Quiz #7

September 13, 2005

Question 1

Initially a proton moves at a constant velocity, at a speed of 0.1 ms, horizontally to the left, due to both the gravitational and magnetic field of the Earth. However, after a Physics 7C student turns on a circuit such that a current of $I = 2.0$ Amps flows through the horizontal wire, the trajectory of the proton is deflected from its (initially) horizontal direction.

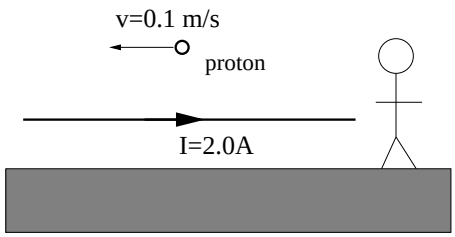
Decide which one of the following statements below must be true after the current is switched on. Choose and defend one statement only:

a) At the location of the proton, the magnetic field of the Earth and the magnetic field of the wire point in the *same* direction.

b) At the location of the proton, the magnetic field of the Earth and the magnetic field of the wire point in *opposite* directions.

c) At the location of the proton, the magnetic field of the Earth and the magnetic field of the wire point in completely different (but not opposite) directions.

d) Not enough information given to determine the directions of the magnetic field of the Earth and the magnetic field of the wire relative to each other.

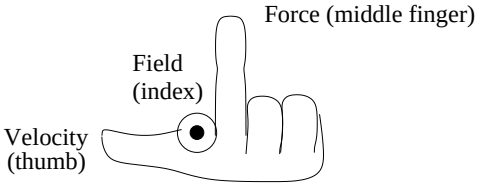


Solution:

Initially the proton travelling at a *constant* velocity v. As the velocity is constant we know that the acceleration is zero. Thus the net force is also zero (this is Newton's first law of motion).

We know the only two initial forces are the gravitational force of the Earth and the force from the magnetic field of the Earth. (It tells us that the proton's motion is due to the gravitational and magnetic fields of the Earth in the problem). We know that gravity will pull the proton down, so the force from the magnetic field of the Earth must pull up as the sum of the forces is zero.

Now we know the direction of the magnetic *force* from the Earth on a proton travelling to the left, i.e. we know F_B and v. We know that RHR #2 relates the direction of v, B and F_B. Using RHR # 2 we can find the direction of B responsible for this force:

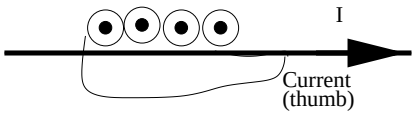


Right hand rule #2

The magnetic field responsible for the force is *out of the page*.

When the wire is switched on, it has a current which also generates a field. To figure out which way the field goes we use RHR #1.

Right hand rule #1



Above the wire, the field is coming out of the page. Thus, we know that a component of the field of the Earth and the field of the wire point in the same direction.

A good answer is **A**, as we seem to have shown that the wire's field and the Earth's field are parallel. The trouble is, that the part of the Earth's field that is parallel to **v**, the proton's velocity, will not exert a force on the proton (I missed this when explaining it as well). So while we know this component exists, there could be a component pointing left or right – we just do not know. So the strictly correct answer is **D**. (Lots of credit is given for answer **A** with the above reasoning).

A summary of the reasoning is:

- The forces balance.
- The magnetic force points up, as the gravitational force points down.
- Use RHR #2 to figure out that a component of the Earth's field points out of the page.
- Use RHR #1 to get that the wire's field points out of the page.