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# Why Conventional Engineering Laws Should Be *Abandoned*, and the New Laws That Will Replace Them

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*Abstract-* There are three reasons why laws such as q = hΔT and **σ** = E**ε**, and parameters such as h and E, should be *abandoned*. 1. The laws are analogs of y = (y/x)x and, if y is a nonlinear function of x, analogs of (y/x) (such as h and E) are *extraneous variables* that greatly complicate problem solutions. 2. Parameters such as h and E were created by assigning dimensions to *numbers*, in violation of the modern view that dimensions must *not* be assigned to numbers. 3. The laws purport to describe how the numerical value *and* dimension of parameters are related when, in fact, equations can rationally describe only how the *numerical values* of parameters are related.

When conventional engineering laws are abandoned, they will be replaced by new laws described by the following: 1. They are *dimensionless* because parameter symbols in equations represent *only* numerical value. 2. They are analogs of y = f{x}. 3. They contain *no* analogs of y/x, and consequently they contain *no* extraneous variables. 4. They make it possible to *abandon* analogs of y/x (such as modulus and heat transfer coefficient), greatly simplifying the solution of nonlinear problems by reducing the number of variables. 5. They have *no* parameters that were created by assigning dimensions to numbers. 6. They are *inherently* dimensionally homogeneous because parameter symbols in equations represent *only* numerical value. 7. They state that the *numerical value* of parameter y is *always* a function of the *numerical value* of parameter x, and the function may be proportional, linear, or nonlinear.

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# Why Conventional Engineering Laws Should Be *Abandoned*, and the New Laws That Will Replace Them

Eugene F. Adiutori

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When conventional engineering laws are abandoned, they will be replaced by new laws described by the following: 1. They are *dimensionless* because parameter symbols in equations represent *only* numerical value. 2. They are analogs of y = f{x}. 3. They contain *no* analogs of y/x, and consequently they contain *no* extraneous variables. 4. They make it possible to *abandon* analogs of y/x (such as modulus and heat transfer coefficient), greatly simplifying the solution of nonlinear problems by reducing the number of variables. 5. They have *no* parameters that were created by assigning dimensions to numbers. 6. They are *inherently* dimensionally homogeneous because parameter symbols in equations represent *only* numerical value. 7. They state that the *numerical value* of parameter y is *always* a function of the *numerical value* of parameter x, and the function may be proportional, linear, or nonlinear.

## I. Conventional Engineering Laws—Why and When They Work Well, and Why and When They Do *Not* Work Well

Conventional engineering laws work well when applied to phenomena that exhibit *proportional* behavior because laws such as Eqs. (1) and (2) are *proportional* equations, and proportional equations accurately describe proportional behavior.

$$q = h\Delta T \tag{1}$$

$$\sigma = E\varepsilon \tag{2}$$

Conventional engineering laws do *not* work well when applied to phenomena that exhibit *nonlinear* behavior because laws such as Eqs. (1) and (2) are proportional equations, and proportional equations *cannot* describe nonlinear behavior. For example, if q is a nonlinear function of ΔT (as in natural convection, condensation, and boiling), Eq. (1) does *not* state that q is a nonlinear function of ΔT. It states *only* that h is a symbol for q/ΔT—ie states *only* that h and q/ΔT are *identical* and *interchangeable*.

## II. Parameter Symbolism in Conventional Engineering

Since the beginning of science, scientists and engineers have agreed that parameter symbols in equations represent numerical values *and* dimensions. Therefore the meaning of equations such as Eqs. (1) and (2) should be described in the following rigorously correct manner:

*The numerical value and dimension of q equal the numerical value and dimension of h times the numerical value and dimension of ΔT.*

*The numerical value and dimension of* ***σ*** *equal the numerical value and dimension of E times the numerical value of* ***ε****.*

In the rest of this article, the meaning of conventional engineering equations is oftentimes described in the above rigorously correct manner in order to illustrate that Hooke and Newton were correct—dimensions *cannot* rationally be multiplied or divided.

## III. The First Conventional Engineering Law

Equation (1) was the first conventional engineering law.

$$q = h\Delta T \tag{1}$$

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It was published in 1822 in Fourier's treatise *The Analytical Theory of Heat* [1a][1]. However, the meaning of Eq. (1) has changed considerably since 1822. Until sometime near the beginning of the twentieth century, Eq. (1) meant:

- It applies *only* if heat transfer is by the steady-state forced convection of ambient air flowing over a solid, warm body.
- It is *always* a proportional equation. It states that the numerical value and dimension of q are *always* proportional to the numerical value and dimension of ΔT, and the numerical value and dimension of h are *always* the proportionality *constant*.
- h is *always* a symbol for q/ΔT—ie h and q/ΔT are *always* identical and interchangeable.

Since sometime near the beginning of the twentieth century, Eq. (1) has meant:

- It applies to *all* forms of convection heat transfer.
- It states that the numerical value and dimension of q *always* equals the numerical value and dimension of h times the numerical value and dimension of ΔT.
- It may or may *not* be a proportional equation.
- The relationship between q and ΔT may be proportional, linear, or nonlinear.
- h may be a constant or a *variable* dependent on ΔT.
- If q is *not* proportional to ΔT (as in natural convection, condensation, and boiling), Eq. (1) reveals *only* that h is *always* a symbol for q/ΔT—ie reveals *only* that h and q/ΔT are *always identical* and *interchangeable*.

## IV. Why Equations Could *Not* Describe How Parameters Are Related Until the Nineteenth Century

Until the nineteenth century, scientists and engineers agreed that equations *cannot* describe how parameters are related because parameter symbols in equations represent numerical value *and* dimensions, and it was globally agreed that dimensions *cannot* rationally be multiplied or divided. That is why Hooke's law is a proportion rather than an equation. It is also why Newton's second law of motion published in Newton [3] is *not* force equals mass times acceleration. It is acceleration is proportional to force.

## V. How Fourier made it Possible to Create Equations that Quantitatively Describe how Parameters are Related

Early in the nineteenth century, Fourier conceived the *revolutionary* views that parameters in equations *can* be multiplied and divided, and dimensions *can* rationally be assigned to numbers. This made it possible, for the very first time, to create equations that quantitatively describe how parameters are related. Fourier's entire nearly 500 page treatise *The Analytical Theory of Heat* [1] is predicated on:

- His revolutionary view that dimensions can rationally be multiplied and divided.
- His revolutionary view that dimensions can rationally be assigned to numbers.
- The prevailing view that parameter symbols in equations represent numerical value *and* dimension.
- The prevailing view that parametric equations *must* be dimensionally homogeneous.

Fourier made no effort to prove the validity of his revolutionary views. In his entire treatise, Fourier's [1b] only defense of his revolutionary views is the following paragraph:

*. . . every undetermined magnitude or constant has one dimension proper to itself, and the terms of one and the same equation could not be compared if they had not the same exponent of dimensions. . . (This view of homogeneity) is the equivalent of the fundamental lemmas (axioms) which the Greeks have left us without proof.*

Fourier's treatise does *not* include the axioms the Greeks left us without proof, it does *not* specify which axioms Fourier referred to, and it does *not* cite a reference where the pertinent axioms could be found. Presumably Fourier's colleagues accepted his unproven views because, using his revolutionary views, he was able to solve heat transfer problems that had never been solved. His revolutionary and unproven views are fundamental and important views in modern engineering science.

[1] Adiutori [2] states that Fourier made so many contributions to modern engineering science that he should be considered the father of modern engineering. For example, Fourier should be credited with the concepts of flux, heat transfer coefficient, thermal conductivity, dimensional homogeneity, the solution of boundary condition problems, the sciences of convective and conductive heat transfer, and the methodology required to create dimensionally homogeneous laws.

## VI. How Fourier Created the First Conventional Engineering Law

Fourier performed experiments in convection heat transfer. His purpose was to determine a dimensionally homogeneous equation/law that describes how the numerical value and dimension of convective heat flux are related to the numerical value and dimension of the boundary layer temperature difference.

From his data, Fourier concluded that, if heat transfer is by the steady-state forced convection of ambient air flowing over a solid, warm body, the relationship between the numerical value and dimension of q and the numerical value and dimension of ΔT is *always* proportional, and is described by Eq. (3) in which c is the numerical value of the proportionality *constant*.

$$q = c\Delta T \tag{3}$$

Fourier was not satisfied with Eq. (3) because it is *not* dimensionally homogeneous. Fourier recognized that Eq. (3) could be transformed to a homogeneous equation only if it were rational to assign dimensions to numbers, and rational to multiply and divide dimensions. Consequently, Fourier conceived the revolutionary view that dimensions can rationally be assigned to numbers, and dimensions can rationally be multiplied and divided. To *number* c in Eq. (3), Fourier assigned the symbol h, the dimensions of (q/ΔT), and the name *coefficient*, resulting in Eq. (4), the dimensionally homogeneous law of forced convection heat transfer to ambient air flowing in steady-state over a solid, warm body.[2]

$$q = h\Delta T \tag{4}$$

In Fourier's view, Equation (4) states that, if heat transfer is by the steady-state forced convection of ambient air flowing over a solid, warm body, the numerical value and dimension of q are *always* proportional to the numerical value and dimension of ΔT, and the numerical value and dimension of h are *always* the *constant* of proportionality. Fourier [1c] defined h in the following:

*We have taken as the measure of the external conducibility of a solid body a coefficient h, which denotes the quantity of heat which would pass, in a definite time (a minute), from the surface of this body, into atmospheric air, supposing that the surface had a definite extent (a square metre), that the constant temperature of the body was 1, and that of the air 0, and that the heated surface was exposed to a current of air of a given invariable velocity.*

## VII. Proof That h Is Unnecessary and Undesirable

In natural convection heat transfer, heat flux and temperature difference are often determined by *first* determining the heat transfer coefficient from a chart of Nusselt number vs Rayleigh number. If the chart is used to determine heat transfer coefficient given temperature difference, the chart can be read in a direct manner because Rayleigh number is independent of heat flux. But if the chart is used to determine heat transfer coefficient given heat flux, it *cannot* be read in a direct manner because temperature difference is implicit on both axes (since the Nusselt number hD/k (ie qD/ΔTk) is *inversely* proportional to ΔT, and the Rayleigh number is *directly* proportional to ΔT). Therefore the chart *must* be read in an *indirect* manner.

However, h can be *eliminated* from the chart by plotting the *product* of Nusselt number and Rayleigh number vs Rayleigh number. This *eliminates* h because it eliminates the ΔT in the denominator of Nusselt number, leaving qD/k in place of qD/ΔTk .

*After* h has been *eliminated* from the chart, the chart of Nusselt number times Rayleigh number vs Rayleigh number can be read *directly* to determine *heat flux* given temperature difference, or *temperature difference* given heat flux.

*Q.E.D. h is unnecessary and undesirable.*

## VIII. Proof That Fluid Friction Factor f Is Unnecessary and Undesirable

In conventional engineering, if fluid flow is laminar, the relationship between fluid flow and pressure drop is described by a simple equation. But if fluid flow is *turbulent*, the relationship between flow rate and pressure drop is *nonlinear*, and flow rate or pressure drop is usually determined by *first* determining the fluid friction factor f from the Moody chart, a chart of f vs Reynolds number. If the flow rate is given and f is to be determined, the Moody chart can be read in a direct manner because the Reynolds number is independent of pressure drop. But if the pressure drop is given and f is to be determined, the Moody chart *cannot* be read in a direct manner because fluid flow rate is implicit on both axes. Therefore the chart *must* be read in an *indirect* manner.

[2] Although Newton is generally credited with both h and Eq. (4), Adiutori [4] and Bejan [5] credit Fourier with both h and Eq. (4). Equation (4) is generally said to be "Newton's law of cooling", but Equation (4) cannot be Newton's law of cooling because cooling is transient behavior, and Eq. (4) is a steady-state equation.

However, since f is *inversely* proportional to flow rate squared, and Reynolds number is *directly* proportional to flow rate, f can be *eliminated* from the chart by plotting the *product* of f and Reynolds number squared vs Reynolds number. This *eliminates* f from the chart because it *eliminates* flow rate in the f denominator.

After f has been *eliminated* from the chart, the chart can be read *directly* to determine *flow rate* given pressure drop, or *pressure drop* given flow rate.

*Q.E.D. f is unnecessary and undesirable.*

## IX. Proof That Hooke and Newton Were *Correct*—Dimensions *Cannot* Rationally Be Multiplied Or Divided

Multiplication is repeated addition. Six times eight means *add* eight six times. Therefore things that cannot be added cannot be multiplied.

It is generally agreed that dimensions *cannot* rationally be added. Therefore dimensions *cannot* rationally be multiplied because they *cannot* rationally be added, and multiplication is repeated addition.

Since six times eight means *add* eight six times, "kilograms times meters" *must* mean *add* meters kilograms times. Because "add meters kilograms times" has no meaning, dimensions *cannot* rationally be multiplied.

Since twelve divided by four means how many fours are in twelve, "meters divided by seconds" *must* mean how many seconds are in meters. Because "how many seconds are in meters" has no meaning, dimensions cannot rationally be divided.

*Q.E.D. Dimensions cannot rationally be multiplied or divided.*

## X. Why Laws Such As $q = h\Delta T$ and $\sigma = E\varepsilon$ Are Anathema In Mathematics and Engineering

In conventional engineering, Eq. (5) is the law of convection heat transfer.

$$q = h\Delta T \tag{5}$$

Rearranging Eq. (5) results in Eq. (6).

$$h = (q/\Delta T) \tag{6}$$

Combining Eqs. (5) and (6) results in Eq. (7).

$$q = (q/\Delta T)\Delta T \tag{7}$$

Equations (5), (6), and (7) are *identical*. All three equations are analogs of Eq. (8), and h and $q/\Delta T$ are analogs of (y/x).

$$y = (y/x)x \tag{8}$$

Equation (8) is anathema in mathematics and engineering because, if parameter y is a nonlinear function of parameter x, parameter (y/x) is an *extraneous variable*, and it complicates problem solutions.

Consequently *all* laws that are analogs of Eq. (8), and *all* parameters that are analogs of (y/x), should be *abandoned* because, if parameter y is a nonlinear function of parameter x, parameter (y/x) is an *extraneous variable*, and it complicates problem solutions.

## XI. How the Modern View of Dimensional Homogeneity Differs from Fourier's View

Fourier [1b] is generally credited with the modern view of dimensional homogeneity. However, the modern view of dimensional homogeneity differs from Fourier's view in one important way. In the modern view, it is *irrational* to assign dimensions to numbers. In 1951, Langhaar [6] stated:

*Dimensions must not be assigned to numbers, for then any equation could be regarded as dimensionally homogeneous.*

## XII. Why Laws Such As Eqs. (9) and (10) *Violate* the Modern View of Dimensional Homogeneity, and Consequently Are *Irrational*

Laws such as Eqs. (9) and (10) are *irrational* because parameters such as h and E were created by assigning dimensions to numbers, in violation of the modern view that "Dimensions *must not* be assigned to numbers, for then any equation could be regarded as dimensionally homogeneous."

$$q = h\Delta T \tag{9}$$

$$\sigma = E\varepsilon \tag{10}$$

Consequently *all* laws that are analogs of Eq. (8), and *all* parameters that are analogs of (y/x) in Eq. (8), *should* be abandoned because they were created by assigning dimensions to numbers, in violation of the modern view that dimensions must *not* be assigned to numbers.

However, laws that are analogs of Eq. (8), and parameters that are analogs of (y/x) in Eq. (8), have *not* yet been abandoned in spite of the fact that they have, for almost a century, violated the prevailing view that dimensions must *not* be assigned to numbers.

## XIII. Why Engineering Parameters *Cannot* be Proportional

It is axiomatic that pigs *cannot* be proportional to airplanes because pigs and airplanes are different things, and different things *cannot* be proportional. Therefore it is axiomatic that parameter y *cannot* be proportional to parameter x because parameter y and parameter x are different things, and different things *cannot* be proportional. However, the *numerical value* of parameter y *can* be proportional to the *numerical value* of parameter x because different *numerical values* are *not* different *things*.

## XIV. Hooke's Error

In 1676, Hooke [7] concluded from his data that, in the elastic region, stress is proportional to strain. Hooke was *wrong*. Stress *cannot* be proportional to strain because stress and strain are different *things*, and different *things* *cannot* be proportional. Hooke should have concluded the following:

*In the elastic region, the numerical value of stress is proportional to the numerical value of strain.*

## XV. Why Equations *Cannot* Describe How Engineering Parameters Are Related

It is axiomatic that equations *cannot* describe how pigs and airplanes are related because pigs and airplanes are different things, and different things *cannot* be related. Therefore it is axiomatic that equations *cannot* describe how parameter y is related to parameter x because parameters y and x are different *things*, and different *things* cannot be related. However, equations *can* describe how the *numerical value* of parameter y is related to the numerical value of parameter x because different *numerical values* are *not* different *things*.

## XVI. Fourier's Error, and the Heat Transfer Law He Should Have Conceived

From his data, Fourier [1a] concluded that, in steady-state forced convection heat transfer from a warm, solid body to ambient air, heat flux is *always* proportional to temperature difference.

Fourier was *wrong*. Heat flux *cannot* be proportional to temperature difference because they are different things, and different things *cannot* be proportional. Fourier should have concluded that:

- The *numerical value* of heat flux is proportional to the *numerical value* of temperature difference.
- Parameter symbols in equations represent *only* numerical value. Therefore rational parametric equations are *inherently* dimensionally homogeneous because they are dimensionless.
- If an equation is quantitative, the dimension units that underlie parameter symbols *must* be specified in an accompanying nomenclature.
- Equation (11), Fourier's law of steady-state forced convection heat transfer to ambient air, is *irrational.* Equations *cannot* rationally describe how heat flux and temperature difference are related because they are different things, and different things *cannot* be related.

$$q = h\Delta T \tag{11}$$

- Equation (12) is the law Fourier should have conceived. It should have meant that the numerical value of q is *always* proportional to the numerical value of ΔT, and the numerical value of c is the constant of proportionality.

$$q = c\,\Delta T \tag{12}$$

Fourier rejected Eq. (12) because parameter symbols represented numerical value *and* dimension, and therefore Eq. (12) was *not* dimensionally homogeneous.

## XVII. Ohm's Error

From his data, Ohm [8] concluded that electromotive force is proportional to electric current. He was *wrong*. Electromotive force cannot be proportional to electric current because they are different things, and different things cannot be proportional. Ohm should have concluded that the *numerical value* of electromotive force is proportional to the *numerical value* of electric current.

In modern conventional engineering, the dimensionally homogeneous Eq. (13) is referred to as Ohm's law. It applies *only* if E is proportional to I.

$$E = IR \tag{13}$$

If E is not proportional to I, charts of Eq. (14) are often used in spite of the fact that, in modern conventional engineering, Eq. (14) is *not* dimensionally homogeneous.

$$I = f\{E\} \tag{14}$$

## XVIII. The Purpose of Engineering Laws

The purpose of engineering laws is to identify the primary parameters, and to describe how the numerical values of the primary parameters are related. The relationship between the numerical values of primary parameters cannot generally be described in a specific way because most engineering phenomena exhibit more than one type of relationship.

For example, the relationship between the numerical value of convective heat flux and the numerical value of temperature difference may be proportional, linear, or nonlinear. The relationship between the numerical value of stress and the numerical value of strain may be proportional, linear, or nonlinear. The relationship between the numerical value of electromotive force and the numerical value of electric current may be proportional, linear, or nonlinear.

## XIX. A Mathematical Analog of the New Laws

Assuming that symbols in equations represent numerical value but *not* dimension, Eq. (15) states that the numerical value of y is *always* a function of the numerical value of x, and the function may be proportional, linear, or nonlinear.

$$y = f\{x\} \tag{15}$$

Equation (15) is a mathematical analog of the new laws.

## XX. The New Laws of Engineering

The new law of convection heat transfer is Eq. (16). Equation (16a) states that the numerical value of heat flux is *always* a function of the numerical value of temperature difference, and the function may be proportional, linear, or nonlinear. And similarly for Eq. (16b). In other words, Eq. (16) applies to *all* forms of convection heat transfer.

$$q = f\{\Delta T\} \tag{16a}$$

$$\Delta T = f\{q\} \tag{16b}$$

The new law of stress and strain is Eq. (17). Equation (17a) states that the numerical value of stress is *always* a function of the numerical value of strain, and the function may be proportional, linear, or nonlinear. And similarly for Eq. (17b). In other words, Eq. (17) applies in *both* the elastic and inelastic regions.

$$\sigma = f\{\varepsilon\} \tag{17a}$$

$$\varepsilon = f\{\sigma\} \tag{17b}$$

The new law of resistive electrical behavior is Eq. (18). Equation (18a) states that the numerical value of electromotive force is *always* a function of the numerical value of electric current, and the function may be proportional, linear, or nonlinear. And similarly for Eq. (18b). In other words, Eq. (18) applies to *all* conductors and semi-conductors.

$$E = f\{I\} \tag{18a}$$

$$I = f\{E\} \tag{18b}$$

## XXI. Why the New Engineering Laws Will Replace Conventional Laws

The new engineering laws, such as Eqs. (16) to (18), will replace conventional laws because:

- Conventional laws are analogs of y = (y/x)x. Therefore if parameter y is a nonlinear function of parameter x, analogs of (y/x) (such as h and E) are *extraneous variables* that greatly complicate problem solutions. The new laws have *no* analogs of (y/x), and therefore they have *no* extraneous variables.
- Conventional laws and parameters such as h, E, and R were created by assigning dimensions to numbers, in violation of the modern view that dimensions *must not* be assigned to numbers. The new laws contain *no* parameters created by assigning dimensions to numbers.
- Parameters such as h, E, R, and f are *unnecessary* and *undesirable*. They are unnecessary because, as demonstrated in Sections 7 and 8, problems are readily solved without them. They are undesirable because, as demonstrated in Sections 7 and 8, when a conventional law is applied to nonlinear behavior, parameters such as h, E, R, and f are *extraneous variables* that complicate problem solutions. In the new laws, there are *no* parameters such as h, E, R, and f.
- If Eq. (19) is used to solve a problem that concerns boiling heat transfer, the solution will include the *three* thermal variables q, q/ΔT, and ΔT (q/ΔT is a variable because the relationship between q and ΔT is nonlinear). If Eq. (20) is used to solve the problem, the solution will include only the *two* thermal variables q and ΔT. (And similarly for other branches of engineering.)

$$q = h\Delta T \tag{19}$$

$$q = f\{\Delta T\} \tag{20}$$

  It is axiomatic that any problem that can be solved using the *three* thermal variables (q, q/ΔT, and ΔT) can also be solved using the *two* thermal variables (q and ΔT). It is also axiomatic that it is *much* more difficult to solve problems that concern *three* variables than problems that concern *two* variables.

- Conventional engineering laws are irrational because they purport to describe how parameters are related, in spite of the fact that equations *cannot* rationally describe how parameters are related. Equations can rationally describe *only* how the *numerical values* of parameters are related. The new laws describe *only* how the numerical values of parameters are related.
- The new laws make it much easier to learn engineering science because there are fewer parameters to learn about and to think about and to apply, and because the new laws make it possible to solve nonlinear problems with the variables *separated*, the preferred methodology in mathematics.

## XXII. How Texts Based On the Laws of Conventional Engineering Can Be Transformed to Texts Based On the New Laws

Texts based on conventional engineering laws can be transformed to texts based on the new laws by modifying the texts so that:

- Parameter symbols represent *only* numerical value.
- Laws are analogs of y = f{x}.
- Primary parameters are *always separated*.
- *No parameter* is created by assigning dimensions to numbers.
- *No parameter* is created by combining primary parameters.
- If an equation is quantitative, the dimension units that underlie parameter symbols are specified in the nomenclature.

## XXIII. How a Heat Transfer Text Based On Conventional Laws Can Be Transformed To a Text Based On the New Laws

A heat transfer text based on conventional engineering laws can be transformed to a text based on the new laws by modifying the text in the following ways:

- Replace Eq. (21) with Eq. (22).

$$q = h\Delta T \tag{21}$$

$$q = f\{\Delta T\} \tag{22}$$

- Because the numerical value of $q_{conduction}$ is *generally* proportional to the numerical value of dT/dx, Eq. (23) is generally the *dimensionless* law of conduction heat transfer. If there are materials that do *not* exhibit the proportional relationship indicated by Eq. (23), Eq. (24) replaces Eq. (23).

$$q_{conduction} = k\,(dT/dx) \qquad (23)$$

$$q_{conduction} = f\{dT/dx\} \qquad (24)$$

- In the nomenclature, state that parameter symbols represent *only* numerical value. Also state that if an equation is quantitative, the dimension units that underlie parameter symbols are specified in the nomenclature.
- In *all* equations and charts in which h is explicit or implicit (as in Nusselt number), replace h by q/ΔT, then separate q and ΔT. When Eq. (22) is the law of convection heat transfer, *all* parameter groups that include h are *abandoned*.
- In *all* equations and charts in which k/t is explicit or implicit, replace k/t by q/ΔT, then separate q and ΔT.
- Separating q and ΔT in Eq. (25) results in Eq. (26). Replace Eq. (25) with Eq. (26)

$$U = 1/(1/h_1 + t/k + 1/h_2) \qquad (25)$$

$$\Delta T_{total} = \Delta T_1\{q\} + \Delta T_{wall}\{q\} + \Delta T_2\{q\} \qquad (26)$$

Equations (25) and (26) are *identical*. They differ only because q and ΔT are *combined* in Eq. (25), and *separated* in Eq. (26). Equation (26) states that the numerical value of $\Delta T_{total}$ equals the numerical value of $\Delta T_1$ plus the numerical value of $\Delta T_{wall}$ plus the numerical value of $\Delta T_2$.

*All* problems that can be solved using Eq. (25) *and* h can also be solved using Eq. (26) and *not* h. If q{ΔT} is a proportional equation, the solution is quite simple using either Eq. (25) *and* h or Eq. (26) and *not* h. However, if q{ΔT} is a nonlinear equation, the solution is much simpler using Eq. (26) and *not* h.

## XXIV. Conclusions

The new laws will replace conventional laws because they result in a more rational and much simpler science of engineering.

## Symbols

*Note:* Depending on the context in which a parameter symbol is used, the symbol may represent numerical value *and* dimension, or may represent *only* numerical value.

| | |
|---|---|
| c | pure number |
| E | modulus σ/ε, or electromotive force |
| $E_{elastic}$ | elastic modulus, σ/ε in the elastic region |
| h | heat transfer coefficient, q/ΔT |
| I | electric current |
| q | heat flux |
| R | electrical resistance, E/I |
| T | temperature |
| x | unidentified parameter |
| y | unidentified parameter |

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