Name (please print legibly!) _____

Gravitational Waves: Assignment 4
GW Detectors

1. Read the 1997 paper entitled, "If light waves are stretched by gravitational waves, how can we use light as a ruler to detect gravitational waves?" by Peter Saulson: `https://pdfs.semanticscholar.org/393a/af6b1ced305ee40d175d5f3c3a2b6020348d.pdf`. Note that this was written before LIGO and Virgo were fully built. Answer the following questions:

   (a) In your own words, describe the two points-of-view of how an interferometer responds to GWs. What is the apparent paradox in the co-expanding point-of-view?

   (b) Starting with Eq. 1, derive the result for the amount of time it should take a light ray to travel along the x-axis in the presence of a gravitational wave of amplitude $h(t)$.

   (c) Show that the time separation $\Delta\tau$ between two pulses traveling separately down the x- and y-axes caused by a passing gravitational wave in the form of a step function $h(t) = h_0 H(t - \tau)$ is given by $\Delta\tau = (2L/c)h_0$ where L is the unstretched distance of the axis.

   (d) In your own words, describe how conceptual misunderstandings about cosmological redshift are analogous to the misunderstandings about how an interferometer responds to GWs.

   (e) Do GWs stretch light? If so, how can we detect gravitational waves with light? Phrase your answer to describe what happens just before, immediately after, and sufficiently after a step-function gravitational wave has passed. If needed, include a diagram outlining your argument.

2. FYI: It is not required but if you are interested to learn more about the technical details of GW interferometric detectors, a good resource is the paper by Black and Gutenkunst entitled, "An introduction to signal extraction in interferometric gravitational wave detectors" from 2002: `https://aapt.scitation.org/doi/10.1119/1.1531578`