Great Britain Journals Press

RESEARCH FINGERPRINT

IDENTIFIER
LJRS-227871

PEER REVIEW
Double Blind

SIMILARITY CHECK
Perplexity AI and iThenticate

ACCESS
Open Access

LANGUAGE
English

PRINT ISSN
2631-8490

ONLINE ISSN
2631-8504

EDITION

ABBREVIATION
LJRS

VOLUME
26

ISSUE
5

YEAR
2026

KEY DATES

RECEIVED
2026-05-15

ACCEPTED
2026-05-25

ONLINE PUBLISHED
2026-06-19

PUBLISHED
2026-05-30

CATALOGING

CROSSMARK DOI
10.34257/LJRS227871UK

PACS CLASS
06.20.f, 06.20.fa

MSC CLASS
70A05

UDC CLASS
53.081



Article Record

# Action and Entropy: Base Physical Quantities

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## ABSTRACT

Action, entropy, frequency, speed, electric charge are proposed as base physical quantities of a new system. Base quantities would be directly linked to fundamental constants of physics h, k_B, Δν_Cs$^{133}$, c and e. Each base quantity would be defined independently of the others.

Index Terms: Action • Entropy • base quantities • base units

FUNDING
No external funding was declared for this work.

CONFLICTS
The authors declare no conflict of interest.

AI USAGE
No generative AI was used for analysis or results.

HOW TO CITE
R.M. Morin (2026). Action and Entropy: Base Physical Quantities. London Journal of Research In Science: Natural and Formal, 26(5), 40-45. DOI: 10.34257/LJRS227871UK

ACCESS ONLINE

## METADATA CONTINUATION

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### ARCHIVAL RECORD

LJRS · Vol 26 · Issue 5 · 2026

Article ID LJRS-227871 · DOI 10.34257/LJRS227871UK

Print ISSN 2631-8490 · Online ISSN 2631-8504

CROSSREF DOI 10.34257/LJRS227871UK

RESEARCH ARTICLE

# Action and Entropy: Base Physical Quantities

**Luc R.M. Morin***

**Abstract**

Action, entropy, frequency, speed, electric charge are proposed as base physical quantities of a new system. Base quantities would be directly linked to fundamental constants of physics h, k_B, Δν_Cs[133], c and e. Each base quantity would be defined independently of the others.

**Keywords:** *Action, Entropy, base quantities, base units*

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## 1 Introduction

According to de Broglie, action and entropy are base physical quantities [1].
*"As a man who has devoted his whole life to the study of matter... I can tell you as a result of my research about the atoms this much: there is no matter as such."* Such were the words Planck addressed to a conference in Florence in 1944 [2].
In 2018, 26th-CGPM [3] defined SI base units on a set of seven constants (figure 1) and redefined the mass unit, no longer by reference to the *mass* of a prototype, but by setting the value of ... Planck constant.
26th-CGPM [3] mass defining method, together with Planck and de Broglie thoughts, suggests to consider a new system in which *action* and *entropy* would be base physical quantities [8].

## 2 SI Historical

*"The creation of the decimal metric system at the time of the French Revolution and the subsequent deposition of two platinum standards representing the metre and the kilogram, on 22 June 1799, in the Archives de la République in Paris, which can be seen as the first step that led to the present International System of Units." [4]*
In November 2018, the 26th CGPM [3] redefined *"the SI on a set of seven defining constants, drawn from the fundamental constants of physics and other constants of nature, from which the seven base units are deduced"*.

Table 1 displays SI base physical quantities, SI base units and their SI symbols [5].

| base quantity name | base quantity symbol | Base unit name | base unit symbol |
|---|---|---|---|
| time | $t$ | second | s |
| length | $l, x, r$, etc. | metre | m |
| mass | $m$ | kilogram | kg |
| electric current | $I, i$ | ampere | A |
| thermodynamic temperature | $T$ | kelvin | K |
| amount of substance | $n$ | mole | mol |
| luminous intensity | $I_v$ | candela | cd |

**Table 1.** SI base Physical Quantities, base units and symbols [5]

Within SI system, frequency, electrical charge, speed and molar entropy are derived physical quantities. Table 2 shows their units, as functions of SI base units [6]. It is noticed that action is not mentioned as a derived quantity.

| derived quantity | quantity symbol | unit name | unit symbol | unit in SI base units |
|---|---|---|---|---|
| frequency | | hertz | Hz | $s^{-1}$ |
| electric charge | | coulomb | C | A s |
| speed, velocity | $v$ | | | m $s^{-1}$ |
| molar entropy | | | | kg $m^2$ $s^{-2}$ $mol^{-1}$ $K^{-1}$ |

**Table 2.** SI derived Physical Quantities and SI derived units [6]. Blank boxes correspond to symbols or names that are not defined in BIPM 9th ed. [5]

Figure 1 shows SI links between fundamental constants of physics ($\Delta\nu_{Cs}, c, h, e, k_B, N_A, K_{cd}$) and SI base units [7].

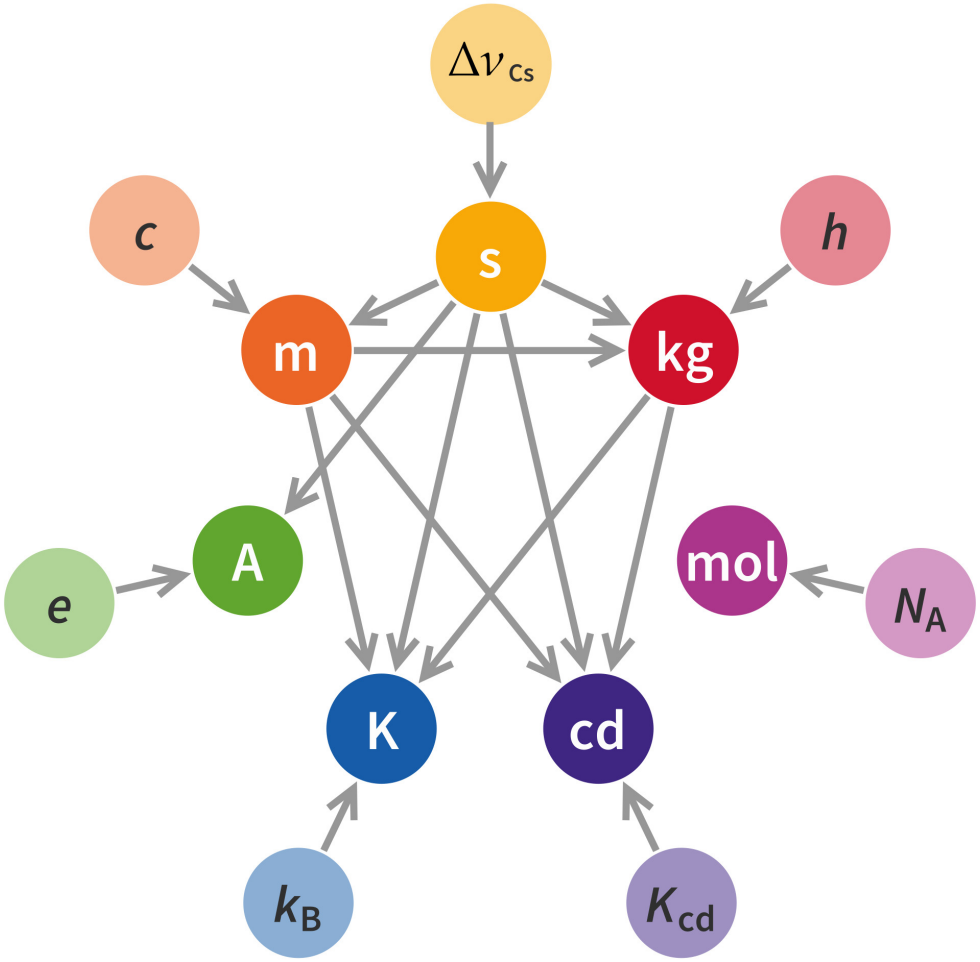


**Figure 1.** Links between fundamental constants of physics and SI base units [7].

## 3 New System: base quantities, units, symbols

*Note: in present paper, the amount of substance and the luminous intensity are not studied. Only, action, entropy, frequency, speed and electric charge are studied here.*

### 3.1 Proposed base physical quantities

26$^{th}$ CGPM [3] defining method, together with Planck and de Broglie thoughts, suggests that we should consider a new system of base physical quantities. In such a system, action, entropy, frequency, speed and electric charge would be base physical quantities.
Each of these physical quantities would be directly linked to fundamental constants of physics: Planck constant $h$, Boltzmann constant $k_B$, hyperfine transition frequency of the Caesium 133 atom $\Delta\nu_{Cs}^{133}$, speed of light in vacuum $c$ and elementary charge $e$ (figure 2).

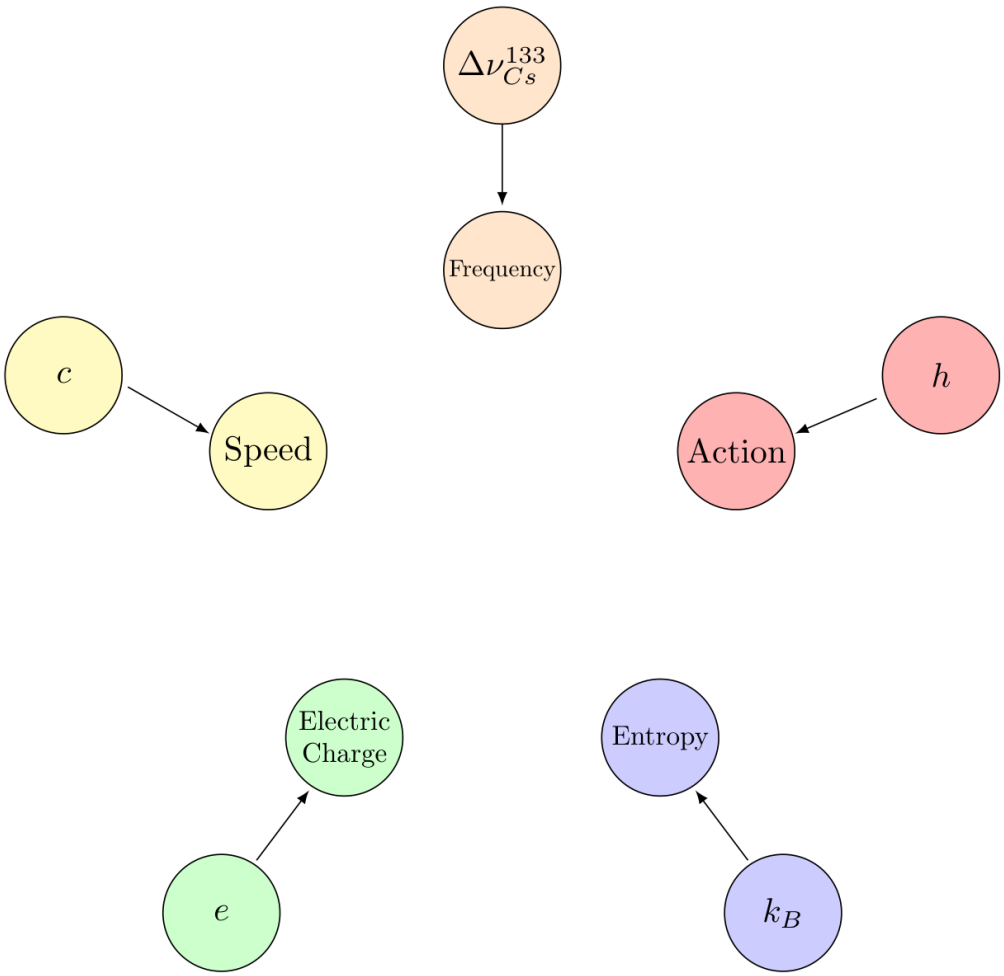


**Figure 2.** Links between fundamental constants of physics and proposed new system of base physical quantities.

### 3.2 Proposed quantities symbols

Table 3 shows the proposed base quantities names and the proposed base quantities symbols. It is proposed to use capital calligraphic fonts for base physical quantities of the new system $\mathcal{A}, \mathcal{S}, \mathcal{N}, \mathcal{V}, \mathcal{Q}$ (Table 3).

| quantity name | quantity symbol |
|---|---|
| Action | $\mathcal{A}$ |
| Entropy | $\mathcal{S}$ |
| Frequency | $\mathcal{N}$ |
| Speed | $\mathcal{V}$ |
| Electric charge | $\mathcal{Q}$ |

**Table 3.** Base quantities: names and symbols - New system

### 3.3 Proposed unit names and unit symbols

Within the new system NS, each of the fundamental constants $h, k_B, \Delta\nu_{\mathrm{Cs}}^{133}, c$ and $e$ would be equal to one.

The proposed name of the unit of action is the planck, symbol Pk. One planck is the NS numerical value of the Planck constant, i.e., $h = 1$ Pk.

The proposed name of the unit of entropy is the boltzmann, symbol Bz. One boltzmann is the NS numerical value of the Boltzmann constant, $k_B = 1$ Bz.

The proposed name of the unit of frequency is the elementary frequency, symbol $\nu_{\mathrm{Cs}}$. One elementary frequency is the NS numerical value of the frequency of the unperturbed ground-state hyperfine transition of the Caesium 133 atom, i.e., $\Delta\nu_{\mathrm{Cs}}^{133} = 1\ \nu_{\mathrm{Cs}}$.

The proposed name of the unit of speed is the light speed, symbol Ls[1]. One light speed is the NS numerical value of speed of light in vacuum, $c = 1$ Ls.

[1]Alternatively, it would be possible to name the unit of speed after Arago.

The proposed name of the unit of electric charge is the elementary electric charge, symbol Qe[2]. One elementary electric charge is the NS numerical value of the elementary charge, i.e., $e = 1$ Qe.
Table 4 shows the proposed names of the NS base units and the proposed symbols of the NS base units. Table 5 shows the fundamental constants, their symbols and their new system numerical values.

| unit name | unit symbol |
|---|---|
| planck | Pk |
| boltzmann | Bz |
| elementary frequency | $\nu_{\mathrm{Cs}}$ |
| light speed | Ls |
| elementary electric charge | Qe |

**Table 4.** Base units: names and symbols - New system

| name | symbol | n value |
|---|---|---|
| Planck constant | $h$ | 1 Pk |
| Boltzmann constant | $k_B$ | 1 Bz |
| hyperfine transition $Cs^{133}$ | $\Delta\nu_{\mathrm{Cs}}^{133}$ | 1 $\nu_{\mathrm{Cs}}$ |
| speed of light in vacuum | $c$ | 1 Ls |
| elementary charge | $e$ | 1 Qe |

**Table 5.** Fundamental Constants within NS

Table 6 converts new system units to SI units. Table 7 converts SI units to new system units (NS). Table 8 summarises the NS base quantities and the related fundamental constants of physics.

| Unit name | Unit value in SI |
|---|---|
| planck | 1 Pk = $6.62607015 \times 10^{-34}$ m$^2$ kg s$^{-1}$ |
| boltzmann | 1 Bz = $1.380649 \times 10^{-23}$ m$^2$ kg s$^{-2}$ K$^{-1}$ |
| elementary frequency | 1 $\nu_{\mathrm{Cs}}$ = 9192631770 s$^{-1}$ |
| light speed | 1 Ls = 299792458 m s$^{-1}$ |
| elementary electric charge | 1 Qe = $1.602176634 \times 10^{-19}$ A s |

**Table 6.** Units Conversion NS → SI

| SI Unit | SI Unit in NS units |
|---|---|
| second | 1 s = 9192631770 $\nu_{\mathrm{Cs}}^{-1}$ |
| metre | 1 m = 30.6633319 Ls $\nu_{\mathrm{Cs}}^{-1}$ |
| kilogram | 1 kg = $1.4755214 \times 10^{40}$ Pk $\nu_{\mathrm{Cs}}$ Ls$^{-2}$ |
| ampere | 1 A = $6.789687 \times 10^{8}$ Qe $\nu_{\mathrm{Cs}}$ |
| kelvin | 1 K = 2.2266653 Pk $\nu_{\mathrm{Cs}}$ Bz$^{-1}$ |

**Table 7.** Units Conversion SI → NS

| Quantity name | Quantity symbol | Unit name | Unit symbol | Unit value |
|---|---|---|---|---|
| Action | $\mathcal{A}$ | planck | Pk | 1 Pk = $h$ |
| Entropy | $\mathcal{S}$ | boltzmann | Bz | 1 Bz = $k_B$ |
| Frequency | $\mathcal{N}$ | elementary frequency | $\nu_{\mathrm{Cs}}$ | 1 $\nu_{\mathrm{Cs}} = \Delta\nu_{\mathrm{Cs}}^{133}$ |
| Speed | $\mathcal{V}$ | light speed | Ls | 1 Ls = $c$ |
| Electric charge | $\mathcal{Q}$ | elementary electric charge | Qe | 1 Qe = $e$ |

**Table 8.** Summary of proposed new system base quantities and related fundamental constants of physics

### 3.4 Conversion of dimensions of base quantities NS ⟷ SI

According to the new system, time, length, mass, temperature and electric current would not be base physical quantities but NS derived physical quantities.
Table 9 shows proposed symbols for the dimensions of NS base quantities. Table 10 converts the new system dimensions to the SI dimensions. Table 11 converts the SI dimensions to the new system dimensions.

[2]Alternatively, it would be possible to name the unit of electric charge after Stoney.

| Base quantity | Symbol for dimension |
|---|---|
| Action | A |
| Entropy | S |
| Frequency | N |
| Speed | V |
| Electric Charge | Q |

**Table 9.** Symbols for dimensions of NS base quantities

| Base quantity | Quantity dimension (NS) | Quantity dimension (SI) |
|---|---|---|
| Action | A | $L^2M^1T^{-1}$ |
| Entropy | S | $L^2M^1T^{-2}\Theta^{-1}$ |
| Frequency | N | $T^{-1}$ |
| Speed | V | $L^1T^{-1}$ |
| Electric Charge | Q | $I^1T^1$ |

**Table 10.** Dimension conversion NS → SI

| Base quantity | Quantity dimension (SI) | Quantity dimension (NS) |
|---|---|---|
| time | T | $N^{-1}$ |
| length | L | $VN^{-1}$ |
| mass | M | $ANV^{-2}$ |
| electric current | I | QN |
| temperature | Θ | $ANS^{-1}$ |

**Table 11.** Dimension conversion SI → NS

## 4 Discussion

What is studied here is not only a matter of units, but mainly a matter of physical quantities. Several points must be stressed:

### 4.1 Definition of base physical quantities

Figure 1 shows how the SI base physical quantities are entangled. Here, each base quantity is defined independently of the others. Figure 3 shows the proposed new system of base quantities: each base quantity would be defined by reference to only one physical constant.

### 4.2 Action and Entropy

Physical quantity action is not mentioned in BIPM reports as a base quantity, nor as a derived quantity. Here, following de Broglie [1], action and entropy would be considered as base physical quantities.

### 4.3 Temperature

The treatment of temperature is modified. Within the SI, temperature is a base physical quantity. Within the new system, temperature is not a base quantity, but a quantity derived from the NS base physical quantities action, frequency and entropy. Temperature is homogeneous to action × frequency × (entropy)$^{-1}$.

### 4.4 Mass

The treatment of mass is modified. Within the SI, mass is a base physical quantity. Within the new system, mass is not a base quantity, but a quantity derived from the NS base physical quantities action, frequency and speed. Mass is homogeneous to action × frequency × (speed)$^{-2}$.

### 4.5 Definition of units of action and entropy

As action is considered a base physical quantity, it is necessary to define a unit of action. The proposed name of the unit of action is the planck, symbol Pk. One planck is the NS numerical value of the Planck constant, i.e., $h = 1$ Pk.

As entropy is considered a base physical quantity, it is necessary to define a unit of entropy. The proposed name of the unit of entropy is the boltzmann, symbol Bz. One boltzmann is the NS numerical value of the Boltzmann constant, i.e., $k_B = 1$ Bz.

### 4.6 Comparison with BIPM reports

BIPM [5] establishes the international system of **units**, which is based on seven defining constants, drawn from the fundamental constants of physics.

Appendix 3 of the 26$^{\text{th}}$ CGPM [3] defined the kelvin, symbol K, is the SI unit of thermodynamic temperature. It is defined by taking the fixed numerical value of the Boltzmann constant $k$ to be $1.380\,649 \times 10^{-23}$ when expressed in the unit J K$^{-1}$, which is equal to kg m$^2$ s$^{-2}$ K$^{-1}$, where the kilogram, metre and second are defined in terms of $h$, $c$ and $\Delta\nu_{\text{Cs}}$. This definition of the kelvin is based on four constants $k_B, h, c$ and $\Delta\nu_{\text{Cs}}^{133}$.
The same remark applies to:

- the kilogram which is defined by reference to three constants $h, c$ and $\Delta\nu_{\text{Cs}}^{133}$
- the metre, which is defined by reference to two constants $\Delta\nu_{\text{Cs}}^{133}$ and $c$

- the ampere, which is defined by reference to two constants $e$ and $\Delta\nu_{\mathrm{Cs}}^{133}$.

Only the second is defined independently of the other units.
Present paper proposes a system of five base physical quantities: action, entropy, frequency, speed and electric charge. These quantities are related to fundamental physical constants: $h, k_B, \Delta\nu_{\mathrm{Cs}}^{133}, c$ and $e$.
Each base physical quantity of the new system is defined independently of the others. Table 12 summarises physical quantities and defining constants according to BIPM [5] from one part and physical quantities and defining constants according to the proposed new system from the other part.

| **BIPM [5]** | | **Proposed new system** | |
|---|---|---|---|
| **Physical Quantity** | **Defining constants** | **Physical Quantity** | **Defining constant** |
| time | $\Delta\nu_{\mathrm{Cs}}^{133}$ | frequency | $\Delta\nu_{\mathrm{Cs}}^{133}$ |
| length | $\Delta\nu_{\mathrm{Cs}}^{133}, c$ | speed | $c$ |
| electric current | $\Delta\nu_{\mathrm{Cs}}^{133}, e$ | electric charge | $e$ |
| mass | $\Delta\nu_{\mathrm{Cs}}^{133}, c, h$ | action | $h$ |
| temperature | $\Delta\nu_{\mathrm{Cs}}^{133}, c, h, k_B$ | entropy | $k_B$ |

**Table 12.** Physical quantities and defining constants according to BIPM [5] and to proposed new system

## 5 Conclusion

Action and entropy are considered as base physical quantities. Mass and temperature are considered as derived physical quantities. Figure 3 summarises the links between the proposed new system of base quantities, the fundamental constants and the proposed units. Each base quantity of the new system is defined independently of the others (Table 12, Figure 3).

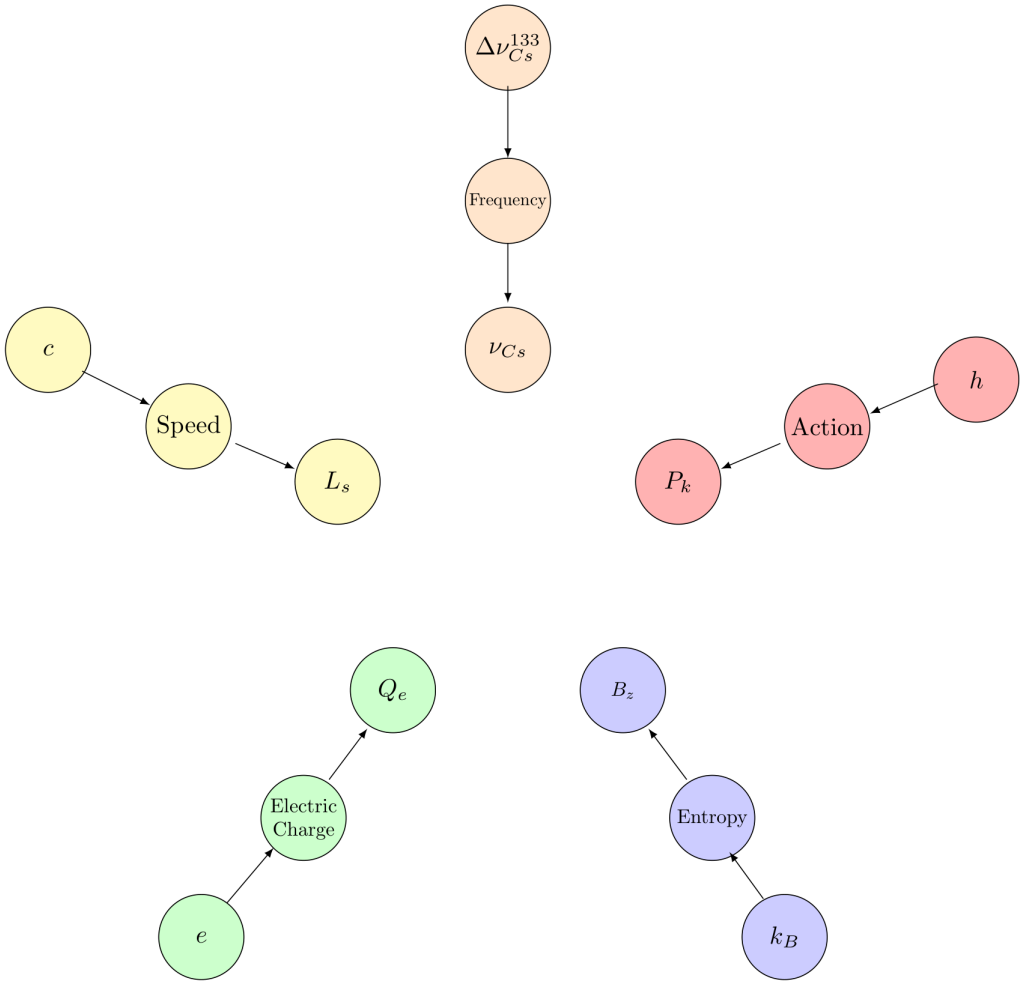


**Figure 3.** New system of base quantities, fundamental constants, units.

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