DEPARTMENT OF PHYSICS & ASTRONOMY
3459 EXAM-2
14:00 - 17:00 : March 23rd 2010

Please read the exam guidelines, rules, instructions and marking criteria at
`http://moodle.ucl.ac.uk/mod/wiki/view.php?id=13963&page=Final+exam`
(linked from the *Exams and Coursework* page).

This exam is worth 50% of your final mark for the course. The duration of the exam is 3 hours. Students should upload the Java source code files for their solution using Moodle under the section headed "Exam 2".

Note : no knowledge of nuclear or particle physics is required to answer this question.

Part 1: 15/50 marks

The neutrinoless double-beta decay experiment EOX searches for the nuclear decay process $^{136}_{54}\mathrm{Xe} \rightarrow {}^{136}_{56}\mathrm{Ba} + 2e^-$. The two electrons are emitted with a total energy of 2.5 MeV. The experiment measures the total energy with a resolution of 10%, or 0.25 MeV.

Write a program to do the following :

- Simulate each EOX measurement by generating a single number representing the total energy of the two electrons. This total energy should be randomly distributed according to a Gaussian distribution with mean 2.5 MeV and a standard deviation of 0.25 MeV. You may find the result quoted below (under *Gaussian Smearing*) useful.
- Simulate 100 such measurements, and write the results to a file called `signal.txt` (in the `N:` drive) with each line containing a single smeared total energy.

Part 2: 20/50 marks

A similar program has generated 1000 simulated events, available at :
`http://www.hep.ucl.ac.uk/undergrad/3459/exam-data/eox-signal.txt`

The EOX experiment suffers from backgrounds, which can produce fake neutrinoless double-beta decay events. The following file contains 1000 simulated background events :
`http://www.hep.ucl.ac.uk/undergrad/3459/exam-data/eox-background.txt`
Each line contains the measured total energy for a single background event.

Write a program using appropriate classes and methods to do the following :

- Using the file of signal events provided, calculate the number of events with a measured total energy greater than some minimum energy X MeV; call this number S. Using the background event file, calculate the number of background events above the same minimum energy; call this number B. Calculate the signal-to-background ratio S/B.
- Consider values of the minimum energy X ranging from 1.0 MeV to 3.0 MeV in steps of 0.1 MeV. Find the value of X that maximises the ratio S/B.

Part 3: 15/50 marks

Make the following enhancements to your code :

- Define an interface to represent any metric, such as S/B, that can be used to optimise the minimum energy cut-off.
- Modify your code so that it uses this interface.
- Provide an alternative implementation which uses the quantity $S/\sqrt{B}$ as the metric for a given choice of minimum energy cut-off. Your code should report the results of optimising the selection using each of the metrics S/B and $S/\sqrt{B}$.

Uploading your work

If you use your own classes from earlier modules, make sure you upload them as well as any new classes you create during the exam. You do not need to upload the file `signal.txt`.

Gaussian Smearing

The `nextGaussian()` method of Java's `Random` class generates a Gaussian distributed random number with a mean of 0.0 and a standard deviation of 1.0. Denote this by $G(0.0, 1.0)$. Then a Gaussian distributed random number with a mean of μ and standard deviation σ is obtained as follows :

$$G(\mu, \sigma) = \sigma \times G(0.0, 1.0) + \mu$$

END OF PAPER