Physics (0-1) Class Notes—Orientation to the Class: The Structure of Physics

Preassessment—On a 3 x 5 note card, tell me why you think it might be useful to create a visual organizational outline of a large amount of new material you are trying to learn.

A Functional Organizational Scheme of Physics

Learning Target

what*: *The student will understand the importance of being able to use an organizational framework—a graphic organizer—to organize course content in a useful, meaningful way
why*: *knowing WHAT YOU NEED TO KNOW, especially in the format of a graphic organizer, enhances learning
how*: *students will be able to list four or more reasons an organizational structure is important; students will be able to explain how each section of the chemistry organizer is related to the step above it; students will be able to state that EVERYTHING we do and learn about in this course rests on OBSERVATION

For a really good short article about how and when to use graphic organizers see https://www.cultofpedagogy.com/graphic-organizer/

Why you want to do this

You are going to learn a great deal of information this year related to the field of physics. Research overwhelmingly suggests that one of the best ways to begin to deal with such a large amount of information is to create an organizational structure—one that is visual—that organizes the information you will be learning, in a logical fashion. There are many reasons to do this—

(1) This allows you to ____
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(2) Having this map where the connections between each section "make sense" ____
____

(3) As learning occurs you can ____
____

(4) Understanding WHAT you need to learn before learning it __________
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My favorite way to organize large amounts of information related to a big topic is to start with a single major idea, and by asking a sequence of logical questions, expand the structure to smaller details. Many of the pieces you won't have a great deal of understanding of yet, but it's important that we create this structure right from the start anyway. Despite this, you'll find that even if you don't know what the pieces are exactly, their place in the structure WILL make sense.

There is no magic in how I create an organizational structure—you are more than welcome to create your own or find one on the internet you like better. In fact, if you go out to the internet and bring me a copy of a different version of a graphic organizer that organizes the content of a physics course, I may give you some extra credit. However, the one that I will model for you is the basis for the organization of the content of this course, and the one I will refer to as we move through the course.

At The Core

The study of physics revolves around relationship between three main concepts:

____________________ which gives rise to
____________________ which give rise to
____

Lets dive into this a little and see why it makes sense. First consider the term energy—you have likely heard a very simple definition for this term, **energy is ________________ ____.** While this is actually a very good definition, my guess is that most of you think it is at least unclear and maybe even uncomfortable. Why do you think this is the case—what is it about this definition that is unsettling? ____
____
____

We can make this idea of energy seem a little more real if we decide that one way we can measure or "see" an amount of energy is by finding out how much work we can do with a certain amount of energy. If I throw a baseball, you are aware that after the ball leaves my hand it can be stated to have a certain amount of kinetic energy—the energy of motion. To get that amount of kinetic energy, I had to do the same amount of work on the ball. What unit do we measure energy in? _________________ So, if the ball ends up with 100 J of kinetic energy, I had to do 100 J of work on the ball to accomplish that. We may not have a good idea of what “the ability to do work” really means, but we do know that if we have 100 J of kinetic energy, somehow, 100 J of work must have been done to create it. Now, does the baseball that has 100 J of kinetic energy have the ability to do work? Of course! The definition of energy tells us this. How much of an ability? __________________.

The next question then, is, how does this energy accomplish doing work? ____________ ______________________________. Would you agree that if I am throwing the baseball at a milk jug in a carnival game, if it hits the milk jug it will apply a force to jug. ____________. Again, ENERGY GIVES RISE TO A FORCE. But, how much of a force? What are the units of measurement for force? _________________. Because the amount of work done on the jug by the baseball has to equal the amount the amount energy the baseball had (we are assuming a direct hit and that all of the energy of the ball is transferred to the jug), we are saying that the ball did 100 J of work on the jug. One of the many things we will learn in this class is that work done on an object equals the force applied to the object times the distance the object then travels. If the jug travels 1 m, and 100 J of work was done on it, the force applied to the jug must have been ____________. So, again, the energy gave rise to a force, and because we know the relationship between energy, work and force, we would be able to calculate how much force the energy gave rise to.

But wait, there’s more. The energy gave rise to the force, but what did the force give rise to? _____________________. How much motion? The jug was initially at rest, and then all of a sudden, it was in motion. How fast was it going the instant after the ball hit it? What was the acceleration? Because we will learn an even more important relationship between force, acceleration and mass—that is, acceleration equals the force applied to an object divided by its mass, if the jug had a mass of 1 kg, and the force applied was 100 N, we could figure out the acceleration, and from that we could figure out the velocity of the jug right after the ball hit it.

I don’t expect you to know all of this for some time yet, but this does illustrate the central theme of all of physics, ENERGY GIVES RISE TO FORCES WHICH GIVE RISE TO MOTION. This becomes our starting point then, for our graphic organizer, which will outline all of the stuff we are going to learn this year. Add this into the diagram as shown in the presentation or as seen on your final diagram.

In general, as we study physics we will always start with the simplest concepts and work toward more difficult ones. Although energy is the thing that makes everything else happen, it is also the most difficult concept. We will start by looking first at how to describe motion, then at how forces cause motion (and how much motion), and then finally at how energy gives rise to forces.

Motion

The study of motion is called ________________________. Why does this make sense?
____

There are many types of motion we could consider but some of these are beyond to scope of this class. Initially, we will look at motion outside the context of the forces that cause the motion. This will allow us to develop basic vocabulary and understanding of mathematical formulas and graphic representations of motion without distraction.

The simplest type of motion we can talk about will be motion that occurs in a straight line, also known as ______________ motion or motion in ________________________. This is the simplest case because there is basically only one way to accomplish motion along a straight line. This should intuitively make us think, however, that we can also talk about motion in two dimensions. The simplest type of two-dimensional motion is ________________________motion—the motion of objects launched either horizontally or at angle.

Add these two types of motion into the diagram.

Although additional types of motion we will talk about could be placed under the heading of either one- or two-dimensional motion, we cannot talk about these types of motions without discussing the forces that cause the motion and energy changes occurring during the motion. Because of this, we usually talk about forces and energy, and then come back to tackle these more complex motions under their own headings.

As we talk about basic kinematics we will develop a set of terms, mathematical formulas, and graphs to provide a description of motion. Some of the terms you are familiar with because you have seen them in previous math or science classes. Let's create the main list of terms we use to describe motion.

____
____
____
____

We will have two main types of diagrams to help us visualize the process of problem solving:

____
____

and three main types of graphic representation showing the relationship between various feature of motion and time.

____
____
____

Add these features into the diagram.

Forces

The study of forces—the "things" that give rise to motion—is called ________________. You may be aware that the basic definition of a force is that it is a push or a pull. With regard to forces, the main thing we are going to want to know is, what is the relationship between the amount of force applied, and the amount of motion resulting? It should make sense that in general, the greater the force, the greater the effect on motion. It should also make sense that how a certain force affects motion, also depends on the mass of the object being pushed or pulled. The same force will have less effect on the motion of an object containing greater mass. Newton formalized the relationship between force, mass and motion by realizing that a net force (what is a net force? ___________________ _______________________________) causes an object to undergo acceleration, and the degree of the that acceleration depends on the mass:

$$acceleration = \frac{force}{mass} \quad or \quad a = \frac{F}{m} \quad or \quad F = ma$$

Acceleration is the feature of motion that allows us to connect the amount of force to a certain amount of motion. This is **Newton's __________________ Law of Motion**. Because this relationship quantifies what happens as a result of a net force on a single object or particle, problems related Newton's Second Law are often referred to as "<u>unbalanced force</u>" problems.

Newton also necessarily realized, as did Galileo before him, that if **no net force** is acting on an object, whatever motion the object is in, it will remain constant (including a constant motion of zero). This is **Newton's ____________ Law of Motion**. Another way of stating this is that an object, whether in motion or at rest, resists acceleration. The property of an object resisting acceleration is called inertia. The inertia of an object depends on its mass. It should make sense that a 10 kg object will resist acceleration more than a 1 kg object. Because it describes the concept of inertia, Newton's First Law is also called the Law of Inertia.

> Further recognize that the state of having no net force being applied could be the result of multiple forces acting on the object and cancelling each other out—it does not necessarily mean there are no forces acting on the object at all. Being in this state of balanced forces is referred to as being in a state of _________________________. As no acceleration is occurring, there is no change in velocity—this is a "static" state. Therefore, problems related to Newton's First Law are often referred to as <u>equilibrium</u> problems.

Finally, Newton realized that when one object exerts a force on another object, the second object must exert a force of equal amount in the opposite direction on the first object. This is **Newton's _______________ Law of Motion**, and it will cause us a great deal of confusion. The participating forces are often called __________________ forces.

Throughout the course we will describe a great number of different types of forces depending on the source of the force. These are too numerous to put into our graphic organizer at this point, but we will expand our framework to incorporate these when we start to talk about them.

The main tool we will have at our disposal to look at dynamics problems is the ______________________________ diagram. This is a diagram that will allow us to visualize the interaction of all forces acting on an object in a way that will significantly facilitate problem solving.

Circular Motion

Once a basic understanding of forces is accomplished, we can see how force may interact with objects to create more complex types of motion.

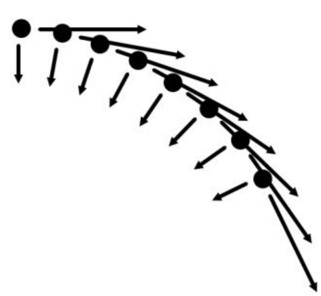
Consider an object traveling in a straight line at a constant velocity—are any net forces acting on it? _______ Are any forces acting on the object? ___________

Now, suppose a new force acts on the object in a direction that is perpendicular to the motion of the object. What happens to the path of the object as a result of the force?____

____

If the new force is then quickly removed what happens to the path of the object? ____

If the force continues to be applied in a direction that is perpendicular to the motion, what will happen?



At any instant in time, while the object will want to travel in a straight line because of its inertia, the force directed toward the center of the circle will cause the object's path to be altered into that of a circle.

Because gravitation can give rise to circular motion, Newton's Law of Universal Gravitation and planetary motion will also be discussed in this section.

Energy Concepts

The remaining types of motion we will talk about after we understand more about energy and how energy relates specifically to forces and motion, and in particular, how this relates to the motion concept of momentum.

In particular, with energy we will discuss the concept of "how much energy" gives rise to "how much force," in the relationship called the work-energy theorem. We know that the amount of work done on an object is equal to the force applied times the distance moved. A certain amount of work done is equivalent to a certain amount of energy used, so we can easily relate force and energy.

We are also aware of the concepts of kinetic energy—that is, the energy of motion ($KE = \frac{1}{2} mv^2$) and potential energy—that is, energy stored in an object based on its position is relationship to a gravitational body ($PE = mgh$). We are also intuitively aware that as PE energy is lost, KE is gained, and vice versa. This back and forth conversion between KE and PE will be very useful in solving many types of force and motion problems.

This concept also leads into the understanding that energy is conserved—that is, it is not lost, it is simply transformed into other forms during interactions of matter. Finally, it should make sense that we can quantify an amount of energy used during a certain period of time—this is the concept of power—J/s.

Linear Momentum

Once we understand the relationship between energy and forces, we are in a better position to understand a more advanced concept of motion called momentum. Before, we simply talked about the parameters that describe motion, position, displacement, velocity and acceleration. Now we want talk about a "quantity of motion" or an "amount of motion." This feature of motion includes not only a description of the motion, but also the effect of the mass of the object on the motion.

You are aware that if you use the same force to push two objects of different masses, the more massive object will move more slowly than the less massive object. The product of the mass of an object and its velocity is called the momentum. For objects traveling in a straight line (what kind of motion?), again, this represents an amount of motion rather than just a description of the motion. The usefulness of this is that we can relate an amount of force that will give rise to a certain amount of momentum through a mathematical relationship called the impulse-momentum theorem. Impulse is the product of the force applied and the amount of time over which the force is applied. In general, the greater the force, the greater the resulting momentum. Likewise, the greater the amount of time over which the force is applied, the greater the momentum. This concept becomes useful in analyzing the effects of collisions on motion, because momentum is conserved—the total momentum before a collision must equal the total momentum after a collision.

Oscillations

Once we understand momentum as a quantity of motion, we are better equipped to understand an additional type of motion—motions that occur as oscillations, or "back and forth" types of motions like those exhibited by springs and pendulums.
As with other types of motion, we will use the features of displacement, velocity, acceleration and momentum to develop a new set of formulas to describe these motions.

Mechanical Waves

The ideas of oscillations leads into the topic of mechanical waves. We will find out that this is a type of motion where energy is transferred through matter without the movement of the matter from the beginning point to the ending point. Although this is a more complex type of motion, we will still find that we can use many of our familiar concepts to help us undertand.

Electricity and Circuits

Finally, we will apply some of the concepts of force and energy we have learned about to describe the interactions and forces that develop between charged particles. In particular we will learn about fields of force that exist around charged particles and how they can be used to create flows of charged particles, from which we can obtain useable energy in electric circuits.