Mass-Energy Equivalence Problems

Name: _____ Date: _____

1. Calculate the rest energy of a proton (m_p = 1.673x10^{-27} kg) in joules, J, and in mega electron volts, MeV.

2. The rest energy of a small object is 4.5x10^4 MJ. Calculate its rest mass.

3. The rest mass energies of a proton and a neutron are 938.3 MeV and 939.6 MeV, respectively. Calculate the difference in their rest masses in kilograms.

4. Calculate how much energy can be produced by the conversion of just 5% of the mass of a 20 kg steal ball directly into energy.

5. When hydrogen atoms react in the interior of the Sun, in a process called fusion, mass is converted into energy at the rate of 4.1x10^9 kg/s (that is the loss of mass of the sun every second!). Calculate the amount of energy that is released every second from the Sun. If one chocolate bar contains about 100 KJ of chemically available energy for humans, how many chocolate bars would this amount to? The bomb dropped on Hiroshima at the end of WWII released about 63 TJ (a TJ = 1 terajoule or 10^{12} J) of energy, calculate how many "Hiroshima bomb" equivalents the Sun releases in one second.

6. Earth, of mass 5.98x10^{24} kg, revolves around the Sun at an average speed of 2.96x10^4 m/s (about 8200 km/h). Calculate how much mass, if converted into energy, could supply the energy required accelerate the Earth from rest to that speed.

7. Calculate the energy required to accelerate a proton (m_p = 1.673x10^{-27} kg) from rest to 0.90*c*.

8. An electron (m_e=9.11x10^{-31} kg) moves with a speed of 0.97c through a linear accelerator.
   a) Calculate the total energy of the electron in the laboratory frame. (in joules and MeV)
   b) Calculate the kinetic energy of the electron in the laboratory frame. (in joules and MeV)

9. A hypothetical particle has rest energy of 1.60 MeV and (in a certain inertial frame) a total energy of 3.20 MeV.
   a) Calculate its rest mass.
   b) Calculate its kinetic energy in the given frame.

10. In a study it was determined that 4 L of gasoline produces 1.05x108 J of energy and that this energy is sufficient to operate a car for 30 km. An Aspirin tablet has a mass of 325 mg. if the Aspirin could be converted completely into thermal energy (by converting 100% of its mass into energy), how many kilometers could the car go on a single tablet?

11. Deuteron, a heavy hydrogen nucleus ($^{2}_{1}H$), consists of a proton and a neutron. Its rest energy is 1875.6 MeV. How much energy is liberated, as kinetic energy and as a gamma ray, when a deuteron is created from a separate proton (a particle of rest mass energy 938.9 MeV) and a neutron (a particle of rest mass energy 939.6 MeV)?