Bra-kets  
Lyrics by Walter F. Smith, Fall 2010  
Tune: Downtown, by Petula Clark

Intro (piano, 2X):
E   A/E  B/E
/  /  /  /  /  /  /

Verse 1:
E                                            A                      B                              E                        A    E
I know a product that will work in any Hilbert space that you can get – bra-ket!
E                                                    A                      B                        E                        A    B
I know it sounds funny, but it’s cheerful and sunny, it’s my favorite yet – bra-ket!
E                                                       C#m
Invented in the thirties when the world was in depression,
E                                                       C#m
It solves notation problems, it’s so easy and refreshin’!

Refrain:
G#m                             A     B                 A
How can you lose?  No need to pull out your hair,
A      C#m                 F#               C#m                 F#
You can forget all your troubles, forget all your cares,
E   C#m    A                                       E  C#m
Just use bra-kets,  Put ‘em together now, bra-kets,
A                      B                  E    C#m      A                     B                  E         (A   B  ad lib)
Things will be better now, bra-kets – Everything’s waiting for you!

Verse 2:
E                                            A                      B                              E                        A    E
Paul Dirac may have been a little bit strange, but he invented them – bra-kets!
E                                                A                      B                           E                      A    B
It was a joke, the small extent that he spoke, but we will always love bra-kets!
E                                            C#m
The ket is just a vector that is basis independent,
E                                                       C#m
Its adjoint is the bra, they make a couple that’s resplendent.

[Refrain]
Verse 3:
E A B E A E
If you’re a chemist or a quantum mechanic, you should always use bra-kets.
E A B E A B
For paired oscillators, they’re your best navigators, so do not refuse bra-kets!
E C#m
You might evaluate ‘em using 3D integration,
E C#m
But for just a few dimensions stick with matrix multiplication.

[Refrain]
(You've Got Me) Lasing
Lyrics by Becky Thompson-Flagg
Tune: (You Drive Me) Crazy, recorded by Britney Spears, written by Jörgen Elofsson,
Max Martin, Per Magnusson, David Kreuger, and Kirk Herbstreit
Key: Cm (original performance key, suitable for singalong)

Cm Ab  G  Cm Ab  G  Cm
[Intro]Lasing

Ab       G                  Cm
1. Baby, you start with a core. First one was ruby but now there are more.
   Ab       G                  Cm
Pumping shakes its electrons around, so they transition from a state that is ground

Ab       G                  Cm
In a mirrored cavity, quantum transitions set the frequency.

Ab       G                  Cm
Emission makes a laser lase, photons emitted are all in phase

Ab       G                  Cm
[Chorus] You've got me lasing! Electrons leap,
   Ab       G                  Cm
Releasing photons so I can keep / lasing, and it looks so bright
Cm       Ab                  G                  Cm
Baby turn me on, you've got coherent light.

Ab       G                  Cm
2. Coherence is the property that makes it a laser not just an LED.
   Ab       G                  Cm
Normal light doesn't work as a team. Photons are in step in a laser beam
Ab       G                  Cm
Emission makes a laser lase, photons emitted are all in phase

Ab       G                  Cm
[Chorus] You've got me lasing! Electrons leap,
   Ab       G                  Cm
Releasing photons so I can keep / lasing, and it looks so bright
Cm       Ab                  G                  Cm
Baby turn me on, you've got coherent light.
[Bridge] Lasing, electrons quantum leap, releasing photons, I've got to keep
Cbmaj7 Bbm7 Ebm7 Cb Bb7sus Bb7
Lasing and it looks so bright! Now you’ve got coherent light.

[Instrumental interlude] Cm Ab G Cm Ab G Cm

Ab G Cm

[Chorus] You've got me lasing! Electrons leap,
Ab G Cm Ab Bb Eb Bb/D
Releasing photons so I can keep / lasing, and it looks so bright
Cm Ab G Cm Ab G Cm Ab G Cm
Baby turn me on, you've got coherent light.

Ab G Cm

[Chorus] You've got me lasing! Electrons leap,
Ab G Cm Ab Bb Eb Bb/D
Releasing photons so I can keep / lasing, and it looks so bright
Cm Ab G Cm
Baby turn me on, you've got coherent light.
Cm Ab G Cm
Baby turn me on, you've got coherent light.
I’m Atoms, Lyrics by Derek Muller, Tune: I’m Yours, by Jason Mraz

Intro: A   E   F#m   D

    A
Well an atom's made of protons, neutrons, and electrons
    E
the first two in the nucleus, the third around it
    F#m             D
it's mostly empty space, but it feels solid in any case

    A
The elements are all the different types of atoms
    E
they differ by the number of protons in the middle.
    F#m             D
Hydrogen has only one, but Uranium has a ton

A   E   F#m   D   D9
It's just chemistry that you and me are made of these atoms

A   E
Mmm, mmm, mmm mmm

F#m   D
Ayy, Ayy --  Ayy, Ayy, Ay.

    A   E
Well atoms bond together to form molecules
    F#m
Most of what's surrounding me and you
    D
Water, sugar, things yet undreamed of of of of
A E
Look around you, see the combinations in a eucalypt tree
F#m
Mendeleev's periodicity
D D9
gives us sand and water and the air above ove ove ove ove
A E F#m D D9
It's just chemistry that you and me are made of these atoms
A E F#m D D9
Hydrogen, Oxygen, Carbon, Nitrogen, make up the world's life forms
A E
Do do do you, do do do do you
F#m
but do you wonder how
D
matter forms something strange
B
when there's a chemical change?

A
Buh buh buh buh buh buh buh buh buh
E
Buh buh, buh buh, buh buh.
F#m
Buh ba ba da-tah.
B
Zaba, Zaba, zabah--
Where did these atoms come from? They were fused in stars
Light elements combine releasing light from afar
Fusion in the sun, creates Helium

I guess what I be saying is you gotta use your reason
To open up your mind and see the cause of the seasons
How do we know what's true? The scientific method shows you

It's just chemistry that you and me are made of these atoms
Atoms bond together to form molecules
Most of what's surrounding me and you
Water, sugar, sand and you'll find things undreamed of

So Argon, Neon, Xenon
There's no need to overstate
'Cause we are of course
This, of this, of this, we're made: atoms
Graphene
Lyrics by Prof. Andy Zangwill, Georgia Tech

Intro riff (repeat 6 times):
E E E7 E - E E D

E                D                     E E E7 E - E E D
1. If you wanna beat Moore, you need carbon to the core – graphene.
E                D                     E E E7 E - E E D
If you need C-MOS, then this is your boss – graphene.
E                D                     E E E7 E - E E D
She goes fast, she goes fast, she goes fast – graphene.

Interlude: repeat riff a total of 8 times

E                D                     E E E7 E - E E D
2. When you need a buck, and you gotta conduct – graphene.
E                D                     E E E7 E - E E D
If you got bad gates, and you need quantum states – graphene.
E                D                     E E E7 E - E E D
She goes fast, she goes fast, she goes fast – graphene.

Interlude: repeat riff a total of 8 times

E                D                     E E E7 E - E E D
3. If your gain is gone and you need to switch on – graphene.
E                D                     E E E7 E - E E D
Don’t forget Dirac, straight bands are a fact – graphene.
E                D                     E E E7 E - E E D
She goes fast, she goes fast, she goes fast – graphene.

Interlude: repeat riff a total of 4 times

E                D                     E E E7 E - E E D
She goes fast, she goes fast, she goes fast – graphene.
Hey Joe
Lyrics by Prof. Matti Alatalo, Tune: Hey Joe, by William M. Roberts

Intro: E7

C  G  D  A  E
1. Hey Joe, where you goin' with that pen in your hand?
C  G  D  A  E
Hey Joe, where you goin' with that pen in your hand?
C  G  D  A  E
I'm going to solve an equation, so far solved by no other man.
C  G  D  A  E
I'm going to solve an equation, so far solved by no other man.

C  G  D  A  E
2. Hey, Joe, I heard you nailed your problem down.
C  G  D  A  E
Hey, Joe, I heard you nailed your problem down.
C  G  D  A  E
Yes I did, I got a closed form solution without a frown.
C  G  D  A  E
Yes I did, I got a closed form solution without a frown.

C  G  D  A  E
3. Hey Joe, where you going to run to now?
C  G  D  A  E
Hey Joe, where you going to run to now?
C  G  D  A  E
I'm going way up north, way up to Stockholm way.
C  G  D  A  E
I'm going way up north, way up to Stockholm way.
“Holes” To the tune of "Crazy Rhythm" by Caesar, Meyer & Kahn
Lyric by Marian McKenzie, 2013

Gma7     G6     Gma7     G6
Don'tcha love a juiced-up band state
Gma7     G6     Gma7     G6
  Buzzing with a plus-charged mandate?
D7              Am         D7                      G        D7
  And we know it's all because of holes!
Gma7     G6     Gma7     G6
  I'm a fan of Russell Ohl, for
Gma7     G6     Gma7     G6
  He showed what to use a hole for
D7              Am              D7                      G
  And this song's right from my soul for holes!

D7
You know that -
G7                                                        C
  When an n state meets a p state / That's when you'll see some fun -
Cm
  Those electrons start to migrate
G                                A7                   D7
And soon they yield / A built-in field.
Gma7     G6     Gma7     G6     A7
  And that gives us the canonice / Base of all things electronic.
D7                                      G
  That is why all physicists love holes!
You know that

When the p type met the n type, / Things were turned upside down;

The transistor could be made and

Soon vacuum tubes / Were just for rubes.

Don't disparage p-n junctions - They have lots of nifty functions,

That is why all physicists love holes!
What's Pairs Got To Do With It  (In E minor, the key Tina Turner sings it )
(Words by L. H. Greene, with deep apologies to Tina Turner)

(intro in Am and Em)

Am                                            Am                                               Em
You must understand though the touch of a flange / Makes my pulse react
Am                        Am                            Em
That it’s only the thrill of growing a film  / Cations impact
F     G                       F           G                          F                                    G
It’s high-Tc, electrons hold the key  / You must never ignore Cooper pairs interact
Am  F                    G                  F                 G                    C
Chorus: Oh---  What’s Pairs Got To Do, Got to Do With It
G                    F                  G                  C
Cooper pairs strongly correlated electrons
G                   F                  G
What’s Pairs Got To Do, Got to Do With It
Am                          G
Who needs a pair when a pair can be broken

Am                                            Am                                               Em
It may seem to you that I’m acting confused / Reading data sets
Am                        Am                            Em
If I tend to look dazed, I’ve read it someplace / A mechanism exists
F     G                       F           G                          F                                    G
But, there’s no name for it, there’s no phrase that fits  / But whatever the reason they’re paired at Tc
Chorus

Short instrumental interlude in D

C                                    D                        C                            D
I’ve been taking on a new direction     /    But I have to say
Bb                                                 C                        C                                      D
    I’ve been thinking about a mechanism  / It scares me to think that way
Chorus

(now in higher key)

Bm G                   A                  G                 A                      D
Oh---  What’s Pairs Got To Do, Got to Do With It
A                  G                              A                 D
BCS may be a sweet old-fashioned notion
A                  G                A
What’s Pairs Got To Do, Got to Do With It
Bm                          A
Who needs a pair when a pair can be broken.     (End with instrumental outro.)
TE AMO (THE SERENADE)

Words and Music by Tom Lehrer

BEIS: Te a-mo, vida de mi vida. Te a-mo con todo mi corazón.

D7: zón. Por ti yo muerro, mi querida, Déjame de

G: The moon is high above, and I'm

in the mood for love, and I just love the song that he's playing. The

night is so romantic, but it's driving me just frant-tic, 'cause I
certainly not lazy. But I think I'll soon go crazy, 'cause I

© 1951 Tom Lehrer (renewed).
I don't understand a word he's saying. My troubles all might vanish if I didn't understand a word he's saying. I hope they overlook this course for him.

I knew a little Spanish, but I'm afraid it's only Greek to me. And why I ever took this course will always be a mystery to me. But

Yet I wish I knew just what the guy would do if I should say "Si, still I wish I knew just what the dean will do if I don't get a"

Mia-mor, the force times (ar: Yo te)

Si! I think he said "Amor," I've heard that word before.

Pido. Mia-mor, the force is the mass.

I'm almost sure that love is what he's thinking.

Si - to de contestación.

(of.

There he goes again! The
moon is high above and I'm in the mood for love, and I just love the song that he's try my level best and I cram for every test, and I do all my work without de-

playing. The night is so romantic, but it's driving me just frantic, 'cause I lay-ing, I'm cer-tain-ly not lay-ing, but I think I'll soon go crazy, 'cause I

don't under-stand a word he's say-ing. My troubles all might van-ish if I don't under-stand a word he's say-ing. I hope they o-ver look this course, for-

knew a lit-tle Span-ish, but I'm af-raid it's only Greek to me, And why I ev-er took this course will always be a mys-te-ry to me, And But

yet I wish I knew just what the guy would do, If I should say, "Si, still I wish I knew just what the dean will do, If I don't get a

Si, Si! Si, Si? Si, Si? El-la di-ce "Si, Si!" Si, Si! (to him) Si, Si! Si, Si! So we shall see, Si, Si! C. a C, a C, if I don't get a C!
MAKE A CIRCUIT WITH ME (Tim Worman - Phil Bloomberg)
THE POLECATS (MERCURY 6059.588, 1982)

Intro ad lib: D G D G D G D G D G
D G E A D G E A

D G E A
A sweet romance is not for me, I need electricity!
D G E A
If you wanna make me flip, hit me with a micro chip!

[CHORUS:] I'll be a diode, cathode, electrode, Overload, generator, oscillator-
A D G E A
Make a circuit with me

D G E A
Just plug in and go-go-go, I'll be a human dynamo!
D G E A
Signals in my power cord, Impulse on my circuit board.

[Repeat chorus]

F# Bm
[BRIDGE:] I'm an AC/DC man, You can read my circuit diagram.
Em A
I feed on electric jolts, I need fifty-thousand volts!

[Repeat chorus] [Instrumental interlude] [Repeat chorus]

D G E A
A sweet romance is not for me, I need electricity
D G E A
If you wanna make me flip, come on and hit me with a micro chip!

[Repeat chorus] [Repeat Bridge]

[Repeat chorus 6X, skipping from “Make a circuit with” to “diode”, except last time]
Modern Theory Quark
Lyrics by Emily Hecht, Tune: The Major General Song, by Sir Arthur Sullivan

I am the very model of a modern quantum theory quark,
I make up everything you know from minerals to Tony Stark
Think of the smallest thing you can, I'm smaller than an atom's parts
To understand me, Harvard kid, you'll have to use all of your smarts!

Let's start off with the basics, you know atoms are the building blocks
Inside the atom, protons, neutrons, and electrons, not a shock
But let's go smaller, shall we, to the really fundamental bits
To quarks, force carriers, and leptons, see what you can make of it.

Let's start with quarks, they're particles, not characters from DS9
There are six flavors, they're in pairs, know all of them and you'll be fine
There's up and down, and charm and strange, and top and bottom, that's all six
These particles are fundamental, take that with an asterisk!

Now quarks have charge, but here's the thing, that charge is not an integer
For up and charm and top, just know it is a positive two thirds
For down and strange and bottom it's one third but it is negative.
For each of these the anti version's charge is plus or minus switched.

Quarks come in hadrons only, these are little groups of two or three
The groups of two and three are mesons, baryons respectively
A proton is a baryon, a neutron is a baryon
But a quark and anti-quark's a meson, now it's time to carry on.

Now on to leptons, you'll find there are only six of those to see
Each neutrino and matching lepton make up lepton families
The negative 1 charge electron, muon, tau are half of each
Neutrinos have no charge, and in lepton decays we must stay green.

Now let's slow down a bit so you can get the all of the bosons straight
There are four kinds of interactions carriers facilitate
We haven't found the graviton, it's merely theoretical
But gravity is sure to work on all the kinds of particle.

The force that holds the nucleus together is called simply Strong
it happens because color charges force the quarks to get along
Quarks and strong force carrier are color charged, but leptons aren't
Quarks come together by trading gluons, don't you know, it's so smart.

We've only barely just begun, but trust me there is more to know
We're running out of measures but we still have two forces to go
Oh well, I guess we're done for now, Professors and TFs depart
I am the very model of a modern quantum theory quark
Unless I figure out Garageband simply lets me loop the song
Which I just did, bear with me we'll be finished up in not too long, We have some forces and decays to get through, so let's start it up This takes a lot of energy, hold on let me get powered up. Before we leave strong force behind I have to stress a major rule.

Hadrons are color neutral using gluons as their major tool Three different colored quarks are neutral in a baryon and then Anti-quark has anti-color, for meson color cancelling Electromagnetic force is a hard phrase to scan but need to know.

It causes chemical reactions which are anything but slow The carriers are photons acting both like particles and waves But that gets complicated so we'll save it for another day Electromagnetic force can work on quarks and leptons that are charged.

The bonds between the atoms caused by opposite attracting parts The last force to get through we call weak, it's not an insulting name Weak force is at the top of the big particle decaying game The carriers of weak force are charged W's and also Z.

Electromagnetic force and weak force also called "electroweak" You know Weak force includes emission of the famous positron Electron emission too, cause weak can change a quark from down to up There are many interactions far too numerous for just one song.

But hopefully you get the basics and I haven't got it wrong Check out some Feynman diagrams and particle adventure site And I have one thing more to talk about before we say goodnight In all these interactions and in life one constant still remains.

And no I am not talking about constancy of constant change In quantum life you must remember conservation rules the world And in a way it also impact lives of every boy and girl What I mean by that is several things must always stay the same.

Momentum, angular momentum, energy a few to name Velocity, charge, lepton number also must stay evened out Or else the interaction's one reality can do without

Thank you Sci 20, you have taught me many many many things From why we think the way we think to why some birds have fancy wings But what is life? Is it a whole or many tiny parts -- Are we all tiny models of the modern quantum theory quark?
The Center for Defect Physics Song
Tune: Dark as a Dungeon, by Merle Travis, Lyrics by Dr. Gene Ice

A                      D                  E
1. Come eager young scholars, with visions and dreams,
   A                                            D                 A
To understand defects by completely new means!
   D                      E/B
We’ve a Center for you where your dreams can come true,
   A                                D                A
Where everything done is exciting and new!

E/B                                  A
[Chorus:] ‘Cause it’s defects determine how most things behave.
   E/B             E                A
A deep understanding is what we most crave.
   D                 E/B
Integrated and novel, we’ll push the frontier.
   A                                     D                    A
It’s important and urgent, this much is quite clear!

A                      D                  E
2. Three thrusts form the Center for Defect Physics.
   A                                  D                  A
They’re connected together with strong science links.
   D            E/B
One’s discrete interactions, femtosecond is two,
   A                                     D                  A
And they’re all held together with a third theory glue.

[Repeat Chorus]
3. Discrete defect physics – What do defects do, When placed near another defect or two? With nanobeam probes, we’ll resolve them to find How everything changes, keeping theory in mind.

[Repeat Chorus]

4. Radiation cascades evolve in short times ‘Til now what’s been measured like the sum of old crimes. But with ultra-fast pulses from hard x-ray beams The crimes can be captured; it’s the stuff of our dreams.

[Repeat Chorus]

5. Electrons do scatter, like waves on the pond, But demand that the defects to their wills do respond. First principles methods pushed past where they’ve been Defect understanding will be a big win!

[Repeat Chorus]
One-electron atom, Words by Prof. Anonymous  (Tune: “Ring of Fire”, by Johnny Cash)

INTRO (and interlude between verses): G C G G D G
G C G D G

1. Last night, I had a dream / that life’s not what it seems
G C G D G
I dreamed, and I was hurled / into a Quantum World

D C G

[Chorus:] I was part of a one-electron atom
D C G
I was bound, bound, bound / To a hydrogenic system
G C G D G
And I learned, learned, learned / About the atom / About the atom

G C G D G

2. Spectra and theory meet / When energies are discrete
G C G D G
Balmer series and Lyman lines / In Bohrs’ model they all work fine

D C G

[Chorus:] I took part in a photon emission
D C G
I fell down, down, down / Through an orbital transition
G C G D G
And I learned, learned, learned / About the atom / About the atom

G C G D G

3. To let my wavefunction / Quantize ang’lar momentum
G C G D G
My quantum numbers were n, l, m, / Plus s and m-sub-s (they’re for spin)

D C G

[Chorus:] I was part of a one-electron atom.
D C G
I was bound, bound, bound / By a Coulomb attraction.
G C G D G
And I learned, learned, learned / About the atom / About the atom
Sixteen Tips

Words by Marian McKenzie

"Sixteen Tons" by Merle Travis

1. I got drunk at a meeting where microscopists throng.
2. Some say a tip is made of tungsten and hope.
3. My graduate students have not bathed in a week.

Em    Am    B    Em    G

made a lot of promises, and don't get me wrong. My new collaborators are the
I say I'm coming to the end of my rope. 'Cause Lorraine out at Berkeley needs some
that and the epoxy, just imagine the reek! We emptied all the coffee from the

C    B7    Em    Am    B

smartest I've had, But I think I've overcommitted a tad-
scans she can use, The group at MIT is really turning the screws,
ven-ding ma-chine, The tower of piz-zas boxes is be-gin-ning to lean
Sixteen Tips

Words by Marian McKenzie

"Sixteen Tons" by Merle Travis

Chorus:

You load sixteen tips, and what ta you get? You

waste an o ther week and get no im ages yet! Oh, ho ney, don't cha call me, I

can't come home - I owe res ults to To ma so in Rome!

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In My Mind I’ve Got Physics Equations
by Charles Collett and Katie Baratz
Tune: Goin’ to Carolina in My Mind, by James Taylor
Chords by Marian McKenzie

Refrain:
D                                    G                              A
In my mind I've got physics equations,
G                              A               G                               A
Faraday and Ampère tell you how to be where.
D                                 Bm                                 G                          A
Governing the world we live in: this is why I care,
D                      G            A             D
And have physics equations in my mind.

Verse 1:
D                                            C                           G             A
Force that's due to electric field is kqq over r squared,
Bm                       G                              A
Which also equals q times E.
G                             D                       Bm       A
And voltage equals U over the test charge;
G       A          D                               G             A             D
Now I've got physics equations in my mind.
D                                         C                      G                             A
Now V's the minus integral of E dot dl from A to B,
Bm        G                             A
And E equals minus del V.
G                          D                     Bm              A
But voltage superposes and is kq over r;
D                      G            A             D
I've got physics equations in my mind.

(refrain)
Verse 2:

D          C          G          A
E dot _n-hat times dA is what we call electric flux.

Bm        G          A
Q over epsilon-naught as well.

G          D          Bm        A
But for flux due to a magnet just use B instead

D          G          A          D
I've got physics equations in my mind.

Bridge:

G          D          Bm
And the EMF is just the time derivative

Bm        C          G
Of magnetic flux times minus one.

C          G          D
And magnetic force is qv crossed with B . . .

C          A
But no monopoles . . .

G          A          D          G          A          D
So I've got physics equations in my mind!

(refrain) x2