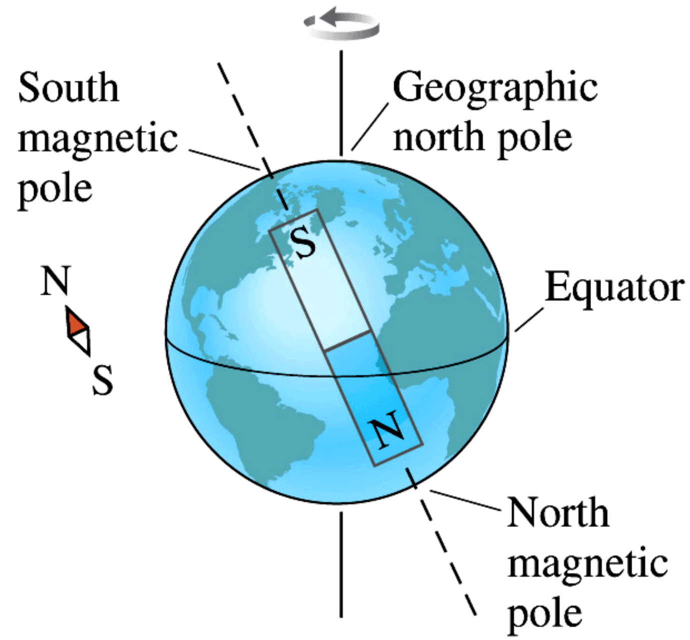
Physics 115
General Physics II

Session 26

Magnetism
Magnetic fields



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Lecture Schedule

12-May	Mon	23	DC Circuits & Meters	21.5-21.8
13-May	Tues	24	DC Circuits	21.5-21.8
15-May	Thurs	25	RC circuits	21.6-21.7
16-May	Fri	26	Circuits - Neurons	
19-May	Mon	27	Magnetism	22.1
20-May	Tues	28	Magnetic Force	22.2-22.5
22-May	Thurs	29	Magnetic Fields	22.6-22.7
22-May	Fri	30	Induced EMF, Applications	23.1-23.3
26-May	***holiday***		NO CLASS	
27-May	Tues	31	Energy, RL circuits	23.4-23.8
29-May	Thurs	32	Transformer	23.9-23.10
30-May	**Fri**		**EXAM 3 - Chapters 21,22,23**	
2-Jun	Mon	33	AC circuits	24.1-24.3
3-Jun	Tues	34	AC circuits	24.4-24.5
5-Jun	Thurs	35	Resonance, Applications	24.6
6-Jun	Fri	36	Last class - review	
June 9	**FINAL EXAM**		**2:30-4:20 p.m.**	**Comprehensive**
	Mon		**Monday, June 9, 2014**	

Today

Clicker results page was updated today

Course grade will be based on:

From 1st day of class

- Exams
  - ALL exams will be multiple choice, YOU must bring your own mark-sense sheet (available at physics café) and pencil
  - Midterm Exams: 40%
    - 3 midterm exams: April 18, May 9, May 30
    - In-class, formula sheet provided, closed book/notes
    - Only your 2 best exam scores (out of 3) will be used, so you can miss one exam without loss, so no makeup exams
  - Final exam 30%
    - Monday June 9, 2:30-4:20 pm, this room
- Homework assignments (Webassign online): 15%
  - Best ~~6 out of 8~~ 7 out of 9 scores for complete homework sets
- Clicker quiz scores: 15%
  - Only your best 10 (out of 20 or more) grades will be used, so no makeup clicker quizzes

Grades on a curve? Sort of...

- Must rescale mid-term scores since they have different averages
  - Higher numerical scores for 'easier' tests
  - Scale using mean and std. deviation from each ("z-score")

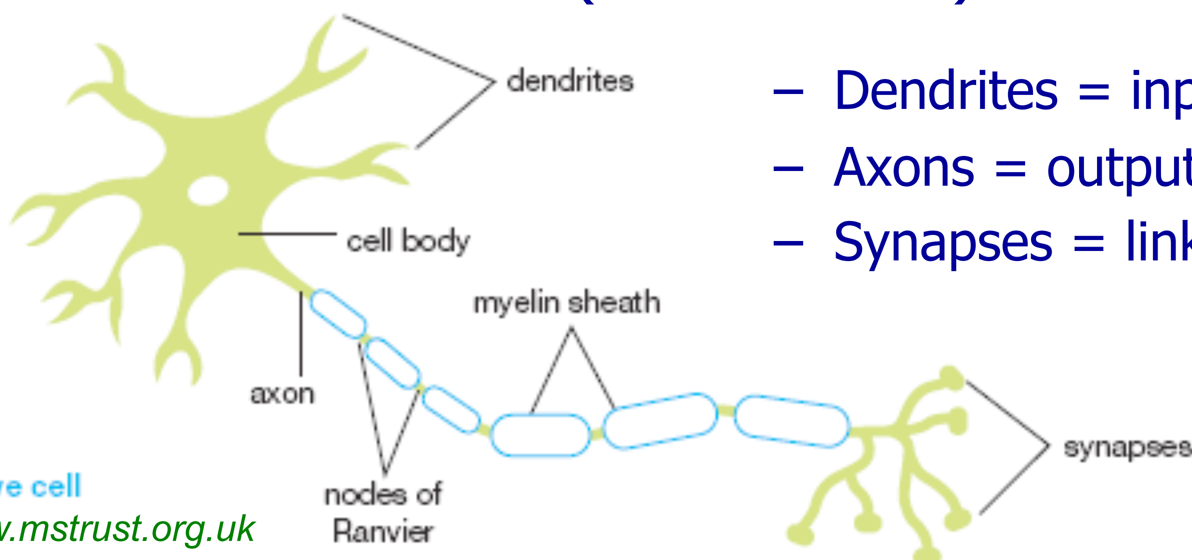
  z = (your score – average score)/(std. dev)

  Then all exams will have mean = 0 and std dev.=1.0

  z < 0 → below average, z ~ 0 → average, z > 0 → above avg
- Next: what z score (= percentile) → what grade ?
  - *Theory:* z score distributions look like a *bell shaped curve*
  - *My experience:* Every class has bumpy distributions
  - SO: I do **not** arbitrarily assign a certain percentage A's ,B's, C's
    - <2.0: you did not do minimum homework or quizzes, and were far below avg on exams
    - 2.0-2.4: you met minimum requirements, but your scores were well below avg.
    - 2.5 → 4.0: you met minimum HW/quiz requirements, and got exam scores ranging from below average to far above average
    - Class average grade: *approx* 3.1 (depending on bumps!)

Application of RC circuits: neurons

- Neurons = cells (10^{10} of them) in brain and nerves



www.mstrust.org.uk

  - Dendrites = inputs
  - Axons = outputs
  - Synapses = links to other neurons

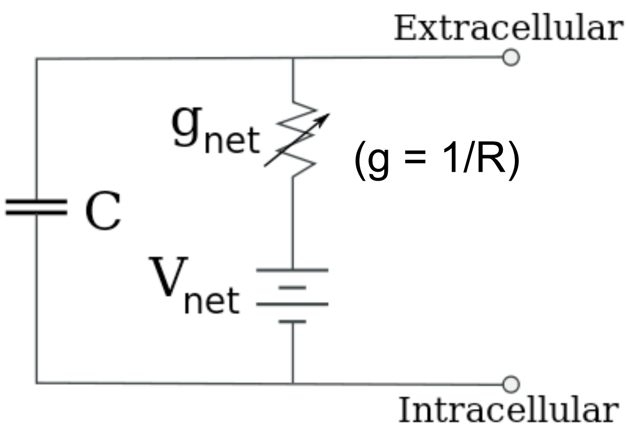
Neural network: produces output only for specific set of inputs

- Cell is active source of EMF, fueled by body chemistry
  - Aqueous environment contains salts → ions (~seawater)
  - Fluid inside neuron body is separated from surrounding fluids by thin (5~10 nm) membrane
  - Cell can change membrane permeability to move ions in and out

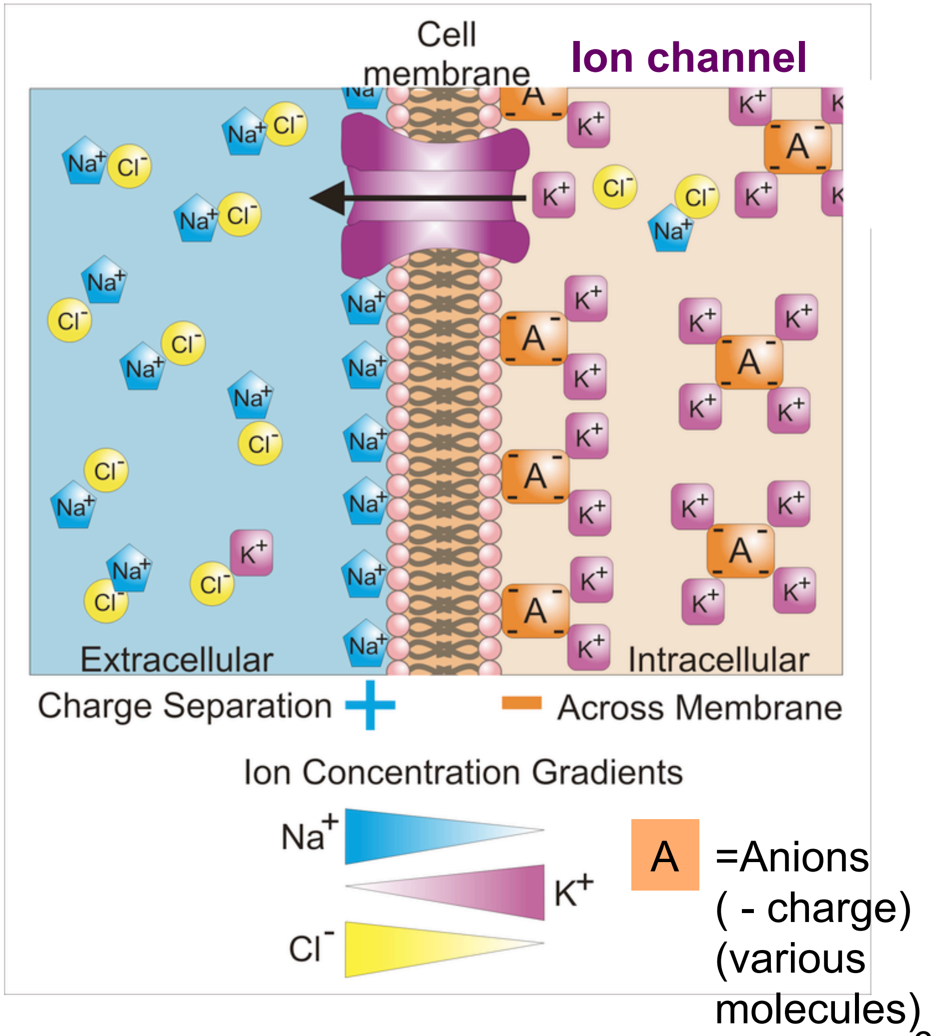
Chemical activity and model circuit

- "Ion pump" proteins can actively push selected ions across the membrane

- K+ ions pumped out → -ΔV across membrane
- Cell can 'decide' to pump Na+ inward, causing + pulse in ΔV
- Equivalent circuit for cell:

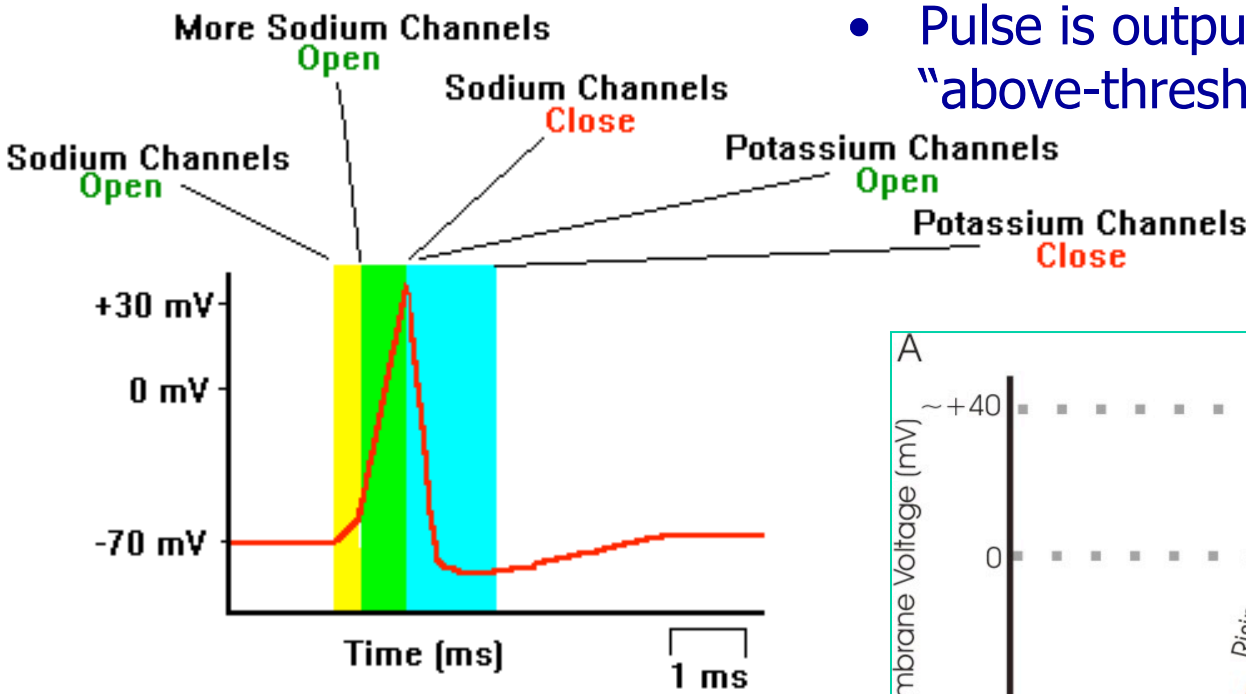


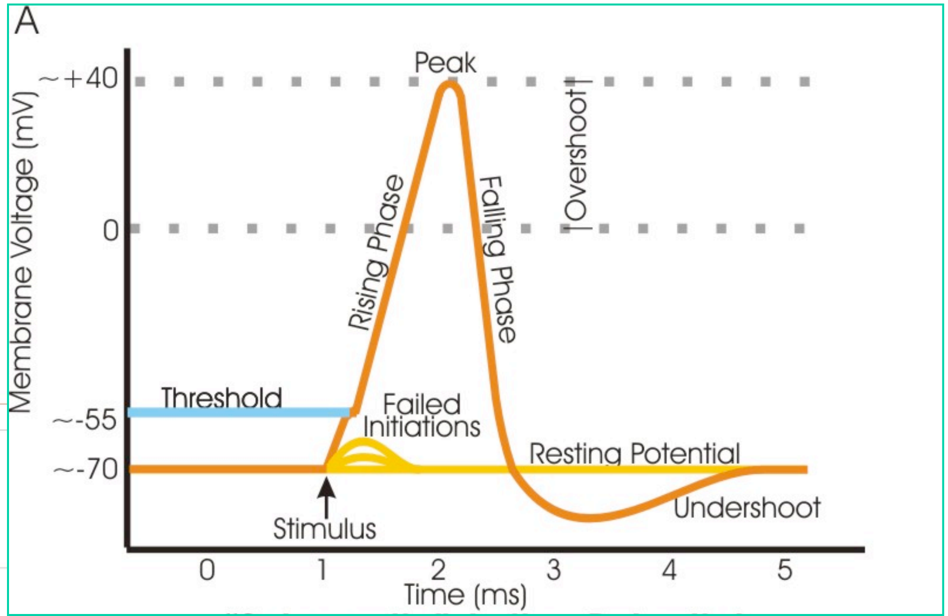
- Typical RC ~ few millisec

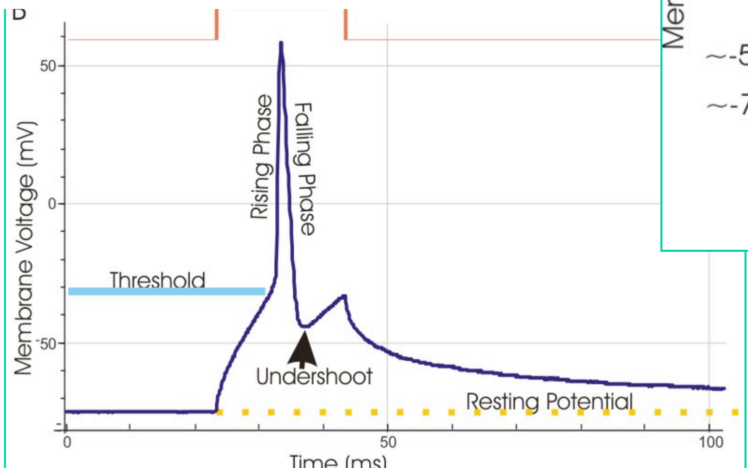


Axon signals: "action potential"

- Pulse is output when inputs provide "above-threshold" signals







"Real" Action Potential

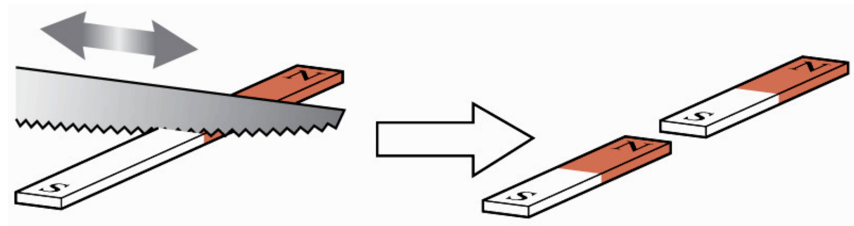
Last time

Conclusions from this collection of facts:

1. Like electricity, magnetism is a ***long range force***. The compass needle responds to the bar magnet from some distance away.
2. Magnetism is ***not*** the same as electricity. Magnetic poles are similar to charges but have ***important differences***.
3. Magnets have ***two poles***, "north" (N) and "south" (S). Like poles repel and opposite poles attract.
4. Poles of a magnet can be identified with a ***compass***. A north magnetic pole (N) attracts the south-seeking end of the compass needle (which is a south pole).
5. Some materials (e.g., iron) stick to magnets and others do not. The materials that are attracted are called ***magnetic materials***.
6. Magnetic materials are attracted by ***either pole*** of a magnet. This is similar in some ways to the attraction of neutral objects by an electrically charged rod by induced polarization.

One interesting fact: no **monopoles** ever seen

Every magnet that has ever been observed is a ***magnetic dipole***, containing separated north and south poles. Attempts to isolate one pole from the other fail.

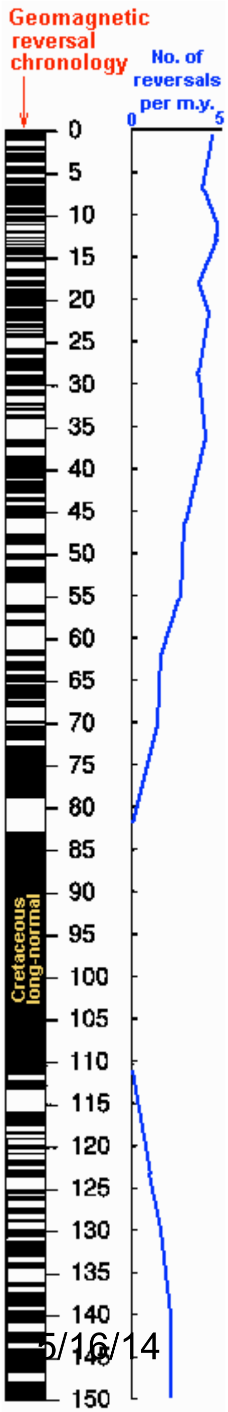


In principle it is possible to have magnetic monopoles, i.e., isolated magnetic poles with a "north" or "south" magnetic "charge". (Meaning: no fundamental physical law prohibits them.)
They would have to be in some new type of elementary particle.

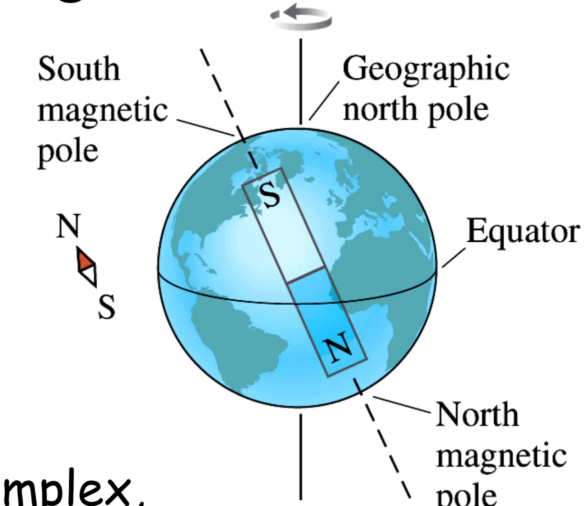
Many searches for subatomic particles carrying a monopole have been performed: no such thing has ever been detected.

For this course, we will assume that isolated magnetic monopoles do not exist...

Compasses and Geomagnetism

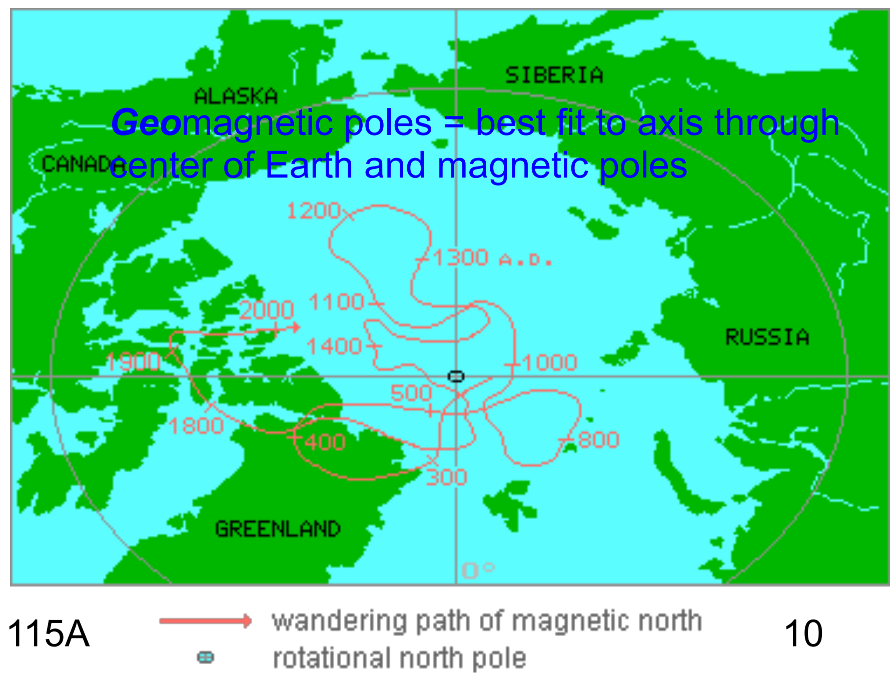


The north (N) pole of a compass needle is attracted toward the north magnetic pole of the Earth, and repelled by its south pole.
SO: The Earth acts as a large magnet, with a south-seeking pole near the Earth's geographic north pole.



The causes of Earth's magnetism are complex, involving currents in the Earth's molten interior.

Magnetic poles are separated from the geographic (rotation axis) poles, and "wander" over time.
Geological evidence shows the Earth's field has often reversed polarity at varying intervals over millions of years. (process is not yet fully understood)



Geomagnetic poles = best fit to axis through center of Earth and magnetic poles

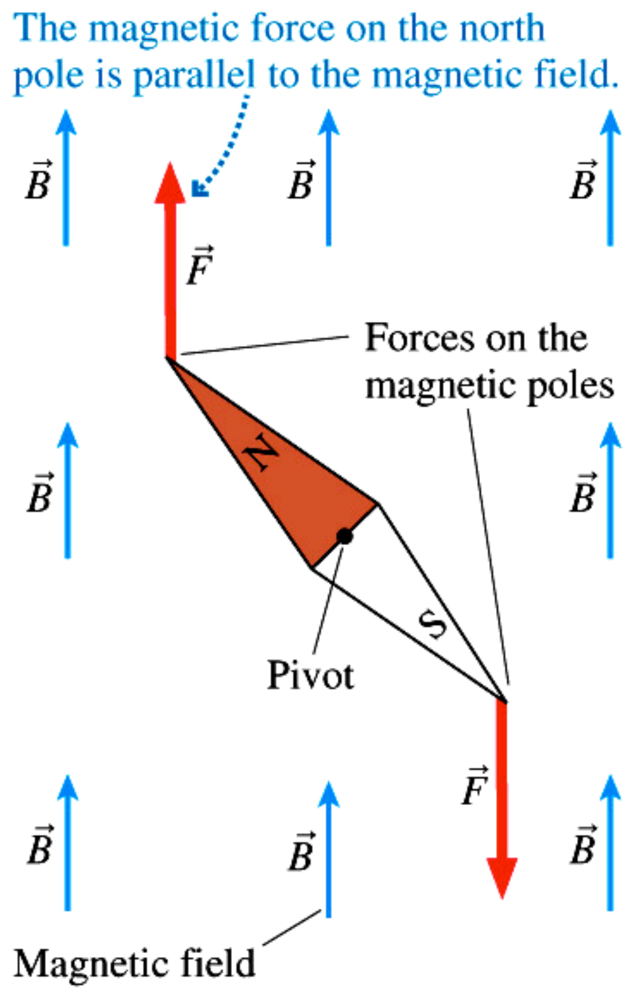
The Magnetic Field

Definition of the magnetic field:

(1) The magnetic field at each point is a ***vector***, with both a magnitude, which we call ***the magnetic field strength B***, and a 3-D direction.

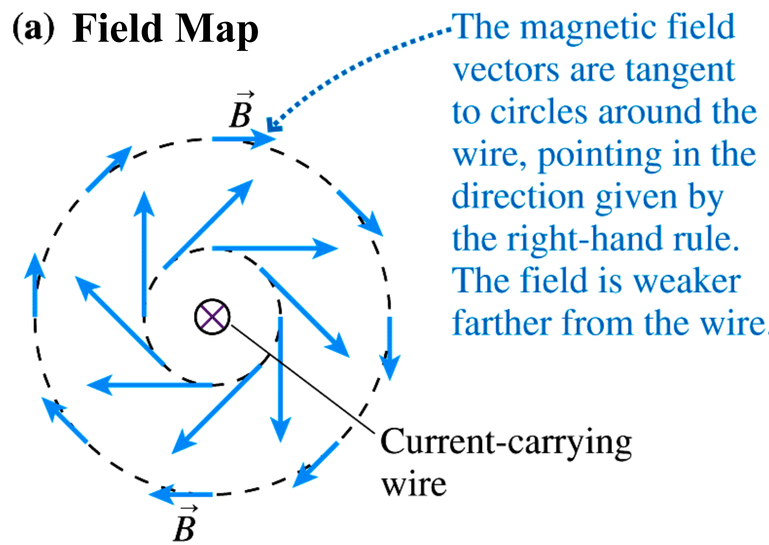
(2) A magnetic field is created ***at all points in the space*** surrounding a current carrying wire.

(3) The magnetic field exerts a ***force on magnetic poles***. The force on a north pole is parallel to $\vec{\mathbf{B}}$, and the force on a south pole is anti-parallel to $\vec{\mathbf{B}}$.

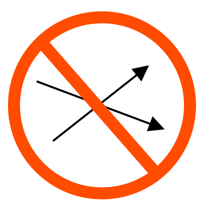


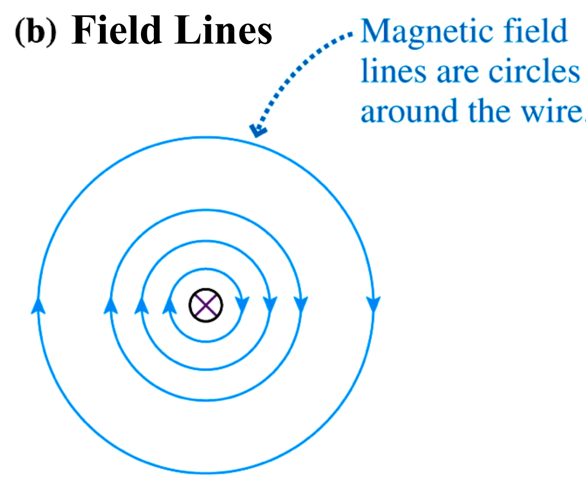
Magnetic Field Lines: like and unlike E fields

The magnetic field can be graphically represented with a map of field lines.
As with **E**, the tangent to a field line at any point gives the local field direction, and the density of field lines shows the local field strength.
The **B** field line direction indicates the direction of force on a **north** magnetic pole, just as an **E** field line shows the direction on a + charge.

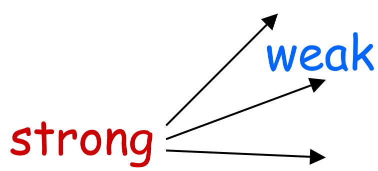


B-field lines never cross.

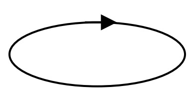




B-field line spacing indicates field strength

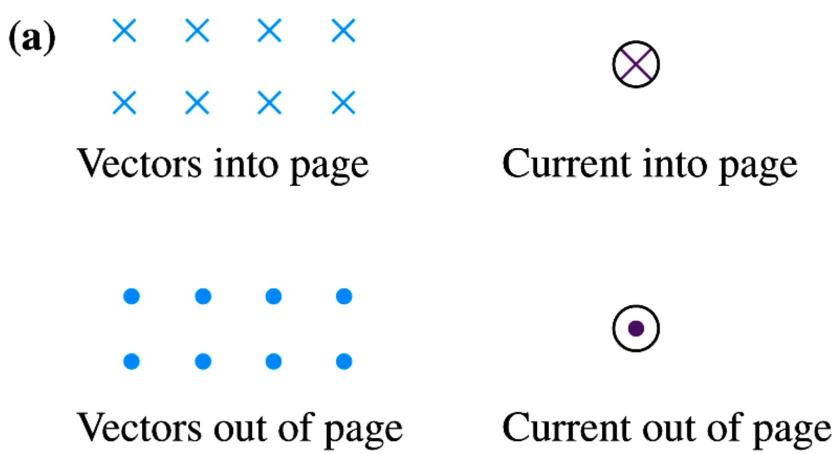


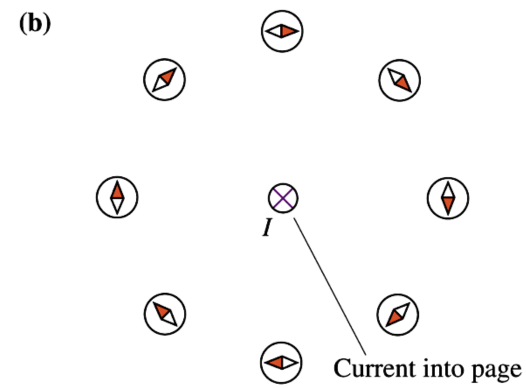
Unlike **E** fields, the B-field lines ***always*** form closed loops.



Why? No monopoles = isolated magnetic charge

3D Vector Drawing Conventions





Example: field around a current.

For discussions of magnetism, we will need a 3-dimensional perspective. , but must use 2-dimensional diagrams (on paper or screen).

To get the 3rd dimension into a two-dimensional diagram, we will indicate vectors into and out of a diagram by using crosses and dots, respectively.

Rule: a dot (•) means you are looking at the point of an arrow coming **toward** you; a cross (×) means you are looking at the tail feathers of an arrow going **away** from you.

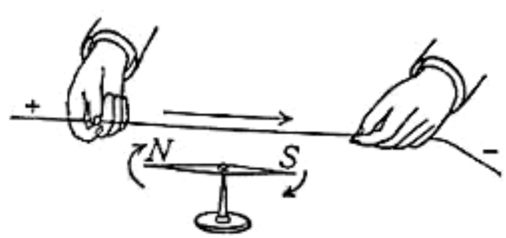
Discovery of the connection between electricity and magnetism

In 1820, Danish physicist Hans Christian Oersted gave an evening lecture in which he was demonstrating the heating of a wire when an electrical current passed through it.

He noticed that a compass that was nearby on the table deflected each time he made the current flow.

Until that time, physicists had considered electricity and magnetism to be unrelated phenomena. Oersted discovered that the "missing link" between electricity and magnetism was the electric current.

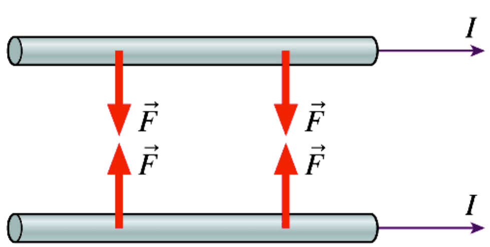
Hans Christian Oersted
(1777- 1851)



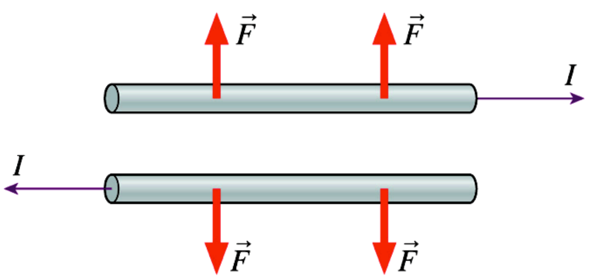
Ampere's Experiment

When Ampere heard of Oersted's results, he reasoned that if a current ***produced*** a magnetic effect, it might ***respond*** to a magnetic effect. Therefore, he measured the force between two parallel current-carrying wires.

He found that parallel currents create an attraction between the wires, while anti-parallel currents create repulsion.



"Like" currents attract.



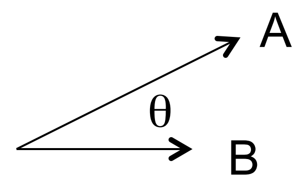
"Opposite" currents repel.

André Marie Ampère
(1775 – 1836)

First: Another way to multiply vectors

- We have already seen one way to multiply two vectors: the scalar ("dot") product

$$\boxed{\vec{B}\cdot\vec{A} = B\,A\cos\theta}$$



  - Recall the symmetry of dot product: we can say it is
    1. "(component of B parallel to A) times (A)", OR
    2. "(B) times (component of A parallel to B)"
  - Result is a *scalar* (single number, no direction)
- Another way: the vector ("cross") product

$$\boxed{\vec{B}\times\vec{A} = B\,A\sin\theta}$$

Also symmetrical: but now

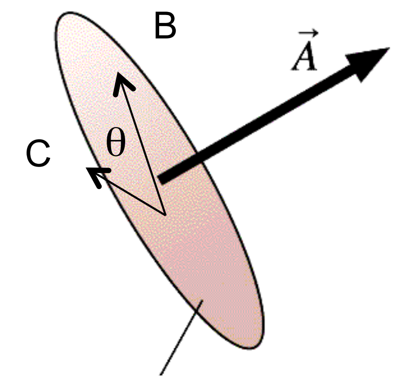
1. "(component of B perpendicular to A) times (A)", OR
2. "(B) times (component of A perpendicular to B)"

  - Result is a *vector* : but what direction should it have?
    - What unique direction can be associated with 2 vectors?
      - Two vectors define a plane (like any 2 non-parallel lines)
      - Only direction uniquely defined by a plane is its normal

Direction for vector products

– Recall the idea we encountered when talking about fluxes through surface area patches
  - Vector normal (perpendicular) to a surface is the only direction uniquely determined by the surface
  - But there are 2 such directions...

$$\boxed{\vec{A} = \vec{B} \times \vec{C} = B\,C\,\sin\theta}$$



Plane defined by B and C

Recall:
"deep thought: how to choose which direction perpendicular to surface to use ? (we could reverse **A**)"

There is **no physical reason** to prefer either.
But we have to be consistent in our choices.
We need a simple rule to remember, so we choose the direction given by the **Right Hand Rule**:

1. Point fingers of right hand in direction of B
2. Curl them toward C
3. Then right thumb points in the direction of A

Order matters!
Notice: C x B gives you the opposite direction:
C x B = - B x C
Cross products "do not commute"

Magnetic force on a moving charge

Electric current I = moving electric charges.

Ampere's experiment showed that a magnetic field exerts a force on a current → moving charges.

(The exact form of the force relation was not discovered until later in the 19th century.)

Experiments show the force is :

...Proportional to q, its speed v, and B

...Depends on the relative directions of **B** and the velocity **v** of the moving charge: proportional to sine of the angle between them

...perpendicular to both **v** and **B**.

So, applying our usual procedure about proportionality:

Force on moving q:

$$F \propto qvB\sin\theta \Rightarrow F = q\left(\vec{v}\times\vec{B}\right)$$

$$\boxed{F = q\left(\vec{v}\times\vec{B}\right)}$$

Order matters!