MTH 437/537 **HW #1** Spring 2013

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* $\vec{\boldsymbol{u}}$*; one often writes*

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

2. **EARTH DISTANCE**

Corvallis is located at approximately (44.6°N,123.3°W), that is, 44.6° north of the equator (latitude), and 123.3° west of the prime meridian (longitude). Tangent is located at approximately (44.6°N,123.1°W), and Eugene, is at approximately (44.1°N, 123.1°W).

Portland is located at approximately (45.5°N,122.5°W), that is, 45.5° north of the equator (latitude), and 122.5° west of the prime meridian (longitude). San Francisco is located at approximately (37.5°N,122.5°W), and Richmond, VA, is at approximately (37.5°N, 77.5°W).

Assume the Earth is a perfect sphere, with radius $r \approx 4000$ *miles, and the line element:*

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

(a) Find the approximate distance between Corvallis and Tangent.

(b) Find the approximate distance between Tangent and Eugene.

(c) Find the approximate distance between Corvallis and Eugene.

(d) Find the approximate distance between Portland and San Francisco.

(e) Find the approximate distance between San Francisco and Richmond.

(f) Find the approximate distance between Portland and Richmond.

(g) 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 Galileo?

(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.