THE PENTAGON

A Mathematics Magazine for Students

Volume 66 Number 1 Fall 2006

Contents

Typeset in Scientific WorkPlace Printed in the United States of America.

The Pentagon (ISSN 0031-4870) is published semiannually in December and May by Kappa Mu Epsilon. No responsibility is assumed for opinions expressed by individual authors. Papers written by undergraduate mathematics students for undergraduate mathematics students are solicited. Papers written by graduate students or faculty will be considered on a space-available basis. Submissions should be provided in both electronic and typewritten form. The electronic copy can be sent as an e-mail attachment (preferred) or on disk. Either a TeX file or Word document is acceptable. The typewritten copy should be double-spaced with wide margins on white paper. Standard notational conventions should be respected. Any special symbols not typed should be carefully inserted by hand in black ink. Graphs, tables, or other materials taken form copyrighted works MUST be accompanied by an appropriate release form the copyright holder permitting their further reproduction. Student authors should include the names and addresses of their faculty advisors. Contributors to The Problem Corner or Kappa Mu Epsilon News are invited to correspond directly with the appropriate Associate Editor.

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The Topeka Public School Busing Problem: It's Simplex

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Presented at the 2005 National Convention and awarded "top four" status by the Awards Committee.

1. Introduction

Recently, the Topeka Public Schools have been criticized for changing the mile limit associated with busing children. According to the district the change was necessary due to a decrease in district transportation funds. This change was published only months after a celebration commemorating the 50th anniversary of the historic Brown versus the Board of Education case. These events caused me to consider whether or not there was a cost-effective plan for busing students to the middle schools that would also support the contemporary goal of Brown for schools reflecting the diversity of the Topeka community.

Simply stated, my objective was to minimize the cost associated with busing middle school students while satisfying a number of constraints. The form of this problem led me to formulating the problem as a linear programming problem and to use the Simplex method to investigate potential solutions. The Simplex method of linear programming was first developed by George Dantzig in 1947. The idea for this method of optimization came from his work with the United States Air Force, where he used a basic desk calculator to solve training schedules, logistical supplies, and the deployment of troops. The long and tedious hours spent on solving these optimization problems inspired Dantzig to invent a more efficient method. One of the first large-scale applications of the Simplex method used a system of nine equations with seventy-seven unknowns. Using desk calculators, this problem would have taken 120 days to solve. However, using a computer to run the Simplex algorithm, this problem could be solved in less than a day. Since the introduction of the Simplex method in 1947, the applications have been endless. The Simplex method has been used to solve optimization problems, including scheduling, production, marketing strategies, investment portfolios, and more.

2. The Simplex Method

I will work through an example to show the computational elegance of solving linear programming models using the Simplex method. This will provide the necessary foundation for the Topeka busing problem. One of the most commonly used examples is the Wyndor Glass Co. problem (Hillier & Lieberman, 1995). The problem is as follows:

> The Wyndor Glass Co. has three plants which produce two different products, doors and windows. Plant One produces one batch of doors per production hour and has four available production hours per week. Plant Two produces one batch of windows per two production hours and has twelve available production hours per week. Plant Three produces one batch of doors per three production hours and one batch of windows per two production hours and has eighteen available production hours per week. Each batch of doors has a profit of $3000. Each batch of windows has a profit of $5000. Determine how many batches of doors and windows should be produced each week to maximize profits.

The first step is to determine the value to be optimized. In this case, the profit, Z, is going to be maximized. Here

$$Z = 3000x_1 + 5000x_2,$$

where x_1 represents the number of batches of doors, and x_2 represents the number of batches of windows. The function being maximized is called the objective function.

The next step is to determine the constraints which are derived from the limits on resources. In this case each plant produces the doors and windows at different rates. Additionally, each plant only has so many available production hours. The first constraint listed below is for plant one. This equation indicates that plant one can produce one door (x_1) in one hour and has four hours of available production time. The second constraint is for plant two. This equation indicates that plant two can produce one window (x_2) in two hours and has twelve hours of available production time. The third constraint is for plant three. This equation indicates that plant three can produce one door in three hours and one window in two hours. It also indicates that plant three has eighteen hours of available production time. The last two constraints are the non-negativity constraints. These constraints ensure that our model will not produce a solution in which a plant produces a negative number of doors or windows. The constraints are as follows:

$$\begin{aligned} x_1 &\leq 4 \\ 2x_2 &\leq 12 \\ 3x_1 + 2x_2 &\leq 18 \end{aligned}$$

and

$$x_1 \geq 0, \ x_2 \geq 0.$$

Next, a slack variable is added to each of the first three inequalities. Slack variables are added to the left hand side of each constraint to construct equalities. After adding the slack variables, the new augmented form of the model is as follows:

Maximize

$$Z = 3000x_1 + 5000x_2,$$

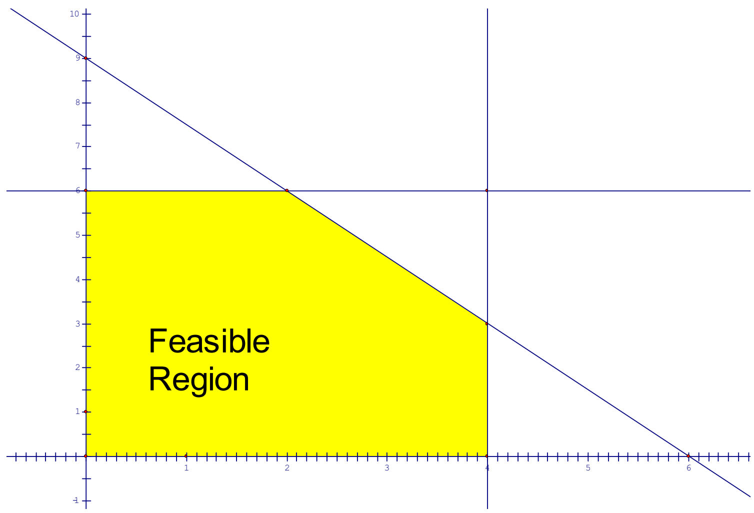
subject to

$$\begin{aligned} x_1 + x_3 &= 4 \\ 2x_2 + x_4 &= 12 \\ 3x_1 + 2x_2 + x_5 &= 18 \end{aligned}$$

and

$$x_j \geq 0, \ \text{for } j = 1, 2, 3, 4, 5.$$

The Simplex method is a computational method for optimizing the objective function. To begin the Simplex algorithm, I need to find a feasible starting place. It is pretty standard to begin with the solution (0,0). This is because it is the most obvious basic feasible solution. A basic feasible solution is an augmented corner point feasible solution, meaning that in a graphical definition the point would lie in the corner of the feasible region. In the Wyndor Glass Co. example, the graph of the feasible region is as follows:



From the graph above, the corner point feasible solutions are (0,0), (4,0), (4,3), (2,6), and (0,6). I will begin the iterations using (0,0). Including the the slack variables, the initial basic feasible solution is (0,0,4,12,18). Solving the constraint equation with x_1 and x_2 equal to zero, I am able to determine the values for the slack variables. The initial set of equations in tabular form is as follows:

Basic Variable	Equation	Coefficient of:						Right side
		Z	x_1	x_2	x_3	x_4	x_5	
Z	0	1	-3	-5	0	0	0	0
x_3	1	0	1	0	1	0	0	4
x_4	2	0	0	2	0	1	0	12
x_5	3	0	3	2	0	0	1	18

In the first column of the table is the basic variable. The basic variables are variables that equal zero in the objective function Z, which is equation 0 in the table. The second column indicates what equation each row is to represent. Equation 0 is the objective function, while equations 1 through 3 are the constraint equations. The next 6 columns indicate the coefficients for the variables. Z is for the cost equation, which will always be 1 in equation 0 and 0 in equations 1, 2, and 3 because Z is not in those equations. The last column is for the right side of the equation. The right side shows the values assigned to the basic variables: x_3, x_4, x_5. The non-basic variables, x_1 and x_2, are equal to zero.

The next step is to carry out iterations that will improve the solution. Currently, (0,0) is not a good solution. It is feasible, but it does not result in any profit. To determine what variable to change first, I look for the most negative variable in row 0. The most negative coefficient is -5. I want to change this variable (x_2) first because it has the greatest growth in profit, \$5 per window is greater than \$3 per door. The column $\begin{bmatrix} 0 \\ 2 \\ 2 \end{bmatrix}$ below this row is called the pivot column. Using only the positive coefficient in this column, divide its right-side value by its coefficient to find its ratio. Row 2 has a ratio of 12/2 or 6. Row 3 has a ratio of 18/2 or 9. Row 2 has the smallest ratio, so the basic variable for that row (x_4) is the leaving basic variable, which will be replaced with x_2, the most negative coefficient I found earlier.

Next, I need to use elementary row operations to solve for the new basic feasible solution. First I want to replicate the first table's pattern of coefficients in the x_4 column, , to the x_2 column. To do this, I divide row 2 by the pivot column number, 2. Then I add 5 times the new row 2 to row 0. Finally I subtract 2 times the row 2 from row 3. These elementary row operations yield the new table:

Basic Variable	Equation	Coefficient of:						Right side
		Z	x_1	x_2	x_3	x_4	x_5	
Z	0	1	-3	0	0	$5/2$	0	30
x_3	1	0	1	0	1	0	0	4
x_2	2	0	0	1	0	$1/2$	0	6
x_5	3	0	3	0	0	-1	1	6

Since this new solution still has a negative coefficient in row 0, the solution is still not optimal, and I need to repeat the process of determining which basic variable is leaving and then using elementary row operations to solve for the new basic feasible solution. I know that x_1 will be the entering basic variable because it is the only negative coefficient in row 0. This makes the pivot column $\begin{bmatrix} 1 \\ 0 \\ 3 \end{bmatrix}$. Next, I need to find the ratio for the non zero rows, which are rows 1 and 3. The ratio for row 1 is 4/1 or 4. The ratio for row 3 is 6/3 or 2. Since row 3 has the lowest ratio, x_5 will be the leaving basic variable. Then I need to replicate column x_5,

$\begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$, in column x_1 since x_1 is the basic entering variable. To do this I use elementary row operations again. First, I divide row 3 by the pivot number (3). Then I add three times the new row 3 to row 0. Finally, I subtract the new row 3 from row 1. This yields the new table:

Basic Variable	Equation	Coefficient of: Z	x_1	x_2	x_3	x_4	x_5	Right side
Z	0	1	0	0	0	$3/2$	1	36
x_3	1	0	0	0	1	$-1/3$	$-1/3$	2
x_2	2	0	0	1	0	$1/2$	0	6
x_1	3	0	1	0	0	$-1/3$	$1/3$	2

Since there are no more negative coefficients in row 0, this is the optimal solution. From examining the column, I can see that new basic feasible solution is (2,6,2,0,0) and that $Z = 36$. This means that the optimal solution for the Wyndor Glass Co. problem is for the company to produce 2 batches of doors and 6 batches of windows per week, resulting in a profit of $36,000 per week.

3. The Topeka Busing Problem

In 1952, the Brown versus the Board of Education of Topeka case was presented to the Supreme Court. This was a class action suit with nearly 200 plaintiffs from various parts of the country. The case argued that the "separate but equal" doctrine violated the Fourteenth Amendment and was therefore unconstitutional. Prior to the Brown case, minority children were not allowed to attend the same schools as white children. Even if they lived in the same neighborhood they could not attend the same school. However, this practice came to an end in 1954 when the Supreme Court ruled in favor of the plaintiffs of the Brown case. The court found that the "separate but equal" doctrine was inherently unfair in the public education system and ruled it unconstitutional because it left minority children with a feeling of inferiority for not being able to attend the same schools as the white children.

Since 1954, the Brown versus the Board of Education of Topeka case has been reopened. In 1979, three men petitioned the court to reexamine the Brown case and to determine if all practices of segregation had been ended. What the courts found was still unsatisfactory and as a result, the Topeka Public Schools District (USD 501) built three magnet schools in an attempt to further desegregate the public school system.

Currently, the Topeka Public Schools District contains twenty-one elementary schools: Avondale East, Avondale West, Bishop, Highland Park Central, Linn, Lowman Hill, Lundgren, McCarter, McClure, McEachron, Meadows, Quincy, Quinton Heights, Randolph, Ross, Scott Magnet, Shaner, State Street, Stout, Whitson, and Williams Magnet. These twenty-one elementary schools feed into six middle schools: Chase, Eisenhower, French, Jardine, Landon, and Robinson. The goal of this project is to use linear programming to develop a model for assigning students to each of the six middle schools. Since school funding is an issue, the goal will be to minimize cost while satisfying the diversity constraints. Much of the data for the model is public information obtained from the Topeka Public Schools website (http://www.topeka.k12.ks.us). However, additional data was obtained through the cooperation of the Topeka Public Schools administration.

The first stage of developing the model was to obtain data on student demographics from the Topeka Public Schools' website and elementary school attendance zones from the administration. Next, the data was augmented so that it would be more useful in the model. The desired diversity outcome was considered to establish the constraints. I was then able to formulate the linear programming model. The final step was to use the Simplex method to find a solution.

Data Collection

The map found in the appendix shows the attendance areas for each elementary school in the District. The blue star in each elementary school area indicates the approximate midpoint of the area. The red stars on the map indicate the location of each middle school. Using the midpoints indicated on the map, the distance from each of the twenty-one areas to each of the six middle schools was determined using Mapquest (http://www.mapquest.com). The distances in miles are as follows:

Area	Elementary School	Chase Distance	Eisenhower Distance	French Distance	Jardine Distance	Landon Distance	Robinson Distance
1	Avondale East	5	1.71	5.74	2.89	8.96	3.62
2	Avondale West	5.62	3	3.74	0.8	8.35	2.3
3	Bishop	12.88	4.4	2.13	0.54	6.73	3.7
4	Highland Park Central	3.49	1.12	7.38	3.67	8.36	3.13
5	Linn	6.05	1.63	4.8	2.36	9.42	3.84
6	Lowman Hill	4.05	5.26	9.25	4	4.05	1.34
7	Lundgren	1.14	5.42	12.7	12.28	7.51	5.14
8	McCarter	7	9.43	3.06	6.44	0.29	3.45
9	McClure	10.8	6.68	1.14	2.77	2.48	4.18
10	McEachron	11.68	6.55	1.01	1.9	5.53	4.2
11	Meadows	3.18	7.62	8.83	4.61	3.64	1.96
12	Quincy	2.26	5.96	10.97	5.8	5.78	2.87
13	Quinton Heights	3.78	2.96	6.34	2.64	7.74	1.29
14	Randolph	4.62	5.49	4.51	3.41	2.98	0.93
15	Ross	4.26	0.15	6.6	3.64	9.12	4.94
16	Scott Magnet	1.61	2.8	12.88	5.35	7.69	2.63
17	Shaner	12.08	3.29	3.06	0.7	7.67	3.32
18	State Street	0.12	4.4	12	6.53	6.81	3.98
19	Sout	4.74	3.92	4	2.32	4.09	1.21
20	Whitson	7.32	6.2	3.21	2.75	2.29	2
21	Williams Magnet	2.61	1.8	11.67	4.35	7.47	3.29

Data Augmentation

To determine the busing cost per student, several factors were considered. First, a school bus holds 40 students. The daily rental cost of a bus is $160, which is a per student cost of $4 a day. The average cost of diesel is $1.80 per gallon, and a school bus consumes diesel at a rate of 4 miles per gallon. With this information, I computed a rate of $.01125 per student per mile. A school year has 180 school days. The equation used for determining busing cost per area is as follows:

$$\text{Busing Cost per student} = [(\text{miles from school}) \times \$.01125 + 4] \times 180.$$

Using the above equation, the busing cost per student for each area to each middle school is as follows:

Area	Chase	Eisenhower	French	Jardine	Landon	Robinson
1	$730.13	$723.46	$731.62	$725.85	$738.14	$727.33
2	$731.38	$726.08	$727.57	$721.62	$736.91	$724.66
3	$746.08	$728.91	$724.31	$721.09	$733.63	$727.49
4	$727.07	$722.27	$734.94	$727.43	$736.93	$726.34
5	$732.25	$723.30	$729.72	$724.78	$739.08	$727.78
6	$728.20	$730.65	$738.73	$728.10	$728.20	$722.71
7	$722.31	$730.98	$745.72	$744.87	$735.21	$730.41
8	$734.18	$739.10	$726.20	$733.04	$720.59	$726.99
9	$741.87	$733.53	$722.31	$725.61	$725.02	$728.46
10	$743.65	$733.26	$722.05	$723.85	$731.20	$728.51
11	$726.44	$735.43	$737.88	$729.34	$727.37	$723.97
12	$724.58	$732.07	$742.21	$731.75	$731.70	$725.81
13	$727.65	$725.99	$732.84	$725.35	$735.67	$722.61
14	$729.36	$731.12	$729.13	$726.91	$726.03	$721.88
15	$728.63	$720.30	$733.37	$727.37	$738.47	$730.00
16	$723.26	$725.67	$746.08	$730.83	$735.57	$725.33
17	$744.46	$726.66	$726.20	$721.42	$735.53	$726.72
18	$720.24	$728.91	$744.30	$733.22	$733.79	$728.06
19	$729.60	$727.94	$728.10	$724.70	$728.28	$722.45
20	$734.82	$732.56	$726.50	$725.57	$724.64	$724.05
21	$725.29	$723.65	$743.63	$728.81	$735.13	$726.66

It does need to be noted that this is an estimated cost, based on current information, for several reasons. First of all, the Topeka Public Schools District does not own its own buses. Instead, it has a negotiated contract with Durham School Service, a busing service. I contacted Durham and Topeka Transit Authority to obtain the above factors of capacity, miles traveled, gas prices, and miles per gallon, all of which contributed to the contracted cost. Additionally, this equation does not factor in the cost to drive around the neighborhood. The equation also only factors in one trip a day even though the child must be picked up and returned home each day (two trips). Finally, this equation assigns a cost to every student, regardless of how close each is to the school. However, the Topeka Public Schools District only provides busing for students who live more than 2.5 miles away from the school. This would considerably reduce the busing cost of this model, but I wanted to use a model that provided busing for all students so I assigned a cost regardless of how close the students live to the school.

While this cost is estimated, it is important to note that the cost is based on the distance the student lives from the school. Essentially, by assigning students to the school closest to them, the cost will be minimized. However, an estimated cost provides a more valuable measure of improvement in the model than just minimizing distance.

The number of students in each of the twenty-one areas was determined by using the total number of students in grades third, fourth, and fifth at each area elementary school. The student numbers and minority percentages being used are from the 2003-2004 school year. I will then use these numbers to predict the student assignment pattern most accurately for the 2007-2008 school year. The number of students in each area and the minority percentage for that area are as follows:

Area	# of Students	% Minority
1	76	68.8
2	90	54.2
3	133	45.8
4	186	64.9
5	75	69.3
6	140	51.6
7	98	48
8	178	45.3
9	175	44.3
10	133	38.1
11	268	48.6
12	111	43.4
13	73	62.7
14	187	33.7
15	152	72.9
16	266	78.4
17	97	53.9
18	138	52.6
19	94	44
20	228	42
21	280	65.6

When I assign students to each middle school, an important constraint will be the capacity of each middle school. The capacity of each middle school was determined by looking at past enrollment years and rounding up for an increased number of students. The capacities of each middle school are as follows:

Jardine	520 students
Eisenhower	470 students
French	610 students
Jardine	560 students
Landon	460 students
Robinson	520 students

Using the Simplex Method

When there are only a few variables and constraints, such as in the Wyndor Glass example, it is easy to implement the Simplex method by hand. However, in cases with the magnitude of the Topeka busing problem, implementing the Simplex method by hand is just not practical. There are many computational tools available for performing the Simplex algorithm. Largely due to availability, I selected to use the Excel Solver for this problem.

The Linear Program Model

As with the Wyndor Glass example, the linear programming model must be developed. In the Topeka busing problem, the cost of busing needs to be minimized. The objective function is as follows:

$$Z = \sum_{i=1}^{21} \sum_{j=1}^{6} BC_{ij} X_{ij},$$

where BC_{ij} is the busing cost per student for area i attending middle school j, and X_{ij} is the number of students from area i assigned to middle school j.

The next step is to formulize the set of constraints the model needs to follow. One constraint that was already mentioned was school capacity. When I assign students to each middle school, it is important to pay careful attention to the middle school capacities. If a constraint is not made on school capacity, then a school may be assigned too many students and not have enough space or resources to provide an adequate education.

Equally important is that every student is assigned to one and only one school. Additionally, each student cannot be assigned to more than one school.

To address my primary concern, I need to determine a constraint that diversifies each middle school population. The total population of students to be assigned is 54 percent minority. This means that if the schools were perfectly distributed each middle school would have 54 percent minority. Initially, to provide a bit of leniency I am going to have the constraint be that each middle school must have between 50 and 58 percent minority. This range is large enough to help minimize cost but still small enough to ensure diversity in the model.

Finally, there needs to be a non-negativity constraint. This ensures there will not be a negative number of students assigned to a middle school. If negative numbers were used, the solution would not be a feasible one.

To review, the constraints discussed above are as follows:

1. A middle school's student capacity cannot be exceeded.
2. All students must be assigned to one, and only one, of the six middles schools.
3. Each middle school must have between 50 and 58 percent minority.
4. Only non-negative solutions are allowed.

Using the above objective function and constraints, the linear model is as follows:

Minimize

$$Z = \sum_{i=1}^{21} \sum_{j=1}^{6} BC_{ij} X_{ij},$$

subject to

1. $\sum_{i=1}^{21} X_{ij} \leq SC_j$ for $j = 1, 2, 3, 4, 5, 6$ (where SC_j is the capacity for middle school j)
2. $\sum_{i=1}^{6} X_{ij} \leq S_i$ for $i = 1, 2, 3, ..., 21$ (where S_i is the number of students in area i)
3. $\sum_{i=1}^{21} M_i X_{ij} \leq (0.59 - .50) \sum_{i=1}^{21} X_{ij}$ for $j = 1, 2, 3, 4, 5, 6$ (where M_i is the percent of minority students in area i)
4. $X_{ij} \geq 0$ for $i = 1, 2, 3, ..., 21$ and $j = 1, 2, 3, 4, 5, 6$.

Solution

Using the objective function and constraints listed above, I set up a worksheet on Excel and then used the Excel Solver to find the optimal solution. The Excel Solver assigned each student to a middle school using the Simplex method. The tool also provided me the opportunity to review iterations as the algorithm progressed. Additionally, an analysis of the solution is available if needed. The optimal solution found by the Excel Solver has a cost of $2,311,124.79. The solution to the student assignment is as follows:

Area	Chase	Eisenhower	French	Jardine	Landon	Robinson
1	0.0001	0.0829	0.0000	75.4543	0.0000	0.4627
2	0.0000	0.0061	69.7884	20.1988	0.0002	0.0065
3	0.0000	0.0022	112.6391	20.3554	0.0010	0.0024
4	0.0000	138.4034	0.0000	0.0000	0.0000	47.5966
5	5.0280	17.8848	20.1485	16.6551	0.0000	15.2835
6	14.4960	17.8591	17.6292	21.5207	41.5779	26.9170
7	73.8718	6.0736	0.3403	0.0000	8.4916	9.2225
8	11.0459	22.3870	38.5891	28.6702	42.7132	34.5946
9	0.0000	10.7397	45.6833	38.3428	43.0082	37.2260
10	0.0000	0.8283	38.5308	32.5966	30.9889	30.0555
11	63.0732	34.0936	38.2424	40.4857	46.2392	45.8660
12	51.7001	9.2323	7.1789	10.9424	15.1757	16.7707
13	16.9956	9.6822	10.6872	12.0984	8.1382	15.3983
14	17.1900	32.2212	33.9600	31.2104	36.0998	36.3186
15	32.1284	27.8760	24.2060	24.4329	19.8646	23.4921
16	83.5023	3802663	28.9155	36.4557	36.9123	41.9480
17	0.0000	7.5763	25.4073	24.6741	17.7214	21.6209
18	77.2822	12.5896	6.6060	10.8496	14.6028	16.0698
19	3.6888	13.6183	19.4682	17.6467	19.0155	20.5626
20	6.7880	36.4783	47.1945	43.4207	48.3581	45.7604
21	73.2097	44.0986	34.7854	41.9896	41.0913	44.8254
Total	530	480	620	548	470	530
Minority	57.1707	58	50.5766	54.5067	50.7133	53.39421

While the above solution follows the constraints, it is still not a viable solution because the student assignment numbers are not integers. Obviously, dividing a student into parts and sending each part to a different middle school is not an option. One way to fix this problem is to use integer programming. However, in this initial work, I rounded each number instead of reformatting the model. After rounding, the cost of busing is \$2,311,125.89. The rounded solution is as follows:

Area	Chase	Eisenhower	French	Jardine	Landon	Robinson
1	0	0	0	76	0	0
2	0	0	70	20	0	0
3	0	0	113	20	0	0
4	0	138	0	0	0	48
5	5	18	20	17	0	15
6	14	18	18	21	42	27
7	74	6	0	0	9	9
8	11	22	38	29	43	35
9	0	11	46	38	43	35
10	0	0	39	33	31	30
11	63	34	38	41	46	46
12	52	9	7	11	15	17
13	17	10	11	12	8	15
14	17	32	34	31	36	37
15	32	28	24	24	20	24
16	84	38	29	36	37	42
17	0	7	25	25	18	22
18	77	12	7	11	15	16
19	4	14	19	18	19	20
20	7	37	47	43	48	46
21	73	44	35	42	41	45
Total	530	478	620	548	471	531
% Minority	57.177	58.029	50.581	54.495	50.731	53.375

It is important to note that the minority constraint is violated for Eisenhower Middle School. However, this is only because of the rounding. The original solution, which was not comprised of integers, did not violate the minority constraint. Otherwise, this solution provides a feasible solution that minimizes cost while diversifying the middle schools.

Analysis

Currently, the Topeka Public Schools District does not have a student assignment pattern that provides as much diversity as the solution developed using the Simplex method. Using the elementary school feeder patterns that show what percent of each elementary school will attend each of the middle schools, I determined the student assignments for the 2007-2008 school year. These assignments are as follows:

Area	Chase	Eisenhower	French	Jardine	Landon	Robinson
1	0	5.32	0	70.68	0	0
2	0	0	0	90	0	0
3	0	0	0	133	0	0
4	0	161.82	0	24.18	0	0
5	0	70.5	0	4.5	0	0
6	0	0	0	0	100.8	39.2
7	98	0	0	0	0	0
8	0	0	53.4	0	124.6	0
9	0	0	175	0	0	0
10	0	0	133	0	0	0
11	0	0	0	0	32.16	235.84
12	111	0	0	0	0	0
13	0	0	0	27.74	0	45.26
14	0	0	0	0	31.79	155.21
15	0	152	0	0	0	0
16	231.42	34.58	0	0	0	0
17	0	0	0	97	0	0
18	138	0	0	0	0	0
19	0	0	0	33.84	0	60.16
20	0	123.12	0	104.88	0	0
21	50.4	229.6	0	0	0	0
Total	628.820	653.820	484.520	480.940	394.230	535.670
% Minority	60.796	68.226	42.124	54.414	45.367	45.177

When one compares the solution using the Simplex method and the solution that is currently being used by the district, it is not hard to see that the Simplex solution provides more diversity. Only one school in the current student assignment pattern is actually within the 50 to 58 percent range. The range in percent minority is 23.049 percent in the current assignment pattern, while in the Simplex solution the range is 7.29 percent. Also in the current solution, the school capacity constraints are violated. This leads me to believe that by 2007-2008 there might be a change in the feeder pattern. Hopefully this change will result in a more diversified distribution.

While the Simplex solution made a considerable difference in the diversity of the middle schools, it did not actually cost that much more. Currently, the district busing cost is \$2,298,219.40 when calculated using the same equation to figure busing cost as in the Simplex solution. The Simplex solution cost is \$2,311,125.89. This is only \$12,906.49 more than the current solution. Per student, this is only \$4.06 more per year than the current solution.

Improving Diversity

After analyzing the solution, I started to wonder, how could I further diversify the middle schools? Although the model satisfies the 50 to 58 percent minority constraint, I wanted to distribute the students by a set of constraints that was more specific on ethnicity. To meet this objective, I modified the set of constraints by replacing the 50 to 58 percent minority constraint with four new constraints. The total population has 22 percent African American students, 16.5 percent Hispanic students, 15.4 percent other minority students, and 46.1 percent Caucasian students. With an eight percent range on these total population percentages, the new constraints are as follows:

1. Each middle school must have between 18 and 26 percent African American students.
2. Each middle school must have between 12.5 and 20.5 percent Hispanic students.
3. Each middle school must have between 11.4 and 19.4 percent other minority students.
4. Each middle school must have between 42.1 and 50.1 percent Caucasian students.

With these adjustments, the revised model is as follows:
Minimize

$$Z = \sum_{i=1}^{21} \sum_{j=1}^{6} BC_{ij} X_{ij},$$

subject to

1. $\sum_{i=1}^{21} X_{ij} \leq SC_j$ for $j = 1, 2, 3, 4, 5, 6$ (where SC_j is the capacity for middle school j)
2. $\sum_{j=1}^{6} X_{ij} \leq S_i$ for $i = 1, 2, 3, ..., 32$ (where S_i is the number students in area i)
3. $\sum_{i=1}^{21} A_i X_{ij} \leq (0.58 - .50) \sum_{i=1}^{21} X_{ij}$ for $j = 1, 2, 3, 4, 5, 6$ (where A_i is the percent of African American students in area i)
4. $\sum_{i=1}^{21} H_i X_{ij} \leq (0.58 - .50) \sum_{i=1}^{21} X_{ij}$ for $j = 1, 2, 3, 4, 5, 6$ (where H_i is the percent of Hispanic students in area i)
5. $\sum_{i=1}^{21} O_i X_{ij} \leq (0.58 - .50) \sum_{i=1}^{21} X_{ij}$ for $j = 1, 2, 3, 4, 5, 6$ (where O_i is the percent of other minority students in area i)
6. $\sum_{i=1}^{21} C_i X_{ij} \leq (0.58 - .50) \sum_{i=1}^{21} X_{ij}$ for $j = 1, 2, 3, 4, 5, 6$ (where C_i is the percent of Caucasian students in area i)
7. $X_{ij} \geq 0$ for $i = 1, 2, 3, ..., 21$ and $j = 1, 2, 3, 4, 5, 6$.

Solution to Improved Diversity

After adjusting the Excel spreadsheet used in the first model, I again used the Excel Solver to implement the Simplex method on the revised model. The optimal solution found by the Excel Solver has a cost of $2,314,404.96. The student assignment pattern generated by the Excel Solver is as follows:

Area	Chase	Eisenhower	French	Jardine	Landon	Robinson
1	0.0007	0.0044	8.3224	55.6702	0.0000	12.0023
2	0.0015	0.0017	60.1848	15.4754	0.0000	14.3365
3	0.0000	0.0002	87.0880	26.8959	0.0011	19.0147
4	30.2243	69.5546	28.6958	27.8708	0.0000	29.6544
5	20.8909	13.7631	14.1041	13.6828	0.0000	12.5591
6	26.3544	20.3218	20.0403	21.7524	27.7591	23.7720
7	47.0488	10.9909	8.2114	6.2563	13.8152	11.6774
8	22.6622	25.7289	33.3132	28.4730	37.0796	30.7431
9	3.6211	30.2020	37.1562	33.6446	37.8020	32.5741
10	0.0000	20.3684	30.6122	27.5282	28.7093	25.7819
11	55.1934	39.2028	41.0319	41.9620	46.6357	43.9741
12	36.1031	13.5980	12.5419	14.1933	18.1457	16.4179
13	16.0955	10.6965	10.8780	11.4133	11.4783	12.4383
14	29.1354	28.4133	31.9052	30.4665	34.7302	32.3494
15	30.0822	26.3611	24.2117	24.1852	23.9617	23.1981
16	64.3812	41.3370	36.4316	39.8748	42.0354	41.9400
17	0.0000	15.6546	21.5340	21.0518	19.6970	19.0626
18	50.5038	17.6576	14.6351	16.5143	20.2389	18.4504
19	11.8283	14.1965	16.8836	15.8852	18.4785	16.7280
20	25.0581	36.7576	41.7756	39.8509	44.1374	40.4204
21	60.8151	45.1889	40.4429	43.7267	45.2950	44.5315
Total	530.0000	480.0000	620.0000	556.3736	470.0000	521.6264
% African American	0.2173	0.2292	0.2168	0.2369	0.1901	0.2173
% Hispanic	0.1941	0.1666	0.1471	0.1527	0.1764	0.1629
% Other Minority	0.1531	0.1566	0.1589	0.1574	0.1504	0.1552
% Caucasian	0.4356	0.4476	0.4773	0.4530	0.4831	0.4647

In a comparison of costs, this revised model is more expensive than the first model. The first model cost \$2,311,124.79, which is \$3,280.17 more than the revised model or a \$1.04 increase per student per year. However, the revised model does provide more diversity. The distribution of the percent of students that are African American (AFR), Hispanic (HIS), other minority (MIN), and Caucasian (CAU) for the first model is as follows:

	Chase	Eisenhower	French	Jardine	Landon	Robinson
AFR	0.1950	0.2656	0.2073	0.2413	0.1878	0.2155
HIS	0.2276	0.1538	0.1386	0.1466	0.1686	0.1639
MIN	0.1491	0.1606	0.1599	0.1571	0.1508	0.1545
CAU	0.4283	0.4200	0.4942	0.4551	0.4929	0.4661

For the revised model, the range in percent African American is 4.68 percent, while the first model has a range of 7.78 percent. The range in percent Hispanic is 4.7 percent for the revised model, while it is 8.9 percent for the first model. The range in percent other minority is 0.85 percent for the revised model, while the range for the first model is 1.15 percent. Finally, the range in percent Caucasian is 4.75 percent for the revised model, while it is 7.42 percent for the first model. While this revised model does cost more, it does improve the diversity of the middle school student population. However, considering the cost of plans implemented in the elementary level, this is a reasonable mechanism for improving the diversity of the middle schools.

The revised model with ethnicity constraints provides much more diversity than the current student assignment pattern used by the Topeka Public Schools District. The distribution of the percent of students that are African American, Hispanic, other minority, and Caucasian for the current student assignment pattern is as follows:

	Chase	Eisenhower	French	Jardine	Landon	Robinson
AFR	0.1628	0.3707	0.1015	0.2592	0.1562	0.2126
HIS	0.3210	0.1281	0.1797	0.1209	0.1530	0.0666
MIN	0.1242	0.1834	0.1401	0.1638	0.1444	0.1725
CAU	0.3920	0.3177	0.5788	0.4560	0.5463	0.5482

For the current student assignment pattern the range in percent of African American students is 26.92 percent compared to 4.68 percent for the revised model. The range in percent of Hispanic students is 25.44 percent for the current student assignment pattern compared to 4.7 percent for the revised model. The range in percent of other minority students for the current student assignment pattern is 5.92 percent compared to 0.85 percent for the revised model. Finally, the range in percent of Caucasian students is 26.11 percent for the current student assignment pattern compared to 4.75 percent for the revised model. This shows a drastic improvement in diversity for the revised model compared to the current student assignment pattern used by the Topeka Public Schools District.

However, this added improvement in diversity does come at a cost. The current busing solution used by the Topeka Public Schools District costs $2,298,219.40, while this revised busing solution costs $2,314,404.96. This is a $16,185.56 increase in busing cost, which is a $5.09 increase per student per year.

4. Conclusion

Immediately following the celebration of the 50th anniversary of the Brown versus the Board of Education case, it seems appropriate to consider adjusting the student assignment pattern to create a more diversified population of students in the middle schools. Also considering the concerns with finance, it is only logical to reassign the students in a way that will minimize cost. Both of the models used in this paper meet the conditions of diversifying the middle school populations while minimizing busing costs. However, I believe the model that diversifies by ethnicity is a better solution. It provides each middle school with an equally diverse population and only costs $5.09 more per student per year than the current busing solution used by the Topeka Public Schools District. I think by using this student assignment pattern, the students in the Topeka Public Schools District would benefit substantially from the implementation of more multicultural classrooms.

My initial approach to solving this problem was to use linear programming and the Simplex method. While the solution I found is feasible and an improvement to the current student assignment pattern, I did have to subject the solution to rounding to make it useful because student assignments should really be treated as integers. Further improvement to this model could be made by using integer programming to find a solution.

Acknowledgements: I would like to take a moment to thank Dr. Donna Lalonde for all her guidance and encouragement on this project. I would also like to thank the staff members of the demographics office of the Topeka Public Schools District for their cooperation in providing a map of the District. Additionally, I would like to thank Dr. Roy Sheldon for taking the time to edit my paper. Finally, I would like to thank Linda Strick, a 5th grade teacher at Stout Elementary School, for providing a picture of her students with the school buses that is found on the cover page of another version of this article.

References

[1] "Black, White and Brown." KTWU website. 6 January 2005 `http://ktwu.washburn.edu/productions/brownvboard/`.

[2] Hillier, Frederick S., and Gerald J, Lieberman. Introduction to Operations Research. New York: McGraw-Hill, 1995.

[3] MacDonald, Ziggy. "Teaching Linear Programming using Excel Solver." Computers in Higher Education Economics Review. 9.3 (1995).

[4] O'Connor, J. J., and E. F, Robertson. "George Dantzig." 1 April 2003. 6 January 2005 `http://www-groups.dcs.st-and.ac.uk/~history/Mathematicians/Danzig_George.html`.

Consecutive Numbers in Lotteries

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1. Abstract

Minimum consecutiveness of numbers drawn without replacement can be examined through distance to calculate such probabilities. After obtaining a formula, a comparison is made to the birthday paradox to explore minimum balls drawn for a probability of one-half.

2. Introduction

As lotteries are increasing in popularity, some individuals have attempted to derive patterns to increase the chance of winning. Although probabilities remain constant regardless of the technique of choosing numbers, we have noticed that there is often a pair of consecutive numbers in the winning list. Our goal was to seek the probability that the winning ticket had *at least* one pair of consecutive numbers.

Any "powerball" is ignored since it is often drawn with replacement. We considered a lottery consisting of n balls, numbered 1 through n. Several balls, say k, are randomly selected without replacement. The Missouri Powerball draws 5 balls from a pool of 55 and then places the drawn balls in numerical order. For notational convention:

- NC: number of non-consecutive sequences
- $P_C\,(n, k)$: probability of at least two consecutive balls, drawing k balls from 1 through n.

For example, the probability in the Missouri lottery is: $P_C\,(55, 5)$.

3. First attempt

My initial idea was to construct a tree. It shows the probability of each stem at a glance. The first branch has k balls, second branch contains $k-1$ balls, and so on. Simply add up all the consecutive pairs to deduce the probability. It is clear that you must have at least $2k-1$ balls to have non-consecutives. For example, when drawing 3 balls you must have a pool of at least 5. From a (5,2) tree we can note that the middle 3 branches, {2,3,4}, have 2 consecutive pairs per branch, or $2(n-2)$. Outside branches, {1,5}, have 1 each. The total number of stems are products of branches, or $n(n-1)$. This results in the formula

$$\frac{2\,(n-2)+2}{n\,(n-1)} = \frac{2n-2}{n^2-n}.$$

The result holds for all n. Since the result came within 15 minutes, it seemed $k > 3$ would also be easy.

For $k > 3$, the first and last branches would have to be considered separately since they only neighbor one other number. With three columns of branches, the predominant difficulty was the necessity of comparing each column with the others. For example, if the balls drawn are {4, 7, 9}, then each of these have to be compared with the other. Recursive formulas were compiled to accommodate branch columns, middle numbers, and ends. However, the formula varied by n with exponential increase. After much investigation, I discovered that complexity was a direct result of the distance between two drawn balls.

4. Another approach

It was noted that non-consecutive balls have distances greater than one after being placed in order. Let $X = \{x_1, x_2, ..., x_k\}$ represent the selected lottery numbers and $D = \{d_1, d_2, ..., d_n\}$ represent the number of balls between numbers. For instance, the distance between 27 and 29 is 1. Zero is included to create consistency among distances. To find the number of non-consecutive numbers, we add up the total ordered sequences that have distances ≥ 1 for all k.

The probability of an event is only true if all outcomes are equally likely. It can be shown that there exists a 1-1 correspondence between X and D. For instance, given $n = 8$, $X = \{2, 5, 8\}$, then D must be $\{1, 2, 2, 0\}$. Conversely, given $n = 8$, $D = \{1, 2, 2, 0\}$, then $X = \{2, 5, 8\}$.

First, we must obtain the upper bounds for the summations. For $P_C\,(10, 3)$ we know{6,8,10} are the last possible non-consecutive balls.

This helps us find the upper bounds for summations.

- $1 \leq x_1 \leq 6$
- $d_1 + 1 \leq x_2 \leq 8$
- $(d_1 + 1) + (d_2 + 1) \leq x_3 \leq 10$

To generalize summations across all n lottery numbers, we must find the upper bound for the left summation. The largest d_1 can be is $n - k - (k-1)+1 = n-2k+2$. We also note that grabbing another ball constitutes a new summation. This yields

$$\sum_{d_1=1}^{6} \sum_{d_2=1}^{7-d_1} \sum_{d_3=1}^{8-d_1-d_2} 1.$$

The result of 56 non-consecutives was verified by hand. Further simplification of the formula yields $[(n-4)(n^2-5n+6)]/6$, which holds for a Pick 3 lottery. The probability of non-consecutive sequences for 55 chosen 3 at a time is $NC/\mathrm{ncr}(55,3) = 89.3\%$. Thus, $P_C\,(55,3) = 10.7\%$. I applied the same process for $n = 10$, $k = 4$ for summations:

$$\sum_{d_1=1}^{4} \sum_{d_2=1}^{5-d_1} \sum_{d_3=1}^{6-d_1-d_2} \sum_{d_4=1}^{7-d_1-d_2-d_3} 1$$

Again, this result was verified. With this observation, I generalized for $(n, 4)$ to obtain

$$[(n-6)(n-5)(n-4)(n-3)]/24.$$

At this point, I was starting to see a pattern so I jumped to $k = 6$.

$$\frac{n^6}{720} - \frac{n^5}{16} + \frac{167n^4}{144} - \frac{545n^3}{48} + \frac{11131n^2}{180} - \frac{2131n}{12} + 210$$

As before, this simplifies dramatically to

$$[(n-10)(n-9)(n-8)(n-7)(n-6)(n-5)]/720.$$

Combining these elements, I derived the formula for the number of non-consecutive sequences from n choose k balls:

$$NC(n,k) = \frac{(n-k+1)!}{k!(n-2k+1)!}$$

Dividing by $\binom{n}{k}$ and subtracting from one gives us our answer:

$$P_C(n,k) = 1 - \frac{(n-k)!(n-k+1)!}{n!(n-2k+1)!}.$$

To answer our original problem on the probability that the Missouri Powerball will have at least one pair of consecutive numbers (ignoring the "powerball"), compute $P_C\,(55,5)$. Answer: 32.47%. When six balls are drawn, the probability is 45.18%.

5. Minimum k

Our problem can be compared to the famous *birthday paradox*. The paradox asks, "What is the minimum number of people who need to be in a room so that the probability that at least two of them have the same birthday is greater than 50%?" [1] It is similar to our problem since it is solved by considering birthdays without replacement. As the number of people increase, the probability that birthdays are the same increases dramatically. Against intuition, only 23 people are needed in one room for the probability to be greater than one-half.

Similarly, for a given pool of balls, we ask what the minimum k can be for the probability of consecutiveness to be greater than 50%. Some values are surprising.

N	4	5	10	20	25	50	100	150	200	1000
$\min(k)$	2	3	3	4	5	7	9	11	12	27

The minimum for k is called the *threshold number*. Further possible research includes a formal proof of its existence. Although our deductions have not improved our chances of winning a lottery, it is evident that consecutive balls are not an anomaly.

Acknowledgements: Dr. Don Tosh, Evangel University, Springfield, Missouri.

References

[1] D. Berman, Lottery drawings often have consecutive numbers, *The College Mathematics Journal* **25** (1994), 45-47.

[2] R. Johnson, So You Think You're Going to Win the Powerball Lottery!, `<http://silver.sdsmt.edu/~rwjohnso/module5.htm>`, Oct. 31, 2005.

[3] K. Rosen, Kenneth H, *Discrete Mathematics and Its Applications*, 5th Ed., McGraw Hill, 2003.

An Investigation of Spiral Length

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1. Background

A few years ago, Washburn University's Department of Mathematics and Statistics received a phone call from a publishing company asking for help in deriving a formula the company could use to determine the remaining length of a polymer left on a spool. Carpeting, newspaper and tape are examples of materials which are stored on some type of spool (see Figure 1).

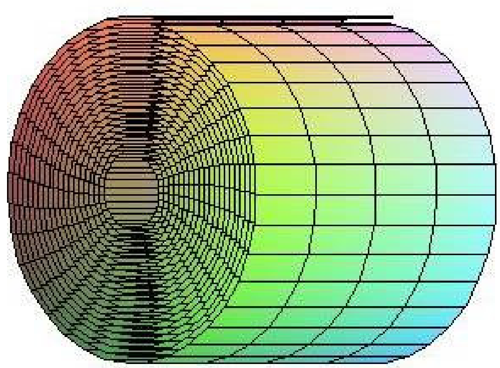

Figure 1

A cross-section view of a polymer is given in Fig. 2. In this figure, a is the known inner radius (the radius of the roll), b is the known outer radius (the radius of a full spool of polymer), and also known is the length L of a full roll of polymer. Also, t is the unknown thickness of the polymer (in the case of such things as tape and newspapers, t cannot be measured accurately and so is unknown to the user). Any compression of the roll is ignored so the thickness t will be assumed to be constant throughout the entire roll. Finally, n is the number of layers of the polymer on the full spool (also immeasurable and therefore not known to the user).

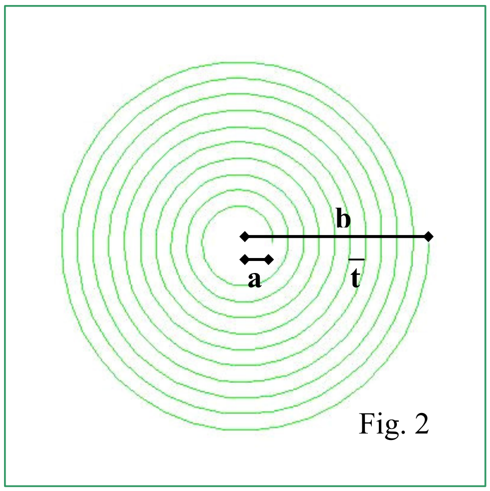

Fig. 2

Knowing only the core radius a, full radius b, and full length L, the company wished to know the length of the polymer remaining on the spool $L(r)$ determined only by measuring the radius r of the roll of polymer remaining at that time. Using this notation, $L(b) = L$ and $L(a) = 0$.

2. A Discrete approach for approximation

First consider the spiraled polymer as individual layered concentric circular rings as seen in Fig. 3. Initially, circles formed by taking the inner circle of each concentric ring layer will be considered. The radius r is selected to match some layer k of the polymer. Accordingly, $r = a + kt$ for some $k \in \{0, 1, 2, ..., n-1\}$, where n is the number of layers in a full roll of polymer. The length of the polymer remaining would approximate the sum of the circumferences of k individual circles formed by the concentric rings. Whether the inner or outer radius of each ring is used will make little difference since the polymer is very thin.

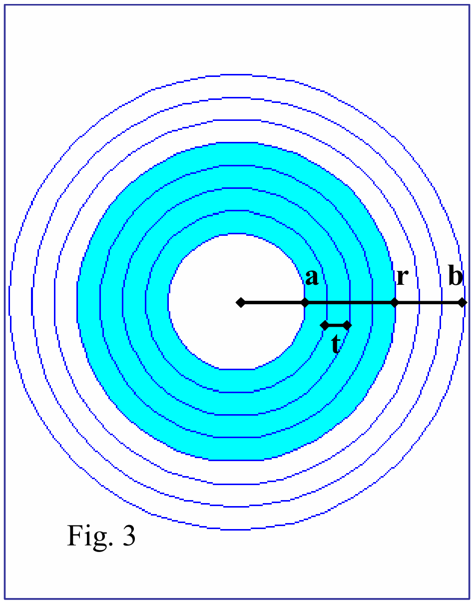

Fig. 3

Using the inner radius of each ring, the first circle would have a circumference of $2\pi a$. The next would equal $2\pi\,(a+t)$. The third would equal $2\pi\,(a+2t)$. This continues for k layers until $a+(k-1)t=r$ is reached. Summing gives

$$L(r)=2\pi(a)+2\pi(a+t)+2\pi(a+2t)+\cdots+2\pi(a+(k-1)t).$$

This simplifies algebraically to:

$$\begin{aligned} L(r) &= 2\pi[a+(a+t)+(a+2t)+\cdots+(a+(k-1)t)] \\ &= 2\pi[ka+(t+2t+\cdots+(k-1)t)] \\ &= 2\pi[ka+t(1+2+\cdots+(k-1))]. \end{aligned}$$

Borrowing a known arithmetic sequence formula from high school algebra, $1+2+3+\cdots+(k-1)=\dfrac{k\,(k-1)}{2}$, we obtain

$$L(r)=2\pi\left[ka+t\cdot\frac{k(k-1}{2}\right].$$

Restating $r=a+kt$, so that $k=\frac{r-a}{t}$, then factoring out a k and substituting gives

$$
\begin{aligned}
L(r) &= 2\pi\left(\frac{r-a}{t}\right)\left[a+\frac{t\left(\frac{r-a}{t}-1\right)}{2}\right] \\
&= 2\pi\left(\frac{r-a}{t}\right)\left(\frac{r+a-t}{2}\right) \\
&= \pi\left[\frac{\left(r^2-a^2\right)-(r-a)\,t}{t}\right].
\end{aligned}
$$

This simplifies to a nice formula for $L(r)$ involving the unknown thickness t:

$$L(r)=\pi\left(\frac{r^2-a^2}{t}+a-r\right).$$

Now recall $L(b)=L$, the length of a full roll of polymer, so

$$L=\pi\left(\frac{b^2-a^2}{t}+a-b\right),$$

and solving this equation for t yields

$$t=\frac{\pi(b^2-a^2)}{L+\pi(b-a)}.$$

Substituting the value of t back into the formula for $L(r)$ yields

$$
\begin{aligned}
L(r) &= \pi\left[\frac{r^2-a^2}{\left(\frac{\pi((b^2-a^2)}{L+\pi(b-a)}\right)}+a-r\right] \\
&= \left[\frac{\left(r^2-a^2\right)\left(L+\pi\left(b-a\right)\right)}{(b^2-a^2)}+\pi\left(a-r\right)\right].
\end{aligned}
$$

Recall a is the radius of the core, b is the radius of the full roll of polymer, and L is the length of the full roll of polymer, all known values. Also, r is the measured radius of the roll of polymer remaining on the spool. Essentially, this is the solution for $L(r)$ which was initially reported to the publishing company which requested the formula. After a period of use, they conveyed the results based upon application of the formula coincided with their previous in-house experiences and were pleased they could now more accurately predict the remaining length of polymer on a partially used roll. Unfortunately the formula is rather cumbersome to apply, especially for users with minimal algebraic skills.

It is not helpful to redo this formula using the outer radii of the concentric rings in Fig. 3 rather than the inner radii. A formula for $L(r)$ with the same level of complexity and accuracy would be obtained. On the other hand, if the midpoint between the inner and outer radii is chosen, one might expect a slight improvement in accuracy. Unfortunately, one might also expect an ever more complicated formula for $L(r)$.

Consider the radius of each circle measured at the midpoint of each layer. If each thickness is t, then the midpoint of t lies at $\frac{t}{2}$. Again, assume $r = a + kt$ for some $k \in \{0, 1, 2, ..., n-1\}$, where n is the number of layers of polymer in a full roll of length L. Then

$$\begin{aligned}
L(r) &= 2\pi\left(a+\frac{t}{2}\right)+2\pi\left(a+\frac{3t}{2}\right)+2\pi\left(a+\frac{5t}{2}\right) \\
&\quad +\cdots+2\pi\left(a+\frac{(2k-1)t}{2}\right) \\
&= 2\pi\left[\left(a+\frac{t}{2}\right)+\left(a+\frac{3t}{2}\right)+\cdots+\left(a+\frac{(2k-1)t}{2}\right)\right] \\
&= 2\pi\left[ka+\left(\frac{t}{2}+\frac{3t}{2}+\frac{5t}{2}+\cdots+\frac{(2k-1)t}{2}\right)\right] \\
&= 2\pi\left[ka+\frac{t}{2}\left(1+3+5+\cdots+(2k-1)\right)\right].
\end{aligned}$$

Now utilizing another arithmetic sequence formula

$$1+3+5+\cdots+(2k-1)=k^2,$$

we have

$$L(r)=2\pi\left(ka+\frac{tk^2}{2}\right).$$

Simplifying using the previously shown fact $k=\frac{r-a}{t}$,

$$\begin{aligned}
L(r) &= 2\pi\left(ka+\frac{tk^2}{2}\right) \\
&= \pi\left(2ka+tk^2\right) \\
&= \pi\left[2\left(\frac{r-a}{t}\right)a+t\left(\frac{r-a}{t}\right)^2\right] \\
&= \pi\left(\frac{r^2-a^2}{t}\right) \\
&= \pi\left(\frac{r-a}{t}\right)\left[2a+(r-a)\right].
\end{aligned}$$

Recall $L(b) = L$, so $L = \pi \left(\frac{b^2 - a^2}{t} \right)$. Solving for t,

$$t = \frac{\pi \left(b^2 - a^2 \right)}{L}.$$

Substituting the above solution for t into the formula for $L(r)$ and simplifying gives

$$\begin{aligned} L(r) &= \pi \left(\frac{r^2 - a^2}{\frac{\pi \left(b^2 - a^2 \right)}{L}} \right) \\ &= \frac{L \left(r^2 - a^2 \right)}{b^2 - a^2}. \end{aligned}$$

Perhaps surprisingly, this midpoint approach produced a formula for $L(r)$ which is *much* less complicated than the first formula using the inner radii and accuracy has been improved in the process.

3. A Continuous Approach Using Calculus

Although there is no real-world need to consider other solutions to improve accuracy, it is of mathematical interest to consider a continuous spiral of polymer rather than the discrete concentric ring layers. Consider the polar curve

$$r = a + k\theta,$$

with $\theta \geq 0$ from calculus, which defines a spiral as seen in Fig. 4, starting at the polar point $(a, 0)$ and wrapping around the core circle $r = a$ in a counterclockwise direction. This spiral will approximate the path of the inner side of the polymer roll. Note that after one revolution, $\theta = 2\pi$ radians, so r will be $a + 2\pi k$. In one revolution, r has increased by $2\pi k$ units, so the thickness of a polymer layer is $2\pi k$ units. If n is the number of revolutions in a full roll of polymer with radius b, then $b = a + 2\pi n$, which implies

$$k = \frac{b - a}{2\pi n}.$$

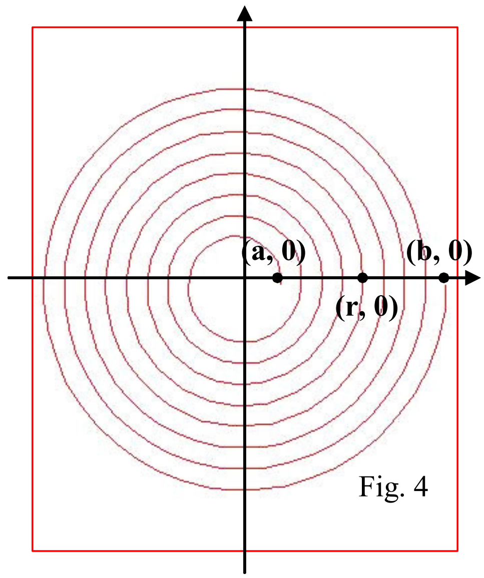

Fig. 4

From calculus, arc length s of a given polar curve $r = f(\theta)$ as θ moves from α to β is given by

$$s = \int_{\alpha}^{\beta} \sqrt{r^2 + \left(\frac{dr}{d\theta}\right)^2} d\theta.$$

Now $f(\theta) = a + k\theta$, so $\dfrac{dr}{d\theta} = k$, and θ is defined from 0 to $2\pi n$. Here, $\theta = 0$ indicates the beginning of the roll, and $\theta = 2\pi n$ represents the end of a full roll of a polymer of length L. Accordingly,

$$L = \int_0^{2\pi n} \sqrt{(a + k\theta)^2 + k^2} d\theta,$$

The goal is to evaluate the above integral in terms of a, b, and n. With the roll length L known, hopefully the result could be solved for n. This in turn would give a value for k. With the number of revolutions in a full roll n, and the spiral formula $r = a + k\theta$ known, it prepares the way for setting up the integral for $L(r)$, where r is an appropriate radius of a partial roll polymer.

Using Maple, the evaluated integral results in:

$$L = \frac{A}{2k},$$

where

$$
\begin{aligned}
A \;=\; & -\sqrt{a^2+k^2}a + k^2\ln(k) - k^2\ln\left(a+\sqrt{a^2+k^2}\right) \\
& +2\sqrt{a^2+4ak\pi n+4k^2\pi^2n^2+k^2}k\pi n \\
& +\sqrt{a^2+4ak\pi n+4k^2\pi^2n^2+k^2}a + k^2\ln\left(\frac{a+\sqrt{a^2+k^2}}{k}\right).
\end{aligned}
$$

The value of k is replace by $\dfrac{b-a}{2\pi n}$, and Maple produces an even more complicated result.

For obvious reasons, the author of this paper had no chance to solve this equation for n. Maple also failed; however, the equation can be simplified considerably by specifying that the variables a, b, n, k, and $(b-a)$ are all non-negative. Actually, using integration techniques from calculus and solving by hand delivers an even more compact solution for L, but even in its simplest algebraic form, it is not possible to explicitly solve for n in terms of a, b, and L.

To retrieve a meaningful utilization of the above results, it is possible to numerically solve for n for specific values of a, b, and L. Once n is determined, the thickness of each polymer layer $2\pi n$ can be found for these specific values. With the help of Maple, $L(r)$ can be calculated for specific values of r on a given roll of polymer. Results of such calculations are shown in the next section.

4. Comparison of Results

The company provided approximations from previous rough, in-house measurements which can be used to verify accuracy of the formulas developed for $L(r)$. A specific roll of polymer had been observed. This roll had a core radius $a = \frac{3}{2}$", a full roll radius $b = 9$", and the length of a full roll $L = 16,000$". Also provided by the local business were approximate lengths at two specific radii for this observed roll: $L\,(6.5") = 8000"$ and $L\,(19/4") = 4000"$. Using the formulas found during this investigation, the results are as follows (in inches, rounded to the nearest ten-thousandth):

Radius	Company Provided Results	Discrete Inner Radius Results	Discrete Midpoint Radius Results	Continuous Spiral Results
9	16,000	16,000	16,000	16,000
6.5	8000	8123.2441	8126.9841	8126.9848
4.75	4000	4122.8514	4126.9841	4126.9850
1.5	0	0	0	0

Most interesting in the above chart is the miniscule differences between the results in the spiral case column compared to those in the midpoint case column. These results are for roll of polymer, that when full is nearly $\frac{1}{4}$ of a mile long! Note that certain company results are over 100 feet different than the formula results but this is easily explainable. First, the company results were rounded-off approximations. Secondly, a measurement even off 1/16" in a 6.5" radius would result in an error in the remaining roll length of well over 10' of polymer.

5. A Real-World Application

As mentioned previously, the first formula for $L(r)$ obtained, the inner radius formula, was returned to the publishing company to be used on a specific roll of polymer. Since the second formula for $L(r)$, the midpoint formula, was much easier to use, the business was revisited by the author of this paper. The company, Southwest Publishing and Mailing Corporation of Topeka, KS is a printing and mailing company whose primary customers are non-profit organizations. They can handle up to 850,000 mailings a day and are currently processing over 400,000.

Figure 5

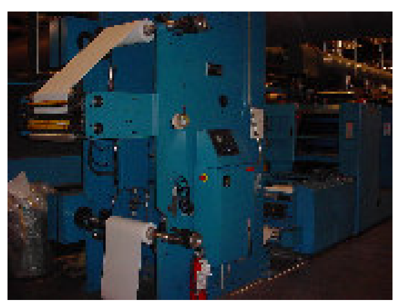

Figure 6

Beginning with a large roll of paper (Fig. 5), they print and cut the paper, running it through their various presses (Fig. 6), into any form needed, i.e. normal 8.5”X11” paper or perforated printer paper, then separate the printings, and prepare them for mailing. They receive a database containing the mailing list, personalize each mailing, and fill envelopes on an automated assembly machine. Not only do they use the rolls of paper, but also another type of polymer in the form of plastic; this is used as the clear plastic seen in envelopes. They were eager to receive the new formula, finding it much easier to use as well as one which could easily be used for all of their rolls of polymers.

6. An Agonizing Admission

After all of this heavy lifting, there was a rather painful finding. There is an intermediate algebra level solution to this problem. It seems reasonable to assume the length of the polymer $L(r)$ remaining on a roll at radius r (and given inner radius a and outer radius b) is directly proportional to the area $A(r)$ of a cross section of the area of the remaining polymer as shown in Fig. 7.

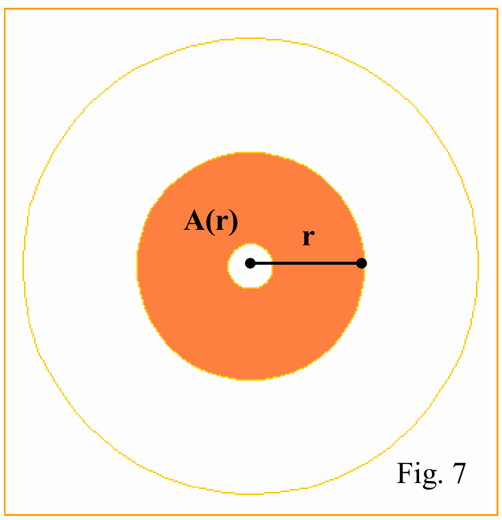

Fig. 7

Assuming $L(r)$ is directly proportional to $A(r)$ yields the proportionality equation $L(r) = kA(r)$ for some real number k. The area of the concentric circle region $A(r)$ is $\pi\left(r^2 - a^2\right)$. Substituting this back into the proportionality equation gives $L(r) = k\pi\left(r^2 - a^2\right)$. As $L(b) = L$, b can be substituted into the equation which results in $L = k\pi\left(b^2 - a^2\right)$. Therefore, the proportionality constant k is given by

$$k = \frac{L}{\pi(b^2 - a^2)}.$$

Substituting this into the above formula for $L(r)$ yields

$$L(r) = \frac{L\left(r^2 - a^2\right)}{b^2 - a^2}.$$

Note that this simple solution is identical to the previously derived formula in the discrete case when the midpoints of the layers of the concentric circles were used to determine $L(r)$.

7. Conclusion

This investigation has introduced four different approaches to solve a company's problem involving a simple roll of polymer. The mathematics encountered along the way involved a variety of rich and interesting techniques. Certainly the spiral case could be explored further. Also, in all solutions, any compactification of the rolls was ignored and the polymer thickness was considered as constant. It would be interesting to consider the additional condition where each layer of polymer is some constant multiple c of the layer above it, where $0 < c < 1$.

Acknowledgements: This research project was conducted under the direction and guidance of Dr. Al Riveland, Washburn University Mathematics and Statistics Department. I wish to thank him for the generous time he spent with me. Also, I wish to express my gratitude to Dr. Kevin Charlwood for both his suggestions and his time spent helping me work with Maple. Finally, I would like to show my appreciation to Angie McAtee, Vice President of Southwest Publishing for not only her time, but for introducing me to her company.

The Fox, the Rabbit, and Zeno's Paradox

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1. Introduction

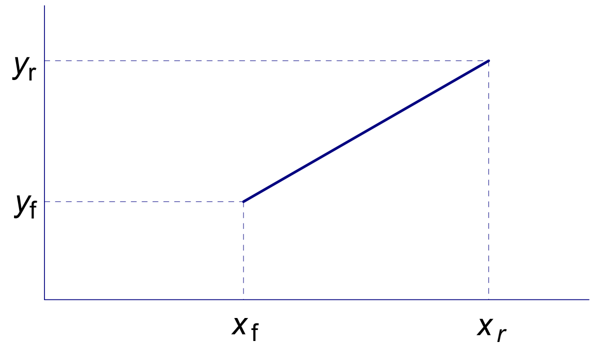
This paper is concerned with the numerical solution of a system of ordinary differential equations in first-order form. The system belongs to a class of problems called pursuit problems. Pursuit problems are to be found in some texts on differential equations, for example p. 107 of [2] and p. 618 of [1].

For a system of differential equations, initial values are required to define the solution. I integrated the equations numerically using the Runge-Kutta method from the beginning to a stopping point. The method has the advantages of begin self-starting and having about the same error as other methods.

If a predator is to stand a chance of succeeding in its pursuit of the prey, the predator has to have a speed advantage over the prey. I investigated what the minimum speed advantage must be, assuming the speed of both predator and prey are constant. The predator is a fox with position and velocity coordinates x_f, y_f, x'_f, y'_f. The prey is a rabbit with coordinates x_r, y_r, x'_r, y'_r.

Although this is not so in biology, let us assume that a fox always varies its velocity vector so as to keep it pointing to where the rabbit is. (Figure 3) The fox doesn't realize the advantage obtained by pointing its velocity vector toward where the rabbit will be. It would be like a hunter who does not lead the bird. The separation of the rabbit from the fox has components $x_r - x_f$ and $y_r - y_f$. The slope of the fox's velocity vector is

$$\frac{y'_f}{x'_f} = \frac{y_r - y_f}{x_r - x_f}. \tag{1}$$



Suppose the rabbit is observed by the fox, which is at the lower left hand corner of a square field of unit length on each side, to be at the lower right hand corner of the square field. (Figure 1) Suppose there is a rabbit-proof fence along the right hand side of the square field and a fox-proof rabbit hole at the upper right hand corner.

Then the rabbit's only option is to run in the y-direction, at constant velocity $\frac{dy_r}{dt}$, which I have taken to be one unit length per unit time. Its position is given by equation 2:

$$x_r = 1, \int_0^t \frac{dy_r}{dt} dt = \int_0^t dt. \tag{2}$$

The question is, what speed advantage k must the fox have, if the fox is to just catch the rabbit at the upper right hand corner of the square field? The rabbit's speed (unity), multiplied by the fox's speed advantage, k, is the fox's speed, equation 3. What I did was to assume some speed advantage, k, solve the equations 4 and 5 to a stopping point, then to compare the fox's position and the rabbit's position to see how closely they match. Refining the speed advantage of the fox, I iterated the process until the fox's position and the rabbit's position matched at the stopping point.

$$\left[\left(\frac{dx_f}{dt}\right)^2 + \left(\frac{dy_f}{dt}\right)^2\right]^{1/2} = k\left(\frac{dy_r}{dt}\right) = k\,(1)\,. \tag{3}$$

Using k for the fox's velocity, decompose the velocity into components in the x-direction and the y-direction by means of the slope implied by equation 1, obtaining equations 4 and 5, remembering that $x_r = 1$ and $\frac{dy_r}{dt} = 1$.

When integrated, equations 4 and 5 give the position of the fox.

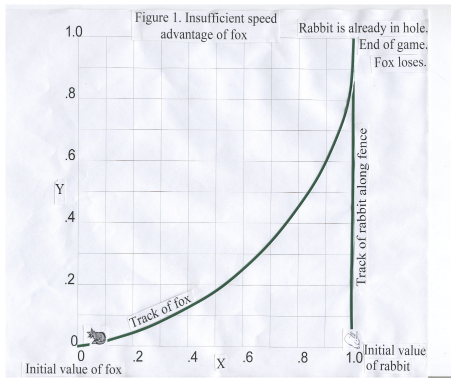


Figure 1. Insufficient speed advantage of fox

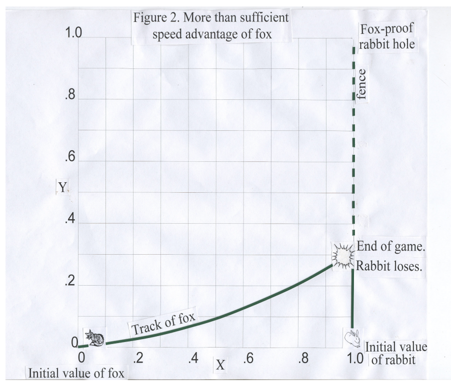


Figure 2. More than sufficient speed advantage of fox

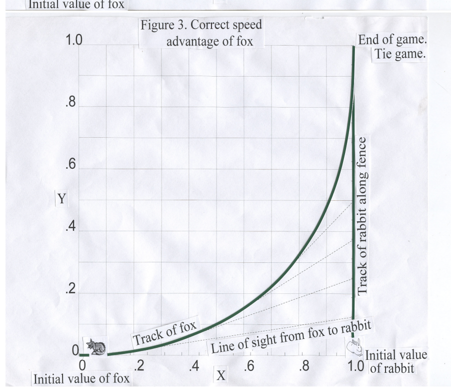


Figure 3. Correct speed advantage of fox

2. Fourth-order Runge-Kutta method

Equations 4 and 5 are a system of differential equations of the first order in two unknowns which can be solved for the change in position of the rabbit and the fox from the n^{th} instant to the $n+1^{st}$ instant. The initial conditions are $x_r = 1$, $y_r = 0$, $x_f = 0$, and $y_f = 0$.

$$\frac{dx_f}{dt} = \frac{k\left(1-x_f\right)}{\left[\left(1-x_f\right)^2 + \left(y_r - y_f\right)^2\right]^{1/2}} \tag{4}$$

$$\frac{dy_f}{dt} = \frac{k\left(y_r-y_f\right)}{\left[\left(1-x_f\right)^2 + \left(y_r - y_f\right)^2\right]^{1/2}} \tag{5}$$

The increments of position change were obtained by the Runge-Kutta method ([3], p. 334 and [4], pp. 588-594), instead of obtaining them analytically. (My intention is to provide the student with an example of numerical solution.) One-sixth of the sum of the quantities in the parentheses in equations 6 or 7 is a kind of weighted average of the current derivative with respect to time, and multiplying that by the time increment, h, furnishes the increment of the coordinate at the n^{th} instant, to be added to the coordinate at the n^{th} instant, to obtain the coordinate at the $n+1^{st}$ instant.

$$x_f^{(n+1)} = x_f^{(n)} + \frac{h}{6}\left(j_0^{(n)} + 2j_1^{(n)} + 2j_2^{(n)} + j_3^{(n)}\right) \tag{6}$$

$$y_f^{(n+1)} = y_f^{(n)} + \frac{h}{6}\left(k_0^{(n)} + 2k_1^{(n)} + 2k_2^{(n)} + k_3^{(n)}\right) \tag{7}$$

$$x_r = 1, y_r^{(n+1)} = y_r^{(n)} + h \tag{8}$$

Equations 6 and 7 cannot be solved until their components are solved for in the following equations. The components j and k are at the heart of the method and are summed in equations 6 and 7. The j_0 and k_0 at the n^{th} instant of time are shown below. (The equations for the components j and k will be different for different differential equations.)

$$\begin{aligned}
j_0^{(n)} &= \frac{k\left(1-x_f^{(n)}\right)}{\left[\left(1-x_f^{(n)}\right)^2 + \left(y_r^{(n)} - y_f^{(n)}\right)^2\right]^{1/2}} \\
k_0^{(n)} &= \frac{k\left(y_r^{(n)}-y_f^{(n)}\right)}{\left[\left(1-x_f^{(n)}\right)^2 + \left(y_r^{(n)} - y_f^{(n)}\right)^2\right]^{1/2}}.
\end{aligned}$$

The j_1 and k_1 at the n^{th} instant require the inclusion of the j_0 and k_0.

$$\begin{aligned}
j_1^{(n)} &= \frac{k\left(1-x_f^{(n)}-\frac{h}{2}j_0^{(n)}\right)}{\left[\left(1-x_f^{(n)}-\frac{h}{2}j_0^{(n)}\right)^2+\left(y_r^{(n)}+\frac{h}{2}-y_f^{(n)}-\frac{h}{2}k_0^{(n)}\right)^2\right]^{1/2}}\\
k_1^{(n)} &= \frac{k\left(y_r^{(n)}+\frac{h}{2}-y_f^{(n)}-\frac{h}{2}k_0^{(n)}\right)}{\left[\left(1-x_f^{(n)}-\frac{h}{2}j_0^{(n)}\right)^2+\left(y_r^{(n)}+\frac{h}{2}-y_f^{(n)}-\frac{h}{2}k_0^{(n)}\right)^2\right]^{1/2}}.
\end{aligned}$$

The j_2 and k_2 at the n^{th} instant require the inclusion of the j_1 and k_1.

$$\begin{aligned}
j_2^{(n)} &= \frac{k\left(1-x_f^{(n)}-\frac{h}{2}j_1^{(n)}\right)}{\left[\left(1-x_f^{(n)}-\frac{h}{2}j_1^{(n)}\right)^2+\left(y_r^{(n)}+\frac{h}{2}-y_f^{(n)}-\frac{h}{2}k_1^{(n)}\right)^2\right]^{1/2}}\\
k_2^{(n)} &= \frac{k\left(y_r^{(n)}+\frac{h}{2}-y_f^{(n)}-\frac{h}{2}k_1^{(n)}\right)}{\left[\left(1-x_f^{(n)}-\frac{h}{2}j_1^{(n)}\right)^2+\left(y_r^{(n)}+\frac{h}{2}-y_f^{(n)}-\frac{h}{2}k_1^{(n)}\right)^2\right]^{1/2}}.
\end{aligned}$$

The j_3 and k_3 at the n^{th} instant, require the inclusion of the j_2 and k_2.

$$\begin{aligned}
j_3^{(n)} &= \frac{k\left(1-x_f^{(n)}-hj_2^{(n)}\right)}{\left[\left(1-x_f^{(n)}-hj_2^{(n)}\right)^2+\left(y_r^{(n)}+h-y_f^{(n)}-hk_2^{(n)}\right)^2\right]^{1/2}}\\
k_3^{(n)} &= \frac{k\left(y_r^{(n)}+h-y_f^{(n)}-hk_2^{(n)}\right)}{\left[\left(1-x_f^{(n)}-hj_2^{(n)}\right)^2+\left(y_r^{(n)}+h-y_f^{(n)}-hk_2^{(n)}\right)^2\right]^{1/2}}.
\end{aligned}$$

Using a trial value of k, I programmed the Runge-Kutta method on a computer to compute x_f, y_f, $x_r = 1$, and y_r in steps until the end of the chase at $y_r = 1$. Then I compared x_f and y_f to see if they match the rabbit's x_r and y_r. If this match occurred before the rabbit reached safety at the upper right hand corner of the field, then the fox's speed advantage multiple k of the rabbit's speed was too large. (Figure 2) If the fox never caught the rabbit before the latter reached safety, then the multiple k was too small. (Figure 1) A few iterations with subsequently refined speed advantage k produced Figure 3. Figure 3 shows the path of the fox and the path of the rabbit when the speed advantage is just right. The rabbit's speed was one unit length per unit time, and the step size was 1/16th of the unit time, so that sixteen steps accomplished the end. The just right fox's speed was $\frac{\pi}{2}$ unit lengths per unit time. Actually I stopped iterating when an inspection of the plot showed that the fox's journey is one fourth of a circle of unit radius, i.e., $2\pi\,(1)\,/4$ units of distance. As the fox's journey is trekked in one unit of time, the fox's rate of speed, and the fox's speed advantage is $\frac{\pi}{2}$.

But, with the rabbit and the fox each simultaneously reaching the upper right hand corner of the field, does the fox catch the rabbit, or does the rabbit dive into the hole? It depends on the truncation of the speed advantage, k an otherwise infinitely many decimal place real number, it depends on the round-off error of the computer, and it depends on the step size. And it depends on the accuracy of the Runge-Kutta method. These error sources are discussed in [3], p. 332, [4], pp. 576-582, and [2], p. 598.

Leaving these caveats aside, consider the last moments of the chase. It is practically a one-dimensional foot race in the y-direction. What you have in the separation of the fox and the rabbit is an infinite monotone sequence. Of interest is the question as to the limit of the sequence as approaching zero.

3. Zeno's paradox (Zeno of Elea, 5th cent. BCE Greek philosopher)

Rather than investigating the fox-rabbit infinite sequence, it is interesting to investigate an analogous infinite sequence proposed by Zeno of Elea.

Zeno's paradox of Achilles and the tortoise has the narrative that the tortoise has a head start on Achilles. Although Achilles runs faster than the tortoise, he would never catch up, says Zeno, since, while Achilles is covering the original distance to the tortoise, the tortoise is opening up a new distance from where he was to where he is now at a second position. Then, when Achilles reaches this second position of the tortoise, the tortoise has reached a third position, and so on. Let the tortoise's speed be 10 units of distance per unit of time. Let Achilles' speed be 20 units of distance per unit of time. Let the head start of the tortoise be 10 units. (Figure 4) Then Achilles' run time to the first position of the tortoise is $\frac{10}{20} = \frac{1}{2}$ units of time. The distance from the first tortoise position to the second tortoise position (half of the head start) is $\frac{10}{2} = 5$ units. Achilles' run time to the second position is $\frac{5}{20} = \frac{1}{4}$, and so on. It's a sequence each of whose terms is $\frac{1}{2^n}$. This infinite monotone sequence sums to unity and converges because $\lim\limits_{n \to \infty} \frac{1}{2^n} = 0$. Achilles' pursuit takes one unit of time. But the tortoise's run times are also $\frac{5}{10} = \frac{1}{2}$, $\frac{2\frac{1}{2}}{10} = \frac{1}{4}$, and so on, summing up to unity. Inasmuch as Achilles and the tortoise start out at the same instant and have the same pursuit time, they reach the infinitely last position simultaneously. Contrary to Zeno, Achilles catches the tortoise. Unlike the rabbit, the tortoise has no Achilles-proof hole to dive in to.

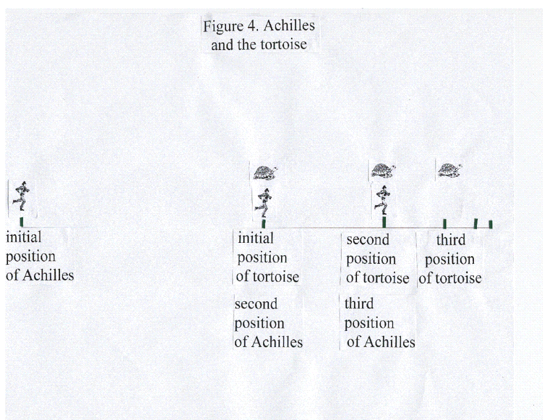


Figure 4. Achilles and the tortoise

References

[1] M. Fogiel, Ed., *The Differential Equations Problem Solver, Vol. 1*, Research and Education Associates, 1978.

[2] R. Redheffer and D. Port, *Differential Equations: Theory and Applications*, Jones and Bartlett, 1991.

[3] D. L. Powers, *Elementary Differential Equations*, Prindle, Weber, and Schmidt, 1987.

[4] M. M. Guterman and Z. H. Nitecki, *Differential Equations: A First Course*, 2^{nd} ed., Saunders College Publishing, 1988.

The Problem Corner

Edited by Pat Costello and Kenneth M. Wilke

The Problem Corner invites questions of interest to undergraduate students. As a rule, the solution should not demand any tools beyond calculus and linear algebra. Although new problems are preferred, old ones of particular interest or charm are welcome, provided the source is given. Solutions should accompany problems submitted for publication. Solutions of the following new problems should be submitted on separate sheets before July 1, 2007. Solutions received after this will be considered up to the time when copy is prepared for publication. The solutions received will be published in the Fall, 2007 issue of *The Pentagon*. Preference will be given to correct student solutions. Affirmation of student status and school should be included with solutions. New problems and solutions to problems in this issue should be sent to Pat Costello, Department of Mathematics and Statistics, Eastern Kentucky University, 521 Lancaster Avenue, Richmond, KY 40475-3102 (e-mail: pat.costello@eku.edu, fax: (859)-622-3051)

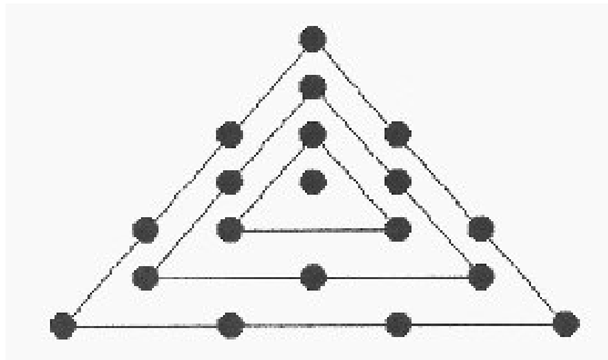
NEW PROBLEMS 604-610

Problem 604. *Proposed by Ovidiu Furdui, Western Michigan University, Kalamazoo, MI.*

Find the sum $\sum_{n=1}^{\infty} (-1)^{n-1} \left(1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n} - \ln n - \gamma\right)$, where γ is the Euler-Mascheroni constant.

Problem 605. *Proposed by Cathy George (student) and Russell Euler, Northwest Missouri state University, Maryville, MO.*

Geometrically, *centered triangular numbers* consist of a central dot with three dots around it and then additional dots in the gaps between adjacent dots (see figure). The first four centered triangular numbers are 1, 4, 10, 19. Prove that a positive integer $m \geq 5$ is a centered triangular number if and only if m is the sum of three consecutive triangular numbers.



Problem 606. *Proposed by Mathew Cropper and Bangteng Xu (jointly), Eastern Kentucky University, Richmond, KY.*

Show that for any nonnegative integer n,

$$a_n = \frac{2}{7}(-1)^n + \frac{1}{2\left(4+\sqrt{2}\right)}\left(\frac{2}{2+\sqrt{2}}\right)^{n+1} + \frac{1+2\sqrt{2}}{14\sqrt{2}}\left(\frac{2}{2-\sqrt{2}}\right)^{n+1}$$

is an integer, and a_n is even when $n \geq 2$.

Problem 607. *Proposed by Russell Euler and Jawad Sadek (jointly), Northwest Missouri State University, Maryville, MO.*

A point P is moving on a quarter circle with center O, and P is bounded by two points A and B. Let PQ be the perpendicular from P to the radius OA. Choose a point M on the ray OP such that

length of $OM =$ length of $OQ +$ length of QP.

Find the locus of the points M as P moves on the quarter circle.

Problem 608. *Proposed by Russell Euler and Jawad Sadek (jointly), Northwest Missouri State University, Maryville, MO.*

Let C be a circle with center O and radius R. Let $ABCD$ be a parallelogram circumscribed about C. Express

$$\frac{1}{(AC)^2} + \frac{1}{(BD)^2}$$

in terms of R.

Problem 609. *Proposed by Mathew Cropper, Eastern Kentucky University, Richmond, KY.*

Let the n vertices of a given graph G be labeled $v_1, v_2, ..., v_n$. Form a new graph $M(G)$ from G in the following way:

1. Add to G an additional $n+1$ vertices, $u_1, u_2, ..., u_n, w$.
2. Connect each vertex u_i by a new edge to every vertex v_j where there is an edge from v_i to v_j in G.
3. Connect each vertex u_i by an edge to vertex w. Join each vertex u_i by an edge to vertex w.

Starting with a graph which is just two vertices and one edge between the two vertices, find a formula for the number of edges in the iterated graph $M^{(n)}(G) = M(M(M \cdots (M(G))))$, where the graph formation is iterated n times.

Problem 610. *Proposed by the editor.*

Let $f(x) = x^n + a_{n-1}x^{n-1} + \cdots + a_1 x + 4$, where all coefficients a_i are positive reals. If $f(x)$ has n real roots, prove that $f(1) \geq 2^{n+1}$.

Please help your editor by submitting problem proposals.

SOLUTIONS 585, 587, 589-596

Problem 585. *(Corrected) Proposed by José Luis Diaz-Barrero, Universitat Politècnica de Catalunya, Barcelona, Spain.*

Suppose that the roots $z_1, z_2, ..., z_n$ of
$$z^n + a_{n-1}z^{n-1} + a_{n-2}z^{n-2} + \cdots + a_1 z^1 + a_0 = 0$$
are in arithmetic progression with difference d. Prove that
$$d^2 = \frac{12\left[(n-1)a_{n-1}^2 - 2na_{n-2}\right]}{n^2(n^2-1)}.$$

Solution *by the proposer.*

From the Cardan- Viete formulae, we have
$$z_1 + z_2 + ... + z_n = -a_{n-1}$$
and
$$z_1^2 + z_2^2 + ... + z_n^2 = a_{n-1}^2 - 2a_{n-2}.$$
The expression for d^2 can be rewritten as
$$a_{n-1}^2 - 2a_{n-2} = (\frac{1}{n})a_{n-1}^2 + \left[\frac{n\left(n^2-1\right)}{12}\right]d^2,$$
or equivalently we need to prove that
$$z_1^2 + z_2^2 + ... + z_n^2 = \frac{(z_1 + z_2 + ... + z_n)^2}{n} + \left[\frac{n\left(n^2-1\right)}{12}\right]d^2.$$
In fact,
$$\begin{aligned} z_1^2 + z_2^2 + ... + z_n^2 &= \sum_{k=0}^{n-1}(z_1 + kd)^2 \\ &= \sum_{k=0}^{n-1}(z_1^2 + 2z_1kd + k^2d^2) \\ &= nz_1^2 + 2dz_1\sum_{k=0}^{n-1}k + d^2\sum_{k=0}^{n-1}k^2 \\ &= nz_1^2 + 2dz_1 \cdot \frac{n(n-1)}{2} + d^2 \cdot \frac{n(n-1)(2n-1)}{6} \end{aligned}$$

$$= \frac{\left[z_1 + \frac{(n-1)d}{2}\right]^2 n^2}{n} + \frac{n\left(n^2-1\right)d^2}{12}$$
$$= \frac{(z_1+z_2+...+z_n)^2}{n} + \frac{n\left(n^2-1\right)d^2}{12},$$

and we are done.

Editor's Comment: The Cardan-Viete formulae are also known as elementary symmetric functions of the roots of an equation and Newton's Relations.

Problem 587. *(Corrected) Proposed by José Luis Diaz-Barrero, Universitat Politècnica de Catalunya, Barcelona, Spain.*

Show that if A, B, C are the angles of a triangle, and a, b, c its sides, then

$$\prod_{\text{cyclic}} \sin^{1/3}(A-B) \leq \sum_{\text{cyclic}} \frac{\left(a^3+b^3\right)\sin(A-B)}{3ab}.$$

Solution *by the proposer.*

From the determinant

$$\begin{vmatrix} \cos A & \sin A & \cos A \\ \cos B & \sin B & \cos B \\ \cos C & \sin C & \cos C \end{vmatrix} = 0,$$

expanding and re-ordering the terms, we obtain the identity

$$\cos A \sin(B-C) + \cos A \sin(B-C) + \cos A \sin(B-C) = 0. \quad (9)$$

Using the Law of Cosines, we obtain $\cos A = \dfrac{b^2+c^2-a^2}{2bc}$. Similarly, $\cos B = \dfrac{c^2+a^2-b^2}{2ac}$, and $\cos C = \dfrac{a^2+b^2-c^2}{2ab}$. Putting these results into (1) yields

$$\left(\frac{b^2+c^2-a^2}{2bc}\right)\sin(B-C) + \left(\frac{c^2+a^2-b^2}{2ac}\right)\sin(C-A)$$
$$+ \left(\frac{a^2+b^2-c^2}{2ab}\right)\sin(A-B) = 0,$$

or equivalently,

$$a(b^2+c^2)\sin(B-C)+b(c^2+a^2)\sin(C-A)+c(a^2+b^2)\sin(A-B)$$
$$= a^3\sin(B-C)+b^3\sin(C-A)+c^3\sin(A-B).$$

Applying the AM-GM Inequality to the RHS of (3) yields

$$a^3\sin(B-C)+b^3\sin(C-A)+c^3\sin(A-B)$$
$$\geq 3abc\left(\prod_{\text{cyclic}}\sin(A-B)\right)^{1/3}.$$

Therefore

$$a(b^2+c^2)\sin(B-C)+b(c^2+a^2)\sin(C-A)$$
$$+c(a^2+b^2)\sin(A-B)\geq 3abc\left(\prod_{\text{cyclic}}\sin(A-B)\right)^{1/3}$$

The desired inequality immediately follows by dividing both sides of the preceding inequality by $3abc$. Note that equality holds when ΔABC is equilateral.

Problem 589. *Proposed by the editor.*

Find a, b, c, d, and e so that the number

$$a8b2cd7e3$$

is divisible by both 73 and 137, where a, b, c, d, and e are distinct integers chosen from the set $\{0,1,2,3,4,5,6,7,8,9\}$, and $a>0$.

Solution *by the editor.*

Let N denote the number $a8b2cd7e3$. Since N is divisible by both 73 and 137, N is also divisible by $10001 = 73 \cdot 137$. Then since any power of 10 is relatively prime to 10001, we will construct a set of smaller numbers which are also divisible by 10001 whenever 10001 divides N. We construct

$$N_1 = \frac{N - 3 \cdot 10001}{10} = a8b2\{c-3\}d7e$$

which is clearly divisible by 10001 whenever 10001 divides N. Proceeding similarly we construct

$$N_2 = \frac{N_1 - e \cdot 10001}{10} = a8b\{2-e\}\{c-3\}d7;$$

$$N_3 = \frac{N_2 - 7 \cdot 10001}{10} = a8\{b-7\}\{2-e\}\{c-3\}d;$$

$$N_4 = \frac{N_3 - d \cdot 10001}{10} = a\{8-d\}\{b-7\}\{2-e\}\{c-3\};$$

and finally

$$N_5 = \frac{N_4 - (c-3) \cdot 10001}{10} = \{a+3-c\}\{8-d\}\{b-7\}\{2-e\}.$$

Now since N_5 is divisible by 10001, $N_5 = 0$ and either each digit must be zero or $N_5 = 1001$ so that $\{2-e\} = 1$ and $\{a+3-c\} = 10$ simultaneously.

- Suppose that $N_5 = 0$. Then $b = 7$, $d = 8$, $e = 2$ and $c = a + 3$, and there are six possible values for N which are 187248723, 287258723, 387268723, 487278723, 587288723, and 687298723, of which only 187248723, 387268723, and 687298723 satisfy the distinctness of a, b, c, d, and e.
- Otherwise $N_5 = 1001$ so that $\{2-e\} = 1$ and $\{a+3-c\} = 10$ simultaneously. Here $b = 7$, $d = 8$, $e = 1$ and $a - 7 = c$ so that $(a, c) = (9, 2)$ or $(8, 1)$ yielding two more possible values of N which are 987228713 and 887218713, of which only 987218713 satisfies the distinctness of a, b, c, d and e.

Hence the problem has the four solutions:

$$187248723, \; 387268723, \; 687298723, \; \text{and } 987228713.$$

Also solved by Chad Birch, Eastern Kentucky University, Richmond, KY. A partial solution was received from David Ritter, student, Messiah College, Grantham, PA.

Problem 590. *Proposed by José Luis Diaz-Barrero, Universitat Politècnica de Catalunya, Barcelona, Spain.*

Evaluate the following sum: $\displaystyle\sum_{n=1}^{\infty}\left(4^n\cos^2\frac{\pi}{2^{n+2}}\right)^{-1}$

Solution *by the proposer.*

From the identity

$$\frac{1}{\sin^2 x}=\frac{\sin^2\frac{x}{2}+\cos^2\frac{x}{2}}{4\sin^2\frac{x}{2}\cos^2\frac{x}{2}}=\frac{1}{4\sin^2\frac{x}{2}}+\frac{1}{4\cos^2\frac{x}{2}},$$

we get

$$\frac{1}{4\cos^2\frac{x}{2}}=\frac{1}{\sin^2 x}-\frac{1}{4\sin^2\frac{x}{2}}.$$

Applying this recursively, we have

$$\begin{aligned}\sum_{n=1}^{N}\frac{1}{4^n\cos^2\frac{x}{2^n}} &= \frac{1}{\sin^2 x}-\frac{1}{4\sin^2\frac{x}{2}}+\frac{1}{4\sin^2\frac{x}{2}}-\frac{1}{4^2\sin^2\frac{x}{2^2}}\\ &\quad+\cdots+\frac{1}{4^{N-1}\sin^2\frac{x}{2^{N-1}}}-\frac{1}{4^N\sin^2\frac{x}{2^N}},\end{aligned}$$

and

$$\sum_{n=1}^{\infty}\frac{1}{4^n\cos^2\frac{x}{2^n}}=\lim_{N\to\infty}\left(\frac{1}{\sin^2 x}-\frac{1}{4^N\sin^2\frac{x}{2^N}}\right).$$

Setting $x=\frac{\pi}{4}$ in this expression and using L'Hopital's Rule twice yields

$$\sum_{n=1}^{\infty}\frac{1}{4\cos^2\frac{\pi}{2^{n+2}}}=2-\frac{16}{\pi^2}=\frac{2\left(\pi^2-8\right)}{\pi^2}.$$

Also solved by Russell Euler and Jawad Sadek (jointly), Northwest Missouri State University, Maryville, MO.

Problem 591. *Proposed by Stanley Rabinowitz, MathPro Press, Chelmsford, MA.*

Express

$\cos A\cos B\sin(A-B)+\cos B\cos C\sin(B-C)+\cos C\cos A\sin(C-A)$

as the product of three sines.

Solution *by the proposer.*

We have

$$\cos A \cos B \sin(A-B) + \cos B \cos C \sin(B-C) \\ + \cos C \cos A \sin(C-A) = \sin(A-B)\sin(B-C)\sin(C-A)\,.$$

This problem was inspired by problem 2353 from Crux Mathematicorum [1999, p. 316], which showed as part of the problem that

$$\sin A \sin B \sin(A-B) + \sin B \sin C \sin(B-C) \\ + \sin C \sin A \sin(C-A) = \sin(A-B)\sin(B-C)\sin(C-A)\,.$$

Just replace each angle in the Crux result by its complement to get the result for the given problem.

Solution *by Russell Euler and Jawad Sadek, Northwest Missouri State University, Maryville, MO.*

Using the product and factoring formulas of sines and cosines, we have

$$\begin{aligned}
& \cos A \cos B \sin(A-B) \\
& + \cos B \cos C \sin(B-C) + \cos C \cos A \sin(C-A) \\
= \; & \cos A \cos B \sin(A-B) \\
& + \cos C\,[\cos B \sin(B-C) + \cos A \sin(C-A)] \\
= \; & \cos A \cos B \sin(A-B) \\
& + \frac{1}{2}\cos C\,[\sin(2B-C) - \sin C + \sin C - \sin(2A-C)] \\
= \; & \cos A \cos B \sin(A-B) \\
& + \frac{1}{2}\cos C\,[2\cos(A+B-C)\sin(B-A)] \\
= \; & \cos A \cos B \sin(A-B) + \cos C \cos(A+B-C)\sin(B-A) \\
= \; & \sin(A-B)\,[\cos A \cos B - \cos C \cos(A+B-C)] \\
= \; & \sin(A-B)\,[\frac{1}{2}\cos(A+B) + \frac{1}{2}\cos(A-B) \\
& - \frac{1}{2}\cos(A+B) - \frac{1}{2}\cos(2C-A-B)] \\
= \; & \frac{1}{2}\sin(A-B)\,[\cos(A-B) - \cos(2C-A-B)] \\
= \; & \frac{1}{2}\sin(A-B)\,[-2\sin(C-B)\sin(A-C)] \\
= \; & -\sin(A-B)\sin(C-B)\sin(A-C) \\
= \; & \sin(A-B)\sin(B-C)\sin(A-C)
\end{aligned}$$

Problem 592. *Proposed by Stanley Rabinowitz, MathPro Press, Chelmsford, MA.*

The points $(0, 0)$, $(1, 0)$, $(1, 1)$, and $(0, 1)$ are the vertices of a square S. Find an equation in x and y whose graph in the xy-plane is S.

Solution *by the proposer.*

Start with the equation $|x| + |y| = 1$, which is the graph of a diamond. Rotate the axes $45°$ and perform a scaling to get the equation $|x - y| + |x + y - 1| = 1$.

Solution *by Russell Euler and Jawad Sadek, Northwest Missouri State University, Maryville, MO.*

One equation that works is $\max(x, y) = \min(x + y, 1)$.

Problem 593. *Proposed by Kenneth M. Wilke, Washburn University, Topeka, KS.*

Let $N = p^2 + q^2 + r^2 + s^2$, where p, q, r, and s are positive integers such that $pq = rs$. Prove or disprove that N is prime.

Solution *by Carl Libis, University of Rhode Island, Kingston, RI.*

The proof is by contradiction. Assume that N is prime. Since p, q, r, and s are positive and N is prime, we know that N is an odd prime and that at least one of p, q, r, and s is even. Since $pq = rs$, more than one of p, q, r, and s must be even. If exactly two are even, then N is even and therefore not prime. So exactly three of p, q, r, and s are even. Say p, r, and s are even, with $r = 2y$, and $s = 2z$. This implies that $p = 4x$. Thus,

$$\begin{aligned} N &= 16x^2 + 4y^2 + 4z^2 + q^2 \\ &= 16x^2 + 4y^2 + 4z^2 + \frac{y^2z^2}{x^2} \\ &= \frac{16x^4 + 4x^2y^2 + 4x^2z^2 + y^2z^2}{x^2} \\ &= \frac{\left(4x^2 + y^2\right)\left(4x^2 + z^2\right)}{x^2}. \end{aligned}$$

Since $x^2 < 4x^2 + y^2$ and $x^2 < 4x^2 + z^2$, N has two non-trivial factors, which contradicts our assumption that N was prime. Therefore, N is not prime.

Problem 594. *Proposed by the editor.*

The sequence $x_0, x_1, x_2, \ldots$ is defined by the conditions $x_0 = 0, x_1 = 1$, and $x_{n+1} = \dfrac{nx_n + x_{n-1}}{n+1}$ for $n \geq 1$. Determine $\lim_{n\to\infty} x_n$.

Solution *by Russell Euler and Jawad Sadek (jointly), Northwest Missouri State University, Maryville, MO.*

Since the coefficients of x_n and x_{n-1} are positive and add up to 1, one can show that the given sequence is bounded, the subsequence with even indices is increasing, and the subsequence with odd indices is decreasing, and the two subsequences converge to the same limit, L. Now write

$$\begin{aligned} x_{n+1} &= \frac{n}{n+1}x_n + \frac{1}{n+1}x_{n-1} \\ &= \frac{n}{n+1}\left(\frac{n-1}{n}x_{n-1} + \frac{1}{n}x_{n-2}\right) + \frac{1}{n+1}x_{n-1} \\ &= \frac{n}{n+1}x_{n-1} + \frac{1}{n+1}x_{n-2}. \end{aligned}$$

The second and last equalities imply that

$$x_n - x_{n-1} = \frac{x_{n-2} - x_{n-1}}{n}.$$

Taking into account that $x_0 < x_2 < x_4 < \cdots < x_{2n} < \cdots < L$ and $x_1 > x_3 > x_5 > \cdots > x_{2n+1} > \cdots > L$, an induction argument gives

$$x_n - x_{n-1} = \frac{(-1)^n}{(n+1)!}. \, (*)$$

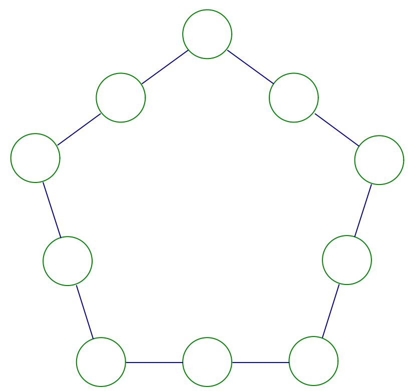
Setting $S_{2n} = (x_2 - x_0) + (x_4 - x_2) + \cdots + (x_{2n} - x_{2n-2}) = x_{2n}$, we get $\lim_{n\to\infty} S_{2n} = \lim_{n\to\infty} x_{2n} = \lim_{n\to\infty} x_n = L$. Finally,

$$\begin{aligned} L &= \lim_{n\to\infty} S_{2n} \\ &= \lim_{n\to\infty}[(x_2 - x_1) + (x_1 - x_0) + (x_4 - x_3) + (x_3 - x_2) \\ &\quad + \cdots + (x_{2n} - x_{2n-1}) + (x_{2n-1} - x_{2n-2})] \\ &= \sum_{n=1}^{\infty} \frac{(-1)^{2n-1}}{(2n)!} + \sum_{n=1}^{\infty} \frac{(-1)^{2n}}{(2n-1)!} \text{ by } (*) \\ &= \sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{n!} \\ &= 1 - e^{-1}. \end{aligned}$$

Also solved by the proposer.

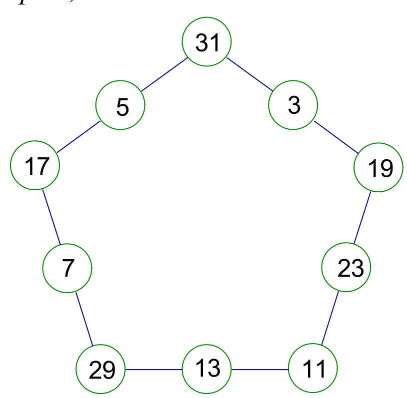
Problem 595. *Proposed by the editor.*

Place the first 10 odd primes $3, 5, 7, 11, 13, 17, 19, 23, 29, 31$ into the circles on the pentagon so that the sum of the entries on each side is the same.



[Thanks to Robert Buskirk for assistance with the diagram.]

Solution *by Sr. Marcella Louise Wallowicz CSFN, Holy Family University, Philadelphia, PA.*



Also solved by Carl Libis, University of Rhode Island, Kingston, RI and Sam Bailie, Eastern Kentucky University, Richmond, KY.

Problem 596. *Proposed by the editor.*

A phone number has the *lazy-finger property* when the next number that you dial (on a touch-tone phone) is either the same number or a number up or down one button or a number to the left or right one button. For example, 555-2365 has the lazy-finger property. How many 7-digit phone numbers that start with a 5 have the lazy-finger property?

Solution *by the proposer.*

Let $p\,(m, n)$ be the number of $(n+1)$-digit phone numbers that have the lazy-finger property and start with m. In particular, $p\,(5, 1)$ counts the phone numbers 52, 54, 55, 56, 58. Hence $p\,(5, 1) = 5$. Using this function and a computer program that counts the number of possibilities that can be reached from each particular button, one obtains $p\,(5, 6) = 5033$. There are 5033 phone numbers that start with 5 and have the lazy-finger property.

Kappa Mu Epsilon News

Edited by Connie Schrock, Historian

Updated information as of August 2006

Send news of chapter activities and other noteworthy KME events to

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Reports of the Regional Conventions

Report of the North Central Regional Convention

April 21-22, 2006

The KME North Central Regional Convention was held April 21-22, 200 at University of Northern Iowa in Cedar Falls, Iowa. 66 people attended from 9 different chapters in 3 states. The host chapter was Iowa Alpha. Six student papers were presented, with awards going to the top two papers. The award winners were Fai Ng from Kansas Delta Chapter and Justin Peters from Iowa Delta Chapter. Dr. Joel Haack of University of Northern Iowa gave an after-lunch talk titled “Counting and Clapping: A Number Theoretic Question from Music.”

Report of the South-Central Regional Convention

April 28 - 29, 2006

The South-Central Regional Convention was held on the campus of Texas Women's University (Texas Gamma) in Denton, Texas on April 28 and 29, 2006. The very capable Corresponding Secretary at Texas Gamma is Dr. Mark Hamner. There were 37 Kappa Mu Epsilon members in attendance and four schools represented. President Don Tosh was able to attend, as well. The convention began Friday with a mixer where KME members in attendance were able to enjoy free pizza, drinks, and snacks provided by the Texas Gamma Chapter. Attendees were also able to participate in some board games, pool, and good discussion with other KME members. On Saturday six student papers were presented. The prizes were awarded, as follows:

- First Place: Virginia Foster Texas Gamma "Optimal Temperature Profile in a Tubular Reactor for the First Order Irreversible Consecutive Reaction"
- Second Place: Timothy Butterworth Oklahoma Delta "Ideal Wheel Path Relationships"
- Third Place: Quentin Schmieding Texas Gamma "Explorations in the Applications of the Vedic System of Mathematics"

A fine banquet was then served at noon on Saturday, followed by a talk by Dr. Junnalyn Navarra-Madsen of Texas Women's University titled "KNOT or NOT: Molecular Biology Ramifications." Awards were then presented to the winners mentioned above. I would like to thank every one at Texas Gamma who helped put on an excellent convention!

Chapter News

AL Alpha – Athens State University

Chapter President– Anne Mariel Gray, 33 Current Members, 15 New Members

Other spring 2006 officers: Allison Stanford, Vice–President; Nicolas Retherford, Secretary; Dottie Gasbarro, Corresponding Secretary.

On April 12, 2006, Athens State University students were initiated into the Alabama Alpha Chapter of Kappa Mu Epsilon.

New Initiates – Sun Bulak, Crystal Gilliland Clowdus, Bethany Franklin, Anna Mariel Gray, Nancy Theresia Gregson, Nancy M. Higdon, Gene McGee, Brandi McIntyre, Erin McConnell McLemore, Meaghan Mitchell, Pao-chen Peng, Nathan Purves, Nich Retherford, Allison Stanford, Sarah Lynn Jones.

AL Zeta – Birmingham Southern College

Chapter President– Gardner Moseley, 11 Current Members, 5 New Members

Other spring 2006 officers: Kelly Bragan, Vice–President; David Ray, Secretary; Jill Stupiansky, Treasurer; Mary Jane Turner, Corresponding Secretary.

There have been guest speakers on campus sponsored by KME. Dr. Jonathan Clark was one of these. His topic pertained to mathematics and the medical field.

CA Delta – California State Polytechnic University

Chapter President– Johanna Tam and Hernan Osco, 30 Current Members, 0 New Members

Other spring 2006 officers: Veselka Danova, Vice–President; Brian Kim, Secretary; Ed Schore, Treasurer; Patricia Hale, Corresponding Secretary.

Ten students were inducted into the National Honor Society. Nine students (3 teams) participated in the COMAP Math Modeling Competition in February 2006; all teams won the second highest award. Several groups of students presented posters at the Sectional Spring Meetings of the MAA; one poster won second place. Several members will be participating in Summer REU Programs.

New Initiates – Megan Bailey, Frank Bermudez, Ken Hendrick, Karen Hoang, Brian Kim, Nathan Olson, Johanna Tam, Nathan Wells, Lam Wong.

CO Delta – Mesa State College

Chapter President – Austin Schneider, 189 Current Members, 6 New Members

Other spring 2006 officers: Matthew Seymour, Vice-President; Eric Miles, Secretary; Michael Brooks, Treasurer; Erik Packard, Cor. Sec.

CO Gamma – Fort Lewis College

Deborah L. Berrier, Corresponding Secretary.

New Initiates – Katherine Crawford, Brian Geisinger, Cassady L. Harraden, Matt Del Margo, Anne Maurer, Keely Moorhead, Jessica Saiz.

CT Beta – Eastern Connecticut State University

Chapter President

Other spring 2006 officers: Mizan R. Khan, Treasurer; Christian L. Yankov, Corresponding Secretary.

New Initiates – Megan T. Amorando, Robert D. Andruskiewicz, Jose A. Aponte, Jessica L. Dow, Erin E. Drew, Megan E. Fearon, Padric W. Hagan, Amanda N. Lakowsky, James W. Lincoln, Daniel D. Piccione, Andrea D. Tarbox.

FL Beta – Florida Southern College

Chapter President– Melena Frett, 10 Current Members, 12 New Members

Other spring 2006 officers: Melissa Nolet, Vice–President; Worthy Sizemore, Secretary; Allen Wuertz, Corresponding Secretary.

New Iniatiates – Kristin Louise Alfero, Courtney J. Baker, Jacqueline L. Barenborg, Cathy C. Cherenfant, Dominic A. Girod, Rebecca Anne Jackey, Michele Lynn Mitchell, Melissa J. Nolet, Christina A. M. Parks, Justin J. Quinn, Worthy Jean Sizemore, Lindsey Diane Tryon.

GA Alpha – University of West Georgia

Scott Sykes, Corresponding Secretary.

New Initiates – Achilke A. Areh, Michael Berglund, Andrea Dee Chaney, Heather Renae Dahlin, Michael Davis, Anthony Thomas Gray, Jennifer M. Kelly, Dawn D. Liverman, Anne E. Marmann, Michael H. McClain, Todd L. Moody, Chertl L. Moore, Jalpa Patel, Ashley Ribera, Chris Shacklady, Gerald A. Shumake, Jennifer Wells, Tracey Williams.

GA Delta – Berry College

Chapter President – Matt Evans, 24 Current Members, 18 New Members,

Other spring 2006 officers: Daniel Murphree, Vice-President; Sunan Zhang, Secretary; Ron Taylor, Corresponding Secretary.

New Initiates – Trinity Leigh Allen, Allison Ann Arrendale, Laura Katherine Baugh, Cori Amanda Cason, Evelyn Ruth Cowan, Sarah Michelle Earl, Charles Matthew Evans, Susanne Elise Galyon, Susan Grout, Blake Joshua Jackson, Daniel Thomas Murphree, Molly McKellar Nelson, Justine Elizabeth Nickerson, Erin Paige Ricker, Rosann Rumstay, Amanda Nicole Stiefel, David Christopher Webb, Sunan Zhang.

IA Alpha – University of Northern Iowa

Chapter President– Lynne Dieckman, 37 members, 5 New Members.

Other spring 2006 officers: Jake Ferguson, Vice–President; Erin Conrad, Secretary; Paul Grammens, Treasurer; Mark D. Ecker, Corresponding Secretary.

Student member Brad Schoening presented his paper “Modeling Wins in Major League Baseball" at our first spring KME meeting on

February 13, 2006 at Professor Syed Kirmani's residence. Our second meeting was held on March 20, 2006 at Professor Mark Ecker's residence where student member Erin Conrad presented her paper on "The Birthday Problem".

The Spring 2006 KME Regional conference was hosted this year by Iowa Alpha; 56 students and faculty from across the Midwest traveled to the University of Northern Iowa (66 total attendance including UNI). Six students presented their KME papers at the conference and Professor Joel Haack gave the after-lunch talk entitled "Counting and Clapping: A Number Theoretic Question from Music".

Student member Kyle Nodurft addressed the spring initiation banquet with "Blackjack Probabilities". Our banquet was held at the Great Taste Buffet in Waterloo, IA on April 24, 2006 where five new members were initiated.

New Initiates – William Freese, Colby Goetsch, Linda Isenhower, Dr. Shangzhen Luo, Ben Zaugg.

IA Delta – Wartburg College

Chapter President– Justin Peters, 21 Current Members, 0 New Members
Other spring 2006 officers: Joee Williams, Vice–President; Jill Seeba, Secretary; Tim Schwickerath, Treasurer; Dr. Brian Birgen, Corresponding Secretary.

We sent a number of students to the KME North Central Regional Convention in nearby Cedar Falls, Iowa. One of our members, Justin Peters, presented on research from a summer REU and won one of two awards for top paper. A Wartburg alum who works as a cryptographer for Motorola was the speaker at our annual banquet and initiation ceremony, which was held on April 1; eight members were initiated. We sent two teams of students to participate in the Iowa Collegiate Math Competition in Decorah, Iowa.

IL Beta – Eastern Illinois University

Andrew Mertz, Corresponding Secretary.

New Initiates – Emily E. Brand, Nikkole M. Buchholtzer, Maria Christina Carrillo, Kevin D. Coulton, Lindsey DiPietro, Molly M. Finley, Chistina Fosdick, Robin M. Grey, Mark B. Johns, Lewis R. Lancaster, Quang (Vince) T. Luong, Dr. Andrew E. Mertz, Hillary L. Nottmeyer, Gregory R. Taeger, Amanda Vozari, Susan C. Wolf.

IL Delta – University of St. Francis

Richard J. Kloser, Corresponding Secretary.

New Initiates – Alain D. Bedi, Kelley M. Craig, Janae E. DeBartolo, Connie M. Diorio, Gina R. Erio, Sarah M. Fryklund, Ryan W. Haun, Jason R. Hischier, Daniel E. McCarthy, Brandon J. Muzzarelli, Erin R. Schubert, Steven C. Sinish, Jeffrey P. Soukup, Jessica M. Sucich.

IL Eta – Western Illinois University

Boris Petracovici, Corresponding Secretary.

New Initiates – Travis Berth, Scott Mikos, Rita Jefferson, Eric Cathelyn.

IL Iota – Lewis University

Margaret M. Juraco, Corresponding Secretary.

New Initiates – Karen Benefield, Robert Denney, Raphael Mascari, Judy Mrgan, Joseph Ninh, Katarzyna Piorek-Olsen, Siobhan Shay.

IL Theta –

Lisa Townsley, Corresponding Secretary.

New Initiates – Laura Boyer, Bradley Callard, Aimee- Jasmine Paran, Debra Witczak.

IN Beta – Butler University

Chapter President– Rebecca Mitchell, 15 Current Members, 8 New Members

Other spring 2006 officers: Taryn Schmidt, Vice–President; Laura Laycock, Secretary; Ezekiel Maier, Treasurer; Amos Carpenter, Corresponding Secretary.

In addition to our monthly meetings, we had three invited speakers. "Nowhere zero 3-flows and mod $(2p + 1)$-orientation in graphs" by Dr. Hong-Jian Lai, "Magical Groups of Imps, Toads and Asteriods" by Prof. Jeremiah Farrell, and "Research Problems for Undergraduates and Some High School Students" by Dr. Joel Rogers.

IN Delta – University of Evansville

Joanne Redden, Corresponding Secretary.

New Initiates – Luanne Benson-Lender, Patrick Blandford, Kevin Daniel Claycomb, Philip Crone, Ryan Egbert, Stephanie Belle Ernst, Brian Albert Fillenwarth, Erica Johnson, Jesse Kahle, Ranjit Lama, Daniel Langenberg, Ashley Ann Lievers, James McDaniel, Molly McLaughlin, Brian Meunier, David Mills, Ashley Neuman, Lori Ogg, Pemba Sherpa, Sarah Elizabeth Schonaman, Lauren Maria Ramsey, Benjamin Sitzman, Addisu Taddese, Joseph A. Turner, Courtney R. Wahl, Amanda Watkins, Maria Ann Weber, Christina Williams, Natalie Youngblood, Talitha Washington.

IN Gamma – Anderson University

Stanley Stephens, Corresponding Secretary.

New Initiates – Laura G. Carpenter, Ryan E. Black, Joshua D. Campbell, Eric B. Davis, Bonnie S. Sorensen, Jacqueline C. D. Vos, Casey Jo Snyder.

KS Alpha – Pittsburg State University

Tim Flood, Corresponding Secretary.

New Initiates – Jennifer Bearden, Justin Fountain, Luke Henke, Michael Humphrey, Sung Wook Kim, Stephanie Schumacher, Justin Tate, Piyush Goyal, Brandy Hill, Jeremiah Johnson, Dusty Peterson, Nathaniel Smith, Krystal Troutman, Katherine Walsh.

KS Beta – Emporia State University

Chapter President– Jacob Magnusson, Current Members, New Members

Other spring 2006 officers: Larry Parks, Vice–President; Mike Moore, Secretary; Greg Stout, Treasurer; Connie Schrock, Corresponding Secretary.

This year Kansas Beta sent teams to the MAA Kansas Section Meeting, in Arkansas City, Kansas. Kansas Beta also participated in the 3rd Annual Pikes Peak Regional Undergraduate Mathematics Conference, and KME Regional Convention in Cedar Falls, Iowa. Jacob Magnusson presented his paper, "An Algorithm for Evaluating Farkel Strategies", at the KME Regional Convention. Some guest speakers over the semester included; Richard Gill of Blue Valley High School, Frank Anderson of Oklahoma City Community College, Dr. David Ewing of Central Missouri State University, Dr. Chuck Moore of Kansas State University. We also attended a talk (Explosive Math by Dr. David Bitters) at UMKC in Kansas City and saw the movie, Proof, afterwards. Some mathematics education majors attended the NCTM conference.

KS Delta –Washburn University

Chapter President– Kristin Ranum, 25 Current Members, 13 New Members

Other spring 2006 officers: Fai Ng, Vice–President; Carolyn Cole, Secretary; Carolyn Cole, Treasurer; Kevin Charlwood, Corresponding Secretary.

The Kansas Delta chapter of KME met for three luncheon meetings with the Washburn Math Club during the semester. Fai Ng prepared to present his research work at the KME regional convention at the University of Northern Iowa by giving a practice talk at one of these meetings. The chapter's annual KME initiation banquet was held on February 20, 2006 with 14 new initiates. Faculty members Mike Mosier and Ron Wasserstein took students Tamela Bolen, Carolyn Cole, Emily Huelskamp, Alexandria Jeannin, Jeff Kingman, Brandy Mann, Richard Nelson II, Fai Ng, and Kristin Ranum to the regional KME convention at IA Alpha in April of 2006. Fai Ng presented his paper, "Health Insurance – Time will Tell" at the meeting, and won a "top two" prize in the judging of both written and oral presentation of his paper, out of the seven presenters at the convention.

New Initiates – Carl Amerine, Earl Amerine, Kimberly A. Bahre, Tamela Kay Bolen, Neal Fultz, Daniel Gorjestani, Kyle A. Groundwater, Kerry J. Helms, Alexandria M. Jeannin, Clint Edward Kendrick, Brandy Mann, Richard W. Nelson II, Sam Thompson, Patrick G. Truitt.

KS Gamma – Benedictine College

Chapter President – Chris G'Sell , 9 Current Members, 5 New Members
Other spring 2006 officers: Erica Goedken , Vice-President; Josie Villa, Secretary; Linda Herndom, Corresponding Secretary.

The Kansas Gamma Chapter was pleased to initiate 5 new members on March 27 since the five current members all graduated on May 13. One member, Stephen Cole, was one of the co-valedictorians of this year's graduating class. He maintained a 4.0 GPA while majoring in mathematics and computer science.

New Initiates – Erica Goedken, Chris G'Sell, Athanasios Markou, Danny Noonan, Josie Villa.

KY Alpha – Eastern Kentucky University

Chapter President– Tracie Prater, 39 Current Members, 18 New Members
Other spring 2006 officers: Meghan Krueger, Vice–President; Katie Gruenwald, Secretary; Erica Cepietz, Treasurer; Pat Costello, Corresponding Secretary.

The February meeting included planning for the semester and a talk by Dr. Pat Costello on "The Chicken Nugget Problem." In March, student KME members Marci Nash, Bobby Adkins, Sarah Morris, Brittany Hensley, and Robert Bassett gave presentations at EKU's 20th Annual Symposium in the Mathematical, Statistical, and Computer Sciences. There was some interest in attending the regional convention in Evansville, but it was the same weekend as the KYMAA meeting. Initiation was held during Dead Week of the semester. Dr. Patrick Costello gave a presentation on "Fibonacci Numbers and the Golden Ratio." After the ceremony, there was cake and drinks to welcome the new members.

KY Beta – University of Cumberlands

Chapter President - Kyle Harris, 40 Current Members, 0 New Members
Other spring 2006 officers: Lane Royer, Vice-President; Kelly Schnee, Secretary; James D. Roaden, Treasurer; Jonathan Ramey, Corresponding Secretary.

On February 24, 2006, the Kentucky Beta chapter held an initiation and a joint banquet with Sigma Pi Sigma, physics honor society at the Cumberland Inn. Kappa Mu Epsilon inducted seven new student members and one new faculty member at the banquet, presided over by outgoing president, Kyle Harris. As an additional feature, senior awards were given by the department at the banquet.

Jointly with the Mathematics and Physics Club, the Kentucky Beta Chapter hosted Dr. Carroll Wells from David Lipscomb University on April 11. He spoke about "Michelangelo to Japan by Way of Grandma's- The Trail of a Geometric Construction." On April 12, members also assisted in hosting a regional high school math contest, held annually at the University of the Cumberlands. On April 25, the entire department, including the Math and Physics Club, Sigma Pi Sigma (Physics Honors Society), and the Kentucky Beta Chapter, held the annual spring picnic at Briar Creek Park.

LA Delta – University of Louisiana at Monroe

Jonathan Cox, Corresponding Secretary.

New Initiates – Teresa Bandrowsky, Amanda Jane Bartlett, Anna Elizabeth Beaubouef, Sunny Brown, Jennifer Ellerbe, Kenwick Mantrall Larkins, Stephanie Mullins, David Philips, Ruby Elizabeth Riles, Thomas Savage, Terrell Sharplin, Kimberly Vaughn, Michael Broome, Amanda Carter, Tedi Cox, April Picard, Connie Smith.

MA Alpha – Assumption College

Chapter President– Brent Hager, 11 Current Members, 12 New Members
Other spring 2006 officers: Heather Leaman, Vice–President; Kathryn Sullivan, Secretary; Maura Heney, Treasurer; Charles Brusard, Corresponding Secretary.

New Initiates – Alexandra T. Cannon, Stacy R. Comer, Ashley E. Daly, Bethany Hordern, Erin L. Hurley, Kristin L. Kenney, Katy M. Lanouette, Courtney E. Markey, Jeffrey McNeil, Stacey L. Stewart, Matthew S. Stopp, Heather Tierney.

MD Alpha – College of Notre Dame of Maryland

Chapter President – Sarah Wassink, 18 Current Members, 6 New Members
Other spring 2006 officers: Allison Kingsland, Vice-President; Amanda Reiner, Secretary; Alka Sharma, Treasurer; Margaret Sullivan, Corresponding Secretary.

Our chapter provided tutoring services to students in beginning courses both semesters. At our April Induction Ceremony we welcomed 6 new members and celebrated twelve members' coming graduation. Our speaker, Colonel John Wassink of the US Marine Corps and currently working at the Pentagon, shared his personal experiences of mathematical applications encountered in flight training including his time spent as a test pilot and a pilot flying from aircraft carriers.

MD Beta – McDaniel College

Dr. Harry Rosenzweig, Corresponding Secretary.

New Initiates – Jessica Dittman, Katherine Williams.

MD Delta – Frostburg State University

Chapter President – Kimberly Embrey, 20 Current Members, 9 New Members.
Other spring 2006 officers: Matt Crawford, Vice-President; Terry Apple, Secretary; Jeff Meyer, Treasurer; Dr. Mark Hughes, Corresponding Secretary.

The Maryland Delta Chapter had an organizational meeting in February where we planned for fundraisers to be held in March. As with last year, members held a Pi Day bake sale and a candy Easter egg sale. These events were rather successful with about $140 raised altogether. Several members worked hard to prepare the baked goods for Pi Day. During our April meeting officers for the upcoming school year were elected. Timothy Smith will be serving as President backed up by Kyle Conroy as Vice President, Brad Yoder as Treasurer and Nicole Garber as Secretary. Other April activities included helping the FSU Mathematics Symposium run smoothly and sponsoring Dr. Edward White's famous "1 = 2" lecture. In May, we held a picnic for KME members and math majors. This semester we bid farewell to Dr. White who retires after 27 years at FSU and decades of service to KME.

MD Epsilon – Villa Julie College

Chapter President – Zack Haney, 24 Current Members, 17 New Members

Other spring 2006 officers: Rachel Bauer, Vice-President; Pam Smith, Secretary; Tami Ford, Treasurer; Dr. Christopher E. Barat, Corresponding Secretary.

The Chapter was officially installed and the initial 17 members were initiated at a ceremony on December 3, 2005, in VJC's St. Paul Companies Pavilion. Dr. Donald Tosh, President of KME, was present to conduct the installation. During the spring semester, the Chapter held a raffle and a drawing to raise funds for future activities. 24 students and 4 faculties were invited to be initiated into KME in Fall 2006.

MI Alpha– Albion College

Mark Bollman, Corresponding Secretary.

New Initiates – Carmen Weddell, Brian Dick, Dustin Turner, Kate Walton.

MI Epsilon (Section A) – Kettering University

Chapter President– AJ Norton, 106 Current Members, 13 New Members

Other spring 2006 officers: Adam Koestler, Vice–President; Jason Pieper, Secretary; Ben Koestler, Treasurer; Boyan N. Dimitrov, Corresponding Secretary.

There was a Pizza Party/Movie on 3rd Thursday (January 26) at 12:20 in one of the large class rooms. The movie was "Leonardo da Vinci. Renaissance Master." There was another free movie shown in our McKinnon Theatre on Tuesday, February 21, at 6:30 pm. The movie "Infinite Secrets" presented an amazing story about the lost book of Archimedes, the book which could accelerate the development of science by hundreds of years.

The Initiation Ceremony for our new KME members was hold on 9th Friday (March 10) at 6:30 p.m. in the Sunset Room of the Kettering cafeteria. There were 13 initiates and 21 family members attending the ceremony. The Keynote Speaker, Bill Guttrich, now Global Sales Manager at Gasoline Management Systems at Delphi Energy and Chases System, a former Kettering graduate talked about his experience in the use of Mathematics as a student, worker, manager, and in his inter-relationships in the market.

MI Epsilon (Section B) – Kettering University

Chapter President– Scott Porter, 121 Current Members

Other spring 2006 officers: Michaei Koch, Vice–President; Dave Minock, Secretary; Tony Heitmann, Treasurer; Boyan N. Dimitrov, Corresponding Secretary.

On May 9th, 2006 the movie Show "Numb3ers (Protest)" took place for all the students. Here is the Show Summary:

In the Los Angeles office of the Federal Bureau of Investigation, Special Agent Don Eppes and his team investigate critical and baffling crimes with a special edge. That advantage is Don's brother, Charles Eppes, a brilliant Universalist mathematician who uses the science of mathematics with its complex equations to ferret out the trickiest criminals. With this team, the forces of evil learn their number is up. Don and his team investigate an anti-war bombing outside an Army recruiting center that resembles the work of a 1970s anti-war activist who disappeared 30 years earlier after being accused of planting a bomb that killed two people. Retired Agent Thomas Larson, who tried to solve the case 30 years ago, returns to help but questions Don's loyalty when it is revealed Alan knew the radical activist and participated in demonstrations with him, thus causing tension within the family.

The Initiation Ceremony for new members of Section B students was postponed for the Fall term of 2006.

As exciting news we have that the planned sometime ago for students "Applied Mathematics Award" started. We have collected two nominations: One is from professor Brian McCartin (the former KME Faculty sponsor), for Matthew F. Causley, and one from professor Boyan Dimitrov (the KME Corresponding Secretary, and founder of this award), for George Hayrepetyan. There is $500 for this award offered each year and it is still in process, who will be the awarded nominee. Both students are our Applied Mathematics majors.

I am happy also to inform you that Matt Causley, one of the nominated students above, has been awarded an NJIT Presidential Fellowship to pursue his PhD in their Department of Mathematical Sciences. This includes a $24K yearly stipend together with tuition remission ($17K/yr) and textbooks. If you would like to offer congratulations, his email address is matt.causley@gmail.com.

New Initiates – Andrew J. Boes, Mary Katherine Cole, Marcin Zbigniew Fracz, Sean Robert Hill, Kizzmett Mary Pringle, Martin Schroeder, Emily Kate Barry, Stephen T. Bozymowski, Samuel Joseph Cooper, Pangnu Hang, Juan E. Ornelas, Jason L. Sanger, Katherine Christin Thome.

MO Alpha – Missouri State University

Chapter President– April Williams, 25 Current Members, 4 New Members
Other spring 2006 officers: Samantha Cash, Vice–President; Chad Gripka, Secretary; Uriah Williams, Treasurer; John Kubicek, Corresponding Secretary.

During the Spring Semester we held monthly meetings. Programs included two faculty presentations and a presentation by a group of students form differential equations showing some of the applications they have studied. Jim Black, April Williams, and the faculty sponsor attended the regional convention at the University of Northern Iowa. April Williams received the KME Merit Award for this academic year.

New Initiates – Thomas J. Buck, Annie Johnson, Nicole A. Clark, Matthew Knepper.

MO Gamma – William Jewell College

Chapter President– Andrew Gard, 8 Current Members, 12 New Members
Other spring 2006 officers: Cameron Cupp, Vice–President; Elizabeth Jones, Secretary; Dr. Mayumi Sakata Derendinger, Treasurer; Dr. Mayumi Sakata Derendinger, Corresponding Secretary.

New Initiates – Alan Dale Richey, Maria Tollefson, Cameron Cupp, Elizabeth Jones, Thomas Rychlewski, Tim Skalland, Jessica Williams, Ryan Alvarado, Stephen Bader, Allison Cobb, Lea Hogsett, Zack Reed.

MO Iota – Missouri Southern

Chip Curtis, Corresponding Secretary.

New Initiates – Robert S. Brown, Shari Gates, Joshua Smith, Steven Tackett, Tracy Theissen, Alexandar Vassilev, Jared Wilkinson.

MO Kappa – Drury University

Carol Browning, Corresponding Secretary.

New Initiates – Colleen Boerner, Rachel Burnham, Keith Coates, Jared Durden, Jason Lowenthal, Whitney Morris, Heidi Mundle, Amanda Newton, Cody Pace, Forrest Schaeffer, Jessica Sierzchula, Veronica Smith, Nathan Thieman.

MO Lambda – Missouri Western State College

Chapter President– Whitney Schell, 20 Current Members, 11 New Members
Other spring 2006 officers: Logan Compton, Vice–President; Tammy Liebersbach, Secretary; Jason Briscoe, Treasurer; Steve Klassen, Corresponding Secretary.

MO Nu – Columbia College

Chapter President- Heidi Steenblock, 13 Current Members, 6 New Members

Other spring 2006 officers- Mandy Jorgenson, Vice President; Chris Schoonover, Secretary; Laurie Weaver, Treasurer; Dr. Ann Bledsoe, Corresponding Secretary.

KME members had worked on several projects during the spring semester 2006: they prepared a wallet size tip tables and posted them on the KME bulletin board; organized and conducted the spring 2006 KME initiation ceremony, held on April 7, 2006; and finally volunteered at the Ronal McDonald House (prepared and served hot meals there).

New Initiates – Amanda E. Jorgenson, Athanasios T. Kardon, Mark A. O'Laughlin, Christina D. Schoonover, Heidi A. Steenblock, Laura P. Weaver.

MO Theta – Evangel University

Chapter President– Josh Thomassen, 14 Current Members, 4 New Members.

Other spring 2006 officers: Lurena Erickson, Vice–President; Don Tosh, Corresponding Secretary.

Meetings were held monthly, with the final meeting held at the home of Dr. Tosh. At the first meeting in January four students were initiated. In April Dr. Tosh and five students traveled to the regional convention in Cedar Falls, Iowa, where two chapter members, Dianne Henry and Andrew Reed, presented papers.

New Initiates – Matthew DeVore, Lurena Erickson, Lindsay Hull, Monica Pederson.

MO Zeta – University of Missouri

Roger Hering, Corresponding Secretary.

New Initiates – Ryan Andrews, Nathan Brandt, Scott Buchholz, Jessica Edgar, Benjamin Irwin, Jamie Klemmer, John Koch, Nicholas Mentesana, Elizabeth Milster, Josh Mueller, Michael Mueller, Gavin Risley, Aaron Terrell, Ryan Tarrell.

MS Alpha – Mississippi University for Women

Chapter President – Sarah Sheffield, 15 Current Members, 1 New Member

Other spring 2006 officers: May Hawkins, Vice-President; Johanna Rodriguez, Secretary; Vasile (Johnny) Bratan, Treasurer; Dr. Shaochen Yang, Corresponding Secretary.

MS Alpha had two meetings during spring 2006. Initiation of new members was held on Feb. 23, 2006. MS Alpha also held a game night on March 3, 2006.

MS Epsilon – Delta State University

Paula A. Norris, Corresponding Secretary.

New Initiates – Mary Katherine Dempsey, David Jay Hebert, Bryan Kelley, April Sanders, Ryne Shackleford, Mack Smith, Mary Clair Thompson, Lee Inmon Virden.

NE Alpha – Wayne State College

John Fuelberth, Corresponding Secretary.

New Initiate – Haley Thorpe.

NE Beta – University of Nebraska at Kearney

Chapter President – Neil Hammond, 17 Current Members, 6 New Members

Other spring 2006 officers: Ty Haussler, Vice-President; Amber Norman, Secretary; Adam Sevenkar, Treasurer; Dr. Katherine Kime, Corresponding Secretary.

In spring 2006, KME members graded tests and assisted with activities in Math Counts on the UNK campus. We also had Math Fun Day at a local elementary school for the second year. We initiated new members at the Alumni House and had pizza afterwards. One graduating KME member, Lindsay Higgins, received honors recognition by the College of Natural and Social Sciences and was presented at the ceremony by Dr. Kime. Our pink and grey KME honor cords, previously designed by the membership, are available for KME members to wear at graduation.

NE Delta – Nebraska Wesleyan University

Chapter President– Marcus Hatfield, 8 Current Members, 0 New Members

Other spring 2006 officers: Zach Brightweiser, Vice President; Kyle Nelson, Secretary; Kyle Nelson, Treasurer; Melissa Erdmann, Corresponding Secretary.

New Initiates – Cody Caster, Kyle Elsasser, Marcus Hatfield, Kyle Nelson, Stephen Ray, Jeremy Sokol, Bruce Thummel, Melissa Boettcher.

NH Alpha – Keene State College

Vincent J. Ferlini, Corresponding Secretary.

New Initiates – Chloe Holmes, Don Leger, Melanie Preve, Jill Riehl, Kaitlyn Taft, Susanna Ayers, Williams Coutts, Boyd Schiemann.

NJ Beta – Montclair State University

John G. Stevens, Corresponding Secretary.

New Initiates – Jachkson Kemper Burton III, Michelle Enderle, Renee C. Heller, Tao Jian, Priyanka Koul, Kristina Oriente, Steven Spero.

NJ Gamma – Monmouth University

Judy Toubin, Corresponding Secretary.

New Initiates – Nichole M. Camasta, Ian Christopher Craig, Kelly Fitzgerald, Lauren M. Francis, Katharine M. McDonough, Kristen N. Muscarella, Audrey Leigh Nelson, Michael A. Pizzulli, Karen Szabunia.

NM Alpha – University of New Mexico

Pedro Embid, Corresponding Secretary.

New Initiates – Miena Armanious, John Binnert, Chryssa Charalambides, Vicki Chavez, Erik B. Erhardt, Jillian Erickson, Carl Grover, Shadi Khalil, Hyeonju Kim, Shannon Kinkead, Alan Means, Juan Ortiz, Adam Ringler, Erin Shrouf, Jason Terry, Lindsey Wesenberg.

NY Eta – Niagara University

Chapter President– Matt Nethercott, 30 Current Members, 15 New Members

Other spring 2006 officers: Adam Meyer, Vice–President; Megan Zdrojewski, Secretary; Megan Zdrojewski, Treasurer; Richard Cramer-Benjamin, Corresponding Secretary.

Our main event this semester was the initiation of new member which took place April 5, 2006. About 50 persons, including initiates, students, friends, relatives and faculty were in attendance. Dr. William Price entertained the group with an enlightening presentation on the topic of mathematics and magic.

New Initiates – Robert Vincent Abrams III, Aris Margaret Allen, Sarah Blaisdell, Connie Devlin, Samantha E. English, Leslie Ann Ferguson, Caroline Eliza Gundel, Daniel Krolewski, Jacquie Lynn Lunser, Heather Ricciuti, Lindsay C. Roberts, Karen Lynn Schmitt, David J. Stoveld, Katharine Striewing, Ashley Wood.

NY Iota – Wagner College

Dr. Zohreh Shahvar, Corresponding Secretary.

New Initiates –Corrine Travous, Giovanni Farro, Patricia Marrone, Cory Rhoades.

NY Kappa – Pace University

Lisa Fastenberg, Corresponding Secretary.

New Initiates – Michael Brady, Tian Cai, Rebecca Conley, Laura Jacob, Marissa Marchetti, Lorelei Reynolds, Ashley Wallace.

NY Lambda – Long Island University

Chapter President– Laura G. Silverman. 12 Current Members, 8 New Members

Other spring 2006 officers: Dr. Andrew M. Rockett, Corresponding Secretary.

Eight students were initiated into the New York Lambda Chapter by Laura G. Silverman and Andrea M. Lorusso during our annual banquet at the Greenvale Town House restaurant on the evening of April 23rd, bring the Chapter membership to 272. Kimberly Pina spoke on The Prime Number Theorem and the evening concluded with the announcement of the 2005-2006 departmental awards: the Claire F. Adler Award to Jennifer Flynn, and the Joseph Panzeca Memorial Award to Kimberly Pina; the Dean Schmidt Scholarship Award for Graduate Study to Ana Santos;

and the presentation by Dr. James V. Peters of several MAA students memberships.

New Initiates – Daniel Bartolomeo, Maria Convey, Lorraine Hanly, William Miller, Thomas Moran, Kimberly Pina, Ana Santos, Robert Stoffers.

NY Nu – Hartwick College

Chapter President– Michaela Kollisch-Singule, 20 Current Members, 19 New Members

Other spring 2006 officers: Melissa Wasson, Vice–President; Caitlin Gilman, Secretary; Nichola Thomas, Treasurer; Ron Brzenk, Corresponding Secretary.

New Initiates – Joseph Fayton, Anees Gharzita, Caitlin Gilman, Gregory Hamilton, Ryan Hughes, Michael Lichtenberger, Kathryn Nilsen, Michael Stuart.

OH Alpha– Bowling Green State University

Dr. David E. Meel, Corresponding Secretary.

New Initiates – Kathryn M. Brainard, Kelli R. Brown, Danielle D. Champney, Timothy J. Cieplowski, P. Matthew Claxon, Ryan S. Eiben, Paul T. Erford, Brandon M. Fitch, Dale P. Golden, Matthew P. Gruenwald, Mallory A. Harransky, Georgia C. Harris, Bethany J. Hausch, Scott A. Jones, Zachary S. Kaple, Justin D. Kear, Jieun Kim, Brittany L. Loparich, Elizabeth L. Madsen, Sarah M. Manley, Marelya Mares, Ian R. Nemitz, Melissa M. Pressnell, Amber E. Rinehart, Therese L. Stefanko, Derek A. Steffan, Kyle S. Stellar, Alyssa M. Toole, Jaime L. Utendorf, Kathleen M. Weber, Randy A. Patton, Steven M. Schreck, Curtis J. Bunner.

OH Epsilon – Marietta College

Chapter President – Phil DeOrsey, 15 Current Members, 13 New Members

Other spring 2006 officers: Matthew Hunnefeld, Vice-President; Dr. John C. Tynan, Corresponding Secretary.

New Initiates – Christopher Brewer, Phil DeOrsey, Dan DeZordo, Hannah Erb, Jessica Fleming, Yie Hou, John Hull, Matthew Hunnefeld, Jeremy Jones, Kelsie McCartney, Matthew Rucker, Daniel Stanley, Carl Starkey.

OH Eta– Ohio Northern University

Donald Hunt, Corresponding Secretary.

New Initiates – Gretchen Johanna Deeg, James Ference, Steven Garofalo, Jameson K. George, Nicole R. Hume, Charise M. Kazmierczak, Brittany Metz, Katie Morgan Miklovic, Heather Schimmoeller, Matthew Shonkwiler, Amanda C. Stype, Ashley Yontz.

OH Gamma– Baldwin-Wallace College

Chapter President - Katherine Hastings, 60 Current Members, 19 New Members

Other spring 2006 officers: Mary Mazurkiewicz, Vice-President; Christine Culbertson, Secertary; Stacey Batcha, Treasure; David Calvis, Corresponding Secretary.

New Initiates – Stacey E. Batcha, Amie M. Blaha, Rosa Maria Carosielli, Jennifer L. Cawrse, Michelle M. Clem, Christine E. Culbertson, Berhane T. Ghaim, Kimberly A. Kickel, Ashlee M. Latevola, Lindsay M. Moomaw, Megan E. Moran, Michael A. Morningstar, Amal F. Mustafa, Stephen T. Nawrocki, Susan A. Niese, Angela S. Ricotta, Kay C. Stefanik, Rebecca A. Trendell, Amanda L. Youngmann.

OH Zeta – Muskingum College

Dr. Richard Daquila, Corresponding Secretary.

New Initiates – Kristen Bauer, Cody Brown, Richard Buckalew, Scott Carpenter, Taylor Hammond, Charles Miller, Marissa Mills, Deena Rini, Jamie Snee, Holly Soper.

OK Alpha – Northeastern State University

Chapter President– Josh Hamit, 74 Current Members, 12 New Members
Other spring 2006 officers: Leticia Stone, Vice–President; Jeff Smith, Secretary; Andy Hathcoat, Treasurer; Dr. Joan E. Bell, Corresponding Secretary.

Our spring activities began with a presentation by John Hornsby from the University of New Orleans. Over 200 students and faculty attended his Math Class Goes to Hollywood presentation. This entertaining and educational talk contained the GOOD, the BAD, and the UGLY mathematics-related videos. The spring initiation of twelve new initiates was held at a local Chinese restaurant. A Sudoku contest was the main feature at the February meeting. In March we sponsored a presentation by Chesapeake Energy Corporation. One of our recent KME grads, Casey Miller, is a Chesapeake employee. He shared information about this Oklahoma City based company, which is one of the six largest U.S. independent natural gas producers. Our chapter again designed a math T-shirt and we sold 77 shirts. Since each student orders the shirt in his favorite color, our “Wear Your Math T-shirt” days really stand out! The main feature of our March meeting was reruns of our favorites from Math Class Goes to Hollywood. We also worked on problems from The Pentagon while snacking on popcorn. Our last activity was our annual Ice Cream Social.

New Initiates – Bobbie L. Back, Carey L. Brashear, Beatrice N. Drywater, Ronald D. Green, Peggy A. Hladik, Billy J. Hulsey, Michael G. McMahan, Misty D. Megee, Melissa D. Randell, Jeri A. Sappington, Seana E. Smith, Megan R. White, Lauren R. Woods, Tetsuya Yamamoto.

OK Delta – Oral Roberts University

Chapter President – Vijay L. Masillamoni-Karlsson, 150 Current Members, 9 New Members
Other spring 2006 officers: Eric Dunn, Vice-President; Drew Hubbeling, Secretary; Drew Hubbeling, Treasurer; Vincent Dimiceli, Corresponding Secretary.

New Initiates – Collins Chibonga, Eric Dunn, John Estes, Mark Gabbidon, Grant George, Drew Hubbeling, Terata Kanu, Kenya McKinney, Mercy Ndackson.

PA Alpha – Westminster College

Chapter President – Lauren Beichner. 29 Current Members, 10 New Members

Other spring 2006 officers: Sarah Spardy, Vice-President; Christie Grewe, Secretary; Amanda Ganster, Treasurer; Carolyn Cuff, Corresponding Secretary.

New Initiates – John Cochran, Lisa Gayetsky, Michael Henninger, Benjamin Jarrett, Evan King, Dana Larson, Alison McNary, Nicole Panza, Andrew Polack, Curtis Yenyo.

PA Beta – LaSalle University

Chapter President – Meridyth Mascio, 6 Current Members, 3 New Members

Other spring 2006 officers: Thomas Plick, Vice-President; Ami Edwards, Secretary; Melissa Meyer, Treasurer; Dr. Anne E. Edlin, Corresponding Secretary.

The speaker at our induction ceremony was Jonathan Knappenberger who spoke on Cryptography.

New Initiates – Brian Story, Jeremiah Noll, Melissa Ann Meyer.

PA Delta – Marywood University

Chapter President – Elizabeth Dittrich, 2 Current Members, 0 New Members

Other spring 2006 officers: Sr. Robert Ann van Ahnen, Corresponding Secretary.

PA Gamma – Waynesburg College

James R. Bush, Corresponding Secretary.

New Initiates – Brandon Berkshire, Scott Garet, Aaron Giorgi, Ashley Hoover, Marcus Imrich, Denise Kennedy, Christopher Moore, Merissa Scozio, Jennifer Sible.

PA Iota– Shippensburg University

Chapter President – Kristina Yost, 12 Current Members, 5 New Members

Other spring 2006 officers: Shawn Henry, Vice-President; Melinda Meisel, Secretary; Robyn Wolfe, Treasurer; John Cooper, Corresponding Secretary.

Performed road clean up and helped out at Epadel.

PA Kappa – Holy Family University

Sister Marcella Louise Wallowicz CSFN, Corresponding Secretary.

New Initiates – Kevin Anderson, Danielle Fortuna, Nusrat Jahan, Gary Kisselback.

PA Lambda – Bloomsburg University of Pennsylvina

Chapter President – Nick Dermes, 35 Current Members, 11 New Members

Other spring 2006 officers: Dr. Elizabeth Mauch, Corresponding Secretary.

New Initiates – Michael Ganno, Taryn Fox, Nicholas A. Gensel, Christopher Leidich, William B. Mattis, Ashley N. Miller, Sarah O'Brian, Anup Sharma, April Stepanski, Steven Tuckerman, Jason E. Yeager.

PA Mu – Saint Francis University

Katherine S. Remillard, Corresponding Secretary.

New Initiates – Jill Bonanno, Ashlei Eckert, Holly Greene, Lauren Kulak, Jettie Marshall, Jonathan Miller, Samantha Milosh, Steven Nelson, Kelly Sivec, Leah Warmkessel, Brianne Waters, Dr. Norbert Youmbi.

PA Nu – Ursinus College

Jeffrey Neslen, Corresponding Secretary.

New Initiates – Kelly Magnin, Lisa Gilardi, Lynne Erickson, Jessica Furman, Jayne Kunaszuk, Gillian Harnitchek, Jill Reganato, Melissa George, Daniele DeKovitch, Isa Muqattash, Timothy Seibert, Adam Ebling, Zachary Benzier, Jocelyn Gasper, Kevin Metz, Francis Szymanski, Marylisa Gareau, Adam Gordon.

PA Omicron – Univ. of Pittsburgh at Johnstown

8 Current Members

Dr. Nina Girard, Corresponding Secretary.

Our chapter has been inactive on the campus for academic year.

PA Pi– Slippery Rock University

Chapter Presiden – Josh Harpst, 10 Current Members, 6 New Members

Other spring 2006 officers: Emily Hendrickson, Vice-President; Stacey Reynolds, Secretary; Elise M. Grabner, Corresponding Secretary.

New Initiates – Dustin R. Hemphill, Joshua D.A. Harpst, Stacey N. Reynolds, Jared M. Matis, Emily S. Hendrickson, Michelle Komo.

PA Sigma– Lycoming College

Chapter President – Jessica E. Gough, 20 Current Members, 5 New Members

Other spring 2006 officers: Amanda L. Borden, Vice-President; Elizabeth M. Sullivan, Secretary; Dung A. Tran, Treasurer; Dr Santu de Silva, Corresponding Secretary.

The Pennsylvania Sigma Chapter held two formal business meetings, and the annual Induction. The first meeting was in order to approve the proposed inductees, including one faculty member. Subsequent to the induction the annual elections were held, at which Jess Gough was elected to a second term as chapter president. (We use a self-nominating secret ballot, since our numbers are small.) In addition to meetings, the Chapter co-sponsored the Annual Math Awareness Day activities with AMIS (the

Math Club), as well as a Colloquium with the MathSci Department, at which the speaker was Darren Glass of Gettysburg College. (Of the existing weekly Mathematics Colloquia, KME has resolved to sponsor one every Spring semester, most likely the Tuesday immediately preceding the Induction.)

New Initiates – Dr. David G. Fisher, Elizabeth M. Sullivan, Dung A. Tran, Heather E. Weller, Amanda L. Borden.

PA Theta– Susquehanna University

Chapter President – Jacki Jensenius, 40 Current Members, 15 New Members

Other spring 2006 officers: Kristen Aurand, Vice-President; Anuj Sainju, Secretary; Robert Nowicki, Treasurer; Kenneth Brakke, Corresponding Secretary.

The Pennsylvania Theta Chapter of KME held its spring 2006 initiation ceremony on April 9. The graduating seniors wanted to wear KME honor cords at graduation, but since the KME web site says nothing about honor cords, we had to improvise with silver and pink. But we did get honor cords for everybody, which the members could purchase at cost, and we now have a stock for next year.

New Initiates – Travis S. Boop, Alan J. Hack, Katherine V. Halderman, Justin S. Hill, Danielle M. Kahl, Mary A. Korch, Heather M. Nober, Ashley A. Rowell, Lawrence T. Rush, Erin M. Shay, Jeremy Wright.

PA Xi – Cedar Crest College

Chapter President – Meredith Williams, 8 Current Members, 3 New Members

Other spring 2006 officers: Marie Wilde, Corresponding Seccretary.

We had a wonderful year of mostly social activities and a lovely Induction Ceremony on April 20, 2006.

New Initiates – Shelby R. Ellery, Traci Stroherker, Meredith Williams.

SC Epsilon – Francis Marion University

Chapter President— Regina Quick, 6 Current Members, 8 New Members

Other spring 2006 officers: William M. Putnam, Vice-President; Joshua Kevan Croteau, Secretary; Joshua Kevan Croteau, Treasurer; Damon Scott, Corresponding Secretary.

This year, the South Carolina Epsilon chapter at Francis Marion University hosted the Kappa Mu Epsilon Region Three regional conference. This it did in conjunction with the Francis Marion Undergraduate conference sponsored by the National Science Foundation. Several students from different universities with KME chapters attended and presented their work.

SC Gamma – Winthrop University

Dawn Strickland, Corresponding Secretary.

New Initiates – Robert Lee Fischer, Joshua Richard Jones, Kyle Matthew Neeley, Anna Lindsay Sacks.

SD Alpha – Northern State University

Dr. Mike Melko, Corresponding Secretary.

New Initiates – Dan DeWitt, Tracy Haan, Laura Nelson, Angie Olson, Renee Zomers, Alyssa Malsom, Brandi Johnson, Daniel Stanton.

TN Beta – East Tennessee State University

Dr. Lyndell Kerley, Corresponding Secretary.

New Initiates – Kinberly Campbell, Paul Giblock, Glenn Quarles, Hamilton Scott, David Simpson, Jennifer Woodell.

TN Delta – Carson-Newman College

16 Current Members, 10 New Members.

B. A. Starnes, Corresponding Secretary.

New Initiates – Kenneth P. Massey, R. Alex Cate, Brittany E. Hall, Brian McLaughlin, Lindsay Leigh McLaughlin, N. Brett Ray, Stephanie R. Taylor, Samantha Jo Wymer, Daniel M. Young, Anna E. Davis.

TN Epsilon – Bethel College

Chapter President – Daniel Cooley, 10 Current Members, 7 New Members.

Other spring 2006 officers: Jessica Smith, Vice-President; Kamela Rogers, Secretary; Heather Brannon, Treasurer; Mr. Russell Holder, Corresponding Secretary.

New Initiates – Stephenie Brown, Rebeca Lewis.

TN Gamma – Union University

Chapter President– Denise Baughman, 14 Current Members, 5 New Members

Other spring 2006 officers: Kendal Hershberger, Vice–President; Josh Shrewsberry, Secretary; Josh Shrewsberry, Treasurer; David Moses, Webmaster; Bryan Dawson, Corresponding Secretary.

The TN Gamma chapter met at the Old Country Store on Thursday, April 6 for our annual initiation banquet. The speaker was former chapter vice president Caroline Ellis ('02); five new members were initiated.

An end-of-year party jointly hosted with the local ACM chapter and the departments of Mathematics and Computer Science was held in a gazebo behind Poplar Heights Baptist Church on Tuesday, May 9. Seniors were honored and departmental awards were announced. Among the honorees was chapter president Denise Baughman, who won the award for highest score among Union students on the mathematics Major Field Achievement Test. Additional awards were presented the following day at the university's Awards Day ceremony; Denise Baughman won the academic achievement medal in mathematics (for graduating seniors) and new initiate Matthew Dawson won the Wolfram Award in Computational Science (for freshmen calculus students).

New Initiates – Matthew Glenn Dawson, Rachel Humphrey, Kenneth Lewoczko, Robbyn Reynolds, William L. Trautman.

TX Alpha – Texas Tech University

Dr. Anatoly B. Korchagin, Corresponding Secretary.

New Initiates – Edward G. Alvarado, Jason A. Arnold, Jacob A. Barela, Travis M. Bayer, Audrey Anna Bostedt, Corey A. Branson, Belinda L. Brooner, Angelica Carrillo, Billy R. Clark, Samuel A. Cuevas, Brittani R. Francke, , Caleb L. Francis, Michael C. Grimm, Trevor M. Hannon, Mark J. Harding, Matthew P. Hershey, Kale M. Jackson, Jeremy V. Kight, Kyle A. King, John A. Kissko, Miles D. Kroeger, Glenn E. Lahodny, Lindsay R. Lamons, Robert B. Lyon, Sibi Mathew, Evan J. Matthews, Ryan C. McAuliffe, Isaac D. Medina, Jessica D. Meixner, Russell L. Miller, Troy Jered Mills, Jacqueline V. Molina, Adam Namal, AnaLaura Olvera, Alex G. Pearson, Kevin M. Phelan, Graham R. Reiff, Matthew A. Reyes, Tara A. Scarborough, Jason K. Schneider, Whitney L. Shaeffer, Morris R. Tk, Homer A. Torres, Christian Vega, Ryan R. Warmke, Ryan M. Warren, Matthew S. Wilhelm, Marc Zachrau, Jennifer L. Ziervogel.

TX Eta – Hardin–Simmons University

Chapter President- Melissa McClanahan, Current Members, 10 New Members

Other spring 2006 officers: Josh Vaughn, Vice-President; Virginia Aguilar, Secretary; Kenneth Davis, Corresponding Secretary.

The 30th annual induction ceremony for the Texas Eta Chapter was held March 28, 2006. There were ten new members: Virginia Aguilar, Jacob Almack, Beth Ann Craig, Brian Fields, Ryan Flanigan, Jerry Fowler, Chandra Hayes, Blake Koch, K'rin Nabors, Sid John Regala, Amy Smith and Kelsey Watts. With the induction of these members, total membership in the local chapter stands at 261. Leading the induction ceremonies were President Melissa McClanahan, Vice-President Mica Henson and Secretary Stephanie Irwin. Following the ceremony and the taking of the club picture, KME adjourned. Then the members and chapter sponsors enjoyed pizza and cold drinks. Mica Henson received Holland Metal for outstanding graduating mathematics senior, while Beth Ann Craig and Jerry Fowler received the Holland Scholarship for the exceptional academic achievements in the school of Mathematics and Natural Science.

Newly elected chapter officers for the 2006-2007 year are: President McKade Marshall, Vice-President Josh Vaughn and Secretary Virginia Aguilar. Dr. Edwin Hewett, Dr. Andrew Potter, Mr. Patrick Miller are chapter sponsors.

New Initiates – Virginia Aguilar, Jacob Almack, Beth Craig, Brian Fields, Jerry Fowler, Blake Koch, K'rin Nabors, Sidjohn Regala, Amy Smith, Kelsey Watts.

TX Kappa – University of Mary Hardin–Baylor

Chapter President– James Parten, 10 Current Members, 4 New Members

Other spring 2006 officers: Peggy Cain, Vice-President; Mark Leech, Secretary; Peter H. Chen, Corresponding Secretary.

New Initiates – Kimberly Eskew, Amada Fritz, David Johnson, John Mixon.

TX Lambda– Trinity University

Diane Saphire, Corresponding Secretary.

New Initiates – Erin Algeo, Jason Ballengee, Susan Beall, Nichole Bouley, Ryan Cook, Thomas Dietzel, Brittney Elko, William French, Colby Frerich, Megan Gallant, Anna Grossman, Trupti Kansara, Kelly Leyendecker, Andrew Maloney, Jordan Marshall, Robert McKinney, Jocelyn Stokes, Kate Walker, Sharon Wells.

TX Mu – Schreiner University

Chapter President- Matthew Casey, 7 Current Members, 4 New Members

Other spring 2006 officers: Aaron Mayes, Vice–President; Christian Sasam, Secretary; Meagan Goodson, Treasurer; William M. Silva, Corresponding Secretary.

VA Alpha – Virgina State University

Chapter President – Ronald Daviss II, 15 Current Members, 3 New Members

Other spring 2006 officers: Nathaniel X. Grace III, Vice-President; Christal Harris, Secretary; Dr. Emma Smith, Treasurer; Dr. V. S. Bakhshi, Corresponding Secretary.

All initiates presented research papers at the initiation ceremony. This research was conducted during the summer, 2005 in the Undergraduate Research Program.

New Initiates – John Girchuru, LeVar Henderson, William Renkin.

WV Alpha – Wheeling Jesuit University

Chapter President – Tracy Moody, 8 Current Members, 5 New Members

Other spring 2006 officers: Scott Richardson, Vice-President; Christopher Lim, Secretary; Marc Moody, Treasurer; Dr. Mary Ellen Komorowski, Corresponding Secretary.

WV Beta – Wheeling Jesuit University

Theodore S. Erickson, Corresponding Secretary.

New Initiates – Marc Brodie, Enrique Garcia Moreno E., Christorpher Z. Lim, Tracy L. Moody, Scott D. Richardson.

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KME National Website:
http://www.kappamuepsilon.org/

Active Chapters of Kappa Mu Epsilon

Listed by date of installation

Chapter	Location	Installation Date
OK Alpha	Northeastern State University, Tahlequah	18 April 1931
IA Alpha	University of Northern Iowa, Cedar Falls	27 May 1931
KS Alpha	Pittsburg State University, Pittsburg	30 Jan 1932
MO Alpha	Missouri State University, Springfield	20 May 1932
MS Alpha	Mississippi University for Women, Columbus	30 May 1932
MS Beta	Mississippi State University, Mississippi State	14 Dec 1932
NE Alpha	Wayne State College, Wayne	17 Jan 1933
KS Beta	Emporia State University, Emporia	12 May 1934
AL Alpha	Athens State University, Athens	5 March 1935
NM Alpha	University of New Mexico, Albuquerque	28 March 1935
IL Beta	Eastern Illinois University, Charleston	11 April 1935
AL Beta	University of North Alabama, Florence	20 May 1935
AL Gamma	University of Montevallo, Montevallo	24 April 1937
OH Alpha	Bowling Green State University, Bowling Green	24 April 1937
MI Alpha	Albion College, Albion	29 May 1937
MO Beta	Central Missouri State University, Warrensburg	10 June 1938
TX Alpha	Texas Tech University, Lubbock	10 May 1940
KS Gamma	Benedictine College, Atchison	26 May 1940
IA Beta	Drake University, Des Moines	27 May 1940
TN Alpha	Tennessee Technological University, Cookeville	5 June 1941
MI Beta	Central Michigan University, Mount Pleasant	25 April 1942
NJ Beta	Montclair State University, Upper Montclair	21 April 1944
IL Delta	University of St. Francis, Joliet	21 May 1945
KS Delta	Washburn University, Topeka	29 March 1947
MO Gamma	William Jewell College, Liberty	7 May 1947
TX Gamma	Texas Woman's University, Denton	7 May 1947
WI Alpha	Mount Mary College, Milwaukee	11 May 1947
OH Gamma	Baldwin-Wallace College, Berea	6 June 1947
CO Alpha	Colorado State University, Fort Collins	16 May 1948
MO Epsilon	Central Methodist College, Fayette	18 May 1949
MS Gamma	University of Southern Mississippi, Hattiesburg	21 May 1949
IN Alpha	Manchester College, North Manchester	16 May 1950
PA Alpha	Westminster College, New Wilmington	17 May 1950
IN Beta	Butler University, Indianapolis	16 May 1952
KS Epsilon	Fort Hays State University, Hays	6 Dec 1952
PA Beta	LaSalle University, Philadelphia	19 May 1953
VA Alpha	Virginia State University, Petersburg	29 Jan 1955
IN Gamma	Anderson University, Anderson	5 April 1957
CA Gamma	California Polytechnic State University, San Luis Obispo	23 May 1958
TN Beta	East Tennessee State University, Johnson City	22 May 1959
PA Gamma	Waynesburg College, Waynesburg	23 May 1959
VA Beta	Radford University, Radford	12 Nov 1959
NE Beta	University of Nebraska—Kearney, Kearney	11 Dec 1959
IN Delta	University of Evansville, Evansville	27 May 1960
OH Epsilon	Marietta College, Marietta	29 Oct 1960

MO Zeta	University of Missouri—Rolla, Rolla	19 May 1961
NE Gamma	Chadron State College, Chadron	19 May 1962
MD Alpha	College of Notre Dame of Maryland, Baltimore	22 May 1963
CA Delta	California State Polytechnic University, Pomona	5 Nov 1964
PA Delta	Marywood University, Scranton	8 Nov 1964
PA Epsilon	Kutztown University of Pennsylvania, Kutztown	3 April 1965
AL Epsilon	Huntingdon College, Montgomery	15 April 1965
PA Zeta	Indiana University of Pennsylvania, Indiana	6 May 1965
AR Alpha	Arkansas State University, State University	21 May 1965
TN Gamma	Union University, Jackson	24 May 1965
WI Beta	University of Wisconsin—River Falls, River Falls	25 May 1965
IA Gamma	Morningside College, Sioux City	25 May 1965
MD Beta	McDaniel College, Westminster	30 May 1965
IL Zeta	Domincan University, River Forest	26 Feb 1967
SC Beta	South Carolina State College, Orangeburg	6 May 1967
PA Eta	Grove City College, Grove City	13 May 1967
NY Eta	Niagara University, Niagara University	18 May 1968
MA Alpha	Assumption College, Worcester	19 Nov 1968
MO Eta	Truman State University, Kirksville	7 Dec 1968
IL Eta	Western Illinois University, Macomb	9 May 1969
OH Zeta	Muskingum College, New Concord	17 May 1969
PA Theta	Susquehanna University, Selinsgrove	26 May 1969
PA Iota	Shippensburg University of Pennsylvania, Shippensburg	1 Nov 1969
MS Delta	William Carey College, Hattiesburg	17 Dec 1970
MO Theta	Evangel University, Springfield	12 Jan 1971
PA Kappa	Holy Family College, Philadelphia	23 Jan 1971
CO Beta	Colorado School of Mines, Golden	4 March 1971
KY Alpha	Eastern Kentucky University, Richmond	27 March 1971
TN Delta	Carson-Newman College, Jefferson City	15 May 1971
NY Iota	Wagner College, Staten Island	19 May 1971
SC Gamma	Winthrop University, Rock Hill	3 Nov 1972
IA Delta	Wartburg College, Waverly	6 April 1973
PA Lambda	Bloomsburg University of Pennsylvania, Bloomsburg	17 Oct 1973
OK Gamma	Southwestern Oklahoma State University, Weatherford	1 May 1973
NY Kappa	Pace University, New York	24 April 1974
TX Eta	Hardin-Simmons University, Abilene	3 May 1975
MO Iota	Missouri Southern State University, Joplin	8 May 1975
GA Alpha	State University of West Georgia, Carrollton	21 May 1975
WV Alpha	Bethany College, Bethany	21 May 1975
FL Beta	Florida Southern College, Lakeland	31 Oct 1976
WI Gamma	University of Wisconsin—Eau Claire, Eau Claire	4 Feb 1978
MD Delta	Frostburg State University, Frostburg	17 Sept 1978
IL Theta	Benedictine University, Lisle	18 May 1979
PA Mu	St. Francis University, Loretto	14 Sept 1979
AL Zeta	Birmingham-Southern College, Birmingham	18 Feb 1981
CT Beta	Eastern Connecticut State University, Willimantic	2 May 1981
NY Lambda	C.W. Post Campus of Long Island University, Brookville	2 May 1983
MO Kappa	Drury University, Springfield	30 Nov 1984
CO Gamma	Fort Lewis College, Durango	29 March 1985
NE Delta	Nebraska Wesleyan University, Lincoln	18 April 1986

TX Iota	McMurry University, Abilene	25 April 1987
PA Nu	Ursinus College, Collegeville	28 April 1987
VA Gamma	Liberty University, Lynchburg	30 April 1987
NY Mu	St. Thomas Aquinas College, Sparkill	14 May 1987
OH Eta	Ohio Northern University, Ada	15 Dec 1987
OK Delta	Oral Roberts University, Tulsa	10 April 1990
CO Delta	Mesa State College, Grand Junction	27 April 1990
PA Xi	Cedar Crest College, Allentown	30 Oct 1990
MO Lambda	Missouri Western State College, St. Joseph	10 Feb 1991
TX Kappa	University of Mary Hardin-Baylor, Belton	21 Feb 1991
SC Delta	Erskine College, Due West	28 April 1991
SD Alpha	Northern State University, Aberdeen	3 May 1992
NY Nu	Hartwick College, Oneonta	14 May 1992
NH Alpha	Keene State College, Keene	16 Feb 1993
LA Gamma	Northwestern State University, Natchitoches	24 March 1993
KY Beta	Cumberland College, Williamsburg	3 May 1993
MS Epsilon	Delta State University, Cleveland	19 Nov 1994
PA Omicron	University of Pittsburgh at Johnstown, Johnstown	10 April 1997
MI Delta	Hillsdale College, Hillsdale	30 April 1997
MI Epsilon	Kettering University, Flint	28 March 1998
KS Zeta	Southwestern College, Winfield	14 April 1998
TN Epsilon	Bethel College, McKenzie	16 April 1998
MO Mu	Harris-Stowe College, St. Louis	25 April 1998
GA Beta	Georgia College and State University, Milledgeville	25 April 1998
AL Eta	University of West Alabama, Livingston	4 May 1998
NY Xi	Buffalo State College, Buffalo	12 May 1998
NC Delta	High Point University, High Point	24 March 1999
PA Pi	Slippery Rock University, Slippery Rock	19 April 1999
TX Lambda	Trinity University, San Antonio	22 November 1999
GA Gamma	Piedmont College, Demorest	7 April 2000
LA Delta	University of Louisiana, Monroe	11 February 2001
GA Delta	Berry College, Mount Berry	21 April 2001
TX Mu	Schreiner University, Kerrville	28 April 2001
NJ Gamma	Monmouth University	21 April 2002
CA Epsilon	California Baptist University, Riverside	21 April 2003
PA Rho	Thiel College, Greenville	13 February 2004
VA Delta	Marymount University, Arlington	26 March 2004
NY Omicron	St. Joseph's College, Patchogue	1 May 2004
IL Iota	Lewis University, Romeoville	26 February 2005
WV Beta	Wheeling Jesuit University, Wheeling	11 March 2005
SC Epsilon	Francis Marion University, Florence	18 March 2005
PA Sigma	Lycoming College, Williamsport	1 April 2005
MO Nu	Columbia College, Columbia	29 April 2005
MD Epsilon	Villa Julie College, Stevenson	3 December 2005