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Superconducting Accelerator Magnets

Example of Use as Term Project

in High School or College Introductory Level Course

Term Project Plan

Foreword

This project is to develop a 'preliminary proposal' for the superconducting dipole magnets that would be required in a proton accelerator of a specified energy. The proposal would be based on the material presented in designated lessons in the courseware. The lessons serve as both background (with explanations of the concepts involved) and illustrative examples that show how to determine the magnet requirements and their design.

The student would find background information and illustrative examples of the procedures to be followed in these lessons:

Lesson 1-1: Introduction to particle physics and the role of accelerators in studying the structure of matter.

Lesson 1-2: Brief history & principles of accelerators.

Lesson 1-3: The function of dipole and quadrupole magnets in accelerators; description of basic magnet parts and field multipoles.

Lesson 1-5: Introduction to superconductivity and superconductor use in magnets.

Lesson 1-7: Basic design types and examples of accelerator magnets.

Lesson 2-3: Definition of parameters for Niobium-Titanium superconductors for magnets.

Lesson 2-4: Superconducting materials for accelerator magnets.

Lesson 3-4: Optimizing the design of a superconducting magnet.

The student would be given some guidelines to enable him/her to arrive at the conceptual dipole design:

- The assumption of a proton accelerator with a specified energy.
- The choice to use either Niobium-Titanium or Niobium-Tin superconductor (for which properties and parameters are given in the referenced lessons).
- Specification for basic magnet guidelines such as the diameter of magnet inner bore, the use of an iron yoke, and the magnet operating margin.

- The assumption that the dipoles occupy 82% of the bending region of the accelerator. (The bending region is the full circumference for a circular accelerator but only the end portions for a race track shape. Although quadrupoles, accelerating stations, and interconnections are required in a real accelerator, they will be omitted from the present 'preliminary proposal'.)

The student would then follow this procedure:

- Pick a site at student's school or neighborhood (e.g. beneath an athletic field, building, or local park) where the accelerator could be placed. This would set the dimensions.
- Determine accelerator layout that will fit on this site. Consider circle or race track. What is required bending radius for beam? What field strength dipole magnet does that require? What length is suitable for the dipole magnet and how many such magnets would be needed?
- Using the interactive procedure in Lesson 3-4 design a dipole magnet with that field strength and good field quality (acceptable amount of undesired multipoles). Consider feasible values for the superconductor size and current capacity, either the defaults or a reasonable 'commercially available' alternative.
- Tabulate some basic parameters for the magnets; i.e. magnetic field, operating temperature, current. Check the electrical resistance of the magnet at 295 K and 10 K by interactive procedure in Lesson 2-5 to find resistance of copper and superconductor at a given temperature.
- Make a list of some local, state, or national companies that are prime suppliers of the materials needed.
- Estimate amount of superconductor and iron needed, and give a rough cost.

Further Extensions

- If student has interest in particle physics itself, she/he could do some research to learn what could be studied at the energy of the proposed accelerator. Information about current accelerators and their research programs is available on the web sites for principal laboratories with accelerators. (Links are available from the MJB Plus web site at www.mjb-plus.com.)
- Students who want to continue with more detail can consider superconductor design and testing issues (based on Unit 2) and further magnetic optimization (based on Unit 3).