Engineering Mechanics
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Statics - 5.1

Hi this is Mr. Venkat Rao. I am going to ask him a question. It's a simple question don't be nervous. The question is simple, I just have to know there is a body here just like what you see here. It has a weight on it equal to mg, I want to know the frictional force on this block. How do you find out? I want to know the frictional force on the block offered by the surface. Can you write down the magnitude of that? You can come this side. Can you write the magnitude of that? [Student: unless it is subjected to a movement] but there is a frictional force [Student: we don't know what is the frictional force, directional frictional force] but there is a frictional force. What is the frictional force [student: I have a weight of mg, we will get exactly opposite to the weight of the…] that's the normal reaction [Student: normal reaction] this is the normal reaction.

Let's call this as N. N is equal to mg. What will be the frictional force? If N is the normal force, the frictional force is related to normal force. [Student: that is what friction will be same] Supposing I am applying a force like this. The frictional force is opposite to the direction of the applied force which is equal to… mg is given [student: zero] what is the frictional force if mu is given? mu-mg, write it down. [Student: supposing the body is moving this direction] No, supposing I am applying a force here. The frictional force here is related to this. [Student: coefficient of friction into weight mu-mg] very good. Thank you.

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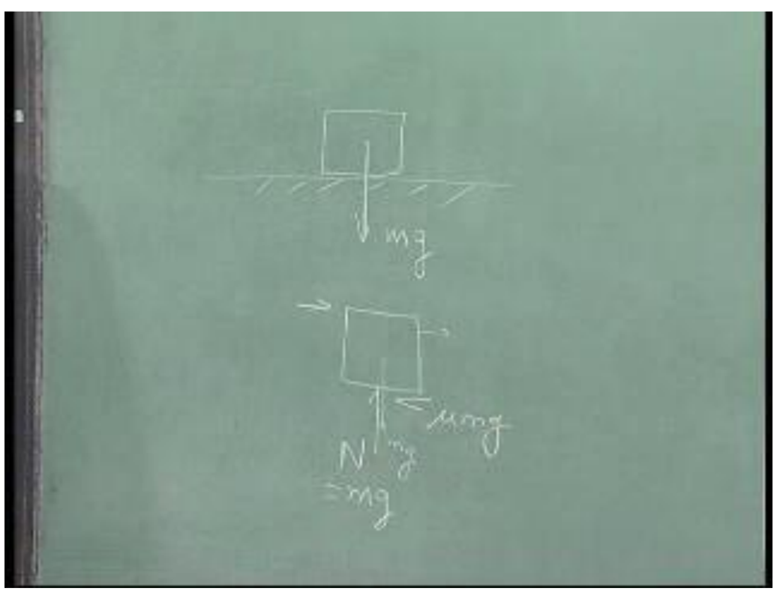

Often this is the mistake many students make. Here I am not pin pointing one student, most students will immediately write the frictional force to be mu times mg. I am going to argue and discuss that this is not always the case. Let's just look at it more seriously and understand this particular problem. Let me start off with a simple idea here. Let's say this is the body, there is a weight acting on it. Am I audible? If I draw the free body of this then mg is acting like this, there is a normal reaction N that much is correct. When I apply a force lets say like this equal to F. The question I am asking now is what is the frictional force? Yes, the answer is partially correct. The frictional force is opposite to the force applied but saying that this is equal to mu-mg is not always correct. This is the notion that many students have a problem with. Of course in this particular case when I say mu, mu_s is the coefficient of friction that I am talking about, static friction this is true only when the body starts to move or is about to move.

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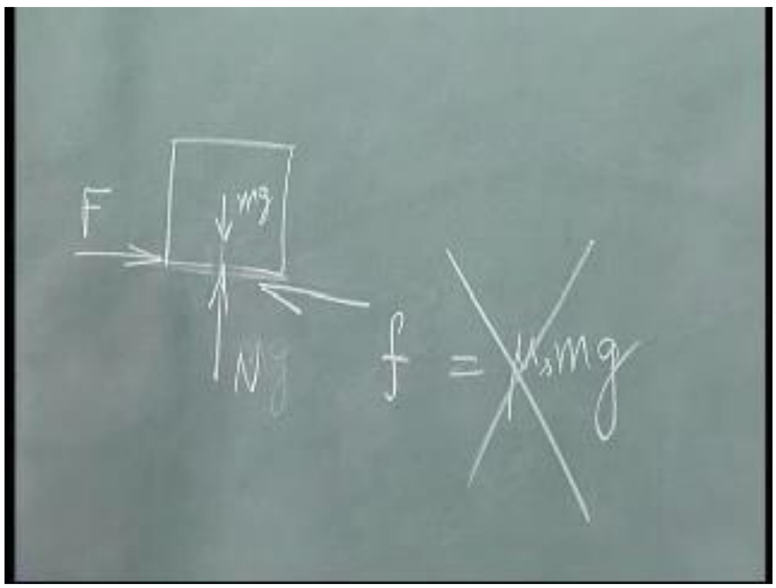

If I draw the frictional force f versus the actual force applied like this, mind you I am applying at the bottom so that it is easily understood that these two don't form a couple. What will be the force here? Supposing I apply lets say 5 kilo Newton over here, lets say that is less than mu times mg, what will happen is this is a 45 degree line which means that the 2 f is equal to F in magnitude. But when it reaches a particular value which is equal to mu times mg that is when the whole thing changes. The frictional force cannot be above the particular value. Let us assume mu static is equal to mu kinetic, just for now so that the argument is simple, the discussion becomes simple. When it reaches this particular value, please remember the frictional force cannot increase at all. Can the force F increase?

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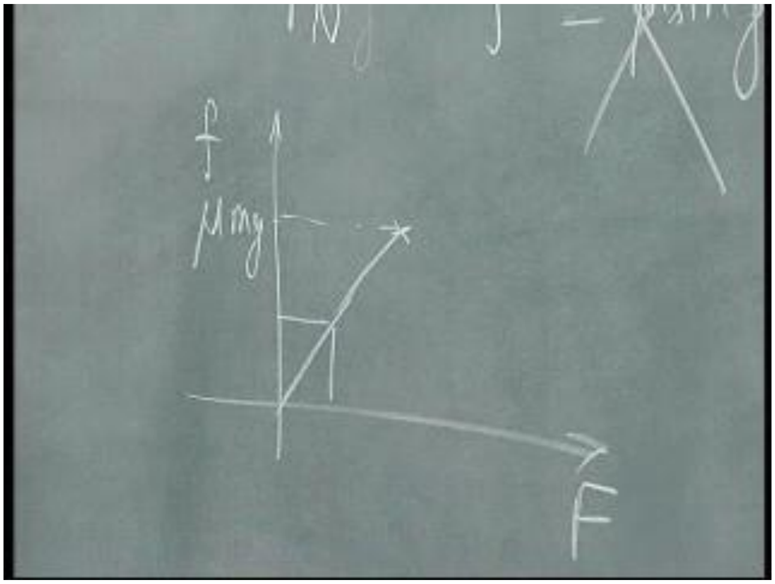

It can increase, supposing it goes like this. What happened to the additional force that has been offered? The additional force offered goes towards accelerating the body. Is this understood? This is very important. If I am looking at static situation, it is only one instant when F is equal to mu times mg. That is at the threshold of starting to move. When I have this body and I am applying a force, for it to move I need to apply a force that is equal to mu times mg for it to start move.

When it starts to move mu kinetic, coefficient of kinetic friction will play a role. This is often a mistake that students make and please remember f is equal to F comes purely by equilibrium. If I look at this free body and find out, let me write it down here sigma F along x direction if this is x direction, lets say this is y direction is equal to 0 for static condition. Immediately I have only two forces taking part, this is F, this is f means F minus f because the direction is negative to this is equal to 0 which automatically tells me that F is equal to f.

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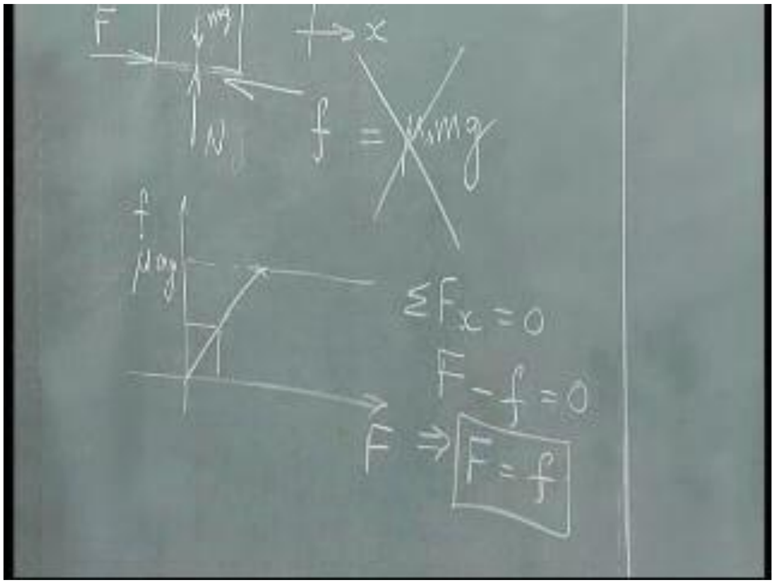

When is this true? It is true only when the right hand side is zero. What is right hand side? It is nothing but saying that it is in static condition. Supposing it is in dynamic condition then F equals ma which means that sigma F_x should be equal to m times a_x. If I insert these values, I have F minus f is equal to m times a_x. When a_x is equal to zero at the static condition, this is equal to zero F equals f but if a_x is non zero in the condition when it is non-zero, remember there is a motion involved which means this reaches. So in motion r at impending motion about to move then f is equal to mu times mg. What is this? This is the property of the surface, the two surfaces that interact with each other. This has nothing to do with equilibrium unless and told f equals mu-mg, it is indeterminate.

Once I know it is mu equals mg then I can write F is equal to m times a_x plus mu times mg. So part of the force is taken by the frictional force and part of it goes towards accelerating it. This is a very crucial point that has to be understood. There is one more point that is very important. When I asked Mr. Venket Rao, he immediately answered that if I apply a force like this, the frictional force will act opposing the motion. Please remember the statement I am making. Let me go over there and write it down. Frictional force is acting in a direction, let me come back to direction. Supposing this is the body and let's say this is the force acting. He said that the frictional force acts in the opposite sides.

Now I am going to twist it a little bit. I have F_1 acting like this, F_2 acting like this, F_3 acting like this. Now tell me what is the direction of f? A simpler way of looking at it, what he is saying is it is opposing the resultant of this. A simpler way of looking at it is, it is actually opposing not the force but the motion. It is the resistance to the motion or in other words in a direction opposite to the motion or impending motion. Of what? Of a surface on a surface. Of a surface, which is this surface. On a surface which is this surface. This is on, this is of. Is this clear?

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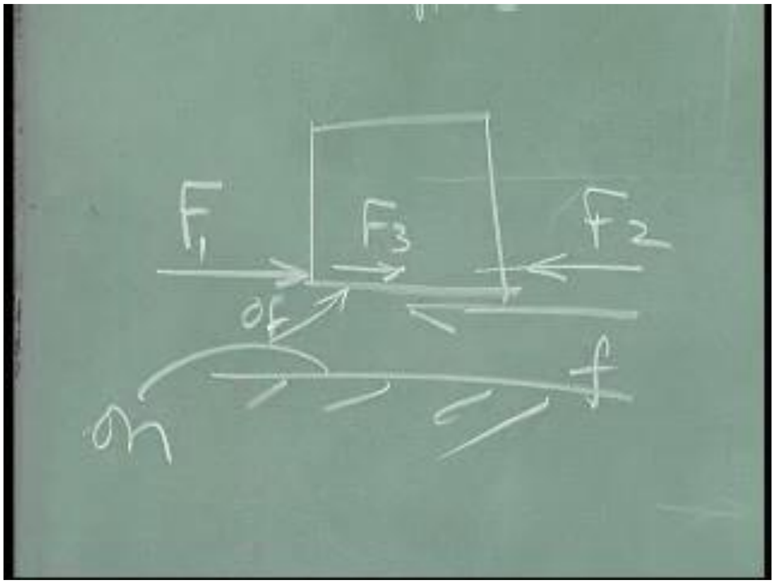

This should be understood clearly which means what? If I have a body, so let me just make it very clear to you in this scenario. If I have a body like this and I am applying a force F and if I say the impending motion is in this direction, I will apply a frictional force. Since the impending motion is in this direction, it should be opposing it. I will put this f, since it is intending it has reached the maximum value. I can turn around and say what if this is negative. I am pushing it a little bit and then I am pulling it. Remember when I pull it, again once I reach an impending motion in the opposite direction, if the impending motion is in this direction then f will act in this direction.

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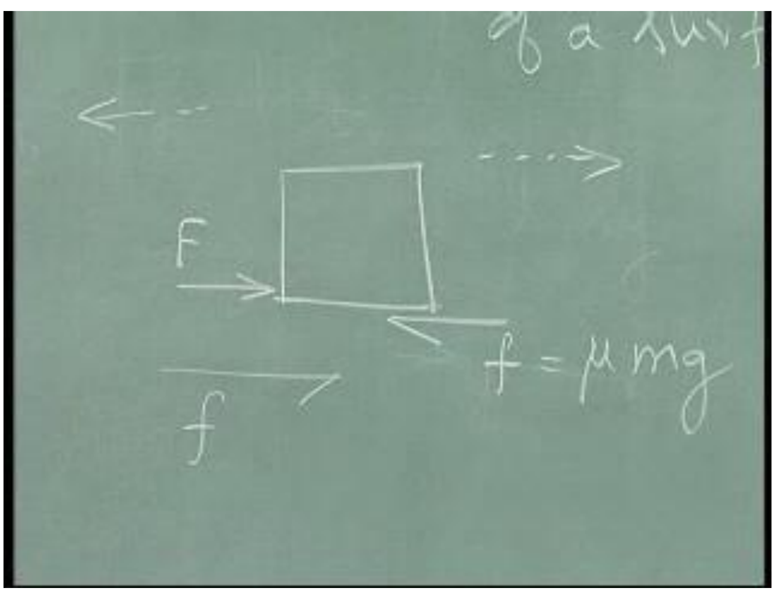

This should be understood which means between a force that reaches mu-mg in this direction and a force that reaches mu-mg in this direction, the body is in static equilibrium and the frictional force changes from positive value to negative value. If I plot this F versus the frictional force, when I am applying in this direction, let's say it is positive. It will keep on increasing, this is f, till it reaches mu times mg. Similarly if I move in this direction, if the impending motion is in this direction, till the motion occurs it will keep on decreasing. Again when it reaches a particular point mu-mg in this case minus mu-mg, it will not be moving. So between this and this region, if I have this value and this value specified. This is mu times mg, the reason is this is at a 45 degree angle. This is minus mu times mg. When the force is within this region, it is in static equilibrium and the f is equal to F.

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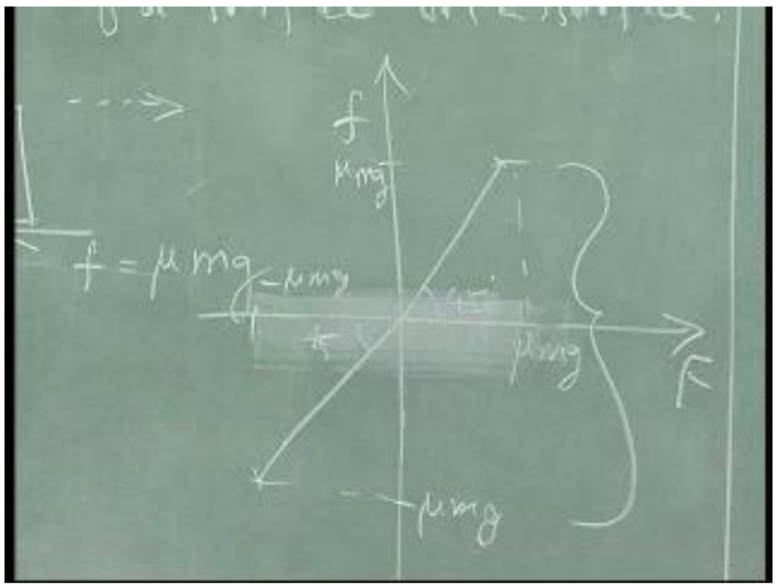

Beyond this there is motion, beyond this there is motion in two different directions. Is that understood? Third point. Supposing I have a block like this. This is again a mistake that is often made by the students. I just want to point out such a mistake. Let's say a homogeneous body mg is acting like this. There is a force acting like this F basically I have something like this and I am applying a force like this. I need to now draw the reaction forces. That's very simple. One might remove this. Where is the normal reaction? Here. Where is the frictional force?

Since it is opposing motion in this direction this is f. If it is static this is equal to this. That condition of static is very important, the condition of motion is a different story. The answer is not correct. This is not correct. Most of the students who are used to drawing this, from physics get confused, unless this force is over here, you will see… What is this equal to? (Refer Slide Time: 16:28). This is equal to F which means this and this form a couple which is like this. This is the height h, F times h is a couple that is acting. Where is the resistance to that couple?

The resistance is offered by a variation. For example if I draw normal reaction to be uniform like this then its resultant is along mg. Actually, since I have to offset this couple in this static case, N will shift like this so that this will form an opposite couple. This is equal to mg, N equals mg when I find the vertical equilibrium.

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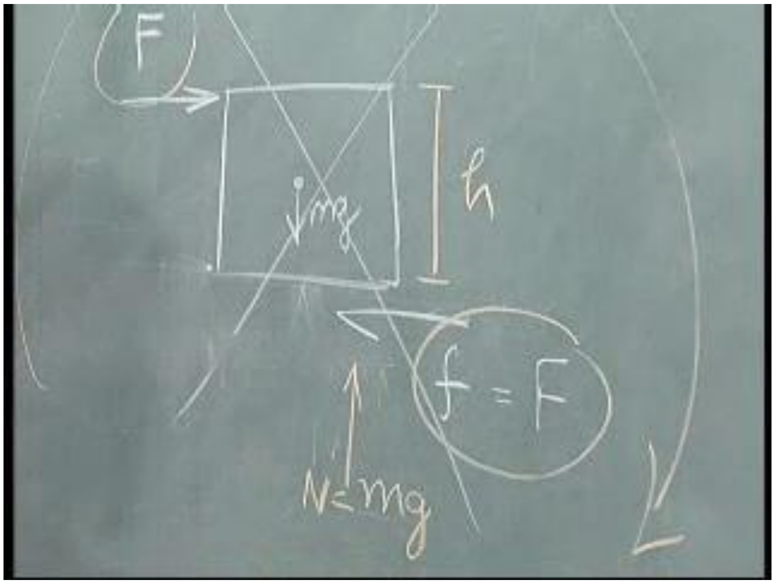

The distance between these two is such that it is equal to F-h divided by mg or in other words mg times this distance will offer the opposite reaction. What is this N? This is the net resultant reaction that comes from the pressure that is offered by the surface. This is a resultant please remember that. Sometimes when I cut like this, one of the mistakes people do is they will say N is acting like this, there is no N here. This is nothing but a representation of a distribution of this sort. The resultant of which is what is drawn like this. When I cut like this, I will have this reaction coming. This is the third mistake that is often made. With this as the basis most of frictional problems can be solved.

Let's take up one problem which is often used in friction type of applications. Where all do we encounter friction? Where all do we use friction to our advantage, where all do we encounter a problem with a friction? It is often already talked about. One of the cute applications in which friction is used positively is a belt drive. What is a belt drive? Let's say I have a motor over here, the motor has a roller over here, rotor and that's rotating. I have another let's say this is a wheel. I need to rotate this wheel. What do I usually do? I connect this with a belt. Let me draw it with another color. I connect it with a belt so what is basically happening is when this is rotating, the friction between the pulley and this, so here when it is rotating the belt has a friction on this rotor that takes it up along the belt. The belt transfers the friction through this so that this rotates and this rotates. There could be slipping, there need not be slipping. The two conditions are handled very similar to handling motion and statics over here. Let's do this kind of a problem because this is one of the problems that we will encounter in mechanical engineering and similar engineering applications.

The aim is to find out, supposing I fix this and I apply a force over here, tension over here say T_1. Let us say it is in motion. What is the tension in this? Is this clear? This is not moving, I am pulling this with a tension T_1. What do you realize? Is T_2 less than T_1? The answer is yes, because there is some friction that is eaten away some of the tension. T_2 will be less than T_1. Can I find out T_2 that's the question. Let's answer that question. Why is it important? By answering this question, I will be able to tell you depending on T_1 and T_2 whether slipping has occurred in this or in this. If no slipping has occurred then the entire thing is transferred directly to this. This is usually called the effort and this is the load.

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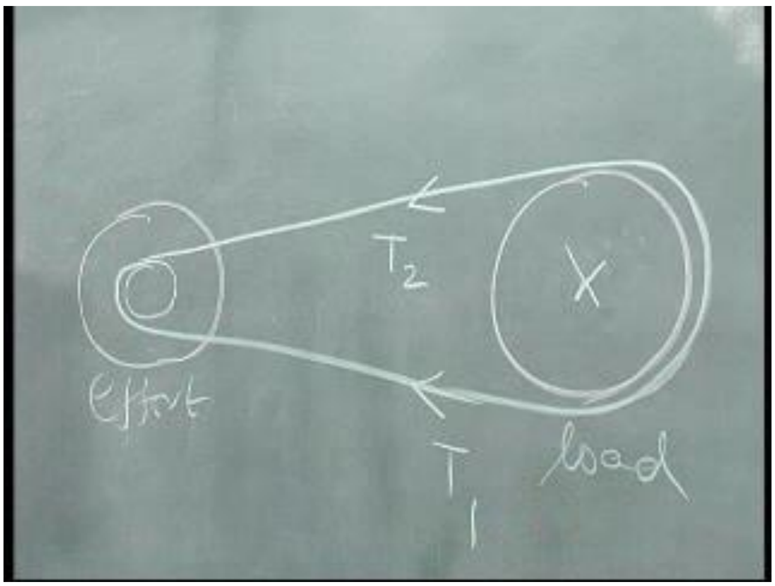

You don't want the power to be wasted in friction because friction is going to convert it to heat and there is a loss of energy unnecessarily in addition to the other losses that we encountered.