Inclined Planes

Purpose: To explore the manner in which variables such as incline angle, mass, and coefficients of friction affect or do not affect the motion of an object down an inclined plane.

Getting Ready: Navigate to the **Inclined Plane** simulation found in the **Physics Interactives** section at **The Physics Classroom**.

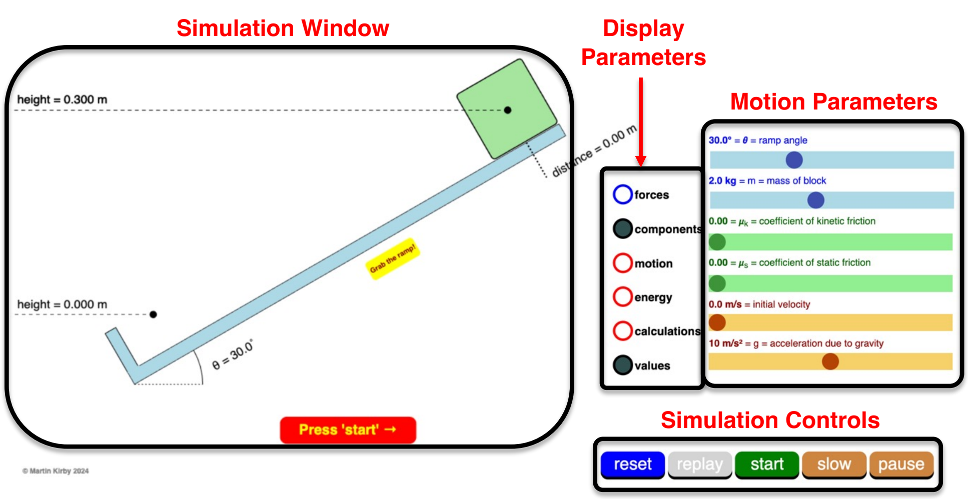
https://www.physicsclassroom.com/Physics-Interactives/Forces-in-2D/Inclined-Plane

Navigation:

www.physicsclassroom.com => Physics Interactives => Forces in Two Dimensions => Inclined Plane Simulation

Getting Acquainted/Play:

This interactive consists of a **Simulation Window** on the left side of the screen. There are **Display Parameters**, **Motion Parameters**, and **Simulation Controls** on the right side of the screen.

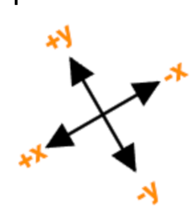


Observe how the **radio buttons** control the various displays. Experiment with the various display options, turning each on and off by tapping on the check boxes and observing what they do.

The **sliders** control the values of the motion parameters for the object and inclined plane. Experiment with the sliders and observe their effect upon the simulation. The incline angle can also be changed by dragging the plane in the simulation window.

The **Reset** button returns all Collision Parameters to their start-up value. More often than not you will want to be using the **Replay** button which returns the most recent simulation to its time = 0 s state. Take some time to get acquainted with the interface and various parameters.

Finally, observe the axes displayed at the top of the Simulation Window. Throughout this exercise, the + x direction is defined as parallel to and down the incline.



Background

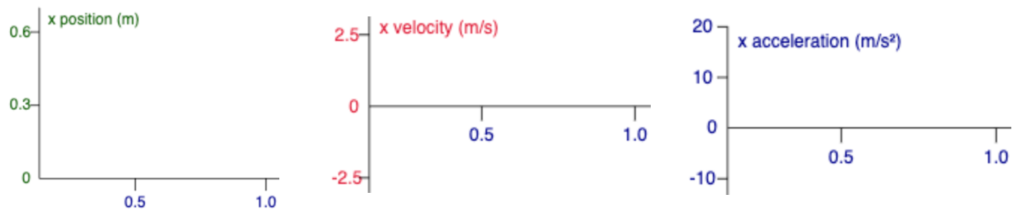
The Inclined Plane simulator provides a virtual playground for exploring a variety of concepts associated with inclined planes. The kinematics and dynamics associated with the motion of an object along an incline can be explored. We have provided a three basic explorations on this activity sheet. Don't be bashful about conducting some explorations of your own.

Exploration #1: Angle Effects

1. Tap the **Reset** button. Set the coefficient of static friction (**μ_s**) to 0.00. The **μ_k** value should also set to 0.00. Enable the **motion** and **values** display parameters.

2. Tap the **Start** button. Observe the motion and the motion graphs. Record (with some degree of detail) the motion plots:

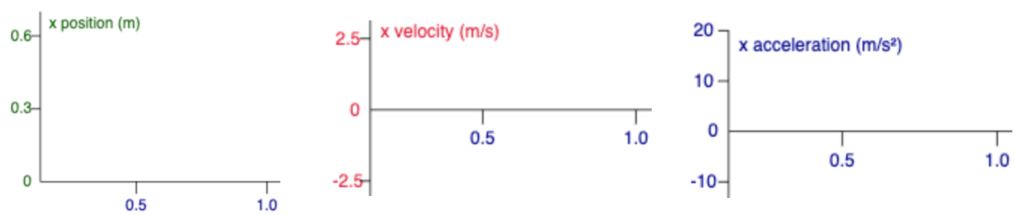
Θ = 30°



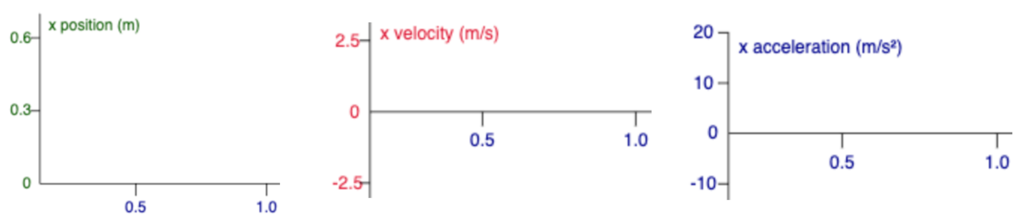
3. Does the object accelerate down the inclined plane? ____________________

4. Tap the **Replay** button (avoid tapping **Reset**). Repeat two additional trials with approximately twice the angle and one-half the angle. Record the angle values you used. And sketch with some degree of detail the resulting motion graphs.

Θ = _____°



Θ = _____°



5. Describe the effect that increasing incline angle has upon …
   a. … the acceleration value: ____
   b. … the time to reach the bottom of the incline: ______________________________
   c. … the velocity at the bottom of the incline: ________________________________

Exploration #2: Force Effects

6. Tap the **Reset** button. Insure that the incline angle (**Θ**) is set to 30.0°. Set the coefficient of static friction (**μ_s**) to 0.00. The **μ_k** value should also set to 0.00. Enable the **forces**, **components**, and **values** display parameters. Observe that a free-body diagram is drawn on the object. The values of the forces are displayed in the simulation window. The components of the gravity force are also displayed.

7. Change the angle Θ and observe the effect the changes have on the force values. (**NOTE**: Θ can easily be changed by dragging the incline in the simulation window.) Answer the following questions:

   a. As Θ increases, the force of gravity (F_g) _______________ (↑, ↓, no Δ).
   b. As Θ increases, the normal force (F_{normal}) _______________ (↑, ↓, no Δ).
   c. As Θ increases, the parallel component of gravity _______________ (↑, ↓, no Δ).
   d. As Θ increases, the perpendicular component of gravity ______________ (↑, ↓, no Δ).
   e. At the low Θ extreme (0.0°), the net force is ____________(enter value for m=2.0 kg).
   f. At the high Θ extreme (90.0°), the net force is __________(enter value for m=2.0 kg).

8. You will now investigate the effects of friction. Reset the Θ to 30°. Enable the **calculations** in addition to the **forces**, **components**, and **values** display parameters. The simulation distinguishes between two *types* of friction – kinetic friction and static friction. The kinetic friction is the friction the object experiences as it is slides down the incline. The static friction is the friction the object experiences when at rest on the incline. The object can not experience both kinetic and static friction. It either moves and experiences kinetic friction or remains at rest and experiences static friction. Change the values of μ_k and μ_s, observe values, and record.

Θ = 30° **m = 2.0 kg** **g = 10 m/s²** **$F_{g\text{-parallel}}$ = 10.0 N**

$\mu_k = \mu_s$	**Moves or At Rest?**	**Friction Force** (either $F_{kinetic}$ or F_{static})	**F_{net} (N)**	**a (m/s^2)**
0.00				
0.10				
0.20				
0.30				
0.40				
0.50				
0.60				
0.70				

9. Somewhere between $\mu_k = \mu_s = 0.50$ and $\mu_k = \mu_s = 0.60$, the static friction is sufficient to hold the object at rest. For a $\mu_k = \mu_s$ of 0.60, what parameters can be changed (other than μ) to result in acceleration down the inclined plane. Make a claim and support it with evidence and reasoning.

10. Can the static friction force ever be greater than the parallel component of gravity (mgsinΘ)? _______________ Propose a reason why this is the case.

11. With a μ_s value of 0.600, slowly change the Θ from 30° to 0°. Observe how all the values change. Give your best explanation for why the friction force is 0.0 N at 0°.

Exploration #3: Mass Effects

12. Tap the **Reset** button. Insure that the incline angle (Θ) is set to 30.0°. Set the coefficient of static friction (μ_s) to 0.00. The μ_k value should also set to 0.00. Enable the **calculations** and **values** display parameters. Change the mass of the block to collect values for the following table.

Θ = 30° g = 10 m/s² μ = 0.0

m (kg)	F_{net} (N)	a (m/s²)
1.0		
2.0		
3.0		
4.0		

13. Does the mass of the object affect its acceleration in a no-friction situation?

14. Set the μ_k and μ_s to 0.20. Change the mass of the block to collect values for the following table. Enter acceleration values, rounded to the second decimal place.

Θ = 30° g = 10 m/s² μ = 0.20

m (kg)	F_{net} (N)	a (m/s²)
1.0		
2.0		
3.0		
4.0		

15 Does the mass of the object affect its acceleration in a friction situation?

Extensions
Check with your instructor to see if he/she would want you to do the following extensions.

In the next two questions, you will use Newton's second law and trigonometry functions to derive equations. Do not use numbers. Only variable symbols can be used. Show each step in the derivation and provide an annotation for each step. An annotation is a short note that identifies what was done in the step.

16. Derive an equation to show that for an incline angle of Θ, the maximum ***μ*** value for which there will still be acceleration down an inclined plane is given by the equation ***μ* = tanΘ**.

17. Derive an equation to show that for an incline angle of Θ and a coefficient of ***μ***, the acceleration **a** does not depend upon mass **m**.