[background music]

Eric: We have a lot of ground to cover. I'm going to try to go fast over the introductions here. First of all, form set two was posted. It's due a week from now. If you need help with it, we have posted our office hours. Mine, for example, are Wednesday mornings, 10 to 12. Feel free to make abundant use of that if you feel you need help. One very important announcement has to do with the projects.

We're only two weeks away from fair number one and it is absolutely important that you order your project materials by tomorrow at the latest. Today or tomorrow. If not, you won't have them next week and we'd like to have them to you on Monday, so you have 10 days to put your project together. Which is not much. Okay? This is a short project. The next one will be longer and the last one will be short again.

Also, work with your mentor. Each team has been assigned a mentor. Make use of the mentor both in the classroom, if he or she is around, as well as outside of the classroom to put your project together. You can go to the teaching labs between nine and six on weekdays and next weekend we'll also make times available. That's the weekend before the fair. We'll post the details of that online. You may want to plan with your team already times that you can work together outside of the regular hours.

We're already quite a ways into the first project. It's amazing how quickly it goes. It's February 14th. We'll do two things today, we'll have learning Learning Catalytics until about until ten o'clock and then we'll end with a tutorial. Talking about the tutorial, I want to repeat something I said before. We don't hand-out, because we're not allowed to do so, the solutions to the tutorial. We're not allowed by the publisher and the author of the tutorials.

You need to make sure before you walk out of this door that you feel confident about everything that's on there and that somebody from the staff has looked at your answers to make sure that what's on the worksheet is correct, so that you can use it as a reference. Nothing is worse than thinking you get it, write down the wrong things, take it home and then use it as reference because that only reinforces things that are wrong.

Be sure that you don't walk out of this room without feeling confident that, A, you have the right answers on your worksheet and, B, you understand them. If, for some reason, you can't do that, be sure to look up your team mentor or one of the people on the staff in charge of the tutorial to work through it in office hours. It's really important because that's what clears up most misconceptions.

You may have noticed that we did not do our Learning Catalytics sessions on Gauss's law. We thought we'd spend the first 10 minutes talking about electrostatic shielding, which is a concept that often brings up confusion and it's important in the rest of this course. I'll explain very briefly electrostatic shielding and then--

Federico: Experiments.

Eric: Federico will show two experiments of electrostatic shielding at work. Let me tell you what we're doing because we're embarking on a long journey here this term. Essentially, the problem we're trying to address is, I have a couple of charges here and I may be moving them and I have some other charges here and they may be moving too, what's the effect of these charges on the other charges?

You may think, "Is that not a very theoretical problem?" Well, every time you pop-out your cellphone to look something up or make a phone call to somebody else, that's exactly what is happening. There are some electrons that are moving up and down in your phone and are making some electrons moving up and down in an antenna and that makes it possible to communicate at a distance.

From a technological point of view, this has been an enormous advance, not just an enormous scientific advance, also an enormous technological advance. That whole answer is to some degree as suggested by Coulomb's law. As Federico likes to keep pointing out to me, it's all Coulomb's law, but Coulomb's law is painful so we learned one trick, Gauss's law and today you'll learn another trick, potential.

Gauss's law has only very limited ability but it's very powerful because if you get Gauss's law, you can make, in certain conditions, enormous simplifications. You don't have to go through integrations, you don't have to go through any complications. What we're going to show you here, both as a real experiment, but first on the screen as a conceptual experiment is electrostatic shielding.

Imagine we have a negatively charged object right there where I'm writing the end, and we hold it close to a conducting cylinder. As you know, it will polarize the conducting cylinder. The positive charges will get attracted as close as they can to this negative object here and the negative charges will be repelled. Now in a conductor such as a metal, it's only the electrons that can move but as they move from one side to the other, they leave an excess positive charge behind. Even though these positive charges don't really move there, they're left behind by the electrons that move to the opposite side.

Now, Gauss's law tells us that-- Well, no, not Gauss's law. Sorry. There are so many freely moving charges in a conductor, that's the definition of a conductor, that the electric field inside a conductor is always zero. Why? Because if it weren't zero, then whatever charges that are in there would move in order to counteract the external field. Right now in the situation that is shown on the screen, with E equals zero inside the conducting object, the field due to this negative object, which points towards the negative object, is counteracted by an internal field due to the polarization of the objects. The sum of the induced field here, plus the external field of the negative charge, the sum of those two is zero. This is essentially the vectorial sum-- I should write vector signs here. Of the eternal field-- The induced field, pardon me, plus the external field.

What happens now when you have a cavity inside? Let's go and imagine that there's a cavity inside. Is the electric field also zero inside? The temptation might be big to say, "Yes, it's zero inside," but it's not immediately obvious because you could have some negative charges on the left wall of the internal cavity and some positive on the internal cavity, there's nothing that would prevent that from happening. In fact, it would be consistent with Gauss's law because if I take a surface, a Gaussian surface like this, Gauss tells me that the flux through that surface is equal to the enclosed charge divided by the surface area.

Well, what is the enclosed charge here? The enclosed charge is equal to, well, there are two minuses here and two plusses so that's zero, therefore, the flux is zero. Indeed, you can see that the flux is zero because on this part of the surface, everything is zero because this is inside the conductor, and we already know that inside the conductor that E equals zero, therefore, the flux will also be zero and here, this is parallel to the electric field lines in zero too. What I'm showing there is perfectly consistent with Gauss's law.

The reason that this cannot happen is slightly different and we explained why. Let's not choose a Gaussian surface but let's choose a path. That dotted line right now is a path. Imagine that I take a positively charged particle here. Here it is, I put it here at the top and I move it along that path. I move it here, here, here, here, here. Takes me no work whatsoever, right? Because there's no electric field there, therefore, there's no force on it, therefore moving it takes no work.

As soon as it gets here, however, I'd need to exert positive work. Or actually, why don't we go the other way around? Let's go this way. We go this way towards the right, and then we get here and as I get inside, the positively charged particle wants to get accelerated away from here and it'll arrive on the opposite side with excess kinetic energy. Now, it keeps moving along that path, it gets back here, gets accelerated more and it gets back here and it gets accelerated more, and it gains and gains and gains energy out of nothing because we're not putting anything in, it's just the static distribution of particles. It'd be terrific, it would solve any energy problem we could potentially think about, but as far as we know, that's impossible, and therefore, there can't simply not be an electric field because the conclusion that we are led to is one that cannot be correct.

That's the real reason that the electric field inside the conductor is zero. Let's do the demo, so you can see it. Those who have been to the Science Museum have probably already seen it, which is the big Van de Graaff generator there, but we've sort of reproduced it here, with a much smaller one.

Federico: Let's have fun, this is going to be great. This summarize centuries of physics and experiments and theory. We are going first-- Let me show you here what the Van de Graaff generator looks like. Do you see the dome there to the right, everyone sees it?

Students: Yes.

Federico: What happens is-- Let's actually turn it on and start to have fun here. You see the spark? This is safe, don't worry, this is safe. I actually can touch it. See, no problem. What is happening? Basically, there is a belt here and there is a brush here that makes contact with this rotating belt and this belt charges up. It brings us positive charge here, and then it is actually transferred to this dome here.

We can have a voltage up to basically 10 kilovolts. In fact, in the largest Van de Graaff we visited in southern of France, it was 1 million volts. That's kind of a record. What I'm doing here, of course, as I turn this here, I have a natural spark. Why do I have a spark? Because this is grounded, right? What happens I have it discharged, from here to here it's constantly charging up and discharging through this.

This basically is how Van de Graaff works. Let me say something that the biggest Van de Graaff we have it in the actual atmosphere. When we have a storm, what happens? It's fascinating. There are winds that have convective motion, and the convective motion brings charges from the earth up to the actual clouds, what are we going to, then? A big thunderbolt, right? It's a natural Van de Graaff machine, which I think is actually fantastic.

Now we are going to see what happens here, and now I'm going to just look at the thing here. You should agitate a bit this here, making sure it doesn't stick. Now what we do, we ground everything. Yes, let's ground this one. Now if physics works, which usually does, something should happen. Nothing happens. Now, this is interesting, let me explain what happens. I just discharged my big head, no problem.

[laughter]

There's very little current. You see it's being repelled. Now, you might ask why. This is actually positive. How can that-- If it's repelled, it's still repelled kind of a bit, it means there is positive charge there. You might say, "How can this happen?" There is a so-called Corona effect, and this happens strictly on the humidity of the air, today's quite humid. There are a lot of actually positive and negative ions. There are electrons also. What happens that the positive ions get repelled towards from here to there, they charge up-- That's Mylar coated with actually metal, so there is a repulsion, right?. Is that clear?

Now, I would say and actually last night I repeated the experiment downstairs, and it's attracted actually because there were no ions, there was not a lot of humidity, so it gets charged by induction and so forth and gets a bit complicated. For the time being, that's positively charged. Yes?

Herman: If I move it far away such that it doesn't get charged. You can move it far away such that the charge don't transfer, so there's like million volts, positive volts over here.

Federico: 30 kilovolts.

Herman: 30 kilovololts, If it's far away then it shouldn't transfer to here. If you turn it on, ideally it should attracting to it. You can move it a bit closer and closer. You see, it's actually starting to attract, but if I move it too close-- If we repeat it again now-

Federico: It's clear.

Herman: -they will actually be repelled as you've seen before.

Federico: In one case, just to make it simple, so it's not too complicated, first thing is a Corona type of effect. Corona is a bit that the ions of the opposite side are repelled with a charge positive in that thing. The other effect if that's far away, however, the ions rarely don't get there. What you see is just an attraction by polarization, right?, polarization, right?.

What happens the Mylar sheet which is coated with a metal gets polarized, it means there are negative charges that get attracted towards the positive, positive are repelled. However, the field closer to here is higher, so the net effect is an attraction.

You have these two regimes. Now we should really go to the shielding, otherwise we are taking too much time here.

Now, Eric gave you a really nice summary of Gauss. Now, what we expect to happen is that if we turn this on **[unintelligible 00:16:30]** , there is zero field inside. Now, zero field is this, look, this is charged up, this is charged up. There must be a counteracting field, that cancels the field due to the dome. Is that clear? In fact, if we take this-- I think there should be some remaining charge here, I don't know if I did it in the right order, but actually there should be some remaining charge.

No, I did it in the actual wrong order. Anyway, there is some remaining charge here that creates-- This charges up to cancel the field of this, that's what we were seeing before. Is that clear? If it's not clear just say, you don't have to agree, this is science. Now, the next one is actually quite cool. What he's going to do now-- This is a dipole. Basically, you have these two-metal disks that are on an insulating--on a-- on a-- a paper arrow.

First, we are going to charge it up, essentially create a difference in charge between the right disk and the left disk, so there is an actual dipole. Now, then we will see the effect of the-- Why don't we do this? What he's doing, watch his hands, when he is rubbing-- this is a Teflon block. As he rubs it, it becomes negatively charged, and there is an effect. Now what he's doing now he is charging it, he's first shorting the two ends. Do the next thing, he removes the disks, he charges basically by induction. The actual -- There are motions, you see that it tends to get attracted because there is a net charge.

In fact, there is a net because it's attracted. There is a net positive charge on that dipole. Is that clear? Now what we do is the real part relating to what Eric demonstrated before. We are going to lower very carefully. Now, this is a conducting-- Look here what I'm holding, these are conductive stripes here that, however, have gaps in between. They are only connected by plastic circles.

They're actually not necessarily at the same potential, they are separated from each other from an electrical point of view. This is important. It means that this right now does not shield any field, this is not equipotential. Is that clear? I hear always people saying, "Yes." I hope sometime says, "No. I disagree." This is science. We are supposed to disagree sometime. Not most of the times, of course. Okay? Now he's lowering this charged object and we can see it's fairly-- It's not actually doing anything. It's sort of bouncing around.

Now why don't you actually rotate the thing? You see, it tracks the motion as he moves the rod, left, up or actually down. It tends to actually track it. Why? It feels a non-uniform field incidentally. This is like a charged cylinder of Teflon. It's a non-uniform field. It actually tracks it. There is both an attractive force and there is a torque also. But, The reason it happens is because it does not shield, because these are separate stripes.

Now here is the magic moment. What Eric now is going to do is, put around a conducting blade. What does that do? Putting around a conducting blade, what does it do? Someone say it. It makes it equipotential. Therefore, now it should act like a shield. You see, as he rotates around, look at the shadow, as he rotates around with the Teflon cylinder, it doesn't track the motion.

The next experiment is truly, in my opinion, one of the most beautiful in electrostatics. Why? Because they will show directly the effect, there is a background field. There is a screening field that shunt cancels the field due to the Teflon rod, so that you have screening. If you remove the screening now, there should be charging remaining on these copper stripes, and we should see the field due to them.

Now do your magic trick, Herman. Make it rotate. Now you see he has removed the Teflon. You see, as he rotates the cylinder around the axis, the dipole tracks it. What is that? That is the electric field that was set up originally to screen the field due to the Teflon rod.

We have removed the actual Teflon rod. Before, by superposition the field was actually sealed, now we remove one of the field. What we'll have is the remaining charges on those copper stripes that, show, represent, create this field that cancels the original field. We are directly seeing the effect of what causes screening. It's actually the screening field. Is that clear? Everyone? Good.

Eric: Can you reset the projection? Can you reset the projection?

Eric: That was about shielding and Gauss's law. Something that we haven't had a chance to discuss in class. I want to give you a brief feedback on the annotations for chapter 26. Thank you. I saw lots of very thoughtful annotations. I'm just picking three out. The questions that we're going to discuss afterwards in Learning Catalytics, and I'm going to show you the session ID in a second.

You might want to get on Learning Catalytics in the meanwhile. I'm just going to pick three and the questions that are in Catalytics are going to hopefully address some of the remaining questions. This was something that was voted several times. Potential energy and potential difference. The difference between those two.

Here's one example annotation. The difference between the electric potential energy between two points is something I would just call potential energy difference. That's fine. How does this differ from the potential difference they are talking about here? Potential difference is not an energy. It's a different quantity. It's actually an energy divided by charge, and therefore it cannot be an energy because it's Joule over Coulomb.

The reason that we introduce this quantity potential in electrostatics is because you can measure it with a voltmeter. Potential is given in volts and a voltmeter which you will use in the course of this course is something that measures potential. Actually, potential difference. The potential difference between two points.

The definition of potential difference is given in the first equation in the quantitative part of this chapter. The potential difference between point A and point B, which is the potential at point B minus the potential at point A is defined, and in the beginning seems kind of weird, but I'll explain to you why there's that sign, minus the work done by the electric field or the electrostatic field, I should say, in moving particle Q from A to B, divided by the charge on that particle.

You may wonder why is it negative. It's negative for this reason. Imagine that we have a point A and we have another point B here, and we're moving from point A to point-- No, we're moving from point A to point B, but at the same time the electric field will take it to also point in that direction, from A to B. What is the work done by that electric field on the particle?

When the force points in the same direction as the displacement, the work is positive, so that means that w-e is upon q, is a positive quantity as we move from A to B, and because of this minus sign in the definition here, that means that the potential difference, v-a-b, is negative. Which means that the potential at point B is smaller than that at point A. Sorry, I should have written A here. V-a.

The one at A is larger than the one at B, which means that you can simply remember this. A positively charged particle tends to move when you let it go from a point of higher potential to a point of lower potential.

That is perhaps the most important statement in that quantitative part of the chapter. It's a lot of words to explain that, and you have to convince yourself that it's consistent, but if I took that particle and just let it go, it would move from A to B because the electric field pushes it that way, and it moves from a point of higher potential to a point of lower potential. If it were a negative particle, it would go the other way around.

Balls always run downhill from points of higher potential energy to points of lower potential energy, but we don't have negative masses. With charge we have the opposite sign. They roll uphill. They go from a point of lower potential by themselves to a point of higher potential, so electrons would run uphill, up the potential hill as opposed to positively charged particle.

That's the difference and that's why we need to introduce potential. Why did we introduce energy in mechanics? We introduce energy in mechanics because it's a scalar quantity. You can forget about vectors and so on. You can just add them. Three plus four is seven, but a vector of length three does not always add with a vector of length four to a vector of length seven. It could be anything between lengths one and length seven.

The great thing about introducing potential is, it makes it unnecessary to include directions of vectors. Somebody else said highlighting this passage here, "When charged particles are moved around in electrostatic fields, no energy is irreversibly converted to other forms of energy." The person here said, "Is this just in a theoretic or perfect world? I thought at any time particles move there's entropy. Referring to the thermodynamics law. Even a particle small as it is must interact, lose some energy traveling from something as small as the resistance of travel."

If it's just the electrostatic field, the answer is no, there's no dissipation whatsoever. If there are other things in the way, like other particles it bumps into collisions, this and that, and the other, which will be the case inside a wire for example or inside a fluid like air or liquid, the answer's yes, but if you have a vacuum and you have a particle, and it's just electrostatic field, there is no dissipation whatsoever.

Somebody else said, and this is related, a comment, "Good to know that--" the word electrostatic was not there, but that's what it referred to. "Electrostatic work is independent of the past taken." The answer is yes that's because there are no dissipated interactions, interactions that dissipate any energy. If you have not taken AP58 or if you feel shaky in some of the things that we're doing today, you should review chapter five and nine. If you have not taken AP58, I would highly recommend you read chapter five and chapter nine. Otherwise, you'll get into terminology problems and not quite understand what we're doing moving forward.

Having said that, use the book as a resource. When you're looking to solve your problem set or an RA, there are lots of examples that are completely worked out. There's a summary of the chapter in the practice book. To get to the practice book, you have to scroll down all the way to the bottom and perusal. The first 32 chapters are the principles chapter and then the next 32 chapters are the 32 practice chapter corresponding each to the principle's chapter.

Let's get on to Learning Catalytics. One quick thing, don't forget units if you need to include units. Not that important here in what we're doing in Learning Catalytics, as we're doing today, but when we get to the RAA, do not forget units. Unit prefixes are fine. The system knows that 0.00001 kilogram is one E minus six kilograms or one milligram. It knows how to convert it, you don't have to worry about that.

Lastly, do not use algebraic expression for numerical answer. If you enter a numerical answer do not type, let's say, for this quantity that is shown here. Do not type in 4.37 times 10 to the minus three. That will unfortunately not work. You need to type it in the way it will be on a calculator.

Federico: Also, we noticed this for the RA, we didn't hold it against you. You see, if you're asked-- In most of the question except one, there was not calculating an actual number. Which is a quantity which has a unit, a unit like Coulomb. It was just calculate, derive a simple formula. That's an equation. When we ask you that, don't put units. Units are only if we measure something, then there is a unit to put, but if it's just an equation, A = (C x B) + W. There are no units that you should put after that. Because actually the system will count it as an actual error.

Eric: We'll remind you of that when we have the RA next week. Also, we can correct errors that occur. We'll keep an eye on it. Use the boards. I noticed that many people when we're doing Learning Catalytics do not use the boards. Use the boards. Teach one another. Which is why we put them out today. Here's the first question. I'm sending it to your device. If you don't have the session ID, it's 30465236. I'll put down the next screen too.

We have a positively charged rod that is held near a conducting sphere as shown on this illustration here. A positively charged particle is moved from point A to point B. The electrostatic work done on the positively charged particle during the motion is? Choose an answer. We have about 50% right answers. I want to get that higher up because if you get this wrong, then it's very hard to get the rest like potential and so on wrong. Find a neighbor at your table who has a different answer, and then see if you can convince him or her that you're right and he or she's wrong. Again, if you need the boards, go to the boards and use the boards. Go ahead.

[students discussing]

Student 1: This a negative because this is moving against-- It's a positive recharged particle moving from A to B. It's moving to an area of higher potential energy because it's getting closer to the other positively charged or the positive charge rod.

Student 2: Yes, so then there's work done on it. It's like if you're moving something from the ground up, you're going from more favorable to less favorable, then you're doing positive work on it.

Student 1: That's positive if you're doing work on.

Student 2: I think so.

Student 1: I think that's right because I feel like if you have negative work, work is leaving [crosstalk]

Student 2: [inaudible 00:34:52]

Student 3: This was positive going like this. Then A is moving against that. Then it'd be positive work. Okay, that makes sense.

Student 4: Do we need to order anything else?

Teaching Fellow: What are we thinking?

Student 3: Positive.

Teaching Fellow: Why is that?

Student 2: We said you need to put an input of energy for it to go against the electrical field. Because if you bring a positive charge closer to a positive charge, you need an input energy in order for that to occur.

Teaching Fellow: Okay. Everybody agrees?

Student 2: No.

[laughter]

Teaching Fellow: Let's think about this in terms of displacement. To what direction is the displacement?

Student 2: Direction? To the left.

Teaching Fellow: To the left. Correct. Then in what direction is the electrostatic force acting on the particle?

Student 2: To the Right.

Teaching Fellow: To the right. So, conceptually speaking if a [crosstalk] is towards the right.

Eric: Enter what you now believe to be the right answer.

Student 3: You need to put work in, so it's positive.

Teaching Fellow: Let's see what Eric has to say.

Student 1: I think we just have the nomenclature wrong [crosstalk]

Eric: This is not an electrostatic's question, this is simply a mechanic's question. Electrostatic work, what we mean by that is the work done by the electric field. The electric field exerts an electric force. Then we need to decide whether that work done is positive or negative. Remember the work done by an object is the force exerted on it as a vector dot product times the displacement of the point of application of that force. If these two vectors point in the same direction, the work is positive. If these two vectors point in opposite directions, then the work is negative.

For the electrostatic work, we add an E here and we add an E there, which means it's the Coulomb force, which is simply the particle Q, times the charge on the particle Q times the electric field. What about the electric field? In which direction is it going to point? Is it going to point from B to A or from A to B? Ignore the positive particle that we are moving. It's going to point from wherever there are positive charges to wherever there are negative charges. It's going to point in the general direction from B to A. That's the direction of the electric field.

Now, we put a positively charged particle and we move it from A to B. Here's a positively charged particle. A little bit higher up but I have no space to draw it there. It's plus Q. I'm moving it from A to B in the opposite direction of the force that is exerted by the electric field. These two vectors here. This vector and that vector point in opposite direction. Therefore the correct answer is-- I'm going to show it on your screen to see how many people had the right answer. The electrostatic work done is negative.

As you can see initially 46% had it correct, and then after discussion it went up to 59, but it really should be going up to 100%. Review this if you still had it wrong the second time around. What does this mean for potential? Remember, V-a-b is defined as minus the electrostatic work from A to B on particle Q divided by Q. If the work done in going from A to B is negative then V-a-b is positive. If V-a-b is positive then VB-- Is it positive? Yes. Then VB is larger than VA. Indeed we have to push the particle to go from A to B. It would like to go the other way because VB is at a higher potential than VA and we have a positively charged particle.

Student 5: I have a question.

Eric: Yes.

Student 5: Does it depend more on the direction of the electric field or the positively charged particle?

Eric: The question is does it depend more on the direction of the electric field or the charging particle? Really good question. Thank you for asking that. Imagine I had taken a negatively charged particle. I raise this plus here, well, I raise the whole charge. I want to put it back here. I get one that’s negative here. Now the force that is exerted on that negative particle points in which direction? It points towards the left, it wants to get away from those negative charged particles.

Maybe I should put this in a way that you can see it. I should enlarge it a little bit. The electric field points towards the right, this negatively charged particle if it’s close to A, wants to move away from A because there’s all that other negative charge around. The electrostatic work that is exerted on the negatively charged particle is not negative but positive.

However, this is the beauty of potential when we determine what the potential is, we divide by the charge, so now we have a positive electrostatic work that we divide by a negative charge, and we end up with exactly the same potential difference. Thank you for asking that question because what it shows is that potential is independent of whatever charge you use to measure it. Whether it’s a positive charge of one Coulomb or a positive charge of two Coulomb or a negative charge of one microcoulomb, it's always the same. You always get the same consistent answer. You may want to run this over in your mind when you have more time to think after class. Yes?

Student 6: Can you verify if the work should be negative or would be positive?

Eric: Which work?

Student 6: The--

Eric: The electrostatic one?

Student 6: It's the same question but a negative particle.

Eric: If you have a negative particle, then the work is positive rather than negative. If you have a positive particle, then the work is negative, which was the answer to the question that we were answering because it asked for a positive particle. If you have a negatively charged particle, then the work will be positive, but that will not affect our answer for the potential, which is why it’s so much better to talk about potential than about work.

Any other questions? These were both really good questions. I’m glad that this question triggered those two good questions. Good. Let’s get to the next Learning Catalytics question. By the way, I think we'll only get to do about four or so of Learning Catalytics questions. We have a total of 12 in there. You can always go back and test yourself on the remaining questions that we don’t do.

We walk into class, there's many more questions that we can ask because we want to be able to adjust to whatever question come up in your mind, and depending on how you answer the previous question. Here is the next one. I’m going to send it to your device. A positively charged rod is held near a grounded surface, as illustrated below. Compare to ground, that horizontal line you see at the bottom, what is the potential at point A? Higher, the same, lower or undefined.

Take a minute to think about this. Please choose an answer. I’m delighted to see how well you're doing. I had expected a lower percentage of correct answer, we're at 74%. I’m not going to ask you to talk to each other. We're just going to launch straight into the next question. Let me run quickly through the reasoning here. We have this positively charged rod, what is it going to do? It's going to attract in the ground some negatively charged particle close to the surface of the ground that is near that rod, so there’s going to be an electric field that is pointing downward from point A roughly to the surface of the earth.

If you were to put a positively charged particle, which way would it go? It'd go towards ground, and as I told you earlier on, a positively charged particle tends to go from higher potential to lower potential, therefore the potential at point A is higher than that at the ground. 74% of you got that right. If you're on the 26% who haven't gotten it right and my explanation didn’t do the trick, then either in the second half of this class or tonight, you may want to go over this one more time. Let’s go to the next question, which Federico will do.

Federico: A positively charged rod is held near a neutral conducting sphere, as illustrated below. A positively charged particle is moved from point A on the actual sphere to actually point B, so the potential difference remain to B is?

[students discussing]

Federico: It's going actually pretty well. We are close to, nearly 100% so far have gotten it right. 96% out of 45. Good job. Continue.

[students discussing]

Federico: There are two things to remember, again we don’t want to sound like broken records but definitions are important. The potential difference is the negative of the electrostatic work per unit charge. Now if we look As we move the work at the particle positive from A to actually B by the electrostatic field on a positive charge, what we have is basically that the work is actually negative because the electrostatic force and the displacement are in opposite direction.

Displacement, if you look at my hands, is this way here. We're taking a positive charge from the sphere to the actual rod. This is a negative displacement with respect to the actual force that is in the opposite direction. Out of that it follows, then, the two things putting together that the answer A is actually positive. The great majority of you, more than 90%, got it right. Good job.

Eric: Next question.

Federico: We're going to six because I think the concept of ground is important. As you've seen here, we're grounding everything before we're getting wonderful sparks. A positively charged rod is held near a neutral conducting sphere on an insulating stand, the displace on a natural ground at surface. The question is, compared to ground, which is the horizontal surface where everything stands, the potential of point A is? What is it? Higher, the same, lower or undefined. I think Eric has started the session. Start discussing with your neighbors.

[students discussing]

Student 3: I wasn't really sure. [crosstalk]

Student 2: I said the same because I was like, "If it's conductive--" Because their point is very close to negative, but on our screen, it's like in the middle of the negative [crosstalk]

Student 3: No, I think that's the wrong question because we don't have a point B, do we?

Student 2: No we don't.

Student 3: I don't know. I just kept thinking if it's a neutral conducting sphere. There's no interaction-

Student 2: If it's overall neutral. [crosstalk] Isn't the ground

Student 3: Also, yes. Then does distance have anything to do with--

Student 2: Yes, maybe uncertain. What does undefined mean?

Student 3: Maybe it's undefinable?

Student 2: What does undefined mean?

Student 4: That you can't--

Student 3: You wouldn't be able to tell.

Student 2: Yes, that's kind of ambiguous.

Student 4: The fact that it's an insulating stand is that everything?

Student 3: Wait because it's a conducting sphere.

Student 2: Unless you're [crosstalk] ground there's not really--

Student 1: If it wasn't an insulating stand wouldn't it just be the same as ground because it would pretty much be connected to ground?

Student 2: Yes. Maybe with the insulating fan it's higher.

Student 3: Higher, so maybe closer to the rod. Maybe the potential's higher?

Student 4: Just guessing again. [laughs]

Student 1: It can't be lower. Can it be lower?

Student 3: I don't think so.

Student 1: That gets rid of one of them. My main reason for this saying was that we had a problem just like this and it was higher.

Student 3: We'll see what they explain .

Student 1: Should we split our answers between the **[unintelligible 00:51:55]**

Student 3: Yes.

Federico: It is higher than ground. Again, the way to think about it is in terms of field lines, there are two parts of the story in terms of field lines like that. The field lines from this here and they point in this direction here. Again, you have to think in terms of the positive charge. You are moving a positive charge from here to here, and then the field lines from here to here point in this direction. The next step is we can ask now when we move one positive charge from here to here, there are two steps, we move to here from here to here from here to here, and what happens is that the electrostatic work is actually positive.

The direction of the force is in the same direction of the displacement. There is a total of positive work, which means what? As we're going from here to here? That the potential difference is therefore negative when you are going in this actual direction here. It's actually negative. Remember, the definition of actual potential. It means that the potential of the sphere then has to be higher than that of ground.

Eric: I guess we're going to stop the Learning Catalytics here because the tutorial is equally important.

Federico: Yes, we're running out of time.

Eric: As I said there are many more questions online, so do review them and if you have questions about them come and ask me or Federico.

Federico: If I recommend--

Eric: The tutorial, where is the tutorial? As to the tutorial, remember what I said, be sure that an hour from now when you walk out of here you feel confident that you A have the right answers on your sheet and B that you understand them. If not come and see one of us. We'll come around the tables and help you along.

Student 1: This is where we do a little experiment together?

Student 2: I think yes or in the packet.

Student 3: Yes. Did you all sign this?

Student 2: Somebody have an extra pen I could borrow?

Student 3: Yes, I probably do.

Student 2: Thanks.

Student 3: Sacrifice his own

[laughter]

Student 2: I got a new backpack, and I forgot to shift everything from my old backpack to my new backpack, and I'm like I don't have paper or a pen.

[background conversation]

Student 2: The show arrows in the relative direction to the force in the space **[inaudible 00:55:01]** When the force and the displacement are in the same direction work is positive, right?

Student 1: Yes.

Student 2: Then zero is there just no force? **[unintelligible 00:55:18]** one of them has to be zero right?

[background conversation]

Student 4: I went up and down. I don't know why I just--

Student 3: Maybe because if you're thinking like mechanics.

Student 4: Yes I think about it in terms of gravitational.

Student 3: Yes that's **[unintelligible 00:55:53]** what zero?

Student 2: I think there's no force.

Student 4: Technically correct.

Student 1: We're not wrong, definitely not wrong.

Student 3: There's no displacement. Can there still be force without displacement?

Student 2: Work is force times displacement [crosstalk]

Student 1: If it doesn't move. If you have an electric field and the particle just doesn't move, there's no work.

Student 2: There's no force and then zero displacement.

Student 3: Can you have displacement without-- You can't have displacement without force.

Student 4: I think displacement just has to be zero.

Student 3: Yes. Perfect. [crosstalk]

Student 2: Wait it's going from A to B. Force is going the opposite direction of displacement, so it's negative.

Student 3: It's travelling-

Student 1: Then it turns into positive [crosstalk]

Student 2: Because it goes against it and then once it crosses the point, it goes with it [crosstalk]

Student 1: They probably meant for those to cancel out even though--

Student 2: Wait, if it's going to A to B-

Student 1: A to B.

Student 2: Where is it again?

Student 4: A to b because this force points this way, so it's going against force one, and once it crosses here it's going with force two.

Student 2: What it's asking is the total work done on the object by force one.

Student 1: Oh by force one-

Student 4: Force force one got it. So Three is going to be zero.

Student 2: Yes, three is zero.

Student 4: Great. Force one because F one and F two are equal in magnitude Wait. I did that wrong.

Student 1: Force one is negative. Force two is positive, and then net force is zero.

Student 4: If the net work is zero, shouldn't the speed not change?

Student 1: If it's going from A to B--

Student 2: The acceleration has **[unintelligible 00:58:06]**

Student 3: We don't know-- This has nothing to do with electric potential yet, so we don't know what context this this is. I think it's just equal.

Student 1: At point B isn't it-- It's going with the force, whereas at point A it's going against the force?

Student 2: I think it slows down an equal amount that it speeds up, maybe.

Student 1: You're saying to overcome the force in F one, it needs to have some sort of--

Student 2: Yes, so it slows down because F one speeds up the same amount.

Student 1: You're saying it come in with some velocity?

Student 2: Yes.

Student 1: That makes sense.

Student 2: I don't know how else to explain. You know we have to go through it with the TF's anyways. They'll tell us [laughs]

Student 3: Wait when's our check in?

Student 2: They'll just float around [crosstalk]

Student 3: [unintelligible 00:59:13] travels from point A to point B **[inaudible 00:59:14]**

Student 2: Unequal **[unintelligible 00:59:17]** so F three is larger then F four? It's going to be negative, positive, then negative overall?

Student 1: I agree.

Student 2: The speed of the object at point B should be less than.

Student 3: That's because of what you were just explaining where it would slow down because force is opposite of its--

Student 1: Yes because the F three vector is larger in magnitude, it's going to do more slowing down than F four is going to do speeding up.

Student 3: Does it have anything to do with the sign of the net work done?

Student 3: I'm going by the sign of the net work.

[students discuss]

Student 2: I am like, if it's negative [unintelligable] . State the work-energy theorem in your own words. That's just like work and energy are equivalent, right? [crosstalk] I mean, work's in joules, energy's in joules, so any work done, it takes energy to do.

Student 3: Do you know what the Work-Energy theorem is?

Student 4: As much as change in energy is equal to work?

Student 2: Yes. It's change in energy is equal of work. **[unintelligible 01:00:48]**

Student 3: It wouldn't be yes because--

Student 2: Because when we talked about the speed, [crosstalk]

Student 1: Yes. The work done by the cell motor forces act in the particle is equal to the change in [crosstalk]

Student 3: We had negative work, and we said at less speed--

Student 1: The work done by the cell motor forces on a particle is equal to the change of kinetic energy on that particle, which makes sense because we have negative work. We'll get there.

Student 2: Do we have check-ins?

Student 3: No, it doesn't say.

Student 2: We don't have check-ins.

Student 3: We'll wait until someone--

Student 2: Until someone comes up to us.

Student 3: Now, we're going into electric fields.

Student 2: Yes. For all of the field vectors, we have W, X, Y, Z. It's a top view of a positively charged Y, so it's going away. It's like this, it's pointing away. [crosstalk] A particle is charged plus Q travels along a straight-line path, W to X. Once an electric field is positive, this displacement in electric force are in the same direction.

Student 3: Yes.

Student 2: Force is this direction and displacement is this direction. X to W, so it's like-- [crosstalk]

Student 3: Same magnitude but different--

Student 2: Yes, to X, still negative.

Student 4: Wait, same magnitude, different--

Student 2: Different directions of displacement. Is everyone good with everything till C?

Student 4: Yes.

Student 5: Is the word done in displacement?

Student 2: We said for part B, we said that the work-- so From W to X, we're saying it's positive because the electric field force is the same direction as your displacement. We say that's positive, and when it's going X to W, your displacement is the opposite direction of your force, so we said that is negative. So part C. Is the work done by the electric field on the particle positive, negative, or zero? This is kind of upward or it's like **[unintelligible 01:04:23]**

Student 1: It cannot defer on the path it takes, so we can think of this as going from X to the midpoint here or X to the charge brought and then from the charge onto Z, in which case it would be zero work equal the opposite.

Student 4: That makes sense.

Student 3: Wait, can you explain that again? Going from X to W to the midpoint.

Student 1: The particle, it only depends on its initial and final position. It doesn't matter what path you take to get there. The easiest path to know the values of is if you go from X to W to the midpoint and to the charge itself.

Student 3: Okay, and that's sum negative value.

Student 1: That's sum negative value, and if we go from the charge drawn to the Y to Z, that's sum positive value of equal magnitude, exactly.

Student 3: Awesome.

Student 4: Sweet.

Student 1: That's when we have zero work.

Student 4: On part two?

Student 3: Yes, we're on part two.

Teaching Fellow: Do you mind if we go back one line? First question, everyone's in agreement, is that, so what do we have? The first part, this is a review of work. Chapter five, chapter nine.

Student 1: For part A?

Teaching Fellow: What's the takeaway? Yes.

Student 2: When they go in the same directional force and displacement go in the same direction, it's positive work and when they go different directions, it's a negative.

Teaching Fellow: Does this clarify some of the learning catalytic to some of the-- [crosstalk]

Student 2: Especially the first one, I think we were very confused, so this clarifies that.

Teaching Fellow: The rest of that looks good, so then moving on to the second part.

Student 3: We said for the work-energy theorem, it's basically that the change in energy equals the change in work. There are answers in part C for testing, and part C we found that the net worth was negative in that the **[unintelligible 01:06:45]** to the object decreased or was less than where it started, which means it lost energy. This would be a negative work, probably in math or whatever, so that's the first quarter.

Teaching Fellow: Okay, so our theorem, the change of energy of the system equals the work done?

Student 3: Yes.

Teaching Fellow: Part two, have you finished part two yet? You're still working on it? [crosstalk]

Teaching Fellow: Till C. Okay. Is there a pattern that's emerging?

Student 2: What the force of distance direction is? That's like the pattern that will be. They're the same as positive and then their opposite direction is negative.

Teaching Fellow: I'll let you make a little bit more progress, starting on part C and then I'll come back to check in on you,. The thing to keep in mind is to think about work in relation to the pathway.

Student 1: And it's path-independent, just to clarify.

Teaching Fellow: Exactly. That's the point. [crosstalk]

Student 2: Awesome, and then we'll still work through it. Thank you.

Student 1: All right, so if we use the same logic on W to Z.

Student 3: W to X?

Student 2: Oh, it says W to Z. Isn't it the same?

Student 3: It goes against and with, so that cancels, and then[crosstalk]-- W to X, oh, yes.

Student 2: It's equivalent to Y to Z and W and X.

Student 4: Because if you look like W to X, it's one minute, right, and then W to midpoint to Y--

Student 3: Oh, yes. [crosstalk]

Student 4: W to Y.

[background conversation]

Student 4: This is kind of fun.

Student 2: Travels from W to X and the particle goes into C to Y.

Student 3: Wait, did they change?

Student 4: What is this arrow? It's like the path.

Student 2: I think that W to X is still positive and then Z to Y is negative.

Student 4: Yeah, so it's the same magnitude, opposite sign.

Student 2: Yes.

Student 1: Which makes sense, because if you went straight from W to Y, it would also be zero.

Student 4: Then the total is zero.

Student 2: W, X, Y. [crosstalk]

Student 1: They're really driving this point home

Student 2: I know [laughs] It's zero again, right?

Student 1: Yes.

Student 4: That's got to be the same, it doesn't matter.

Student 3: W to Y along--

Student 4: It's got to be the same

Student 1: There is path **[inaudible 01:10:44]**

Student 4: Yes, it's consistent-- **[inaudible 01:10:50]**

Student 2: Perfect. W to X. [crosstalk] Wait, suppose the charge of the particle is actually two to increase, does it increase from--

Eric: Did anybody enroll in the 501?

Group: Yes

Eric: I saw a lot of misconceptions like the one due-- Good. The work **[inaudible 01:11:31]** Work is the change in energy, a lot of people know work as the change in kinetic energy, happens to be true here, because the only form of energy is kinetic energy its a particle. In general terms, the work done on a system is the change in the energy of the system, which is what you were hoping to hear.

Eric: Once you get to the end of two and somebody--

Student 2: We finished.

Eric: You are? So should I even go over it?

Student 4: Yes.

Eric: Do You all agree about part two?

Group: Yes.

Eric: Did you all discuss it with each other?

Group: Yes.

Eric: So why don't I look at --You all have the same answers?

Group: Yes.

Eric: I need to refresh my own memory, so bear with me. Diagram, W positively charged rod right here, point W and Y and X and zero equidistant , draw electric field rep, so it points away from your rod. And a newer point is longer, further away. W and Y should have equal arrows pointing away from the rod, and X and Z shorter in the same direction. A particle is charged plus Q travels along a straight line from W to X, worked on by the electric field, positive negative zero. It's positive because F points in the same direction as displacement. Compare the work done by the electric field to that from W to X to then from X to W. We flipped the displacement around, forced it into the same direction, work is the dot product force and work, so it just rips on. The particle travels from X to Z along a circular arc, if zero, why is it zero?

Student 2: It's path independent.

Eric: Forget about path independent, let's say that I only want to talk about that paths, how can I argue that the work is zero?

Student 1: Beacuse, it's essentially like equal radius away from the positive charge on all points right, so its a eco-potential line?

Eric: Yes, that's another way.

Student 1: Travel along that like there's no difference.

Eric: Suppose we are trying to think about it purely in terms of mechanics. Here's the rod, and this is a circular arc, right? The distance is always the same. Let's consider a few points here, point one, point two, point three. What is the electric field that's pointing one and which way does it point? Straight away from here like that, right? What about point two?And how does that arrow-- Same one, right? I didn't draw it completely right. What about here? What do we know about those arrows compared to the path it takes

Student 3: They're existing over the same--

Eric: Same magnitude. What about the direction?

Student 1: They're all perpendicular to the path.

Eric: All perpendicular, this is perpendicular, this is perpendicular. Wherever we are it's perpendicular, so if you take a small displacement D-R, this is the electric static force. What do we know about this? D-R-F dot D-R.

Student 3: Very close.

Eric: That's this times this times the cosign of the of the angle which is?

Group: Zero.

Eric: This is zero always, everywhere, that's the best way of explaining it, the force is always equal to the displacement. It's better to do that because they want you to use that answer later on and show that it's past independent, but if you put the conclusion in the beginning, you defeat the purpose. Zero net work because the force is always perpendicular to the displacement. That's what you have in one-- Actually, let's go back to one.Let's go back to one. I agree it's positive. I agree it's negative, what about zero? What did you draw for your zero?

Student 1: We drew no displacement.

Student 2: You could also draw it like this.

Eric: We might have went over this.

Eric: I'm at roman numeral two C two, is that correct?

Student 2: Yes.

Eric: W-X-W-X-Z. X-Z doesn't add anything, not only is it positive work for. both [crosstalk]

Student 1: The magnitude is also equal.

Eric: The answer is the same. Suppose W to X and then Z to Y, this is positive work. This is negative work at the same magnitude so zero. Total work done, **[inaudible 01:17:27]** Wait, compare W to X and Z to Y, so they are opposite.So this is not zero work In D one, the answer is--

Student 1: They're equal and that includes opposite directions, yes.

Eric: W to X is positive. You have positive, its correct. Then Z to Y is negative, same magnitude. What is the total work done as you go around? The two cancel. W-X and Z-Y cancel and X to Z is zero, so it's zero. Suppose the particle on the arc show, is the work done by the particle positive negative zero. Suppose the particle travels along the straight path, is the work done on the particle by the electric field positive negative or zero? Let me make a drawing on the board.

Student 2: Is this one different now because it's not--

Eric: What is the rod? [crosstalk] Its this paths, right?

Student 1: Yes.

Eric: It's kind of weird. What about the force right here, it's going to be pointing perpendicular to the paths, so we know that the work done right at this part is zero. What about right here? The force is going to be like this, the displacement is going to be pointing in this direction, but at a point opposite, is going to be this vector and this displacement, F-F-F and this is the displacement of the point of replication of the force. What do we know about these two?

Student 2: They are in the same group.

Eric: The same in magnitude but the opposite side and same four points everywhere else. For each point here there is an equivalent little displacement there that cancels it out. These are all going to be negative and these are all going to be positive adding up to zero.

I would make that drawing to remind yourself of the reasoning.

[pause 01:20:20]

Last one. No.

Student 1: Yes, next one is--

Eric: Next page. E, last one. Compare the work done as the particle travels from W to Y along the three different parts in part B. They're all zero

Eric: Its independent. I don't know.

Student 1: I wrote, "there." That's not "there."

[laughter]

Eric: It's consistent. I don't know how to explain that.

[laughter]

When you get to three, ask somebody to try.

Group: Okay, thank you.

Eric: Welcome.

Student 2: [laughs] 'there'. I liked that

[laughter]

Student 3: This is our last section? Yes

Student 2: Oh, Really?

Student 3: Yes.

Student 4: Oh, Wow, nice.

Student 3: This is a good one. Suppose the charge of the particle **[inaudible 01:21:34]**

[pause 01:21:37]

Isn't it if you increase the potential, the work--

Student 2: Potential and work are just opposite signs.

Student 1: Didn't it say that if you divide potential difference by the charge, because that's how you get the negative. I don't know.

Student 4: Wait, there's potential energy and potential difference. One of them takes into account charge, one of them doesn't.

Student 1: It's got to be energy, doesn't it?

Student 2: Yes, he told us right here, in the bottom, that's work over charge, right?

Student 4: Nice, nice, that's potential difference?

Student 2: Yes.

Student 3: Where is the-- it's right here. [laughs]

Student 1: Potential difference-

[pause 01:22:44]

- multiplied by--

Student 2: No, no, is it the work is the same, but the potential difference is not?

Student 1: Yeah, the electric potential difference is going to change because there is a charge in the denominator does the work change is a good question. I feel like it does, right?

Student 2: I think it does.

Student 1: Work is like a mechanic, its like if you are lifting a block and the block is heavier, you have to apply more force over the same displacement, right?

Student 2: The equation we're working with supports **[inaudible 01:23:38]**

Student 1: Won't the force be greater if you're lifting something that's- I guess--

Student 2: That's mass and acceleration.

Student 1: Right, so if the mass is greater in this case as the charge is greater?

Student 2: Then, K-Q-Q over R squared. If you increase Q, then your force is increasing as well.

Student 4: I feel like it's got to be greater.

Student 1: Yeah, it seams like.

Student 4: It's like logic.

Student 2: Maybe the work is greater and potential difference is the same

Student 4: I think that might be it.

Student 1: That would make sense right?-- [crosstalk]

Student 2: Because then you divide by Q again, your Q's cancel out and you're getting equals to that.I feel like that's the answer. It's greater.

Student 4: It's greater?

Student 2: Then the work divided by the charge does not change.

Student 4: Yes. **[inaudible 01:24:33]**

Student 2: Yes.

Student 2: They're asking, does the quantity of electric potential difference-- The sign matters, but not the magnitude?

Student 1: Yeah, the magnitude itself, he said doesn't because the work divided by the charge is not affected.

Student 2: Does the sign matter? There is a negative W over here.

Student 4: Right, and when we change the sign, then we reverse the direction of W. We reverse Q, so it should--

Student 1: We mentioned this earlier in class today.

Student 2: Yes, so if you're saying you're going from here to here, positive charge--

Student 1: Yes, potential difference from any point A to B is the same regardless of what the test charge sign is.

Student 2: Okay, because the work will flip sign and the Q will flip sign.

Student 1: Yes.

Student 2: The magnitude also is not affected, right?

Student 1: Yes.

Student 2: It's becoming a little less fun.

Student 3: I know

[laughter]

Student 2: A charged particle with mass 3 times 10 to negative 8--

Student 4: It's probably positive, it's positive.

Student 2: [unintelligible 00:06:08] It's still positive, the electric field is still going that way

Student 1: As you later observed the passed coordinates.

Student 4: We just have to compare the speeds?

Student 2: Wait, suppose that the mass of the charge--

Student 3: Wait, what does the mass have to do with anything? [crosstalk]

Student 2: I think it's mass times acceleration because you know that--

Student 3: Is it? Okay.

Student 2: Wait, [crosstalk] one half M V squared, right?

Student 4: Oh are we looking at energy?

Student 2: I was going to calculate the acceleration.

Student 4: You could do that.

Student 2: It's the same

Student 4: Yes.

Student 2: There is the mass, 3 **[inaudible 01:26:59]** 3 squared plus 40, 22 times 40--

Student 3: Where did you get the 30 minus 8?

Student 2: 24 times 10 to the negative 7. 2.4 times--

Student 3: One half--

Student 1: 2.4 times 10 to the negative 5?

Student 2: Negative five.

Student 4: 2.4

Student 1: Meters per second.

Student 2: Joules. Then the work done on the particle by the electric field, it's got to be the change in kinetic energy.

Student 1: Yeah, I agree.

Student 4: Potential difference is the negative work? Do we have to divide by Q?

Student 2: Yes. Wait, we don't know that. We know Q.

Student 4: It's V equals negative W over Q.

Student 2: We know Q is 2 times 10 to the negative 6. That's one point. Is this negative 12 volts?

Student 1: What was the potential difference we used? Was it the joules we just calculated?

Student 2: Potential difference? Isn't this W over Q, negative W over Q?

Student 1: Then we plug in Q we know and then--

Student 2: Two times 10 to the negative 6. W is there.

Student 1: Right, because the work is equal kinetic energy?

Student 2: Yes.

Student 4: Is that negative 12?

Student 2: I got negative 12 volts.

Student 4: Owen are you good with --

Student 5: Yes. Can we go back to 2A real quick?

Student 2: 2A, yes.

Student 1: The formula for kinetic energy is one half MV squared. We know the mass-

Student 5: We know the velocity.

Student 1: We know the velocity. Then we plug those in and it comes out as 2.4 times 10 to the negative 5 joules. Then for the next one, we know the equation is the negative work over the charge gives us the potential difference, right?

Student 2: Yes, negative W over Q.

Student 1: Negative W over Q, and we found earlier that the--

Student 5: Kinetic energy equal to the work.

Student 1: Exactly, so we plug that in to the work, then we divide that by the charge which they give us and that comes out to-- What does that come out to?

Student 2: Negative 12 volts.

Student 1: That's convenient.

Student 5: Negative 12--

Student 2: Negative 12 volts.

Student 3: Every time the sun goes down. I think that said it with that one or something changes sometime because I've been [crosstalk]

Student 2: The same particle or at least Y **[unintelligible 01:30:33]**

Student 3: I think it would be equal because you have the same mass and it's travelling the same distance, you have coming from the same charged source. Nine times the charge. [crosstalk]

Student 2: Actually, potential difference-- Because the charge cancels off the top because the velocity would not produce still. This has released from rest, so before it was released from rest and then it accelerated to 40 **[unintelligible 01:31:36]** now we're **[unintelligible 01:31:38]** it's not going to start for 40. It should not-- I

Student 4: I think just the work is going to change proportionately to the charge. We're dividing by charge to get the potential difference.

Student 1: Didn't we say that in the last phase the potential difference is the same for all particles?

Student 2: The speed would be different.

Student 3: Wait, it's less? Would it be greater?

Student 2: Yes, the force , it's greater.[crosstalk]

Student 3: Particle and mass-- From point C. Too much schematics.

Student 2: You launch toward the rod from point C. It turns around at point Y. It goes around.

Student 1: It turns around to point Y.

Student 2: The particle has charge Q-- What speed should it be launched?

Student 1: 40 meters per second.

Student 3: When it say it turns around at point Y, does that mean is that zero?

Student 2: The charge must zero.

Student 4: Yes, it is meters er second.

Student 3: Yes, because if you goes from Y to Z-- Yes, it is. It has to be. [crosstalk] Now, when you have nine Q.

Student 4: I think it's got to be nine times eight.

Student 2: Is it through 60.

Student 1: Do we have a formula that relates to --

Student 2: You have one half MV squared 40 meters er second. squared. We're looking at--

Student 1: Force and speed.

Student 2: Force and speed. It's going to be accelerating so mass times acceleration. Acceleration when A is equal to what's going to B if its going to be B plus eight. Then to the velocity. This is zero. You've got to square plus eight X. In a time independent equation in the I zero. It's just like your VF provided by that.

Student 1: If we use Coulomb's law.

Student 2: Do you divide by Q again? Or is it 3 times 40? Because you square your velocity then you divide by nine and Q instead of-- I think three times four. I think it's 120. You divide by nine Q again. If its work over Q. Now, we know that work is one half MV squared over Q, and then if you want this to be equal and its 40 squared over 1. Now we're shifting it to something divided by nine and you want this ratio to be equal. It's going to be 40 times X squared. It should be three I think. Then you should be 120. Should we call TF over and then call it a day?

Student 1: If you want. Can you explain the last part to them?. Yes ,I get it. I don't want to explain it.

Student 2: Yes, are you good with the last part? We have V is equal to W over Q. We know that stays the same. We said that W is equal to one half MV squared. We know it's one half MV squared over Q and that has to be equal for both this and this. We said for this part that it would be 1 half times 40 squared over Q. We want to be equal to one half times N times sum velocity squared over nine Q right? Everything cancels. The sides like the 40 squared is equal to sum V squared over 9. It's like 40 squared times 9 squared is equal to V squared. Then you do the square root of 40 squared times 3 squared plus 9. It's supposed to be square, so these equal to 120. Does that make sense?

Student 5: Can you help with that one, one more time? 40 squared. God.

Student 2: I'm ready to head out.

Student 1: Yes, I agree, brilliant.

Student 3: Thanks for letting me borrow your pen.

[01:37:42] [END OF AUDIO]