Eur. J. Phys. 9 (1988) 299–300. Printed in the UK

The definition of special relativity

R H Good

Physics Department, California State University, Hayward CA 94542, USA

Received 13 November 1987

Abstract Two different definitions of special relativity are currently in use: this situation is discussed, with examples.

Resumé Deux définitions différentes de la relativité restreinte sont couramment utilisées; cette situation est discutée et illustrée par des exemples.

1. Introduction

Upon reading about phenomena behind the event horizon, a colleague recently endeavoured to engage me in a conversation couched in general-relativistic terms. When I reminded him that the uniformly accelerated reference frame belongs to the area of special relativity, we fell into a discussion of definitions. And I recalled that I had participated in such debates at various times in the past, never with much success. This note is the outcome of such discussions.

In any scholarly field, definitions are of primary importance; and in this connection I can think of no other branch of physics in which there are two mutually exclusive definitions extant, both of them to be found currently in textbooks, articles, and informed discussions. The situation is exacerbated by the fact that often—perhaps usually—the definition being employed is not clearly stated.

I will call the two definitions 'original' and 'modern' because these terms are fairly descriptive, if not altogether precise. Perhaps a reader can suggest more acceptable names.

2. The 'original' definition

Einstein's original papers seem unambiguous: they place the accelerated frame in general relativity. In his 1905 paper on the electrodynamics of moving bodies (Einstein 1905), Einstein bases his considerations on 'systems of coordinates in uniform translatory motion'. In his 1916 paper on general relativity, Einstein states the special principle of relativity, which holds for coordinates 'moving in uniform translation . . .' (Einstein 1916) and implies that this forms a basis for the special theory of relativity. Later in the same paper he states (p 142): 'A freely movable body not subject to external forces moves, according to the special theory of relativity, in a straight line and uniformly'. Thus special relativity is restricted to inertial frames of reference.

Corresponding statements are found in Tolman (1934) and in other work. The following is from a journal: '. . . the special theory of relativity is restricted to transformations between non-accelerating reference frames . . .' (Fisher 1972). Such a view appears to be accepted at least by implication in most college-level texts today; for example: 'The special theory . . . concerns . . . inertial reference frames moving with constant velocity relative to each other . . . . On the other hand, the general theory . . . is concerned with accelerated reference frames and gravity' (Tipler 1982).

3. The 'modern' definition

The alternative view is most clearly stated in Synge (1956): 'The special theory of relativity is the theory of flat space-time, interpreted physically . . . . The theory of gravitation based on the curvature of space-time is Einstein's general theory of relativity'. A similar opinion was already expressed by Eddington in 1924: '. . . a region of the world in which the g's are constant . . . is called *flat*. The theory of this case is called the 'special' theory of relativity . . . other cases must be referred to the general theory' (Eddington 1924).

This is the position taken by most active relativists today. Since the space-time in the accelerated reference frame is flat, and since curvature cannot be transformed in or away, it implies that the accelerated frame properly belongs in special relativity. This has the advantage of invariance, as is appropriate for the theory of relativity.

With the 'modern' definition, many of the phenomena popularly associated with general relativity are brought into special relativity via the accelerated frame. The event horizon, for example, is found in both general and special theories (differing in some aspects): in general relativity it occurs at a black hole, and in an accelerated reference frame it is located at a distance c^2/g from the observer of proper acceleration g. (Some would even hold that 'general relativity' is a misnomer for a relativistic theory of gravitation.)

The gravitational red shift, too, is found in both special and general relativity. In this connection, the well known text of Misner *et al* (1973) contains a significant error: they assert, following Schild, 'Gravitational redshift implies spacetime is curved'. But this is based on the misinterpretation of a spacetime diagram, as pointed out in Marsh and Nissim-Sabat (1975).

The 'original' definition is the one usually first encountered by students. However, the 'modern' one could well be presented instead, still at an elementary level. After a treatment of special relativity, one might add something like the following: 'It is found that, near a massive object, spacetime is curved in such a way that clocks run slower and that there is more volume than would be expected on the basis of Euclidean geometry. Special relativity is restricted to flat spacetime, and curved spacetime is the realm of general relativity'.

4. Concluding remarks

This note will have served its author's purpose if it provokes discussion of the proper place of the accelerated reference frame. It will exceed his modest hopes if others are thereby induced to state explicitly, and even to agree upon, their definition of special relativity.

References

Eddington A S 1924 *The Mathematical Theory of Relativity* (Cambridge: CUP) p 16; reprinted 1965

Einstein A 1905 *Ann. Phys., Lpz.* **17** 891 (Engl. Transl. 1952 *The Principle of Relativity* (New York: Dover) p 41)

—— 1916 *Ann. Phys., Lpz.* **891** 111, 142

Fisher G P 1972 *Am. J. Phys.* **40** 1772

Marsh G E and Nissim-Sabat C 1975 *Am. J. Phys.* **43** 266

Misner C W, Thorne K S and Wheeler J A 1973 *Gravitation* (New York: Freeman) p 187

Synge J L *Relativity: the Special Theory* (New York: Interscience) pp 34–5

Tipler P A 1982 *Physics* 2nd edn (New York: Worth) p 930

Tolman R C 1934 *Relativity, Thermodynamics and Cosmology* (Oxford: OUP) p 165