Prolegomena to a field theory of heat

Alireza Jamali*

August 19, 2020

Abstract

Following an epistemological consideration we propose that none of SI basic units can correspond to emergent phenomena and must be taken as fundamental. We therefore take temperature as the scalar potential function of a fundamental field called *heat*, produced by a property of fundamental particles called *calor*.

Contents

1 Introduction

It is known that according to Fourier's theory of heat conduction, heat spontaneously flows from a hotter to a colder body. Since heat is just a manifestation of energy, it should follow the principle of locality, while the current classical theory of heat is a theory of *action-at-distance*.
From the remarkable success of the *phonon* assumption in the theory of solids, on one hand, and from the wave-like behaviour of heat conduction in superfluids on the other hand, it is clear that we can have a *quantum of heat*, justifying the assumption of heat as a quantum field theory. As every quantum field is based on a classical field, we should first consider a *classical field theory of heat*.
By comparing Fourier's law

$$\mathbf{q} = -k\nabla T \tag{1}$$

*alireza.jamali.mp@gmail.com, snail-mail: 3rd Floor - Block No. 6 - Akbari Alley - After Dardasht Intersection - Janbazané Sharghi - Tehran - Iran

and Ohm's law

$$\mathbf{j} = \sigma \mathbf{E} \tag{2}$$

we conclude that **Temperature is the potential function for heat field**.

2 Temperature-potential correspondence

On the basic level this correspondence needs a justification: Temperature as a potential function would result in a *fundamental* theory, while temperature is thought to be an *emergent* property of a bulk of matter. To this we object an epistemological consideration: SI basic units cannot be emergent. Physics without experimental test is futile. After hundreds –if not thousands– of years, we have finally settled on some basic quantities, i.e. SI base units. Anything we said and say in physics, ultimately boils down to a mixture of these base units. It is not that we cannot introduce more basic quantities but the epistemological limitations tie our hands very tightly. New basic quantities need not come only in the case of new phenomena. Occasionally theoretical consistency demands introduction of whole new independent base concepts which might not be possible to measure even after having constructed a whole new theory. Whatever we want to propose and test should ultimately come in a base units system with finite number of units; but how far can we go here in deepening our basic units? ultimately there is a place where not ontologically but epistemologically we cannot continue to dig down our basic units. we may already be at such boundary. What we can dream of our experimental means to probe is far from what we have in our basic units. Suppose we decide to fix the current SI system as the aforementioned epistemological boundary. In such system a quantity like temperature is a key basic element. how are we then going to explain the emergence of temperature when everything we say in such hypothetical explanation has to be explained in terms of SI base units?! To see this point, take the current so-called explanation of temperature as an emergent property of a large number of particles. In this 'explanation' temperature is taken as the average kinetic energy of many particles, i.e.

$$T = \frac{1}{2k_B} m \langle v^2 \rangle$$

but what is k_B? It is a constant given by

$$k_B = 1.3806 \times 10^{-23} \; [J/K]$$

where K is the unit for absolute **temperature**! We leave the decision whether this is an explanation or a mere vicious circle to the wise reader! Consequences of the identification of temperature as a potential function are far-reaching. The fact that an absolute scale exists for temperature suggests that we must also have absolute scales for gravitational and electromagnetic potentials.

2.1 Absolute scales for potentials

Some candidates for such scales are:

2.1.1 Gravitational potential

$$\phi_{\min} = \frac{\rho_\Lambda l_P^3}{m_P} \approx 10^{-106} \; [joules/kg] \tag{3}$$

where ρ_Λ is the vacuum energy density, l_P Planck length and m_P Planck mass.

2.1.2 Electric potential

$$\varphi_{\min} = \frac{\rho_\Lambda l_P^3}{q_P} \approx 1.2 \times 10^{-96} \; [volts] \tag{4}$$

where ρ_Λ is the vacuum energy density, l_P Planck length and q_P Planck charge.

2.2 Entroy from potential function

We know that we can define temperature using entropy, by

$$\frac{1}{T} = \frac{\partial S}{\partial E},$$

but if temperature and potential function are analogous, we might as well define entropy for an arbitrary field given by its potential function, therefore

Definition *Entropy of a field* Suppose a physical field $\mathbf{F}$ with potential function φ is given. Then

$$\frac{1}{\varphi} = \frac{\partial S_{\mathbf{F}}}{\partial E_{\mathbf{F}}} \tag{5}$$

Accordingly we shall henceforth distinguish between different forms of entropy corresponding to different fields. In our terminology therefore, *heat* entropy is yet another entropy for a particular field called heat.

3 Classical theory

Definition *Heat Field* Consider a temprature field $T : \mathbb{R}^4 \to \mathbb{R}$ of class C^2 in vacuum, we define the heat vector field C_μ as

$$C_\mu := -\partial_\mu T, \tag{6}$$

where

$$\partial_\mu = \left(\frac{1}{c}\frac{\partial}{\partial t}, -\nabla \right).$$

Definition *Calor k*

To each fundamental particle, we associate a property of existence called *Calor* which has the same physical units as the Boltzmann constant.

Now we are ready to propose the fundamental law of heat fields,

$$\boxed{\partial^\nu C_\nu = \varsigma \rho_k} \tag{7}$$

where ς is a fundamental constant we call *Heat constant* and ρ_k is the calor density.