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The Mechanical Equivalent of Heat Interpreted as the Angular Momentum of Thermons

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***Abstract* — There were derived many forms of theories of heat during the past three hundred years. At its origins, thermodynamics was the study of heat and engines and therefore, we should be connected to these roots. In this model we present thermons as carriers of heat from hot bodies to cold bodies. The flow of heat is modelled as the transfer of angular momentum of these thermons in the direction from the higher angular momentum to the lower angular momentum of thermons. The mechanical equivalent of heat J is defined as the ratio of the angular momentum of thermons to the temperature of the surrounding. This model newly defines the quantity of heat – entropy S – as the ratio of the angular momentum of thermons to the temperature of the surrounding. This model can open a new window to the microworld where quantum particles transfer their heat content in one direction. However, this direction can be changed via the work done on these quantum particles and to reverse the flow of the angular momentum from lower angular momentum to higher angular momentum of those quantum particles. It will be shown that these very well-known formulae of S to all scholars might still keep some hidden surprising properties.**

***Keywords* —** Carnot´s heat engines, Measure of the quantity of heat S, Mechanical equivalent of heat J, Thermon angular momentum, Thermon transfer of heat.

I. Introduction

The theoretical and experimental observations of heat processes passed through hands of many great old masters, e.g. [1]-[11]. One of those earlier models of heat was based on the carrier of heat termed as caloric, e.g. [12]-[31]. There is one old topic in physics - entropy – the term entropy was introduced by Clausius in 1865 [5] and since that time the meaning of the entropy was many times discussed and evaluated, e.g. [32]-[41].

Benjamin Thomson, Count Rumford, had observed the frictional heat generated by boring cannon immersed in water and showed that the supply of frictional heat was seemingly inexhaustible [42]. James Joule in 1850 [43] determined the mechanical equivalent of heat during his experiments with the friction of water molecules, mercury molecules, and cast-iron atoms in his famous paddle-wheel apparatus. Based on these experiments the effect of heat was ascribed to the mechanical motion of atoms and the caloric theory disappeared from following theories of heat.

Recently, Stávek [44] introduced thermons as possible carriers of heat and proposed several experimental tests for the evaluation of the reality of that model. Can we newly interpret the mechanical equivalent of heat J and the quantity of heat termed as the entropy S?

II. The Mechanical Equivalent of Heat (MEH)

The cornerstone of the mechanical theory of heat is the equivalence principle or the mechanical equivalence of heat where heat and mechanical work are equivalent. The historically very important experiment of Joule with his paddle-wheel apparatus was recently discussed [45] and repeated [46]. The experimental values of MEH measured in the 19th century were collected by Greenslade [47] and Kipnis [48]. It is very difficult to achieve experimentally more precise value of MEH and therefore in the modern time the value of MEH was defined as J = 4.1860 J/cal. Table I from reference [47] surveys these MEH values measured in the 19th century.

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TABLE I: SOME VALUES OBTAINED FOR THE MECHANICAL EQUIVALENT OF HEAT IN THE 19TH CENTURY - FROM [47]

Year	Experimenter(s)	Method of experiment	Value in J/cal
1842	Mayer	Difference between C_P and C_V	3.58
1843	Joule	Heating coil in stationary water	4.51
1843	Joule	Forcing water through small holes	4.14
1845	Joule	Compressing air	4.27, 4.42
1845	Joule	Free expansion of air	4.41, 4.38, 4.09
1845	Joule	Falling weights stirring water	4.79
1847	Joule	Falling weights stirring water or oil	4.203
1848	Joule	Falling weights stirring water	4.15
1849	Joule	Falling weights stirring water	4.1545
1849	Joule	Falling weights stirring mercury	4.1619
1849	Joule	Rubbing cast-iron disks together	4.1669
1860-61	Hirn	Percussive effects	4.17
1865	Hirn	Stirring water; use of dynamometer	4.234
1867	Joule	Heating coil in stationary water	4.295
1870-78	Joule	Stirring water; use of dynamometer	4.1538
1877-78	Rowland	Stirring water; use of dynamometer	4.189
1896	Reynolds & Morby	Work output of steam engine	4.1609
1883	Griffiths	Heating coil in stationary water	4.195
1892	Miculescu	Stirring water; use of dynamometer	4.187
1895	Schuster & Gannon	Heating coil in stationary water	4.190
1899	Callender & Barnes	Heating coil in flowing water	4.184
		Modern defined value	**4.1860**

The Joule´s constant J describes the ratio of the work and heat of that system and was defined at the begin of the 20th century. It was ultimately realized that the constant is simply the specific heat of water, a quantity that varies with temperature between the values of 4.17 and 4.22 J g^{-1} $°C^{-1}$, given in (1).

$$J = 4.1860 = \frac{work}{heat} \qquad \left[J\ cal^{-1}\right] \tag{1}$$

The mechanical equivalent of heat states that motion and heat are mutually interchangeable and that in every case, a given amount of work would generate the same amount of heat, provided the work done is totally converted to heat energy.

III. THE ANGULAR MOMENTUM OF THERMONS

Recently, Stávek [44] introduced a new model with thermons as carriers of heat and described some of their properties. One interesting property of thermons is their measure of the quantity of heat S, given in (2).

$$S = \frac{h\,\nu}{T} = \frac{h\,c}{\lambda\,T} = 3\,k_B \qquad \left[J\ K^{-1}\right] \tag{2}$$

where h is the Planck constant, ν and λ are frequency and wavelength of those thermons, T temperature of the surroundings, k_B the Boltzmann constant.

One new property of those thermons could be their angular momentum [49] that depend on the surroundings. E.g., this angular momentum can be modified via mechanical action and the surroundings temperature and thus change the “heat content” of thermons. The “heat content” of thermons for the case of ideal gas can be written as (3).

$$2\pi\,h\,\nu = \frac{3}{2}\,k_B\,T \tag{3}$$

We can derive the Joule´s constant J as (4).

$$J = \frac{4\,\pi}{3} = \frac{k_B\,T}{h\,\nu} \approx 4.188790 \tag{4}$$

In this model thermons can very flexibly react to the system conditions and transfer their “heat content” from places with higher angular momentum → to the lower → angular momentum. In this new language the power of heat engines is interpreted as the angular momentum transfer of thermons from hot bodies to cold bodies, as given in (5) and (6).

$$S_{HOT} = \frac{2\,\pi\,h\,\nu_{HOT}}{T_{HOT}} \rightarrow S_{COLD} = \frac{2\,\pi\,h\,\nu_{COLD}}{T_{COLD}} \qquad \Delta S = S_{HOT} - S_{COLD} = 0 \tag{5}$$

$$2\pi\,h\left(\nu_{HOT} - \nu_{COLD}\right) = \frac{3}{2}\,k_B\left(T_{HOT} - T_{COLD}\right) \tag{6}$$

The Carnot condition for the heat engine efficiency η is fulfilled as (7).

$$\eta = \frac{\left(\nu_{HOT} - \nu_{COLD}\right)}{\nu_{HOT}} = \frac{\left(T_{HOT} - T_{COLD}\right)}{T_{HOT}} \tag{7}$$

This resurrection of carriers of heat might bring a new additional view into the microworld with the heat transfer processes. Table II and Table III surveys the properties of the Solar photons and the Solar thermions [44].

TABLE II: PROPERTIES OF THE PHOTON WITH ITS ENERGY E = 1 EV – [44]

Parameter	Unit	SI value	Comment
Energy	eV	ε_{eV} =1.602 176 63 * 10^{-19} J	-
Mass	eV/c^2	m_{eV} = 1.782 661 92 * 10^{-36} kg	-
Momentum	eV/c	p_{eV} =5.344 285 99 * 10-^{28} kg m/s	-
Wavelength	hc/eV	λ_{eV} = 1.239 841 98 * 10^{-6} m	-
Frequency	eV/h	ν_{eV} = 2.417 989 24 * 10^{14} Hz	-
Wavenumber	eV/hc	$1/\lambda_{eV}$ = 8.065 543 94 * 10^5 m^{-1}	-
Wien temperature	K	T_{WIEN} = 2337 K	Wien displacement law
Heat temperature	eV/3 k_B	T_{HEAT} = 3868 K	Dulong – Petit law
Sun temperature	K	T_{SUN} = 5 800 K	Fitting temperature
Heat displacement law: λ_{eV} * T_{HEAT} = hc/(3*k_B) = 4.795 922 93 * 10^{-3} m K (analogy to the Wien displacement law for photons)			

TABLE III: PROPERTIES OF THE SOLAR THERMONS – [44]

Parameter	Unit	Value at the Sun	Value at the Earth at 1 AU
Energy	eV	$\varepsilon_{\odot}$ = 0.9778 eV	$\varepsilon_{\oplus}$ = 0.06673 eV
Wavelength	m	$\lambda_{\odot}$ = 1.268 * 10^{-6} m	$\lambda_{\oplus}$=18.58 * 10^{-6} m
Frequency	Hz	$\nu_{\odot}$= 2.364 293 * 10^{14} Hz	$\nu_{\oplus}$ = 1.613 522* 10^{13} Hz
Wavenumber	cm^{-1}	$1/\lambda_{\odot}$ = 7886 cm^{-1}	$1/\lambda_{\oplus}$ = 538.2 cm^{-1}
Heat temperature	K	$T_{HEAT\odot}$ = 3782 K	$T_{HEAT\oplus}$ = 258.03 K
Heat displacement law	m K	hc/(3*k_B) = 4.795 922 93 * 10^{-3} m K (analogy to the Wien displacement law for photons)	

IV. WHAT IS THE MEANING OF THE QUANTUM OF HEAT?

Clausius [5] introduced the quantity first called as “transformation” (Verwandlung), or to emphasize the substance-like nature of quantity “transformation content” (Verwandlungsinhalt). Clausius later suggested the name entropy S according to the Greek word τροπη, the transformation, the entropy of the body.

In this model thermons transfer their “heat content” via the transformation of their angular momentum from places with higher angular momentum to places with lower angular momentum. A similar model of heat consisting in rotary motion of the atoms and molecules was proposed by Rankine in the period 1850-1854, [50]-[53].

The meaning of this quantity S is still very actively discussed, e.g. [13]-[41]. Can the model of thermons contribute to this discussion? What will be the next evolution stage [54] of the entropy?

V. CONCLUSION

At its origins, thermodynamics was the study of heat and engines. This science made the great progress during the past three hundred years but still some topics should be discussed in our epoch, too.

1. The models of theories of heat made several jumps during the past three hundred years.
2. The thermons as carriers of heat were presented.
3. Thermons as carriers of heat transfer their angular momentum from hot bodies to cold bodies.
4. The mechanical equivalent of heat was newly defined as the angular momentum of thermons.
5. The entropy S was defined as the ratio of the angular momentum of thermons to the temperature of the surroundings.
6. There is the direction of this transformation given by the flow of higher angular momentum to the lower angular momentum of thermons.
7. The external work done on thermons can change the flow of the angular momentum transfer from low values to high values of their angular momentum.
8. This new presentation of the entropy S might bring a deeper insight into thermal processes in our Solar System.

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CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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