PERMISSION TO ADD:

MATH TEACHING LIMERICKS

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MATH 101

Functions are just like numbers.
They get lugged around like lumber.
They get add- and subtracted
and more interacted
making us dumb and dumber.

(Cost Analysis)
The cost of producing is mixed.
Part of that cost is fixed.
And the rest, never-ending
on level depending
(or maybe on politics).

(Rational Functions)
Said your favorite Zada or Tante
“for an asymptote horizonta
“you need to use both
“of the leading coeff’s
“whether or not you wanta.”

(Exponential Functions)
The bottom is perfectly noble
but x is now upwardly mobile
so that constant, poor dear
must downsize it’s career
and it’s feeling a bit claustrophob-al.

These guys are as busy as beavers.
They’ve got Monday morning fever.
They just grow, grow, and grow.
They’re NEVER zero.
And they don’t remain one for long, either.

Do logs give you logarrhea?
Is a logjam drawing near?
Just use your credentials
and take exponentials
to make those ol’ logs disappear.

(Matrix multiplication)
Just pair off each row with each column.
Take the sums of those products so solemn.
Yes, beat the odds
with those scalar prods
or whatever the devil you call ‘em.

(Compound Interest)
“Nothing succeeds like success,”
as these formulas show with finesse.
Thus again and again
A gets bigger with n
though not quite as big as you’d guess.

(Annuities)
And now here’s another fine source
(to tickle your brain in this course)
of mo’ and mo’ dough.
It’s dough a go-go.
Oh, don’t you just wish it was yours.

CALCULUS LIMERICKS

Diff-ing x-to-the-n is fun.
Change the n to n minus one.
Then go back to n
and use it again
in front of it all, and you're done.

It is not my intention to vex.
It is not my intention to hex.
My only intention
is merely to mention:
The diff of x-square is 2x.

It is not my intention to glare.
It is not my intention to scare.
My only intention
is merely to mention:
The diff of x-cube's 3x-square.

There's a general rule for all this
(in case someone pulls a pop quiz):
n steps down two ways
for the rest of its days
and x remains right where it is.

"Than receive it is better to give."
Also, "live, live, and let live."
These are words to clutch
but not as much
as "velocity equals deriv".

(General Power Rule)
Are you bored with powers of x?
What would you like to do next?
Some powers of g
will do nicely
but watch out for the special effects.

On, Dasher! On, Dancer! On, Prancer!
Don't forget the power in the answer.
It gives it might
and makes it right
also a little fancier.

Three cheers for parentheses!
They make forests out of trees.
But be careful about
what's in and what's out
or they'll look like they have some disease.

(Product Rule)
Don't forget -- f appears twice.
g will behave likewise.
If you make like a dunce
and write them just once
... well, you'll get what you get for half-price.

Said a wiseguy named Georgy O'Porgy,
"Let's have a Quotient Rule orgy.
"On top, to be nice
"let g appear twice
"and then on the bottom one more g."

(Chain Rule)
Rinky, dinky, dinky.
g provides the link-y.
But the x and the f
are not to be left
unless we run out of ink-y.

For lazy exec's and high techs
presenting: e-to-the-x.
To diff it's a cinch
(to the nearest square inch)
do nothing at all, just relex.

Ln x, you can't just be.
You have to get diff'd, yessirree.
So give ln the slip
then take the recip
to get one-over-x, easily.

(General Ln Rule)
On bottom goes the copy.
And what goes on the top-py?
Why, the diff, g-prime.
It makes it rhyme.
And please don't write it sloppy.

The diff of x-square we all love.
But what is x-square the diff OF?
The answer is easy.
Just change 2 to 3-zy
and put it below and above.

(Integrating Powers of x)
There's a general rule for all this
(and it's something you don't want to miss):
n moves up and down
all over the town
and x remains right where it is.

(Integrating Exponentials)
And now here's a grave admonition
delivered with proper precision:
It's about that k.
It steps down just ONE way
and the x doesn't go where it isn't.

Minus-one is a cool special case
delicious and dainty as lace.
So don't play the hero.
Don't divide by zero.
If you do, be sure to erase.

(Curve-sketching)
We can plot and plot 'til we plotz.
But we've got to plot the right spots.
Or those lows and those highs
could elude us like flies.
Likewise the flips and the flops.

There was a young man named Kareem
who explained, "For a local extreme
"the tangent at a
"to rest must lay
"and we wish it the pleasant-est dream."

Said his kissin' cousin Trix
"But not vice versa -- nix.
"That tangent can flatten
"as low as Manhattan
"with no min, no max, just a mix."

A fair maid from North Minnesota
was drawing a steep asymptot-a.
When it got 'way too high
she murmured bye-bye
and mourned not a single iota.

(Integration by Parts)
"We need f and g-prime," said Mitch
"and it matters which is which."
"But not to worry,"
said his cousin Murray.
"It doesn't work out, we'll switch."

Root-a-toot too-a-falutin'.
It's time for some substitutin'.
Take stuff on display
and collapse it away
right along with Leibniz and Newton.

The differential
is essential.

(Definite Integral, Fundamental Theorem)
This one begins geometric
and then it becomes quite eclectic.
It sports f's with grace
upper and lower case
and its a's and b's go hectic.

(Area between Curves)
If the graph of x-to-the-sixth
with x-to-the-eighth is, not mixed
only placed, for our practice
on one set of axes
then subtract to find what's in betwixt.

Don't forget, curves might cross
in which case you should take time to pause
so you don't subtract
when add's where it's at.
'Twould be a lamentable loss.

To split or not to split?
'Til the question that stymied Hamlet.
But when you're in doubt
don't leave the split out
though it's harder, I admit.

We could sit all prim and proper
privileged as gold and copper
but 'twould perk our careers
if we'd get off our rears
and become intersection-hoppers.

(Solids of Revolution)
A strapping young woman named Evvie
was handed a solid of rev-y
and asked for the volume.
She answered, quite solemn
"it's not very big but it's heavy."

(Average Value of a Function)
Riki tiki tavi.
Here's some calculus savvy.
The inteGRAL
o'er the interVAL
will give us our function's av-y.

(Integration Techniques: Sine-Saving)
Said a technique freak named Zeek
"If you think sine-saving is chic
"and you want to save
"yourself into the grave
"try cos and tan and sec."

Here's a litty ditty
helpful if not cute:
What we save is the deriv
of what we substitute.

(Deriv's of Trig Functions)
A darling named Clementine
said, "First sine, then cos, then sine.
"And the minus and plus
"make things even wuss.
"Can't it make up its mind?"

A Non-Limerick:
Can we integrate tan?
Yes, we can.
Can we integrate secant?
No, we can't.

(Trig-triggers -- i.e., trigonometric substitutions)
A trig-trigging trickster from Beacon
is stuck on an odd-powered secant.
An integral table
would render him able
but his conscious is prodding "no peekin' ".

Trig, trigger, triggerest.
Try not to be too vigorous.
If you trig too much trig
it'll get too big
and you'll fall down just like Icarus.

(l'Hospital's Rule) (Good Golly, Miss Molly! Here comes l'Hospital-y.)
There was a fair maid from Nepal
who was expert in ol' l'Hospital.
She diff'd 'til she dropped
on bottom and top
then murmured "Nice knowing y'all."

(Hyperbolic Functions) (Are you a hyperbolic-aholic?)
Take the trig I.D.'s, all kinds
add h to those cos's and sin's
and this derring-do
leaves them all still true
except for a few miinus-signs.

(Completing the Square)
When the middle term nerdily lurks
use this to get rid of the jerk.
Sometimes a wild guess
will get rid of the mess.
And algebra always works.

(Approximate Integration)
The Trapezoid Rule can be fun.
All those 2's will get the job done.
But watch out, my friends
for the left and right ends.
At those we will need only 1.

Cheer up. (Don't look like such wrecks.)
I know this seems pretty complex.
And there's many a y
where the midponts lie
but there's only one delta-x.

Just look at those sixes and fours!
They're the prettiest things in this course.
And this cool rule of Simpson
will stay sweet and winsome
once you've become sophomores.

(Improper Integrals)
Said a ship-shape chap from the Congo
"Since our region is infinite long-o
"it's likely that you'd
"be inclined to conclude
"that it's infinite big, but you're wrong-o."

Said a dashing young bloke named Apollo
"Since our region is infinite tall-o
"It's likely you'll dig
"it be infinite big
"but sorry, that doesn't quite follow."

(Separable Differential Equations)
A ditzo from hither or thither
refused to get all in a tither.
"'Tis true," said he, "I
"can't tell x from y
"but can't tell left from right-y, either."

The vertical line test's a pity.
It stops curves from being pretty.
But we can make loops
without saying "Ooops?"
with parametric graph-iti.

(Polar Coordinates)
With these we can also be arty.
We can have a plotting party.
While away the hours
making petals and flowers
along with Mercenne and Descartes.

Would you like to come up to the board
and draw r and theta coord's?
We'll get hulas and hoops
and loop de loops
and other delicious rewards.

(Geometric series)
The first in our fine repertoire
is one-over-one-minus-r.
We shouldn't forget it
for where we are headed
or else we won't head very far.

A savvy young fellow names Frederick
summed an infinite geometric.
But he did not addition
just subtract- and division
for he knew his rote and his rhetoric.

(Infinite Series -- Comparison Test)
Smaller than small is small.
Taller than tall is tall.
And that's how it goes
and that's how one knows
whether anything happens at all.

(Limit Comparison Test)
Eventually smaller than small
and eventually taller than tall
is as small and as tall
as we need things to fall
and that will take care of it all.

(Integral Test)
If we know what happens with n's
all x's will follow, my friends.
It's all essentially
the same, consequentially
and on each the other depends.

(Alternating Series)
However they rageth and roareth
and wobbleth back and forth,
you'll eventually find
that they make up their mind
someplace between south and north.

An industrious lad from the near East
was summing a long Taylor series.
At the twentieth head
he just shrugged and said,
"That's as far as I'm going, my dearies."

(Maclaurin Series)
The coeff. of x-to-the-n
is as simple as counting to ten.
There's a derivation
and an exclamation
again and again and again.

(Taylor Series about x_0)
Up to now x-nought was zer-e-o.
But now we've got this new theory-o
in case Maclaurin
was gettin' borin'
and you were gettin' weary-o.

Can you count? Then here's one for you:
One less x to the minus-two.
It's quite easy.
Write 1, 2, 3
and the powers and the plus-signs, too.

(Separable Differential Equations)
A ditzo from hither or thither
refused to get all in a tither.
" 'Tis true," said he, "I
"can't tell x from y
"but can't tell left from right-y, either."

(Partial Deriv's)
We x 'em and we y 'em.
But not both at the same time.
f_x is one
f_y's also fun
though we never get to f-prime.

(End-of-Term Farewell)
Yes, I know, it's 10:49.
But this proof needs one more line.
I promise I'll write
with all of my might.
(Keep mum if I'm off by a sign.)

COMPLEX ANALYSIS

A reality complex had Fred.
He felt kind of bad in the head.
So he took Complex Var
with Cohen Mar
got a complex complex instead.

There was a young lady named Suzie
who couldn't add 2z and 2z.
She said, "Can't it be
"without that ol' z?"
She's being a little too choosy.

(nth Roots of Unity)
There are n ot them sprawled on a wheel.
Among them at most two are real.
The others must go
half above, half below.
But they get paired off in the deal.

e-to-the-z is exotic.
And it changes a sum to a product.
It has no root
but it's kind of cute
and it's vertically periodic.

A young man named Kenny macKenzie
had trouble computing ln z.
He breezed through the r-part
with the slickness of pop art
but the theta-part gave him a frenzy.

Here's the key to z-to-the-c:
It's just e-to-the-c-ln-z.
But watch for ln-y.
Its values are many
though sometimes e makes them agree.

(Said Sin and Cos)
"In trig and in calc, all through
one was the limit we knew.
But now we're set free.
Now we can be
anything we desire such as two."

How smart the conditions of C-R !
They're almost as brilliant as we are.
But they're known for their sly-ness.
Watch out for that minus
or we'll spend half the night in the E.R.

Yes, here they come, hot off the griddle
spiffy and spicy and little.
One sports a plus
the other mi-nus
and none of them sports the middle.

The research team Cauchy and Goursat
was busting its brain and its torso.
They went huffin' and puffin'
but came up with nothin'.
Now they're living on noodles and orzo.

The pretty professor from Jersey
just stood there and pleaded for mercy.
She said "in complex
"v-y equals u-x --
"or maybe it's vice vers-y."

i after e after u
after pi after n after 2
after p'renthesis ln
and then no more spellin'
unless we can find something new.
(Thanks to Bob Blackard for getting me started on this one.)

Our pretty professor's a rarity.
Her lectures the height of clarity.
Except that when
she does minus-one to the n
n turns out to be the wrong parity.

The pretty professor, our rarity
was engulfed in hyper-hilarity
'cause again she had spun
a spare minus-one.
She said, "Well, we can give it to charity."

(About $\oint f(x)/(z-z_o)^n$)
When C's end is at its beginnin'
ask "Is z-nought out'n or in'n ?"
Draw the point, draw the curve.
Then stand back and observe.
If in doubt get a second opin'on.

Computing it's easy as pie
(especially if you try).
There's a derivation
and an exclamation
and don't forget two pi i.

This classroom is water- and sun-proof
and poison- and noisin'- and gun-proof.
It's as pure as the Gospel
of everything poss'ble
except that it's not minus-one-proof.

Geometric ser's are a gem.
But let's add that little m --
OUTSIDE, if you please
the parentheses.
Did you hope I'd forget about them?

The last of those spunky Mohicans
was at work on a long Cauchy sequence.
It was i - pi - y
from Mon to Fri
and he took it home on the weekends.

Can you count? Then here's one for you.
One less z to the minus-two.
Write 1, 2, 3
then blank, z, z
and the pow'rs and the plus-signs, too.

A fair maid from Northern Miami
was at work on the triple-whammy.
She tried subtraction
and partial fractions.
Then she called for her pappy and mammy.

A lazy young lad named Laurent-o
used his series to integrate pronto.
Just b-one will do
and as for b-two
you need only find that it you want to.

O what will the fair miad named Tessa do?
She's been after a simple-pole residue.
She says, "NOW I see.
"It's q-prime UNDER p.
"Then I plug in z-nought -- or I guess I do."

TEACH-TONE PHONE (Remember, I gave out my phone number? Well, no one ever called, but if you had, here's what my recording said -- See what you missed?)
For Cauchy-Goursat
press O.

For some integral fun
press 1.
For a residue
press 2.
For $l / (l - z)$
press 3.
For contours galore
press 4.
But to find out the fate of a minus sign
be patient, please, and stay on the line.

LINEAR ALGEBRA

Allow me some words of great wisdom
about any linear system:
It is represented
by a matrix, augmented
which explains this course's existence.

Do row op upon row op.
Keep doing them 'til you drop
or until rectangular
becomes triangular.
(And the triangle's on top.)

The form which is just-plain row ech-
means surely you'll still have to thresh
with back substitution
so keep on reducin'
to get x-sub-i in the flesh.

(Matrix multiplication)
Just pair off each row with each column.
Take the sum of those products so solemn.
Yes, beat the odds
with those scalar prods
or whatever the devil ya call 'em.

(Definition of Determinant)
O, nothing could ever be finer
than replacing A major with minor.
Of course, for most n
we must do it again.
And the signs will get sign-er and sign-er.

(det A x det B = det AB)
I don't mean to cause you to squirm
but the computations confirm
that determ before prod
(in the eyes of God)
gives the prod before the determ.

When we wish that our fingers were toes
and we wish that the columns were rows
and the i's and the j's
are turned the wrong ways,
'tis time to bring on the transpose.

(how to find A-inverse)
On cofactors get yourself versed.
But start with the transpose first.
And do not forget
to divide by det
or you'll wind up forever cursed.

If you know how to cut and to paste
and can figure determ's with great haste
and one more aside:
if you've learned to divide
then by Cramer's cool rule you are graced.

(to decide whether a given set of functions is linearly independent)
Line up all the functions in sight.
Then diff them with all of your might.
Then sing a sweet song
of right and of wrong
as we get that ol' Wronskian right.

A young man named Timothy Tigen
was searching for values eigen.
But the characteristic
and other logistics
were such that he needed to try 'gain.

(how to diagonalize)
E-values will get us big-D.
E-vectors will get us homefree.
Yep, string up the specs
and line up the x
and we'll get where we needed to be.

If its set of e-vectors is sizeable
then A is diagonalizable.
And the converse, too
has been tried and true.
(I hope that is all recognizable.)

(how to exponentiate a matrix)
Proceed as the previous verse
has instructed (for better or worse).
Treat D as you're tempted
and X is exempted
except we'll still need its inverse.

(Definition of vector space)
We plus 'em and muss 'em and mess 'em.
We shrink 'em and stretch 'em and press 'em.
And still they will be
inside our big-V.
Such fine loyal souls, the Lord bless 'em.

(subspaces)
We can push and pull and stress
and otherwise make a big mess
and they'll not only be
iniside our big-V
they'll also remain in big-S.

Can we get infinity from fin
(without committing a sin)?
Oh yes we sure can
with the kind help of span.
(After all, it's the past tense of spin.)

(dimension)
Each basis goes by its own name.
Each vector goes by its own aim.
But if you would count
the number-amount
the answers will turn out the same.

Base B can be used to express
any member of V or of S.
But the thigamabob
that will pull off the job
depend on which B we possess.

To get thigamabob for C
from thigamabob for B
will require the rendtion
of matrix, transition
and seldom will they agree.

(linear operators)
They're linear, down to the core.
They take zero to zero, no more.
And sums and doubles
and all other troubles
to what they had been before.

(Multiplication by any matrix is a linear operator.)
Said a fair young maid named Alexis
"Ax will double if x does
and A takes a sum
into something hum-drum
and there won't be any more extras."

(rank)
A matrix has n column-vectors.
Indeed, it's a vector collector.
It's all touchy-feel-y
but how many, really
are there and how many are exter?

(Column rank = row rank)
You can put them in lines or in layers.
And then, if you say the right prayers
it won't matter which.
The quarter-turn switch
won't change what's essentially there.

(Every linear operator = left multiplication by some matrix.)
Just take what L does to each e
and line them all up merrily.
And that's a good way
to get your big-A.
(Watch out so you don't get a B.)

Let's all do a little Gram-Schmidt
get orthogonal vectors that fit.
At every stage k
I'll show you the way.
(At k = n we can quit.)

VECTOR ANALYSIS

Here's something we might contemplate:
A vector's an arrow so straight.
For forces, its length
expresses its strength
and direction expresses its fate.

Two vectors, whatever the size
can be added, component-wize
so make so this rhymes
by adding three times
then put in the k, j, and i's.

(Scalar Multiplicatoin)
A spunky young woman named Ralpha
would muliply vectors by alpha.
She thought it quite nice
to multiply thrice
in this city of Philadal-pha.

(Scalar Product)
Here's the most fun you ever had:
Take products three times and then add.
Yes, do mind your mommas
and DON'T put in commas
(or momma will tell your Dad).

(Vector Product)
In this glossy and glorious firmament
nothing's more perfect or permanent
or more fancy-free
for u criss-cross v
than our ever-lovin' determinant.

i, j, and k are cute
and they're specially fixed to compute.
E.g., i cross j
is lower-case k.
but as arrows, they're too short to shoot.

(Some curve parametrization hints)
Straight lines are quite matter-of-fact
if you know how to add and subtract.
True, there's multiplication
in this situation
but nothing on which you need act

Although we are all mere amateurs
iin this business of making parameters
when it's circles in question
I have a suggeston:
Try not to forget the diameters.

(Formula for Curvature)
r-dot dot r-dot-dot.
Yes, sometimes we dot a lot.
But dot-dot-dot?
Or r-quad-dot?
. . . Well, sometimes we do not.

For that curvature for t' compute
that formula's really a beaut.
But when figuring kappa
do mind your Pappa
and don't you forget that square root.

It's easy and fun to do grad.
It makes us feel gleesome and glad.
Don't you feel so alive
when you partial-deriv?
But put commas, now -- don't you dare add.

Here's something no one will object to:
When doing the div please expect to
takes partials, three
of componenets of v
and be careful which with respect to.

Aloha, tres bien, and shalom.
May I mention a vital syndrome?
Towards the end of the div
you should get additive
(or just wait 'til your father gets home).

Now, the hardest is curl, we agree.
But let's have a determinant spree.
First, three vectors little
next, del in the middle
and then on the bottom goes v.

All told (and telling it true)
there's more in the curl to do.
We've got partials six
and note how they mix
and the answer's a vector, too.

(Directional Deriv.)
If we're out in the wide blue yon
rates of change depend, which directi-on.
So divide b by mag
then dot it with grad
and we'll find out how quickly we've gone.

(Unit Normals to Surfaces Given in the Form f(x, y, z) = C)
Said a dashing young man named Aeneas
"I've got a few dandy ideas:
"Just take our f's grad
"divide by the mag
"and it doesn't much matter what C is."

(Reality check)
When these poems you so dutif'ly edit
keep one thing in mind (to my credit):
I realize that mag
does not rhyme with grad
but the point is: YOU won't forget it.

(Surface Parametrization Hints -- Plane)
If you want to be this term's winner
remember, the keyword is linear.
So let us let z be
ua + vb
(for integrals outer and inner).

(Cylinder)
First, think of the xy-plane.
(That's not such a drain on the brain.)
Next, move once around
and then up and down.
If tired out, go hop on the train.

(Sphere)
Said a student from South Singapore
"We use cosines and sines galore
"or the sum of three squares
"would give us nightmares --
"Yes, that's what the trig stuff is for."

(Line Integrals)
And now we've got functions three.
What could the integral be?
The answer, essential:
Component, tangential.
It gets things in terms of small-t.

(Surface Integrals)
Next, functions (three) with a surface
(And Murphy's Law gets more Murfish).
But the answer, informal:
Component, normal
to get u's and v's at our service.

(Triple Integrals)
Now, triple int's can be quite chic
so of them we'll now start to speak.
But one thing clear:
No vectors here
(or you're grounded for a week).

(Divergence Theorem)
Next, the surface int. above
that we've all come to know and love
will be giving 'way
on this fabulous day
to a triple int. of the div. of.

(Stokes Theorem)
And now it is late, not early.
'Tis time for Stokes' Theorem, surely.
Any int. (closed line)
can be redesigned
as an int. involving the curl-y.

(Reality Check)
Again, as these lim'ricks you edit
remember one thing (to my credit):
I know that designed
does not rhyme with line
but it rhymes more than how Stokes said it.

DIFF EQ

($y^{(n)} = f(y^{(n-1)}, y^{(n-2)} ... y', y, t)$ -- the general differential equation)
A math buff named Mathie Mathias
said “Praise the above to the highest.
“Just look at those n’s
“as they sprout from our pens.
“And the f and the t
“like a grand filigree.
“And jamborees
“of parentheses.
”And then, for high dramas
“those wonderful commas.
”There’s so much good stuff
“(enough for a buff).
“We just need to find out what y is.”

(keystrokes for solving diff eq’s on the TI89 or 92)
Morale-ful and most rationale-ful
are you with F3 and then ALPHA.
Next, something quite pleasant --
a left-leaning crescent
that springs us as spry as alfalfa.

It’s time to punch in the equation.
Two hints for this happy occasion:
2nd equals for prime
(It works every time.)
and star for the multiplication.

And now to move in for the kill.
(I’m certain that all of you will.)
Two letters, two commas.
(You’ll need them, I promise.)
That crescent, then ENTER, then chill.

(To solve any first order linear equation -- y’ + py = g -- use the formula,

$$y = \frac{1}{\mu}[\int \mu g + C] \qquad \text{where} \quad \mu = e^{\int p}$$)

Don’t forget -- μ appears twice.
I think that advice is quite nice.
But only one g
and only one C.
(We should sometimes economize.)

A fair maid from Northwest Virginia
was solving a first order linear.
But that exponential int.
was too large to print
so she just make it shorter and skinnier.

To deal with conditions initial
(and to make the whole thing official)
just plug in t-naught
(as I carefully taught).
If you need some assistance, just whistle.

(Reality check)
As these poems you so dutifully edit
keep one thing in mind to my credit:
I know that “initial”
does not rhyme with “whistle”.
The point is that YOU won’t forget it.

(Separable equations)
A ditzo from hither or thither
refused to get all in a tither.
“ ‘Tis true,” said he, “I
“can’t tell t from y
“can’t tell left from right-y, though, either.”

(Sect. 2.4, First Order Linear Appreciation Week)
Sing praises and sound the fanfare
for these creatures so extraordinaire
with solutions all
at our beck and call
uniquely explicity there.

Yes, the perks we will find pretty broad.
Perhaps we should stand and applaude.
Solutions torpedo
just where p and g do.
It’s not about t- or y-naught.

(Reality check)
As you go through those poems like a pro
keep one thing in mind, apropos:
I realize that “naught”
does not rhyme with “broad”
but neither does “zero” or “oh”.

(Picard’s successive approximations, proof of existence of solutions to first order equations)
Again and again and again
from n - 1 to each n.
We’ll get closer and closer
(If cos, we’ll get cos-er.)
but making no promises when.

(Sect. 2.5)
Autonomous first orders mean
no t's on the right-hand scene
which leads to inclusion
of straight-line solutions
and curved ones in between.

Some of these level straight lines
will separate growths from declines.
Sat'ration, tresholds
make up today's specials
assuming that you are all buyin'.

(Reality check)
As these poems you so carefully edit
keep one thing in mind, to my credit:
I realize that "buyin."
and "declines" don't rhyme.
But it'll still work if you let it.

According to my nifty notes
some straight lines will be asymptotes.
They swim side by side
swept along by the tide.
The others just lazily float.

(2nd-order linear homogeneous, constant coefficients)
With a, b, and c not of t
we're footloose and most fancy-free.
Change the primes to powers.
It takes seconds, not hours.
(At least that's how long it takes me.)

Take each of r-one and r-two
and place it as I always do:
Upper-right, e
in front of the t.
Connect with the C's and you're through.

I hope you don't mind one small glitch:
If those roots we can't tell which is which
then do as you've done
but only with one.
The other to t we must hitch.

There are many solutions diverse-y.
But two's all we need to disburse-y.
y-one and y-two
one for me, one for you
(or maybe it's vice vers-y).

Yes, we've got these solutions so sundry.
And we can ignore them on Sunday.
And that's very sweet.
But don't hit delete.
We'll need every one come next Monday.

(Reduction of Order)
We've y-one but are missing y-two.
So whaddaya think we should do?
We don't need to panic
nor call a mechanic.
We'll just change the C to a u.

(3rd order linear homogenious)
Solutions sprawl over the city.
But we need just three for this ditty.
y-one, two, and three.
Two for you, one for me
(or maybe one for the kitty).

(higher order linear homogenious)
All over the country they swarm-y
which makes for some very good karm-y.
y-one to y-n.
It's all very Zen.
And enough to supply the whole army.

(2nd order linear INhomogenious)
Solutions exist by the ton more.
But we only need to find one more.
We'll do that now.
I'll show you how.
(It's the same as at Swarthmore or Bryn Mawr.)

(Reality Check)
As these poems you so carefully weigh
keep one thing in mind for today:
I realize that "Bryn"
and "one" don't begin
to rhyme, but I think that's okay.

(Method of Undetermined Coefficients)
p and q are just constants -- how nice.
Yes, that left side's like paradise.
But all-hell will explode
from the right of the ODE.
Well, at least that side doesn't have y's.

(Reality check)
As these poems you so carefully edit
keep one thing in mind, to my credit:
I know that "y's"
does not rhyme with "nice"
but "wice" would be just as airheaded.

Those g's can be bigtime heartbreakers.
But we can turn into matchmakers
and look for y-p's
that go with those g's
and all will be peaceful as Quakers.

Sometimes all we need recommend
is to multiply g by some friend.
But sometimes, indeed
to diff we will need
and then maybe diff once again.

(modified Method of Undetermined Coefficients)
When faced with a difficult g
that's the same as y-one or y-three
(or some combo of)
just change the above
to above multiplied by t.

(Modified modified...)
And if that new g is still rude
as to one of the y-i include
then take it from there
by using t-square
or wouldja believe t-cube?

(Extra-credit limerick -- variation of parameters (not covered in this syllabus --
for when g doesn't lend itself to the Method of Undetermined Coeff's)
We've y-one and y-two sublime.
But g isn't zero this time.
So do Var. of Par.
with Cohen Mar
to help with the rhythm and rhyme.

$$W(y_1, y_2 \ldots . y_n) = \begin{vmatrix} y_1 & y_2 & \cdots & y_n \\ y_1' & y_2' & \cdots & y_n' \\ \vdots & \vdots & \vdots & \vdots \\ y_1^{(n)} & y_2^{(n)} & \cdots & y_n^{(n)} \end{vmatrix}$$

Line up all the functions in sight.
Then diff them with all of your might.
Next, sing a sweet song
or right and of wrong
as we get that ol' Wronskian right.

There was a fair maid from the Bronx-kies
who quite enjoyed tink'ring with Wronskies.
She diff'd 'til she dropped
to bottom from top.
Then she shrugged and called out her so-long-skies.

(Chapter 4: higher order equations)
As n becomes higher and higher
the frying pan turns into fire.
The text gets texture
and x gets x-er
and y becomes y-er and y-er.

(nth roots of 1)
There are n of them spread on a wheel.
Among them at most two are real.
The others must go
half above, half below.
But they get paired off in the deal.

(Reduction of Order)
We've y-one but are missing y-n
and you're asking me "Vat denn?"
Well, do Red of Ord
though you might get bored
'cause you'll do it again and again.

(Chapter 5: power series)
An ambitious young lad from the Near East
was summing a long Taylor series.
At the twentieth head
he just shrugged and said
"That's as far as I'm going, my dearies."

(using power series to solve $y'' + py' + qy = g$)
Right now they seem mystic as voodoo
and I know them better than you do.
But soon, you will see
you'll know them like me
and then you can put them on U-tube.

(Reality Check)
As you scrutinize that, my fine fellas
I hope you're not overly zealous.
I realize that "voo-doo"
does not rhyme with "U-tube".
But neither does anything else.

The ODE we're about to discuss is
about to turn Taylor's for us's.
p, q, g, y --
all will comply
except for the equals and plusses.

Yep, series are pretty okay.
Three cheer-ies for series today.
But there is one catch:
The powers won't match.
Or rather, they won't right away.

Of one other thing to be wary:
The first n will be arbitrary.
But the others, so mercifully
beckon recursively.
That seems to be customary.

(Euler-Cauchy equations)
They sport both a dx and dy
as well as an x-square and by.
The thing to do next:
guess a power of x.
Go plus it all in and you'll see why.

(regular singular points)
Although they might be homogenious
and although you might be quite a genius,
some ODE's will meet Taylor
with nothing but failure.
For success you must turn to Froebenious.

(Chapter 6: Laplace transform)
At first L will seem like a mess
gulping down t to excess.
But we'll soon get our due
as we follow it through
and watch as L spits out an s.

(L(1) = 1 / s)
1 is a cinch to abide --
to add or subtract or divide.
But it's tricky to tell
how 1 fares under L.
Here's a hint: It does not run and hide.

(L(e^{at}) = 1/ (s-a))
If ever you find it essential
to big-L an exponential.
All you need say
is s minus a.
(You needn't say 1; that's tangential.)

(L(t^p) = $\Gamma(p+1) / s^{p+1}$)
It's easy to big-L a power.
(the LaPlace bargain of the hour.)
On top, with much glamor
sits a lofty gamma
and on bottom a higher power.

(Reality Check)
As these poems you so caref''ly review
keep one thing in mind as you do:
I knew that last time
I missed a true rhyme.
But I think that's fine, don't you?

(L(cosh at) = $s/(s^2 - a^2)$, s > $|a|$)
There is a fine student named Josh
who's seeking the transform of cosh.
On top, his wild guess
of just plain-old s
works great, but the bottom's mishmosh.

(L(sin at) = $a/(s^2 + a^2)$)
Another math student so fine
can easily L any sin.
She says, with a flair
"On bottom go squares
"and on top something small and benign."

(L($e^{at}\sin bt$) = $b/[(s-a)^2 + b^2]$)
May I dare the suggestion to drop
that the answer to any long slop
has got to be long
if it's not to be wrong
though it needn't be long at the top.

$$L[u_o(t)f(t-c)] = e^{-cs}(Lf)(s)$$
$$L[e^{ct}f(t)] = (Lf)(s-c)$$

Now we come to two formulas shifty
which turn out to be nifty and thrifty.
Indeed, there's no doubt
that they really help out
(even when c's more than fifty)

$$L(f^{(n)}) = s^n(Lf) - s^{n-1}f(o) - s^{n-2}f'(o) - ....$$
$$sf^{(n-2)}(o) - f^{(n-1)}(o)$$

A young man named Trevory-y Treffis
is happy to write this short preface:
"The formula with
"L-ing a deriv
"is valid no matter what f is."

(More about that formula, all that stuff on the right)
The first term's a big-L rendition
The others have big-L omission.
They're a polynom
(good for this poem)
with coeff's from initial conditions.

He says and she says and we says
"If g of t is in pieces
"we don't need to sell it
"we need only L it
"thus ironing out all the creases."

(Reality check)
As these poems each of you-folks addresses
you have to admit my successes:
The last seven stanzas --
perfection bonanzas
(give or take one or two s's).

It isn't so horribly brutal
to L the whole kit and caboodle
except that it ends
with inverse-L, my friends
and that can be faroff as Pluto.

(Chapter 7: Systems)
Are you feeling zany-brain-eous?
Then try some simultaneous.
Yes, further O.D.E.
(in case we were greedy)
plus matrices miscellaneous.

(about the solutions to x' = Ax -- the matrix form of the linear system of diff'l equations)
The values go next to the t's
the vectors go next to the e's.
Then all will be well
(we'll be able to tell)
once they're combined with the C's.

Well, now that we found out what y was
(Were you almost as anxious as I was?)
we all can go home
at the end of this poem.
(Drive safely along the highways.)

(Reality check)
As you read through that previous poem
don't be too hard on Dr. Cohen.
I know that highways
does not rhyme with y was.
But let's leave well enough alone.

ADDENDUM: Legendre and Bessel

There was a young woman named Sally.
Legendre was right up her alley.
“Minus-x-square plus one
“is what starts the fun
“and n-square plus n’s the finale.”

Her cousin named Mary Magee
said “Bessel seems besser to me.
“x-square WITHOUT one
“seems much more fun
“and nu’s cooler than n,” said she.

Their cousin from Doodle-Skadiddle
said, “Yes, but what’s in the middle?”
Answered they, “we suspects
“it’s x or 2x.
“We’re feeling a big non-committal.”

An attractive young ms. named Cassandra
was solving equations Legendre.
a-nought was do-able
a-one construable
but a-(n+2) was beyond ‘er.

There was a fine fellow named Ian
who was ready to give up on p_n.
He said, “Too much mess
“with the n and the x”.
And sometimes I can’t help agreein’.

Let’s do J_n versus P_n,
The former’s a much smaller bein’
with much less subtraction
and all told, less action
‘cept: more plus-signs in between.

(Bessels)
In these guys the x appears twice
‘cause the pow’rs get strategically sliced.
The x that is mighty
goes to the right-y.
To the left goes the x that is nice.

PDE

A lad thought he'd service society
by studying math and psychiatry.
But his plans went a-ragin'
with the first wave equation
'cause he got Separation Anxiety.

Four, Fourier, Fouriest --
Isn't it just-plain glorious?
How, from sin's and cos's
we get (by osmosis)
so much, and emerge victorious.

(Fourier Series in Exponential Form)
Those functions e-to-the-in-x
can be treated like cos x and sin x.
And if they can't
call me Bell Atlant-
or try MCI or Ninex.

(Fourier Integral)
Are we feeling all morbid and mopey
just 'cause f(x) has no p?
Don't be so timid.
Go to the limit.
When there's life, there's always hope-y.

It's Jan. 14 and our prof
by a factor of TWO is off.
Is she going to cry?
Says she, "No, not I.
"In fact, I'm more likely to laugh."

Do you think this is getting hum-drum?
It's time to consider a drum-drum.
We'll get double series
and double theories
and B's and B*'s under 'em.

Next we make our rod very lengthy
thus increasing its impact and strength-y.
So we've lost the L
but gained integrell.
For thy patience, I humbly thank thee.

There was a spry guy from North Saigon
who was searching for values eigen-.
But the boundary conditions
surpassed all his wishin's
and wouldn't let bygones be bygone.

Oh, trig functions bellow and bark
and Bessel's go bump in the dark.
but Sturm-Liouville creatures
have all sorts of features
and fill up the whole Noah's ark.

ABSTRACT ALGEBRA

We're a sad bunch of nincompoops.
We can't get a grip on our groups.
We ask, in a frenzy
"Z_n or nZ?"
guess wrong, so grin and go "Ooops".

This quarter we're all pretty group-y.
It can get pretty meaty and soup-y.
Z_3 order 3
Z_p order p
and D-sub-p order 2p.

(You know how that religious mathematician Kronecker said "God created the integers; the rest is the work of man" -- Well . . .)
"Integers are neat," said God
"both the even and the odd.
"So I'll give you some, Kronecker
"for Christmas or Chanukkah.
"Do you mind if I package them mod?"

Said a group theory pro named McClellan
"We've too many isom and elem
"and homom and autom
"but already bought 'em.
"Perhaps we could try to re-sell 'em."

(Automorphisms)
Some're outer and some're inner.
All're autom's (although it's winter).
Some turn out to be
the mere identity.
But that's good when you're a beginner.

Rub-a-dub, rub-a-dub, bub-bub.
What, pray tell, what, is this hub-bub?
It's subgroups so cool.
They obey the strict rule:
Order-wise, they divide what they're sub ub.

In the kitchen you'll hear lots of slubbering.
In the bathroom you might see a tubring.
But the classroom, I claim
is quite tidy and tame.
All it's got is a subgroup or subring.

(More dialog between God and Kronecker)
”Intergers are great,” said God
“and it’s fun doing sum and prod.
“But I’ve now got some notions
“to tackle the quotients”
and all except K oo’d and ah’d.

“It was nice dividing by bd.
“But now I’m getting more greedy.”
Thus spake our Lord
standing straight at the board
writing Q-bracket-x and Q.E.D.

“One was good for a laugh.
“And two was a treat for my staff.
“But I’ve now got a hankerin’
“to do some tankerin’.
“I’ll start with one-and-a-half.”

“For seven long days labored I
“with integers low, then high.
“But now ‘tis day eight.
“’Tis time to create
“quotients and roots and pi.”

Deep in waters hot, not tepid
feeling rueful but intrepid
our two creators
and integer-traitors
shrugged “Sorry, we just can’t he’p it.”

“Please forgive me,” said Kronecker L.
“I hope you won’t send me to hell.
“But x caught my attention
“and x led to extension”
and the rest we know only too well.

Yes, pity the genius and hero
who fiddled, but not like Nero.
He started with F.
Now he’s got nothing left
for he sold his soul for a zero.

(Primitive Element Theorem)
A fair maid from Alabam-y
was given a double whammy.
But she knew how to mingle
so’s to make it a single
and ace the final exam-y.

(When is F(a) isomorphic to F(x) ?)
If about a we have so spec's
then a might as well be x.
And e and pi
are good a's to try
though it's not quite clear how it checks.

We might grow up to be tax-collectors
or city or country inspectors.
But Chap. 23
ensures that we
will never be angle-trisectors.

(God confesses to Kronecker)
First I couldn't stop at ten.
The I couldn't stop at n.
Then Z and then Q
and the square root of two.
But I've now come to C. Amen.

(Epilogue: by God and Kronecker)
We work together like brothers.
One creates, the other discovers.
And Galleon writes.
And Cohen recites.
And we welcome any others.

PROBABILITY

(Set theory)
Hippity hippity hoppity.
A set can be built through a property
with nouns and verbs
and blubs and blurbs
or any ol' thigamabob-ity.

A set can also be seen
as an element-making machine.
That set will consist
of all s in some list
with commas in between.

A fair maid from North Beelzabub said
"I don't want to get us all upset
"but if s in B
"implies s in C
"then B is of C a subset."

(The empty set)
Here comes phi, consisting of nada
and neither your mada or fada
can fill-er it up
for lunch or for sup
not even with air or with wada.

(Union and Intersection)
The union of 9th and Race
is something we'd care not pace.
But the intersection
leads to detection
of that fabulous Thai lunchplace.

(Universal Set)
Here is one more thigamajig
that we'll need for this whole shindig.
Yup, time for big-U
too big to be true
but not too true to be big.

(Complement)
Whatever set A hath not
is what A-prime hath got.
And their intersection
defies detection
but their union is a lot.

(Cartesian Product)
Let A be of women a set
and B be of men; then we get
from A-cross-B troubles
all possible couples
providing we know they're all het.

($n(A \cup B) = n(A) + n(B)$)
Here's one more essential point:
If A is from B disjoint
then to give you, I'm glad
permission to add
at the risk of seeming flamboyant.

($n(A \cup B) = n(A) + n(B) - n(A \cap B)$)
And now here's another cool fact
on which you might soon need to act:
You still, my comrade
have permission to add
and orders to also subtract.

(to calculate $P_{n,r}$)
Write down n, and then when you're done
write parentheses n - 1.
The next thing to do:
Write n - 2.
Keep going, but not down to none.

(to calculate $C_{n,r}$)
Here's something that's redder than henna:
our blood when computing $C_{n,r}$
and the sweat and the tears
as we and our peers
do cancelling more than we wanna.

A fair maid named Mary Maltese
got her P's all mixed up with her C's.
She said "I do figure
"the P's must be bigger
"but hey! there are no guarantees."

Said her kissin' cousin Muriel
"I'll give you a little tutorial.
"In case you've forgotten
"the C's, on the bottom,
"sport an extra r-factorial."

(Mississippi & Co.)
And now here's a new little game:
permuting when some are the same.
Permuting these some
will feel sort of numb
although there might still be some pain.

(Reality Check)
As these poems you so dutifully edit
keep one thing in mind, to my credit:
I realize that pain
does not rhyme with same.
But it will if you're less anal-headed.

(Binomial Formula)
I'm sure you've a loyal FOIL-er
and I won't be a FOIL-er spoiler.
But when n, for its britch
gets too big, you should switch
and be to this formula loyaller.

(Outcomes)
When you do an experiment-y
the possible outcomes are plenty.
And it's kind of fun
to find out which one.
(It's a good one, Deo volente.)

(Sample Space)
And now let us go with the flow.
Take the set of all outcomes, just so.
Yep, time for big-S.
Yes! yes! yes!
Don't you dare say no!, no!, no!

(Events)
Here's something we'll use infinitum:
Events (We'll both say 'em and write 'em.)
And to poet-ize:
Size-wize, they lies
between the two previous items.

(Another Reality Check)
As these poems you all superintend
allow me to make some amends.
I know that "they lies"
is bad grammar, you-guys.
But what's one s among friends?

(Probability at last)
We can now introduce big-P.
It means probability.
P of S is one.
P of phi is none.
In between lies P of E.

(Probability of Disjoint Unions)
Said a dude with a shrewd attitude
“If events doth each other preclude
“then it’s easy to tune in
“the prob of their union
“providing we’re in the right mood.”

($P(E \cup F) = P(E) + P(F) - P(E \cap F)$)
The above should inspire deja vu.
Take the rule from 6.2
change the n to P.
It seems clear to me.
I hope it seems clear to you.

($P(E') = 1 - P(E)$)
For the prob of E’s compliment
take the prob of that E-event
subtract it from one
and you’ll be all done.
(You can give it up for Lent.)

If the prob of each outcome you do know
then by Jupiter!, Jove! and by Juno!
the sum of them all
will happen to fall
extremely close to uno.

($P(E) = n(E) / n(S)$)
And now here’s our big opportune
to do what we’ve always been doin’ --
permute and combine
but twice this time
on this beautiful late-afternoon.

(One More Reality Check)
As these poems you so dutif’ly edit
keep one thing in mind, to my credit:
I know that time
and combine don’t rhyme
but I’m not overly poetic.

(Expected Value)
First, the possible values collect.
And then, to their prob’s connect.
The grand finale:
Expected val.
What else could we hope to expect?

(Variance and Standard Deviation)
Here’s a question a trible mischevious:
Are the deviations devious?
The answer, I’m ‘fraid
can’t be bought at Rite Aid.
Perhaps we can get it at CVS.

(Binomial Distribution)
n trials, each a yes or a no.
We want x yes's, just so.
The prob of that mix
involves n-choose-x
and the p's and the q's also.

There's no need to moan and groan
'cause it's easy to do Poisson.
There's nary a care
with Cohen Mar
and less with Marion Cohen.

(Markov chains)
And now let us make a mad dash
-- a transition matrices bash
with gobs and gobs
of "throwing prob's"
regardless of whether we catch.

To see how to get here from therebaout
P is all that we care about.
But we're gonna need v
most definitely
for info concerning the whereabout.

(The Last Reality Check, promise...)
As these verses you classify
as to whether the rhymes apply
you'll notice that mix
does not rhyme with x.
The same would be true of y.

(Some farewell wisdom)
So now that we've had quite our fill
here's a life-lesson from my quill:
The prob's, woebetide
won't be on our side
but the possibilities will.

STAT

(Intro)
I promise, the mean isn't mean.
Nor the deviation obscene.
Nor is any statistic
overtly sadistic.
It hurts? I'll give you morphine.

(Summary)
Too big is a populace
to get all the info in place.
So we gather a sample
(one that is ample)
and infer 'til we're blue in the face.

(Data-values)
You write them all down on a sheet.
(You try hard to make them look neat.)
Some will be qual-
and some wil be quant-
and ne'er the twain shall meet.

(Reality check)
As that last you so dutifully edit
keep one thing in mind, to my credit:
I know qual- and quant-
(although I might want)
don't rhyme -- still, I'm glad I said it.

(More about data-values)
Continuous, maybe discrete
in inches, in yards, or in feet
they're numbers all
some big, some small
and some of them dare to repeat.

(Some notation, for a population)
The size is denoted big-N.
The mean is small-mu, and so then
for standard dev, sig-
ma (little not big)
or so we would recommend.

(Some notation, for a sample)
Small-n, for the much smaller size
(How could we proceed otherwise?).
Then take the wild guess
of X-bar and small-s
or so we would strongly advise.

(Histograms)
The small x's, if you so please
are the values that big-X doth seize
and the various y
so high and so spry
are the relative frequencies.

(z-scores -- "x minus μ / and Tyler, too.")
Three cheers for x minus μ.
It brings on those z-scores for you.
For trains or for cats
it makes for good Stats.
But there's stuff on the bottom, too.

(Mean = average)
Just add up the numbers, each one
divide by the n, and you're done.
Gee, that sure was quick.
(There must be some trick.)
Time sure flies when you're having fun.

(Standard deviation)
Each number's some distance from μ
and those each have squares (powers 2).
Now, add those squares duly
divide by n truly
then take the square root, and you're through.

(Variance = the square of the standard deviation. -- a non-limerick))
This next is something you might love
since it is almost like above.
Do everything the very same
except that last -- no, no! for shame!
Take no square root -- no, no, no, no!
Just leave it as it is, just so.
I know it's tempting, but refrain
from that last step, control your brain.
I know it's hard; I know you'll grapple.
But don't be like Eve; don't eat that apple.

(In other words: The var / is the square.)

(Another standard deviation non-limerick, based on a popular song)
"There was a man named Michael Finnegan.
"He had whiskers on his chin-agin."
He said, "Oh, no, must I divide by n again."
"Yes, you must, so begin again."

(Epilogue)
He was quite tired of that shenanigan.
But he began again.

(A little more standard deviation)
Here's a question a trifle mischevious:
Are the deviations devious?
The answer, I'm 'fraid
can't be bought at Rite Aid.
Perhaps we can get it at CVS.

(Some probability limericks)
When you do an experiment-y
the possible outcomes are plenty.
And it's kind of fun
to find out which one.
(It's a good one, Deo volente.)

(Sample space)
And now let us go with the flow.
Take the set of all outcomes, just so.
Yep, time for big-S.
Yes! yes! yes!
Don't you dare say no! no! no!

(Events)
Here's something we'll use infinitum:
Events (We'll both say 'em and write 'em.)
And to poet-ize:
Size-wize, they lies
between the two previous items.

(Reality Check)
As these poems you all superintend
allow me to make some amends.
I know that "they lies"
is bad grammar, you-guys.
But what's one s among friends?

(Complement of an event)
Whate'er event A hath not
is what A-comp. hath got.
And their intersection
defies detection
but their union is a lot.

(Probability at last)
We can now introduce big-P.
It means probability.
P of S is one.
P of phi is none.
In between lies P of E.

($P(E') = 1 - P(E)$)
For the prob. of E's complement
take the prob of that E-event
subtract it from one
and you'll be all done.
(You can give it up for Lent.)

($P(A \cup B) = P(A) + P(B)$)
Here is one more essential point:
If A is from B disjoint
then to give you, I'm glad
permission to add
at the risk of seeming flamboyant.

($P(A \cup B) = P(A) + P(B) - P(A \cap B)$)
And now here's another cool fact
on which you might soon need to act:
You still, my comrade
have permission to add
and orders to also subtract.

(Expected value = mean of a random variable)
First, the possible values collect
and then, to their prob's connect.
The grande finale:
Expected val.
What else could we hope to expect?

(Binomial probabilities)
n trials, each a yes or a no.
We want x yes's, just so.
The prob. of that mix
involves n-choose-x
and the p's and the q's also.

(Reality check)
As these verses you classify
as to whether the rhymes apply
you'll notice that x
does not rhyme with mix.
The same would be true of y.

"The trouble with a kitten is that
"eventually it becomes a cat."
And the trouble with Probability is that
eventually it becomes Stat.

(Binomial distributions)
There's one for each n and each p
in this functional big family.
n, for our files
is the number of trials
and p is the rel-frequency.

(to find the binomials prob's P($X_{n,p}$ = x) on the TI83+ -- a non-limerick)
2nd VARS will get us flowing.
0 gets us where we're going.
n, a comma, p, another
x -- and then it's almost over.
Just make sure that you don't miss
hitting end-parenthesis.
And if you want to see this through
ENTER is the thing to do.

(to find P($X_{n,p} \leq x$) -- another non-limerick)
This is something you should love
siince it's exactly as above.
Only once diverge the path:
Instead of 0, ALPHA MATH.

(normal random variables)
The standard normal's a wonder.
At the ends it's tossed asunder.
Its mu is none.
Its sigma is one
which is also the area under.

That curve is an exponential
but knowing that isn't essential.
The 83+
is enough for us
to get a good job at Prudential.

(Non-standard normals)
These curves are all wondrous, too.
But they've got different sigma and mu.
Mu is the head
and sigma's the spread
but the area's one, never two.

(Continuous random variables)
It isn't the curves so grandee.
It's the areas under, you see
that do the fine job
of giving the prob
that X lies between a and b.

(normal less-than probs, P(Z < z)
As long as big-Z is our venue
go right to your TI menu.
Yes, 2nd VARS 2
will start it for you
and negative 10 will continue.

(Reality check)
As that last you so hastily edit
keep on thing in mind, to my credit:
I realize this “venue”
won’t rhyme with “continue”.
But the point is YOU won’t forget it.

(Normal greater-than probs, P(Z > z)
Again, 83 goes with Z.
And again, 10 will join the soiree.
But this time 10’s sign is
a plus, NOT a minus.
Then all will proceed merrily.

(Fuzzy Central Limit Theorem -- one reason that normals are important)
Honest, this isn’t a scam
that the top of the histogram
(and I do not err)
for “most” X, yes sir
is a normal curve, yes ma’m.

(finding prob’s of NON-standard normals -- If you’re wize / you’ll standardize.)
Step One: Just take x minus μ
divide by the sigma. Step two:
Dig into your pocket
or where’er you stock it
and with your TI rendenvous.

(Central Limit Theorem)
If, ladies and fine gentlemen
we take all the samples, size n,
the set of their means
fulfills all our dreams
for n at least three times ten.

(Confidence intervals for the population mean)
We can never exactly find mu.
That goes for approximate, too.
But the more the dissent
the more confident
we can be; that’s the best we can do.

(finding confidence intervals with the TI83+)
We start with STAT arrow-right twice
and then choose the Z Int device
next, put in our data
some this-a, some that-a
and CALCULATE makes it precise.

(Hypothesis testing -- H-sub-A / leads the way.)
For this very significant lesson
H-A is the thing to obsess on.
H-nought is there
more for the flare.
It makes things a little more pleasant.

(Various “tails” -- a non-limerick on the popular verse)
“A one-l lama is a priest.
“A two-l llama is a beast.
“And I would bet a silk pajama
“there isn’t any three-l lllama.”

A one-tailed test is quite a doozy.
A two-tailed test can drive you whoozy.
And I would bet a treasure chest
there isn’t any three-tailed test.

(The Test Statistic)
Though its various symbols encumber
it really is only a number.
On top goes the gap
on bottom more crap
making us dumber and dumber.

(Rare Event Rule -- “Blame the claim.”)
If that test statistic is rare
and H-nought implies it ... well, there
is some explanation
spelling H-nought’s cessation
and H-sub-A’s premiere.

(Using the TI83+ for hypothesis testing)
From our trusty TI83
we squeeze out the value of P.
If alpha is steeper
H-A is a keeper
unless further tests disagree.

Yes, do trust out most trusty one.
It says do, consider it done.
And if P is foremost
H-A is toast.
(We can eat it with cinnamon.)

(Doing hypothesis tests on the TI83+ -- same limerick as for confidence intervals)
We start with STAT arrow-right twice
and then choose the proper device
next, put in our data
some this-a, some that-a
and CALCULATE makes it precise.

(the family of distributions, Student's t)
Guiness had said that he cudent
so Gossett decided he wudent
and so little t
is more famous than he
and bears the proud name of Student.

(hypothesis test, or confidence interval, for the difference between two population means)
"Difference between" implies two
and that will affect what we do.
There should be two x
(on the screen, in the text).
I think that's a pretty good clue.

(Reality check)
As these poems you so dutifully edit
keep one thing in mind, to my credit:
I know that x
does not rhyme with text.
But I'm not overly poetic.

(A little regression session)
The data get listed in pairs
(and we hope there won't be any spares).
So the first thing to do:
L1 and L2.
(We won't mind if the data is scarce.)

The screen will show r-square and r.
Both tell us how near or how far
to or from
a straight line outcome
those points, when they're plotted, are.

(ANOVA)
H-zero is quite long and lean
a change from the same old routine
with one or two lines
of equal signs
and the mu-sub-i inbetween.

H-A is much shorter and sweeter.
No, it isn't an equal-sign breeder.
It only needs one
to counter H-none
(and to help with the rhyme and the meter).

A fair maid from northeast Andover
said "What's the big deal with ANOVA?
"It's mostly a matter
"of listing the data
"and soon after that it's all over."

Said her kind cousin Mary Magee
“Ah, but what of the poor 83?
”It contends right and left
“with test stat. big-F”.
Said the maid, “I’m just glad that’s not me.”

(Farewell)
If the pain persists on morphine
try an anti-histamine
or caffeine, or saline
or dentine, or codeine
or an anti-statistics vaccine.

ADDENDA: Bayes, and calculator tips

The theorem of Bayes is fun.
And it’s certain to get the job done
with sensitivity
and specificity
and some help from P-D and one.

(TI83+ Keystrokes for finding Cumulative Prob’s) (Warning: Non-limerick)
If this, instead of Earth, were Mars
we might hit VIRTH instead of VARS.
If Earth were square instead of round
we’d arrow up instead of down.
And if we meant “Return to Sender”
what we hit would not be ENTER.
If our goal were finding z
the next four strokes just wouldn’t be.
And if we didn’t know which z
we wouldn’t hit it, natur’ly.
And if we want to poof this venture
we’ll forget to punch in ENTER.
But since none of these is true
we’ll do just fine with what we do.

(TI83+ Keystrokes for finding z when we know the cumulative prob up to z)
This might be something we all love
since most of it is like above.
Just, if we think it’s much too nice
we’ll arrow once instead of twice.
And if we’re masochists, indeed
we’ll do those four strokes we don’t need.
And if we didn’t know which P
we wouldn’t hit it, natur’ly.
And if we were intent-preventers
we’d foget to punch in ENTER.
All in all, it works out great
with cause, effect, and help from fate.

TOPOLOGY

We all know the concept of set
but not of topology yet.
The latter's a class
of the first, but alas

there's more to the story than thet.

E.g., it is quite necessary
that they all be in X, solitary
and that intersects, fin-nite
also be in it
and union, arbitrary.

(Accumulation points)
These are points which a set seems to touch
but not, we observe, very much.
They can get just as close
as your eye or your nose
but never as close as your guts.

(Definition of continuity)
No epsilon-delta in this
since numbers don't even exist.
No fractions, decimals,
infinitessimals.
Instead, we must find a new twist.

Points jump from the old to the new
as the sets they comprise also do.
And so, in this scrimmage
the f-inverse image
of each V must be some U.

Tau from tau.
That's the law.

(Base for a topology)
Hee-haw! Hee-haw! Hee-haw!
A base is a sub-class of tau
whose various u-
nions hit through and through
though it itself doesn't at all.

(Sub-base)
Rub-a-dub, rub-a-dub, dub.
A sub-base is not always sub.
But it is a base
in certain ways
so we welcome it into the club.

If X is discrete (tau not slight)
we claim continuity bright
for any old f
from X (on the left)
no matter what Y's on the right.

And here's something equally deft:
If Y is discrete (not bereft)
then open, we cite,

is Y on the right
no matter what X on the left.

(Homeomorphisms)
Oh, bring out the violins
for here's where the drama begins:
Whither goeth the first
(for best or for worst)
doth goeth the second -- they're twins.

(Metric spaces)
These spaces we truly adore
'cause they provide numbers galore
for us to grab onto
whenever we want to
(just like we used to before).

(Hilbert space)
Square-summable sequences come
with a metric involving square-sum.
And it's isomet-
to a proper subset
which might seem surprising to some.

(first countable)
This means something's countable, yes.
But what? Well, each point must possess
a base local
that is countable
(perhaps more than one, but not less).

(second countable)
Again something's countable, true.
But this time just ONE thing will do
for this kind of space:
one countable base.
I promise, we will not need two.

(separable spaces)
They're countable, in some weird sense
'cause some countable subset is dense
thus reigning them in
agin and agin
making things rather intense.

A fair maid named Mary Michelle
was smitten with Heine-Borel
and her fair cousin Dinah
liked Borel-Heine.
They got on exceedingly well.

A net is a sort of jet-set.
There's no fish that it cannot get.
With an epsilon-pole

it reaches its goal
and manages not to get wet.

(totally bounded)
Hippety, hippety, hoppety!
A set which possesses this property
is finite, of sorts
(by all sound reports)
though by thinking a trifle sloppity.

(The Separation Properties --- Seeya later, separator...)

Heigh-ho! Heigh-ho! Heigh-ho!
Three cheers for our trusty T-oh.
It separates points
all over the joint --
really just one of them, though.

T-one is a nifty go-getter.
It's a tasty trusty trend-setter.
Yep, it's very hep
the way it doth sep-
and it separates them better.

Yahoo! Yahoo! Yahoo!
It's time for our trusty T-two.
It deftly gets
TWO open sets.
Yes, that's what we trust it to do.

(regular spaces)
Here comes a whole different name
playing a whole different game.
It dares to make bets
on points and closed sets
putting the others to shame.

(normal)
This guy does a little duet.
It can take on any two sets
that are diagnosed
as being closed.
It's the best separator yet.

SEPARATION STEW
We learned T-oh
to and fro.
And then T-one
was lots of fun.
We did T-two
fro and to.
Went through T-three
with glitz and glee.
And T-three-and-a-half

gave us a laugh
until T-four
walked in the door.

I'm sure T-five
would really jive
and with T-six
we'd get our kicks.
Lucky T-seven
would be pure heaven.
Likewise T-eight
would be just great.

T-alept-null
would be wonderful.

But we stop at four.
There is no more.

(In any normal space, any two closed sets can be "separated by a continuous function".)
How very superb and eclectic
to deal with this layout so hectic.
With mere open sets
cool Urysohn gets
all these numbers with nary a metric.

CATEGORY THEORY

(Introduction: "Functions" in the Raw))
O hear ye! O mathematician!
Let us make the momentous decision
to give up x and y.
We can if we try

and still get to keep composition.

("Arrows only")
Now, objects are nice and compact.
They stay put and concise and intact.
But the stars of our show
are those things that go
from one to the other and back.

(Discrete category)
What's wrong with this party?, pray tell us.
No one talking to anyone else.
They stand in their corners
like old Sunday mourners
conversing with only themselves.

(poset categories, non-discrete)
This party's a bit more grandiose
sporting conversation verbose.
Just one way, true
and one line, too
but at least that one line isn't closed.

(Larger categories)
Uh-oh, I am getting a hunch
that somebody's spiking the punch.
That the gang is all here
is most crystal clear
and it's up to the raunchiest stunts.

There once was a chap from Milano
who couldn't tell epi from mono.
I told him "get wize
"and just memorize"
but I'm willing to bet he's not gonna.

(Duality)
Hippity hippity hop.
Ev'ry C has its own Op.
But off C-Op-Op
both Op's we can drop.
Yop, after one Op we can stop.

(Universal mapping properties)
O, what are little UMP's made of?
And what are big UMP's made of?
Arrows galore
and much much more
and that's just what we were afraid of.

(Product = projection-collection)
This hunter shoots many a spear
but just one into each object here.

And any who dare
to likewise fare
must take a quick step to the rear.

(Co-product = injection-collection)
It's the object of this grand old hunt.
(Don't worry; the arrows are blunt.)
And if anything tries
to fare likewise
it must take a quick step to the front.

(Are you an equalizer-sympathizer?)
Its claim to fame is plain.
Its aim is to tame the twain.
Whatever the arrows
how wide or how narrow
so long as both ends are the same.

(Equalizers and co-equalizers)
We can't get these kids to agree.
They fight like Mohammed Ali.
But between Dad and Mom
on both sides, so calm
methinks we can tame the twee.

(Pullbacks and pushouts)
If one end is not the same
we can still pay the game, I proclaim
for a similar deal
reinvents the wheel
and we would be fools to complain.

(Limit)
It's next in our grande repertoire
shooting arrows so near and so far.
And further, t'boot
they have to commute
with the arrows that already are.

(Products and equalizers get us all limits.)
We don't need pullbacks or initials
or ceremonies judicial.
All we will need
to finish the deed
and all we will ask
to accomplish the task
and all we request
to pass the test
and all we require

to light our fire --
yes, all we need seek
are prod's and eq's.
So on we will plod
with eq's and prod's --
to make the whole thing official

(Functors)
Here they come, marching in droves.
Both the contrav's and the cov's.
Some imbed
and some forget
and some we don't yet even know of.

(Adjoints: Hom (FC, D) ≅ Hom (C, UD))
It's Old Hom Weekend, it seems.
And in fact there are TWO Hom teams.
But, except in name
those teams are the same
if we take matters to extremes.

(F and U)
Things would turn out mighty rotten
and F would feel pretty downtrodden
and most disappointed
because un-adjointed
if forgetful meant also forgotten.

(Seeya later, Yoneda)
Any C can be co-completed.
Small-y is all that is needed.
And if there's a goof
somewhere in our proof
don't worry, we'll simply delete it.

(Endo-functors and P-algebras)
Endo's are sprightly as minnow
and they endo where they doth begin-o.
Their activities buzz
with P-algebras.
Get ready for that to contin-o.

(Finale)
See, there's life after x's and y's.
Do you savor the fun and surprise?
Do you like how it works?
And relish the perks
like no compound fractions or pi's?

FERMAT'S LAST THEOREM PROVEN

Fermat said the proof was too large
to fit in the right or left marg-.
True, back of the paper
or proof made to taper
might help, but he said, "I'm in charge".

Now, Wiles didn't mind paper waste.
In fact, it was true to his taste
to use up whole reams
to realize his dreams
and he crossed out instead of erased.

Fermat was all snickers and smiles
as he smugly stayed clear of the aisles
and he thought "they'll be glum
"but that proof will succumb
"though it's going to take quite a-Wiles".

A COMPUTER NON-LIMERICK

A one-r erol is a strain.
A two-r errol is a pain.
But we would be in greater peril
if there were a three-r errrol.