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## THERMODYNAMICS AND RELATIVITY. II

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### (5) CONSEQUENCES OF RELATIVISTIC THERMODYNAMICS

To complete our discussion, we must now consider the possible consequences of relativistic thermodynamics. The technical modifications in thermodynamic theory needed to secure its extension to relativity may have seemed too trivial and obvious to warrant the expectation that these consequences could be very novel or interesting. Nevertheless, the actual effect of replacing classical ideas as to the nature of space and time by relativistic ideas is so fundamental as to lead to important differences between the results of classical and relativistic thermodynamics. Three examples may now be given to illustrate both the essential novelty and the inherent rationality of the consequences of relativistic thermodynamics.

(a) *Temperature Gradient in Gravitational Field.* In the classical thermodynamics we have become accustomed to the conclusion that a system which is in thermal equilibrium will necessarily have uniform

temperature throughout. As a result of relativistic thermodynamics, however, it is found that this conclusion must be modified in the presence of appreciable gravitational fields. Thus if we consider a spherical distribution of material held together in static equilibrium by its own gravitational forces, corresponding to the line element,

$$ds^2 = -e^{\mu} (dr^2 + r^2 d\theta^2 + r^2 \sin^2 \theta d\phi^2) + e^{\nu} dt^2 \quad (23)$$

where  $\mu$  and  $\nu$  are functions of  $r$  alone, it can be shown<sup>8</sup> that the condition for thermal equilibrium is given by

$$\frac{d \log T_0}{dr} = -\frac{1}{2} \frac{d\nu}{dr} \quad (24)$$

where  $T_0$  the proper temperature as measured by a local observer decreases as we go outward instead of remaining constant. And for the more general static case of a system, not necessarily having spherical

<sup>8</sup> Tolman, *Phys. Rev.*, 35: 906, 1930.