# **Problem Definition / Overview**

In various topics in the subject of mathematics, it is often beneficial to the understanding of students to show them what the graph of an equation looks like on a set of axes. Also, it would be favourable for the program to calculate various identities, like where to graphs intersect.

With reference to the GCSE Maths specification, many uses of graphs and functions can be found. Some applications of such include:

* Finding the gradients and intersections of graphs at a certain point
* Solve linear inequalities
* Various transformations
* Recognition, interpretation and sketching of trigonometric functions (sin, cos, tan)

The amount of subjects that would benefit from this in the A-Level specification would only be even higher. For visual learners, the visualisation of these graphs is a very appealing way to revise because it helps the students to remember how something looks. It also accelerates the teaching in lessons, as instead of the teacher drawing the entire graph, this could be solved in several clicks through the use of an automated graphing calculator.

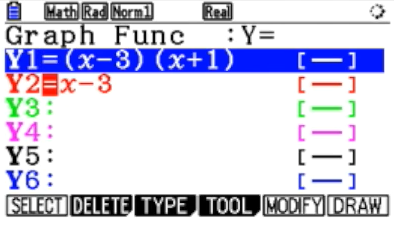
The target audience for my project will be students of A-Levels, GCSEs and even University Degrees as the tool will be so widely used in many different subjects. Also teachers of these subjects will have access to this tool as well. So, if a teacher wants to show their class a specific function on a graph, teach transformations or show how inequalities are displayed on a set of axes, my program is more than capable of instantly showing the result of the inputted formula. In addition, a target for my project would be people who deal with finances. This is because my program allows for simple and compound interest calculations quickly and easily, also various other financial operations can be carried out.

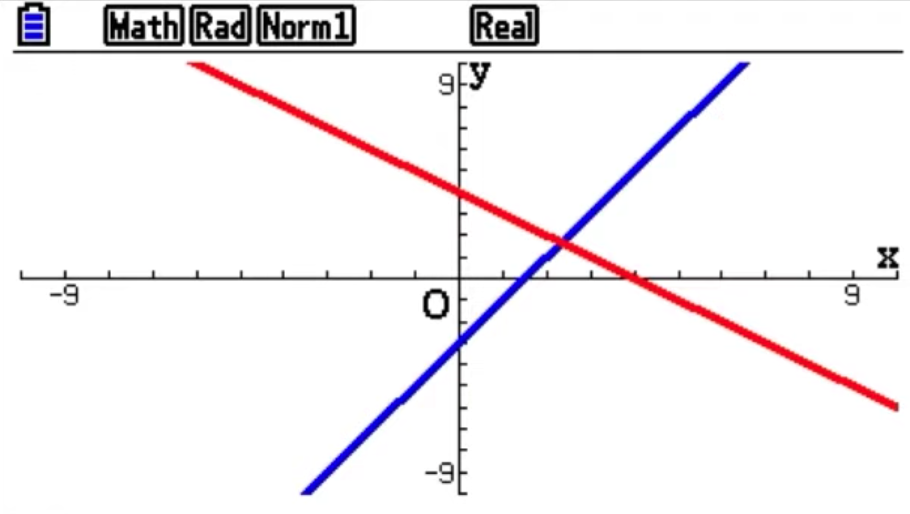
My project tends to address the lack of offline, usable graphing calculator software with intuitivity as the objective that the project revolves around, especially in schools and institutions. There are few solutions, each with their own limitations and drawbacks. A small range of these products are shown in the large amount of research I have completed for the project below.

# **Research**

**Casio FX-CG50**

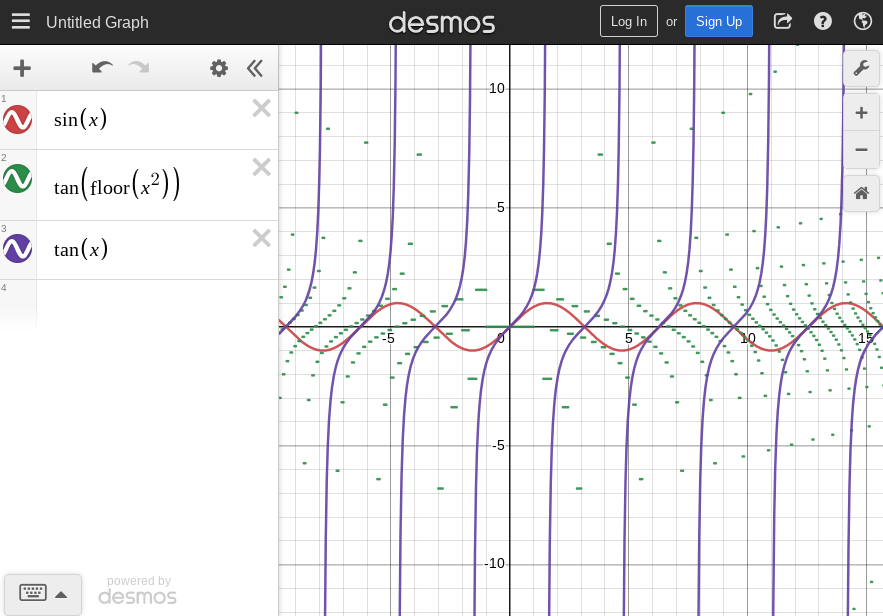
After researching this project over, I have found a few applications and pieces of hardware capable of doing the job. The first application I thought to look at was my own graphing calculator: the Casio FX-CG50. This calculator has many functions, one of which being the ‘Graph’ applications. It allows for equations to be entered that can be of many different types, like y=, x=, and r=, and has various functions including trigonometric, logarithmic and hyperbolic functions - these are useful in GCSE and especially A-Level where more complex mathematical functions are necessary. It is a rather powerful tool when you have learned it, but it is very time-consuming and difficult to learn the full ins and outs of the machine - the user’s guide is over 620 pages long!



Another problem with the device is the size and resolution of the screen. The screen has a resolution of 216 x 384, which is workable but the calculator commonly uses massive fonts that decrease the calculator’s usability. As well as this, it makes some of the applications awkward to use, namely the ‘Graph’ application, where panning and dragging the graph around is an often repeated process. This is made worse by the fact that the calculator takes a solid second or two to calculate the result, which makes using the graphing application a time-consuming, slow process. Finally, this calculator comes with a hefty price-tag of £140, which is not ideal for anyone, let alone a schooling environment where the budgets cannot cover this much of a financial burden.

**Desmos Graphing Calculator**

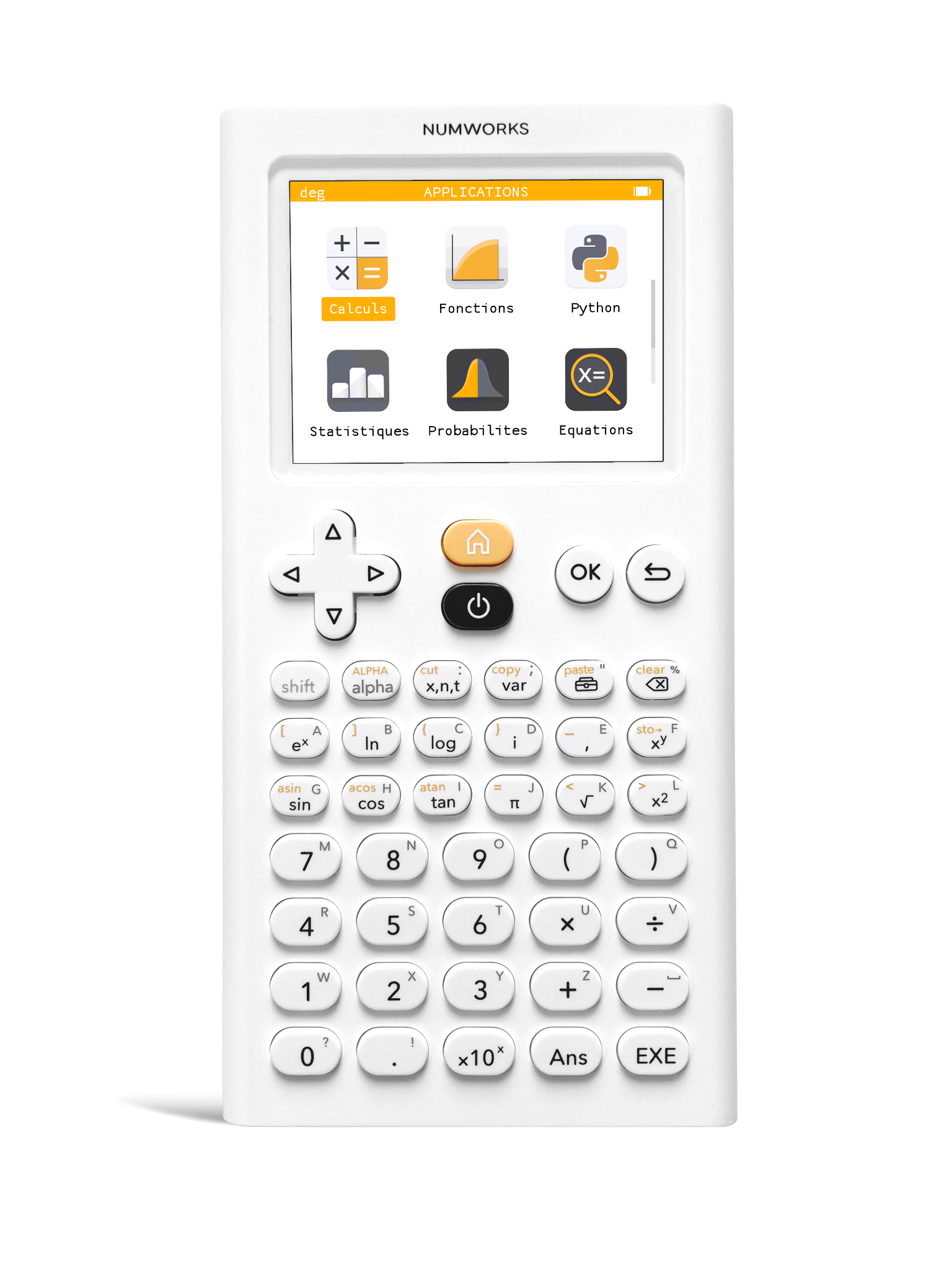
The second piece of research I conducted was on the Desmos online graphing calculator. Being online, this calculator is accessible for everyone and is a very powerful tool for showing these graphs on a set of axes. By simply typing in an equation into an entry box, the calculator is able to show the graph.

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**The Desmos calculator showing the graphs of 3 trigonometric equations**

The Desmos calculator solves the issues produced by the former Casio FX-CG50 calculator, such as price. This is completely free and completely accessible to all, provided you have an internet connection. This is the main issue with Desmos, that it is completely dependent on your connection to the internet. If you don’t have a connection to the internet, then you cannot use this application in any manner, apart from the mobile version.

The mobile version is however rather difficult a lot of the time due to the lack of precision that you achieve with your fingers on a small 6” screen than that of a mouse on a bigger laptop or desktop. I feel that too much was crammed into the offline mobile version of Desmos as it is half the time, when you want to zoom in on a point, if you accidentally only zoom on one axis, only that axis will zoom in. That is a good feature, but for the majority of times it ends up making the graph look incorrect, as one axis is scaled more or less than the other. The keyboard input for this mobile version is so painfully small as well that I often find myself pressing the wrong button multiple times, then having to rewrite the entire equation.



**Numworks Online Calculator Emulator**

Numworks is an American company that, like Casio, produces physical calculators for use in exams, especially to correspond with the American syllabus. Alongside the calculator, there is an online emulator that can be used to imitate what the real hardware would perform as software on the computer. However this is not online only: the .html file holding the emulator can simply be downloaded allowing for use of this system offline.

This is similar to a thing that Casio did, where you could download an emulator for their own Casio FX-CG50 calculator. This was, however, locked behind a requirement to input the licence key for your own physical calculator. Because I got my hands on my calculator through my school, and was just directly given it, I was unable to input the licence key on the packaging into the installer and therefore cannot install the software. Through looking at pictures and reviews of the software online, I have come to the conclusion that the emulation is rather poor in regard to its accuracy, and visual glitches and artefacts are plentiful when using this emulator.

Returning to the emulator from Numworks, the translation between inputs on the keyboard and inputs on the calculator are far from ideal. A select few buttons on the keyboard map directly to buttons of the calculator, but most of the buttons are required to be clicked using the mouse. This makes the ergonomics of this emulator far from efficient, as your hand needs to constantly move back and forth between the keyboard and the mouse.

Also, the user interface is designed for the calculator, so, once again, the ergonomics do not translate very well. To be honest, the whole operating system on the calculator is spread out so sparsely that there are probably many functions of the calculator that I haven’t even found in my research of it. Compared to the earlier Casio calculator, the font size is dialled right back, and screen size and resolution is increased, meaning that using the thing is no longer so zoomed in and so becomes more usable. But it seems that this new screen real estate has not been used, giving the calculator lots of room where something could be displayed but isn’t. This is not as big as an issue with the input translation, but an issue nonetheless.

These 3 examples of graphing calculators, whether physical devices or software on the internet, all have certain issues when it comes to their usability. It is all comes down to one or more of these three issues for each of these pieces of software:

1. The software is only accessible when unrelated criteria is met (like the use of the Internet)
2. The software uses UI that is too tightly compressed to fit in the screen
3. The software has bad input translation

# **Interview**

To help develop the final objectives I need to gain a better understanding of the user requirements for the project, I conducted an interview with my Maths teacher Mr Smith. Here are some of the questions I asked him and alongside them the responses he gave.

**“How do you feel about the usage of these Casio graphing calculators in class?”**

**“**The Casio calculators are, by all means, very powerful devices that can perform a multitude of tasks. However I think that, in some ways, they have too much functionality, so much so that to the students it is very difficult to get the solution to a question. A lot of the time, my students ask me how to do certain things, especially in the graphing application, and a lot of my lesson time is wasted on showing them how to do things. This doesn’t surprise me, sometimes I can’t find something on it!”

**“Do you think the Desmos application provides a good interactive experience to plot graphs? How beneficial is it to your lessons?”**

“Desmos is a very hit-or-miss application for me. At times, I can load it up and quickly show what a plotted graph looks like. I find its user interface kind of lacklustre but usable, and it can quickly show a graph. I also very much like that you can pan and zoom the image, to show how the graph looks when zoomed in or out or in a different position. My main issue with Desmos is that it requires the internet. My office/classroom is in a position where the internet is frequently dropping out, or it might be a dodgy piece of hardware in my laptop. Either way, a lot of the time I am unable to access Desmos and so as an application, half the time it is redundant.”

**“What would you want in an application that plots graphs?”**

“It is a necessity that it is usable offline, for the same reason I gave in your last question. It doesn’t help if the software is unavailable to me half the time. Also a quick easy to use user interface would be beneficial to everyone.”

**“What do you feel should be at the forefront of a project like this?”**

“Usability. The amount of time I waste trying to find out how I press or do something in one of these applications is not to be understated. I am not very good with computers in the first place, so I find it difficult to do some things in the software. It should have an easy to use GUI with self-intuitivity at the forefront.”

My program will be coded in Python, specifically the Tkinter framework, that assists in creating graphical user interfaces with an easy-to-use programming structure. As well as this, the Tkinter module supports a feature where you can insert a Turtle window in the GUI. Turtle is a module that comes under the Tkinter framework, in which users can create pictures and shapes by providing them with a virtual canvas. Users can easily draw to the screen using Turtle’s simple yet powerful coding structure.

Also Tkinter provides a tabling interface, called TreeView. This would allow data to be shown in a large tabular structure, in the case that the end user would want to see the data produced by my program in a standard grid, rather than having it plotted on a graph. This would be more interactive, allowing for the user to specify exact boundaries, like the range and increment of values to calculate.

The target audience for my project would be people who need to quickly and simply plot graphs and see how they look. For example, a few potential users of my program would be:

* Mathematics teachers. When teaching mathematics, teachers often show proof for various mathematical expressions, like relational calculus.
* People who deal with finances. My program allows for simple and compound interest calculations quickly and easily, also various other financial operations can be carried out by my program.
* Mathematics students. Often when revising, students may find the need to display a graph of a mathematical function as a way to help with revision. My program can simply and quickly help out students who are in need of some help to see how functions are drawn.