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Kappa Mu Epsilon, mathematics honor society, was founded in 1931. The object of the society is fivefold: to further the interests of mathematics in those schools which place their primary emphasis on the undergraduate program; to help the undergraduate realize the important role that mathematics has played in the development of western civilization; to develop an appreciation of the power and beauty possessed by mathematics, due, mainly, to its demands for logical and rigorous modes of thought; to provide a society for the recognition of outstanding achievement in the study of mathematics at the undergraduate level; to disseminate the knowledge of mathematics and to familiarize the members with the advances being made in mathematics. The official journal, THE PENTAGON, is designed to assist in achieving these objectives as well as to aid in establishing fraternal ties between the chapters.

SOME COMMENTS ON $\frac{1}{\text{SIN } X}$ AND $\frac{1}{X}$ ON $(0, \frac{\pi}{2}]$

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Often in mathematical analysis, when functions have limits (finite or infinite), the limits are approached asymptotically. As such a function converges it can have either a 'vertical or a horizontal limit', however, not all functions converge at the same rate as they approach the same limit. Sometimes a relationship between functions may be found which leads to a better understanding of one or both of the functions.

A fairly simple example is the relationship between the functions[1] $\frac{1}{\sin x}$ and $\frac{1}{x}$. If these functions are considered on the interval $(0, \frac{\pi}{2}]$ it is obvious that they are continuous. By looking at a graph of these functions (see Diagram 1), one also sees that

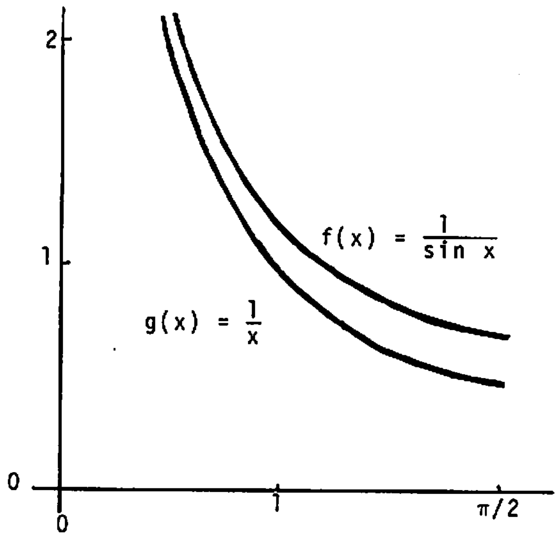

Diagram 1

$\lim_{x\to 0^+} \frac{1}{\sin x} = +\infty$ and $\lim_{x\to 0^+} \frac{1}{x} = +\infty$. In other words, as these functions approach 0 from the right their values approach positive infinity.

A logical first thought might be, is $\frac{1}{\sin x}$ greater than $\frac{1}{x}$ for all values of x as x approaches 0 from the right? Diagram 2, showing the relationship between

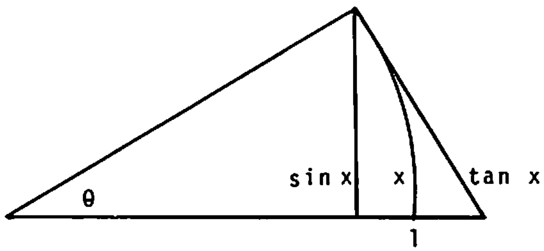

Diagram 2

sin x and x, will help answer this question. In the diagram as well as in the equations, x is measured in radians. One can see that even as θ approaches 0, x must be greater than sin x; in fact, it is clear that $x > \sin x$ for all $x > 0$. By taking the reciprocal of these functions it is indeed found that $\frac{1}{\sin x}$ must be greater than $\frac{1}{x}$ for all x on the interval $(0, \frac{\pi}{2}]$. Thus as the functional values approach positive infinity the graph of $\frac{1}{\sin x}$ will always remain above the graph of $\frac{1}{x}$. However, it is not yet known how much $\frac{1}{\sin x}$ remains above $\frac{1}{x}$ as $x \to 0^+$. That is, what are the relative rates at which $\frac{1}{\sin x}$ and $\frac{1}{x}$ approach positive infinity as x approaches 0 from the right?

At this point very little is understood about the relationship between the convergence of these functions as they approach positive infinity. Another technique that will be helpful is to take the difference between the functions and examine this new function carefully. That is, consider the function $f(x) = \frac{1}{\sin x} - \frac{1}{x}$, for $0 < x \leq \frac{\pi}{2}$. A graph of this new function (see Diagram 3)

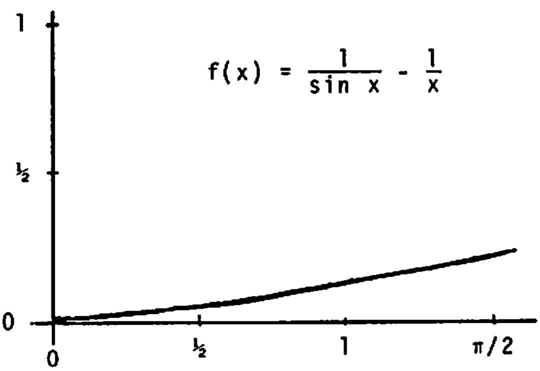

Diagram 3

actually yields very little information; one can surmise that perhaps the function is increasing over the interval.

An obvious test to perform is the first derivative test to see if $\frac{1}{\sin x} - \frac{1}{x}$ is, in fact, increasing.

$$f(x) = \frac{1}{\sin x} - \frac{1}{x} = \csc x - \frac{1}{x}$$

$$f'(x) = -(\csc x)*(\cot x) + \frac{1}{x^2} = \frac{1}{x^2} - \frac{\cos x}{\sin^2 x}$$

$$f'(x) = \frac{\sin^2 x - x^2 \cos x}{x^2 \sin^2 x}$$

One observes that the denominator of $f'(x)$ is positive over the entire interval $(0, \frac{\pi}{2}]$, however it is not clear that the sign of the numerator is positive over the entire interval. For the derivative $f'(x)$ to be positive over the domain $(0, \frac{\pi}{2}]$, $\sin^2 x - x^2 \cos x$ must be proved to be greater than 0 for all x in the domain. Therefore, the inequality $\sin^2 x > x^2 \cos x$ is examined; because x and sin x are both positive one may divide through by x sin x without affecting the sense of the inequality, resulting in $\frac{\sin x}{x} > \frac{x}{\tan x}$ for all x between 0 and $\frac{\pi}{2}$. A geometric interpretation (see Diagram 2) does not prove to be fruitful in establishing the inequality. That is, if indeed it is true. One can see that both $\frac{\sin x}{x}$ and $\frac{x}{\tan x}$ are less than 1,but this does not seem to be helpful in showing the relationship to be true.

Another attack for comparing $\frac{\sin x}{x}$ and $\frac{x}{\tan x}$ is through the use of Taylor's polynomials, where Taylor's formula with the LaGrange remainder is given by:[2]

$$f(x) = f(a) + \frac{f'(a)}{1!}(x-a) + \frac{f''(a)}{2!}(x-a)^2 + \frac{f'''(a)}{3!}(x-a)^3$$

$$+\ldots+ \frac{f^n(\&)}{n!}(x-a)^n \text{ where } \& \text{ is between } x \text{ and } a.$$

Thus if a = 0, then:

$$\sin x = \sin 0 + \frac{\cos 0}{1!}(x)^1 - \frac{\sin 0}{2!}(x)^2 -$$

$$\frac{\cos 0}{3!}(x)^3 + \frac{\sin (\&)}{4!}(x - \&)^4 \text{ where } 0 < \& < x,$$

or

$$\sin x = x - \frac{x^3}{6} + \text{a positive remainder.}$$

In particular, $\sin x > x - \frac{x^3}{6}$.

For tan x, if a = 0, then:

$$\tan x = \tan 0 + \frac{\sec^2 0}{1!}(x)^1 = \frac{2 \sec^2 0 \tan 0}{2!}(x)^2$$

$$+ \frac{4 \sec^2 0 \tan^2 0 + 2 \sec^4 0}{3!}(x)^3$$

$$+ \text{a positive remainder, for all } 0 < x < \frac{\pi}{2}.$$

In particular, $\tan x > x + \frac{x^3}{3}$

Now $\frac{\sin x}{x} > \frac{x - \frac{x^3}{6}}{x}$, and likewise,

$$\frac{x}{\tan x} < \frac{x}{x + \frac{x^3}{3}} .$$

Since $\qquad 3 > x^2$ for $0 < x \le \frac{\pi}{2}$,

we have $\qquad 3x^4 > x^6$,

$$x^2 + \frac{x^4}{6} - \frac{x^6}{18} > x^2,$$

$$(x - \frac{x^3}{6})*(x + \frac{x^3}{3}) > x^2,$$

or finally
$$\frac{x - \frac{x^3}{6}}{x} > \frac{x}{x + \frac{x^3}{3}} .$$

Thus, $\frac{\sin x}{x} > \frac{x - \frac{x^3}{6}}{x} > \frac{x}{x + \frac{x^3}{3}} > \frac{x}{\tan x}$ for $0 < x < \frac{\pi}{2}$.

From this digression it is proven that the first derivative of $f(x) = \frac{1}{\sin x} - \frac{1}{x} > 0$ on the interval $(0, \frac{\pi}{2}]$. Consequently $f(x)$ is not only positive, but also increasing on the interval. Getting back to the point at hand one asks what exactly does this say about the two functions on the interval? This digression reveals that even though $\frac{1}{\sin x}$ is constantly greater than $\frac{1}{x}$ as x approaches 0^+, these functions are getting closer together at all times.

One does not know if these functions are converging at relative or independent rates. The second derivative test for $f(x) = \frac{1}{\sin x} - \frac{1}{x}$ may reveal information on this.

$$f''(x) = \frac{-2}{x^3} + \csc^3 x + (\csc x)*(\cot^2 x)$$
$$= \frac{x^3*(1 + \cos^2 x) - 2 \sin^3 x}{(x^3)*(\sin^3 x)}$$

The denominator of $f''(x)$ is positive over the entire interval and if it can be proven that the numerator is also positive, then the concavity of the function will be known, We ask, is

$$x^3 * (1 \cos^2 x) - 2 \sin^3 x > 0 \text{ for all } 0 < x \leq \frac{\pi}{2},$$

or is

$$1 + \cos^2 x > 2*\left(\frac{\sin x}{x}\right)^3 ?$$

It is again fruitful to resort to Taylor's polynomials for the sine and cosine functions. Their Appropriate Taylor representations are:

$$\cos x = 1 - \frac{x^2}{2} + \text{a positive remainder, and}$$

$$\sin x = x - \frac{x^3}{6} + \frac{x^5}{120} + \text{a negative remainder.}$$

Therefore $$\sin x < x - \frac{x^3}{6} + \frac{x^5}{120}$$

and $$\cos^2 x > (1 - \frac{x^2}{2})^2;$$

thus $$\frac{\sin x}{x} < \frac{x - \frac{x^3}{6} + \frac{x^5}{120}}{x} = 1 - \frac{x^2}{6} + \frac{x^4}{120}$$ and

$$1 + \cos^2 x > 1 + (1 - \frac{x^2}{2})^2 \text{ for all } 0 < x \leq \frac{\pi}{2} .$$

Also,

$$(1 - \frac{x^2}{6} + \frac{x^4}{120})^3 > (\frac{\sin x}{x})^3 .$$

Now $$(1 - \frac{x^2}{6} + \frac{x^4}{120})^3 =$$

$$1 - \frac{x^2}{2} + \frac{13x^4}{120} - \frac{7x^6}{540} + \frac{13x^8}{14400} - \frac{x^{10}}{28800} + \frac{x^{12}}{1728000}$$

and $$1 + (1 - \frac{x^2}{2})^2 = 2 - x^2 + \frac{x^4}{4} .$$

Since $1 > \frac{13}{15} - \frac{14x^2}{135} + \frac{13x^4}{1800} - \frac{x^6}{3600} + \frac{x^8}{216000}$ for all x on $(0, \frac{\pi}{2}]$, we have:

$$2 - x^2 + \frac{x^4}{4} > 2 - x^2 + \frac{13x^4}{60} - \frac{7x^6}{270} + \frac{13x^8}{7200} - \frac{x^{10}}{14400} + \frac{x12}{1728000},$$

or $$1 + (1 - \frac{x^2}{x})^2 > 2(1 - \frac{x^2}{6} + \frac{x^4}{120})^3.$$

In particular,

$$1 + \cos^2 x > 1 + (1 - \frac{x^2}{2})^2 > 2(1 - \frac{x^2}{6} + \frac{x^4}{120})^3 > 2(\frac{\sin x}{x})^3 ,$$

for all x between 0 and $\frac{\pi}{2}$.

This proves that the function $\frac{1}{\sin x} - \frac{1}{x}$ has a positive second derivative over the interval. That in turn proves that f'(x) is concave upward, or as x goes from 0 to $\frac{\pi}{2}$, the rate at which f(x) is increasing, is increasing. Returning to the two asymptotic functions, one sees that the slope at which $\frac{1}{x}$ approaches $+\infty$ is always greater than the slope at which $\frac{1}{\sin x}$ approaches $+\infty$ as x approaches 0 from the right.

A basic understanding between the functions has now been presented. Yet another interesting point of this relationship is what happens as the limit of x is taken at 0^+. One conjectures from the graph that $\lim_{x \to 0^+} \frac{1}{\sin x} - \frac{1}{x} = 0$. This is proved below with the use of L'Hospital's rule.

$\frac{1}{\sin x} - \frac{1}{x} = \frac{x - \sin x}{x * \sin x}$ is of the indeterminant form $\frac{0}{0}$; this makes it in a proper form for using the rule. The results are:

$\frac{1 - \cos x}{\sin x + x * \cos x}$ which is still of the indeterminate form $\frac{0}{0}$, so the process is repeated, yielding:

$$\frac{- \sin x}{2 \cos x - x * \sin x},$$

this form does have a value as x approaches 0^+. The limit of this is $\frac{0}{2}$ or 0. That indicates that $\lim_{x \to 0^+} \frac{1}{\sin x} - \frac{1}{x} = 0$. This, in turn, implies that $\frac{1}{\sin x}$ and $\frac{1}{x}$ approach their vertical asymptotes at the same rate.

However, it is not the case that the slope of $f(x) = \frac{1}{\sin x} - \frac{1}{x}$ (i.e. its derivative) approaches zero as x approaches zero from the right. In fact, we show here that the derivative approaches $\frac{1}{6}$, as $x \to 0^+$. The limit of the slope is determined by using the method of L'Hospital again. The first derivative of f(x) was derived earlier to be:

$$f'(x) = \frac{\sin^2 x - x*\cos x}{x^2*\sin^2 x}\ .$$

This is in the proper form to use L'Hospital's rule. The process yields:

$$\frac{(2 \sin x)*(\cos x) - 2x*\cos x + x^2*\sin x}{2x*\sin^2 x + 2x^2*(\sin x)(\cos x)}\ ,$$

unfortunately this is still of the indeterminate form $\frac{0}{0}$; the process needs to be repeated several more times before a limit can be found. The intermediate steps are listed in their simplified forms now:

$$\frac{2 \cos 2x - 2 \cos x + 4x*\sin x + x^2*\cos x}{2 \sin^2 x + 8x*(\sin x)(\cos x) + 2x^2*\cos x} \to \frac{0}{0}$$

$$\frac{-4 \sin 2x + 6 \sin x + 6x*\cos x - x^2 \sin x}{12(\sin x)(\cos x) + 12x*\cos 2x - 4x^2 \sin 2x} \to \frac{0}{0}\ .$$

The next repetition of this yields the determinable form:

$$\frac{-8 \cos 2x + 12 \cos 2x - 8x{*}\sin x - x^2 \cos x}{24 \cos 2x - 32 \sin 2x - 8x^2{*}\cos^2 x} \rightarrow$$

$$\frac{-8 + 12}{24} = \frac{1}{6}\text{, as } x \rightarrow 0^+.$$

This exercise in repetition of L'Hospital yields the limit of the derivative of $f(x) = \frac{1}{\sin x} - \frac{1}{x}$, as $x \rightarrow 0^+$, as being $\frac{1}{6}$. However, it is far more interesting as to what this says about the relationship between the two asymptotic curves as they converge at $x = 0$. From the results one perceives that limits of the slopes of $\frac{1}{\sin x}$ and $\frac{1}{x}$, as x approaches zero from the right, do not become tangent to each other.

Although there is much more that can be learned about these two functions and how they relate to each other, a basic understanding has been presented and a foundation to work from has been set. One realizes now that the two asymptotic functions $\frac{1}{\sin x}$ and $\frac{1}{x}$ both approach infinity at the same rate yet they never become tangent to one another. This basic exercise can be applied to many sets of asymptotic functions. Of course, these methods may not be suitable and in many cases no results may be determinable, yet in some cases it is apparent that relationships may be found and meaningful insight to the functions may be gained.

BIBLIOGRAPHY

[1]Problem #1160, Mathematics Magazine 55, no. 5 (November, 1982), p. 300.

[2]Munem, Mustafa A. and David J. Foulis, Calculus with Analytic Geometry, New York: Worth Publishers, Inc., 1978.

THE MATHEMATICS OF MUSICAL SCALES

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Music, like photography, gardening, or surgery, is both a science and an art. The science of music forms a strong foundation for the art which people have enjoyed through the centuries. Pythagoras, a 6th century B.C. Greek mathematician, is credited with the first discoveries about the science of music, in particular, the mathematical basis of music. He was able to transform music from probability and guesswork into a "rational pursuit." (Gorman, 1979, p. 161) His musical scale forms a base for various other scales--the scale of just intonation, the scale based on frequencies and partials, and the scale of equal temperament.

A scale is a progression of musical tones. Although there are many scales, this paper will treat only the diatonic scale, the musical progression based on the seven major or minor tones. Recall the song "Do Re Mi" from the musical The Sound of Music. The progression "do - re - mi - fa - so - la - ti - do" is the diatonic scale.

Strings, when vibrating, produce musical tones. Pythagoras discovered the first simple laws of music by observing the ratios of the lengths of these vibrating strings. An interval is the musical distance between two tones. (Machlis, 1970) When an interval is harmonious, its ratio can be expressed in whole numbers. The basic interval in music, the octave, has a ratio of 2:1. A string of any length and a second string of either twice or half that length produce an octave when vibrating. Two other natural intervals, the fourth and the fifth, have ratios of 4:3 and 3:2, respectively. (Boyer, 1968)

The Pythagorean scale is built from the octave and the fifth, beginning with a base note of ratio 1 and the fifth above with ratio 3:2. Positive powers of $^3/_2$ give notes of higher pitch; negative powers of $^3/_2$ give notes of lower pitch. Halving and doubling these ratios as necessary brings those notes by octaves into the base octave. The diatonic scale is formed by using the powers of $^3/_2$ ranging from -1 to 5 and arranging these new ratios in ascending order. (Taylor, 1965) See Table 1.

Table 1

powers of $3/2$	halving, doubling	ascending order	ratio between	
		2		
			$256/243$	semi-tone
$(3/2)^5 = 243/32$	$243/128$	$243/128$		
			$9/8$	whole-tone
$(3/2)^4 = 81/16$	$81/64$	$27/16$		
			$9/8$	whole-tone
$(3/2)^3 = 27/8$	$27/16$	$3/2$		
			$9/8$	whole-tone
$(3/2)^2 = 9/4$	$9/8$	$4/3$		
			$256/243$	semi-tone
$(3/2)^1 = 3/2$	$3/2$	$81/64$		
			$9/8$	whole-tone
$(3/2)^0 = 1$	1	$9/8$		
			$9/8$	whole-tone
$(3/2)^{-1} = 2/3$	$4/3$	1		

(Taylor, 1965)

When the scale is expanded to thirteen notes roughly a semitone apart by adding the sixth power and the remaining negative powers of $^3/_2$, two different notes fall between the fourth and the fifth intervals. See Table 2. Further extension of the powers of $^3/_2$ results in two different notes in each whole tone interval. The notes derived from the positive powers of $^3/_2$ (going up in fifths) are called sharps, and the notes derived from the negative powers of $^3/_2$ (going down in fifths) are called flats. (Taylor, 1965) In all, twenty-two notes comprise the Pythagorean octave.

Table 2

1	$\frac{256}{243}$	$\frac{9}{8}$	$\frac{32}{27}$	$\frac{81}{64}$	$\frac{4}{3}$	$\frac{729}{512}$	$\frac{1024}{729}$	$\frac{3}{2}$	$\frac{128}{81}$	$\frac{27}{16}$	$\frac{16}{9}$	$\frac{243}{128}$	2
C		D		E	F	F#	Gb	G		A		B	C

(Taylor, 1965)

The scale of just intonation was devised by Claudius Ptolemy about 150 A.D. Often called the just scale, it is constructed similarly to the Pythagorean scale. The first five harmonics are produced from a base note with ratio of 1, a fifth above the base note with ratio of

$^3/_2$, and a fifth below the base note with ratio of $^2/_3$. These harmonics are then reduced to the base octave by halving or doubling as necessary. The arrangement of the ratios in increasing order forms the diatonic scale on C. See Tables 3 and 4. (Redfield, 1928; Taylor, 1965; Taylor, 1976) A comparison between the just scale

Table 3

	base	reduced to octave	fifth up	reduced to octave	fifth down	reduced to octave
1st harmonic	1	1	$^3/_2$	$^3/_2$	$^2/_3$	$^4/_3$
2nd harmonic	2	1	$^6/_2$	$^3/_2$	$^4/_3$	$^4/_3$
3rd harmonic	3	$^3/_2$	$^9/_2$	$^9/_8$	$^6/_3$	1
4th harmonic	4	1	$^{12}/_2$	$^3/_2$	$^8/_3$	$^4/_3$
5th harmonic	5	$^5/_4$	$^{15}/_2$	$^{15}/_8$	$^{10}/_3$	$^5/_3$

(Taylor, 1965)

Table 4

Diatonic scale on C (C = base note 1)							
1	$^9/_8$	$^5/_4$	$^4/_3$	$^3/_2$	$^5/_3$	$^{15}/_8$	2
C	D	E	F	G	A	B	C

(Taylor, 1965)

and the Pythagorean scale reveals similarities and differences as illustrated in Table 5.

Table 5

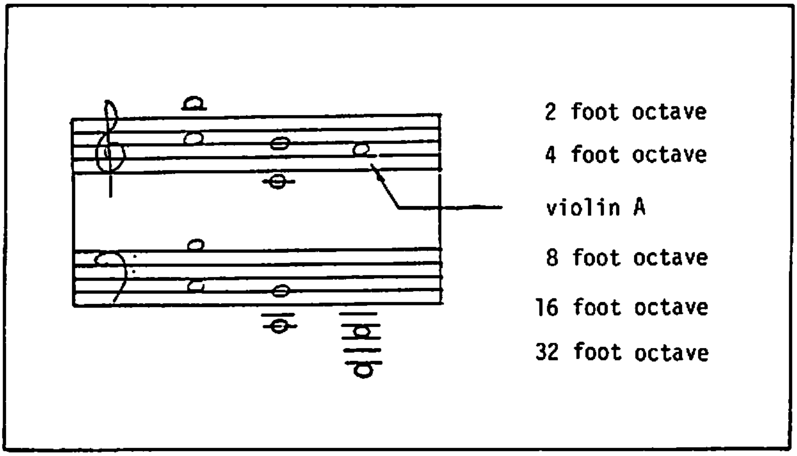
	ratio adjoining notes	Pythagorean scale	Just scale	ratio adjoining notes	
		1	1		
whole tone	9/8			9/8	major tone
		9/8	9/8		
whole tone	9/8			10/9	minor tone
		81/64	5/4		
semi tone	256/243			16/15	semi tone
		4/3	4/3		
whole tone	9/8			9/8	major tone
		3/2	3/2		
whole tone	9/8			10/9	minor tone
		27/16	5/3		
whole tone	9/8			9/8	major tone
		243/128	15/8		
semi tone	256/243			16/15	semi tone
		2	2		

(Taylor, 1965)

The diatonic scale on D is formed by multiplying the scale on C by $^9/_8$, which is the ratio between C and D. The diatonic scale on E is formed by multiplying the scale on D by $^{10}/_9$, the ratio between D and E (Taylor, 1976) The diatonic scales on each note are found in the same manner. In each successive scale, new ratios are found, thereby requiring at least thirty distinct ratios or tones for the octave (Olson, 1967) See Table 6.

A second method for construction of the just scale involves frequencies, pulsations, and partials. Tones of the same pitch have the same frequency and length of pulsation. Higher pitched tones have increased frequencies and shorter pulsations; lower pitched tones have decreased frequencies and longer pulsations. Since the pulsation for middle C has a length of approximately four feet, the octave beginning on middle C is called the four foot octave. The next higher octave is the two foot octave; the next lower octaves are the eight, sixteen, and thirty-two foot octaves. The A in the four foot octave, called violin A, is defined in America as the "tone having 440 pulsations per second in air of ordinary moisture and at a temperature of 68 Fahrenheit." (Redfield, 1928, p. 45) See Illustration 1.

Illustration 1

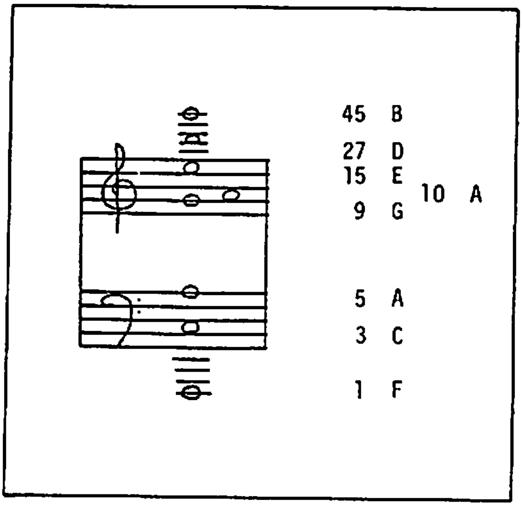


(Redfield, 1928, p. 42)

Each musical tone is composed of other simple tones, called partials. The partial with the lowest pitch is the fundamental; it has the longest pulsation and least frequency. The remaining partials are called overtones and have pulsation lengths of one-half, one-third, etc., the length of the fundamental (Redfield, 1928).

The diatonic scale on C is constructed using F of the thirty-two foot octave as the fundamental. The 1st, 3rd, 5th, 9th, 15th, 27th, and 45th partials of F (and octaves of these partials) are the only partials that can be represented on the musical staff. They represent the notes F, C, A, G, E, D, and B respectively (Refer to Illustration 2).

Illustration 2



(Redfield, 1928)

Violin A, with its 440 pulsations, is the 10th partial of F. F then has $^{1}/_{10} \times 440 = 44$ pulsations. Successive doubling--44, 88, 176, 352--gives the pulsations of F in the four foot octave. The values for the other notes of the scale are obtained in the same manner. See Table 7.

Table 7

C	3rd	partial of F	3 x 44 = 132	pulsations	132, 264, 528
A	5th	partial of F	5 x 44 = 220	pulsations	220, 440
G	9th	partial of F	9 x 44 = 396	pulsations	396
E	15th	partial of F	15 x 44 = 660	pulsations	660, 330
D	27th	partial of F	27 x 44 = 1188	pulsations	1188, 594, 297
B	45th	partial of F	45 x 44 = 1980	pulsations	1980, 990, 495

(Redfield, 1928)

When the notes are arranged in order to form the diatonic scale on C, the previously noted ratios for the just scale occur. See Table 8. Frequencies of the notes in

Table 8

C	264 pulsations			
D	297 pulsations	=	9/8	x 264
E	330 pulsations	=	10/9	x 297
F	352 pulsations	=	16/15	x 330
G	396 pulsations	=	9/8	x 352
A	440 pulsations	=	10/9	x 396
B	495 pulsations	=	9/8	x 440
C	528 pulsations	=	16/15	x 495

(Redfield, 1928)

all the diatonic scales are obtained by building on a keynote using these ratios. The notes in the four foot octave for all the sharp and flat keys require thirty-five different frequencies (Redfield, 1928).

During the Baroque period (1600--1750) a shift from medieval church modes to major-minor tonality and from vocal counterpoint to instrumental harmony required a simplification of the harmonic system. Although keyboard instruments gave pure sounds in keys with three or less sharps or flats, they became increasingly out of tune with more than three sharps or flats (Machlis, 1970). The scale of even temperament is a compromise between the Pythagorean and the just scales. By slightly mis-tuning the intervals within the octave, the octave is divided into twelve equal semi-tones. The distinction between sharps and flats disappears (Machlis,1970; Taylor, 1965). Each note in the octave has a ratio to the note immediately preceding it of $2^{1/12}:1$. Only thirteen notes comprise the chromatic scale within the octave. The maximum deviation of the equal-tempered scale to the just scale is 2% (Machlis, 1970).

It is interesting to note that,with the just scale, a keyboard instrument such as the clavichord, harpsichord, or piano, would have to be tuned for each piece played in keys with three or more sharps or flats. The even-tempered scale eliminated that need for retuning.

J. S. Bach, to show the advantage of the equal-tempered scale, wrote a set of preludes and fugues in every key, called "The Well-Tempered Clavier."

The musical scales are necessary as a form of standardization for both writing and performing music (Taylor, 1965). Although the Pythagorean scale is no longer used, the just scale is used for some stringed instruments. The equal-tempered scale, although diverging slightly from the natural scales, allows modulation from one key to another freely and so is the most common scale for conventional instruments. Mathematics has supported the developments in the musical scales demanded by changes in the art of music over the past 2500 years. With the rise of electronic and computerized music, it is likely that mathematics will continue that role.

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THE PROBLEM CORNER

EDITED BY 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. 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 problems should be submitted on separate sheets before 1 February, 1985. The solutions will be published in the Spring 1985 issue of *The Pentagon*, with credit being given to student solutions. Address all communications to Kenneth M. Wilke, Department of Mathematics, 275 Morgan Hall, Washburn University, Topeka, Kansas 66621.

PROPOSED PROBLEMS

Problem 372: Proposed by the editor.

Consider the sequences $[nA]$ and $[nB]$ where $[x]$ denotes the greatest function and n is a natural number. Let $A = 3 + \sqrt{3}$ and $B = 3 - \sqrt{3}$. Then the sequence $[nA]=4,9,14,18,\cdots$ and the sequence $[nB]=1,2,3,5,6,\cdots$. Show that each natural number appears in either $[nA]$ or $[nB]$ but not both.

Problem 373: Proposed by the editor.

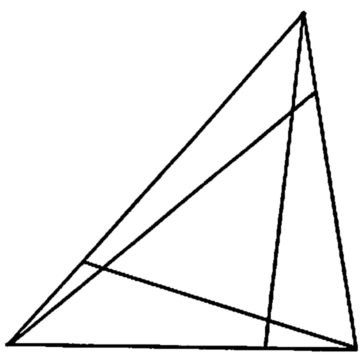
Let $f(x)$ be a polynomial having integer coefficients. For the distinct integers $a,b,c,$ and d, we have $f(a)=b$, $f(b)=c$, $f(c)=d$, and $f(d)=a$. Find all such polynomials or show that none exist.

Problem 374: Proposed by the editor.

Solve the following system of interrelated alphametics: ABCD/AE=FD;AG+AH=CB;ABBA/CI=CC; ABCD-AG=ABBA; AE+AH=CI; and FD-CB=CC.

Problem 375: Proposed by the editor.

Consider a triangle each of whose sides have been divided into four equal parts. Proceeding in a clockwise direction, from each vertex draw a line to the first division to the right of the next vertex on the opposite side as shown in the figure. How does the area of the inner triangle compare with the area of the original triangle? What is the corresponding result if 4 is replaced by n?



Figure

Problem 376: Proposed by the editor.

Egyptian fractions were based upon the representation of a given fraction as the sum of a finite number of fractions whose numerators are equal to 1. Erdös has conjectured that the fraction 4/n can be expressed as the sum of three or fewer such fractions having distinct denominators for all natural numbers $n \geq 3$. Prove that the conjecture is correct for at least 95% of the natural numbers.

SOLUTIONS

352: Proposed by Charles W. Trigg, San Diego, California.

Gargantuan Gastronomy

A	R	O	M	E	restaurant
	O	N	C	E	made history by
serving	M	C	M	L	
	E	E	L	S	at a single meal.

In the word square above, each word represents a square decimal integer. Each different letter uniquely represents a digit. Convert the word square into a square of squares.

Solution by Clayton W. Dodge, University of Maine at Orono, Orono, Maine.

First we search for four-digit squares which fit the MCML and EELS patterns: MCML is one of (2025,3136,6561,8281) while EELS is one of (1156,3364,8836) since $E \neq 0$. From the MCML list, L = 1, 5, or 6. Hence EELS = 1156 or 3364 and MCML = 2025 or 3136. Since EELS = 3364 and MCML=3136 are inconsistent, EELS = 1156 and MCML = 2025. Thus ROME end in 21 and ONCE ends in 01. Thus ROME = 7921 and ONCE = 9801. The unique solution is:

7 9 2 1
9 8 0 1
2 0 2 5
1 1 5 6.

Also solved by: Fred A. Miller, Elkins, West Virginia; Bob Prielipp, University of Wisconsin-Oshkosh, Oshkosh, Wisconsin and the proposer.

353: Proposed by Charles W. Trigg, San Diego, California.

Find a product of three consecutive integers which has the form abcabc.

Solution by Fred A. Miller, Elkins, West Virginia.

Let N be an integer such that

$N = (x-1)(x)(x+1) = abcabc = 1001 \times (100a + 10b + c)$.

Since $1001 = 7 \times 11 \times 13$, each of these must divide one of the factors $x-1$, x, or $x+1$. Checking multiples of 11, one finds the solution

$$76 \times 77 \times 78 = 456{,}456$$

If one allows $a = c$, then there is the additional solution

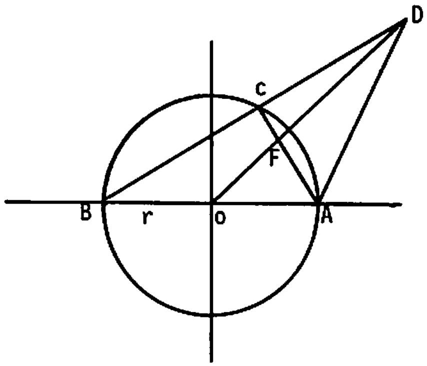
$$77 \times 78 \times 79 = 474{,}474.$$

Also solved by: Clayton W. Dodge, University of Maine at Orono, Orono, Maine; Brian Eschner, St. Charles, Missouri and the proposer.

354: Proposed by Fred A. Miller, Elkins, West Virginia.

In a circle with O as its center, draw the fixed diameter AOB and the chord BC. Extend the chord BC to a point D such that BC = CD. Find the locus of the point of intersection of OD and AC.

Solution by Charles W. Trigg, San Diego, California.



Figure

Point $C(x_1,y_1)$ lies on the circle $x^2 + y^2 = r^2$. Then BC is extended to $D(2x_1 + r, 2y_1)$. F is the intersection of AC and OD.

AC and OD are the medians of the triangle BAD, so $OF = OD/3$. Thus the coordinates of F are $x=(2x_1+r)/3$ and $y = 2y_1/3$. Whereupon $x_1 = (3x - r)/2$ and $y_1=3y/2$. Since (x_1,y_1) lies upon the circle, we have

$$\left[\frac{3x - r}{2}\right]^2 + \left[\frac{3y}{2}\right]^2 = r^2$$

a circle which is the locus of F.

Also solved by: Clayton W. Dodge, University of Maine at Orono, Orono, Maine and the proposer.

355. Proposed by the editor.

Find all three digit numbers N such that N is the arithmetic mean of all numbers formed by permuting the digits of N; exclude the trivial case where all three digits are the same.

Solution by Bob Prielipp, University of Wisconsin-Oshkosh, Oshkosh, Wisconsin.

Let $N = abc = a \cdot 100 + b \cdot 10 + c$ be a three-digit number. When a, b, and c are distinct, permuting the digits of N yields six positive integers (abc, acb, bac, bca, cab, and cba). If the arithmetic mean of these numbers is abc, then

$$[(2a + 2b + 2c) \times 111]/6 = 100a + 10b + c.$$

It follows that: $7a = 3b + 4c.$ (A)

Equation (A) has the following non-trivial solutions:

b	a	c	abc
0	4	7	407
1	5	8	518
2	6	9	629
7	3	0	370
8	4	1	481
9	5	2	592.

When exactly two of a, b, and c are equal, say $b = c$, similar analysis yields the equation $63a = 63b$, making $a = b$. Therefore, the non-trivial solutions to this problem are those given above.

Also solved by: Brian Eschner, St. Charles, Missouri; Fred A. Miller, Elkins, West Virginia and Charles W. Trigg, San Diego, California.

356: Proposed by R. S. Luthar, University of Wisconsin Center, Janesville, Wisconsin.

If a, b and c are the sides of a triangle, prove that

$$\frac{b+c}{a} + \frac{c+a}{b} + \frac{a+b}{c} + \frac{a}{b+c} + \frac{b}{c+a} + \frac{c}{a+b} > 6.$$

Solution by Hao-Nhien Qui Vu, Lafayette, Indiana.

Starting with the true inequality:

$$(n - 1)^2 > 0, \; n \neq 1$$

one has: $n^2 + 1 > 2n$ or $n + \frac{1}{n} > 2$ for all real numbers n.

Now put $n = a/(b + c)$. Then $\frac{a}{b+c} + \frac{b+c}{a} > 2$ (1)

since $a < b + c$.

Taking $n = \frac{b}{a + b}$ and $\frac{c}{b + c}$ respectively, one obtains two similar inequalities which can be added to inequality (1) above to produce the desired result.

Also solved by: Curtis Cooper, Central Missouri State, Warrensburg, Missouri; Bob Prielipp, University of Wisconsin-Oshkosh, Oshkosh, Wisconsin; Charles W. Trigg, San Diego, California and the proposer.

THE HEXAGON

EDITED BY IRAJ KALANTARI

This department of THE PENTAGON is intended to be a forum in which mathematical *issues* of interest to undergraduate students are discussed in length. Here by *issue* we mean the most general interpretation. Examination of books, puzzles, paradoxes and special problems, (all old or new) are examples. The plan is to examine only one issue each time. The hope is that the discussions would not be too technical and be entertaining. The readers are encouraged to write responses to the discussion and submit it to the editor of this department for inclusion in the next issue. The readers are also most encouraged to submit an essay on their own issue of interest for publication in THE HEXAGON department. Address all correspondence to *Iraj Kalantari, Mathematics Department, Western Illinois University, Macomb, Illinois 61455.*

Computers here, computers there, robots everywhere! But are they intelligent and can they think? From '2001: A Space Odyssey' to 'Star Wars' we see the likes of HAL, C23PO and R2D2; but can they exist?

The question of how 'smart' can we program our computers to be, has fascinated many people. In the Fall, 1981 issue of The Pentagon, we printed (for this department) an article: "Computers and Chess," in which the author (Robert Filman) brought us up-to-date on the state-of-the-art of computers playing chess. The following article is on a different game a computer could be programmed to play.

IK

TURING'S TEST: "CAN MACHINES THINK?"

Tamara Jane Lakins*

In 1950,Alan M. Turing raised a question which has since helped to create a new field of computer science called artificial intelligence. The question that Turing asked was, "Can machines think?" There were, and still are, different opinions and theories about this subject that disagree with each other. In this paper, we show the progress and problems that artificial intelligence has experienced over the past thirty years or so.

Turing replaced his original question, "Can machines think?" by "What will happen when a machine takes part in the imitation game?" (see [9] page 54.) The *imitation game*, or the *Turing test* as it is more commonly known, consists of three players, a human being, a digital computer, and an interrogator. The person, the computer, and the interrogator are in three separate rooms, and they communicate to each other via

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*Tamara Lakins is a student at Western Illinois University major-in mathematics. Her other interests include computer science and music.

a teletype (if this constraint were not present, the problem would become trivial.) The object of the game is for the interrogator to pose certain questions to the person and to the computer so that the answers given will enable him to distinguish which is the human being. Obviously, the interrogator must be a knowledgeable person. Now, although the person is doing his best to convince the interrogator that he is the human being, the computer has also been programmed to do its best to convince the interrogator that it (the computer) is human. This means that the computer is programmed to make occasional mistakes and to not perform calculations instantaneously, as computers seem to do. Basically, Turing claimed that if a machine can win the imitation game, that is, pass the Turing test, then the machine can be said to be able to think as a human being (see [9] pages 53-54.) Turing also maintained that it would be possible to program a computer to pass his test 70% of the time by approximately fifty years after he wrote his article (see [9] page 57.)

Although most computer scientists agree that we will not have this ability by the time Turing had predicted, Turing's beliefs have caused many to investigate the question "Can machines think?" to quite some length. In the process, the science of artificial intelligence has come about. Many experts are currently working on this problem.

Throughout the years, researchers have formed their own ideas of the goal, description, and aims of artificial intelligence. In the article "How Smart Can Computers Get?" by Begley, Carey, and Reese in *Newsweek*, it is stated that the goal of artificial intelligence is to "determine how close a computer can come to simulating the human mind and, perhaps, transcending it." (see [1] page 52.) Marvin Minsky of Massachusetts Institute of Technology, on the other hand, prefers to describe artificial intelligence as "'the science of making machines do things that would require intelligence if they were done by men.'" (see [5] page 13.) In fact, Minsky has also thought of a way to test the machine's intelligence. He proposes that the computer be told a fairy tale and then be asked questions to test its understanding (see [4] page 26.) David Hite, senior technical associate and computer consultant for a computer firm, has pinpointed what he believes to be the aims of artificial intelligence. He believes them to be showing the human functions of game-playing, speech recognition, language understanding, vision, and knowledge representation (see [4] page 28.) Some of these aims will be discussed here because of the problems they present to artificial intelligence researchers.

How does one solve the problem of programming a computer to "simulate" the human mind? Recall what Marvin Minsky said about machines doing things that would require intelligence if performed by a human being. The problem with this, as stated by John Anderson, professor of psychology and computer science at Carnegie-Mellon University, is that the moment a computer becomes able to do something, humans no longer consider that to be intelligent (see [6] page 32.) Hence, it seems as though humans belittle the advances made by artificial intelligence researchers, thus making their job more difficult.

When one considers solving the problem of artificial intelligence, or AI, one runs into many obstacles, many of which disappointingly concern the aims of AI given by Hite. Hite believes that the problem of AI is that thinking machines need to 'know' about the world. He states that, presently, "computers don't know anything about the world and computer scientists aren't even sure how to go about telling them." (see [4] page 24.) He does concede, however, that many computer scientists have tried to tell computers about the world, and some are still trying (see [4] page 25.) Along the same line, Patrick Huyghe, a noted journalist for science magazines, adds that, once a way to give the computer all of this information is discovered, researchers still have to learn how to program a computer to transmit the smallest amount of information possible (see [6] page 34.) Both of these ideas deal with the problem of knowledge representation. John McCarthy of Stanford University, one of the founders of AI, points out that computer scientists have not even formulated the facts of the common sense world, much less discovered how to tell a computer. Also, he states that if AI researchers do manage to represent this knowledge in computers, "they are still faced with the problem of getting answers out of the computer in a reasonable time." (see [7] page 1238.)

The learning problem is another major problem in AI. Researchers are working on how to program a computer to 'learn' new information. Years ago, M. Ross Quillian, a graduate student at Carnegie-Mellon

University, stated that learning consists of constructing an ever-growing "network of concepts" in the mind. While trying to base a computer-search technique on a model of the human brain, Quillian discovered that this network is one of the most profound differences between the human mind and the computer (see [6] page 32.) Patrick H. Winston of M.I.T. adds that "'machines won't be intelligent until they acquire what they need on their own.'" (see [1] page 53.) Obviously, learning is critical in AI.

Language, another aim described by Hite, is also a problem in AI. Hoover remarks that machines have always had a "struggle with language" (see [5] page 13.) Because people are forced to communicate with the computer on its terms, they are limited in their communication. Obviously, the ideal solution to this limitation is to teach English to computers. However, computer scientists have yet to perfect programming a computer to deal with "the ambiguities of a natural language" (see [5] page 15.) The natural languages, such as English, German, and French, are simply too complex because of many grammar rules and words with multiple meanings. One prime example of the problems a computer experiences with natural languages was illustrated when a computer was programmed to translate "The spirit is willing, but the flesh is weak" from English to Russian to English. The computer responded with "The wine is agreeable, but the meat has spoiled"! (see [4] pages 29-30.) The problem of speech-recognition is related to the problem of language. Little progress has been made on this obstacle so far; today's best speech-recognition machines can only understand up to a few hundred words. They take hours to do the actual processing, and they make some very strange mistakes (see [4] page 30.)

Computer vision has been said to be the most "intractable" concept of AI research. Presently, computers can only see arrays of multi-colored dots as presented through photocells (see [4] page 31.) Obviously, much research remains in this area of study.

Another major problem in AI research is the representation of common sense in the computer (this is related to knowledge representation). Representing common sense in a computer has been declared as "unclear" by Gina Kolata, (see [7] page 1237) and as "tricky" by Huyghe (see [6] page 34.) Huyghe goes on to say that common sense is "one of the things keeping us human beings a step ahead of the machines..." (see [6] page 28.) John McCarthy believes that common sense facts can be expressed in terms of first order mathematical logic. Kolata disagrees with McCarthy, stating that "common sense reasoning is often quite different from this mathematical logic" (see [7] page 1238.) Minsky, on the other hand, believes that we are merely asking the wrong question. He feels that we should program the computer to avoid the ways it can fail, rather than to follow a line of thought leading to a good decision (see [6] page 34.) It is obvious that there has been quite a lot of debate on the subject of common sense.

The dual of common sense, or creativity, has long been the subject of heated debate among AI researchers. Terry Winograd of Stanford has the opinion that, as it stands, AI falls under the definition of problem solving only. However, AI researchers have learned that true human intelligence also involves the "elements of will, consciousness and creativity" (see [1] page 52.) Presently, today's computers are incapable of these elements (see [1] page 52.) Douglas R. Hofstadter, a computer scientist at Indiana University, believes that someday the computer will be able to create, feel, and have the qualities of will, intuition, and consciousness. He and other AI experts believe that a machine will be able to possess consciousness once a programmer can "get a computer to think about thinking and to understand its own process of thinking" (see [1] page 53.) However, although Hofstadter believes that a computer will eventually be creative, most computer scientists disagree with him (see [1] page 53.) Marvin Minsky hopes that, when compared to programming common sense, giving a computer creative thinking will be simple. He believes that ordinary and creative thought are one and the same; only when someone demonstrates an unusual performance of ordinary thought do we tend to call it creativity (see [6] page 34.) There appears to be as much controversy over creativity as there is about common sense. Programming emotions into a computer is just as controversial. Although many disagree with him, Minsky believes that emotions will be programmable once human thinking can be programmed into a computer (see [6] page 34.) John McCarthy, on the other hand, has a totally opposite viewpoint. He believes that computer scientists should not program emotions into a computer; he calls it a "bad idea" (see [8] page 46.)

Now that we have seen the problems in solving the AI question, we should ask about the possibility of the question ever being solved. Marvin Minsky, John McCarthy, and many others in the field of AI are convinced that eventually, computer scientists will be able to design and program computers to have common sense and intelligence. Both Minsky and McCarthy agree that many more new ideas are needed for the problem of common sense to be worked on further (see [7] page 1238.)

Furthermore, we should deal with the effect AI research has had on society. Because of AI, we have "introduced more structure into our thinking about thinking" (see [6] page 28.) We are now faced with the problem of deciding whether or not to extend our concept of thinking to include the accomplishments of "thinking machines" (see [6] page 28.) Because giving computers intelligent thought forces us to relinquish our position as *the* measure of intelligence, many people are experiencing some uneasiness (see [6] page 34.) In other words, as Terry Winograd of Stanford remarks, man is learning that soon he may not be the only thinking being. Hans J. Berliner of Carnegie-Mellon University recommends that if intelligent computers really make us too uncomfortable, we can always pull the plug! (see [1] page 53.) McCarthy adds that AI researchers do not want to make an "'omniscient computer program. We only want to make it as good as people'" (see [7] page 1238.)

Currently, there are two major opposing philosophical approaches to solving the AI problem. John McCarthy, as was stated previously, believes that designing computer programs to reason according to mathematical logic is the way to solve the AI problem. He has developed a version of nonmonotonic reasoning he calls *circumscription*. Mathematical reasoning is monotonic because, if you are given a set of premises and a set of conclusions, the same conclusions will be drawn even when you are given additional facts. Circumscription, however, restricts the predicate of a logic statement as much as possible so that conclusions may easily follow via mathematical logic. For example, suppose a computer is asked whether or not a certain animal is a bird and if it can fly. The computer has been programmed with the biological context of birds, that is, feathers, wings, flying, and egg-laying.

McCarthy would also use a predicate called "prevented from flying" in order to include penguins, dead birds, and etc. Hence, the computer could reason that "'If Joe is a bird and Joe is not a member of the set "prevented from flying" then Joe can fly'" (see [7] page 1238.) Circumscription is not yet being applied in actual programs. Kolata believes that circumscription is not enough to make a computer have common sense because it must leave something out (see [7] pages 1237-1238.) Marvin Minsky, on the other hand, has developed an approach to solving the AI problem called frame systems. This system, which is ever-changeable, "is a collection of frame definitions which set the scene for common sense reasoning" (see [7] page 1237.) For example, if you know someone in two different frames, such as business associate and friend, you understand and deal with him differently depending upon which frame you are viewing him in. Frame systems are currently being used; for example, Ira Goldstein of Hewlett-Packard has developed a computer language called "frame representation language" (FRL) which is now being used in developing expert systems (see [7] page 1237.)

We have examined two current approaches to the AI problem; let us now examine some past and present attempts at developing "thinking machines." One of the earliest attempts to solve the AI problem took place in the early 1960's. A group of computer scientists tried to build a machine that would simulate the electro-chemical operation of the brain using electronic circuitry. They hoped it would be able to learn about the world just as a human brain does. This early attempt was not successful; in fact, it now seems absurd because of our current limited knowledge of how the brain functions (see [4] page 28.)

Another early attempt at machine intelligence was the computer program ELIZA written by Joseph Weizenbaum of Massachusetts Institute of Technology in 1966. ELIZA was programmed to be a nondirective Rogerian psychiatrist who responds to client's statements in the form of questions. Many people exposed to ELIZA began to treat it like a true psychiatrist. Weizenbaum himself, however, considered ELIZA to be a toy and not to be considered intelligent. He was very shocked and dismayed to find that many people considered ELIZA to be the first step toward machine intelligence (see [4] pages 25-26.) We believe that most people today have realized that ELIZA cannot be considered intelligent; it merely mimics what is said to it.

An outgrowth of the study of AI has been the development of programs designed to accomplish some tasks now done by human experts. These programs are called expert systems, and they basically have two parts, a data base, or collection of information known to the human experts, and an "'inference engine,'" (see [2] page 48) that is, the set of rules that apply to the data base. An example of an expert system is CADUCEUS, which is located at Stanford University and acts as a consultant for internal medicine. Expert systems are just now beginning to be used in the real world. A couple of these systems are now in actual use, while many others are being planned or developed (see [2] page 48.)

Currently, researchers have concluded that the only way to give a machine intelligence is to use *effective procedures*. Effective procedures tell the computer how to imitate man and the world (see [4] page 28.) To be an effective procedure, the following conditions must hold:

1. A set of finite, exact instructions exists that explicitly explain how to execute the procedure.
2. Random devices are not being used.
3. If the procedure is a decision procedure, it must produce within a finite amount of steps a "yes" or "no" answer, when given a well-formed formula (see [3] page 60.)

The scientists who are trying to discover the effective procedures that will cause a computer to imitate the behavior of a man believe that subjective things, such as "love, flattery, or piety can be defined mechanistically" (see [4] page 28.) One such AI researcher is Marvin Minsky. This particular approach to AI seems to be the most promising.

We have discussed many aspects of AI, from the Turing test to the problems in solving the AI question to the "thinking machines" at our disposal today. There are many different ideas and conflicting viewpoints among the experts. Much research has been devoted to this subject, and, most likely, much more will be devoted to the subject now and in the future. When the first actual "thinking machine" has been programmed, it will be most interesting to find out if it *can* actually pass the Turing test.

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THE CURSOR

EDITED BY JIM CALHOUN

This is the first appearance of this department in THE PENTAGON. The topics presented here can be broadly classified as belonging to computer science but their direction is more narrowly defined. Like most applied sciences, computer science depends heavily upon a large body of mathematical theory and it is our aim that the discussions presented address the interface between the disciplines of mathematics and computer science. Specifically, we seek to relate ideas from the theory of mathematics to an understanding of concepts in computer science. Readers are encouraged to submit articles on any topic which seems directed toward this goal.

THE CURSOR was chosen as the name of this department because of the role which mathematics plays in pointing the way toward understanding of important concepts of computer science.

"INSIDE EVERY LARGE PROBLEM IS A SMALL PROBLEM STRUGGLING TO GET OUT"

Tony Hoare

Introduction

Computer science, like mathematics, depends upon abstraction for its more important tools. In mathematics, for example, a definite integral may represent the area of a region whose boundaries are given by a set of functions. The power of this abstraction comes from being able to reason about the area of the region through the logical properties of the integral while suppressing the lower level detail of the general definition of the integral. In computer science we also depend heavily upon the use of abstractions. Have you listened to (or have participated in) discussions comparing the differences between programming languages? The important differences are related to the differences between the sets of abstractions supported by the languages. One simple example is the procedure abstraction. (A procedure and a subroutine are synonymous.) Once a programmer determines that a procedure is correct and has identified its logical properties (i.e., what the procedure does), she may use these logical properties to reason about the correctness of any program which uses the procedure. So both the definite integral and the procedure are abstractions whose power is felt through their use in problem solving. Like many abstractions they help to simplify and bring order to the complex process of solving large problems.

Algebra and Data Types

In mathematics there is an important distinction made between numbers and numerals. A number is a concept or idea while a numeral is a name or representation for a number. For example, no matter what his/her native language, each person possesses a concept of "twoness" but the concept has an existence which is independent from numerals such as "2", "II", and "two", which name it. Now consider the way in which one learns about the natural numbers (we let NATURAL_NUMBERS be the set of natural numbers.) Our early counting experiences are based on several assumptions. They include the assumptions that

i) there is a first natural number,

ii) for each natural number there is a next natural number (which we call the <u>successor</u> of the number)

and

iii) any natural number may be constructed by a multiple application of the successor operation to the first natural number.

So when learning to count, one is learning a set of concepts called the set of natural numbers, a set of numerals to represent this set of concepts, and the correct correspondence between them. The three properties given above constitute an inductive definition for the natural numbers and also serve as an important part of a set of axioms known as Peano's Axioms. Peano's axioms serve as a foundation for our understanding of arithmetic and are characterized below (see Fig. 1). Our characterization of NATURAL_NUMBERS is in two parts which together give the meaning of the three operations, "CREATE", "SUCCESSOR" AND "EQUAL". The first part is the syntax which gives the domain and range of each of the operations. For example, the operation "EQUAL" accepts ordered pairs of natural numbers as its domain and has its range the set {false, true} . Of special note is the "CREATE" operation because of its empty domain. It is a god-like operation which creates the first natural number. The operation "SUCCESSOR" is a more earthly operation in that it can only create a natural number from another natural number. Operations such as "CREATE" and "SUCCESSOR" are called <u>constructor operations</u> because they construct new values for the set of values being defined, while an operation such as "EQUAL", which only gives information about elements of the set, is called a <u>transfer operation</u>.

<u>SYNTAX</u>: (Operations on NATURAL_NUMBERS)

1. CREATE : ---> NATURAL_NUMBERS
2. SUCCESSOR : NATURAL_NUMBERS ---> NATURAL_NUMBERS
3. EQUAL : NATURAL_NUMBERS X NATURAL_NUMBERS ---> boolean

AXIOMS: (Semantics of the Operations on NATURAL_NUMBERS)

4. for each natural number n,

   EQUAL(SUCCESSOR(n),CREATE()) = false
5. EQUAL(SUCCESSOR(n),n) = false
6. if EQUAL(n,m) = false then

   EQUAL(SUCCESSOR(n),SUCCESSOR(m)) = false

Fig. 1

The second part of the characterization is a set of axioms which gives the meaning (or semantics) of the operations. The operation "CREATE" gives the first natural number and axiom 4 states that this number is not the successor of any natural number. Axiom 5 states that no number is its own successor and by axiom 6 different natural numbers have different successors.

Each high level programming language contains a set of primitive data types such as integer, real, fixed, character_string or boolean. Each value of a given type has a representation (bit pattern) which identifies or names it. For example, the pattern "00000010" might represent two, while "10000010" represents negative two. Obviously, another computer system could represent these integers with different bit patterns but the logical properties of integers should remain independent of how the integers are represented. An understanding of the logical properties of a data type, including the meaning of its operations, is essential if one is to declare and use objects of this type within a program. It is not necessary, however, for the programmer to be concerned about the bit level representation, say for example, of an integer. In fact, a secure language will check to make certain that a programmer does not misuse the operations associated with a data type. For example, if the operation "concatenation" is an operation which appends one character string to another, a secure language will not allow the concatenation of two values which are not character strings.

In response to our concern for management of data within a program, we use arrays, linked lists and other structuring facilities of the language to construct (what are usually referred to as) "data structures". Some of the most difficult problems in programming, however, come from the need to keep track of what is going on between these structures and the operations on them. In a very large program with multiple structures and operations, the resulting complexity at this lower level of detail is beyond human comprehension. In our discussion we view a data object in two parts: its structure and the value it holds. For example, a data object consisting of a list of integers might have a linked list as its data structure and a list of integers as its value (note that the list of integers is viewed as one value). We will refer to the set of all lists of integers as the set LIST_OF_INTEGERS. We now identify <u>all</u> operations on this structure in a new light. We think of the set LIST_OF_INTEGERS as a set of concepts much in the same way as we did the NATURAL_NUMBERS and think of the operations on LIST_OF_INTEGERS in terms of their logical properties. With this view we refer to LIST_OF_INTEGERS and its set of associated operations as an <u>abstract data type</u>.

Consider the following specification of the abstract data type LIST_OF_INTEGERS and note its similarity to the one given for NATURAL_NUMBERS.

SYNTAX: (Operations Associated with Type LIST_OF_INTEGERS)

1. CREATE : ---> LIST_OF_INTEGERS
2. INSERT : LIST_OF_INTEGERS x INTEGER ---> LIST_OF_INTEGERS
3. DELETE : LIST_OF_INTEGERS x INTEGER ---> LIST_OF_INTEGERS
4. SEARCH : LIST_OF_INTEGERS x INTEGER ---> BOOLEAN

AXIOMS: (Semantics of the Operations)

5. SEARCH(CREATE(),i) = false
6. SEARCH(INSERT(L,i),i) = true
7. DELETE(INSERT(L,i),i) = L
8. if SEARCH(L,i)=true then INSERT(DELETE (L,i),i) = L
9. SEARCH(INSERT(L,i),j) = SEARCH(L,j) if i≠j

Fig. 2

Operations "CREATE", "INSERT" and "DELETE" are the constructor operations while "SEARCH" is a transfer operation. Operation "CREATE" creates the first value of type LIST_OF_INTEGERS and by axiom 5 this value must be an empty list. Axioms 6 and 7 imply that "INSERT" produces new values of LIST_OF_INTEGERS.

The specification of LIST_OF_INTEGERS like that of NATURAL_NUMBERS is algebraic in nature. The operations for LIST_OF_INTEGERS differ from those of NATURAL_NUMBERS in that their domains contain values outside the type of interest. For example, the domain of "INSERT" contains ordered pairs with the first element of the pair a value of type LIST_OF_INTEGERS and the second a value of type integer. Conventional (homogeneous) algebra is not appropriate as a foundation for abstract data types because it doesn't provide for this heterogeneous nature in the domains of its operations. Heterogeneous algebras do allow for this possibility and thus are well-suited as a foundation for abstract data types.

An algebraic specification of an abstract data type such as the one given for LIST_OF_INTEGERS is really an axiomatic system. Our first experience with such a system is in plane (Euclidean) geometry where a set of axioms serves as a basis from which all results are derived. So each time a programmer creates a data type, she is really creating an axiomatic system with the same set of difficulties that are faced when designing any axiomatic system. Mathematicians have long known that there are dangers inherent in the process of choosing which axioms to include when defining a system. The inclusion of an ill-chosen axiom or the failure to include a sufficient number of axioms can result in an unreliable system. The major properties desired in such a system are the properties of consistency and completeness. Completeness relates to the need for each object of the system to have a meaning while consistency speaks to the desire that each object of the system have exactly one meaning.

A powerful tool is now appearing within the newest generation of high level programming languages which aids the programmer in adopting this view. It is a program module (in the Ada programming language this module is called a "package") which can be used to isolate and enclose both the definition of the data structure and the implementation of the operations which act upon it. At an abstract level, however, the programmer can view the module as defining a data type.

In addition, however, the module can be so constructed that the programming language gives the same protection to data types created by the programmer as it does to primitive data types provided as part of the language.

The appearance of such mechanisms within programming languages did not happen overnight. It took many years of work by computer scientists such as John Guttag and J. J. Horning [3] to arrive at a good way of thinking about data types. Although these developments in computer science came about in the mid 1970's, it was earlier work in mathematics (late 1960's) by Birkoff and Lipson [2] which pointed the way. We will not attempt to include a formal treatment of their work here but have tried to show that their ideas as reflected in the work of Guttag and Horning give a fresh way of looking at data structures and data types. This conceptual view of data types is in many ways analogous to the understanding of the natural numbers gained through Peano's Axioms.

One importance of this work is that programmers now view data structures in a new light. Anytime a programmer constructs a data structure she should be asking the question, "Where's the abstract data type?".

That is, what is the set being defined, what are its operations and what are the logical properties of the system? When the data structure has many operations applied to it and the interaction of these operations is complex, it is especially important that a specification of the abstract data type be completed before any code is written or even before the data structure is chosen. What often happens when this is not done is that the code requires repeated changes and the addition or deletion of operations in order to produce an acceptable program. What is really going on during this process is that the programmer is informally changing the set of axioms until it appears that the result is complete and that all inconsistencies have been removed. It is usually more efficient to make these modifications at the abstract level through an examination of the set of axioms given in the specification. Even if one cannot prove that the system has the desired properties, just writing down a specification forces the programmer to informally look for potential problems. The use of this technique is directly reflected in the coding process and the quality of code itself. The coding process is more efficient, the code is better organized, the code is easier to follow and more importantly the chances that the code will be correct is greatly increased.

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3. Guttag, J. V., Horning, J. J., "The Algebraic Specification of Abstract Data Types", Acta Informatica, vol. 10, pp. 27-52(1978).

KAPPA MU EPSILON NEWS

EDITED BY HAROLD L. THOMAS, HISTORIAN

News of chapter activities and other noteworthy KME events should be sent to Dr. Harold L. Thomas, Historian, Kappa Mu Epsilon, Mathematics Department, Pittsburg State University, Pittsburg, Kansas 66762.

CHAPTER NEWS

Alabama Gamma, University of Montevallo, Montevallo
Chapter President - Lisa D. Kirkwood
7 actives, 1 initiate

The chapter has made plans to sponsor a lecture on the history of mathematics by Dr. Joe Albree, professor of mathematics at the University of Auburn in Montgomery. In addition, mathematical problems will be prepared for use in the Shelby County mathematics tournament among high school students. A spring picnic is also planned for mathematics majors,minors,and faculty and families. Other 1983-84 officers: Deborah A. Evans, vice president; Pamela J. Spigarelli, secretary; Joseph Cardone, corresponding secretary; Angela Hernandez, faculty sponsor.

Alabama Zeta, Birmingham-Southern College, Birmingham
Chapter President - Thomas Herring
32 actives

The chapter sponsored a team of three of its student members to represent the organization in the Alpha Lambda Delta Scholars' Bowl. This activity was very exciting and gave Kappa Mu Epsilon an opportunity to exercise some of its talents. A Halloween party, held by all the Science Clubs on campus, gave KME members a chance to relax and socialize with their professors and fellow students. Dr. Arthur Segal was the fall semester guest speaker. He is a biomathematician at the University of Alabama in Birmingham. Dr. Segal's lecture was a demonstration of the important role that mathematics plays in medicine and medical research. Kappa Mu Epsilon also held a Christmas luncheon this fall. The activity was an opportunity for faculty and student members to get together before the Christmas holidays. Other 1983-84 officers: Judy Tanquary, vice president; Carol Anderson, secretary; Richard Sturgeon, treasurer; Lola F. Kiser, corresponding secretary; Sarah Mullins, faculty sponsor.

Arkansas Alpha, Arkansas State University, State University
Chapter President - Diana Hester
20 actives, 7 initiates

On October 7, 1983, Arkansas Alpha held a faculty-student drop-in. There was a good turn out of both faculty members and students,and the drop-in was a huge success. In addition to this social, meetings were held bi-weekly, with guest lecturers. Topics discussed were: "The History of Calculus" by Dr. Terri Stevens: "Mathematics in the Last Ten Years" by Dr. Martin Guest; "The Mathematical Theory of Meetings" by Dr. Kachoon Yang; and "The First Integral" by Dr. Tom Bennett. The last activity of the semester was a Christmas party sponsored by the chapter. The faculty from the Computer Science, Mathematics and Physics Departments were invited along with their families. Other 1983-84 officers: Judy Spence, vice president; Donna Douglas, secretary and treasurer; Susan Walden, reporter; Jerry Linnsteadter, corresponding secretary; Tom Bishop, faculty sponsor.

California Gamma, California Polytechnic State University, San Luis Obispo
Chapter President - Ken Hoyt
30 actives, 25 initiates

Weekly meetings were held with speakers from business and industry. The chapter assisted the Mathematics Department in hosting a joint SIAM/MAA meeting. A Christmas social and pledge ceremony was held at the end of the fall quarter. Other 1983-84 officers: Jennifer Martin and Fina Masatini,vice presidents; Diane Formea, secretary; Greg Kucala, treasurer; George R. Mach, corresponding secretary; Adelaide T. Harmon-Elliott, faculty sponsor.

Colorado Alpha, Colorado State University, Fort Collins

Faculty sponsor, Arne Magnus, reports that the chapter has not been very active the past few years. Plans to revive it this spring semester are being made.

Connecticut Beta, Eastern Connecticut State University, Willimantic
Chapter President - Hans Weidig
37 actives, 9 initiates

Other 1983-84 officers: Michael Rousseau, vice president; Virender Gupta, secretary and treasurer; Steve Kenton, corresponding secretary and faculty sponsor.

Florida Beta, Florida Southern College, Lakeland
Chapter President - Debbie Waldo
15 actives

Other 1983-84 officers: Liz Palmer, vice president; Ellen Fluck, secretary and treasurer; Henry Hartje, corresponding secretary and faculty sponsor.

Georgia Alpha, West Georgia College, Carrollton
Chapter President - Yolanda Haisty
22 actives

Other 1983-84 officers: Kim Huckeba, vice president; Maureen Ramey, secretary; Bob Ingle, treasurer; Joe Sharp, corresponding secretary and faculty sponsor.

Illinois Zeta, Rosary College, River Forest
Chapter President - Deborah Wagner
7 actives, 2 initiates

Members of the Illinois Zeta chapter took part in an exhibit intended to acquaint students of Rosary College with honor societies and clubs on campus. Memory books, containing photographs and souvenirs of national and regional conventions, attracted favorable attention. Some members have taken part in tutoring of students in the degree completion program. To finance attendance at the regional convention in Spring, 1984, members sold plants that they had raised. Other 1983-84 officers: Sheila Ruh Schultze, secretary; Monica Behnke, treasurer; Sister Nona Mary Allard, corresponding secretary and faculty sponsor.

Illinois Eta, Western Illinois University, Macomb
Chapter President - Judith Smithhisler
10 actives, 5 initiates

The chapter began the semester by taking an active role in recruiting new members by writing letters to all new or transfer math students. Activities throughout the semester included a student program by Judith Smithhisler and Tami Lakins, a short discussion by faculty advisor Dr. Iraj Kalantari, and a presentation given by Dr. Michael Moses. The chapter's annual Faculty Chili Lunch was a great success. Acting department chairperson Dr. Jerry Shryock was the speaker at the Fall 1983 Initiation held on December 1. A pizza party followed the initiation. Other 1983-84 officers: Tamara J. Lakins, vice president; Shelly Strode, secretary and treasurer; Alan Bishop, corresponding secretary; Iraj Kalantari, faculty sponsor.

Indiana Delta, University of Evansville, Evansville
Chapter President - Emily Reisinger

Other 1983-84 officers: Blake Middleton, vice president; Suzzie Halwes, secretary; Melba Patberg, corresponding secretary; Duane Broline, faculty sponsor.

Iowa Alpha, University of Northern Iowa, Cedar Falls
Chapter President - Kirk Montgomery
28 actives, 3 initiates

Two students presented papers at local KME meetings: Burton Marlowe talked on Taxi Cab Geometry and Chris Goarcke discussed problems in maintaining a computer system. Vice President, Andrea Bean, presented a talk on Computer Crime at the initiation banquet held November 30 at the Golden Corral restaurant. In October, Professor Emeritus and Mrs. Hamilton hosted the annual KME homecoming breakfast which continues to draw alumns, faculty and active student members. Iowa Alpha sponsored the sale of windbreaker jackets with the department name stencilled on the front. Student members elected to cancel the Christmas party this year since they were "too busy studying!" Other 1983-84 officers: Andrea Bean, vice president; Loraine Maruth, secretary; Kande Hooten, treasurer; John S. Cross, corresponding secretary and faculty sponsor.

Iowa Beta, Drake University, Des Moines
Chapter President - Coni Johnson
12 actives

Other 1983-84 officers: Sheryl Shapiro, vice president; Mary Bernard, secretary; Craig Kalman, treasurer; Joseph Hoffert, corresponding secretary; Lawrence Naylor, faculty sonsor.

Kansas Alpha, Pittsburg State University, Pittsburg
Chapter President - Brad Averill
34 actives, 10 initiates

The chapter held monthly meetings in October, November, and December. In addition, a fall picnic was hosted for all mathematics and physics students. Fall initiation for new members was held at the October meeting. Ten new members were received at that time. The October program was given by Mark Million on "Turbulence Theory." Jeanine Carver spoke at the November meeting about her work with computers at the PSI Systems Corporation. In December, a special Christmas meeting was held at the home of Dr. Helen Kriegsman, Mathematics Department Chairman. Judy Weber gave the program on "Mathematical Modeling in Inventory Control." Other 1983-84 officers: Kendall Draeger, vice president; Rebeca Graham, secretary; Lisa Burgan, treasurer, Harold L. Thomas, corresponding secretary; Helen Kriegsman and Gary McGrath, faculty sponsors.

Kansas Beta, Emporia State University, Emporia
Chapter President - Mary Kuestersteffen
22 actives, 8 initiates

The Kansas Beta Chapter began its fall semester by co-sponsoring a picnic with the Physics and Chemistry clubs. The club held meetings every two weeks, to plan several fall activities such as monthly social gatherings and a Christmas party. On October 26, 1983, the KME members helped the math faculty with the annual Donald L. Bruyr Math Day. At the fall initiation, the chapter initiated eight new members. KME member Joe Kincaid spoke about "Life Without a Calculator" at this ceremony. The club is presently organizing a fund-raiser and trying to get KME T-shirts. Other 1983-84 officers: Galen Zirnstein, vice president; Elisabeth Henkle, secretary; Sherri Spade, treasurer; John Gerriets, corresponding secretary, Thomas Bonner, faculty sponsor.

Kansas Gamma, Benedictine College, Atchison
Chapter President - Jenny Farrell
12 actives, 12 initiates

The chapter sponsored two speakers during the fall semester. In October, Dr. Russell Waite, chairman of the college's Music Department, demonstrated the use of the Music Department Apple Computer to generate tones and for the composition of music in his talk entitled "Sound on the Apple." "Math Modeling and Cool Buttermilk in the Summer" was the fascinating title of the talk presented at a November meeting by Dr. Mary Kay Corbitt from the University of Kansas. Social activities during the semester included the fall picnic and the traditional Christmas Wassail party. Both were well attended. Plans are being made for a January Computer Dance. Other 1983-84 officers: Ann Devoy, vice president; Karen Henneberry, secretary and treasurer; Sister Jo Ann Fellin,corresponding secretary and faculty sponsor.

Kansas Delta, Washburn University, Topeka

Corresponding Secretary, Robert Thompson, reports that the chapter was rather "inactive" during the fall semester. They hope to have an initiation in the spring and "revitalize" the chapter.

Kansas Epsilon, Fort Hays State University, Hays
Chapter President - Jeff Sadler
30 actives, 4 initiates

The chapter,along with the Math Club, has helped the department with Math Relays and the University with Parents' Day activities. Also, with the Math Club, the chapter sponsored a Halloween party for mathematics students and faculty, sponsored a Faculty Appreciation Christmas dinner and has published a departmental newsletter, the π'd Piper. Five of the student members attended the NCTM meeting in Colorado Springs,Colorado. Other 1983-84 officers: Betty Burk, vice president; Bev Musselwhite,secretary and treasurer; Charles Votaw, corresponding secretary; Jeffrey Barnett, faculty sponsor.

Kentucky Alpha, Eastern Kentucky University, Richmond
Chapter President - Karen Applegate
40 actives, 3 initiates

The chapter sold computer-generated calendars at a campus festival. At one of the regular bi-weekly meetings, Dr. Patrick Costello gave a talk on "Questions in Number Theory." Other 1983-84 officers: Monica Feltner, vice president; Greg Allender, secretary; Philip White,treasurer; Patrick Costello, corresponding secretary; Donald Greenwell, faculty sponsor.

Maryland Beta, West Maryland College, Westminster
Chapter President - Stephen Coffman
15 actives, 1 initiate

In September, a planning meeting of the officers was held at the home of the Corresponding Secretary, Dr. Lightner. On October 18, one new member, Nettie Berrick, was inducted. A talk by Dr. Jack Clark on various ways to sum a special series, based on a problem in the Mathematics Monthly was presented at the initiation. In November, two members, Cliff Martin and Cheryl Wheatley, each presented talks to the group. A joint meeting with several nearby chapters is planned for the spring. Other 1983-84 officers: Wende Reeser, vice president; Chris Brown, secretary; Michael Armacost,treasurer; James E. Lightner, corresponding secretary; Jack Clark, faculty sponsor.

Maryland Delta, Frostburg State College, Frostburg
Chapter President - Vincent Costello
28 actives

Employment opportunities are of interest to many students and Maryland Delta members are no exception. Presentations by Gary Cruttenden, Joe Olah, and Susan Hurt, who described their internship experiences, were very enlightening and well received. Other 1983-84 officers: Joseph Olah, vice president; Susan Hurt, secretary;Lynn Harpold, treasurer; Don Shriner, corresponding secretary; John Jones, faculty sponsor.

Michigan Beta,Central Michigan University, Mt. Pleasant
Chapter President - Porterfield
60 actives, 29 initiates

The fall semester began with a KME picnic for KME members and mathematics faculty. Dr. Robert Chaffer of the CMU Mathematics Department was guest speaker for the fall initiation. The chapter provided mathematics help for freshman-sophomore mathematics students. A Coffee Hour was hosted for KME alumni at Homecoming. Other 1983-84 officers: William Ruelle, vice president; Kathy Baker, secretary; Dan Roche, treasurer; Arnold Hammel, corresponding secretary and faculty sponsor.

Mississippi Alpha, Mississippi University for Women, Columbus
Chapter President - Melesia Coleman
10 actives, 7 initiates

Mississippi Alpha Chapter designed and had printed T-shirts with the KME emblem on it so that they could advertise their presence on campus. Other 1983-84 officers: Susal Furlow, vice president; Yvonne Stewart, secretary and treasurer; Jean Ann Parra, corresponding secretary; Carol B. Ottinger, faculty sponsor.

Missouri Alpha, Southwest Missouri State University, Springfield
Chapter President - Shelly Robbins
52 actives, 14 initiates

Monthly meetings were held with either a student or a faculty member presenting a paper. Other 1983-84 officers: Sharyn Birkenbach, vice president; Ellen Capehart, secretary; Keith Huffman, treasurer; M. Michael Awad, corresponding secretary; L. T. Shifflet, faculty sponsor.

Missouri Beta, Central Missouri State University, Warrensburg
Chapter President - Alice Hink
24 actives, 4 initiates

The chapter held 4 regular meetings with one initiation. The program for the meetings included Dr. Craven, who spoke on her statistical research on back pain; Dr. Cooper who spoke on the ACM Regional Programming Contest; and Dr. Schrag, whose lecture was entitled, "Are round pizzas different from square ones, or are they both just 'plane' delicious." The activities included a picnic and a Halloween party which were held in October, and a Christmas party during the month of December. Other 1983-84 officers: Barry Hayden, vice president; Janette Mize, secretary; Brenda Enke, treasurer; Homer F. Hampton, corresponding secretary; Larry Dilley and Gerald Schrag, faculty sponsors.

Missouri Epsilon, Central Methodist College, Fayette
Chapter President - Judy Frazee
8 actives

Other 1983-84 officers: Robin Hamil, vice president; Cheryl Mathewson, secretary and treasurer; William D. McIntosh, corresponding secretary and faculty sponsor.

Missouri Zeta, University of Missouri-Rolla, Rolla
Chapter President - James Farley
39 actives, 14 initiates

Meetings were held in September, October, November and December. The annual faculty student picnic on October 7 was especially successful. Help sessions for all math classes through Differential Equations were conducted on a regular semiweekly basis. The initiation banquet was held on November 20 at Judy's Restaurant. Professor Louis Grimm was the speaker. He gave a very amusing and anecdotal talk on his experiences attending mathematics conferences behind the Iron Curtain. Other 1983-84 officers; Sherri L. Riggs, vice president; Tom Lonski, secretary; Ervan Darnell, treasurer; Tom Powell, corresponding secretary; Jim Joiner, faculty sponsor.

Missouri Eta, Northeast Missouri State University, Kirksville
Chapter President - Sandy Nelson
23 actives, 8 initiates

Missouri Eta Chapter sponsored a book sale on campus, with the proceeds being donated to the United Fund. A volleyball match was held against the Mathematics faculty. The chapter and the Mathematics faculty had a pizza party. For meeting programs, four seniors made presentations with topics ranging from methods of mathematical proofs to computer techniques. A Christmas party for the KME members and math faculty closed the semester. Other 1983-84 officers: Edward Jurawtich, vice president; Becky Hutton, secretary; Robert Clark, treasurer; Sam Lesseig, corresponding secretary; Mary Beersman, faculty sponsor.

Nebraska Alpha, Wayne State College, Wayne
Chapter President - Annette Schmit
17 actives

The club participated in the fall college homecoming activities by painting and erecting a billboard and by entering a team in the Greek Olympics. The all female team placed second in their category. Brenda Mandel was awarded the $25.00 book scholarship which is awarded to a KME member each semester. Members, Debby Lofton and Bonnie Rupprecht, along with members of the mathematics department, attended the National Council of Teachers of Mathematics convention held in Omaha, Nebraska, in October. The major money-making project for the club was monitoring the Math-Science Building in the evenings. The club terminated an active semester with a pizza party held at a local restaurant. Other 1983-84 officers: Kim Prchal, vice president; Deb Lofton, secretary and treasurer; Mike Rood, historian; Fred Webber, corresponding secretary; James Paige and Hilbert Johs, faculty sponsors.

Nebraska Beta, Kearney State College, Kearney
Chapter President - Sharon Hostler
30 actives, 10 initiates

The chapter held weekly meetings with guest speakers. Mathematics books were sold as a fund raising project. Joint social functions were held with computer science students (ACM). Other 1983-84 officers: Jodi Shoup, vice president;Dawn Winchell, secretary; Mark Jacobson, treasurer; Charles Pickens, corresponding secretary; Nelson Fong, faculty sponsor.

Nebraska Gamma, Chadron State College, Chadron
Chapter President - Annette Wiemers
13 actives, 6 initiates

Other 1983-84 officers: David Mundt, vice president; Steve Dent, secretary; Gene McDowell, treasurer; James A. Kaus, corresponding secretary; Monte Fickel, faculty sponsor.

New Jersey Beta, Montclair State College, Upper Montclair
Chapter President - Donna Jean Cedio
14 actives, 5 initiates

During the fall semester, the chapter held several meetings. Bagel sales were organized to raise money. The film, "Future Careers: A Personal Interview" was shown. Members were given the opportunity to experiment with the Computer Science Department microcomputers. Aphesteon will be sending a representative to lecture at the March MAA meeting also. In addition, members participated in the National Putnam Competition. The initiation dinner was held at the Robin Hood Inn, Clifton, New Jersey on November 18, 1983. Other 1983-84 officers: Maryann Dworak, vice president; Raquel Hernandez, secretary; Lisa Rutkowski, treasurer; Dr. Stevens, corresponding secretary; Dr. Devlin, faculty sponsor.

New Mexico Alpha, University of New Mexico, Albuquerque
Chapter President - Martin Murphy
60 actives

Other 1983-84 officers: Stephanie Hendrix, vice president; Terry Hardin, secretary; Richard Metzler, treasurer; Merle Mitchell, corresponding secretary and faculty sponsor.

New York Eta, Niagara University, Niagara
Chapter President - Jim Krzyzanowski
17 actives

Most of the fall activities this year centered around assisting the Mathematics Department which hosted the fall meeting of the Seaway Section of the Mathematical Association of America. The students registered attendees to the meeting and helped to direct out-of-town visitors around the campus. Plans are now being made for the spring initiation ceremony and for some fund-raising activities. Other 1983-84 officers; Kevin Kernin, vice president; Dennis Holtschneider, secretary; Chris Reilly, treasurer; Robert L. Bailey, corresponding secretary; James Huard, faculty sponsor.

New York Lambda, C. W. Post Center - Long Island University, Greenvale
Chapter President - Joanne Carlough
16 actives

Plans are being made for a spring speaker and initiation ceremony. Other 1983-84 officers: Steve Buonincontri, vice president and treasurer; Sharon Kunoff, corresponding secretary and faculty sponsor.

Ohio Alpha, Bowling Green State University, Bowling Green
Chapter President - Debra Steffens
45 actives

The semester began with a KME picnic for the faculty and their families, the graduate students, and all KME members. The chapter was also privileged to help Phi Beta Kappa welcome guest lecturer, Saunders Maclane, a distinguished mathematician from the University of Chicago. Future plans include a tour of Marathon and a visit to the university's new planetarium. Initiation for this school year will occur in the spring. Other 1983-84 officers: Susan Kaeck, vice president; George Rosekelly, secretary; Cheryl Noe, treasurer; Fred Leetch, corresponding secretary; Wallace Terwilliger, faculty sponsor.

Ohio Gamma, Baldwin Wallace College, Berea
Chapter President - Pamela Botson
25 actives

Other 1983-84 officers: Alice Kruzel, vice president; Kelly Flood, secretary; Mark Maceyko, treasurer; Robert Schlea,corresponding secretary and faculty sponsor.

Oklahoma Beta, University of Tulsa, Tulsa
Chapter President - Kathy DeHart
20 actives

Richard Redner is now corresponding secretary and faculty sponsor.

Oklahoma Gamma, Southwestern Oklahoma State University, Weatherford
Chapter President - Cynthia Phillips
25 actives, 13 initiates

Fall semester activities included a picnic, a speaker from Oklahoma State University, initiation of new members, a fall bake sale during Math Day and a Christmas pizza party. Other 1983-84 officers: Robert Estes, vice president; Scott Goeringer, secretary and treasurer; Wayne Hayes, corresponding secretary; Kelvin Casebeer, faculty sponsor.

Pennsylvania Alpha, Westminster College, New Wilmington
Chapter President - Kirsten Pealstrom
30 actives

A fall picnic was held to meet new math and computer science majors and to renew acquaintances. The chapter provided a tutorial service for the math classes and assisted the Mathematics Department with the Annual High School Math Competition by proctoring and grading tests. Internship Night was held when several students related their experiences with internships. The semester ended with a Christmas party which was enjoyed by all. Other 1983-84 officers: Barry Hall, vice president; Sheri Walker, secretary; Mary Curran, treasurer; Miller Peck, corresponding secretary; Barbara Faires and Thomas Nealeigh, faculty sponsors.

Pennsylvania Delta, Marywood College, Scranton
Chapter President - Chris Adams
1 active, 5 initiates

Some members attended the NCTM Regional Conference in Philadelphia, Nov. 9-11, 1983. Preparations were also made for a math contest for area high school students to be held in the spring. Sr. Robert Ann von Ahnen is corresponding secretary.

Pennsylvania Epsilon, Kutztown University, Kutztown
Chapter President - Jeff Herbein
12 actives, 12 initiates

Other 1983-84 officers: Melodie Schumaker, vice president; Kelley Green, secretary; Brian Balthasar, treasurer; I. Hollingshead, corresponding secretary; E. Evans, faculty sponsor.

Pennsylvania Zeta, Indiana University of PA, Indiana
Chapter President - Susan Garrett
20 actives, 3 initiates

Mathematics Department Faculty presented talks at meetings in October, November, and December. Speakers and their topics included Dr. Joseph Angelo, "Transfinite Numbers";Dr. Douglas Frank, "Geometric Probabilities"; and Mr. Gary Thompson, "Rational Numbers and Repeating Decimals and Interesting Oddities about Pascal's Triangle." New members were initiated in October. Other 1983-84 officers: Allan Williams, vice president; Kelly Orndorff, secretary and treasurer; Ida Z. Arms, corresponding secretary; William R. Smith, faculty sponsor.

Pennsylvania Eta, Grove City Village, Grove City
Chapter President - Mary Ann Friedrich
26 actives, 21 initiates

Twenty students were initiated as new members in PA ETA Chapter during a dinner meeting in Mary Anderson Pew dormitory on October 12. Dr. Ed Daggit spoke to the KME group during another after dinner meeting on November 8. He related his experiences and observations while on a trip to China this past summer. Mr.

Schlossmagel,chairman of the Math Department hosted the group for the annual Christmas party on December 12. Other 1983-84 officers: Sue Lowin, vice president; Diane Brosius, secretary; Marci Barkich, treasurer; Marvin C. Henry, corresponding secretary; Dan Dean, faculty sponsor.

Pennsylvania Kappa, Holy Family College, Philadelphia
Chapter President - Linda Rafferty
5 actives, 5 initiates

The KME chapter members attended the NCTM Philadelphia Conference November 9-11, 1983. Because the Computer Literacy is becoming so very important, the members plan to tutor anyone interested to learn about the microcomputers in the spring of 1984. Other 1983-84 officers: Christina Niescier, secretary and treasurer; Sister M. Grace, corresponding secretary.

Pennsylvania Lambda, Bloomsburg University, Bloomsburg
Chapter President - Sue Jurgill
30 actives, 10 initiates

The chapter celebrated its 10th anniversary with a special induction banquet. James Lightner, Past National President of KME from Western Maryland College was the keynote speaker. Alumni members were invited to attend. Other 1983-84 officers: Richard Stec, vice president; Diane Chesky, secretary; Virginia Q. Atkins, treasurer; James Pomfret, corresponding secretary; Joseph Mueller, faculty sponsor.

South Carolina Beta, South Carolina State College, Orangeburg
Chapter President - Lorraine Samuels
7 actives, 2 initiates

On November 20, 1983,induction ceremonies were held. Among these ceremonies, Kappa Mu Epsilon acquired two new members. They presented projects to the faculty and members. The agenda for the year was planned which includes various activities such as "Meet the Mathematics Seniors" and a Quiz Bowl. Other 1983-84 officers: Derrick Green, vice president; Ella Thomas, secretary; Rodney Ragin, treasurer; Frank Staley, corresponding secretary; Manuel Keepler, faculty sponsor.

South Carolina Gamma, Winthrop College, Rock Hill
Chapter President - Anita Anderson
17 actives, 2 initiates

Three meetings were held during the fall semester. Chuck Baldwin and Don Aplin each presented a talk on mathematics. The placement officer of the college presented a talk on opportunities in mathematics. Other 1983-84 officers: Phil Blankstein, vice president; Kenneth Peay, secretary; Chuck Baldwin, treasurer; Donald Aplin, corresponding secretary; Edward Guettler, faculty sponsor.

Tennessee Alpha, Tennessee Technological University, Cookeville
Chapter President - Sherri Menees
130 actives

The Tennessee Tech Chapter of KME met last fall to see a presentation by Dr. Carl Ventrice on his research in lasers. Other 1983-84 officers: Lynn Matthews, vice president; Elisa Gould, secretary; Mike Sessions, treasurer; Ed D. Dixon, corresponding secretary; S. B. Khleif, faculty sponsor.

Tennessee Gamma, Union University, Jackson
Chapter President - Judy Escue
25 actives, 4 initiates

Other 1983-84 officers: Marcy Boston, vice president; Sandy Hale, secretary; Laurie Hale, treasurer; Richard Dehn, corresponding secretary; Rich Nadig, faculty sponsor.

Tennessee Delta, Carson-Newman College, Jefferson City
Chapter President - Dennis Beal
17 actives

Although consisting of only nine members on campus, this year's chapter of KME had a very active year. The year's activities began with a joint hike with the Society of Physics Students in the Smoky Mountains in October. A campus bowl team, the "Infinite Series", was organized and participated in the campus-wide bowl. On November 7, a four-member panel of Carson-Newman graduate math majors told about their particular careers and how they used mathematics in their current occupation. The panel members' occupations included a systems analyst, high school math teacher, engineer, and COBOL computer programmer. On November 29, two representatives from the Air Force came and presented a film on what opportunities the Air Force has for undergraduate math, physics, and engineering majors. After the film, the Air Force treated those attending to free pizza and cokes. One of the biggest events in our KME chapter history came on December 1. The members of KME sponsored a Mathematics Professor Appreciation Day. The semester closed with a Christmas party, which was a Progressive Dinner. Other 1983-84 officers: Susan Saylor, vice president; Jeff Knisley, secretary; Susan Williams, treasurer; Albert Myers, corresponding secretary; Carey Herring, faculty sponsor.

Texas Eta, Hardin-Simmons University, Abilene
Chapter President - Randall Bradshaw
20 actives

A get-acquainted party was held at the home of Dr. and Mrs. Edwin J. Hewett. The purpose and activities of the society were explained to prospective members and recently inducted members received their shingles. Other 1983-84 officers: Dana Allen, vice president; Linda Haire, secretary; Robbie Chesser, treasurer; Mary Wagner, corresponding secretary; Charles Robinson and Edwin Hewett, faculty sponsors.

Wisconsin Alpha, Mount Mary College, Milwaukee
Chapter President - Bonnie Best
8 actives

Wisconsin Alpha sponsored the annual mathematics contest for junior and senior high school girls on November 19, 1983. Time was spent discussing means of raising funds. A doughnut sale and a Christmas ornament sale was held. Other 1983-84 officers: Veronica Walicki, vice president; Linda Schmidt, secretary; Barbara Schilter, treasurer; Sister Adrienne Eickman, corresponding secretary; Sister M.Petronia Van Straten, faculty sponsor.

Wisconsin Gamma, University of Wisconsin-Eau Claire, Eau Claire
Chapter President - Joe Lesniak
22 actives

Dr. Hsiung from Cray Research of Chippewa Falls spoke at the October 11th meeting. His talk was centered on the speed and organization of their supercomputers. For a fund raiser, on Saturday, October 15th, KME members worked at the Wisconsin Mathematics Council meeting. They worked registration, sold books for NCTM and kept a refreshment stand. November 15th's meeting featured Sue Kelly as the student speaker. Her talk was on the application of elementary differential equations to determine the authenticity of paintings. The examples used in the talk were the Van Meegeren 20th century forgeries of alleged Vermeer masterpieces. Other 1983-84 officers: Sue Kelly, vice president; Ray Skurierczynski, secretary; Sandra Rekstad, treasurer; Tom Wineinger, corresponding secretary; Wilbur Happe and Bob Langer, faculty sponsors.

ANNOUNCEMENT OF TWENTY-FIFTH BIENNIAL CONVENTION

The 25th Biennial convention of Kappa Mu Epsilon will be held on April 11-13, 1985 at Southern Methodist University, Dallas, Texas. Each chapter that sends a delegation will be allowed some travel expenses from National Kappa Mu Epsilon funds. Travel funds are disbursed in accordance with Article VI, Section 2 of the KME constitution.

A significant feature of this convention will be the presentation of papers by student members of KME. The mathematics topic which the student selects should be in his/her area of interest, and of such scope that he/she can give it adequate treatment within the time allotted.

Who May Submit Papers? Any student member of KME, undergraduate or graduate, may submit a paper for use on the convention program. A paper may be co-authored; if selected for presentation at the convention it must be presented by one or more of the authors. Graduate students will not compete with undergraduates.

Subject: The material should be within the scope of the understanding of undergraduates, preferably those who have completed differential and integral calculus. The Selection Committee will naturally favor papers within this limitation, and which can be presented with reasonable completeness within the time limit.

Time Limit: The minimum length of a paper is 15 minutes; the maximum length is 25 minutes.

Form of Paper: Four copies of the paper to be presented, together with a description of the charts, models, or other visual aids that are to be used in the presentation, should be presented in typewritten form, following the normal techniques of term paper presentation. It should be presented in the form in which it will be presented, including length. (A long paper should not be submitted with the idea it will be shortened for presentation.) Appropriate footnoting and bibliographical references are expected. A cover sheet should be prepared which will include the title of the paper, the student's name (which should not appear elsewhere in the paper), a designation of his/her classification in school (graduate or undergraduate), the student's permanent address, and a statement that the author is a member of Kappa Mu Epsilon, duly attested to by the Corresponding Secretary of the student's Chapter.

Date Due: January 18, 1985

Address to Send Papers: Professor James L. Smith
Mathematics & Computing
Science Department
Muskingum College
New Concord, OH 43762

Selection: The Selection Committee will choose about fifteen papers for presentation at the convention. All other papers will be listed by title and student's name on the convention program, and will be available as alternates. Following the Selection Committee's decision, all students submitting papers will be notified by the National President-Elect of the status of their papers.

Criteria for Selection and Convention Judging:

- A. The Paper
  1. Originality in the choice of topic
  2. Appropriateness of the topic to the meeting and audience
  3. Organization of the material
  4. Depth and significance of the content
  5. Understanding of the material
- B. The Presentation
  1. Style of presentation
  2. Maintenance of interest
  3. Use of audio-visual materials (if applicable)
  4. Enthusiasm for the topic
  5. Overall effect
  6. Adherence to the time limit

Prizes: The author of each paper presented at the convention will be given a two-year extension of his/her subscription to The Pentagon. Authors of the four best papers presented by undergraduates, based on the judgment of the Awards Committee, composed of faculty and students, will be awarded cash prizes of \$60, \$40, \$30, and \$20 respectively. If enough papers are presented by graduate students, then one or more prizes will be awarded to this group.

Prize winning papers will be published in The Pentagon, after any necessary editing. All other submitted papers will be considered for publication at the discretion of the Editor.

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