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Today

- Announcements:
  - HW#3 is due Wednesday Sept. 28th by 8:00 am.
  - HW#4 is due Wednesday Oct. 5th by 8:00 am.
  - HW#5 on electric and magnetic forces will be due after the exam.
  - The exam #1 review sheet has been posted.
  - Please check your grades on the on-line grade link. I do not have the correct clicker number for several people.
- Videos/ Time Travel/ Electric and Magnetic Forces

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Discussion of the Videos from Last Week

- Knowledge or Certainty – Ascent of Man
- Journeys in Space and Time - Cosmos

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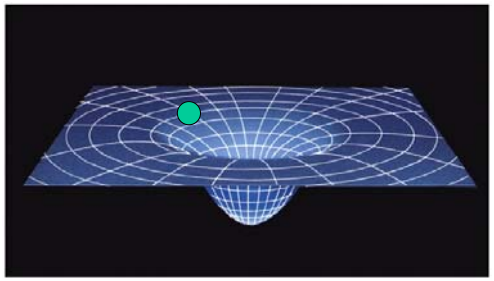
General Relativity

Acceleration in one direction is like gravity in the other direction.



The presence of mass causes space-time to be stretched. Gravity is actually the result of warped space.

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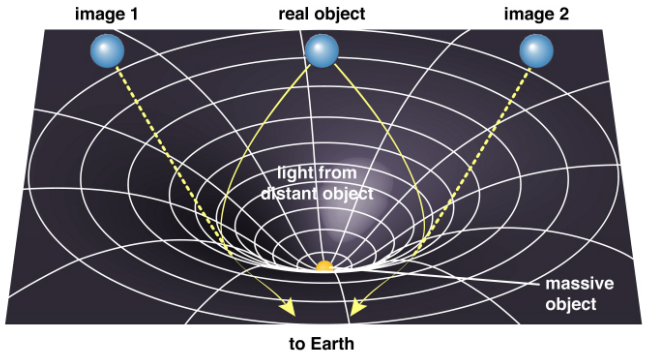
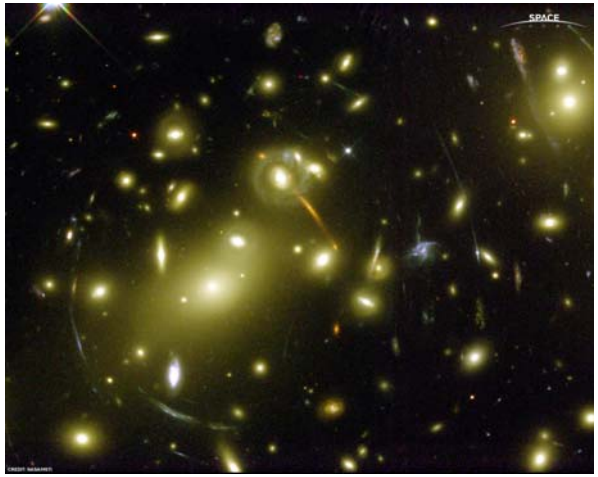
Proof of General Relativity II

Gravitational Lensing: Routinely observed and used to measure the mass of distant clusters of galaxies.

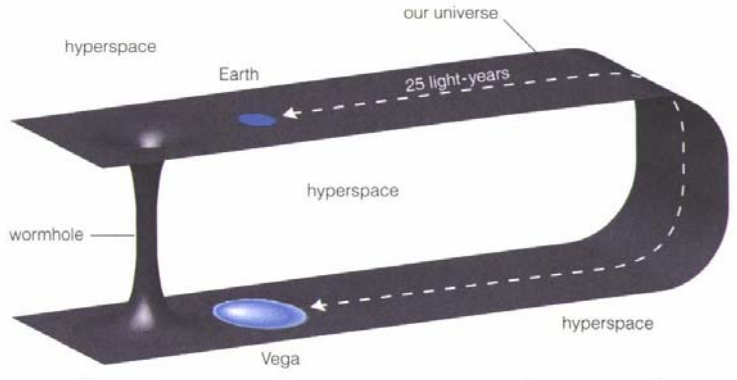


Real picture from the Hubble Telescope



Abel galaxy cluster

Wormholes



This could be the basis for a time machine.

Paradoxes in Time Travel

- If we can travel back in time, it would be possible for use to influence things so that we are not born.
- Three theories to resolve the paradox
  - Travel back in time is not possible
  - There are a very large number of parallel universes
  - Something about nature prevents us from influencing the past

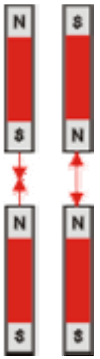
Einstein Equation

$$R_{ij} - \frac{1}{2} R g_{ij} - \lambda g_{ij} = \frac{8\pi G}{c^4} T_{ij}$$

• A tensor equation that describes how space-time is influenced by mass.
• The details of what the symbols mean does not matter. Approximately, the left side is the curvature and motion of space and the right side is the location and motion of mass.
• Rij is the Ricci tensor, g is the metric of space, G is the gravitational constant, etc.

Magnetic Forces

- Ancient Greeks noticed that certain rocks attracted each other – lode stones
- Compass needles point toward the Earth's north pole.
- Magnets come with a north and a south pole – always
- Like poles repel, opposites attract.



Clicker Questions

- Which of the following arrangements would be in equilibrium (stable)?
- A | N S | S N |
- B | S N | N S |
- C

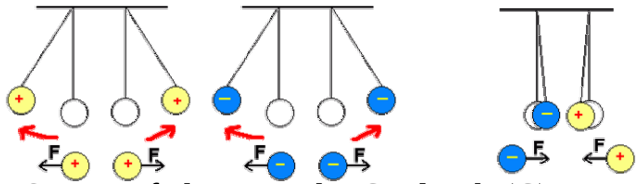
N	S
S	N

- D | N N | N N |
- E

N	S
N	S

Electric Forces

- Charge is a property of matter.
- Like charges repel, unlike charges attract

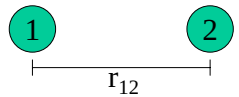


- The SI unit of charge is the Coulomb (C)
- The charge on an electron is -1.6x10^{-19} C, the charge on a proton is +1.6x10^{-19} C.
- The elemental unit of charge is e = 1.6E-19 C; no smaller amount of charge has ever been found.

Coulombs Law

- The force between two charges is:

$$F = \frac{kq_1q_2}{r_{12}^2}; k = 8.99\times10^9\,\frac{Nm^2}{C^2}$$

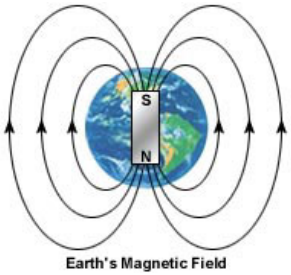


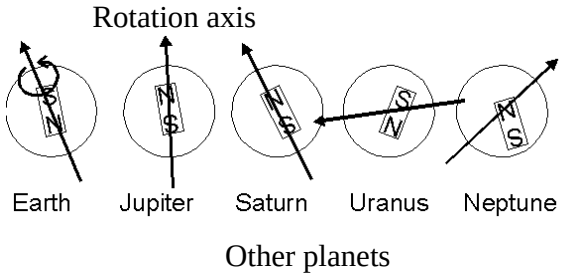
- Example: q1 = 1C; q2 = 3C; r = 1.1 m

$$F = \frac{kq_1q_2}{r_{12}^2} = \frac{8.99\times10^9\,\frac{Nm^2}{C^2}\times1C\times3C}{(1.1m)^2} = 2.23\times10^{10}\ N$$

The Earth behaves as a large magnet

- The Earth is like a large magnet with a south magnetic pole at the North geographic pole.





Clicker Question

If the north pole of a compass points to the north geographic pole of the Earth, what can we say about the Earth's magnetic poles? Choose the wrong answer:

A)The Earth has a south magnetic pole near its North geometric pole.

B) The north pole of a magnet will point to the South geometric pole of the Earth in the southern hemisphere.

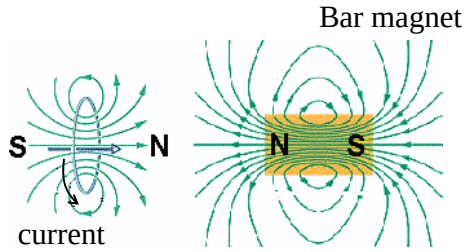
C) A south pole of a magnet will point toward the South geometric pole of the Earth.

D) The Earth has a north magnetic pole near its South geometric pole.

Why does the Earth's magnetic field?

- Moving charge, current, causes a magnetic field.
- Current is the flow of charge (electrons) in a wire, similar to water flowing in a pipe.
- Large scale current in the Earth is due to the liquid core of the earth and its rotation. The exact nature is not known.
- IMPORTANT: Moving charge creates a magnetic field

The correspondence of a loop of current and magnet



Important observations

- The magnetic force and the electric force are related.
- The electric force is much stronger than the gravitational force
  - $k = 8.99E+9\ N\text{-}m^2/C^2$
  - $G = 6.67E\text{-}11\ N\text{-}m^2/kg^2$
- Why?