EE-208-F:
Fundamentals of Electromagnetics

LECTURE 2

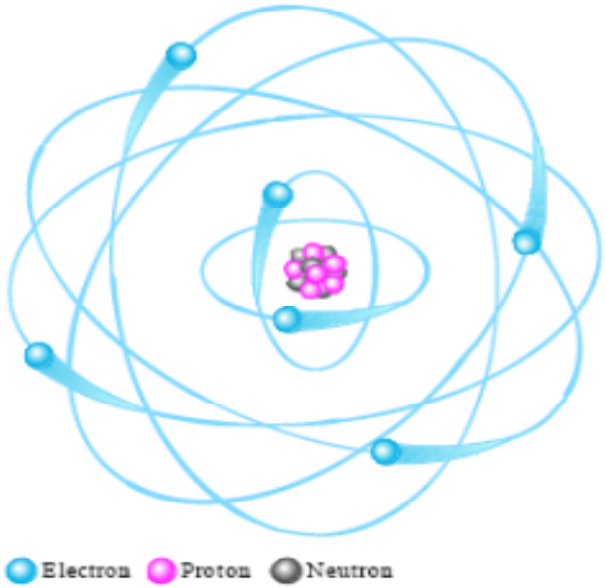
Topics Covered

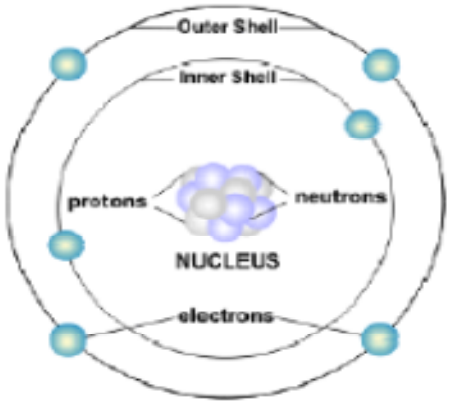
- Vector calculus
- Charge
- Electromagnetics fundamentals
- Scalar fields
- Vector fields

What is a charge q?

What is CHARGE (q): A fundamental conserved property of some subatomic particles (electron, proton, neutron).

It exists because of an excess or a deficiency of electrons.





Electrical charge exists in discrete quantities, which are integral multiples of the charge on an electron -*e*,

$e = 1.602 \times 10^{-19}$ (C)
6.24×10^{18} electrons carry a charge of 1 coulomb

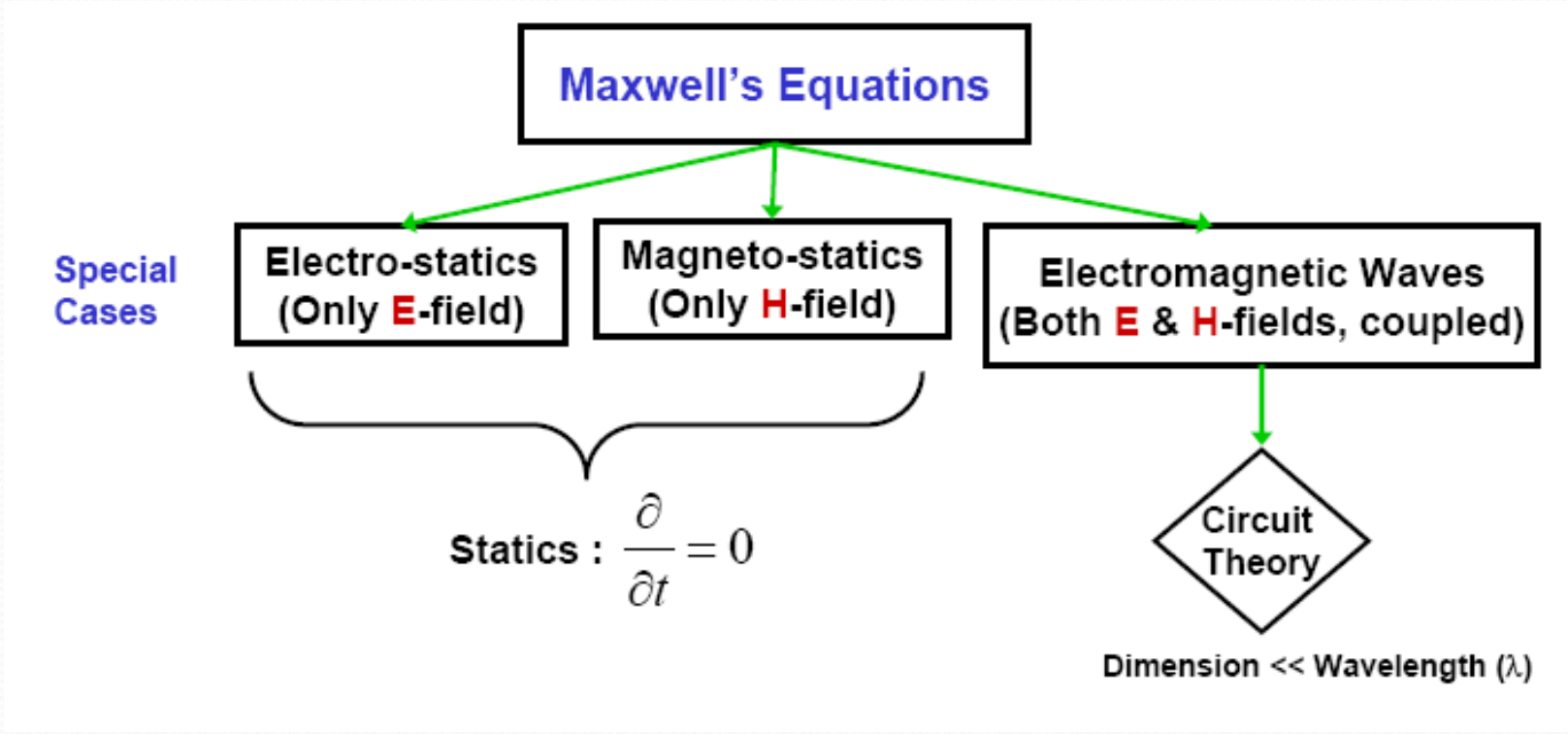
On the macroscopic level, charge is assumed to be "continuous"

Varieties: Positive (+)

Negative (-)

Charge is conserved !

Fundamental Laws of Electromagnetics



Steps in Studying Electromagnetics

Define basic quantities (e.g., **E**-field, **H**-field)

Define the rules of operation (mathematics) of these quantities (e.g., Vector Algebra, PDEs)

Postulate fundamental laws

Fundamental Relationships

$$c_0 = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

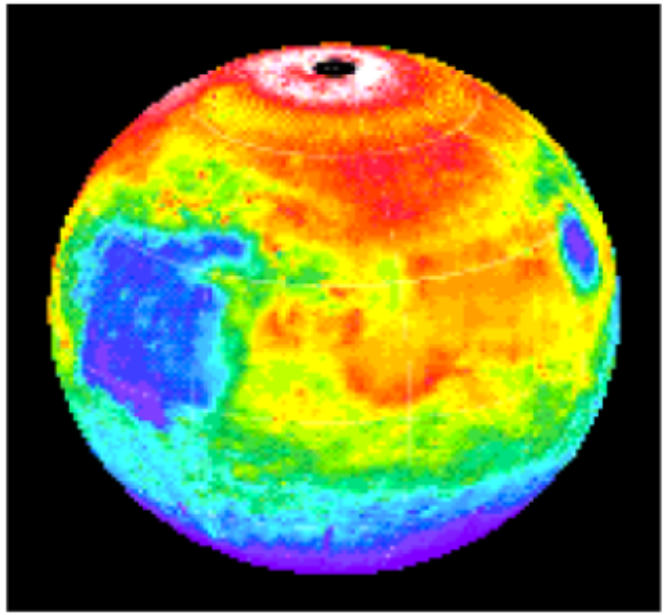
$$\left.\begin{aligned} \mathbf{D} &= \varepsilon_0 \mathbf{E} \\ \mathbf{B} &= \mu_0 \mathbf{H} \end{aligned}\right\} \text{Constitutive Relations}$$

Scalar and Vector Fields

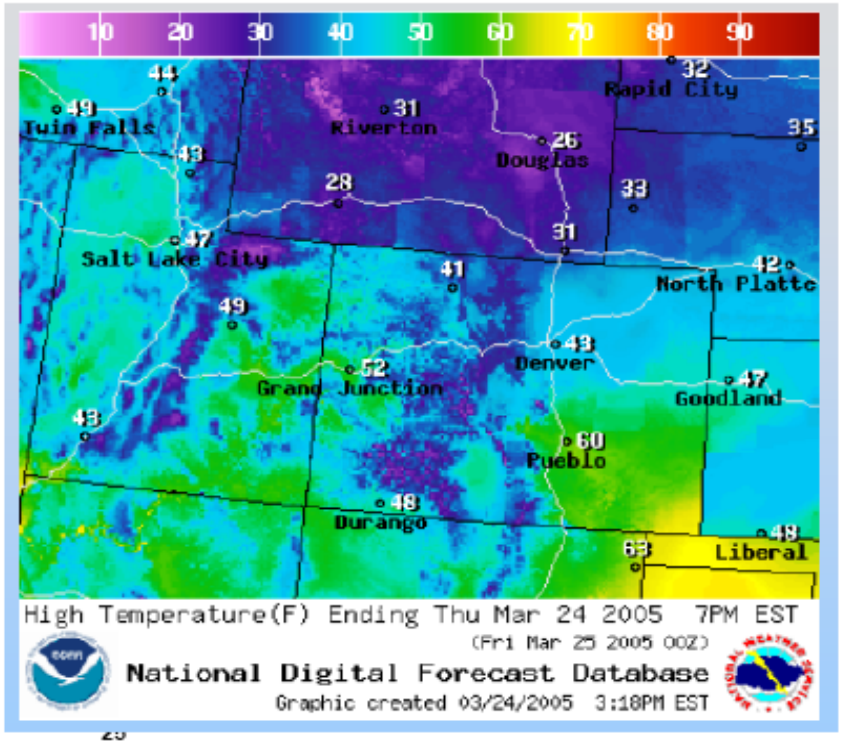
- **A scalar field is a function that gives us a single value of some variable for every point in space.**
  - **Examples: voltage, current, energy, temperature**
- **A vector is a quantity which has both a magnitude and a direction in space.**
  - **Examples: velocity, momentum, acceleration and force**

Example of a Scalar Field

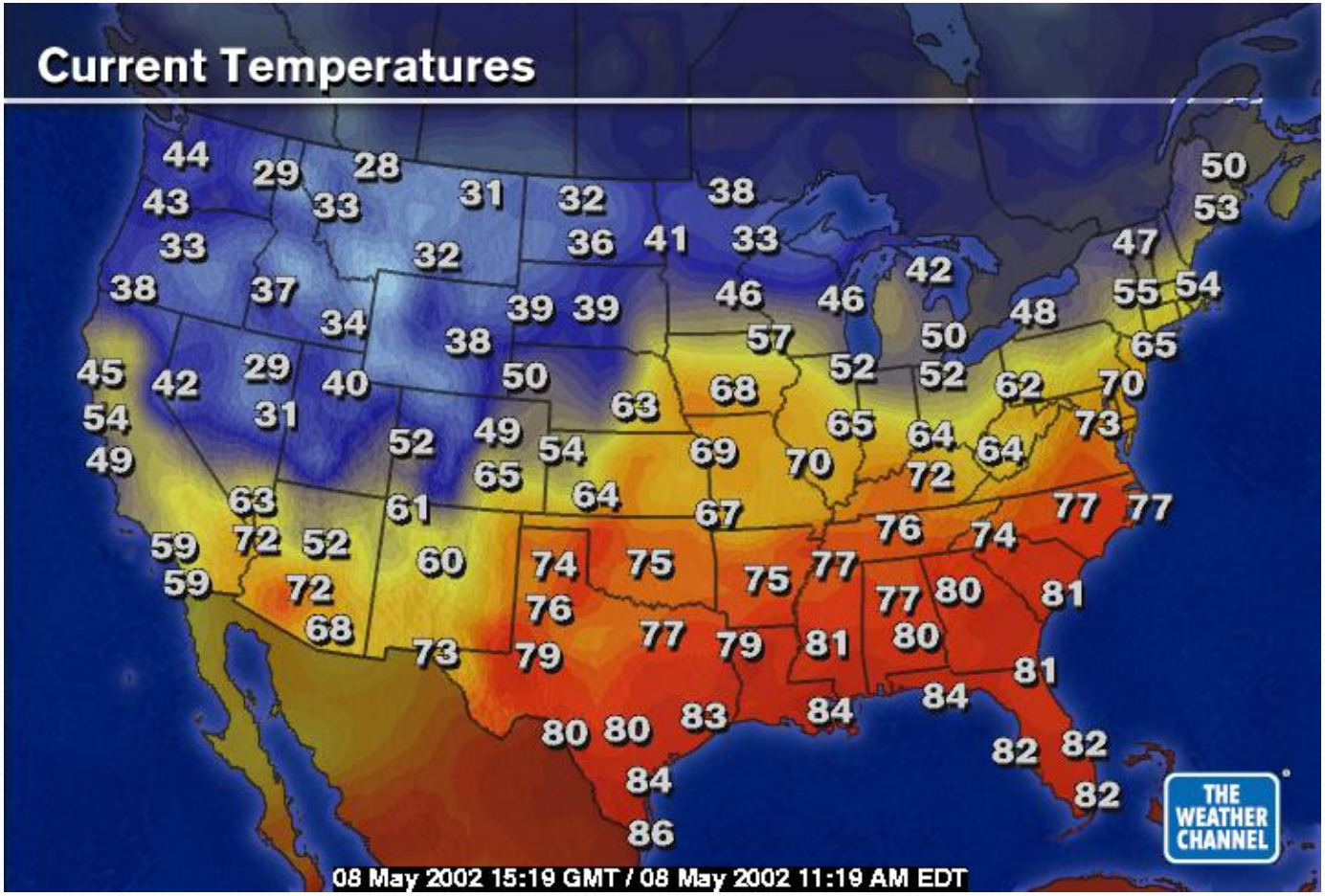
Temperature: Every location has associated value (number with units)



Nighttime temperature map for Mars

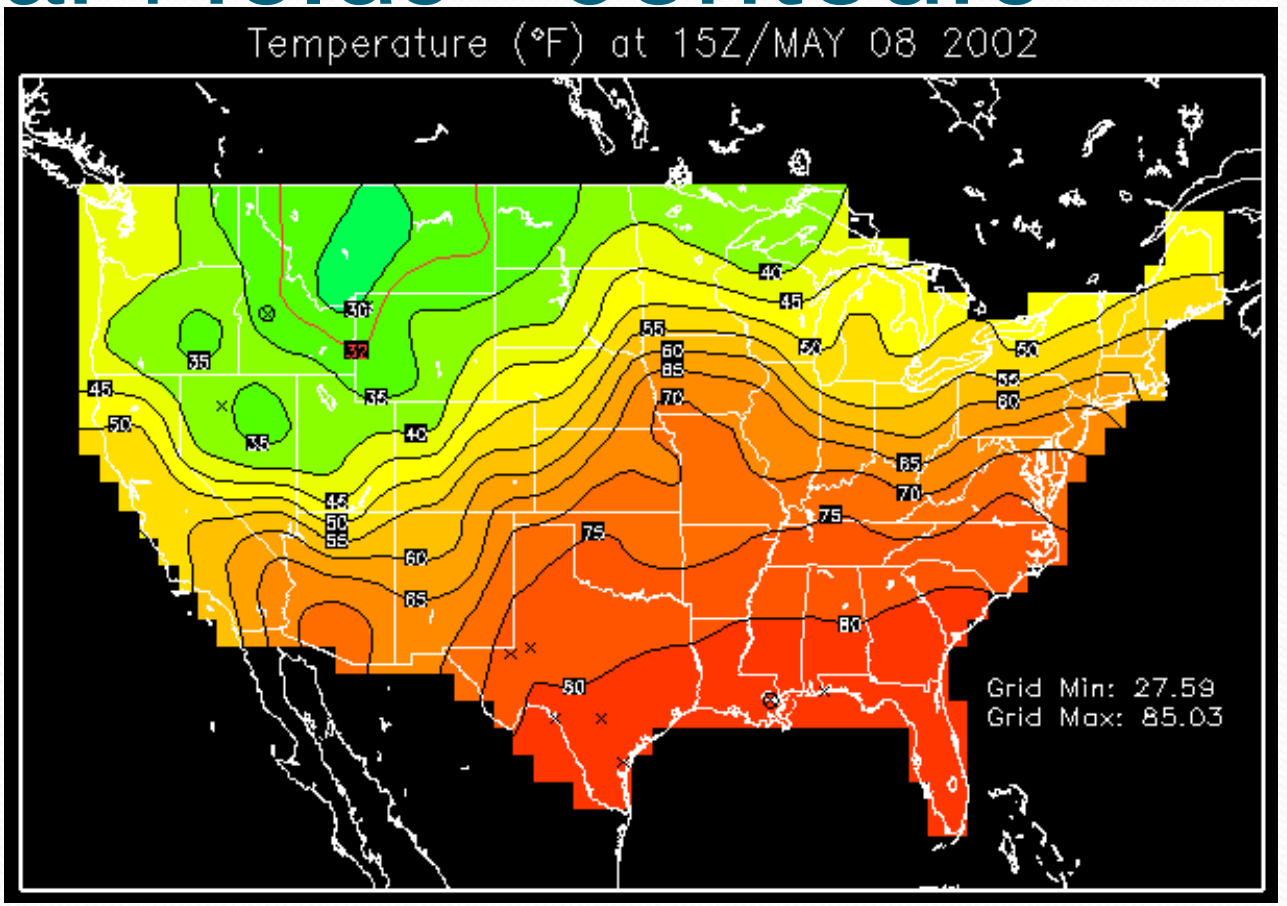


Scalar Fields



e.g. Temperature: Every location has associated value (number with units)

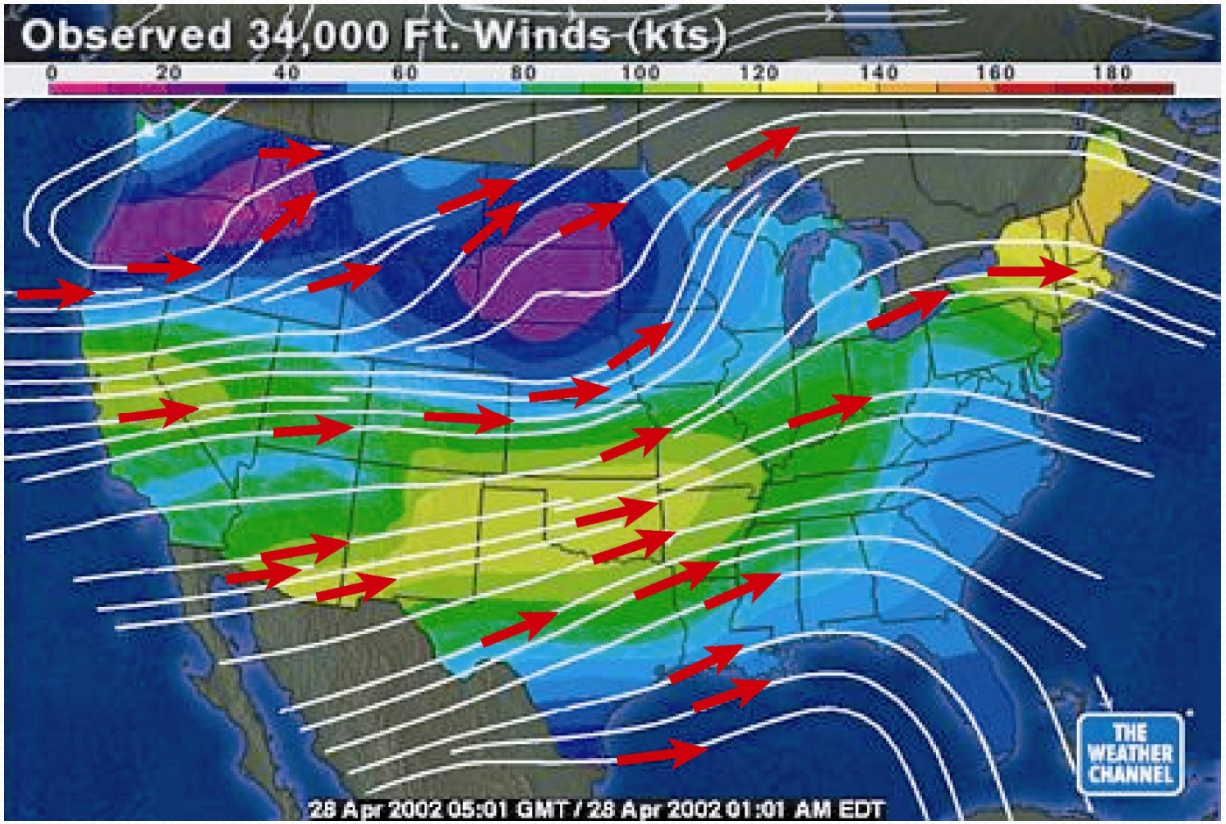
Scalar Fields - Contours



- Colors represent surface temperature
- Contour lines show constant temperatures

Vector Fields

Vector (magnitude, direction) at every point in space

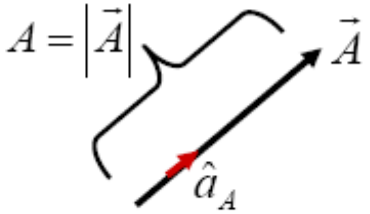


Example: Velocity vector field - jet stream

Vector Fields Explained

Vector has both **magnitude** and **direction** in space.

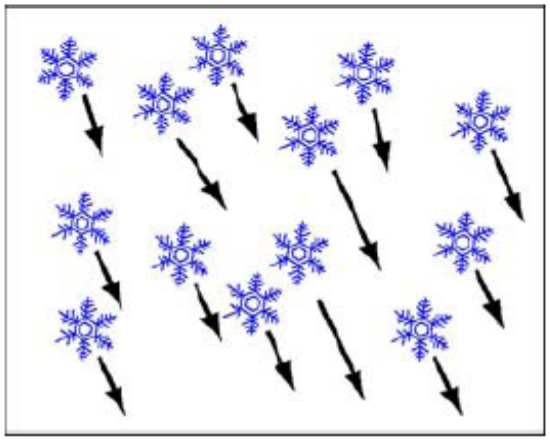
$$\vec{A} = \hat{a}_A A$$



$A = |\vec{A}|$ Magnitude of the vector $\vec{A}$

$\hat{a}_A = \dfrac{\vec{A}}{|\vec{A}|}$ Unit vector in the direction of $\vec{A}$

Falling Snowflakes

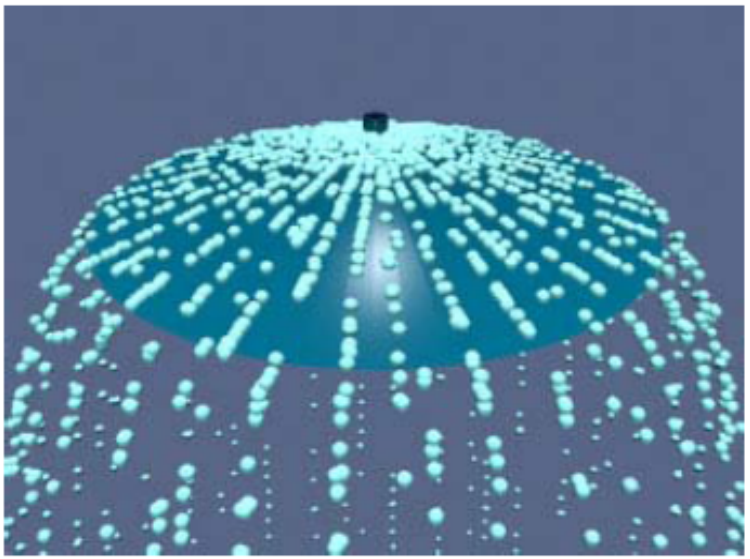


Velocity vector

Examples of Vector Fields

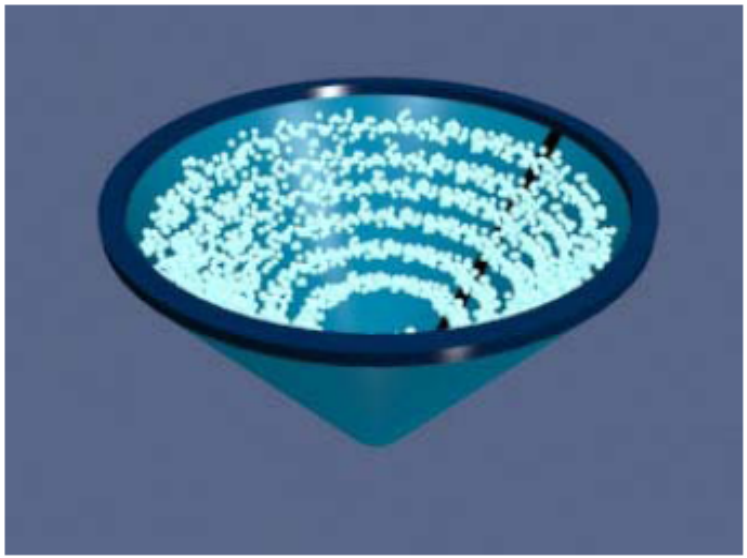
Fluid flow field
(Fluid is represented by a finite number of particles.)

Fluid flow associated with a source (or "faucet")



The vector velocities of the particles are all directed outwards from the center of the cone

A circulating flow of particles

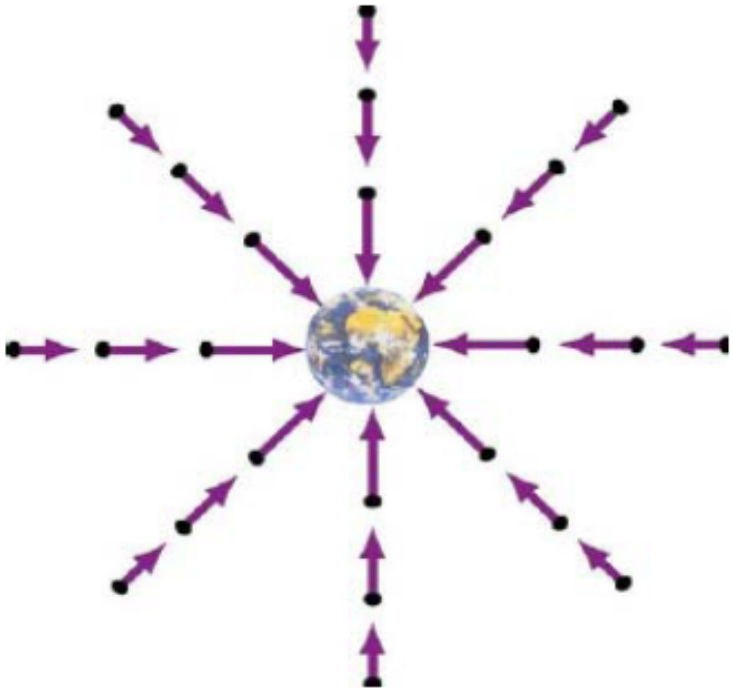


The vector velocities of the particles as seen from above are directed counterclockwise about the center of the cone

Examples of Vector Fields

Gravitational Field

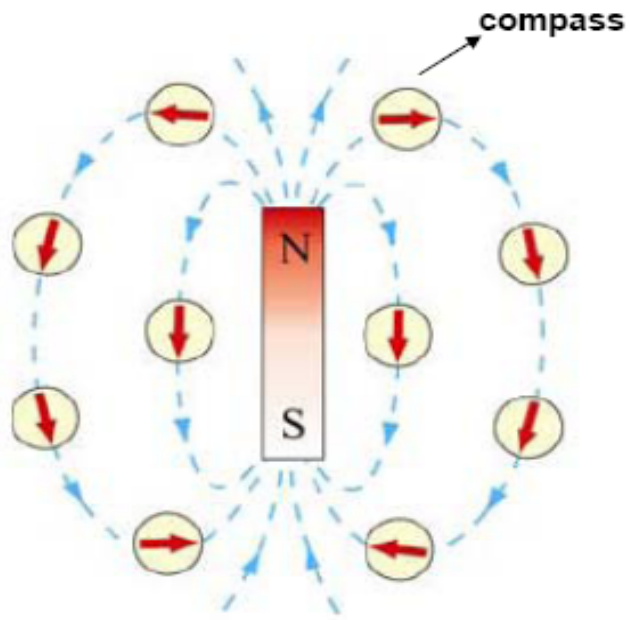
The gravitational field describes the interaction between a massive object and the Earth.



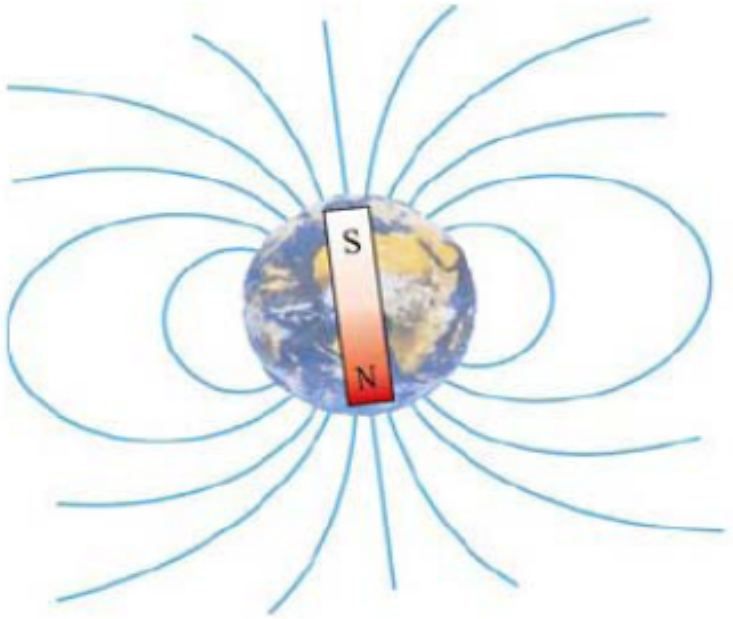
The gravitational field points toward to the center of the Earth.

Examples of Vector Fields

Magnetic Field of a bar magnet



The needle aligns itself along the direction of magnetic field.



The Earth's magnetic field behaves as if there were a bar magnet in it.