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SUBJECT *Engineering, General*
TYPE OF WRITING *Explanation*

EFFICIENCY IN ENGINEERING OPERATIONS (OPTIMUM CONVERSION)

Unlike the scientist, the engineer is not free to select the problem which interests him; he must solve the problems as they arise, and his solutions must satisfy conflicting requirements. Efficiency costs money, safety adds complexity, performance increases weight. The engineering solution is the optimum solution, the most desirable end result taking into account many factors. It may be the cheapest for a given performance, the most reliable for a given weight, the simplest for a given safety, or the most efficient for a given cost. Engineering is optimizing.

To the engineer, efficiency means output divided by input. His job is to secure a maximum output for a given input or to secure a given output with a minimum input. The ratio may be expressed in terms of energy, materials, money, time, or men. Most commonly the denominator is money; in fact, most engineering problems are answered ultimately in dollars and cents. Efficient conversion is accomplished by using efficient methods, devices, and personnel organizations.

The emphasis on efficiency leads to the large, complex operations which are characteristic of engineering. The processing of the new antibiotics and vaccines in the test-tube stage belongs in the field of biochemistry, but when great quantities must be produced at low cost, it becomes an engineering problem. It is the desire for efficiency and economy that differentiates ceramic engineering from the work of the potter, textile engineering from weaving, and agricultural engineering from farming.

Since output equals input minus losses, the engineer must keep losses and waste to a minimum. One way is to develop uses for products which otherwise would be waste. The work of the chemical engineer in utilizing successively greater fractions of raw materials such as crude oil is well known. Losses due to friction occur in every machine and in every organization. Efficient functioning depends on good design, careful attention to operating difficulties, and lubrication of rough spots, whether they be mechanical or personal.

The raw materials with which engineers work seldom are found in useful forms. Engineering of the highest type is required to conceive, design, and achieve the conversion of the energy of a turbulent mountain stream into the powerful torque[1] of an electric motor a hundred miles away. Similarly many engineering operations are required to change the sands of the seashore into the precise lenses which permit us to observe the microscopic amoeba[2] in a drop of water and study the giant nebula in outer space. In a certain sense, the successful engineer is a malcontent[3] always trying to change things for the better.

SMITH, R. J. *Engineering as a Career*, McGraw-Hill.

[1] *torque:* combination of forces producing a rotating or twisting motion.

[2] *amoeba:* single-celled life-form having no definite shape.
[3] *malcontent:* a person who is never satisfied with what is achieved.

Assignments

1 The extract above has been taken from a book whose objective is to introduce engineering as a career to beginning students of that discipline. Consult your specialist teachers or, better still, a practising specialist about the career opportunities, different specializations, duties and responsibilities of your own discipline. Give an oral report in English of your investigation to the rest of the class who should then ask questions.

2 In lines 19–25 it is stated that any problem involving the low-cost production of large quantities of any item is an engineering problem even if the item itself originated in the work of other disciplines. Explain how any given result of (a) medical research, (b) agricultural research, (c) nuclear physics, (d) optical research is likely to need solutions requiring the skills of an engineer.

3 Explain in detail why (a) 'efficiency costs money', (b) 'safety adds complexity', (c) 'performance increases weight' (ll. 3–5). Is this always true? Interview a practising engineer and give an abstract in English of his reply.

4 In lines 5–6 it is stated that the engineering solution to most problems is the 'most desirable end result taking into account many factors'. Does this apply to your own discipline? If so, explain in what way.

WHAT IS PSYCHOLOGY?

References to psychology in the daily press and in popular periodicals are now numerous, but the variety of ideas as to the nature of psychology is correspondingly extensive.

The existence of so many varied conceptions of the nature of psychology is no doubt related to the many aspects of psychological work. The psychiatrist dealing with 'mental' breakdown, the educator moulding human development, the vocational counsellor advising on the choice of jobs, the social scientist studying the prevention of crime, the personnel manager smoothing human relations in industry, the industrial psychologist streamlining industrial processes to suit the nature of human capacities: all these are concerned with psychology. Human behaviour is complex and varied, and the science which studies it must have many aspects. It may be useful for us to consider samples of psychological work in various areas.

CASE I—A SIMPLE INDUSTRIAL PROBLEM

A large London catering firm became concerned about the excessive number of breakages by its employees. It therefore decided to impose a penalty to reduce carelessness. Strange to say, the system of fines led to an increase in breakages. The management decided that the problem was more complex than they had thought, so they called in a psychologist to investigate and recommend appropriate remedies. The psychologist first posed the question as to when breakages occurred. He kept a record of the breakages occurring during half-hour periods over a number of days, and it soon became evident that most accidents occurred during the rush periods when the girls were worried by their inability to cope with the number of orders. It was now obvious why the system of fines had only made matters worse. They added to the anxiety of the already over-strained girls and simply made them more nervous.

CASE II—READING DIALS

The handling of modern planes (aircraft) places a severe strain on the pilot who must deal with many things in rapid succession. He has to keep watch on a number of dials which give him vital information about his speed, altitude, etc. It is essential that these dials should be easily read and not subject to error. What form should they take? They may have vertical scales or horizontal scales, they may be semicircular or completely round: the whole scale may be visible or only part through a small 'window'. Only careful trials with a number of observers can establish which is the preferred form. An investigator (Sleight) conducted some research to discover the best form for such dials and found that the window type is the best. This seems reasonable since only a part of the scale appears in the window, and so there is less effort required to read the precise point on the scale, but the psychologist has learned never to trust reasoning of this kind. Reasoning may suggest the answer, but we must always try it out.

CASE III—LEARNING

If you have to learn a skill or commit something to memory, the question arises as to whether you should complete the job in one sitting, or whether it is better to spread the learning over a number of periods. A number of experiments have been carried out to decide this matter and, although results vary according to specific circumstances, the general trend is quite definite. In one of the investigations, two similar groups of subjects were set to memorize material. The first group read through the material sixteen times in one day. The other group also read through the material sixteen times, but spread the readings over sixteen days at the rate of one per day. Each group was tested a fortnight (14 days) after completion of the learning to see how much had been retained. The results showed a startling difference. The first group remembered 9% of the material while the second group remembered 79% despite the fact that there was so much opportunity to forget during the 16-day period of learning.

ADCOCK, C. J. *Fundamentals of Psychology*, Penguin Books Ltd.

signments

1 From the examples mentioned in the passage (ll. 6–12) and the cases described, try to formulate a satisfactory and reasonably complete definition of Psychology.

2 Describe any examples known to you in which psychology has been applied in any of the following fields: industry; medicine; education; crime; government.

3 Imagine you were the investigator involved in Case II. Prepare a short lecture (in English) to be given before an international audience, explaining the problem and giving details of the way you solved it.

4 Case I depended for its solution mainly upon accurate measurement; Case II depended upon designing an adequate experimental set-up. In your own local surroundings, can you think of any simple problem which could be solved by one, or both, of these methods? Describe clearly one of these real-life problems, and indicate how you would proceed to tackle it.

5 As you know, a great deal of work has been done on the psychology of learning. Nevertheless, the methods employed by the majority of university and college students are notable for their inefficiency. Can you suggest how to plan and undertake a scientific investigation designed to improve their study methods?

THE PRESSURE TO CONFORM

Suppose that you saw somebody being shown a pair of cards. On one of them there is a line, and on the other, three lines. Of these three, one is obviously longer than the line on the first card, one is shorter, and one the same length. The person to whom these cards are being shown is asked to point to the line on the second card which is the same length as the one on the first. To your surprise, he makes one of the obviously wrong choices. You might suppose that he (or she) perhaps suffers from distorted vision, or is insane. But you might be wrong: you might be observing a sane, ordinary citizen, just like yourself. Because, by fairly simple processes, sane and ordinary citizens can be induced to deny the plain evidence of their senses—not always, but often. In recent years psychologists have carried out some exceedingly interesting experiments in which this sort of thing is done.

The general procedure is this: Someone is asked to join a group who are helping to study the discrimination of length. The victim[1], having agreed to this seemingly innocent request, goes to a room where a number of people—about half a dozen—and the experimenter, are seated. Unknown to the victim, none of the other people in the room is a volunteer, like himself; they are all in the league with (i.e. collaborating with) the experimenter. A pair of cards, like those I have described, is produced; and everyone in turn is asked which of the three lines on the second card is equal to the line on the first. They all, without hesitation, pick[2]—as they have been told to pick—the same *wrong* line. Last of all comes the turn of the volunteer. In many cases, faced with this unanimity, the volunteer denies the plain evidence of his senses, and agrees.

Stanley Milgram of Harvard used sounds instead of lines, and the subjects were merely asked to state which of two successive sounds lasted longer. The volunteer would come into a room where there was a row of five cubicles with their doors shut and coats hanging outside, and one open cubicle for him. He would[3] sit in it and put on the earphones provided. He would then hear the occupants of the other cubicles tested in turn, and each would give the wrong answer. But the other cubicles were, in fact, empty, and what he heard were tape-recordings manipulated by the experimenter. Milgram conducted a series of experiments in this way, in which he varied the pressure put upon the subjects, and clearly showed that, faced with the unanimous opinion of the group they were in, people could be made to deny the obvious facts of the case in up to 75 per cent of the trials. I find this more than a trifle[4] alarming—and very thought-provoking.

You may reply that there is no cause for alarm, because in real situations the total unanimity of a group is rare. The more usual case concerns the effects of what we might call a 'pressure group'.

This has been examined, at least partially, by W. M. and H. H. Kassarjian. They used the 'group in a room' and 'lines on cards' situation, and made things much easier for their volunteers. In the first place, the genuine volunteers were in a majority: 20 out of 30. Secondly, the volunteers never had to make their selections aloud, but always enjoyed the anonymity of paper and pencil. The experimenter explained that some people would be asked to declare their choices publicly, and then asked only his 'primed'[5] collaborators. Thus each volunteer heard the views of only a third of the group he was in. Nevertheless, a substantial[6] distortion was still produced: almost, though not quite, as large as in the conditions we looked at first. So there is only small comfort here.

HAMMERTON, M. broadcast talk reprinted in *The Listener*, 18 October, 1962.

1 *victim:* Here, a humorous way of referring to the subject of the experiment.
2 *to pick:* to choose.
3 *would:* In this context, *would* (used for all persons) is used to express actions in the past which were repeated regularly and thus constituted a habitual procedure or routine.
Note the different use of *would* in l. 55, where it is the past tense of *will*.
4 *more than a trifle:* very.
5 *primed:* previously prepared by the experimenter.
6 *substantial:* considerable.

Assignments

1 Imagine that you are the experimenter in the experiments outlined in the extract, and that the other members of your class are 'subjects' and 'collaborators' respectively. For each experiment, explain clearly in English.

(a) what the 'collaborators' have to do,
(b) what the 'subjects' have to do.

Both 'collaborators' and 'subjects' may ask further questions (in English) to make sure that they understand the instructions given.

2 In this sort of experiment, the degree of conformity (i.e. percentage of conformers) probably varies according to the psychological 'pressure' exerted by the experimenter. Can you design some experiments which could establish this point? If so, explain the procedure clearly in English.

3 Explain some of the dangers to society revealed by the experiments outlined in the extract.

4 It is possible that individuals vary in their susceptibility or resistance to suggestibility. How could you find out whether there are certain factors which

(a) predispose people to conform,
(b) enable people to resist false conformity.

and if so, what these factors are?

NOTE: This is a matter of great practical importance in view of Question (3) above.

PROBABILITY

The mathematics to which our youngsters are exposed at school is, with rare exceptions, based on the classical yes-or-no, right-or-wrong type of logic. It normally doesn't include one word about probability as a mode of reasoning or as a basis for comparing several alternative conclusions. Geometry, for instance, is strictly devoted to the 'if-then' type of reasoning and so to the notion (idea) that any statement is either correct or incorrect.

However, it has been remarked that life is an almost continuous experience of having to draw conclusions from insufficient evidence, and this is what we have to do when we make the trivial decision as to whether or not to carry an umbrella when we leave home for work. This is what a great industry has to do when it decides whether or not to put $50,000,000 into a new plant abroad. In none of these cases—and indeed, in practically no other case that you can suggest—can one proceed by saying, 'I *know* that A, B, C, etc. are completely and reliably true, and therefore the inevitable conclusion is . . .' For there is another mode of reasoning, which does not say: 'This statement is correct, and its opposite is completely false,' but which says: 'There are various alternative possibilities. No one of these is *certainly* correct and true, and no one *certainly* incorrect and false. There are varying degrees of plausibility—of probability—for all these alternatives. I can help you understand how these plausibilities compare; I can also tell you how reliable my advice is.'

This is the kind of logic which is developed in the theory of probability. This theory deals with not two truth values—correct or false—but with all the intermediate truth values: almost certainly true, very probably true, possibly true, unlikely, very unlikely, etc. Being a precise quantitive theory, it does not use phrases such as those just given, but calculates for any question under study the numerical probability that it is true. If the probability has the value of 1, the answer is an unqualified 'yes' or certainty. If it is zero (0), the answer is an unqualified 'no', i.e. it is false or impossible. If the probability is a half (0·5), then the chances are even that the question has an affirmative answer. If the probability is a tenth (0·1), then the chances are only 1 in 10 that the answer is 'yes'.

It is a remarkable fact that one's intuition is often not very good at estimating answers to probability problems. For example, how many persons must there be in a room in order that the odds be favourable—that is, better than even—that there are at least two persons in the room with the same birthday (born on the same day of the month)? Remembering that there are 365 separate birthdays possible, some persons estimate that there would have to be 50, or even 100, persons in the room to make the odds better than even. The answer, in fact, is that the odds are better than even when there are 23 persons in the room; with 40 persons, the odds are better than eight to one that at least two will have the same birthday. Let us consider one more example: Everyone is interested in polls, which involve estimating the opinions of a large group (say all those who vote) by determining the opinions of a sample. In statistics the whole group in question is called the 'universe' or 'population'. Now suppose you want to consult a large enough sample to reflect the whole population with at least 98% precision (accuracy) in 99 out of a hundred instances: how large does this very reliable sample have to be? If the population numbers 200 persons, then the sample must include 105 persons, or more than half the whole population. But suppose the population consists of 10,000 persons or 100,000 persons? In the case of 10,000 persons, a sample, to have the stated reliability, would have to consist of 213 persons: the sample increases by only 108 when the population increases by 9,800. And if you add 90,000 more to the population, so that it now numbers 100,000, you have to add only 4 to the sample! The less credible this seems to you, the more strongly I make the point that it is better to depend on the theory of probability rather than on intuition.[1]

Although the subject started out (began) in the seventeenth century with games of chance such as dice and cards, it soon became clear that it had important applications to other fields of activity. In the eighteenth century Laplace laid the foundations for a theory of errors, and Gauss later developed this into a real working tool for all experimenters and observers. Any measurement or set of measurements is necessarily inexact; and it is a matter of the highest importance to know how to take a lot of necessarily discordant data, combine them in the best possible way, and produce in addition some useful estimate of the dependability of the results. Other more modern fields of application are: in life insurance; telephone traffic problems; information and communication theory; game theory, with applications to all forms of competition, including business, international politics and war; modern statistical theories, both for the efficient design of experiments and for the interpretation of the results of experiments; decision theories, which aid us in making judgements; probability theories for the process by which we learn; and many more.

WEAVER, W., a talk reprinted in *Think*, April 1961.

[1] It should be remembered that the figures given in the example quoted in ll. 54–66 refer to completely representative samples, i.e. those that reflect the total population in all the aspects under consideration—a very difficult matter in the human sciences. Eds.

Assignments

1 Ask your mathematics teacher to show you the mathematical demonstration of the 'birthday problem' referred to in ll. 40–50. Then explain it to your classmates in English. What is the probability if there are 50 people in the room.?

2 Explain how you think probability theory could be used in any of the activities listed in ll. 80–87.