Introduction

Exercise 1 (From Emery, Sereno, and Shang)
At the end of the Fermilab Alvarez Linac the protons have a kinetic energy of 400 MeV.

a) Calculate the total energy of the protons.

b) Calculate the momentum of the protons.

c) Calculate the relativistic gamma factor.

d) Calculate the proton velocity in units of the velocity of light.

Exercise 2 Two particles with equal rest masses have a total energy E in the Laboratory frame (Lab), in which one is at rest. In their center of mass frame (COM) their energy is ECM. Relate the two energies.

Exercise 3 A proton and an anti-proton collide to produce a W+ W- pair. The W has a mass of 80 GeV/c^2. Find the minimum energy of the beam to produce the two W's if

a) the anti-proton beam hits stationary protons in a fixed hydrogen target.

b) if the proton beam collides head-on with the anti-proton beam of equal energy.

Exercise 4 (From Emery, Sereno, and Shang)
Calculate the length of the first four drift tubes in a Wideroe linac for the following parameters: starting kinetic energy 100 keV, energy gain per gap 1 MeV, rf frequency 7 MHz. Perform the calculations for protons and for electrons and compare the results. Assume the accelerating gaps to be very short compared to the drift tubes.

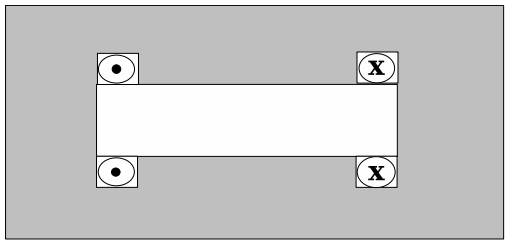
Exercise 5
Protons in the Fermilab Tevatron get accelerated from 150 GeV to 1 TeV. They are essentially at the speed of light at injection, so that the revolution frequency of the protons may be considered constant. The radius of the Tevatron ring is 1000 m.

a) What is the revolution frequency of protons circulating in the Tevatron?

b) What is the minimum peak voltage of the accelerating system needed to go from 150 GeV to 1 TeV in 40 seconds?

c) If it is possible to accelerate up to 1113 bunches in the ring at one time, what is the RF frequency? What is the harmonic number?

Exercise 6 (From Edwards and Syphers)



A simple bending magnet is made as shown in the figure above. There are N turns of conductor carrying current I wound about each pole of the iron magnet. The poles are separated by a distance h. Assuming the permeability of the iron to be infinite, show that the field in the gap of the magnet is given by

$$B = \frac{2\mu_0 N I}{h}$$

Exercise 7
The LHC has a circumference of 26659 m. Each proton beam in the LHC has an energy of 7 TeV.

a) What is the effective bending field in the LHC?

b) The actual magnetic field of a dipole magnet is 8.3 Tesla. What percentage of the LHC contains dipole magnets?

c) There are 1232 dipole magnets in the LHC. How long is each one?

Exercise 8
A synchrotron of 25 m radius accelerates protons from an energy of 50 MeV to 1 GeV in 1 s at which point the dipole magnets in the ring saturate.

a) What is the maximum energy 4He++ (A=4, Z=2) that this synchrotron can accelerate?

b) What is the revolution frequency for protons?

c) What is the revolution frequency for helium?