Ay 10 - Section Worksheet 6
Einstein is GRrrrrrrreat!

1. General Relativity (GR) Concepts

   (a) During a solar eclipse, you can actually see stars right next to the Sun!!! (the sky is dark enough). If you do this precisely, you might notice that the positions of the stars differ ever so slightly than when the Sun is nowhere near that part of the sky. Using GR, exlain why this happens (a diagram may be helpful).

   (b) Consider two super-bright flashlights that are at equal distances from Earth. They are both turned on at the same time. The light path of one flashlight is located far from the Sun, whereas the other light path is very close to the Sun. Which lightbeam will the observer detect first? Why? (again, a diagram might be useful).

2. Gravitational Redshift and its CrAzY Consequences

   (a) What is the **event horizon** of a black hole?

   (b) For light that's begin emitted just outside the event horizon, you can think of the black hole's gravity as "pulling" the light toward the black hole. Even though the light can escape the black hole at this point in space, it can be seriously altered by the black hole's extremely high gravitational force. This is known as **gravitational redshift**. Why does this term make sense to describe this phenomenon?

   (c) Consider light (i.e. photons) being emitted just outside a black hole's event horizon.

      i. Based on your answer above, does the wavelength of the photons get longer or shorter?

      ii. Does the frequency of the photons get larger or smaller?

      iii. Does the energy of the photons get larger or smaller?

      iv. Does the period of the photons get larger or smaller?

v. Does the speed at which the photons travel get larger or smaller?

Another thing to note is that according to general relativity, time appears to run slower near the event horizon of a black hole if we're looking at it from pretty far away.

(d) Finally, we're going to perform what astronomers (and scientists in general) call a **thought experiment**. If an experiment's too complicated or dangerous or just plain impossible to perform, we can use our knowledge of the situation to *IMAGINE* what would happen if we actually performed such an experiment.

As I'm sure you realize, this is quite useful for astronomers since we can't actually visit most of the objects we've talked about in this class even though we know a lot about them.

So here we go: Describe what observers on Earth would see as an extremely strong digital clock that showed hours, minutes, and seconds in huge blue numbers fell toward the event horizon of a black hole.

i. How would the color of the numbers change? Why?

ii. How would the brightness of the numbers change? Why?

iii. Would we need to switch to a different telescope in order to keep observing the clock? Why or why not?

iv. How would the time between seconds shown by the clock change? Why?

v. Why did I say that the clock was "extremely strong"?

(e) Eventually, the clock will appear to be *right at* the event horizon of the black hole.

i. What color are the numbers now?
ii. How bright do the numbers look now?
iii. How long do we have to wait to see another second tick by on the clock?
iv. When will we actually see the clock fall through the event horizon?

(f) If you were holding the clock as it approached the event horizon, will you see the changes in color and brightness of the numbers that we discussed above? Will you see the clock (and yourself) fall through the event horizon?