<https://www.khanacademy.org/science/physics/mechanical-waves-and-sound/harmonic-motion/v/intuition-about-simple-harmonic-oscillators>

**SIMPLE HARMONIC OSCILLATORS:**

[Instructor] Alright, we should talk about oscillators. And what an oscillator is is an object or variable that can move back and forth or increase and decrease, go up and down, left and right, over and over and over. So for instance, a mass on a spring here is an oscillator if we pull this mass back, it's gonna oscillate back and forth, and that's what we mean by an oscillator. Or another common example is a pendulum, and a pendulum is just a mass connected to a string, and you pull the mass back and then it swings back and forth. So you've got something going back and forth, that's an oscillator. These are the two most common types. Masses on springs, pendulum, but there's many other examples and all those examples share one common feature of why they're an oscillator. So you could ask why do these things oscillate in the first place, and it's because they all share this common fact, that they all have a restoring force. And a restoring force, like the name suggests, tries to restore this system, but restore it to what? Restore the system to the equilibrium position. So every oscillator has an equilibrium position, and that would be the point at which there's no net force on the object that's oscillating. So for instance, for this mass, if this mass on the spring was sitting at the equilibrium position, the net force on that mass would be 0 because that's what we mean by the equilibrium position. In other words, if you just sat the mass there it would just stay there because there's no net force on it. However, if I pull this mass to the right, the spring's like uh uh, now I'm gonna try and restore this mass back to the equilibrium position, the spring would pull to the left. If I push this mass to the left, the spring's like uh uh, we're movin' this thing back to the equilibrium position, we're trying to push it back there. So if I push left, the spring pushes right. And if I pull the mass right, the spring pulls left. It tries to restore always, it tries to restore mass back to the equilibrium position. Sam for the pendulum. If I pull the pendulum to the right, gravity is the restoring force trying to bring it back to the left. But if I pull the mass to the left, gravity tries to pull it back to the right, always trying to restore this mass back to the equilibrium position. That's what we mean by a restoring force. Now there's lots of oscillators, but only some of those oscillators are really special, and we give those a special name. We call them Simple Harmonic Oscillators. And you might be thinking, that's a pretty dumb name because that doesn't sound very simple. But they're something called the Simple Harmonic Oscillator. So what makes Simple Harmonic Oscillator's so special is that even though all oscillators have a restoring force, Simple Harmonic Oscillators have a restoring force that's proportional to the amount of displacement. So what that means is if I pull this mass to the right there will be a restoring force, but if it's proportional to the displacement, if I pulled this mass back twice as much, I'd get twice the restoring force. And if I pulled it back three times as much, I'd get three times the restoring force. Same down here. If I pulled this pendulum back with two times the angle, I'd get two times the restoring force. If that's the case, then you've got what we call a Simple Harmonic Oscillator. And you still might not be impressed, you might be like who cares if the restoring force is proportional to the displacement. Why should I care about that? You should care about that because these satisfy some very special rules that I'll show you throughout this video and it throughout that even though this doesn't sound very simple, they are much simpler than the alternative of Non-Simple Harmonic Oscillators. So these are what we typically study in introductory physics classes, and it turns out a mass on a spring is a Simple Harmonic Oscillator, and a pendulum also for small oscillations, here you have to make a caveat, you have to say only for small angles, but for those small angles, the pendulum is a Simple Harmonic Oscillator as well. Now in this video, we're just going to look at the mass on the spring to make it simple. We could look at the pendulum later. So I'm going to get rid of the pendulum so we can focus on this mass on a spring. Now you might not be convinced, you might be like how do we know this mass on a spring is really a Simple Harmonic Oscillator? Well we can prove it because the force that's providing the restoring force in this case is the spring. So the spring is the restoring force in this case, and we know the formula for the force from a spring, that's given by Hooke's Law. And Hooke's Law says that the spring force, the force provided by the spring, is going to be negative. The spring constant times x, the spring displacement, so x is going to be positive if the spring has been displaced to the right because the spring's going to get longer. So this would be a positive x amount. And if you compress the spring, the length of the spring gets smaller, that's going to count as a negative x value. But think about it, if I compress the spring to the left, my x is going to be negative, and that negative combines with this negative to be a positive so I'd get a positive force. That means the spring is there's a force to the right. And that makes sense. Restoring, it means it opposes what you do. If you push the mass to the left, the spring is going to push to the right. And if we did it the other way, if we pulled the mass to the right, now that would be a positive x value. If I have a positive x value in here and combine that with a negative, I'd get a negative spring force. And that means the spring would be pulling to the left, it's restoring this mass back to the equilibrium position. And that's exactly what an oscillator does. And look at it up here, this spring force, this restoring force, is proportional to the displacement. So x is the displacement, this is a force that's proportional to the displacement. And that's the definition. That was what we meant by Simple Harmonic Oscillator. So that's why masses on springs are going to be Simple Harmonic Oscillators, because the restoring force is proportional to the displacement. Now to be completely honest, it has to be negatively proportional to the displacement. If you just had f equals kx with no negative, then if you displaced it to the right, the force would be to the right which would displace it more to the right, which would create a larger force to the right, this would be a runaway solution, this thing would blow up, that wouldn't be good. So it's really forces that have a negative proportionality to the displacement. That way it's going to restore back to the equilibrium position and if this is proportional, you get a Simple Harmonic Oscillator. And so we should talk about this, what the heck do we mean by simple? Like what is simple about this? It turns out that what's simple is that these types of oscillators are going to be described by sin and cosin functions. So Simple Harmonic Oscillators will be described by sin and cosin and that should make sense because think about sin and cosin, what do those look like? Sin and cosin look like this. So here's what sin looks like, it's a function that oscillates back and forth. And cosin looks like this, it starts up here, so it's also a function that oscillates back and forth. And so these are simple, turns out those are very simple functions that oscillate back and forth. And because of that, we like those. In physics, we love things that are described by sin and cosin, it turns out they're pretty easy to deal with mathematically. Maybe you don't feel that way, but they're much easier than the alternatives of other things that could oscillate. So that's what Simple Harmonic Oscillators mean. But let's try to get some intuition, what is really going on for this mass on a spring? So let's imagine we pull the mass back, right? So the mass, if the mass just continues to sit at the equilibrium position, it's a pretty boring problem because the net force right there would be 0 and it would just continue to sit there. So let's say we pull the mass back, we pull it back by a certain amount. Say we pull it back this far, and then we let go. So since we let go of the mass, we've released it at rest. So it started at rest. And that means the speed initially over here is 0. So it starts off with 0 speed, but the spring has been stretched. And so the spring is going to restore, right, the spring is always trying to restore the mass back to the equilibrium position. So the spring pulling the mass to the left, speeding it up, speeds the mass up until it gets to the equilibrium position, and then the spring realizes, oh crud, I messed up. I wanted to get the mass here but I pulled it so much this mass has a huge speed to the left now. And masses don't just stop on their own, They need some force to do that. So this mass has inertia, and according to Newton's First Law, it's going to try and keep moving. So even though the spring got the mass back to the equilibrium position, that was its goal, it got it back there with this huge speed and the mass continues straight through the equilibrium position and the spring starts getting compressed and the spring's like oh no, I've gotta start pushing this thing to the right. I want to get the mass back to the equilibrium position. So now the spring's pushing to the right, slowing the mass down until it stops it, but the spring is compressed, so it's going to keep pushing to the right. Now it's pushing in the direction the mass is moving. Now it's got it going back to the equilibrium position again, which is good, but again, same mistake, the spring gets this mass back to the equilibrium position with a huge speed to the right, and now the spring's like oh great, I did it again, I got this mass back where I wanted it, but this mass had a huge speed and it's got inertia, and so this mass is going to keep moving to the right, past the equilibrium position. And this is why the oscillation happens. It's a constant fight between inertia of the mass wanting to keep moving because it's got mass and it's got velocity, and the restoring force that is desperately trying to get this mass back to the equilibrium position and they can never quite figure it out because they keep overshooting each other and this oscillation happens over and over and over. So just knowing the story, let's you say some really important things about the oscillation. One of them is that at these end points, at these points of maximum compression or extension, the speed is 0. So this mass is moving the slowest, i.e. it's not moving at all at these maximum points of compression or extension because that's where the spring has stopped the mass and started bringing it back in the other direction. Whereas in the middle, at the equilibrium position, you get the most speed. So this is where the mass is moving fastest, when the spring has got it back to the equilibrium position and the spring at that point realizes oh crap, this mass is going really fast, and the mass is coming at it or going away from it too fast for the spring to stop it immediately. So if the equilibrium point this mass has the most speed during the oscillation. So we could also ask where will the magnitude of the restoring force be biggest and where will it be least during this oscillation? And we've got a formula for that. Look at, the spring force is the restoring force. So we could just ask where will the spring force be biggest? That's going to be where this x is biggest or smallest. So if we wanted to know where the magnitude of this f is largest, we could just ask where will the magnitude of the x be largest? If we don't care about which way the force is, we just want to know where we'll get a really big force, we just try to figure out where will I get the biggest x? X is displacement. So the x value at the equilibrium position is 0. So there's no displacement of the spring right here, that's what it means to be the equilibrium position, this is the natural length of the spring. That's the length that the spring wants to be. If the spring has that shape right there, it doesn't push or pull. But if you've displaced it this way, or the other way, this would be positive displacement, and this would be negative displacement, now the spring's going to exert a force. So where will the force be greatest? It's where the spring has been compressed or stretched the most. So at these points here, at the points of maximum extension or compression, you're going to have the greatest amount of force. So greatest magnitude of force, because the spring is really stretched, it's going to pull with a great amount of force back toward the equilibrium position. And we can say which way it points, right? This spring's going to be pulling to the left, so there's going to be a great spring force to the left. Technically that'd be a negative force, so I mean, if you're taking signs into account, you could say that that's the least force because it's really negative. But if you're just worried about magnitude, that would be a great magnitude of force. And then also over here, at the maximum compression, this spring is really pushing the mass to the right, you get a great amount of force this way because your x, even though it's very negative at that point, it's going to give you a large amount of force. And so here you would also have a great amount of magnitude of force which can be confusing because look it. At these end points, you have the least speed, but the greatest force. Sometimes that freaks people out. They're like, how can you have a great force and your speed be so small? Well that's the point where the spring has stopped the mass and started pulling it in the other direction. So even though the speed is 0, the force is greatest. So, be careful, force does not have to be proportional to the speed. The force has to be proportional to the acceleration, right? Because we know net force, we could say that the net force is equal to ma. So wherever you have the largest amount of force, you'll have the largest amount of acceleration. So we could also say at these endpoints, you'll have not only the greatest magnitude of the force, but the greatest magnitude of acceleration as well. Because where you're pulling or pushing on something with the greatest amount of force, you're going to get the greatest amount of acceleration according to Newton's Second Law. So at these endpoints, the force is greatest, the acceleration is also greatest. The magnitude, the acceleration is also greatest even though the speed is 0 at those points. So those are the points where you get the greatest force and greatest acceleration. Where will you get the least amount of magnitude of force and magnitude of acceleration? Well look at up here. The least force will happen where you get the least possible displacement. And the least possible displacement's right here in the middle, this equilibrium position is when x equals 0. That's when the spring is not pushing or pulling. When it's at this point here. So when the mass is passing through the equilibrium position, there is 0 force. Right, that's the point where the mass got back there and the spring was like I'm glad I got it back to the equilibrium position and then the spring quickly realized, oh no, this mass, I got it back there, but the mass was moving really fast, so it shot straight through that point. But right at that moment, the spring had this glorious moment where it thought it had done it and it stopped exerting any force because at that point, the x is 0. And if x is 0, we know from up here, the force is 0. So this would be the least possible force. And I guess I should say it's actually 0 force, it's not just the least, there is 0 force exerted at this point. And if there's 0 force, by the same argument, we could say that there's 0 acceleration at that point. Hopefully that gives you some intuition about why oscillators do what they do and where you might find the largest speed or force at any given point. So recapping, objects with a restoring force that's negatively proportional to the displacement will be a Simple Harmonic Oscillator and for all Simple Harmonic Oscillators, at the equilibrium position you'll get the greatest speed but 0 restoring force and 0 acceleration. Whereas at the points of maximum displacement, you'll get the maximum magnitude of restoring force and acceleration but the least possible speed.

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**AMPLITUDE and PERIOD:**

[Instructor] Alright so there's some terminology you gotta get used to when dealing with simple harmonic oscillators because people and books and teachers and professors are gonna throw these terms around like crazy, and if you are not used to them, it all can sound like mathematical witchcraft. So the first term you gotta know is that if you displace a mass from equilibrium, and why wouldn't you do that. That's how you get the thing to oscillate, by displacing it from equilibrium. The maximum magnitude of displacement, so this amount right here, whatever that distance is here, is called the amplitude. So we represent the amplitude with a capital A, and it's called the amplitude, and it's defined to be the maximum magnitude of displacement for that oscillator. So if this mass only ever makes it this far away, so from here to here. And I'm drawing arrows, but this is not a vector. It's the magnitude. Right? Magnitude of the displacement. So it's the magnitude of the vector, so it's always positive. So we can draw that over here. If we want to, we can just say this amplitude here. This would also be the amplitude, because we're just talking about the maximum magnitude of displacement. So it's gonna get displaced equally on either side of the equilibrium position and that maximum amount is called the amplitude. So in other words, if I pulled this mass back 20 centimeters then that means 20 centimeters would be the amplitude, or if you wanted it in meters it would be point two meters, and then, that means, when it shoots through the equilibrium position, it would also come over here and compress this spring by 20 centimeters on this side. So it's always equal on both sides. Now there's another term that you gotta get used to, and that's the period. So the period is represented with a capital T. Why is the period represented with a capital T when there's no T in the word Period? Not sure. But capital T is kind of like time, so T might stand for time. Maybe they thought that was a good idea. Because what the period means, is the time required for an entire cycle. So what does this mean. An entire cycle? What we mean is that you got oscillations going on. So this process is repeating itself. So in other words: if you start with the mass over here, it's gonna eventually make it over to this end over here, right? Goes over here, compresses the spring, then it's gonna come back. The time it takes, oh, that's a little hard to see, sorry. Let me draw that up here. So the time it takes for it to go to here, and then come all the way back after this happened, the whole thing just repeats. Now it's back here, the spring is gonna pull it back to the left, and go to the right. It's gonna pull it back to the left, push it back to the right. So this process is repeating itself. There's not something new happening. It's just the same process over and over. The time it takes to go through one entire cycle; ie: The time it takes to reset, essentially, once this entire system resets to the same position, that's the period. And so it's gonna be the same. Wether I count this as from this point back to that point, or if I imagine just starting my clock here, from this point is gonna go over to here, then it's gonna come back here, that would also be the period, because it's the time it took to reset. So the time it takes for this process to reset is what we call the period. It will be given in seconds, so for the sake to making this a little less abstract, let's say for example, the period of this mass on the spring was six seconds. What would that mean? It would mean that it took six seconds for the mass to go from this point and then all the way back to that point resetting itself. Now, this is getting kind of messy. And honestly, for that reason people often draw what the simple harmonic oscillator looks like on a graph. It turns out to be particularly elegant and useful to represent these ideas on a graph. Because, look it. If you just drew what's happening, you'd be like: alright, the mass goes here, and then there, and then there and then there, you are drawing all over yourself. So that's kinda ugly looking. It's better to represent this on a graph. What would that look like? So let me get rid of this. It would look like this. You would have a graph of the horizontal position X. So what does that mean? That means this. So we are essentially graphing what this is. This is X. The horizontal position has a function of time. Now already you might be upset. You might be like: Wait a minute. Why did we stick the horizontal position on the vertical axis? Isn't that a dumb thing to do? Well, perhaps. But long ago physicists decided: You know what? Time, if time is involved, we are sticking that bad boy on the horizontal axis. This is just designated. This is just by default. It's gonna go on the horizontal axis. So if you have anything else you wanna graph with it, that's gotta go on the vertical axis. And so unfortunately we're gonna be graphing horizontal position on this vertical axis. What that means is that this equilibrium position, remember this is the point where the net force, the restoring force, that net restoring force is zero. The only force on this mass, in this case, is the spring force which is given by Hook's law and that means this equilibrium position is gonna be the point where X equals zero. If I want my force to be zero, I better have x equals zero. So this equilibrium position right here, this is the line right here, let me give it a special color, this equilibrium position, is essentially just this X equals zero line. Right? These two lines are representing the same thing. They represent X equals zero. And if I go this way, if I pull this mass to the right, I'm essentially going up on this graph. Because I am going towards positive horizontal positions. And if I go to the left, if I push this mass to the left, I'm essentially going down towards negative horizontal positions on this graph. So hopefully that doesn't freak you out too bad. Let me show you what this looks like. If we do displace this mass, Let's say we pull it to the right. So like we had over here, right? We have this mass, we pull it to the right, and if we started 20 centimeters from the equilibrium position and let go. What's that gonna look like on this graph? Well it started to the right. If it starts to the right, I'm gonna start way over here, at this point is my initial position. That means I'm gonna start up here. I'll start up here at X equals 20 centimeters. If we put that in meters, technically SI units, you should have meters for the default units, so this would be point two. Zero point two meters, and that's also the amplitude. So remember, this is the amplitude. So this distance here is the amplitude. Then what does the mass do? Well it shoots back toward equilibrium, that's X equals zero. And then it oscillates. It goes through that point and comes back, so essentially what you're gonna have on here goes toward equilibrium, so it looks like this, goes toward equilibrium, BOOM! Hits equilibrium. And that's when it's at X equals zero. Passing through this point right here. Then it's gonna come back down, so eventually is gonna compress the spring and stop. That's when you're way over here and you've then stopped. The mass has been stopped by this spring. And it's gonna come back up and this process is gonna repeat, it's gonna go back through the equilibrium position and come back up. Which by up it means over here back to this initial point. That's one whole cycle. Look it, that has gone through a whole cycle. I kinda made this a little too high. Let me make that a little better. It should never go any higher that it started here. So it's gonna look something like that. Come back down and this whole process repeats over and over and over. And If I was drawing this perfectly, it'd be perfectly smooth, but hopefully you get the idea. And this is great! 'cause now we can draw the variables we talked about earlier like amplitude, because amplitude is the maximum magnitude of displacement from equilibrium. That would equal point two meters. That's what we represented on this graph here. And we can also represent the period. Remember, the period was the time it takes to go through an entire cycle. So if our mass started here, to go through an entire cycle, it better get back to that point and have reset completely, so that would be to here. So on this graph, this is the period. So the time it took to do that is one whole period. That would be the period T, which if we recall what we said earlier, we said that the period was six seconds. So if it really is six seconds, we can say that this here would be, if we count this is time T equals zero, this would be six seconds, this would be three seconds, that would be half of the period, or half of the cycle. This would be nine seconds, this would be 12 seconds, which would be two whole periods. And in a sense, it has gone through two whole cycles once it gets back to that point. Now notice, you didn't have to measure the period from peak to peak. You could have measured it from, sometimes people call these troughs or valleys, so you can measure it trough to trough, or valley to valley, took three seconds to nine seconds. That's a time of six seconds. It took six seconds to go from three seconds to nine seconds. That's still one whole period. Or you can go from this point here, I guess this would be like seven point five seconds all the way to what is this, 13.5 seconds? That would also be one whole period. Just make sure you don't do this: Sometimes people are like: oh, a period, eh? Repeat a whole cycle, eh? Alright I'm gonna go from this equilibrium position back to that equilibrium position. That's not a whole cycle. Look at it. This point the mass is going that way, and this point the mass is going that way. So you can't start your clock when the mass is going that way. Stop it when the mass is going the other way and see if you have gone through a whole cycle. Because that hasn't fully reset. If you're gonna fully reset, you gotta go from mass heading to the left through equilibrium, all the way back to mass heading to the left through equilibrium. So you would have to go from this equilibrium point, all the way to that equilibrium point to have a full cycle. A cycle would look like this whole process right there. So recapping: the amplitude of a simple harmonic oscillator is the maximum magnitude of displacement from the equilibrium position. You can measure it that way or you can measure it this way, you would get the same amount. And the period is the time it takes for an oscillator to complete one entire cycle, which you can find on a graph by measuring the time it takes to go from peak to peak, from valley to valley, or from equilibrium position, skip an equilibrium position, and then get to the next equilibrium position.

**VOCABULARY:**

to oscillate:( ileri geri) salınmak

oscillator: salınıcı

back and forth: ileri geri

over and over: tekrar tekrar

for instance: mesela

spring: yay, (su) kaynak

common: yaygın

pendulum: / pencılım/ sarkaç

to swing: sallanmak sallamak

swing: salıncak

to share: paylaşmak

share: pay

feature: hususiyet, özellik

in the first place: her şeyden evvel

to restore: eski haline getirmek, yenileştirmek

restoring force: eski haline getirici kuvvet, çekici kuvvet

equilibrium: denge hali, denge

lots of = a lot of

dumb: salak, aptal

to sound: gibi görünmek

If that's the case: hal bu ise

you've got = you have

to care: bakmak, umursamak

to satisfy: sağlamak, tatmin etmek

throughout: boyunca, başından sonuna

to turn out: happen, olmak

to make a caveat: /kaviyaat/ ikazda bulunmak

to convince: ikna etmek

providing: şartı ile

Hooke's Law: Hooke kanunu

to combine: birleştirmek

to oppose: karşı koymak

honest: dürüst

runaway: kontrolden çıkmış

to blow: (hava rüzgar) esmek, üflemek dont blow on your soup

to blow out: patlamak the tire blew out

to blow up: aşırı dereced büyümek, patlamak, patlatmak

boring: can sıkıcı

to release: bırakmak, salıvermek

to stretch: germek, gerinmek,esnetmek

crud: çöp, pislik, rezil, saçma

crud=rubbish

to mess up: berbat etmek, yüzüne gözüne bulaştırmak

mess: (bir miktar) yiyecek, yemek yenilen yer = mess hall

mess:dağınıklık, düzensizlik

mistake: hata, yanlışlık

to fight: dövüşmek, mücadele etmek

fight: dövüş

inertia: eylemsizlik ( mass is the measure of inertia of an object)

desperately: ümitsizce

quite: tam olarak, gayet

to overshoot :hedefi aşırmak

to compress: sıkmak,sıkıştırmak

to squeeze: sıkmak, sıkıştırmak,ezmek

technically: teknik olarak

over here: burada, buraya come over here

over there: orada, oraya

to freak out: son derece şaşırtmak, aşırı heyecanlandırmak

glorious: muhteşem

glory: ihtişam

to exert: uygulamak, tatbik etmek

witch: cadı

witchcraft: cadılık, büyücülük

amplitude: genlik

capital A: büyük A

upper case, lower case

to shoot: hızla ileri gitmek, şutlamak, silahı ateşlemek

shotgun: av tüfeği, çifte

shot: atış

to represent: temsil etmek, göstermek

to stand for: göstermek, temsil etmek

to repeat: tekrar etmek

to reset: ayarlamak, baştaki haline getirmek

ugly looking: çirkin görünüşlü

to graph: grafik çizmek

upset: üzgün,sinirli, altüst olmuş

by default: otomatik seçimle

default values

in a sense: bir bakıma

trough /traaf/ troo: yalak, tekne, bir dalganın en düşük yeri

cycle: devir