1.1 Construction and use of a cloud chamber.

Name of your Institution: University of Birmingham

Title of the educational scenario template: Inquiry-based teaching

Title of your educational scenario: Construction and use of a cloud chamber

Educational problem:

Particle physics with its “invisible” particles moving at essentially the speed of light seems at first sight well beyond everyday experience. However by building a cloud chamber using basic scientific principles and straightforward techniques, one can see particle tracks and use them to study radioactivity and cosmic rays. These fundamental investigations are not at all beyond the scope of the interested student and enquiring layman.

Educational scenario objectives:

During the scenario, participants will:

1. understand how charged particles interact as they pass through matter, in particular how they may be detected by the trails of ionisation which they produce
2. discuss how these trails of ionisation, constituting tiny amounts of electrical charge, may be detected
3. construct a cloud chamber, following detailed instructions
4. at each stage, understand the basic physics principles involved and discuss the choice of parameters
5. observe vapour trails in the cloud chamber, corresponding to the passage of charged particles.
6. investigate and understand the origin of these trails: *alpha particles* from radioactive decay and *cosmic rays*
7. measure the numbers of tracks observed per minute and check whether these rates agree with estimates
8. demonstrate the cloud chamber to others to illustrate the insight it gives to particle physics

Characteristics and needs of students:

Students may have heard of the basic structure of matter (atoms and protons and electrons) perhaps and of the large centres of research, such as CERN, but may not realise how such knowledge has been obtained. This scenario allows students to build a particle detector and understand at first hand how charged particles interact with matter.

By observing tracks via their vapour trails in the cloud chamber, students will be able to measure the lengths of the tracks and the rates of their occurrence. These measurements can then be compared with expectations which can be investigated and studied via scientific web sites. The combination of measurement and comparison with theory will enable students to sample the scientific experience.

In planning their investigations, students can divide their efforts as they think fit between experimental measurements and theoretical investigation. Finally the various subgroups will report back to each other. This will allow the development of communication and collaboration skills.

In all, the scenario will enlighten students' views of science and what it means to be a scientist.

Rationale of the Educational approach and Parameters guaranteeing its implementation:

The scenario is designed to give students experience working in groups, both in constructing a particle detector and in analysing the data it provides. In both activities, students will appreciate the importance of making approximations in design and in estimating uncertainties in their measurements and calculations. Finally the groups will merge and discuss together their results, preparing a joint report.

In all these activities, students will be encouraged to experiment with the chamber design and to follow their own investigations into radioactivity and cosmic rays. But at each stage a teacher will be on hand to offer guidance and advice.

To implement this scenario, several square metres of table space are required as well as some PCs with access to the Internet. Also the various components required to construct the cloud chamber (described later) should be obtained in advance.

Learning activities:

Phase 1: Question Eliciting activities

Discussions, led by the teacher or leader, on the following topics

- what is matter made of? (*atoms; nuclei and electrons*)
- what might happen when a charged particle passes through matter? (*ionisation)*
- how to detect this weak trail of ionization? (*droplets in vapour -> cloud chamber; bubbles in boiling liquid -> bubble chamber; sparks along ionised trail -> spark chamber*)

Phase 2: Active investigation

Critical investigations on the following topics

- the principles of operation of the diffusion cloud chamber, backed up by web searches (*large leak tight container; alcohol vapour; hot and cold surfaces – obtained how?*)
- sources of charged particles (*electrons and alpha particles from radioactive decay; cosmic rays*)
- discuss how to match the cloud chamber parameters to possible sources of particles
- does the design presented in the Manual match the requirements?

Phase 3: Creation

The students build the detector and in parallel investigate what they expect to see:

- construct the cloud chamber following the Instructions Manual, described in :

http://epweb2.ph.bham.ac.uk/user/lazzeroni/outreach/cloud-chamber/

- an article describing the chamber construction is here:
  http://iopscience.iop.org/0031-9120/47/3/338
- follow the exercises described in the Manual, discussing together at each stage
- note down as accurately as you can the lengths of tracks which you observe
- note also whether the tracks seem to come from the radioactive source (*alpha particles* mainly) or just seem to pass through the chamber at an arbitrary position and angle (*cosmic rays*)
- estimate the expected rate of cosmic rays passing through the chamber
- from the strength of the radioactive source, how many alpha particles do you expect to see per second?

Phase 4: Discussion

- Do these estimates agree with your experimental results?
- Then the scientific discussion ensues: what are the uncertainties involved in measurement and in prediction? Are the measurements consistent with the predictions?

Phase 5: Reflection

Students appreciate the implication of their results and begin to see a connection with current topical research. For example,

- In the cloud chamber, the trails of alpha particles are usually several cm long. What does this imply for radiation protection? (*alpha particles cannot penetrate a sheet of paper; they are absorbed by our skin*)
- The cosmic rays observed in the cloud chamber may occur in *extensive air showers*, being studied, for example, in the Auger project in Argentina:

  http://www.auger.org/

Participating roles:

Students

- Construct a particle detector
- Gain experience of data taking
- Assess uncertainties
- Estimate what results are to be expected and compare with measurements
- Consider the implications of their results

Teacher

- Encourages the students to read the Manual as a starting point.
- Explains the basic principles of particle detection
- Advises how the cloud chamber works
- Guides the students laboratory work and their investigations on the WWW.
- Helps the students in evaluating their results
- Guides the student to further open-ended study

Tools, services and resources:

Part of a room or laboratory in which to build the detector.

The cloud chamber components and parts listed in:

http://epweb2.ph.bham.ac.uk/user/lazzeroni/outreach/cloud-chamber/cloud-chamber-manual.pdf

PCs with Internet access.

A whiteboard on which discussions can be based, estimates can be made and results described.