Date: Group name: Name:

Activity 4.2
Force, Acceleration, Mass, and Newton's Second Law

20 Points Text Reference: Ch. 4.3, 4.4

Part A: Force and Acceleration

Introduction

Here, you will attempt to observe the relationship between force and acceleration. Here, an unbalanced force will be applied and the resulting motion observed.

Equipment

- spring scale
- skateboard
- computer with stopwatch

Procedure

The observations to be made here will require the efforts of three people: one (a student volunteer) to be the object in motion, one (Dr. Sagle) to apply a constant force, and a third (you) to time the motion. We will use about 15 feet of unobstructed, unoccupied, flat floor. A student will sit on the skateboard and hold the hooked end of the spring scale. I will then tow them across the floor with a constant horizontal force. Observe the resulting motion and describe it qualitatively below.

The skateboarder will start from rest and you will measure the time for a known displacement using the stopwatch. Below, derive an equation for the acceleration (assuming it to be constant) of the skateboard in terms of these measurable quantities.

Note that this equation includes a displacement. Record the displacement for the skateboarder's motion below in feet and convert it into meters.

$\Delta s =$

Now, we'll time the skateboarder as they are towed. You may use a stopwatch if you have one in your possession or you may use the stopwatch webpage linked to Dr. Sagle's homepage. We'll do this three times for the same constant force and average the results. These forces will be measured in pounds. Convert and record them in Newtons. Then, we'll do three more trials each for three more different forces. Fill in your data below.

Trial	time (s)	Trial	time (s)	Trial	time (s)	Trial	time (s)
#1		#1		#1		#1	
#2		#2		#2		#2	
#3		#3		#3		#3	
Ave.		Ave.		Ave.		Ave.	
a (m/s^2) =		a (m/s^2) =		a (m/s^2) =		a (m/s^2) =	
Force (lb) =		Force (lb) =		Force (lb) =		Force (lb) =	
Force (N) =		Force (N) =		Force (N) =		Force (N) =	

A plot of force in Newtons versus acceleration in m/s^2 will be made by each student using LoggerPro. Use the computer in laptop mode. Open the file 'Pull' in your course folder. Enter your data into the columns in the table. Reformat the axes if your data does not fill the graph.

Describe in words the relationship between force and acceleration observed on the resulting graph.

To find the best fit line to this data, select 'Analyze' 'Linear Fit'. 'Save' your file. To print, select 'File', 'Print Graph'. Be sure that the graph shows the linear fit data box before printing. We'll analyze and explain this data further in a subsequent activity.

Part B: Mass and the Application of Newton's Second Law

Introduction

The relationship between force and acceleration is formalized here as Newton's Second Law. Some general applications of this Law will be explored. The concept of mass will also be introduced.

Discussion

In Part A, you observed the relationship between force F and acceleration a through data plotted on a graph. If you obtained quality data, a linear relationship between force and acceleration should be apparent. If we ignore the y-intercept for the moment, we can state that force and acceleration are proportional to one another. Algebraically, $F \alpha a$.

Here, we will define the constant of proportionality between force and acceleration as mass m. Thus, for the student towed on the skateboard, we could write $F=ma$. However, a more general form of this equation is required to account for the vector nature of the quantities involved and the possibility that more than one force is simultaneously exerted on the mass. The result is called Newton's Second Law or the Law of Acceleration.

Newton's Second Law (The Law of Acceleration)

The net force acting on an object is equal to the object's mass multiplied by the object's acceleration.

$$\Sigma \vec{F} = m\vec{a}$$

Above are two different statements of Newton's Second Law.; a statement in words and an equation. Both force and acceleration are vectors, meaning that the net force and the acceleration vectors point in the same direction. It should be pointed out that this mathematical relationship represents the forces acting on this object during a single instant in time. If these forces change with time, then so does the object's acceleration. Also, note here that if the acceleration is zero, the object is in mechanical equilibrium and the forces must add to zero, as described by Newton's First Law.

Mass is defined as the constant of proportionality between net force and acceleration. Thus, it appears as a slope on a graph of force versus acceleration. Mass measures how much inertia (the ability to resist changes in motion) an object possesses. It is a measure of the quantity of matter of an object.

The SI standard of mass is the kilogram (kg). It is defined by the mass of a platinum-iridium alloy cylinder kept in France. Thus, mass units, like length and time units, are fundamental units in the metric system.

The units of force are drawn from the units on the right-hand side of Newton's Second Law (ie. the "$m\vec{a}$" part of "$\Sigma \vec{F} = m\vec{a}$"). Note that these units are mass units multiplied by acceleration units. The SI units of mass are the kilogram (kg), while the SI units of acceleration are m/s^2. Thus, the SI units of force are $kg \cdot m/s^2$. To shorten this representation and to honor Sir Isaac Newton, physicists have defined a unit called the Newton (N), such that $N = kg \cdot m/s^2$. Therefore, N is the SI units of force, as well. The Newton is a derived unit (as opposed to a fundamental unit) because it depends on other units for its definition.

Pounds (lb) are the force units used in the USCS system of units. As with SI units, where Newtons $N = kg \cdot m/s^2$, the USCS pound $lb = slug \cdot ft/s^2$. Note that ft/s^2 represent the USCS standard for acceleration, while slugs are the little-used units of mass in this system of units.

<u>Questions</u>

Force is a vector. Like other vectors (position, velocity, etc.), the rules of vector addition are used to determine the sum-of-the-forces portion of $\Sigma\vec{F} = m\vec{a}$. When only a single force is acting on an object, $\Sigma\vec{F} = m\vec{a}$ becomes $\vec{F} = m\vec{a}$. In this situation, the force and acceleration vectors act in the same direction. The following is an application of this most simple of problems.

Question 1

An 86 lb force is applied to a 42 kg object at a 65^0 angle. Determine the object's acceleration magnitude and direction.

Newton's Second Law (the Law of Acceleration) is written algebraically as $\Sigma\vec{F} = m\vec{a}$. Applying this Law in one dimension is fairly straightforward, since directions for the vectors $\vec{F}$ and $\vec{a}$ can simply be provided using plus and minus signs.

Question 2

A 500 g cart moving at 0.56 m/s to the right on a 2-m long track experiences two forces simultaneously; a 6.2 N force to the right and an 8.4 N force to the left. a) Determine the cart's acceleration. b) Determine how long it will take this cart to come to rest, assuming that this acceleration is constant.

In two dimensions, vector addition is required to determine the sum of the forces $\Sigma\vec{F}$. This means working with components. As a result, $\Sigma\vec{F} = m\vec{a}$ becomes two one dimensional problems: $\Sigma F_x = ma_x$ and $\Sigma F_y = ma_y$.

Question 3

Consider two forces exerted on a 65 kg object; one of 200. N acting at 25^0 and another of 100. N acting at 45^0.a) Find the net force acting on the object. b) Find the object's acceleration.