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**Race Cars with Constant Speed around Curve:**

So we have some race cars racing, right here. And I have an interesting question to ask you. If we assume that these cars are making this turn right over here, that all of them are making this turn at a constant speed of 100 kilometers per hour, my interesting question for you is, are these cars accelerating while they make this turn? So is acceleration happening? And you might say, well, gee, look, my speed was constant, it's not changing. If I looked at the speedometer for the car here, if I looked at the speedometer over here, it won't budge, it just stays at 100 kilometers per hour. I don't have any change in speed over time. And so then you might say that you don't have any acceleration. But then you might be saying, well, why would Sal even make this video? And why would that question even be interesting? And your second suspicion would be true, because these cars actually are accelerating despite having a constant speed. And you can pause it and think about that for a second, if want to. But I wanted to point this out to you, because in an example like this, the difference between speed and velocity starts to matter, speed being a scalar quantity only having a magnitude. And velocity being a vector quantity, being speed with a direction, having a magnitude and a direction. And to think about-- let's take a top view of this thing, and then I think it'll become a little bit clearer the difference between speed and velocity and why these things are accelerating. So if I were to take a top view of this racetrack-- I'll do my best attempt to draw it-- so it might look something like this. This is the top view. I could even draw this red and white. So red, just to give you the idea. So this is the red, and there's some white in between. Obviously I'm not drawing as many dividers as there are in the actual picture, but it gives you an idea of what I'm actually drawing. And then there's some grass out here, there's some grass over here, and then there's some grass over here. And let's focus on this orange car and this red car right over here. And this is a top view, so this is its path right over here. And we're saying it has a constant speed of 100 kilometers per hour. So if you think about its velocity, the magnitude of it's velocity is constant, it's 100 kilometers per hour. But what is happening to the direction of the velocity? Remember, velocity is a vector quantity. It has magnitude and direction. So up here, when it's starting to enter the curve, it's going in this direction. And you tend to show vectors by arrows like this. And what you do is, the arrow's going in the direction of the velocity, in this case, and normally you would draw the length of the arrow shows what is the velocity. The magnitude of the velocity, I should say. So it's velocity's constant. So the length of this arrow will always be constant. But as we see, it's direction changes. When it's halfway through the turn, it's not going in that same direction. It is now going in a different direction, and when it comes to the bottom of the turn, it's going in a very different direction. And the direction keeps changing as long as it is turning. And I'm not going to go into the math here. We're going to wait for the math on this a little bit later. But remember, acceleration is a change in velocity over time. Acceleration is equal to a change in velocity over time, or we could say over a change in time. And although the velocity's magnitude is constant here, it's direction is changing. If there was no acceleration on it, it's magnitude and the direction of it's velocity would be constant, and the car would just keep going in that direction. So somehow, the car's direction is changing inward over and over and over again. And so this is just kind of a little bit of a trick question, something for you to think about, we're going to discuss the math in more detail in future videos. But what's happening here is the cars actually are accelerating. And they're actually accelerating inwards, and that's what's changing inwards. And when I say inwards, they're being accelerated towards the center of the curve, and that's what's allowing their direction to actually change.

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Centripetal Force and Acceleration

Let's say we observe some object-- let's say for the sake of argument, it's happening in space It's traveling in a circular path with the magnitude of its velocity being constant Let me draw its velocity vector The length of this arrow is the magnitude of the velocity I want to be clear. In order for it to be traveling in the circular path the direction of its velocity needs to be changing So this time the velocity vector might look like that After a few seconds the velocity vector might look like this After another few seconds the velocity vector might look like this I'm just sampling. I actually could've sampled after a less time and it would be right over there but I am just sampling sometimes as it travels around the circle After a few more seconds the velocity vector might look something like that I want to think about what needs to happen what kind of force would have to act in particular the direction of the force would have to act on this object in order for the velocity vector to change like that? This remind ourselves if there was no force acting on this body this comes straight from Newton's 1st Law of motion then the velocity would not change neither the magnitude nor the direction of the velocity will change If there were no force acting on the subject it would just continue going on in the direction it was going it wouldn't curve; it wouldn't turn; the direction of its velocity wasn't changing Let's think about what the direction of that force would have to be and to do that, I'm gonna copy and paste these velocity vectors and keep track of what the direction of the change in velocity has to be Copy and paste that So that is our first velocity vector Copy all of these. This is our second one right over here Copy and paste it I'm just looking at it from the object's point of view how does the velocity vector change from each of these points in time to the next? Let me get all of these in there This green one That. Copy and paste it That. I could keep going, keep drawing velocity vectors around the circle but let me do this orange one right over here Copy and paste So between this magenta time and this purple time what was the change in velocity? Well, we could look at that purely from these vectors right here The change in velocity between those two times was that right over there That is our change in velocity So I take this vector and say in what direction was the velocity changing when this vector was going on this part of the arc It's roughly--if I just translate that vector right over here it's roughly going in that direction So that is the direction of our change in velocity This triangle is delta; delta is for change Now think about the next time period between this blue or purple period and this green period Our change in velocity would look like that So while it's traveling along this part of the arc roughly it's the change in velocity if we draw the vector starting at the object It would look something like this I'm just translating this vector right over here I'll do it one more time From this green point in time to this orange point in time and obviously we're just sampling points continuously moving and the change in velocity actually continues changing but hopefully you're going to see the pattern here So between those two points in time, this is our change in velocity And let me translate that vector right over there It would look something like that change in velocity So what do you see, if I were to keep drawing more of these change in velocity vectors you would see at this point, the change in velocity would have to be going generally in that direction At this point, the change in velocity would have to be going generally in that direction So what do you see? What's the pattern for any point along this circular curve? Well, the change in velocity first of all, is perpendicular to the direction of the velocity itself And we haven't proved it, but it at least looks like it Looks like this is perpendicular And even more interesting, it looks like it's seeking the center The change in velocity is constantly going in the direction of the center of our circle And we know from Newton's first law that if--the magnitude could stay the same but the velocity change in any way, either the magnitude or the direction or both there must be a net force acting on the object And the net force is acting in the direction of the acceleration which is causing the change in velocity So the force must be acting in the same direction as this change in velocity So in order make this object go in this circular there must be some force kind of pulling the object towards the center and a force that is perpendicular to its directional motion And this force is called the centripetal force Centripetal Not to be confused with centrifugal force, very different Centripetal force, centri- you might recognize as center and then -petal is seeking the center. It is center seeking So this centripetal force, something is pulling on this object towards the center that causes it to go into this circular motion Inward pulling causes inward acceleration So that's centripetal force causing centripetal acceleration which causes the object to go towards the center The whole point why I did this is that at least it wasn't intuitive to me that if you have this object going in a circle that the change in velocity, the acceleration, the force acting on this object would actually have to be towards the center The whole reason why I drew these vectors and then translate them over here and drew these change in velocity vectors is to show you that the change in velocity is actually towards the center of this circle Now with that out of the way, you might say, well, where is this happening in in everyday life or in reality in some way it perform And the most typical example of this and this is something that I think most of us have done when we were kid if you had a yoyo My best attempt to draw a yoyo If you have a yoyo and if you whip it around on a string you know that the yoyo goes in a circle Even though its speed might be constant, or the magnitude of its velocity might be constant we know that the direction of its velocity is constantly changing It's going in a circle and what's causing it to go in a circle is your hand right over here pulling on this string and providing tension into the string So there's a force, the centripetal force in this yoyo example is the tension in the string that's constantly pulling on the yoyo towards the center and that's why that yoyo goes in a circle Another example that you are probably somewhat familiar with or at least have heard about is if you have something in orbit around the planet So let's say this is Earth right here and you have some type of a satellite that is in orbit around Earth That satellite has some velocity at any given moment in time What's keeping it from not flying out into space and keeping it going in a circle is the force of gravity So in the example of a satellite or anything in the orbit even the moon in orbit around the Earth the thing that's keeping an orbit as opposed to flying out into space is a centripetal force of Earth's gravity Now another example, this is probably the most everyday example because we do it all the time If you imagine a car traveling around the racetrack Let's draw a racetrack. If I have a racetrack Before I tell you the answer, I'll have you think about it It's circular. Let's view the racetrack from above If I have a car on a racetrack. I want you to pause it before I tell it to you because I think it's an interesting thing think about It seems like a very obvious thing that's happening We've all experienced; we've all taken turns in cars So we're looking at the top of a car. Tires When you see a car going at a constant speed so on the speedometer, it might say, 60 mph, 40 mph, whatever the constant speed but it's traveling in a circle so what is keeping--what is the centripetal force in that example? There's no obvious string being pulled on the car towards the center There is no some magical gravity pulling it towards the center of the circle There's obviously gravity pulling you down towards the ground but nothing pulling it to the side like this So what's causing this car to go in the circle as opposed to going straight? And I encourage you to pause it right now before I tell you the answer Assuming you now unpaused it and I will now tell you the answer The thing that's keeping it going in the circle is actually the force of friction It's actually the force between the resist movement to the side between the tires and the road And a good example of that is if you would remove the friction if you would make the car driving on oil or on ice or if you would shave the treads of the tire or something then the car would not be able to do this So it's actually the force of friction in this example I encourage you to think about that

**VOCABULARY**

Race: yarış

To race: yarışmak

Racing car: yarış arabası

İnteresting: ilginç, enteresan

100 kilometers per hour: saatte 100 km

Gee: vay canına

To Budge: kımıldamak, hareket etmek, oynamak

Suspicion :şüphe

To suspect :şüphe etmek, şüphelenmek

Despite: e rağmen

Being: olarak, olduğundan

velocity being a vector quantity: hiz bir vektör büyüklüğü olarak (olduğundan)

Racetrack : yarış pisti

Attempt : teşebbüs

To attempt: teşebbüs etmek

To Divide: bölmek

Division: bölüm

Grass: çimen

To focus: odaklanmak

Focus: odak, odak noktası

Curve: eğri, viraj

To curve: eğrilmek

Arrow: ok

Keeps changing: değişmeye devam eder

as long as: müddetçe, sürece

although: e rağmen

somehow: nasılsa

to allow: müsade etmek, izin vermek

to observe :gözlem yapmak

observation: gözlem

for the sake of argument : argumanın hatırına

sampling: örnekleme, seçme

sample: numune, örnek

act :hareket

neither the magnitude nor the direction of the velocity will change: hızın ne büyüklüğü ne de yönü değişecek

I'm gonna: I m going to

point of view: bakış açısı, görüş açısı

purely: safça, sadece, yalnızca, sırf

pure: saf

to translate: tercüme etmek, ötelemek

delta: delta harfi

pattern: desen, örnek

perpendicular :dik

vertical: dik

to prove: ispat etmek

proof: ispat

to cause: sebep olmak

ause: sebep

intuitive: sezgisel

yoyo: yoyo

string: ip, sicim

to provide: tedarik etmek

tension: gerilim

tense: gergin

orbit: yörünge

planet: gezegen

satellite: uydu

as opposed to: e karşı olarak

space: uzay, feza

to imagine: hayal etmek

imagination: hayal

to experience: tecrübe etmek,denemek, maruz kalmak, başına gelmek

experience: tecrübe, başa gelen hadise

experiment: deney

gravity: yerçekimi, kütle çekimi, ağırlık

to encourage : cesaretlendirmek, teşvik etmek

to pause: duraklamak

pause: duraklama

friction: sürtünme

friction force: sürtünme kuvveti

to shave: tıraşlamak, tıraş etmek

shave: tıraş

tread: araba lastiğindeki çıkıntı

tire: araba lastiği

wheel: tekerlek

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

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. I'll see