

## Physics 211 - Week 3

### Force and Simple Dynamics: Exit Ramp (**Solutions**)

On a trip to the Colorado Rockies, you notice that when the freeway goes steeply down a hill, there are emergency exits every few miles. These emergency exits are straight ramps which leave the freeway and are sloped uphill. They are designed to stop runaway trucks and cars that lose their brakes on downhill stretches of the freeway even if the road is covered with ice. You are curious, so you stop at the next emergency exit to take some measurements. You determine that the exit rises at an angle of  $10^\circ$  from the horizontal and is 100m long. What is the maximum speed of a truck that you are sure will be stopped by this road, even if the frictional force of the road surface is negligible?

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The maximum speed that the truck can have and still be stopped by the 100m road is the speed that it can go and be stopped at exactly 100m. Since there is no friction, this problem is similar to a projectile problem. You can think of the problem as being a ball tossed into the air except here you know the highest point and you are looking for the initial velocity needed to reach that point. Also, in this problem, because there is an incline, the value of the acceleration due to gravity is not simply  $g$ ; it is the component of gravity acting *parallel* to the incline. Since we are working parallel to the plane, also keep in mind that the highest point is given in the problem as 100m. Solving for the initial velocity needed to have the truck stop after 100m, you should find that the maximum velocity the truck can have and be stopped by the road is 18.5 m/s.

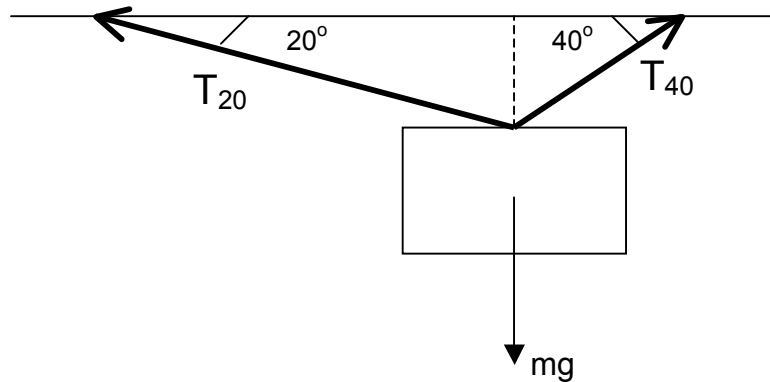
## Physics 211 - Week 3

### Force and Simple Dynamics: Hanging Sculpture (Solutions)

You are part of a team to help design the atrium of a new building. Your boss, the manager of the project, wants to suspend a 10-kg sculpture high over the room by hanging it from the ceiling using thin, clear fishing line (string) so that it will be difficult to see how the sculpture is held up. The only place to fasten the fishing line is to a wooden beam which runs around the edge of the room at the ceiling. The fishing line that she wants to use is known to be able to support a vertically hanging mass of 10 kg, so she suggests attaching two lines to the sculpture to be safe. Each line would come from the opposite side of the ceiling to attach to the hanging sculpture. Her initial design has one line making an angle of  $20^\circ$  with the ceiling and the other line making an angle of  $40^\circ$  with the ceiling. She knows you are taking physics, so she asks you if her design can work.

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We can begin to find the maximum safe tension by finding the tension in the string when it vertically suspends the 10kg hanging mass. Then we need to compare the tension in each of the two strings in the proposed design to the maximum tension to see if the sculpture will be secure. The tensions in the two strings can be broken down into x and y components. For the sculpture to remain horizontally stationary, the x-components of the tension in the two strings must have the same magnitude. The y-components of the tensions both point in the upward direction; these components need to have a combined value equal to the weight of the sculpture. Using this information to set up a system of equations you should be able to solve them and obtain values of 86.77 N for the  $20^\circ$  wire and 106.4 N for the  $40^\circ$  wire. Since the fishing line she wants to use is only shown to support a tension of 98.1 N (found by vertically suspending the 10kg mass) and the  $40^\circ$  wire exceeds that tension, this design will not work.



## Physics 211 Week 3

### Newton's Laws: Friction Intro Solution

- a. A block of mass  $M = 5 \text{ kg}$  slides on a horizontal table. The kinetic coefficient of friction between the block and the table is  $\mu = 0.38$ . If the initial speed of the block is  $8 \text{ m/s}$ , how many seconds does it slide before stopping.
- b. A block of mass  $M = 15 \text{ kg}$  is pulled across a horizontal table by a string. The kinetic coefficient of friction between the block and the table is  $\mu = 0.69$ . If the speed of the block is constant at  $2 \text{ m/s}$ , what must the tension in the string be?
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a. The block has an initial velocity; its motion is stopped by the force of friction causing the mass to decelerate until it reaches zero velocity. Find the deceleration using Newton's second law and the force of friction. We are on a flat surface so the normal force is equal to the gravity. Once you have the value of deceleration, you can use kinematics equations with initial and final velocities to find the unknown time. You should obtain 2.15 seconds.

b. Since the speed of the block is constant, we know that the acceleration must be zero. This means that the net force is zero. Drawing a free body diagram for the block, you can see that the two forces acting on the block are the tension and force of friction. Since the net force is zero, we know these forces must be equal in magnitude. Find the force of friction by using the given coefficient of friction and the normal force, which can be determined using the given mass. The force of friction is equal to the tension, a value of 101.5 N.

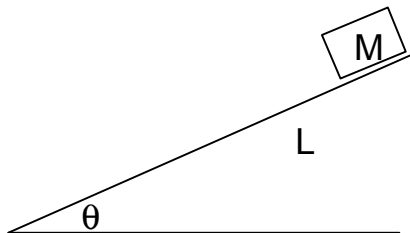
## Physics 211 - Week 3

### Newton's Laws: Determine Friction by Time

A block of mass  $M$  is released from rest on an incline of length  $L$  which makes an angle  $\theta$  with the horizontal. The block reaches the end of the incline in time  $T$ . Show how the coefficient of kinetic friction can be determined from the measurement of time  $T$ .

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It is a good idea to begin by drawing a labeled picture.



You can utilize Newton's second law to determine a net force equation. There should be three forces on your free body diagram: the frictional force from the incline on the block, the gravitational force from the earth on the block, and the normal force from the incline on the block. Since the acceleration is along the ramp, it is easiest to use a "tilted" coordinate system with the  $x$ -direction parallel to the incline. The force of gravity should be broken into components so that you can describe the motion parallel to the plane. The frictional force is entirely parallel to the plane, but it depends on the normal force, which will be equal to the component of gravity that is perpendicular to the plane. You should be able to write an equation for the acceleration of the block down the incline in terms of gravity, the angle, and the coefficient of friction.

The other part of the solution utilizes kinematics equations of motion. You can manipulate the kinematics equation describing the motion of the block down the plane to obtain a second equation for the acceleration- this one in terms of the length  $L$  and time  $T$ . Using the two equations to eliminate the acceleration, you can find the coefficient of kinetic friction in terms of the given angle, length, gravity, and time. You should obtain some equivalent form of the expression

$$\mu = \tan \theta - \frac{2L}{gT^2 \cos \theta}$$

## Physics 211 - Week 3

### Force and Simple Dynamics : Emergency Stop (**Solutions**)

Your friend has been hired to design the interior of a special executive express elevator for a new office building. This elevator has all the latest safety features and will stop with an acceleration of  $g/3$  in the case of an emergency. The management would like a decorative lamp hanging from the unusually high ceiling of the elevator. He designs a lamp which has three sections which hang one directly below the other. Each section is attached to the previous one by a single thin wire, which also carries the electric current. The lamp is also attached to the ceiling by a single wire. Each section of the lamp weighs  $7.0\text{ N}$ . Because the idea is to make each section appear that it is floating on air without support, he wants to use the thinnest wire possible. Unfortunately the thinner the wire, the weaker it is. Since he knows that you have taken a course in physics, he asks you to calculate the force on each wire in case of an emergency stop.

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One way to begin solving this problem is to draw three separate free body diagrams- one for each section of the lamp. After you have labeled the forces, you can create net force equations for each section. You should have three unknowns: the tension in each of the three wires. The acceleration can be determined from the information given: the elevator is designed to have an acceleration of  $g/3$  in an emergency. The emergency would be that the elevator is falling, so the acceleration is in the upward direction to stop the elevator's motion. Keep your directions consistent while creating your equations and you should be able to obtain tensions in the wires, from top to bottom, of  $28\text{ N}$ ,  $18.67\text{ N}$ , and  $9.33\text{ N}$ .