Physics

by Tom Erekson

Lone Peak High School

Unit 4 – Balanced Forces

UNIT 4 READING: Balanced Forces

What exactly is a ***force***?

We all came to Physics with certain ideas about what a *force* is. For the purpose of this class, we will define a force as ***an interaction between two objects that results in a push or a pull***. There are two important aspects of this definition. First, there must be two objects involved in order for a force to be present. Second, there are many types of interactions between objects. Forces only deal with interactions that result in a push or a pull.

There are two types of forces—***contact*** forces and ***long-range*** forces.
Contact forces occur when two objects in direct contact (touching) result in a force.

Some examples of contact forces include:

- **Friction (F_f)—**a contact force between a surface and an object, always parallel to the surface, and opposing motion.
- **Normal (F_N)—**a contact force between a surface and an object, always perpendicular to the surface.
- **Tension (F_T)—**a pulling force along strings, ropes, cables, etc.
- **Applied Force (F)—**a contact force applied by another object or person that is not Friction, Normal, or Tension.

Long-range forces result when a force is exerted over a distance, without direct contact.

Some examples of long-range forces include:

- **Gravity (F_g)—**the force between any two objects with mass. (Usually the force between the Earth and an object.) $F_g=mg$
- **g=10 N/kg** for objects near the Earth's Surface.

- Electric force- we won't be using this one yet.
- Magnetic force- we won't be using this one yet either.

Newton's First Law: Objects in motion will remain in motion (with constant velocity) *unless* acted upon by unbalanced forces.

Newton set out to find the relationship between forces and motion. He concluded that **forces** can produce *changes in motion*. If forces acting on an object are balanced, then there should be no changes in the motion. Therefore, changes in motion occur only when forces are not balanced.

Just what do we mean by "balanced?" Well, forces are balanced if the UP forces equal the DOWN forces and the LEFT forces equal the RIGHT forces. We need to look at the up, down, left, and right components of forces as we analyze these situations.

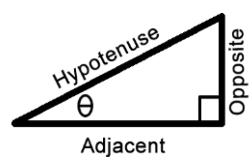
Force Components:

When a force is at an angle, then it is part vertical and part horizontal. We call these 'parts' the ***components*** of the force.

For example, the following force could be described as part **right** and part **up**. We can draw a triangle with legs in the horizontal and vertical directions. Label these Fx and Fy (the x and y components of force F).
This forms a **right triangle**. There are special properties of right triangles that we can use to find these force components.

Trigonometry:
The longest side of a right triangle is called the **hypotenuse**. It is the side that does not touch the right angle. The two sides that form the right angle are called the **legs** of the triangle. The leg that touches a given angle θ is called the **adjacent side**. The leg that is opposite the given angle θ is called the **opposite side**.

There are three special ratios (fractions) that relate the angle to the sides.

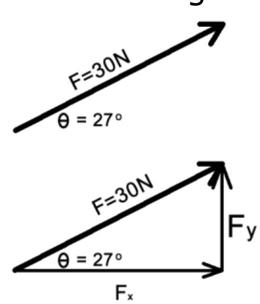


Sinθ=Opp/Hyp
Cosθ=Adj/Hyp
Tanθ=Opp/Adj

The Pythagorean Theorem can be used on right triangles to find the third side if two sides are known: $\mathbf{Adj^2+Opp^2=Hyp^2}$

Example: A 30 N force acts at a 27° angle.

- Draw the triangle.
- Label the sides and known angle.
- Use sin, cos, or tan to find missing side.



$\cos 27° = F_x / 30$
$30 \cdot \cos 27° = F_x$
$\mathbf{26.7N = F_x}$

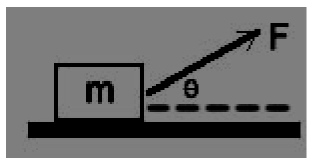
$\sin 27° = F_y / 30$
$30 \cdot \sin 27° = F_y$
$\mathbf{13.6N = F_y}$

Solving Balanced Force Problems:

1. Draw the **force diagram**. (line up axes, choose a direction for positive)
2. Write out **U=D** and **L=R**. Leave room to work underneath.
3. **Identify** the Up, Down, Left, and Right components of forces.
4. **Plug in** numbers, **find values** of components, **Solve** for unknown values.

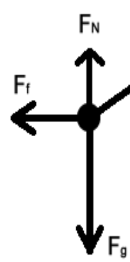
Example:
You pull a 50 kg box across the floor with a 200 N force, directed 30º above the horizontal as shown.

How much friction is present?
How much normal force is present?



Solution:

Step 1:

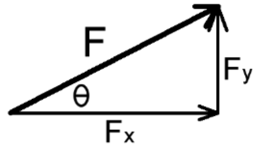


Step 2: **U=D** **L=R**

Step 3: $F_N+F_{Ty}=F_g$ $F_f=F_{Tx}$

$F_N+F_{Ty}=500$ $F_f=F_{Tx}$

Step 4: Let's find F_{Ty} and F_{Tx} .



$\cos 30° = F_{Tx}/200$
$200 \cdot \cos 30° = F_{Tx}$
$173N = F_{Tx}$

$\sin 30° = F_{Ty}/200$
$200 \cdot \sin 30° = F_{Ty}$
$100N = F_{Ty}$

So, $F_N + 100 = 500$. **$F_N = 400$ N**.

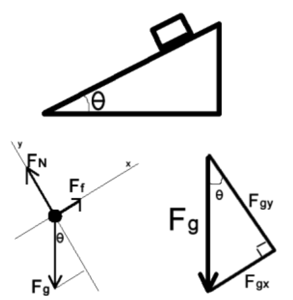
$F_f = F_{TX} = 173$ N. **Ff = 173 N**.

Ramp Problems:

We often encounter objects that are on ramps or inclines. When this occurs, the only thing we need to remember is that the object *would* accelerate along the ramp. Let's choose to make the surface of the ramp our x-axis. Then perpendicular to the surface would be our y-axis. (This is especially convenient since friction is parallel to the surface and normal is perpendicular to the surface.)

Ramp problems often involve finding x and y components of the force of gravity. (**F_{GX}** and **F_{GY}**) When drawing the triangle for this force, remember to begin with the **F_G**, then draw the legs of the triangle so they line up with your x and y axes. *The angle between **F_G** and the y-axis will be the same as the ramp's angle measured from the horizontal.*

In the example below, I chose downhill to be the positive X direction (because that is the direction the block would accelerate if it does!).
So, to find **F_{GX}** you would use the ***sine*** of 30º, and to find **F_{GY}** you would use the ***cosine*** of 30º.



Once you have figured out how to find **F_{GX}** and **F_{GY}** you would be able to use U=D and L=R with balanced force problems.

Because F_g=mg, we can always find F_{gx} and F_{gy} on a ramp problem:

$$\mathbf{F_{gx}=mg\cdot\sin\theta}$$

$$\mathbf{F_{gy}=mg\cdot\cos\theta}$$