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Why Conventional Engineering Laws are *Irrational,* and a *Paradigm Shift* that Results in *Rational* Laws

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Abstract- Conventional engineering laws are irrational for three reasons: When the laws are applied to *nonlinear* behavior, they have *three* variables to describe how *two* variables are related; they are founded on Fourier's *erroneous* claims that dimensions *can rationally* be assigned to *numbers,* and dimensions *can rationally* be multiplied or divided. Until now, it has been globally accepted that parameter symbols in rational equations represent numerical value *and* dimension. The proposed paradigm shift *requires* that parameter symbols in equations represent *only* numerical value, *and* if an equation is *quantitative*, the dimension units that underlie parameter symbols *must* be specified in an accompanying nomenclature. The proposed paradigm shift results in laws and equations that are dimensionally homogeneous because they are *dimensionless*. The new laws are analogs of $y = f\{x\}$. The new laws state 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 are rational because they *always* have only *two* variables, they do *not* require that dimensions be assigned to numbers, and they do *not* require that parameter dimensions be multiplied or divided.

Keywords: dimensional homogeneity, dimensions, irrational equations, irrational laws, newton's laws, paradigm shift, parameters, proportions, rational equations, rational laws.

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Keywords: dimensional homogeneity, dimensions, irrational equations, irrational laws, newton's laws, paradigm shift, parameters, proportions, rational equations, rational laws.

I. Introduction

Conventional engineering laws such as Eq. (1) are irrational because:

$$q = h\Delta T \qquad (1)$$

- If q is a nonlinear function of ΔT (as in free convection, condensation, and boiling), h is a *variable*. Consequently Eq. (1) has *three* variables (q, h, and ΔT) to describe how *two* variables (q and ΔT) are related. It is *irrational* to use equations that have *three* variables to describe how *two* variables are related.
- The laws are based on Fourier's *erroneous* claims that dimensions *can* rationally be assigned to *numbers*, and parameter dimensions *can* rationally be multiplied or divided.

The proposed paradigm shift *requires* that parameter symbols in equations represent *only* numerical values, and if an equation is *quantitative*, the dimension units that underlie parameter symbols *must* be specified in an accompanying nomenclature. The proposed paradigm shift results in the replacement of laws that are analogs of Eq. (1) with laws that are analogs of Eq (2).

$$y = f\{x\} \qquad (2)$$

Equation (2) 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 make it *much simpler* to learn and apply engineering science because they *always* contain only *two* variables, and because *all* parameters (such as h and E) that were created by assigning dimensions to *numbers* are *abandoned*. They are *not* replaced because they are *not* necessary.

a) *Dimensional Homogeneity until 1822*

Until 1822, scientists and engineers such as Galileo and Newton agreed that:

- Parameter symbols in proportions and equations represent numerical value *and* dimension.
- Parameters *cannot* be multiplied or divided because parameter dimensions *cannot* be multiplied or divided.[1]
- Equations *cannot* describe how parameters are related because parameters *cannot* be multiplied or divided.
- Proportions need *not* be dimensionally homogeneous.
- Equations *must* be dimensionally homogeneous.

Because proportions need *not* be dimensionally homogeneous, and because proportions that relate two

[1] However, a dimension *can* be divided by the *same* dimension. For example, meters *can* be divided by meters, and seconds *can* be divided by seconds, but meters *cannot* be divided by seconds. In the qualitative equations that result, all terms are dimensionless ratios. This methodology was used by Galileo.

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parameters do *not* require that parameters be multiplied or divided, proportions are generally used instead of equations. That is why Hooke's [2] law is Proportion (3) instead of an equation, Newton's [3] law of cooling[2] is Proportion (4) instead of Eq. (5), and Newton's [4] second law of motion is Proportion (6) instead of Eq. (7).

$$\sigma \alpha \varepsilon \tag{3}$$

$$(dT_{body}/dt) \alpha (T_{air} - T_{body}) \tag{4}$$

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

$$a \alpha f \tag{6}$$

$$f = ma \tag{7}$$

b) Fourier's Heat Transfer Experiment, and the Proportion and Equation that Resulted

Fourier performed a heat transfer experiment in which a warm, solid body is cooled by the steady-state forced convection of ambient air. Fourier concluded that Proportion (8) and Eq. (9) correlate the data.

$$q \alpha \Delta T \tag{8}$$

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

Newton and his colleagues would have been satisfied by Proportion (8), but it did *not* satisfy Fourier because he wanted an *equation*, and it *had* to be dimensionally homogeneous. Equation (9) did *not* satisfy Fourier because it is *not* dimensionally homogeneous.

c) Fourier's Revolutionary and Unproven View of Dimensional Homogeneity that Enabled him to Transform in Homogeneous Eq. (9) to Homogeneous Eq. (10)

Fourier recognized that Eq. (9) could be transformed to a dimensionally homogeneous equation *only* if it were rational to *assign* dimensions to *number c* in Eq. (9), *and* rational to *multiply and divide* parameter dimensions. Fourier [1] describes his *revolutionary* and *unproven* view of dimensional homogeneity in the following:

. . . 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 dimension. . . this consideration 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*.**

It is important to note that, in Fourier's nearly 500 page treatise, *The Analytical Theory of Heat* [1], he made *no effort* to prove that his view of dimensional homogeneity is rational. He did *not* include the Greek lemmas, he did *not* cite a reference where the Greek lemmas could be found, and he did *not* include his own proof.

Fourier's *revolutionary* view of dimensional homogeneity includes the following *erroneous* claims:

- Dimensions *can* be assigned to *numbers*.
- Parameter *dimensions can* be multiplied or divided.

In accordance with his *erroneous* view of dimensional homogeneity, Fourier *assigned* the symbol *h* and the dimension of $q/\Delta T$ to *number c* in Eq. (9), then *multiplied h* and ΔT, resulting in dimensionally homogeneous Eq. (10).

$$q = h\Delta T \tag{10}$$

d) The Definition of h

American heat transfer texts generally do not define *h*. Nomenclatures in heat transfer texts generally state only that *h* is "heat transfer coefficient". However, rearranging Eq. (10) results in Eq. (11).

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

Equations (10) and (11) state that *h* and $q/\Delta T$ are *identical* and *interchangeable*. They also state that *h* is a symbol for the *dimensional group* $q/\Delta T$.

Combining Eqs. (10) and (11) results in Eq. (12). Note that Eqs. (10) and (12) are *identical* because *h* and $q/\Delta T$ are *identical* and *interchangeable*.

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

The nomenclature in *every* conventional heat transfer text should state "*h* is a symbol for the dimensional group $q/\Delta T$—*i.e. h* and $q/\Delta T$ are *identical* and *interchangeable"*.

e) What Eq. (10) meant in Most of the Nineteenth Century

In most of the nineteenth century, Eq. (10) was *always* a *proportional* equation, and *h* was *always* a proportionality *constant*. Fourier warned that Eq. (10) applies *only* if a solid, warm body is cooled by the *steady-state forced convection* of *ambient air*. He *emphasized* that Eq. (9) does *not* apply if a solid, warm body is cooled by the *natural convection* of ambient air because the coolant flow rate would *vary*, and consequently the relationship between *q* and ΔT would *not* be proportional.

[2] American heat transfer texts generally refer to Eq. (5) as "Newton's law of cooling", and claim that Newton created *h*. However, Eq. (5) *cannot* be Newton's law of cooling because cooling is a *transient* phenomenon, and Eq. (5) is a *steady-state* equation. Also because Eq. (5) *requires* that *h* and ΔT be multiplied, whereas in Newton's time, it was *irrational* to multiply parameters. Newton could *not* have created *h* because he could *not* rationally have multiplied *h* times another parameter.

f) What Eq. (10) has meant Since Sometime near the End of the Nineteenth Century

Sometime near the end of the nineteenth century, the heat transfer community decided to ignore Fourier's warning that Eq. (10) applies *only* if the heat transfer behavior is proportional. It decided to apply Eq. (10) even if the relationship between q and ΔT is *nonlinear*.

When Eq. (10) is applied to *nonlinear* heat transfer phenomena, it is *not* an equation because a *proportional* equation *cannot* describe *nonlinear* behavior. Even though Eq. (10) is a proportional equation, it *must now* be interpreted to mean that the relationship between q and ΔT *may* be proportional, linear, or nonlinear, and h *may* be a *constant* or a *variable*.

g) The Equation that should have Replaced Eq. (10) when it began to be Applied to Nonlinear Phenomena

When the decision was made to apply Eq. (10) to nonlinear phenomena, Eq. (10) *should* have been *abandoned* because it obviously *cannot* describe *nonlinear* behavior. Equation (10) should have been replaced by Eq. (13) because it correctly states that the relationship between q and ΔT may be *proportional, linear, or nonlinear*, and h may be a *constant* or a *variable*.

$$q = h\{\Delta T\}\Delta T \qquad (13)$$

Note that Eqs. (13) and (13a) are *identical*. They *both* state that q is a function of ΔT, and the function may be proportional, linear, or nonlinear.

$$q = f\{\Delta T\} \qquad (13a)$$

However, Eq. (13a) could *not* rationally have replaced Eq. (10) because, based on conventional parameter symbolism, Eq. (13a) is *not* dimensionally homogeneous.

h) Why Conventional Engineering Laws are Irrational

Substituting $q/\Delta T$ for h in Eq. (13) results in Eq. (14).

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

Equation (14) is a *rigorously correct* expression of the modern law of convective heat transfer. Note that Eq. (14) is an analog of Eq. (15), and $q/\Delta T$ (i.e. h) is an analog of $(y/x)\{x\}$.

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

In mathematics, if y is a *nonlinear* function of x, Eq. (15) is *never* used because $(y/x)\{x\}$ is a *third* variable, and it *greatly* complicates problem solutions. Equation (16) is *always* used because it *always* has only *two* variables, and therefore it *always* allows nonlinear problems to be solved in the simplest possible way—ie with y and x *separated* rather than *combined* in an analog of $(y/x)\{x\}$.

$$y = f\{x\} \qquad (16)$$

Laws such as Eqs. (10), (12), (13), and (14) are *irrational* because, if q is a nonlinear function of ΔT, they have *three* variables (q, $q/\Delta T$, and ΔT) to describe how *two* variables (q and ΔT) are related. And similarly for *all proportional* engineering laws that are applied to *nonlinear* phenomena.

i) Proof that Fourier was Wrong. Dimensions cannot Rationally be Assigned to Numbers

Langhaar [5] explains why dimensions *cannot* rationally be assigned to numbers:

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

j) Proof that Fourier was Wrong. Dimensions cannot Rationally be Multiplied or Divided

Conventional engineering laws and equations are based in part on Fourier's *unproven* claim that parameter *dimensions can* be multiplied or divided. Fourier was *wrong*. As demonstrated by the following, parameter dimensions *cannot* rationally be multiplied or divided.

"Multiply four times seven" means "add seven four times". Therefore "multiply meters times kilograms" *must* mean "add kilograms meters times". Because "add kilograms meters times" has *no meaning*, dimensions *cannot* be multiplied.

"Divide forty by five" means "how many fives are in forty". Therefore "divide meters by seconds" *must* mean "how many seconds are in meters". Because "how many seconds are in meters" has *no meaning*, dimensions *cannot* be divided.

k) Irrational Views in Conventional Engineering

The following are irrational views in conventional engineering.

- Hooke's law, Proportion (17), *and* Young's law, Eq. (18), are *identical*. They *both* state that stress equals a constant times strain. Therefore it is *irrational* to *require* Young's law to be dimensionally homogeneous, and *not* require Hooke's law to be dimensionally homogeneous.

$$\sigma \,\alpha\, \varepsilon \qquad (17)$$

$$\sigma = E_{elastic}\varepsilon \qquad (18)$$

- A chart of q vs ΔT is a picture of Eq. (19).

$$q = f\{\Delta T\} \qquad (19)$$

It is *irrational* to *reject* Eq. (19) because it is *not* dimensionally homogeneous, and to *accept* a *chart* of Eq. (19) that is *not* dimensionally homogeneous.

- Charts are *dimensionless* because they describe how the *numerical value* of parameter *y* is related to the *numerical value* of parameter *x*. If a chart is *quantitative,* the dimension units that underlie parameters *x* and *y must* be specified on the chart, or in an accompanying nomenclature.

Because charts are pictures of equations, and because charts are *dimensionless*, it is *irrational* to *not* have equations in which parameter symbols are *dimensionless*.

The above *irrational* views have *no place* in the engineering science that results from the paradigm shift.

l) What Equations can Rationally describe about how Parameters are Related

Equations *can* rationally describe how the *numerical values* of parameters are related because dimensionless equations are *inherently* dimensionally homogeneous. If a dimensionless equation is *quantitative*, the dimension units that underlie parameter symbols (that are *not* in dimensionless groups) *must* be specified in an accompanying nomenclature.

m) The Proposed Paradigm Shift

The proposed paradigm shift *requires* that parameter symbols in equations represent *only* numerical value. If an equation is *quantitative*, the dimension units that underlie parameter symbols *must* be specified in an accompanying nomenclature.

n) The Engineering Science that Results from the Proposed Paradigm Shift

The engineering science that results from the proposed paradigm shift is described by:

- *All* proportions and equations are *dimensionless* because *all* parameter symbols represent *only* numerical value.
- *All* proportions and equations are *dimensionally homogeneous* because they are dimensionless.
- If an equation is *quantitative*, the dimension units that underlie parameter symbols are specified in an accompanying nomenclature (except for symbols in dimensionless groups).
- *All* engineering laws are replaced by analogs of Eq. (20) 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.

$$y = f\{x\} \tag{20}$$

- There are *no* parameters that were created by assigning dimensions to numbers.

o) How to Transform Conventional Texts to Texts based on the Proposed Paradigm Shift

To transform conventional engineering texts to texts based on the proposed paradigm shift:

- Replace laws with analogs of $y = f\{x\}$.
- In equations that include analogs of *(y/x)*, replace analogs with *y/x*, then separate *x* and *y*.

For example, to transform Eq. (21) to a paradigm shift equation, replace *h* and *kwall/twall* with $q/\Delta T$, then separate *q* and ΔT, resulting in Eq. (22).

$$U = (1/h_1 + t_{wall}/k_{wall} + 1/h_2)^{-1} \tag{21}$$

$$\Delta T_{total} = \Delta T_1\{q\} + \Delta T_{wall}\{q\} + \Delta T_2\{q\} \tag{22}$$

It is important to note that Eqs. (21) and (22) are *identical*. They mean *exactly the same thing*. Equation (21) is written in the *opaque* language of conventional engineering. Equation (22) is written in the *transparent* language of the proposed paradigm shift. (Convection heat transfer correlations are generally in the form $\Delta T\{q\}$ because that is the form required by Eq. (22).

Textbooks for other branches of engineering are transformed to paradigm shift texts in the same way heat transfer texts are transformed—i.e. by replacing conventional laws with laws that are analogs of Eq. (16), and transforming equations by *separating x* and *y*.

p) How Data are Correlated in Conventional Engineering, and in Engineering based on the Proposed Paradigm Shift

Experimenters *cannot* obtain *h* data or *E* data because there is *no such thing* as *h or E*. They are *symbols* for *dimensional groups* $q/\Delta T$ and Δ/Δ.

In conventional engineering, experimenters obtain *q* data and ΔT data, and use it to determine $q/\Delta T$ values and $(q/\Delta T)\{\Delta T\}$ correlations—ie to determine *h* values and $h\{\Delta T\}$ correlations.

In engineering based on the proposed paradigm shift, experimenters obtain *q* data and ΔT data, and use it to determine $\Delta T\{q\}$ correlations. And similarly for other engineering branches.

q) Correlation Transformations and Experiments

It is important to note that the proposed paradigm shift does *not* require that experiments that resulted in *conventional* correlations be *repeated*. It requires merely that conventional correlations be transformed by separating parameter *x* and parameter *y* as described in Section 16, or that the data that resulted in conventional correlations be used to determine correlations that are analogs of $y = f\{x\}$.

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II. Conclusions

Conventional engineering science works well when applied to problems that concern *proportional* behavior because it is founded on laws that are *proportional* equations, and the coefficients in the laws (such as *h* and *E)* are *proportionality constants*. It does *not* work well when applied to problems that concern *nonlinear* behavior because the coefficients in the laws (such as *h* and *E*) are *extraneous variables*, and they *greatly* complicate problem solutions.

Engineering science should be founded on the proposed paradigm shift because it results in laws that work well with *all* forms of behavior—proportional, linear, and nonlinear. The new laws make it *much simpler* to learn and apply engineering science because they *always* have only *two* variables, and because *all* parameters (such as *h* and *E*) that were created by assigning dimensions to *numbers* are *abandoned*. They are *not* replaced because they are *not* necessary.

Nomenclature

a acceleration
c arbitrary constant
E modulus
F force
h $q/\Delta T$
k $q/(dT/dx)$
m mass
q heat flux
T temperature
t time or wall thickness
x arbitrary variable
y arbitrary variable
ε strain
σ stress

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