
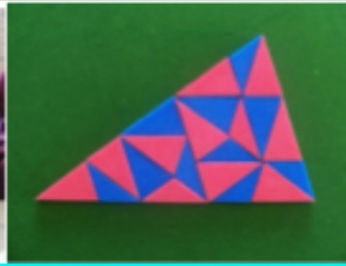


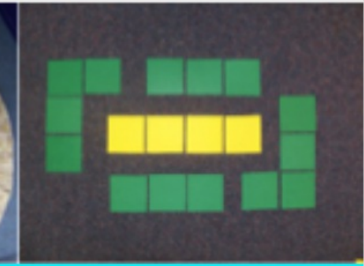

"Same or Different" and other VCE appropriate tasks.

Damian Howison,
St Mary MacKillop College, Swan Hill

dhowison@mackillopsh.vic.edu.au

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Number Charts
Multiplication in a table format
Fraction estimation
Multo
Factorgrams
Licorice factory
Walk the plank
This goes with this
Angle estimation
Biggest Volume
Area of a triangle
Newspaper pathways
Newspaper shapes
Country maps
Building views
Garden beds
First principles percent
Four cube houses
Backtracking
Rectangle fractions
Chocolate cake
Fraction magic squares
Protons and anti-protons
Knight's tour
Circumference of a circle
Pentagon triangles
Algebra walk
Area of a cirle
Birth month paradox
Planets
Duelling dice
Pythagoras and other polygons
Baby in the car
Mushroom hunt
Cylinder volumes and the Pacific Ocean
Algebra charts
Jumping kangaroos

Year 7/8 Algebra and Pattern

Task	#
Addition Totals	8
Find My Pattern**	10
Lining Up	11
Heads and Legs	14
Eric the Sheep	45
Algebra Through Geometry*	71
Snail Trail	82
Square Numbers	111
Icecream Flavours*	118

Task	#
Red to Blue*	132
Painted Rods	152
4 Arm Shapes	154
Mirror Patterns 2*	159
Crossing the River 1	173
Unseen Triangles	179
Making Monuments	180
Pointy Fences*	181
Smooth Edge Tiles*	220

Year 8 Space & Geometry

16. Octaflex	90. Tricube Constructions B
31. Cube Nets	95. Reflections
36. Making Triangles	150. Chess Queens
44. Latin Squares	153. Knight Protectors
66. Pentominoes	155. 64 = 65
67. Making Solids	157. Paving Views
68. Six Square Puzzle	166. Sphinx
70. Symmetric Shapes	237. Trisquares
77. Tricube Constructions A	238. Growing Trisquares

Year 9 Chance

Task	#
Dice Differences	34
Cat And Mouse	223
Final Eight*	1
First Down The Mountain	87
Have A Hexagon	53
Same Or Different	18
What's In The Bag?	198

Task	#
Choosing Beads	191
Counter Escape	6
Highest Number 2**	128
Greedy Pig	200
Duelling Dice	46
Dice Footy*	232

Year 10 Algebra

Task	#
Can Stack **	27
Cube Numbers**	208
Difference Between Two Squares **	64
Double Staircase	61
Fold Up Houses **	55
How Many Triangles? **	48
Intersections **	206
Money, Money, Money **	233
Painted Cubes	160
Pyramid Puzzle	101

Task	#
Time for Tiling	140
Squares Around Squares **	24
Tetrahedron Triangles **	186
Tower of Hanoi	142
Triangles and Colours *	221
Triangles around Triangles **	42
Two Squares **	57
Star Numbers **	236
Smooth Edge Tiles **	220

Today we will touch on:

Gradient Functions

Making Monuments

Biggest Volume

Farmyard Friends

Trigonometry Walk

Same or Different

Gradient Functions

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Lesson 136

Gradient Functions

Overview | Lesson Plan | Classroom Contributions

Lesson Plan

Years: 10 - 12 **Time: 2 - 4 lessons** **Strands: Measurement, Number, Space**

Related worksheets

- Investigation Sheet
- Recording Sheet

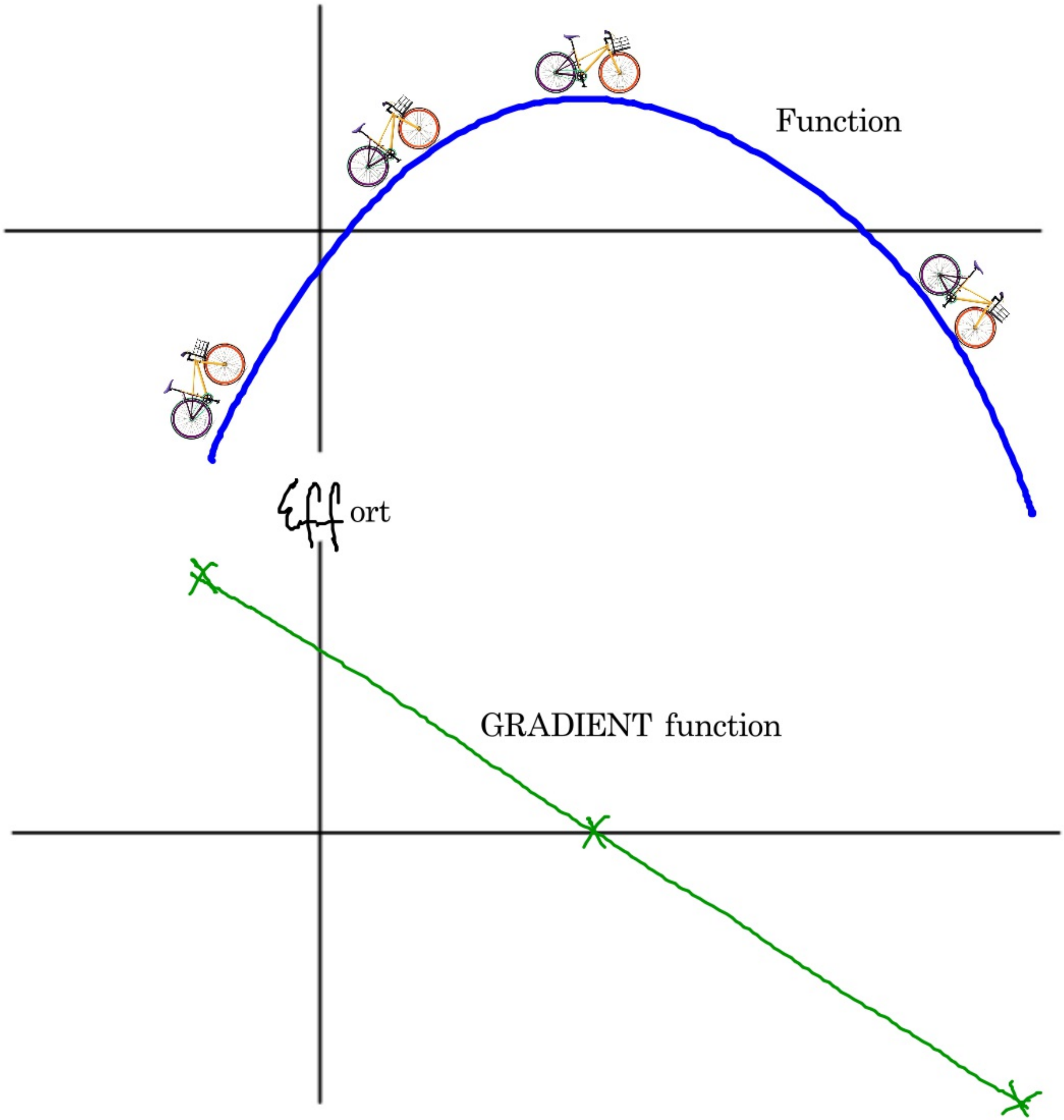
Summary

This lesson explores the concept of the gradient function, that is, the function that describes the way the gradient changes.

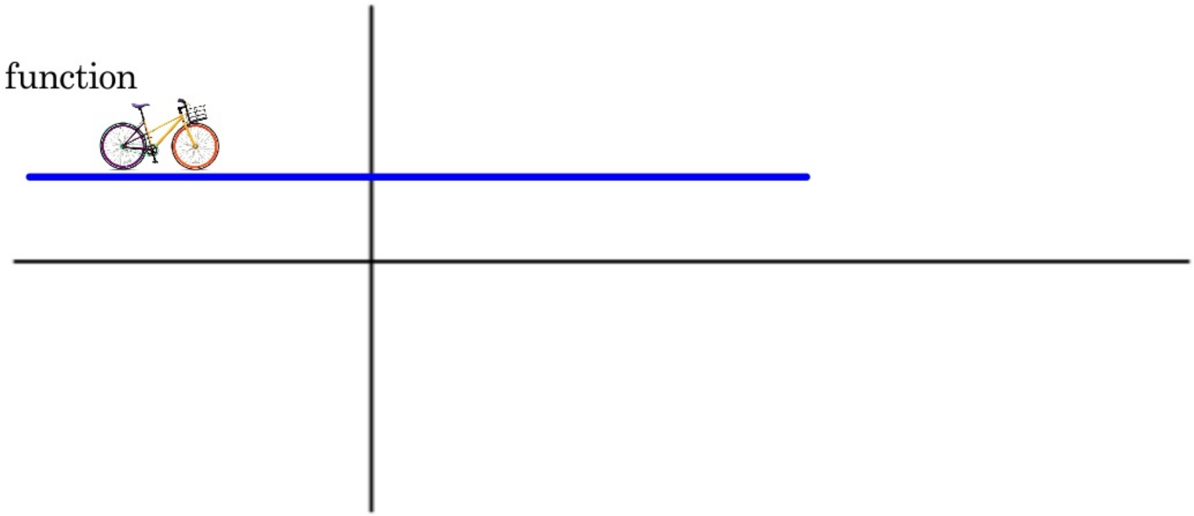
Having focused on the idea of the gradient of a function through their own experiences with riding a bicycle up and down hills, students are invited to explore the relationship between the x-value of the function and the gradient at the point (x, y).

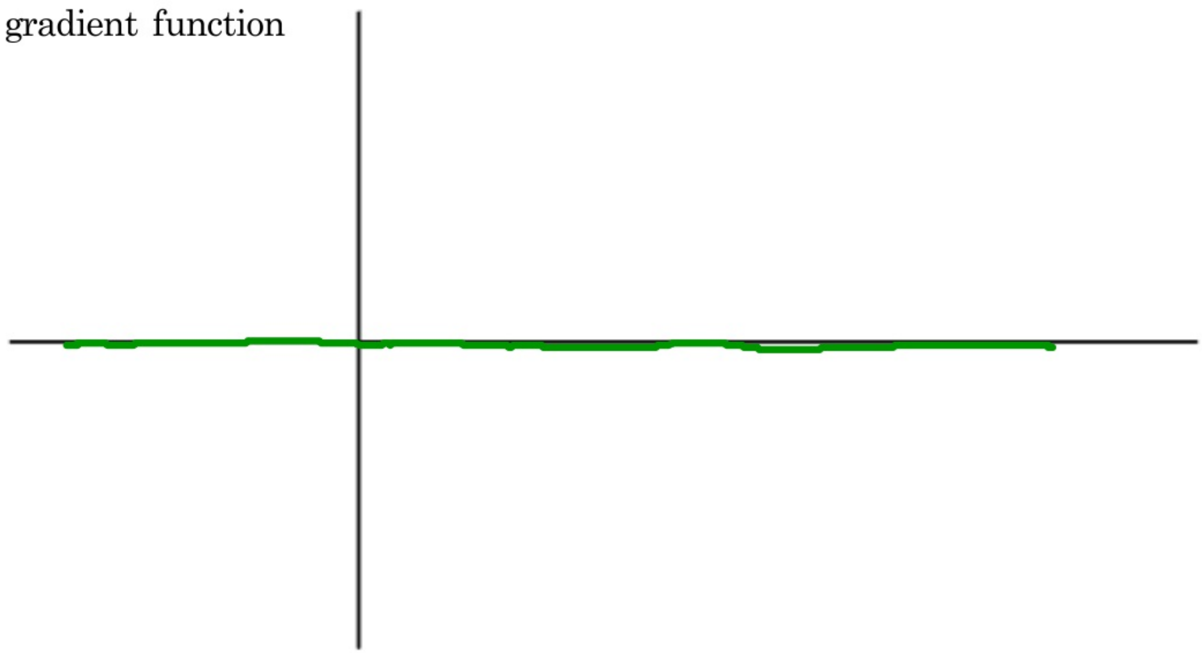
Secondary goals include:

- a growing ability to visualise the shape of a gradient function just by looking at a graph
- recognition of the types of functions that gradient functions can be
- how this is related to the type of initial function
- awareness that continuity is an important feature of a graph for a gradient function to exist.

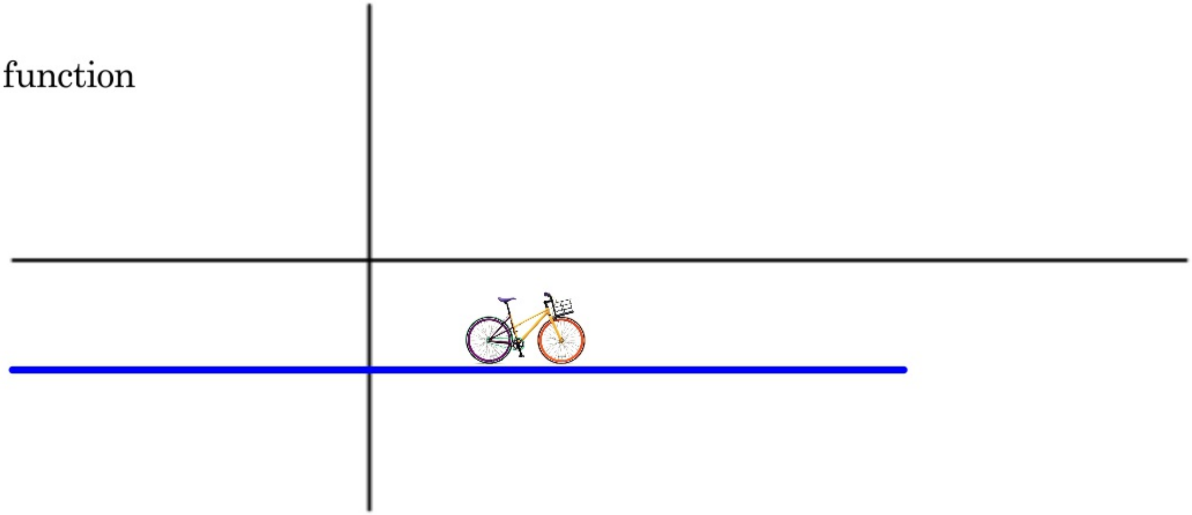


Relating the gradient of a function to the effort required to ride a bicycle over the function.


function

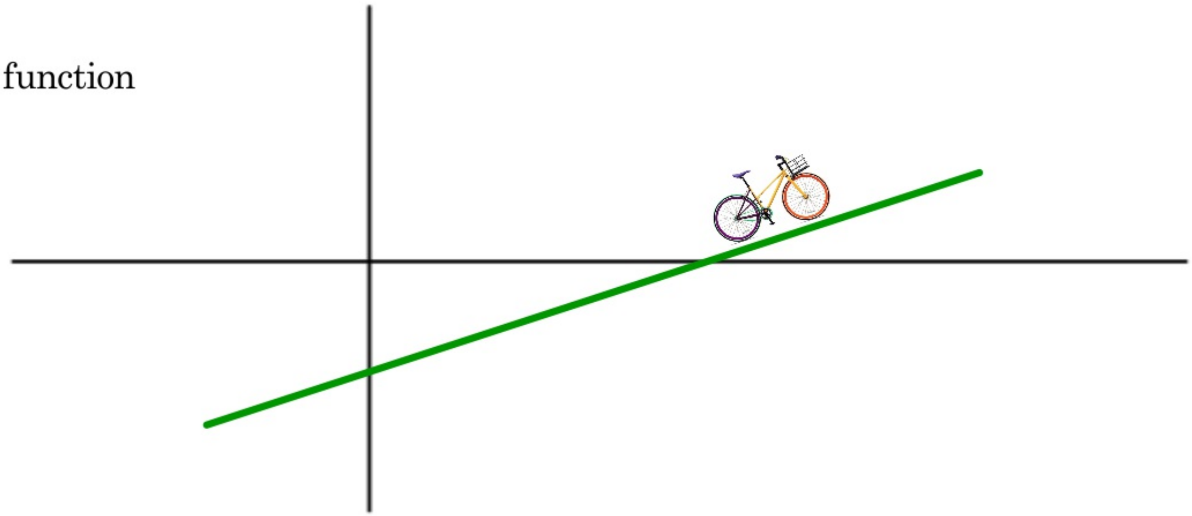

gradient function

function

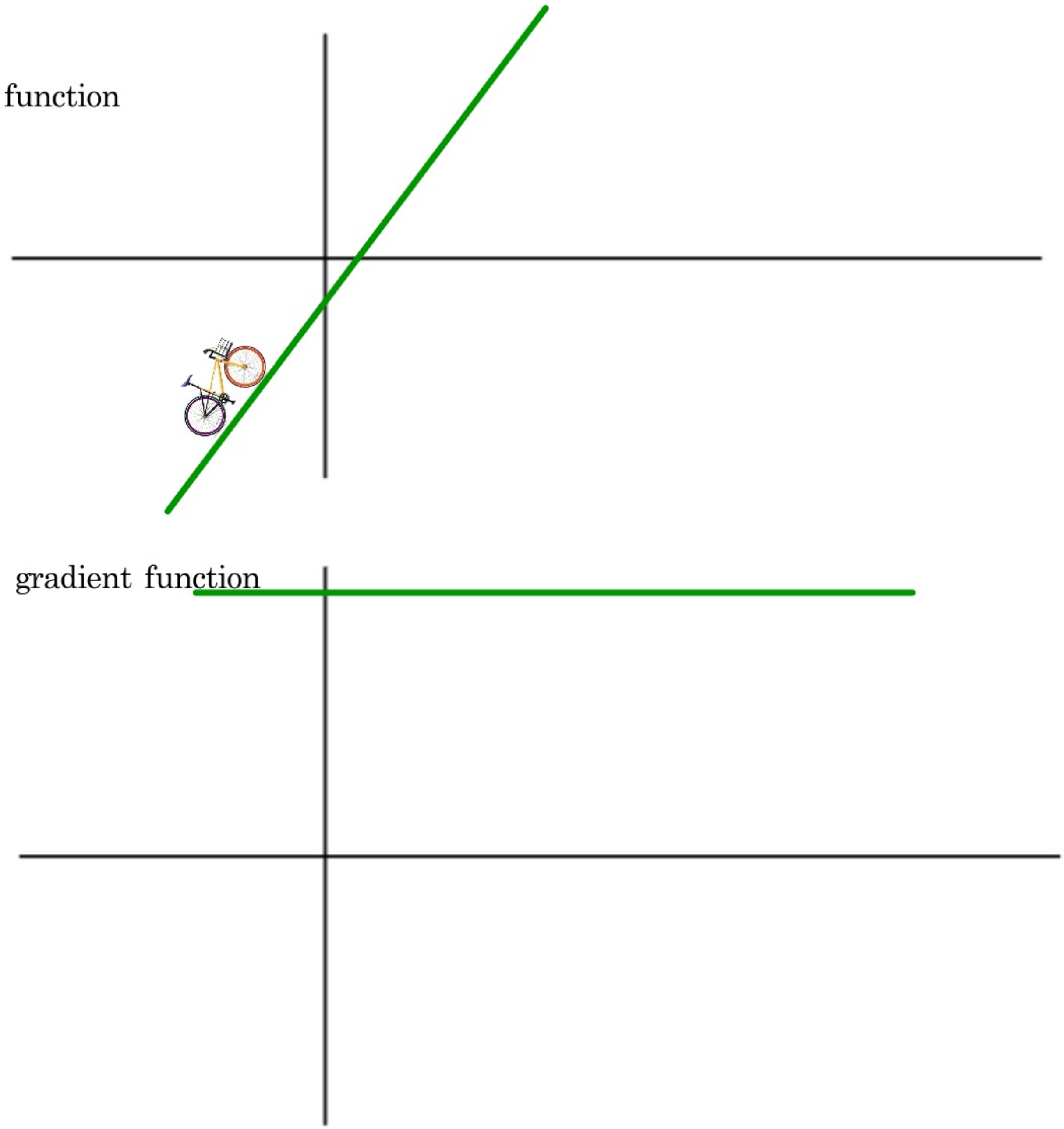


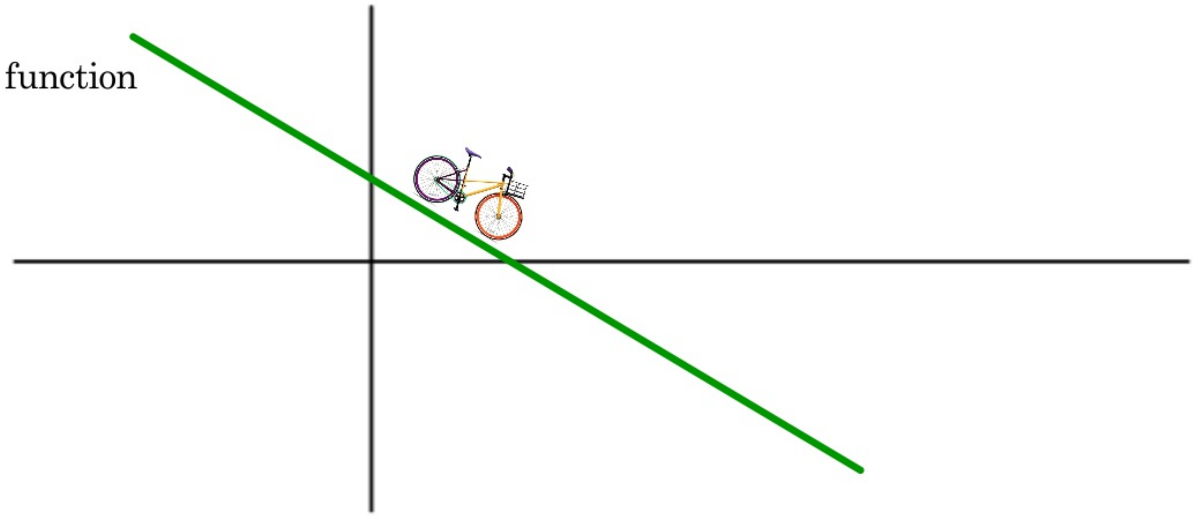
gradient function

function

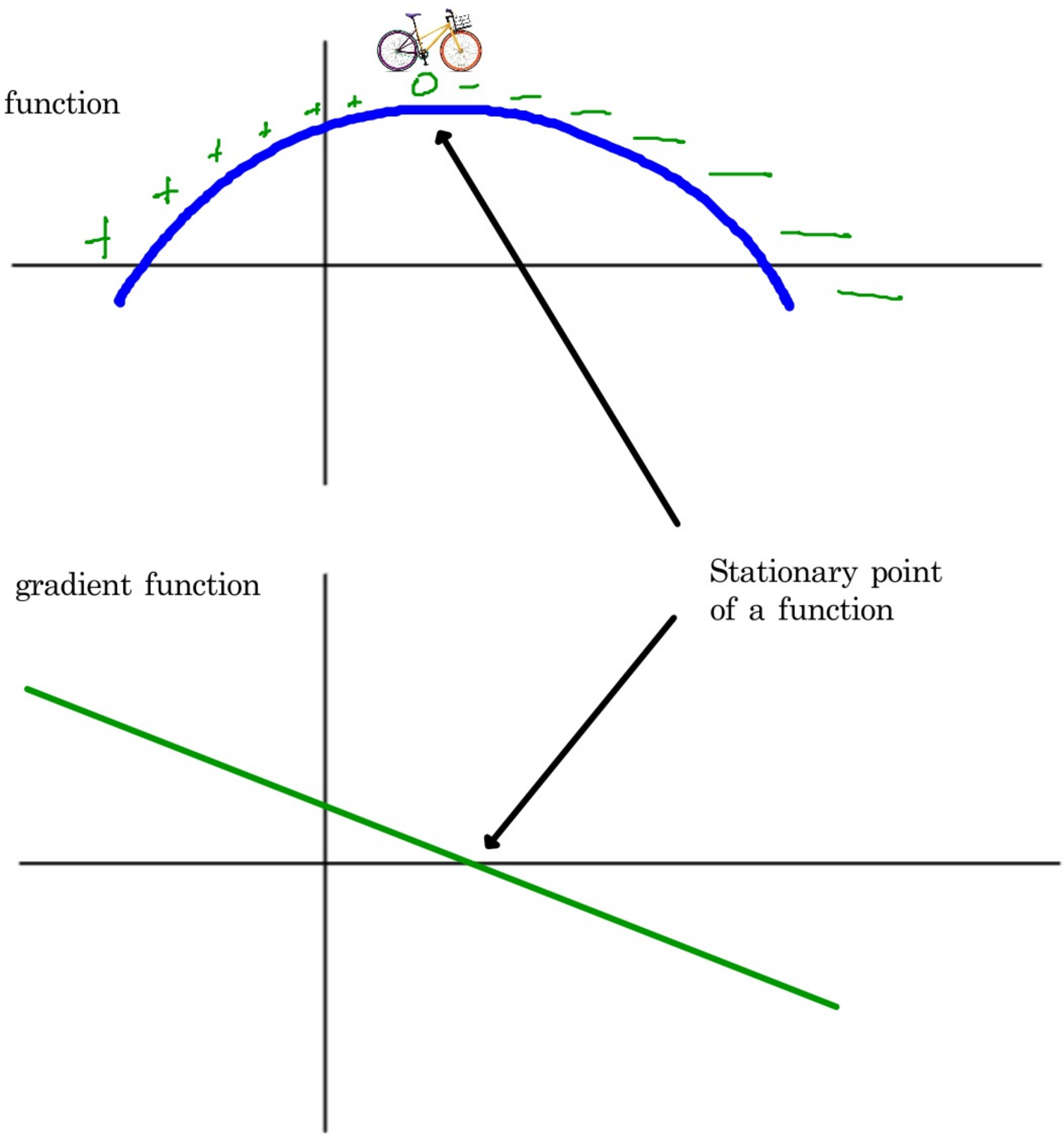


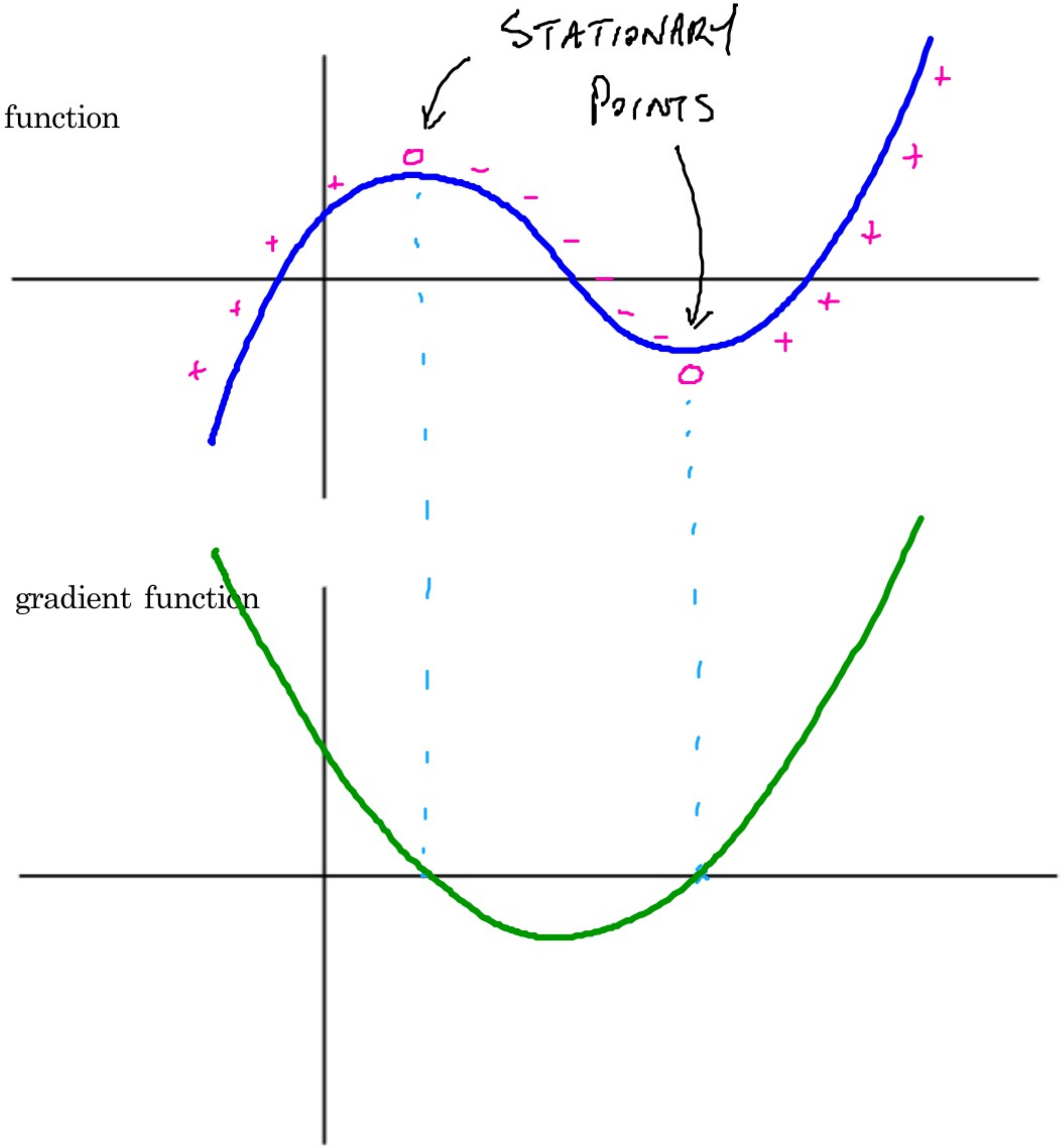
gradient function

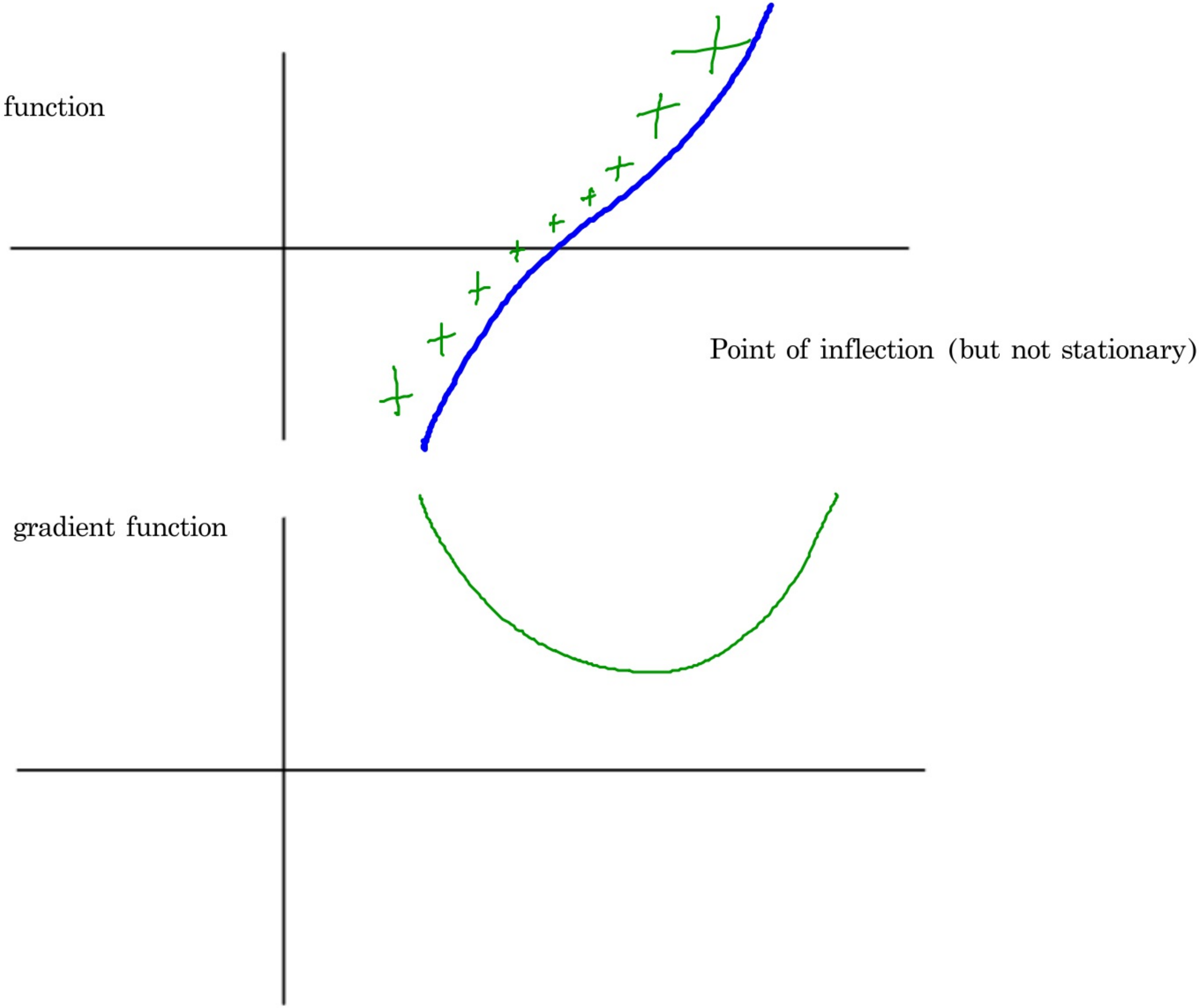

function
gradient function


function


gradient function


function
gradient function
Stationary point of a function


STATIONARY
POINTS
function
gradient function


function
Point of inflection (but not stationary)
gradient function

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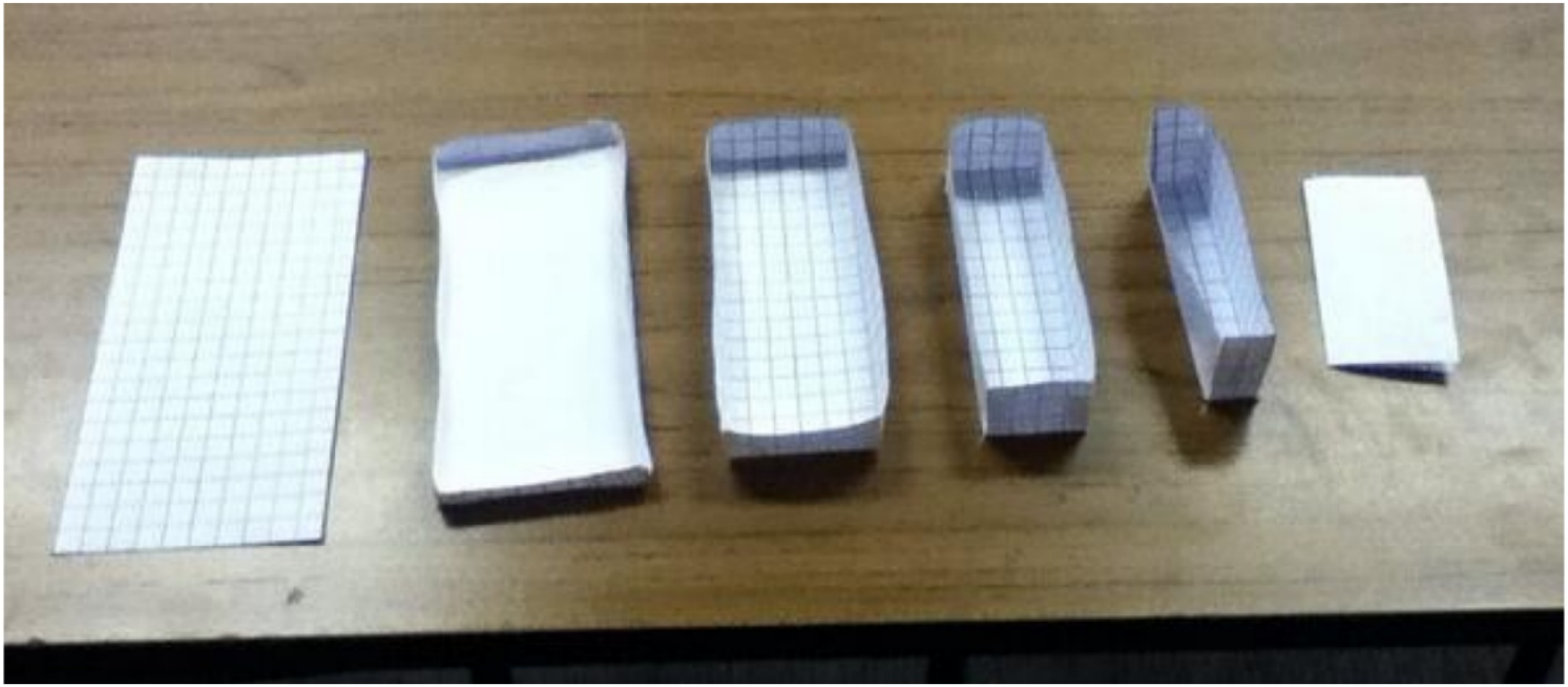
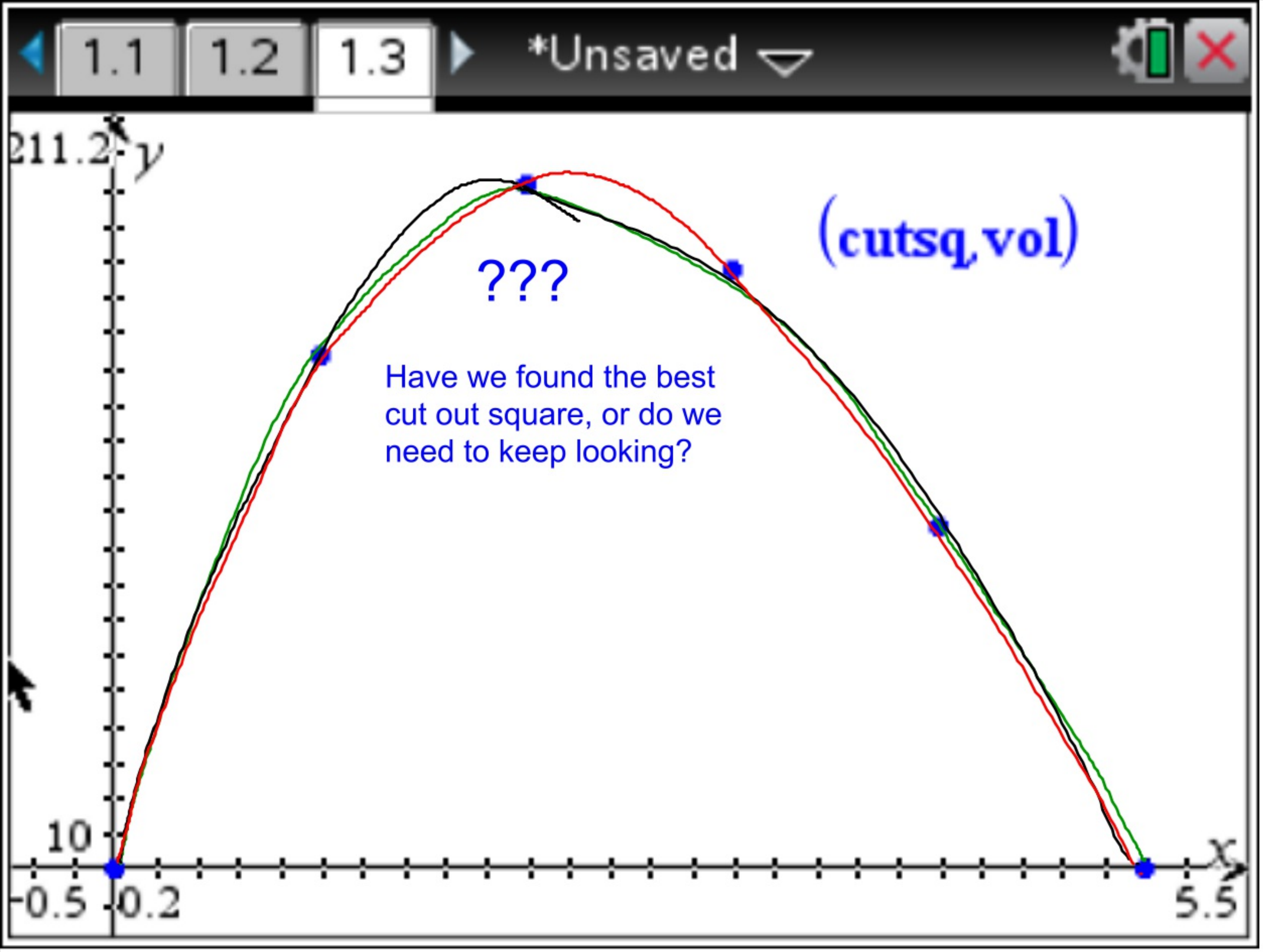
Which has the biggest volume?

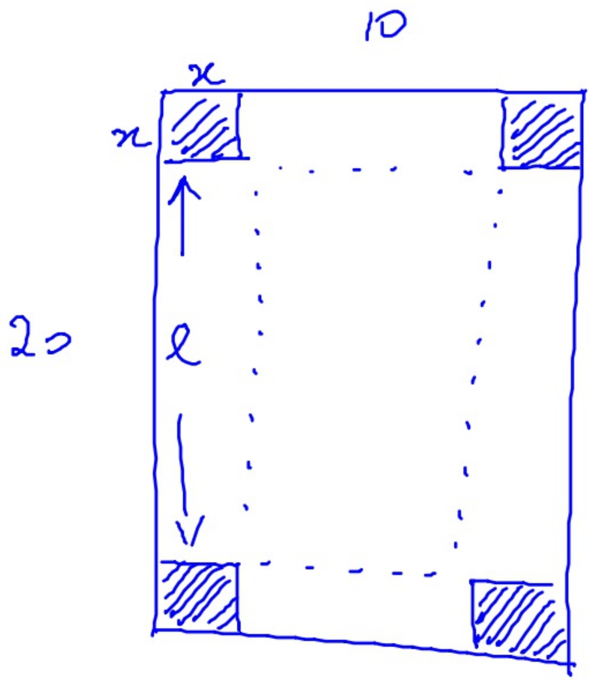


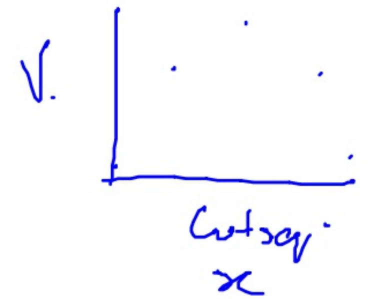
Cut out Sq	L	W	H	V
0	20	10	0	0
1	18	8	1	144
2	16	6	2	192
3	14	4	3	168
4	12	2	4	96.
5	10	0	5	0



1.1
1.2
1.3
*Unsaved
211.2
y
10
-0.5
0.2
5.5
x
(cutsq,vol)
???
Have we found the best cut out square, or do we need to keep looking?

Setting the problem up to use CALCULUS





$$V = l \times w \times h$$

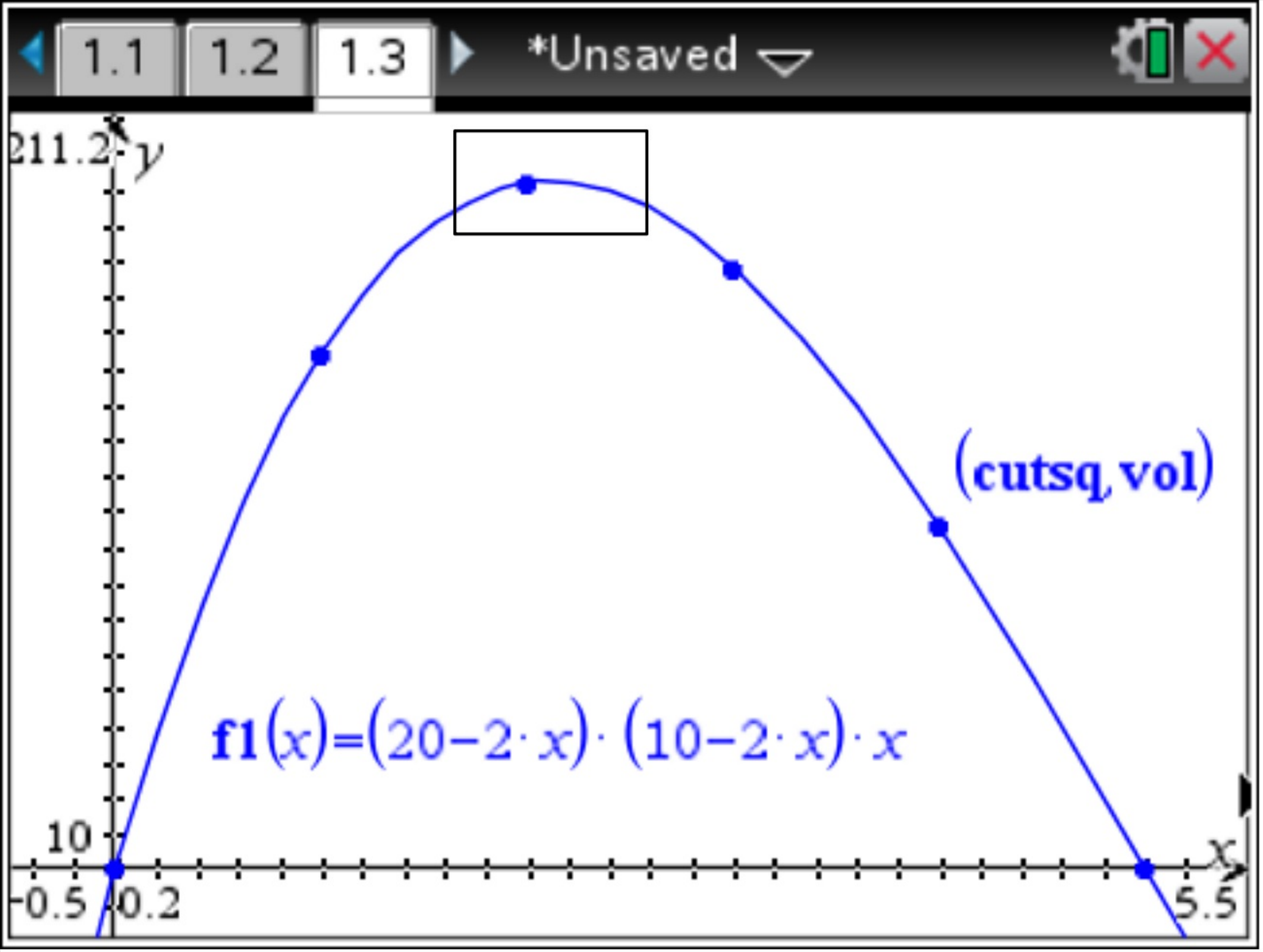
$$l = 20 - 2x$$

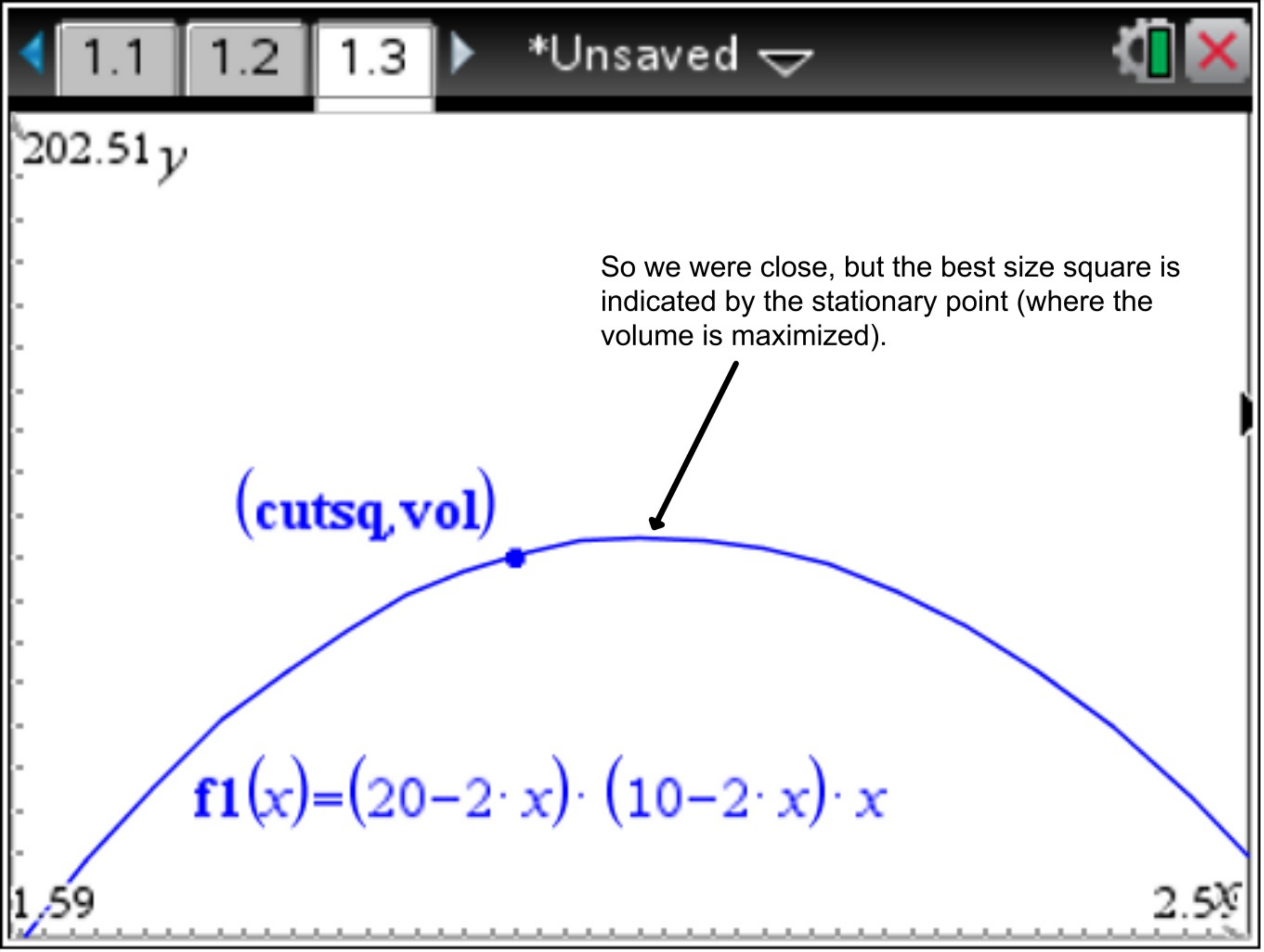
$$w = 10 - 2x$$

$$h = x$$

$$V(x) = (20 - 2x)(10 - 2x)x$$

A function for the volume where x is size of the cut-out square


1.1
1.2
1.3
*Unsaved
211.2
y
(cutsq,vol)
f1(x)=(20−2·x)·(10−2·x)·x
10
x
-0.5
0.2
5.5


1.1
1.2
1.3
*Unsaved
202.51 y
So we were close, but the best size square is indicated by the stationary point (where the volume is maximized).
(cutsq,vol)
f1(x)=(20−2· x)· (10−2· x)· x
1.59
2.59 x

Calculus will let us find the exact values of the stationary point

Solve $V'(x) = 0$ for x (ie find the stationary point).

$$V(x) = (20-2x)(10-2x)x$$
$$= (200 - 60x + 4x^2)(x)$$
$$= 200x - 60x^2 + 4x^3$$

$$V'(x) = 200 - 120x + 12x^2$$

Let $12x^2 - 120x + 200 = 0$

$3x^2 - 30x + 50 = 0$

$$x = \frac{-b \mp \sqrt{b^2 - 4ac}}{2a}$$
$$= \frac{30 \mp \sqrt{900 - 4(3)(50)}}{2(3)}$$
$$= \frac{30 \mp \sqrt{300}}{6}$$

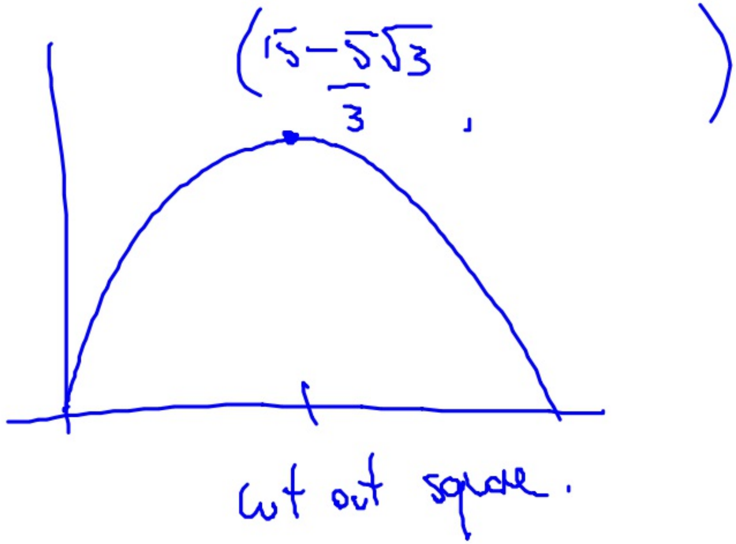
$$x = \frac{30 \mp 10\sqrt{3}}{6}$$
$$= \frac{15 \mp 5\sqrt{3}}{3}$$
$$= \frac{15 - 5\sqrt{3}}{3}$$

the optimal value of x

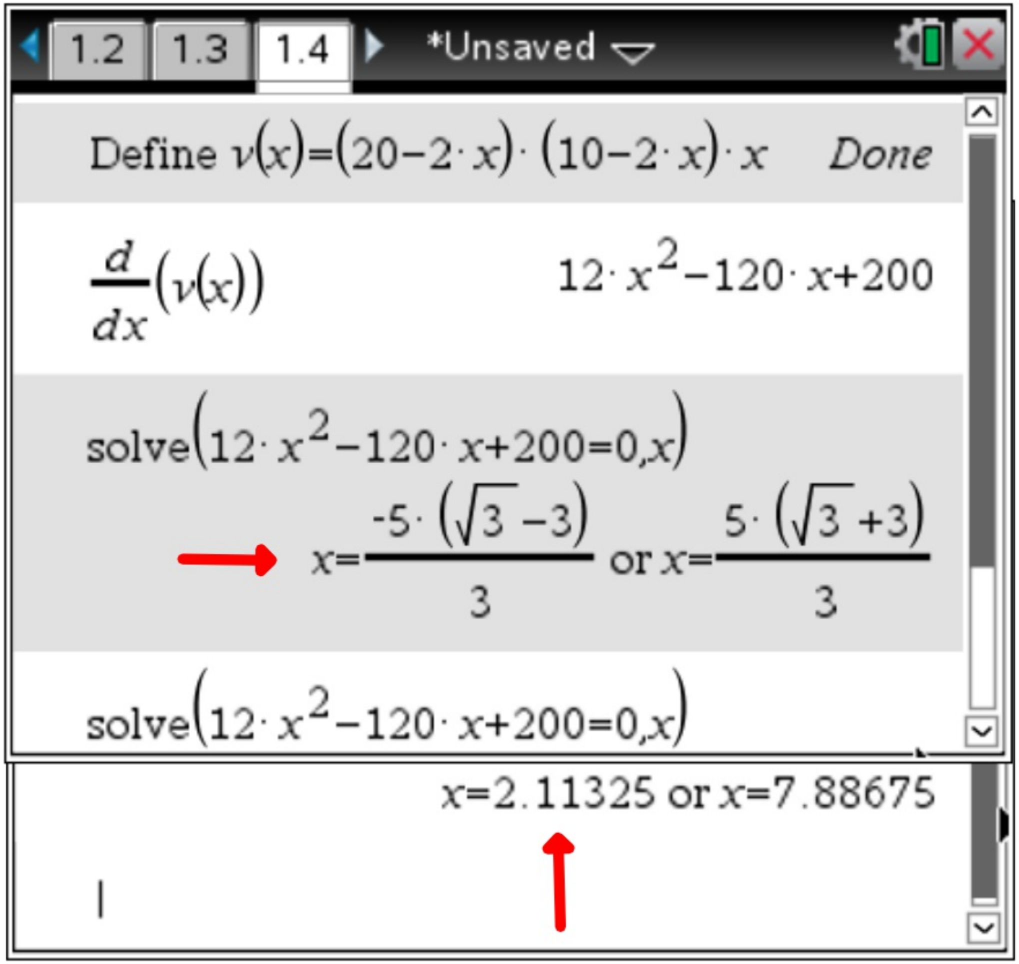
(since $\frac{15+5\sqrt{3}}{3}$ is too big ie. > 5)

The solution for the optimum cut out square is $\frac{15-5\sqrt{3}}{3}$

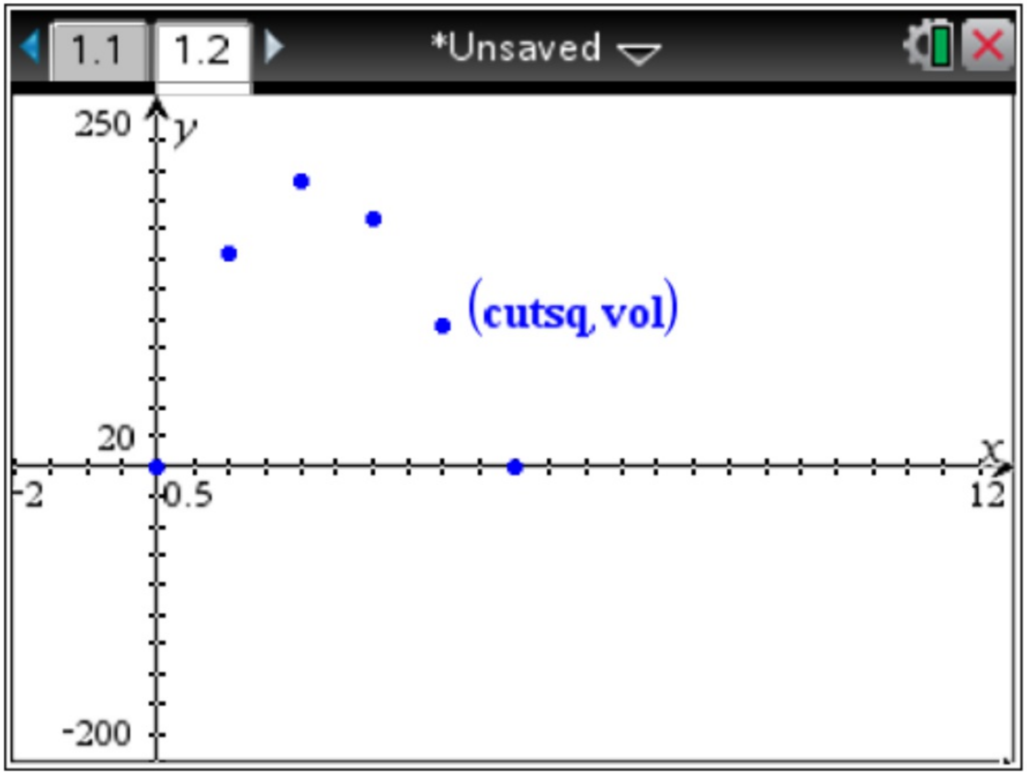
This approximately 2.11325



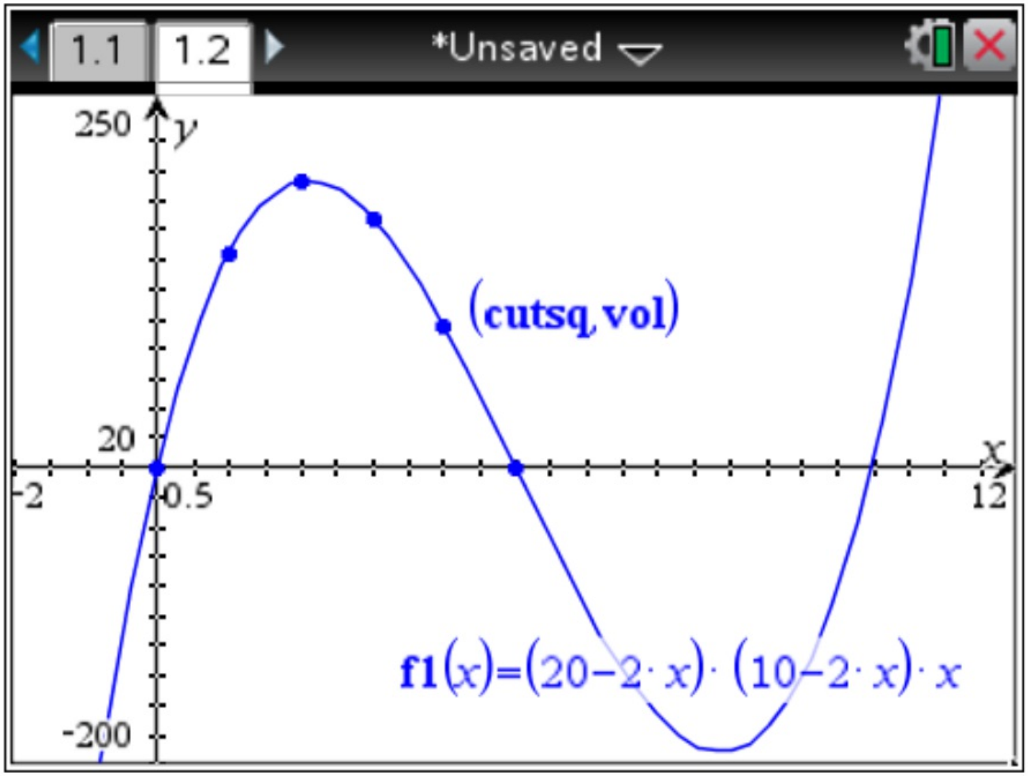
Solving the problem using CAS calculator



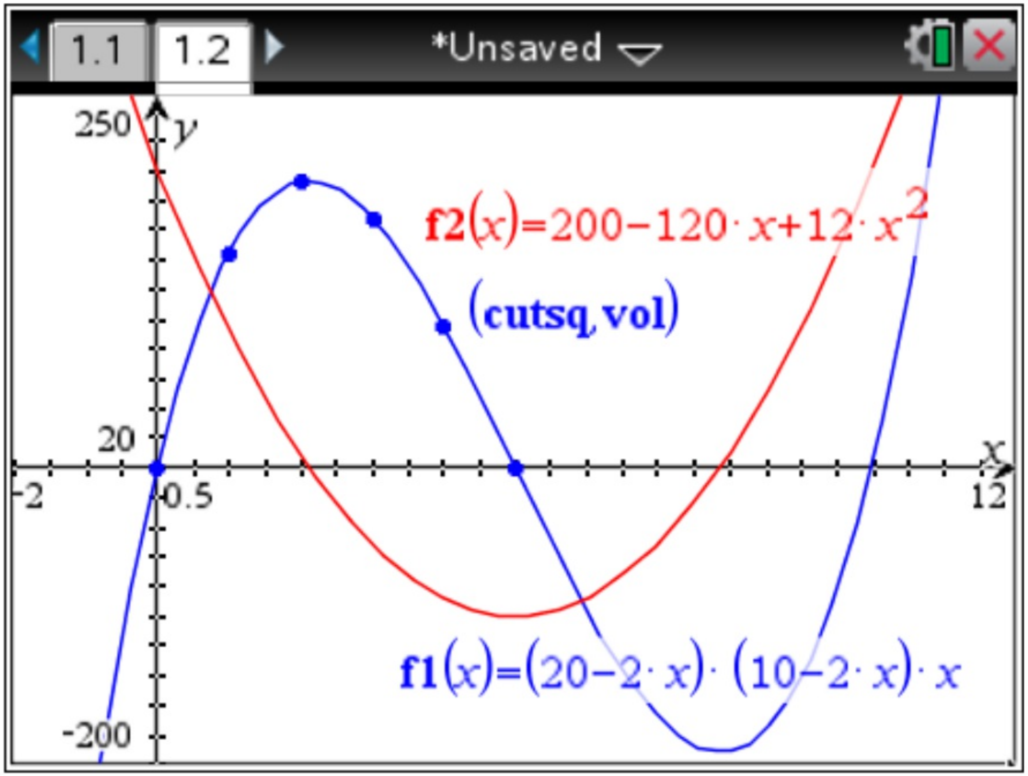
The same concept, the calculator just does all of the "number-crunching".

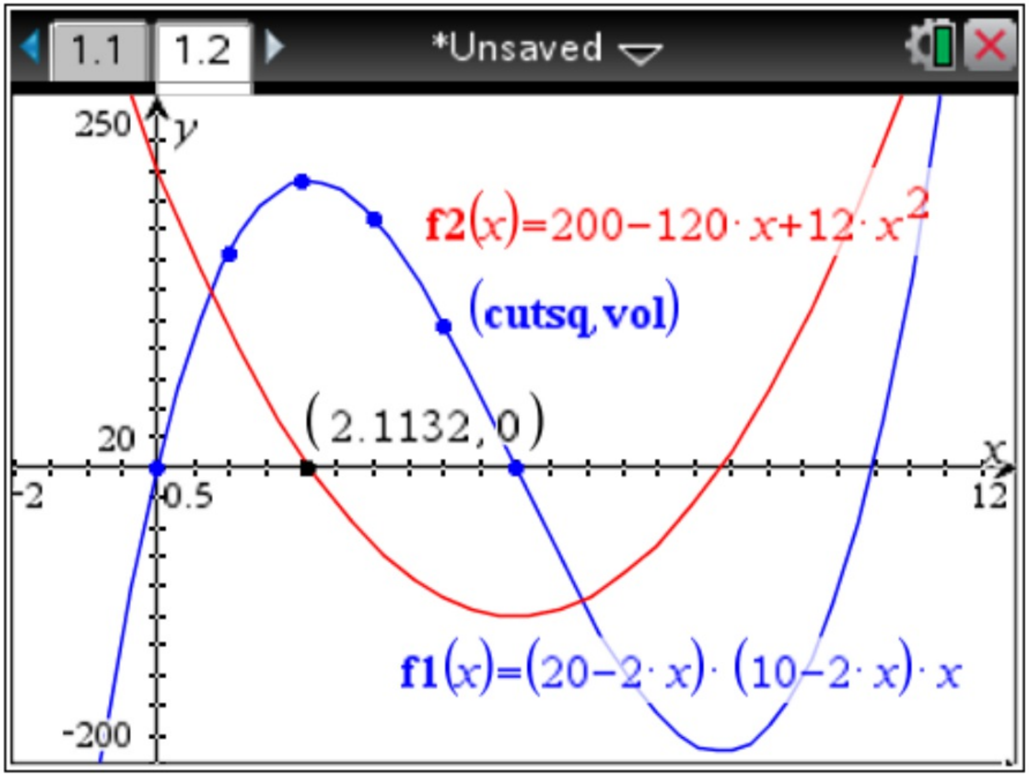


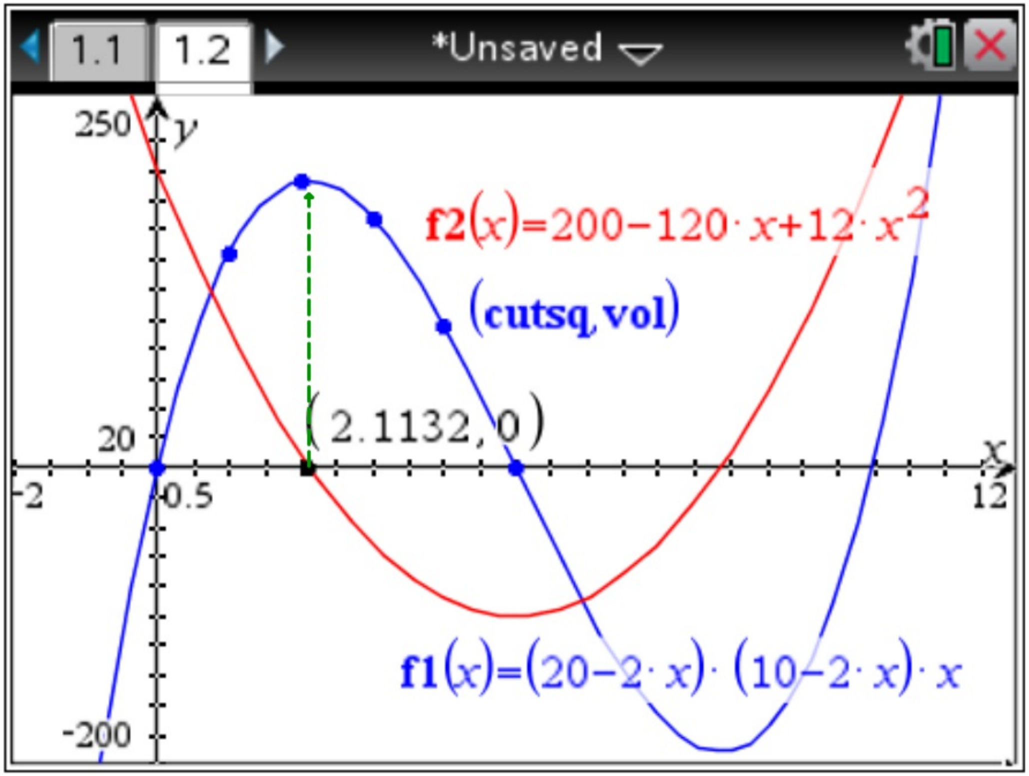
1.1
1.2
*Unsaved
250
y
(cutsq,vol)
20
x
-2
0.5
12
-200



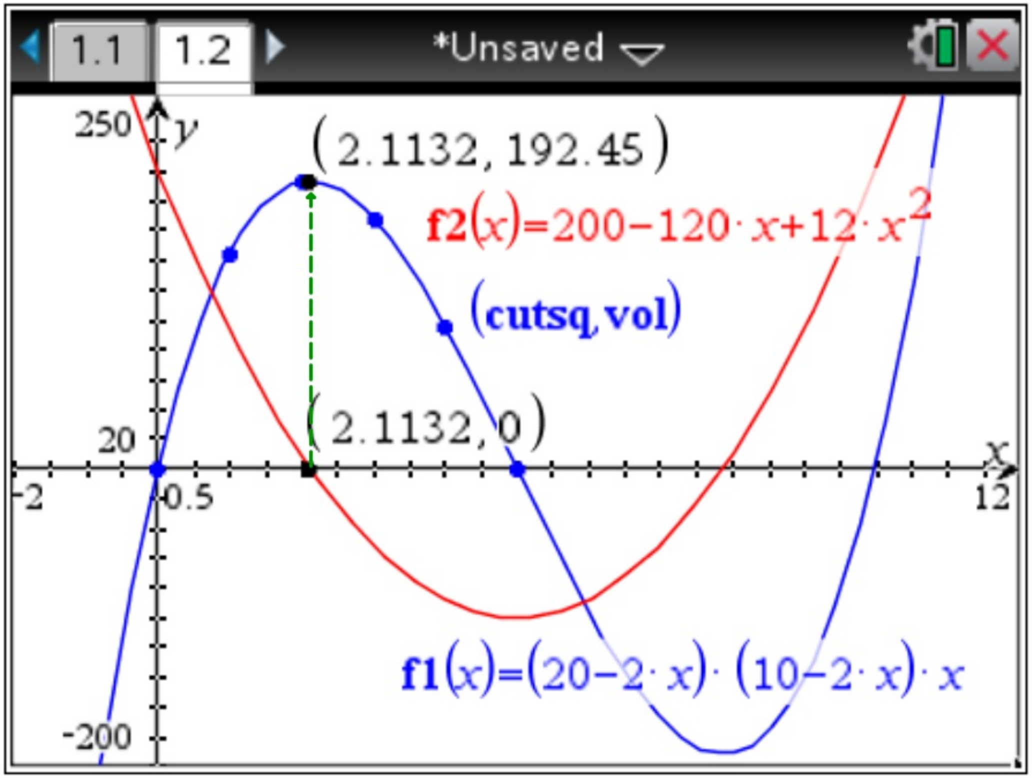
1.1
1.2
*Unsaved
250
y
(cutsq,vol)
20
x
-2
0.5
12
f1(x)=(20−2·x)·(10−2·x)·x
-200


1.1
1.2
*Unsaved
250
y
f2(x)=200−120·x+12·x^2
(cutsq,vol)
20
x
-2
0.5
12
f1(x)=(20−2·x)·(10−2·x)·x
-200

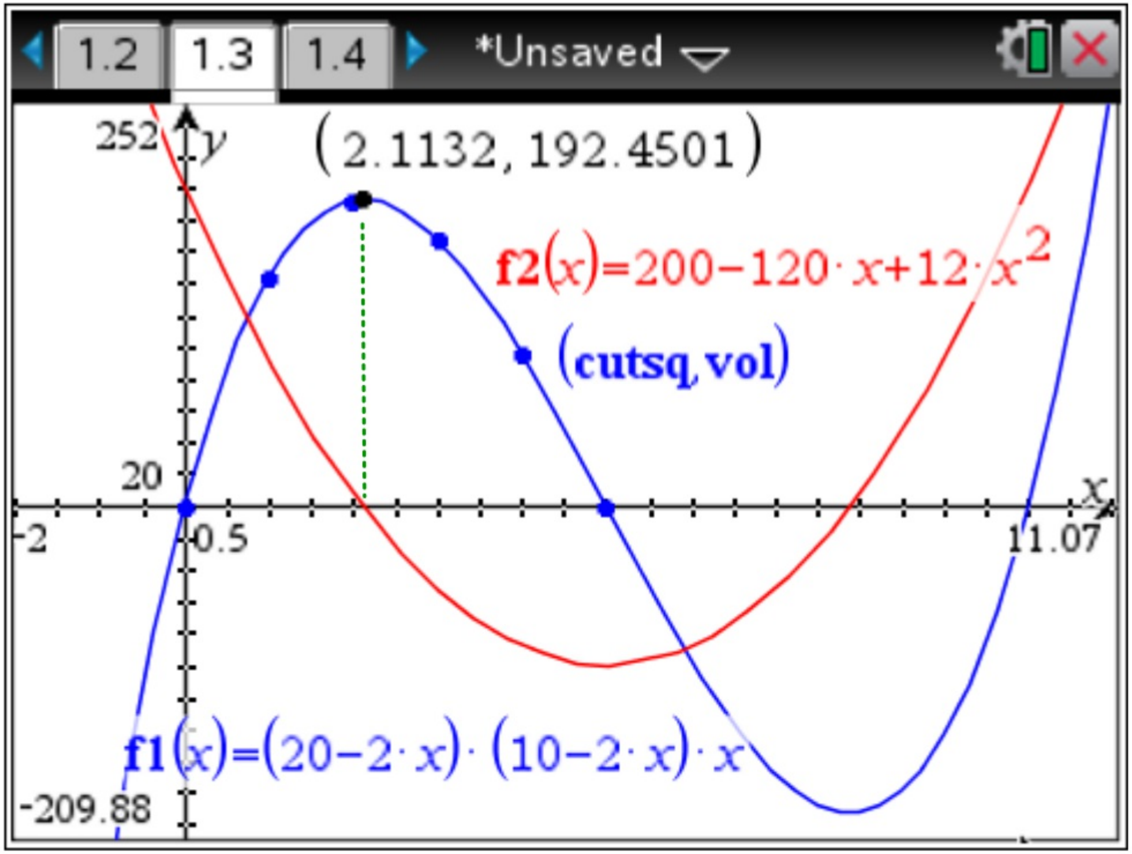

1.1
1.2
*Unsaved
250
y
f2(x)=200−120·x+12·x^2
(cutsq,vol)
(2.1132,0)
20
x
-2
0.5
12
f1(x)=(20−2·x)·(10−2·x)·x
-200



1.1
1.2
*Unsaved
250
y
f2(x)=200−120·x+12·x^2
(cutsq,vol)
(2.1132,0)
20
x
-2
0.5
12
f1(x)=(20−2·x)·(10−2·x)·x
-200


1.1
1.2
*Unsaved
250
y
(2.1132, 192.45)
f2(x)=200−120·x+12·x^2
(cutsq,vol)
(2.1132, 0)
20
x
-2
0.5
12
f1(x)=(20−2·x)·(10−2·x)·x
-200

The "Big Picture"



Here we can see

- the initial volumes we found,
- the volume function we defined,
- the gradient function,
- the solution where the gradient function is zero,
- the maximum volume of the cuboid.

Trigonometry Walk

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Damian Howison @DaHowi · 2h

Waggin' class? Nah, doin some trig-walkin #math #maths300 #mathmethods

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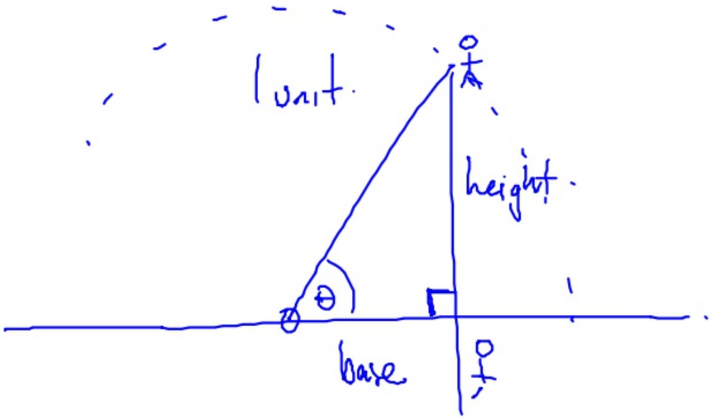
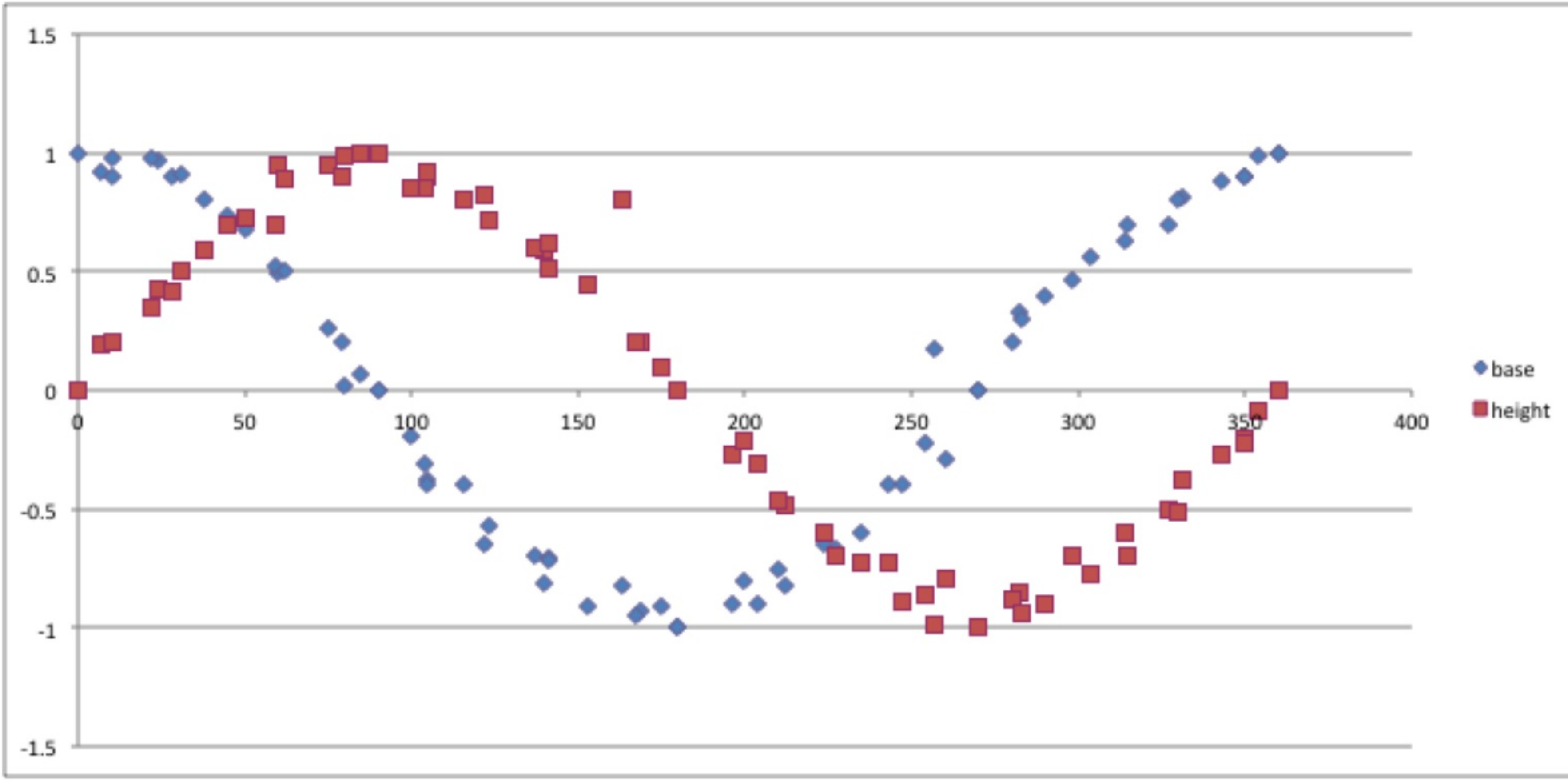
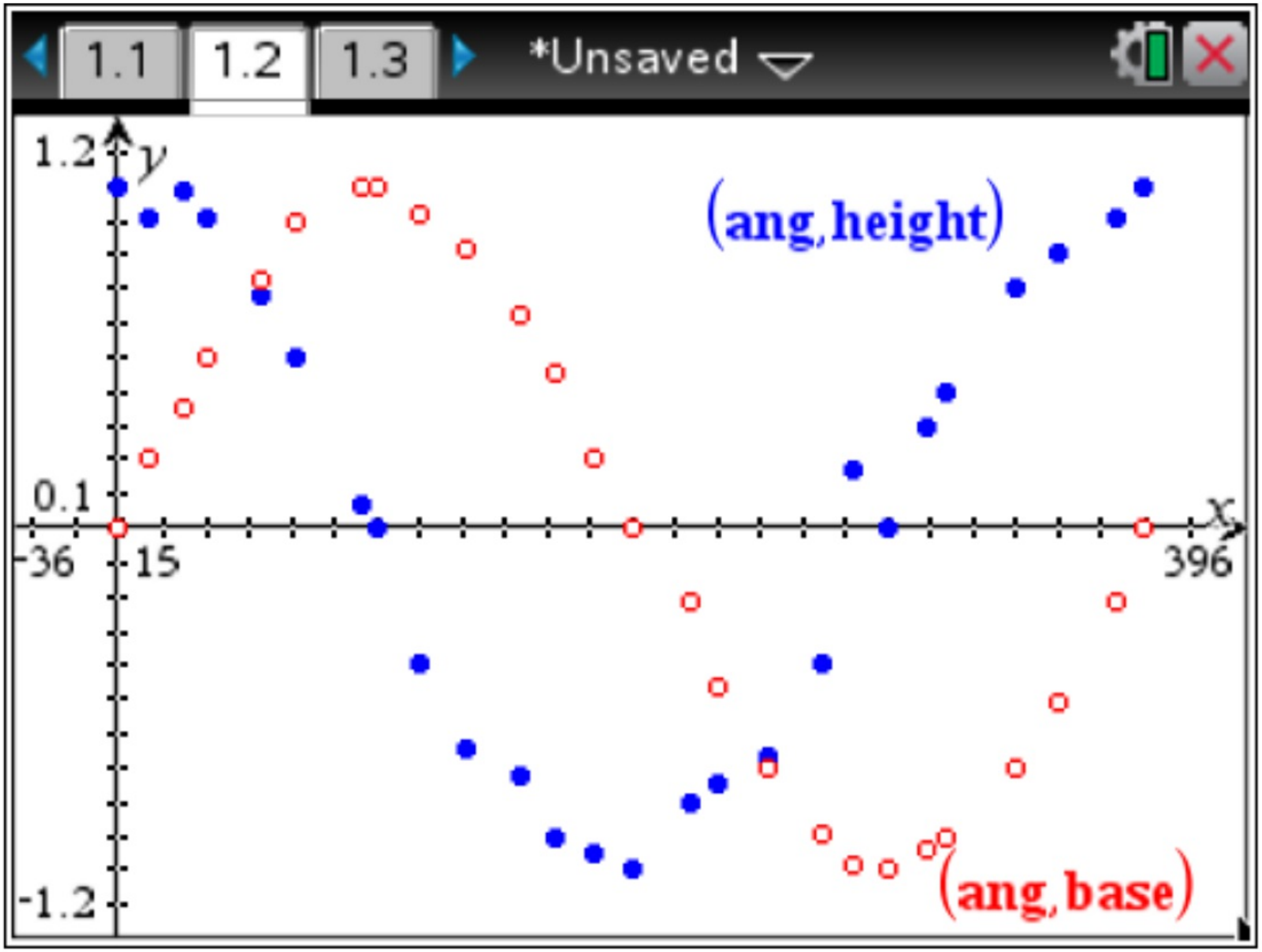


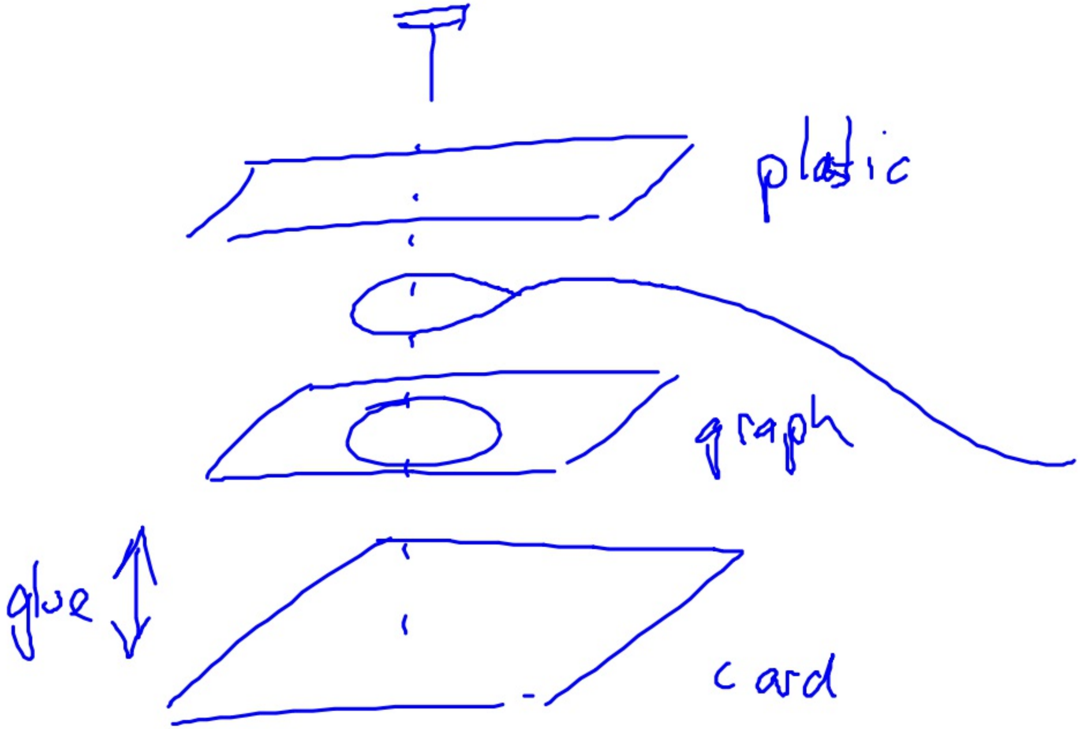
Circle Measurement
(radius = 1 unit)

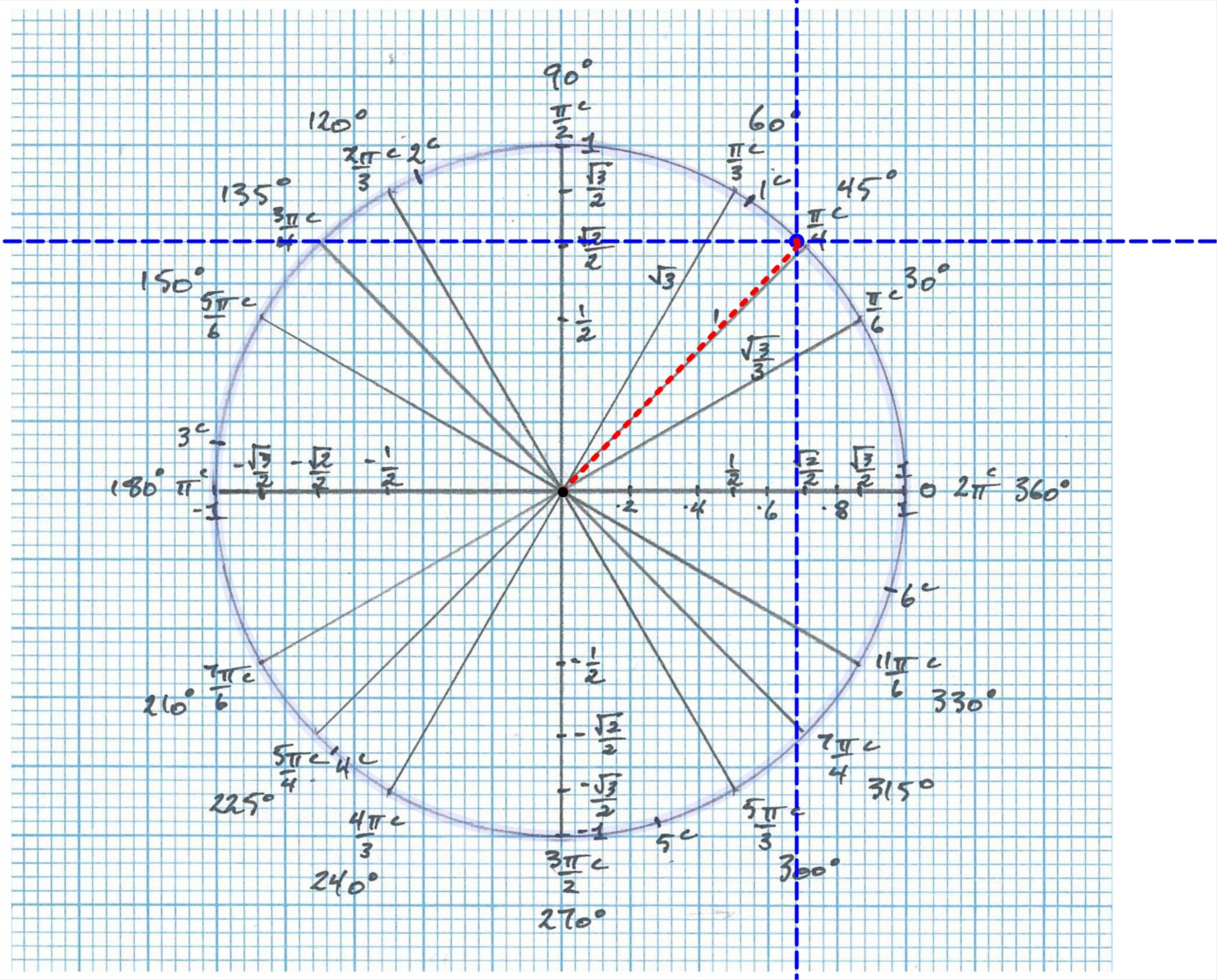
Angle	Height	Base



1.5
1
0.5
0
-0.5
-1
-1.5
0
50
100
150
200
250
300
350
400
base
height

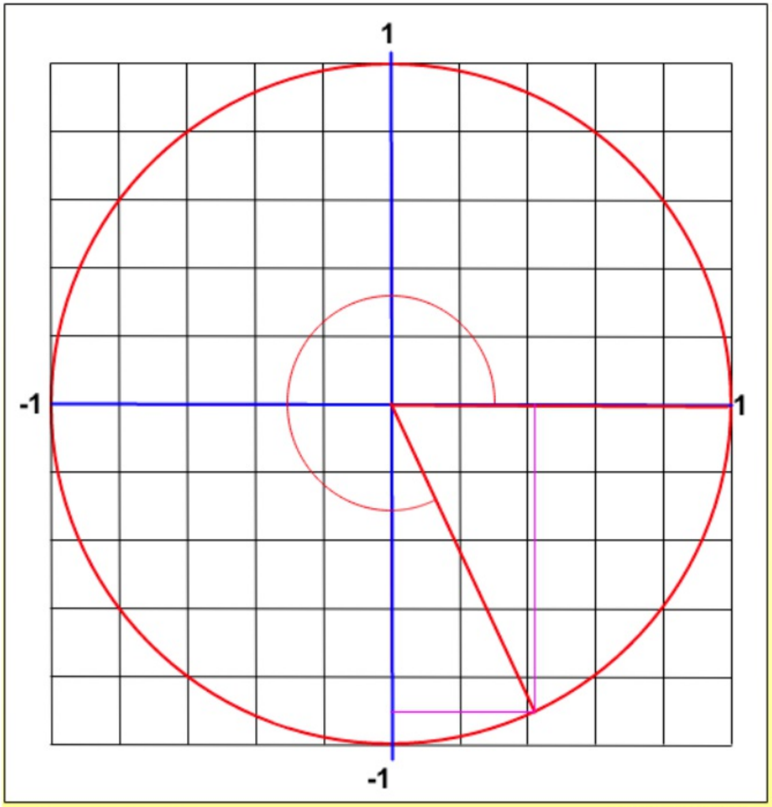

1.1
1.2
1.3
*Unsaved
1.2
y
0.1
-1.2
-36
15
396
x
(ang,height)
(ang,base)


plastic
graph
glue
card



90°
$\frac{\pi}{2}^c$
120°
$\frac{2\pi}{3}^c$
2^c
60°
$\frac{\pi}{3}^c$
1^c
45°
$\frac{\pi}{4}^c$
135°
$\frac{3\pi}{4}^c$
150°
$\frac{5\pi}{6}^c$
30°
$\frac{\pi}{6}^c$
$\sqrt{3}$
1
$\frac{\sqrt{3}}{3}$
3^c
180°
π^c
0
$2\pi^c$
360°
$\frac{\sqrt{3}}{2}$
$\frac{\sqrt{2}}{2}$
$\frac{1}{2}$
$-\frac{1}{2}$
$-\frac{\sqrt{2}}{2}$
$-\frac{\sqrt{3}}{2}$
-1
.2
.4
.6
.8
6^c
$\frac{11\pi}{6}^c$
330°
210°
$\frac{7\pi}{6}^c$
$\frac{5\pi}{4}^c$
4^c
225°
$\frac{7\pi}{4}^c$
315°
$\frac{4\pi}{3}^c$
240°
$\frac{3\pi}{2}^c$
270°
5^c
$\frac{5\pi}{3}^c$
300°

Intro to solving trig equations



A = 295 degrees

Click on the circle.

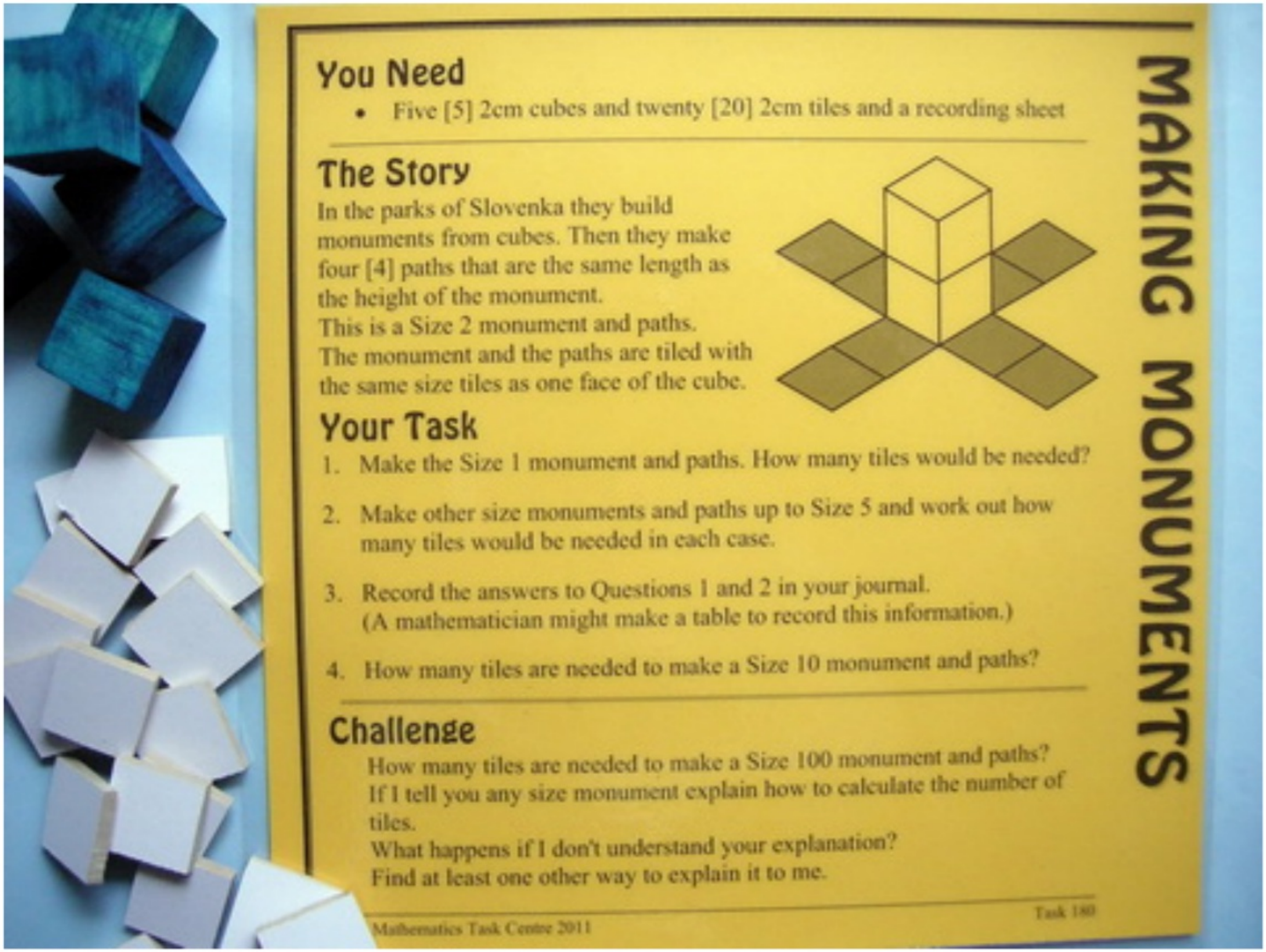
Use the unit circle to estimate both angles (within 1 degree accuracy) for the following trigonometric ratios.

Ratio	angle 1	angle 2
tanA = -1		
sinA = -0.9	245	295
cosA = 0.3		
cosA = -0.8		
sinA = 0.3		

244 296

OK

Answers



MAKING MONUMENTS

You Need

- Five [5] 2cm cubes and twenty [20] 2cm tiles and a recording sheet

The Story

In the parks of Slovenka they build monuments from cubes. Then they make four [4] paths that are the same length as the height of the monument.
This is a Size 2 monument and paths.
The monument and the paths are tiled with the same size tiles as one face of the cube.

Your Task

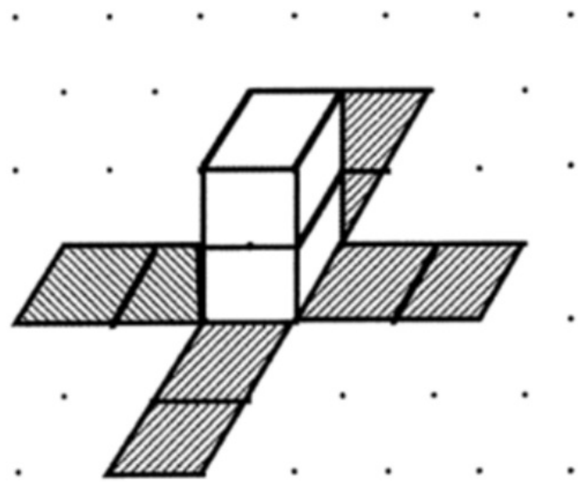
1. Make the Size 1 monument and paths. How many tiles would be needed?
2. Make other size monuments and paths up to Size 5 and work out how many tiles would be needed in each case.
3. Record the answers to Questions 1 and 2 in your journal.
   (A mathematician might make a table to record this information.)
4. How many tiles are needed to make a Size 10 monument and paths?

Challenge

How many tiles are needed to make a Size 100 monument and paths?
If I tell you any size monument explain how to calculate the number of tiles.
What happens if I don't understand your explanation?
Find at least one other way to explain it to me.

Making Monuments: Investigation Sheet No.1

Monuments are scattered all through the parks of Stonia. They are made so that the length of the paths leading up to them is the same as the height of the monument. This is a Size 2 monument:



Once the monuments and paths have been built they are tiled. The monuments *and* paths are both tiled with the same size square tiles.

1. Make a Size 1 monument and its paths. How many tiles would be needed?

2. Make Sizes 2, 3, 4 & 5 and for each one work out the number of tiles needed to tile the monument and its paths.

3. Organise the results you have so far. Can you predict the number of tiles needed for the Size 10 monument? Check by drawing.

4. Imagine the Size 100 monument. How many tiles does it need? Explain your answer.

$$f: \mathbb{Z}^+ \to \mathbb{Z}^+, \quad f(x) = 8x + 1$$

- f: the **name** of the function
- first $\mathbb{Z}^+$: **domain** — what are the possible inputs?
- $\to$: mapped into
- second $\mathbb{Z}^+$: **codomain** — what type of values can we expect for the outputs?
- $f(x) = 8x + 1$: the **rule** for the function.

How many tiles for a size 30 monument?

$$f(30) = 30 \times 8 + 1 = 241$$

Continuous v Discrete problems

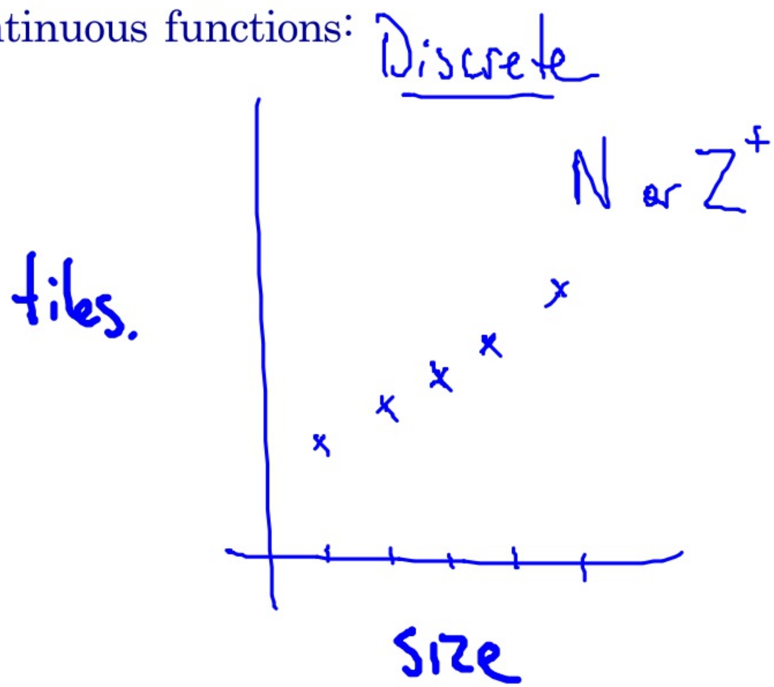
7. What if a monument was built to a height of 5½ blocks, or maybe 6.2 blocks? How could you find the number of tiles needed?

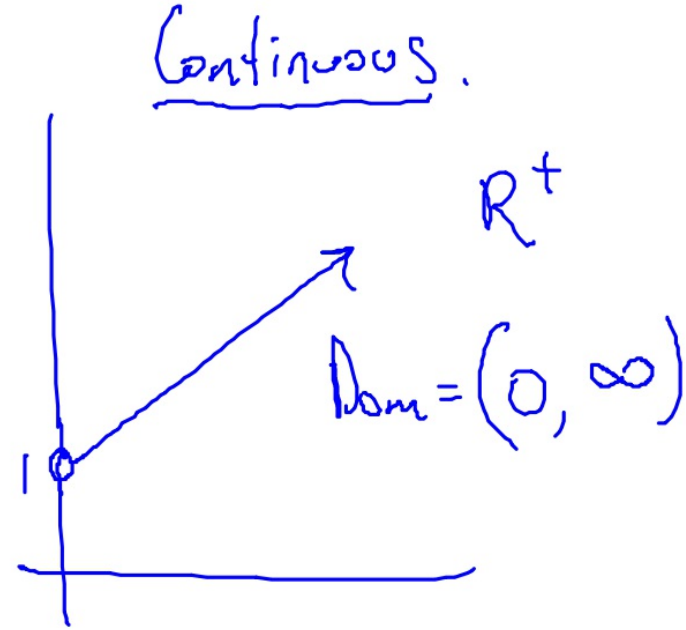
$f: \mathbb{R}^+ \rightarrow \mathbb{R}^+, \; f(x) = 8x + 1$

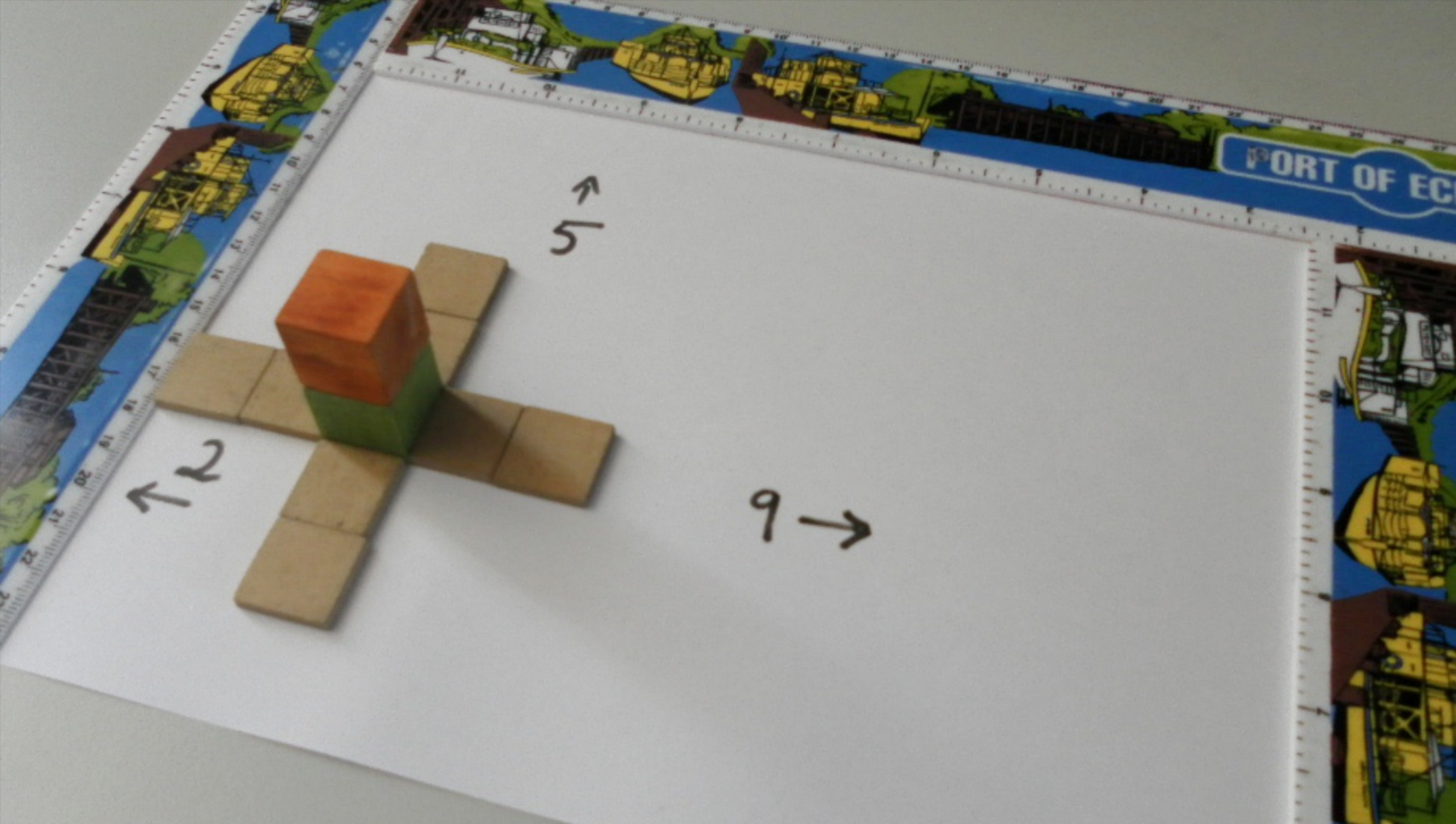
∘ (

• [

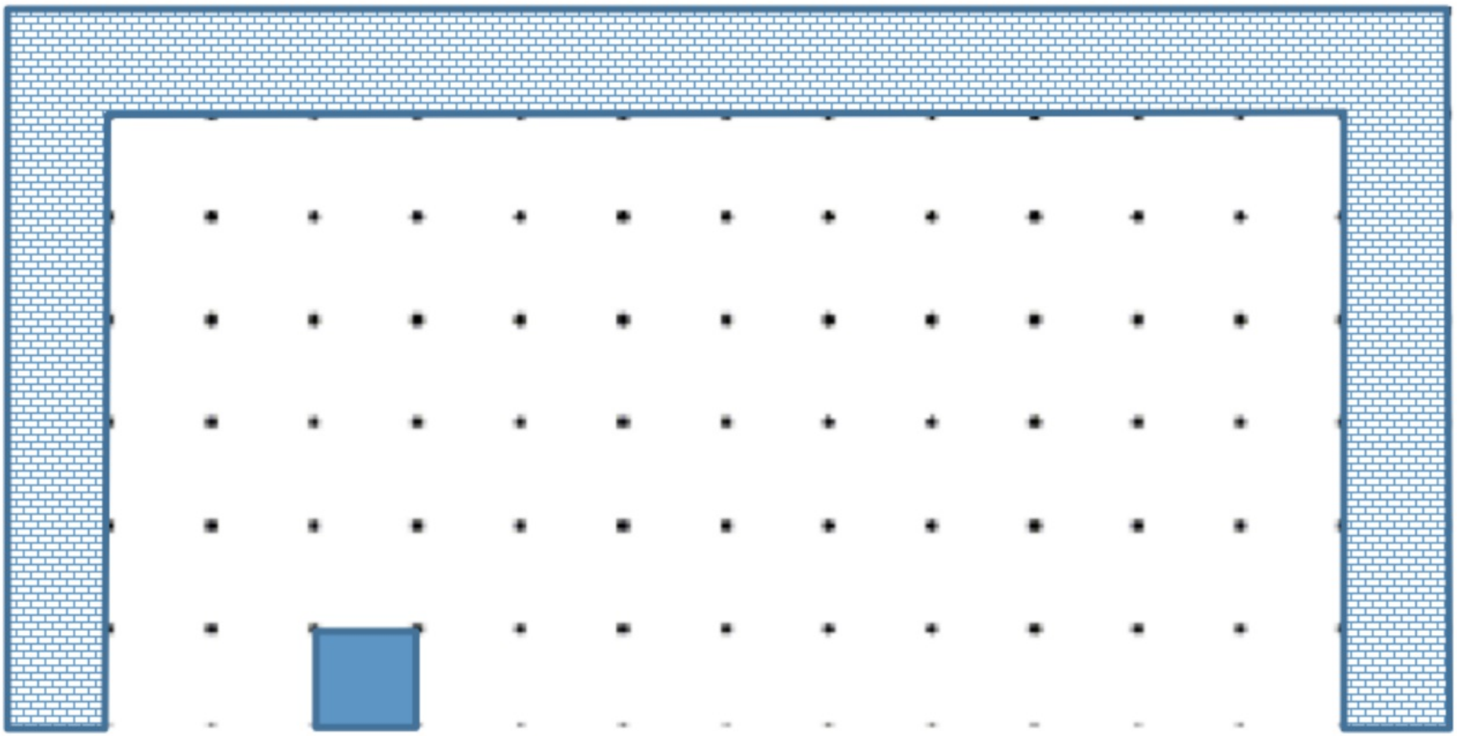
Compare the graphs and the notation of discrete and continuous functions:







How would you write a rule for finding the number of tiles needed given the height of the monument?



How would you write a rule for finding the number of tiles needed given the height of the monument?

Make a table:

	1	2	3	4	5	6	7	8	9	10			
	9	17	24	32	40	46	54	62	70	77			

31 38

Break the problem into parts.

① Until we hit the '2' wall. $f(x) = 8x + 1$

$x \in \{1, 2\}$

② After the '2' wall, until we hit the '5' wall.

$f(x) = 7x + 3 \quad , x \in \{3, 4, 5\}$

$$f(x) = \begin{cases} 8x+1, & 0 < x \leq 2 \\ 7x+3, & 2 < x \leq 5 \\ 6x+8, & 5 < x \leq 9 \\ 5x+17, & x > 9 \end{cases}$$

x	S	1	2	3	4	5	6	7	8	9	10	11	12	13
$f(x)$	T	9	17	24	31	38	44	50	56	62	67	72	77	82

The function for tiling our monument in the courtyard would be

$$f: R^+ \rightarrow R^+, \quad f(x) = \begin{cases} 8x+1, & 0 < x \leq 2 \\ 7x+3, & 2 < x \leq 5 \\ 6x+8, & 5 < x \leq 9 \\ 5x+17, & x \geq 10 \end{cases}$$

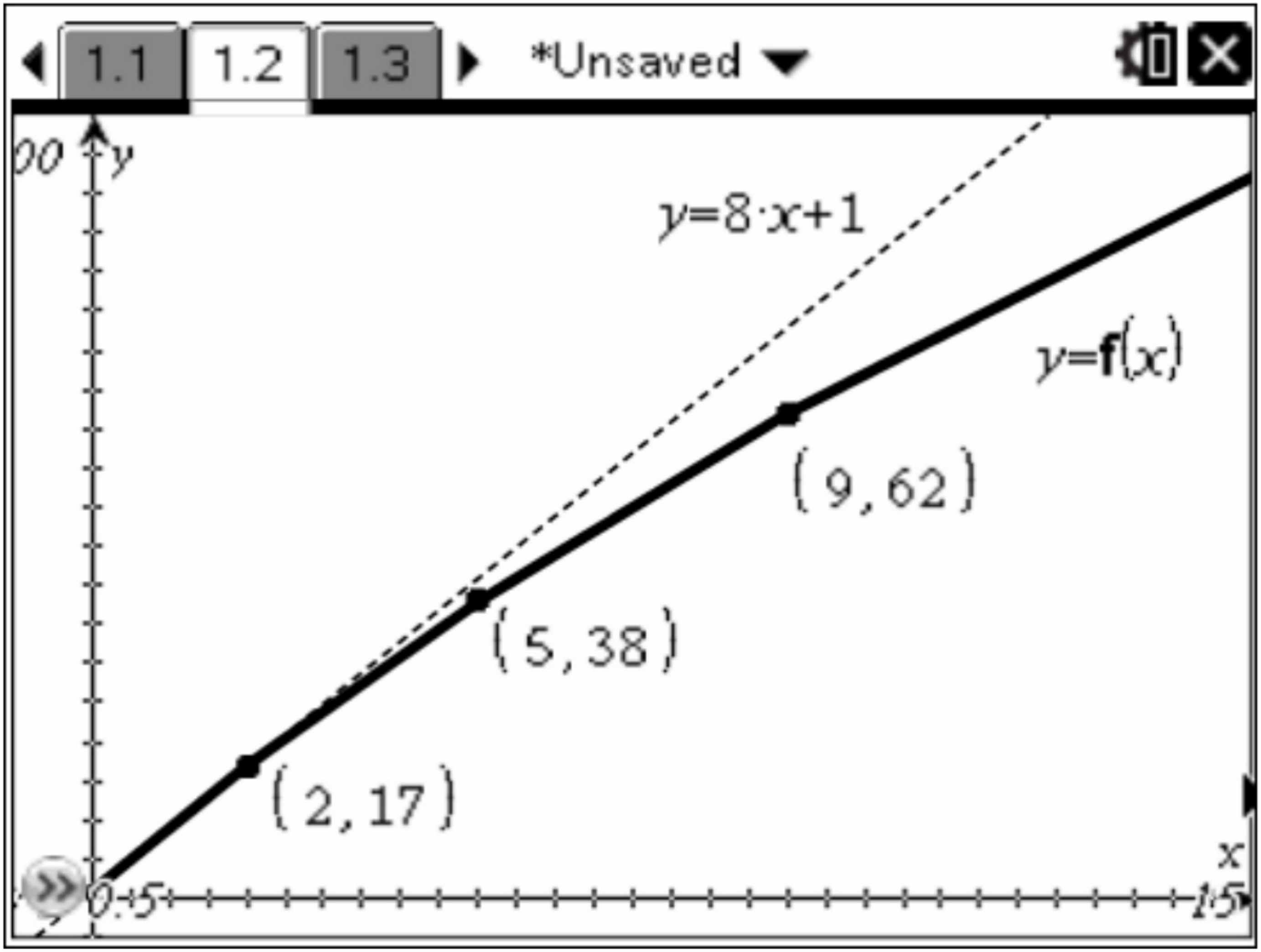
When we express functions this way they are called HYBRID functions **(or piecewise functions).**

1.1 *Unsaved

$$\text{Define } f(x)=\begin{cases} 8\cdot x+1, & 0<x\le 2 \\ 7\cdot x+3, & 2<x\le 5 \\ 6\cdot x+8, & 5<x\le 9 \\ 5\cdot x+17, & x>9 \end{cases}$$ *Done*

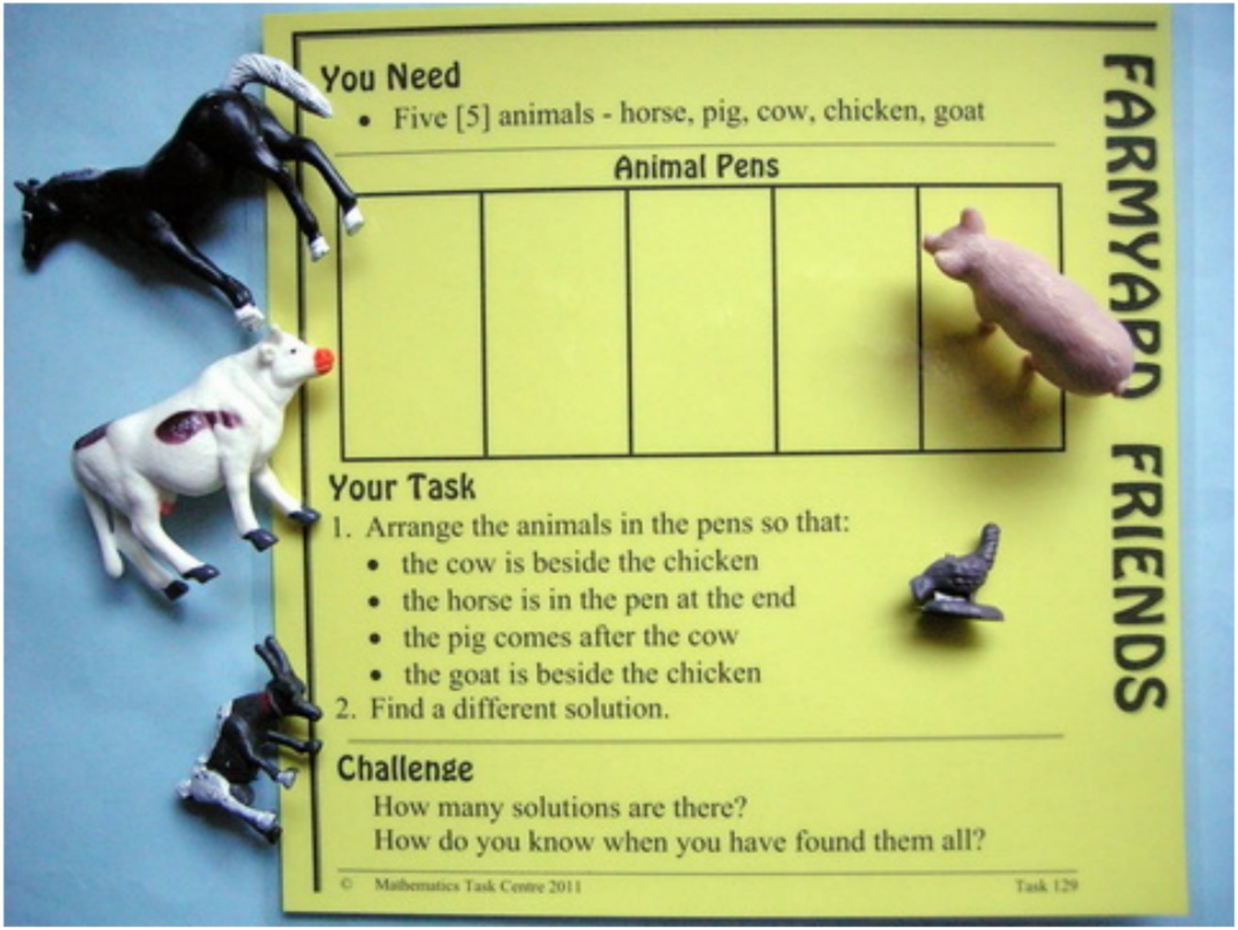
$f(6)$	44
$f(4)$	31
$f(12)$	77

4/99


1.1
1.2
1.3
*Unsaved
y
y=8·x+1
y=f(x)
(9,62)
(5,38)
(2,17)
x
0.5
15

maths 300

Supporting excellence in mathematics teaching



Arrange the animals in the pens so that

- the cow is beside the chicken
- the horse is in the pen at the end
- the pig comes after the cow
- the goat is beside the chicken

Is there another solution?

How many are there?

How will you know you have found them all?

Farmyard Friends

otherwise entitled

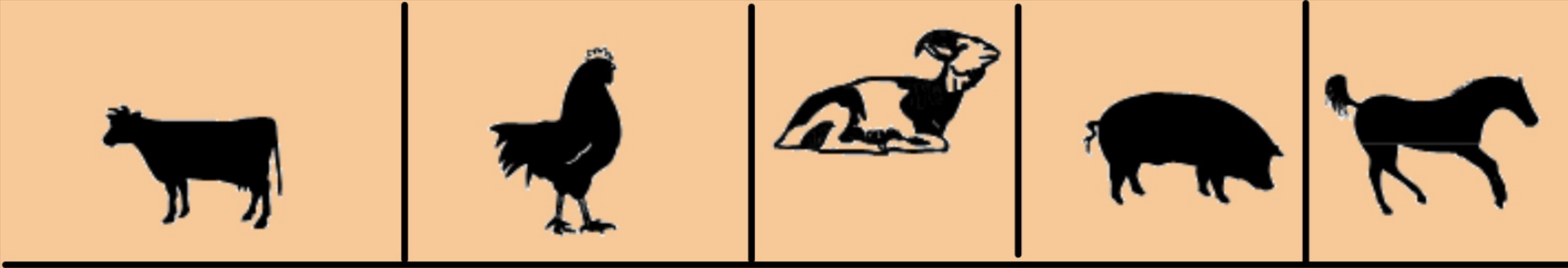
"The Case of the Invisible Chickens".

the cow is beside the chicken

the horse is in the pen at the end

the pig comes after the cow

the goat is beside the chicken.



PERMUTATIONS.

GOAT	CHICK	COW	PIG	HORSE
HORSE	GOAT	CHICK	COW	PIG
COW	CHICK	GOAT	PIG	HORSE.
HORSE	COW	CHICK	GOAT	PIG
PIG	COW	CHICK	GOAT	HORSE
PIG	GOAT	CHICK	COW	HORSE
HORSE	PIG	GOAT	CHICK	COW.
HORSE	PIG	COW	CHICK	GOAT

Puzzle A

- Suppose only one clue is given:

The cow is in the pen at the end.

GOAT	CHICK	HORSE
GOAT	HORSE	CHICK
CHICK	GOAT	HORSE
CHICK	HORSE	GOAT
HORSE	GOAT	CHICK
HORSE	CHICK	GOAT

6

$$24 \times 2 = 48$$

	4	3	2	1

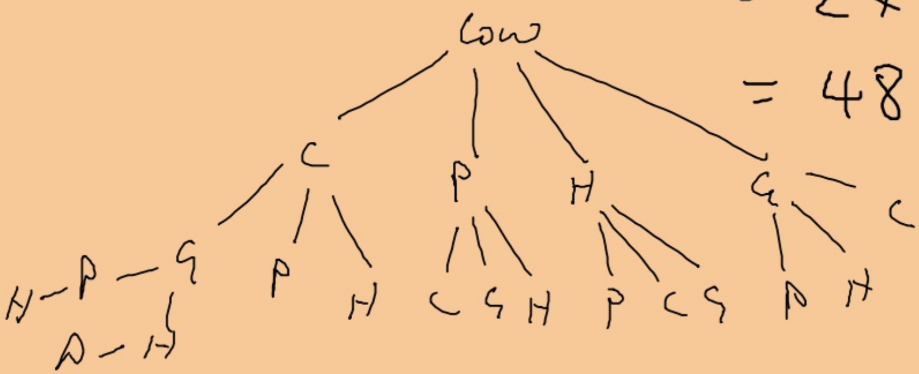
$$4 \times 3 \times 2 \times 1 = 4!$$

"4 factorial"

N^o permutations $= 2 \times 4!$

$= 2 \times 24$

$= 48.$



No restrictions

5 animals.

5 positions.

$$5! = 120$$

Puzzle B

- Another one line clue:

The horse is not next to the pig.

	3	2		1

$12 \times 3!$

$= 12 \times 6$

$= 72$

COMPLEMENT = HORSE NEXT TO PIG

$= 4! \times 2 = 48.$

$5! - 2 \times 4! = 72$

(no restrictions) (complement) (answer we want)

Puzzle C

- Multiple clues:

The cow is in the end pen….

…and the goat is not next to the cow.

$2 \times 4! = 48.$

$2 \times 3! = 12$

$2 \times 4! - 2 \times 3!$

$= 48 - 12$

$= 36.$

$3! \times 3 \times 2$

C	3	2	1	G

6

C		G		
C			G	
C				G
		G		C
	G			C
G				C

$-3!$

Probability

- If the animals wandered in from the field and randomly selected their pens, what is the *probability* that…
- …the horse is next to the pig.
- …the chicken is not in the end pen.

Even more puzzles

- What if the five animals wandered in from the field but there were only three pens?

- *In how many ways could the pens be occupied?*

5 animals, 3 pens

5	4	3

$$5 \times 4 \times 3 = 60$$

n animals, r pens.

$$\frac{5 \times 4 \times 3 \times 2 \times 1}{2 \times 1} = \frac{5!}{2!}$$

7 animals, 2 pens.

7	6

$= 42$

$$\frac{7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1}{5 \times 4 \times 3 \times 2 \times 1} = \frac{7!}{5!}$$

10 animals, 4 pens.

10	9	8	7

$= 5040$.

$$\frac{10!}{6!}$$

If I have <u>n things</u> available, and arrange only <u>r things</u> at a time, the number of permutations is:

$$^{n}P_{r} = \frac{n!}{(n-r)!}$$

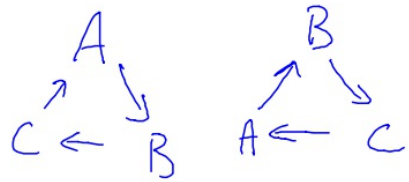
Eg.

$$^{10}P_{3} = \frac{10!}{(10-3)!}$$

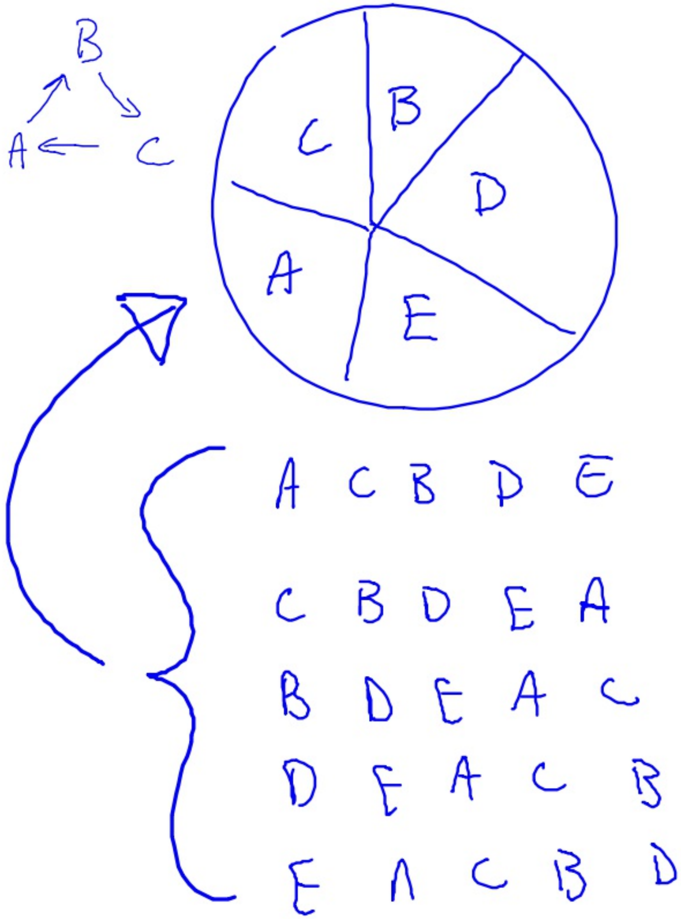
$$= \frac{10!}{7!}$$

$$= \frac{10 \times 9 \times 8 \times \cancel{7!}}{\cancel{7!}} = 720.$$

What if the pens were arranged in a circle?



A B C
B C A



5 things in a row would give 5! or 120

$$\frac{120}{5} = \underline{\underline{24}}$$

24 unique circular arrangements.

COMBINATORICS

6 things in a circle?

$$\frac{6!}{6} = \frac{6 \times 5!}{6} = 5!$$

10 things in a circle?

$$\frac{10!}{10} = \frac{10 \times 9!}{10} = 9!$$

n things in a circle?

$$(n-1)!$$

What if there were 8 animals and 8 pens, but 3 of the animals were identical chickens?

1 2 A B 3 4 C 5

B	A	C
A	C	B
C	B	A
C	A	B
B	C	A

$3!$

$$\frac{8!}{3!}$$

If there are n objects, and k objects are identical

the number of unique permutations

is $$\frac{n!}{k!}$$

n objects

k_1 identicals

k_2 identicals

⋮

(12) B ~~C~~ D E F

$$\frac{n!}{k_1!\,k_2!\,k_3!\cdots\cdots}$$

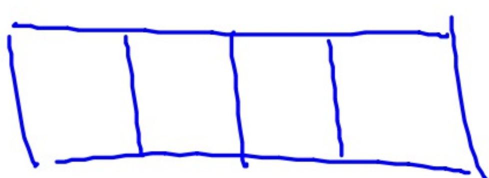
Factorial $n! = n \times (n-1) \times (n-2) \times \ldots \times 3 \times 2 \times 1$

→ in a row.

In a circle: $(n-1)!$

Identical objects: $\dfrac{n!}{k_1!\,k_2!\ldots}$

$^nP_r = \dfrac{n!}{(n-r)!}$ (n objects taken r at a time)

Box technique 

Using the **complement** – calculating the opposite.
because it's more efficient.

What if there were 7 pens available, but only 4 animals to occupy them?

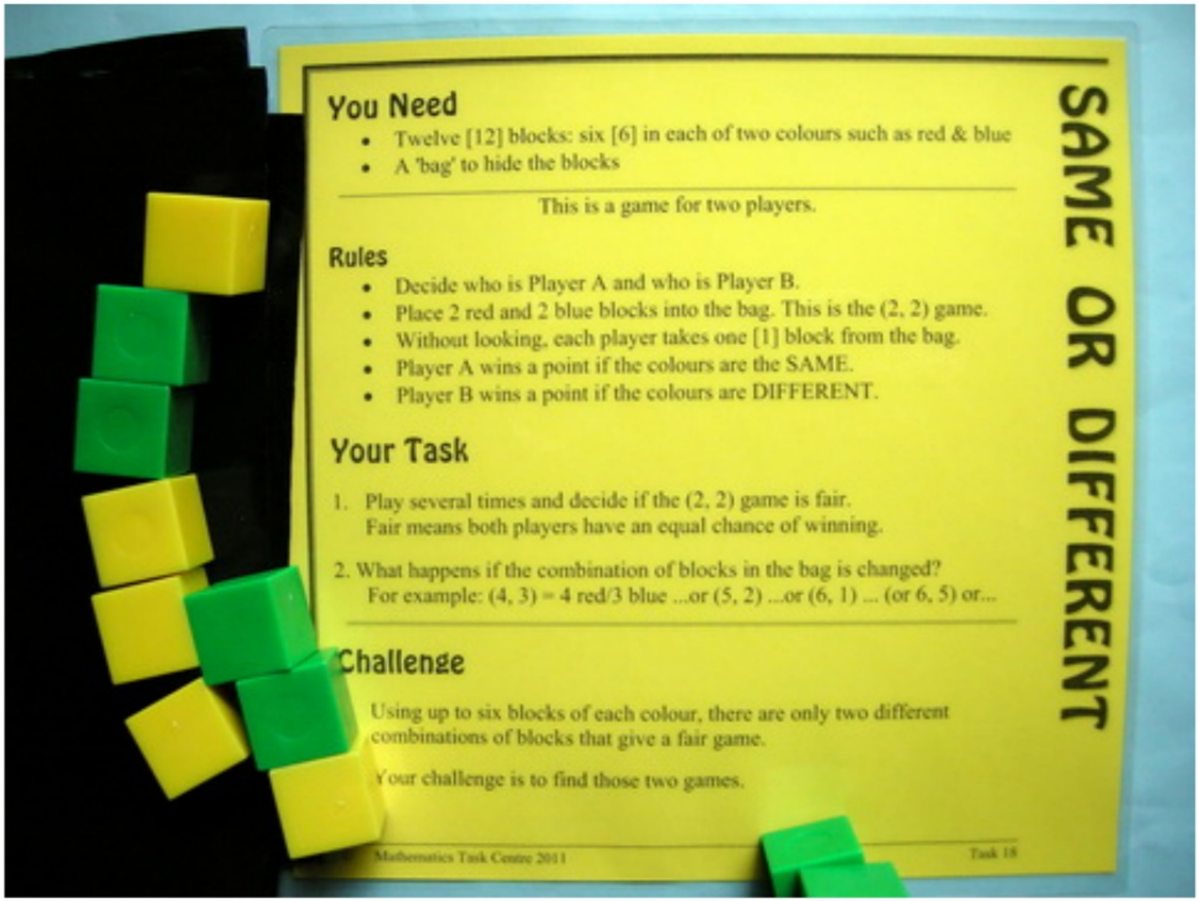
What if there were 7 pens available, but only 4 animals to occupy them?

$$\frac{7!}{3!} = 840$$

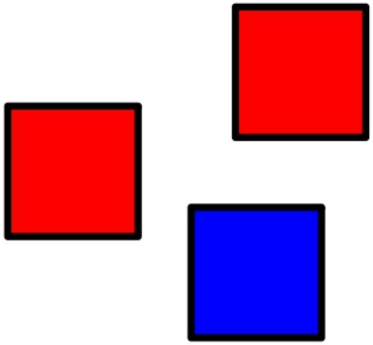
invisible chickens.

maths 300

Supporting excellence in mathematics teaching



Draw two blocks out of the bag.
You win if the blocks are the same colour?



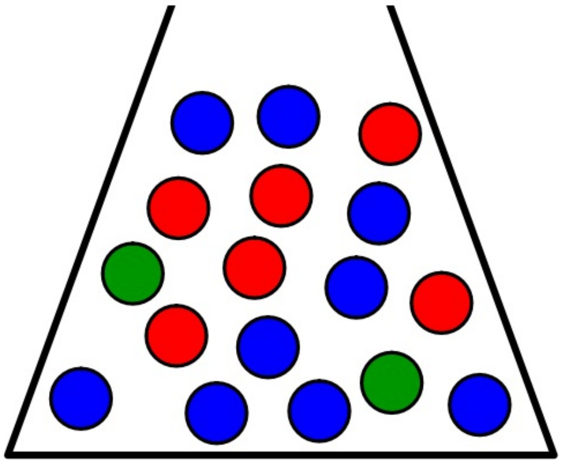
Is this game fair?

If yes, why?

If no, how can you make it fair?

Same or Different?

Exploration
(Unit 1/2 Math Methods)



Introduction to the (1,2) game.

A	B
SAME	DIFF
7, 5, 6	22, 16, 23
10, 12, 8	22, 24, 8
48	115

163

Empirical data

$$\Pr(\varepsilon) = \frac{n(\varepsilon)}{n(S)}$$

$\varepsilon \equiv$ SAME

$$\Pr(\text{SAME}) = \frac{n(\text{SAME})}{n(\text{TOTAL})}$$

$$= \frac{48}{163}$$

$$= 0.294$$

or 29.4%

$$Pr(\text{DIFF}) = 1 - Pr(\text{SAME})$$ (COMPLEMENT)

$$= 1 - 0.294$$

$$= 0.706$$

(2,2) game

SAME	DIFF
11, 13, 15	19, 21, 20
15, 15,	25, 33,

Setting the challenge. Find fair games empirically.

GAME	Pr(S)	Pr(D)
(2,1)	0.294	0.706
(2,2)	0.369	0.631

CHALLENGE:

SEARCH FOR A FAIR GAME.

Combinations found empirically that we could

a) support with the computer software,

b) confirm using probability theory ✓

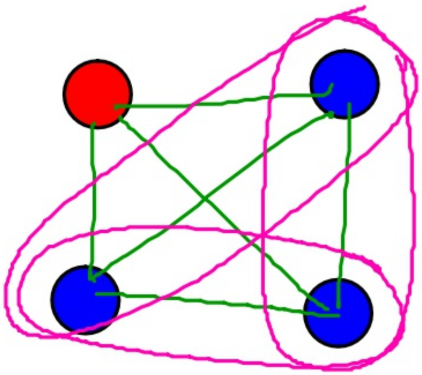
COMBINATIONS WE WANT TO TEST FOR FAIRNESS.

(2, 3) (3, 3) (2, 4) (6, 4)

(3, 4) (3, 5) (3, 6) ✓ (10, 5)

(4, 8) (1, 3) ✓ ~~(12, 8)~~ ~~(9, 13)~~

Using probability theory to prove fairness



6 possible pairs.

3 pairs are same.

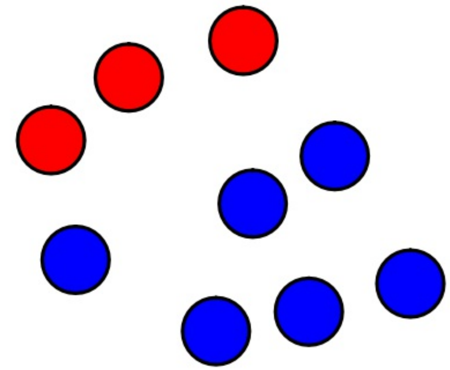
$$Pr(\text{same}) = \frac{n(\text{same})}{n(\text{total})} = \frac{3}{6} = \frac{1}{2}$$

Same $\quad {}^{3}C_{2}$

total $\quad {}^{4}C_{2}$

$$Pr(\text{same}) = \frac{{}^{3}C_{2}}{{}^{4}C_{2}} = \frac{3}{6} = \frac{1}{2}$$

$(3, 6)$?



same $\ {}^{6}C_{2} + {}^{3}C_{2}$

total. $\ {}^{9}C_{2}$

$Pr(\text{same})$

$$= \frac{{}^{3}C_{2} + {}^{6}C_{2}}{{}^{9}C_{2}}$$

$$= \frac{1}{2}$$

Games that appeared fair on the computer were proved to be close, *but not perfect*.

$(8, 12)$

$$\Pr(\text{same}) = \frac{{}^{8}C_2 + {}^{12}C_2}{{}^{20}C_2}$$

$$= \frac{47}{95}$$

close!

$(9, 13)$

$$\Pr(\text{same}) = \frac{38}{77}$$ close!

$$(6, 9) \rightarrow \frac{17}{35}$$ close!

These combinations make perfectly fair games:

$(1, 3) \quad (3, 6) \quad (6, 10) \quad (10, 15)$

Pairs of triangular numbers provide perfectly fair games.

1, 3, 6, 10, 15, 21, 28, 36, ...

$$\Pr(\text{same}) = \frac{{}^{28}C_2 + {}^{36}C_2}{{}^{64}C_2} = \frac{1}{2}$$

Can you have a fair game with three colours?

Same rules: If I draw two blocks and they are the same colour, I win.

	A	B	C
1		Number of Blocks	Pairs
2	BLUE	4	6
3	RED	5	10
4	GREEN	10	45
5			
6			
7			
8			
9	Numerator	61	
10	Denominator	171	
11			
12	Probability	0.3567	

=IF(B2>1,COMBIN(B2,2),0)

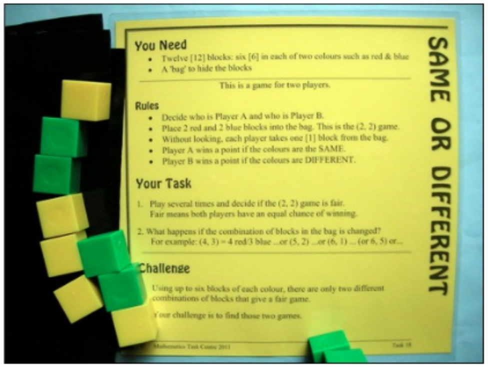
=SUM(C2:C4)

=COMBIN(SUM(B2:B4),2)

=B9/B10

http://mathematicscentre.com/taskcentre/018same.htm

Mathematics Centre



From The Classroom

Damian has also used *Same Or Different* with has Year 12 class. He was pretty impressed that they suggested using a tool developed for a totally different investigation a year earlier in Year 11. That story is below. This story is about mathematicians asking the question *What happens if...?* then taking an adventure together when even the teacher doesn't know the end point.