Unit PEF

LESSON 3: Magnetic and Static Electric Interactions and Energy

Purpose and Key Question

Previously you learned about magnetic and static electric interactions. In this lesson we will learn how to describe these interactions in terms of energy.

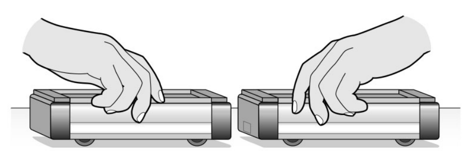
How can we describe magnetic and static electric interactions in terms of energy?

Predictions, Observations and Making Sense

Part 1: How can we explain action-at-a-distance?

In the previous unit you examined several different examples of contact push/pull interactions. What all of these had in common was that the objects involved had to touch each other in order for an interaction to take place between them. But can objects push or pull on each other without touching?

Watch a movie **(UPEF L2 Mov1)** in which two carts with magnets attached are brought close together, but not touching, and then released. One of the magnets will be removed from its cart, turned around, and reattached. The demonstration will then be repeated.



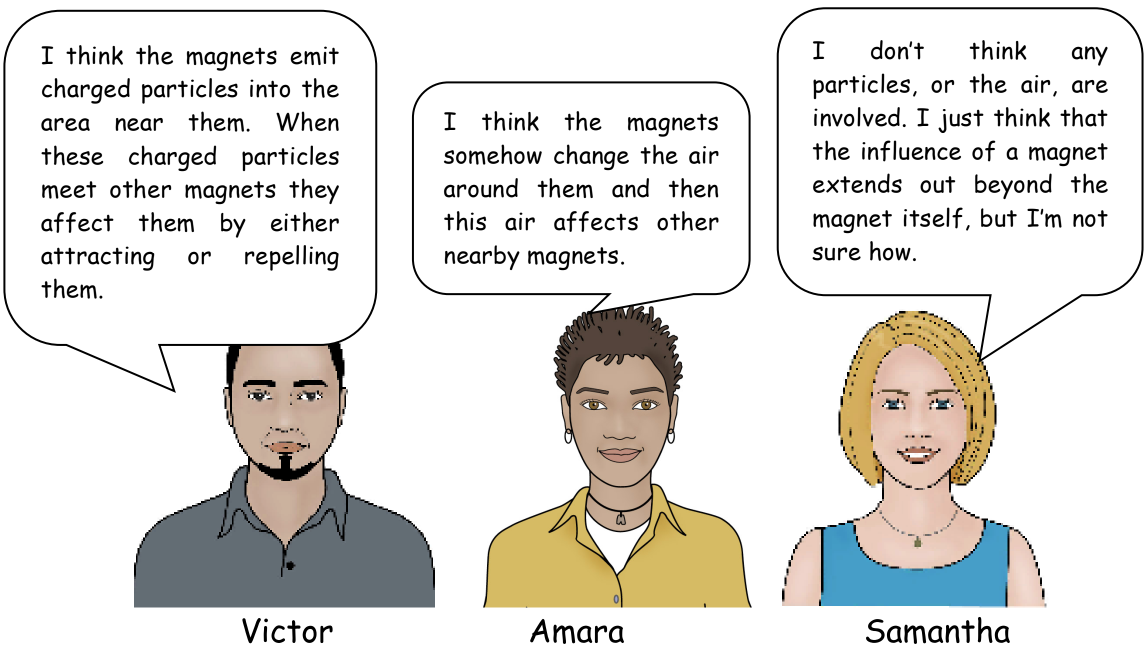
Note: You know that the two carts, on their own, will not interact without touching. However, by attaching the magnets to the carts this will allow you to more easily observe if there is any interaction between the two magnets.

Was there an interaction between the two magnets? How do you know?

Why do you think the behavior of the magnet-carts was different when one of the magnets was turned around?

When two magnets either attract or repel each other (or interact with another magnetic material), we call this a **magnetic interaction**. Since the magnets affected each other without touching, the magnetic interaction is an example of what scientists call an ***'action-at-a-distance'*** type of interaction. That is, an interaction in which objects can exert pushes and pulls on each other **without touching**.

When asked how they think two magnets can interact without touching, three students gave the following suggestions.

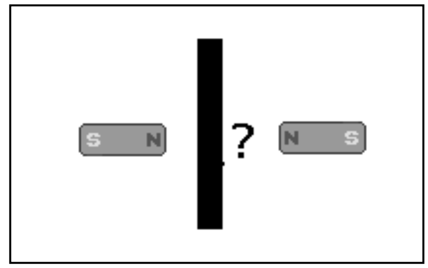


CQ 3-1: Do you agree with Victor, Amara or Samantha, or do you have another way of thinking about how two magnets can affect each other without toughing?

A. Victor
B. Amara
C. Samantha
D. Some other idea—you describe it.

Now consider two simple experiments that could be used to support or refute some of these ideas.

First, suppose you placed a large barrier between two interacting magnets. In this situation, would you still expect the two magnets to interact with each other? Why do you think so?

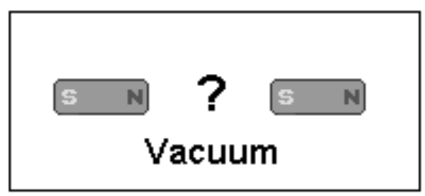


To check your thinking, watch a movie **(UPEF L3 Mov2)** of the situation.

Describe what you observed. Do the two magnets still interact when there is a physical barrier between them?

Assuming the physical barrier prevents charged particles from going through it, which person's idea in CQ 3-1 is refuted by the result of this experiment?

Now suppose you placed two interacting magnets in a container and then pumped the air out. After this is done, do you think the magnets would still interact with each other or not? Why do you think so?

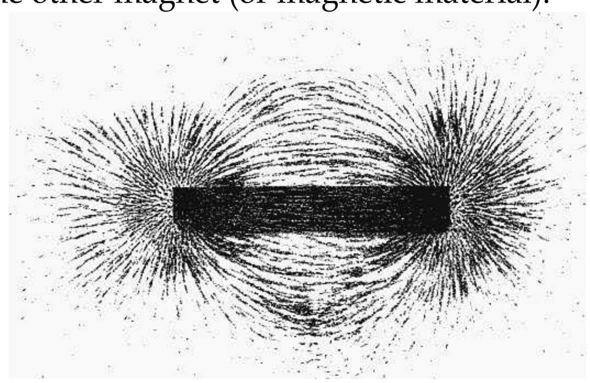


Watch a movie **(UPEF L3 Mov3),** in which two magnets will be brought close together in a container in which the air is being pumped out.

Describe what you observe. Do the two magnets still interact when there is no air in the container?

Since there is no air in the container, which person's idea in CQ 3-1 is refuted by the result of this experiment?

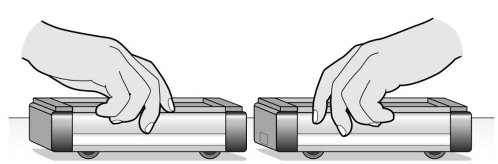
So how can we account for the 'action-at-a-distance' nature of magnetic interactions? Scientists find the idea of there being an invisible 'field of influence' or 'field' around a magnet to be the most useful in accounting for the observation that magnetic interactions can occur without physical contact. They call it a ***magnetic field*** and consider it to be present around the magnet all the time. However, it is only detectable when it produces an effect on another magnet (or an object made of magnetic material). This effect takes the form of pushes or pulls that act on the other magnet (or magnetic material).



Indeed, you may have seen how the magnetic field around a magnet can be demonstrated by allowing small pieces of a magnetic material (iron filings) to feel its influence. You will also investigate the magnetic field around a magnet further in the extension activity following this lesson.

Part 2: Magnetic interactions and energy

In the first lesson you saw two carts joined by a stretched rubber band start to move when released. In this case, the rubber band was the energy giver, and it decreased in elastic potential energy as the carts increased in kinetic energy.



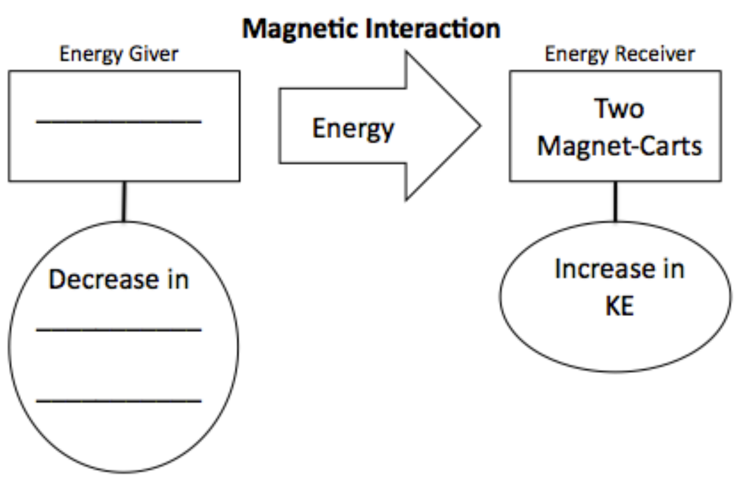
In Part 1 of this lesson you saw that two attracting magnet-carts started to move when they were held close together (but not touching) and then released.

CQ 3-2: Do you think there was some object or entity that was an energy giver in the interaction that started the magnet-carts moving?

A. No, there was no energy giver.
B. Yes, there was an energy giver and some form of energy associated with it increased.
C. Yes, there was an energy giver and some form of energy associated with it decreased.

As well as being a useful model for explaining 'action-at-a-distance', scientists find the idea of a magnetic field is also useful when thinking about magnetic interactions in terms of energy. As you probably deduced, since there was an increase in the kinetic energy of both magnet-carts in the interactions you examined, by the law of conservation of energy there must have been a decrease in some other form of energy associated with the magnets, which we will call ***magnetic potential energy (MPE)***. Scientists find it useful to think of the magnetic field as being the energy giver during such interactions, with the magnetic potential energy being associated with the magnetic field itself.[1]

Use this idea to complete the following G/R diagram for the magnetic interaction that started the attracting magnet-carts moving.



[1] Previously, you were introduced to *chemical potential energy* and *elastic potential energy* as forms of energy that are 'stored' in different ways and have the potential to produce changes in other types of energy, such as kinetic energy. In the same way, you can think of *magnetic potential energy* as energy stored in the magnetic fields around magnets that has the potential to produce changes in the kinetic energy of the magnets themselves.

Complete the statement of conservation of energy for this magnetic interaction.

Decrease in _________________ *of* _____________________	=	*Increase in* __________________ *of* ____________________

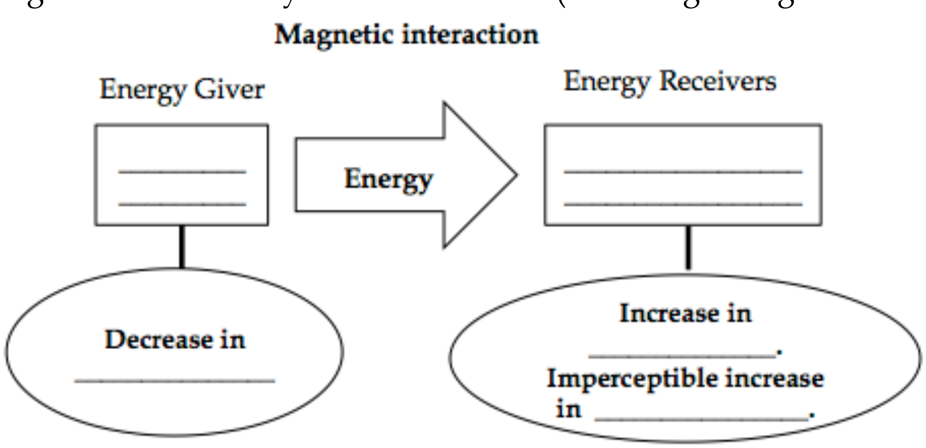
Compare your diagram and energy statement with two other groups and try to resolve any differences.

Suppose one of the two attracting magnet-carts had more mass than the other. How would the increases in each of their KEs after they were released compare to when they both have the same mass? Explain your reasoning.

Watch a movie **(UPEF L3 Mov4)** of an experiment to check your thinking to this last question.

If the carts do not behave as you predicted, describe what does happen.

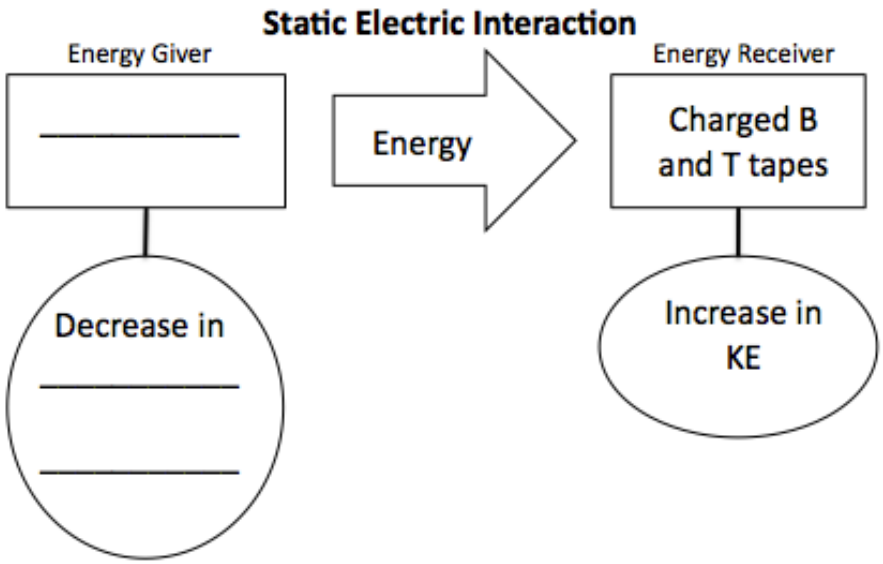
Complete the G/R energy diagram below for a situation in which the magnet-carts had very different masses. (We are ignoring friction effects.)



Part 3: Static electric interactions and energy

As you observed previously, objects that are charged with static electricity (like tapes) can also attract and repel each other (and attract uncharged materials) without touching. This means that the *static electric interaction* is another example of an 'action-at-a-distance' interaction that can be accounted for using the idea of a field, in this case the ***electrostatic field***. We can describe this interaction in terms of energy in a way similar to what we did for the magnetic interaction. The energy stored in the electrostatic field is called ***electric potential energy*** (Elec. PE).

Complete the G/R energy diagram and statement of conservation of energy below for the static electric interaction in which a pair of charged B and T tapes are held near to each other and start to move together.



Write down a statement of the conservation of energy for this situation.

Chemical Potential Energy revisited

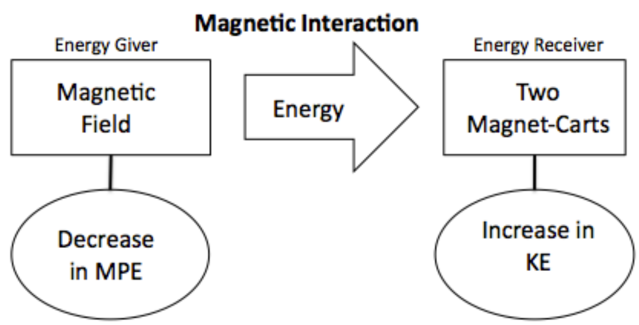
Recall that in the previous unit, when referring to people and dry cell batteries, we said that it was *chemical potential energy* (CPE) that decreased in them when they were the energy giver in an interaction. Now that we have seen how to explain static electric interactions in terms of energy, we can also see that CPE can be regarded as just another name for the potential energy stored in the electric field around the charged particles that form the atoms and molecules of the materials. When a chemical reaction occurs, some of the electrons get rearranged, meaning the distance in between them (and between them and the positively charged protons in the nucleus) changes. Thus, the amount of potential energy stored in the associated electric field may increase or decrease depending on the details of this rearrangement. When we say that the chemical potential energy of an object has decreased, this is another way of saying that the electrons in the object have been rearranged such that the potential energy stored in the electric field has decreased.

Summarizing Questions

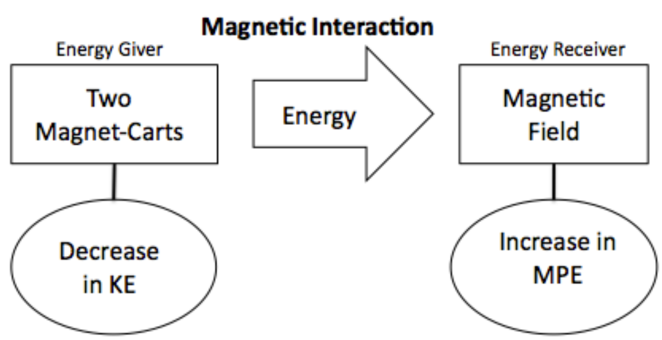
S1. Imagine you were to hold two attracting magnet-carts close together, but instead of simply releasing them you give them a quick push away from each other. After your push, they get further apart, slowing down as they do so, before eventually reversing direction and coming back together again.

CQ 3-3: Which of the G/R energy diagrams below would be appropriate for the two attracting magnet-carts as they are moving further apart and slowing down (after the initial push)? (We are ignoring any effects of friction.)

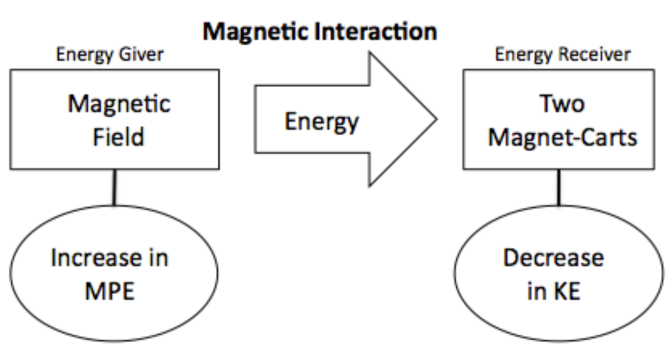
A



B



C



S2. Three elementary students are discussing an engineering project in which they have been asked to design a way for an astronaut to keep his tools handy while he is working outside in space.

Jada: "Let's put small magnets inside his belt and some other small magnets on the tools. Then the tools will stick to the belt."

Patrick: "That won't work because, if the magnets are inside the belt, there will be a barrier between the magnets so they won't interact. If we put the magnets on the outside of the belt, it would work because there would be nothing between them."

Katie: "That won't work either because there's no air in space, so the magnets won't stick together."

Which student's thinking do you agree with, if any, and why?