Why modern engineering laws are *irrational*, and the *rational* laws that will replace them.

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Abstract
For more than one hundred years, engineering laws have been founded on the following tenets: (1) Dimensions *can* be multiplied or divided. (2) Dimensions *can* be assigned to numbers. (3) *Faux* parameters such as *h* and *E can* be created. (4) *Proportional* laws *can* be used to solve *nonlinear* problems. (5) Parameter symbols in equations *must* represent numerical values *and* dimensions. (6) Equations *must* be dimensionally homogeneous, but proportions need *not* be dimensionally homogeneous. Critical appraisal of these tenets proves that the tenets and the laws founded on them are *irrational*. This article presents new tenets and laws that are *rational*. The new laws are analogs of $y = f\{x\}$ which states that the *numerical value* of parameter *y* is a function of the *numerical value* of parameter *x*, and the function may be proportional, linear, or nonlinear. The new laws *require* that parameter symbols in ***all*** equations and proportions represent ***only*** numerical values, and *require* that ***all*** *faux* parameters such as *h* and *E* be ***abandoned***. If parameter symbols are in *quantitative* equations, the dimension units that underlie parameter symbols ***must*** be specified. If parameter symbols are in *qualitative* equations *or* proportions, dimension units are ***not*** specified. This article explains how modern engineering textbooks can be transformed to textbooks founded on laws that are analogs of $y = f\{x\}$, and parameter symbols that represent ***only*** numerical values.

Key words: Engineering science, *Faux* parameters, Fourier, Irrational laws, Parameter symbols, Proportions, Rational laws, Tenets.

1. Introduction

Until 1822, ***all*** engineering laws were ***proportions.*** A book by Fourier (1822) proposed a paradigm shift in which engineering laws would ***also*** be *equations*. Fourier created *faux* parameter *h* and Eq. (1), the *first* engineering law in the form of an equation, and the first *faux* parameter. The methodology he used to create *faux* parameter *h* and Eq. (1) was later used to create other *faux* parameters and laws.[1] Fourier warned that because Eq. (1) is a *proportional* equation, it applies ***only*** if *q* is proportional to ΔT.

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

[1] Most American heat transfer texts state that Eq. (1) is "Newton's law of cooling" and cite Newton (1701). Equation (1) *cannot* be "Newton's law of cooling" because cooling is a *transient* phenomenon, and Eq. (1) is a *steady-state* equation, and because until 1822, scientists and engineers globally agreed that parametric equations such as Eq. (1) are ***irrational***. The origin of *h* and Eq. (1) is described in Adiutori (1990) and Adiutori (2005).

This article:

- Describes and appraises engineering science from the Middle Ages until now.

- Explains why modern engineering laws are *irrational*.

- Describes the *rational* engineering laws that will replace modern engineering laws.

- Explains how modern engineering textbooks can be transformed to textbooks founded on the proposed engineering laws, and parameter symbols that represent ***only*** numerical values.

2. Engineering science from the Middle Ages until 1822.

From the Middle Ages until 1822:

- ***All*** engineering laws were ***proportions***. Scientists and engineers such as Galileo, Hooke, and Newton agreed that equations ***cannot*** describe how parameters are related because parameter dimensions ***cannot*** rationally be multiplied and/or divided.

- Scientists and engineers agreed that proportions that describe how two parameters are related *can* describe engineering phenomena because they do *not* require that parameter dimensions be multiplied or divided.

3. Why engineering proportions *must* be dimensionless

Engineering proportions ***must*** be dimensionless because parameter dimensions ***cannot*** be proportional, and because proportions ***cannot*** be dimensionally homogeneous. The ***correct expression*** of engineering laws that prevailed in the 18th century are:

- Hooke's law in Hooke (1676): The *numerical value* of strain is proportional to the *numerical value* of stress.

- Newton's law of cooling in Newton (1701): The *numerical value* of the rate of temperature change of a warm body is proportional to the *numerical value* of the temperature difference between the warm body and the coolant.

- Newton's second law of motion in Newton (1726): The *numerical value* of acceleration is proportional to the *numerical value* of force.

4. The first engineering law in the form of an equation

4.1 Fourier's experiment and results

Fourier (1822) performed an experiment in which a warm, solid body is cooled by the steady-state flow of ambient air. He concluded that the heat flux is proportional to the temperature difference between the surface of the warm body and the ambient air. Correlation of his data resulted in Proportion (2) and Eq. (3).

$$q \ \alpha \ \Delta T \tag{2}$$

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

Newton and his colleagues would have been satisfied with Proportion (2) because it does *not* require that parameter dimensions be multiplied or divided. But Fourier wanted an equation that is ***always*** dimensionally homogeneous, and Eq. (3) is ***not*** dimensionally homogeneous.

4.2 How Fourier transformed dimensionally ***in***homogeneous Eq. (3) into dimensionally homogeneous Eq. (1)

Fourier recognized that he could transform Eq. (3) into a dimensionally homogeneous *equation* only if it were rational to:

- Multiply or divide parameter dimensions.

- Assign to *constant c* the dimensions that would make Eq. (3) dimensionally homogeneous.

To *constant c* in Eq. (3), Fourier assigned the symbol *h*, the name heat transfer coefficient, and the dimensions that made Eq. (3) dimensionally homogeneous, resulting in *faux* parameter *h* and Eq. (1), the *first* engineering law in the form of an equation. The methodology Fourier used to create *faux* parameter *h* and Eq. (1) was later used to create other engineering laws and *faux* parameters such as *E* and *R*.

4.3 How Fourier (1822) validated his revolutionary view that dimensions ***can*** be multiplied and/or divided, dimensions ***can*** be assigned to numbers, and parametric equations ***must*** be dimensionally homogeneous.

Fourier emphasized that he could ***not*** validate his revolutionary view that dimensions ***can*** be multiplied and/or divided, dimensions ***can*** be assigned to numbers, and parametric equations ***must*** be dimensionally homogeneous. However, in the following, Fourier states that ancient Greeks used similar methodology, but unfortunately they left ***no proof*** that their methodology is valid.

Article 160: *It must now be remarked that* ***every*** *undetermined* ***magnitude or constant*** *has one* ***dimension*** *proper to itself, and that the terms of one and the same equation could not be compared if they had not the same* ***exponent of dimension****. We have introduced this consideration into the theory of heat, in order to make our definitions more exact, and to serve to verify the analysis; it is derived from primary notions on quantities; for which reason, in geometry and mechanics, it is the equivalent of the fundamental lemmas which the Greeks have left us without proof.*

Fourier's nearly 500 page treatise is predicated on the validity of the fundamental lemmas of Greek methodology, yet he did *not* present the lemmas, *nor* did he cite a reference where the lemmas could be found.

4.4 Fourier's definition of *h*

Fourier (1822) defined h in the following:

Article 36. *We have taken as the measure of the external conducibilty 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. This value of h is determined by observation.* (The temperatures are degrees Reaumur.)

4.5 Why Fourier chose $q = h\Delta T$ instead of $q = h\{\Delta T\}\Delta T$

Fourier was a world class mathematician, and he knew that, if heat transfer is by natural convection, q is ***not*** proportional to ΔT, and h is ***not*** a constant—h is a *variable dependent on* ΔT. Fourier also knew that, in order that his law would apply to ***both*** forced convection ***and*** natural convection, the law would have to be Eq. (4) which *correctly* states that h may be a constant ***or*** a variable dependent on ΔT.

$$q = h\{\Delta T\}\Delta T \qquad (4)$$

Presumably, Fourier chose Eq. (1) because he knew that Eq. (4) would ***not*** be dimensionally homogeneous if h were a variable dependent on ΔT, and he wanted a law that is ***always*** dimensionally homogeneous.

4.6 Fourier's warning

Fourier warned that, because Eq. (1) is a *proportional* equation, it applies ***only*** if q is *proportional* to ΔT—ie ***only*** if h is a *constant*.

5. Engineering science from sometime near the end of the 19th century until now

5.1 The engineering community decided to ignore Fourier's warning

Sometime near the end of the 19th century, the engineering community decided to *ignore* Fourier's warning, and to apply *proportional* laws such as Eq. (1) even if the behavior is *nonlinear.*

5.2 How *proportional* laws are used to solve *nonlinear* problems in modern engineering

If the value of $h\{\Delta T\}$ is determined from a *nonlinear* $h\{\Delta T\}$ correlation, the value of q is determined from the calculated value of $h\{\Delta T\}$, the given value of ΔT, and ***Eq. (1)***.

Although the correct answer results, it is ***irrational*** to use Eq. (1) because it is a *proportional* equation, and $h\{\Delta T\}$ is a ***variable*** dependent on ΔT.

6. Why *h* and *E* are *faux* parameters.

As indicated by Eqs. (6) and (9), h and E are *not* parameters. They are *ratios of parameters*—i.e. they are *faux* parameters. h is a symbol for $q/\Delta T$, and E is a symbol for σ/ε. Note that Eqs. (7) and (10) are revealing forms of Eq. (5) and (8).

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

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

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

$$\sigma = E\varepsilon \tag{8}$$

$$\therefore E = \sigma/\varepsilon \tag{9}$$

$$\therefore \sigma = (\sigma/\varepsilon)\varepsilon \tag{10}$$

7. Tenets that have been the foundation of engineering laws for more than 100 years.

(1) Dimensions *can* be multiplied or divided.

(2) Dimensions *can* be assigned to numbers.

(3) *Faux* parameters such as *h* and *E can* be created.

(4) *Proportional* laws *can* be used to solve *nonlinear* problems.

(5) Parameter symbols in equations *must* represent numerical values *and* dimensions.

(6) Equations *must* be dimensionally homogeneous, but proportions need *not* be dimensionally homogeneous.

8. Why tenets that have been the foundation of engineering laws for more than 100 years are *irrational*, and the *rational* tenets that will replace them.

8.1 Tenets (1) and (1a)

Tenet (1): Dimensions *can* be multiplied or divided.
"Multiply six times eight." means "Add eight six times.". Therefore "Multiply meters times kilograms." *must* mean "Add kilograms meters times.". Because "Add kilograms meters times." has ***no meaning***, it is *irrational* to multiply dimensions.

"Divide twelve by four." means "How many fours are in twelve." Therefore "Divide meters by minutes." *must* mean "How many minutes are in meters." Because "How many minutes are in meters." has ***no meaning***, it is *irrational* to divide dimensions.

Tenet (1a): Parameter dimensions *cannot* be multiplied or divided. Only the ***numerical values*** of parameters can be multiplied or divided.

8.2 Tenets (2) and (2a)

Tenet (2): Dimensions *can* be assigned to numbers.
A book by Langhaar (1951) states: *Dimensions **must not** be assigned to **numbers**, for then any equation could be regarded as dimensionally homogeneous.*

Tenet (2a): Dimensions ***must not*** be assigned to numbers because then ***any*** equation could be dimensionally homogeneous.
Since sometime before 1951, the laws of modern engineering science *should* have been considered ***irrational*** because *faux* parameters such as *h* and *E* were ***created** by assigning dimensions to numbers*.

8.3 Tenets (3) and (3a):

Tenet (3): *Proportional* laws *can* be used to solve *nonlinear* problems.
(See Section 5.2).

Tenet (3a): It is *irrational* to solve *nonlinear* problems using *proportional* laws.

8.4 Tenets (4) and (4a)

Tenet (4): *Faux* parameters such as *h* and *E can* be created.
American heat transfer texts generally do *not* reveal what *h* is, presumably because authors generally assume that *h* is a *real* parameter. That is why nomenclatures in texts generally state

only that h is named "heat transfer coefficient". However, h is ***not*** a real parameter. h is a *faux* parameter, and nomenclatures in heat transfer texts *should* state "h is a symbol for $q/\Delta T$", as indicated by Eqs. (11) to (13). Note that Eqs. (11) and (13) are ***identical and interchangeable***.

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

$$\therefore h = (q/\Delta T) \tag{12}$$

$$\therefore q = (q/\Delta T)\Delta T \tag{13}$$

Equations (11) and (13) apply ***only*** if h (i.e. $q/\Delta T$) is a *constant*. If h *is* a variable dependent on ΔT, Equation (14) applies, but it would be *irrational* because it would *not* be dimensionally homogeneous.

$$\therefore q = (q/\Delta T)\{\Delta T\}\Delta T \tag{14}$$

Equations (11) and (13) are analogs of Eq. (15), and Eq. (14) is an analog of Eq. (16).

$$y = (y/x)x \tag{15}$$

$$y = (y/x)\{x\}x \tag{16}$$

In pure mathematics:

- Eq. (15) is used *only* if (y/x) is a *constant*.
- If (y/x) is a variable dependent on x, Eq. (16) is ***never*** used because (y/x) would be an ***extraneous*** *variable*.
- If (y/x) is a variable dependent on x, Eq. (17) is *always* used.

$$y = f\{x\} \tag{17}$$

The proposed laws are analogs of *desirable* Eq. (17), and the *de facto* laws of modern engineering are analogs of *undesirable* Eq. (16).

Tenet (4a): *Faux* parameters such as h (symbol for $q/\Delta T$) must *not* be used because when they describe linear or nonlinear behavior, they are *extraneous* ***variables*** that complicate problem solutions, and they result in laws that are ***not*** dimensionally homogeneous.

8.5 Tenets (5) and (5a):
Tenet (5): Parameter symbols in equations *must* represent numerical values *and* dimensions.

Tenet (5a): Parameter symbols in equations *must* represent ***only*** numerical values because ***only*** numerical values can be *multiplied or divided*, and ***only*** numerical values can be *related*.

8.6 Tenets (6) and (6a):
Tenet (6): Equations *must* be dimensionally homogeneous, but proportions need *not* be dimensionally homogeneous.

Tenet (6a): Equations *and* proportions are ***inherently*** dimensionally homogeneous because parameter symbols represent *only numerical values*.

9 Data, correlations, and Hooke's error

9.1 What are data?
Data are the *numerical values* of parameters measured in an experiment.

9.2 Are parameter dimensions data?
No. Parameter dimensions are *required information* ***only*** if parameter symbols are in ***quantitative*** equations. Parameter dimensions are ***not*** required information if parameter symbols are in ***qualitative*** equations or ***proportions***.

9.3 What can data correlations describe?
Data correlations can describe *only* how the *numerical values* of parameters are related. Data correlations *cannot* describe how numerical values *and* dimensions are related because:

- Dimensions ***cannot*** be related.

- Dimensions ***cannot*** be multiplied or divided

9.4 Dimensionally homogeneous proportions
All proportions are dimensionless and dimensionally homogeneous because ***all*** parameter symbols in proportions represent ***only*** numerical values.

9.5 Hooke's error
Hooke probably placed his data in two columns. One column was the numerical value of strain, the other column the numerical value of stress. Presumably, Hooke looked at his two data columns and concluded "strain is proportional to stress".

Hooke was ***wrong***. He should have concluded that "The *numerical value* of strain is proportional to the *numerical value* of stress." because that is *in fact* what his data indicated.

9.6 Rational engineering equations

Rational engineering equations are *inherently* dimensionless and dimensionally homogeneous because parameter dimensions ***cannot*** be related and ***cannot*** be multiplied or divided.

10 Engineering laws.

10.1 The purpose of engineering laws

The purpose of engineering laws is to *identify* the primary parameters, and *qualitatively* describe how they are related.

10.2 How rational engineering laws are determined.

Rational engineering laws are determined by performing experiments that include all forms of behavior, and correlating all of the data—i.e. all of the *numerical values* of parameters measured in the experiments. For example, to determine the law of convection heat transfer, experiments in all types of convection heat transfer must be performed, then all of the data must be correlated in order to find an equation/law that identifies the primary parameters, and *qualitatively* describes how the primary parameters are related.

10.3 Rational engineering laws

Correlation of engineering data indicates that rational engineering laws are analogs of Eq. (18) which states that the *numerical value* of parameter y is a function of the *numerical value* of parameter x, and the function may be proportional, linear, or nonlinear.

$$y = f\{x\} \tag{18}$$

For example, correlation of convection heat transfer data indicates that Eq. (19) is the law of convection heat transfer. It states that the *numerical value* of q is a function of the *numerical value* of ΔT, and the function may be proportional, linear, or nonlinear.

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

Similarly, correlation of engineering data indicates that Eq. (20) is the law of stress and strain. It states that the *numerical value* of σ is a function of the *numerical value* of ε, and the function may be proportional, linear, or nonlinear.

$$\sigma = f\{\varepsilon\} \tag{20}$$

11 How modern engineering texts are transformed into texts in which laws are analogs of $y = f\{x\}$, and parameter symbols represent *only* numerical values

Modern engineering texts are founded on *de facto* laws that are analogs of $y = (y/x)\{x\}x$, and parameter symbols that represent numerical values *and* dimensions. Modern engineering texts can be transformed into texts in which laws are analogs of $y = f\{x\}$, and parameter symbols represent *only* numerical values, by doing the following:

- *Replace* ***all*** engineering laws with analogs of $y = f\{x\}$ which states that the *numerical value* of parameter y is a function of the *numerical value* of parameter x, and the function may be proportional, linear, or nonlinear.

- *Require* that ***all*** parameter symbols in proportions and equations represent ***only*** numerical values.

- *Replace* all *faux* parameters with the ratio of primary parameters that created them, then ***separate*** the primary parameters. For example, replace both h and k/t with $q/\Delta T$, then separate q and ΔT.

- *Require* that, if an equation is ***quantitative***, the dimension units that underlie parameter symbols are specified. Note that all engineering laws and proportions are ***qualitative***.

For example, when *faux* parameters have been eliminated, Eq. (21) is replaced by Eq. (22), and Eq. (23) is replaced by Eq. (24).

$$h_1\{\Delta T\} = 0.40\ (\Delta T_1)^{.33} \tag{21}$$

$$\Delta T_1\{q\} = 1.99q^{.75} \tag{22}$$

$$U = 1/(1/h_1\{\Delta T_1\} + t_{wall}/k_{wall} + 1/h_2\{\Delta T_2\}) \tag{23}$$

$$\Delta T_{total}\{q\} = \Delta T_1\{q\} + \Delta T_{wall}\{q\} + \Delta T_2\{q\} \tag{24}$$

Note that Eqs. (22) and (24) are simpler and more obvious than Eqs. (21) and (23). Also note that Eq. (24) is *much* easier to solve than Eq. (23) because it has only *one* unknown variable, q, whereas Eq. (23) has *two* unknown variables, h_1 and h_2—i.e. $(q/\Delta T)_1$ and $(q/\Delta T)_2$.

12. Conclusions

Modern engineering science is *irrational* because it is founded on *irrational* tenets and laws. It should be replaced by the engineering science that results from the following:

- Parameter symbols in proportions and equations represent ***only*** numerical values.

- ***All*** laws are analogs of $y = f\{x\}$ which states that the *numerical value* of parameter y is a function of the *numerical value* of x, and the function may be proportional, linear, or nonlinear.

- ***All*** proportions and equations are *inherently* dimensionless and dimensionally homogeneous.

- If parameter symbols are in *quantitative* equations, dimension units ***are*** specified. If parameter symbols are in *qualitative* equations or proportions, dimension units are ***not*** specified.

- There are ***no*** *faux* parameters such as h (the symbol for $q/\Delta T$) and E (the symbol for σ/ε).

Nomenclature

a	acceleration
c	unspecified constant
E	symbol for σ/ε or volts
f	force
h	symbol for $q/\Delta T$
I	electric current
k	symbol for $q(\Delta x/\Delta T)$
q	heat flux
R	symbol for E/I
T	temperature
x	unspecified parameter
y	unspecified parameter
ε	strain
σ	stress

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