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Incline Plane with Trolley and Weights
#INCLPLN

Warning:

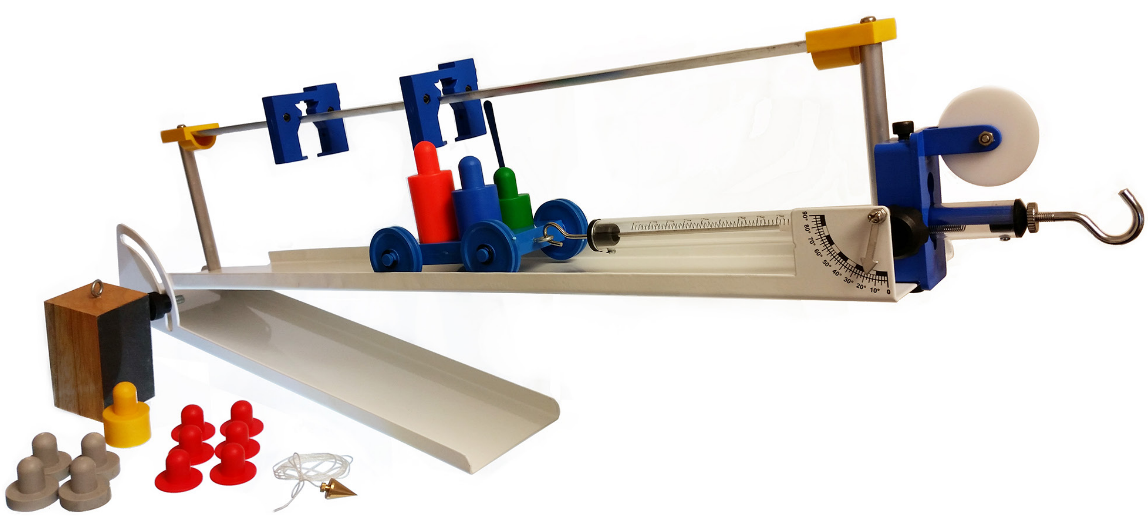
- **Not a toy; use only in a laboratory or educational setting.**
- **Contains small parts.**
- **California Proposition 65 Warning: This product may contain chemicals known to the State of California to cause cancer and birth defects or other reproductive harm.**

Introduction

Use this kit to explain and demonstrate friction and moment of inertia. The Inclined Plane consists of a rectangular base plate with "U" shaped profile. A knob on the protractor allows you to adjust the angle of incline. A 50mm diameter pulley and a dynamometer, with three different graduations 0-200.000 DINA, 0-200gf, 0-2N is fitted on the apparatus and is adjustable. Two photo-gates are fitted on a metal strip above the angular "U" shaped profile.

Components

1. Inclined Plane
2. Dynamometer with pulley
3. Injected trolley with grooves for weights and plastic bar for photogates
4. Wooden block, one side plain and one side rigid
5. Thread with plumb bob
6. Plastic weights, 1 gram (x6)
7. Plastic weights, 5 grams (x4)
8. Plastic weight, 10 grams
9. Plastic weight, 15 grams
10. Plastic weight, 20 grams
11. Plastic weight, 25 grams



Theory

Friction exerts a force in the direction opposite to the direction in which something is moving or trying to move. The friction force is proportional to the normal force, which in this case is the component of the gravitational force on the object in a direction perpendicular to the plane. If the plane is inclined at an angle (**θ**) with respect to the horizontal such that the object (say trolley) is sliding or just about to slide, the friction force is directed upward along the plane and has a magnitude $\mathbf{f = \mu w \cos\theta}$, where **w** is the weight and **μ** is the coefficient of friction. The quantity **μ** is typically in the range of 0.01 to 1.0 and depends on the materials and the roughness of the surfaces but not on the area of contact. The coefficient of friction depends somewhat on the velocity of the object and, in particular, is greater when the object is at rest (static friction) than when it is in motion (kinetic friction).

Sliding friction: It is the friction between two surfaces of the bodies in sliding motion.

Force of sliding friction: It is the least force required to make a body start sliding over a surface.

Force of friction $\mathbf{F \propto R}$

$$\mathbf{F = \mu R}$$

Where μ = coefficient of friction, R is the normal reaction.

At equilibrium, $\mathbf{F = P + p}$

and $\mathbf{R = W + w}$

The block will begin to slide when the component of the gravitational force in a direction along the plane (**wsinθ**) just equals the friction force, and thus

$$\tan\theta = \frac{\sin\theta}{\cos\theta} = \frac{1}{\mu}$$

is independent of the weight **w**. A measurement of the critical angle (**θ**) at which the object (trolley) begins to slide thus provides a measure of the coefficient of friction. Friction converts the potential energy of the block at the top of the incline into heat as the block slides down so that it can arrive at the bottom with no potential energy and very little kinetic energy.

When the angle of the plane is sufficiently small that an object (trolley) can roll down the plane without slipping, there is no relative velocity between the point on the object that is in contact with the plane and the plane, and thus the friction does no work on the object, and the total mechanical energy is conserved. However, as the object rolls down the plane, its initial potential energy is converted into both translational energy of the center-of-mass and also into rotational energy. The ratio of the rotational to the translational energy is $\mathbf{I/mr^2}$ where **I** is the moment of inertia, **m** is the mass, and **r** is the radius of the object. The moment of inertia is mr^2 for a hoop, $\mathbf{1/2mr^2}$ for a cylinder and $\mathbf{2/5mr^2}$ for a sphere. Thus the hoop acquires the most rotational energy and the least translational energy and velocity; and thus takes the longest to get down the plane. The sphere is the fastest, and the cylinder is intermediate. Since the initial potential energy and the final kinetic energy are both proportional to mass and independent of the radius, objects of the same shape but different mass and radius move down the plane at the same rate. If the plane is inclined too steeply, the object will slip, friction will do work, and the rate at which the objects roll is more difficult to predict.

How to Use

1. Place one weight on the trolley and tie it with thread the block.
2. Place the trolley along with the weight on the inclined plane so that the trolley begins to slide. Measure the angle with the help of protractor.
3. Repeat the experiment with the objects of different masses and note the angle at which the trolley begins to slide.

Observations

1. Observe that the slide angle is different for different materials.
2. Also observe that for a given material, the critical angle is independent of the mass of the object and of the area of contact.
3. Observe that the angle at which the block starts to slide is slightly greater than the angle required to keep it sliding once it is in motion.
4. With the plane inclined at a fixed angle, one rolls cylinders, spheres and hoops down the plane. Before this is done, ask the students to predict which will reach the bottom first. Repeat with objects of different size and the same mass and with objects of the same size and different mass. Show that if the plane is inclined too steeply the objects will slide rather than roll.