CONTRADICTS FOURIER'S LAW OF HEAT CONDUCTION THE THEORY OF RELATIVITY?

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Abstract

This paper is about the reasons of why the well known Fourier´s Law of heat conduction is inconsistent with one of the main results of Einstein´s theory of relativity, namely that the greatest known speed is that of the electromagnetic waves propagation in vacuum. Simple (but on solid physical arguments constructed) modifications to the laws of heat conduction will be presented that help to overcome this apparent paradox. Some of their fields of applications will be also presented with the aim to introduce teachers and students dealing with heat transfer problems to these questions that are not often discussed in standard text books and courses.

Keywords: Heat transfer, Fourier's Law, relaxation time

Resumen

Este artículo trata sobre las razones de por qué la ley de Fourier para la conducción del calor es inconsistente con uno de los principales resultados de la teoría de la relatividad de Einstein, aquel que plantea que la mayor velocidad conocida es la de la propagación de las ondas electromagnéticas en el vacío. Se presentarán modificaciones sencillas (pero construidas sobre argumentos físicos sólidos) a las leyes de la conducción del calor que ayudan a resolver esa aparente paradoja. Se mostrarán también algunos campos de aplicación con el objetivo de introducir a estudiantes y maestros interesados en fenómenos de transferencia de calor en esas cuestiones que no se discuten normalmente en los cursos y libros de texto estándar.

Palabras clave: Transferencia de calor, Ley de Fourier, tiempo de relajación.

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I. INTRODUCTION

The answer to the question giving title to this article is **yes**. Fourier's law of heat conduction predicts an infinite speed of propagation for thermal signals, i.e. a behavior that contradicts Einstein´s relativity theory. This theme is often overlooked in heat transfer text books and in engineering and physics courses. Therefore it is the aim of this paper to call the attention of teachers and students to it, explaining how the above mentioned paradoxical situation can be overcome using a simple model. Some fields of research will be highlighted where this model will be useful.

II. FOURIER´S LAWS.

In 1822, Joseph Baptiste Fourier, a French scientist, pointed out his most famous work named "Analytical Theory of Heat", and proposed the famous law of heat conduction having his name [1]. The **(first) Fourier's Law** states that the time rate of heat transfer through a material is proportional to the negative gradient of temperature and to the area at right angles through which the heat flows. In differential form it lauds

$$\bar{q} = -k\nabla T \qquad (1)$$

where q is the heat flux (W/m^2), k is the thermal conductivity and T is the temperature.

This is a very simple empirical law that has been widely used to explain heat transport phenomena appearing often in daily life, engineering applications and scientific research.

When combined with the law of energy conservation for the heat flux Eq. (1) leads to:

$$\frac{\partial E}{\partial t} = -div(\bar{q}) + Q \qquad (2)$$

where Q represents the internal source of heat and $\partial E/\partial t = \rho c \partial T/\partial t$ is the temporal change in internal energy, E, for a material with density ρ and specific heat c, and assuming