PHYSICS 571 – Master's of Science Teaching

"Electromagnetism and Light"
Lecture 1 – Introductions / Magnetic Field
Instructor – Richard Sonnenfeld

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575-835-6434

About Instructor

BSE Physics and Mech. Engineering

(Princeton U)

Ph.D. Experimental Physics – Tunneling microscopes

(University of California, Santa Barbara)

IBM Almaden Research

(Tribology of Hard Disk Drives)

Engineering Dir. – Hard disk drives

(Seagate, Maxtor, Quantum Corps)

Physics Professor – NM Tech

Physics of Lightning, instruments to measure lightning

Tell me about yourselves
What do you want from this course?

I am glad to answer individual questions about points of curiosity or how to integrate this into your classroom.

Give me suggestions on how to strengthen science teaching in NM in general.

Grading

Do the homework, watch the lectures, think about the labs (just like you tell your students!)

Primarily based on homework (which includes labs). There may be an "oral exam" (by telephone)

I am here to help you learn physics so you can teach it.
I already assume you are committed.

Text

I tried to find a text that was appropriate for smart people who had not had a physics course before.

The text I selected is "Conceptual Physics Fundamentals" by Paul. G. Hewitt.

Hewitt makes physics fun. The text is light on mathematics but good for concepts.

The lectures (and homework) will be at a higher level than the text. I am also referring to Knight's "Physics for Scientists and Engineers"

Course Goals – Physics

I hope at the end of this course you will know how to calculate magnetic fields and forces. You will also understand how a motor, a generator, and a transformer work. You will know why light is called an "electromagnetic wave". You will appreciate the general properties of waves, including reflection, refraction, diffraction, as well as how lenses work.

Course Goals – Math

You are assumed to know scientific notation and basic vector math (from the Electricity course).

You will learn about vector cross products.

You will learn how to relate sine and cosine functions to properties of waves.

You will learn GREAT applications of trig., algebra and fractions to physics.

Course Goals – Engineering

You will learn how to build a galvanometer and a generator.

The Lab Kit!

– Your lab fee pays for a kit containing materials for experiments.

It includes:

A multimeter

Light bulbs, wire, and alligator leads

A large battery

LEDs

Lenses

Compasses

Magnets

Iron filings

Additional materials.

Electromagnetism and Light

Magnetic fields, forces and motors
[Hewitt 11]
Magnetic induction, generators
[Hewitt 11]
Properties of waves (sound and light) – interference, diffraction
[Hewitt 12]
Light waves, diffraction, and refraction.
[Hewitt 13, 14]
Lenses, polarization
[Hewitt 14]

Electricity and Magnetism

Static Electricity – Forces & fields of non-moving charges. Voltage is potential energy per unit charge.

Currents and Circuits (Electrodynamics) – Practical electric circuits and the physics of how currents happen and what resistance means. [Electricity Course]

Static Magnetism – When currents in wires are constant, they create constant magnetic fields which exert force on moving charges (or currents)

Induction and electromagnetism – When currents change, they cause changing magnetic fields AND electric fields.

Outline

Fields of Magnets

Difference between electric and magnetic fields.

Why are they called fields?

Are fields real?

How loops of wire are like magnets.

Electric Dipoles and Magnetic Dipoles

Building up a dipole field by vector addition.

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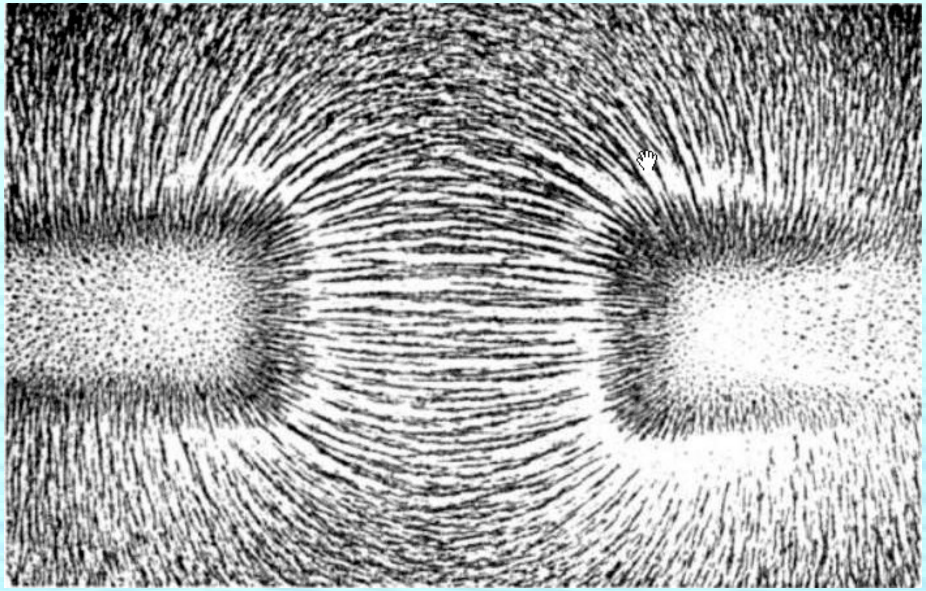
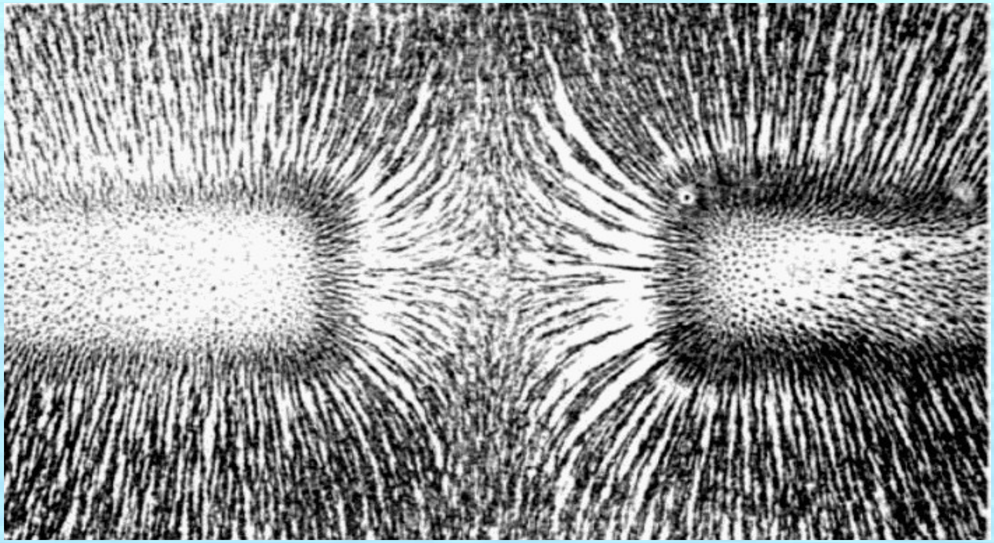
B-Field lines are visible if decorated with iron filings





The top and bottom Pictures are:

[A] Two North poles and Two South Poles
[B] Two South Poles and Two North Poles
[C] A north-south pair And Two North Poles
[D] A north-south pair And either two North or Two south poles

Magnetic Poles
CHECK YOURSELF

A weak and strong magnet repel each other. The greater repelling force is by the

A. stronger magnet.
B. weaker magnet.
C. both the same
D. none of the above

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Electricity

Positive charges emit electric fields, neg. charges absorb field lines.

Charges feel electric Fields whether the charges Are moving or not.

Magnetism

North poles emit field lines, south poles absorb them.

Only moving charges or currents Feel magnetic fields

Electricity

(Electrostatics)

Effect of stationary q

Electric fields "emitted" by charges.

Electric force is directed along electric Field lines.

$$\vec{F} = q\vec{E}$$

Magnetism

(Magnetostatics)

Effect of constant I

Magnetic fields at right angles to currents & moving Charge.

Magnetic force at right angles to field Lines and velocity.

$$\vec{F} = q\vec{v} \times \vec{B}$$

Electric Field

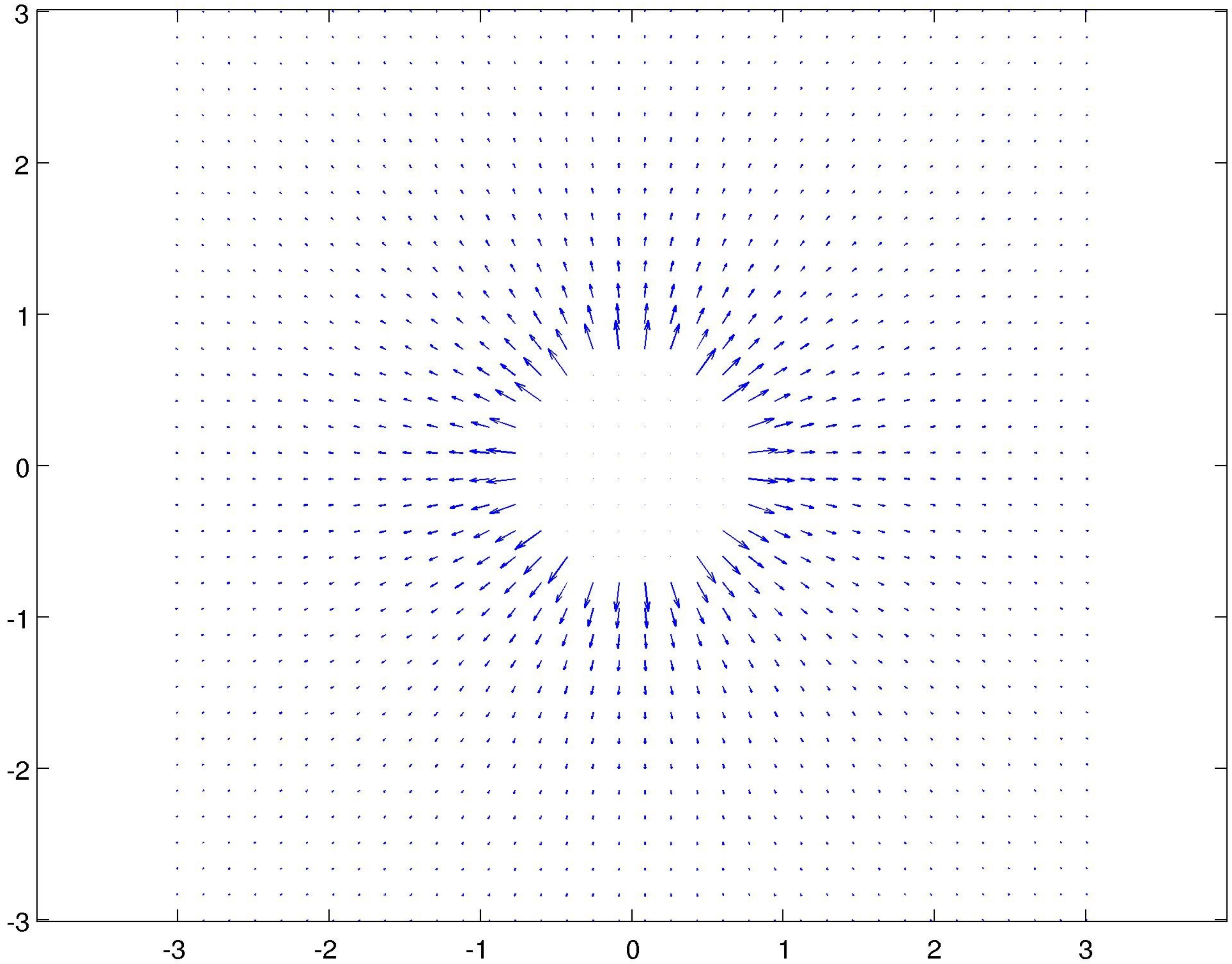
A vector-field that gives the force that would be felt by an infinitely small charge placed at every point.

$$\vec{F} = q\,\vec{E}$$

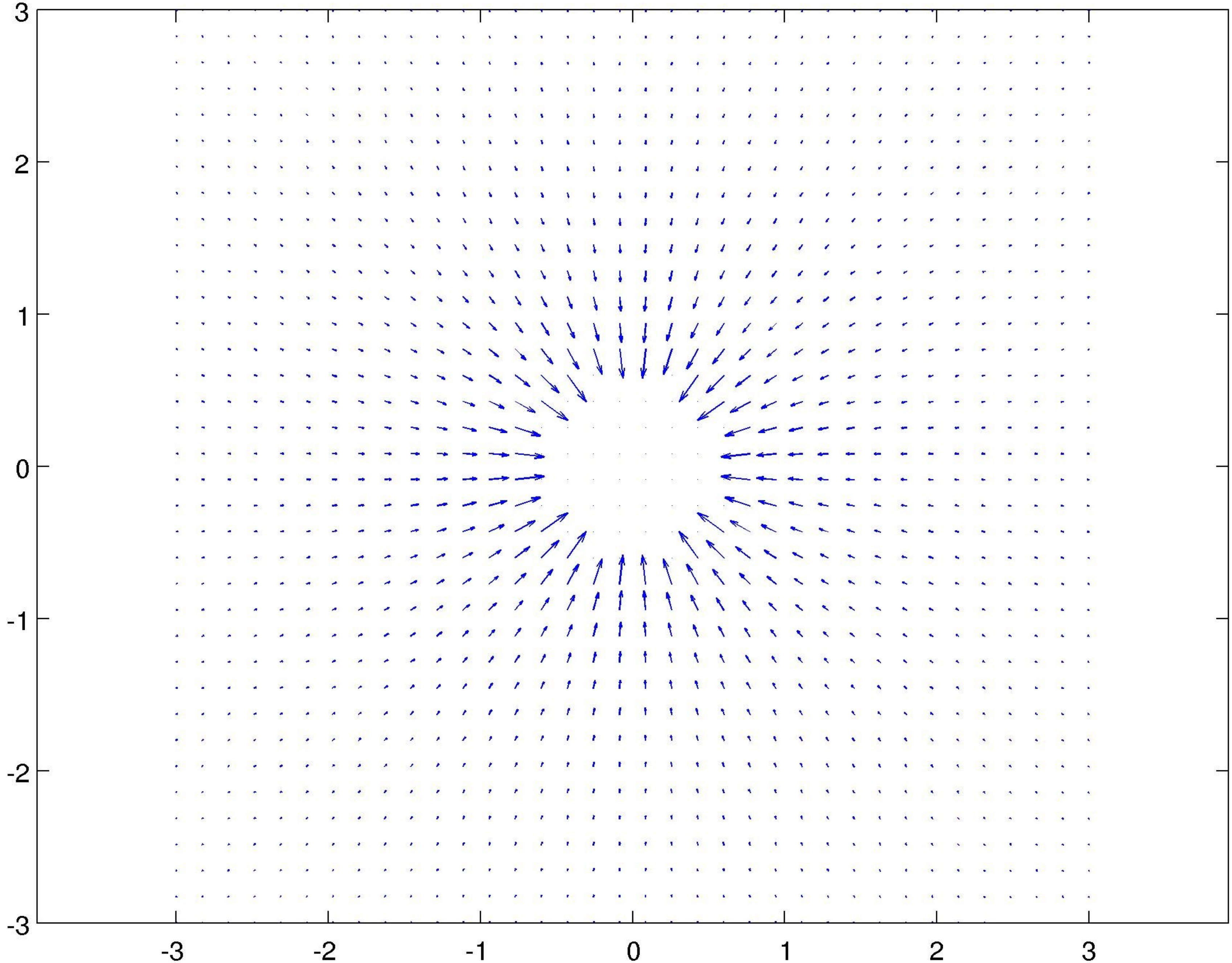
Units of E are Newtons/Coulomb

$$\vec{F} = k\frac{q_1 q_2}{r^2} = q_1\left[k\frac{q_2}{r^2}\right]$$

E-Field Around A Positive Charge



E-Field Around A Negative Charge



pHeT

In the electricity course, you were able to play with charges and see what Electric fields were created. Feel free to review:

http://phet.colorado.edu/en/simulation/charges-and-fields

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Why are they called fields?

If you measure the length of every stalk
Of corn in a “field”, your table of height
Of corn-stalks vs. position is called a
“scalar field”.

If at every point you also measure the
Angle the corn-stalk makes with the
X-axis, you have a “vector field”.

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Why bother with Electric field (why not just use Coulomb's law?)

The electric field allows you to ignore the charges that made it. (And it's measurable)

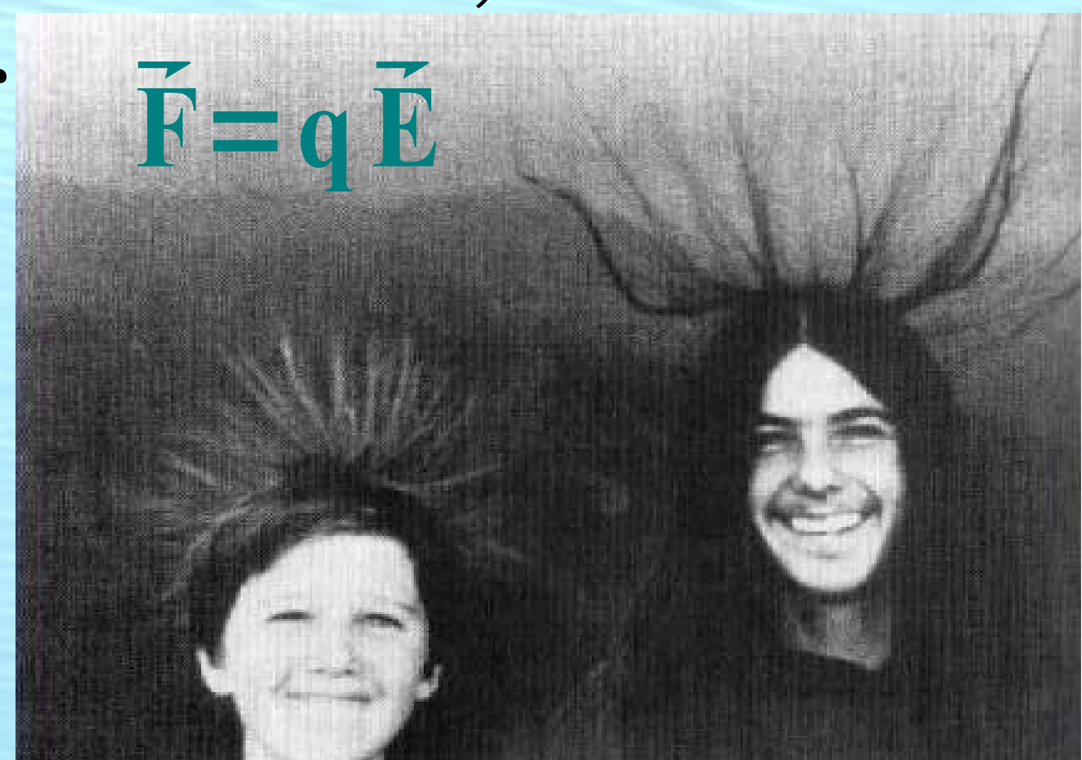
The electric field travels at the speed of light so you can get the effect of a charge on a distant star.

Electric forces might be understandable without fields, but magnetic forces are a mess!

Fields are measurable

Electric field – Torsion balance, Kelvin probe, FET or charge amplifier

Magnetic field – Force balance, Hall probe, search-coil or



… or Hair!

“The Force” is an energy field created by all living things. It surrounds us, penetrates us, and binds the galaxy together.

"The magnetic field" is a vector-field created by all currents. It surrounds us, penetrates us, and can exert forces on moving charges across galaxies.

What is true about a field diagram?

[A] The field only exists where the vectors are drawn.

[B] The field is the same everywhere along each vector arrow.

[C] The field exists everywhere, you just can't draw vectors everywhere. The arrow tells you the field only at the tail of the arrow.

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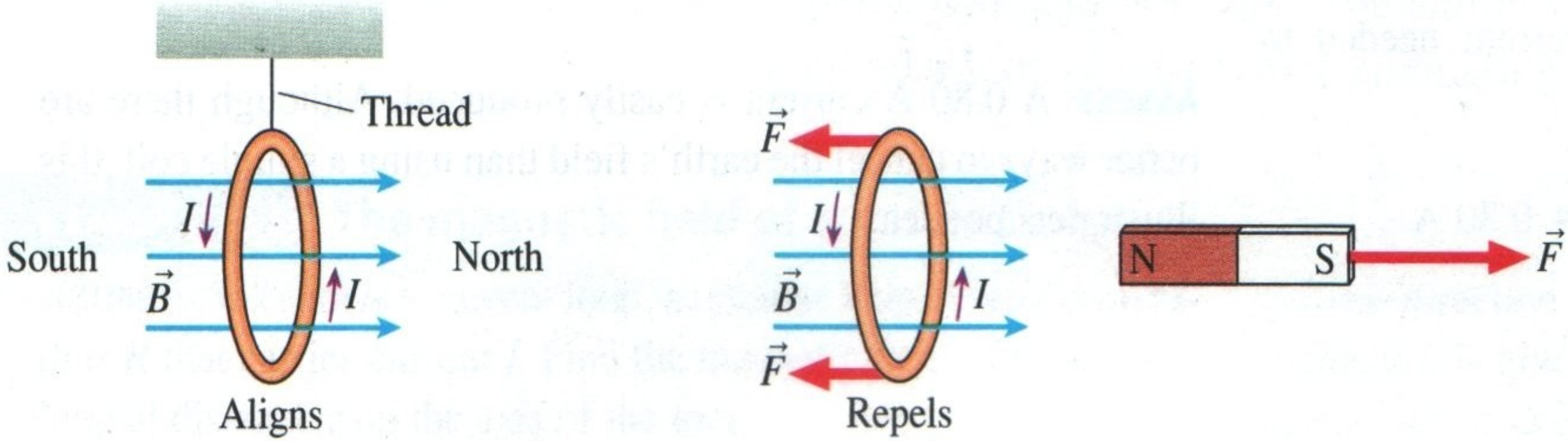
The physics of magnetism starts with a loop of current

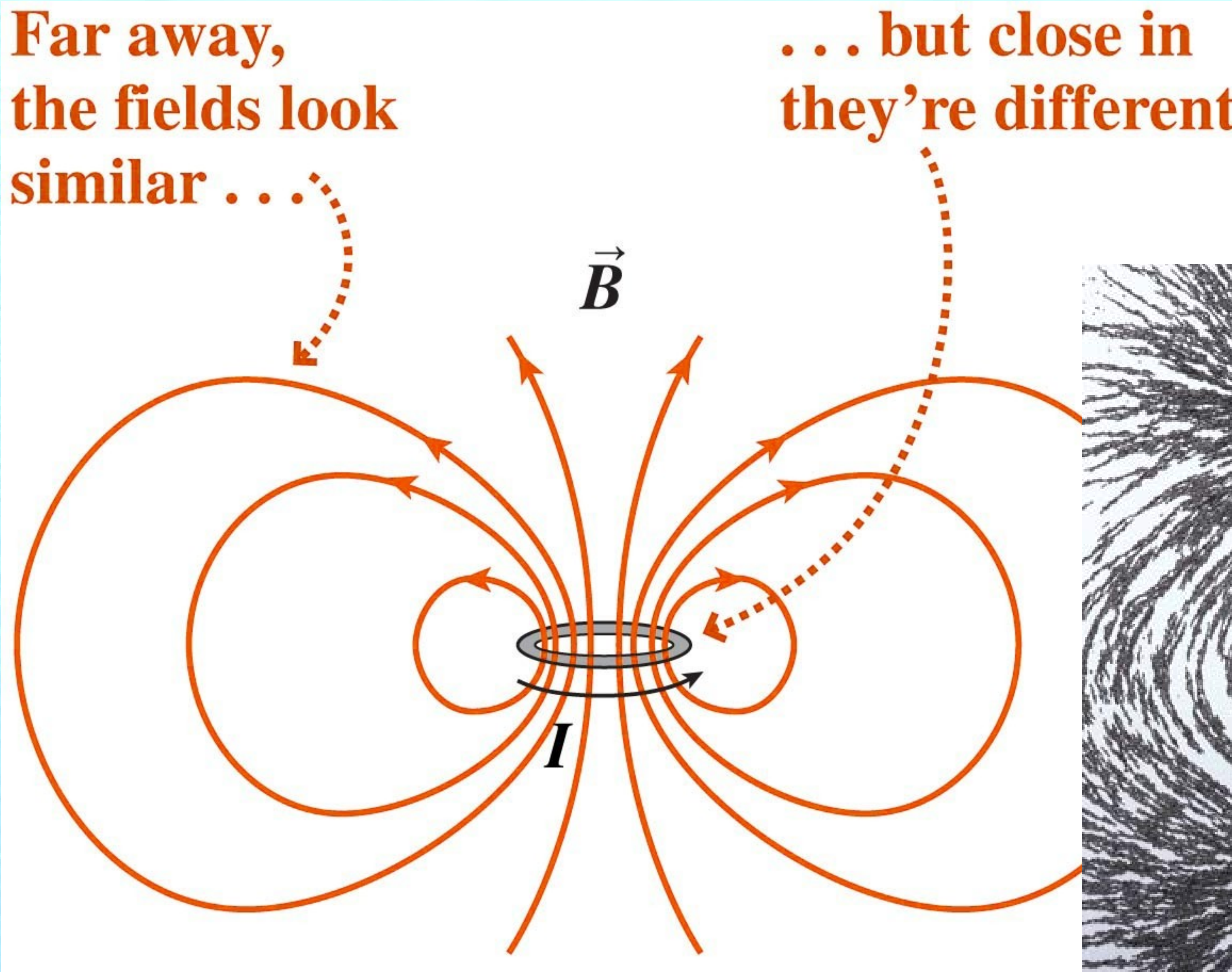
Investigating current loops



A current loop hung by a thread aligns itself with the magnetic field pointing north.

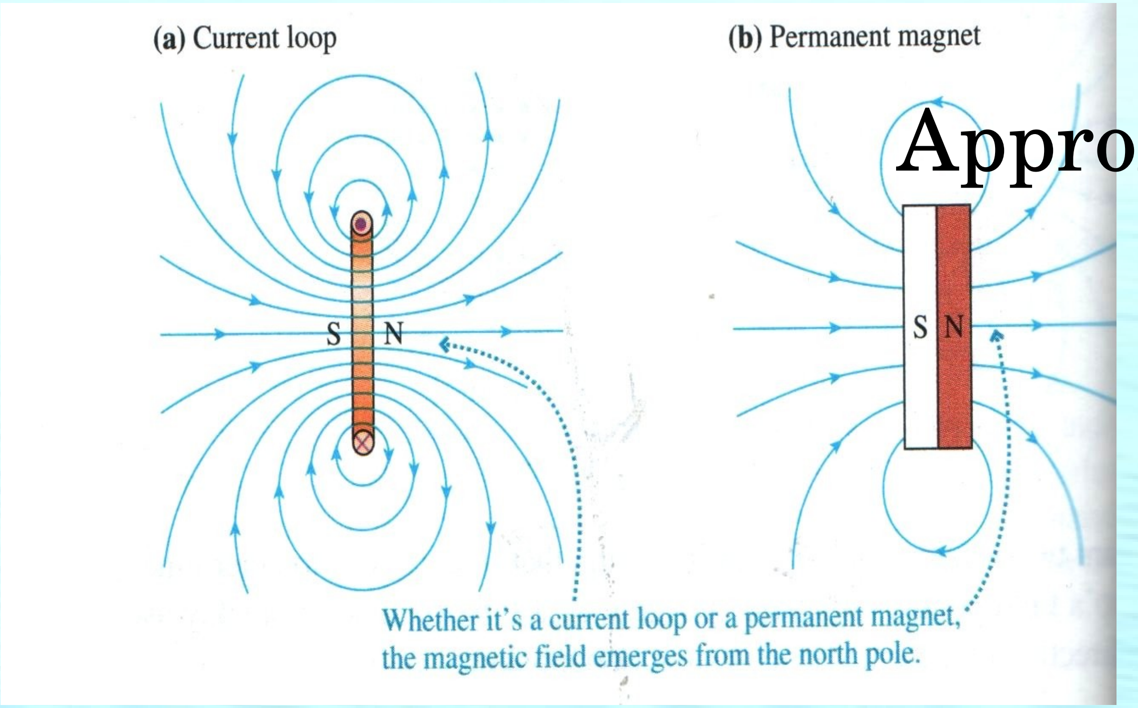
The north pole of a permanent magnet repels the side of a current loop from which the magnetic field is emerging.

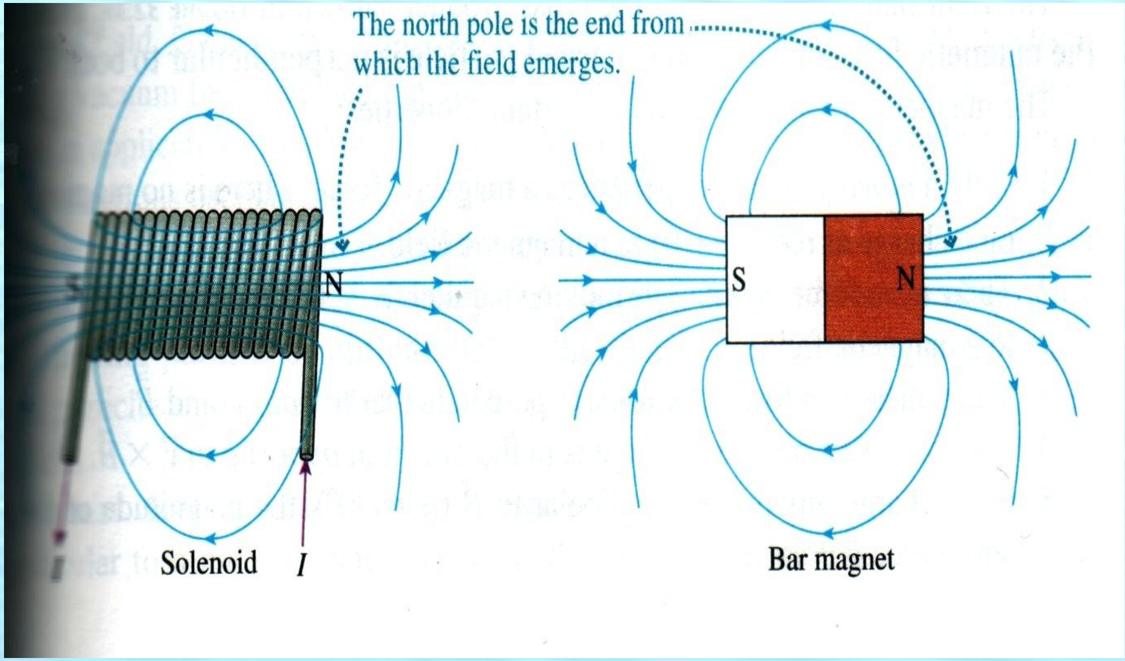
The field of a bar magnet is approximated By a current loop

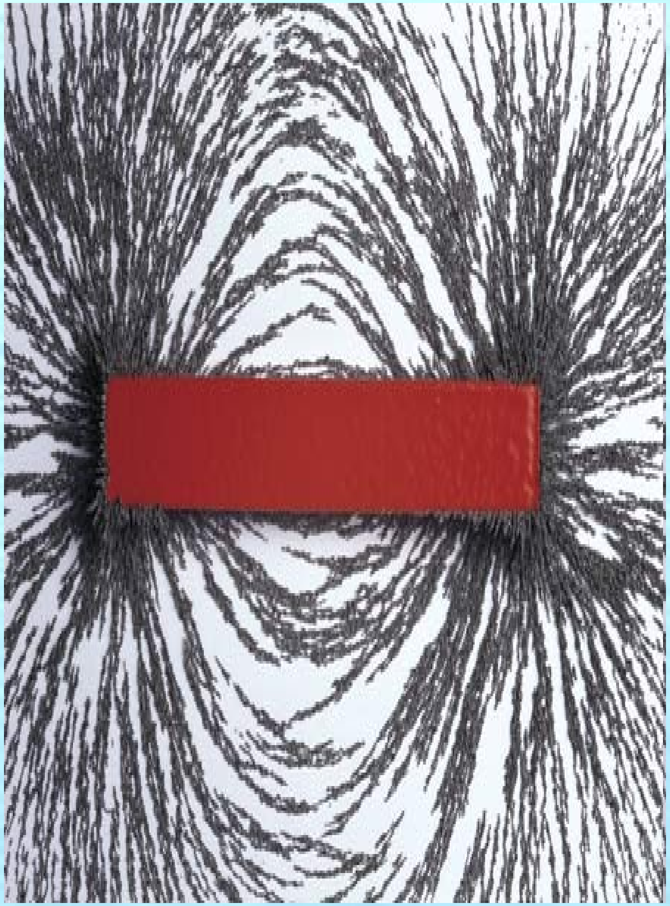


(b)

A coil of wire better Approximates a bar magnet







Where do magnetic fields come from?

(more than one “correct” answer)

Magnetic fields come from moving charges. If you have lots of moving charges, you have a current.

So … magnetic fields come from currents.

But … magnetic fields also come from magnets!!

What can you conclude about magnets?

[A] Magnets are just different

[B] Magnets are made of magnetic materials, they don't need currents.

[C] Magnets contain currents

[D] Nothing makes sense, where is the battery in a magnet … how can there be a current w/ no voltage source?

[E] C and D.

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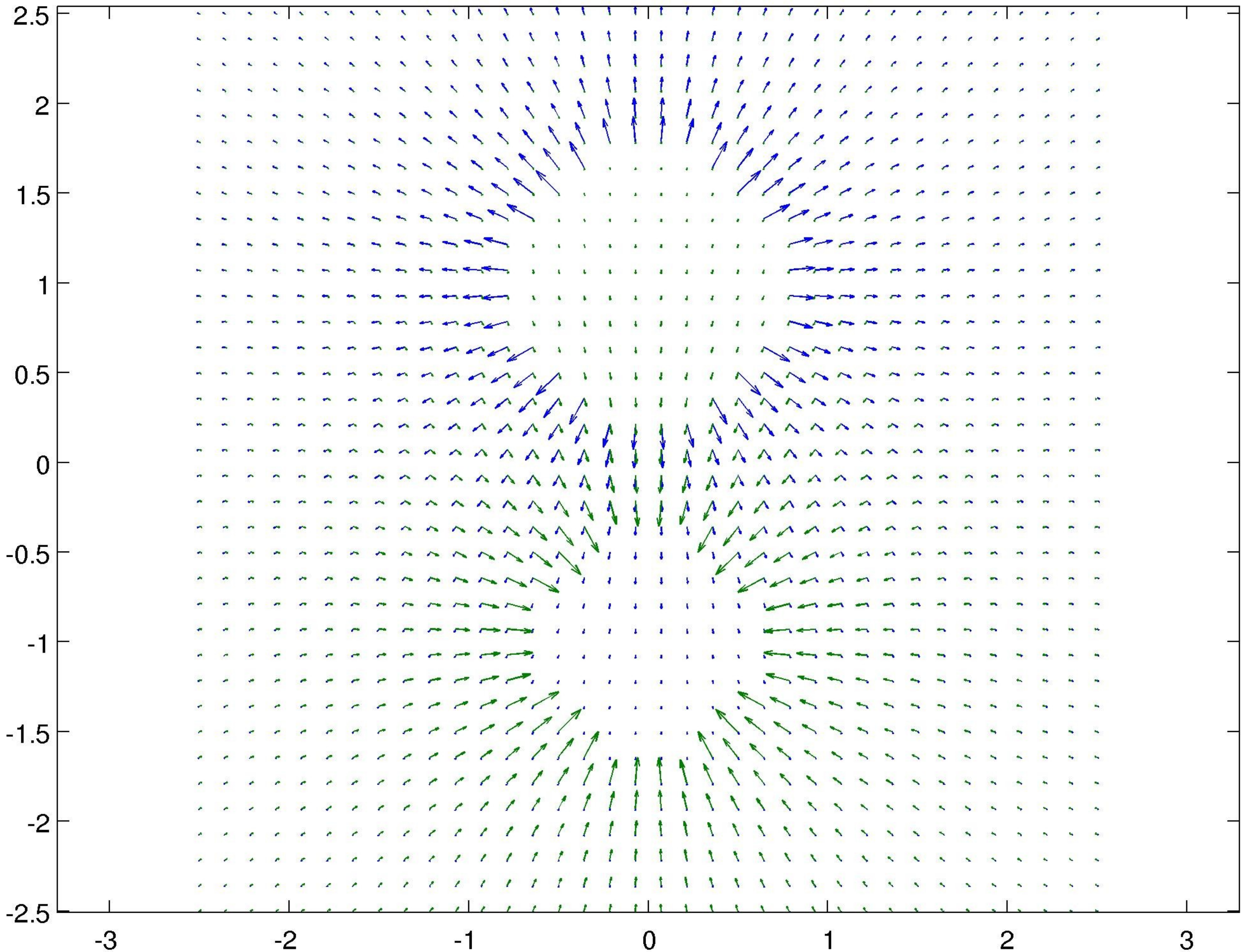
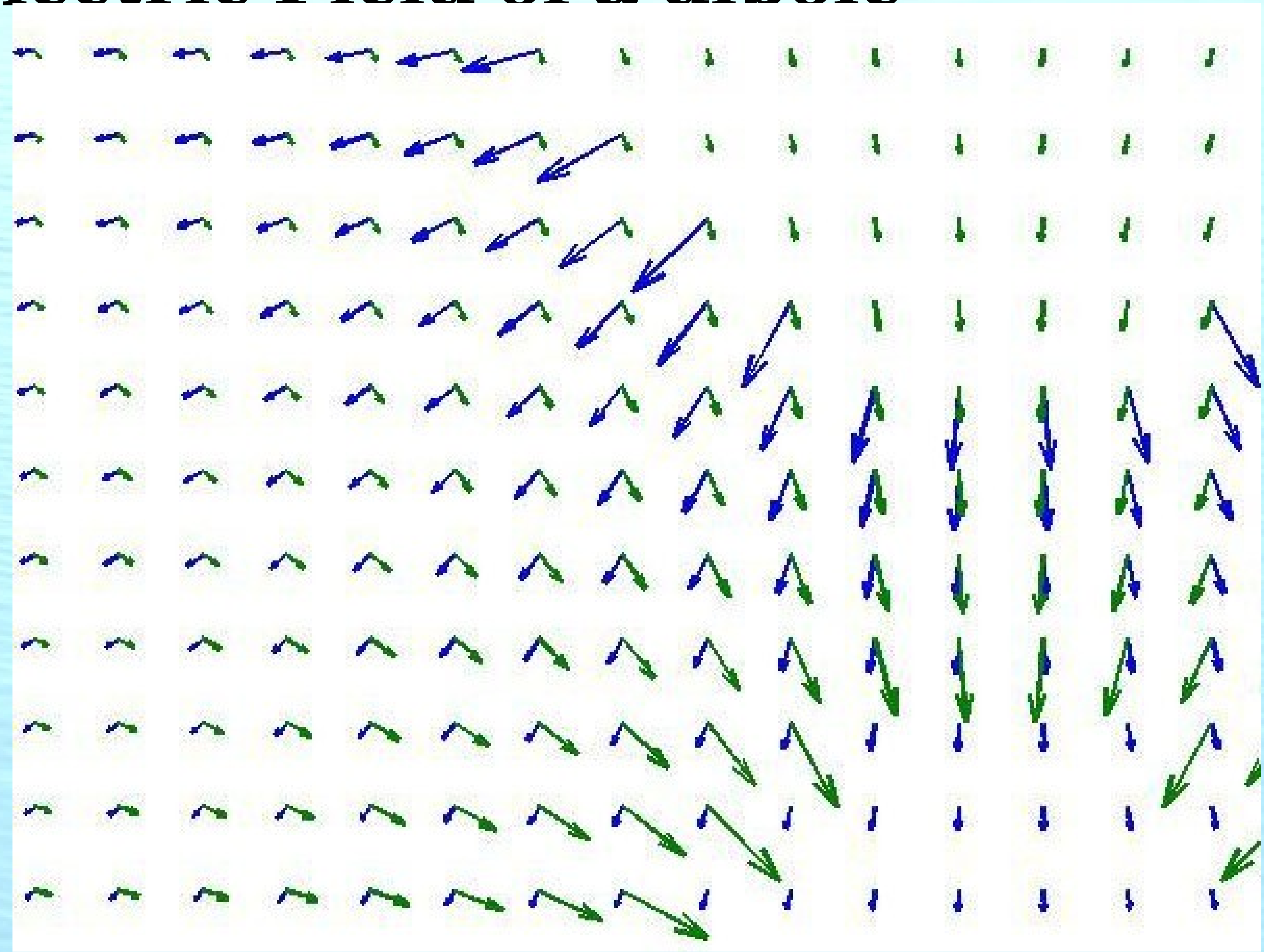
E-Field Around positive and negative charge

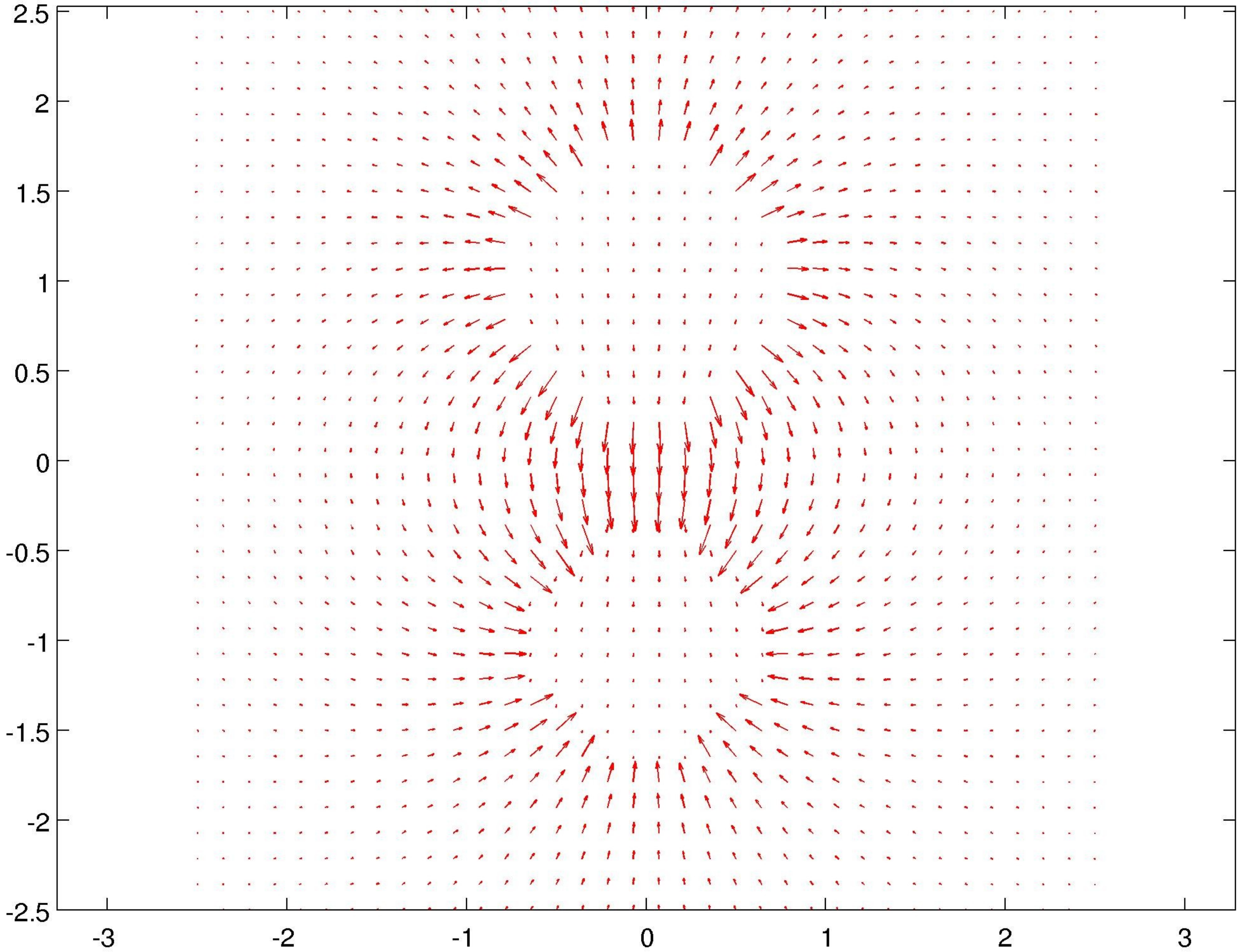


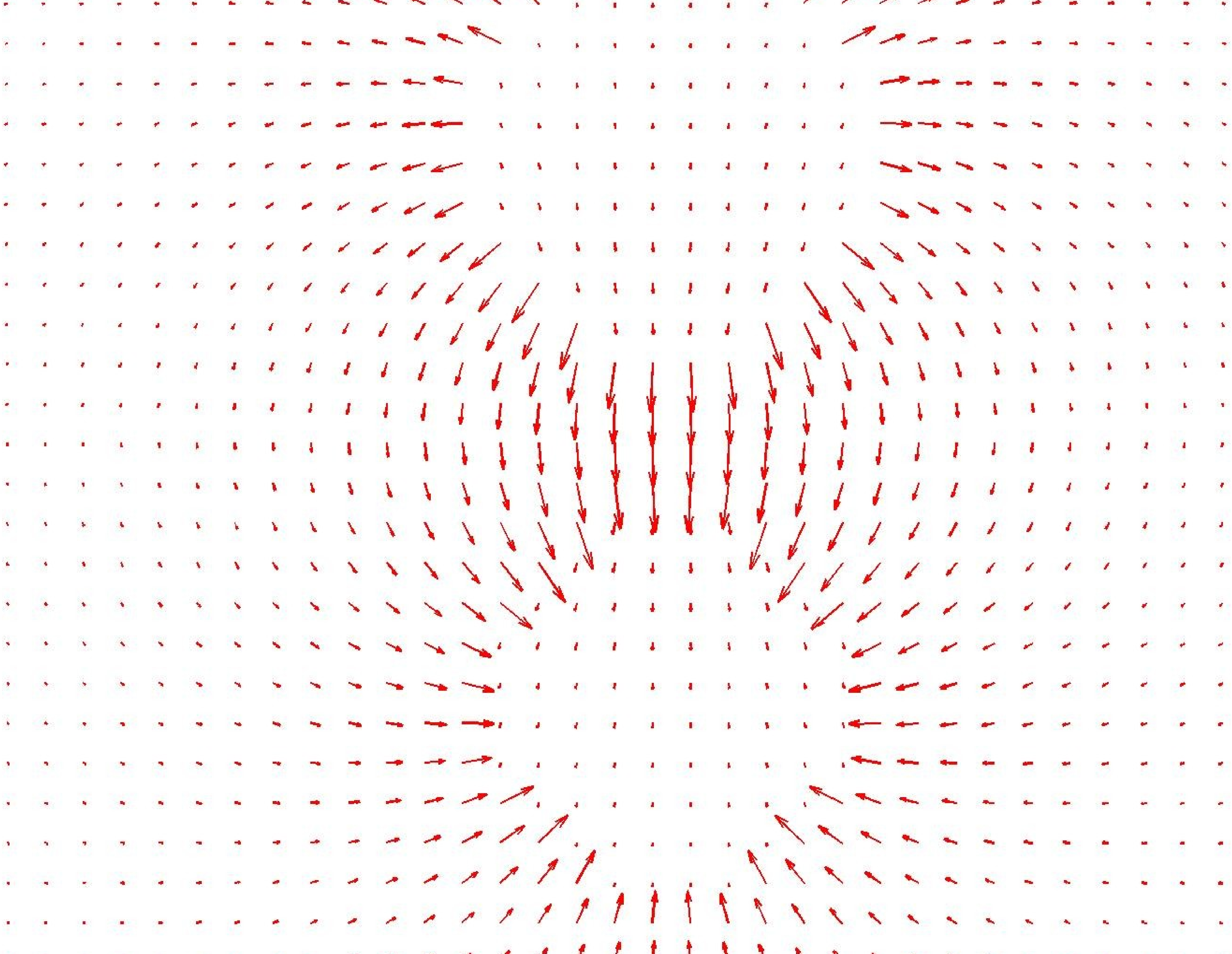
Vector Practice – Tip to Tail method

Electric Field of a dipole



Resultant E-Field Around positive and negative charge



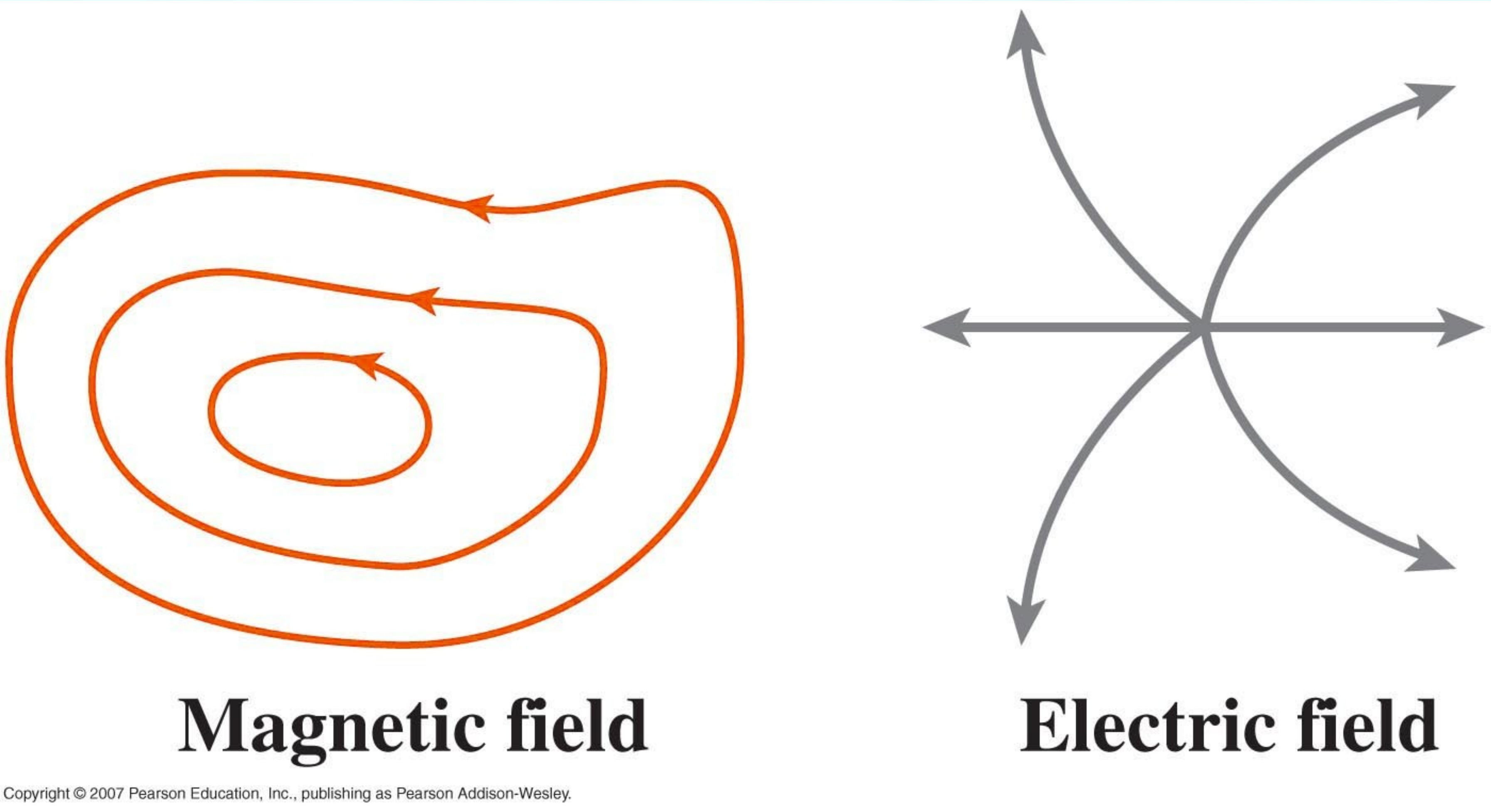


Magnetostatics

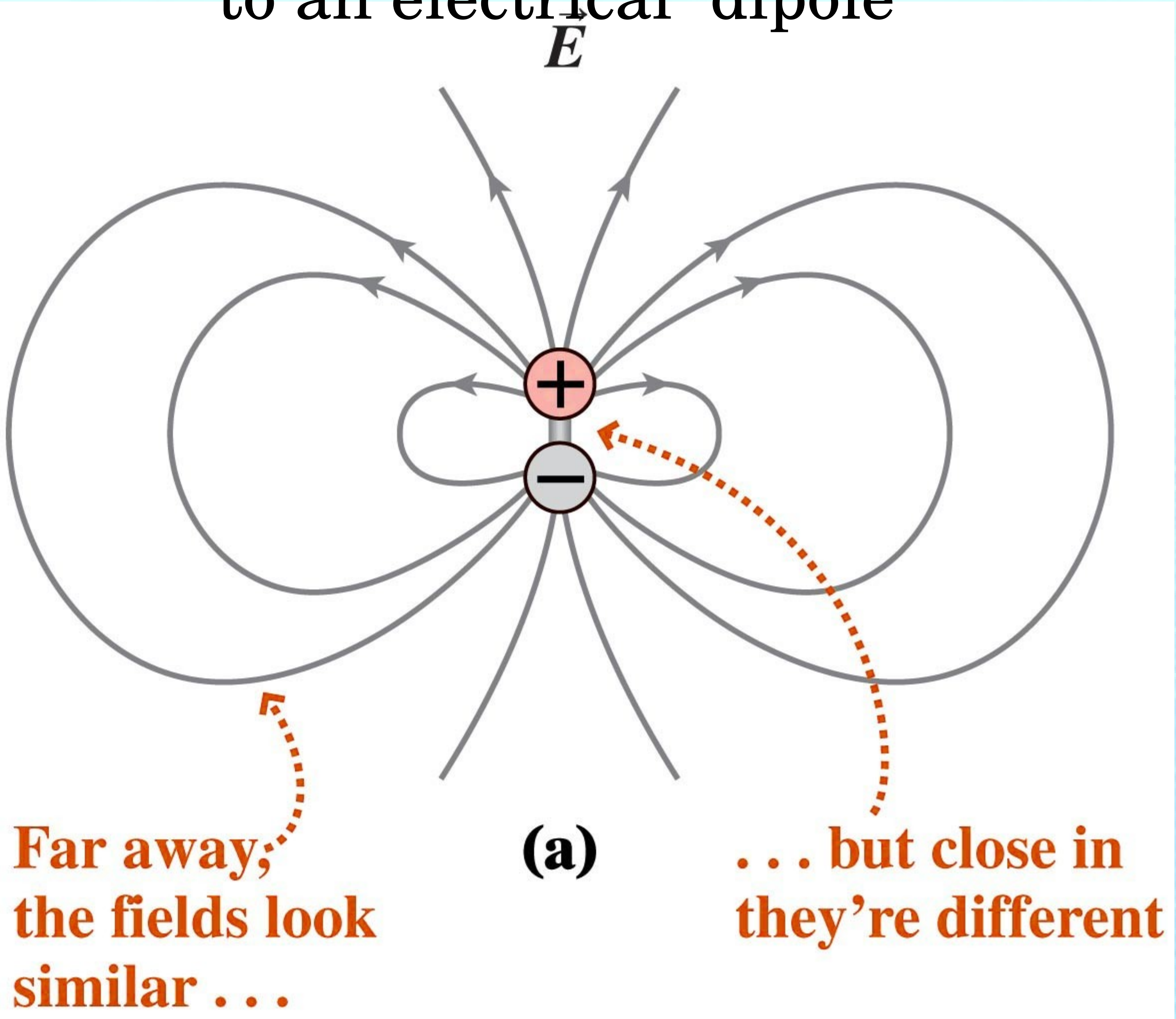
Field lines always Close (circle)

Electrostatics

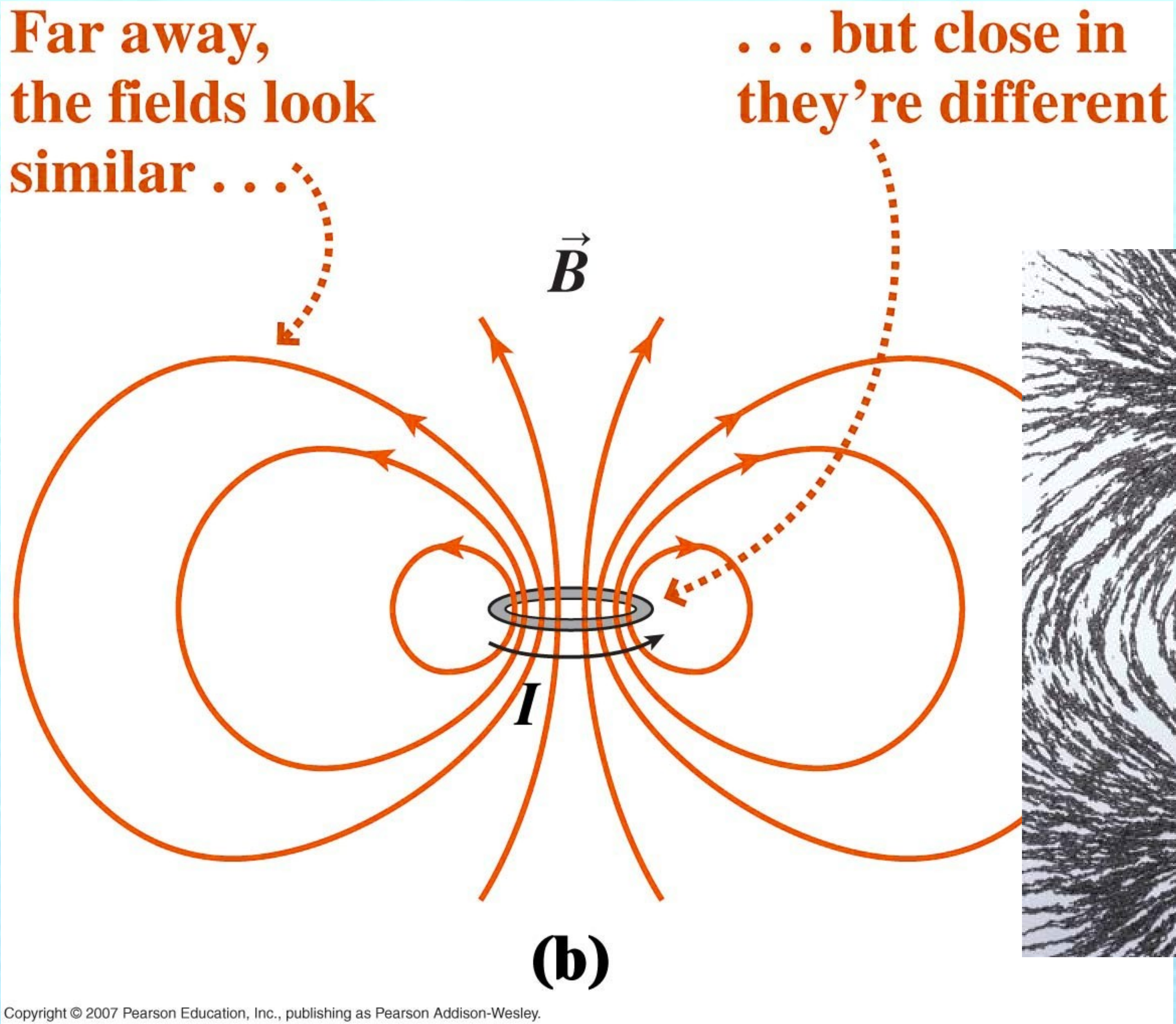
Field lines can emerge from a point



Mose elementary magnetic field is similar to an electrical dipole



The field of a bar magnet is approximated By a current loop

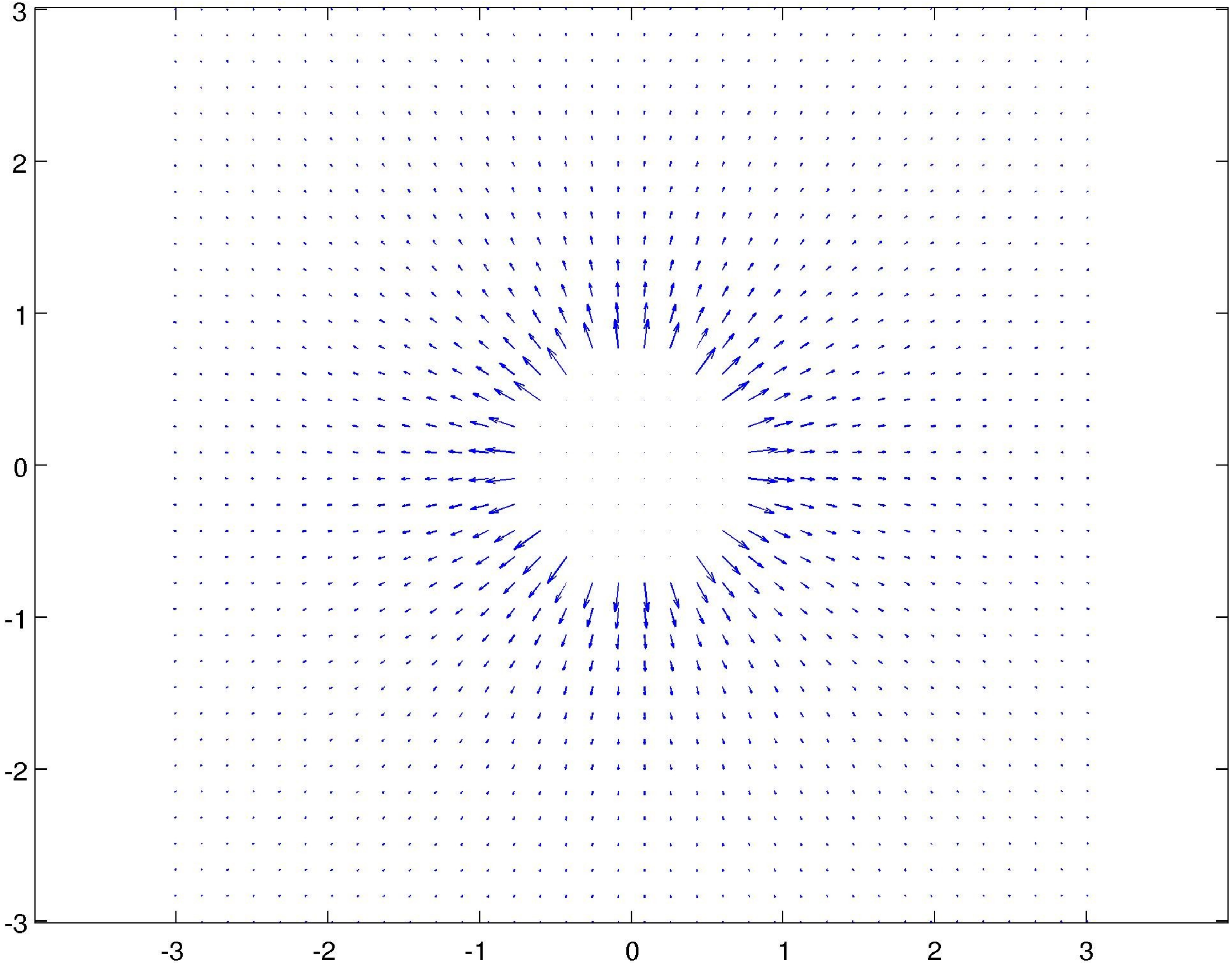


Building complex from simple

The simplest magnetic field makes circles around a wire.

The following set of slides shows you how you get something that looks like a magnetic dipole by vector addition of circular fields.

E-Field Around A Positive Charge



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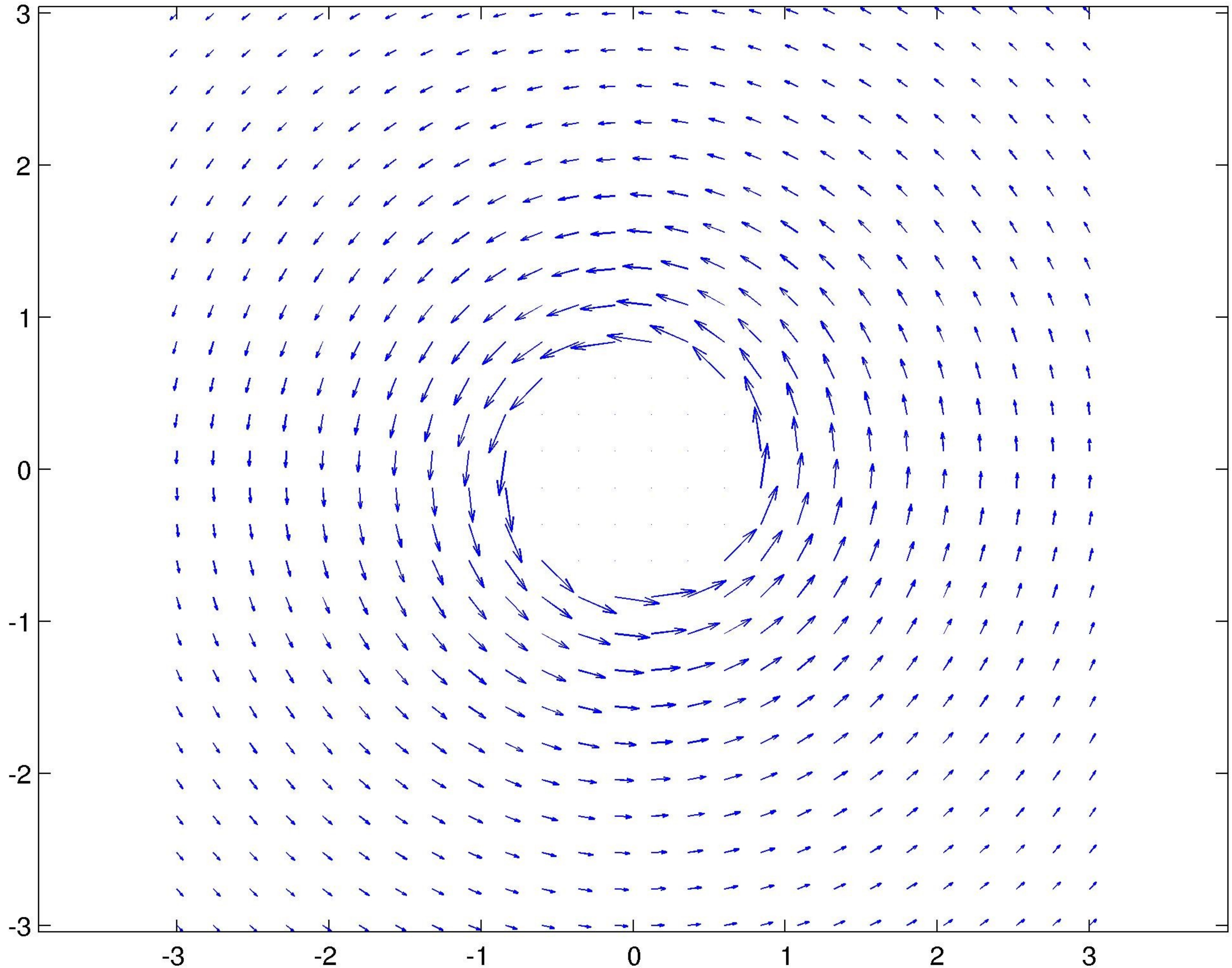
As of: 08-Jul-2013

B-Field Around A Wire

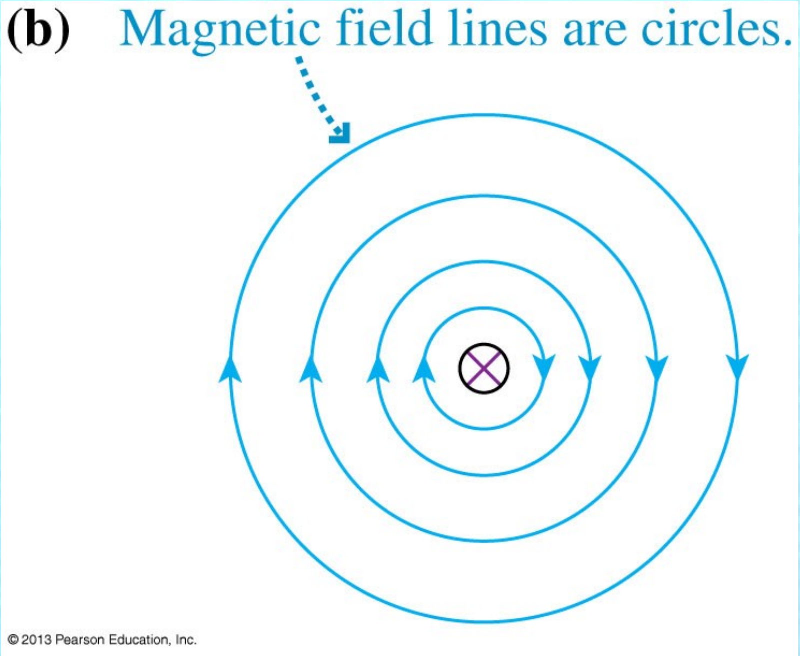


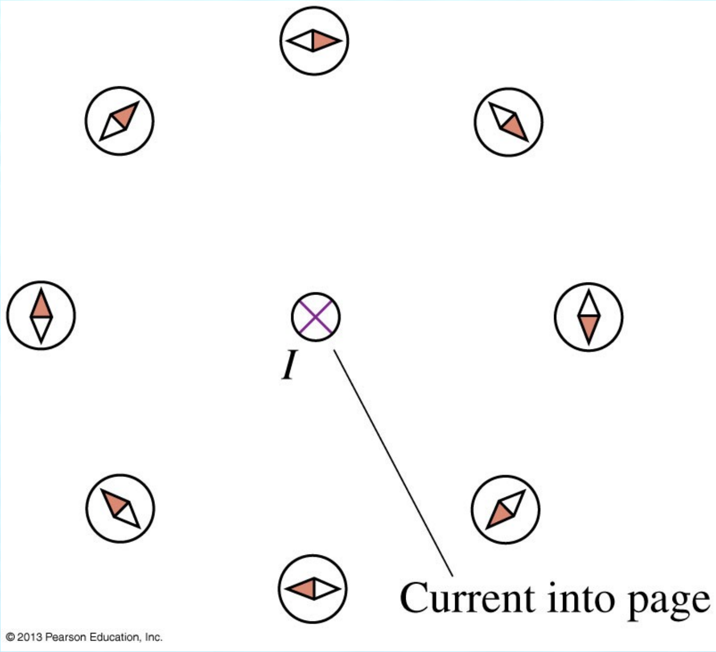
Electric Currents and Magnetic Fields

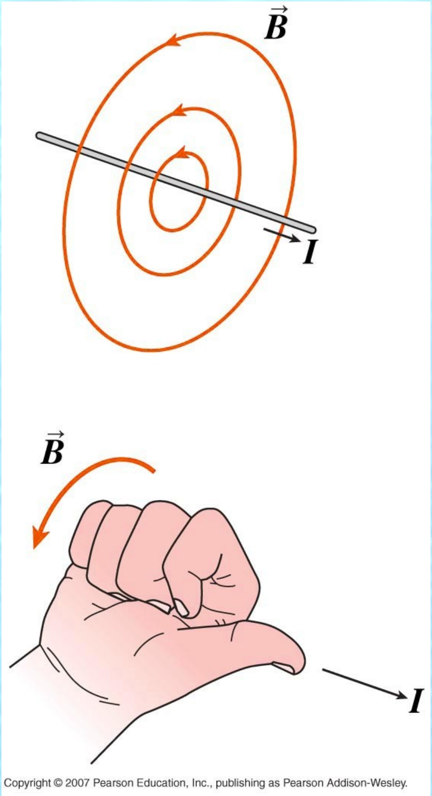
magnetic field forms a pattern of concentric circles around a current-carrying wire

when current reverses direction, the direction of the field lines reverse

The "hitch-hikers right hand rule" relates current direction to B-field.







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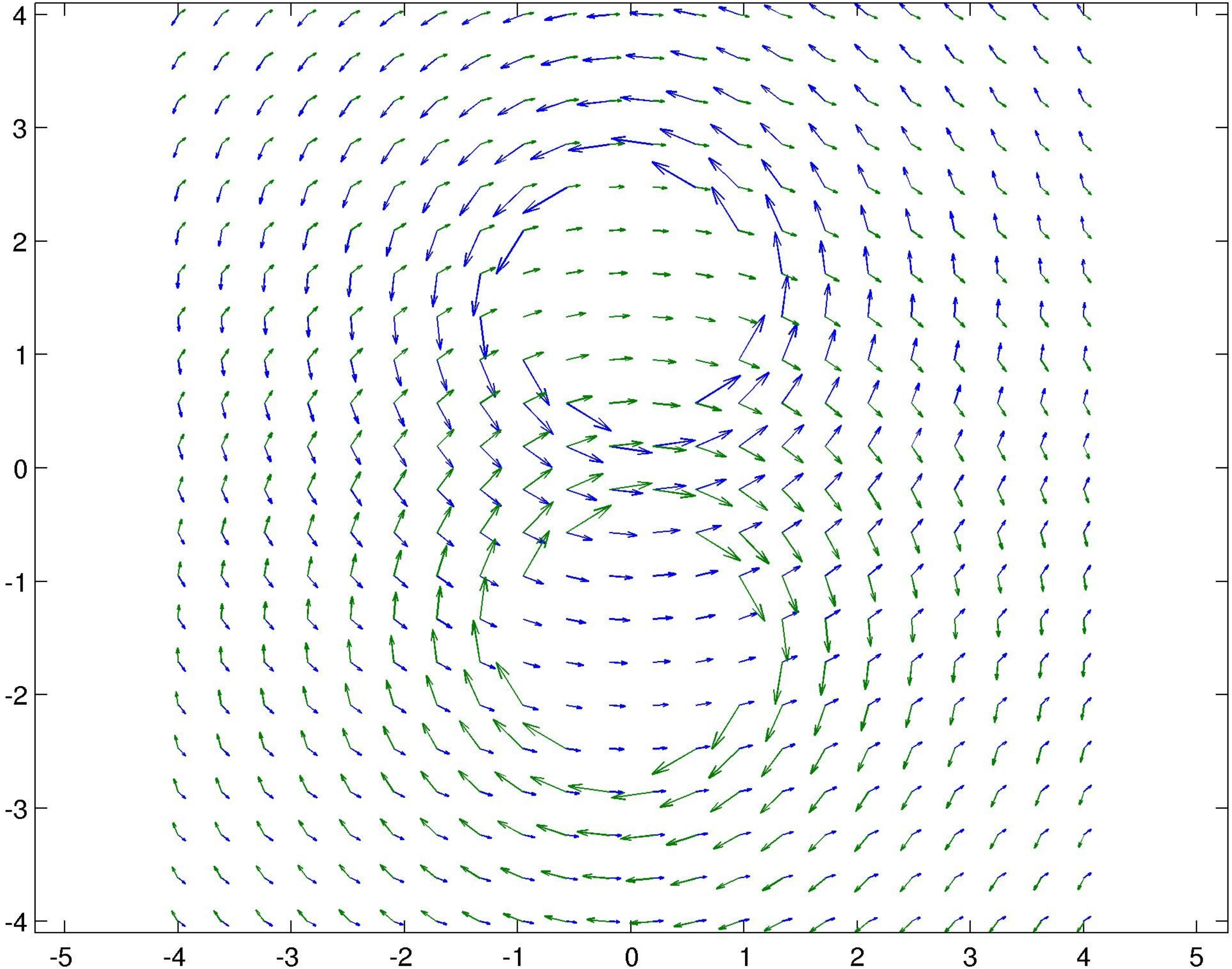
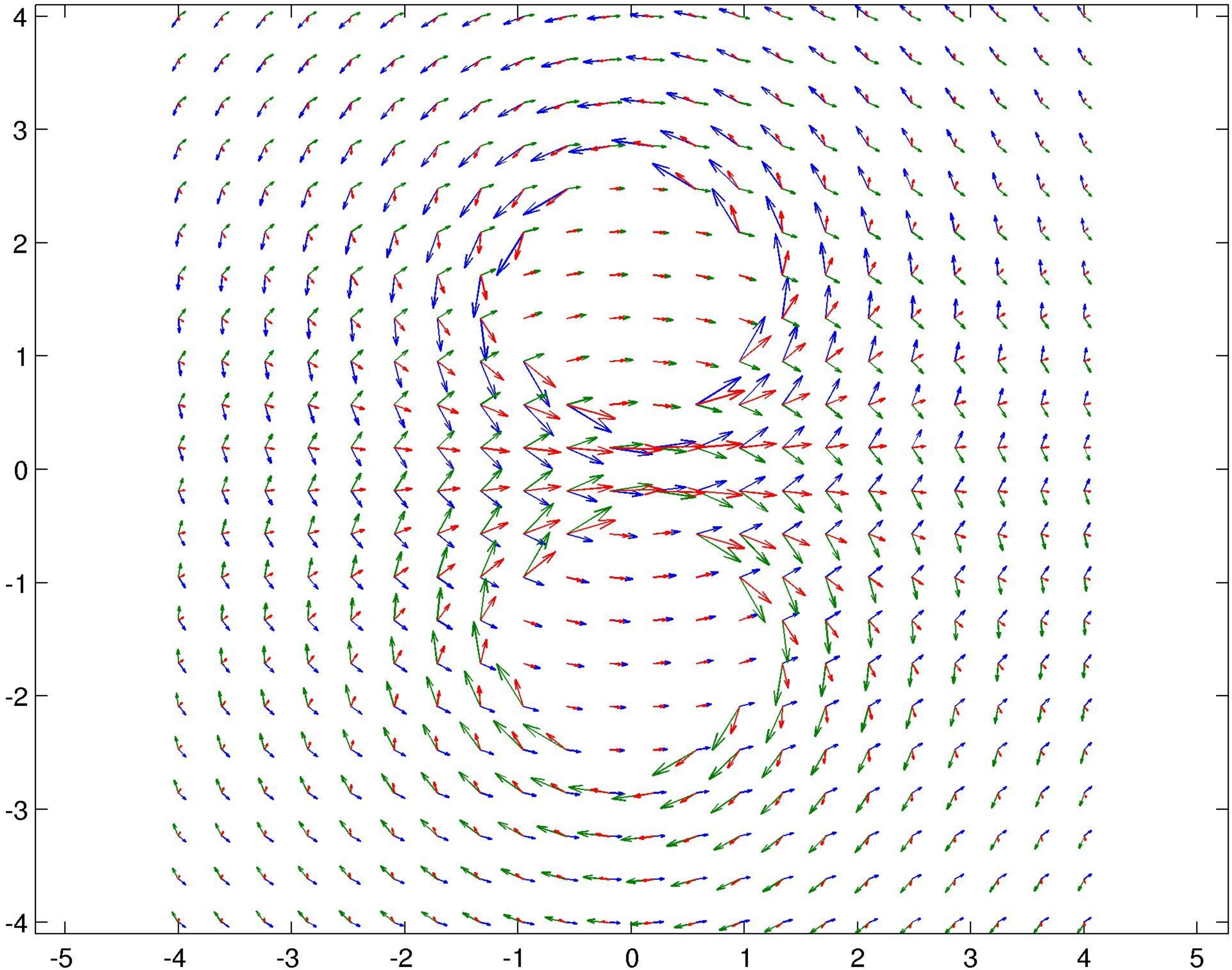
B-Field Around Two Wires



Vector Sum of B-Field Around Two Wires



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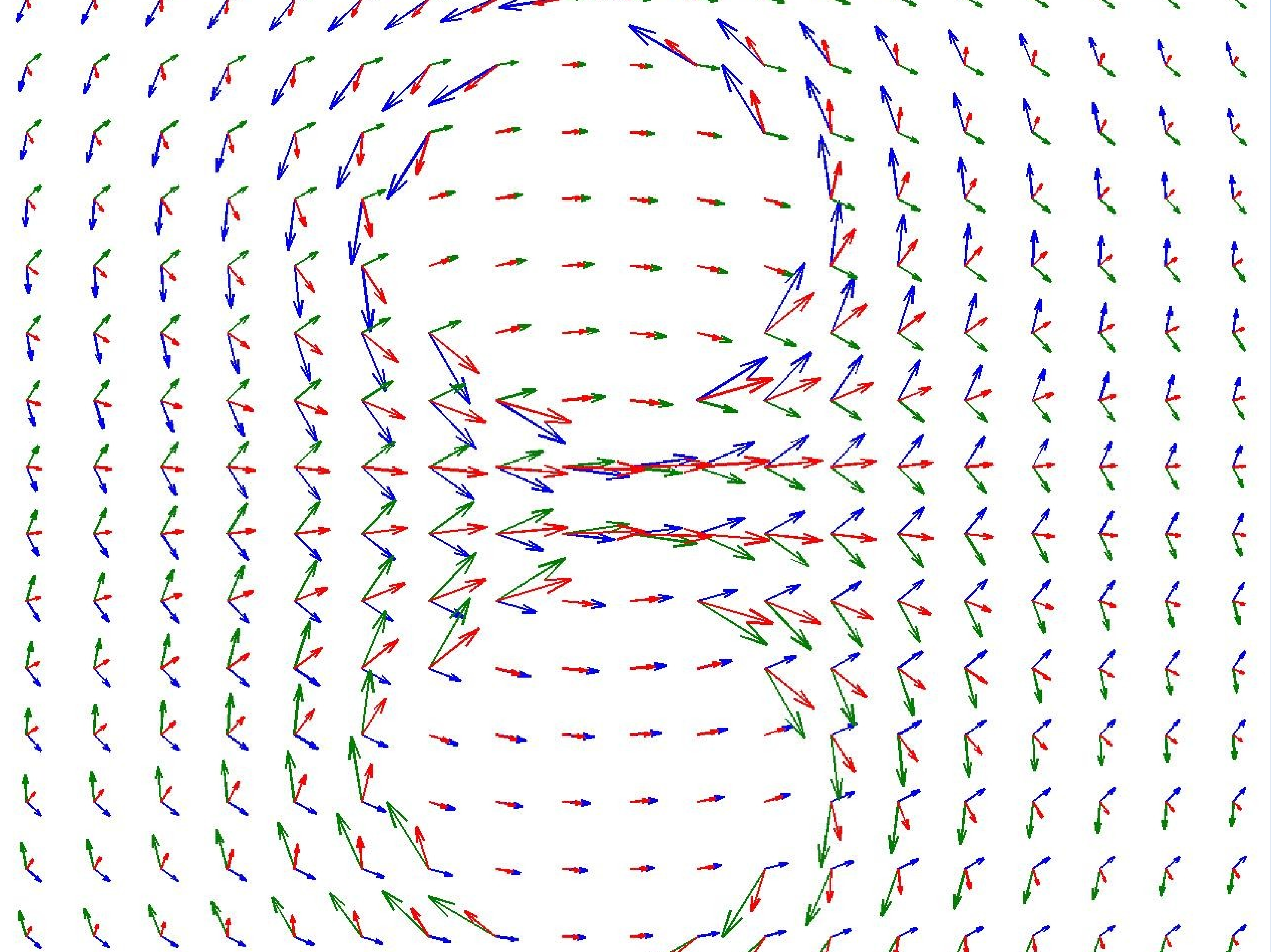
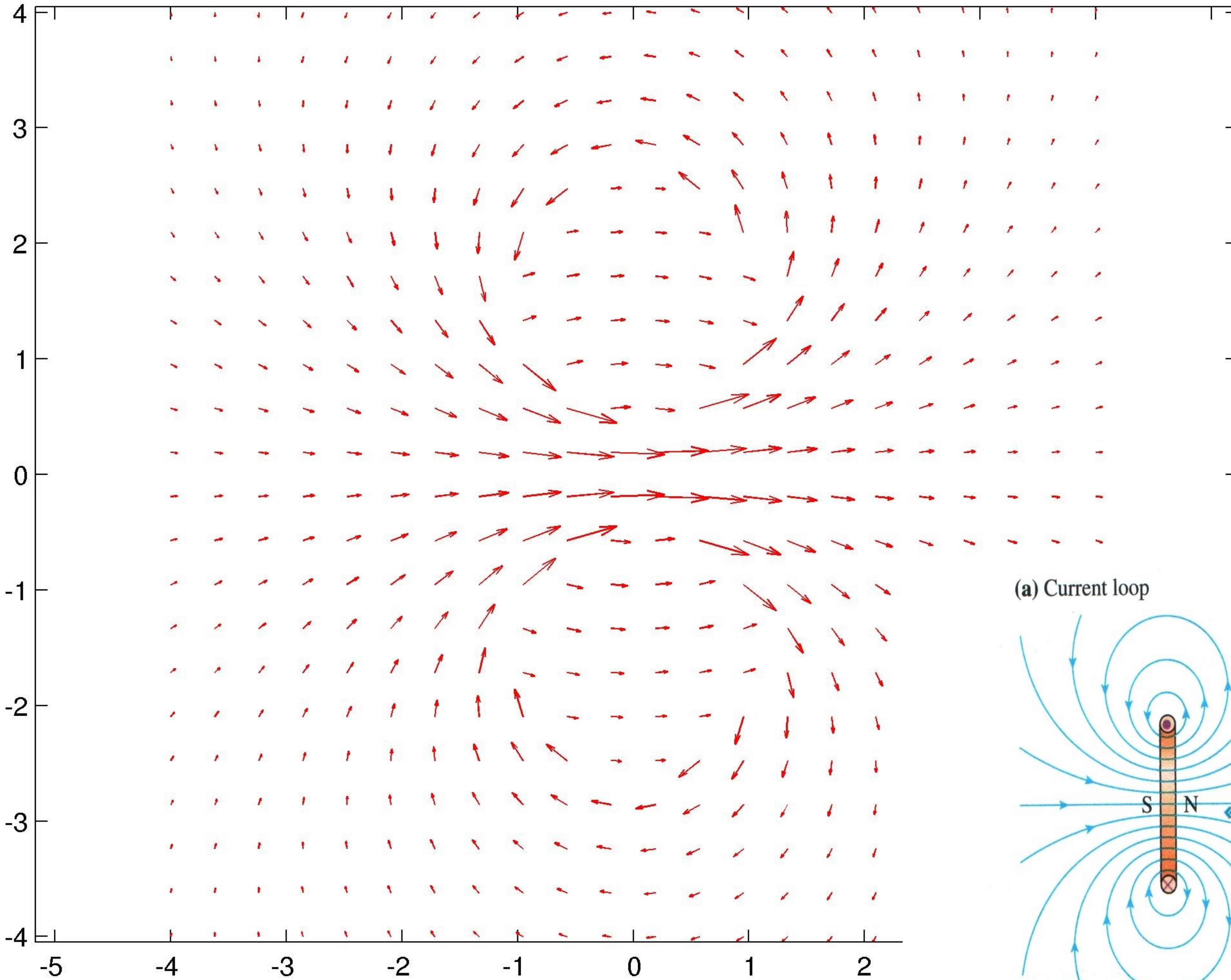
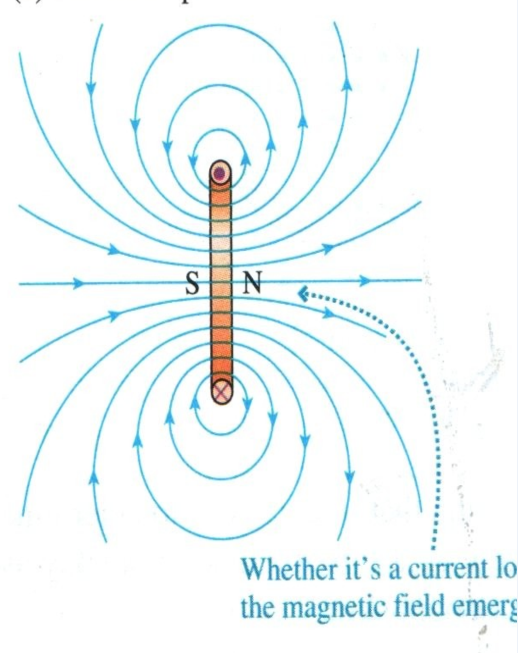


B-Field Around A Wire Loop





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What we learned

A field is a useful mathematical abstraction … and it's measurable and can be considered "real".

Magnetic field around a straight wire is circular

A loop of wire has a field that look like a flat magnet with north pole given by right hand rule.

A "solenoid" (coil of wire) has a field that looks like a bar magnet with north pole given by RH rule.

At a distance, the field of a coil is mathematically identical to the field of + and – electrical charges (a dipole)