9.5: Parable of the Two Travelers

space curvature on a sphere accounts for relative acceleration of travelers

One traveler, A, stands at the equator, ready to travel straight north. A's companion B, standing against him shoulder to shoulder, wheels 90 degrees and marches straight east. She paces off 20 kilometers along the equator. There she again turns a sharp 90 kilometers (Figure 9.5.1). In the beginning their tracks are strictly parallel. Moreover, no travelers could be more conscientious than they are in continuing precisely in their original directions. Each of them deviates neither to the right nor to the left. Yet an umpire sent out to measure their separation after their 200-kilometer treks finds it to be less than the original 20 kilometers. Why? We know perfectly well: The surface of the globe is curved. If they continue north, their paths will meet at the north pole.

Already at this early stage of their trip the travelers are approaching each other, although they had started out not approaching at all. Initially their velocity relative to one another was zero; now they move toward one another with a small relative velocity. In this sense they are slowly accelerating toward each other.

Curvature of Earth demonstrated by change in separation of two originally parallel paths.

The travelers accelerate toward each other as surely as two tiny ball bearings in a free-fall horizontal railway coach accelerate toward each other (Figure 9-5). We ascribe the relative acceleration of ball bearings in the railway coach to the "tidal" effects of nonuniform gravitation near Earth. To be sure, the relevant picture for the travelers is the two-dimensional curved space of the surface of Earth, whereas what counts for the ball bearings is curvature of spacetime. This parallelism between the geometrical concept of curvature and the gravitational concept of tide-producing effect foreshadows Einstein's geometrical interpretation of gravity.

The two travelers, who started out so conscientiously on parallel tracks and deviated neither to the left nor to the right, have been told by the umpire of distances that despite all precautions they are now slowly accelerating toward one another. They blame this development on the existence of some mysterious ' 'gravitational force" that deflects their paths. They explore the nature of this "gravitational force." Repeating the travel with bicycles, motorcycles, light cars, and heavy trucks all moving northward with the same speed, they find always the same relative acceleration toward one another. They conclude that the "gravitational force" leads to the same acceleration of all objects, no matter what they are made of or how massive they are

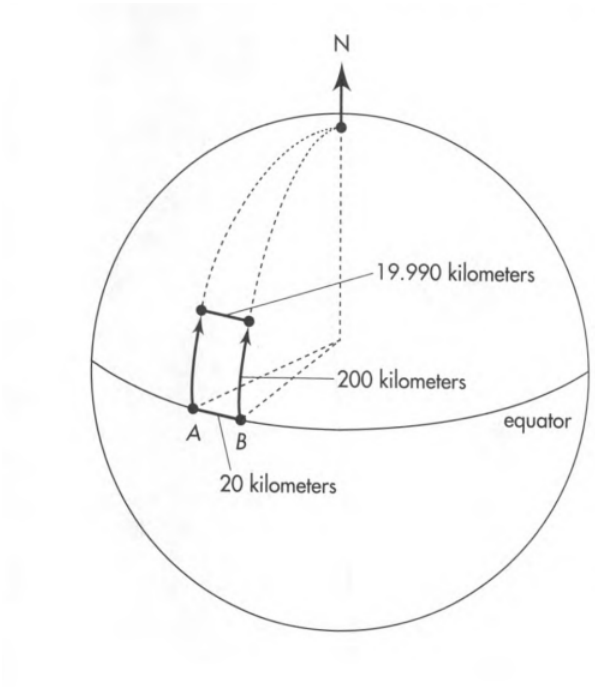

Figure 9.5.1: Travelers A and B, starting out parallel and deviating neither to the left nor to the right, nevertheless find themselves approaching each other after they have traveled some distance. Interpretation I: Some mysterious force of "gravitation " is at work. Interpretation 2: They are traveling on a curved surface. Figure not drawn to scale.

Learned would-be pundits analyze the motion of travelers. They say, in words utterly mysterious to us, "See here. You find the same acceleration for every vehicle you try. This means that the ratio of gravitational mass to inertial mass is the same for all sorts of objects. You have made a great discovery about mass."

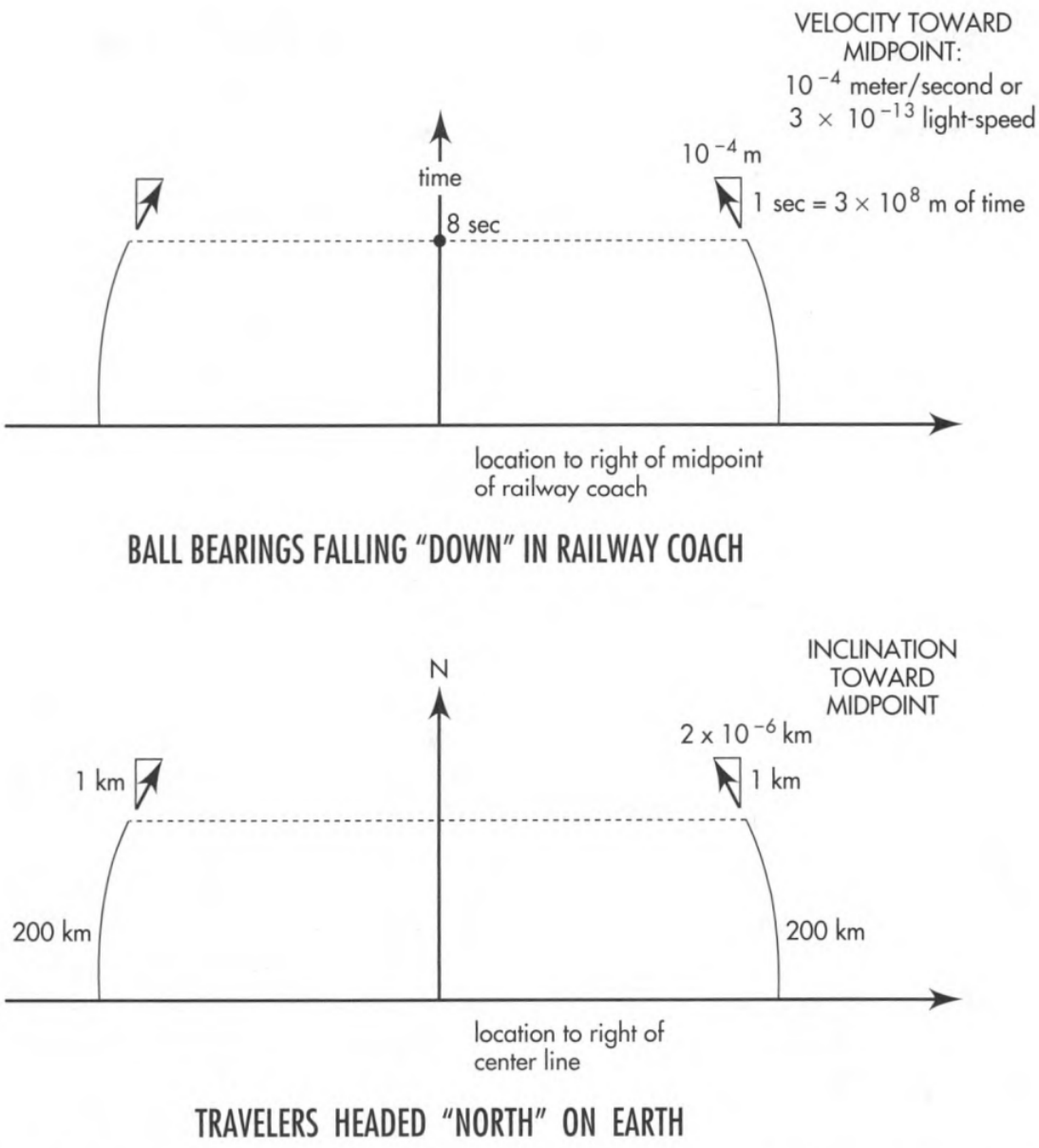

Figure 9.5.2: Comparison of the paths of northward travelers on Earth's surface with the worldlines of ball bearings released side by side from rest near Earth's surface. In both cases the "path" of each "traveler" starts parallel with that of the second traveler (zero initial relative velocity). In both cases this "path" gradually inclines toward the centerline ("relative acceleration"). In both cases the paths can be accounted for in terms of the local curvature of geometry (curvature of Earth's surface for the travelers; curvature of spacetime geometry - gravitation' - for the ball bearings). In each diagram, vertical distances are drawn-for vividness - to a different scale than horizontal distances. Both diagrams suffer from this additional imperfection: they attempt to show, on the flat Euclidean surface of this page, trajectories that can be correctly represented only in terms of a curved geometry.

Curvature alone accounts for relative acceleration

All this time we and our space-traveler friends are looking down from on high. We see the many treks. We watch the many measurements of distance. Through our intercommunication system we hear and approve as our friends on the ground interpret distance shortening as relative acceleration - and relative acceleration as "gravitation." But then they get into weighty discussions. They start speaking of "gravitation" as action at a distance. We smile. What is at issue - we know-is not action at a distance at all,

but the geometry of curved space. All this talk about the identity of "gravitational mass" and "inertial mass" completely obscures the truth. Curvature and nothing more is all that is required to describe the increasing rate at which A and B approach each other.

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