Appendix A: Complete transcriptions

Group One

(0:00)
BELINDA: We can measure the area of the magnet.
DORIA: But how do we measure...
BELINDA: Pressure...
ANGIE: But it's not... pressure times area...
CONSUELA: It's magnetic force...
BELINDA: Oh yeah, it's E Q.
DORIA: No, but that's electric. Force of a magnet is just F equals Q V B sine theta. There's no distance in it.
BELINDA: Where are you coming up with that?
DORIA: It's in the book. And it's in... haven't you learned it for MCATs yet?
BELINDA: No.
DORIA: Really?
BELINDA: Really.
DORIA: That's the hardest stuff.
CONSUELA: Oh gosh.
BELINDA: Hey when do you get your scores back?
CONSUELA: I know, that's what you guys just said, and I was like oh yeah...
BELINDA: All right so F equals Q V B sine theta. What is this? Equal to M V squared over R. What's your R? Your radius?
(1:00)
DORIA: That's like the... because... well you see… not between two magnets. That's like... magnetic field caused by centripetal...
BELINDA: What is... what is B?
DORIA: B is the field strength of the magnet.
BELINDA: But how are we going to measure any of that?
DORIA: Yeah, I know. So I don't know how it depends on distance.
CONSUELA: How the hell are we supposed to do this?
BELINDA: All right. If you like...
DORIA: I feel like it should be the same as like...
(enter student from another group)
S: What's acceleration? It's like one half... delta X... the one formula... like I know acceleration is delta V over delta T but...
BELINDA: Oh V... It's D equals V oh T plus one half A T squared.
DORIA: That one?
S: D equals V oh T plus one half A T squared.
BELINDA: So like, you could get rid of, yeah, it's the V

initial, so if V initial is zero you can get rid of that and D equals one half A T squared.
(2:00)
S: Okay.
ANGIE: What is (un)
(student leaves)
BELINDA: I was at the gym yesterday, and all of a sudden like right here started... like touch it and it really hurts...
CONSUELA: What are they doing? They're doing the... They're measuring the... that doesn't work though, right? They're measuring acceleration, but what is that gonna do? Force equals...
BELINDA: Well force is A… force equals M A.
CONSUELA: So they're using mass.
DORIA: B equals...
BELINDA: What is mu right there?
DORIA: Mu... is that thing... what is it called?! (slaps book) Mu is the permeability of free space, and we don't really have to know what it is.
BELINDA: Oh, so it's a constant.
DORIA: Right.
BELINDA: So good. So we know constant times what, current?
(3:00)
DORIA: Yeah.
BELINDA: We don't know... how are we gonna measure current?! This is bad.
DORIA: No, this is just to... because the... as R, you know, increases, F decreases. And it should be a linear relationship.
BELINDA: We have three equations for D. They are this.
CONSUELA: We could do it that way.
BELINDA: That one. And then you could do Vf squared equals Vo squared plus 2 A D. But if you're oooooooh...!
DORIA: Isn't it plus...
BELINDA: Plus or minus... depends on like... um... this is used for like, projectile motion. So like the first half would be... add it and um...
(4:00)
BELINDA: What if we... okay... because if we're holding the magnets... like say we connect the one to a string... and we had them dangle *gasp* we had it dangle off this thing (motions to force probe).
DORIA: Can we look at that?
BELINDA: (brings force probe down) So, you tie up the string, right?

DORIA: What is that?
BELINDA: It measures the force... of the thing pulling down on it.
DORIA: Okay.
BELINDA: So you put a string and you... put your weight on it... I mean your magnet. You tie on the magnet somehow. Okay? And then, we take the magnet and we'll just move in... however much...
DORIA: Will it measure that? Or will it measure…
BELINDA: You can measure distance, you can also measure... well won't it have a less pull, like, hanging straight will have some weight... if it moves out, you'll have some weight, M G. If it moves out, we can measure this, we can find the weight in this direction.
(5:00)
DORIA: Can't we just put it below so that we don't have to measure angles and see how much it stretches? Well that doesn't really stretch, no that doesn't stretch at all.
BELINDA: Unless you use a spring.
CONSUELA: Spring.
BELINDA: But I don't think a magnet has enough... do you think it has enough force to pull a spring? But then you're dealing with Hooke's Law and stuff.
DORIA: Yeah.
BELINDA: I was thinking like, the string, and then however much it moves out towards it... we'll have a distance, and then you'll also know the component of the weight in the x-... in this direction... that would be... sine of... no cosine of the angle... M G cosine of the angle equals... this. X. So you know that there's a difference between this and this.
(6:00)
DORIA: I don't know. Um…
BELINDA: Well that's our... okay, if it's hanging on a string, right? If you only, if you do a force body diagram, the only thing really is... it's weight down. You can sort of neglect the string, I guess. I think we can neglect it. Maybe not. But then if it moves here... you have the weight... oh and then now you do have the tension. Hm...
CONSUELA: That's a lot.
BELINDA: I'm trying to... I don't...
ANGIE: Don't damage it.
BELINDA: I know. I'm trying to think of a way...
ANGIE: Who's the critic? Who's critic?
(7:00)

BELINDA: You are! You're evaluation. That's critic.
CONSUELA: Oh yeah.
ANGIE: Am I supposed to ask other people?
BELINDA: If you have...
DORIA: Umm..
BELINDA: See here's the thing... we can't hold both of them, cause you can't measure how much something's gonna move. So if we let drop one of the string, and we move the other one.
DORIA: If we drop one?
BELINDA: You're controlling the distance, what? If you just (un) so it can act on its own. We control the distance... and as we control the distance, this is gonna move in some manner.
DORIA: Right.
BELINDA: Which is... how it moves is controlled by force, right?
ANGIE: But then we have to measure the angle. How are we going to measure the angle (un) if it'll probably be going like this (swings pen back and forth)
CONSUELA: Yeah.
BELINDA: Yeah. Well I don't know. How else are you going to measure... you can't hold the two magnets. And then you can't measure any...
(8:00)
(1 leaves)
BELINDA: My hand really hurts. Look at how dark it is! That's nasty!
CONSUELA: What happened? In the gym?
BELINDA: Yeah, I was working out and all of a sudden it really started hurting. Which is weird, I didn't knock it on anything.
CONSUELA: What were you working on?
BELINDA: I was just doing cardio stuff, I don't know...
CONSUELA: *laughs*
BELINDA: I wanna look at materials.
DORIA: *moans*
(silence)
(9:00)
(more silence)
DORIA: You know... this book just sucks. I don't get it!
(10:00)
(re-enter 1)
CONSUELA: What are they doing?
ANGIE: They were gonna measure acceleration between the two but... since they attract so quickly, you really

can't measure that.
CONSUELA: How the hell are we...
DORIA: How are they going to measure that?
ANGIE: They're not doing it.
DORIA: God um...
CONSUELA: So using a spring would be too messy because of those...
ANGIE: Yeah, I think it would be, I think would complicate it too much.
CONSUELA: How else are we supposed to like...
(re-enter 2)
BELINDA: All I know is that we'll need a ruler of some sort. I came up with that.
ANGIE: All I know is that... we didn't have pre-lab discussion.
(11:00)
BELINDA: He said that we're gonna do a lot of thinking for this experiment.
CONSUELA: Can we at least have them... I feel like it would be easier... I want to see the magnets.
BELINDA: If we can control the distance...
ANGIE: They did give us the protractor.
DORIA: I think if the string is going to be like (un)
BELINDA: Okay, why couldn't we say... measure it in time?
ANGIE: What if we did it this way?
DORIA: See how much it moves?
ANGIE: Have like the length this way... and we could... it would be much easier to measure it.
CONSUELA: While it's on the... laying down?
(12:00)
DORIA: So if we had a magnet attached. Did they hang on it?
CONSUELA: With the string attached to it?
BELINDA: But this is gonna... if you don't hang it, it's not gonna produce.. this is just acting as a... something holding the string. You could use anything. This will not measure the force. What if we... wait...
ANGIE: What if we had the magnet attached to a string and then put it this distance away from another magnet and how fa... how much it pulls on it? It would measure that.
CONSUELA: It would measure that?
ANGIE: You would think if it's gonna...
CONSUELA: Pull on that.
ANGIE: Pull on it. But... bring up the old motion detector.

BELINDA: How are you going to hook that up though?
ANGIE: Just... which is it...
CONSUELA: Turn the box off for five seconds and then on again.
BELINDA: Two.
CONSUELA: Is it two?
BELINDA: Yeah.
(13:00)
BELINDA: What if we measured... all right... we have the thing hanging and we held it out for like five centimeters... see how fast they go together...
CONSUELA: That's all we have to do?
BELINDA: Then you hold it out ten centimeters, see how fast they come together. Then fifteen and see... you can measure...
ANGIE: You can't measure how fast it comes together because they're so strong that they come together like that. (slaps)
DORIA: Yeah.
ANGIE: Turn the box off and turn it back on. Judy?
BELINDA: There's no... wait... that'll do it. All right so... what we... put this... make sure it's like here... we measure where it starts...
ANGIE: (un)
BELINDA: I'm going to measure how much... if you put like one at ten, we'll see the first one at ten and then we can do like... fifteen and see how much it pulls...
(14:00)
BELINDA: ...twenty and see how much it pulls... twenty-five... then keep the first one at ten the first time, and see how much the pull is.
ANGIE: Start.
ANGIE: It's distance... distance... change the y-axis...
CONSUELA: Can we do it again?
BELINDA: Yeah... I'm pulling at a constant thing right now.
CONSUELA: Pull it hard.
BELINDA: Okay, I can't pull much harder than that.
DORIA: Well that sucks.
BELINDA: Try it again.
ANGIE: It's 100 Newtons.
CONSUELA: How about don't pull it, and then pull it. What the hell's..?
BELINDA: Let's ask him.
DORIA: Paul?
(15:00)
BELINDA: Uumm...

CONSUELA: Try like holding it.... I don't really see a difference.
BELINDA: Does this only measure how much a spring goes down? Should it? We should ask him, I think this is a good idea.
CONSUELA: They're using a spring to do it. Are they neglecting the...
BELINDA: (oooh face)
DORIA: What?
BELINDA: What's Hooke's Law?
DORIA: Force equals negative K X.
BELINDA: We probably wouldn't know the.. we wouldn't know the K of the spring.
DORIA: Right.
(16:00)
BELINDA: But if you can measure... if you can do the spring first one, and then put a second one... and then you can look at how much the spring changes, the length of the spring, and come up with a force that way.
DORIA: And just say like, force is X K.
BELINDA: But, yeah, cause K is constant.
DORIA: Right.
ANGIE: He said we're looking at relative. So we don't have to know exactly what it is, we're just looking for relative.
BELINDA: So, force equals delta K... delta C... K is going to be constant anyway, so and we're relatively speaking. Hook up your spring, and at the bottom you have a magnet. Then you hold the magnet at different lengths... away.. from whatever...
DORIA: Whatever the change...
BELINDA: This'll be measured... oh no, this'll be measured.
DORIA: Right.
BELINDA: The change in spring. How easy will that be though? We need a pretty pliable spring. Not something taut, cause if it's real taut you won't be able to see a difference.
DORIA: Right.
(1 leaves)
CONSUELA: Are we going to hang it... hang it down..
(17:00)
BELINDA: Yeah, I think it needs to be. Because the spring will... will have a bigger change when it's hanging.
DORIA: But the magnet's pretty heavy. We're going to have to... we can't have a too flimsy spring, because

then it won't have anywhere to go.
BELINDA: That's the only thing... can we hang it from like... can we hang it from higher? Because, otherwise how are you going to...
DORIA: Suck. Well we need to feel how heavy the frickin' magnets are.
CONSUELA: That's what I mean.
DORIA: Are we not allowed to take it?
CONSUELA: We just need an idea, and then he'll give us the magnets, he said.
ANGIE: This one doesn't require a lot of force.
DORIA: Oh Paul... can we have a magnet?
BELINDA: Well can we talk to him about our thing?
(18:00)
DORIA: Yes. It sucks. But I mean...
BELINDA: Oh yeah, we have a question...
(enter TA)
BELINDA: Well, this is what our idea is thus far. So, we're thinking that, we hang the spring... it's right here... we hang the spring. And at the bottom of this would be our magnet. Then we would control the distance that... we would take another spring and like put it five centimeters... within ten centimeters, twenty-five centimeters, and at each different distance, we can measure the distance of the spring, how much it goes down. Because according to Hooke's Law, which is this, if we use the same spring, relatively speaking, we don't need to know the spring constant.
ANGIE: (un)
BELINDA: I don't know. So we don't need to know this. So we can kind of verify that the change in the spring distance as the one magnet on the bottom is attracted to the other one we hold up against it would kind of approximate the force between the two?
(19:00)
TA: Yeah, it would *be* the force. My only question is, are you going to get enough data points...
BELINDA: Yeah, that's the only thing, I was thinking like, if, cause if we hang it from here... that's not good because you can only hold it so far away from each other... but can we hang it somehow from the ceiling... or something?
TA: What you have... you're gonna use a spring *and* this? Is that what you said?
DORIA: We don't really have to use that at all.
BELINDA: Well we don't need to use this, we're not measuring it... something to hold onto the spring.

TA: Okay, so, the spring, all right, the displacement of the spring, you're saying, is what tells you the force.
DORIA: Yeah.
BELINDA: Yeah.
TA: And the distance is the part I'm not so sure about. How are you going to measure that, exactly?
CONSUELA: The distance?
DORIA: We'll put like, one magnet on the spring, measure the distance...
BELINDA: No, he's saying how are you going to measure the difference? Like just with a ruler? Like how accurate would that be?
(20:00)
TA: The distance between the magnets.
BELINDA: Oh, the distance between the magnets? Well can't we just...
ANGIE: No, go ahead... no no no no, go, go.
BELINDA: Are you asking how we're going to measure the spring? How to change that? Or just when the spring's hanging there's a magnet on the bottom, like, to show that at different distances you would hold the other magnet like five centimeters away first and see the difference in the spring, and then ten centimeters...
TA: So it sounds like what you need to happen is you need this to come to an equilibrium so that you can measure it.
BELINDA: Right.
DORIA: Right.
TA: Okay. If you can do that, this would be perfect. I don't know if you can or not.
BELINDA: So wait, why... why wouldn't we be able to impose an equilibrium? Cause if we move it real fast, like, if we move the magnets to it...
TA: You can see these magnets.. they... if there's nothing between them, they, for a short while, become attracted until they stick together.
(21:00)
BELINDA: Okay.
TA: So, you're suggesting that you want a range of distances over which it's attracting but not sticking together. It might be difficult to do.
CONSUELA: Yeah.
BELINDA: Yeah, I see what you're saying.
TA: Now, another group is doing something a little bit different. Instead of telling what (?) they're sticking them together, and then pulling them and seeing at what... what stretch they come apart.

BELINDA: Makes sense.
TA: So in order to do that, they put something in between... so if you can put something between them, you can vary that amount, if you can vary the distance between them.
BELINDA: Wait, what "amount" are you talking about? You're varying what amount?
TA: Okay, we want to measure the distance between the two magnets.
BELINDA: Correct.
DORIA: Right.
(22:00)
TA: Say... a hundred pages... and then I measure the force it takes to pull them apart. Then I take fifty pages.
BELINDA: Oh, I gotcha.
TA: Because you want to be able to vary that distance in a measurable way.
BELINDA: But then how are you...
DORIA: How are you measuring the force?
BELINDA: How are you measuring the force?
TA: That's... that's the other part. This is how you measure the distance. Your spring idea may be sufficient to measure the force. Because the force will be the force it takes it to pull apart.
BELINDA: I got you. All right.
DORIA: All right, which thing...
(TA leaves)
BELINDA: So now, how are we going to... the only question is how are we going to... this is our weight... how are we going to...
DORIA: Um... we need string.
CONSUELA: You can put like...
BELINDA: This is not a bad one... does it stick to it?
DORIA: Yeah, we'll have to have string and then tape it. Otherwise it'll fall off.
(23:00)
CONSUELA: Where's... is there string?
ANGIE: Not enough that if you were to do something like that...
DORIA: We need...
CONSUELA: Do we need to weigh it? See we have to do two different things, like, one thing like that, and one thing with the spring? That measures the distance and this measures the force?
BELINDA: Why didn't we get those big magnets? Are those the only ones left? Are there little ones? Can we use

little ones? Let’s get little ones. What is she looking for?
CONSUELA: Strings. So we can make a hook on these bars. (?)
(Exit 3)
BELINDA: Oh um, they have it.
ANGIE: I’m enjoying myself.
(24:00)
BELINDA: So why do we use these big weight... these big, heavy magnets.
DORIA: Those are the only magnets we have.
BELINDA: No, there’s some more over there. Small ones.
DORIA: Oh. So, if we put stuff in between it...
BELINDA: I really don’t see how this is gonna work.
DORIA: I don’t understand how... how... what are we measuring...
BELINDA: All right, so like... here you’d have your spring, right? (DORIA: Right) And you’d have a magnet (DORIA: Yeah) And you’d have ‘em... at the end of the spring you’d have ‘em like this.
DORIA: With something there.
BELINDA: Oooh! Oops, wrong (?)
DORIA: Right.
BELINDA: Right. So hanging off of this... it’s gonna displace a certain amount.
DORIA: Yeah.
CONSUELA: But we don’t get to see...
BELINDA: And then... when you... so, that would be like... your initial displacement. And then when you pull away, how much force it takes to pull it away.
DORIA: Is the amount it contracts.
(25:00)
BELINDA: Yeah.
ANGIE: Stretches?
DORIA: But it’s gonna bounce!
BELINDA: This is just annoying to me right now. But the question... the better question here is if you do this, right? And then you put two pages in between... so it should... the spring should be less.
DORIA: Well no, it should be the amount it expands.
ANGIE: Yes. So if you put two pieces of paper in between... and you have it attached to this, right? When... (DORIA: When it’s just chilling there) the spring... when you’re pulling on it... the amount it takes... as you’re stretching it... hmm...
BELINDA: Well first of all we’re definitely not using them.

CONSUELA: We're not using them?
BELINDA: We... we can't! We have to use smaller ones.
(26:00)
BELINDA: Look how cheap this little spring is.
CONSUELA: About what? What did she say?
BELINDA: I don't know.
(Enter 1)
ANGIE: (?) two little ones.
BELINDA: Two little ones.
ANGIE: Two little ones don't stick together at all. You don't believe me?
BELINDA: No, I believe you. Okay well no no, this is the one we can hang off... we can hang this off the spring and just move it...
ANGIE: I believe you.
BELINDA: I have no idea what's going on.
(27:00)
(TA calls for discussion)
(Group 1 presents)
(28:00)
(Group 5 presents)
(29:00)
(Group 4 presents)
BELINDA: So the probe is measuring the force.
(30:00)
(Group 6 presents)
(31:00)
CONSUELA: That's pretty much what we said.
BELINDA: That's pretty much what we were thinking. We were trying... we were gonna relate it using a spring to Hooke's Law... and... find the force that way. Just measuring the differences of the spring. But we hadn't decided how we were controlling the distance yet... if we were just... um... if we were going to be putting things between the magnets or... I... (?) so... I don't know. Haven't got that far.
(32:00)
(TA sums up discussion)
(33:00)
BELINDA: Okay, so...
CONSUELA: What did they say they were going to do?
ANGIE: I really like their idea.
BELINDA: Theirs?
ANGIE: Yeah.
CONSUELA: Me too.
DORIA: Theirs?
BELINDA: But where how do you... the distance thing, it

seems like it...
DORIA: But when you try to uh... exactly... work...
BELINDA: Our transducer? This is a transducer, right? Oh my gosh.
CONSUELA: Ok, ready? I don't understand, maybe (?)
BELINDA: We need to ask... (CONSUELA: Paul!) Paul, we need your help.
CONSUELA: Maybe it's the wrong one, like...
BELINDA: I get a... I have a (?) about Polish people, which I am, therefore...
ANGIE: Try switching ports... try changing the port... try to change the port.
BELINDA: It's like cords, it's not a... it's like ripping... I didn't do anything.
(34:00)
BELINDA: All right, I'm changing it to uh port one. That's the only other option. There are two ports.
ANGIE: What happened to our screen?
DORIA: Our computer sucks.
ANGIE: Paul!
CONSUELA: What the hell is going!?
ANGIE: Paul! This is not (?)
TA: All right, who's screaming for Paul?
BELINDA: Our computer is on... not helping us... not working...
TA: What happened? Oh. Close the windows.
BELINDA: The transducer's not even working though.
CONSUELA: How come it doesn't let me like open. Oh, there it is. Great.
TA: Um, close it out and restart.
CONSUELA: Restart.
DORIA: We love our computer.
(35:00)
TA: Give me the mouse, will you? Quit. Why aren't you quitting. Close! Quit! Please!
BELINDA: Do anything! Oh wait. That reset it. And just end uh, yeah.
CONSUELA: Okay.
TA: Whatever you did, don't do it again.
BELINDA: But it's not work... can you help us try to work it...
DORIA: Yeah, it's not working.
BELINDA: It was in port two, we moved it to port one. Go back to port... do you want me to go back to port two? Okay, so, when we change it to force, this was still... wait, is it even plugged in?
CONSUELA: Because it's not plugged in down there.

DORIA: Then it wasn't measuring!
CONSUELA: It was doing something!
TA: You want this in port one, you want that in port two.
(36:00)
BELINDA: You want this in port two?
DORIA: Well then what was it measuring?
CONSUELA: It was definitely measuring something!
BELINDA: This was measuring something.
DORIA: But there was... nothing going on.
BELINDA: All right, let's try this out.
DORIA: We're not measuring acceleration, we're measuring force.
BELINDA: Just hook it up. All right. Now just say okay... let's see... wait wait wait.
CONSUELA: Oh duh...
(37:00)
CONSUELA: Does this have to be (?) or something? I don't understand...
BELINDA: I don't think so. Why is this not working?
ANGIE: Why is (?)
BELINDA: All right, first we'll all...
DORIA: Just switch the ports.
CONSUELA: Yeah, try switching the ports.
DORIA: Yeah, switch them.
BELINDA: Let's hang that off the table.
ANGIE: I gotta figure out what's going on.
BELINDA: All right.
DORIA: Try switching the ports.
BELINDA: All right...
ANGIE: Is it going?
BELINDA: See, it only reads the motion probe in the other...
(38:00)
CONSUELA: Then why is it not...
BELINDA: All right.
DORIA: What is going on with our computer?
CONSUELA: Is there something wrong with this?
BELINDA: Click on the question mark. I don't know why. Zero?
(Enter helper with advice)
CONSUELA: Oh.
BELINDA: Just put ten. Can you highlight it? It won't delete. And then just go down here. Excellent!
CONSUELA: Do you want to start that again?
BELINDA: Yeah, try that again. And thank you, by the way. Hopefully that works. Or maybe not.

CONSUELA: Wait... it...
(39:00)
BELINDA: Here, wait, put this on it.
ANGIE: I'm pulling on it as hard as I can.
BELINDA: I know, it should, yeah, I know, it should. Let's just see.
CONSUELA: What in the hell, we're not ever...
BELINDA: Put this on the... I don't think that needs to be there though...
CONSUELA: You don't think?
DORIA: Yeah, what is that... (?)
BELINDA: Here. Don't know. Yep, definitely not working. Try acceleration. Acceleration and force will be the same.
DORIA: We don't have to use the computer if we're just doing the change in X.
CONSUELA: Yeah.
BELINDA: But we're not.
DORIA: We're not? What're we doing?
BELINDA: I thought we (?)
DORIA: Are we?
BELINDA: Oh yeah! This IS measuring.
CONSUELA: Isn't this still... does it need to be smaller?
DORIA: I mean, I don't.
BELINDA: Okay, we're confused. Our thing is not working.
(40:00)
(Enter TA)
BELINDA: It shouldn't even need the motion detector, if we're just measuring force here.
TA: First of all, you're way too close to the motion detector. It doesn't... it won't see it that close.
BELINDA: But... should we even need that if we're just measuring the force, cause this...
TA: Why are you using it?
BELINDA: We're not.
CONSUELA: We're not.
BELINDA: It said, it couldn't measure without this, so we were thinking maybe this was it, but we didn't...
TA: It just needs to be plugged in to work.
BELINDA: That's what we thought but it's still not working with just this.
TA: Here, um, hit zero.
CONSUELA: Here?
TA: Yes.
BELINDA: Slow computer.

DORIA: I demand (?)
TA: Okay, now start it.
(41:00)
CONSUELA: Oh gosh, what's going on?
DORIA: It's connected though!
BELINDA: Yeah, it's connected.
TA: Is it connected... is it in the right one? Is it...
BELINDA: This one is port two. And the other one is port one.
CONSUELA: Okay.
TA: Try again.
BELINDA: Whoa.
CONSUELA: Okay, it's working now.
TA: Now it's working. Okay, you need to change the scale so that you can see the features, but now it's working. I think it's just a loose connection.
ANGIE: What did you do?
TA: I just... pushed it in and out.
CONSUELA: I think it's when we do... should we set it up now? How are they... what are they doing... (?)
DORIA: So what are we doing?
ANGIE: Can we try it with this just to see if it measures enough for us?
CONSUELA: Tell me when.
(42:00)
ANGIE: Now.
DORIA: Oh my. That's not gonna work.
CONSUELA: That's like the worst graph I've ever seen.
ANGIE: Maybe we should do the fishing rod thing... how they're doing it.
DORIA: Do what? Put stuff in...
ANGIE: They're hanging a magnet from a fishing rod and then (?) seeing how much it attracts to (?)
BELINDA: How are they measuring attraction?
ANGIE: They have one... they have one hanging from a string.
BELINDA: Off of the transducer?
ANGIE: Yeah. And then... seeing how much like...
BELINDA: The pull is. The string doesn't change lengths.
ANGIE: The string changes lengths.
BELINDA: It can't... if you have it tied onto there.
ANGIE: You can cut it off and change the length of the string to change the distance between them.
BELINDA: No... you change the distance, but the string isn't going to change. It's just the force pulling down on the string.

(43:00)
DORIA: You know you'll just... you're not using a spring, you're using...
BELINDA: Yes. It's a string.
ANGIE: I know. They cut the string to change its length.
BELINDA: No, I get all that. (ANGIE: Okay then, what are you talking about?) The string isn't going to move down, it's just the weight (ANGIE: Yes!) gonna attract it.
CONSUELA: That's the way they're doing it?
DORIA: Well... will that... the computer measure the force between them? Or just the force that the weight is pulling down?
CONSUELA: It's the weight that it's pulling down.
BELINDA: It'll just measure this.
DORIA: Then how is that measuring the force between 'em?
ANGIE: Because if this one is attracted to this one...
BELINDA: The other one is attracted the same way.
ANGIE: ...it's going to pull down more.
BELINDA: All right, let's do this then. You need to hook us up.
(Exit 1 and 2)
(silence)
(44:00)
CONSUELA: So the... we're going to be changing the distances of the strings, right?
(silence)
(45:00)
(group puts together apparatus)
(46:00)
(47:00)
(inconsequential talk about materials)
(48:00)
(49:00)
DORIA: You want... this?
BELINDA: We need to make sure that this is ninety degrees. So how do we do it?
DORIA: Oh, the level?
BELINDA: Protractor or level?
DORIA: Level.
(50:00)
ANGIE: Who's doing the journal?
CONSUELA: Do they do the design of the experiment? Or do I?
BELINDA: You're the journal... wait... you're the data. Tell me when it's level, try it again. And then, let's

see (?)
(51:00)
(52:00)

Group 2

(0:00)
DAPHNE: I guess we have to see like, just, if we hold it and let it go, will they come together?
CATHY: *moans*
ASHLEY: If we hold one stationary, maybe see...
DAPHNE: I was about to say, “Why don’t we drop it?” but it would all fall, so that wouldn’t work, would it?
BONNIE: It would magically float apart in the air!
DAPHNE: They wouldn’t come together.
BONNIE: It was so strong it would overcome gravity.
DAPHNE: I hate this discussion we always have. I don’t want to hear about all this stuff...
(1:00)
(TA hands out lab notebooks, inconsequential chatter)
(TA instructions)
(2:00)
CATHY: How does the force between two magnets change?
TA: I’m gonna warn you right now, this lab can be pretty tough.
DAPHNE: The force we would measure if we could test a spring through the tension... is proportional to the force pulling it this way, right?
ASHLEY: ?
DAPHNE: Yeah, and then have something attached to like...
ASHLEY: Wood?
DAPHNE: And then how much this stretches?
(skip ahead)
(8:00)
DAPHNE: So we need to think if this is going to work. I don’t see why that wouldn’t work. Cause what would be changing is like, make we’d have this magnet at this distance, this distance, and this distance, and measure how far it would...
BONNIE: What are we measuring exactly?
DAPHNE: If we change the distance then we’re finding the force. I think what he said was, you have to vary one of the two... to figure it out. And I have no idea how you vary the force. I guess by changing the different magnets or something? You can’t change the charge of the magnets. So if we measure the distance, then if this force is proportional to this force, then we’re measuring the force.
CATHY: So how would we get the spring first of all to lay like... straight?

DAPHNE: We can do it with the one we did last semester.
(9:00)
CATHY: And so we would measure how far it... like we would measure the distance of the spring at like...
DAPHNE: The change of the spring. The change in distance of the spring.
CATHY: All right. It's worth a try.
DAPHNE: We can try and see what... let me get the magnets.
ASHLEY: I'll get the spring.
CATHY: And maybe some silly puddy too.
(1, 2, and 4 leave)
(10:00)
(re-enter 2)
BONNIE: Okay, I don't quite understand what we're doing. Which is not good, cause I'm the journal person.
CATHY: We have to measure both of these, though.
BONNIE: Right, but we vary one. Yeah, we have to find some way of measuring force based on the spring. I'm not sure how it works.
CATHY: Ummm...
BONNIE: Those are strong magnets.
CATHY: See, I don't think they're so... look... like, I really don't think they're gonna... move a spring.
BONNIE: Yeah, once the distance...
CATHY: Cause, in order to get the...
(11:00)
BONNIE: The other thing is, there aren't going to be a lot of distances, cause one you get it like two inches away or so, it stops...
CATHY: Then I guess maybe it moves... So we would have to keep... we would have to keep one of them... in place, right? It would have to be like... that doesn't do anything... that doesn't do anything.
BONNIE: So we do the other side too, the attraction side (CATHY: Yeah) So like, turn one around... see how close they can get to...
CATHY: It's gonna be really hard because... it's not gonna pull back... it's gonna get to a point and automatically it's just gonna go this way.
(12:00)
BONNIE: Yeah. So we I guess find this point, like, if you, can you hold it back so far... and it won't do anything...
DAPHNE: See, the idea is you tape this on and hold it like... I guess we'd have to hold the other side of the spring fixed, wouldn't we?

BONNIE: *laughs* That spring is...
DAPHNE: We wanted a stretchier one cause it's gonna be... it won't... if the spring isn't stretchy enough then these probably won't even come together.
BONNIE: Oh, yeah, I know.
DAPHNE: But we have to hold this side fixed, don't we?
BONNIE: Yeah.
DAPHNE: We can tape it to the paper...
ASHLEY: This is just trying out.
BONNIE: Idea number one.
DAPHNE: All right, if we take the... we need scissors... are there scissors in the um...
BONNIE: Yeah.
DAPHNE: ...thing? Is it stronger if you hold the magnet like that?
(13:00)
CATHY: What do you mean? You know, I think you have to just one end, cause it would just attract, you know, like...
DAPHNE: So it's not like... oh... it might be easier to do it that way, wouldn't it?
CATHY: But then you have these repulsing at the same time, like, I think you can only deal with either attracting or...
DAPHNE: So you can't do it like... oh... doesn't work, does it?
ASHLEY: This way would do... attract both sides... know what I mean?
BONNIE: Yeah?
DAPHNE: If you flipped the magnet the other way, you mean?
ASHLEY: Like, if this is red and this is red...
DAPHNE: But then it attracts both if you line..
ASHLEY: Right, so it's a strong... stronger force, right?
DAPHNE: It attracts both sides.
BONNIE: Does it though?
DAPHNE: But how are we going to measure that?
CATHY: Yeah, I think we can only pay attention to one thing at a time.
(14:00)
DAPHNE: But, as long as we keep it constant then we're keeping the... like if we do it like this... it's probably gonna be able to stretch the spring better than if we do it like that. Cause we're measure... we're trying to figure out the distance, so... if we tape one end of the spring down... we can tape it to the table...

come off easier... so, you know... start like here and... it’s gonna be close, I guess.
CATHY: Yeah (un)... I think it’s easier to... if we’re picking, it’s easier to measure repulsion because...
BONNIE: Yeah.
CATHY: Like... we can go here... nothing... nothing...
ASHLEY: So maybe how far...
CATHY: It’s like... how far this one like retracts back.
DAPHNE: Get it closer...
BONNIE: It can do a variety of things.
ASHLEY: What if you...
DAPHNE: I just want to see if it actually works.
ASHLEY: We have so many ideas!
(15:00)
DAPHNE: Yeah. Well, we have to figure out which one’s...
CATHY: And... do we have to measure the distance between like, repulsive forces and attractive forces?
ASHLEY: No. I think it’s just... force.
CATHY: But might they be different?
ASHLEY: Um...
DAPHNE: I would think that they shouldn’t be. But I always think the wrong thing.
(silence)
(16:00)
(Enter TA)
TA: What are you going to try?
DAPHNE: We’re just trying to see... (BONNIE: The spring) if you change the distance...
BONNIE: Change the distance with the spring (?)
ASHLEY: Here.
DAPHNE: I don’t know if this is going to work. Cause we have to hold one of ‘em. This, I guess, is what we’re moving, isn’t it? It’s not gonna work. The spring like...
ASHLEY: What if that was held constant and we...
BONNIE: Yeah, what if we...
ASHLEY: ...and we moved this...
DAPHNE: If we moved this one?
BONNIE: Yeah, this one. And then watch.
DAPHNE: So we hold it at it’s, like, equilibrium position (giggles)?
BONNIE: If we can *find* an equilibrium position.
DAPHNE: But how are we going to measure that... the force?
BONNIE: You don’t hold this one fixed.
DAPHNE: Yeah.

(17:00)
DAPHNE: So it’s stretched that far. Wouldn’t it stretch the same, I guess? Something’s not right.
BONNIE: *sigh*
DAPHNE: It’s stretched that much.
CATHY: Cause it’s like, once it gets to that point, every time it’s going...
DAPHNE: It’s gonna...
BONNIE: Yeah.
CATHY: And they’re so thick... they’re so thick that to have it this direction... like...
DAPHNE: Yeah, it might be better to...
CATHY: You can’t... you can’t like, move it... that whole length.
BONNIE: Yeah.
DAPHNE: Can we see how far the spring would stretch for them to come apart? I guess that would just... once the spring can’t stretch anymore then we have to pull it apart. That wouldn’t work.
BONNIE: Yeah, that wouldn’t.
DAPHNE: It just seems that it’s so much easier to measure distance than it is to measure force. How do you measure the force... without... so if we measure how far it... goes? What if we, like, hold it, until you get it to the right spot, and then let it go.
(18:00)
CATHY: Or like we would have a, like ruler... down here...
DAPHNE: Hold that like that, and then let go of that one, and see how far it goes. And hold it there... like if we hold it... we hold it one inch... it doesn’t go anywhere. Two inches... (?) go anywhere... three inches.. it goes...
ASHLEY: Well I guess (?)
DAPHNE: Two inches... one inch... and let it go. Like.. go.
CATHY: Hm... that’s weird.
DAPHNE: It just moved! It’s not going anywhere. Not quite half an inch... (?)
BONNIE: Theoretically we could do this *without* a spring.
DAPHNE: Yeah. (?)
(19:00)
(Enter TA)
DAPHNE: ...and it goes back a whole lot more (ASHLEY: Even more!) What if we do it this way? But that’s... attracting. I was wondering why it was pulling my hands

down... like it moves it away at an inch, but at the other one, it didn't.
CATHY: But it also moves... this back. Like... it's not like a straight...
DAPHNE: Why does it move the red back more than the black?
CATHY: I don't know!
BONNIE: Just... it probably could do either...
DAPHNE: It's harder to push it together this way. And it's a bigger difference so it would be easier to... like could we take the average of... like where the black is and where the red is, and then take the average... at the middle?
BONNIE: Wait, what do you mean?
DAPHNE: Like when it comes off at an angle like that, take an average of the position so that it's not here or here, it's there (BONNIE: Oh... right) do you know what I mean? So it's right between the two.
(20:00)
BONNIE: Yeah, I don't see how else we could...
DAPHNE: Cause it... you could measure it. I mean, it's a big difference. When you hold it like that it goes... and then when you hold it like this, it's just not going very far at all. You know what I mean?
BONNIE: We could do it both ways and sort of see... or...
DAPHNE: And have that be different trials, maybe?
ASHLEY: What if you did the red end... does that make the black end go farther?
BONNIE: Is it just the one that's up?
ASHLEY: Yeah, it stretches the outside...
CATHY: I think probably because it's going against...
DAPHNE: So I should hold it away from the ruler. It might just be because of the way I'm holding my hand.
BONNIE: I think they're the same. I think it's just, you know.
DAPHNE: What if we held it like... that...
CATHY: It's hard to...!
ASHLEY: Ooh, sorry!
DAPHNE: What if we... (?) the ruler up... it's still kinda... we'll just take the average of the...
(21:00)
BONNIE: Probably just the red part...
DAPHNE: Get off!
BONNIE: You're not allowed to be together.
ASHLEY: That's not as bad. (DAPHNE: Yeah) And then we just have a piece of tape for all the... ten places...

BONNIE: Yeah, we have two rulers so we could do...
DAPHNE: Yeah, then just measure. Well if we could get a piece of tape...
CATHY: But then how are we...
DAPHNE: Like should.. would this be our only... only with these magnets when there's like... like would we be able to do it with the small magnets and have like... results that can be compared?
CATHY: We could do it... orient the magnet different ways.
DAPHNE: This way... this way... this way...
BONNIE: We only get one pair of magnets so...
CATHY: Oh we do? Oh we do.
DAPHNE: This way.
BONNIE: But it should be the same for all... and then could we measure the attraction also? Or is that... see how close you can get it before...
DAPHNE: Before what?
(22:00)
CATHY: I think that's really hard because it like... (BONNIE: Yeah, I know it is) it can only be measuring one point.
ASHLEY: At what point does it attract each other.
DAPHNE: Cause it will attract the same... well I guess it won't.
ASHLEY: Once it gets to like two inches.
DAPHNE: Can't really measure, cause it would... so we're measuring repulsive force.
ASHLEY: So we want to measure repulsion...
BONNIE: We need... spring...
DAPHNE: And we're not allowed to have more than one kind of magnet?
BONNIE: Well... maybe we can, I don't know.
DAPHNE: If we like put this back, and then...
BONNIE: Yeah, I'm sure we can test another one, we just can't have more than one set at a time.
DAPHNE: At a time.
BONNIE: Yeah.
DAPHNE: Cause we could get more data. But then the size of the magnet is different. But the relationship should still be the same, right? The size of the magnet shouldn't matter. It's... the relationship of the force and the distance?
BONNIE: (writing) Measure repulsion not attraction...
DAPHNE: Did that make sense (?)?
CATHY: So like, on those little ones they're set up exactly the same, like, half of it's positive, half of

it’s negative.
DAPHNE: I didn’t notice. I didn’t look at the... if we use this piece of paper to do it, can we draw a ruler on here?
(23:00)
BONNIE: Ooh.
ASHLEY: Ah!
DAPHNE: So we don’t have to...
ASHLEY: Except for the stupid...
(Enter TA)
TA: (?) Idea?
DAPHNE: Yeah... I think we can start.
CATHY: It’s very simple.
DAPHNE: Um, we’re going to... hold magnets at different distances... away from each other, and then let it go and see how far it pushes it back... and see if holding it closer makes it push back farther. (TA: Okay) And by how much.
ASHLEY: And we’re measuring repulsion.
DAPHNE: We’re measuring repulsion, not attraction.
TA: Okay, how would you measure the force though?
DAPHNE: By the distance...
BONNIE: The distance that it goes?
TA: Is it proportional?
DAPHNE: (dunno noise)
BONNIE: Maybe?
DAPHNE: We’ll see! I don’t know.
(24:00)
TA: Okay, so, a method like this fine... if you can make a clear... connection between distance and force. You have to measure force. If you’re just measuring distance, you need a way to change it to force.
DAPHNE: Oh. Right.
CATHY: We can’t only do this...
TA: I’m just saying... with this method you might make a perfectly persuasive argument about the relationship between initial distance and how far apart it goes. But not distance and force, and that’s what you have to do.
CATHY: Ok. We have to change this. I don’t think we should even try taking... since we’re not measuring one of the... components... I don’t think we should...
DAPHNE: Oh, force?
BONNIE: How do we measure force?
CATHY: Something like... (DAPHNE: Well can’t we say like...) hooking up to the computer with it like... what did we use the first time?
DAPHNE: What if we use that (motion detector) and change

it to a force graph?
(25:00)
CATHY: How do we hook that up though? How is this...
DAPHNE: Like... hold it here... it goes back, like, half an inch. So that was an inch away. If you... increase the dis... is that doubling it? Decreasing the distance by one half... then it goes... dammit... then it goes... a certain amount... and the factor that it goes, like, the amount... if we're... changing the distance away by like you know, if we do two... one... if we're like cutting the distance in half every time... then it goes that far. If we put it (?) how much it goes that far and do a relationship between how... what the...
ASHLEY: Like when we were doing here... times... two...
(26:00)
DAPHNE: If we do... we do one and two way...
BONNIE: Can we time it to find the velocity and acceleration (?)
DAPHNE: That would be really hard, it's really fast. (BONNIE: I know) It's too fast. So if we do an inch away...
CATHY: Wait, how is this telling us force again?
DAPHNE: The relationship between the distances... that it goes.
CATHY: But how do we know that's a property of force?
DAPHNE: I don't know.
BONNIE: That's what we don't know.
ASHLEY: So right now we know that the reason why these two are going away is because... (BONNIE: They're repelled by some force but we can't measure that force.) because we know that there's force.
CATHY: Then I guess what we're supposed to assume is that (DAPHNE: We actually have to...) we know whether there's a force or not.
DAPHNE: And we actually have to measure that a force exists.
BONNIE: Right... prove that there is a force.
DAPHNE: Point five inches away then it goes two inches...(?)... it goes... it goes...
(27:00)
DAPHNE: (mumbles)
(silence)
DAPHNE: So... couldn't the force... be... what we multiply by to get that?
CATHY: That's like assuming that... that's the relationship. Like you're just assuming... we can multiply. And we don't have anything to like tell us

that that's... like why isn't it like... it's the metal... that causes it to go this distance... you know like...
(28:00)
DAPHNE: But we're not changing the... charge... so... it can't be the metal... because if we're not changing the charge in the metal then...
CATHY: I just think it could be anything and we're just assuming... charge... and we haven't proven any...
BONNIE: He told us we have to find a way... to measure the charge... to measure the charge...
DAPHNE: We can measure the charge!
BONNIE: Not the charge, the force.
DAPHNE: The force.
BONNIE: I don't know how to do that.
DAPHNE: Is that even gonna work? These are pretty low. (BONNIE: I don't know) I guess maybe if we put it farther out. We're gonna have to make sure we keep the (?) distance away...
BONNIE: Someone else is turning on a computer so...
DAPHNE: So what are we measuring? How far it pushes it back, the closer we hold it?
BONNIE: Yeah, which way are we measuring it though, this way?
(29:00)
DAPHNE: So if we... but..
BONNIE: I don't know, I'm going to have to see the graph...
DAPHNE: If we... we hold it a certain distance and that is gonna pick up how far it goes. (CATHY: If we hang it...) And then... how far it goes, and how far it goes.
ASHLEY: That brings in gravity.
CATHY: But it would always be con... like, the gravit... the same gravity would always be there. Can we measure how much it causes the spring to bounce up? You know just like we were gonna measure...
ASHLEY: That's still measuring just...
DAPHNE: But it's still so small and... how do you measure, how do you eyeball that?
CATHY: Well we were going to do that with this.
DAPHNE: But it's easier when it's here because you can hold it up to a ruler and if you don't move the weight...
CATHY: So couldn't we hold the ruler this way? And measure this...
DAPHNE: But would it stay? Because are you going to have to be like 'oh that's what it was.'? Cause that would be kind of hard.

BONNIE: Where's our mouse?
ASHLEY: Cause gravity would pull it back down.
DAPHNE: ...pulls it right up.
(30:00)
CATHY: I know but if that's... I know but if that's the only... like what we have here is not measuring force in any way.
ASHLEY: Well what if it was like this?
BONNIE: Where's our mouse?
ASHLEY: Like this will detect that it's coming closer to... right?
(Enter TA)
TA: I don't know if it will see that. I mean what... you're trying to measure separation again, aren't you?
ASHLEY: Mmhmm.
BONNIE: The force between them.
TA: How are you going to do that?
BONNIE: There's an option... force graph?
TA: Uh there's... okay... and how does it get the force graph?
CATHY: From the distance graph.
BONNIE: The velocity... er no...
TA: It gives you the force graph cause there's a force probe connected to it.
DAPHNE: Oh... so we're measuring the force? Right? With the force probe! (laughs)
(31:00)
TA: Um... that's not the force probe.
BONNIE: Where's the force probe?
TA: That's it. No, on top of the box. That.
BONNIE: Force probe... model F P 2.
CATHY: What does that look like?
BONNIE: I'm guessing you have to untangle this.
CATHY: How does that work?
BONNIE: (?) (fiddles with force probe)
DAPHNE: What do you... put with it? What do you attach to it? One end... one of the magnets?
ASHLEY: Or a spring.
DAPHNE: But we already... but it seems that you can't measure repulsion with that.
(32:00)
DAPHNE: And we already know that... that's not going to work.
BONNIE: Yeah.
DAPHNE: You're supposed to attach (?) to that?
CATHY: The probe isn't...
DAPHNE: How does that work?

TA: Don't do that!
CATHY: We would attach something down here.
TA: Let me see this to make sure it's actually hooked up appropriately. So attach things to the hook. This magnet... I mean, it's a magnetic force probe. But we found... yeah... we found that it can work though with magnets here... and here and here.
(33:00)
DAPHNE: So what, you attach the magnets to each other? Attach a magnet to that?
TA: Or if you want to get the magnets far away, you could string one of them up. Like use a string or something. And attach a magnet here. And then bring this magnet around... and see... and see the effect.
ASHLEY: But then would you have to just measure attraction?
TA: You can measure repulsion too.
ASHLEY: But like... say this is attached to this, right? If I go like this... it's gonna move backwards. Does this register backwards?
TA: It won't □ecessary... okay...
ASHLEY: Do you see what I mean?
TA: Yeah, I see what you mean but...
ASHLEY: Or does it only pull this way and...
TA: So let's say you strung this up... okay, and the string is supporting this, and without this magnet, this just feels the weight of this. Right? If you do attraction, and this thing wants to get pulled down and the reading will increase. If you do repulsion, this'll be pushed up a bit and you'll get...
(34:00)
ASHLEY: It'll record something?
TA: Yeah. Oh, absolutely. As long as you zero it with whatever... whatever weight hanging from it that you want. Then it'll appear as positive or negative.
BONNIE: We have to attach it with a string or something?
TA: You can do whatever you want. (BONNIE: Okay) I mean... some other groups are trying this already, so you can check that out.)
DAPHNE: But didn't we already figure out that there's only one... point at which they're going to attract, and everything else after that it's not really... I mean, if we measure attraction, we're only measuring one thing. Unless we hold it apart... and then let it go.
CATHY: Well he just said that it could measure repulsion.
ASHLEY: Yeah, so we can still measure repulsion.

DAPHNE: Is it just going to be more negative... the more it repels?
ASHLEY: Mmhmm.
CATHY: Yeah.
ASHLEY: Do you want to open the... longer thing?
(35:00)
(unintelligible talk about screen)
ASHLEY: We wouldn't want a spring here... because that'll move... (DAPHNE: A string) (CATHY: I think we just want string) that'll be tension on...
(Exit 1)
DAPHNE: So how are we going to...(?)
CATHY: And should we just attach this to the side of the table?
BONNIE: Okay, but how... why would we attach it to this... because we...
CATHY: Well this has to... I mean, we can't be holding this cause this is gonna be (?) has to be like stationary.
BONNIE: But where are we gonna (?) hold the magnets underneath it?
DAPHNE: Can we tape a ruler to the table or something? (?) to know exactly... tape a meterstick to the table so we know exactly... how far we're holding it?
(36:00)
CATHY: Mmhmm.
(Re-enter 1)
DAPHNE: Are we going to tape it? Because I would think that tying a string to a place they're going to repel would be... destructive. Should we tape the string to the top here?
ASHLEY: Yeah... did he take our...
BONNIE: I've got the tape.
(talk about constructing tape and string)
CATHY: Maybe... maybe we should just tie it cause... we just don't know how far it's gonna like... come back up.
(37:00)
ASHLEY: Doesn't it feel weird?
CATHY: Mmhmm.
BONNIE: The thing is, I am left-handed...(?)
DAPHNE: So how do you want to tape it on like one... like this...?
ASHLEY: Yeah... that's what I... cause that would keep it level.
DAPHNE: Keep it level?
(talk about taping, inconsequential)
(38:00)

DAPHNE: What if we do two strings, and we hold it on its side? Do one on this side and one on the other side? Cause... this is gonn.. this isn't gonna hold it like this.. it's gonna... so if we do...
CATHY: What if you looped it around... like...
DAPHNE: But didn't... didn't we say that putting it on the side it was supposed to be repelling would kind of be disruptive?
(39:00)
DAPHNE: The only way to hold it like this would be to put a st... string on this side. And then another string on the opposite side and hold it to... otherwise it's not going to hold it. It'll hold it like that if we do that if we make the string the exact same length.
ASHLEY: Or you can put... are you going to put another one on the...
DAPHNE: Other side.
ASHLEY: Yeah.
DAPHNE: Try and tape it... get off!
(40:00)
CATHY: So we have to figure out how to secure this to the side.
ASHLEY: Okay.. so we're going to change distance here and find the force here. Yes. Okay.
DAPHNE: Get off.
(41:00)
CATHY: Why did he say at the beginning that we had a force reader?
ASHLEY: And as we do them, I guess we should save...?
DAPHNE: Yes.
(Enter TA)
(TA helps group do something with the monitor)
(42:00)
CATHY: Okay, we can tape this up to the side so we can... would it work just having this rest on the side?
(43:00)
(TA adjusts program)
(44:00)
TA: So there you go, huh?
CATHY: So do we decide (?) or is force in Newtons?
TA: It's not Newtons. It's not calibrated. But as long as you, as long as you zero it with everything that you want on there, um...
BONNIE: It'll give you a force.
TA: Then what you do with the magnet will be force relative to that, so...
(Exit TA)

ASHLEY: Um, can we change the axis, because I'm pulling... PULLING to get those little things. So we need like... (CATHY: Oh you mean, oh I see) two and minus two.
(45:00)
ASHLEY: Try and click on the axis.
(chatter about scaling graph)
CATHY: And we don't care at all about time.
BONNIE: No. Because it should happen quickly and it...
CATHY: So we will... pick a distance... record the distance... measure the force... and just keep... going up in (?)
BONNIE: Do we have a meterstick? Need to get one.
(46:00)
ASHLEY: Let me try that here...
ASHLEY: I guess we can still decide whether... attractive or repulsive would be better. So we could just switch that one. Can you push start for a second?
CATHY: Yeah.
(starts program)
CATHY: So if it's minus you are... what are you doing to it?
ASHLEY: Oh sorry, go ahead. Start it again and I'll show you what I'm doing. Pushing up... pulling down... pushing up... pulling down...
(47:00)
CATHY: Okay.
BONNIE: Ehh... there we go.
DAPHNE: So pulling down makes a negative force?
ASHLEY: Makes it go up.
BONNIE: Wait, pulling down makes it go up?
CATHY: Wait, do it again, do it again.
DAPHNE: So pulling down makes a negative force.
BONNIE: That makes sense. Negative goes down.
CATHY: We probably want to write that... in something that we would do... one of these...
(2 writes in journal)
(48:00)
CATHY: I really think... I really didn't think we had a way to measure force based on like what he said. Okay, I think we'll be ready. So what... kind of increments should we go in?
ASHLEY: Hold on a second...
CATHY: Is it not lined straight?
BONNIE: No, it's like twisting around.
ASHLEY: As I put the magnet towards it.
(problem with hanging magnet)

ASHLEY: Actually, can you start it?
CATHY: Oh sure.
BONNIE: Just a little practice run here, hold on.
(49:00)
ASHLEY: Let me try it again.
CATHY: Okay.
DAPHNE: Which are you moving?
BONNIE: Here, make it touch...
(fiddling with magnet)
ASHLEY: Try making it one and negative one. I would love a way to (?)
CATHY: Do you want to be writing down everything?
BONNIE: Yeah, I do.
CATHY: And I can go over there...
(50:00)
ASHLEY: It's not pulling down... as this comes closer it twists around...
CATHY: Do we have too much string?

Group Three

(0:00)
(1:00)
ALLISON: All right. I was thinking... could we... have something in the middle, like... a paperclip or something, for instance? And measure, like the further... what?
(2:00)
CHUCK: I thought we were just doing two magnets.
ALLISON: We are doing two magnets but with the... like, with the distance it's going... to... what was I saying? I don't know, like, I feel like... you can feel the force... oh, no, I'm wrong. Never mind. (Exit)
BRANDON: I have an idea. We can put some kind of weight on the top of (?) and make 'em go in slow motion. It's harder, but then you'd have to know what the force of friction was.
CHUCK: No friction! (laughs)
(3:00)
BRANDON: Yeah. Why do you think that (?)
ALLISON: To see if...
CHUCK: Wasn't force mass times velocity?
BRANDON: Mass times acceleration.
ALLISON: We can see when at.. like at what height it... flipped over.
BRANDON: That's good.
ALLISON: Like here, feel it. Where exactly... does it go over. And then for here... oops, sorry. For here, like, where... it comes out.
BRANDON: There's K X squared. You just brought K X squared to the table. Thanks.
DJANGO: Hooray, but we don't know the spring constant!
(4:00)
BRANDON: We don't need to.
ALLISON: Is there any way to attach them to 'em?
DJANGO: Tape.
BRANDON: What's the idea?
DJANGO: I don't really know.
BRANDON: You just got the stuff. This is tough.
DJANGO: I know.
ALLISON: I think...
CHUCK: We're trying to answer the question, "how does the force between two magnets.
DJANGO: How about, this is attached to one side, and this is attached to another, and that magnet pulls it... till... there's not enough force... the spring...

BRANDON: You don’t want...
DJANGO: Where’s the other magnet?
CHUCK: “How does the magnetic FORCE between ‘em depend on the distance?”
DJANGO: (?)
ALLISON: We could do... I don’t think that we should use the springs.
CHUCK: Springs don’t make sense right now.
(5:00)
CHUCK: “How does the magnetic force BETWEEN two magnets depend on the distance BETWEEN them?”
ALLISON: Basically, we have to prove F equals K Q one Q two over R squared.
CHUCK: What?
ALLISON: F equals K Q one Q two over R squared.
BRANDON: Yeah. Except with magnets instead of charges.
ALLISON: With magnets instead of charges. So...
BRANDON: I mean, we can figure out a max distance. Yeah, there’s gonna be a max distance where...
DJANGO: Don’t we have to figure out force though?
BRANDON: Right, before that...
CHUCK: F equals K Q one Q two over R squared...
BRANDON: No, that’s the wrong side. There’s gonna be a max distance... that it’ll allow itself to be, before attracting all the way.
CHUCK: That brings back friction....
ALLISON: I don’t think it matters.
(6:00)
CHUCK: It just scared you!
BRANDON: I know!
ALLISON: Cuz’ we’re not measuring the force. We’re seeing how the force is affected.
DJANGO: That’s gravity.
BRANDON: Who could think of all those equations? This is the spring constant!
ALLISON: I don’t think it matters with these, cuz’ we’re not trying to find the exact force, we’re just trying to find how force... how force and... distance relate. We’re not looking, we’re not... we’re not saying like...
BRANDON: There you go.
ALLISON: I think that... what we need to do is... mark a spot where one magnet is gonna start out at. And bring the other one closer...
BRANDON: What if you tape one to the thing...
DJANGO: We need something that...
BRANDON: Can’t move.
DJANGO: No friction.

BRANDON: Space?! You want... space?
CHUCK: Let's ice the table over!
DJANGO: We should go to space...
(7:00)
ALLISON: We could... hang something... in the air. There's like... air friction, but that's not... if we hang them.
DJANGO: Yeah, like a... thing where they... like a pendulum kind of thing?
CHUCK: Yeah.
DJANGO: We need string! (leaves)
ALLISON: If we have like...
BRANDON: I don't understand this pendulum idea.
ALLISON: I'm trying to explain it to you now. It's so you have... two things like hanging, and then you bring them like... they're on a string, so there's no...
BRANDON: Oh, so M G will be the same on them.
ALLISON: What?
BRANDON: If they weigh the same, M G will be the same if they're both on the string... bring the strings closer together.
ALLISON: To weigh them?
CHUCK: Do we have anything to hang them to weigh them from though?
BRANDON: Bring the strings closer together.
ALLISON: To weigh them?
CHUCK: I mean, to hang them from.
BRANDON: We could make something.
ALLISON: Well, we'll make a little contraption.
BRANDON: We could make something using a box... cardboard box.
ALLISON: So like...
CHUCK: We could use the microphone!
ALLISON: Just pull up (?) Sorry.
(8:00)
CHUCK: No it's (?) probably short out the mic or something. I know it's a bad idea. I'm just curious what would happen if you put a magnet near a microphone. I'm not going to do it, I'm just curious what happens if you put a magnet near a microphone. A microphone.
BRANDON: Do each thing hanging down...
ALLISON: I feel like... okay... oh, I like... okay, ready, look at this for a second. See like, I'm pushing these two magnets apart, right? If we can get the distance of where... it repels it too, then that's like our starting...
BRANDON: That's more supposed to be (?)

ALLISON: No, still from hanging from those.
BRANDON: How can you get the distance from hanging, it's... especially if it's hanging off the side, it's gonna go up like this... you're gonna have to measure the height...
(9:00)
CHUCK: I say we do... the most you could do is lower it, using one of the things to keep it steady.
BRANDON: No, this idea that you had was great. Actually, this was a really great idea. Because you can tape one of these, well, for the repulsion, you can still tape one to there and (ALLISON: Just figure out how far) you can get... this value. (laughs)
CHUCK: Should we tape 'em down to see (?)
BRANDON: That's like a dipole.
ALLISON: I feel like if we do all parts of it on like...
BRANDON: No, I mean, remember that homework he asked about dipole?
DJANGO: Oh yeah, so they have to do that.
ALLISON: I feel like there's a force of friction.
CHUCK: Keep the one away from it!
(10:00)
ALLISON: Wait, I did it... hold on, I did it before and it didn't mess up. Let's see 'em.
BRANDON: This one doesn't have rubber on it.
CHUCK: There's another problem. Find another magnet without rubber.
ALLISON: No, you hold the one rubber one.
DJANGO: Yeah, you hold the rubber one, and you let the other one move.
ALLISON: See, and then you get this... yeah, as long as the friction is... you can neglect it.
CHUCK: Hold on, question, question, question, question... When the velocity... I have a question, when the velocity, for example, if you have it around here... it's only that initial force...
ALLISON: (gasps and applauds) I know what to do!
CHUCK: What?
ALLISON: All right. We measure. We take it like... this is like... all right, ready? Here's like our farthest point. You move it a little bit closer.
CHUCK: Where's our ruler?
ALLISON: What? And then, like, there, no.... it's not working... like see how it...
CHUCK: You mean a centimeter at a time?
ALLISON: (?)
(11:00)

DJANGO: We need it on wheels.
BRANDON: We need something that...
CHUCK: That's just too complex... we should do it in the, hey guys, we should do it in the pipes!
BRANDON: Jesus Christ.
DJANGO: Think about those little skateboards that you used to play with. (crosstalk)
BRANDON: You know what? That's a better idea than the one we have right now, because with that you can do different distances.
DJANGO: Hot Wheels? (laughter)
BRANDON: Well I guess can too, but... we need to do, we need to make up a table with like distance... one millimeter, two millimeter, three millimeter, four millimeter.
CHUCK: Uh, centimeters.
ALLISON: Millimeters.
BRANDON: Millimeters.
CHUCK: You want to do one millimeter at a time?
BRANDON: Yeah.
CHUCK: Ouch.
BRANDON: So like one millimeter and you're, we're like, okay, this is zero millimeters... like that far...
ALLISON: If we had a piece of paper that we can...
BRANDON: And if we do them upright, that will reduce friction, so that's a good... so that's like...
(12:00)
CHUCK: Why would it reduce friction?
BRANDON: Because there's less surface area touching the table.
CHUCK: There's still... there's still surface area... on the walls of the thingie. If anything, this would be less friction, because if you're pushing against it like this...
BRANDON: No, but this one's wider, so that doesn't get any on the walls. Since that one's wider, it saves it.
DJANGO: Everyone's writing theirs.
CHUCK: Yeah, that's what I was thinking, we should write.
ALLISON: What?
DJANGO: We could balance it off (?)
BRANDON: Because they have to weigh... equal...
CHUCK: We could fly it off the balance!
DJANGO: We need some Hot Wheels.
ALLISON: We do need some Hot Wheels. All right. I think... this is what I think. Oh, they're not here...
CHUCK: I'm listening.

(13:00)
ALLISON: All right. I think if we have something... very specific, you know, distances, like one millimeter, like, every mark is a millimeter. We'll just mark the thing.
CHUCK: Okay.
ALLISON: So every time it moves we'll mark the distance. And from that distance, we can get... that's our R.
CHUCK: Okay.
ALLISON: That's the R where they repul... repel... or that's the R where they started to attract.
CHUCK: The problem I'm personally having is that, when you do bring the two magnets together... the closer they are the stronger the force is, the faster the velocity should be...
ALLISON: Oh, so we need the velocity to prove that the force... changes.
CHUCK: Well... what ends up happening is that you have the... you have... the... you have the... when it's closer, it's gonna push away harder, so it's gonna travel farther. You have like a tight... when the force is barely touching it, it's barely gonna push it away... does that make sense?
(14:00)
ALLISON: Right, okay, so that will... that proves it though. That's the, how does the magnetic force between the two magnets depend on the distance. The force... the further it goes... the stronger the force. So, the closer it is, the further it's going to go.
CHUCK: Okay.
ALLISON: So, as long as we figure out a way to get... to prove that. Like that's what we're trying... we're gonna measure...
CHUCK: The attraction...
ALLISON: All right. For... all right, this...
BRANDON: (?) as long as we put thought into (?)
ALLISON: Well this is, okay, ready? We're trying to measure...
(crosstalk)
ALLISON: All right, we're trying to measure.. the... how force is affected by the distance. So, say you have them together. The closer they are together, the further the one is going to go away, which means the more force, you know, is on it.
BRANDON: Well that's we're testing, but yeah, that's our hypothesis.
(15:00)

ALLISON: Right, so then there... so we have to get like the distance between each, right? Between like how far it goes (BRANDON: Yeah) so... there's more force. Right. But then... how do we do (BRANDON: Together one?) Yeah.
BRANDON: The same idea. Except... (CHUCK: You can't have the friction) you measure it... you just begin by measuring it... there's no... I mean, there's no perfect... you would just have to set this at... like, let's say this is zero... it's obviously (?)... and this is, you'd have to start it at one. And our answer would have to be... just discrete. It'd have to be yes or no. Cause we can't... we don't know the rate...
DJANGO: Shouldn't it be ideally be the same on both?
BRANDON: Yeah. And a good support for that is this... the reason I believe it's the same for both is this (puts magnets together, lets them fly apart.)
(16:00)
ALLISON: So we only have to do the one way and say that it represents the other way because...
CHUCK: No, you should do both.
ALLISON: Right. Well, we'll do both.
CHUCK: We should do... guys, for this one, let's do multiple experiments.
DJANGO: Doing both? But they (?) the same.
(crosstalk)
ALLISON: So we need a way...
CHUCK: So we need a sheet of paper to do this on. Don't (?), do it on a piece of paper. Mark off distances...
BRANDON: Well let's write our hypothesis. You can write that. Might as well (?)
CHUCK: Do big bold lines! Are you sure you want to do this on a track?
ALLISON: (?) a blank... like a clear sheet...
CHUCK: A what?
ALLISON: Like a blank, um, I guess we could do it like this.
(17:00)
BRANDON: Oh, we're doing it on a piece of paper? Make it attract? (ALLISON: That way we have...) That's a great idea, yeah.
ALLISON: That way we can, we'll mark every... millimeter. We won't put a number, we'll just mark it.
DJANGO: How about this?
ALLISON: D'ya think? (holds one magnet up, knocks it over with another one.)
BRANDON: Niiice.
ALLISON: The distance?

CHUCK: That's a matter of different surface areas. Cause watch...
BRANDON: But that's constant!
CHUCK: No no no no no no no, it's gonna be able to go closer because of the surface area difference.
BRANDON: Oh yeah?
CHUCK: Whereas, if you have it like this, hold on (BRANDON: I have an idea...) But look, already here... (?) the entire thing...
BRANDON: No, no, that's a great idea. I got it... it's great, you just do it on this...
CHUCK: It's close.
ALLISON: Can we mark that?
(18:00)
BRANDON: No, that's not what I mean. Hold on. No, this is there. Okay? You can put a ruler right here... this is constant... friction... how close does this have to go to that before it knocks over.
CHUCK: Different surface area.
BRANDON: But it's the same for your tra... as long as (DJANGO: This is the same.) in your experiment you're recording the same... what do you mean?
CHUCK: The amount of surface area of this area right here is different from that surface area.
BRANDON: Well then we'll find something flatter.
DJANGO: Yeah, but then we can't do attract...
BRANDON: Stop being specific, think of ideas.
DJANGO: We can't do attraction that way.
ALLISON: Yeah... I think that...
BRANDON: Well you can kind of do attraction this way too, it's just...
ALLISON: I think that we need this, because we need to prove the distance in order to say the stronger... the closer together, the stronger the force.
BRANDON: The problem is (?) we're gonna come up with a max value, and everything within it is gonna be encompassed.
CHUCK: That's why we're doing... that's why we're doing the track.
DJANGO: What if we went this way...
BRANDON: See if you can make it (?)
DJANGO: Then they have the same surface area.
(19:00)
CHUCK: Huh?
DJANGO: Then they would have the same surface area.
CHUCK: The same surface area.
BRANDON: My point is, no matter how you measure this,

once you (?) the max distance... what is... what is... what are you gonna.. are you gonna time how fast this thing goes?

CHUCK: No, no.

BRANDON: Once you figure out a mass distance... max distance... everything within that distance is encompassed, and you just write “yes”.

ALLISON: No, that’s why you need this, because you need to say how far it travels. Like, it travels further...

BRANDON: In an amount of time.

ALLISON: No, I don’t... that doesn’t matter. It just travels further the closer together... no....

DJANGO: But that’s...

BRANDON: But you’re gonna get a... oh the repel one!

ALLISON: The repel.

CHUCK: Why don’t we just do repel.

BRANDON: Yeah, the repel... yeah.

ALLISON: We need the track.

CHUCK: For the repel... need the track.

DJANGO: I don’t know how to compare to the... to the attract...

CHUCK: The attraction... we basically see just how fast...

BRANDON: The max value...

CHUCK: What happens with the attraction is the closer it is the faster (?) closer to the (?)

(20:00)

DJANGO: Right, but look. We have to find... force on distance... depends on distance.

ALLISON: So this is distance.

DJANGO: By this... jumpin’ out there, it’s not gonna have any more. It’s, it’s gonna get to a point where it’s not even gonna... beat off each other, and it’s gonna still keep going.

CHUCK: Yeah, that’s what we were talking about.

BRANDON: I think that’ll work for repel. But, but I don’t know about... I know it won’t work for the attract. It can’t. Are you saying there’s a max distance for repel, too?

ALLISON: There’s a max distance, which is when they’re right next to each other. When you get them a millimeter apart...

BRANDON: That’s true, cause you’re going the opposite... that’s the opposite as the attracting force. See with the opposite... with the repel, you start, that’s the max... it’s gonna go.

ALLISON: Well we can just... all right...

DJANGO: It’s supposed to go that way.

ALLISON: Here’s how we do attract. We start at the very end. We start at, you know, as far apart as possible. No, no, no, no... listen... with

(21:00)

repel, we’re putting.. we’re starting them together... with attract... you start them far apart. You’re like, okay, nothing happens, move it a little closer together... nothing happens, nothing happens, nothing happens... so you’re proving that with distance nothing happens but when you get closer, something does happen, and once something happens, then it all happens (BRANDON: That’s true, you’re right, you’re right, you start...) but we just have to show that we like, when we start back, nothing happens, so, as distance moves closer... as the distance moves closer the force... increased.

BRANDON: Rather than actually drawing this map right now, just draw... we should draw a big overview of it, and we should draw what, what, we should already... we should draw what we’re measuring... what our graph’s going to look like.

CHUCK: Remember (?)

ALLISON: What do you mean, what our graph is gonna... (BRANDON: Yeah, like) here.

BRANDON: Yeah, different paper. Cause you’re already... you already did a lot of work.

ALLISON: I’m just going to continue, cause we’re going to need this eventually, right?

BRANDON: So we’re gonna have a track, right? We’re gonna have a track like this. I mean, some of you guys gotta help me to make sure I’m not...

(22:00)

CHUCK: We’re gonna have a track.

BRANDON: There’s a track, right?

CHUCK: We’re gonna have a, we’ll have it on a scale.

BRANDON: Ah, should I call.. what do you guys want to call distance? D, R, or S?

ALLISON: D.

BRANDON: Okay. Um. Distance is going... is there going to be one taped down...

ALLISON: Yeah. We’re gonna hold... cause the rubber one isn’t gonna move. Cause we want one to move and not the other. So we’ll hold the one. We can hold it at a certain point. We’ll like mark a point. Yeah.

BRANDON: Okay. Uh... how are we going to set it in place, just hold it?

ALLISON: Somebody can hold it there.

(23:00)
DJANGO: Should I like, bring some sort of wheels for that though?
CHUCK: (laughs) No wheels!
ALLISON: I really want... I think that wheels would...
CHUCK: It's great, but it's not gonna work.
BRANDON: We need a long track, though. Long and... we have to bring a level, to make sure it's level.
DJANGO: There's a level over there.
ALLISON: What about one of those... um... like ah.... air... like ah...
DJANGO: Then it would just go on forever.
ALLISON: Oh, that's true.
CHUCK: Keep going.
BRANDON: As long as you keep the same track for everything. That's fine.
ALLISON: Yeah, we're using the same thing. We are... doing...
BRANDON: Distance?
ALLISON: Distance. Distance and...
DJANGO: I think we should come up with several ways to study this.
BRANDON: Yeah, I like that.
CHUCK: Tim?
BRANDON: For this experiment right now...
CHUCK: Wheels of some sort? Hot Wheels or something?
(24:00)
TA: Let me call my supplier.... It'll be here in six to eight weeks.
BRANDON: ...we're using distance... which is... which is substituted in as force.
ALLISON: Right.
CHUCK: Right at the end of the semester.
DJANGO: Let's go to Toys R Us or something.
TA: Do you have a way of measuring force yet?
CHUCK: Yes!
ALLISON: Yes.
DJANGO: Yeah.
ALLISON: We're...
TA: Okay, what's your plan?
CHUCK: We set up a track like so. With millimeters. We have one stationary magnet.
TA: Uh huh.
BRANDON: This is all repulsion, by the way.
TA: You're doing repulsion.
ALLISON: Mmhmm.
TA: Got it.

BRANDON: Um, we take another... magnet...
ALLISON: Hold it.
BRANDON: ...hold it at various distances away from this one (TA: Yes) and let it go (TA: Okay)
ALLISON: We measure the distance that it goes.
BRANDON: The distance that it goes is going to be big D, which is our... acting as our force.
ALLISON: It's like, the closer together, the larger the force.
BRANDON: That's our hypothesis.
TA: Okay, okay, so... so if there's more force, right, you expect it go farther.
ALLISON: Further.
(25:00)
TA: Okay. So, my question for you is, what is the relationship between force and that distance. Is it linear, or do you not know, or what is it?
ALLISON: It should be linear.
TA: Huh?
ALLISON: Should it be linear?
BRANDON: It seems, it...
ALLISON: Cause each... like as you get...
CHUCK: It's R squared.
BRANDON: It would seem that, just from our hypothesis...
TA: What's R squared? What's R squared?
ALLISON: Linear, right? No?
CHUCK: F equals K Q one Q two over R squared.
TA: Why are you using that equation?
BRANDON: This is magnetic.
CHUCK: (?)
TA: Well, I mean, this is about motion anyway, right? Isn't it also true, like, let's say I move this to two centimeters, and it goes away, right? Let's say I move it to one, it'll move away farther, you'd think, right?
ALLISON: Yeah.
TA: On the way, it will go past two. It's still... I mean, while it's being pushed away, it's constantly receiving a force, and that force is changing.
BRANDON: Yeah, it's receiving a force for a longer period of time at the one than it is...
(26:00)
TA: It's pretty tough to measure that force. I mean, how are you going to measure what the force is at the start? As it's pushing away, that distance is changing.
BRANDON: We need distance over time.
(Exit TA)
ALLISON: So we should...

BRANDON: Stopwatch.
CHUCK: Wait a second... mass... times... gravity!!!
BRANDON: I see what he's saying. He's sayin' let's say... this is one, this is two, this is three...
ALLISON: When it gets to two, it's still feelin' the force.
BRANDON: It's not the same force. If you do a rate, if you do a rate...
CHUCK: I'm just havin' fun.
BRANDON: Distance versus... what do you think about doing a rate thing?
CHUCK: We'll need the tracks.
BRANDON: How much time does it take to get to there, from there, from one, from two, from three...
ALLISON: You guys, this isn't going to work.
CHUCK: That's why we need the track.
(27:00)
BRANDON: Cause what he was saying was, if you do it from zero, you're still getting that... let's say you do it from one. Do it from zero, it goes this far, right? Well, you're still feeling the force from one, from two, and from three... wouldn't that make it exponential?
CHUCK: Parabolic.
ALLISON: It's stick to ah... it's sticking to the paper.
CHUCK: Parabolic's exponential.
BRANDON: Yeah, you're right. It makes parabolic. It doesn't matter, we've got to set something up.
ALLISON: It's not working cause it's... cause there's too much friction...
CHUCK: It's a relationship between friction and uh lack of...
ALLISON: Well, we can use these... within the track...
BRANDON: We're running out of time.
(28:00)
BRANDON: Okay, we got fifteen minutes before we should probably start taking data.
CHUCK: Well we should still be thinking about how to design the experiment.
BRANDON: All right, there's gonna be a session where we get feedback.
DJANGO: I'm gonna work on experiment two.
BRANDON: What's experiment... two?
(Exit 4)
ALLISON: There's like so much friction that it's not... going away... like... would it slide better on that? That's slippery, isn't it?
DJANGO: I'll get some Hot Wheels.

BRANDON: We need to stop and think about... what does time do if we bring it into this equation.
CHUCK: Get a... get a nice long strip of that.
ALLISON: I don't think it would work. There'd be like bumps.
(29:00)
DJANGO: It's.. it's kind of... it's one of those things that's kind of smooth and stick sometimes.
ALLISON: It's like (?)
BRANDON: At least we could convert it into a velocity, which is a... vector.
ALLISON: Velocity. And then velocity... make sure you... make sure that there's no... no wrinkles allowed.
CHUCK: I know, I know. There you go... nice... smooth... (applies tape to table) They're hanging it.
BRANDON: That's what I was thinking of.
(30:00)
BRANDON: I need one of those...
CHUCK: What?
ALLISON: Wait.
BRANDON: These?   (L-shaped wood thing)
ALLISON: It does work on this thing better.
CHUCK: It does? It works better?
ALLISON: Mmhmm.
CHUCK: Uh huh. But wouldn't you make those lines a little bigger?
BRANDON: It need to go this way.
ALLISON: I know. (?)
CHUCK: What?
ALLISON: We'll do this experiment and then... I don't know if we can actually measure time.
CHUCK: Time isn't necessary here. This is a matter of (?) acceleration and deceleration.
BRANDON: Okay, let's think about... this height... we shouldn't think about design. We can design it however we want. We should start, we should do theory. Like what's your theory here.
(31:00)
CHUCK: No, we need to design the experiment!
BRANDON: This IS the design. I mean, it really is. Once you have this, you can make anything. There's not any limitations.
DJANGO: So like, my theory is.
BRANDON: You got this magnet hanging from... a lever
(1 & 3 crosstalk)
BRANDON: Like that?
DJANGO: This one's better for distance. Different

distances.
DJANGO: Do we have to use both batteries like that?
(32:00)
BRANDON: Use what?
DJANGO: Like both batteries against each other?
ALLISON: Magnets?
DJANGO: Could it like, pick up some... (BRANDON: Something) paperclips?
BRANDON: Yeah. That's a very good idea.
ALLISON: But we're trying to... the force between the two magnets, depending...
DJANGO: No it's...
BRANDON: (?)
CHUCK: Watch this. It launches.
ALLISON: All right. Where...
(33:00)
BRANDON: Are you making this so that the string difference... something needs to be different. Something needs to move. Something needs to be our measuring device. Like... like how much it stretches, or how much (?) right here.
CHUCK: Guys, if we need a blade, I have one. Guys... a blade?
ALLISON: All right, yeah, um...
BRANDON: That's great.
ALLISON: This's really hard. Are they all going to be like... there's no way to do this... type of thing?
CHUCK: Great Caesar's ghost!
(34:00)
CHUCK: We can tape this down or we can like... something so that we don't have to hold it like that... where's the other one?   He has the other magnet.
BRANDON: So what are you measuring?
DJANGO: I don't know.
CHUCK: He's just having fun.
DJANGO: I'm thinking.
CHUCK: Guys we have our table, we have our little uh slider ready...
BRANDON: What if... get something... it can't... I guess it can't be metallic. But it has to weigh... as much as this puppy here. (ALLISON: So (?) like this is our starting point.) You put an even weight on the other string...
CHUCK: Do... do units of five on that thing... like every five make it longer since we know...
BRANDON: Start at a...
ALLISON: Wait, one... one, two, three, four...

CHUCK: First one’s zero.
(35:00)
ALLISON: Zero, one, two, three, four, five...
DJANGO: You’re missin’ it.
BRANDON: I know, I’m trying. I was thinking that would be weighed into it, but like if you had a weight on this side, and you bring that closer to this... it’s how much it pulls the weight... up.
DJANGO: Wouldn’t it go until it hits this, then?
BRANDON: (laughs) Maybe. I don’t know... hold on... but I do like it. Yeah, it’s someth... (DJANGO: We need two pulleys) we need something that measures, do you know what I’m sayin’? No, no, no. You want this other rope... attached to the weight. But you can’t have it... you can’t have the other weight metal, cause you don’t want it to attract this.
DJANGO: We’d have to get them to repel, and see how much it repels it there.
BRANDON: No, because... if the other side of the pulley was on it, it would be.. and you had the same weight, it’d be like equalized right there... so let’s say my finger’s the other weight I’m talking about. It’s hanging onto this.
(36:00)
BRANDON: And that’s equal. That’s at an equal distance, right? Now you take a meter stick upright... now that’s gonna pull my thing up... a certain distance... it’s gonna pull this weight up that distance.
DJANGO: Right.
BRANDON: But then it goes back to that same problem he was talking about with the time. Because no matter what, this zero is gonna pass the same measurement you made for one, which is gonna pass the same measurement you made for two, pass the same measurement you made for three... or... you could always subtract this guy... no, you can’t. Well, think about a different kind of force. Like height. As you get higher, the tension... the force gets... the force doesn’t...
CHUCK: Guys... I say we should try this one.
ALLISON: We could time it.
CHUCK: Time what? The repulsion? Or the attraction?
(37:00)
BRANDON: So what is this... but we’re gonna time it...
ALLISON: Can I see the... can I just see the...
CHUCK: Why don’t you measure the time of repulsion?
ALLISON: Because... of what...
CHUCK: You don’t have to.

DJANGO: Until it stops... is that what you're talking about?
ALLISON: Yeah.
CHUCK: You don't need that cause...
ALLISON: No, because... from here... oh... no, I don't think the time... because it's less... it's not going as far... (CHUCK: Exactly) so it's not gonna be as long.
CHUCK: You have to measure distance on this.
ALLISON: But he said... okay, what Tim was saying though, is that, as it passes, like, one millimeter, it's gonna get the force from like each close...
BRANDON: ...from two, and it's gonna get the force from when you start at three. If you start at zero...
CHUCK: That's why it shoots the farthest.
BRANDON: ...it moves out here, yeah, because you keep getting that force. (?)
DJANGO: There's an equation for that, isn't... you can just do exponential, right?
(38:00)
BRANDON: Yeah, that's what I'm saying, it's mathematical. It's a mathematical relationship. Is it exponential, is it? When you keep, when add this and you add that and you add that you keep adding that distance as you go. You keep adding that next one.
DJANGO: I wish I was smart.
ALLISON: Isn't it like...
BRANDON: Me too! Like... the zero... is the max repulsion because... all these added up. And then you have your four repulsion, which is gonna be equal... which is gonna be... three is gonna equal... uh, some number minus the four repulsion. Two is gonna equal... some number minus the three plus four repulsion. One is gonna equal some number plus... you know what I mean? That number is... is the force... that's happening.
DJANGO: So there's a constant.
(39:00)
BRANDON: Maybe.
DJANGO: But we got to find every single millimeter in between too.
BRANDON: Yeah, that's true. If that's really a constant.
ALLISON: Gimme a piece of paper, please.
BRANDON: What do you need?
ALLISON: Can I have a piece of paper out of there?
BRANDON: I don't have much paper left.
ALLISON: It's my notebook!
BRANDON: Okay... that's a good idea, actually. We gotta

use the spring constant. It’s complicated. We just need to figure out these mathematics. Once we figure out the mathematics, we’ll be fine.
(Enter TA)
(40:00)
DJANGO: We’re not sure if that’s like an exponential growth or decline or if there’s a constant involved.
TA: Do you know, do you know... right.
BRANDON: There’s gotta be a max... that we’re gonna be able to...
TA: Do you know how far it’ll go, distance-wise? You will have to know how the force depends on distance. Because, whatever the force is, that affects what the acceleration is.
BRANDON: That’s what our question is.
TA: That’s what the question is, so... you’re trying to measure force, and to do it by moving it distance, in that kind of way, is circular.
ALLISON: But... but we’re saying that the distance is... the...
BRANDON: We need to use... other forces...
ALLISON: We’re trying to say like, that the distance... is the... like the further it goes... the more force. Like that’s... you can assume that.
(41:00)
TA: Um... yes. There’s more... I mean, right. The farther it goes, the more force is must’ve had on it to start with, but, you need to relate that distance you measured to the force you’re actually interested in. Okay.
ALLISON: No.
TA: You’re trying to measure force. The thing you’re physically measuring is distance. You need a bridge to get from that distance to force, somehow. You get to (?), it might not be linear. It might take twice as, or four times the distance.
(Exit TA)
ALLISON: I don’t understand.
BRANDON: A bridge to get from... the force... the distance...
ALLISON: So do you think... well, the timing won’t work.
BRANDON: That’s why (?)
CHUCK: I think we got a stopwatch (?)
BRANDON: It’s definitely a hanging deal.. (laugh)
CHUCK: Meters per second squared.
(42:00)
ALLISON: Yeah, but how do you...

BRANDON: Gravity’s... see, here’s M G H, if it’s hanging. Um... it’s just a... um... it’s just uh...
(inactivity)
BRANDON: These are pulleys. And this was that weight.
ALLISON: Distance is...
BRANDON: This was the same weight...
DJANGO: So if we get the opposite with the same (BRANDON: same) here, and push... and put it at certain point, and then flip it up and see how... that’s the same thing, man.
BRANDON: Same idea.
DJANGO: Yeah.
BRANDON: Because you measure distance. We can, we can figure out um.. how much weight it will lift up... different weights...
DJANGO: Yeah...
(43:00)
ALLISON: To be... put something onto one of the weights... like one weight is holding it, and this is holding something else...
BRANDON: It takes force to lift something! It’d be M G H then, if we lift it, and M would be...
ALLISON: *gasp* We put paperclips on them! And the more paperclips, the heavier it’s gonna be... so we just see...
BRANDON: Same height...
ALLISON: At the same...
BRANDON: Same... we can’t do paperclips, we’d need a lot of them... for that...
ALLISON: Well we do like little...
BRANDON: We need two pulleys... we need two pulleys.
ALLISON: So weight is a force, so it’s showing the force... but what... where does distance come into play? Do we measure the distance?
BRANDON: And another pulley!
(TA calls for students to hold discussion)
ALLISON: I like this idea.
BRANDON: I don’t know... I guess...
ALLISON: I feel like that’s what they’re doing...
BRANDON: This idea... I like this idea...
ALLISON: All right. Screw that. I’m the... it’s like...
BRANDON: What kind of relating...
ALLISON: Force... we’re relating two forces.
BRANDON: How much force does it take to lift it...
ALLISON: How does that relate to distance?
(45:00)

BRANDON: Weight. How it relates to weight.
ALLISON: Yes, but we have to depend on the distance between them...
(TA instructions)
BRANDON: We have to take data today?!
(TA instructions)
(46:00)
BRANDON: Okay, well first we thought maybe we could design a track and measure distance. But then, when you do that, you end up, kind of, going in circles with the force that you're trying to get. Cause you're trying to say that distance is the force. So then we started thinking maybe we should use, um, something uh hanging off of like two pulleys, and, use weight, sort of, like M G H... different weights... and how that relates to the attraction between magnets. We're on that wavelength right now.
(Group 3 presents)
(47:00)
(Group 1 presents)
(48:00)
(49:00)
(Group 4 presents)
(50:00)
(Group 5 presents)
(51:00)
(52:00)
BRANDON: Yeah, I was just thinking that, like, we're sort of measuring a force like M G going up, based on a certain distance that magnets are away from each other, but the thing that's changing there is mass, and then the distance that you space them. So I was just gonna run this by everybody, cause I don't always catch things. If you do trials with different distances the magnets are from each other, based on... and you do different masses for each of those.
V: How are you attaching your... the mass to the magnets? How are you.. are you actually attaching...
(53:00)
BRANDON: No, it's on a pulley system, so the mass is actually on the other side. (V: Oh, okay) And then the magnets are gonna be set a certain distance, and what you're measuring is the attractive force.
V: Any idea how much the change in...
BRANDON: Yeah, in some ways it might not even lift. But we do five trials and we would do.. uh, you would do different... that's how... those five trials would

represent different distances those magnets were. And as the one pulled closer to the stationary one's down here... as the one pulled closer to the stationary, it would lift the weights.
V: So do you think that (?) so the magnets come together and they don't move at all? I mean, or...
BRANDON: No, you're going to have different.. different weights to be able to tell how... the M G is what you're measuring the force over there... to tell you...
DJANGO: I don't know whether or not what you're saying is...
ALLISON: Yeah, I'm like, oh, I don't know what you're saying.
BRANDON: That's why I ran it by the group.
TA: Tyler had a question... cause, they claim they ran into problems because they're doing something where you're attracting magnets, right?
(54:00)
V: (something about what 2 just said)
TA: Okay, so, how is what you are doing different than.. you're not actually attracting them and letting them snap together are you? I mean, how is what you are doing different? Are you starting with them sort of...
BRANDON: Well there's a resistence already with this weight. Sometimes it might just attract together. What we're doing is... okay, here, I guess we need a visual on this.
V: Would you be like, would you be putting weights on it to see like...
TA: Maybe I just don't understand what you said.
BRANDON: Okay, that's usually the case. Um... not you personally, but anyway... you have one stationary magnet that's like taped. That's down here. The other one is on a pulley system with different weights that have to be set and established, cause we don't, I don't know how much these things way. So, then there's different trials. And those trials are based on different distances away from that magnet. You're gonna have to find a set weight though, for it to be sort of equal so you can position it where you want it.
(55:00)
TA: When you take a data point, though, nothing is moving? Is that true?
BRANDON: When you take a data point, your trial's at... you're only measuring the amount of weight, so, you're measuring just a force. At different distances though, you have five different trials. So you can plot it

several different ways. You could plot it as force against distance, or you could just plot mass versus distance.
TA: I can't picture this.
DJANGO: I think we'll have to do it. Cause I can't picture it.
ALLISON: I can't picture it.
V: (question)
BRANDON: The distance is already set. The weight is the variable.
V: You just vary the weight?
BRANDON: Yeah.
(58:00)
TA: So if you want to keep communicating about this, I would suggest that you build it, and then, you just check out what it is they're doing, and see if it works better. I don't know.
BRANDON: And if it doesn't, yeah, I mean, I don't know.

Group Four

0:00)
BETH: (reading from lab report grading) "Very good also, except that the term 'all slopes' in your rule is not very clear. All slopes... to be...
AMELIA: "Between any two points or between consecutive points only." (?) Well, we were looking...
DIANE: *laughs* Did you see this guy? Which action figure is that, anybody know? My lack of...
CARL: Magneto maybe? I don't know.
TA: Of course it's Magneto!
DIANE: Is it?
AMELIA: I love that movie.
DIANE: That makes sense...
CARL: It just looks different in the movie.
(TA gives instructions on lab handout.)
(1:00)
(2:00)
(TA asks class to brainstorm ideas. "What do you have to measure?" "How would you measure distance?"
(3:00)
(TA asks "How would you measure force?")
CARL: (whispers) Computer program.
BETH: How far it moves from its initial position? I don't know. Cause if, like, you pulled the two centimeters and you moved it in right away, you know that the force is stronger. But maybe if you move it out like six centimeters it'll move in a centimeter (?) move in the whole way?
TA: Okay, something that you could compare forces and know which ones are stronger and weaker.
BETH: But I don't know how to measure the magnitude.
(4:00)
TA: But we need an actual magnitude.
(Another group suggests timing it. This group responds skeptically. "It moves really fast." Another group suggests charges, TA points out that magnets are not charges.)
AMELIA: Do you actually want 'em in a force, or can we use something that's representative... of it.
TA: Not only do we want, but we absolutely MUST have a FORCE.
AMELIA: Oh. Aight.
(5:00)
(Class talk)
TA: Have you ever seen a detector that measures force?

I’m asking, have you?

DIANE: The tension? When we’re doing like a spring, like the oscillation, wasn’t it like a force density thing?

TA: You mean when we did that thing with the springs and we had that little force probe that measured the force?

DIANE: Yeah.

TA: That? Oh yeah, if you look at that little box you have, you’ll see one of those. I wasn’t saying that you were wrong, I just wanted you to remember that yes you had used this thing before. Now, so you have this, and you can use it, and you know the program is on here to do the, you know, it’s the Old Motion Detector program that you used last time. There’s also a motion detector in there you could use, if you want. There are other ways to measure force as well, and there’s other...

(6:00)

TA: You can use anything in the room that you want... so... how would you like to do that? So you have... to think about precisely how you’re gonna set this up to measure force and how you’re going to get this distance between the magnets. Now, here’s the other issue. What... what sort of data do you need? Good answer! You’re gonna have to find the relationship between force and the distance... apparently there was enough force there (?) distance.

(7:00)

(Class talk “Is one data point enough” No.)

DIANE: Because one is not... well you know the relationship between force and that one distance but... that doesn’t tell you how it varies.

TA: Okay.

(Class talk. Think about how to get different distances.)

(8:00)

AMELIA: All right guys, what are we gonna do first? I’ll be data. I haven’t done data in...

BETH: I can be the journalist. I haven’t done that in...

AMELIA: Have done eval... no... okay, I know what we should do for this...

(9:00)

BETH: How did (?) last time?

CARL: I was journal. Katie was checker.

BETH: And the week before journal you were what?

CARL: Checker.

BETH: Checker, yeah, so we are going in the right order.

AMELIA: I’m going to be evaluator next.
CARL: So I’ll be data?
BETH: After check... I haven’t done journal yet.
AMELIA: Journal is...
BETH: Then I’ll do journal again last. We do the first thing... aw, you’re lucky.
AMELIA: I just don’t want to be evaluator. I can’t do that, with the...
CARL: Yeah, we’ll see what we get this week.
AMELIA: I don’t want them to be like ‘this group, there’s something fishy... conspiracy...’.
BETH: I don’t understand how we’re going to use this thing.
AMELIA: Oh I know. Well, I don’t...
CARL: We need a spring... then we need to hook it up.
(10:00)
AMELIA: Hey, you’re a guy. You should know how to do this.
(Exit 3)
(Re-enter 4)
DIANE: These are more powerful and like you could probably see a better effect, except that it’s... like hard to...
BETH: Can I play?
CARL: Should I go to...
AMELIA: What we need to do... here guys, this is what we need to do. Come here, guys. I know how we should do this.
DIANE: What are you thinking?
AMELIA: Now the best thing is... the relationship between force and distance we’ll have to do um...
BETH: Jeez, this is so fun!
DIANE: How are we gonna... how we gonna measure it with this?
AMELIA: Well yeah but... we’ll have to do different distances, and then what we have to do is we do it like ten trials per each distance and we...
DIANE: With what... how are you gonna set it up though?
AMELIA: I don’t know. I figured Ryan’s a guy, he should know how to do it. But my point is that once we like...
BETH: Should we attach... something to the magnet... like, put them on...
DIANE: Do you want the less strong one? If that’d be easier to work with. Like this we could see a bigger effect.
(11:00)
BETH: Yeah, it’s so weird to like... (?)

(crosstalk)
AMELIA: So are we gonna have to like... put tape on these, like, closer to the spring?
CARL: I don't know. We gotta figure out how we're gonna measure force or whatever.
DIANE: I think we're gonna have to like, we'll have to keep, like, if you keep this, like, here, and then you have this attached somehow to up here, and then, yeah, well, what feels it? It's this thing pulling down?
BETH: Yeah. So I guess, if we hook the spring onto (?) that's the spring.
AMELIA: Right. So if it pulls... oh we need a loose spring, cause that's not gonna...
(Exit 2 and 4)
(12:00)
(setting up equipment)
(13:00)
(14:00)
(15:00)
(Enter TA)
TA: Why are you doing that? What are you gonna do?
AMELIA: Tie a magnet (?)
(conversation is going on off-camera)
DIANE: Oh and for this we're going to have to... we're gonna have to use the motion detector, right? Cause it'll pull it down a certain length and then we'll have to translate that thing into a force.
AMELIA: Well the thing is, we like... we like... you... a couple inches...
(16:00)
(phantom voice)
CARL: See, when we change the spring the (?) If we just... if we just... if we just changed the length of the fishing line... that might work. Like if we hook it over top of the force probe... put this... you make sure this stays on the ground... that'll give you something.
BETH: Tape that to the ground and then change the length of...
DIANE: All right let's try... let's see if that's better for what...
BETH: So we can make a loop?
DIANE: How are we gonna keep that on there? You could tape it on there.
BETH: Yeah, gimme a piece of tape.
CARL: Wait, are we gonna (?)
BETH: Well I think we should wait until the hook (?) and then we can run a piece of fishing line through it. Then

let the (?) change the length, like pull it up higher.
(17:00)
CARL: Or we can just (?) really long piece? If we tape a long piece of line, then we don't have to... cause (?) tape, do you know what I mean?
BETH: So just cut the... get a little piece and just cut it?
CARL: Or just like pull it up a couple of inches (?)
BETH: Okay.
(Exit 2)
DIANE: Which program is this?
CARL: For the motion detector.
DIANE: Hm, the only one (?) Uh oh. That's like cause this is not... is this... is this anywhere... is it plugged in or anything?
CARL: You need to find which way they attract and which way... they attract that way...
(18:00)
BETH: (?)
DIANE: If you just slipped a little string inside, would it just stay there? Oh no, we have to secure it anyway, I think it'd be... well you know like the force between... two... we just hold it between it?
AMELIA: How about we hang the...
BETH: Wait... what do you mean, between these two?
DIANE: Yeah.
BETH: It's glued together.
DIANE: Oh.
AMELIA: Wait... are you saying to put like... hold that one by the string and let that one just be attracted to that?
DIANE: Yeah we have to keep one like... planted on the ground.
CARL: No we have to... we have to let this one plant on the ground because there's... it's gotta feel force.
AMELIA: And why couldn't it go up that way? Why can't they attract that...
CARL: Because then that wouldn't measure the force because... this is what measures force.
DIANE: Oh that's true... and we would only be...
AMELIA: Yeah, it's that they are repelling... (?) this is gonna measure like something...
DIANE: Yeah we'd only be going one di... we'd only be going the attraction force then, yeah. That's what...
CARL: (?)
DIANE: Yeah that would be very difficult to know the compression.

(19:00)
AMELIA: So are just going to do different distances and then measure them and do like... do to see if it's like an inverse or direct relationship type thing?
DIANE: Sure... yeah.
BETH: You can wrap it the way you were... and then I'll wrap the tape around it...
AMELIA: (?)
BETH: So that the bottom is still exposed.
DIANE: But this is not working. The box is connected, the box is powered, the box is turned on. No, this is not on, probably, right? What does this (?) on the bottom?
Oh like a CD port.
BETH: So when you wrap it around (something technical about fastening magnets)
(20:00)
(Enter TA)
TA: All right what's up here. What's the plan?
BETH: All right. We think we're going to put this on the ground and tape it down so it can't move. And then, put this so that it's attracted to this, and then, tie it on here and change the length of like...
TA: Oh right, so you change how far apart they are.
BETH: Yeah.
TA: ...force for each of those different distances.
BETH: Yes.
TA: Okay.
BETH: Yeah.
DIANE: So we don't... we don't need... we can just measure the force use... okay... so we don't need the box here?
TA: You need the box. The little box in the back? Yes. But you don't need *that*.
DIANE: Yeah, that's...
TA: So... okay...
DIANE: Go on with that.
TA: No no no, that was wrong.
DIANE: Oh.
TA: The box I was referring to was that little box back in the corner that you plug this thing into.
DIANE: This plugs into...?
TA: So you want to exit the program. This force probe is plugged into a box.
(21:00)
(something)
TA: That box goes into the computer. You are using that

box. But you are not using the motion detector.
DIANE: The motion detector. How do I get out of here?
TA: That wasn't a question (?) Start it up again.
DIANE: It is this one though.
TA: Pick "Com 1"
BETH: So should we measure like lengths, like make (?) lines.
CARL: Make what lines?
AMELIA: Well I mean this one is being still.
(crosstalk)
TA: (something about program) Make sure the little box is plugged into the computer, oh, make sure the box is ON. Is the little box turned on? There's a power switch somewhere.
AMELIA: No. Yeah, I guess.
(22:00)
DIANE: So how did you guys end up doing that?
BETH: We're trying to figure that out.
AMELIA: Will it still be attracting when... I can't wait for the third X-Men.
DIANE: You're just trying to keep it on there?
(talk about hanging the equipment)
(23:00)
(24:00)
(This part is hard to hear. They discuss the mechanics of how to build the equipment.)
DIANE: All right. So let's start... let's see like what we can see based on, yeah, with what distance and what's possible to measure.
(?)
(25:00)
DIANE: Down to the floor.
AMELIA: Let's put some tape like on the bottom.
CARL: (?)
(More inaudible talk about setup.)

Appendix B: SCL-2 Materials

Everything You've Ever Wanted To Know About Lab… But Were Afraid To Ask

Mission Statement

You are going to learn three basic things this semester:

1. **How to recognize *relationships*.** All the complicated stuff that goes on in a physics lab can be boiled down to a simple premise: if you change one thing, another thing changes too. First we identify *what* changes. Then we try and decide *in what way* it changes. This is what we call *functional dependence*. That's all physics equations are, really, a precise statement about how changing one thing will affect another thing. In this lab, we will explore many different kinds of physical phenomena and try to figure out *what affects what* and *how.*

2. **How to make a persuasive case for your data.** In physics, answers don't just pop up out of the ground, ready to be printed in a textbook. Data from an experiment doesn't make much sense at a first glance. First you must be able to understand what data *means.* Then you need to be able to *present* this data to others in such a way that it will persuade them that the *conclusions* you've drawn from this data are correct. In order to do these things, you must have a good understanding of the limitations of your observations, or *how precise your data is* and *how well you can trust it.* For this, we will try to develop quantitative estimates of how accurate our results are.

3. **How to make a computer do the hard stuff.** We will be using the *Microsoft® Excel* spreadsheet to tabulate data, crunch numbers, and construct graphical representations of our data. Not that we can't do these things by hand, it's just that a computer can do it a lot faster, relieving us of a lot of busy-work and allowing us to do a lot more with our data. If you plan on going into research, it is essential to know how to use a computer spreadsheet.

The Experiments

This semester we will be doing five experiments, each of which will span two weeks. The first week is devoted to **data collecting,** *while the second week is devoting to* **data analysis.** *This is what you'll be doing:*

Week One

- *Brainstorming and Planning:* You will not be given step-by-step instructions on how to do the experiment. You will receive a short description of what you'll be investigating, and it will be up to you to design your *own* experiment. There are many ways to do this, so be creative and <u>work with the physics that you know.</u>
- *Data Collecting:* You will be given ample time to collect as much data as will be useful for you.

- *Presentation and Discussion:* Here you have an opportunity to show the rest of the class your method, and to see what other groups did.

Week Two

- *Analyzing Data:* Using Excel, you will be taking a close look at your data in order to decide what it means and how you can *prove* to others what it means.
- *Presentation and Discussion:* Different groups will frequently have contradictory results. This is your chance to present your case, observe other groups' cases, engage in healthy debate, and possibly reconsider your conclusions.
- *Class Consensus:* In some cases, each lab section will be trying to come to a single consensus conclusion.

Materials

Please bring with you to class each week:

- Loose-leaf paper for writing your lab reports. These will be collected by the TA and each group member will be given a copy. You may want to keep a folder or notebook for these labs, as they will be a useful reference for future labs and lab quizzes. (Papers torn out of a bound NB will not be accepted.)
- A calculator.
- <u>Anything at all</u> that you think will be useful. Our lab room has a huge supply of odds and ends for you to use in designing your experiment, however, feel free to bring in anything from outside that you feel may help your group out.

Grading

The lab grade makes up part of your total course grade. This grade will be based on:

- Lab reports
- Participation in the planning, experiment, presentation, and class discussion
- Lab practicals

Lab Reports

At the end of the two-week experiment, you will hand in a complete lab report. This report will include:

- *The Journal:* A discussion of what you did, how you designed your experiment, and what results you got, written so that an absent student could understand what you did.
- *Data and Interpretation:* Your data, in a form that would be easy for an absent student to understand. Here is also where you discuss what your data

means, what conclusions you've drawn from it, and a persuasive *case* proving that your conclusion is valid.
- *Evaluation:* After you've had a chance to see what data and conclusions other groups have gotten, it's important to go back and reconsider what you've done. Here is where you discuss how you could improve upon your experiment, in light of what you learned during lab and during the class presentations.

In writing your lab report, it is important to consider the following things:

- <u>Design and thoughtfulness</u>. Did you do a careful and thoughtful job in creating your experiment, and was this thought reflected in the journal?
- <u>Clarity and completeness</u>. Were you able to clearly explain your experiment so that someone could reproduce it?
- <u>Persuasiveness</u>. What conclusions did you draw from your data, and were you able to back up these conclusions with this data, in a convincing way?
- <u>Evaluation</u>. After observing the experiments of other groups, were you able to critique your own lab, make constructive changes, or if this is the case, explain why your experiment was better than those of your classmates?

Your grade <u>will not</u> depend on whether or not your conclusions agree with some accepted standard.

Roles

You will be working in groups of *four.* The division of labor will be as follows:

1. *The Journalist:* This person is responsible for taking notes of everything that happens during the experiment, and writing up the "Journal" section of the lab report.
2. *The Data Interpreter:* This person deals with tabulating and displaying the data, operating the computer, and writing up the "Data and Interpretation" section of the lab report.
3. *The Critic:* This person is responsible for taking notes during the class presentations and discussions, and for writing the "Evaluation" section of the lab report.
4. *The Checker:* This person is responsible for checking all sections of the lab report before it is turned in, and reading the comments made by the grader on past lab reports, and suggesting ways to improve.

You must rotate roles every week, so that each person gets a chance to do every task at least twice. While the lab report is a group grade, it is necessary that you show that you are pulling your own weight in the group work.

Participation

A portion of your grade will depend on your participation in the class activities. This includes taking an active role in presenting to the class and participating in the class discussions. Your TA will be observing your activity throughout the semester.

Lab Practicals

There will be two lab practicals this semester. As opposed to other lab activities, you will do this on your own and receive an individualized grade.

Attendance

The labs are an integral part of this physics course, so missing a lab will affect your comprehension of the course material and impair your progress through both the lab and the lecture part of this course. There are no makeup labs. If you miss or have missed a lab, contact your TA immediately. If have a VALID WRITTEN EXCUSE, you will be allowed to do a makeup activity that will take at least two hours. If you do not have a written excuse, you will get a zero for that lab.

Lab 0:

How To Use Excel To Illustrate Data

The purpose of this activity is to:

- ***Guide you through an example of what this semester's lab activities will be like.***
- ***Show you some of the features of Microsoft Excel that you will need to know about for future labs.***

This lab will <u>not</u> be turned in for a grade, however, it is a good reference for future labs and a good review for lab practicals, so keep it handy.

WALKING TO SCHOOL

Microsoft Excel is a spreadsheet program that can be used to tabulate, analyze, and illustrate information in a variety of different ways. You will use this program in every lab this semester to help understand your experiments and to communicate your results with others. Keep in mind that Microsoft Excel is available on almost every public computer in the university, in case you want to work with it outside of lab.

Suppose you are asked the following question:

How long does it take you to walk to school?

For the next ten days, you time how long it takes for you to walk from your apartment to school. You get the following times: 21 min, 25 min, 22 min, 22 min, 19 min, 26 min, 23 min, 24 min, 19 min, and 21 min.

In the next sections, you will learn how to illustrate your data using the Excel spreadsheet so that it conveys the right amount of information.

Creating a Data Set

A. **Double click the** Excel **icon. This will open the program**

B. **In cell** A1, **label the "A" column "Days". In cell** B1, **label the "B" column "Times".**

Under the "Days" column, you want to list the ten trials you took. Sometimes, when the number of trials is large, it can be a pain to have to fill in every number by hand. There is shortcut around this. In A2, **type "1". In** A3, **type "2". Now select these two cells. Notice a small square on the lower right corner of the selected cells. This is the** fill handle.

C. **Click the fill handle and drag it all the way down to 10, or however far you want. Excel will automatically fill in the rest.**
D. **Under the "Times" column, enter your data, the times recorded to get to school. Now you have a simple data set to work with.**

Graphing Data

At the top of the screen is a blue, yellow, and red icon, the Chart Wizard **icon. Click this and a menu will pop up. Here are fourteen different ways in which your data can be graphically illustrated. You'll find during this semester that different kinds of data are best shown with different kinds of illustrations. Select** XY (Scatter) **and hit** Next.

A. **Here Excel asks you which data set you want to graph. Using the mouse, highlight the two columns of information you want to use. It will give you a preview of how this chart is going to look. This illustration is a basic point plot graph with the days on the x-axis and the times on the y-axis. Hit** Next.

B. **Excel now asks you to select what data you want to graph. Highlight the two columns (without the titles) and hit** Next.

C. **A graph needs to be detailed enough so that one can understand it without an explanation, yet concise enough to be understood at a glance. That's why you must always give your chart a title and label your axes. Title your chart "Time it Takes to Walk to School". Label your x-axis "Days" and your y-axis "Time". Hit** Next.

D. **Now Excel will give you the option to either place this chart next to your data, or on a separate sheet. For this chart, select** As new sheet, **and hit** Finish. **You now have a chart that displays your data!**

Certainty Bars

Very few things you can measure in the real world can be determined "exactly". Therefore, when referring to a scientific figure, it is important to specify how "certain" any figure is. For example, there is a big difference between saying that something costs "five dollars and six cents", and saying that something costs "around five dollars". Any time you take a measurement, it is important to determine how certain you know that calculation and to include that certainty with the calculation itself.

Let's say that after you finish timing your walks to school, you notice that there are discrepancies between the different timing devices you used. Some days you used a wristwatch. Some days you looked at the clock in your apartment before you left, and checked the clock at school when you arrived. And some days you asked a friend for the time.

After comparing these different clocks, you determine that there is at most a 3 minute discrepancy between different devices. Since you're just doing this experiment for fun, it is not important to be more precise, but it is still necessary to determine how well you know your result. You're going to place a 3 minute error bar **on each data point, so that you can see that any given point could be either 3 minutes too high or low.**

A. **On your chart, double-click one of the data points. Select** Y Error Bars. **Choose** Display Both. **Select** Fixed Value **and type in "3". Hit** Okay. **Now each of your data points has a certainty assigned to its time value. Keep in mind that you can also assign a certainty to the x-axis parameter, if necessary.**

There are many ways one can determine the precision of a measurement.

Some lab devices actually state a "tolerance level", or, how close it can determine that it is measuring. Things like reaction time can be measured by you. And other things, like the reading on a scale, one can make a rough estimate of how well one can read the needle.

But however you do it, it is absolutely important that you assign a level of certainty to <u>any</u> calculation.

☆ **Check with your TA before proceeding.**

BURNING OUT LIGHT BULBS

Now that you know the basics of compiling and plotting data, you will now perform an actual experiment and produce illustrated data for a grade.

How much voltage does it take to burn out a light bulb?

Normally it will be up to you and your group to design your own experiment to accomplish this task. Today you'll be guided through it.

Collecting and Analyzing Data

A. **You have been given an** electrical power source**. This box can supply a current of electricity to an electrical circuit. Notice the** voltage dial. **You can change the amount of electricity this box produces by raising or lowering the voltage.**

B. **You have been given six** Christmas lights**. Notice that there are two wires leading out of the bulb. Using an** alligator clip **and a** cable, **connect one of these wires to the red plug on the power source marked with a "+". Connect the other wire to the black plug marked with a "-".**

C. **Find out how much voltage is required to burn a bulb out! Do this with all six bulbs. Keep track of your data on a new Excel spreadsheet and create an appropriate graph of your data.**

D. **How well were you able to determine the maximum voltage of each bulb? Create the appropriate error bars on your graph.**

The Test

What's the highest voltage at which *most* of a collection of bulbs will stay lit without burning out?

Your group will be asked by the TA to submit a value answering this question. At the end of the class, the TA will light a bulb up until it burns out. The group that submits the highest voltage *without* going over the burning-out voltage will receive extra credit.

☆ Class Discussion

To Hand In

Make sure your groups' names are on your two spreadsheets. Save your data to your group diskette for a grade.

Optional

You'll be using Microsoft Excel all throughout this course, so you'll need to get used to it. If you have time at the end of lab, or in your spare time, try experimenting with different charts. There are many different ways you can display your data. Remember that neatness counts and creativity is rewarded.

Excel Hints

Graphing Equations

Let's say you want to make a graph of a function. In the "A" column, fill in a list of x-values you want to use as your range (1 through 10, for example). Next, click on the cell B1. In here, fill in the function you want to use, preceded by an equal sign, for example: "=3*x" to make a linear plot with a slope of 3, or "=x^2" for a parabolic function. In B1, the y-value corresponding to A1 will automatically appear. Drag the fill handle down to fill in the rest. Finally, plot the data.

Remember, you can work with several sets of data at once, as well as refer to different sets when tabulating a new set. For example, if you have data in columns A, B, and C, you can make a sum of this data in the D column by filling in cell D1 with "=A1+B1+C1".

Multiple Plots

When plotting your data, you can select several different columns and plot them simultaneously on the same graph. This is useful for comparing data. **Highlight** several columns of data and hit the **plot** icon. It will automatically use the first column as your x-values and each other column as a y-plot.

Error Bars

There are a few different ways you can put error bars on your data. On the graph, double click one of the data points and a menu will pop up. Under **X Error Bars** or **Y Error Bars,** you can select the **Error Amount.**

- Selecting **Fixed Value** will put the same size error bar on all your data points.
- Selecting **Percentage** will create error bars whose size is proportional to the value of the data point.
- You can also enter in manually the error bars for each data point by selecting **Custom** and specifying both a column that contains "upper limit" values and a column that contains "lower limit" values for the error bars.

Which method you use depends on how you determined the uncertainty in your measurement. You must be able to justify *why* you chose particular error bars.

Other Tools

Click on the "Σ" at the top of the screen. Here is a list of useful tools that can be used with data sets:

- To **Sum** data**,** first highlight a cell you want the sum to appear in, then select **Sum** under the Σ icon. Next, highlight the data you want to sum and hit enter. The sum will appear in the cell.
- To **Average** data**,** first highlight a cell you want the average to appear in, then select **Average** under the Σ icon. Next, highlight the data you want to average and hit enter. The average will appear in the cell.

Lab 1: Damped Oscillations, Part One

You have been asked to design a metronome for a famous pianist, and you have decided to use a spring with a small mass attached, which will bounce up and down with the beat. Now, this metronome will only be useful if the *period* (or the time it takes for one full cycle) of an oscillation stays the same over a long enough time interval (at least for a three minute tune). When you let the spring oscillate for a long period of time, you observe that the amplitude gradually gets smaller. What about the period?

Question: *Does the period of a spring stay the same over time?*

This week you will focus on **data-collecting.** Next week, we will do a lot more with your data and try to answer some more questions about your metronome, so use your time wisely and take as much data as time allows.

Timetable

I. Introduction:		**10 min**	**Whole class**
II. Brainstorming and Planning:		**10 min**	**Groups of 4**
III. Carrying out the Experiment:		**40 min**	**Groups of 4**
IV. Class Discussion:		**30 min**	**Whole Class**
V. Evaluate and Reconsider:		**15 min**	**Groups of 4**

Lab 2: Damped Oscillations, Part Two

This week is a continuation of last week's activity.

You have been asked to design a metronome for a famous pianist, and you have decided to use a spring with a small mass attached, which will bounce up and down with the beat. Now, this metronome will only be useful if the *period* (or the time it takes for one full cycle) of an oscillation stays the same over a long enough time interval (at least for a three minute tune). When you let the spring oscillate for a long period of time, you observe that the amplitude gradually gets smaller. What about the period?

Question: *What happens to the period of a spring over time?*

This week you will focus on **data analysis.** Last week you took data to decide whether or not the period stayed the same. Today you're going to *prove* whether it does or doesn't. Your goal is to develop a strong, quantitative argument proving that either (a) the period stays the same, or (b) the period changes over time.

Timetable

I. Introduction:	**10 min**	**Whole class**
II. Brainstorming and Planning Meeting:	**10 min**	**Groups of 4**
III. Carrying out the Experiment	**40 min**	**Groups of 4**
IV. Class Discussion	**30 min**	**Whole Class**
V. Evaluate and Reconsider:	**15 min**	**Groups of 4**

You will be turning in the following things in your lab report for a grade.

(From last week)

1. Journal
2. Evaluation

(From this week)

3. Data interpretation
4. Evaluation

Lab 3: Ohmic Materials, Part One

There are some materials that conduct electricity so that the *current* that flows through it is *linearly proportional* to the applied *voltage*. Such a material is called "Ohmic". If you know that a material is Ohmic, you can tell what the current is just by knowing how much voltage you are applying. Predictability is important for certain electrical hardware.

Questions: *Is an electrical resistor Ohmic?*
Is a light bulb Ohmic?

This week you will focus on **data-collecting.** Make sure to collect enough to data so that next week you can *prove* whether or not these materials are Ohmic.

Before you begin, present a plan of how you're going to carry out this experiment and how much data you're going to take, i.e. how many trials and data points you will collect.

Timetable

I. Pre-lab Discussion	**10 min**	**Whole class**
II. Planning the Experiment	**20min**	**Groups of 4**
III. Data Collecting	**40 min**	**Groups of 4**
IV. Class Discussion	**25in**	**Whole Class**
V. Writing the Report	**15 min**	**Groups of 4**

Lab 4: Ohmic Materials, Part Two

This week is a continuation of last week's activity.

There are some materials that conduct electricity so that the *current* that flows through it is *linearly proportional* to the applied *voltage*. Such a material is called "Ohmic". If you know that a material is Ohmic, you can tell what the current is just by knowing how much voltage you are applying. Predictability is important for certain electrical hardware

Question: Propose a "rule" that determines whether data is linear or not.

According to this rule, are either of your materials Ohmic?

For the class discussion, be prepared to state clearly what your standard for linearity is, and prove whether or not the resistor and the light bulb are Ohmic.

Timetable

I. Introduction:	**10 min**	**Whole class**
II. Brainstorming and Planning Meeting:	**10 min**	**Groups of 4**
III. Carrying out the Experiment	**40 min**	**Groups of 4**
IV. Class Discussion	**30 min**	**Whole Class**
V. Evaluate and Reconsider:	**15 min**	**Groups of 4**

Lab 5:   Magnetic Force, Part One

When you hold two magnets close to one another, they feel either an attractive or a repulsive force between them, depending on their orientation. It appears that the magnitude of this force depends on the distance between the two magnets. But how?

Question: How does the force between two magnets change if you change the distance between them?

Timetable

I. Pre-Lab Discussion		**10 min**	**Whole class**
II. Planning the Experiment		**20 min**	**Groups of 4**
III. Data Collecting		**20 min**	**Groups of 4**
IV. Class Discussion		**20 min**	**Whole Class**
V. More Data Collecting, Lab Report		**40 min**	**Groups of 4**

Lab 6: Magnetic Force, Part Two

When you hold two magnets close to one another, they feel either an attractive or a repulsive force between them, depending on their orientation. It appears that the magnitude of this force depends on the distance between the two magnets. But how?

Question: Describe *quantitatively* the relationship between magnetic force and distance between the magnets. Use whatever tools and techniques you'd like, as long as they can be explained to the rest of the class during the presentation.

<u>Timetable</u>

Planning the Analysis	10 minutes	Groups of 4

- ***How are you going to illustrate your data?***
- ***How are you accounting for uncertainty in the measurements?***
- ***What seems to be the behavior or features of this relationship?***
- ***How can you quantify this relationship so that it can be communicated to others?***

Data Analysis	**50 minutes**	**Groups of 4**
Class Discussion	**40 minutes**	**Whole Class**
Writing the Report	**10 minutes**	**Groups of 4**

Lab 7: Light Refraction, Part One

When light moves from one medium into another, it appears to change direction. We call this change of direction "refraction". We would like to explore the refraction of light through water.

Questions:

What determines how much light refracts when it enters water? How can you describe the refraction quantitatively?

<u>Timetable</u>

I. Pre-Lab Discussion		**5 min**	**Whole class**
II. Planning the Experiment		**30 min**	**Groups of 4**
III. Class Discussion		**20 min**	**Whole Class**
IV. Data Collecting		**40 min**	**Groups of 4**
V. Writing the Lab Report		**15 min**	**Groups of 4**

Lab 8: Light Refraction, Part Two

When light moves from one medium into another, it appears to change direction. We call this change of direction "refraction". We would like to explore the refraction of light through water.

Questions:

What determines how much light refracts when it enters water? What is the quantitative relationship between this factor and the refraction?

<u>Timetable</u>

I. Pre-Lab Discussion		**5 min**	**Whole class**
II. Analysis:		**50 min**	**Groups of 4**
III. Group Presentations:		**30 min**	**Whole Class**
IV. Class Discussion:		**10 min**	**Whole Class**
V. Evaluate and Reconsider:		**15 min**	**Groups of 4**

Lab 9: Double-Slit Interference, Part One

When a beam of light passes through two thin slits, something funny happens. The light creates a pattern on the other side that looks like this:

This is what we call an "interference pattern". This week you will be investigating this phenomenon.

Questions:

1. What things might affect the spacing between the bright spots? After you've brainstormed some ideas, call your TA over to help you narrow it down to *two* factors for you to investigate experimentally.
2. What is the relationship between the spacing of the bright spots and the two factors? Design an experiment that will explore these relationships.

<u>Timetable</u>

I. Brainstorming:		**15 min**	**Whole class**
II. Taking Data:		**30 min**	**Groups of 4**
III. Class Discussion:		**10 min**	**Whole Class**
IV. Taking Data-:		**30 min**	**Groups of 4**
V. Writing the Lab Report:		**25 min**	**Groups of 4**

Lab 10: Double-Slit Interference, Part Two

When a beam of light passes through two thin slits, something funny happens. The light creates a pattern on the other side that looks like this:

This is what we call an "interference pattern". This week you will be investigating this phenomenon.

Questions:

3. You have chosen two factors to explore for a possible relationship to the spacing of the bright spots. How well can you describe these relationships?
4. After observing what other groups in the class have done, can you pool together all the information and build a more accurate model of what things affect the spot spacing?

Timetable

I. Data Analysis:		**60 min**	**Groups of 4**
II. Group Presentations:		**25 min**	**Whole Class**
III. Class Discussion:		**10 min**	**Whole Class**
IV. Writing the Lab Report:		**15 min**	**Groups of 4**