Part III Objectives

In the first part of the book we have seen that the kinematic consequences of special relativity are in fact manifestations of the reality of spacetime. Those who take for granted that the world is three-dimensional and regard Minkowski spacetime as nothing more than a mathematical space will certainly be quick to point out that the kinematic consequences of special relativity can be expressed in a four-dimensional language, but that is not the only possibility; these effects are predictions of special relativity, which was initially formulated in the ordinary three-dimensional language. Three-dimensionalists often claim that it is wrong to regard relativistic effects as a proof of the four-dimensionality of the world, since they can be described in both three-dimensional and four-dimensional language. Unfortunately, such claims are not based on a rigorous analysis of the relativistic effects *themselves*. The fact that these effects can be formulated in both languages is irrelevant to the question of dimensionality of the world – a three-dimensional world can be described in a two-dimensional language as well, provided that the third coordinate is regarded as a parameter in the way three-dimensionalists treat time as a parameter.

As we have seen in Chap. 5, the question that is relevant to the issue of the dimensionality of the world is: Are the kinematic consequences of special relativity possible if the world (and the physical objects) are three-dimensional? The analysis carried out there has demonstrated that the answer to this question is negative. Therefore the relativistic effects are indeed manifestations of the four-dimensionality of the world. We have developed two sets of arguments for the four-dimensionalist world view:

- in Chap. 4, we showed that, if the world is four-dimensional, its four-dimensionality will manifest itself in effects which exactly coincide with the relativistic effects,
- in Chap. 5, we argued that the relativistic effects would be impossible if the world were three-dimensional.

It appears natural to ask whether there are other manifestations of the four-dimensionality of the world in addition to the known relativistic effects. On the one hand, such a possibility looks unlikely, since special relativity has turned out to be a theory of the four-dimensional world we live in, as Minkowski argued, and for this reason all manifestations of the world's four-dimensionality are already described by the theory of special relativity. On the other hand, however, Minkowski himself appeared to have expected more manifestations of the four-dimensionality of spacetime. He realized the importance of the fact that physical particles are worldlines in spacetime and anticipated that [9, p. 76] "physical laws might find their most perfect expression as reciprocal relations between these world-lines". Unfortunately, so far Minkowski's program has not been pursued rigorously. The reason is that the four-dimensionality of the world and the reality of worldlines in particular have not been taken too seriously. As a result, we may have missed an opportunity to resolve some open questions in physics.

Take as an example the origin of inertia. It looks different in three-dimensional and four-dimensional worlds. In a three-dimensional world, inertia is what has been for centuries – an outstanding puzzle. In the Minkowski four-dimensional world, however, the ordinary three-dimensional particles are four-dimensional objects – the particles' worldtubes – and we can gain an insight into the origin of inertia if we assume that the worldtube of an accelerating particle is indeed a *real* four-dimensional object. If a particle moves by inertia (non-resistantly), its worldtube is a straight line in Minkowski spacetime. In the case of an accelerating particle, there are two facts which have not been linked so far:

- the particle resists its acceleration,
- its worldtube is *deformed*.

If the particle's worldtube is a real four-dimensional object then it is quite natural to assume that, like a deformed three-dimensional rod, the deformed worldtube of the accelerating particle also resists its deformation and a restoring force arises and tries to return the worldtube to its non-deformed (geodesic) state. This restoring force will manifest itself as the inertial force resisting the acceleration of the particle.

When a particle is at rest in a gravitational field, its worldtube is also deformed, since the particle is prevented from falling and its worldtube is not geodesic. The deformation of the worldtube also gives rise to a restoring force which manifests itself as what is traditionally called the gravitational force acting on a particle supported in a gravitational field. But the restoring force in this case is of the *same* nature as that in the case of an accelerating particle, since it also tries to restore the geodesic shape of the worldtube of the particle that is at rest in the gravitational field. In other words, inertial and gravitational forces can be regarded as originating from a four-dimensional stress[1] in the deformed worldtube of a non-inertial particle (accelerating or at rest in a gravitational field). The four-dimensional stress arises when the particle's worldtube is deformed, and this in turn is caused by the deviation of the worldtube from its geodesic state.

In the last chapter of this part we will examine the link between the issue of the nature of spacetime and the open question of inertia, and will argue that inertia is another manifestation of the four-dimensionality of the world. In order to determine whether the restoring force arising in the deformed worldtube of a non-inertial particle can be regarded as the inertial force acting on the particle, we will first examine the origin of the inertial force acting on an electric charge. For its calculation we need to address an issue that has received little attention so far – that the propagation of light (and any electromagnetic disturbances[2]) in non-inertial reference frames is anisotropic. The restoring force acting on a non-inertial charge can be calculated in the non-inertial reference frame, where the charge is at rest, by taking into account the anisotropic velocity of light there. For this purpose the anisotropic propagation of light in non-inertial reference frames is studied in Chap. 8. As the scalar and vector potentials of a charge described in a non-inertial reference frame are affected by the anisotropic velocity of light there, their calculation is carried out in Chap. 9.

Apart from the fact that they are needed to deal with the question of inertia, the issues which Chaps. 8 and 9 address are consequences of the analysis of the nature of spacetime. More specifically, the anisotropic propagation of light in non-inertial reference frames and its effect on the potential and field of a charge there are caused by the absoluteness of acceleration, which in turn follows from the absolute distinction between a geodesic and a deformed worldline.

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[1] This assumption is obviously based on the analogy with a three-dimensional rod – the restoring force in a deformed three-dimensional rod originates from a three-dimensional stress arising in the deformed rod.

[2] For brevity we will use the term 'light' instead of 'electromagnetic disturbances'. As we will see later the propagation of all interactions is anisotropic in non-inertial reference frames.