

Engaging Activities & Ideas for Teaching Discrete Math

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Bellarmino College Preparatory (San Jose, CA)

Looking for ways to engage students in authentic mathematics regardless of their algebraic competence? Come see how graph theory and number theory can provide realistic, understandable opportunities for students to engage in rich mathematics regardless of their algebra ability.



Contact & Resource Information

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<http://tinyurl.com/amathurin-Asilomar2012>

① WARM-UP ACTIVITY

BIG IDEAS: Identifying Patterns, Making Connections, Algorithms



Step #1: Using the last two digits of your phone number, create a two digit number.

Step #2: If the number is even, then divide it by 2 and record the result.
If the number is odd, then multiply it by 3 and add 1 and record the result.

Step #3: With the new number you just wrote down, repeat step #2.

Example:

$$58 \rightarrow 58 \div 2 = 29$$
$$29 \rightarrow (3 \times 29) + 1 = 88$$
$$88 \rightarrow 88 \div 2 = 44$$
$$44 \rightarrow 44 \div 2 = 22$$
$$22 \rightarrow 22 \div 2 = 11$$
$$11 \rightarrow (3 \times 11) + 1 = 34$$
$$\vdots \quad \quad \quad \vdots$$

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$$22 \rightarrow 22 \div 2 = 11$$
$$11 \rightarrow (3 \times 11) + 1 = 34$$
$$\vdots \quad \quad \quad \vdots$$

What do you think will happen if you continue the process?

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Extension Ideas/Further Exploration

- Would starting with a negative number affect the result?
- Given a start value, can you predict how long it will take to enter the cycle?
- Are there other algorithms that generate different cycles?



Preliminaries

- * Goals
- * Format
- * Background/Context



Preliminaries

* Goals

- ✓ *Spark Interest in Exploring More*
- ✓ *Highlight “Big-Ticket” Mathematical Ideas*
- ✓ *Provide Ideas for Links & Extensions*

* Format

* Background/Context

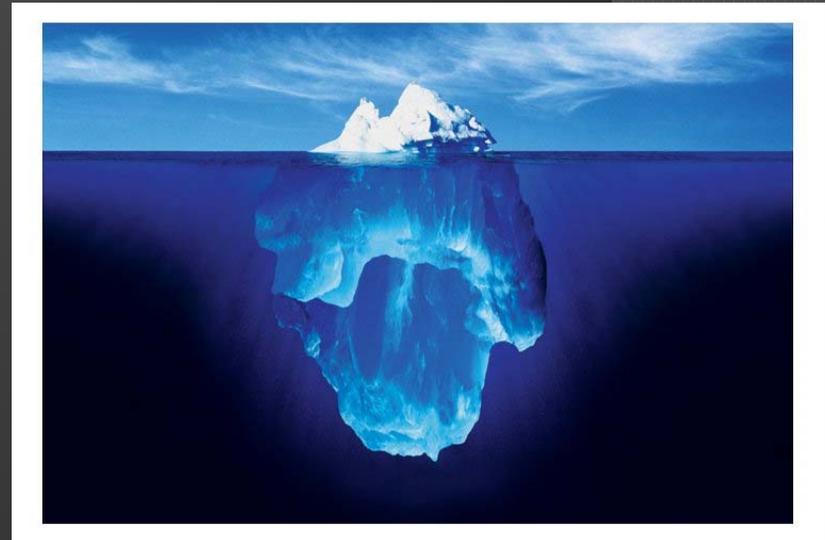
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Preliminaries

- * Goals

- * Format

 - ✓ *Graph Theory, Number Theory*

 - ✓ *Quick Introductory Activity*

 - ✓ *More In-Depth Investigation Activity*

 - ✓ *Discuss Variations for Implementation*

- * Background/Context



Preliminaries

- * Goals
- * Format
- * Background/Context
 - ✓ *Evolution & Relevance*
 - ✓ *Unknown & Undervalued*
 - ✓ *Meaningful & Timely*



NATIONAL COUNCIL OF
TEACHERS OF MATHEMATICS



Calculus

A Joint Position Statement of the Mathematical Association of America
and the National Council of Teachers of Mathematics

Question: How should secondary schools and colleges envision calculus as the course that sits astride the transition from secondary to postsecondary mathematics for most students heading into mathematically intensive careers?

MAA/NCTM Position

Although calculus can play an important role in secondary school, **the ultimate goal of the K–12 mathematics curriculum should not be to get students into and through a course in calculus by twelfth grade but to have established the mathematical foundation that will enable students to pursue whatever course of study interests them when they get to college.** The college curriculum should offer students an experience that is new and engaging, broadening their understanding of the world of mathematics while strengthening their mastery of tools that they will need if they choose to pursue a mathematically intensive discipline.

1 QUICK START >> ANIMAL SURVIVAL

BIG IDEAS: Visual Representations, Equivalence, Appearance vs. Structure

source of this activity: <http://www.colorado.edu/education/DMP>

The zoo keeper of a major zoo wants to redo the zoo in such a way that the animals live together in their natural habitat. Unfortunately, it is not possible to put all the animals together in one location because some are predators of others. The X marks in the chart at right show a predator-prey relationship, so those pair of animals cannot be safely placed in the same location.

Create a graph that represents the relationships indicated in the chart.

	A	B	C	D	E	F	G	H
A		X			X			
B	X			X			X	
C								X
D		X				X		
E	X							
F				X				
G		X						
H			X					

1 QUICK START >> ANIMAL SURVIVAL

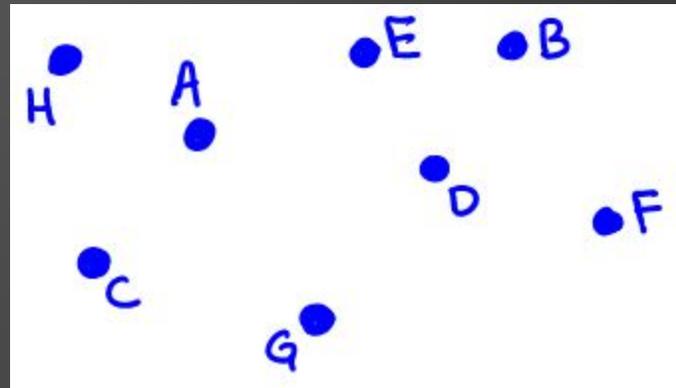
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A		X			X			
B	X			X			X	
C								X
D		X				X		
E	X							
F				X				
G		X						
H			X					



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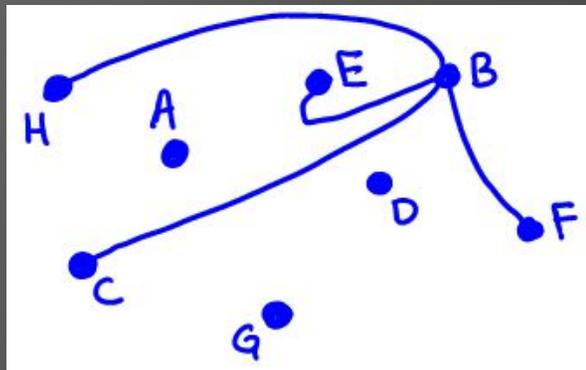
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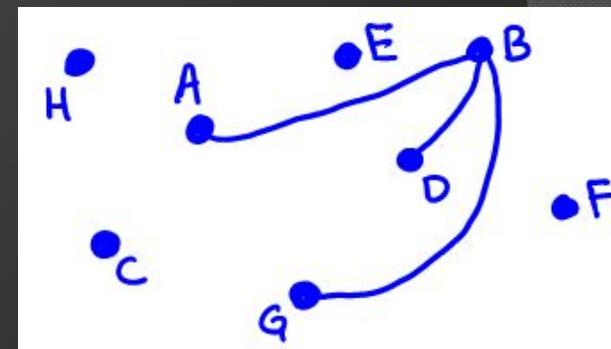
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	A	B	C	D	E	F	G	H
A		X			X			
B	X			X			X	
C								X
D		X				X		
E	X							
F				X				
G		X						
H			X					



What's the Difference?



1 QUICK START >> ANIMAL SURVIVAL

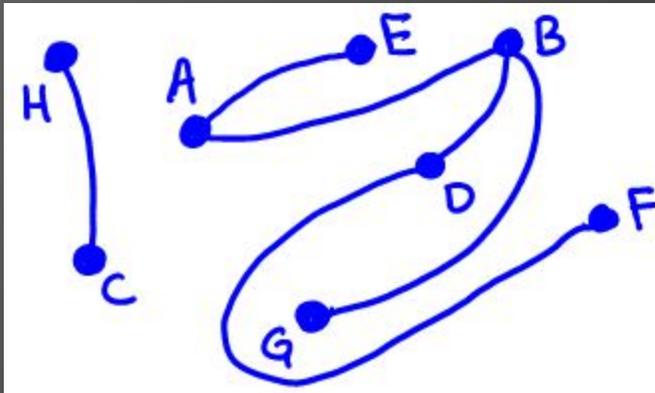
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Create a graph that represents the relationships indicated in the chart.

	A	B	C	D	E	F	G	H
A		X			X			
B	X			X			X	
C								X
D		X				X		
E	X							
F				X				
G		X						
H			X					



Is Your Graph the Same as My Graph?

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	A	B	C	D	E	F	G	H
A		X			X			
B	X			X			X	
C								X
D		X				X		
E	X							
F				X				
G		X						
H			X					

Some Connections/Ideas for Extensions

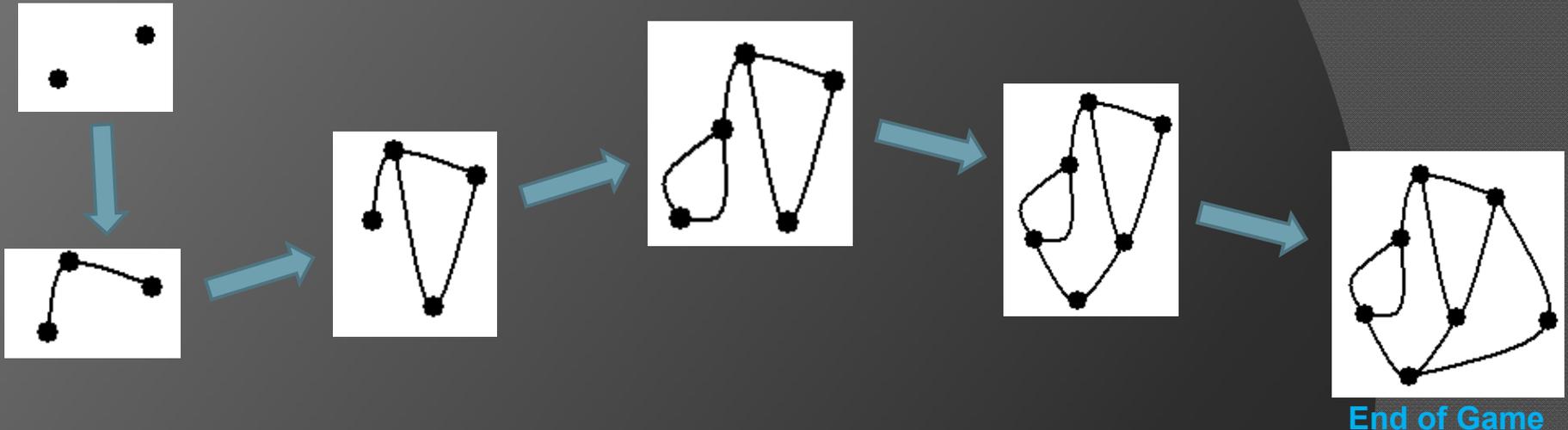
- What is the minimum number of locations required to safely house all of the animals? (4-Color Problem)
- If the graph represented a computer network, what are the most crucial edges? (Connectivity)
- If you needed to deliver items to 6 different classrooms, what would be the most efficient route? (Flow)

2 ACTIVITY: SPROUTS

BIG IDEAS: Quantifiable Differences, Data Collection & Analysis, Pattern Recognition

The Game of Sprouts was invented in 1967 by Princeton mathematician John H. Conway and by Michael S. Paterson, when both were at the University of Cambridge in the UK.

Start of Game



Graph Theory & Number Theory

Engaging Activities & Ideas for Teaching Discrete Math

2 ACTIVITY: SPROUTS

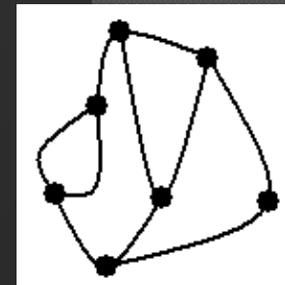
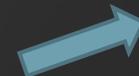
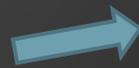
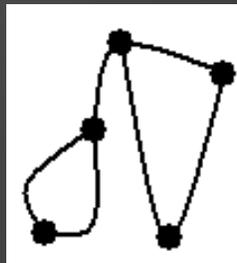
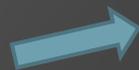
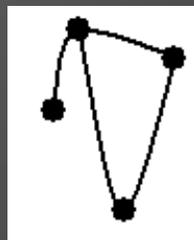
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Rules for Playing Sprouts

1. The winner is the player who makes the last move.
2. No vertex have more than 3 edges.
3. A move starts by drawing an edge such that:
 - the edge starts and ends at a vertex
 - the edge does not cross an existing edge
4. The move ends by placing a new vertex along the newly drawn edge.

Start of Game



End of Game

Graph Theory & Number Theory

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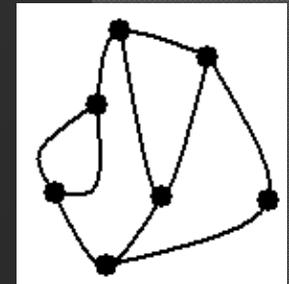
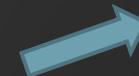
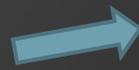
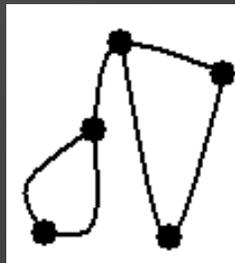
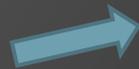
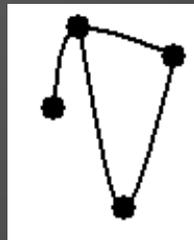
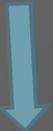
Determine the maximum number of moves possible in a Sprouts game that begins with 42 vertices.
(without actually playing a game with that many vertices)

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Start of Game



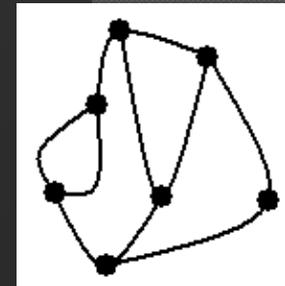
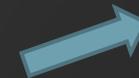
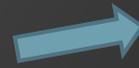
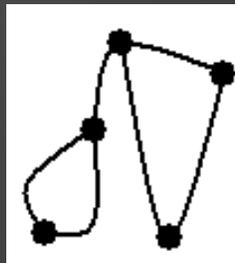
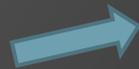
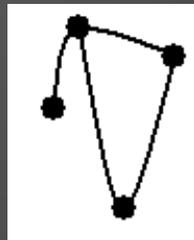
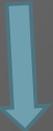
End of Game

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Start of Game



End of Game

Graph Theory & Number Theory

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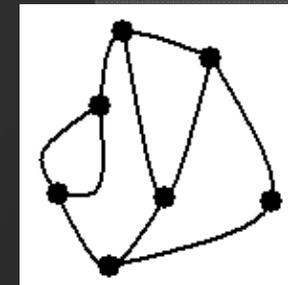
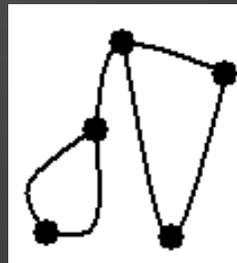
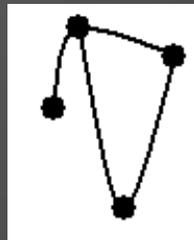
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Start of Game



Move Number	Number of Vertices	The Degree of Each Vertex (separate each using a comma)	Sum of all Degrees	Number of Edges
0	2	0, 0	0	0
1	3	1, 1, 2	4	2
2	4	1, 2, 2, 2	8	4



End of Game

Graph Theory & Number Theory

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1	3	1, 1, 2	4	2
2	4	1, 2, 2, 3	8	4
3	5	2, 2, 2, 3, 3	12	6
4	6	2, 2, 3, 3, 3, 3	16	8
5	7	2, 3, 3, 3, 3, 3, 3	20	10

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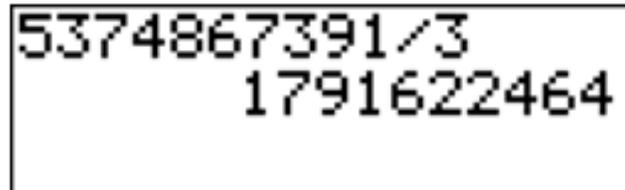
Some Connections/Ideas for Extensions

- What would happen to the game if you changed some of the rules?
- How could you figure out if there is a winning strategy?
- How are Sprouts games connected to 3-dimensional nets and Euler?

3 QUICK START >> DECEPTIVE CALCULATOR

BIG IDEAS: Divisibility Rules, Number System, Limits of Technology

Below is a screen capture from a division calculation done using a TI-84 calculator.



A screenshot of a TI-84 calculator display showing a division calculation. The top line displays the dividend 5374867391 followed by a division symbol and the divisor 3. The bottom line displays the quotient 1791622464. The decimal part of the quotient is truncated, which is a common feature of basic calculators.

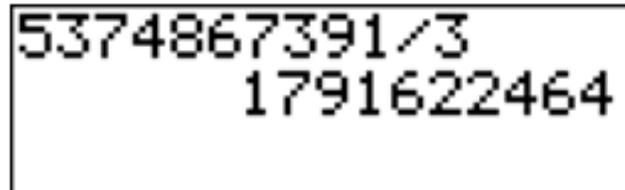
$$\begin{array}{r} 5374867391 \div 3 \\ 1791622464 \end{array}$$

Discuss at least two ways that you can show that the calculator is providing false information.

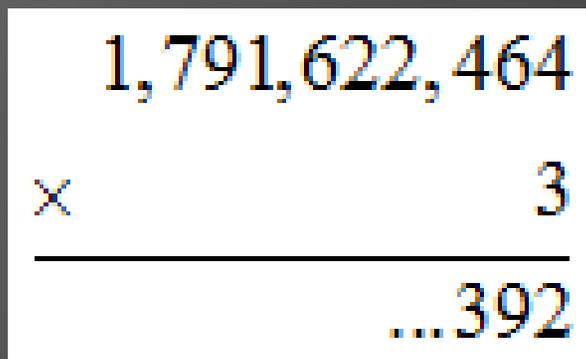
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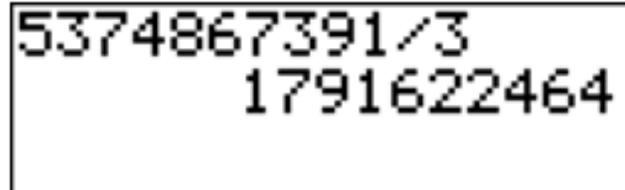

$$\begin{array}{r} 1,791,622,464 \\ \times \qquad \qquad \qquad 3 \\ \hline \qquad \qquad \qquad \dots 392 \end{array}$$

Forwards Argument

3 QUICK START >> DECEPTIVE CALCULATOR

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5374867391 / 3
1791622464

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Subtle Argument

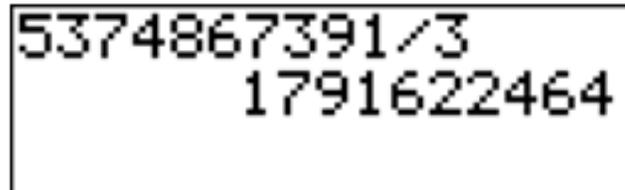
$$5 + 3 + 7 + 4 + 8 + 6 + 7 + 3 + 9 + 1 = 43$$

43 is not divisible by 3

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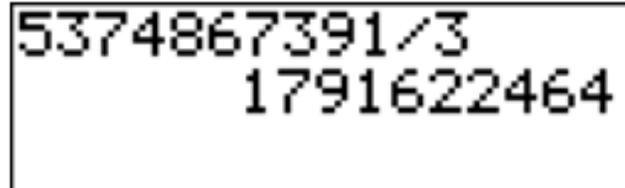
$$\begin{aligned}472 &= 400 + 70 + 2 \\ &= 4(100) + 7(10) + 2(1) \\ &= 4(99 + 1) + 7(9 + 1) + 2(1) \\ &= 4(99) + 4(1) + 7(9) + 4(1) + 2(1) \\ &= 4(99) + 7(9) + 4(1) + 7(1) + 2(1)\end{aligned}$$

$$\begin{aligned}5 + 3 + 7 + 4 + 8 + 6 + 7 + 3 + 9 + 1 &= 43 \\ 43 &\text{ is not divisible by } 3\end{aligned}$$

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5374867391/3
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Some Connections/Ideas for Extensions

- What is “casting out nines” and why was it important before computing devices?
- Is there a divisibility rule for multiples of 7?
- What are some algorithms for determining if a number is prime or composite?

4 ACTIVITY: UNLUCKY 13

BIG IDEAS: Organizing Patterns, Modular Arithmetic, Taming the Infinite, Proof



What is the maximum number of times Friday the 13th that can occur within a single January to December calendar year? Show/Explain your method.

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Mon	Tue	Wed	Thu	Fri	Sat	Sun
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
1	2	3	4	5	6	7
8	9	10	11	12	13	14

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11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
1	2	3	4	5	6	7
8	9	10	11	12	13	14

Mon	Tue	Wed	Thu	Fri	Sat	Sun
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31
32	33	34	35	36	37	38
39	40	41	42	43	44	45
46	47	48	49	50	51	52
53	54	55	56	57	58	59
60	61	62	63	64	65	66
67	68	69	70	71	72	73

4 ACTIVITY: UNLUCKY 13

BIG IDEAS: Organizing Patterns, Modular Arithmetic, Taming the Infinite, Proof

What is the maximum number of times Friday the 13th that can occur within a single January to December calendar year? Show/Explain your method.

Mon	Tue	Wed	Thu	Fri	Sat	Sun
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
⋮	⋮	⋮	⋮	⋮	⋮	⋮
			42	43	44	
⋮	⋮	⋮	⋮	⋮	⋮	⋮
			70	71	72	
⋮	⋮	⋮	⋮	⋮	⋮	⋮
			98	99	100	101
102	103					
⋮	⋮	⋮	⋮	⋮	⋮	⋮

The 13 th of	Corresponding Day of Year
JAN	13
FEB	$31 + 13 = 44$
MAR	$28 + 44 = 72$
APR	$31 + 72 = 103$
MAY	⋮
JUN	⋮
JUL	⋮
AUG	⋮
SEP	
OCT	
NOV	

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What is the maximum number of times Friday the 13th that can occur within a single January to December calendar year? Show/Explain your method.

The 13 th of	Corresponding Day of Year	Partitions Based on 7	Modular Form	Same Day of the week as
JAN	13	$13 = 1(7) + 6$	$13 \equiv 6 \pmod{7}$	6 th
FEB	$31 + 13 = 44$	$44 = 6(7) + 2$	$44 \equiv 2 \pmod{7}$	2 nd
MAR	$28 + 44 = 72$	$72 = 10(7) + 2$	$72 \equiv 2 \pmod{7}$	2 nd
APR	$31 + 72 = 103$	$103 = 14(7) + 5$	$103 \equiv 5 \pmod{7}$	5 th
MAY	⋮	⋮	⋮	⋮

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MAY	⋮	⋮	⋮	⋮

How can this chart help answer the original question?

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MAY	⋮	⋮	⋮	⋮

Is there a better way to answer the original question?

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MAY	⋮	⋮	⋮	⋮

Doh! What about Leap Years??

4 ACTIVITY: UNLUCKY 13

BIG IDEAS: Organizing Patterns, Modular Arithmetic, Taming the Infinite, Proof



What is the maximum number of times Friday the 13th that can occur within a single January to December calendar year? Show/Explain your method.

Some Connections/Ideas for Extensions

- How can you tell if a book ISBN number is valid or not?
- What is Goldbach's Conjecture and how is it related to partitions?
- How do you deal with negative numbers in a modular system?

5 EFFICIENT TRAVEL

BIG IDEAS: Counting, Developing & Evaluating Strategies/Algorithms

*You are planning your holiday visit with family in who live in 5 different cities.
Below is a matrix of the names and distances between these 5 cities.*

		1	2	3	4	5
1 Tampa FL			10	27	6	15
2 Seffner FL		10		30	15	6
3 Clearwater FL		27	30		22	30
4 Lutz FL		6	15	22		19
5 Brandon FL		15	6	30	19	

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4 Lutz FL	6	15	22		19
5 Brandon FL	15	6	30	19	

If you wanted to achieve the absolute minimum traveling distance for visiting each city, where should your plan to stay?

6 CHALLENGE ACTIVITY

BIG IDEAS: Identifying Patterns, Making Connections, Algorithms

The letters in the phrase "What is Discrete Math" have been scrambled and placed in groups of three.

Scramble #1:	HTA	TEM	ERC	DIS	SIT	WHA
Scramble #2:	WET	HRE	ACM	TSA	IIT	SDH
Scramble #3:	STE	DMA	ITT	HAW	REI	SCH
Scramble #4:	AHW	TME	IAT	STE	DHR	ISC

One of the scrambles was generated by randomly selecting the message letters from a hat while the other three scrambles were generated using an algorithm based on a basic geometrical concept.

Identify which is the random selection scramble and explain how/why you arrived at your decision.

Does this help?

#1	#2	#3	#4
HTA	WET	STE	AHW
TEM	HRE	DMA	TME
ERC	ACM	ITT	IAT
DIS	TSA	HAW	STE
SIT	IIT	REI	DHR
WHA	SDH	SCH	ISC

6 CHALLENGE ACTIVITY

BIG IDEAS: Identifying Patterns, Making Connections, Algorithms

The letters in the phrase "What is Discrete Math" have been scrambled and placed in groups of three.

Scramble #1:	H T A	T E M	E R C	D I S	S I T	W H A
Scramble #2:	W E T	H R E	A C M	T S A	I I T	S D H
Scramble #3:	S T E	D M A	I T T	H A W	R E I	S C H
Scramble #4:	A H W	T M E	I A T	S T E	D H R	I S C

One of the scrambles was generated by randomly selecting the message letters from a hat while the other three scrambles were generated using an algorithm based on a basic geometrical concept.

Some Connections/Ideas for Extensions

- How would using other shapes affect the scrambling algorithm? (Geometry)
- How many total possible ways are there for scrambling the letters in the phrase? (Combinatorics)
- What are some modifications could you make to the scrambling algorithm? (Cryptography)