VP240-1 Recitation class
Week #6

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SJTU - UMJI — October 21, 2019

Brief introduction

- Try to do some exercises by yourself. More chances.
- Analyze some mistakes happen in the midterm exam.
- Please stick to the basic idea and build some models for yourself.
- **MK's note** is really important.

1 Short Review

1. magnetic field

   We represented electric interactions in two steps:

   1. A distribution of electric charge creates an electric field $\vec{E}$ in the surrounding space.

   2. The electric field exerts a force $\vec{F} = q\vec{E}$ on any other charge q that is present in the field.

   We can describe magnetic interactions in a similar way:

   1. A moving charge or a current creates a magnetic field in the surrounding space (in addition to its electric field).

   2. The magnetic field exerts a force $\overrightarrow{\boldsymbol{F}}$ on any other moving charge or current that is present in the field.

   > **Info:**
   >
   > - Similar to the electric filed with some dual property.
   > - **A moving charge or current** creates it.

2. magnetic force on a moving charge

   Four key characteristics of the magnetic force on a moving charge:

   1. its magnitude is proportional to the magnitude of the charge.

   2. the magnitude of the force is also proportional to the magnitude.

   3. the magnetic force depends on the particle's velocity.

   4. we find by experiment that the magnetic force $\vec{F}$ does not have the same direction as the magnetic field $\vec{B}$ but instead is always perpendicular to both $\overrightarrow{\boldsymbol{B}}$ and the velocity $\overrightarrow{\boldsymbol{v}}$.

   $$\overrightarrow{\boldsymbol{F}} = q\overrightarrow{\boldsymbol{v}} \times \overrightarrow{\boldsymbol{B}} \tag{1}$$

Notice:

- Right-hand rule. Step 1, 2 and 3.
- The unit:
$$1 \text{ tesla } = 1\mathrm{T} = 1\mathrm{N}/\mathrm{A}\cdot\mathrm{m} \tag{2}$$
- Another useful unit is gauss $\left(1\mathrm{G} = 10^{-4}\mathrm{T}\right)$.

3. magnetic filed line

   Where adjacent field lines are close together, the field magnitude is large; where these field lines are far apart, the field magnitude is small. Also, because the direction of $\overrightarrow{B}$ at each point is unique, field lines never intersect.

Info:

- Unlike electric field lines, magnetic field lines do not point in the direction of the force on a charge
- The direction of the force depends on the particle's velocity and the sign of its charge, so just looking at magnetic field lines cannot tell you the direction of the force on an arbitrary moving charged particle. Magnetic field lines do have the direction that a compass needle would point at each location; this may help you visualize them.
- Use the symbol a dot $(\cdot)$ to represent a vector directed out of the plane and a $\mathrm{cross}(\mathrm{X})$ to represent a vector directed into the plane.

4. magnetic flux

   We define the magnetic flux Φ_B through a surface just as we defined electric flux in connection with Gauss's law in Section 22.2.
$$\Phi_B = \int B\cos\phi dA = \int B_\perp dA = \int \vec{B}\cdot d\vec{A} \tag{3}$$

Info:

- the unit $1\mathrm{Wb} = 1\mathrm{T}\cdot\mathrm{m}^2$.

5. Gauss's law for magnetism

   In Gauss's law the total electric flux through a closed surface is proportional to the total electric charge enclosed by the surface. For example, if the closed surface encloses an electric dipole, the total electric flux is zero because the total charge is zero. (You may want to review Section 22.3 on Gauss's law.) By analogy, if there were such a thing as a single magnetic charge (magnetic monopole), the total magnetic flux through a closed surface would be proportional to the total magnetic charge enclosed. But we have mentioned that no magnetic monopole has ever been observed, despite intensive searches. This leads us to **Gauss's law for magnetism**:
$$\oint \overrightarrow{\boldsymbol{B}}\cdot d\overrightarrow{\boldsymbol{A}} = 0 \tag{4}$$

Info:

- Unlike electric field lines, which begin and end on electric charges, magnetic field lines never have endpoints; such a point would indicate the presence of a monopole.

6. DC motor

   - Fig 27.39 Page 929:
     Schematic diagram of a simple dc motor. The rotor is a wire loop that is free to rotate about an axis; the rotor ends are attached to the two curved conductors that form the commutator. (The rotor halves are colored red and blue for clarity.) The commutator segments are insulated from one another.

2 Discussion

- Q27.1 Can a charged particle move through a magnetic field without experiencing any force? If so, how? If not, why not?
- Q27.2 At any point in space, the electric field $\hat{E}$ is defined to be in the direction of the electric force on a positively charged particle at that point. Why don't we similarly define the magnetic field $\vec{B}$ to be in the direction of the magnetic force on a moving, positively charged particle?
- Q27.4 The magnetic force on a moving charged particle is always perpendicular to the magnetic field $\vec{\boldsymbol{B}}$. Is the trajectory of a moving charged particle always perpendicular to the magnetic field lines? Explain your reasoning.
- Q27.14 Is it possible to create a helical path for an electron using only a magnetic field? If not, then what additional field do you require and in which direction?
- Q27.16 Why do we see auroras in the sky only near the poles and not near the equator of the earth? How is this affected by the magnetic field of the earth?

3 Problems and exercises

Question 1

A particle of charge q enters a region of uniform magnetic field B (pointing into the page). The field deflects the particle a distance d above the original line of flight. Is the charge positive or negative? In terms of $a, d, B,$ and q find the momentum of the particle.

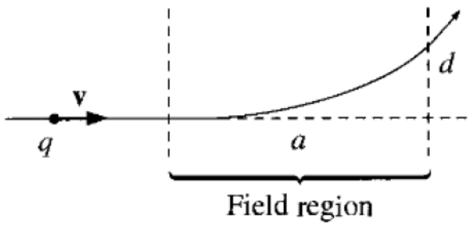

Figure 1: Rehash table using double hashing

Question 2

A plane wire loop of irregular shape is situated so that part of it is in a uniform magnetic field B (in the figure below the field occupies the shaded region and points perpendicular to the plane of the loop). The loop carries the current I. Show that the magnitude of the net magnetic force on the loop is $F = IBw$, where w is the chord subtended. What is the direction of the force?

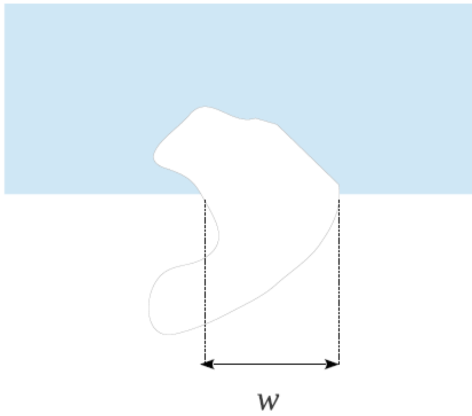

Figure 2: Rehash table using double hashing

Question 3

Exercises: 27.8, 27.24, 27.31, 27.39, 27.44.

Question 4

Problems: 27.62, 27.71, 27.75, 27.91 (challenge problem).