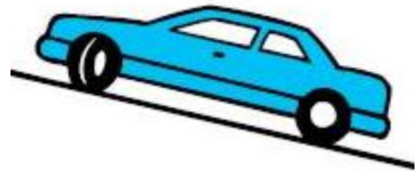
Name____________________________________

Reading 1: Forces[1]

You exert forces on objects and objects can exert a force on you. You push or pull on a door to open it. Gravity pulls "down" on you which holds you to the surface of the earth. Friction from the surface of a hill exerts a force on your car that keeps it from sliding down the hill when parked.



Forces can intuitively be thought of as a push or a pull however it's more appropriate to define a <u>force as an interaction between **two** objects since forces requires contact, *most of the time.*</u>

<u>Types of Forces</u>

There are many **types** of forces between objects that are differentiated (distinguished) by the way in which two objects interact. The forces can be roughly categorized by *contact* forces and *non-contact* forces.

Here is a list of the contact we will use most frequently in this course (though many more exist or go by different names).

- Forces perpendicular to a *surface* are called **normal**[2] forces. Here *normal* is a term meaning perpendicular to a surface. We consider the boundary between two objects, where the objects are in contact with each other, a *surface.*

- When two objects slide across each other, there is a force parallel to the surface. This is called a **frictional** force and is a resistive force that *prevents* motion or *resists* motion. Friction is directed in the opposite direction of a force or motion. Two main forms of friction exist – static and kinetic friction - which we will discuss later in detail.

- Without friction, we would not be able to walk or cars would not be able to move forward. Our shoes grip the floor and car tires grip the road to move forward. This forward friction force is called **traction**. Gym and other sport shoes have thick rubber soles to aid in making sudden movements. Dancing shoes are very smooth to help in the graceful movements on a polished dance floor. In the winter, you often hear squeals from car tires trying to get out of icy parking spots. Since ice decreases the amount of friction between two objects, there is a decreased amount of traction to move a car forward. (What are some ways to get a car out of an icy parking spot?)

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[1] This should be read after demonstrations and derivation of normal force.

[2] The term **perpendicular** describes the right angle between two lines/vectors. **Normal** is a right angle relation between a line/vector and a point of a smooth surface. **Orthogonal** right angle relation for a collection of vectors (often 3 dimensions

- Extended or linked materials such as a *string* or *chain* exert **tension** forces on an object.

- Springs, whether reasonably stretched or compressed, return to their default state. This results in a *restorative* force that points in the opposite direction of the push or pull. Though we consider it as a **spring** force, this behavior is applied to objects that have an elastic quality.

- When an object interacts with a fluid, such as water or air, forward propulsion forces are called **thrust.**

- Resistive forces in a fluid (air, water) are called **drag.** Air friction and water friction are synonyms for this force.

- Floating forces in a liquid are called **buoyant.** This is due to the relative density of the floating object to the density of the fluid.

- Floating forces in air are called **lift.** Lift often comes from the difference in air pressure.

Other textbooks and resources will name an **applied force. This label is too vague for our discussions so we will avoid this description. Usually we can rename the "applied force" as a tension or normal force.

When two objects interact *without touching*, they exert forces through a force field.

- Earth exerts a **gravitational** force us even after we are no longer in contact with the Earth. When we jump up and are no longer in contact with the ground, Fgravity pulls us back down to the Earth) Earth exerts a gravitational force on the Moon even though the Earth and Moon do not touch.
- Other non-contact forces include **electric** and **magnetic** forces[3] which come from stationary or moving charged particles in an object

Labeling Forces

When we label forces, we want to be accurate and precise with the type of interaction between the objects (kind), what object the force is acting on (victim) and the source of the force (agent). Therefore, we will use the following notation:

$$\mathbf{F}_{\text{kind, on victim, by agent}}$$

For example, the gravitational force on you would be written:

$$\mathbf{F}_{\text{gravity, on you, by earth}}$$

Avoid using abbreviations until you are comfortable with the labels

[3] Outside of these are the **strong nuclear force** and the **weak nuclear force** which will be discussed at a later time.

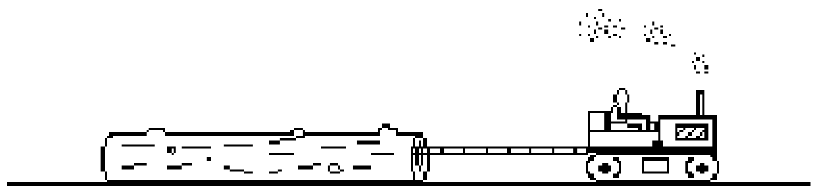
Reading 2: Drawing Force Diagrams[4]

An important first step in the force analysis process is to carefully determine the object of interest that will be the focus of our analysis. We refer to focus (victim) as the **system,** and everything else in the environment that might in any significant way affect the system as the **surroundings**. This analysis process can often times be greatly simplified by utilizing a technique of constructing **force diagrams** to assist you in selecting the relevant forces and appropriately representing these forces with **vector** notations.

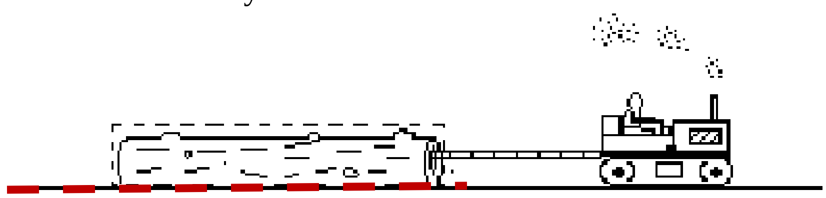
In general, we will follow the following steps when creating force diagrams.

1. Enclose the system within a system boundary.
2. Draw a dotted line for any surfaces in contact with the system.
3. Shrink the system to a point at the center of coordinate axes with one axis parallel to the direction of motion.
4. Represent all relevant forces (across the system boundary) with a labeled vector.
5. Indicate which forces (if any) are equal in magnitude to other forces.\
6. Create equations that relate the size of the forces.

Consider the analysis of forces acting on a **log** as a tractor pulls it at a *constant speed*.
The analysis proceeds as follows:



Step 1. In order to assist in the identification of the relevant forces acting on the system, enclose the system (here it is the log) within a closed boundary line.

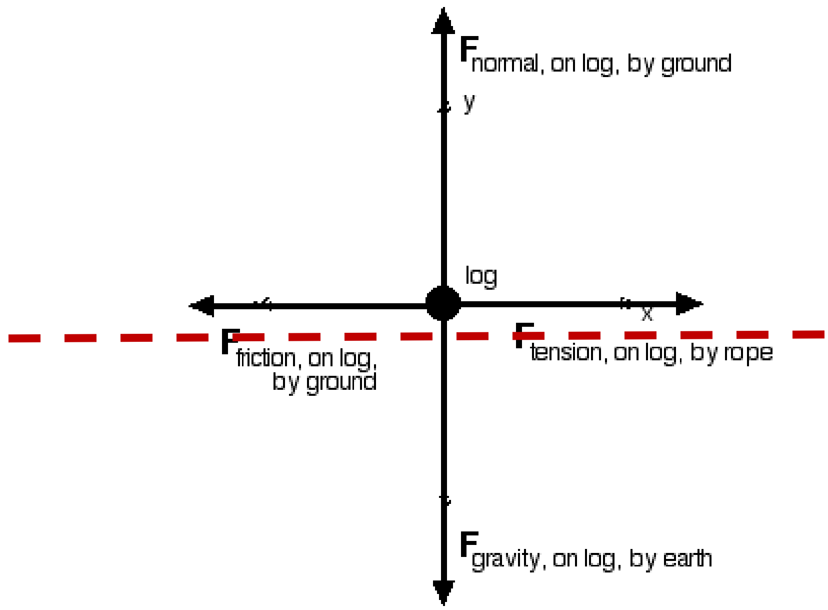


Step 2. Since the log (system) is in contact with the ground, there is a surface between the log and ground. Dashed line shown above.

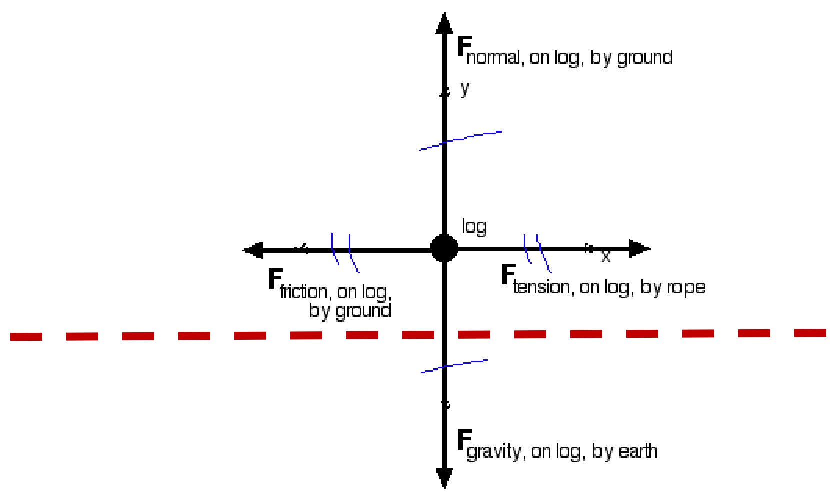
Step 3: Since the shape of the object is unimportant and the forces interacting inside of the system are unimportant, we shrink the system to a point. The coordinate plane follows as in graphing (y-axis is up and down, x-axis is left to right)

[4] This should be read after discovery of constant velocity and balanced forces and discussion of net force

Step 4. Proceed around the system boundary line and identify all points at which there is contact between the system (log) and its surroundings. Construct vectors (indicate directions and **relative** magnitudes) to represent these forces.



Step 5: Indicate which forces (if any) are equal in magnitude to other forces. In the vertical direction, the log is being pulled downwards toward the Earth but does not continue to fall down. This is because the ground pushes the log back up at the same strength as the Earth pulls down on the log. The problem states that log is moving with constant velocity. This implies that forces acting on the log are balanced and the tension on the rope must be the same value as the friction acting on the log. Note that we use double equality markings to differentiate the vertical from the horizontal.



Step 6: Create equations that relate the size of the forces acting on the system. Here we use the equality markings to guide this step. Since all forces are balanced, there is no leftover force and Fnet = 0N

Ffriction = Ftension

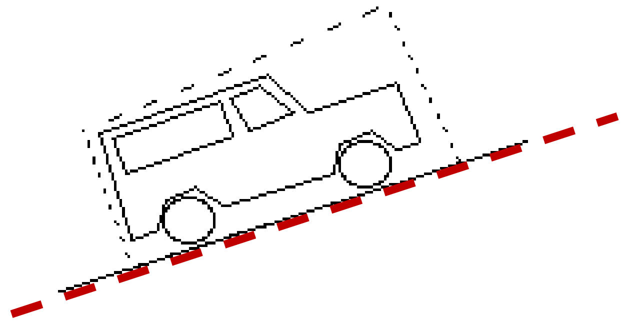
Fgravity = Fnormal

Fnet = 0N

Reading 3: Object on an incline & Forces at an angle

Here is a slightly different scenario:

A car parked on a hill.

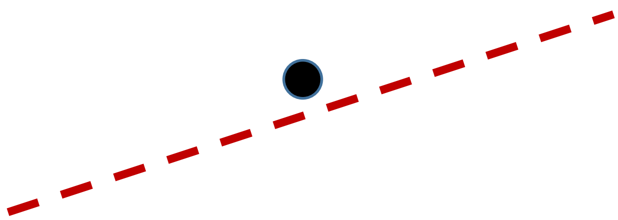


We will follow the same steps with a slight variation.

Step 1. Enclose the system within a system boundary.

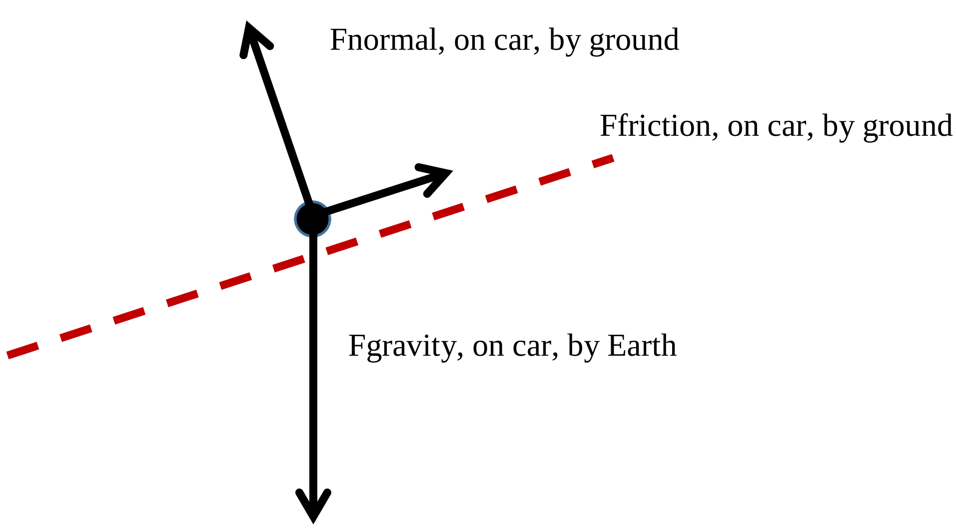
Step 2. Since the car (system) is in contact with the ground, there is a surface between the car and ground. Dashed line shown.

Step 3. Shrink the system to a point at the center of coordinate axes with the surface still at a slant.



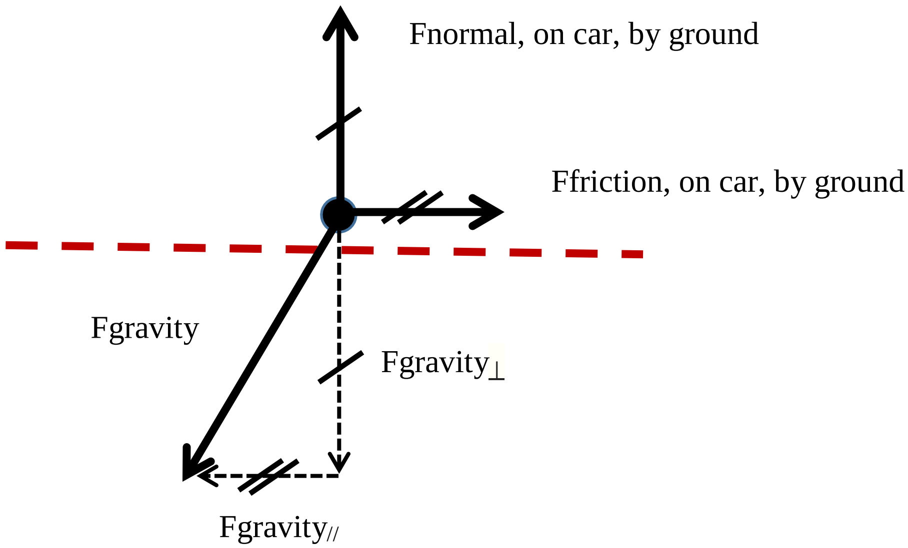
Step 4: Proceed around the system boundary line and identify all points at which there is contact between the system (car) and its surroundings. Construct vectors (indicate directions and **relative** magnitudes) to represent these forces.

Gravity always points toward the center of the earth (down). The normal force is perpendicular to the road/tire surface. The car is parked on the hill and not moving because of the friction from the car's tire. Without friction, the car would slide down the hill. Therefore, friction exerts a force up the hill to resist the tendency of the car to slide down the hill due to gravity.



Step 5: Rotate the diagram with the surface directed horizontally. This helps with the analysis as it is similar to the force diagrams we previously studied.

Fnormal is now directed up towards the page. Friction is directed horizontally to the right. Fgravity however is directed downwards AND to the left. To determine equality with balanced forces, we need to break Fgravity into its component vectors, $F_{gravity//}$ and $F_{gravity\perp}$ which are named for their relationship to the orientation of the surface.



Step 6: Indicate which forces (if any) are equal in magnitude to other forces.

$F_{friction} = F_{gravity//}$
$F_{gravity\perp} = F_{normal}$

$F_{net} = 0N$

Here's a very different looking situation, but the analysis is very similar. Try it out for yourself. You may choose to include or ignore friction which changes the diagram slightly.

A rock climber on a cliff: