1. In the Stanford linear collider, small bundles of electrons and positrons are fired at each other. In the laboratory's frame of reference, each bundle is approximately 1.0 cm long ad 10 μm in diameter. In the collision region, each particle has an energy of 50 GeV, and the electrons and positrons are moving in opposite directions. Given:

$$E = \gamma mc^2$$

and for electrons/positrons,

$$mc^2 = 0.511 \text{ MeV}$$

find γ and proceed (this is from Relativistic Energy which we will cover in more detail next week).

a) How long and how wide is each bundle in its own reference frame?

b) What must be the minimum proper length of the accelerator for a bundle to have both its ends simultaneously in the accelerator in its own reference frame? (The actual proper length of the accelerator is less than 1000m.)

Please go on to the next page. . .

2. Unobtanium (Un) is an unstable particle that decays into normalium (Nr) and standardium (St) particles.

   (a) An accelerator produces a beam of Un that travels to a detector located $100m$ away from the accelerator. The particles travel with a velocity of $v = 0.866c$. How long do the particles take (in the laboratory frame) to get to the detector?

   (b) By the time the particles get to the detector, half of the particles decayed. What is the half-life of Un? (Note: half life as measured in rest frame of particles).

   (c) A new detector is going to be used, which is located 1000 m away from the accelerator. How fast should the particles be moving if half of the particles are to make it to the new detector?

3. Observers in reference frame S see an explosion located on the $x-$axis at $x_1 = 480m$. A second explosion occurs 5.0 μs later at $x_2 = 1200m$. In reference frame S', which is moving along the $x-$axis in the $+x$ direction at speed v, the two explosions occur at the same point in space. What is the separation in time between the two explosions as measured in S'?

4. **BONUS:** This is a qualitative question that results in one bonus percentage point.

   What will a square that is 5 meters by 5 meters at rest, is located 100 meters away from you, and is traveling at the following speeds, look like at speeds such as $v = 0.6c, v = 0.8c, v = 0.99c$?

   Think about the following factors: Length contraction, the time delay it takes for light from different parts of the square to reach your eye.