

1. VECTORS IN MINKOWSKI SPACE

Show that a timelike vector cannot be orthogonal to a null vector or to another timelike vector. Show that two null vectors are orthogonal if and only if they are parallel. (Assume these vectors are nonzero.)

Try to do this in 4 spacetime dimensions, rather than 2. A convenient notation is to view a 4-vector \mathbf{u} as consisting of a timelike component u^t and spacelike components making up an ordinary 3-vector $\vec{\mathbf{u}}$; one often writes

$$\mathbf{u} = \begin{pmatrix} u^t \\ \vec{\mathbf{u}} \end{pmatrix}$$

2. EARTH DISTANCE

Corvallis is located at approximately (44.55°N,123.25°W), that is, 44.55° north of the equator (latitude), and 123.25° west of the prime meridian (longitude). Tangent is located at approximately (44.55°N,123.1°W), and Eugene, is at approximately (44.05°N, 123.1°W).

Gresham, OR, is located at approximately (45.50°N,122.4°W), Millbrae, CA, is located at approximately (37.60°N,122.4°W), and Richmond, VA, is at approximately (37.60°N, 77.50°W).

Assume the Earth is a perfect sphere, with radius $r = 3959$ miles, and line element:

$$ds^2 = r^2 (d\theta^2 + \sin^2\theta d\phi^2)$$

- (a) Approximate the following distances using the Pythagorean Theorem:

Corvallis to Tangent; Tangent to Eugene; Corvallis to Eugene.

- (b) How good are your approximations?

- (c) Approximate the following distances using the Pythagorean Theorem:

Gresham to Millbrae; Millbrae to Richmond; Gresham to Richmond.

- (d) How good are your approximations?

You should avoid doing messy computations! If you really feel one is necessary, it is sufficient to describe the computation without completing it.

3. THE GETAWAY

This problem is optional, but good practice. Do not turn it in, but feel free to discuss it with me. Do try to solve it without help first.

The outlaws are escaping in their getaway car, which goes $\frac{3}{4}c$, chased by the police, moving at only $\frac{1}{2}c$. Realizing they can't catch up, the police attempt to shoot out the tires of the getaway car. Their guns have a muzzle velocity (speed of the bullets relative to the gun) of $\frac{1}{3}c$.

- (a) Does the bullet reach its target according to Newton?

- (b) Does the bullet reach its target according to Einstein?

- (c) Verify that your answer to part (b) is the same in all four (!) reference frames: ground, police, outlaws, and bullet.