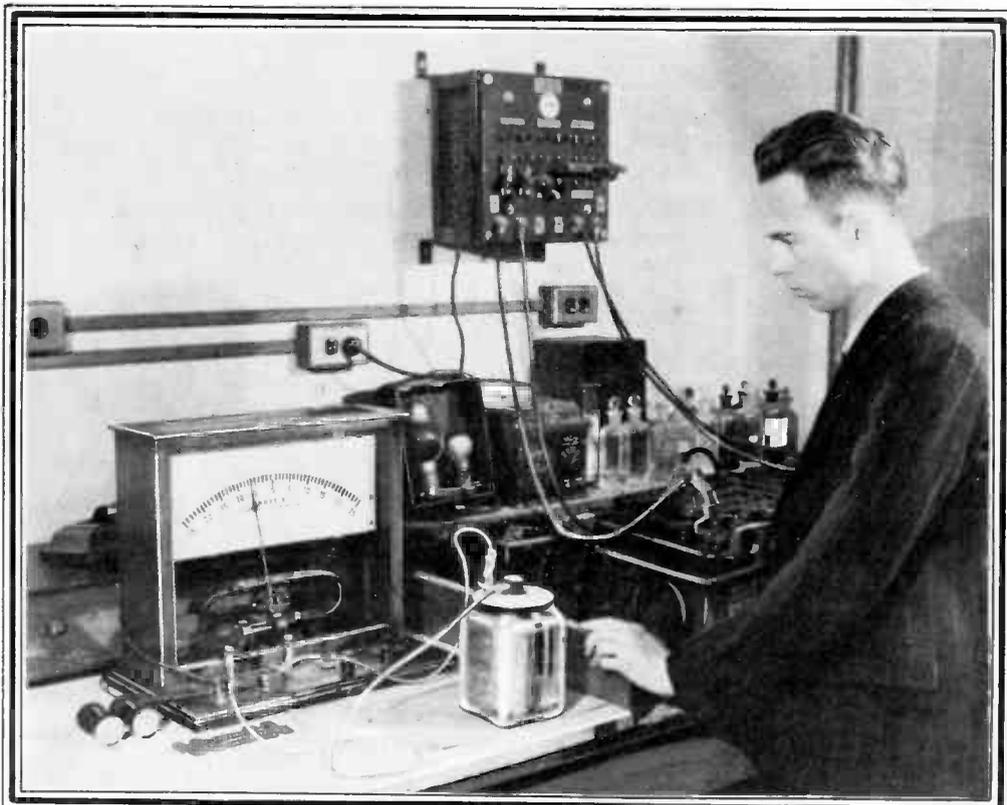


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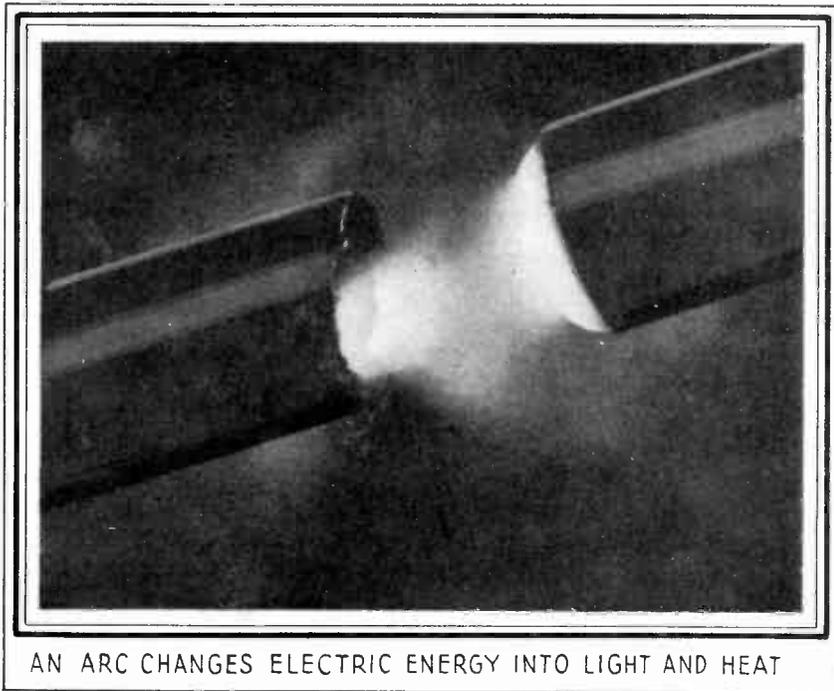


THE DEFLECTION OF THE METERS' POINTER INDICATES THE ELECTRICAL PRESSURE (E.M.F.) PRODUCED BY THE PRIMARY CELL OR JAR

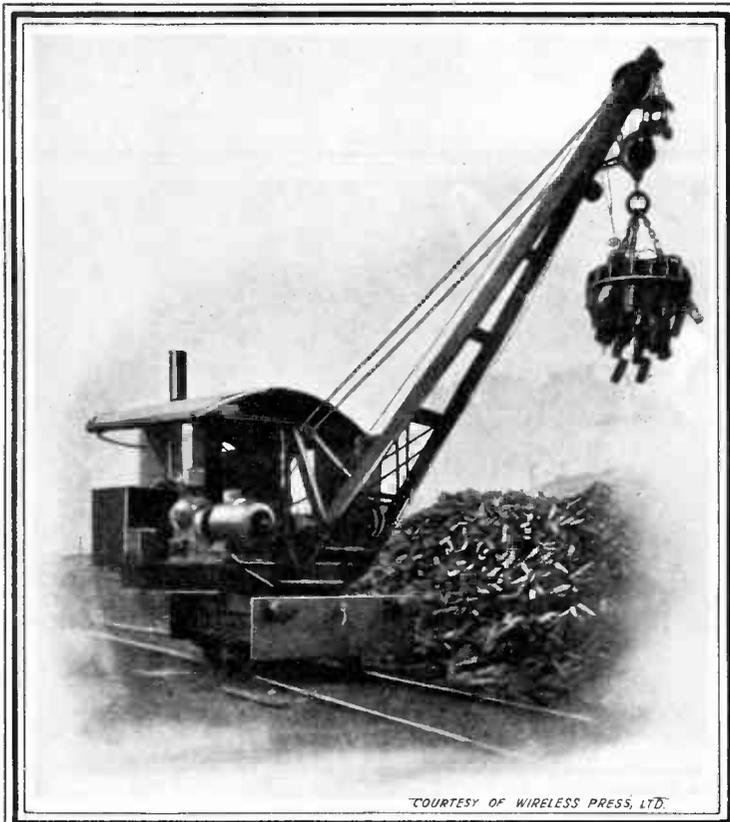
**HOW ENERGY IN ELECTRICAL FORM IS  
PROVIDED BY THE PRIMARY CELL**

**VOL. 10 No.5**

DEWEY DECIMAL CLASSIFICATION R100



AN ARC CHANGES ELECTRIC ENERGY INTO LIGHT AND HEAT



*COURTESY OF WIRELESS PRESS, LTD.*

AN ELECTRICALLY OPERATED MAGNETIC CRANE CONVERTS  
ELECTRICAL ENERGY INTO MECHANICAL ENERGY

(Problems cont'd from previous page)

Note: Solve the following problems which relate to direct current circuits. Use the form suggested in worked-out examples in this lesson where the formula is written first, the known values substituted next, and so on.

7. If 3 amps. pass through the lamp in Figure 6, and the line voltage at the wall outlet is 110 volts, what power is being expended?
  8. Suppose an electrical heater, rated at 350 watts, is placed in operation and by measuring the current strength with an ammeter, we find it to be 3 amps. Find the line voltage.
  9. If the load on a generator supplying an electrical circuit is such that a current of 200 amperes flows at a pressure of 120 volts, what is the capacity of this machine in watts? Also, in kilowatts?
  10. In this problem you are given the following data: The e.m.f. is 120 volts, the current drawn is 20 amperes and the generator is maintained in operation 12 hrs. Find kilowatt-hours of energy expended.
-

EXAMINATION QUESTIONS

1. Give the definitions of the following units, expressing them in your own words. Do not use the exact wording given in the lesson.
 

(a) volt	(d) coulomb	(g) farad
(b) ampere	(e) watt	(h) kilowatt-hour
(c) ohm	(f) henry	(i) ampere-hour
  
2. (a) What is a megohm? (d) Micro-microfarad?  
 (b) Microhm? (e) Microfarad?  
 (c) Kilowatt?
  
3. (a) Can energy be created? (d) What unit of time is electrical measurement based on?  
 (b) Name two practical sources for obtaining electrical pressure. (e) Write 35 mmfd. in the unit mfd.  
 (c) What must we first have in an electrical circuit before current will flow?
  
4. Suppose the capacity of a generator when carrying a load is 3500 watts. Express this value in kilowatts and horse-power. Show your work.
  
5. What is the difference between work and power? What is force and energy? Use an analogy, if you wish, in order to explain the meanings.
  
6. (a) Write the formula you would use if the power and current of a circuit were known and you were asked to find voltage.  
 (b) Write the formula you would use to find current strength if the voltage and wattage of a circuit were known.  
 (c) Write the formula you would use to find the wattage of a circuit if the voltage and current were known.

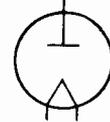
(Problems cont'd on next page)



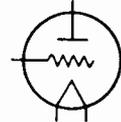
STANDARD RADIO SYMBOLS

Vacuum Tubes

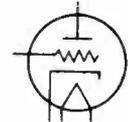
Diode  
(or half-wave rectifier)



Triode  
(with directly heated cathode)



Triode  
(with indirectly heated cathode)



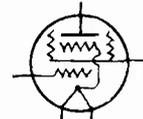
Screen Grid Tube  
(with directly heated cathode)



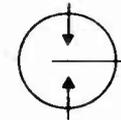
Screen Grid Tube  
(with indirectly heated cathode)



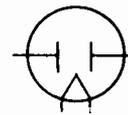
Pentode  
(with directly heated cathode)



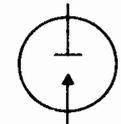
Rectifier Tube, Full-Wave  
(Filamentless)



Rectifier Tube, Full-Wave  
(with directly heated cathode)

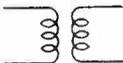
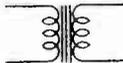
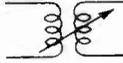


Rectifier Tube, Half-Wave  
(Filamentless)



Part IV

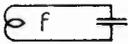
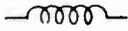
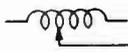
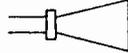
STANDARD RADIO SYMBOLS

Resistor	
Resistor, Adjustable	
Resistor, Variable	
Spark Gap, Rotary	
Spark Gap, Plain	
Spark Gap, Quenched	
Telephone Receiver	
Thermoelement	
Transformer, Air Core	
Transformer, Iron Core	
Transformer, With Variable Coupling	
Transformer, With Variable Coupling (With moving coil indicated)	
Voltmeter	
Wires, Joined	
Wires, Crossed, not joined	

Part III



STANDARD RADIO SYMBOLS

Frequency Meter (Wavemeter)	
Galvanometer	
Glow Lamp	
Ground	
Inductor	
Inductor, Adjustable	
Inductor, Iron Core	
Inductor, Variable	
Jack	
Key	
Lightning Arrester	
Loud Speaker	
Microphone (Telephone Transmitter)	
Photo electric Cell	
Piezoelectric Plate	

Part II



STANDARD RADIO SYMBOLSCourtesy, Institute of Radio Engineers

Aerial	
Ammeter	
Arc	
Battery (the positive electrode is indicated by the long line)	
Coil Antenna	
Condenser, Fixed	
Condenser, Fixed, Shielded	
Condenser, Variable	
Condenser, Variable (with moving plate indicated)	
Condenser, Variable, Shielded	
Counterpoise	
Crystal Detector	

Part I

CHART OF THE TYPICAL UNITS OF WORK AND POWER

WORK = Force x Distance, or  $W = FD$

UNITS OF WORK

Joule = Watt second, or  $J = PS$

$$= EIS$$

$$= EQ$$

$$= I^2RS$$

$$= \frac{E^2S}{R}$$

$$= 10^7 \text{ ergs}$$

Erg = dyne centimeter

$$= \frac{\text{gm cm}}{\text{sec}^2} \times \text{cm}$$

$$= \frac{\text{gm cm}^2}{\text{sec}^2}$$

POWER =  $\frac{\text{Work}}{\text{Time}}$ , or  $P = \frac{W}{T}$

UNITS OF POWER

Watt = Volt ampere

$$= EI$$

$$= I^2R$$

$$= \frac{E^2}{R}$$

$$= \frac{\text{joule}}{\text{second}}, \text{ or } P = \frac{J}{S}$$

$$= \frac{1}{746} \text{ H. P.}$$

$$= \frac{550 \text{ ft lbs}}{\text{sec}} = \frac{746}{746}$$

Key To Abbreviations

cm = centimeter

D = distance

E = volt

F = force

ft = feet

gm = gram

H.P. = horse-power

I = ampere

J = joule

lb = pound

P = watt

Q = coulomb

R = ohm

S = second

T = time

W = work



## GREEK LETTERS, SYMBOLS AND MATHEMATICAL SIGNS

### Greek alphabet

Letters	Names	Letters	Names	Letters	Names
A	$\alpha$ Alpha	I	$\iota$ Iota	P	$\rho$ Rho
B	$\beta$ Beta	K	$\kappa$ Kappa	$\Sigma$	$\sigma$ Sigma
$\Gamma$	$\gamma$ Gamma	$\Lambda$	$\lambda$ Lambda	T	$\tau$ Tau
$\Delta$	$\delta$ Delta	M	$\mu$ Mu	Y	$\upsilon$ Upsilon
E	$\epsilon$ Epsilon	N	$\nu$ Nu	$\Phi$	$\phi$ Phi
Z	$\zeta$ Zeta	$\Xi$	$\xi$ Xi	X	$\chi$ Chi
H	$\eta$ Eta	O	$\omicron$ Omicron	$\Psi$	$\psi$ Psi
$\Theta$	$\theta$ Theta	$\Pi$	$\pi$ Pi	$\Omega$	$\omega$ Omega

### Symbols

$\mu$  = permeability (B/H)  
 $\pi$  = 3.1416  
 $\rho$  = volume resistivity  
 $\tau$  = thickness  
 $\kappa$  = susceptibility  
 $\lambda$  = wavelength in meters  
 $\delta$  = logarithmic decrement  
 $\epsilon$  = 2.7183 (base of Napierian logarithms)  
 $\eta$  = efficiency (per cent)  
 $\theta$  = phase angle (degree or radian)

$\phi$  = angle  
 $\psi$  = difference in phase  
 $\omega$  =  $2\pi f$  (angular velocity in radians per second);  
 $\Phi$  = magnetic flux  
 $\Psi$  = electrostatic flux  
 $\Omega$  = ohm  
 $\Upsilon$  = electric conductivity  
 $\mathcal{E}$  = electric field intensity  
 $\mathcal{F}$  = magnetomotive force  
 $\mathcal{R}$  = reluctance

### Signs

$\propto$  proportional to; varies as  
 $=$  equal to  
 $\times$  multiplied by  
 $+$  plus; addition  
 $-$  minus; subtraction  
 $\div$  divided by  
 $\odot$  circle

$\angle$  angle  
 $<$  is less than  
 $\ll$  much less than  
 $>$  is greater than  
 $\gg$  much greater than  
 $\odot$  cycle

ABBREVIATIONS FOR RADIO TERMS  
Courtesy, Institute of Radio Engineers

<u>Term</u>	<u>Abbreviation</u>
Alternating-current (adjective)	a-c
Alternating current	spell out
Ampere	a
Antenna	ant.
Audio-frequency (adjective)	a-f
Continuous waves	CW
Cycles per second	~
Decibel	db
Direct-current (adjective)	d-c
Direct current	spell out
Electromotive force	e.m.f.
Frequency	f
Ground	gnd.
Henry	h
Intermediate-frequency (adjective)	i-f
Interrupted continuous waves	ICW
Kilocycles (per second)	kc
Kilowatt	kw
Megohm	MΩ
Microfarad	μf
Microhenry	μh
Micromicrofarad	μμf
Microvolt	μv
Microvolt per meter	μv/m
Millivolt per meter	mv/m
Milliwatt	mw
Ohm	Ω
Power Factor	p.f.
Radio-frequency (adjective)	r-f
Volt	v

ABBREVIATIONS FOR METRIC PREFIXES

<u>Prefix</u>	<u>Abbreviation</u>
centi	c
deci	d
deka	dk
hecto	h
kilo	k
mega	M
micro	μ
milli	m

points is one wavelength. Let us try to visualize a wave motion occurring in space, set up by unseen forces. Suppose that an electromagnetic wave is projected from an active transmitting antenna and this energy consists of a succession of rapidly recurring impulses in space, due to the disturbance set up in the space medium. The length of each individual wave or complete impulse of the electromagnetic wave motion is considered from a similar viewpoint as each water wave.

The metric unit of measurement is used to compute such length. Thus the wavelength of an electromagnetic wave sent out by a radio transmitter may be 300 meters, or it may be 1,500 meters or 14.5 meters or any desired length which is governed by the electrical adjustments of the transmitter. One meter equals approximately 39.37 inches. The student must not confuse the distance which a radio wave will actually travel to be intercepted and heard in the receivers (which may be several thousand miles in some cases) with the wavelength of each individual impulse in the complete wave motion.

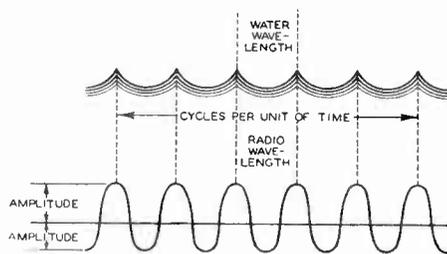


Figure 13

The length of a wave is the distance from the crest of one wave to the crest of the next wave as shown in Figure 13. The variations passed through during one such occurrence are said to constitute one cycle. 1000 cycles are equivalent to one kilocycle. The total number of these cycles which occur in one second is called the frequency.

Figure 14 shows the frequency range or spectrum of all the known forms of vibratory motion. Classifications are not sharply defined as much of the spectrum remains to be fully explored.

The balance of this lesson contains charts and symbols which are followed by the examination questions.

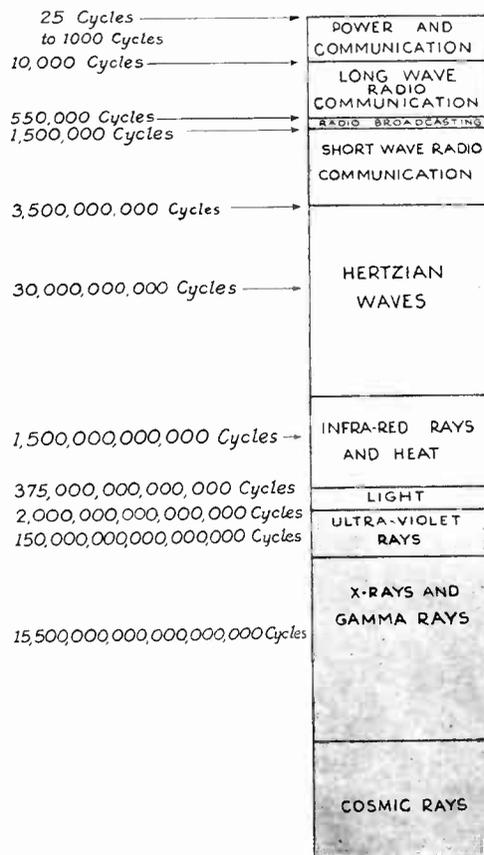


Figure 14



We have already given an equation which states that 550 foot-pounds per second is equivalent to 1 mechanical horse-power. The electrical equivalent of this, or 1 electrical horse-power, would be

$$1 \text{ ELECTRICAL H.P.} = \frac{550}{0.7375} \text{ or, 746 watts.}$$

The above derivation of the number of watts per electrical horse-power is the same as,

$$1 \text{ ELECTRICAL H.P.} = 550 \times 1.356 \text{ or, 746 watts.}$$

The value .7375 is the reciprocal of 1.356, or 1 divided by 1.356, that is,

$$\frac{1}{1.356} = .7375$$

THE METER IS THE UNIT OF MEASUREMENT FOR WAVELENGTH. Wavelength can also be expressed in terms of frequency. These terms are used in connection with electromagnetic wave motion in space, by this we mean radio waves in space. The terms can be interchangeable, it being a simple matter to convert wavelength to frequency and vice versa. This is explained in a subsequent lesson. Refer to Figure 12, which shows a regularly recurring wave motion set up on the surface of water by striking it with equal intensity at regular intervals with a wooden block.

The term wavelength can best be explained with the aid of a drawing of this kind and after once understanding the meaning of wavelength it can be applied to any form of motion that occurs and reoccurs at regular intervals.

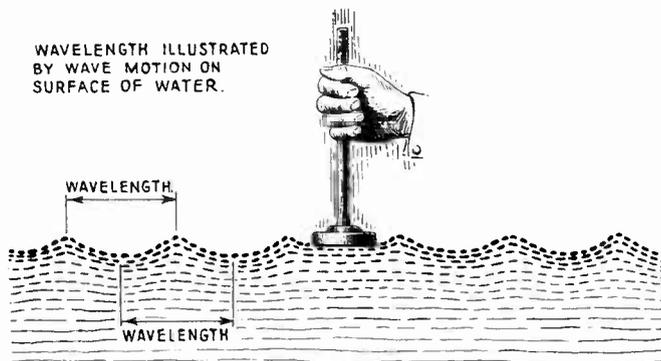


Figure 12

One wavelength is the distance from crest to crest of the wave in Figure 12, or it may be the distance from trough to trough, which naturally would be the same. Moreover, we could consider any point on one wave impulse and compare it to a similar point on an adjoining wave impulse and say that the distance between these two selected

Now, in order to find the rating of an electrical machine, in the unit of horse-power, we have simply to know its capacity in volts and amperes; to find the horse-power multiply the volts by amperes and divide by 746. This is the same thing as saying that the number of watts are divided by 746. Hence, we have.

$$\text{ELECTRICAL H.P.} = \frac{\text{VOLTS} \times \text{AMPERES}}{746} = \frac{\text{WATTS}}{746}$$

The following worked out example is given to aid you in solving problems of this kind. The results can be expressed either in the unit watt, kilowatt or electrical H.P.

PROBLEM: Suppose the current drawn by the motor in Figure 11 is 20 amperes and the line voltage is 220 volts. Find the number of watts of energy consumed?

SOLUTION:

- (1) Write formula:  $\text{WATTS} = E \times I$
- (2) Substitute known values:  $\text{WATTS} = 200 \times 20$
- (3) Solving, we get:  $\text{WATTS} = 4400 \text{ watts. Answer}$

If we wish to express the above answer in horse-power maintained by the motor, simply divide 4400 by 746 as follows:

$$\text{ELECTRICAL HORSE-POWER} = \frac{\text{WATTS}}{746} = \frac{4400}{746}$$

Hence,  $\text{ELECTRICAL HORSE-POWER} = 5.9 \text{ H.P. Answer.}$

This answer expressed in kilowatts is  $4400 \div 1000 = 4.4 \text{ kw.}$

THE BASIS OF COMPARISON BETWEEN MECHANICAL AND ELECTRICAL H.P. The basis for comparing an equivalent amount of mechanical energy measured in "foot-pounds" and electrical energy in "watts" was worked out mathematically many years ago by Dr. Joule. He made a direct comparison between both kinds of energy in performing exactly the same work which consisted of heating a given quantity of water until its temperature was raised to a certain value. In the case of mechanical energy the heat was obtained from the friction set up when paddle wheels were rotated through the water. The amount of power required was figured from the number of foot-pounds of work per second obtained from a certain arrangement of pulleys and weights used in the experiment. In the case of the electrical circuit the power was computed from the amount of current consumed at a certain voltage and the time required in generating the specified amount of heat. Dr. Joule estimated that 1 foot-pound per second = 1.356 watts.



hour, one-half hour or five minutes, or any other interval of time, will determine the "time rate of doing the work," or "the power." Mechanical power is usually estimated in foot-pounds per minute, but in some practical work it may be more convenient to use foot-pounds per second. Hence,

$$\begin{aligned} 1 \text{ MECHANICAL H.P.} &= 33,000 \text{ FT. LBS. PER MINUTE} \\ \text{or, } 1 \text{ MECHANICAL H.P.} &= 550 \text{ FT. LBS. PER SECOND.} \end{aligned}$$

We obtain the 550 in the lower equation, for expressing so many foot-pounds per second, by dividing 33,000 foot-pounds per minute by 60 seconds, that is,  $33,000 \div 60 = 550$ .

In commercial practice the power is estimated according to the amount of work done in horse-power and the period of time involved in hours.

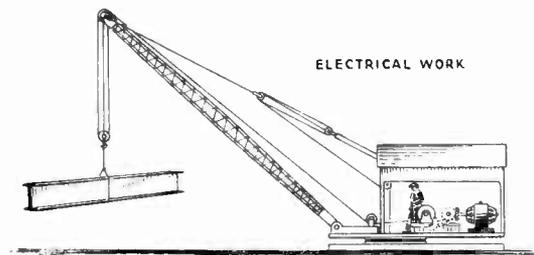


Figure 11

Electrical H.P. Electrical power is measured in watts, the measurements being based upon the second of time and not the minute which is chiefly used in mechanical work.

Let us suppose the horses in Figure 10, are replaced by an electric motor as the source of power as in Figure 11. You will recall that power is estimated according to the amount of work done during a certain period of time. Accordingly, in our computations it will be necessary to know the amount of power that a motor is supplying and length of time it is kept in operation.

In one of the paragraphs in this lesson, under the unit "Joule," it was explained that one joule per second is the unit of electrical power, or the watt. Furthermore, it was explained that the rate in watts at which electrical energy is expended is equal to the voltage of a circuit times the number of amperes of current flowing. Putting these statements together should give you an understanding of the significance of the watts formula; where

$$\text{WATTS} = E \times I$$

Where large amounts of power are handled it is often inconvenient to use a unit as small as the watt, as we previously mentioned and so in the practical work of rating electrical machinery the larger unit "electrical horse-power" is employed. It will be recalled that one electrical horse-power equals 746 watts.



The work done is the result of the force exerted, or power expended, by the horses in overcoming any opposition or resistance which the load presents. The heavy iron beam is the load. The power is the rate at which the work is done, that is, whether it takes the horses 15 minutes, or 1 hour, or any given time to lift the load. The total work includes the power expended and the time.

In summarizing the foregoing facts we can say in a few words that the energy possessed by the horses was converted into mechanical pulling or lifting power. This gives us a good illustration of the laws governing the "conservation of energy." Conservation relates to the transference of energy from one state to another. There is nothing lost, practically speaking, in the transference of energy from one state to another so long as our purpose is fulfilled; that is, so long as the work we desire to be performed is actually completed.

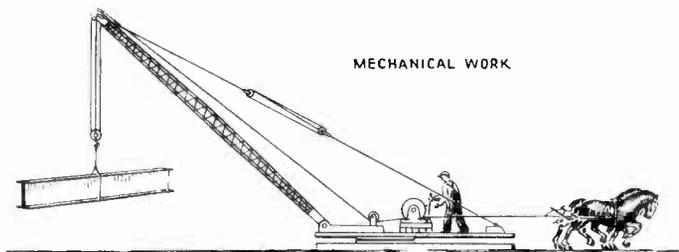


Figure 10

#### ELECTRICAL AND MECHANICAL HORSE-POWER DEFINED

Mechanical H.P. In the illustration in Figure 10, we have shown two horses lifting a heavy iron beam by means of a hoisting crane. The power in this case is the rate at which the work of lifting the beam is accomplished. Mechanical work is measured in "foot-pounds" or "pounds multiplied by feet." Thus, if a weight of 3 lbs. is raised to a height of 5 ft. we have an equivalent of 15 foot-pounds of work. Suppose a  $7\frac{1}{2}$  lb. weight is lifted only 2 feet we would have exactly the same amount of work done as when 3 lbs. is raised 5 ft., or 15 foot-pounds in both cases.

Now, to explain the meaning of mechanical horse-power let us suppose that the iron beam in Figure 10 weighs 33,000 lbs. and is to be raised one foot against the force of gravity, and suppose further that the horses take one minute to do this. Here we have a set of given values. Let us repeat them: 33,000 lbs. is to be raised one foot in one minute. This combination of values is the basis for the rate of doing work which is equal to one mechanical horse-power. If twice this weight, or 66,000 lbs., is raised one foot in twice the time, or two minutes, the "rate of working" would still be the same as in the preceding case, or one mechanical horse-power.

If the horses were replaced by a stronger team that could lift the same beam, the same distance, in just half the time, or let us say, in one-half minute, then it is logical to assume that one team is twice as powerful as the other. Thus, if 33,000 lbs. is lifted one foot in 30 seconds it would give us 2 mechanical horse-power. We see that both teams of horses perform exactly the same total amount of work, but, depending upon whether the work is completed in one

The watt-hour is the unit of measurement that is applied in the calibration of electric meters installed in our homes, factories, office buildings and so on, for indicating the amount of electricity consumed; the meters used for this purpose are usually equipped with several dials for recording and are called watt-hour meters.

Since a watt is equal to a volt multiplied by an ampere, it is easy to see that watt-hours must equal volts multiplied by amperes and time; or stated in a formula, we have

$$\text{WATT-HOURS} = E \times I \times \text{HOURS}$$

In many cases the unit "watt-hour" is too small for practical computations, and for convenience a larger multiple of the unit is employed, called a "kilowatt-hour." Remember that one kilowatt equals 1000 watts. Therefore, a kilowatt-hour is found by first multiplying volts by amperes by hours, and then dividing the product found by 1000. From this we derive the following formula.

$$\text{KILOWATT-HOURS} = \text{KILOWATTS} \times \text{HOURS}$$

$$\text{or, KW-HRS} = \frac{E \times I \times \text{HOURS}}{1000}$$

One kilowatt-hour is defined as the equivalent of one kilowatt (1000 watts) of electrical energy expended in one hour.

EXAMPLES OF HOW THE TERM KILOWATT-HOUR IS USED. Suppose that a generator in a power plant is kept in operation to furnish light and power for a factory. If the output of this generator indicates that one kw. of electrical work is maintained for one hour the factory will use 1 kilowatt-hour; or if 2 kw. is maintained for one-half hour ( $2 \times \frac{1}{2} = 1$ ) the factory will likewise use 1 kilowatt-hour; but, if 4 kw. is maintained  $2\frac{1}{2}$  hours the factory will use 10 kilowatt-hours.

An AMPERE-HOUR is the unit in general use in battery charging service; it represents a continuous flow of current of 1 ampere for 1 hour.

ILLUSTRATING THE PROPER USE OF THE TERMS: POWER, FORCE, WORK and ENERGY. Let us refer to the drawing in Figure 10 where a team of horses is at work raising a heavy iron beam. This illustrates how force applied through a certain distance causes or tends to cause a body to be set into motion. In this instance, motion is actually produced because the horses are strong enough to perform the task imposed upon them. In this action the force might be defined as the physical exertion put forth by the horses in accomplishing the work. The capacity which these horses possess for doing work of this kind is the energy. (Note: The energy cannot actually be created, it is a natural condition existing within the horses.)



formula and the other two is easily found by use of the simple circular chart containing letters W, E, and I shown below in Figure 7. The explanation is as follows:

To use this convenient aid for learning the different forms of watts formula, it is simply necessary to cover one member of the formula, and its relation to the other two members is apparent.

Suppose we desire to know the relation of voltage to current and watts. We cover (E) which designates voltage and find that (E) is equal to  $W \div I$ , which is exactly what the formula  $(E = \frac{W}{I})$  tells us. This procedure is shown in Figure 8.

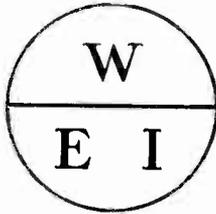


Figure 7

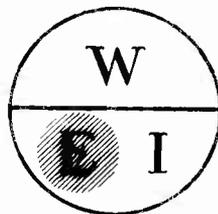


Figure 8

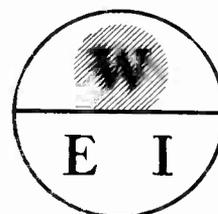


Figure 9

Now, suppose we desire to know the relation of watts to current and voltage. We cover (W) which stands for watts and find that (W) is equal to  $E \times I$ , which is the equivalent of the relation expressed by the formula  $(W = EI)$ . See Figure 9. The relation of current to watts and voltage may be found in the same way by covering (I).

This same arrangement of the parts of a formula may be applied to any equation having three members. The expression EI means the same as  $E \times I$ , or E times I.

Another practical example in the use of the watts formula is worked out below.

PROBLEM: Let the rated power of a circuit be 660 watts and the line voltage 110 volts. What is the value of the current passing through this circuit?

SOLUTION: The formula is written first and the computation completed as follows:

- (1) Write formula:  $I = \frac{W}{E}$   
 (2) Substitute known values:  $I = \frac{660}{110}$   
 (3) Solving, we have  $I = 6$  amperes. Answer.

THE WATT-HOUR AND KILOWATT-HOUR. The watt-hour is a convenient unit to use in practical work for denoting the amount of energy expended in a given number of hours.

One watt-hour is equal to one watt of electrical energy expended in one hour.



Supposing now, that we were required to find the wattage of a circuit without knowing the applied voltage. The problem and its solution is presented to illustrate the second wattage formula, ( $W = I^2R$ ).

PROBLEM: Find the number of watts expended in the circuit of Figure 6 when the EMF is unknown, the current is 0.5 amperes and the resistance of the lamp is 240 ohms.

SOLUTION:

- (1) Write the formula:  $W = I^2R$
- (2) Substitute known values:  $W = 0.5^2 \times 240$  or,  $(0.5 \times 0.5 \times 240)$ , or,
- (3) Squaring 0.5:  $W = .25 \times 240$
- (4) Multiplying:  $W = 60$  watts. Answer.

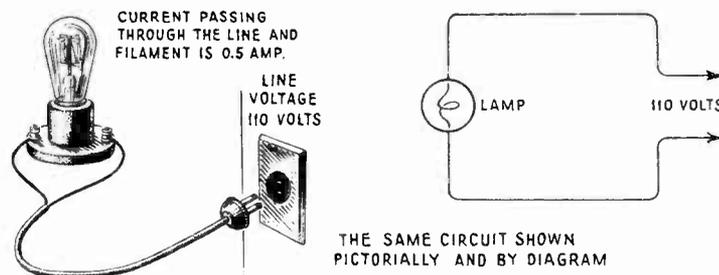


Figure 6

The number of watts may be expressed in the larger unit "horse-power," abbreviated "H.P." In terms of horse-power, one watt is equal to 1/746th of an electrical horse-power. This is equivalent to saying that one electrical horse-power equals 746 watts, or writing this in the form of an expression, we have

$$1 \text{ ELECTRICAL H.P.} = 746 \text{ watts.}$$

Another unit in common use is the "kilowatt." One kilowatt, abbreviated "kw," is equal to one thousand watts, or

$$1 \text{ kw} = 1000 \text{ watts.}$$

PRACTICAL USE OF WATTS FORMULA. The watts formula for direct current can be stated in three ways as shown below for convenience in working out practical problems. Exactly similar relations are represented between the quantities in each of the formulas. An inspection of these formulas show that if the value of any one of the three quantities is unknown it may be easily found providing the other two quantities are known. Using the symbols, we have

$$W = E \times I$$

$$\text{or, } I = \frac{W}{E}$$

$$\text{or, } E = \frac{W}{I}$$

The relation which exists between any one component of the watts

circuit. The same formula is repeated below but using the electrical symbols in their proper relation.

$$W = E \times I$$

From previous instruction of this lesson we have learned that the volt is the pressure required to force a current of one ampere through a circuit having a resistance of one ohm. This expressed mathematically takes the shape of,

$$\text{Volts} = \text{Amperes} \times \text{Ohms}$$

$$\text{or, } E = I \times R$$

Substituting (E) of this formula for the voltage in the watts formula ( $W = E \times I$ ), we have

$$W = I \times I \times R$$

$$\text{or, } W = I^2 R$$

It is clear that if we wish to ascertain the number of watts of power in a direct current circuit, or in the parts which form the circuit, we have simply to multiply the volts by the amperes, or the current squared ( $I^2$ ) by the resistance. However, in our lesson on alternating current (a-c) we will learn that another factor, called power factor, enters into the computation of the wattage of an alternating current circuit or its parts.

The power or watts formula for an alternating current circuit is:

$$W = E \times I \times \text{POWER FACTOR}$$

The following definition of a watt should be learned:

One watt is the power expended when one ampere of current flows steadily through a circuit under a pressure of one volt.

The symbol (W) is used to denote the watt as used above in the formulas.

A practical example is worked out below showing how to find the wattage of a simple circuit.

PROBLEM: Find the number of watts expended in the circuit of Figure 6 when the e.m.f. (E) is 120 volts and the current (I) drawn by the lamp is 0.5 amp.

SOLUTION: The wattage for this circuit is computed as follows:

- |   |                         |   |
|---|-------------------------|---|
| (1) Write the formula:                      | $W = E \times I$        |   |
| (2) Substitute known values:                | $W = 120 \times 0.5$    |   |
| (3) Perform the work as shown at the right: |                         | $\begin{array}{r} 120 \\ \times 0.5 \\ \hline 60.0 \end{array}$ |
| (4) Write the answer:                       | $W = 60 \text{ watts.}$ | Answer.   |



An illustration of electrical work is where an electric flatiron is connected to a 110-volt house-lighting circuit. The work or energy expended in the electrical case is represented by the heat developed in the coils, called heating element, mounted within the iron. In order for this work to be done successfully we know that the voltage on the line was effective in overcoming all the oppositions of the circuit, with the result that a certain value of current was forced through the coils. This teaches us how electrical energy is transferred into heat energy.

The total amount of work done is calculated by multiplying the amount of a force and the distance through which it acts (or is applied) in overcoming resistance which results finally in a transference of energy from one form to another.

The accomplishment of a certain piece of work is independent of time. That is to say, it may require different amounts of time, as for instance a day, a week or perhaps longer to complete a given work. When the element of time is associated with the work we must make reference to the term power.

POWER. Power is the time rate of doing work. It represents both the expenditure of a certain amount of energy and the length of time during which it is maintained. Since the term power includes the element of time we must not confuse it with the total amount of work actually performed. The two terms "power" and "work" are frequently confused. Therefore, we are presenting their relation with a mathematical equation.

The relation of "power," "work" and "time" can be set down as follows:

$$\text{POWER} = \frac{\text{WORK}}{\text{TIME}}$$

THE WATT is the unit of electrical power. From a little consideration of the three explanations previously given in regard to the joule (or unit of work), and the ampere (or the unit of current), and the volt (or unit of pressure) it is evident that the amount of "power" in any electrical circuit must be a combination of these three factors.

Thus, one watt is defined as that unit of power equivalent to one joule divided by one second. This relation may be written as follows:

$$\text{WATTS} = \frac{\text{JOULES}}{\text{SECONDS}}$$

Now we already know that a joule is the amount of work resulting when one ampere of current is maintained for one second under an applied e.m.f. of one volt. Therefore, combining this relation into one expression we have the well-known watts formula:

$$\text{WATTS} = \text{VOLTS} \times \text{AMPERES}$$

The watts formula which we have just given is for a direct current



It is to be understood that force does not always produce motion. This is a fact with which you are perfectly aware. For a simple illustration consider what would happen if you pushed against the side of a house with all your strength; you know that the energy expended would not result in the house being moved regardless of how hard you may have worked to accomplish this purpose. These natural laws are true in the case of electricity; an electromotive force does not in every case act to cause a movement of current but it tends to do so. Thus, it may be said that a force acting over a distance or through space is a factor of work but the action does not necessarily produce motion.

THE JOULE is the unit of electrical energy or work.

One joule represents the amount of work performed or energy expended, including that consumed in generating heat, when an electromotive force of one volt is applied to a circuit and a current of one ampere flows for one second of time.

At this point, it may be well to stress the difference between the COULOMB and the JOULE. From previous instruction you know that a coulomb is equal to one ampere-second. Now, from the above definition we learn that the joule is the equivalent of one watt-second, since a watt is equal to a volt-ampere as will be explained later.

We can express electrical work as the product of the "electro-motive force" in volts and the "quantity of current" in coulombs. Now, since an ampere is equal to one coulomb of electricity multiplied by a time period of one second, then this entire relation can be stated as follows:

$$\text{ELECTRICAL WORK (JOULES)} = \text{VOLTS} \times \text{AMPERES} \times \text{SECONDS, or,}$$

$$J \quad = \quad E \quad \times \quad I \quad \times \quad S$$

The symbol (J) is used to denote the joule.

WORK. Work is performed whenever a force overcomes opposition or resistance, in causing a body upon which it acts to be set into motion. The amount of work done can be conveniently measured whether it is the result of mechanical, chemical, electrical or heat effects. This statement, no doubt, is plainly obvious to everyone and is intended to point out the fact that to do work does not necessarily mean that a weight must be lifted. For instance, work is done by compressed air acting upon a piston in a rivet machine; an explosion of a charge of gasoline vapor acting on one or more pistons provides the power in a gasoline motor for use in boats, automobiles and so forth; steam engines utilize the expansive force of steam on the heads of large pistons as a source of power. Steam may be used in a plant to drive electric generators which are in turn used to supply light, heat and power. We could go on indefinitely citing examples of how power is obtained to do different kinds of work.

A simple illustration of mechanical work is one in which a team of horses is in action, exerting energy in pulling up a very heavy weight by means of suitably arranged pulleys and lines.



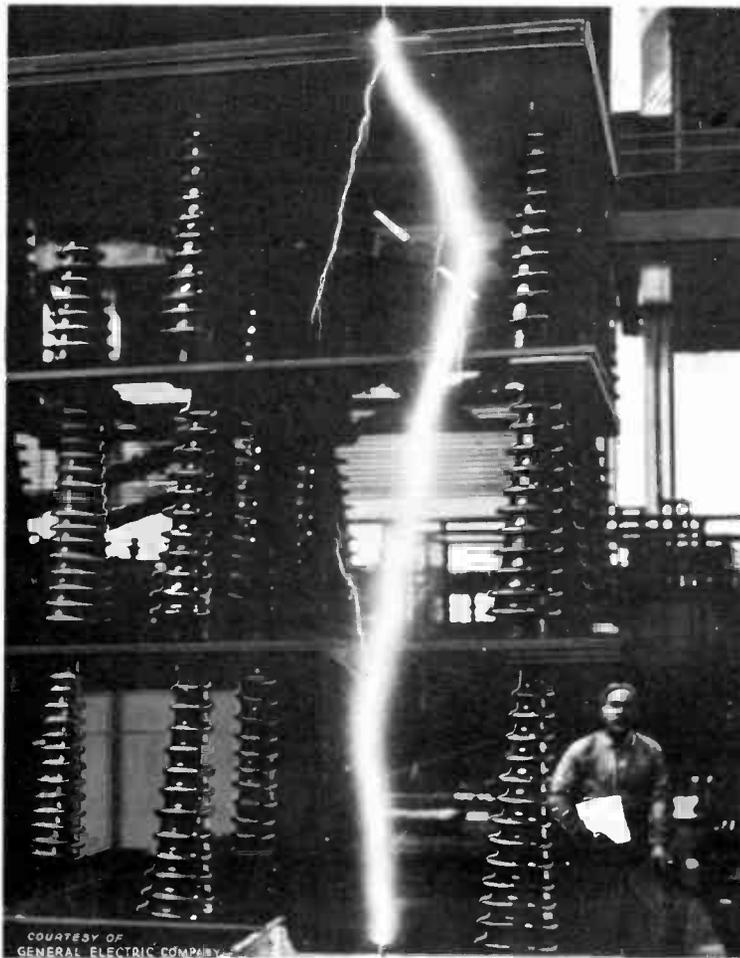
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## **How Current Flow depends on Resistance and Conductance**

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