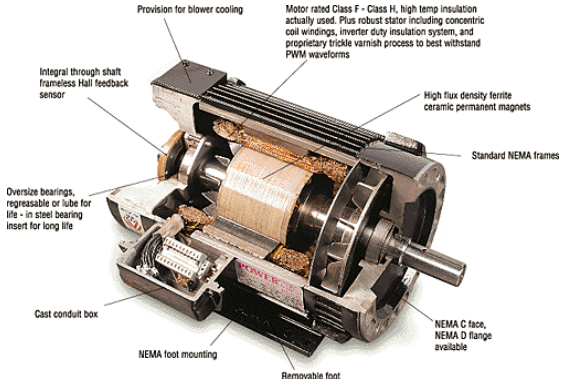
Lecture 27
(Magnetic Fields & Magnetic Flux)

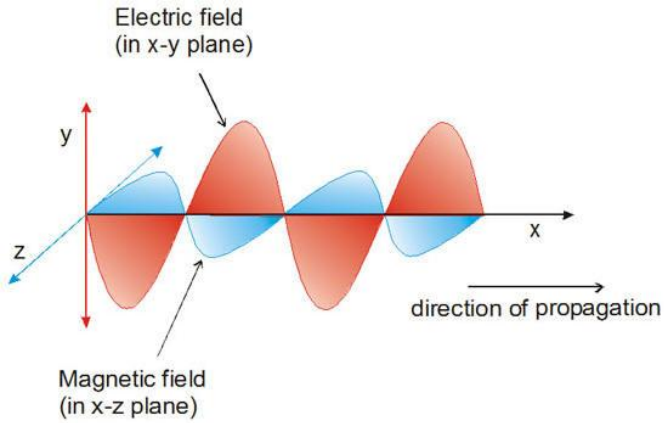
Physics 161-01 Spring 2012

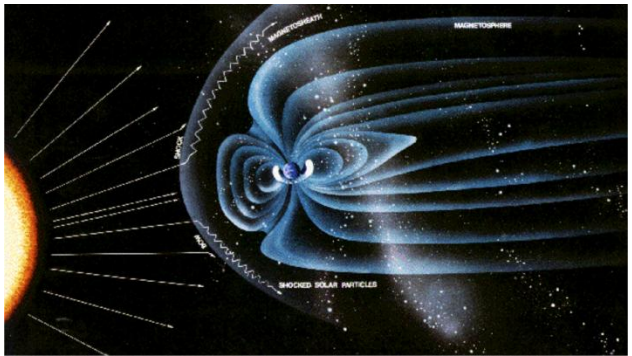
Douglas Fields

Magnets and Magnetic Fields

- Most of us are familiar with magnets in one way or another, from toys to refrigerator magnets.
- But magnetic fields play a more important role in our lives than most of us understand.
- Magnetic fields are at the heart of:
  - Electric motors, generators, transformers, most electrical circuits.
  - Radio, wireless and light transmission.
  - And play an important role in allowing life on our planet.

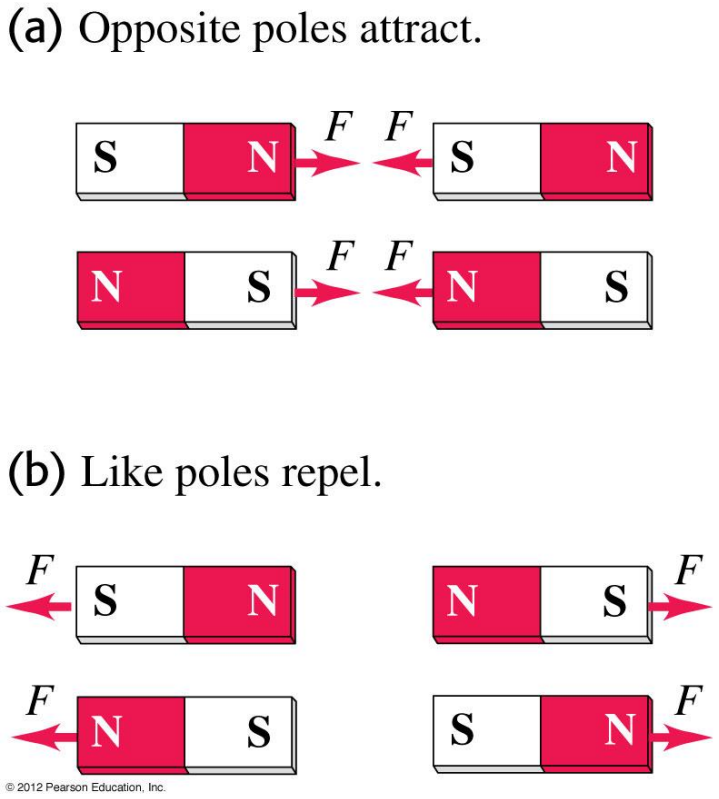






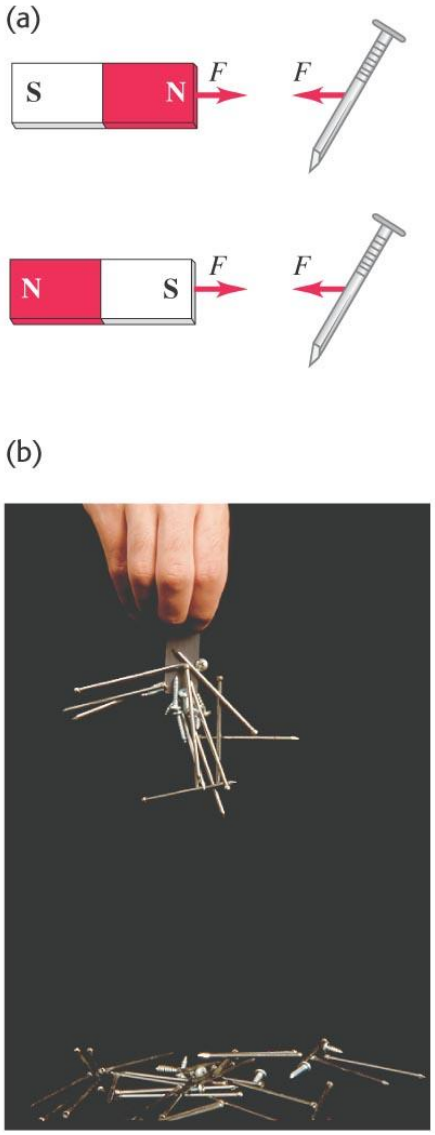
Magnets

- We can begin our exploration by reviewing the most basic experimental observations.
  - Magnets have two “poles”.
  - Opposite poles attract, and like poles repel.
- This makes us wonder if perhaps magnetic forces are just somehow caused by electric fields (since we have seen the whole like charges repel thing before).
- Well, it turns out that there is a relationship, but it is much more complicated.



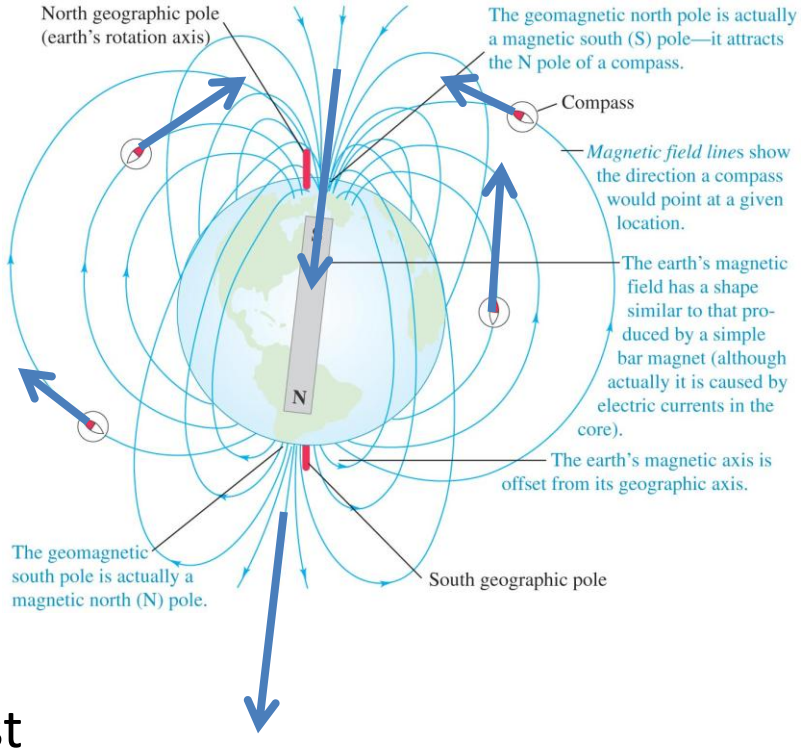
Magnets and Non-magnets

- But, if your refrigerator door isn't made of a magnet, why do magnets stick to it?
- In a similar way that electric fields can polarize neutral objects and create a force…
- We will return to this later and be more quantitative.



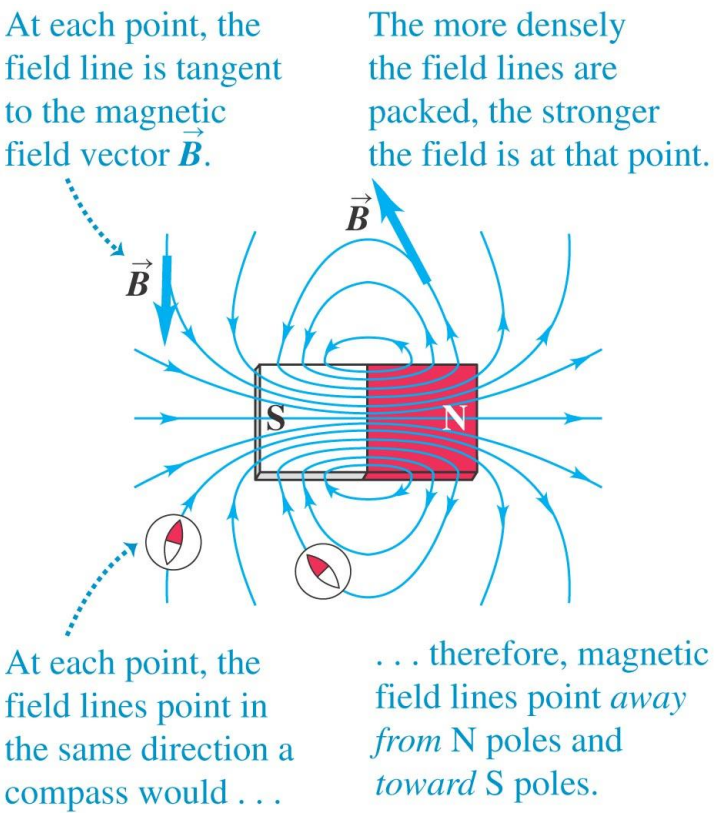
Magnetic Fields and Field Lines

- Magnetic fields are vector fields – at every point in space there is a direction and magnitude for the magnetic field.
- The earth has a magnetic field, and a compass will align itself to the direction of the field.
- Magnetic field lines are follow the direction of the field (the field is always tangential to the lines), and the density of lines (how closely spaced they are) is an indication of the field strength.
- Remember that the field IS NOT THE LINES! The field is a set of vectors at every point in space. The lines are just a way of representing the field.



Magnetic Field and Field Lines

- This point is worth repeating, since many students are confused by this, and it is necessary to understand to be able to understand magnetic flux and the various phenomena associated with it.
- The magnetic field is a vector associated with every point in space.
- Magnetic field lines are just a pictorial representation of the field.



CPS 27-1

At which point is the magnitude of the magnetic field the largest?

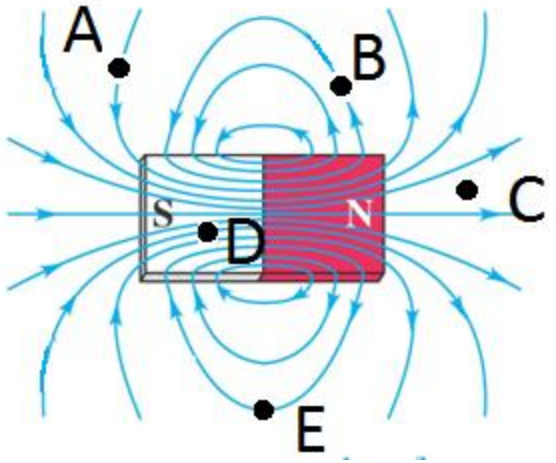
A.

B.

C.

D

E.



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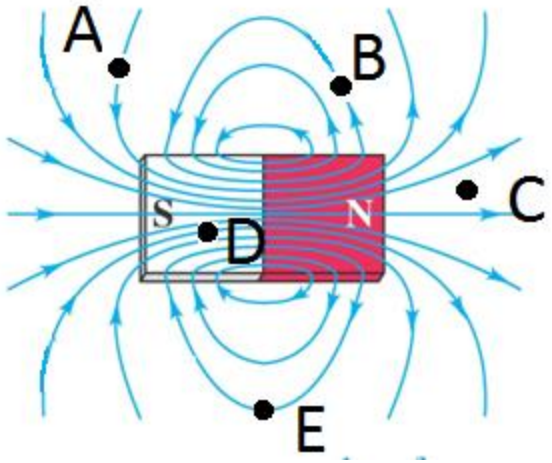


CPS 27-2

At which point is the magnitude of the magnetic field the smallest?

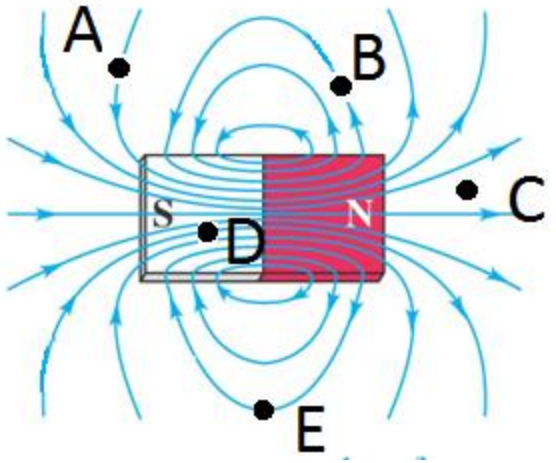
A.

B.

C.

D

E.



CPS 27-2

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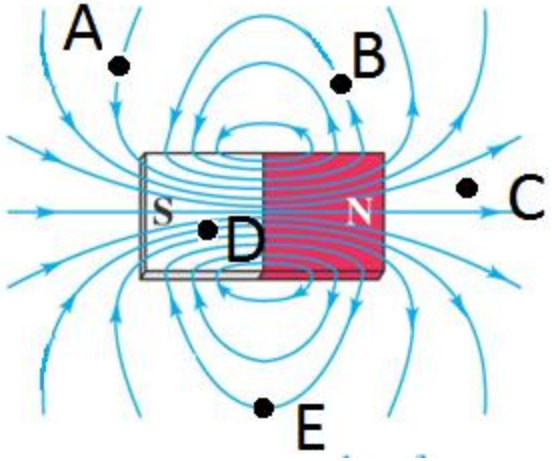
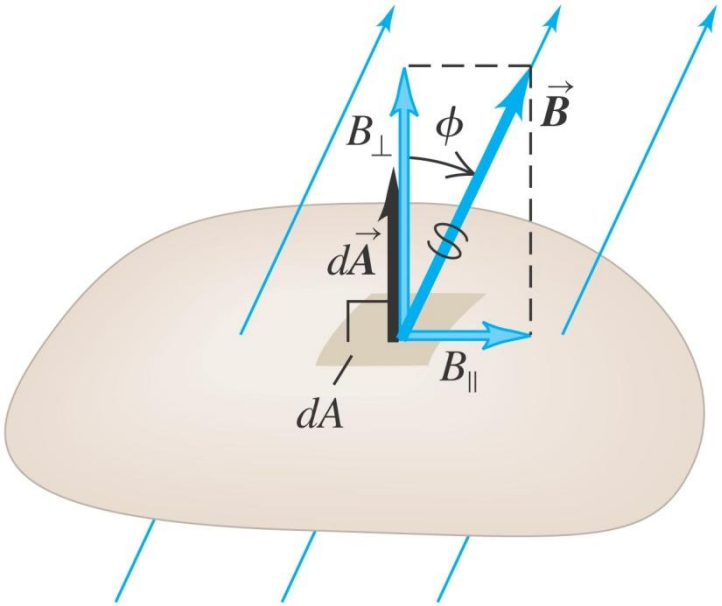


Magnetic Flux

- Yes, back to flux, which means back to surface integrals.
- We can define the magnetic flux in the same way that we defined the electric flux:

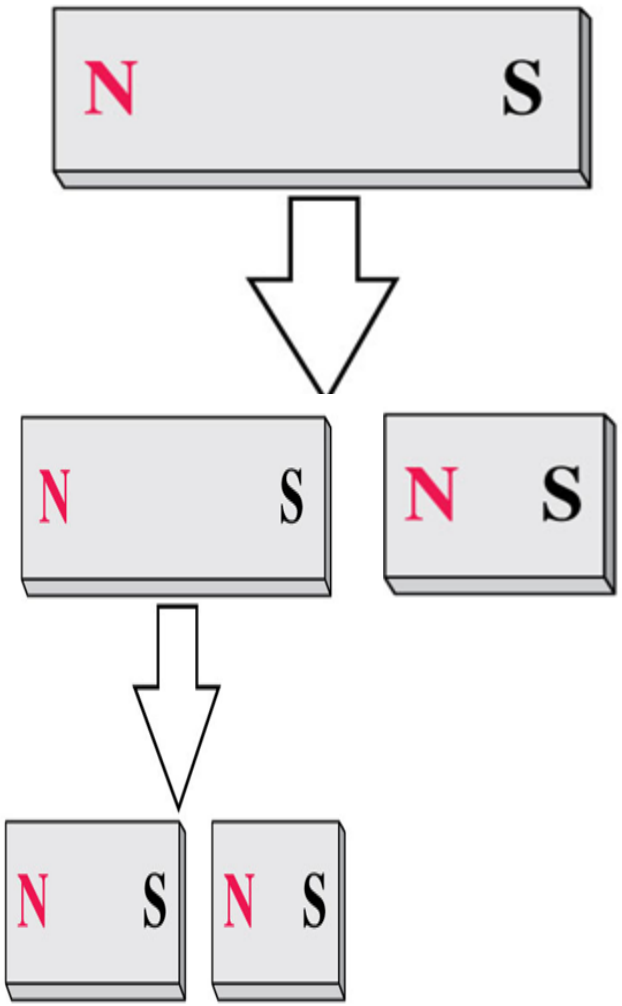
$$\Phi_B = \int_{Surface} \vec{B} \cdot d\vec{A}$$



- Let me go through an example or two…

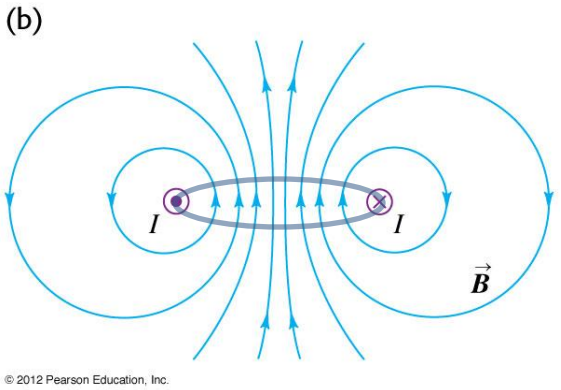
Magnetic Field "Sources"

- If you split a magnet into two pieces, will you have just a north pole in one piece and just a south in the other?
- No, each piece has both poles.
- What if you do it again?
- Same answer – each piece has both a north and south pole.
- What if you keep doing that over and over? What is the smallest source of the magnetic field?



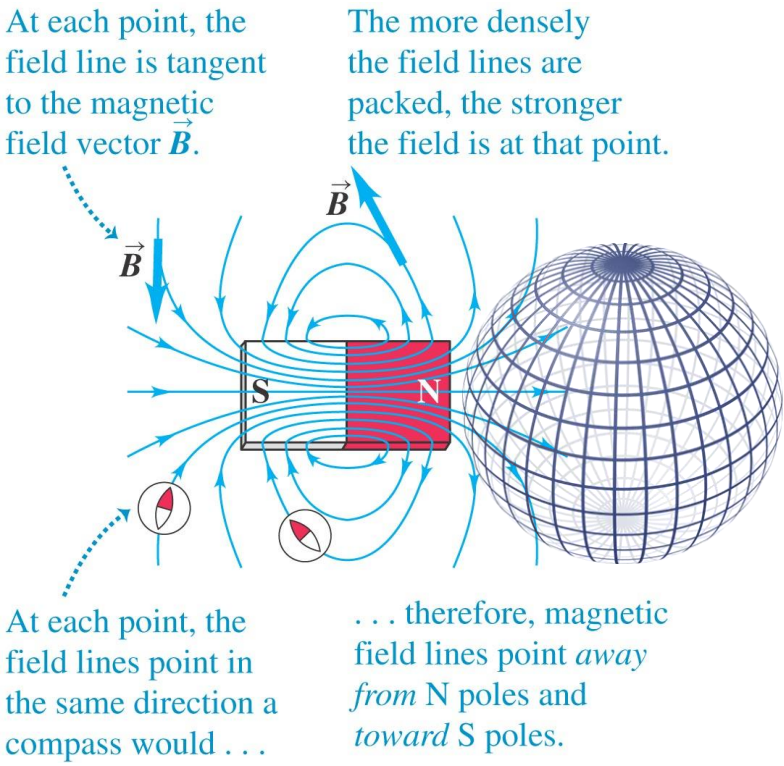
Magnetic Field "Sources"

- The smallest source of a magnetic field is a magnetic dipole – there is still no beginning or end to the magnetic field lines!
- As we will learn in the next chapter, the source of magnetic fields is a moving charge, and in a magnet, it is the electrons in the atoms that cause the field.



Magnetic Field "Sources"

- So, if there is nor source or sink of magnetic fields, there can be no *NET* flux through a closed surface (every field line that enters a closed surface must eventually exit the closed surface)!



CPS 27-3

Under what circumstances is the total magnetic flux through a closed surface *positive?*

A. if the surface encloses the north pole of a magnet, but not the south pole

B. if the surface encloses the south pole of a magnet, but not the north pole

C. if the surface encloses both the north and south poles of a magnet

D. none of the above

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Gauss's Law for Magnetic Fields

- Then, given what we understand about Gauss's Law for the electric field, we can deduce that:

$$\oint \vec{B} \cdot d\vec{A} = 0$$

- In other words, there is no magnetic charge (magnetic monopoles).