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Unit 1 Background Reading:

Frames of Reference and “Zero Reference Levels”

As we continue our study of energy and practice representing the energy states of a system using Energy Bar Graphs, we will often find it necessary to make decisions as to how much energy to reserve for each account. This process can be made easier by agreeing upon conventions for our zero reference levels.

A dictionary definition of the term ***frame of reference*** might be:

a structure of concepts, values, customs, views, etc., by means of which an individual or group perceives or evaluates data,

communicates ideas, and regulates behavior.

The definition above came from Dictionary.com. Also from Dictionary.com, one of the definitions of the term ***convention*** is

general agreement or consent; accepted usage, especially as a standard of procedure.

These ideas can be important in physics in order for various people to be able to communicate ideas about the physical world.

If your physics teacher were to ask you, “How fast are you going,” as you sit still in your seat in physics class, how would you respond?

Your first inclination might be to answer zero. After all, you are sitting “still” in your seat. But what if a fellow student answered 811 miles per hour? Or what if yet another student answered 67,000 miles per hour?

The answer is that each of the students could be correct, but unfortunately, the question that was asked is meaningless without a frame of reference for measuring speed.

If you answered zero, you were assuming a frame of reference that was the surface of the earth (or the floor of the building, etc.). If the question had been, “what is your speed with respect to the surface of the earth?”, then the answer would have been zero.

Under what conditions would the other students have given correct responses? Or another way of asking this is, from what frame of reference is your speed 811 miles per hour or 67,000 miles per hour?

As you know, the earth rotates on an axis making one complete rotation per day. You, as a passenger on the surface of the earth, travel the circumference of a large circle (the length of the latitude line at your location) once per day. In St. Louis, where the latitude is about 38.6° north, that speed is about 811 miles per hour. At the equator it is even greater—around 1000 miles per hour. So if the student, located in St. Louis, answered the question with the earth’s axis of rotation as the frame of reference, 811 miles per hour would be an excellent answer.

Finally, you also recognize that the earth revolves about the sun, making one nearly circular trip per year. Given the tremendous distance from the earth to the sun, the radius of that “circle” is huge, and if you divide the circumference of the earth’s path about the sun by 365 days, you get an answer of around 67,000 miles per hour.

The answer to the question, “how fast are you traveling,” always depends on a frame of reference. If the people communicating about speeds have reached an agreement (developed a convention) that all speeds are measured relative to the surface of the earth, then they can better communicate about speed. Of course, the questioner could have eliminated the confusion by establishing the frame of reference when asking the question. He could have asked, “With respect to the surface of the earth, how fast are you traveling.”

The idea of “frames of reference” is equally important in energy analysis. When you are making your energy bar graphs, the amount of energy you assign to a given energy storage account will depend on what you have chosen as a frame of reference, what we will call a “zero reference level”, for that energy account.

**Zero Reference Level** – the energy state of a system for which we will call the energy stored in a particular energy storage account zero. This will be designated with the acronym ZRL.

While you could communicate, for every problem, what you have chosen as the zero reference level for each energy storage account for that problem, it might be more efficient for us to establish some conventions for our zero reference levels in this course. You can always choose a different zero reference level than the one established by our convention if you choose, but when you do so, you MUST communicate your zero reference level.

**Zero Reference Level Conventions and Rationales for those Conventions**

**Kinetic Energy**—For the purpose of measuring kinetic energy, we will assume that the kinetic energy is zero when the object is not moving relative to the surface of the earth. We will adopt this convention since most people naturally measure speeds with respect to the surface of the earth.

**Elastic Energy**—For the purpose of measuring elastic energy, we will consider the elastic energy of a system if it is undistorted from its “normal” configuration. For instance, a spring system will be considered to have no elastic energy if the spring is neither stretched nor compressed.

**Thermal Energy**—This one is a little trickier than the previous two. It might make sense to call the thermal energy of the system zero if the system was at the lowest possible temperature—absolute zero—since this means essentially no motion at the molecular level. However, at room temperature, where most of our analyses will take place, this would mean that the amount of thermal energy is likely to overwhelm the amounts in the other energy storage accounts to the point of not being able to easily discern changes in the amount of energy in those other accounts. Since the temperature changes we are likely to see in our analyses (perhaps a few degrees Celsius) are usually going to be small compared to the difference between absolute zero (-273 °C) and comfortable room temperatures (around +22° C) using absolute zero as our zero reference level is probably not a good idea. Instead, we will follow this convention: We will establish the initial ambient temperature of our system to be our zero reference level for thermal energy. This means that, in most cases, the amount of energy in the thermal energy account will start at zero. Since nearly all of the processes we are likely to encounter in this course involve the temperature going up or staying the same, we will either see the thermal energy staying at zero or increasing throughout our analysis.

**Chemical Energy**—We are only going to worry about considering chemical energy if something happens to cause it to change. It will only change if a chemical reaction occurs that causes it to change. Therefore we will in general call the initial state of the chemical energy of a system zero unless the process we are analyzing involves some chemical reaction (like burning) in which case we will usually call the final state of the chemical energy zero. In other words, we will ignore chemical energy in our analyses unless a chemical reaction during the situation being analyzed requires us to consider it. Then we will make the initial chemical energy something greater than zero such that the final state of the chemical energy is zero or near zero.

**Gravitational Energy**—This is the one energy storage account for which we will not establish a convention. For each analysis, you should label the position in the physical diagram that you will consider the zero reference level with the acronym ZRL. In general, you will find it convenient to call the lowest position occupied by the object in your system the zero reference level.