Idaho State University – Department of Physics
PHYS 499 / PHYS 630 Accelerator Physics — Spring 2009
4 March 2009

Midterm Exam

Name: _____

Major: _____ ISU ID: _____

Definitions (6 points)

Define the following terms using less than 100 words.

Magnetic rigidity

Linac

Multiple-choice questions (8 points)

An electron is moving with a relativistic factor $\gamma = 10$. Its momentum is

☐ 1 MeV/c ☐ 2 MeV/c ☐ 4 MeV/c ☐ 5 MeV/c ☐ 10 MeV/c

The magnetic rigidity of a 200-GeV proton is

☐ 2 T · m ☐ 6.68 T · m ☐ 20 T · m ☐ 200 T · m ☐ 668 T · m

The De Broglie wavelength of a 5-MeV α particle is

☐ 6 fm ☐ 4 pm ☐ 2 nm ☐ 1 μm ☐ 8 mm

In the HERA machine at DESY, in Hamburg, 26-GeV electrons collided with 820-GeV protons. The center-of-mass energy of the collision was

☐ 846 GeV ☐ 800 GeV ☐ 26 GeV ☐ 0.3 TeV ☐ 0.8 TeV

A quadrupole magnet has a gradient $B' = 10$ T/m and length $l = 10$ cm. Its focal length for 1-GeV electrons is

☐ 1 mm ☐ 2 cm ☐ 3 m ☐ 50 m ☐ 6 km

The cyclotron frequency for a deuteron in a 1-T magnetic field is

☐ 5.1 Hz ☐ 3.8 kHz ☐ 4.2 kHz ☐ 7.6 MHz ☐ 8.9 GHz

In a fixed-target experiment, if the target density is doubled while other parameters are left unchanged, then the luminosity

☐ is unchanged ☐ quadruples ☐ doubles ☐ halves ☐ is reduced to 1/4

In a detector with total efficiency $\varepsilon = 10\%$, the event rate is $R = 1$ kHz for events with a known cross section $\sigma = 1$ μb. The luminosity is

☐ 10^{32} cm^{-2}s^{-1} ☐ 10^{34} cm^{-2}s^{-1} ☐ 10^{36} cm^{-2}s^{-1} ☐ 10^{38} cm^{-2}s^{-1} ☐ 10^{40} cm^{-2}s^{-1}

Problem (8 points)

The CEBAF recirculating linac at Jefferson Lab will produce a beam of 12-GeV electrons.

(a) Suppose that, before reaching the experimental hall, this beam needs to be deflected by an angle $\alpha = 100$ mrad. For this purpose, a dipole magnet is used, with pole gap $h = 2$ cm, $N = 1000$ turns per pole, and length $l = 2$ m along the particles' trajectory. What current I is needed?

(b) The beam consists of bunches at a frequency $f = 0.5$ GHz. The average beam current is 10 nA. Calculate the total charge Q per bunch and the corresponding number of electrons per bunch, N_e.

(c) The experiment uses a hydrogen target with density $\delta = 1$ g/cm^3 and length $z = 3$ cm. Calculate the luminosity L integrated over each bunch crossing and the average instantaneous luminosity $\langle \mathscr{L} \rangle$.

Short essay (8 points)

Discuss some of the similarities and differences that exist between cyclotrons and synchrotrons.