Black Holes, Problem Set 9 for Monday, Nov. 4

Reading from *Exploring Black Holes*

Study Chapter 1 through Section 1.7 (to the end of p. 1-13). I added 1.6 and 1.7. They are short!

Except for Section 1.5, this is review. But it is now presented rapidly and compactly, as if you were juniors who had seen special relativity as sophomores.

Section 1.5 is simultaneously *trivial* and *deep*. Like the invariance of the spacetime interval, the principle of extremal aging (often called "the principle of maximal aging") is a *deep* starting point from which many other things can be derived. However, for your first encounter of the principle applied to flat spacetime, it is nearly *trivial*.

Presentations

Rebecca, Rania, and Walker, see the comments in Problem 1 below.

Jeremy, Kel, and Eli, see the comments in Problem 2 below.

For Problem Set 9

Problem 1 — Examine *Spacetime Physics* Problem 7-12 on p. 215

Your classmates (Rebecca, Rania, and Walker) have volunteered to present this problem. There is nothing for the rest of you to do except examine the problem. Read it enough that you can puzzle over how it is going to work, and even read it all the way to the end so that you can see what Taylor and Wheeler are trying to prove.

Problem 2 — Set up the Derivation of Momentum Conservation

Your classmates (Jeremy, Kel, and Eli), are going to prove momentum conservation from the Principle of Extremal Aging. But in this problem, everyone is going to set it up and turn it parts (a), (b), and (c), below.

On the next page is the figure for the setup:

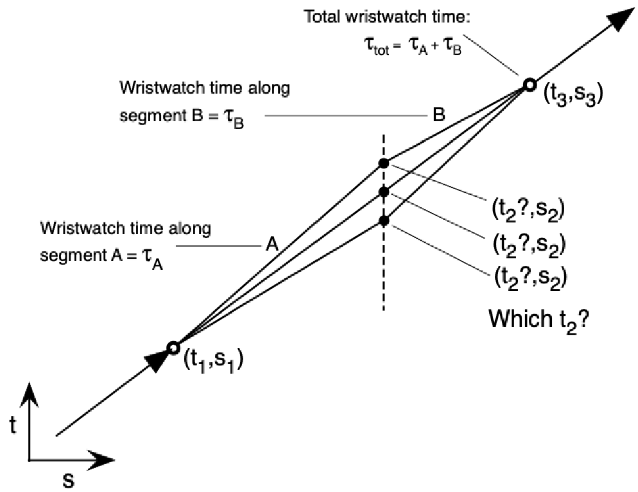

FIGURE 6 Figure for the derivation of the energy of a stone. Examine two adjacent segments, A and B, along an extended worldline plotted in, say, the laboratory frame. Choose three events at the endpoints of these two segments with coordinates (t_1, s_1), (t_2, s_2), and (t_3, s_3). All coordinates are fixed except t_2. Vary t_2 to find the maximum value of the total aging τ_{tot} (Principle of Maximal Aging). *Result:* an expression for the stone's energy E.

(a) What is τ_A in terms of t_1, s_1, t_2, and s_2?

(b) What is τ_B in terms of t_2, s_2, t_3, and s_3?

(c) Take $\frac{d}{d s_2}$ of $\tau_A + \tau_B$. What is the tidiest way that you can come up with to write this combination?

Jeremy, Eli, and Kel volunteered to finish the job by setting whatever you got in (c) equal to 0 and prove momentum conservation from that.

Problem 3 — Do *Exploring Black Holes* Problem 6 on p. 1-23

A critical thing you will need to do for this problem is a formula from Newtonian mechanics, which fortunately is still applicable to the block, because the block is at rest (and certainly not relativistic).

$F_{\text{on block}} = \frac{d p}{d t}$

What will you use for $\frac{d p}{d t}$!? You use the rate at which photons are hitting the block times the momentum per photon.

What will you use for $F_{\text{on block}}$? The weight of 1 gram which is $0.001\ \text{kg} * 9.8\ \text{m}/\text{s}^2 = 0.0098$ Newtons.

As always do things in symbols and then give the symbols their values only at the end.