sengers carried, and with the improvements now adopted by our railway companies in constructing elastic curves, as stated by Mr. Nystrom, in the place of rigid ones, steel bridges and well-ballasted road-beds, all risks are reduced to a minimum.

ELECTRO-DYNAMICS.

By JOHN W. NYSTROM.

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The object of this paper is to criticise the electro-dynamics advanced by Count Du Moncel in his work on "Electricity as a Motive Power," page 297, English edition, and to show the confusion in which that subject is yet involved.

The Count Du Moncel gives three formulas on page 299, intended to express the quantity of work accomplished by an electric current, namely as follows:

$$K = RI^2 \quad 1.$$

$$K = \frac{E^2}{R}. \quad 2.$$

$$K = EI. \quad 3.$$

K = work expressed in kilogrammeters.

R = resistance in the conductor expressed in ohms.

I = intensity of current expressed in ampères.

E = electro motive force expressed in volts.

No formulas can express quantity of work without representing the three simple elements—*force, velocity* and *time*, and as the time is wanting in Count Du Moncel's formulas, they cannot express work.

In the simplest formula for work, namely, $K = FS$, or the product of force and space, the time is included in the space S , which is the product of velocity and time. No work can be accomplished without time.

Work is transformed into power by eliminating the time, and the power is thus expressed "work per unit of time," and therefore no work can be transformed into power without dividing it with the time in which it is accomplished, but the Count divides work by the acceleratrix of gravity, and calls the quotient *power*, namely, as follows:

$$P = \frac{RI^2}{g}. \quad 4.$$

$$P = \frac{E^2}{gR}. \quad 5.$$

$$P = \frac{EI}{g}. \quad 6.$$

P = power in effects, which is expressed in kilogrammeters per second.

To divide work with the constant acceleratrix of gravity $g = 9.81$ meters per second, which is velocity, will give a quotient of momentum of time FT , when a force F acts for a time T upon a mass free to move. Therefore, the formulas 4, 5 and 6 cannot express power, or the work done per unit of time, when formulas 1, 2 and 3 mean work. It appears that the first three formulas mean *power*, which, multiplied by time T seconds, will give work.

The term *intensity* of current is evidently intended to mean a definite physical quantity, which should have a definite unit of measure, but *intensity* is applied to heat, light, and other phenomena without a definite meaning.

It is evident from the formulas, and also by the mode of measuring *intensity* of current by a galvanometer, that *intensity* means velocity of the electric current, and can, consequently, be expressed by any unit of length per unit of time. *Ampère* is the unit of measure of *intensity* of current, which can be expressed by a unit of velocity. The present value of one *Ampère* is, or should be, a velocity of 1,000 kilometers per second. Therefore, the term *intensity* should be abolished in that connection, and call it what it really is, namely, *velocity* of current, and denote the same with V instead of I , which would make the expression intelligible and definite.

Electromotive force is an expression of a definite physical quantity, which can be measured by any unit of weight, but the unit *volt* does not convey an idea of a definite unit of weight or force. The electromotive force of one *volt* is a weight or force of about one milligram. The term *volt* should therefore be abolished in that connection, and call it what it really is, namely, *milligram*, and the electromotive force should be denoted by F , which means force. These proposed changes would make the subject intelligible and definite, like in mechanics, where we have the well-known physical element *force*, *velocity* and *time*, the combination of which, give the functions *power*, *space* and *work*.

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The old and new forms of electro dynamics would compare as follows :

	<i>Old form.</i>		<i>New form.</i>	
Power.	$\left\{ \begin{array}{l} P = \frac{RI^2}{g}. \end{array} \right.$	1.	$P = V^2.$	1.
	$\left\{ \begin{array}{l} P = \frac{E^2}{gR}. \end{array} \right.$	2.	$P = \frac{F^2}{R}.$	2.
	$\left\{ \begin{array}{l} P = \frac{EI}{g}. \end{array} \right.$	3.	$P = FV.$	3.
Work.	$\left\{ \begin{array}{l} K = RI^2. \end{array} \right.$	4.	$K = RV^2T.$	4.
	$\left\{ \begin{array}{l} K = \frac{E^2}{R}. \end{array} \right.$	5.	$K = \frac{F^2T}{R}.$	5.
	$\left\{ \begin{array}{l} K = EI. \end{array} \right.$	6.	$K = FVT.$	6.
Resistance.	$\left\{ \begin{array}{l} R = \frac{E}{I}. \end{array} \right.$	7.	$R = \frac{F}{V}.$	7.
	$\left\{ \begin{array}{l} R = \frac{gP}{I^2}. \end{array} \right.$	8.	$R = \frac{P}{V^2}$	8.
	$\left\{ \begin{array}{l} R = \frac{E^2}{gP}. \end{array} \right.$	9.	$R = \frac{F^2}{P}.$	9.
Electro motive force.	$\left\{ \begin{array}{l} E = RI. \end{array} \right.$	10.	$F = RV.$	10.
	$\left\{ \begin{array}{l} E = \sqrt{gRP}. \end{array} \right.$	11.	$F = \sqrt{PR}.$	11.
	$\left\{ \begin{array}{l} E = \frac{gP}{I}. \end{array} \right.$	12.	$F = \frac{P}{V}.$	12.
Velocity of current.	$\left\{ \begin{array}{l} I = \frac{E}{R}. \end{array} \right.$	13.	$V = \frac{F}{R}.$	13.
	$\left\{ \begin{array}{l} I = \sqrt{\frac{gP}{R}}. \end{array} \right.$	14.	$V = \sqrt{\frac{P}{R}}.$	14.
	$\left\{ \begin{array}{l} I = \frac{gP}{E}. \end{array} \right.$	15.	$V = \frac{P}{F}.$	15.
Time of operation in seconds.			$\left\{ \begin{array}{l} T = \frac{K}{RV^2}. \end{array} \right.$	16.
			$\left\{ \begin{array}{l} T = \frac{KR}{F^2}. \end{array} \right.$	17.
			$\left\{ \begin{array}{l} T = \frac{K}{FV}. \end{array} \right.$	18.

P = power in effects, which is expressed by kilogrammeters per second. R = resistance of conductor in ohms.

$E = F$, the electromotive force expressed in milligrams.

$I = V$, the velocity of the electric current in thousands of kilometers per second; that is, when $V = 1$, the velocity is 1,000 kilometers per second.

T = time of operation in seconds. K = work in kilogrammeters. There are 75 French effects per horse-power.

There is a discrepancy between the old and new formulas for power, which is caused by Count Du Moncel dividing the work by the accelerator g , and calls the quotient *power*. Therefore, his formulas for work do not agree with his formulas for *power*.

The new form gives the *power* ten times greater than the old form, on account of the unit of electromotive force is assumed to be one milligram, and the unit of *velocity* 1,000 kilometers per second, which ought to be the units of these quantities.

Comparison of French and English units of power and work.

English.		French.	
Effects P.	Horse-power HP.	Effects P.	Horse power HP.
1	0·001818	0·1382	0·00184
550	1	76·2	1·0136
7·2334	0·00178	1	0·01333
542·47	0·9863	75	1

The numbers which express units of power are equal to the numbers which express units of work done per unit of time, but the quantities, power and work are different from one another, as explained above.

I beg leave to repeat what I have stated many times within the last twenty years, namely, that the science of electricity can never be cleared up before the electrical savants learn to understand dynamics. The greatest difficulty they have to encounter appears to be the distinction between *force*, *power* and *work*, which quantities they now confound with one another.

The difference between *force*, *power* and *work* is respectively the same as that between *length*, *surface* and *volume*.