4.C.3. We have a particle that moves with a constant velocity. Keep that in mind, a constant velocity. And the velocity vector equals 4, minus 2, 1.

If it has a constant velocity that the sum of all forces must be 0. That is non-negotiable. If it were not 0 the velocity would change. It has a mass, if I'm not mistaken, of 3 kilograms. So there are several forces working on this object, and there is one force, us which is lifted out for this problem, and that one force has in the x direction minus 1, in the y direction plus 2, and in the z direction plus 2 Newtons.

Now the first question is, what is the kinetic energy of this object? The kinetic energy will never change because the velocity will never change. And if the velocity will never change, the velocity vector then of course, the speed will never change either. This is the speed. This is a scalar here where this is a vector. And since the velocity is the square root of the sum of the squares, 16 plus 4 plus 1. That is 21, so v squared must be 21. So I get 1/2 times 3 times 21 joules. And it's never changing because the sum of all forces are 0.

Now comes the question, what is the work done by this force alone as this object travels always in the same direction because the velocity is the same over a distance of 3 meters? Well the object is here at A and this is a distance of 3 meters. And here it is at B. This is that velocity that will never change. And that this v, that force, that one force that we just lifted out. And let the angle here be theta. And somewhere here the object is moving over a distance ds in this direction. And AB equals 3 meters.

So the work that is done by this force equals the dot product. It is the dot product between the force times this placement AB, which I will indicate as a vector. Of course, effectively what it is, it is the integral going from A to B of F dot ds. But that in this case, is the same as here because it's a straight line.

Well, we know what F is, the magnitude of F. Oh, by the way, this also equals the magnitude of F times the magnitude of AB, which is 3 meters, times the cosine of theta.

Now I know F, the magnitude of F equals 3 Newtons. You can easily calculate that. I know that AB is 3 meters. This is 3 Newtons.

So now the question is, what is the cosine of theta? If I have the cosine of theta, then I can calculate the amount of work done by this force. Well F dot v-- the dot product between F and v-- equals Fx vx plus Fy vy plus Fz vz. And that equals F magnitude v magnitude times the cosine of theta. And this allows you immediately to calculate cosine theta.

Fx times vx? Well that's easy. It is 4 times minus 1. That's minus 4. This is minus 2 times plus 2. That is also-- excuse me. Minus 4. And this is 1 times 2. That is plus 2. We know that this is 3. We know that this is the square root of 21. So out pops cosine theta. So you are capable of calculating cosine theta. And I find that cosine theta leads to a value for theta, which is 116 degrees. Which is larger than 90 degrees, so the situation that we have is that v is in this direction and F is in this direction. So that this angle is larger than 90 degrees. And the conclusion therefore is, that this force does negative work. You think about that a little more. We have discussed this now extensively, and so you should be able to convince yourself that the force is negative-- does negative work.

Now, what is now all this business about negative work and positive work? How can it be that I, Walter Lewin, or you, for that matter, how can it be that you do negative work? I can see that at times we're all lazy and that we do no work. But how can we do negative work? Well, perhaps I can show you best with a simple example.

Suppose I am somewhere in outer space, and there is here an object going with velocity v. And I pull on this object and I slow it down. And when I slow it down, I effectively reduce the kinetic energy. So you see I have removed kinetic energy. So I am taking energy out. So I do negative work.

Suppose I was standing on the earth and this was a dog, which was pulling me. And I hold the leash of the dog in my hand, and the dog is pulling me, pulling me, pulling me. And I dig my heels into the sand, which is a similar situation. The dog wants to go this way, I oppose it, and my heels dig into the sand. I am therefore, removing kinetic energy from the dog; slowing the dog down.

Where does this energy go? Can I lose this energy? Yeah, you can lose mechanical energy. You can lose kinetic energy. You can also lose potential energy. But you can never lose energy entirely. It always shows up somewhere. In this case, where the dog is pulling me and I'm digging my heels in, for sure this heat will-- this energy loss will show up in terms of heat. Probably heat at friction at my feet. But sometimes heat can even show up in my muscles. It can come through my body.

We now take an example, which is one whereby I use gravity.

Suppose I have an object that goes like this. I throw it up, it has a velocity here upwards and a velocity here downwards. This is point A, this is point B, and this is point C. Now we have gravity here mg and we have gravity here mg. And what you see now is the object goes from A to B. The kinetic energy decreases, but the potential energy increases. And gravity does negative work.

However, when it goes from B to C, the kinetic energy increases. The potential energy, gravity potential energy decreases, and gravity does positive work.

In this case, unlike in the case when I did the negative work pulling onto the dog when energy was converted to heat. In these case, we have the conservation of what we call mechanical energy. The potential energy at A plus the kinetic energy at A equals the potential energy at B plus the potential energy at B. And it also equals the potential energy at C plus the kinetic energy at C. This is very handy whenever there is no friction and we're dealing with gravity. The same is true for electricity. We have this conservation law. In the case of electricity of course, it's the conservation of electrical potential energy and kinetic energy. Here it is gravitational potential energy and connected energy. This is very useful to use. Very useful in certain problems, and we will see an example of that.