

# PHYS 2020: College Physics

## Manic Monday #4

“We believe that electricity exists, because the electric company keeps sending us bills for it, but we cannot figure out how it travels inside wires.” ~ Dave Barry

### The Right Hand Rule Rules!

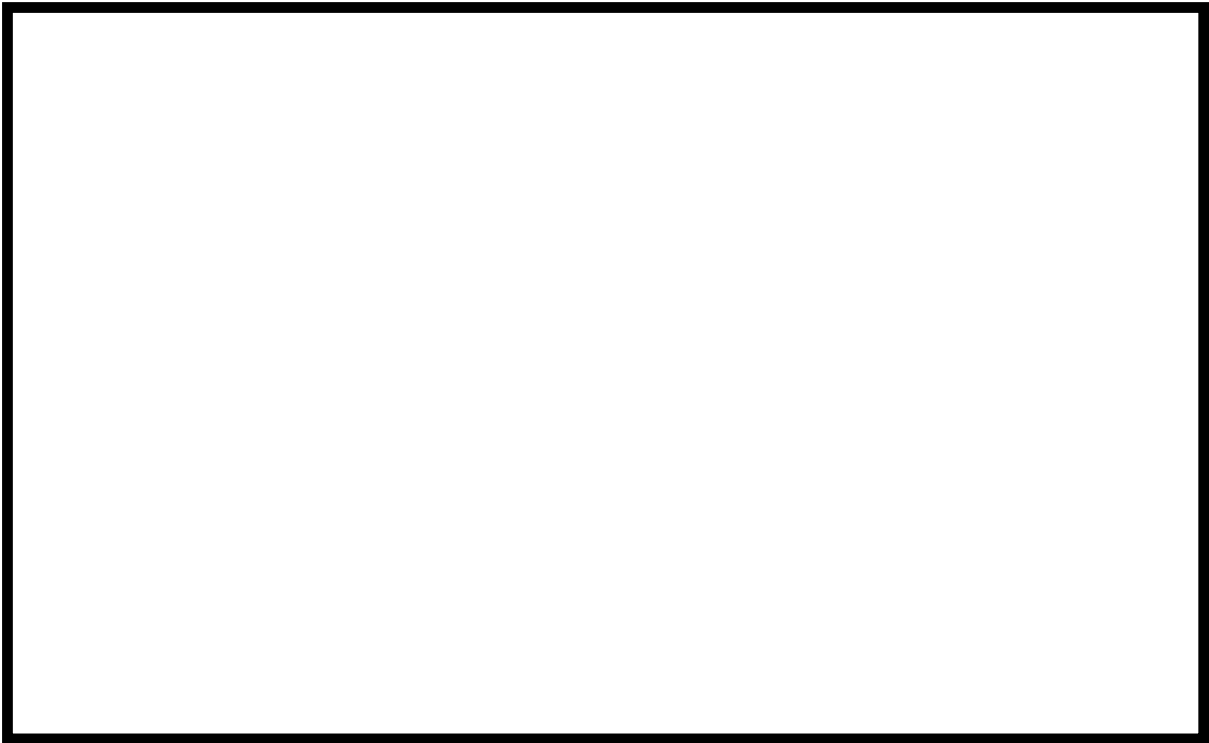
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You may not remember this, but when you were very small, barely a baby in the cradle, your parents used to read you some of your favorite childhood tales out of your favorite book, *The Grimm Brother’s Grim Guide to Physics*. By the time you were three, your parents were so sick of reading to you about magnetic fields they hid the book from you, and never talked about physics again. As the years passed on, you forgot your passion for physics, and were slowly led astray into other life endeavours.

Over the course of this year, that faint sensation you get in physics class — you know the one you keep thinking is panic and dread? — are those childhood memories stirring and attempting to resurface, yearning to take you back to those happy memories of days long gone by, and help you rediscover your love of physics.

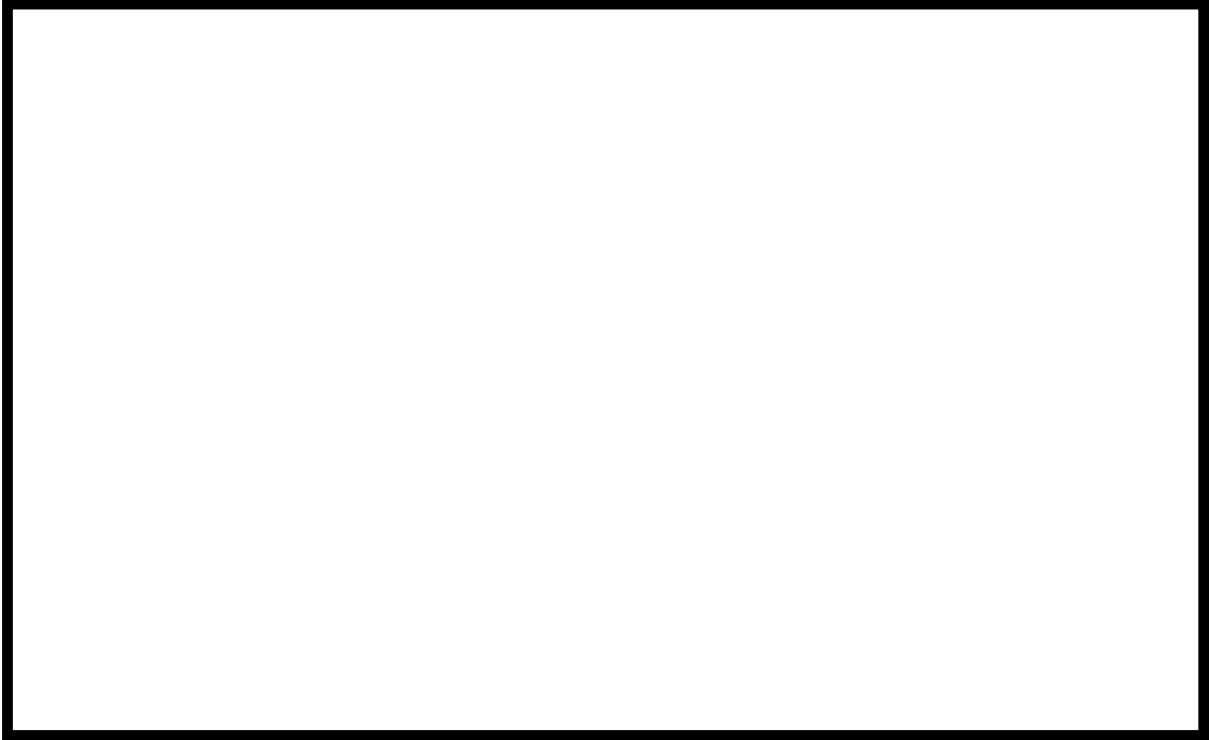
Today, let’s take a trip back in a little exercise I like to call *Magnetic Fairy Tales*. :-)

**A▷ Right Hand Rule 1: Force on Moving Charge & Current** In the square below, draw your right hand, and draw arrows to represent the magnetic field  $\vec{B}$  and the direction of  $\vec{v}$  for a positive charge (or equivalently, the current  $\vec{I}$ ). Write out a simple set of rules (not more than 3 or 4) that describe how to take your hand and find out the direction of the magnetic force on the moving charged particle.



**B▷** What happens to the direction of your force in A if the charge is *negative*?

**C▷ Right Hand Rule 2: Magnetic Field Due to a Current** In the square below, draw your right hand, and draw arrows to represent the magnetic field  $\vec{B}$  and the direction of the current  $\vec{I}$  that creates the field. Write out a simple set of rules (not more than 3 or 4) that describe how to take your hand and find out the direction of the magnetic field due to the current.



## Magnetic Fields at Home and Work

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**D▷** Your new job is much like a job at Dilbert's company. You get a spanky new office (much like mine) and find that directly over your desk is a high voltage wire carrying current to your *left*; this is making your monitor look *wonky*. To make your monitor look correct, you have a powerful bar magnet that you carry around in your pocket. How should you hold the bar magnet (which way should N and S point) to cancel the magnetic field of the high voltage wire at your monitor?

**E▷** The stripe on the back of your credit card can be thought of as a bunch of tiny magnets aligned in particular directions, either in or out of your card. Since a magnet has two directions (N up or S up) it can represent binary numbers. When you are buying Lego at WalMart and swipe your card, the reader is reading off each little magnet at a time by looking at the induced current direction in a small loop parallel to the surface of your card. Looking through the loop at your card, if a S is pointing at the card, what direction does the induced current flow in the loop?

**F**▷ While walking home from work one day, an alien from planet Zepton 7 lands, brandishing a ray gun in your direction. You notice that the ray gun actually shoots electrons. You also notice a sign that says you are standing over a buried electrical line carrying current from your right, to your left. Where should you stand so when the Zeptonian shoots you, the electrons are deflected over your head?

**G**▷ You miss class one day because you were attending a Dr. Pepper convention in Salt Lake City. At the convention center, there is a magnetic gate to get into the parking lot. You hook your ammeter up to the loop in front of the gate, and notice that when your Yugo drives over it, the current flows CCW viewed from above. What direction does the magnetic field from your car point?

**H**▷ In the early 1950s, an apparently unpowered listening device was found in the US Embassy in Moscow. The device baffled western intelligence services, who came to call it *The Thing*<sup>1</sup>. Britain's MI-5 eventually discovered how it worked – current was generated in the device when an electromagnetic beam was aimed at it. Supposed the antenna of The Thing was hanging vertically, and an incoming magnetic field was pointing from left to right. What direction is the force on the electrons in the antenna?

**I**▷ At NASA's Jet Propulsion Laboratory, my identity badge opened the security gates to get me on lab. The cards have a magnetic core with S pointing out the bottom of the badge. When I hold the bottom of my badge against the gate reader, it induces a current in a loop. What direction does the current flow when viewed through my card?

## Magnetic Fields at the Movies

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**J**▷ In all those great spy movies (for example, watch *Enemy of the State* with Wil Smith and Gene Hackman) they always are using sweep devices to look for bugs. There are a variety of ways to do this. An easy way is to have a small loop connected to an ammeter. When the loop runs over a clandestine listening device (“bug”), the magnetic fields from the electric currents in the bug induce a current you can read on your ammeter. Suppose I have a bug in the heel of my shoe, with the bug circuit wires parallel to the ground. When my sweep loop is held parallel to the ground next to my shoe, I get a CCW current on my ammeter. What direction is the current in the bug flowing, viewed from above?

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<sup>1</sup>For an excellent account of The Thing, see *Ultimate Spy* by H. Keith Melton.

**K**▷ In *Star Trek: The Next Generation*, the warp engine core of the *Enterprise* (NCC-1701D) carries negatively charged anti-matter plasma upwards through Engineering. When viewed from above, what direction does the magnetic field from this flow of charge point?

**L**▷ In *The Hunt for Red October*, the *Red October* was equipped with a magnetohydrodynamic drive<sup>2</sup>. This drive functions by passing a current through sea-water (an excellent conductor), and the using a magnetic field to generate a force. Suppose the *Red October* passes a current through the water from port to starboard (left to right). If you are facing the bow (the front of the submarine), what direction must the magnetic field point to accelerate the water and make the submarine move forward?

**M**▷ In the film *Chain Reaction* the lab Eddie works in is working on initiating nuclear fusion. The plasma that results from nuclear fusion is very hot, and must be confined. In reality, hot plasma is confined using magnetic fields. A magnetic bottle keeps charged particles (plasma is made of charged particles) moving in helical orbits within the magnetic field. Suppose Eddie has a magnetic bottle in the fusion lab, such that the magnetic field is pointing up. The plasma particles are spiraling upward from left to right when you are facing the magnetic bottle. What is the charge on the plasma?

**N**▷ In the film *The Black Hole* the *Palomino* journeys through a black hole to emerge on the other side. In general relativity, the only black holes that have such “tunnel-like” behaviour are spinning charged black holes, known as *Kerr-Newman* black holes. Imagine we want to find such a black hole – we can look for its magnetic field! Imagine the black hole has a positive charge along its equator. You approach the black hole in your spaceship, and as it spins, the charge moves from right to left on the side of the black hole closest to you. At the location of your spaceship, what direction does the magnetic field from the black hole point?

**O**▷ One day while watching *Armageddon* on your TV, you recall that the scan lines on your TV are the result of electrons being shot toward the glass screen, and moved back and forth by magnetic fields. When you are sitting in front of the TV, and the electron scan line is being pushed from right to left, what direction is the magnetic field inside the TV pointing?

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<sup>2</sup>In reality an MHD drive would be detectable for a variety of reasons; in the novel the drive was actually a *pumpjet*.