



in partial fulfillment of the requirements for a Bachelor of Arts degree with honors in physics and music For the real Steve, Zack, and Albert,

without whom this would never have been possible

Acknowledgments

Les Phys is the result of three and a half years of hard work, not all of it my own. The greatest help with this project has come from my friend and roommate Aaron Dinkin, who not only gave his wholehearted support from the outset but contributed hours of his time, hours we both should have spent sleeping, to work on shaping the plot, developing the characters, and revising and re-revising the lyrics. Without him I could still have written the show, but it wouldn't have been half as good.

My other friend and roommate Steven Padnick contributed many ideas for the script and storyline, thus transforming it from its previous form—a collection of songs barely held together by minimal dialogue, mostly consisting of dumb gags—to a solid script with real characters, natural dialogue, and not as many dumb gags as I had expected. Several other important contributions were made by yet another friend and erstwhile roommate, Steven Wu. In fact, the rest of my roommates and friends helped out very much, and I'd like to them as well: Jeff Filippini, David Speyer, Erin Larkspur, Sarah Darling, Cendri Hutcherson, Heather Rose, and Jennifer Sunami, not necessarily in that order.

Many thanks go to Prof. Robert Levin, for encouraging me to go ahead with the project; my advisers, Prof. David Cohen and Tom Everett, for helping me fix up the music; and the faculty of the physics and music departments at Harvard University, for somehow letting me get away with submitting this as a thesis. And of course I need to thank Prof. Howard Georgi, David Morin, and Alexia Schulz, who made Physics 16 a course worth writing about.

Finally, I need to point out material that I borrowed: "Fair Harvard" by S. Gilman (lyrics revised 1997); "Ten Thousand Men of Harvard" by A. Putnam; the physics limericks from David Morin's coursebook, *Introductory Classical Mechanics*, 1998 edition; *Monty Python and the Holy Grail*; "Close to You" by Burt Bacharach and Hal David (lyrics altered by Radio Free Vestibule); "I Won't Say (I'm in Love)" from *Hercules*, by Alan Menken and David Zippel; "Another Day" from *Rent*, by Jonathan Larson; "Paul Bunyan" from the hypothetical musical *Paul Bunyan!* by Aaron Dinkin; and "One Day More," "Master of the House," and "On My Own," from *Les Misérables*, by Alain Boublil and Claude-Michel Schönberg, with lyrics by Herbert Kretzmer. All these helped make the musical what it is, and deserve appropriate recognition.

Dramatis Personae

Stephen Herter, STEVE to friends, a Harvard freshman in Physics 16 from Amonate, Virginia Isaac, commonly ZACK, his caustic friend ALBERT, Steve's roommate, who's taking Math 55 CHRISTENE Heisenberg, great-granddaughter of Werner Heisenberg, also in Physics 16 HILDEGUNDE, her friend D.B., short for Deatherage L. Bergman, also in Physics 16 Professor Howard GEORGI, who teaches Physics 16 DAVID Morin, the head teaching fellow of Physics 16 ALEXIA Schulz, the other Physics 16 teaching fellow CHORUS of physics students

Act I

#1 INTRODUCTION

WOMEN:	
Fair Harvard! we join in thy jubilant throng,	
And with blessings surrender thee o'er	MEN:
By these festival rites, from the age that is past,	Ten thousand men of Harvard want vict'ry today,
To the age that is waiting before.	For they know that o'er old Eli Fair Harvard holds sway.
O Relic and type of our ancestors' worth	So then we'll conquer old Eli's men, And when the game ends, we'll sing again:
That hast long kept their memory warm,	Ten thousand men of Harvard gained vict'ry today!

ALL:

First flow'r of their wilderness! Star of their night! Calm rising through change and through storm.

Scene I.i

The curtain opens on the final note of the Introduction to reveal Science Center D, a lecture hall at Harvard University. The time is about 10:05 a.m. on a Tuesday morning. Lecture for Physics 16 is about to start; students are gradually entering and finding their seats. Among the students is CHRISTENE. DAVID and ALEXIA are also there, as TFs ought to be; during the opening dialogue GEORGI enters and begins to prepare for his lecture. ZACK is already seated; shortly after the curtain opens D.B. enters and walks by his desk, bumping it accidentally in the process and scattering some of ZACK's papers. ZACK shoots him a dirty look, but D.B., oblivious, continues to his own seat, which is in the front. As ZACK begins to pick up his fallen papers, muttering, STEVE enters and walks up to him.

- STEVE: (not knowing what's going on) Um...hey, Zack.
- ZACK: (looking up as he finishes gathering his papers) Hey, Steve.
- STEVE: What happened here?
- ZACK: Oh, nothing. Just a little token of affection from my favorite person in the world.
- STEVE: Oh?
- ZACK: Yeah, it's nice to have such considerate classmates around. People like that really make my day.
- STEVE: You wouldn't by chance be talking about our mutual friend D.B., would you?

- ZACK: Yes, I'm talking about Deatherage L. Bergman, that goat-sucking kiss-up in the front row. I swear, sometimes that guy makes me want to just... (*He trails off into a gesture and vocalization implying violence of some dire variety.*)
- STEVE: I know what you mean. Well, at least the semester's almost over.
- ZACK: Oh sure. Except I'm sure he'll be taking 15b next semester. Really, that guy is such a pig-licking, ferret-spawned...
- STEVE: (knowing not to get ZACK started) You start on the homework yet?
- ZACK: (*snorts*) Not this week. My schedule is so bad...
- STEVE: Mine's worse.
- ZACK: I've got two problem sets.
- STEVE: I've got three.
- ZACK: And a midterm.
- STEVE: Me too.
- ZACK: And a three-page paper.
- STEVE: Six pages.
- ZACK: And a...wait, how many classes are you taking?
- STEVE: Five.
- ZACK: Retard.
- STEVE: Ah, so my schedule *is* worse than yours.
- ZACK: Yeah, but you're a retard, so it hardly counts.

GEORGI gets up to begin his lecture.

GEORGI: Okay, I guess I'll go ahead and get started. (*The students gradually subside.*) David and Alexia aren't quite done grading your last problem sets, but we should have them available for you at the end of the day. Today we'll cover rigid body rotation, so after this lecture you should be able to finish the next problem set without too much trouble. So here we go.

#2 RIGID BODY ROTATION

Think of a free symmetrical top—*I*-one the same as *I*-two— Spinning around *x*-three-hat nonstop. Euler's equations tell you That *I* times omega-one-dot plus *I*-three minus *I* times omega-three-two Is zero, so *I*-three-omega is always a constant whatever you do. This produces a simple harmonic effect, which means omega revolves 'Round about *x*-three-hat as we'd expect, and our equation resolves To show that *L* traces a conic with faces precessing around *x*-three-hat. But I'm sure you won't have any problem with that.

Now let's see how this behaves in space, so our equation for LShows very plainly it is the case—principle axes will tell— That I times omega-one times x-one-hat plus omega-two x-two-hat plus I-three times omega-three times x-three-hat gives you L without all of the fuss. So we see that the vectors all lie in a plane—L is a constant, you see, Omega and x-three-hat will remain rotating 'round x-sub-3 While omega-tilde's direction is still the direction that L's pointing at. But I'm sure you won't have any problem with that.

- GEORGI: Yes, a question.
- SMART GUY (OR GIRL): So is angular momentum just a convenient way to solve problems, or does it have any deeper significance?
- GEORGI: That's a good question. Classically it is nothing more than a convenient device, but in particle physics—which is my field, of course—angular momentum is something more meaningful. There you have the concept of spin, a kind of angular momentum intrinsic to all particles, and it's really amazing how much spin affects the interactions between particles.

Ions and muons and pions and gluons and bosons and leptons and quarks And hadrons and photons and tauons we note on selected neutrinos with internal torques Because physics has a music, a rhythm and a rhyme. But that's something other; we still have to cover nutation, and we're almost out of time.

Now what if theta varies a bit? Phi-dot of t can be small. This perturbation that we permit shows, as I'm sure you recall: *I*-phi-dot-dot sin theta minus omega-three theta-dot *I*-three is naught. So omega-s times omega-n-squared minus omega-n-squared-phi-dot Gives the triple derivative phi by dt. Now we can solve this for phi. Set the initial conditions to see how these equations apply: We find that our theta and phi indicate a precession and not something flat. But I'm sure you won't have any problem with that.

Well, we didn't get to everything because we stopped to chat, But I know you'll find, if you keep in mind what I've said today, it'll be okay, 'Cause I know you won't have any problem with that.

Scene I.ii

STEVE and ZACK walk out of the lecture hall as the students file out.

- STEVE: (facetiously) So, do you know how to do all the problems now?
- ZACK: (*also*) Oh, yeah. This stuff is way too easy for me. I wish he'd get on to something harder.

- STEVE: Right. So seeing as we're both pretty lost right now, could you ask David to go over nutation again in your section?
- ZACK: Can't you?
- STEVE: Well, probably not. D. B.'s in my section.
- ZACK: Oh, yeah. Sure, I'll try to bring it up.
- STEVE: We can go over it again when we meet on Wednesday.
- ZACK: My room this time.
- STEVE: Right. See you then.

They exit.

Scene I.iii

The curtain opens on Mass Hall A-42, STEVE and ALBERT's room. ALBERT is lying on his bed doing his homework. This involves him touching the thumb of his right hand to his nose and using two fingers of his right hand and one of his left as the vertices of an imaginary tetrahedron, then rotating it slowly while thinking very hard about what he's doing. STEVE enters.

STEVE: Hey, Albert.

- ALBERT: Good morning. (It's mid-afternoon.)
- STEVE: (Pause.) What are you doing?
- ALBERT: (*Slowly, as his mind is elsewhere*) Professor Etingof wants us to compute conjugacy classes of the group of rotations of the tetrahedron.
- STEVE: Oh. (Pause.) Any progress?
- ALBERT: Not much.
- STEVE: Why do you put yourself through that?
- ALBERT: Through what?
- STEVE: Through Math 55. Through (*obviously quoting*) the most difficult math course at the school, possibly the most difficult in the country, and maybe (*making it up now*) the most difficult class in the infinite span of geological time
- ALBERT: Actually, I heard Math 264 is kinda tough.
- STEVE: Why do you deliberately torture yourself with this stuff? Is it really necessary?
- ALBERT: (looking up, but not moving his hands from his face) I don't know. Math is interesting. It's like...it's like art.
- STEVE: Art?
- ALBERT: Yeah, art.

STEVE: How so?

- ALBERT: Oh...you know. It's much the same thing. (*Pause. STEVE is clearly not satisfied. Eventually ALBERT puts down his hands and turns toward him.*) Both rely on sudden flashes of inspiration. And both are hard but can be beautiful when done properly. See, they're very similar...and besides, look at you. You spend all your time on Physics 16 problem sets. Why do you put yourself through that?
- STEVE: Well, if math is like art, then physics is like music.
- ALBERT: Music.
- STEVE: Yeah, music.
- ALBERT: Really. Well, that may be so, but all the same I'd like to see you sing a song about physics.
- STEVE: I think I will.

#3 THE SOUND OF PHYSICS

Physics leaves some discontent, As it's emotionless to express Nature as experiment. But I say, no, it's filled with wonders yet unknown: The universe's laws each moves and spins with music all its own.

Ptolemy saw crystal spheres, And with each move they made, music played, Turning through uncounted years. And though these days we say there's no celestial dome, I still say he was right: the earth revolves with music all its own.

Every problem's a song, And though I typically get the answer wrong, It makes it worth my tears—music to my ears— Sorrow disappears when I see:

Physics has a music; each equation has a tone. Come listen with me to symphonies untold, 'Cause physics has a music all its own.

Blackout.

Scene I.iv

It is in front of the Science Center, and people are passing out flyers advertising various events around campus. The people to whom they are offering the flyers are clearly unwilling to take them and try to avoid the aggressive pushers, who force the flyers into their hands anyway. The following lines, as well as much that is ad-libbed, should be heard:

- FLYER PUSHER 1: (to various people, always in the exact same tone of voice) Come to the Leverett House Waltz next week. Come to the Leverett House Waltz next week. Come to the...
- FLYER PUSHER 2: Rally this afternoon at Mass Hall. Rally this afternoon at Mass Hall. Rally...

PASSING STUDENT: (fleeing in haste) No! I don't want to go to your stupid rally!

- FLYER PUSHER 3: Come see *Les Phys* in the Ag this weekend. Come see...
- FLYER PUSHER 1: Come to the Leverett House Waltz next week. Come...
- FLYER PUSHER 2: Rally this afternoon at Mass Hall. Rally this afternoon...
- THE SAME SMART GUY OR GIRL AS BEFORE: (*as he or she accepts a flyer*) Thank you. I always need more paper.
- FLYER PUSHER 2: (*is momentarily confused, then, to the next passer-by:*) Rally this afternoon at Mass Hall. Rally...
- HILDEGUNDE: (*entering with CHRISTENE, and seeing flyer pushers*) Argh. I hate this time of year. I feel like I'm running the gauntlet every time I try to get to class.
- CHRISTENE: Oh, it's not so bad. Just think of it as a game. We'll see if we can make it through without anyone trying to give us a flyer.
- HILDEGUNDE: Um, that doesn't sound like a very fun game.
- CHRISTENE: Sure it is.

She grabs her friend and pulls her into the fray. At about this time, STEVE enters from the other direction, sees the flyer pushers, and makes an expression that clearly conveys the sense of "We're going in." He is clearly playing the same game CHRISTENE is. They weave in an intricate pattern through the pushers, using other students to screen them, dodging suddenly in unexpected directions to avoid the flyers. HILDEGUNDE, being inexperienced, is soon snared by a flyer pusher and meekly accepts a flyer about the rally at Mass Hall that afternoon. STEVE and CHRISTENE are both doing fine until they both dart in an unexpected direction at the same time and collide rather roughly. They fall to the floor. A flyer pusher drops a flyer for the Leverett House Waltz on their bodies and walks away to find other victims.

CHRISTENE: Oh, I'm so sorry.

STEVE: (*simultaneously*) Oh, excuse me.

CHRISTENE: I'm so embarrassed. (*by way of explanation*) I was just playing this silly little game where I try to avoid having to take a flyer...

STEVE: I thought everyone did that.

CHRISTENE: Really?

STEVE: At least, I always did. I never thought of it as a game as much as trench warfare, though.

CHRISTENE: Wow. You're the first person I've met who didn't give me a weird look for saying that.

STEVE: (a little embarrassed) Oh, well, I guess I...

CHRISTENE: No, really, you are. Hey, what's your name? I'm Christene.

STEVE: Oh. Well, um, I'm Stephen.

CHRISTENE: Hi. Are you going to the Yard?

STEVE: Actually, I'm going to section. That way. (*He points the way he was headed, the opposite direction she was.*)

CHRISTENE: Oh. Well...

At this point HILDEGUNDE walks up, holding several flyers.

HILDEGUNDE: C'mon, we've got to go.

CHRISTENE: Right. (to STEVE) Sorry, gotta go.

STEVE: Well, um, nice to have met you.

CHRISTENE: Yeah. Maybe I'll bump into you some other time.

STEVE: Hopefully not so hard.

CHRISTENE: Right. Bye!

They both dodge off through the gauntlet of flyer pushers.

Scene I.v

The scene is Jefferson 453. Section is starting; students are in their desks. DAVID and ALEXIA are in front.

#4 THE PHYSICS SECTION SONG

DAVID: Here we are together now in Jefferson four-five-three, And since you've got to see Georgi's lecture,

ALEXIA: We'll be here to answer any questions you might have So you don't need to make your own conjecture.

DAVID: We're your TFs, and we'll be here to help you.

ALEXIA: To show you all the tricks you need to know.

DAVID: **So come along with us**

ALEXIA: So we can all discuss

DAVID and ALEXIA: The great big world of classical mechanics, here in

Physics section, helping you for your correction. Let us show you how apropos we now are for your problem sets. Though the lecture may have been a bit rough, We'll be here to make all things clear, And we'll show you it's not so tough. Let us guide you; if you swallow all your pride, you'll Say we're right and you'll see the light until everything you have seen. Now we're all prepared to come learn here. There's no cause for concern here In Physics 16.

ALEXIA: Everybody!

DAVID and ALEXIA and CHORUS: Physics section: how can we show our affection? Though this class is so hard, we'll pass: there's no obstacle in our way. Come and see the mysteries of the world. Find the source of the tidal force And the meaning of div, grad, curl. We've got no fear; we work hard enough to show we're Gaining knowledge at Harvard College that no one else can demean. Let's go! Now there's no need for panics. Let's learn about mechanics In Physics 16.

DAVID:

For equations with one main condition (Those linear), we give you permission To take your solutions, With firm resolutions, And add them in superposition.

ALEXIA:

This is our method, essential, For equations we solve, differential. It gets the job done, And it's even quite fun. We just try a routine exponential. DAVID: *a* is *dv* by *dt*. Is this useful? There's no guarantee.

ALEXIA:

If it lead to "Oh, heck!"'s, Take *dv* by *dx* And just write out the product with *v*.

DAVID and ALEXIA:

As Noether most keenly observed (And for which much acclaim is deserved), For each symmetry, We can easily see That a quantity must be conserved.

CHORUS:

Physics section, Teaching us about convection. Now we're learning And things discerning Whenever we come to class. Consequently, Nothing's too hard for us. Problem sets will leave No regrets No more hassles and no more fuss. Vectors, tensors, And electrical condensers,

Now we see; there's no Mystery. We know More each time we convene. Let's see: speed of light is invariant.

Nothing rhymes with "invariant"

In Physics 16.

DAVID and ALEXIA: The skill to do math on a page Has declined to the point of outrage. **Equations** quadratica Are solved on Math'matica, And on birthdays we don't know our age. The lemmings get set for their race. With one step and two steps they pace. They take three and four, And then head on for more, Without checking the limiting case. "Your units are wrong!" cried the teacher, "Your church weighs six Joules-what a feature! And the people inside Are four hours wide, And eight Gauss away from the preacher!" On a merry-go-round in the night, Coriolis was shaken with fright. Despite how he walked, 'Twas like he was stalked

By some fiend always pushing him right.

They pull out hats and canes or some equally inappropriate props and dance.

DAVID and ALEXIA and CHORUS: The Lagrangian is the potential VSubtracted from the kinetic energy. And dL by dx will turn out to be The total derivative d by dtOf the partial of L by dx-dot. Q.E.D.

CHORUS:	DAVID and ALEXIA:
Physics section,	The add said, For one little fee,
Coefficient of reflection	You can skip all that course-work ennui.
Conservation and	So send your tuition,
Then nutation and	No need for admission!
Inertial moments too.	Get your mail-order physics degree!
Coriolis	One morning while eating my Wheaties,
Transformation of force:	I felt the earth move 'neath my feeties.
Find the torque	The cause for alarm
On a moving quark.	Was a long lever-arm,
Doppler shift of a distant source.	At the end of which stood Archimedes.
Extreme action,	What would you have thought, Galileo,
Gravitational attraction,	If instead you dropped cows and did say, "Oh!
Prime relations and	To lessen the sound
Time dilations planned—	Of the moos from the ground,
Soon you'll see what we mean!	They should fall not through air, but through mayo!"
We'll learn simple harmonic motion—	Newton looked at the data, numerical,
There's no cause for commotion	And then observations, empirical,
	He said, "But, of course,
Or any emotion;	We get the same force
	From a point mass and something that's
Just see our devotion	spherical!"
To Physics 16!	In Physics 16!

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- STEVE: (entering) Sorry I'm late. Did I miss anything?
- ALEXIA: No, not really. (*The students unravel themselves from their big final pose and the room goes back to normal.*)
- DAVID: Okay, let's get started. Does anyone have any questions on the homework? (*Silence.*) Has anyone started the homework? (*Silence.*) Is anyone still awake? (*Silence. In the silence, D.B. enters.*)
- ALEXIA: Hm. Business as usual, I suppose.
- DAVID: Well, if there are no questions, I guess we can review nutation-
- D.B.: Oh, I have a question.

#5 D.B. ASKS A QUESTION

D.B.: Two questions, actually. And one of them's more of a comment. (*The rest of the class groans. They know what's coming. D.B. saunters forward to the front of the classroom.*)

My question is about the body frame: I know omega won't remain. So when we solve it should involve A frequency that's not the same. Now the orbit of Mercury Has precession very slight By general relativity. So that's the same phenomenon, is that right?

DAVID:

I don't quite see what this has to do with any-

D.B.:

Oh, well, let me tell you how: We know that Einstein set the principle That acceleration's gravity. So light that's passing by planets Will bend toward that cavity.

ALEXIA:

How interesting! Well, let's move on. We've got a lot to do today!

D.B.:

Hang on, I've got another question still; hold on tight. All you students here, listen up closely. I'll make your problems clear; they're trivial, mostly. I've got to show my stuff for everyone to see. So show some respect and listen to me.

STEVE:

He's driving me crazy. I don't know how much I can take.

D.B.:

Take this proof you did on heavy tops: I think there's something wrong.

ALEXIA:

How about we talk about this after class?

DAVID: Much after class.

DAVID and ALEXIA: How's next June?

D.B.:

And one more thing: you know that here you didn't really prove That beta is a constant height, And I've got a counterexample to this step in line two.

DAVID:

That's okay. I've got two proofs.

D.B. Furthermore, this frequency Is just an approximation. Is that right?

STEVE:

I just wish this guy would grow up. I'd like to learn to do physics too, And I can't if he won't shut up!

CHORUS: Shut up! Shut up!

D.B.: Well, let me tell the section what's up.

CHORUS: Shut up! Shut up!

STEVE: I'm warning you: sit down and shut up.

CHORUS: Shut up! Shut up! Shut up! Shut up! Shut up! Shut up! Shut up!

STEVE: If he can't see, I'll just have to tell him to shut up.

DAVID: If you'd just listen to us...

ALEXIA: **Don't waste your breath.**

DAVID: ALEXIA: Let me explain: Some guys just won't You'll understand if you shut up! Listen or shut up. STEVE: Let us learn physics and please shut up! D.B. And I was wondering: In equation eight sixty-three. You dropped the square of *d*-phi-*dt*. I think that's wrong.

DAVID: It's not.

D.B.: It should belong.

ALEXIA: You snot.

D.B.:

We need another term in omega-three.

I'm sure you'll concede,STEVE:Shut up!ALEXIA:concede,I'm warning you:Shut up!Why are you sIf you just do some computin',I guarantee.Please shut up!highfalutin?Let's be agreed.Shut up!DAVID: No, listen.	D.B.: I'm sure you'll concede, If you just do some computin', Let's be agreed.	STEVE: I'm warning you: I guarantee.	CHORUS: Shut up! Shut up! Please shut up! Shut up! Shut up!	DAVID and ALEXIA: Why are you so highfalutin? DAVID: No, listen.
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ALEXIA:

That's an interesting point; why don't you take it up with Newton?

D.B.:	STEVE:	DAVID:	CHORUS:
So, all you students	Physics has a music	Listen to me,	So shut up!
here,	to me.	Don't you try to talk	Shut up!
Listen up closely.	But if you don't sit	right through me.	
I'll make your	down, stupid	DAVID and ALEXIA:	Shut up!
problems clear;	clown,	Let us help you, you	Shut up!
They're trivial,	Just wait and see.	Little whelp, you.	Shut up!
mostly.		You	
		Really don't know a	Shut up!
		thing.	Shut up!
D.B.:		STEVE:	
I've got to show my st So show some respect	tuff for everyone to see. t and listen to me.	Now, you listen to me. I won't be warning you	ı again. You'll see.

D.B.: You know l correct so lis to me.	STEVE: I'm I promise yo ten I can't take	u. more.	DAVID: Listen. DAVID Quiet.	and ALEXIA:	CH Shu Shu Shu Shu	ORUS: at up! at up! at up! at up!
D.B.: Take time to reflect And listen to—	STEVE: You just don't have a clue; Nothing new. Face it, you Know it's true, Now you listen to—	DAVID: You're a start If you' just to—	about to a riot. d only listen	ALEXIA: Silence. Listen to—		CHORUS: Shut up! Shut up! Shut up! Shut up! Shut up! Shut up! Shut—

- STEVE: (standing and slamming his hand on his desk) Shut up!
- D.B.: (spinning around to face him) What?
- STEVE: Shut up! Shut up! We're sick of listening to you try to show off how smart you are! Now could you please just sit down and shut up!
- D.B. Who are you?
- STEVE: Who am I? I'm just one of your classmates who's sick and tired of listening to your irritating little whiny voice ramble on about stuff no one cares about! I think for the moment I have the support of the rest of the class. (*The class nods enthusiastically*. *DAVID and ALEXIA too.*)
- D.B.: Well, I'm sorry, but I'm sure anyone who was paying attention in lecture would have the same questions. If you just don't understand the physics well enough, I think *you* should sit down.
- STEVE: *What?* Look, don't give me that. I can whoop you in physics any day.
- D.B.: Yeah? I'd like to see you try!
- STEVE: Well, okay! Uhh...
- D.B.: We'll see who gets a higher score on the next problem set!
- STEVE: Fine! ... Do you mean the one due this Thursday?
- D.B.: Yeah!
- STEVE: Umm...can we make it next week's instead? I've got an Expos paper due this week.
- D.B.: Oh, yeah, I've got a chem midterm. All right, next week!
- STEVE: You're on!

#6 CONFRONTATION

STEVE: Now comes my big moment; I can wipe off your stupid grin.

Just wait and we'll see: Next week when we turn our next problem sets in.

D.B.:

You've made a big mistake; listen up closely. It's more than you can take: you'll fail grossly. Don't try to show me up; listen well to me. Show some respect; then wait and see.

STEVE:

We'll see like never seen beforeWe'll see if that's true:When I get the higher scoreNext week I'll show youAnd now I look forward to seeing your faceYou'd better stick to this challenge you've
made.When I put you in your place.You'd better stick to this challenge you've
made.We'll be spending most our livesAnd then we'll see who gets the higher grade.Working on these physics paradigms;Tell me why are you so blind to see:
You don't have a plea.

D.B.:

STEVE:

I give you my challenge,

So let the contest now begin. Who's smarter we'll prove Next week when we turn our next problem sets in I'll show you.

D.B.:

So, all you students here Hear my voice vehement: Let no one interfere With our agreement. Soon there shall dawn that day When I declare my win. Then you'll wish you had listened to me.

CHORUS:

Tandem clare te video;

Aliam catenam geres.

Prius quam haec eloqueris, Prius quam me catenabis, Audi me, facturum quoddam.

STEVE: Wait and see.

D.B.: Just one week more.

STEVE: **Our final problem set.**

D.B.: Here's the bet:

STEVE and D.B.: **Then's the time to settle the score**, STEVE: **But then you'll know**—

D.B.: As all the glory shines on me—

STEVE: **That physics has a music.**

STEVE and D.B.: I'll show you who is smarter: Wait and see.

Blackout.

Scene I.vi

ZACK's room, Grays East 42. ZACK is at his desk, working.

#7 Working Till Midnight

ZACK:

Working till midnight— Your eyes are all burning, your stomach is churning— Some little kid might give up and stop right now, And yet this stupid problem just won't come out right. You get the sinking feeling that you won't be getting much sleep tonight. But you keep trying— Your joints are all locking, your knees are still knocking— Indemnifying all of the sleep you've missed, And on you slog with all of your thoughts in disarray: Working until the break of day.

I don't know what I'm doing here. All these sleepless nights really bites, And I'm no engineer; still, I just hope I can pass, Maybe I'm just slow; I don't know Why I ever signed up for this class.

Knock. ZACK goes to the door and lets STEVE in.

Till early morning— Your hands are both shaking, your backbone is aching— You had no warning physics could be so rough, But now you find yourself stuck on problem number one, And so by 2 a.m. you have given up hope you'll ever be done. But you're still working— Your vision is blurring, your speech is all slurring— Although it's irking that you have to do this now. So you press on while cursing your own naïveté, Working until the break of day.

STEVE:

It just can't be this means so much to me That I would sacrifice my health. Yet physics has a music and That means much more to me than all the world's wealth. (CHORUS enters.)

CHORUS: Bum ba dum ba dum ba dum.

CHORUS and ZACK and STEVE: And now you don't know why you're here. You could be sleeping now, yet somehow, Though you seem insincere, You strive on till dawn's first light: Trying each device, checking twice, Hoping this time that your answer's right.

CHORUS:

This problem set—we'll never get this done. So we're: (continues as vocal backup)

ZACK: Working till sunrise—

STEVE:

Your migraine is raging, your brain's disengaging-

ZACK:

You know that some guys think physics is a breeze, And you can't comprehend what the problem's asking you, But you keep on because, well,

STEVE and ZACK:

You just wouldn't know what else you would do. It's getting light now— You feel like dying, your body's complying— You don't see quite how you'll ever get this done. And now the last reserves of your strength are draining away.

ZACK: This class was a big mistake.

STEVE: How long have I been awake?

CHORUS and ZACK and STEVE: Working until the break of day. Yeah!

CHORUS exits. ZACK goes back to working on the problem set.

STEVE: Where's your facebook?

ZACK points. STEVE picks it up and flips through it.

- STEVE: Okay...let's see...H...H-E...
- ZACK: I don't see why they don't index those things by "cute."
- STEVE: (*finding what he was looking for*) *Christene* Heisenberg! There we go. (*to ZACK*) You ever hear of her?
- ZACK: Who?
- STEVE: Christene Heisenberg.
- ZACK: Hmm...I'm uncertain. (*Drum sting. They both groan. ZACK glares at the drummer.*) I don't think I've heard of her. Why do you ask?
- STEVE: She's just this girl I bumped into yesterday.
- ZACK: Umm. Is she at all related to...
- STEVE: She's Werner Heisenberg's great-granddaughter, yes.
- ZACK: Wow. Talk about a legacy.
- STEVE: Yeah. Although apparently she doesn't want to study physics.
- ZACK: Oh?
- STEVE: She sings. In musicals. Student productions. Apparently she's quite good.
- ZACK: So you don't know her name, but...
- STEVE: Well, I was eating in Annenberg alone for dinner—I usually do that Monday nights—
- ZACK: Yes...
- STEVE: (As he talks, he begins walking downstage, where lights come up on an Annenberg scene with a table and chairs. CHRISTENE and HILDEGUNDE sit down with trays.) And I just picked an empty chair at an empty table, and she and her friend were eating nearby. And she was talking about how she just can't see why...
- CHRISTENE: (*simultaneously, as lights go completely down on ZACK's room.*) ... I just can't see why I *have* to study physics!
- HILDEGUNDE: (who has heard this before) Right. Uh huh.
- CHRISTENE: I mean, I don't care if physics is in my blood. I don't care if my great-grandfather invented quantum mechanics. I don't even care if I'm really good at it! ... Which I'm not.
- HILDEGUNDE: Actually...
- CHRISTENE: Anyway, that's not important. Everyone else here gets to choose their

concentrations. Your parents don't make you study physics.

HILDEGUNDE: Heaven forbid.

- CHRISTENE: But I don't have any choice! So I'm stuck here in these stupid physics classes, when (*Monty Python*) all I really want to do is *sing*!
- ZACK: (as lights come up abruptly on his room again, revealing STEVE in the middle of telling the story, in the same Monty Python pose) You can't be serious.
- STEVE: Well, maybe that wasn't exactly what she said...
- CHRISTENE: (*lights back up on Annenberg*) So I'm stuck here in these stupid physics classes, and I really would rather study music. I mean, I like singing. I sing in musicals. I sing in the shower. I sing in class. My TF's hate me for it.
- HILDEGUNDE: Well, it can get irritating. Especially when you break into "Castle on a Cloud" in the middle of a Justice section.
- CHRISTENE: (singing) "There is a fat man on a bridge..."
- HILDEGUNDE: You see what I mean.
- CHRISTENE: It could be worse. If it were a physics class I'd be approximating the fat man as a perfect rolling sphere.
- HILDEGUNDE: Well, why don't you just not study physics then? Your parents aren't here. They can't make you.

#8 CAUGHT IN BETWEEN

CHRISTENE: Huh. Fat chance. If I want them to keep paying my tuition, then I've got to be stuck in the one field that has nothing to do with music, the most boring science in the world...

Why, when I try to get up for Physics 16, I just can't feel inspired The way that my mom and dad always had. Only music excites me so, And I want to know if it means anything That I'm here doing like I was taught; Still I'm always caught in between.

Oh, physics is boring and stultified: Something that none can deny. So all my troubles are multiplied Though I try and try, still I heave a sigh as I wonder why.

When, now and then, I perform a singing routine, I feel so happy inside And every last harmony sets me free. Then it's back to my problem sets, And it always gets so obscene doing them. But I still do all the things I ought, 'Cause I'm always caught in between.

Why must I just confine the two? Why are they far apart? If I could just combine the two: But I can't see how music could allow All these facts I don't embrace. Do they connect? Do their parts intersect? It's a hopeless case.

How, here and now, can I ever feel serene If I am forced to be told, "Don't do what you want to do: don't be you"? Oh, it makes me so mad inside, And my wounded pride wants to scream, "Help me, please!" But no luck, never mind what I thought, or how much I fought, Every thing I sought made me more distraught, Now I'm overwrought, and I feel caught in this scene In between.

Blackout.

Scene I.vii

Mass Hall A-42. ALBERT is on the bed again, contemplating a pretzel. STEVE enters.

STEVE: Hey.

- ALBERT: You know you've done too much math when you start trying to calculate the Euler characteristic of your snack foods.
- STEVE: Umm.
- ALBERT: Anyway, back to work. (*He turns back to his homework*.)
- STEVE: (*After a pause in which it is clear that he wants to say something, but doesn't know how to bring it up.*) Hey, have you ever met a girl named Christene Heisenberg?
- ALBERT: Oh, you mean the great-granddaughter of Werner von Heisenberg?
- STEVE: Oh, so you do know her.
- ALBERT: No, I thought you were joking. You mean she exists?
- STEVE: Yes, she does. She's a freshman.
- ALBERT: Wow. You know, she really ought to have a cat.
- STEVE: Named Schrödinger, right.

ALBERT: She could keep it in a box. So Yard Operations wouldn't find it.

STEVE: Yeah, but she would never be able to open the box. She wouldn't be able to feed it.

ALBERT: So by the end of the year it'd be half dead. (Drum sting.) So why do you bring her up?

STEVE: Well, I ran into her recently—

ALBERT: Ouch.

STEVE: I said sorry!—and well, yeah. That's it. Just someone I met.

ALBERT: I see.

STEVE: Anyway. (*ALBERT goes back to work.*)

#9 Positive-Definite Non-Degenerate Symmetric Bilinear Forms

ALBERT: ... So I need to show that this is orthogonal...

STEVE: Tough problem set?

- ALBERT: You might say that. ... Maybe if I showed that for any positive-definite non-degenerate symmetric bilinear form...
- STEVE: Any what?

ALBERT: A positive-definite non-degenerate symmetric bilinear form. An inner product.

STEVE: So why don't you just call it...or is that a stupid question?

ALBERT:

Don't ask me what the reason was I took Math 55. I wonder now if anyone does get out of it alive. As soon as I get into class, I'm fighting off a swarm Of positive-definite non-degenerate symmetric bilinear forms.

Oh! You stay up all night Tuesday working on them in your dorm. You get the same topology however you transform. You put 'em back together and you get your favorite norm. Those positive-definite non-degenerate symmetric bilinear forms.

My roommate's in Math 22, and his TFs instruct That such a form it's okay to call an "inner product." But powers that be declared that "55-ers must conform To 'positive-definite non-degenerate symmetric bilinear forms.""

STEVE and ALBERT:

Oh! You stay up all night Tuesday working on them in your dorm. You get the same topology however you transform. You put 'em back together and you get your favorite norm. Those positive-definite non-degenerate symmetric bilinear forms.

STEVE:

Though I might stay up all night—and believe me, yes I do— Compared to him I just might be here finding two plus two. But I won't ever have to work—and this thought keeps me warm— With positive-definite non-degenerate symmetric bilinear forms.

STEVE and ALBERT:

Oh! You stay up all night Tuesday working on them in your dorm. You get the same topology however you transform. You put 'em back together and you get your favorite norm. Those positive-definite non-degenerate symmetric bilinear forms.

STEVE:

Let's assume orthonormal bases, Take the magnitude of the two. Find the square and radical, Assign this morphism. Then we'll do Some checks to see if these commute, And yes, they're quite convivial. And is this in the vector space R¹? Of course! It's trivial!

In matrix form, Euclidean scalar Product must be true. So let's assign a zeta such that Zeta equals two. With all these transformations, Eigenvalues, we can see That, *ipso facto*, two plus two is four. Q.E.D.

ALBERT:

Let V be defined as real, And define a metric on PV; We found that alpha must satisfy The triangle inequality. Now show the distance function In this space that's projectivial, Must be complete and bounded, so PV's compact. It's trivial!

Restrict this to R³ And use high school stereometry. This reduces to elementary Spherical geometry. The sphere of dimension *n*–1, Modulo antipodality, Is homeomorphic to the projective space. Q.E.D.

STEVE and ALBERT:

Those positive-definite non-degenerate symmetric bilinear forms. Those positive-definite non-degenerate symmetric bilinear forms! Oh! You stay up all night Tuesday working on them in your dorm. You get the same topology however you transform. You put 'em back together and you get your favorite norm. Those positive-definite non-degenerate symmetric bilinear forms. Those positive-definite non-degenerate symmetric bilinear forms!

They're positive and definite! They'll never be degenerate!

ALBERT: Unless we confine them to an isotropic subspace. Then they would be degenerate. Oh, wait, I said they were positive-definite, didn't I?

STEVE: Uh...I guess.

STEVE and ALBERT:

Those positive-definite non-degenerate symmetric bilinear forms! Those positive-definite non-degenerate symmetric bilinear forms!

Knock. STEVE answers it and ZACK comes in as ALBERT returns to work on his homework.

- STEVE: Hey. Ready to tackle some more physics?
- ZACK: (*storming in*) You know, that guy makes me want to... (*He makes another gesture and vocalization suggesting violence, more drastic than the last.*)
- STEVE: Um...I suppose you're talking about our mutual friend D.B. again.
- ZACK: Saw him on the way here. Had a little "talk" with him.
- STEVE: Uh oh. Is he still alive? Are you going to go to jail?
- ZACK: No, I didn't actually do anything. Which isn't to say I wasn't tempted...but no, we actually just talked. Or he did, anyway. I was trying to restrain myself from tearing him apart.
- ALBERT: (*in a weird voice*) If you continue to antagonize me, I shall be forced to inflict on your anatomy a series of wounds, each more devastating than its predecessor!
- STEVE: Yeah...so what'd he say? Wait, how does he even know who you are?
- ZACK: I don't know, 'cause I certainly never talk to him, but he does.
- STEVE: So what'd he say?
- ZACK: He asked me if I was on my way to study physics, and I responded appropriately.
- STEVE: I don't think beating him to a pulp is generally considered an appropriate response.
- ZACK: No, no, I told him it was none of his business. Anyway, he said to tell you that you'd better be working hard, because he's almost finished with the problem set.
- STEVE: You know, that guy is such a...(*is about to say something obscene, stops with the word in his mouth and gesticulates a bit*)
- ZACK: ...an incestuous spawn of goats?
- STEVE:such a jerk. I hate him.
- ZACK: I think you ought to go up to that guy, rip out his heart, and feed it to him before he dies. And none of this "show him how black it is" stuff, we already know that. He needs to taste the charcoal.
- STEVE: Even that wouldn't be satisfactory enough. What I need to do is beat him on this problem set. I need to be able to see the expression on his face when he realizes that someone in the class knows more physics than he does.

	T	•	. 1 *	1 /
7 A ('K ·	Then you	con rin	out hig	heart
LAUN.	I HOH YOU	can np	out ms	noart.

- STEVE: If you like, yes. But it's getting a higher score that counts. That's the only thing that will satisfy me, and justify my decision to study physics in the first place.
- ALBERT: I thought you said you studied physics because it has a music or something.
- STEVE: Yeah, well, maybe there's more to it than that. I mean, the tune's not so sweet when you have to hear it from D.B.
- ZACK: So how *are* you doing on the problem set?
- STEVE: (looks uncomfortable, and a little despondent)
- ZACK: Not much progress, then.
- STEVE: Not a whole lot, no. By which I mean "none at all."
- ZACK: D.B.'s probably way ahead of you. Do you really think you can beat him?
- STEVE: Sure, why not? He's not that smart.
- ZACK: Neither are you. I mean, you've never beaten him on a problem set, have you?
- STEVE: What, you think I keep track?
- ZACK: (Says nothing, but clearly the answer is "yes.")
- STEVE: Well, okay, so I've never beaten him before. That'll just make it more satisfying when I beat him this time.
- ZACK: And you're sure you can pull that off?
- STEVE: Yes.
- ZACK: Really?
- STEVE: Yes.
- ZACK: Really?
- STEVE: Yes!

Short pause.

- ZACK: Really-
- STEVE: YES!
- ZACK: Okay, okay. Whatever you say. You'd just better get cracking, then. I mean, the problem set's due Thursday. You've only got one day more.

#10 ONE DAY MORE

Music starts and lights fade to dramatic dimness as STEVE steps forward into a spotlight. ZACK doesn't notice.

STEVE-One day more. A—

ZACK: Oh, shut up.

STEVE: Sorry.

One day more—I'll show them I won't succumb. I'll finish that problem set, win that bet, Then I'll just take whatever may come in One day more. Sure I can do it: I'll work harder than ever before. That's all the time I need To finish the last physics problem set: **One day more!**

ZACK:

You realize what you're doing here? Well, I hope you see that D.B. Has beaten you all year. There's nothing that you can do. If he beats you now, breaks your vow, Then you'll wish you'd heard what I told vou. There are some things that cannot be.

Though you work all night, write and write, Still there's no guarantee that You won't lose all the same.

Well, you've got one day. Hope and pray. If you fail then you know who to blame.

CHRISTENE: (*entering*, *as lights go up on her*) Maybe one day I can make my interests agree.

ALBERT:

ZACK:

If you don't get started you won't get past problem one.

And you'll be easily outdone.

feat you will perform.

CHRISTENE:

At least this is the last problem set before I'll be free, happily.

STEVE: Well, wait and see, 'cause we only have one

dav more.

transform

bilinear form.

ALBERT: You'll be up all the night while

And all the while you'll say that this great

But I'll be up late anyway, still trying to

A positive-definite non-degenerate symmetric

working on them in our dorm,

ALBERT:

No use talking of the set until you have begun.

CHRISTENE: This assignment's the final bit, All I need is to finish it.

ALBERT: And now if you don't start you know you never will get done. ZACK: Don't be dumb: change will come. Careful you're not outdone.

ZACK: And don't you think you've won.

CHRISTENE: Here I stay for a short delay But I know I may be finished in one day.

GEORGI, DAVID and ALEXIA, D.B., and CHORUS appear for no good reason.

GEORGI:

You shouldn't have a problem with this: Euler's equations are clear.

ZACK: And, you know, the way he says that seems so sincere.

GEORGI: Just analyze the tidal force. You shouldn't have to review it.

ZACK: But you know he'll forego telling us how to do it.

GEORGI:

This one's a cinch so you don't need to fear. You should get everything right.

ZACK:

You know that means we'll be up all night.

GEORGI:

This combination of Hubble inflation, galactic migration, and acceleration's a breeze!

CHORUS:

Working until the break of day,

CHORUS:	STEVE:
Hoping our work will somehow repay.	This'll be easy—I'll do it in one day more.

D.B.: Now, how well can you do, If you've not begun yet? You should have thought this through; You're not done yet. And when tomorrow comes Then you'll have to see. You'll show some respect and you'll listen to

STEVE:

No, not this time, and we'll see in just one day more.

DAVID and ALEXIA:

Physics section shows you every imperfection. Though you made a vow, I'm afraid that now It doesn't mean a thing. Good luck—heed it, 'Cause you know you're gonna need it. So don't delay; you've got one more day Back here in Physics 16.

CHORUS:

me.

Fair Harvard, though we get the problems all wrong, At least we'll be finished in just one day more. Ten thousand men of Harvard have problem sets tonight, And they'll be working on them till morning's first light.

STEVE, with ALL joining in gradually:

Do this problem set, See what grade I get. Hasn't happened yet, But I'll win that bet. It should be no sweat! I won't be upset. I'll just be trying to finish that problem set.

(The following parts are to be sung simultaneously.)

STEVE:	ZACK:
One day more,	I don't know what I'm saying here.
Then I'll be just in time.	But this passage here
Now something 'bout "problem set"	Doesn't rhyme,
And "that bet."	Just so it fits the meter.
That's what I say to get a good rhyme	There's no more I can say.
But still I guess it doesn't matter what I say.	If I babble some—
'Cause you can't hear me now.	Bum bum—
As long as I just end with "one day more!"	Let's just see what comes in one day more!

ALBERT:

- You stay up all night Tuesday working on them in your dorm,
- You get the same topology however you transform,
- You put 'em back together and you get your favorite norm:

Those positive-definite non-degenerate symmetric bilinear forms.

One day more!

CHRISTENE:

- What could I cut from this song to make myself heard?
- I really want you to hear what I will say to you, doggy doo.
- But there's all of these people who just keep singing and being rude.

So I guess that I'm stuck unless I can just undress but it's too late.

One day more!

GEORGI:

Now let's work on the physics of this. Though I just have to point out. That this is more than most physicists Study as freshmen without Much outside training in various stuff, Quantum mechanics in store. So all this physics is really impossible; lots of it doesn't make sense until—one day more!

D.B.:

Hey, listen to this theme. Isn't it clever. I invert Pachelbel But I never Needed to change a bit To work it with that beat In the confrontation. Well, isn't that neat? One day more!

DAVID:

Newton said as he gazed off afar, "From here to the most distant star, These wond'rous ellipses And solar eclipses All come from a 1 over *r*." Copernicus gave his reply To those who had pledged to deny. "All your addictions To ancient convictions Won't put your place back in the sky." One day more!

ALEXIA:

Physics section, Urinary tract infection. Constipation and flatulation And matriculation too. Physics section, Giving you a big election, An odoriferous eminence. All this in one day more!

SOPRANOS:

Why do birds suddenly appear
Every time you are near?
Could it be you've got bird seed on your head?
Why do stars fall out of the sky
Every time you walk by?
Could it be you've...oh, never mind.
One day more!

ALTOS:

Who'd'ya think you're kiddin'? He's the Earth and heaven to you. Try to keep it hidden, Honey; we can see right through you. Girl, ya can't conceal it: We know how ya feel and Who you're thinking of. You keep on denying Who you are and how you're feeling. Baby, we're not buying— Hon, we saw ya hit the ceiling. Face it like a grown-up. When ya gonna own up That ya got, got, got it bad? One day more!

End simultaneous section.

STEVE:

And so, by tomorrow we'll all see That physics has a music, But I guess that that's just not enough for me.

ALL:

Tomorrow let come whatever may, No matter what other people say, Just plain hard work is the only way To finish the last physics problem set: One day more!

CURTAIN

TENORS:

There's only us. There's only this. Forget regret or life is yours to miss. No other time. No other way. No day but today. One day more!

BASSES: Paul Bunyan! Paul Bunyan! One day more!

ACT II

#11 ONE OF THESE DAYS

CHORUS:

One day more—so here we stand, And as tomorrow nears, it appears Things might not go as we planned, But still tonight, let's hope that we can find the key To finish all our work By 10 a.m. tomorrow. Wait and see.

HILDEGUNDE:

Here's my latest problem set; It's due tomorrow, you see. It's just that I haven't started it yet, But I know it's not just me. Every college student does it Whatever his age, race, or creed. We realize it's a problem But we really don't want to be freed. 'Cause we know the work'll get done; It's just a matter of when. So we just keep on partying And say, "I'll do it then!" Yes, we know it's wrong, And we try to stop, But there's nothing we can do. So we keep making promises We know just aren't true, like:

One of these days, I'll go to bed before midnight. And one of these days I'll do the reading for class. One of these days I'll start my paper early— One of these days—or I don't think I'll pass. Oh, this I promise and this I vow: I'll do anything, but not right now. I'll swear off parties and stop my games, I'll mend my evil ways. I'll stop putting off for tomorrow what I should be doing today, Yes, that's what I'll do one of these days.

MEN:

And one of these days I'll actually read in reading period,

WOMEN: And one of these days I'll stay awake for lecture in Ec 10.

CHORUS:

It's an inborn fault, an original sin, And we try to stop, but we never can win Against P-R-O-C-R-A-S-T-I-N-A-T-I-O-N!

RANDOM MALE CHORUS MEMBER #1: One of these days I'll have to get up early.

RANDOM MALE CHORUS MEMBER #2: And one of these days I'll try to clean my room. RANDOM FEMALE CHORUS MEMBER #1: One of these days I'll have to do my laundry.

RANDOM FEMALE CHORUS MEMBER #2: One of these days I'll learn to use a broom.

RANDOM MALE CHORUS MEMBER #3: One of these days I'll finally wash my underwear.

Awkward pause.

RANDOM MALE CHORUS MEMBER #3: ...Uhh...

CHORUS:

One of these days, or it'll be my doom.

Oh, this I promise and this I swear:

I'd do it now, but I just don't care,

I'll end my drinking and give up sleep.

I've had enough delays.

I'll stop putting off for next Thursday what I should have done Monday night.

Yes, that's what I'll do one of these days.

MEN:	WOMEN:
One of these days I'll try to get some breakfast,	Fair Harvard, we join in thy jubilant throng,
And one of these days I'll cure my RSI.	Or we would if we just had more time.
One of these days I'll get my yearly checkup.	We find we can put off your festival rites;
One of these days, or else my mom'll cry.	After all, it's a victimless crime.
Oh, this I promise and this is true:	And night after night,
I'll do all this and I'll like it too.	As we fight the good fight,
I'll never argue; I won't complain;	To keep our poor memory warm.
'Cause lateness never pays.	
I'll stop putting off for December what I should have done in July.	We hope the professor will never see through
Yes, that's what I'll do, one of these days.	Our efforts to change and reform.

MEN:

And one of these days I won't stay up late writing stupid musicals.

WOMEN:

And one of these days I'll learn the rest of the lyrics to this song.

CHORUS:

(ad lib) La da da da da da da something something

Dum de rum rum "A"'s.

(*not exactly like this*) And one of these days, um, one of these days, er, one of these days and (*confidently*) One of these days!

CHRISTENE enters and makes her way through dancing chorus members to HILDEGUNDE.

CHRISTENE: Hey, what are you doing? C'mon, we've got to get to section.

HILDEGUNDE: What's the rush? The section will still be there when we get there.

CHRISTENE: Well, we don't want to be too late.

HILDEGUNDE: Can't you see I'm in the middle of a song?

CHRISTENE: It's not over yet?

HILDEGUNDE: Heck no. This is just a dance break.

CHRISTENE: All right, all right. Hurry it up. (She goes off to one side.)

WOMEN:

One of these days!

MEN: One of these days!

WOMEN: One of these days!

MEN: **One of these days!**

WOMEN: **One of these days!**

MEN: **One of these days!**

CHORUS: One of these days! Oh, this I promise; I guarantee: I'll do the work; I'll get my degree.

Abstain from foosball and not play Quake,

I'll change my C's to A's.

I'll stop making up lame excuses when I should be doing my work.

Yes, that's what I'll do one of these days.

Yes, that's what I'll do one of these days.

Yes, that's what I'll do one of these days. Yes, that's what I'll do one of these days.

CHRISTENE begins to get agitated, as it appears that the song will never end.

Yes, that's what I'll do one of these days. Yes, that's what I'll do one of these days. That's what I'll do one of these...

CHRISTENE: (to HILDEGUNDE) Hey! We've got to get to section!

CHORUS: Days!

Blackout.

Scene II.i

The scene is in front of a representation of the door to GEORGI's office. The door is closed. STEVE runs in from the side, stops at the door, puts his ear to it, knocks, waits around a little bit, turns away. ALEXIA walks by, carrying a box of stuff.

- STEVE: Hey, Alexia. Do you think you could help me with this problem?
- ALEXIA: Sure, if you don't mind helping me move seventeen boxes of physics books down three flights of stairs.
- STEVE: On second thought, do you know where Professor Georgi is? Shouldn't he be in his office right now?
- ALEXIA: Yeah, he should be. I don't know where he might have gone.
- STEVE: Shoot. Oh, well. What's with the boxes?
- ALEXIA: I'm just moving stuff out of my office, since I won't be here next semester.
- STEVE: You're getting your degree?
- ALEXIA: No, but I'm spending the next semester doing field research. (*excitedly*) Professor Georgi's sending me to work in the salt mines.
- STEVE: Huh?
- ALEXIA: Yeah! Out in Utah!
- STEVE: Is this because your grades weren't good enough, or...
- ALEXIA: What? Oh, no, it's not that kind of salt mines. People don't mine salt from them any more. Now we're just going to fill them full of water.
- STEVE: That would have been my next guess.
- ALEXIA: And take pictures of it all day.
- STEVE: Just what I would do.

ALEXIA: (by way of explanation) We're looking for proton decay. Should only take a few years.

- STEVE: Right. So, no idea where Professor Georgi is, then.
- ALEXIA: Hmm...I guess you could try Leverett House. He is the House Master there. And isn't there some sort of event going on tonight?
- STEVE: Oh, yeah, I think there's a waltz or something.
- ALEXIA: Well, Professor Georgi's probably going to be there, then. If you're really desperate you could try him there.
- STEVE: Hey, yeah, I guess I could. Great, thanks a lot! Have fun in the salt mines.

Scene II.ii

STEVE runs to another lighted area, where ZACK is.

- STEVE: Hey. Don't suppose you're going to the Leverett House Waltz?
- ZACK: I'd rather eat my own liver. (*He looks at STEVE suspiciously*.) You're not going.
- STEVE: I think I am.
- ZACK: No, that wasn't a question.
- STEVE: No, really. I need to ask Professor Georgi about that problem we were working on. You know, the one with the angular velocity term that won't come out right.
- ZACK: So why don't you go to his office hours then? Why go to a room full of pansy-boys dressed in monkey suits pretending to be snobby upper-class elite from the 1950s?
- STEVE: Professor Georgi's gonna be there too.
- ZACK: Why? Oh, right. He's Leverett House Master.
- STEVE: Hey, you know what that makes him?

ZACK: What?

#12 MASTER OF THE HOUSE

STEVE:

Master of the house—

- ZACK: Shut up.
- STEVE: Sorry.
- ZACK: So you're going to a waltz just to ask a professor a question?
- STEVE: The problem set's due tomorrow. What else can I do?
- ZACK: And are you going to dress up in a monkey suit too?

- STEVE: No, but maybe a tuxedo. Actually, I don't have one, but I'll think of something. I'll stop by your room afterwards to work on the homework more.
- ZACK: All right. Have a good time, monkey-boy.

Scene II.iii

#13 LEVERETT HOUSE WALTZ

The Leverett House Waltz. CHORUS MEMBERS are on stage dancing. There is a table of food and stuff at the back of the stage. CHRISTENE is also there, although not attached to any guy in particular. After a while, STEVE enters, dressed in some outlandish approximation of a tuxedo, like a tuxedo jacket and a bow tie over shorts and a T-shirt. He looks around for GEORGI, doesn't see him, goes over to the food table to eat something. In a break in the dancing, HILDEGUNDE comes over to talk to him.

HILDEGUNDE: Nice clothes.

STEVE: Hmm? Oh, thanks.

HILDEGUNDE: Looking for someone?

STEVE: Yes! Have you seen Georgi?

HILDEGUNDE: Who's she?

STEVE: Huh? Oh. Professor Georgi. He's the Leverett House Master.

HILDEGUNDE: Grey hair? Beard? Glasses?

STEVE: Yes. Now you're going to say "Never heard of him," right?

- HILDEGUNDE: I was going to say, he just stepped out for some air. Look (*indicating a window*). See? There, out in the darkness?
- STEVE: Hm. Well, I guess I'll wait for him to get back. After all, I did pay five dollars to get in. And get dressed up. Sort of.
- HILDEGUNDE: Yeah, you should stick around, have some fun. Maybe it's a sign.
- STEVE: Yeah, I—(pause)
- HILDEGUNDE: Yes...?
- STEVE: It is a sine! Uh...shoot, let me...(fumbles around, grabs a napkin, pulls out a pencil, and begins scribbling on it.)

HILDEGUNDE: Um...hello?

STEVE: Um...excuse me, I've gotta...(*He leaves the table, goes over to the side, still scribbling. HILDEGUNDE shrugs, goes and talks to someone else or dances or something. After a little while CHRISTENE walks up and looks over STEVE's shoulder.*)

CHRISTENE: Minus.

STEVE: Huh?

CHRISTENE: *Minus* cosine theta sine theta.

STEVE: (correcting it) Oh, yeah. (looking up) Oh, hey!

CHRISTENE: Hi, Stephen!

STEVE: Hey!

CHRISTENE: (*short pause*) You don't remember my name, do you.

STEVE: No!

CHRISTENE: Christene.

STEVE: Yes!

CHRISTENE: Nice clothes.

STEVE: Um, thanks. Why do people keep saying that?

CHRISTENE: Can't imagine. Doing a problem set?

STEVE: Yep.

CHRISTENE: Here?

STEVE: Well, I came to ask Professor Georgi about problem three.

CHRISTENE: Yeah, I thought that one was hard too.

STEVE: (By the way, STEVE did not know CHRISTENE was in his class. Did I forget to mention that?) Huh?

CHRISTENE: But it goes okay once you figure out how to separate omega-*a* and omega-*p*.

STEVE: Wait a sec. You're...you did...I mean, you're in...you're taking Physics 16?

CHRISTENE: Well, yeah. I sit about three rows in front of you.

STEVE: Really? Wait, turn around. (*She does. He recognizes the back of her head.*) Oh, yeah. Sorry I didn't recognize you before. (*by way of explanation*) I can't help it. I'm a guy.

CHRISTENE: I noticed.

STEVE: Hey, did you do number five yet?

CHRISTENE: No. It looks really hard, though. I don't see how using the Euler angles will help.

STEVE: Yeah, and is it in the space frame or the body frame? I couldn't figure it out.

CHRISTENE: I think it's the space frame. Here, let's try to visualize it.

STEVE: (*standing and pretending to be a top*) Okay, so I'm a top, and I have an angular velocity...

CHRISTENE: An asymmetrical top, don't forget.

- STEVE: (*extending one hand and thus coincidentally forming the waltz position*) So I'm a little asymmetrical top, short and stout, and I'm rotating...let me see....to the left? (*He starts to rotate*)
- CHRISTENE: No, no, I think it's right. (*He starts rotating the other way*.) But there's some nutation involved, too.
- STEVE: Huh? I don't see quite how...
- CHRISTENE: Here, like this. (She grabs his hands, coincidentally completing the waltz position, and begins to waltz in place with him. I feel compelled to point out that neither of them notices they are dancing; they're just visualizing a physics problem. No, really.)
- STEVE: So if it's acted on by an external torque...(on this word he dips her and they begin to waltz around the ballroom)

CHRISTENE: Then it should precess...

STEVE: But not with the old precession frequency L over I, since I is no longer unique...

CHRISTENE: Yes...but that's in the space frame. What about in the body frame?

STEVE: Well, I guess it just oscillates. And if there's a force at a later time t...

- CHRISTENE: The whole system will move...
- STEVE: Clockwise.
- CHRISTENE: (at the same time) Counter-clockwise. (They move in opposite directions, thus performing a spin-out.)
- BOTH: Oh, you're right. (*They spin back together again*.)
- STEVE: Wait, by the right-hand rule...
- CHRISTENE: Let me think... (*They gaze deeply into each other's eyes for a moment, delighting in the fiery passion of their embrace. Then...*)
- BOTH: Clockwise. (*They continue dancing*.)
- STEVE: So do we understand how it works?
- CHRISTENE: Give me a little bit longer to get a better feel for the physics of it.
- STEVE: Okay. (*They dance for a while longer. The song ends, and they end downstage center, bodies pressed close against each other. They gaze deeply into each other's eyes (again), and then, moved by uncontrollable desire, their lips slowly draw nearer.*)
- CHRISTENE: Yeah, I think I've got it now.
- STEVE: That should do it. (*They disentangle and walk away*.)

CHRISTENE: So, should we go over to your place?

STEVE: Huh? Why?

CHRISTENE: To write up that problem.

STEVE: Oh. Of course. Um, I'm actually supposed to be meeting my friend to work on the set, and before that I need to go home and change. Don't want to be so overdressed for a problem set. I'd never hear the end of it from Zack.

CHRISTENE: I wouldn't really worry about being overdressed...

STEVE: Huh?

CHRISTENE: Nothing.

STEVE: Oh. Well, do you...I mean, would you mind coming along?

CHRISTENE: Sure, no problem. (They start to leave.) So where do you live?

STEVE: Mass Hall.

CHRISTENE: (as they leave) Oh, you're one of those people.

Scene II.iv

Now we're in STEVE's room. STEVE and CHRISTENE enter. ALBERT is not there.

STEVE: Well, here we are. Albert? Albert? I guess we're alone...

- ALBERT: Look down. (STEVE does and sees ALBERT who is hidden out of sight on the ground by his bed. I lied before.)
- STEVE: Oh, hi. What are you doing there?
- ALBERT: I was just trying to calculate the seventeenth hyperperfect number

STEVE: Yes...

ALBERT: And I got carried away.

STEVE: I see.

CHRISTENE: You do?

STEVE: Oh, sorry. (*introducing*) Christene, Albert, and vice versa. Albert's my roommate; Christene's a random girl I met ten minutes ago.

ALBERT: (who by now has gotten on top of his bed again) How come that never happens to me?

CHRISTENE looks pitying and is about to say something comforting when ALBERT starts doing the tetrahedron thing with his fingers again. CHRISTENE changes her mind. In the meantime, STEVE begins to change his clothes, which doesn't require any stage nudity or anything, because he's just wearing something absurd like a jacket and bow tie over shorts and a T-shirt.

- CHRISTENE: Anyway, let me look at that problem. (*She sits down to work on it.*) Hmm... how does this reduce? I guess if I add these trig functions and complete the square...
- STEVE: (*looking over her shoulder*) Wait, how'd you get that? Here, I think you forgot the sign of the sine. I mean, the sign of the...um.
- CHRISTENE: Oh, you're right. Stupid mistake. Do you have an eraser?
- STEVE: Oh, sure. (*He reaches his arm around her shoulder—perfectly innocently, mind you—to get it.*) This way it reduces to a tangent.
- CHRISTENE: Yeah, we get tangent theta over two. I forget my half-angle formulas.
- STEVE: Yeah, so do I. Albert? What's tangent theta over two?
- ALBERT: (*molto dramatico*) Only two people know the answer to that question: God and Theodore Roosevelt. And Theodore Roosevelt's dead. (*long pause*)

STEVE: I'll look it up.

ALBERT: It's sine over one plus cosine.

STEVE: Oh, thanks.

CHRISTENE: Are you sure?

ALBERT: Pretty sure.

CHRISTENE: Absolutely sure?

ALBERT: Positively.

STEVE: Definitely.

#14 Positive-Definite Non-Degenerate Symmetric Bilinear Forms (Reprise)

ALBERT and STEVE:

Those positive-definite non-degenerate symmetric bilinear forms!

ALBERT:

I don't know how I can survive Professor Etingof. But once you're on Math 55 there's just no getting off. And I still have to work—by now they stink like chloroform— With positive-definite non-degenerate symmetric bilinear forms!

ALBERT and STEVE:

Oh! You stay up all night Tuesday working on them in your dorm. You get the same topology however you transform. You put 'em back together and you get your favorite norm. Those positive-definite non-degenerate symmetric bilinear forms. Those positive-definite non-degenerate symmetric bilinear forms! CHRISTENE: (looking from one to the other) You guys are so weird!

STEVE: Yeah.

- CHRISTENE: (*finishing the write-up*) Hey, didn't you say you were going to go over to your friend's to work on this?
- STEVE: Oh, shoot. Yeah, I guess we'd better get over there, now that we've written up this problem.
- CHRISTENE: Okay if I go get changed first?
- STEVE: (*noticing for the first time somehow that she's wearing a ball gown*) Huh? Oh, yeah, of course. Just come over to Grays East 42.

CHRISTENE: Okay. See you in a few minutes.

She leaves. STEVE stares after her, then looks down at the problem she wrote up, as if it's the most exciting piece of paper he's ever held in his life. Which, knowing him, might actually be the case. I mean, his life isn't all that exciting. And most pieces of paper aren't much to write home about. Anyway, he eventually starts to move again, finishing removing his absurd approximation of a tuxedo, then stops again and stares into space, or at the audience, which is the same thing.

STEVE: (*with a silly, lovesick grin*) In half an hour's time, light has traveled from the sun to Jupiter, and my heart has traveled to heaven. (*ALBERT makes a face.*)

#15 OF ALL THE STUPID THINGS

STEVE:

I never thought that this would happen to me: That I could meet that special someone. Of all those happy couples that I could see, I never dreamed I might become one. But now I can't stop from thinking of her, And dream what might be, somehow. But of all the stupid things, why now?

Of all the stupid things that could have happened to me, That I should have to fall in love. Of all the awful times to interrupt, just then she Descends like some gift from above. And I can concentrate on nothing, And nothing but her face I see, Till I can't tell my partials from my lower-case deltas. Oh, of all the stupid things, why me?

As he sings, he finishes changing, gathers the papers he needs to bring to ZACK's, and walks outside. As he leaves, ALBERT, who has been working on math, gets carried away and falls out of the bed again. He soliloquizes as he wanders around.

She makes me feel so good whenever she's near, My work I almost could forget. The Fates must have conspired against me To force me to lose this bet.

Of all the stupid things that could have made my life rough, Well, this one really takes the cake. 'Cause every time I try to do some more physics stuff, I always make some dumb mistake. The problem set is due tomorrow, But still I find my mind resists, So I can't tell my currents from my imaginary numbers. Oh, of all the stupid things, why this?

Forget the poets and that romance ado And all they ever said about it: Love is a pain when you've got homework to do, And I could really live without it. And yet my heart still sings; Love just clings and clings.

Of all the stupid things that could have dashed all my hopes Of ever finishing this set, My reason takes my thought and rationale and elopes And ends up somewhere in Tibet. But I'm still here and left with nothing: My brain decides to absentee. Now I can't tell my subscripts from my next row's exponents, In every reference frame, I can only see her name, And every Hilbert space to me looks like her face, And when I see these 2π 's, I just see her two eyes.

Of all the stupid things, Why this? Why she? Why now? Why me?

Suddenly another light comes up to reveal D.B.

STEVE: (with distaste) D.B.

- D.B.: Shouldn't you be working on physics?
- STEVE: I was just on my way to. What brings you out here?
- D.B.: Well, I already finished the problem set, but I wanted to check problem four in the relativistic limit. I was going to go to the physics library to look up some references.

STEVE: (fighting not to display his anger) Oh. Well, great. See you-

D.B.: I hope you're remembering we have a bet going on tomorrow's problem set.

STEVE: I wasn't about to forget.

D.B.: Really? I just would've expected you to be more worried.

STEVE: (feigning levity) Why? What do I have to worry about?

- D.B.: You know you've never beaten me on any other problem sets. I've been paying attention.
- STEVE: So?
- D.B.: So you don't have much of a chance. But if you still want to try, I think you ought to get to work.
- STEVE: Well, I think you ought to shut your ugly mouth before it gets involved in an inelastic collision with my fist.
- D.B.: (momentarily taken aback, as he was clearly not expecting this) Sorry?
- STEVE: Oh, was I not clear enough? Get out of here now before I make your face diffeomorphic to a torus.
- D.B.: (affecting nonchalance, but beginning to get scared, or at least confused) Well, we'll see who gets the last laugh tomorrow. Don't waste your time doing anything stupid. (*Exits, hurriedly. STEVE looks after him with anger, then stalks off the other way.*)

Scene II.v

ZACK's room. ZACK is working on homework as STEVE enters. There is a plate of brownies somewhere on stage.

ZACK: You're late.

- STEVE: (*sniffs*)
- ZACK: They're not for you.
- STEVE: I didn't say anything.

ZACK: You didn't need to.

By this point the stage should be completely covered in flames.

STEVE: Who are the brownies for, then?

ZACK: Me.

STEVE: The whole plate?

ZACK: Late people don't get brownies.

STEVE: Oh, shut up. (*He takes one anyway, sits down*.)

- ZACK: Have you been out dancing with the monkey people this whole time?
- STEVE: Mostly, yes. But I figured out number three and most of number five, too.

- ZACK: Good, because I was working on one and two mostly. Let me see. Was three just some dumb mistake we made?
- Yeah, we put cosine instead of sine. I met someone else at the waltz working on it, STEVE: whom I invited over-hope you don't mind someone else joining us?
- ZACK: If they've got the answer, sure, bring 'em on.

You know I was joking about the flames, right?

- STEVE: Okay, let's see what you've got on number one.
- ZACK: Not much. Here.

#16 Working Till Midnight (Reprise)

- Hmm... (He taps his pencil idly. ZACK knocks on the desk absentmindedly. Eventually STEVE: this breaks into a regular rhythm, punctuated by "hmms" from STEVE as shown in the score.)
- Hmm hm. Hmm hmm hm; hmm hmm hm hm hmm, hm hmm hm hmm hm—hmm hmm hm—hmm hm. Baa baa.

STEVE:	ZACK:
Doo doot. Ba doo doot; ba doo ba dee doo,	Daa ba doo be dah. Baa baa doo: de dah / da
ba doo ba doo doot—ba doo doot—ba doot. (Baa baa.)	doo ba dee bah.
Doo doot. Ba doo doot; ba doo ba dee doo, ba doo—The lecture was borin'	I'm so confused now—
So ask David Morin—	Working till midnight—
Doo doot. Ba doo doot; ba doo ba dee doo, ba da ba, "Doo ba da doot dah."	Those tricks I used now just didn't help at all.
Waa oo-oo. Physics problems: what can we do?	And let's just face it: I still haven't got a clue.
Ba doo ba doo. Ba dum ba dum ba dum.	So much for problem one—have you got any
Physics has a music: Ba doo doot; ba doo	thoughts about problem two?
ba dee doo, ba da—Your homework	It's half past twelve now—
you've damned-da;	I hope you did right—
You still don't know lambda—Doo doot. Ba doo doot; ba doo ba dee doo, ba da ba, "Doo ba da doom ba bam."	We ask ourselves how we'll ever pass this class.
Bam bam bam new integration brings us new dismay.	And each new integration brings us new dismay,
Working until the break of day.	Working until the break of day.

Knock. ZACK gets the door. Lo, 'tis CHRISTENE. ZACK is surprised.

ZACK:

Hey, Stephen. What's she doing here? You've got all the luck. What the—(STEVE "accidentally" throws a brownie at his head. (It's a brownie-in-motion. Get

it?))

STEVE: Duck!

ZACK: Don't mean to interfere, But—

STEVE:	CHRISTENE:
But of all the stupid things.	Here tonight, I guess I'm still caught in
It's this girl I met,	between:
Or this set.	My love for music, which'll never mix while
Wait and see just what tomorrow brings.	I'm in Physics 16.
-	
	1

No, here's the answer: If we just integrate by parts. (with CHRISTENE) {Here, / I'll} give it a try. The cross-terms cancel out. (only STEVE) I think we've got it now. CHRISTENE: (simultaneously) I think I see why we disagreed— Oh, wow!

ZACK:

Now it's two o'clock; what a shock. Can't help but overhear that You're making progress (In more ways than one). This really takes the cake: Working until the break— My fingers ache—and how!

CHORUS enters. CHRISTENE is confused.

CHORUS: Bum ba dum ba dum ba dum.

ZACK and CHORUS: So now you strive and work and toil, As you slave away till break of day,

Learning the midnight Euler. Tonight you're not alone. So the two of you can see it's true: Physics has a music all its own.

CHORUS:

And now it's half past three but you've still got work. So you: (continues as vocal backup as STEVE and CHRISTENE go back to work on the problem)

ZACK:

You keep on trying—			
It's gonna get later			
Before we find theta—	CHRISTENE: (getting an idea)		
And misapplying each theorem that you use.	Suppose we do		
The clock keeps ticking on and it's not about	STEVE: (agreeing, following along)		
to stop.	The minus signs go away.		
	CHRISTENE:		
	Not all of them.		
	STEVE:		
There's nothing you can do but to keep at the	But these <i>i</i> 's		
problem until you drop.	Must give rise		
	To this negative one; that's what we need.		
	CHRISTENE: (simultaneously):		
	Now I see what you mean.		
	STEVE and CHRISTENE (suddenly		
You're not half done yet—	remembering):		
She's got the wrong vector;	This is symmetric!		
You'd better correct 'er.	CHRISTENE:		
But you can't run yet—there's still too much	What we need to know we can show.		
to do.	STEVE: (getting an expression)		
	Here we go!		
By now you wish you'd settled for Physics	CHRISTENE: (looking over at his paper)		
15a:	But where did you get that term?		
	STEVE:		
Working until the break of day.	Let me confirm. (<i>He checks against her work</i> .)		
	You forgot <i>x</i> -squared.		
	CHRISTENE: (agreeing)		
	Oh, and that's convenient now.		
	STEVE: (finishing the problem)		
Working until the break of day.	Working—it's working—I really think it's		
	working.		
	CHRISTENE: (simultaneously)		
	Now this reduces, and it produces		
Working until the break of day.	This term.		
	STEVE and CHRISTENE: (finishing)		
	Here's the calculation and we get the answer		
	right here!		
I III break of day!	CHRISTENE: Wait! The sign's wrong!		

STEVE: Shoot! It's five o'clock now.

ALL: Till break of day!

CHRISTENE: (as CHORUS exits) Who are those guys?

ZACK: Oh, don't worry, that's just the chorus.

- CHRISTENE: Oh. Well, I guess we've finished most of problem two, except for an extra term that doesn't cancel, problem three, and problem five. I think it's time to call it a night.
- STEVE: Already? What about one and four? Watch, I've got an idea about four, I think it might work.

CHRISTENE: Well...

STEVE: C'mon, just a little longer?

CHRISTENE: Well...all right.

ZACK: I'm gonna go get something to drink. You want anything?

CHRISTENE: Thanks, no.

STEVE: Get me a Coke, will you?

ZACK: If you give me money I might.

STEVE: (throwing a dollar at him) Here.

ZACK: And I think a fifteen percent tip?

STEVE: Go away. No tip for you. Lousy service. I demand to see the manager.

ZACK: Right, right. I'll be back soon. Until then I guess you're on your own. (Leaves.)

#17 ON MY OWN

Lights dim dramatically as STEVE steps forward into the spotlight. As he is about to sing—

ZACK: (*entering again suddenly*) Don't even think about it. (*Leaves again*.)

STEVE: Sorry.

STEVE and CHRISTENE continue working for a while. CHRISTENE notices that STEVE looks a little down.

CHRISTENE: Are you okay?

STEVE: Huh?

CHRISTENE: You seem a little...depressed. What's wrong?

STEVE: Oh, nothing. Just thinking about this problem set, and D.B., and the bet I made with him.

CHRISTENE: Is he what's getting you down?

- STEVE: I saw him again on the way here, and you know what? I actually threatened him. Like, with physical violence.
- CHRISTENE: Oh. What'd he say?
- STEVE: He just left. Quickly. But I felt so stupid trying to bully him around. I guess he brings out the worst in me—it's pretty childish, just hurling insults at him. "Yo' mama's so fat she spans R³." Like I'm in junior high or something. (*Pause.*) Well, maybe I never said that in junior high, but...
- CHRISTENE: Why can't you just ignore him? There're guys like that in every class. You should see my Justice section. If you didn't pay any attention to him, you wouldn't have to worry.
- STEVE: No, that's not good enough, because he'd still be irritating the other students, and the TFs and the professor too, wasting their time. I need to put him in his place. And I can only do that by showing that someone he thought posed no threat can do better than he can in physics. It's what I owe to the class, really.
- CHRISTENE: I don't see why that has to be your responsibility. Why can't you just ignore him and have fun with physics instead?
- STEVE: Fun? How can you talk about fun when it's—(he peers at his watch)
- CHRISTENE: I don't know. I've been having fun doing this problem set.
- STEVE: Huh? I thought you hated physics.
- CHRISTENE: I do, I guess, but...well, it's a lot more enjoyable when you're working on it with someone you like a lot.
- STEVE: I don't know. I always feel like it's easy to get distracted that way.
- CHRISTENE: But it's a good kind of distraction—a constructive interference, if you know what I mean. Even if you don't get as high a score on the problem sets, you get to talk, you get to laugh, you get to enjoy yourself. You might not learn as much about physics, but you learn more about *people*.
- STEVE: (*laughing a little*) I don't know about that. I feel like I've learned all sorts of physics tonight.

#18 SPECIAL RELATIVITY

CHRISTENE: Physics?

STEVE: Yeah, physics. About asymmetric tops, and inertial tensors, andoh, all sorts of things.

What is this strange attraction?

It's not just gravity—my mass is too small to exert any noticeable force— An equal and opposite reaction I feel between you and me. Something threw my life off course Like the azimuthal force And I just can't find my new trajectory. And I never thought I'd meet Someone who'd make my set complete Till an elastic collision deflected me.

What does it mean, Christene? No physical laws explain what happened tonight. Or what was the cause of this sense of delight. Like an Atwood's machine, Christene. On a sinusoidal trip off some random tangential And I feel like I'll flip in your electric potential. I never dreamed that I could feel this way, Until that fateful day That I met you— Oh, Christene, of all girls I've seen, You're three standard errors over the mean. So what can I say? It's Special relativity.

CHRISTENE:

What's this strange magnetism?That keeps on pulling us together—which is weird, because the force from a magnetic field acts perpendicular to its velocity.It's like looking at life through a triangular prism

Like drifting off through the nonexistent ether.

I really must remark:

Like a second-family quark

You've really got a strange charm.

Up and down, from top to bottom;

Truth and beauty-now I've got 'em

As we sit here arm in arm.

Together; no longer alone.

Not a theorem can show this magic feeling inside,

One I'd never know without you being my guide.

Together; you're all my own,

Though an orbital half-filled is always unstable,

Now with you our waveforms build, so together we're able.

STEVE: I never thought I'd find my complement. Till by some chance event That I found you: My darling Christene, you are my queen, Since I met you in Physics 16,

So what can I say? It's Special relativity.

CHRISTENE:

And all my life's compact now, My second-order terms suppressed— You've canceled out my stress— And now I'm here within the special case Of your embrace: a vector space without a trace. Oh, what can I say? It's Special relativity.

STEVE and CHRISTENE:

I feel our love like an exothermic process within my soul, And the enthalpy between you and me makes me burn out of control. Our waveforms are nondeterministic; reference frames going relativistic. Lorentz transformed, and my value renormed, So I feel our time dilate, move at a new rate, Now in an excited state.

CHRISTENE: Hey, wanna dance?

STEVE: Huh? I don't know how to dance.

CHRISTENE: Oh, sure you do. Just think of an asymmetrical top...

She grabs him and they begin to waltz gracefully around the room.

STEVE: But what about the problem set...

CHRISTENE: Oh, hush.

STEVE: All right.

They dance for a while, then finish as the music goes out of 3/4 time.

STEVE and CHRISTENE:

Now here we are, like two resistors, Wired in parallel.

CHRISTENE: In series.

STEVE: No. Parallel.

CHRISTENE: Wait. I thought resistors sum in series and as reciprocals in parallel.

STEVE: Wasn't that capacitors?

CHRISTENE: I thought...wait...the voltage is the same across—

STEVE: Oh, forget it.

STEVE and CHRISTENE: I hate to think I might have missed Our mutual inductance: I can't resist.

STEVE:

I was spending all my days With my life all out of phase. Then I found you as my complex conjugate. Now my life no longer varies And no more imaginaries And I'm glad however nonchalant you get.

STEVE:

What's the input routine, Christene?

STEVE and CHRISTENE:

No expression exists which quantifies all our love But nothing resists, as we have come to discover.

STEVE: I'd never foreseen, Christene.

STEVE and CHRISTENE:

It's a strong interaction with a finite cross-section So extremize the action to find out its direction.

STEVE:

Christene, I'll intervene. So you're no longer caught in between. Oh, that's what it is,

STEVE and CHRISTENE: Whatever name you give it: Special relativity.

STEVE: You're my supersymmetric partner.

CHRISTENE: We're a strongly coupled pair.

STEVE and CHRISTENE: **Moving on with superconductivity.**

CHRISTENE: **That's what it means.**

CHRISTENE:

CHRISTENE: When I met you.

You've shown me That I'm no longer caught in between. And now

CHRISTENE: **Before you came to me,**

I was diffuse Unreduced Till that day when I met you.

STEVE: My darling Christene.

STEVE and CHRISTENE: It's special relativity.

They lean closer together and are about to kiss, when-

ZACK: (entering loudly, with drinks) All right, here's your stupid Coke.

They break apart hurriedly.

CHRISTENE: Oh, it's just Zack.

She kisses him anyway. ZACK blinks.

ZACK: You guys been working hard?

STEVE: Oh, yes, very.

- ZACK: Get anywhere?
- CHRISTENE: Not on problem four, no.
- STEVE: It's hard to concentrate.
- ZACK: So I gathered. Here, let me see. (*This sentence refers to the problem set, not anything else. Stop thinking that.*)
- CHRISTENE: You know, I think it's time for me to go home.
- STEVE: What? But we're not done yet!
- CHRISTENE: I know, but it's really late and I've got to take care of my voice. It needs sleep. I've never stayed up this late working on a problem set before, anyway.
- STEVE: Really? How'd you manage to avoid it?
- CHRISTENE: Easy. At about two o'clock I give up, guess the answers, and go to bed.

STEVE: (as this concept has never occurred to him) And just get the questions wrong?

- CHRISTENE: Well, sure. It's not that important. (*STEVE looks horrified.*) Prioritization is important in life. I value my health and sanity above my grades on physics problem sets. Anyway, I've really got to go to bed. Nice to meet you, Zack. See you tomorrow, Stephen. (*She leaves. STEVE stared after her with an air of surprise and, perhaps, a touch of betrayal.*)
- ZACK: (comforting, but in a manly way) It's your bet, Steve, not hers. You can't expect her to care as much as you do about getting a high score on this problem set. (STEVE says nothing.) Besides, you've gotten her to stay up (looks at watch) four hours longer than she ever has before. I'd say that means something. (STEVE still says nothing. ZACK sighs.) So...you think this is something serious? I mean, you and Christene Heisenberg?

- STEVE: (*Still lost in his reverie*) Oh...I'm not certain. (*realizing what he just said*) Oh no! I didn't mean—(*Drum sting. They both groan. STEVE yells at the drummer.*) Would you cut that out?
- ZACK: You know, she's got a point. It's almost 6:30. The sun's coming up. Maybe we should turn in too.
- STEVE: And just get these questions wrong?
- ZACK: Come on! Your stupid argument with D.B. isn't worth this. Maybe you'll lose. So what? You didn't actually wager anything.
- STEVE: You think this is all about the bet? It's not my ego or something, you know. I don't really care whether people think I'm smart or stupid. This is something more! This is physics! This is stuff I love doing!
- ZACK: Fine! Doesn't mean you have to kill yourself over it! What if D.B.'s just smarter than you are?
- STEVE: He *is* smarter than I am! I know it, everyone knows it, there's no argument. That's why I need to do this problem set right—to prove that I can still do just as well by working hard enough on it. Maybe he's just smarter. Maybe I'm just stupid. Fine! I'll make up the difference in intelligence with hard work. He may have more brains—he can keep 'em. I've got the determination to beat him.
- ZACK: But what if you work all night and still get a lower score?
- STEVE: That's not an option. I *will* finish this problem set, and I *will* beat D.B., and I *have* to. That's why I decided to study physics in the first place.
- ZACK: No it's not.
- STEVE: But...it is, though! I love physics; I've always loved physics, and I work really hard on physics. That has to be enough.

#19 GOD'S GIFT TO PHYSICISTS

When I was a boy, my parents would show me A PBS special on video: "The Creation of the Universe." And I don't know just what happened that day, Or what chords it stirred within me. But I knew right then just what I had to be.

The wonders of the universe, The mysteries of the world— How I yearned to understand them: And to grasp the laws that 'round me swirled, And not to say just what happens, But also how and why. Oh, I knew it wasn't easy, But I longed to learn and to apply These facts I hold—what power untold Within my shaking fists! And my hands uplift as I longed to sift And to be God's gift to physicists.

Now in third grade, I gave a report On particle physics of the most obtuse sort. And in fourth grade, and in sixth grade, too, I did projects, papers and an interview. In ninth grade I would give speeches about All the marvelous physics that I had found out When I read all of Feynman and Hawking and such. Oh, I learned a lot, but there's still so much To realize, to comprehend; And ever growing without end, The things that I can't understand. And so many people much smarter than I Just can't see why this troubles me so. 'Cause they don't feel the joy of one who knows that

Physics has a music, But I can't always hear its song. Still I struggle on, Yet I can't see its mystery:

The wonders of the universe, The marvels of the earth— And I just can't understand them, So I don't see if this class is worth All the pain of not knowing what happens, Let alone why or how. And it feels my case is hopeless, That I simply can't fulfill my vow. And I sob and sigh, and I try and try, But this problem still resists. So I've got to shift or my lot's to drift, 'Cause I'm not God's gift to physicists.

They say that brains always beats brawn. I'll show them they're all wrong On this problem set— Let me win this bet!— And with no regret I strive toward That distant dawn. The wonders of the universe The secrets of the spheres— How I need to understand them, As they turn and turn throughout the years. Then to know exactly what happens And not say, "Just because." This problem set's just a facet Of everything creation does. Now to see the cause and the myriad laws By which the world subsists. And with careful thrift and perception swift, Still I'm always miffed that I'm cut adrift, And this endless rift in me persists: I'm not God's gift to physicists.

#20 THE FINAL LECTURE

STEVE: You can go to bed if you need to. I'm not going anywhere.

ZACK: All right. Good luck. See you in the morning.

The passage of time is indicated. Perhaps the stage fades to black before the next lines.

ZACK: Class starts in half an hour. Is the homework done?

STEVE: As done as it's going to be.

ZACK: Is that done enough?

STEVE: It'll have to be. Let's go.

Scene II.vi

Musical interlude indicates the passage of time. Specifically, one week has gone by. When lights come up, they are back in Science Center D. As before, GEORGI is preparing for his lecture as students file in and sit down. In addition to the usual suspects, ALBERT and HILDEGUNDE are there. In the following scene, dialogue take place in two places in the room: one location for STEVE, ZACK, and ALBERT; and another for CHRISTENE and HILDEGUNDE.

ZACK: Think he'll return the problem sets today?

STEVE: It's the last lecture. He'd better.

ZACK: Nervous?

STEVE: You might say that.

ZACK: Wet your pants?

STEVE: Not yet, but I'll keep you posted. (noticing ALBERT) What are you doing here?

ALBERT: Someone told me this lecture is a really interesting one. It made a convenient excuse.

CHRISTENE: (to HILDEGUNDE) What are you doing here?

HILDEGUNDE: It's the finale. Everyone has to be here for the finale.

CHRISTENE: Oh.

ZACK: How's Christene?

STEVE: Fine, thanks. We went out again last night.

ALBERT: Have a good time?

STEVE: Yes, very much.

At this point GEORGI begins speaking and all the students subside.

GEORGI: Okay, here it is, the last gasp. Today's lecture really is for fun; there's no mini-exam or anything. I do have your last problem sets graded, and I'll hand them back to you—after class. Today really is the climax of the course, since I can't go on lecturing any more, but today I'm hoping we can answer some of the questions I put forth at the beginning of the class, especially the question "Why does F=ma?" So...

Last week there was an assumption made: every direction's the same. Since information can't be conveyed in a unique reference frame It seems that there's something that physicists need to explain why the universe now Is constant and yet homogeneous though relativity can't tell us how. But if vacuum has energy then it is known: negative pressures ensue. And the expansion rate then can be shown to be exponential in nu. This theory explains why the cosmos remains by today almost perfectly flat. But we still can find one or two problems with that.

STEVE:

That's all very well, but I don't know how long I can wait.

GEORGI:

Wait and see how the Lagrangian, Taylor expanded, you see, Gives polynomials written in terms of a factor m_p . So when we apply Euler's formulas here, then we find that the Planck mass will serve To make the terms higher than q-double-dot far too tiny to even observe So this really results in F=ma, just as we knew all along. Newton's discovery's still true today, though Einstein showed us it's wrong. But still all these mystic and relativistic effects—also Schrödinger's cat— Show there still remain just a few problems with that.

STEVE:

Yes, I realize that this is intriguing, But I can't seem to concentrate.

STEVE:	D.B.:	
I just want to know	Hey, now that we're all here,	
About the problem set;	Better listen closely.	GEORGI:
Now I won't regret	Make sure this lecture's clear	Here we can see that the
And we're not through yet.	I see you shake with fear.	energy density has a
	So show some respect; the	propensity for an intensity
	time draws near.	going like <i>m</i> -sub- <i>p</i>

GEORGI:

Raised to the power of four because That's what the factor of *T*-squared does. This means that *m* has a factor of ten to the forty-six when there's a negative; then if we try it again we get ten raised to the seventy-six times *m*. Well, there's lots of unsolved problems that we haven't yet looked at. Maybe someday you can tell us what to do With this ten to the one-twenty-two, And I know you won't have any problem with that!

And here's your problem sets back.

He puts them down on the desk. Pandemonium ensues.

D.B.: Hey, all you students here, Listen up closely. Now we all get to hear Who wins.

He picks up his paper from the front.

STEVE: What'd you get?

D.B.: (clearly not altogether satisfied, but still smug) Eighty-four.

STEVE: Now the contest is done We'll see who has one Minute more.

He picks up his paper from the front of the room. Everyone leans forward expectantly as he reads the score on it. Dramatic pause.

STEVE: Seventy-three?

Long pause. No one moves.

STEVE: They say that brains always beats brawn. I guess they were right all along. #21 TRIO OF SURPASSING BEAUTY

CHRISTENE: But what remains isn't all gone. You know that you belong.

ALBERT: And there's something more:

ZACK: Now you can't ignore

ZACK, ALBERT, and CHRISTENE: What you saw before.

ZACK:ALBERT:Don't go to extremes; justDon't give up your dreams, you

CHRISTENE: No matter how dark it seems,

ZACK, ALBERT, and CHRISTENE: Remember what it means.

CHRISTENE: Just like you've shown, Now remember, you're not alone.

ZACK and ALBERT: Remember what you've always known.

ALBERT: Remember how you told me, "Each equation has a tone"?

CHRISTENE: Each equation has a tone.

ZACK, ALBERT, and CHRISTENE: Just wait and see.

#22 PHYSICS HAS A MUSIC

STEVE: Physics has a music, After all problem sets are done. That's why I am here It's not the end; I comprehend I've just begun.

Physics has a music; How could I ever doubt that fact? With each passing year

STEVE and CHRISTENE: I find its harmony sets me free Finally I agree: Now I see, worth every tear.

STEVE and CHRISTENE, with OTHERS joining in gradually:

Though my answers be wrong,I guess I've learned now what I knew all along.If you've got brains or you've got brawn,Come join us in this songYou can lose the bet, but don't be upset;'Cause you can't forget what you know:CHORUS:And now you realize why you're here.

SPECIAL PEOPLE:EVERYONE ELSE (CHORUS):Physics has a music to me.Physics has a music,Whatever grade we get on this set,And each equation has a tone.It's part of that melodyA symphony where each equation has its
tone,Come listen and see.

ALL: Yes, physics has a music. A tune that we've all learned at Fair Harvard. We lift up our voices in song To the music of physics.

STEVE:

Once more, after all things we can see That physics has a music. And now I see that that's enough for me.

ALL:

Yes, physics has a music. A rhythm and a reason All its own.

STEVE: (*to ZACK*) Hey! Do you hear the people sing?

ALL: Shut up!

STEVE: Sorry.

CURTAIN