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On the solution of damped wave conduction and relaxation equation in a semi-infinite medium subject to constant wall flux. (English) Zbl 1153.80333

Summary: Eight reasons are given to seek a generalized Fourier’s law of heat conduction and relaxation. Bounded solutions are obtained for the damped wave conduction and relaxation equation in one dimension in Cartesian coordinates for a semi-infinite medium subject to the constant wall flux boundary condition for the dimensionless heat flux and dimensionless temperature. Three different methods were employed. In the first approach the method of Laplace transforms was used. The solutions are domain restricted. Three regimes can be identified (a) zero transferring regime; (b) rising regime and (c) falling regime. In the second approach a generalized substitution is used to transform the hyperbolic PDE into a parabolic PDE. The transform selected is one with spatiotemporal symmetry. The resulting parabolic PDE can be solved for using the Boltzmann transformation. In the third approach the damping term was first removed from the governing equation. The resulting equation was transformed into a Bessel differential equation using a spatiotemporal symmetric transformation variable. An approximate solution for the flux was obtained. The inertial regime, rising and falling regimes were identified in the solution. A Chebyshev polynomial approximation was used for the integrand with modified Bessel composite function in space and time. Telescoping power series leads to more useful expression for transient heat flux. The temperature and heat flux solutions at the wave front were also developed. The solution for transient heat flux from the method of relativistic transformation is compared side by side with the solution for transient temperature from the method of Chebyshev economization. Both solutions are within 12% of each other. For conditions close to the wave front the solution from the Chebyshev economization is expected to be close to the exact solution and was found to be within 2% of the solution from the method of relativistic transformation. Far from the wave front, i.e., close to the surface the numerical error from the method of Chebyshev economization is expected to be significant and verified by a specific example. The solutions for dimensionless heat flux and dimensionless temperature is found to be continuous across the wave front without any singularities or jumps.

MSC:
80A20 Heat and mass transfer, heat flow (MSC2010)
78A40 Waves and radiation in optics and electromagnetic theory

Keywords:
damped wave conduction and relaxation; constant wall flux; method of relativistic transformation of coordinates; method of Laplace transforms; generalized substitution

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