Part II Computational Physics Exercises marking guide

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1 Introduction

There are marks of 6, 6, and 8 respectively for exercises 1, 2, and 3A or 3B. In the marking, these have been doubled to 12, 12 and 16, to allow greater discretion and reducing the need to use half-marks.

In the first two exercises, we are not marking for code quality, just for successful completion of the tasks. In the last exercise the code quality should enter into the marks as indicated later. High-quality code should include at minimum:

- Structured code: tasks broken down into sensible functions;
- Meaningful function names;
- Meaningful variable names (this is less important than for naming functions: single-letter variable names can be meaningful if the meaning can be inferred from context, e.g. loop counters);
- Appropriate levels of commenting (at minimum identifying what each function does, preferably using doc-strings);
- Sensible use of whitespace to indicate code structure (somewhat obligatory in Python, but e.g. using line spacing to separate functions is something to look for).

2 Marking levels

The following table gives guidelines for the marking levels you are aiming for:

	Ex1/12	Ex2/12	Ex3A/16	Ex3B/16	Total/40
mean	9	9	11	11	29
std deviation	1.5	1.5	3	3	6
range (min–max)	6–12	6–12	6–16	6–16	18–40

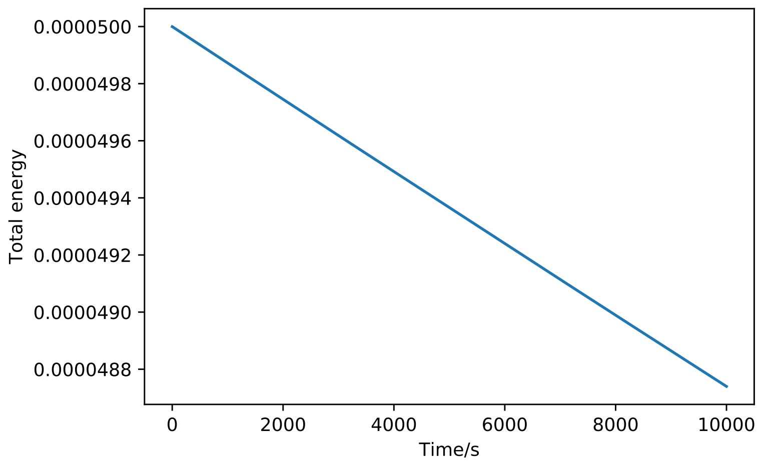
Clearly these are approximate, and you will expect some deviation due to sampling statistics. The range especially is indicative since these are not Gaussian distributions.

3 Exercise 1

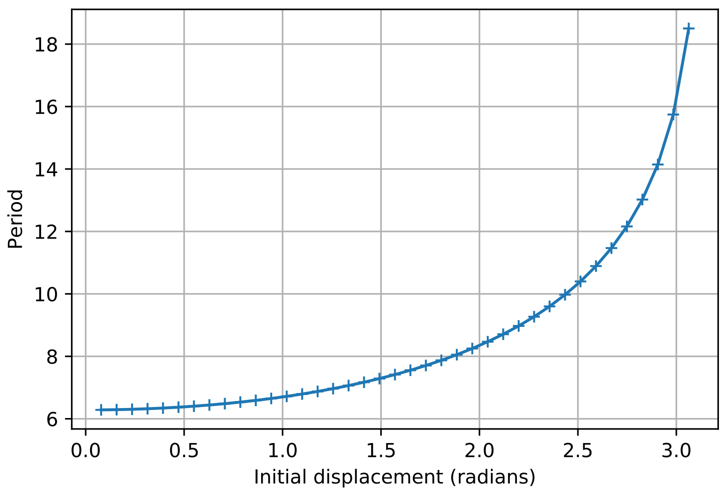
There are 12 marks for this question.

3.1 Core task 1

The core task is to get the code running correctly. Depending on the integrator, the energy plot should be stable to sub-percent values or better over long periods:



The plot of period against amplitude looks like:

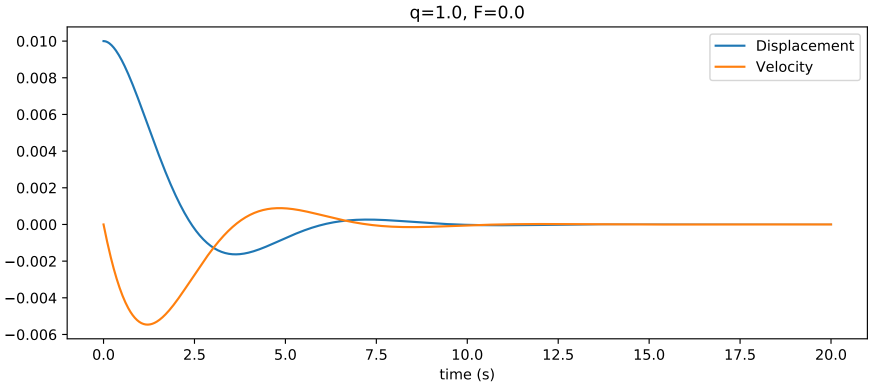


The period required is 7.42 seconds.

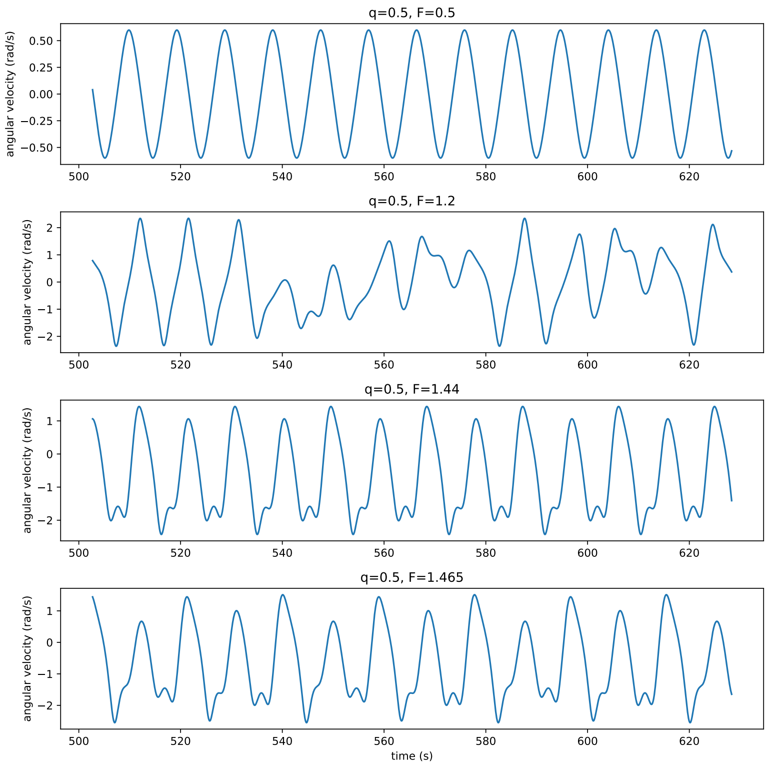
4 marks for a good job at this task.

3.2 Core task 2

The damped, unforced system should look as predicted from linear SHM, e.g.



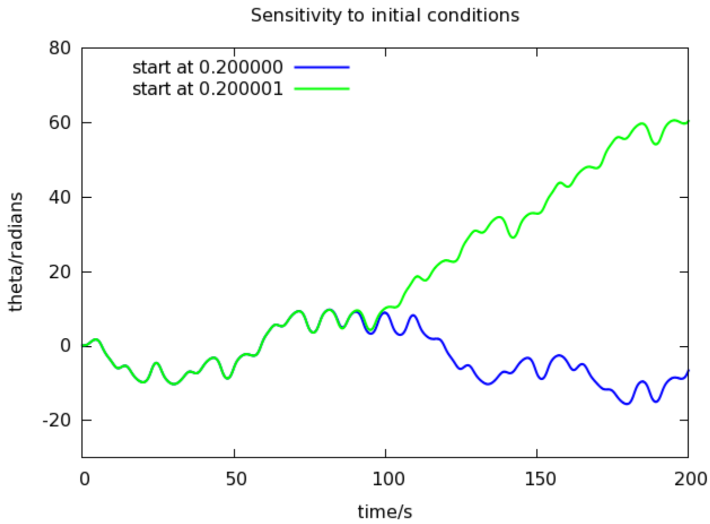
With forcing, we see chaotic behaviour for $F = 1.2$ and period doubling and quadrupling for $F = 1.44$ and $F = 1.465$ — another characteristic feature of chaos. Most people won't explicity spot the period doubling/quadrupling, but give generous credit for worthwhile attempts and doing something useful and accurate.



4 marks for a good job at this task.

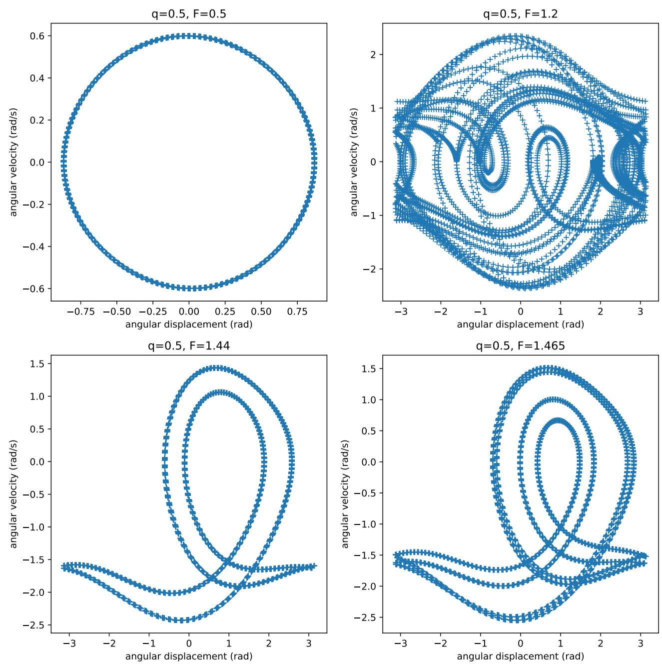
3.3 Supplementary Task 1

Here we see sensitivity to initial conditions



3.4 Supplementary Task 2

Phase-space plots give further evidence for period doubling and quadrupling.



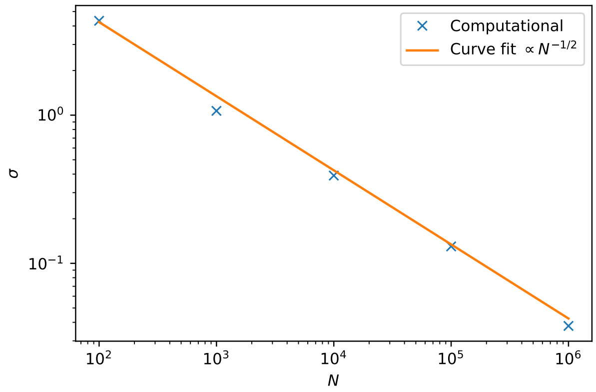
4 marks for the supplementary tasks: the student won't have to do all of the above to get full credit.

4 Exercise 2

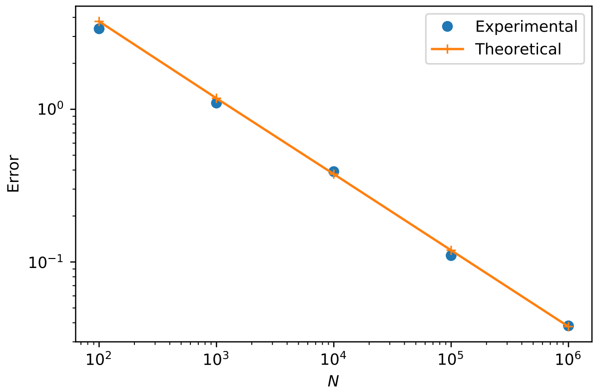
There are 12 marks for this question.

4.1 Core task 1

The key result is that the integral value should be 537.187..., and the student should be able to show (usually with a plot) that the Monte-Carlo error goes as $N^{-1/2}$.



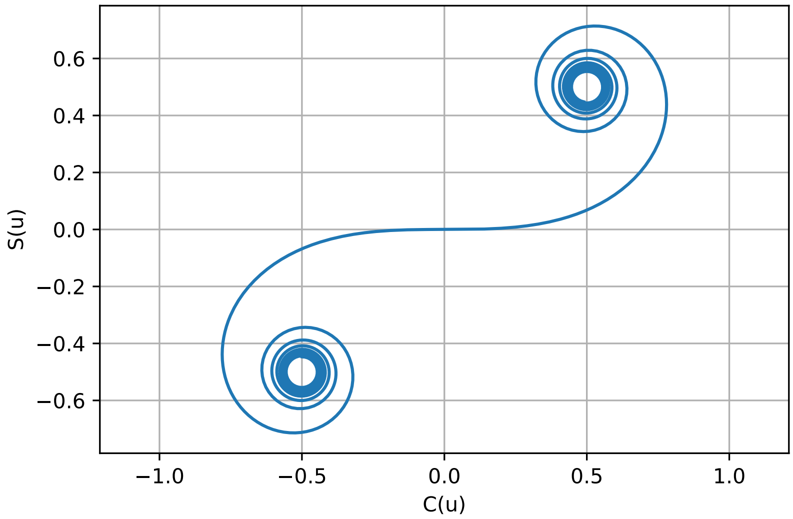
The comparison between the prediction for the error and the experimental error is surprisingly good (on a log-log scale, anyway)



4 marks for a good job at this task.

4.2 Core task 2

This task should produce plots something like this for the Cornu spiral.



4 marks for a good job at this task.

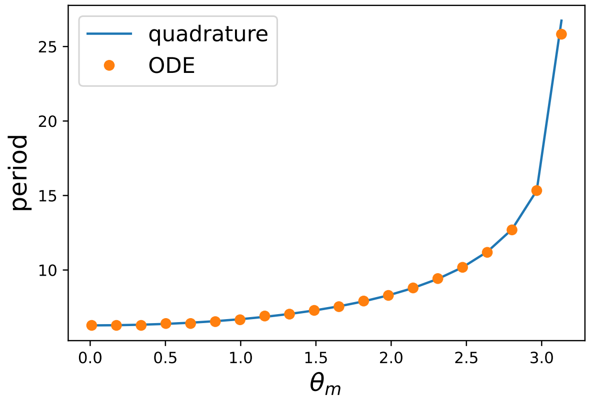
4.3 Supplementary Task 1

The students should be able to show some speed-up from vectorising, typically it can be a factor of around 100 for large N and well-vectorised code compared to explicit for loops.

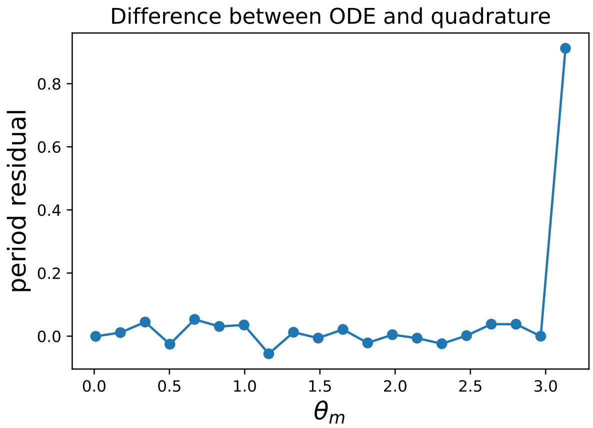
1 mark for showing a speedup, and 1 mark for either (a) checking that both codes give the same answer, or (b) advanced vectorisation, e.g taking into account that we can run out of memory for large N

4.4 Supplementary Task 2

The quadrature result should agree quite well with the results from the ODE in exercise 1 except for initial angles close to π.



For small initial angles the difference between the ODE period and the quadrature period is probably due to the way the period is calculated using the results from the ODE. For initial angles close to π then the period tends to infinity (the pendulum bob is metastable when released from rest directly overhead), so this can cause problems both in the ODE and the quadrature system. The quadrature routine will often complain that its error limits are exceeded, while the ODE will often go wrong but silently, for example not conserving energy very well.



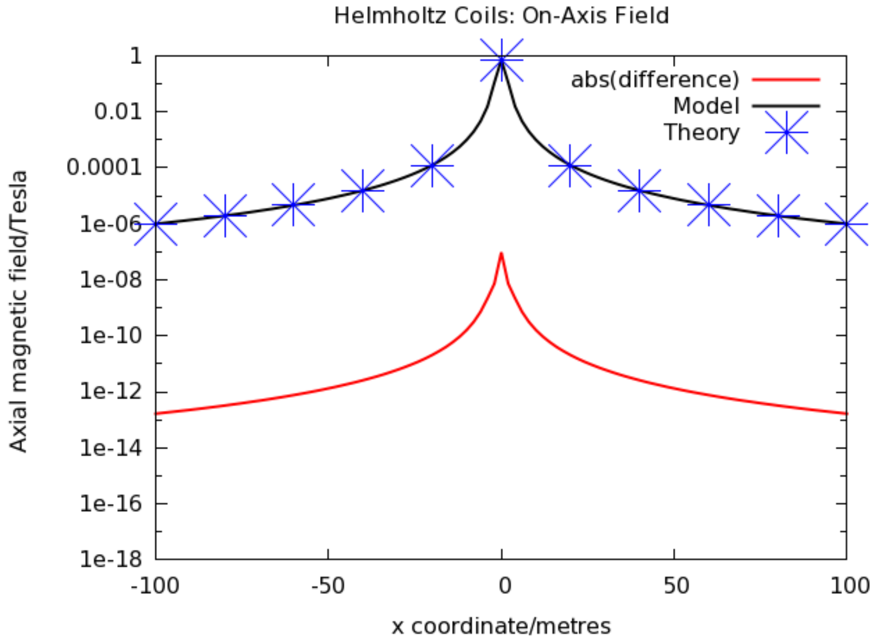
2 marks for any reasonable graphs plus any sensible error discussion.

5 Exercise 3A: Biot-Savart

There are **16 marks** in total for this question. Have a brief look at the source code and award **2 marks** for high-quality code (see intro for what we are looking for).

5.1 Core task 1

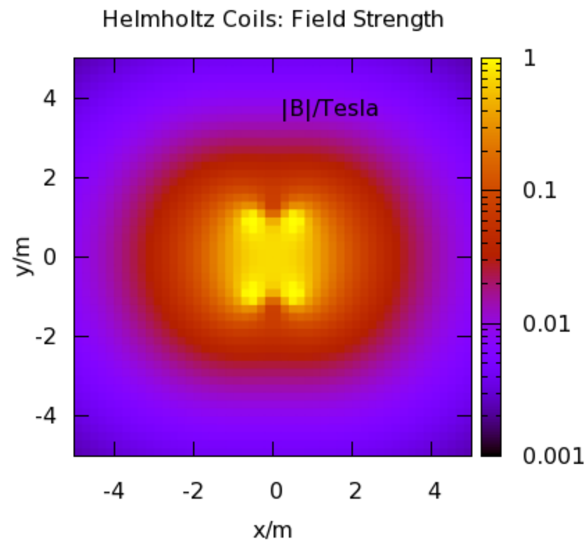
This is a representative plot for an-axis field for a single coil and its accuracy:



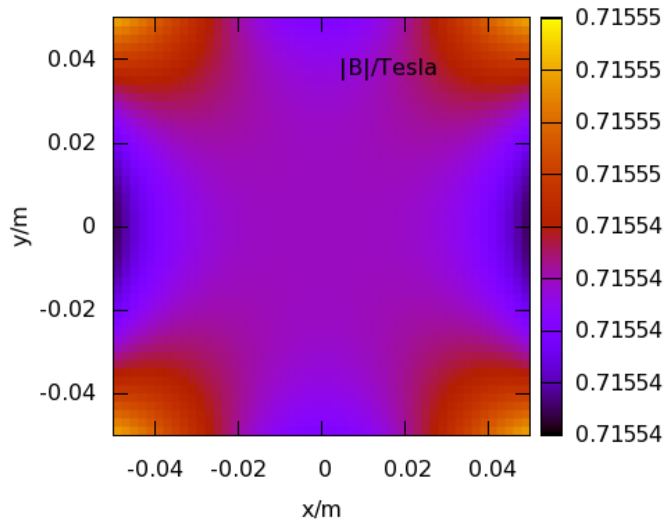
4 marks for a good job at this task.

5.2 Core task 2

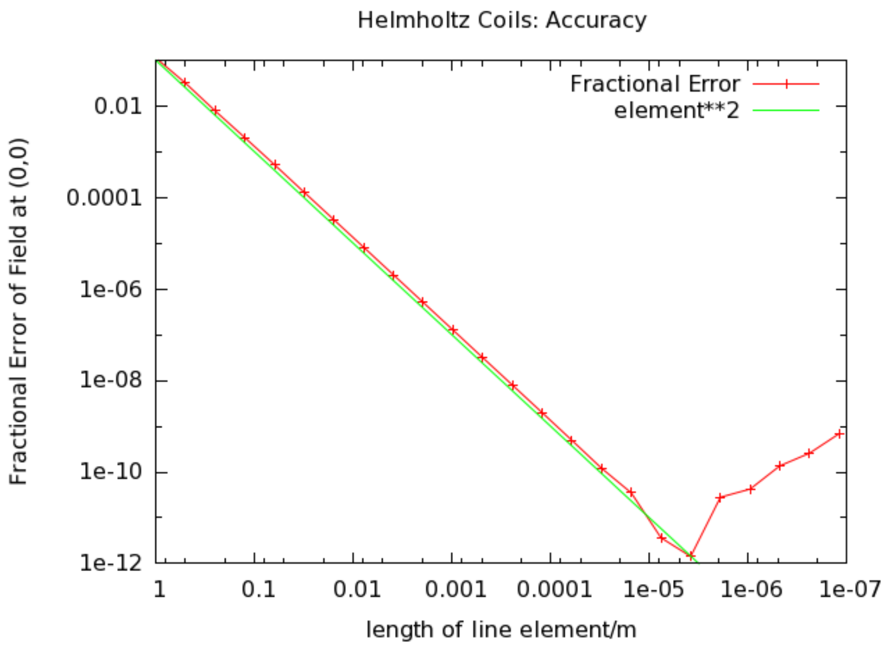
Below is the magnitude of the field for Helmholtz coils:



Plotted with a better colour scale and zoomed in:



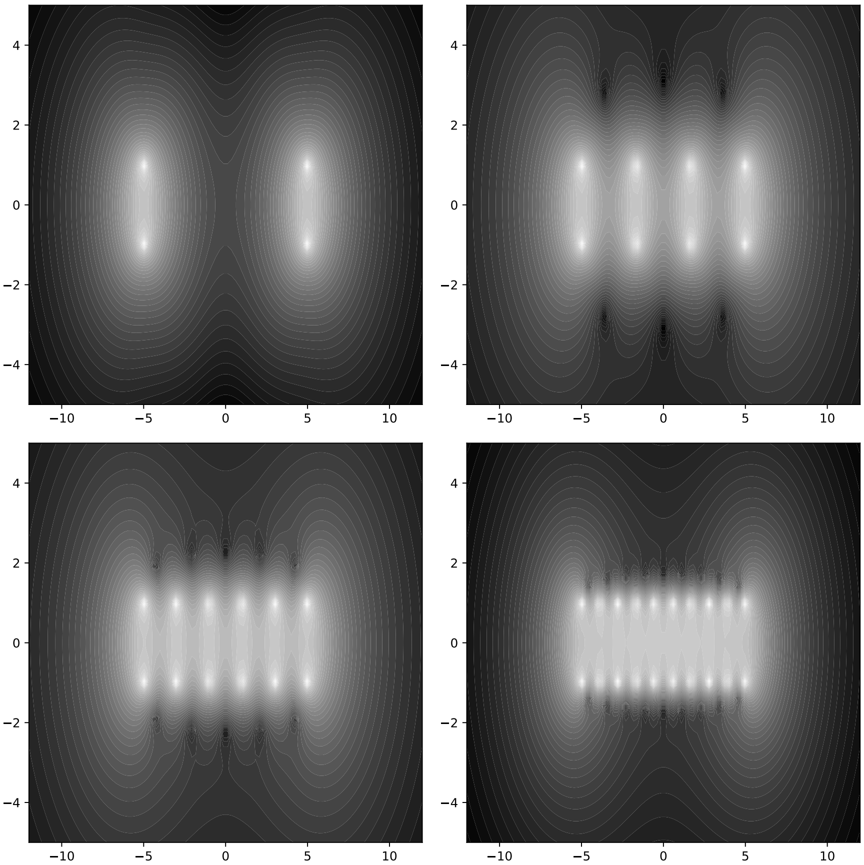
The fractional difference between the field at the edge of the defined cylinder from that at the centre is 1×10^{-5}. The accuracy for a midpoint method increases approximately quadratically with the number of segments:



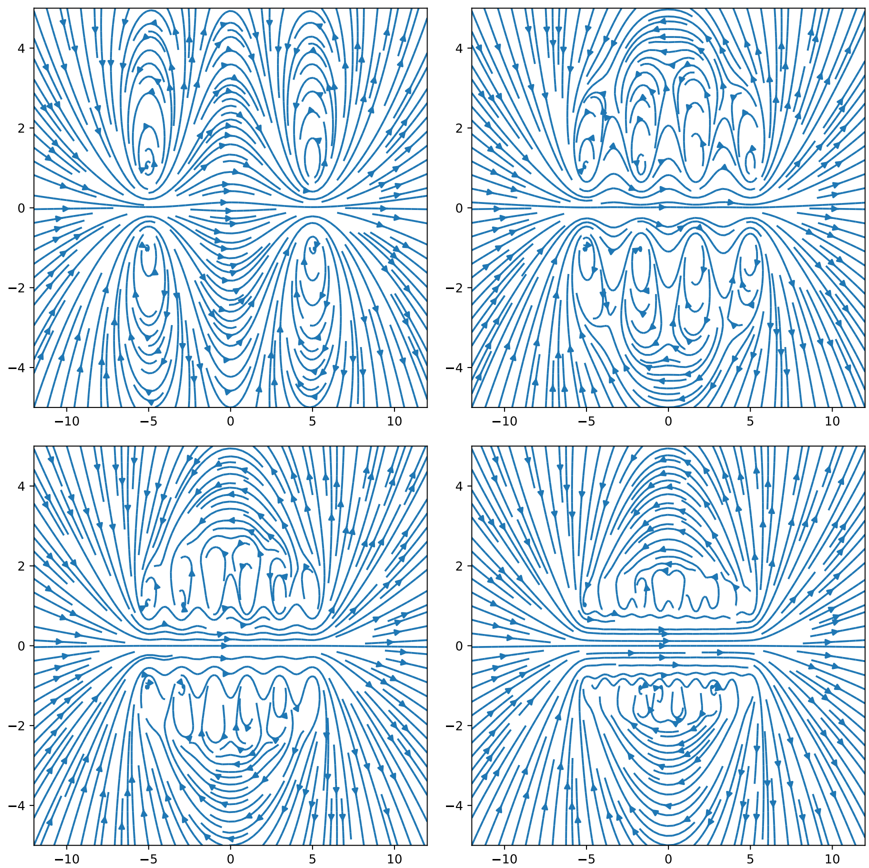
6 marks for getting this substantially correct. Be somehwat lenient here as it is quite difficult to get all of the detail right.

5.3 Supplementary task

Adding more coils gives successive approximations to a solenoidal field. The magnitude of the B-field is plotted below on a log scale; not all the detail will be present in the typical student's plot, but this is acceptable.



Field line plots are also instructive



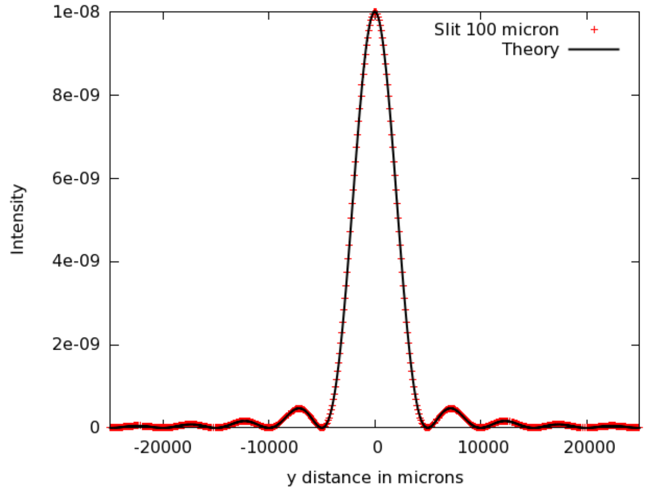
4 marks for a good job at this task.

6 Exercise 3B: diffraction

There are **16 marks** in total for this question. Have a brief look at the source code and award **2 marks** for high-quality code (see intro for what we are looking for).

6.1 Core task 1

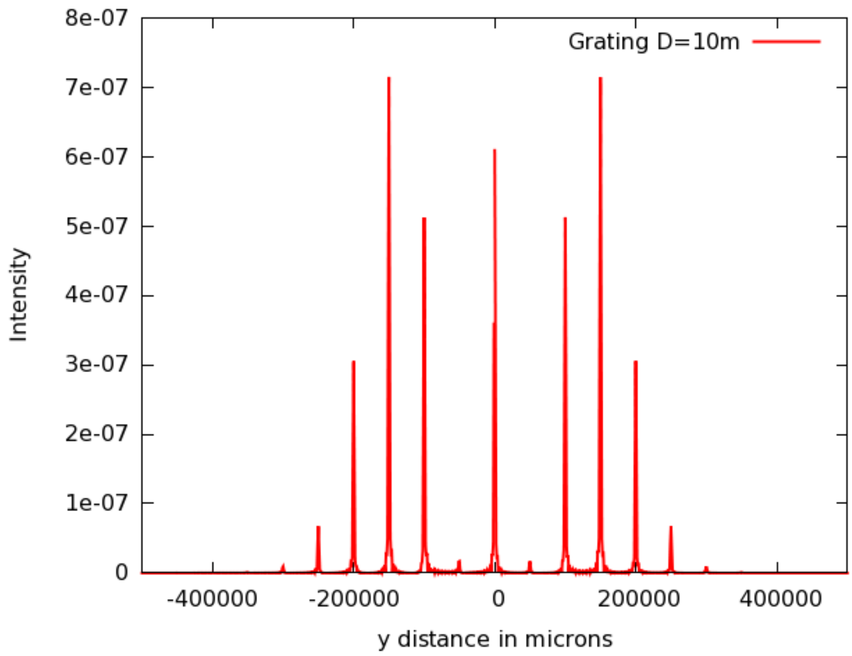
Core task 1 is to find this single slit pattern:



3 marks for a good job at this task.

6.2 Core task 2

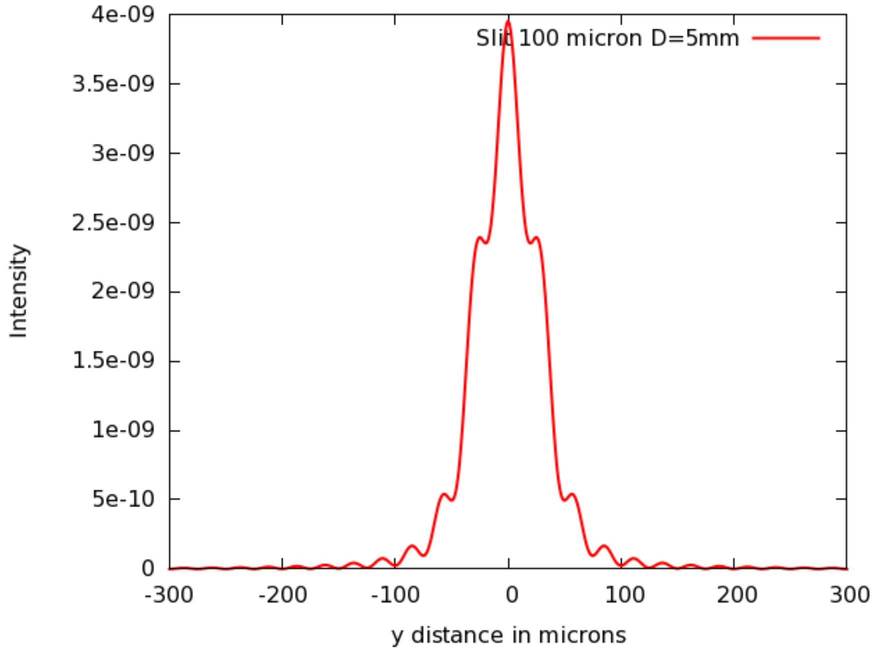
Core task 2 is the pattern of a sinusoidal grating: note the missing diffraction order.



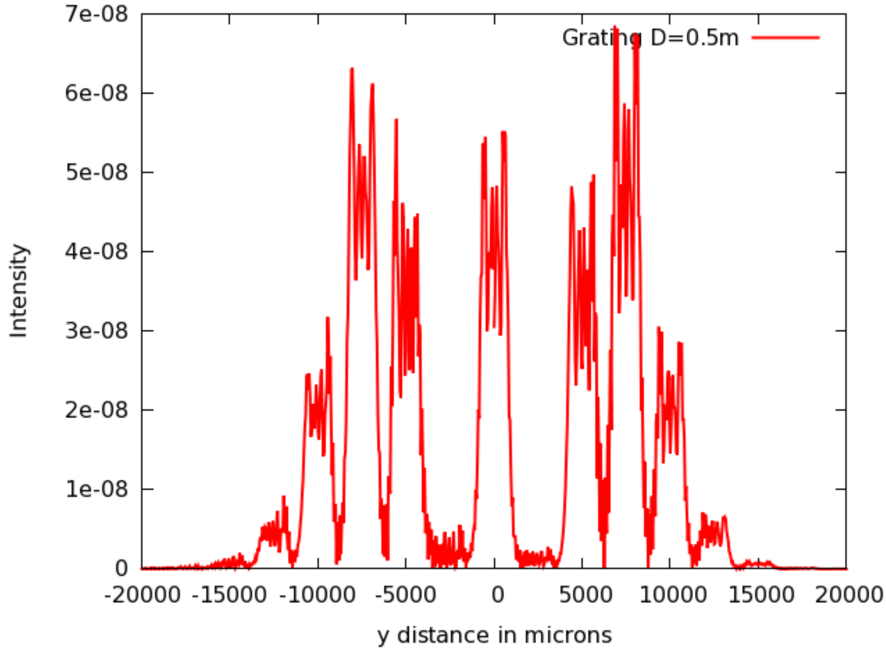
3 marks for a good job at this task.

6.3 Core Task 3

Supplemental task 1: in the near field, these become



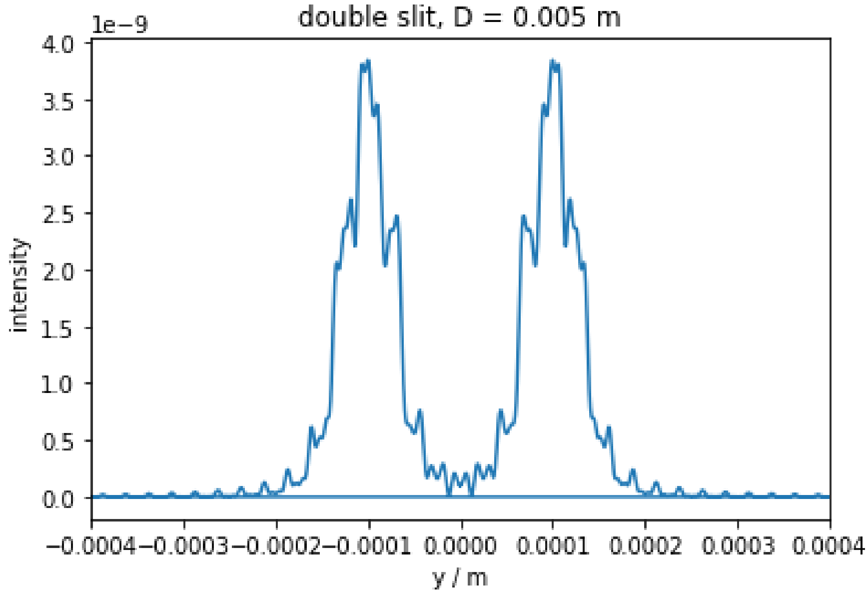
and

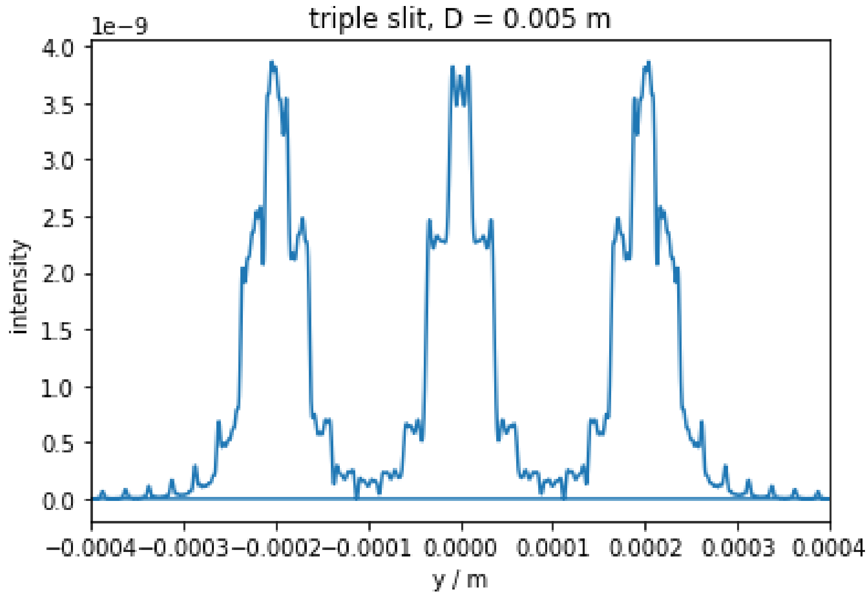


4 marks for a good job at this task.

6.4 Supplementary task

This is mainly a test that they structure their code: the best students will likely write a function that can do a single slit and call it multiple times so that they can generalise to N slits. They should get plots like this for the double and triple slits (turns out I should have made the screen distance larger to get more interference between adjacent slits):





4 marks for a good job at this task.