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SIGNAL MANUAL

PART II

(Radio-communication)

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CONTENTS

Introduction	
Chapter I	Electricity
Chapter II	Magnetism
Chapter III	D.C. measuring instruments
Chapter IV	Dynamo-electric machinery
Chapter V	Single-phase alternating currents
Chapter VI	The transformer
Chapter VII	Electric oscillations and electro-magnetic waves
Chapter VIII	The thermionic valve
Chapter IX	Radio-telegraphic transmitters
Chapter X	Radio-telegraphic reception
Chapter XI	Amplification
Chapter XII	Radio-telephony
Chapter XIII	Radio-frequency measurements
Chapter XIV	Propagation of electro-magnetic waves
Chapter XV	Aerial arrays and transmission lines
Chapter XVI	Radio aids to navigation
Chapter XVII	
Appendix A	Tables
Appendix B	Mathematical notes

Algebraically, if a mass m is allowed to fall freely its acceleration is g , the force acting is the weight w of the mass m , and

$$w = m g.$$

Example.

A mass of 30 lb. is acted upon by a force which produces in one second a velocity of 16 feet per second. Find the magnitude of the force.

$$m = 30 \text{ lb.}, a = 16 \text{ ft. per second per second.}$$

$$\begin{aligned} f &= m a \\ &= 30 \times 16 = 480 \text{ poundals.} \end{aligned}$$

For many heavy engineering purposes, however, the pound-weight (Lb.) is used as the unit of force and the unit of mass is then that mass upon which the force of 1 Lb. produces an acceleration of 1 foot per second per second. Obviously this mass is equal to g pounds of matter. The last example would then become

$$\begin{aligned} m &= \frac{30}{g}, a = 16 \text{ ft. per second per second.} \\ f &= \frac{30}{g} \times 16 = \frac{30 \times 16}{32.2} = 14.9 \text{ Lb.} \end{aligned}$$

To avoid confusion, the symbol "lb." is used to denote pound (mass) and "Lb." to denote pound (force).

13. The momentum of a body is the product of its mass and its velocity or momentum = $m u$. As acceleration is the rate at which velocity is varying, the force acting on a body may also be measured by the rate at which the momentum is changing. For example, take a $2\frac{1}{2}$ lb. hammer head which is moving with a velocity of 40 feet per second and is brought to rest in .001 second.

The average force of the blow will be the rate at which the momentum is destroyed or $\frac{m u}{t}$.

$$\begin{aligned} f &= \frac{2.5 \times 40}{.001} \\ &= 100,000 \text{ poundals.} \end{aligned}$$

Alternatively

$$f = \frac{2.5}{32.2} \times \frac{40}{.001} = 3,105 \text{ Lb.}$$

The effect of force acting through a given space is called the work done. Both force and motion are required to perform work. A body in uniform (straight-line) motion does no work because no force is required to maintain the motion. The unit of work is the foot-pound (ft.-Lb.) and is the work done in overcoming the resistance caused by gravity on a mass of one pound.

Algebraically

$$W = f d.$$

14. It may be noted here that because this unit of work is in universal use the so-called absolute unit of force, the poundal, is hardly ever used by practical engineers.

Examples.—(i) Find the work done by gravity when a mass of 8 lb. falls from a height of 10 feet.

$$\begin{aligned} W &= f d. \\ &= 8 \times 10 = 80 \text{ foot-pounds (ft.-Lb.).} \end{aligned}$$

INTRODUCTION

1. The science of radio-communication depends upon the application of the theories of electricity and magnetism, and before a proper understanding of the former can be gained it is necessary to have some knowledge of the elementary principles of electrical engineering. It is impossible in the space available to give anything but the briefest of outlines and for this reason the principles dealt with are restricted, as far as possible, to those actually encountered.

2. Throughout the following pages the reader should bear in mind that the effects described are capable of demonstration and the explanations advanced are put forward as working hypotheses. It is in the attempt to form mental pictures and describe in words the causes which produce these effects that difficulty occurs, and it must be understood that an explanation may be so simplified for the sake of intelligibility that it is true only when read in its context.

3. One of the first misconceptions which must be rejected is that electricity can be produced. The term production and generation of electricity must be understood to refer to the act of causing electricity to flow, that is to say, nothing is created, but electrons are set in motion, and the flow is controlled in accordance with certain laws.

4. The principle of the conservation of energy states that energy is never created and is never destroyed. Energy may cease to be available for useful purposes, but this energy will invariably be found stored in some form or other. Thus, in a Ground Radio Station, the energy may be stored in the first place as a supply of oil fuel. This energy is liberated in the diesel engine, where it is converted partly into heat and partly into motion of the pistons and crankshaft. The latter drives an electrical generator in which the mechanical energy due to rotation is converted into electrical energy and into heat. Finally in the radio transmitter itself, some of this electrical energy is radiated into space and a portion converted into heat. At each stage of conversion, a portion of the energy is wasted, but not destroyed.

5. Radio communication then, in common with all other applications of electrical engineering, deals with the transmission and conversion of energy, which is defined as the ability to do work. If a body possesses this ability by virtue of its position it is said to possess potential energy, while if its capability is due to the fact that it is in motion it is said to possess kinetic energy. Our knowledge of the laws of nature has been developed by careful observation and experiment, and in these investigations the conceptions of time, space, mass and force are of primary importance. Those taken as fundamental are space, mass and time. Space is measured by its linear dimensions in feet, or metres, while masses can be compared by means of balances or weighing machines. The measurement of time must be derived from solar observation, but in practice is obtained from some form of clock. In all cases it is necessary to postulate some standard of comparison. The English standard of length is the imperial yard, which is deposited in the Board of Trade, and of which copies are maintained in the Royal Mint and other places. For engineering purposes the foot or $\frac{1}{3}$ yard is generally used.

6. The English unit of mass is the imperial standard pound avoirdupois, which is a piece of platinum preserved by the Board of Trade. Both the above units are arbitrary, that is they have no basis in natural phenomena. The unit of time, however, is a natural one. The sidereal day is the period of the earth's rotation on its axis, and from this is derived the mean solar day, or average duration of the sidereal day. This is divided into 24 hours, each containing 60 minutes of 60 seconds. Thus the mean solar second is $\frac{1}{86400}$ part of a mean solar day and this is the standard of time both in physical science and engineering.

7. For scientific purposes, the metric system is in use to a greater extent than the English system of units. Here the unit of time is also the mean solar second, but the unit of length is the metre, which was originally intended to be one ten-millionth part of the distance from the north pole to the equator, measured on the surface of the earth. However, in practice it is the length of a certain platinum rod which is preserved in the French archives. The metric unit of mass is the gram. This is the mass of a certain quantity of distilled water, at 4° C., but actually a platinum standard is maintained.

(ii) If the pressure on the piston of a petrol engine is 100 Lb. per square inch, the piston-head area 4 sq. in. and the length of stroke is 4 inches, find the amount of work done by a single stroke.

$$\begin{aligned}\text{Total force} &= \text{pressure} \times \text{area} \\ &= 100 \frac{\text{Lb.}}{\text{in.}^2} \times 4 \text{ in.}^2 \\ &= 400 \text{ Lb.}\end{aligned}$$

$$\begin{aligned}\text{Work} &= \text{force} \times \text{distance} = 400 \text{ Lb.} \times \frac{4}{12} \text{ feet} \\ &= 133.3 \text{ ft.-Lb.}\end{aligned}$$

The power of an agent is the rate at which it can do work. If the above engine makes 600 strokes per minute the power of the machine is

$$\frac{400}{3} \text{ ft.-Lb.} \times \frac{600}{\text{min.}} = 80,000 \text{ ft.-Lb.}$$

The practical unit of power is the horse-power which is 33,000 ft.-Lb. per minute. Hence the above engine develops a horse-power of $\frac{80}{33}$ or 2.42 horse-power.

15. Energy has already been defined as the capability to do work, and its units are the same as those of work itself. The potential energy stored in a body of mass m , at a height h feet above the earth's surface is $m h$ ft.-Lb. or $m g h$ foot poundals. Thus if $m = 10$ lb. and $h = 144$ feet, the potential energy stored is 1,440 ft.-Lb. or 46,400 foot-poundals. If allowed to fall freely from this height, it acquires kinetic energy and the kinetic energy gained is equal to the potential energy lost. The kinetic energy possessed by a mass m moving with a velocity u is $\frac{1}{2} m u^2$ foot poundals or $\frac{1}{2} \frac{w}{g} u^2$ ft.-Lb. w being the weight of the body as before.

16. A body falling from a height of 144 feet acquires a final velocity of approximately 96 feet per second. The kinetic energy possessed by the above body at the end of its fall will be

$$\begin{aligned}&\frac{1}{2} \times 10 \times 96^2 \text{ foot poundals} \\ \text{or } &\frac{1}{2} \times \frac{10}{32.2} \times 96^2 \text{ ft.-Lb.} \\ &= 46,100 \text{ foot poundals.} \\ &= 1,430 \text{ ft.-Lb.}\end{aligned}$$

Other examples of bodies possessing potential energy are a spring under tension or compression and compressed air.

17. The conservation of energy has already been mentioned. It may be asked what becomes of the kinetic energy, 1,440 ft.-Lb. possessed by the body at the instant of impact with the earth. The answer is that it is converted into yet another form of energy, namely heat. While it is very easy to transform a given amount of energy into heat, no means are known by which the whole of a given amount of heat can be converted into potential or kinetic, that is, useful energy. For this reason heat is regarded as the lowest form of energy.

18. Hitherto, most points have been illustrated with regard to the F.P.S. system. In the C.G.S. system the unit of mass is the gram and that of acceleration the centimetre per second per second. The unit of force is that which gives unit acceleration. Now the value of g in centimetres per second per second is 981, and the unit of force must be $\frac{1}{981}$ of a gram. This unit is called the dyne. Again as work = force \times distance the unit of work is one dyne acting through a distance of one centimetre, and is called the dyne-centimetre or erg.

19. Electrical units are derived from the C.G.S. system. In addition to the fundamental units, which are often inconvenient for practical computation, a system of practical units has been developed. Of these the only one of immediate interest is the Joule which is a practical unit of work and is equal to 10^7 ergs.

20. To illustrate the procedure of conversion the example of the petrol engine will be reworked in C.G.S. units. The method of conversion is as follows. As

$$1 \text{ lb.} = 453 \text{ grams.}$$

$$\frac{1 \text{ lb.}}{453 \text{ grams}} = 1, \text{ or } \frac{453 \text{ grams}}{1 \text{ lb.}} = 1$$

and multiplying by a fraction of this kind will only alter the units in which the result is expressed.

The pressure on the cylinder head is $100 \frac{\text{Lb.}}{\text{in.}^2} \times 4 \text{ in.}^2$ or 400 Lb.

$$400 \text{ lb.} \times \frac{453 \text{ grams}}{1 \text{ lb.}} = 400 \times 453 \text{ grams.}$$

Hence the work done in a single stroke is

$$\begin{aligned} 400 \text{ lb.} \times \frac{453 \text{ grams}}{1 \text{ lb.}} \times \frac{981 \text{ dynes}}{1 \text{ gram}} \times 4 \text{ inches} \times \frac{2.54 \text{ cms.}}{1 \text{ inch}} \\ = 400 \times 453 \times 981 \times 4 \times 2.54 \text{ dyne-cms. or ergs.} \\ = 1.805 \times 10^9 \text{ ergs.} \\ = 1,805 \text{ joules.} \end{aligned}$$

Since 600 strokes are executed in one minute or 10 strokes per second the power exerted by the engine is 1,805 joules per second. One joule per second is also known as one watt. It is chiefly used as an electrical unit.

From the two calculations it is easy to deduce the relationship between the horse-power and the watt for

$$2.42 \text{ horse-power} = 1,805 \text{ joules.}$$

$$\therefore 1 \text{ horse-power} = 746 \text{ watts.}$$

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