175.

Problem 21.55 (RHK)

(a) *In modern experimental high energy physics, energetic particles are made to circulate in opposite directions in so-called storage rings and permitted to collide head-on. In this arrangement each particle has the same kinetic energy K in the laboratory. The collision may be viewed totally inelastic, in that the rest energy of the two colliding particles, plus all available kinetic energy, can be used to generate new particles and to endow them with kinetic energy. We have to show that the available energy in this arrangement can be written in the form*

$$E_{new} = 2mc^2\left(1+\frac{K}{mc^2}\right)$$

where m is the mass of the colliding particles. (b) *We have to find the energy available when* 100-GeV *protons are used in this fashion.* (c) *We have to calculate the proton energy if* 100 GeV *is to be made available.*

Solution:

In colliding beam experiments, protons, mass m, and antiprotons, mass m, move in opposite directions and collide head-on. In such an arrangement proton and antiproton have the same kinetic energy K. The total momentum is zero. The collision may be viewed as totally inelastic, in that the total energy, rest plus kinetic, of the two particles generates new particles. The total available energy in this arrangement is

$$E_{new} = 2\times\left(mc^2 + K\right) = 2mc^2\left(1+\frac{K}{mc^2}\right),$$

where K is the kinetic energy of the colliding particles, i.e. proton and antiproton.

(b)

When 100-GeV proton and antiproton are used, the energy available for particle production will be

$$E = \left(2\times 0.938 + 200\right)\ \text{GeV} = 201.87\ \text{GeV},$$

we have used that $m_p c^2 = 0.938$ GeV.

(c)

Kinetic energy of protons that will make available 100 GeV will be

$$2K = \left(100 - 2 \times 0.938\right) \text{ GeV} = 98.124 \text{ GeV},$$

and

$$K = 49.062 \text{ GeV}.$$