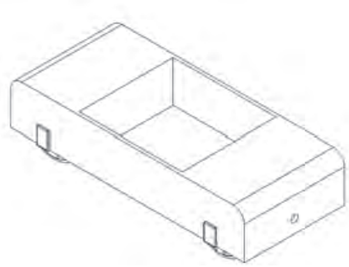
611-0035 (40-250) Inclined Plane
and 611-0036 (40-255) Inclined Plane Kit

Warranty and Parts:

We replace all defective or missing parts free of charge. Replacement parts may be ordered by referring to the part numbers above. We accept Mastercard, Visa, School P.O's. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse, or normal wear and tear.

Materials Needed:
- String or fishing line
- Mass
- Weights
- Halls Car (optional)
  We recommend **611-0040 Halls Car** made by *Science First*®



Halls Car

Assembly:
See Diagram 3 on Page 2.

1. Place incline on smooth horizontal surface.
2. Mount protractor onto base of plane near hinge and secure with screws.
3. Mount support to base using thumb screw and nut. (Top thumb nut is used to adjust angle to various degrees.)
4. Attach one end of string to some mass (i.e. wheeled vehicle or block)
5. Place mass on incline and extend string over pulley making sure it is parallel with plane.
6. Attach other end of string to weight or weight pan.

Note: When using pulley, be sure it is centered properly. To adjust, loosen thumbscrew which secures pulley, adjust pulley until string lies parallel to plane surface and refasten thumbscrew.

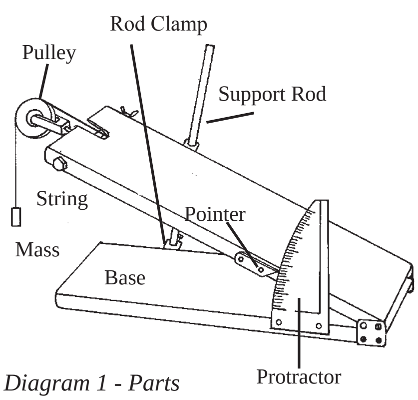


Diagram 1 - Parts

How To Use:
- **To operate Inclined Plane,** raise the incline to the desired level of inclination (angle).
- **To secure the angle,** raise the support rod to meet the incline. Secure the rod to the incline with the remaining thumb screw.

Experiment 1 - Vectors
You Need:
- Scale (to weigh blocks)
- Wood block

Purpose:
To demonstrate the use of vectors and to calculate the magnitude and direction the vectors represent.

Procedure:
1. Find M, mass of a wooden block
2. Place block on inclined plane and secure incline at 30° (or any angle small enough to prevent sliding. Record angle θ.
3. Calculate and record W, the weight of the block.
4. Calculate sine θ and cos θ .
5. Complete *Diagram 2* on Page 2. Include X, Y axis, W, N, F, θ. (See calculations below.)

a. X, Y axis should be tilted so that the X-axis lies parallel to the incline and the origin is at the box center.
b. W is a vector directed straight down (due to gravity). It is the force that the box exerts onto the plane.
c. N is the opposing force which the plane in turn exerts onto the box. It is termed the *Normal Force* and is directed along the positive Y axis.
d. The angle of inclination, θ, lies between W and the negative Y axis.
e. F is the frictional force exerted by the inclined surface on the box. It is the positive X direction.

6. Resolve W into its components.
7. Calculate N.
8. Calculate F. *See Diagram 3.*

Calculations:

a. W = mg
W = (500 g) (-9,8 m/sec^2)
= -4.9 N

b. θ = 30°
cos θ = 0.866
sin θ = 0.500

c. W_x = W cos θ
= -3.243 N

$W_Y = W \sin\theta$
$= -2.45$ N

d. N $= -W_Y$ = 2.45 N
e. F $= -W_x$ = 4.243 N

Corresponding Ideas: (Exp. #1)

1. Show why it is to the student's advantage to tilt the X, Y axis
2. W can be broken into components:
   W_X = W cos θ
   W_Y = W sin θ
3. Since the box is at rest, the sum of all forces is equal to zero.
   F total = W + F = N = 0

Experiment 2 - Static and Dynamic Motion

Purpose:

To analyze the motion of a block on a smooth incline. A static case (box is at rest) and dynamic case (box is accelerating) are studied.

Procedure: (Part A)

1. Place box of mass M on incline and adjust angle so that box will easily slide down. (Try 60°) *See Diag. 4.*
2. Attach weighted string to box so that it remains at rest near top of incline.
3. Calculate F, the force of the string on the box. [F = mg sin θ]
4. Calculate N, the force of the plane on the box. [N = mg cos θ]

Procedure: (Part B)

1. Remove weight so box will accelerate down plane.
2. What is the estimated acceleration? Calculate a (acceleration) using: [Δ = -g sin θ]
3. (Optional) To calculate actual acceleration, when the string is removed from the box, measure the time it takes for the box to reach the end of the incline.
4. Calculate a using:
   $\Delta = \frac{2(x - X_0)}{t^2}$
5. How does estimated acceleration compare with actual acceleration?

Calculations:

acceleration is *down* the incline.

$F_X = max$
$\Delta_X = F - mg \sin\theta$
$\Delta_x = -g \sin\theta$
$\Delta_X = (9.8 \text{ m/sec}^2)(\sin 60°)$
$\Delta_X = -8.49 \text{ m/sec}^2$

To calculate actual acceleration:

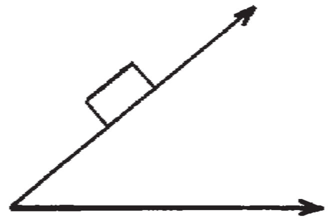


Diagram 2 - Initial

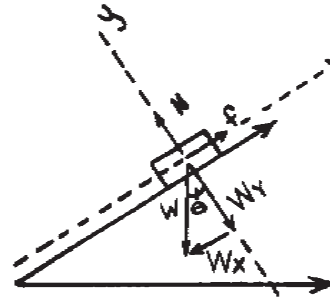


Diagram 3 - Completed

M = 500 g	θ = 30°	N = 2.45 N
G = -9.8 m/s²\	cos θ = .866 sin θ = .500	
W = -4.9 N	W_X = -4.243 N W_Y = -2.45 N	F = 4.243 N

Results - Static Case

M	F	N	Actual Acceleration	Estimated Acceleration
.2 kg	1.7 N	.96 N	-7.50 m/s²	-8.49 m/s²

Results - Dynamic Case

For calculation purposes, let M = 200 g

Static Case:

Since the box is at rest, the sum of all of the forces = 0.

(Assume the force due to friction = 0 also).

Total F = F + N = W = 0
= F + N + mg = 0
F - mg sin θ = 0
F = mg sin θ
F = (.2 kg) (9.8- m/sec²) (sin 60°)

$\Delta = \frac{2(x - x_0 - Vx_0 t)}{t_2}$

where: $x - x_0$ is length of plane
t is time
Vx_0 is starting velocity

Since the box starts from rest,
$Vx_0 = 0$

F = 1.7 N
N = mg cos θ
= (.2 kg) (9.8 m/sec²) (cos 60°)
= .98 N

Dynamic Case:

The pull on the box due to the string is removed. Since the box moves only in the negative X-direction, the direction of

If t = (.4s) and the length of incline is -6.0 cm,

$\Delta = \frac{2(-60 \text{ cm} - 0)}{(4s)^2}$
$= 1.2 \text{ cm}/ .16 \text{ sec}^2$
$= 7.50 \text{ m/sec}^2$
in negative x direction.

Corresponding Ideas: (Experiment #2)

a. To keep the box at rest on the incline initially, angle and weights could have been altered. See what happens to F and N when alternative angles and/or weights are used.
b. The actual acceleration differs from our estimate. Is there human error in timing? (Discuss this.)
c. Another source of error could have been the frictional force which was ignored for our calculations. Look at this in more detail.

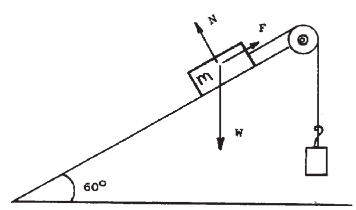


Diagram 4

Experiment 3 - Mechanical Advantage

Raising a mass against gravity requires work.

W = (force) x (distance)

Since work is dependent on both these factors, the same amount of work can be accomplished with a great force as will a quite small force provided distance is altered accordingly.

To demonstrate this concept, we include two examples.

Example A: (*See Diagram 5)*

Suppose a 500 g block is to be raised from the bottom of an incline to the top - a distance of 24 cm and a height of 12 cm. Assuming a frictionless surface, how much work must be done by a force F pushing the block up at constant speed given [$g = 9.80\ m/sec^2$]

Solution:

First find F. Because motion is not accelerated,

F total = F - mg sin θ = 0

Thus

F = mg sin θ
= (2.45 N) ($9.8\ m/s^2$) (12/24)
= 2.45 N

W = Fd
= (2.45 N) (24 cm)
= 58.8 N cm

If a man were to raise the block vertically without the incline,

W = (vertical force) x (vertical distance)
= (.5 kg) ($9.8\ m/s^2$) (12 cm)
= (4.90) (12) = 58.8 N cm

Example B:

at 45°. Place a wooden box on the bottom of the incline using a weighted string. Determine the work done in raising the box to the top of the incline.

2. Using the same angle, place the box on the table directly under the pulley. Attach one end of a string to the box and the other end to a wheeled vehicle at the top of the incline.
3. Add weights to the car until the box is at the top of the incline.
4. Calculate the work done.
5. Compare the distance moved and the force necessary in each case.

To demonstrate this idea using the incline, have the student move a box from Point A to Point B via two routes.

Procedure: *(See Diagram 6)*

1. One example is to set the incline

Corresponding Idea: (Experiment #3)

In the second part of this problem, we didn't actually move the box from Point A to Point B. It was only moved the vertical distance. How does this affect the work done. Why?

Experiment 4 - Work

You Need:

- Wheeled vehicle (**40-215** Halls Car from *Science First® recommended*)
- Weighted string

Procedure:

1. Attach a weighted string to a wheeled vehicle using the pulley.
2. Determine the force required to move the car at 0° incline.
3. Raise the incline. Add additional weights until the car moves again.
4. What is the additional force necessary to move the car?

Corresponding Idea: (Experiment #4)

When considering any force, work can only be accomplished if the force operates in the same direction as the distance between points. If this is not the case, it might be play - consider the seesaw!

Experiment 5 - Friction

Purpose:

To demonstrate the concept of static and kinetic friction and to compute the coefficients of friction.

Procedure:

1. Place Halls Car on a horizontal incline (θ = 0°)
2. Raise the incline until the car just begins to move. (Static friction is equal to the smallest force necessary to start motion.)
3. Record this angle θ.
4. Continue to raise the incline until the car is just moving at constant speed. This demonstrates kinetic friction.
5. Record this angle θ.
6. Calculate the coefficient of static friction (ms = tan θ). Calculate the coefficient of kinetic friction similarly.

Calculations:

$$\mu s = \frac{\text{Force of static friction}}{\text{Normal force}}$$

where N = W cos θ
F = W sin θ
μs = W sin θ = tan θ

Results:

Using the Halls Car, the coefficient of static friction is very low.

θ = about 1.5°
tan θ = about 0.018

***Note:** If for experimental purposes you desire to minimize friction, we recommend use of the **Halls Car**. It makes friction almost negligible.*

Experiment 6 - Advanced Problem in Friction

1. *Locomotive on grade problem.* Attach Halls Car to a block of wood with string and place both on inclined plane at a small angle. Let the block of wood represent a locomotive and the car a loaded train.
2. *Determine the loads that will drag the locomotive downhill* at various degrees of incline.

the train? (2)

- How does one allow for the effect of friction in the train? (3)

Answers:

1 [(Coefficient of friction) x (weight of locomotive) x (cos θ)] - [(weight of locomotive) x sin θ)]
2 (Weight of train including cars and load) x (sin θ)
3 (Weight of train including cars and load) x cos θ) x (coefficient of friction for train)

Questions:

- How does this maximum load of the train depend on the angle of incline and weight of the locomotive.
- Are two locomotives better than one weighing as much as the two?
- Can two locomotives pull the load at twice the incline of one? * (1)
- What equation represents the drag of

SCIENCE FIRST® | 86475 Gene Lasserre Blvd., Yulee, FL 32097 | 800-875-3214 | www.sciencefirst.com | info@sciencefirst.com

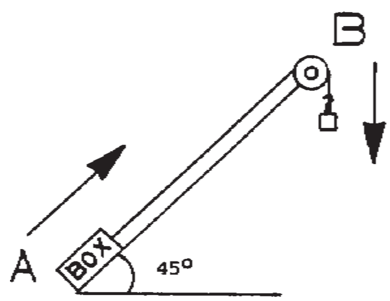


Diagram 5

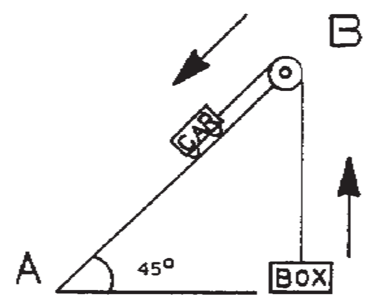


Diagram 6

How to Teach with Inclined Plane

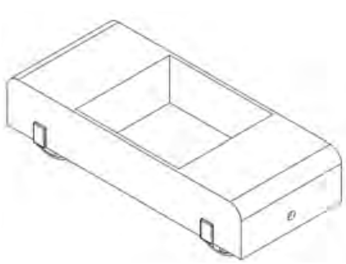
Concepts Taught: Work, energy; Conservation of mechanical energy. Simple machines. Inclined Plane. Mechanical Advantage. Inertia; Frictional force; Gravitational force; Newton's First and Second Laws. Acceleration due to gravity. Vectors. Force as a vector. Coefficient of friction - static and kinetic.

Curriculum Fit: PS, Energy; Force and Motion. **Grades 6-8 up.**

Accessories:

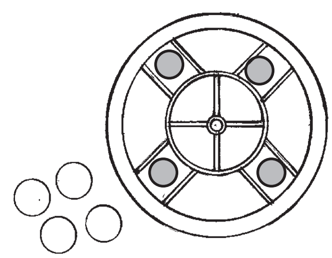
These accessories, examples of many similar science labs manufactured by **Science First®**, *are available through most science education dealers.*

611-0040 Halls Car - Use with inclined plane, pulley and weights to analyze link between work and energy. Nearly frictionless due to oil-free sleeve bearings. High impact resistant ABS plastic car has a deep well for weights. Plastic wheels snap into place even if dropped. Instructions include theory.



611-1035 Pulley with Rod - A handy all-purpose pulley with durable ABS plastic molded body and 50 mm diameter wheel. Mounted on an all-aluminum rod 10 cm long with 5 mm diameter. Coefficient of Friction a very low 0.04 Fits most inclined planes.

611-1035 Variable Inertia - Instantly change distribution of mass with 8 balls inserted into your choice of compartments. Load each of two discs unevenly, roll together down an incline. Which is faster? Why? *Includes:* 8 balls, two discs with hardware, instructions. *Use with Inclined Plane.*



Related Products:

611-2345 Weight of Air - Prove that air has weight. Weigh can when full of air, pump out air, weigh it again. Instructions. Aluminum with plastic valve.

611-1300 Mini Dynamics - Colorful system lets you experiment affordably with elastic and inelastic collisions. Plastic cars have bumpers that attach with screw, deep wells for weights, low friction wheels that snap into place. Includes 2 plastic cars, 2 bumpers with hardware, 2 rubber stoppers, instructions.

611-2350 Free-Fall Tube- Show how heavy and light items fall at the same rate in a vacuum. Includes: butyrate tube; hose cock and rubber hose; instructions; weight set.

611-2325 Magdeburg Hemispheres - Astonish your students with the force of air pressure. Two ABS plastic hemispheres, plastic exhaust valve; plastic molded handles; instructions.

611-1400 Ballistics Car - Demonstrates how the horizontal component of a force is independent of the vertical component. Push the car forward, eject a ball. The ball returns to the moving car. Includes 2 spring settings; ball bearing wheels, 1" ball, lock pin with cord, instructions.

611-1340 Acceleration Trolley - Show how rate of acceleration depends upon angle of incline. 2 low friction pulleys with holes for weights, brackets to place trolley anywhere along the wire. *Includes:* trolley with pulley; 1.5 m wire cable; attachment kit; instructions.

611-0050 Weight Pan - Plastic cup with wire hanger. Low-cost and economical.

611-1215 Ring and Disc - Simple materials with same mass and diameter- PVC ring and hardwood disc - demonstrate how mass is distributed in rolling bodies. Roll together down incline, study difference in acceleration. Instructions. Use with Inclined Plane.

P/N 24-4250