10.7: Gravitational Force and Inclined Planes

Figure 4.1.1

This photograph was taken by Apollo 8 crew member Bill Anders on December 24, 1968, showing the Earth rising above the lunar surface. Gravitational forces keep the moon orbiting the Earth.

Gravitational Force and Inclined Planes

Every object has a **center of gravity**. The center of gravity is the point at which the entire weight of a body may be considered to be concentrated; if supported at this point, the body would remain in equilibrium in any position. For example, if we were discussing a 12-inch ruler, the center of gravity for the ruler would be at the center of the 6-inch line. You could put your finger directly under the 6-inch line to hold the ruler and it would not fall either left or right. If you placed your finger underneath any other place on the ruler, it would fall off to one side or the other.

Figure

The force of gravity acting on an object is directed through this center of gravity and toward the center of the Earth. The object's weight, W, can be represented by a vector directed down (along the line the object would fall if it were dropped). When this object is resting on a level surface, its weight acts perpendicularly to the surface and will be equal to the **normal force**, which is the force keeping the object from falling through the table. The normal force is always perpendicular to the surface; when the surface is not level, the normal force will be equal to some subset of the weight. This is seen in the image below, which shows a box on an inclined plane.

Figure 4.1.2

The weight of the box acts through the center of gravity and directly towards the center of the Earth. The weight vector in the sketch is red and labeled W. The normal force acts perpendicular to the surface of the inclined plane to keep the box from falling through the plane. The force of the box on the plane is equal to the normal force (as specified in Newton's Third Law). Since the normal force and the force of the box acting on the plane are the same, we can reference the force against the plane as the normal force. That force, FN, is purple in the image above. In addition, there is a force acting on the box parallel to the surface of the plane and pushing the box down the plane. This force is drawn in blue and is called the **parallel force**. The normal force and the parallel force add to give the weight.

The triangle of the black inclined plane and the yellow triangle are similar triangles; the corresponding sides are mutually perpendicular. Therefore, the angle at the top of the yellow triangle is also 30°. For a right triangle, if we know one other angle (the 30° angle) and one side (the weight), we can calculate the other two sides. Therefore, we can calculate the parallel force pushing the box down the incline and we could also calculate the acceleration of the box.

Examples

A 500. N box is resting on a plane inclined at 30° with the horizontal.

Example 4.1.1

Find the normal force and the parallel force acting on this box.

Solution

(a) $F_N = W\cos 30°, = (500.\ N)(0.866) = 433\ N$

$F_{parallel} = W\sin 30° = (500.\ N)(0.500) = 250.\ N$

Example 4.1.2

Find the acceleration of the box.

Solution

mass of the box $= 500.\ N / 9.81\ m/s^2 = 51.0\ kg$

$a = F_{parallel}/mass = 250.\ N / 51.0\ kg = 4.90\ m/s^2$ (The direction is down the plane.)

Have you ever been in a car as it is driving around a banked turn? A banked turn is simply a corner of a road that is tilted at an angle and acts as an inclined plane. As a car drives around one of these corners, it experiences the force of friction, gravity and normal force acting on it. Use the PLIX Interactive below to explore how each of these forces affect what the car does in the turn:

Summary

- Each object has a center of gravity, which is the point at which the weight can be considered to be concentrated when balancing the object.
- The weight of an object is a vector that is directed toward the center of the Earth.
- When an object is placed on an inclined plane, its weight vector can be resolved into the normal force, which is equal to the force of the object perpendicular to the plane, and a parallel force, which pushes the object down the inclined plane.

Review

1. A car weighing 12,000 N is parked on a 36° slope.
    1. Find the force tending to cause the car to roll down the hill.
    2. Find the acceleration of the car rolling down the hill.

Additional Resources

Video: Inclined Planes - Overview

Real World Application: Mass Doesn't Matter

Interactive: Ramp And Piano

PLIX: Play, Learn, Interact, eXplore: Centripetal Force Problems: Banked Turns

Video: