3. Equations (2)-(4) are equally valid for an elastic and a totally inelastic collision. Only Eq. (5) changes: for a totally inelastic collision, the change in the y or y′ component of the momentum equals -1 times the initial mommentum (instead of -2 times the initial momentum). Hence Eq. (4) becomes

$$-f(v^2)mv_y = -f(v'^2)mv'_y$$

This differs from Eq. (5) only by the absence of the factor of 2. But that has no effect on the remainder of the derivation [compare Eqs. (6)-(8)].

5. The relativistic energy has the Taylor series expansion

$$\frac{mc^2}{\sqrt{1 - v^2/c^2}} = mc^2\left[1 + \frac{v^2}{2c^2} + \frac{3v^4}{8c^4} + \ldots\right]$$

so the kinetic energy is

$$K = \frac{1}{2}mv^2 + \frac{3}{8}\frac{mv^4}{c^2} + \ldots$$

The second term represents the difference between the relativistic and the Newtonian expressions, and the fractional difference is

$$\frac{3mv^4/8c^2}{mv^2/2} = \frac{3}{4}\frac{v^2}{c^2} = \frac{3}{4}\frac{(2.2 \times 10^6)^2}{(3 \times 10^8)^2} = \boxed{4.0 \times 10^{-5}}$$

11. The rate of mass loss is the rate of energy loss divided by c^2,

$$\frac{dM}{dt} = \frac{3.9 \times 10^{26}\ \text{W}}{c^2} = 4.3 \times 10^9\ \text{kg/s}$$

and in one year,

$$\Delta M = 4.3 \times 10^9\ \text{kg/s} \times 3.16 \times 10^7\ \text{s} = \boxed{1.4 \times 10^{17}\ \text{kg}}$$

12. (a) For 10 kilotons TNT, the energy is $10 \times 4.2 \times 10^{12}$ J, and the rest mass converted is

$$\frac{1}{c^2} \times 10 \times 4.2 \times 10^{12}\ \text{J} = \boxed{4.7 \times 10^{-4}\ \text{kg}}$$

(b) No, since the energy has an associated mass equal to that of the original rest mass.

17. (a) The mass defect is

$2 \times 938.3\ \text{MeV}/c^2 + 2 \times 939.6\ \text{MeV}/c^2 - 3727.4\ \text{MeV}/c^2 = 28.4\ \text{MeV}/c^2$. Accordingly, the binding energy is $\boxed{\text{B.E.} = 28.4\ \text{MeV}}$

(b) The binding energy of the helium nucleus is larger than the binding energy of two deuterium nuclei by

$$28.4\ \text{MeV} - 2 \times 1.3\ \text{MeV} = \boxed{25.8\ \text{MeV}}$$

19. The energy E′ of each of the pions is $E' = 110\text{ MeV} + 140\text{ MeV} = 250\text{ MeV}$. The momentum is $p' = \pm (1/c)\sqrt{E'^2 - m^2c^4} = 207\text{ MeV}/c$. From the inverses of the transformation equations (36) and (37) for energy and momentum we find E and p for the forward pion:

$$E = \frac{E' + Vp'}{\sqrt{1 - V^2/c^2}} = \frac{250 + 0.90 \times 207}{\sqrt{1 - 0.90^2}} = 1001\text{ MeV}$$

$$p = \frac{p' + \dfrac{VE'}{c^2}}{\sqrt{1 - V^2/c^2}} = \frac{207 + 0.90 \times 250}{\sqrt{1 - 0.90^2}} = \boxed{991\text{ MeV}/c}$$

and

$$K = E - mc^2 = 1001\text{ MeV} - 140\text{ MeV} = \boxed{861\text{ MeV}}$$

Likewise, for the backward pion:

$$E = \frac{E' + Vp'}{\sqrt{1 - V^2/c^2}} = \frac{250 - 0.90 \times 207}{\sqrt{1 - 0.90^2}} = 146\text{ MeV}$$

$$p = \frac{p' + \dfrac{VE'}{c^2}}{\sqrt{1 - V^2/c^2}} = \frac{-207 + 0.90 \times 250}{\sqrt{1 - 0.90^2}} = \boxed{41\text{ MeV}/c}$$

and

$$K = E - mc^2 = 146\text{ MeV} - 140\text{ MeV} = \boxed{6\text{ MeV}}$$

20. From Eqs. (36) and (37), with $p_x = \pm E/c$,

$$E' = \frac{E \mp VE/c}{\sqrt{1 - V^2/c^2}} = E\sqrt{\frac{1 \mp V/c}{1 \pm V/c}}$$

$$p' = \frac{p \mp Vp/c}{\sqrt{1 - V^2/c^2}} = p\sqrt{\frac{1 \mp V/c}{1 \pm V/c}}$$

The photons of the light wave have energy $E = h\nu$; hence the transformation law for E must be the same as that for ν.