent engineer pointed out, what is unfortunately too true, that although there was a description of education which was calculated to increase the "skill, dexterity, ability, and success of our practical working mechanic," that those belonging to this country did not receive it. In respect to their attainments, the mechanical workmen of this country stand out in painful contrast to those of the Continent; so much so, that Mr Russell stated in his address that he "himself was obliged to get his very best draughtsmen and mechanics from foreign countries. He had men in his employment from Prussia, Germany, and Holland; and he was bound to say that, as far as preliminary education was concerned, although the workmen of foreign countries had not the skill obtained by the British workmen from practical experience, their scientific knowledge was greater; and that knowledge was telling so rapidly on the present generation of workmen, that we were now equalled (he would not say excelled) by the workmen of many countries upon whom we were inclined to look down a few years ago." To get rid of this very discreditable state of affairs, Mr Scott Russell showed what our education of the "mechanical workman" was. By this term the reader is of course presumed to know that something different is meant than is ordinarily conveyed by it. An engineer who knows his profession, —no matter what his position in life may be, how wealthy, or how bright his prospects,—is a "mechanical workman;" and if he is not a good one, certain it is that he will never be a good engineer. Much of what

Mr Russell says is of course specially applicable to "the working mechanic," but it is no less so, in an educational point of view, to him who goes through the training of a workman in order to be a master in time to come. Mr Russell, at the outset, has no objection to offer to the ordinary system of school teaching. "On the contrary, he would say, continue to teach drawing, reading, writing, and accounting in the best manner you can; but if you have a class of young workmen coming forward to learn, think how you can turn the little time they can afford to give to the best advantage, so that you may raise them higher in the social scale and make them better workmen. In order to do this it is necessary to give them a higher class of education than they were ever taught before. We did not go far enough. The persons to blame were their teachers. Two years was perhaps all the time that could be devoted to education, and six months were often devoted to as many books of Euclid, which were wasted for all practical purposes, unless, indeed, the student intended to become a professor. They should skip over the beginning, and devote the least possible time to Euclid—in fact, he would advise them to do a very heterodox thing—to cut off all the propositions but the useful ones. They might naturally exclaim, 'Then how little will be left.' Very little, he admitted, but plain trigonometry would be left. Suppose, for instance, a man had but six months in which to learn. Six weeks might in that case be given to Euclid, and then trigonometry might be commenced, solid geometry might next follow, and that constituted the whole education of the workman. But that was precisely what he did not get in the present day. He would also teach within the six months conic sections, and afterwards the nature of curves, within the first, second, third, and fourth degrees. He was aware he might be met by the exclamation, 'Oh! but we shall be teaching them more than we ourselves understand;' but to this he would answer, 'That is the fault of your education.' Sir Isaac Newton discovered no less than 130 curves, and nine-tenths of them would be of great use to the mechanic, if he had them in two places—in his head and at his fingers'-ends. . . . Of great importance to the working man was the comprehension of the laws and relations of numbers, so as to enable the working man to think in figures about the immediate business before him. He remembered an instance in which a respectable working man sent in a tender for L.12,500 for a very large piece of work. The tender appeared to be low.

and he obtained the order, and got on some way with his work, when he found he had made a trifling omission—he had forgot to multiply by *two*. His figures were all right, but in one place he had forgot his multiplication, and his whole calculations were wrong. With respect to solid geometry, the two great duties in a workman's life were conversion of materials and adaptation to strength. A mason who used up a wrong stone, or a carpenter who selected a wrong plank or piece of timber, showed that he was ignorant of one of the most useful portions of his art or calling. Now, nothing would teach conversion of materials like solid geometry; it was, in fact, the daily business of the workman. It had been said that every block of marble cut from the quarry contained a beautiful statue, but the art was how to get it out of it. This was very true; for what workmen wanted to know was every shape, and how to get out another shape. The workman who took from a heap a block of stone or piece of timber that cost his master 50s., when a piece could be got, answering quite as well, which cost 25s., inflicted a loss upon his employer perhaps equal to a week's wages. Hence the necessity of acquiring a knowledge of solid geometry. But if there were beauty in the quantity of numbers, and in regular geometrical figures, there was infinitely more beauty in curves. It was the duty of many mechanics, especially of those engaged in ship-building, to make curved lines."

Mr Russell in his address pointed out the necessity which existed for good text-books. "Decent elementary text-books were," he remarked, "wanted for the higher departments in mechanics, but there were many able men versed in the sciences; and what he wanted the department of science and art and the Government to do was, to ask the four cleverest men in England to write, in the fewest possible English words, all that they knew (not all that they had read), or, in fact, so much of their brains as they carried about with them. If Government would but pay handsomely for these books, a set of treatises might be collected such as the world never saw before, and such as would be sufficient to teach any mechanic his business. They might, it was true, say, 'But we do not know where to get these clever men.' But he knew where they were to be got. There were three of the four present at that moment; and if the Government would but give them a thousand pounds a-piece for writing the books, he was sure they would write them."

Mr Russell is also of opinion that there ought to be in educational establishments for the "mechanical workman" "a large quantity of apparatus—a sort of inventory of education—of every conceivable shape and object. In addition to these models, he would have the school-room hung round, not with pictures of animals, but with solid bodies, which could be explained and drawn. He would, in fact, impart any kind of practical rather than book knowledge. If drawings merely were used instead of models, he did not think the student could imbibe so correct a notion of the object to be produced or delineated. There was a mode of studying forms called *la théorie de développement*, but the plain English meant nothing more than making flat surfaces into round and angular forms (as models now made from sheets of paper, which was a most valuable mode of studying forms). If this description of education could be given, he would take the pupils educated in that department and give them three guineas a week. He might afterwards raise them to foremen with salaries of L.500 a year; and that would be far better than remaining all their lives at the bench, earning 30s. a week. Machinery could now be obtained to do all the unintellectual drudgery of mechanism. He was not opposed to machinery, and had no apprehension that it would supersede skilled intellectual handicraft. He would employ machinery to do all the drudgery that degraded the workman into a beast of burden. He would give him higher views of mathematics; he would show him that he was an intellectual, thinking being, with a soul for high and immortal things."

It certainly seems an unfortunate thing for the future of engineering that there is no regular systematic mode in full operation in this country by which the proper education of the young engineer can be ensured. The *Engineer*, in an able article, advocates the legal recognition of the profession of the civil and mechanical engineer, precisely in the same way as the clergyman, the doctor, and the lawyer are recognised, so that "future candidates shall be compelled to undergo a standard test of proficiency," and thus get rid of the disgrace and the danger arising from the practising of those who, although calling themselves engineers, "nevertheless are grossly and outrageously ignorant of the very elements of engineering science in all its branches." This proposition—and that it is a right one is clear enough—to compel each candidate to undergo a "standard test of proficiency," involves this, that some means must be adopted by which candidates will receive that education, theoretical as well as practical, by which they will be enabled to pass that test. This brings the writer of the article to consider the subject to which our attention has been directed in the foregoing pages; and it is thus that he proceeds to state his views:—

"Each year it is becoming more and more apparent that we have no reliable source of instruction for the young engineer entering upon the practice of his calling. The pupil system, after all that can be urged in its favour, is but an incomplete preparation for a young man starting in a general practice; for although it is an undoubted fact that many eminent engineers have commenced life with no better preparation, it is allowed generally that they owe their distinction to their own exertions, and in a great degree to information acquired outside the office. Such men throw a favourable reflection on the system under which they received their education, but there are many of an inferior stamp to neutralise whatever credit the pupil system may have gained. Again, the engineering school is generally voted little, if anything, better than the system of pupilage; for although the student is well grounded in the theory of his profession, he is, till he has had experience, likely to prove unpractical—not, indeed, that such is necessarily the consequence of academic instruction, for practical instruction is just as feasible as theoretical, and much easier to impart and retain, but, for some reason or other, the practical element appears to be made subservient to the study of theory. If the course in the engineering schools was as thoroughly practical as it might easily be made, there would be far less ground for cavil. No one doubts that the most perfect training for a young engineer is a careful education in the principles of his profession, combined with, and followed up by, practical instruction in the application of those principles. Neither theory nor practice will ever make a man a good engineer; but the careful combination of both will do so, if anything can.

"The most obvious method of securing this combination of theory with practice, would be the establishment of a School of Engineering, in which the theory of the science would be taught in all its branches by professors of known practical ability; and in addition to such oral instruction should be imposed at least two years' apprenticeship to an engineer of recognised standing. There would of course be no objection to the period of pupilage being extended, as it might be simultaneous with the course of theoretical instruction —a certain amount of relaxation being permitted, to suit the arrangements of the engineering school.

"The establishment of such an institution need not materially affect the working of the already existing schools of engineering; they might rather act in concert together—the certificates of one being recognised by the others, according to the practice of the medical schools throughout the kingdom."

This article called out the opinions of various correspondents, from which we select the following, as conveying a notion of the system of education proposed, and also because it passes some remarks upon the absurd mode of teaching pursued at schools where engineering science is professedly taught. After proposing a plan of preliminary operation, the writer supposes that a "charter of incorporation will be ultimately obtained, by which the candidates might take rank as Masters, Bachelors, or Passees of Engineering, and might be initialed as M.C.E. or M.M.E., B.C.E. or M.E., C.E. or M.E.

"Of course the board would be best qualified to judge respecting the attainments required for each grade; but I should suggest similar papers to those given to candidates for the engineers' department of the Indian Civil Service or the Naval Engineers, with, however, a more fully developed practical bearing.

"For the C. or M.E., I should consider the following course sufficient: Arithmetic and mensuration, algebra, inclusive of quadratic equations, plane and spherical trigonometry, and the first six and part of the eleventh and twelfth books of Euclid, mechanical philosophy, and its practical applications. The professional part to embrace designing, drawing, estimating, and surveying, with an outline of professional jurisprudence of works and services; these latter papers to be extensive in application, and framed, of course, to suit the civil or mechanical tendency of the candidate.

"For the Bachelor test I should suggest a further excellence in the above, and include conic sections, and the differential and integral calculus. The Master's certificate would be obtained by a refinement upon the preceding, and acquaintance with the writings of ancient and modern authors.

"This scheme may by some be thought visionary, but I feel confident that the course roughly sketched could be easily overcome by any one desirous of so doing, and we should ultimately raise our profession to a position more in accordance with its varied requirements. . . . I would observe that *our ordinary school tuition* has not kept pace with the advancement of the age; as example, who is not aware that a boy's *arithmetic* days are spent in calculating the tare and tret of tea, sugar, and treacle, or in finding the value of so many yards of tape or broad cloth? Again, in mensuration or surveying, he meets with a most happy combination of triangular, square, or circular fields, and can determine with accuracy the distance of the moon, or between two ambiguous points A and B, by conjuring with a table of logarithms; but as far as application to obtain any measurement of the school-yard or common hard by, or the recognition of a theodolite, and its adaptations for finding the height of the parish steeple, in these he is quite at fault. Let us next follow him to the drawing-lesson; he there learns to portray the likeness of some piece of mechanism on another paper, generally by the enlargement and exaggeration of its proportions; and after outlining this effigy with a decoction of ink and water, he elaborates the whole by a display of water colours; but as far as knowing which is bolt, nut, or washer, neck or coupling, one term may be substituted for another without injury to his preconceptions."

Perhaps no better scheme for the education of the civil and mechanical engineer could be met with than that of the Glasgow University, in connection with the Chair of Civil Engineering and Mechanics, occupied by W. J. Macquorn Rankine, C.E., LL.D., F.R.S., whose reputation, as perhaps the first engineering, mathematician, and scientific authority, is world-wide. We deem it useful to be given here :—

"The objects of study may be summed up briefly as follows :—The stability of structures ; the strength of materials ; the principles of the action of machines ; prime movers, whether driven by animal strength, water, wind, or the mechanical action of heat (as the steam-engine) ; the principles of hydraulics ; the mathematical principles of surveying and levelling ; the engineering of earthwork, masonry, carpentry, structures in iron, roads, railways, bridges and viaducts, tunnels, canals, works of drainage and water supply, river works, harbour works, and sea-coast works.

"The University library is well supplied with works on engineering science.

"The engineering school of the University of Glasgow is approved by the Secretary of State for India in Council, as one in which attendance for two years would qualify a student, who had fulfilled the other required conditions, to compete for admission to the engineer establishment in India.

"*Certificate of Proficiency in Engineering Science.*

"1. A course of study and examination in engineering science has been established by authority of the University Court and of the Senate.

"2. Certificates of proficiency in engineering science are granted to students who have gone through that course to the satisfaction of the Board of Examiners.

"3. The course of study consists of—

"I.—Mathematics, junior and senior, or senior mathematics only for those qualified to enter that class at first.

"II.—Natural philosophy, one or two sessions, according to the proficiency shown at the end of the first session.

"III.—Inorganic chemistry, one session.

"IV.—Geology and mineralogy, one session.

"V.—Civil engineering and mechanics, two sessions.

"4. The examinations for certificates of proficiency in engineering science are carried on along with the class examinations after the Christmas holidays, and the number of such examinations in each class of each session is not less than three.

"5. The proficiency of the students in engineering and mechanical drawing is tested to the satisfaction of the Board of Examiners.

"Four prizes (consisting of books or instruments) to be competed for in each year by students of civil engineering and mechanics, were founded by James Walker, Esq., civil engineer, LL.D., F.R.S.S.L. and E.

"The competition is open to all persons who shall have duly entered themselves as attending the class of civil engineering and mechanics during the current session.

"The competitors are examined in April, orally and in writing, by the professors of mathematics, natural philosophy, and civil engineering and mechanics.

"Two of the prizes are awarded by the examiners; the other two by the votes of the class, the competitors included.

"The following notes as to instruction in engineering science have been drawn up by Professor Rankine, for the information of students, and will doubtless be found useful by those who aspire to enter the profession:—

"NOTES AS TO INSTRUCTION IN ENGINEERING SCIENCE,

"DRAWN UP FOR THE INFORMATION OF STUDENTS.

"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 consistent 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 a 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," which may be had from the registrar, Glasgow College, price 1s.

"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."

What has been given in this chapter, now about to be concluded, makes it abundantly evident that much has—nay, we may say everything has—yet to be done before a system of education suited to the requirements of the technical workman—using this phrase in its widest and most suggestive acceptation—will be easily available in this country. Just on the point of going to press with the present sheet, the author has read some remarks upon the subject from the pen of the accomplished editor of the *Practical Mechanic's Journal* (in the number of that magazine for March 1866), which are peculiarly suggestive. These remarks were called forth by the contribution of a writer in the *Journal* on "Engineering Education," which is too long to be given here, but the gist or rather the conclusion of which, as to what is necessary "to make an engineer of the lad," is as follows:—"Give him a good school education, such as befits a gentleman, and for that reason do not take him out of school before he is sixteen; then send him into the workshop, and let him stop there about five years, and keep an eye upon him that he sticks to the work. At the same time do not let him work the full complement of ten hours a-day, but say at most seven, and let him in his spare hours have first-rate instruction in the exact sciences as well as drawing. We believe that some such plan, more or less modified, would produce a very superior class of engineers, such as befits our fast-progressing age." Upon this, and in other parts detailed by his contributor, the editor passes some very suggestive remarks, the gist of which is, that throughout our empire there is not only no good system of technical education existing, but that even the very idea—the "primary conditions and requirements" constituting this—is not so much as entertained amongst, far less understood by us. And, on the subject of education, he has the following, well worthy of careful consideration :—"Let it ever be held in view that *education is the discipline of the mind,* a course of mental gymnastics, in the progress of which some information must subjectively be acquired, but whose primary and all-important object is so to teach the pupil, that upon his further voyage in life he may be *able* and *willing* to gather in and hive, in an orderly manner, information of any sort, and collected in every way—by reading, by converse, by observation, by reflection. Were this once seen and understood by the more intelligent of the middle classes of England at the present day, much of the vulgar nonsense that is met with as to the uselessness, etc., of Latin and Greek, the confused fancies as to some imaginary contrariety between theory and practice, and a good many other half truths or mischievous fallacies, would vanish necessarily. Let it be understood that education must come first, and that the methods for acquiring information should follow that —first, those derived through books, etc.; afterwards, those dependent on observation. A boy thrust at once into the workshop has observational food thrust upon him which he is unfit to choose from, and incapable of digesting."

That the subject is of immense importance, in every sense national, there can be no rational doubt; we have been so long and so complacently congratulating ourselves upon the fact that we stood alone among the people of the earth, as combining all that was essential to national progress, that it is hard to believe there are others nearly as good as ourselves, many who are up to our mark, some who very soon will be, if they not already are, beyond it. The signs are gathering thick around us that our mechanical supremacy is being ably contested by the very nations we have for so long time been accustomed to look upon as altogether unlikely to be in any sense opponents to be dreaded, if, indeed, we have not thoroughly despised their power to become so—that we find it now very difficult to conceive, in the words of an eminent authority which we prefer to quote rather than to give our own, that "Foreign engineers, and masters of manufactories, and workmen, are being found more and more nearly a match for us in all things, and many more than a match." If these things be, as we believe they are so, it is quite time for us to consider well our position, and how best we can bring it more in unison with the requirements of the day.

CHAPTER III.

TECHNICAL EDUCATION—WORKSHOP AND WORKSHOP ROUTINE.

HAVING left school, then, the student may be said to enter upon life, after which period he ought to know that he is expected to take full advantage of all his opportunities of gaining knowledge, and not to trust to others imparting such. If he has also the opportunity of attending college after leaving school, it ought to be solely for the purpose of studying the more advanced branches of mathematics, natural philosophy, chemistry, and probably the modern languages; but we should not recommend too much time being spent at college, especially if the student is intended for any of the branches of mechanical engineering. As the technical education of an engineer is of necessity a protracted one, it is advisable, both in a mental and physical point of view, that the student of engineering should have commenced such education by the time he has reached the age of fifteen, or at the latest sixteen, years.

The reason of this is obvious,—the younger a man is, the more pliable he is, and the easier he is inured to hardship, which we have already shown to be so intimately connected with the study of engineering. If a young man, on the other hand, is allowed to remain at college or school until he has reached, say, the age of eighteen or twenty years, he will find it rather a difficult matter to apply his mind and strength to the study of a profession like engineering. In the first place, he has been accustomed to delicate and gentlemanly treatment—been under comparatively easy discipline, and had probably little physical exertion—his habit of life is so far formed, and it therefore becomes very up-hill work indeed to alter his course to that of a workshop-life, where his treatment is likely to be just the opposite of what he has been accustomed to receive—therefore it is that many such young men give it up in despair, finding it "too hard and too dirty work for their delicate hands."

A young man, therefore, to make progress in the study of engineering, must begin early; he must go to school early, and he must leave early—of course consistent with his required education, which we have already endeavoured to point out. In this way he will have received good sound discipline at school, and, before being allowed any of his own way, he will be launched into the still more rigid discipline of the workshop. He will, therefore, have simply taken a further step in one of the most important branches of his study—namely, discipline; while, from his youth, he will bend with ease into all the hardships of his trade, without, in many cases, considering them hardships at all, at the same time scorning to be intimidated by what many may consider degrading work. Of course we do not mean to assert that, because a young man may have spent several years at college, or in any other way, that he has lost his time, and therefore cannot succeed in becoming an engineer. No one is too old to learn, provided he has the resolute determination to apply himself to study, whatever the nature of that study is: what we affirm is, that experience teaches us that a man, to endure physical and mental hardships, will do so with least inconvenience to himself by beginning to practise it when he is young, and therefore will be likely to make greater progress in professions requiring such, than he who has spent a greater portion of his life in self-comfort and delicacy.

Assuming now that the student has completed the first part of his education—namely, his scholastic education, and that he is ready to enter upon the more immediate studies connected with his profession, we will, before directing his course in the workshop, make a few remarks on the means by which the young student in engineering obtains admittance to the works of an engineer, and the position he occupies when there.

In the first place, that we may be properly understood, we must briefly describe the nature of the works of a mechanical engineer in average practice.

As we have already observed that, although there are several branches even in mechanical engineering, yet the mechanical operations in each of these departments are really the same. The material from which the greater part of machinery and engines are manufactured being iron, nearly the same tools and other means of working iron are employed, whatever be the design of the work; therefore, if we describe works pursuing any one of the branches of mechanical engineering, it will serve to illustrate the whole.

Iron exists in three different states—namely, cast iron, steel, and malleable iron. These three different combinations of iron and carbon are extensively used in the workshop of the engineer. Malleable iron is that in the purest form, and contains about one atom of carbon in combination with four atoms of pure iron.

The properties of such a combination of iron and carbon are great softness, flexibility, ductility, and malleability. It does not in this condition melt, except at very high temperatures, but may be "welded" (that is, the particles melted, so as to render them adhesive and hammered together) at a white heat, the surfaces being united by an incipient fusion. Steel is a metal combining iron and carbon, the latter in greater proportion than malleable iron. The properties of this combination again are comparative hardness, ductility, malleability, and elasticity; it also possesses a property in virtue of which different degrees of hardness can be given to it—hence all edge-tools, and other instruments for cutting, are made of this material. Cast iron is a metal combining the greatest proportion of carbon with pure iron, its chief property being that of brittleness, and being at the same time easily fused. From this fact it takes its name, being cast into the required forms. So much, then, is explained of iron, auxiliary to the description of the workshop.

The works of a mechanical engineer may be said to consist—speaking in a general manner—of men, tools, and materials. The principal materials we have already noticed. The tools are various and numerous, and are every day becoming more so. It is often said, especially by the old "hands" of the shop, that men are not now-a-days as they used to be; this, they affirm, is because of the most part of the skilled labour being prepared by improved machinery, against which many have a great prejudice, considering it a great innovation upon their chances of constant employment. They accordingly affirm that the men are now reduced to mere machines themselves. This is partly true; but the cause is not in the introduction of machinery, but in their want of education, and, in many cases, even their desire for such. The chances, however, now of becoming an engineer are withal much greater than in more primitive days, for then the mechanic had laboriously as well as skilfully to fashion his work with the rude tools he then possessed; whereas now the ponderous steam-hammer—which makes the very earth tremble at every blow—has saved the labour and lives of multitudes of those who were doomed to the laborious work of the forge. In the same manner the planing-machine has taken from the hands of the workman to a great extent the hammer and chisel and file, doing such work in an automatic and much more accurate manner. Such wonderful self-acting machinery, instead of lessening the chance of a man becoming an accomplished engineer and a good workman, rather tends to increase it; at the same time such machinery very fitly illustrates, by the marvellous results obtained, the great triumphs of mind over matter.

A workshop, then, is divided into several sections of shops. There are first, the "pattern-shop," "smiths' shop," a "smithery," "foundry," "machine-shop," and "fitting or erecting shop," and, in some works, a "boiler-shed" is included. Of course there are several works who do not make their castings, and therefore have no foundry, as also no boiler-shed, not making their own boilers. The others, however, are absolutely necessary, and therefore no "works" of any consequence will be found without them. The pattern-shop is that in which a facsimile of the article required is made in wood. The foundry receives such wooden "pattern," and takes an impression of it in sand, running molten iron into the same, and thus producing the article in iron of the exact required form. As, however, such a "casting," as it is termed, is, comparatively speaking, inaccurate and rough, it is requisite to send it to the machine-shop, there to be "planed," "bored," or "turned," as circumstances require. The fitting or erecting-shop receives this again from the turning or machine-shop, and, by the aid of skilled workmen and hand-tools, it is fitted to its place, or otherwise has that completed by hand what cannot be accomplished by machinery. This is the course of any piece of work executed in cast-iron. Wrought-iron, however, being a metal which cannot be cast, being malleable instead, is formed or wrought into the required shape in the "smithy-shop" by the aid of the fire and hammer, all subsequent operations, however, being similar to those already described for cast-iron.

We have thus endeavoured briefly to give a sufficient idea, without the introduction of technicalities, of the routine of the workshop of the mechanical engineer, to render what we have now to say more intelligible. These several departments, however, we hope at another time to be able to explain in detail.

Coming now to the means by which the student gains admittance to such works as pupil and apprentice, the most general questions asked by parents and guardians intending to place a young man in the works of some engineer are, *first*, Have we interest to obtain his admission?—if so, *second*, Does a premium require to be paid, and how much?—*third*, For what term of years does he require to serve? After all, will he be qualified to fulfil his duties of engineer after his term has expired, and will his master guarantee this? These are questions of vast importance, and are always pre-eminent amongst those asked by both parents and students. First, then, as to the influence required to introduce a young man into the works of an engineer. In one sense no influence whatever is required; the young man need only make personal application to the foreman, manager, or master—whoever is in charge—and by waiting until a vacancy occurs he will be admitted. In this way, however, his position in the works will be that of a common apprentice prepared to go through all the drudgery and hard-working routine necessary to make him a workman. He will be compelled to wait his turn, along with other apprentices, such as the sons of workmen; and, generally speaking, unless he has favour with some one in charge, or happens to get into a shop where they make a point of pushing the apprentices on (which we may say in passing is a matter of considerable profit to the master), his progress will necessarily be slow, and a good deal of time lost. Entering in such a way, however, has its advantages, as well as those disadvantages just named (the latter of which he may reduce considerably by pushing himself on—a course of conduct which, we are sorry to say, is not often practised by apprentices of this class); for, besides being subjected to a rigid system of discipline and hard work, from which there is *no escape*, he is, at the same time, remunerated for his labour, and is therefore encouraged to be industrious—an excellent system of inculcating such a valuable habit. Such a course of instruction, however hard to learn at the time, seldom fails to accomplish its object, and, for reasons which we shall afterwards show, it is, although a slow method, yet a very sure one; and we have only to refer the reader to the lives of our very greatest engineers, and it will be found that in such a school as this they laid the foundations of their future success.

Again, the influence required to obtain the admission of a young man into the works of an engineer may be considerable, and such admission attended with great trouble and difficulty. This will be especially the case where the works are large and in good practice, having perhaps several premium pupils or apprentices. The influence required to effect this must include acquaintance with the master or manager of the work; and if he agrees to admit the applicant, he is then admitted on the presumption that he is designed for something above a mere workman. The consequence of this is, that while he is saved all the unnecessary drudgery (although not the hard work), he is pushed on through each consecutive department (to be hereafter detailed), having thus the advantage of acquiring a thorough knowledge of the whole constructive routine of the works. This is a great advantage to the intelligent and well-educated youth, who is sure to take an interest in his work; at the same time he is saved the drudgery of work of a "machine-like" nature, so to speak, and which is particularly disgusting to the youth who has a love for his profession as well as a degree of intelligence—work, indeed, which is practically useless so far as imparting useful knowledge goes, its only benefit that we know of being that of a good exercise for patience. With such a position, however, as his influence gives him, he, being of the better class, is supposed not to depend in any way upon remuneration, and therefore in most cases he receives none. Now this has a bad influence, as it withdraws from him the encouragement to work and be industrious; while to a certain extent, and in consideration of such, the rigid discipline of the works is not enforced to the full extent upon him, that it would otherwise be if he received remuneration for his labour. Upon the whole, however, this position for an educated young man is *the* one in which he will have most advantages, and in which he will have most opportunities of acquiring thoroughly, and that, if he chooses, rapidly, a good sound knowledge of the practice of his profession.

Proceeding now to the consideration of premiums paid for the admission of students to the works of the mechanical engineer, the reader must pardon our going more fully into this subject than its importance would at first sight warrant. We believe, and we hope to demonstrate, that not only is the greater part of premiums paid for the above purpose money thrown away, but in many cases worse than thrown away, for it secures to the young man the very thing which it ought to have secured him against—namely, having too much of his own way, and the relaxing of that rigid discipline so essential to teach a man self-government. Every manager or master of engineering works is entitled to demand a premium for the admission of a pupil to his works, and is bound in return to place within his reach all the advantages and opportunities his works will afford for the professional instruction of such a pupil. More than this, however, he is not bound to do; for instance, if the pupil does not choose to avail himself of such advantages and opportunities of instruction—perhaps exhibits a degree of carelessness or inattention—he may be reprimanded; but a master or manager beyond this will not probably trouble himself. Now with premiums, *per se*, we have nothing to find fault with, so long as masters or managers have it in their power to admit pupils to good practice, for which they are able and willing to pay; it is not the use of such but the abuse that we find fault with, and it is this:—Parents and others come to some terms to pay a large sum as premium, say to the manager of a railway company, to admit perhaps their son into the works of the company. It is accordingly arranged, and the pupil enters these works not so much a premium-apprentice but a privileged apprentice, in virtue of his having paid a large sum for admittance. He has, therefore, great license, and is allowed to work at one thing, then leave it, go to another, and so on, whatever suits his fancy. He is a great friend of the subordinate foremen of the works, all of whom look upon him as a gentleman's son, and *to be treated as such* in the works. He comes at nine or ten o'clock in the morning, goes at probably five in the evening—in each case like a "gentleman."

Now, we should ask any engineer who has undergone a disciplined and practical education, and who has experienced its great benefit, what are we to expect of such a premium-apprentice, a picture of whom we have just drawn? That such a sketch is not extravagant or uncommon we can testify, as can many others who have been educated in large establishments, and who have been surrounded by such "privileged" gentlemen, whose position we were foolish enough at the time to envy when we were undergoing our own hard lot, as we thought, but which we have every reason to be thankful for now. What, then, are we to expect? Why, that such "privileged" gentlemen would be turned out into the engineering world grossly incapable of performing their duties. That there are exceptions we do not doubt, and to them it is the more credit, and shows their love for the profession. Indeed, the ignorance of premium-apprentices and pupils is almost proverbial in the trade, to illustrate which we have only to quote the words of an engineer of high standing, who, on meeting another young engineer in the course of his duties, was struck with his shrewdness in engineering matters. Addressing him, he said, "Were not you one of So-and-so's premium-apprentices?" and on his answering in the affirmative, he exclaimed, "Well! it is a wonder you know so much." This shows, at the same time, what is thought of premium-apprentices, and that there are some who really do credit to the profession; but that is no reason why they, as a body, should pay so much and run so great a risk of learning nothing. Now, there is not only no reason why the generality of such premium-apprentices should turn out so inferior engineers, but there is every reason why they should excel all other apprentices. So long, however, as they have so much of their own way they will never as a body excel those who are under rigid discipline. A premium is intended to secure to him in whose behalf it is paid the best possible professional instruction, and therefore it ought to be most distinctly stipulated that, not only should every opportunity and advantage of gaining practical and theoretical knowledge (as far as the resources of the works enable them) be afforded to the pupil or apprentice, but that such a pupil should be under the correct rules and regulations, or other discipline, of the shop; and, in addition to this, the practical and leading men in the works should have positive instructions to look very sharply after him, seeing that he fulfils in every respect those duties which are to render him a proficient engineer. To give such an apprentice due encouragement he should be paid a weekly remuneration according to the time he has worked, or, in some cases, according to the work he has done. Under such stipulations as these there can be no objection whatever to the payment of premiums, but rather the contrary, as under a proper system it would secure to the pupil many advantages which he would not otherwise receive.

The greatest difficulty is experienced, however, in dealing with premium-apprentices in the workshop. They have paid, it may be, a large sum to be allowed to work and receive information in the works, the term being for a number of years. Such a contract is entered into by the apprentice agreeing to pay so much on the one hand, the master agreeing to receive and educate in his works the said apprentice for a certain term of years, at the expiry of which he is supposed to be qualified to fill responsible situations as engineer. Now this contract is usually made binding upon both parties by means of a heavy penalty to be inflicted upon each or any who may break through such terms as it implies. Such being the case, the foreman, manager, or master cannot freely exercise strict discipline over such a pupil if the latter chooses to defy him. Discipline in the army and navy is enforced by means of imprisonment and other punishment; in the workshop by means of fines, and finally by means of expulsion from the works. Workmen, therefore, who have to depend upon their weekly earnings, and consequently upon employment, are careful how they offend their superiors, or how they infringe upon the rules and regulations of the shop. The young premium-apprentice may or may not, just as he pleases, pay attention to such rules; in many cases he does not; and all this is owing to his superiors not having the same power over him which they have over the other men in the works; they find they cannot fine them, nor yet can they expel them from the works, as they have paid money to be allowed to stay there; hence it so frequently happens, when such apprentices become refractory, foremen and other superiors in the works may remonstrate and even threaten, and without avail, for under the usual system they cannot enforce the rules and regulations of the works.

To better illustrate this important subject, we may as well here state what the general rules and regulations of a well-disciplined shop are—rules which should be enforced upon and obeyed by every man employed within the gates of such works.

RULES AND REGULATIONS TO BE OBSERVED BY THE WORKMEN OF —— —— IRON WORKS.

1. *The bell will be rung at five minutes to six o'clock in the morning, and will continue ringing until six o'clock, by which time every workman is expected to have commenced work. Five minutes grace will be allowed to those workmen who do not make a practice of being late; the doors will, however, be closed at five*

minutes past six, after which no workman will be admitted until nine o'clock.

2. Half an hour will be allowed for breakfast, the bell being rung at nine o'clock for such, and again at half-past nine, when every workman must be at his work; if not, he shall not be admitted until three o'clock.

3. One hour will be allowed for dinner, the bell being rung at two o'clock for such, and again at three o'clock, after which no workman shall be admitted.

4. The bell shall be rung in the evening at six o'clock, excepting Saturdays, when it will be rung at two o'clock, after which no workman will be allowed to remain in the works unless by special instructions.

5. The working hours shall be from six o'clock morning to six o'clock evening, and on Saturdays from six o'clock in the morning till two o'clock afternoon—in all, sixty hours per week—overtime being allowed at the rate of time and quarter for all time over sixty hours per week.

6. Each workman will be furnished with a time-board, having his number attached, which he will be required to receive from the gate-keeper on his passing into the works, and filling up the same with his time, and delivering such board into the box as he passes

out of the works. He will also be required to state on Wednesday evening his total time for the week.

7. Workmen shall receive their wages from the foremen of their respective departments upon each Saturday fortnight, being paid up to the preceding Wednesday, three days' pay being retained as security.

8. Any workman absenting himself from his work without the special permission of his foreman (unless in cases of sickness, in which case word must be sent) will be fined one shilling.

9. Any workman being found in any part of the works during working hours where his business does not require him shall be fined one shilling.

10. Any workman leaving or entering the works otherwise than through the gates of the works shall be fined two shillings and sixpence for the first offence, and shall be dismissed on the second offence.

11. Any workman found smoking in the works during working hours shall be fined five shillings for the first offence, and shall be dismissed on the second offence.

12. Any workman fighting, or otherwise creating a disturbance in the works, shall be instantly dismissed.

13. Any workman bringing intoxicating liquors into the works without special permission, or entering the

works in a state of intoxication, shall be instantly dismissed.

14. Any workman making preparation to leave the works before the bell rings shall be fined one shilling.

15. Any workman leaving his candle or gas burning when not at his bench or post, or when leaving, also leaving his machine running in gear, shall be fined one shilling.

16. *Any workman using oil* to clean his hands shall be fined one shilling.

17. Any workman wilfully or negligently damaging machine tools or work shall be fined two shillings and sixpence, besides the cost of making good such damage.

These, then, are a few of the generality of regulations laid down in a well-regulated shop; of course they differ according to local arrangements and customs of men. Returning, now, to the case of the premium-apprentice. We have already said that, owing to his having paid for his admission, the foremen and others above him have difficulty in making him observe and obey such rules and regulations. We have seen that there are only two punishments implied in such rules and regulations—namely, fines and dismissal. Now, under the general system of premium-apprentices, these cannot be enforced. The former they will not pay. It cannot be stopped from their wages—for they seldom receive any; and, failing this, they cannot be dismissed. What, then, is to be done? We would suggest that a sensible young man, in earnest about learning his business, would pay attention to such rules. This, however, is seldom if ever the case; and we might as well expect a child to learn without the fear of, if not the application of, the cane. But many will say that there is no comparison between such cases; for the young man on entering the shop is educated, and supposed to value the opportunities of knowledge and instruction, besides having, it may be, a taste or love for such a profession. This may be all true; but it may not be borne in mind that the education which the workshop teaches is, in every sense of the word, a hard and laborious one—taxing not so much the mental faculties as the physical energies of the student. Take, for instance, the very first rule of the shop, which requires the apprentice to be at his work by six o'clock. Here, then, is a hardship to be borne. It is necessary that he must be out of bed by five o'clock in the morning, if he has any distance to go to his work. Now, we do not believe there is one in a hundred young men who, after having been accustomed to rising at probably eight o'clock throughout their school-days, who will rise, and continue to do so, summer and winter, at five o'clock, or even half-past five, unless they are compelled to do so. To say nothing of the value of acquiring such a habit, such a course of training inures the young man to hardship, and drives out any of that effeminacy which is too often found in those "fine gentlemen" who are nursed in every delicacy. Let the reader picture to himself the case of a young man who has two or three miles to travel over the side of a bleak mountain on his road to his work, and on one of the coldest and blackest mornings in winter: he starts at five o'clock, having his day's supply of food under his arm; and with his lamp in his hand he ploughs his way through four or five feet of snow, which had fallen during the night; and, after having got a certain way, his foot slips, and he is immersed in snow, which at the same time extinguishes his lamp; he, however, pursues his way in the dark, and, after a good deal of difficulty and labour, arrives at the works just in time to see its doors closed; he is, therefore, excluded until three hours have elapsed, after which he is admitted, half frozen, to go through his day's work. Now, such a case as this seems a very hard one; but we know those who have done all this without thinking much of it, and who, in after life, have had every reason to be thankful for such excellent training when young. They, however, attribute such feats, not to the determination of their own will, but to the fact of their being compelled to be at their post under pain of the disgrace of suspension from work, and perhaps, finally, dismissal. Rule No. 2, in virtue of which the apprentice is required to take his breakfast in half an hour, may be looked upon by the young man who has been accustomed to have plenty of time to take his meals as another hardship; but this also must be submitted to, and he will acquire a habit of frugality—in some cases cooking his own meals, and learning to be independent of those minor details of comfort. Besides being subject to the foregoing rules, workmen are expected to do what work is given them by their foreman or superior, and they are compelled to stick at such work until it is finished. Now, this understood rule is one frequently broken through by premium-apprentices. Most young men, previous to a proper training, are greatly attracted by novelty, and if such is not checked by proper training, they become unsettled, flighty, and wanting in that steady application so necessary to the success of any pursuit. We have known several premium-apprentices of this class who, on any piece of work which seemed to them to be novel or new presenting itself, they seized upon it, commencing to work with great energy, but in a short time, after what may be called the uninteresting or laborious part came, it was then abandoned for some workmen to complete, who are supposed to be able to do anything in that way. Such is the idea of many young premium-apprentices, who think that after they have seen how a piece of work is done, that they, whose time in the shop is comparatively short, should make the most of it by doing a little at every kind of work, forgetting all the while that this doing a little at everything is equivalent to doing nothing properly at anything. There is nothing more dangerous to a young engineer's future success than by such means imperceptibly forming a habit of unsteadiness and inconstancy. We know of a case which came under our own eye where a young premium-apprentice pursued his education in this way in the workshop, doing a little of this and that throughout his three years' apprenticeship. We do not remember of his ever properly completing one piece of work he took on hand; and, so far did such a habit grow upon him, that he found it a matter of the greatest hardship to be urged to draw in the spokes in a wheel of an engine he had just designed, as also such details as the bolts and nuts on the different parts. Now, we firmly believe had this apprentice been compelled to finish his work, and do it well, he would have been prevented forming such a pernicious habit, and have formed the invaluable one of steadiness and accuracy in his work.

Another very great grievance and hardship with the apprentice is the long hours he is engaged at his laborious work. Any work which is continuous, and of long duration, is hard work; indeed, it is hard work to be compelled to do nothing for a lengthened time, much more so than it is hard work to be compelled, it may be, to handle the hammer or file for ten hours per day. Yet such is the lot of him who aspires to become proficient in mechanical engineering; and, however great an enthusiast he may be, with all his love for his profession, he will find the time occasionally hang heavily on his hands, and think that he can surely never be learning anything by such monotonous work which he may have done so often before. Being compelled, however, to do such work, habits of industry and perseverance are promoted and confirmed—to possess which some men would give fortunes. But while impressing upon the mind of the apprentice the absolute necessity that exists for the exercise of a patient industry, that no discouragement or failure to succeed at the first attempt to do important work can daunt, we would at the same time point out to him that all this will be, to a large extent, useless and unavailing, should he disregard *system* and *order* in the arranging and doing of his work. "A place for everything, and everything in its place;" and "Do one thing at a time only, if you wish to do much, and do it well," are homely enough sayings, but which convey a vast amount of useful truth—truth which no one, indeed, gainsays—but which, nevertheless, is too frequently overlooked or ignored; and yet, without *system*, we venture to say that no work will be properly performed; that is, if by the term "properly" all is meant which, by the term, we conceive is in reality meant, the doing of it in the best and most economical manner—economical of time, as well as of material. The habit of carrying out a system and an order in work is of immense service to the apprentice as an individual, enabling him to economise his time (and time is money), and giving him, moreover, that steadiness of mind, so to speak, which enables him to have his wits about him on all, even the most sudden of emergencies; and not only so, but it will be found of essential service when the apprentice is merged in the master; and, in place of obeying the orders and doing the work of others, he is transferred to that position—to which we suppose all our readers look forward—when he is to be engaged in giving orders to others, and to see the work done in which he himself is directly interested; for it may be taken as an axiom in what may be called the "commercial economics" of engineering, that no establishment will pay where system in everything is not the rule. We have at present in our recollection an establishment, of which the master was an eminently able and practical engineer, one who himself had been brought up in an establishment in which system was pre-eminently observed, and yet the lessons of which had had so little practical effect upon him, that his own was possibly as ill-managed as it could be. No system was observed in any of its departments—everything was done at hap-hazard. The supply of working "plant and material" was neglected so frequently, that we have known work-men to wait for both till they were supplied and sent for. Delays not only occurred in the execution of the work, which, in many instances, took off all margin of profit in doing it, and made what ought to have been a gain a positive loss; but as bad a feature, if not the worst, was, that the workmen themselves and the apprentices were all influenced by the want of system and routine, and habits of carelessness and gross wastefulness were, in many cases, created or confirmed. Workmen were kept in bad order, valuable tools were thrown carelessly aside when done with, and often thus lost, so that when again required new ones had to be made. The result of all this was that, notwithstanding the exercise of the greatest industry and skill on the part of the master, nothing but loss ensued. He finished his career at last by knowing that he had worked hard all his life, and for little or no practical result. And yet we venture to say that this lamentable result arose mainly, if not altogether, from the lack of system and proper routine of workshop-labour which prevailed in the establishment; for where there is lack of order in the arranging of work, there will be lack of economy of time and of punctuality in its execution; and it may be taken as true, that where this is the case money will not be made out of it. System in everything, in the minutest as well as the most extensively organised department, is absolutely essential; and the reader will, in after life, have to thank us if what we have here said will induce him to think carefully over its importance, and to carry it out in his practice. To the attainment of which practical end we would further strongly advise the apprentice not to confine his system to the duties of his apprenticeship, but to carry it out at home in everything he does. Let him acquire the habit of arranging his books, his drawings, his notes, his instruments, and *keeping them arranged* in one uniform system; so that he will lose no time in looking for anything, or for any piece of information he requires, but be able to place his hand upon anything he wishes, whether it be a drawing, an instrument, a book, a "note," or a sketch which he is desirous to consult. This habit, exercised in attention to the little things of his ordinary life, will be carried out in the great things; for no man who is systematic and orderly in little matters will fail to be so in great ones. But we would go further, and say, that to a well-ordered mind nothing is "little." It is to the man of system that the importance of little things is alone made known;—grains of sand make the shore—drops, the ocean which rolls its waves over it—they are always present to his mind; and he knows, and, knowing, carefully practises the truth, that if he is *careless* of little he never will be *careful* of great things. It is exceedingly dangerous for a youth to have a contempt for the little things of daily life. A vast deal of truth is conveyed in the homely proverb,—"For want of a nail the shoe was lost, for want of a shoe the horse was lost, for want of a horse the rider was lost." How many are ruined in life in all their attempts to make progress in it through forgetfulness of the close connection that exists between the "nail" and the "rider!"

When the conduct of an engineering establishment is confided to him, the reader will be able at once to appreciate the full value of a steadily acquired, long persisted in, habit of system. He will then at once see the close connection that appears between the systematic doing of work, and the profits arising out of it,—the dependence of such profits upon what many are disposed to call, and call foolishly, the veriest trifles. Everything in the works should be carried out in regular routine; all the work done should be carried progressively forward, from one stage to another—no going back, to and fro, here and there. We have known of work so carelessly systematised, that the mere loss of time involved in taking it to one department, and bringing it back to another, has resulted in adding a large percentage to its cost; and, of course,—what, by the way, is however often lost sight of,—a large deduction from the profit; all of which might have been avoided, had a regular sequence of arrangements been adopted. The reader may set it down as true that, when he visits any engineering establishment, and sees machines dirty and ill-kept,—tools, as files, etc., lying carelessly huddled up in window-sill corners, or lying under foot on the floor,—that the establishment is not a paying one, and is one which he should avoid having anything to do with, if he wishes to learn what is worth learning;—of which, by the way, let parents and guardians be also advised, who may be looking out for a "shop" for the youths under their charge. We may be considered to have said too much upon this point of "system;" but it is impossible to say too much upon it, or to impress it too deeply on the mind of the apprentice desirous to become a successful engineer; indeed, so much value do we set upon it, that if we were asked, what is the first essential to success? we would answer, "system;" and the second? "system;" what the third? "system;" for without it, we will venture to say, all the industry, all the talent and skill, will be of no avail in the daily practice of engineering, if pecuniary as well as professional success is thought of. Having cultivated the habit of system in arranging work to be done, the engineering tyro should next cultivate *the attainment* *of manual dexterity and carefulness in the execution of work.* Under this head it may be at the outset remarked, that apprentices, especially as premium-apprentices, are too apt to run away with the notion that if they know, or think they know, how a thing should be done, they need not much trouble themselves as to the doing of it. But they forget,—or if they are ignorant of the fact, it is our duty here forcibly to remind them of it,—that it is not possible for them to know how work should be done unless they know how to do it themselves. It may appear to be all that is necessary that they should know the general sequence of operations in the doing of the work; but by no other means can they be well acquainted with the fact that the work is being, or has been, done in the most economical manner, and this can only be ascertained by those who know all the intricacies and the necessities of the manual operation. Take, for instance, the operation of "chipping" and "filing:" they may appear very easy and simple, and their application to the preparation of certain parts of mechanism may be considered equally so; but let any one try either of these operations, who has not been previously accustomed to it, and he will rapidly discover that there are two ways of performing it—one good and one bad, or the economical and the wasteful modes. Manual dexterity, allied to intelligence—the mind regulating the hand, and the hand readily (may we say instinctively?) obeying the mind,—this is what makes a first-class workman. That experience which is alone worth in the practice of engineering, can only be obtained by learning to do the work oneself. Knowing its various requirements, how to begin and how to finish them in that regular sequence which is alone productive of good and becomes good workmanship, let it be the earnest desire of the apprentice to *excel in his work*, that he may give his master the very best of which he is capable. It may appear to some a small thing whether good workmanship is given, but upon this depends its working value.

Let the apprentice, then, whatever be the brightness of his prospects, work as hard, and be as careful to know thoroughly all the minutiæ of his work, as if he had no other prospect before him than to work for his daily bread. The more thorough a workman he makes himself to be, the more successful will he be as a master; and the more conscientiously and honestly he does his work as a workman, and fulfils his obligations as such to his master, the more fully will he be entitled to expect his workmen to be honest towards himself, when the time comes that he changes his position from a servant to that of a master.

Let this be thoroughly impressed upon the mind of the apprentice, that the real object of his being such is to learn the business as thoroughly as he possibly can. To which end he must grudge no labour; must not look upon the discipline of the works as painful to bear; nor the patient exercise of skill and intelligence as drudgery. Let him honestly determine to do his best, and there will be no fear of him; nor will he be worse, but much the better, if he cultivate a pride in his profession, making it his endeavour to have the reputation of trying to the utmost to give the very best he is capable of, to whatever he is engaged upon, no matter how trivial that may be—if indeed anything can be trivial which forms part of a system of order or discipline.

Supposing, then, that the apprentice is most earnest in his endeavour to get as much benefit as possible out of his daily work at the bench, or fitting-up shop, we would next advise him to fill up every spare hour *in the practice of drawing, in taking sketches of work done, or machines and tools which he comes across, in the taking out of quantities, and in making calculations* *concerning the various details* of work. This practice is of essential importance to the apprentice who aspires to, or has the hope or prospect of having the conduct of works of his own. It is unnecessary here to dwell upon the importance of a thorough knowledge of mechanical drawing and projection; without it no man engaged in practical construction need hope to excel in his calling, and to pass from the position of a mere handler of the hammer, the chisel, the saw, or the trowel, to that of a master and a director of workmen. But possessed of a thorough knowledge of its details, while at the same time fully capable to perform all the duties of a maker, or a carrier out of the designs of others,—adding to this knowledge the habits of sobriety, prudence, and perseverance, without which all talent is given in vain,—the apprentice or the journeyman may fully anticipate the time when he will rise to the dignity of a designer of work for others. It is indeed worthy of special notice how great a power a knowledge of industrial drawing gives to the constructive artificer—be he an engineer, an architect, builder, or machinist. By its aid he can place upon paper the result of the most patient investigation, or the happiest and the almost intuitive invention, connected with the construction of machines or buildings;

and so place them that those on whom he depends for the practical realisation of his projects are able at once to read, so to speak, all the intricate lines of his drawings, which to the uninitiated appear but a combination utterly unintelligible and worthless. As it has been finely said that the sculptor can trace in his mind's eye, within the block of shapeless marble round which he walks, the beautiful image which is to please the eye and refine the taste of after beholders; so may it be said of the mechanical designer, that he sees on the surface of the flat paper before him the elaborate machine or the complex structure in all its details, as clearly as they will be presented to the spectator when elaborated and completed. From what has been said, then, the importance of a thorough knowledge of industrial drawing to him who aspires to excel in his calling will be obvious enough. Drawing may be defined to be the art of presenting on flat surfaces the appearance of various forms and objects, by means of a combination of lines, straight and curved. The painter or artist can present on his canvas the appearances of various objects; but they are not strictly correct; hence differences arise in the delineation of the same object by different artists, inasmuch as the eye and the hand being alone trusted to, the indications of the former may not be correctly taken up, or if correctly taken up, the manipulation or work of the hand may be faulty. There is thus very frequently a discrepancy met with between the readiness of the eye to estimate distances and appreciate forms, and the dexterity of the hand to embody these on the canvas or paper. But however finely adjusted in any artist may be the powers of the eye and the ability of the hand, there is nevertheless, in even his most accurate work, an inherent fault, which ever operates to prevent it being practically available to the workman who may be desirous to construct a form of which the artist gives him a sketch. And this difficulty arises from the fact, that no true data for dimensions are or can be obtained from an eye-and-hand sketch. *Dimension,* then, being an essential element to be known in a machine which is to work, or a structure which is to be finally put together, it must be obtained from a drawing which, while it possesses precision of parts, has, at the same time, accuracy of form. These attributes are only obtainable in what are called mechanical drawings. Mechanical drawing is strictly a conventional mode of delineating objects necessary for the purposes of the workshop. It does not aim at giving, nor is it meant to give, like free-hand drawing, the apparent forms of objects, or rather a combination of lines which will give what may be called an apparent form. The combinations of lines used in mechanical drawing are, on the contrary, traced in a mode of representation by which dimensions of the various parts, and their relation to one another, can be rigidly ascertained and measured, and which mode is very puzzling to one uninitiated in the art. What are its peculiarities, and how they are applicable in practice, we hope to be able clearly to show. There are two distinct branches of mechanical drawing, the first being that which concerns itself with the delineation of objects having *two dimensions only*, namely, length and breadth, and may be designated the "drawing of superficies." The aid of geometry is essential in this department. The second class concerns itself with the delineation of objects having *three dimensions*—length, breadth, and thickness—and may be designated the "drawing of solids," or "projection," as it is sometimes generally termed.

It is not necessary to take up space, nor to exhaust the patience of the reader, by illustrating and describing in detail the various *instruments* required by the mechanical draughtsman. Sufficient for our purpose will it be to name them here only. The practical inspection of the instruments themselves for a few minutes will do more to make the tyro acquainted with the construction and mode of using them than pages of printed description. We give here, then, a list of those required for what may be called the everyday work of the draughtsman. (1.) Compasses for measuring long distances. These should be provided with a shifting leg, for the adaptation of a pencil and pen leg, with which to describe large circles in pencil or ink. (2.) Spring-compasses of a less size than No. 1, but with no shifting leg. The leg, however, as indicated by the name, is to be provided with a hair-spring, regulated by a screw, by which minute adjustments of distances may be easily made. (3.) Spring-dividers, which may be defined as very small compasses, the distance between the legs or points of which is regulated by a screw. (4.) Bow-pencil compasses; small compasses, in one leg of which a pencil can be placed. When one leg is provided with a drawing-pen, the instrument is called a (5) Bow-pen. Nos. 4 and 5 can be had either with or without springs. It will be advisable for the draughtsman to have both kinds, so that for the drawing in of small circles, these requiring very minute adjustments, the spring-bows may be used. These, as well as the compasses No. 2, should be provided with needle-points, the length of which can be adjusted by screws. (6.) Drawing-pens. These should be had in at least two degrees of fineness; one adapted to draw very fine lines, the other broad or thick lines. (7.) Drawing-board and square. A complete set of drawing instruments comprises more than we have here named; but these will be sufficient for a considerably wide range of practice in the early career of the young engineer. It does not form part of the plan of this work to go into the art or practice of mechanical drawing; it will, however, serve a useful purpose if we glance briefly at the modes in operation in an engineering establishment for the preparation of the drawings required in practice. Mechanical drawing may be divided into two classes—first, "scale or complete," and second, "working or detail" drawings. Drawings of the first class, as their name indicates, are delineations of machines or of structures, as a steam-engine or a bridge, with all the parts completed, the scale to which these are drawn being of necessity small. These scale or complete drawings are for reference in the drawing-office, and are designed to show the relative position of the various parts, their sizes, etc., etc. In order to do this properly, several views of the machine or structure are required to be given;

for where complication of parts to a greater or less extent exists, as it is sure to exist in any machine, one view of one side will not show the parts of another. Hence, as stated above, different views of the same machine are required to show the various parts. These are technically known as "plan," "section," "side elevation," and "back" do., etc.; and to these is sometimes added a perspective view of the whole. In making general or scale drawings, it is usual to prepare the different views consecutively; but where the machine or structure is at all complicated, we would strongly advise the young engineer to get into the habit of carrying on the drawing of the various views at the same time, doing first a little at one view, and then a little at another, till all are finished. If the machine is large, and the scale adopted such as to make a comparatively large drawing, these various views may be required to be on different drawing-boards; in other cases the different views may be all on one board. This plan, which we strongly recommend, of drawing various views at the same time, is likely to save the perpetration of those mistakes which are very apt to arise from the plan of doing one view at a time only, and when finished all the views will be found to be in keeping with one another. The number of separate drawings required will depend upon the nature of the machine. If this be very complicated, it will be advisable to draw at the same time a number of sections and plans, etc., in order that the designer may be able to arrange all the parts in proper relation to one another, so that every facility may be given to the actual erection of the machine, and its repair, when this is essential. When all this care, so essential as we deem it, is not taken, the designer will often be chagrined to find that in erecting the machine one part does not properly fit into another, or that one part prevents another being inserted, or worse still, the integrity of the whole design spoiled,—errors which could have been avoided in designing, on the plan we have indicated and recommended. The number of views which will be required will obviously depend upon the complicated nature of the machine; but the engineer, in determining this point, should never lose sight of the fact, that it is in every sense a more economical plan to prepare a number of drawings, than, by sparing them, to bring about the chance of error in construction. The cost of a drawing bears no proportion to that of rectifying errors in the construction of a machine. Moreover, the drawings are to be as guides to the workman, who is not generally very accomplished in what is technically called the "reading" of a drawing—that is, understanding readily the relation of its different parts; hence the importance of enabling him to readily comprehend all that is necessary to be known; and this is easiest accomplished by having a number of drawings. This brings us to the preparation of "working," "workshop," or "*detail drawings*." These are drawn to a much larger scale than the complete drawings we have been considering, and are, as their name indicates, drawings of the various parts of the machine. The scale adopted varies according to circumstances, but descends from "full size" down to a "quarter" or an "eighth" part of an inch to the foot. A usual scale is "one-fourth full size," or "three inches to the foot," or "one-eighth full size," or "one-and-a-half inches to the foot." In detail drawings all the lines should be drawn in boldly and solid. Detail drawings are often required to be shown in different views, according to the complication of parts, as in plan, section, and various elevations. It is a general practice to figure the dimensions on the drawings of details. It is doubtful, however, whether this practice has not more disadvantages than advantages, as it is apt to cause carelessness on the part of the workman, who may not use his "foot-rule" as frequently as he ought to do. Indeed, it is a good rule to make the workman trust to his own measurements, as taken from the drawing, holding him responsible for the accuracy of these measurements; the draughtsman, on the other hand, responsible for the accuracy of the drawings. When the detail drawings are finished, they are tacked down to a board, or placed in a frame, and provided with a proper number, which is used for reference. It is scarcely necessary to say that to each drawing the scale must be attached.

It will be observed, as has indeed already been stated, that we do not here give directions as to how mechanical drawings are to be executed. This must be learned in the usual way; we simply point out to the tyro certain things which it will be for his advantage to know and practise. Before concluding the subject of drawing, we would again impress upon the engineering pupil the importance, the essential importance, of becoming a first-rate draughtsman. This he can only attain by continual persevering practice. In addition to the practice in the drawing-office of the establishment, in which we here suppose he has made arrangements to be for a certain portion of his time engaged, he should devote a certain portion of his spare time to its careful exercise. It will be good practice for him to scheme out some machine, and make a complete set of scale and working drawings for it. And in his own private practice let him study to be as careful in the execution of his work as if he was doing it under the eye and for the approval of his master. Let him, in fact, study to be conscientious in all things, in his private studies as in his public labours. In addition to the practising of drawings carefully executed by the aid of the instruments, the young engineer should take every available opportunity of filling his "notebook" with sketches of machines and of details. We do not here lose sight of the fact, that in the majority of well-regulated establishments those employed therein are not allowed to take sketches directly in the works. There are obvious enough reasons for this. But the young engineer should endeavour to have every piece of work on which he is engaged so stamped as it were in his mind, that on reaching home he should be able to put down all its peculiarities, and even to remember its dimensions, which he should mark on the drawing. This practice will be of immense value to him, as it will enable him to carry in his mind many a good hint until he is able to put it down on paper. From what we have now said, it will, therefore, be quite unnecessary to dilate upon the importance to the young engineer of availing himself of every opportunity which may present itself, when knocking about from place to place, of taking sketches of everything likely to be useful in his after practice. Hence, also, the benefit of spending his holidays in districts new to him, where he is likely to meet with new methods of working, etc., etc. Hence, also, the advantage of keeping himself current with the engineering literature of the day, and culling from it details which will enrich his note-book.

In addition to the pursuit of all those objects which we have so far detailed, the young engineer should study hard at mathematics, and accustom himself to the "taking out of quantities," that is, to estimate by calculation the weight of various parts of machines, etc., etc., in various materials; and, further, the calculations necessary to enable him to decide upon the strength of various parts of the machine or structure he is constructing or erecting.

Our "hints"—for, within the compass of a work like the present, hints only can they be—must now under the present chapter be brought to a conclusion. From what we have said, the reader will see that, to become a successful engineer, no small amount of hard physical labour, no less than of severe mental and moral discipline, is required. But if the claims of these are honestly attended to, the result will be in every way satisfactory. Certainly the result is worth striving after, in view of the prizes which the exigencies of the time present to the notice of the successful engineer.

APPENDIX.

THE EDUCATION OF THE CIVIL ENGINEER.

WE stated in our Introduction that our remarks would be confined principally to the education of the mechanical engineer, but that much of what was given would be applicable to the civil engineer; and this holding more especially true of the preliminary education, and the mental and moral discipline of the pupil. What is necessary to be given, in order to complete, as far as our pages will allow, the subject of the education—technical as well as preliminary—of the civil engineer, will be found in the following extracts. These we give as embodying the opinion of highest authority on the subject—namely, the President (John Fowler, Esq.) of the Institution of Civil Engineers, as given in his recent opening address of the present session. After giving some introductory remarks, Mr Fowler proceeds to the main purpose of his address—namely, the description of the nature of the functions of the modern civil engineer:—

"Many attempts have been made to define and describe a civil engineer in a few general words, but all such attempts have been more or less unsatisfactory. Still, though it is difficult, if not impossible, to describe an engineer by a short definition, it is not so difficult to enumerate and describe the nature of the works he is required to design and execute, and the professional duties he is called upon to perform.

"He has to design and prepare drawings, specifications, and estimates, and to superintend the carrying out of works which may be thus enumerated:—

"1. Railways, roads, canals, rivers, and all modes of inland communication.

"2. Water supply, gas-works, sewerage, and all other works relating to the health and convenience of towns and cities.

"3. The reclamation, drainage, and irrigation of large tracts of country.

"4. Harbours of refuge and of commerce, docks, piers, and other branches of hydraulic engineering.

"5. Works connected with large mines, quarries, ironworks, and other branches of mineral engineering.

"6. Works on a large scale connected with steam-engines, with machinery, shipbuilding, and mechanical engineering.

"This list, which might be almost indefinitely extended, involves a vast variety of work, and must appear almost appalling to a young engineer; and yet it greatly concerns his future that he should, as far as possible, be prepared to undertake any or all of the works embraced in the list."

This list is much more comprehensive than is usually understood, comprising as it does the duties of the civil engineer; for it includes mechanical engineering, usually taken to be a distinct branch of engineering. Be this as it may, Mr Fowler, after pointing out that it is one of the duties of the civil engineer to inform his employers whether the work upon which he is consulted is, or is not, likely to be commercially successful—a point too often lost sight of—proceeds to show how essential it is to the civil engineer to have a most intimate acquaintance with all the materials used in construction,—their constituents, value, and the most satisfactory and economical modes of using them. A brief but a very valuable *résumé* of all the points in connection with materials is then entered upon; after the discussion of which Mr Fowler proceeds to say that he has selected "these examples for the purpose of illustrating this important fact, that before an engineer can even commence the designs of his works, he must have previously obtained a large amount of preliminary information regarding the nature of all the materials employed upon engineering works, so as to enable him to select for his intended structures those materials which will be on the whole the most suitable, having reference to efficiency, durability, and economy.

"I will now proceed to the question of the kind and degree of knowledge which is required to enable a young engineer to proceed to the actual design of a public work of importance, such as a railway with its stone, brick, and iron structures, its earthworks, and its all-important permanent way, a railway station, a station-roof, docks and their appliances, waterworks, breakwaters, or a Great Eastern steamship.

"Although it has become the practice in modern times for many civil engineers to be employed chiefly, or almost entirely, in some one branch of the profession, I desire to repeat my conviction that it is most important that the early preparation and subsequent study should be as extensive as possible, and should embrace every branch of professional practice, not only for the purpose of securing to a young engineer more numerous opportunities for his advancement, but also because sound engineering knowledge and experience in all branches will greatly add to his efficiency and value in any special branch, in the same manner that a medical man will be more reliable in his practice on the eye and the ear if he possesses a sound practical and theoretical knowledge of every part of the human frame.

"All classes of the profession, but especially the railway, the dock and harbour, and the waterworks engineer, must possess a knowledge of the parliamentary proceedings, so as to be able to avoid all non-compliances with the standing orders of Parliament. This, it is true, is no easy matter, as the clauses are often drawn up with so little care and practical knowledge, that neither engineers nor solicitors, nor the most experienced parliamentary agents, can understand what is intended.

"On the subject of parliamentary proceeding generally, it may be taken for granted that all committees desire to do justice to the cases which are brought before them; and that if they sometimes fail in their decisions, either as regards the interest of the public, or in arranging a fair settlement between antagonistic interests, it is not unfrequently due to the imperfect and crude manner in which cases are presented to them; and I would impress on all young engineers the importance, both to themselves and to their clients, of laying their cases before committees in the most perfect manner possible, by full and correct information, carefully prepared and clearly worked out."

Mr Fowler next proceeds to describe the nature of the knowledge required by the railway engineer, the harbour and dock engineer, the waterworks engineer, and the mining engineer; after which he takes up the consideration of the kind of preparation required to enable all these classes of engineers to perform their duties in a proper manner. These he describes shortly as follows:—

"1. General instruction, or a liberal education.

"2. Special education as a preparation for technical knowledge.

"3. Technical knowledge.

"4. Preparation for conducting practical works.

"All this preparation and training will have to be acquired at some time or other, and in some order or other, and it is known that in the cases of some successful persons of great perseverance, they have been acquired in a very remarkable order; but at the present time, and with all our modern opportunities, there is no reason why they should not be learned in the *most convenient* and methodical manner."

The first two of these heads have been pretty well discussed in the text of this present volume; we have therefore only to add here what Mr Fowler says in connection with the last two, premising that a short course of from one to two years in "manufacturing works," and in some cases a course at one of the Universities, as preliminary to the time to be spent in the civil engineer's office, is recommended by Mr Fowler.

"We will now suppose that the general education and the special instructions have been completed, the short probationary pupilage in workshops has been gone through, languages and mathematics kept up and improved, the University course in certain cases completed, and the period to have arrived for entering a civil engineer's office.

"In selecting such office for a pupil, it is important that it should be well organised, and not be too large; that the engineer should be a comparatively young and rising man, and be accustomed to take pupils; but these should be few in number, and bear some proportion to the number and extent of the works in usual course of construction under the engineer's direction.

"It is not necessary to follow the pupil, when once the engineer's office is entered, with any detailed advice, because he is no longer a boy, unable to appreciate his position and duty; we assume that he has been highly educated and carefully trained, well knowing that his future success or failure will depend on the degree of diligence in availing himself of the opportunities of acquiring knowledge during his pupilage.

"The work in the office and in the field should be done to the best of his ability; and after the pupil has become a skilful draughtsman, and is capable of taking out quantities of engineering works, and preparing detailed estimates methodically arranged, he will then probably proceed to work out details of designs, and make calculations of strengths and strains, and thus become of real value in the office, at the same time making real progress and rapid improvement for himself.

"He should avail himself of every opportunity of mastering the purpose and the principles of construction of the work brought to his notice, both in the office and in execution; and he should ascertain the cost price of all the materials and workmanship employed, separating the items into every minute detail; and he should continue this practice systematically with all works on which he is engaged.

"The information which, amongst much beside, should be obtained during pupilage, and which is necessary to constitute a sound engineer, is—

"1st. A fair knowledge of the most fitting material for any given work, under any given circumstances.

"2d. The power of designing any ordinary work with a maximum of strength and a minimum of material and labour.

"3d. A knowledge of the means of ascertaining the cost price of any ordinary engineering work.

"The information or knowledge included in this brief enumeration may be called practical knowledge, and it cannot be too often urged upon young engineers that theory and practice must always go together hand in hand, and that they are not only not inconsistent nor conflicting, but that they are necessarily united, and must both be fully developed in the same person before he can become a properly qualified 'civil engineer.'

"The period of pupilage should be from three to five years, depending on the circumstances which have been previously indicated; and, in addition to his attention to the office and outdoor works, it will be well, while keeping up his preparatory studies, especially mathematics, that he should improve his acquaintance with the French and German languages, and keep up his knowledge of their engineering literature, and also avail himself professionally and personally of the advantages offered by this institution."

The following, from Mr Conybeare's paper on the Principles and Practice of Civil Engineering, detailing the routine of office and outdoor work of the young civil engineer, will be a useful conclusion to this Appendix :—

"At first he is employed in tracing or copying the duplicates, required for various purposes, of the drawings and specifications of works in course of execution, from such engineer's designs. Such practice is extremely serviceable to himself, as nothing fixes the necessary details of such matters so firmly in the memory as the copying out of good precedents. He is, at the same time, constantly exercised by assisting in the preparation of estimates from working-drawings, by taking out the quantities of each description of work incidental to any proposed structure, and applying the appropriate rates. Such practice familiarises him with the cost of work—a most important point—and enables him hereafter to predicate with considerable accuracy what amount of labour and material will be required to carry any given design into execution.

"He is also employed in copying the sections of any proposed railways that may be in the office, and calculating, by tables based on the prismoidal formulæ, the amount of earthwork that may be involved in their execution. By this he learns the necessity of balancing the cuttings and embankments, and the most economical mode of fitting the gradients of the permanent way to the natural surface of the country, and becomes familiar with what is required for compliance with the standing orders of Parliament in all that relates to the deposit of engineering plans and sections. He also has opportunities for observing and calculating the effect of the petty emendations of the original section (effected after the deposit of the parliamentary plans, but prior to the ultimate staking out of the line)—emendations effected by taking the line into higher or lower ground, to the right or left, to save work in bridge-crossings or their approaches; or by readjusting the gradients, with the object of diminishing the amount of earthwork. He thus becomes familiar with all the considerations that bear on such emendations; and this will greatly assist him, in his subsequent field practice, in determining the best allocation for a line of trial sections, and so initiate him in that most important engineering mystery, the faculty of 'laying out' a line so as to get the straightest and most level course possible at a minimum of expense.

"Having become familiarised with the details of bridges by tracing working-drawings, he is entrusted with the preparation of the drawings themselves from the dimensioned sketches of the engineer, or with inking in and completing the drawings pencilled in from such sketches by the assistant or senior pupil at the head of the drawing-office; and is also practised in the application of formulæ to the construction of bridges, in masonry, brickwork, timber, and cast or wrought iron.

"He is now competent to be of use in the field, and can be employed in staking out the centre line and side widths, and in ranging the curves of railways about to be commenced; in setting out the lines and levels for the foundations of the various bridges and other mechanical structures; in fact, in transferring the ground-plans of earthwork and structures of masonry from the drawings to the ground; also in taking borings at intervals along the centre line of the various cuttings or tunnels, to ascertain the nature of the material to be excavated; as also the nature of the foundation required for bridges, by taking borings and driving trial-piles.

"He will then be employed in taking levels—in running trial sections along a course selected by his *chief as that* apparently best adapted to the requirements of the case for 'laying out' any proposed line of railway. While so employed, he will gain an insight into the principles of laying out a line, and enjoy opportunities for acquiring what is of such immense importance to both civil and military engineers—a rapid and accurate *coup d'œil* for country, that is, the faculty of pointing out mentally a tolerably correct map of a tract of country from a collation of the views obtained from two or three points, or even from a single view from any commanding point; of judging of height and inclination, as well as of limits; what would be the best line for trial sections of a line of road or railway between any two points, which should unite, in the highest degree possible, the three conditions of directness, easy gradients, and inconsiderable alteration of the natural surface. This faculty of 'laying out a line' is of incalculable benefit to the engineer and his employers; in fact, the time and money expended in the thorough elaboration of the laying out of a line always yields a manifold return in the increased economy and perfection of the work.

"The pupil is now fit to be employed as 'assistant engineer,' in superintending the execution of a section of railway, or of any other engineering work. In this capacity it is his duty to see that the works are executed in the best manner, of the best materials, to the proper lines and levels, and in exact accordance to the contract drawings and specifications; to measure the work done by the contractor once a month, ascertaining its amount, and reporting the same to his chief. While so engaged, he enjoys frequent opportunities of acquiring a more or less particular acquaintance with the minor details of work, and stores his mind and his note-book with much practical information that he will reap the benefit of in his future practice. During the remainder of his pupilage, and probably for some years afterwards, the young civil engineer will continue to be employed, either in office or field work, as an 'assistant engineer.'

"If an engineering work is of very considerable extent, or is only one out of many works entrusted to the same engineer-in-chief, or is situated at a considerable distance from such engineer's head-quarters, he is obliged to appoint a resident engineering deputy, under the style of 'resident engineer,' to overlook the assistant engineers engaged on the various sections of the works. The 'resident engineer' is necessarily entrusted with more or less discretionary power, according to circumstances; and his functions consequently vary, from almost those of an engineer-in-chief (that is to say, the planning and designing of the work in all its details) to those of an 'assistant engineer,' who has merely to see that the conditions of the chief engineer's plans and specifications are strictly complied with by the contractor. It will thus be seen that a civil engineer, after completing his course of scientific training has usually at least ten or a dozen years of *actual* experience on works before he obtains any practice on his own account, or is entrusted with the responsibility and chief direction of any work of importance.

"But a thoroughly trained civil engineer's knowledge of practice (that is, of examples of the application of scientific principles and formulæ to all cases of civil engineering) is not confined to the comparatively limited series of works that have actually come under his own personal observation; for during his pupilage he is generally allowed access, under due restrictions, to the far more extended series of engineering cases presented by the records of the office in which he is placed, comprising the working drawings and specifications of all works executed by his chief during his extended professional career, including those which had been used for the construction of some hundreds of miles of actually executed railway. And he should extend this series of examples by the careful study of the literature of his profession, by analysing carefully, note-book in hand, all the published drawings and descriptions of approved examples of engineering that he can obtain access to, entering in his note-book, in each case, the more essential particulars of the example—such as its dimensions, material principle of construction; also whether the end in view, in each particular case, appeared to have been accomplished more or less economically and efficiently than in other cases, where, with a similar diagnosis, a different treatment had been adopted; noting, as far as possible, which were the particular points in each example most worthy imitation, and which, on the other hand, were better treated of in some other example. By this process he will bring himself to a nearer knowledge of the *one* best way of attaining the particular end in view; for in every possible problem in construction there must be some *one* specific way of solving it that is better than any other; and, by thus possessing himself of all that his predecessors had attained, he will *at least* get as near the best way as they did, if he cannot, on the stepping-stones of their experience, rise to higher things in his own practice.

"The practical study of the published accounts of engineering works should not be restricted to English examples; for there is much that is worthy imitation in the practice both of French and of American engineers. The former have always been superior to ourselves as theorists; and the extension of railways and other engineering works in France has of late years given them a more extended field for the application of science to actual practice, which their superior mathematical education has enabled them to turn to the best account. Their more recent works are consequently deserving of the closest study; and their published memoirs are generally models of methodic and scientific description.

"And American engineering is very highly suggestive. 'Necessity is the mother of invention;' and the peculiar circumstances of America *necessitated* the execution of ways of internal communication of immense length—the frequent bridging of mighty rivers, the formation of quays, jetties, and graving-docks for loading, unloading, and docking the largest vessels—in fact, of all the appliances that modern commerce requires, at a mere fraction of the cost which in Europe is considered indispensable for works intended to fulfil the same purposes, and which scarcely fulfil them any better."

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