2-9. The Relativistic Heavy Ion Collider (RHIC) at Brookhaven is colliding fully ionized gold (Au) nuclei accelerated to an energy of 200 GeV per nucleon. Each Au nucleus contains 197 nucleons. (*a*) What is the speed of each Au nucleus just before collision? (*b*) What is the momentum of each at that instant? (*c*) What energy and momentum would be measured for one of the Au nuclei by an observer in the rest system of the other Au nucleus?

2-14. An electron in a hydrogen atom has a speed about the proton of 2.2×10^6 m/s. (*a*) By what percent do the relativistic and Newtonian values of E_k differ? (*b*) By what percent do the momentum values differ?

2-19. In a nuclear fusion reaction two ^{2}H atoms are combined to produce one ^{4}He. (*a*) Calculate the decrease in rest mass in unified mass units. (*b*) How much energy is released in this reaction? (*c*) How many such reactions must take place per second to produce 1 W of power?

2-41. 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 about 1 cm long and 10 μm in diameter. In the collision region, each particle has energy of 50 GeV, and the electrons and positrons are moving in opposite directions. (*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 length of the accelerator is less than 1000 m.) (*c*) What is the length of a positron bundle in the reference frame of the electron bundle? (*d*) What are the momentum and energy of the electrons in the rest frame of the positrons?

2-47. Show that the creation of an electron-positron pair (or any particle-antiparticle pair, for that matter) by a single photon is not possible in isolation, that is, that additional mass (or radiation) must be present. (*Hint:* Use the conservation laws.)