4.4: Other Examples of Forces

Weight

Weight is taken as the force on an object due to gravity, and is different than the mass of an object.

learning objectives

- Infer what factors other than gravity will contribute to the apparent weight of an object

In physics, it is important to differentiate the weight of an object from its mass. The mass of an object is an intrinsic quantity, independent of the location of the object. On the other hand, the weight of an object is an extrinsic quantity. It is considered as the force on an object due to gravity. Since gravitational acceleration changes depending on the location in the universe, weight does as well.

Mathematically, the weight of an object (W) can be found by multiplying its mass (m) by the acceleration due to gravity (g): $\mathrm{W} = \mathrm{M} \cdot \mathrm{g}$. The strength of gravity varies very little over the surface of the Earth. In fact, the greatest percent difference in the value of the acceleration due to gravity on Earth is 0.5%.

For most calculations involving the weight of an object on Earth, it is sufficient to assume that $\mathrm{g} = 9.8 \frac{\mathrm{m}}{\mathrm{s}^2}$.

The weight of an object has the same SI unit as force—the Newton ($1\mathrm{N} = 1\mathrm{kg} \cdot \frac{\mathrm{m}}{\mathrm{s}^2}$).

In US customary units, the weight of an object can be expressed in pounds. Keep in mind that in US units the pound is either a unit of force or of mass. If one must find the weight (as opposed to the mass) of an object in US units, it can be calculated in terms of pounds of force.

It is important to note that the apparent weight of an object (i.e., the weight of an object determined by a scale) will vary if forces other than gravity are acting upon the object. For example, if you weigh a given mass underwater you will find a different result than if you weigh that mass in air. In this case, the weight of the object varies due to the force of buoyancy. While the mass is in the water it displaces fluid, resulting in an upward force upon it. This upward force affects the net force that the mass exerts on the scale, and thus alters its “apparent” weight.

Spring Scale: A spring scale measures weight by finding the extent to which a spring is compressed.This is proportional to the force that a mass exerts on the scale due to its weight.

Normal Forces

The normal force comes about when an object contacts a surface; the resulting force is always perpendicular to the surface of contact.

learning objectives

- Evaluate Newton's Second and Third Laws in determining the normal force on an object

Overview

The normal force, F_N, comes about when an object contacts a surface. According to Newton's third law, when one object exerts a force on a second object, the second object always exerts a force that is equal in magnitude and opposite in direction on the first object. This is the reason that the normal force exists.

A common situation in which a normal force exists is when a person stands on the ground. Because of Newton's third law, the ground exerts a force on the person that is equal in magnitude to the person's weight. In this simple case, the weight of the person and the opposing normal force are the only two forces considered on the person. The person remains still because the forces due to weight and the normal force create a net force of zero on the person.

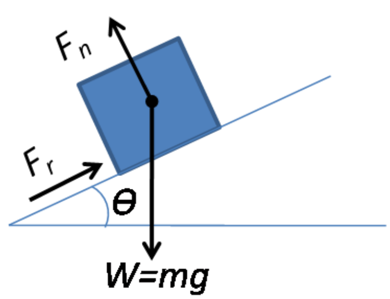
Forces on Inclined Planes

A more complex example of a situation in which a normal force exists is when a mass rests on an inclined plane. In this case, the normal force is not in the exact opposite direction as the force due to the weight of the mass. This is because the mass contacts the surface at an angle. By taking this angle into account, the magnitude of the normal force (F_N) can be found from:

$$F_N = mg\cos(\theta), \tag{4.4.1}$$

where:

- m is the mass under consideration,
- g is the acceleration due to gravity,
- and θ is the angle between the inclined surface and the horizontal.



Inclined Plane: A mass rests on an inclined plane that is at an angle θ to the horizontal. The following forces act on the mass: the weight of the mass ($m \cdot g$),the force due to friction (Fr),and the normal force (Fn).

Another interesting example involving normal forces is when a person stands in an elevator. When the elevator goes up, the normal force is actually greater than the force due to gravity. In this situation there are only two forces acting on the person. The first is the force of gravity on the person, which does not change. The second is the normal force. By summing the forces and setting them equal to m·am·a (utilizing Newton's second law), we find:

$$F_N - m \cdot g = m \cdot a \tag{4.4.2}$$

where:

- F_N is the normal force,
- $m \cdot g$ is the force due to gravity,
- m is the mass of the person,
- and a is the acceleration.

Since acceleration is positive, the normal force must actually be greater than the force due to gravity (the weight of the person).

Key Points

- Weight is taken to be the force on an object due to gravity.
- Weight and mass are not the same thing!
- The weight of a given mass will be different when the acceleration due to gravity is different.
- Apparent weight can change because of the effect of buoyancy.
- The strength of gravity is almost the same everywhere on the surface of the Earth.
- The normal force, F_N, comes about when an object contacts a surface.
- The normal force exists because for every force, there is always an equal and opposite force.
- The normal force is always perpendicular to the plane that the object contacts or rests on.

Key Terms

- **Gravitational acceleration**: Gravitational acceleration is the acceleration that an object undergoes due solely to gravity
- **perpendicular**: at or forming a right angle (to).
- **normal**: A line or vector that is perpendicular to another line, surface, or plane.