

Graphing with Desmos – An online graphing calculator

“At Desmos, we imagine a world of universal math literacy, where no student thinks that math is too hard or too dull to pursue. We believe the key is learning by doing. When learning becomes a journey of exploration and discovery, anyone can understand – and enjoy! – math”- Desmos Team (www.desmos.com/about)

SANGEETA GULATI

The appropriate use of open source technology can enliven the mathematics classroom and open up many learning opportunities. In this article we will describe how Desmos, an online graphing calculator, can enable the visualization of concepts and lead to meaningful explorations by students. Having used Desmos for more than a year, I truly believe in the philosophy and vision of the Desmos team. This online calculator can instantly plot any equation, be it lines, parabolas, derivatives of functions or Fourier series. Data tables can be easily generated and these open up opportunities for curve fitting and modeling activities. Sliders make it a breeze to demonstrate function transformations. As Desmos runs on browser-based html5 technology, it works on any computer or tablet without requiring any downloads. It is intuitive, beautiful math. And best of all: it's completely free.

In this article, we will take a tour of the features of Desmos and explore the possibilities it opens for a teacher and a student.

Keywords: graphing calculator, freeware, dynamic, parameters, slider

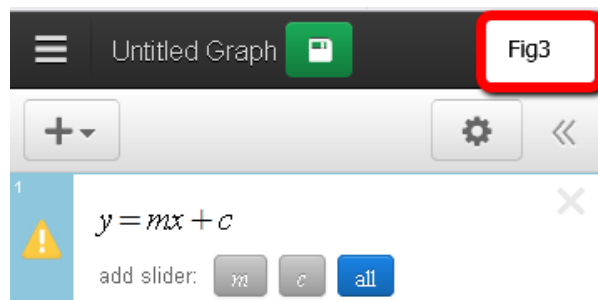
Getting started with Desmos

Desmos may be accessed from www.desmos.com. You can create an account or sign in with your Google account. The “Launch Calculator” option may be used without an account but signing in gives you the option of saving the output for future reference.

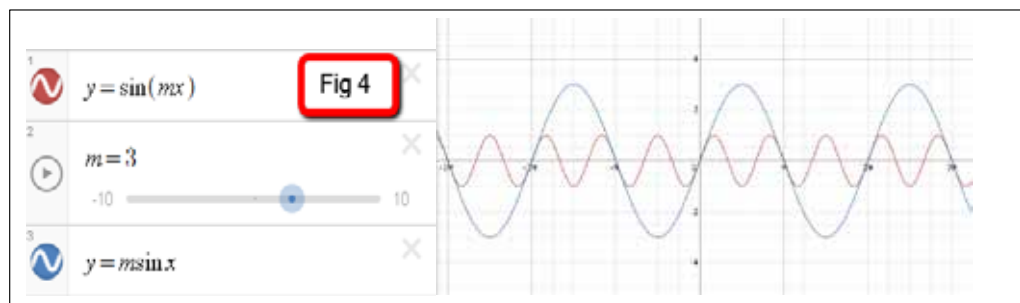


To create a new graph, just type your expression in the expression list bar. As you are typing your expression, the calculator will immediately start drawing your graph on the graph paper (indeed, even before you finish typing!). Once you are done with that task, you can edit your function, hide the function, change the colour or delete the function.

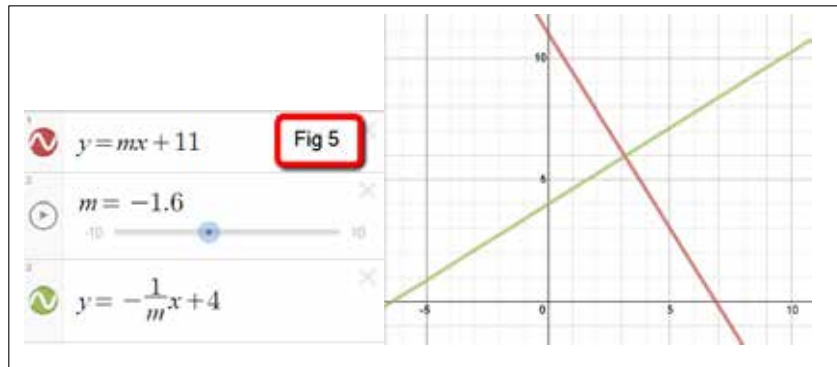
To graph a single line, enter a linear expression like $y = 2x + 3$. To make a dynamic graph, use parameters in place of constants. Typing $y = mx + c$ gives you a prompt to add sliders (Fig 3), for m and c , clicking on ‘all’ brings up a ready-to-use dynamic graph. Drag the sliders to create ‘live’ graphs on the screen!



You can use the same variables in different expressions to plot curves that change together. For example, Fig 4 shows the effect of varying m in the two expressions $y = \sin mx$ and $y = m \sin x$. This allows the teacher and student to explore transformations and visually understand the effect of changing a parameter.

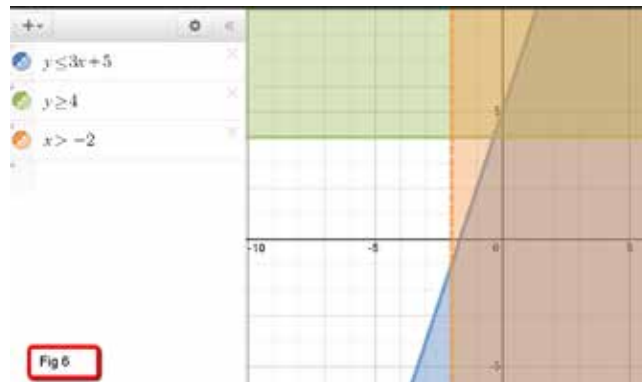


There is no better way but to 'see' (Fig 5) two lines perpendicular to each other when their slopes are negative reciprocals of each other! Desmos brings up many such 'aha' moments.



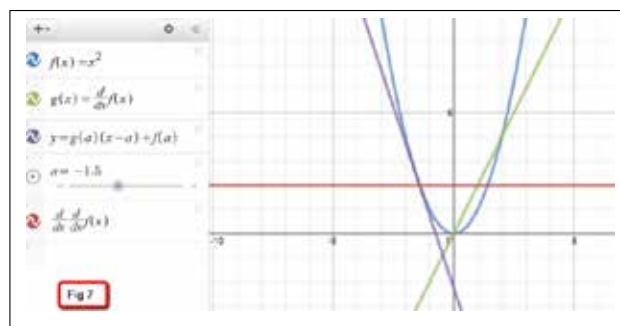
Is any special syntax needed for the input?

Typing expressions into the expression bar does not require the user to know any special syntax; one simply types in the function using a natural syntax (examples: \sqrt{x} gives \sqrt{x} , $\text{abs}(x)$ gives the modulus function $|x|$, π gives π , and so on). Alternatively, we may use the 'Functions' key in the Desmos keyboard to obtain the required functions.



Graphing inequalities

Graphing inequalities (Fig 6) with Desmos is particularly easy. Try typing in $y > x$ or $y > 2x + 3$ or $y > x^2 + 1$ and see what happens. Or check the output from $x^2 + x + 3 > y > x^2 + 1$. The effect will surely come as a surprise! Desmos gives us great freedom to play with inequalities, enabling us to check the effects of making incremental changes in the defining constraints. We are spared much of the tedium of plotting by hand.



Graphing functions and their derivatives

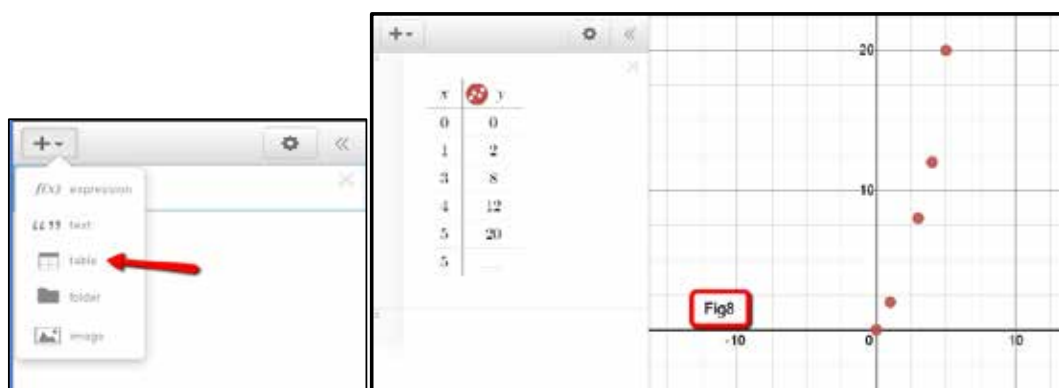
Finding the derivative (Fig 7) of a function is as easy as typing $d/dx f(x)$, or $d/dx d/dx f(x)$ for the second derivative, and you can build a tangent line accordingly using the point-slope form. This makes for an excellent demonstration of the relationship between a function and its derivative.

Graphing functions defined in a piecewise manner

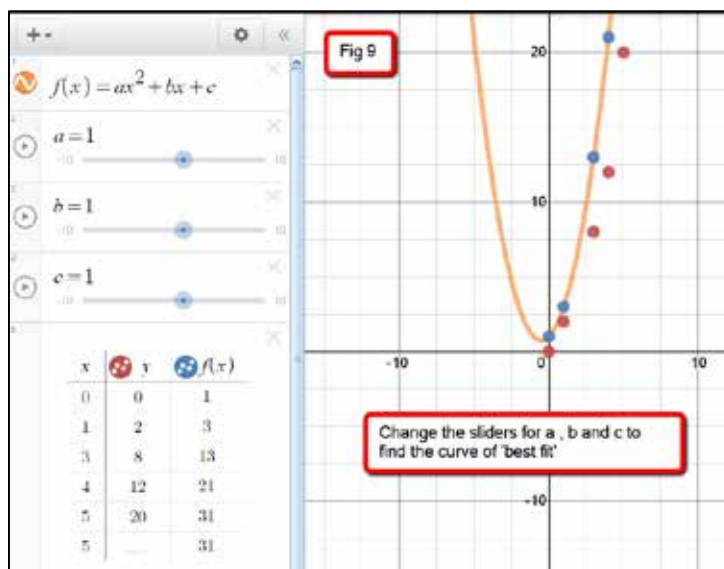
Plotting functions defined in piecewise manner can be handled in a single step. To limit the domain or range (x or y values of a graph), we simply add the restriction to the end of the equation in curly brackets, $\{ \}$. For example, $y = 2x \{x > 0\}$ would graph the line $y = 2x$ for x greater than 0.

Using the 'Table' feature of Desmos

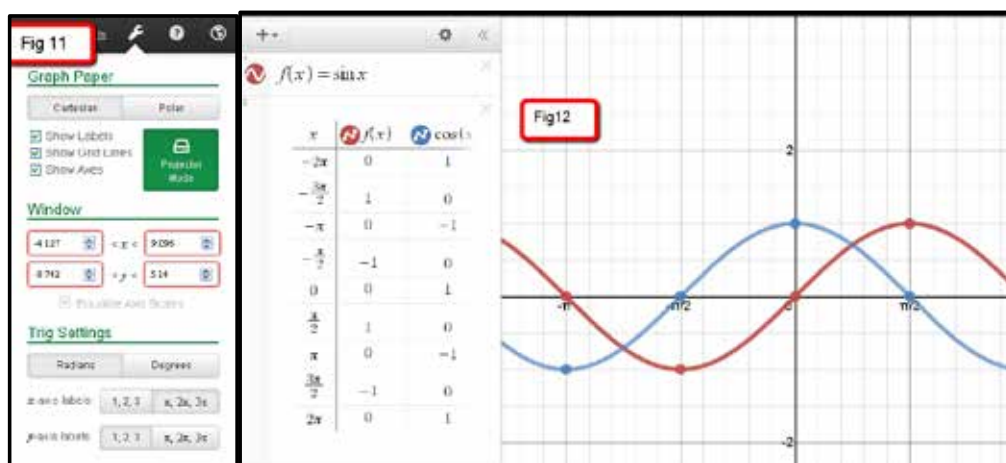
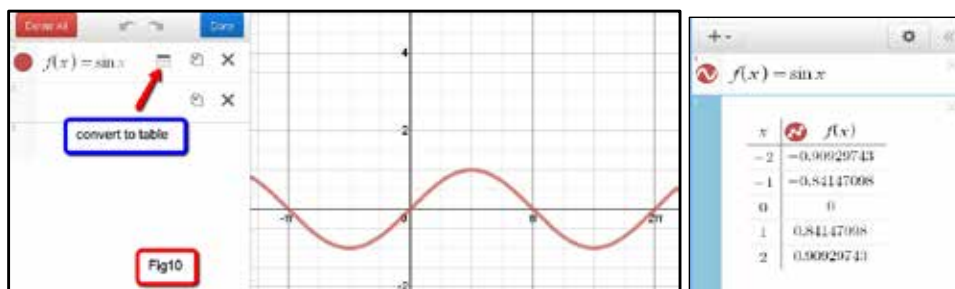
A significant feature of Desmos is the Table (Fig 8); it is excellent for creating a table of data just as one would do with paper and pen. As one enters the values in each row, the corresponding point gets plotted on the graph paper.



Using 'expressions' (+ add item), you can input a function which you think will best fit the curve and add a column in the table with the header $f(x)$ which will automatically fill in the predicted values. This is most effective when instead of typing in one specific function we take a general function (Fig 9) and use sliders to find the curve of best fit.



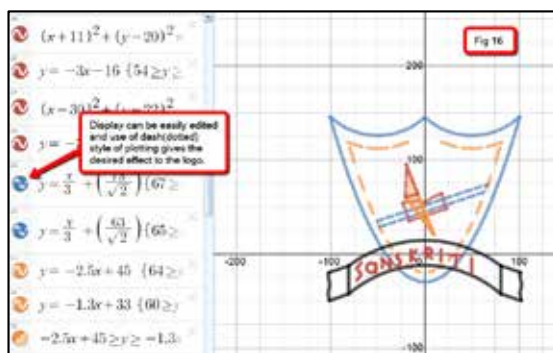
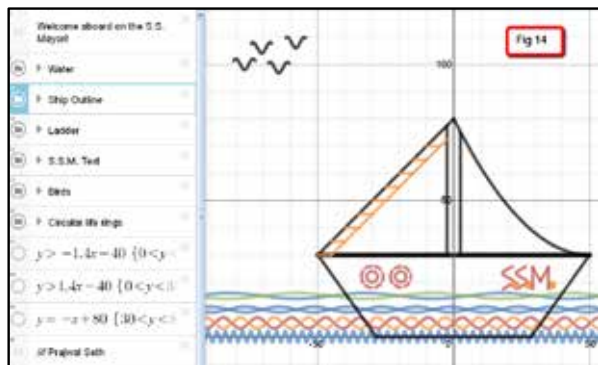
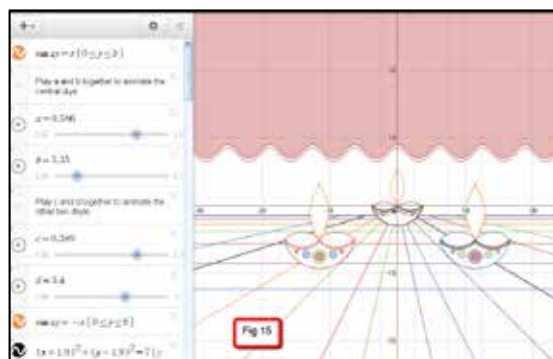
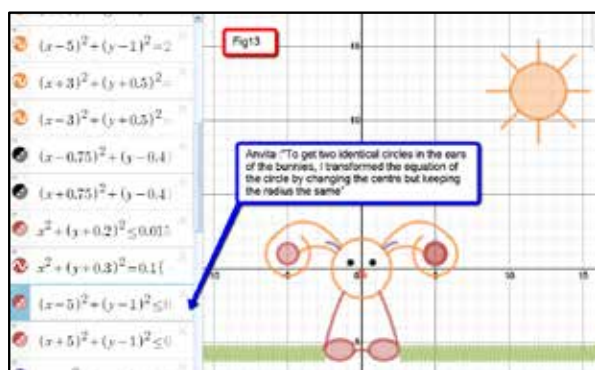
Desmos also allows us to convert a function into a table of values (Fig 10)! And the fun doesn't stop here; if the table so generated does not make sense, as in the case of trigonometric functions, we would like to have values of x expressed in terms of π , we can change each entry by typing in 'pi', 'pi/2' or '-2pi' and the corresponding points will get highlighted on the graph. It is also useful to know that for trigonometric functions, you can change the settings so that the scale on the x - axis is in radians (Fig 11). We can also add a column (Fig 12) for, say, $\cos(x)$ to do a comparison between the two functions. The possibilities are amazing!



Samples of student work

Technology, if used appropriately, can enable teachers to create meaningful learning opportunities for students. The remaining part of the article will describe the explorations done by students of grade 11 on piecewise functions using Desmos. The task assigned to students required them to create an interesting picture, of their own choice, using the elementary functions and their properties. They had to suitably restrict the domains of the functions to obtain the desired output. During this process they developed many new insights on properties of functions. It is known that technology enables educators to help students unlock their potential, and through this exercise Desmos enabled me to witness this happening at first hand with my own students; the results far exceeded my expectations. The students threw themselves into the task with great enthusiasm. They learned about restricting domains of functions and transformations, they explored conics – a topic not discussed till then in class – and came up with beautiful art work (Figs 13, 14, 15, 16: work of Anvita, Prajwal and Narayani of Sanskriti School).

As they presented their work before the class, I could see the high level of understanding they had developed for the functions. I was amazed. What I could not achieve after doing numerous problems on Domain and Range of functions, the students had achieved on their own. They used sliders to create animated graphs which made their work a piece of art.



I hope this tour of Desmos has inspired you to try this beautiful tool for yourself, and explore the many possibilities it opens for all of us.

I am thankful to my students especially Prajwal, Anvita, Harshita and Narayani who put in precious time and effort to create such beautiful work; they reconfirmed my belief that learning and teaching of Mathematics can be fun!

Web links

- [1] www.desmos.com/
- [2] <http://support.desmos.com/home>
- [3] <https://www.youtube.com/user/desmosinc>
- [4] <http://dynamath.wikispaces.com/Maths+and+Art> (to see more samples of students' work)



SANGEETA GULATI is Academic Coordinator and Head of Math Department at Sanskriti School, New Delhi. She has taught Mathematics for over twenty years. She is actively involved in exploring the use of technology in teaching and learning of mathematics. She conducts workshop on GeoGebra, Geometer's Sketchpad and Online Resources. She is a regular resource person with NCERT in developing ICT material and has developed video lessons with Central Institute of Educational Technology, NCERT. Her wikispace (dynamath.wikispaces.com), product of her action based research project during Fulbright Distinguish Award in Teaching fellowship in 2011, is a great resource for mathematics teachers.