**The Ramp (and Friction) PhET Simulation Lab**

**Introduction:**

When an object is dragged across a horizontal surface, the force of friction that must be overcome depends on the normal force as  and the normal force is given by . When the surface becomes an inclined plane, the normal force changes and when the normal force changes, so does the friction. In this lab, you will change the angle of an inclined plane and observe how weight is resolved into its components (Fn and F//) using the basic trig functions.

**Procedure:** *Play with the Sims 🡪 Physics🡪Motion 🡪 The Ramp* 

* Be sure to stay in the part of the simulation. *More features* will be used later when we investigate energy. Start by playing with the cabinet some. Have fun, really… Now…back to work.
* Move the cabinet up and down the ramp by dragging it with your mouse.

Horizontal plane

* Move the ramp to an angle of zero (horizontal) and draw a free body diagram of the cabinet here:
  1. On a horizontal plane, the normal force is \_\_\_\_\_\_\_\_ to the weight.
  2. The cabinet has a mass of 100kg. It therefore has a normal force of \_\_\_\_\_\_\_\_\_ N and a friction force (on the horizontal plane) of \_\_\_\_\_\_\_\_\_\_ **μ = 0.30**

Inclined plane

*  the ramp and draw a free body diagram of the cabinet in the box here:
  1. The force down the plane and normal force are components of \_\_\_\_\_\_\_\_\_\_\_\_.
  2. **Before we add an applied force on the ramp, there is a force of \_\_\_\_\_\_\_\_\_\_\_\_ that acts against the force down the plane( Force parallel).
  3. When we apply a force to get the cabinet moving, the friction force acts in the \_\_\_\_\_\_\_\_\_\_\_\_ direction as movement of the cabinet.
  4. **Slowly** increase angle (0.1 degrees at a time) of the ramp until the cabinet starts to move on its own. What angle is this? \_\_\_\_\_\_\_\_\_\_\_\_ = θ
  5. At this point, the force down the plane is \_\_\_\_\_\_\_\_\_\_\_\_ than the force of friction.
  6. Since the ramp is now at an angle, the normal force is \_\_\_\_\_\_\_\_\_ than the weight.
  7. At the angle above, the normal force equals \_\_\_\_\_\_\_\_\_\_\_N. (hint: what trig function?)
  8. At the angle above, the force down the plane equals \_\_\_\_\_\_\_\_\_\_\_\_N. (trig function?)
  9. Using the formula for friction above, the force of friction is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_N.
  10. If the plane-cabinet were frictionless, what angle would be required for the cabinet to move? \_\_\_\_\_\_\_
  11. Why? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

g = 9.8m/s2

Calculate first, then test each object in the table below with the simulation on a horizontal plane.

Object Mass Weight Normal Force **μ**, Coef of Friction Friction Force to Overcome

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Dog |  |  |  | 0.10 |  |
| Crate |  |  |  | 0.70 |  |
| Piano |  |  |  | 0.40 |  |
| Refrigerator |  |  |  | 0.50 |  |

**Conclusion Calculations: GRADED**

Back to the cabinet (). **μ = 0.30**

Complete the table below. You may check your answers in the simulation.

*Force Applied* is the force required (by you for instance) to make the cabinet move at a constant velocity in either direction *or keep it from accelerating (if applicable)*.

*Recall…constant velocity = \_\_\_\_\_\_\_ net force.*

*Also note: force applied may change direction as the angle increases!*

Angle, θ Mass Weight g = 9.8m/s2 Normal Force, Fn Force parallel F// Friction Force Ff Force Applied, Fa

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 0.00o | 100. kg |  |  | 0.00 N |  | 1. |
| 10.0o | 100. kg |  |  |  | 2. |  |
| 20.0o | 100. kg |  |  | 3. |  |  |
| 30.0o | 100. kg |  | 4. |  |  |  |
| 40.0o | 100. kg |  |  | 5. |  |  |
| 50.0o | 100. kg |  |  |  | 6. |  |
| 60.0o | 100. kg |  |  |  |  | 7. |
| 70.0o | 100. kg |  |  |  | 8. |  |
| 80.0o | 100. kg |  |  | 9. |  |  |
| 90.0o | 100. kg |  | 0.00 N |  | 10. |  |

**Conclusion Questions:**

1. On a horizontal plane, the \_\_\_\_\_\_\_\_\_\_\_\_\_force equals the \_\_\_\_\_\_\_\_\_\_\_\_\_.
2. As the angle of the ramp is increased, the normal force *increases / decreases / remains the same* and the friction force *increases / decreases / remains the same*.
3. As the angle of the ramp is increased, the force parallel *increases / decreases / remains the same.*
4. The angle at which the force down the plane became just slight larger than the force of friction (for the cabinet in step #6) was \_\_\_\_\_\_\_\_\_\_\_\_\_.
5. Consider a very low (zero) friction, 5.0 kg skateboard on a ramp at an angle of 15o to the horizontal. What would be the **net force** that would cause acceleration when the skateboard is allowed to move? \_\_\_\_\_\_\_\_\_\_\_\_\_ N
6. What would be the skateboard’s acceleration down the plane? \_\_\_\_\_\_\_\_\_\_\_\_\_ m/s2
7. Now consider the same no-friction 5.0 kg skateboard on the same 15o ramp. If a 45kg teenager jumps on, what would be her acceleration down the ramp? \_\_\_\_\_\_\_\_\_\_\_\_\_ m/s2
8. Imagine you are pushing a 15 kg cart full of 25 kg of bottled water up a 10o ramp.
9. If the coefficient of friction is 0.02, what is the friction force you must overcome to push the cart up the ramp? \_\_\_\_\_\_\_\_\_\_\_\_\_ N
10. Realizing that there is also a force parallel (as a component of weight) you must ALSO overcome, what is the TOTAL force you must apply to push the cart up the ramp at a constant speed?

\_\_\_\_\_\_\_\_\_\_\_\_\_ N