<https://www.khanacademy.org/science/physics/work-and-energy/work-and-energy-tutorial/v/introduction-to-work-and-energy>

**INTRODUCTION TO WORK AND ENERGY**

Welcome back. I'm now going to introduce you to the concepts of work and energy. And these are two words that are-- I'm sure you use in your everyday life already and you have some notion of what they mean. But maybe just not in the physics context, although they're not completely unrelated. So work, you know what work is. Work is when you do something. You go to work, you make a living. In physics, work is-- and I'm going to use a lot of words and they actually end up being kind of circular in their definitions. But I think when we start doing the math, you'll start to get at least a slightly more intuitive notion of what they all are. So work is energy transferred by a force. So I'll write that down, energy transferred-- and I got this from Wikipedia because I wanted a good, I guess, relatively intuitive definition. Energy transferred by a force. And that makes reasonable sense to me. But then you're wondering, well, I know what a force is, you know, force is mass times acceleration. But what is energy? And then I looked up energy on Wikipedia and I found this, well, entertaining. But it also I think tells you something that these are just concepts that we use to, I guess, work with what we perceive as motion and force and work and all of these types of things. But they really aren't independent notions. They're related. So Wikipedia defines energy as the ability to do work. So they kind of use each other to define each other. Ability to do work. Which is frankly, as good of a definition as I could find. And so, with just the words, these kind of don't give you much information. So what I'm going to do is move onto the equations, and this'll give you a more quantitative feel of what these words mean. So the definition of work in mechanics, work is equal to force times distance. So let's say that I have a block and-- let me do it in a different color just because this yellow might be getting tedious. And I apply a force of-- let's say I apply a force of 10 Newtons. And I move that block by applying a force of 10 Newtons. I move that block, let's say I move it-- I don't know-- 7 meters. So the work that I applied to that block, or the energy that I've transferred to that block, the work is equal to the force, which is 10 Newtons, times the distance, times 7 meters. And that would equal 70-- 10 times 7-- Newton meters. So Newton meters is one, I guess, way of describing work. And this is also defined as one joule. And I'll do another presentation on all of the things that soon. Joule did. But joule is the unit of work and it's also the unit of energy. And they're kind of transferrable. Because if you look at the definitions that Wikipedia gave us, work is energy transferred by a force and energy is the ability to work. So I'll leave this relatively circular definition alone now. But we'll use this definition, which I think helps us a little bit more to understand the types of work we can do. And then, what kind of energy we actually are transferring to an object when we do that type of work. So let me do some examples. Let's say I have a block. I have a block of mass m. I have a block of mass m and it starts at rest. And then I apply force. Let's say I apply a force, F, for a distance of, I think, you can guess what the distance I'm going to apply it is, for a distance of d. So I'm pushing on this block with a force of F for a distance of d. And what I want to figure out is-- well, we know what the work is. I mean, by definition, work is equal to this force times this distance that I'm applying the block-- that I'm pushing the block. But what is the velocity going to be of this block over here? Right? It's going to be something somewhat faster. Because force isn't-- and I'm assuming that this is frictionless on here. So force isn't just moving the block with a constant velocity, force is equal to mass times acceleration. So I'm actually going to be accelerating the block. So even though it's stationary here, by the time we get to this point over here, that block is going to have some velocity. We don't know what it is because we're using all variables, we're not using numbers. But let's figure out what it is in terms of v. So if you remember your kinematics equations, and if you don't, you might want to go back. Or if you've never seen the videos, there's a whole set of videos on projectile motion and kinematics. But we figured out that when we're accelerating an object over a distance, that the final velocity-- let me change colors just for variety-- the final velocity squared is equal to the initial velocity squared plus 2 times the acceleration times the distance. And we proved this back then, so I won't redo it now. But in this situation, what's the initial velocity? Well the initial velocity was 0. Right? So the equation becomes vf squared is equal to 2 times the acceleration times the distance. And then, we could rewrite the acceleration in terms of, what? The force and the mass, right? So what is the acceleration? Well F equals ma. Or, acceleration is equal to force divided by you mass. So we get vf squared is equal to 2 times the force divided by the mass times the distance. And then we could take the square root of both sides if we want, and we get the final velocity of this block, at this point, is going to be equal to the square root of 2 times force times distance divided by mass. And so that's how we could figure it out. And there's something interesting going on here. There's something interesting in what we did just now. Do you see something that looks a little bit like work? Well sure. You have this force times distance expression right here. Force times distance right here. So let's write another equation. If we know the given amount of velocity something has, if we can figure out how much work needed to be put into the system to get to that velocity. Well we can just replace force times distance with work. Right? Because work is equal to force times distance. So let's go straight from this equation because we don't have to re-square it. So we get vf squared is equal to 2 times force times distance. That's work. Took that definition right here. 2 times work divided by the mass. Let's multiply both sides of this equation times the mass. So you get mass times the velocity. And we don't have to write-- I'm going to get rid of this f because we know that we started at rest and that the velocity is going to be-- let's just call it v. So m times V squared is equal to 2 times the work. Divide both sides by 2. Or that the work is equal to mv squared over 2. Just divided both sides by 2. And of course, the unit here is joules. So this is interesting. Now if I know the velocity of an object, I can figure out, using this formula, which hopefully wasn't too complicated to derive. I can figure out how much work was imputed into that object to get it to that velocity. And this, by definition, is called kinetic energy. This is kinetic energy. And once again, the definition that Wikipedia gives us is the energy due to motion, or the work needed to accelerate from an object from being stationary to its current velocity. And I'm actually almost out of time, but what I will do is I will leave you with this formula, that kinetic energy is mass times velocity squared divided by 2, or 1/2 mv squared. It's a very common formula. And I'll leave you with that and that is one form of energy. And I'll leave you with that idea. And in the next video, I will show you another form of energy. And then, I will introduce you to the law of conservation of energy. And that's where things become useful, because you can see how one form of energy can be converted to another to figure out what happens to an object.

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Welcome back. In the last video, I showed you or hopefully, I did show you that if I apply a force of F to a stationary, an initially stationary object with mass m, and I apply that force for distance d, that that force times distance, the force times the distance that I'm pushing the object is equal to 1/2 mv squared, where m is the mass of the object, and v is the velocity of the object after pushing it for a distance of d. And we defined in that last video, we just said this is work. Force times distance by definition, is work. And 1/2 mv squared, I said this is called kinetic energy. And so, by definition, kinetic energy is the amount of work-- and I mean this is the definition right here. It's the amount of work you need to put into an object or apply to an object to get it from rest to its current velocity. So its velocity over here. So let's just say I looked at an object here with mass m and it was moving with the velocity v. I would say well, this has a kinetic energy of 1/2 mv squared. And if the numbers are confusing you, let's say the mass was-- I don't know. Let's say this was a 5 kilogram object and it's moving at 7 meters per second. So I would say the kinetic energy of this object is going to be 5-- 1/2 times the mass times 5 times 7 squared, times velocity squared. It's times 49. So let's see. 1/2 times 49, that's a little under 25. So it'll be approximately 125 Newton meters, which is approximately-- and Newton meter is just a joule-- 125 joules. So this is if we actually put numbers in. And so when we immediately know this, even if we didn't know what happened, how did this object get to this speed? Let's say we didn't know that someone else had applied a force of m for a distance of d to this object, just by calculating its kinetic energy as 125 joules, we immediately know that that's the amount of work that was necessary. And we don't know if this is exactly how this object got to this velocity, but we know that that is the amount of work that was necessary to accelerate the object to this velocity of 7 meters per second. So let's give another example. And instead of this time just pushing something in a horizontal direction and accelerating it, I'm going to show you an example we're going to push something up, but its velocity really isn't going to change. Let's say I have a different situation, and we're on this planet, we're not in deep space. And I have a mass of m and I were to apply a force. So let's say the force that I apply is equal to mass times the acceleration of gravity. Mass times-- let's just call that gravity, right? 9.8 meters per second squared. And I were to apply this force for a distance of d upwards. Right? Or instead of d, let's say h. H for height. So in this case, the force times the distance is equal to-- well the force is mass times the acceleration of gravity, right? And remember, I'm pushing with the acceleration of gravity upwards, while the acceleration of gravity is pulling downwards. So the force is mass times gravity, and I'm applying that for a distance of h, right? d is h. So the force is this. This is the force. And then the distance I'm applying is going to be h. And what's interesting is-- I mean if you want to think of an exact situation, imagine an elevator that is already moving because you would actually have to apply a force slightly larger than the acceleration of gravity just to get the object moving. But let's say that the object is already at constant velocity. Let's say it's an elevator. And it is just going up with a constant velocity. And let's say the mass of the elevator is-- I don't know-- 10 kilograms. And it moves up with a constant velocity. It moves up 100 meters. So we know that the work done by whatever was pulling on this elevator, it probably was the tension in this wire that was pulling up on the elevator, but we know that the work done is the force necessary to pull up on it. Well that's just going to be the force of gravity. So we're assuming that the elevator's not accelerating, right? Because if the elevator was accelerating upwards, then the force applied to it would be more than the force of gravity. And if the elevator was accelerating downwards, or if it was slowing down upwards, then the force being applied would be less than the acceleration of gravity. But since the elevator is at a constant velocity moving up, we know that the force pulling upwards is completely equal to the force pulling downwards, right? No net force. Because gravity and this force are at the same level, so there's no change in velocity. I think I said that two times. So we know that this upward force is equal to the force of gravity. At least in magnitude in the opposite direction. So this is mg. So what's m? m is 10 kilograms. Times the acceleration of gravity. Let's say that's 9.8 meters per second squared. I'm not writing the units here, but we're all assuming kilograms and meters per second squared. And we're moving that for a distance of 100 meters. So how much work was put into this elevator, or into this object-- it doesn't have to be an elevator-- by whatever force that was essentially pushing up on it or pulling up on it? And so, let's see. This would be 98 times 100. So it's 9,800 Newton meters or 9,800 joules. After we've moved up 100 meters, notice there's no change in velocity. So the question is, where did all that work get put into the object? And the answer here is, is that the work got transferred to something called potential energy. And potential energy is defined as-- well, gravitational potential energy. We'll work with other types of potential energy later with springs and things. Potential energy is defined as mass times the force of gravity times the height that the object is at. And why is this called potential energy? Because at this point, the energy-- work had to be put into the object to get it to this-- in the case of gravitational potential energy, work had to be put into the object to get it to this height. But the object now, it's not moving or anything, so it doesn't have any kinetic energy. But it now has a lot of potential to do work. And what do I mean by potential to do work? Well after I move an object up 100 meters into the air, what's its potential to do work? Well, I could just let go of it and have no outside force other than gravity. The gravity will still be there. And because of gravity, the object will come down and be at a very, very fast velocity when it lands. And maybe I could apply this to some machine or something, and this thing could do work. And if that's a little confusing, let me give you an example. It all works together with our-- So let's say I have an object that is-- oh, I don't know-- a 1 kilogram object and we're on earth. And let's say that is 10 meters above the ground. So we know that its potential energy is equal to mass times gravitational acceleration times height. So mass is 1. Let's just say gravitational acceleration is 10 meters per second squared. Times 10 meters per second squared. Times 10 meters, which is the height. So it's approximately equal to 100 Newton meters, which is the same thing is 100 joules. Fair enough. And what do we know about this? We know that it would take about 100-- or exactly-- 100 joules of work to get this object from the ground to this point up here. Now what we can do now is use our traditional kinematics formulas to figure out, well, if I just let this object go, how fast will it be when it hits the ground? And we could do that, but what I'll show you is even a faster way. And this is where all of the work and energy really becomes useful. We have something called the law of conservation of energy. It's that energy cannot be created or destroyed, it just gets transferred from one form to another. And there's some minor caveats to that. But for our purposes, we'll just stick with that. So in the situation where I just take the object and I let go up here, up here it has a ton of potential energy. And by the time it's down here, it has no potential energy because the height becomes 0, right? So here, potential energy is equal to 100 and here, potential energy is equal to 0. And so the natural question is-- I just told you the law of conservation of energy, but if you look at this example, all the potential energy just disappeared. And it looks like I'm running out of time, but what I'll show you in the next video is that that potential energy gets converted into another type of energy. And I think you might be able to guess what type that is because this object is going to be moving really fast right before it hits the ground. I'll see you in the next video

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Welcome back. At the end of the last video, I left you with a bit of a question. We had a situation where we had a 1 kilogram object. This is the 1 kilogram object, which I've drawn neater in this video. That is 1 kilogram. And we're on earth, and I need to mention that because gravity is different from planet to planet. But as I mentioned, I'm holding it. Let's say I'm holding it 10 meters above the ground. So this distance or this height is 10 meters. And we're assuming the acceleration of gravity, which we also write as just g, let's assume it's just 10 meters per second squared just for the simplicity of the math instead of the 9.8. So what we learned in the last video is that the potential energy in this situation, the potential energy, which equals m times g times h is equal to the mass is 1 kilogram times the acceleration of gravity, which is 10 meters per second squared. I'm not going to write the units down just to save space, although you should do this when you do it on your test. And then the height is 10 meters. And the units, if you work them all out, it's in newton meters or joules and so it's equal to 100 joules. That's the potential energy when I'm holding it up there. And I asked you, well when I let go, what happens? Well the block obviously will start falling. And not only falling, it will start accelerating to the ground at 10 meters per second squared roughly. And right before it hits the ground-- let me draw that in brown for ground-- right before the object hits the ground or actually right when it hits the ground, what will be the potential energy of the object? Well it has no height, right? Potential energy is mgh. The mass and the acceleration of gravity stay the same, but the height is 0. So they're all multiplied by each other. So down here, the potential energy is going to be equal to 0. And I told you in the last video that we have the law of conservation of energy. That energy is conserved. It cannot be created or destroyed. It can just be converted from one form to another. But I'm just showing you, this object had 100 joules of energy or, in this case, gravitational potential energy. And down here, it has no energy. Or at least it has no gravitational potential energy, and that's the key. That gravitational potential energy was converted into something else. And that something else it was converted into is kinetic energy. And in this case, since it has no potential energy, all of that previous potential energy, all of this 100 joules that it has up here is now going to be converted into kinetic energy. And we can use that information to figure out its velocity right before it hits the ground. So how do we do that? Well what's the formula for kinetic energy? And we solved it two videos ago, and hopefully it shouldn't be too much of a mystery to you. It's something good to memorize, but it's also good to know how we got it and go back two videos if you forgot. So first we know that all the potential energy was converted into kinetic energy. We had 100 joules of potential energy, so we're still going to have 100 joules, but now all of it's going to be kinetic energy. And kinetic energy is 1/2 mv squared. So we know that 1/2 mv squared, or the kinetic energy, is now going to equal 100 joules. What's the mass? The mass is 1. And we can solve for v now. 1/2 v squared equals 100 joules, and v squared is equal to 200. And then we get v is equal to square root of 200, which is something over 14. We can get the exact number. Let's see, 200 square root, 14.1 roughly. The velocity is going to be 14.1 meters per second squared downwards. Right before the object touches the ground. Right before it touches the ground. And you might say, well Sal that's nice and everything. We learned a little bit about energy. I could have solved that or hopefully you could have solved that problem just using your kinematics formula. So what's the whole point of introducing these concepts of energy? And I will now show you. So let's say they have the same 1 kilogram object up here and it's 10 meters in the air, but I'm going to change things a little bit. Let me see if I can competently erase all of this. Nope, that's not what I wanted to do. OK, there you go. I'm trying my best to erase this, all of this stuff. OK. So I have the same object. It's still 10 meters in the air and I'll write that in a second. And I'm just holding it there and I'm still going to drop it, but something interesting is going to happen. Instead of it going straight down, it's actually going to drop on this ramp of ice. The ice has lumps on it. And then this is the bottom. This is the ground down here. This is the ground. So what's going to happen this time? I'm still 10 meters in the air, so let me draw that. That's still 10 meters. I should switch colors just so not everything is ice. So that's still 10 meters, but instead of the object going straight down now, it's going to go down here and then start sliding, right? It's going to go sliding along this hill. And then at this point it's going to be going really fast in the horizontal direction. And right now we don't know how fast. And just using our kinematics formula, this would have been a really tough formula. This would have been difficult. I mean you could have attempted it and it actually would have taken calculus because the angle of the slope changes continuously. We don't even know the formula for the angle of the slope. You would have had to break it out into vectors. You would have to do all sorts of complicated things. This would have been a nearly impossible problem. But using energy, we can actually figure out what the velocity of this object is at this point. And we use the same idea. Here we have 100 joules of potential energy. We just figured that out. Down here, what's the height above the ground? Well the height is 0. So all the potential energy has disappeared. And just like in the previous situation, all of the potential energy is now converted into kinetic energy. And so what is that kinetic energy going to equal? It's going to be equal to the initial potential energy. So here the kinetic energy is equal to 100 joules. And that equals 1/2 mv squared, just like we just solved. And if you solve for v, the mass is 1 kilogram. So the velocity in the horizontal direction will be, if you solve for it, 14.1 meters per second. Instead of going straight down, now it's going to be going in the horizontal to the right. And the reason why I said it was ice is because I wanted this to be frictionless and I didn't want any energy lost to heat or anything like that. And you might say OK Sal, that's kind of interesting. And you kind of got the same number for the velocity than if I just dropped the object straight down. And that's interesting. But what else can this do for me? And this is where it's really cool. Not only can I figure out the velocity when all of the potential energy has disappeared, but I can figure out the velocity of any point-- and this is fascinating-- along this slide. So let's say when the box is sliding down here, so let's say the box is at this point. It changes colors too as it falls. So this is the 1 kilogram box, right? It falls and it slides down here. And let's say at this point it's height above the ground is 5 meters. So what's its potential energy here? So let's just write something. All of the energy is conserved, right? So the initial potential energy plus the initial kinetic energy is equal to the final potential energy plus the final kinetic energy. I'm just saying energy is conserved here. Up here, what's the initial total energy in the system? Well the potential energy is 100 and the kinetic energy is 0 because it's stationary. I haven't dropped it. I haven't let go of it yet. It's just stationary. So the initial energy is going to be equal to 100 joules. That's cause this is 0 and this is 100. So the initial energy is 100 joules. At this point right here, what's the potential energy? Well we're 5 meters up, so mass times gravity times height. Mass is 1, times gravity, 10 meters per second squared. Times height, times 5. So it's 50 joules. That's our potential energy at this point. And then we must have some kinetic energy with the velocity going roughly in that direction. Plus our kinetic energy at this point. And we know that no energy was destroyed. It's just converted. So we know the total energy still has to be 100 joules. So essentially what happened, and if we solve for this-- it's very easy, subtract 50 from both sides-- we know that the kinetic energy is now also going to be equal to 50 joules. So what happened? Halfway down, essentially half of the potential energy got converted to kinetic energy. And we can use this information that the kinetic energy is 50 joules to figure out the velocity at this point. 1/2 mv squared is equal to 50. The mass is 1. Multiply both sides by 2. You get v squared is equal to 100. The velocity is 10 meters per second along this crazy, icy slide. And that is something that I would have challenged you to solve using traditional kinematics formulas, especially considering that we don't know really much about the surface of this slide. And even if we did, that would have been a million times harder than just using the law of conservation of energy and realizing that at this point, half the potential energy is now kinetic energy and it's going along the direction of the slide. I will see you in the next video.

**VOCABULARY**

introduce: tanıtmak, tanıştırmak

introduction: tanıtma, tanıştırma, giriş, başlangıç

concept: mefhum, fikir, kavram

notion: mefhum, kavram, fikir

context: bağlam,durum

unrelated: ilgisiz, alakasız

related: ilgili, alakalı

to relate: iki şey arasında ilgi, alaka kurmak

relation: alaka, ilgi, bağ

relative: akraba

make a living: hayatını kazanmak

a lot of: bir çok

to end up: neticelenmek, sonuçlanmak

circular: dairesel, kısır döngülü

the math; hesaplama, matematik

to transfer: nakletmek, taşımak, dönüştürmek

reasonable: makul, mantıklı

to looke up: sözlükte vs bakmak, aramak

entertaining: eğlendirici

to entertain: eğlendirmek

entertainment: eğlence

to perceive: sezmek, algılamak

perception: algı, sezgi

ability: kabiliyet, yetenek

frankly: Samimiyetle, açıkcası

tedious: sıkıcı, bıktırıcı, can sıkıcı.

presentation: sunum

to present: /prızent/ sunmak

present:/prezint/ hediye

present tense: şimdiki zaman

at rest: durgun, hareketsiz

to rest: istirahat etmek, dinlenmek

to push: itmek

to figure out: hesap etmek

stationary: durgun, hareketsiz

variable: değişken

to vary:değişmek

variation: değişme

to change: değişmek

change:değişme

to fluctuate: değişmek

fluctuation:değişme

projectile: atılan nesne

projectile motion eğik atış hareketi

variety: çeşit, çeşitlilik,cins, tür

square root: kare kök

to get rid of: kurtulmak, başından savmak

to impute: yüklemek, üstüne yıkmak

common: ortak, yaygın

to converte: (şeklini) değiştirmek

current: akım, halihazır

currently: halihazırda

currency: para birimi

to confuse: kafa karıştırmak

confusing: kafa karıştırıcı

times: kere (five times four is twenty)

approximately : takriben, yaklaşık olarak

to calculate: hesaplamak

calculation: hesaplama

horizontal : yatay

vertical :dikey

the acceleration of gravity: yerçekimi ivmesi

elevator: asansör (British English: lift )

to elevate: yükseltmek

slightly: biraz, azıcık

already: şimdiden , çoktan

net force: net kuvvet, toplam kuvvet

essentially: esas olarak

to let go of : birakmak, salıvermek

other than: ....den başka

still: hala, durgun

fair: adil,makul,dürüst,doğru,beyaz tenli,namuslu,

to conserve: korumak, muhafaza etmek

conservation: koruma, korunma

caveat:ikaz, uyarı

purpose: maksat, amaç

to aim: hedeflemek, gaye edinmek, nişan almak

aim:maksat, gaye

by the time it's down here: burada aşağıda olana kadar

to disappeare: yok olmak

to appear: görünmek

appearance: görünüş

I’m running out of time: vaktim bitiyor, vaktim azaliyor

right: doğru

a bit of : biraz

neat: derli toplu, düzenli

neater :daha derli toplu

simplicity: basitlik

if you work them all out: hepsini hallederseniz, hesaplarsaniz

to create: yaratmak

to destroy: imha etmek, mahvetmek

previous: evvelki, önceki

latter: sonraki

to memorize: ezberlemek

memory: hafıza

memorization: ezberleme

solve for v: v yi çöz

to erase: silmek

eraser: silgi

stuff: madde

lump: yumru, çıkıntı

to slide: kaymak

slope: bayır, eğim

to break it out into vectors: vektörlere ayırmak

to drop: düşürmek, bırakmak