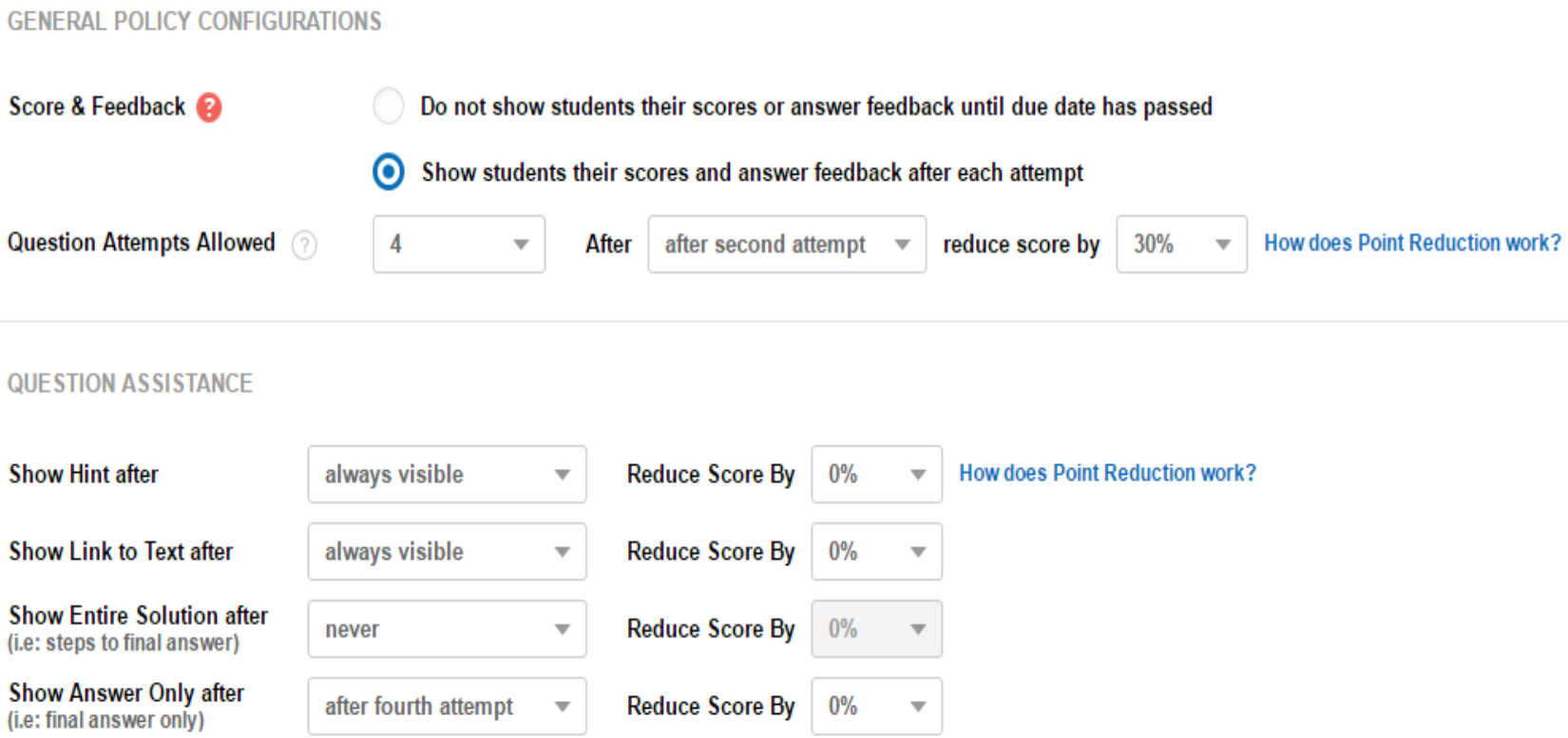
Wednesday Jan 11, 2017

WileyPlus settings

- 4 attempts, 30% deduction after second attempt
- Settings are posted on D2L (folder: WileyPlus)



Today's Lecture

- The language of science and the importance of being specific
- What is a physical theory? How do we know it is correct?
- Forces in nature, electromagnetism
- Introduction to electric charge. What is it? (Hard question to answer!)
- Recent developments in physics (neutrinos)
- Atomic structure

When you hear the word “Energy”, what do you think of?

“Energy” is difficult to consistently define. How we will think of energy in this course:

- The ability of a system to do work
- Can be transformed from one form to another
- Cannot be created or destroyed

A brief glimpse into how I think about energy:

- Contributes to an object’s mass (charged battery, hot object, etc.)
- An object’s momentum through time (from relativity)
- The conserved quantity associated with a symmetry of the laws of physics in time (Noether’s theorem)

The Language of Science:

Words in science have precise meanings that are different from their everyday usage:

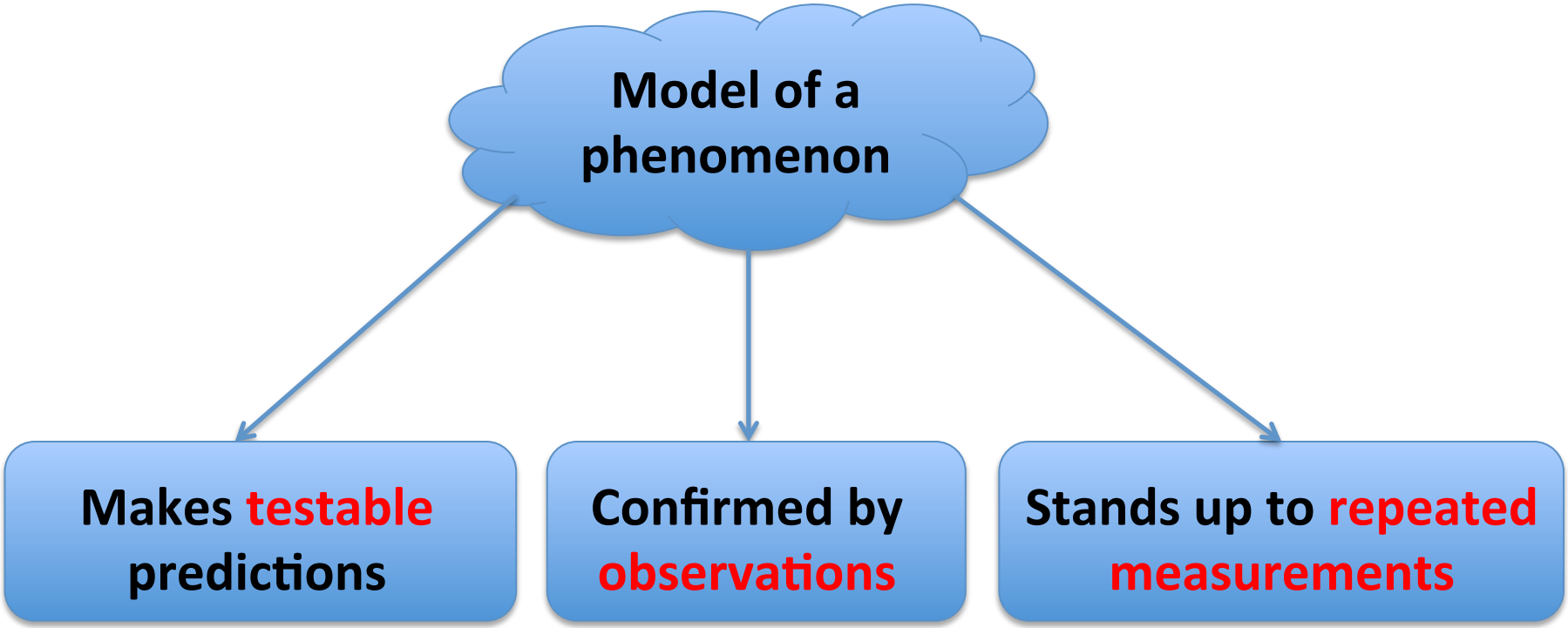
Energy: “you’re giving off good energy”, practically anything in the New Age movement (energy crystals, energy alignment, etc)

Theory: “I’ve got a theory about that…”, “evolution is just a theory” (colloquially used in place of “hypothesis”)

A fun other example:

“I will decimate that ant colony” does not mean you will destroy it.

What is a physical theory?



Lectures

Labatorials

Fundamental characteristics of particles

All fundamental particles can be classified according to two observable parameters: mass and charge.

This simplified model of the Universe is incredibly effective at explaining a wide range of physical phenomena.

All models are wrong, but some are useful. - G. Box

A model is a representation of reality and not reality itself.

Forces in nature

There are 4 fundamental forces in nature (that we know of):

1. Strong Nuclear Force: responsible for holding together protons and neutrons, as well as holding atomic nuclei together. Very short-range (~ 10^{-15} m)

2. Weak Nuclear Force: Responsible for radioactive decay and fusion reactions in the sun. Very short-range (~ 10^{-17} m)

3. Electromagnetic Force: Responsible for nearly everything we observe! Extremely important force to understand. Long range

4. Gravitational Force: Responsible for planetary orbits, holding together galaxies, maintaining an atmosphere. Long range (also not really a force in reality)

Unification of Forces?

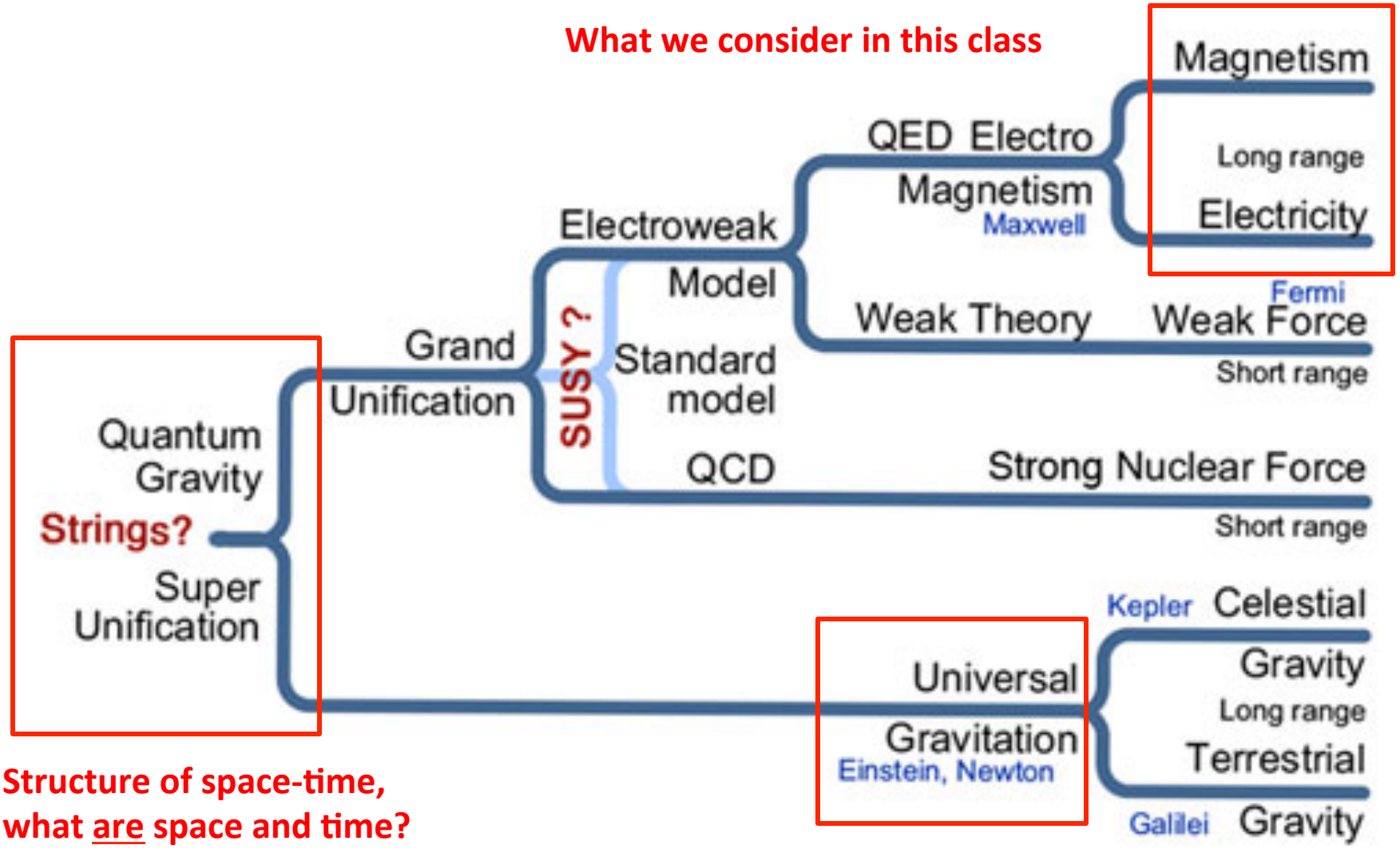


image from http://cmsinfo.cern.ch

What is electromagnetism?

- Electric forces between objects carrying an electric charge.
- Chemical bonds between atoms:
  - Ionic bond is when one atom gives another atom an electron, creating two oppositely charged ions that stick together.
  - Covalent bond is when two atoms share electrons.
- Currents flowing through wires that power electronic devices.
- Magnetic forces between objects carrying electric currents.
- The force responsible for keeping me from falling through the floor.
- Much, much more.

Key concepts

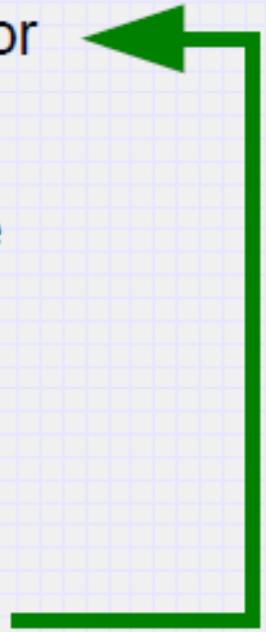
Matter is composed of charged particles and charge is conserved.

Charges can produce electric forces (Coulomb's Law) or electric fields (Gauss's law).

Electric forces or fields can move charges and produce currents (Ohm's law).

Currents can produce magnetic fields (Biot-Savart law, Ampere's law).

Changes in magnetic fields can produce electric fields (Faraday's law).



Maxwell's equations

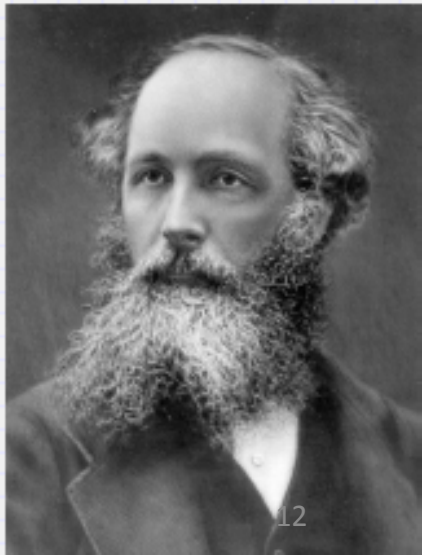
$$\oiint \vec{E} \cdot d\vec{A} = \frac{Q_{enclosed}}{\epsilon_0}$$ Gauss's law for electricity

$$\oiint \vec{B} \cdot d\vec{A} = 0$$ Gauss's law for magnetism

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 \left(i_c + \epsilon_0 \frac{d\Phi_E}{dt} \right)$$ Ampere's law

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt}$$ Faraday's law

James Clerk Maxwell
1831-1879



What is an electric charge?

- Hard to fundamentally define at this stage. Try it! Think, Pair, Share (TPS) exercise.

Step 1: Write something down by yourself without talking to a neighbour.

Step 2: Discuss your answer with a neighbour and come to a consensus.

Step 3: Share what you have so we can come to a consensus as a class

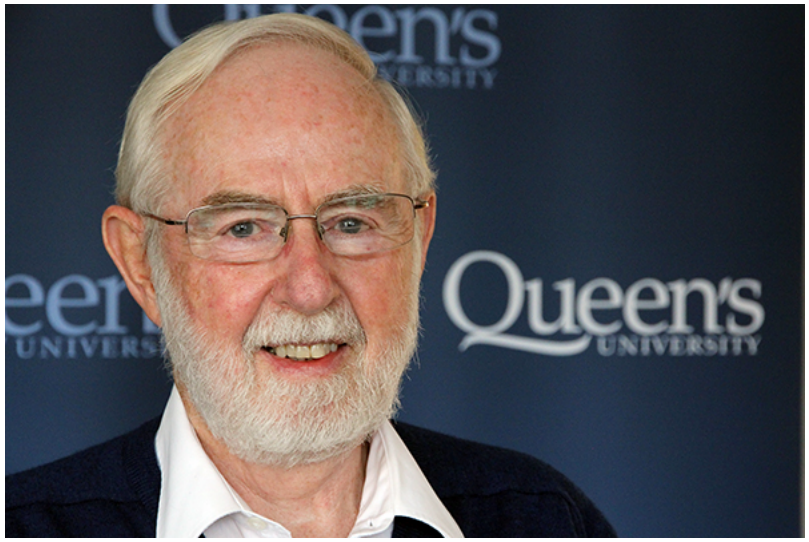
What is an electric charge?

- An intrinsic property of particles: electrons (–) and protons (+)
- A quantity that determines the strength of the electric force between two objects.
- Can't be created or destroyed*
- Can transfer from one object to another
- Like charges repel, opposites attract

Where does charge come from? In reality, there is a symmetry in the equations of quantum electrodynamics. A symmetry always implies that something is conserved!

Nobel Prize in Physics 2015

For the experimental verification that neutrinos have mass



Arthur McDonald
SNO Lab

Takaaki Kajita
Super Kamiokande

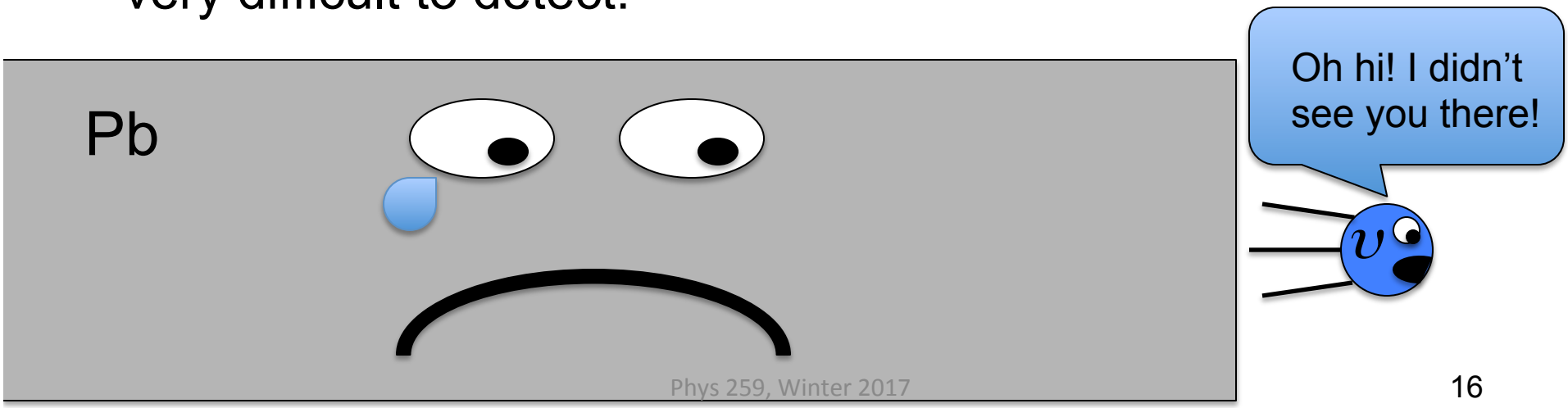
image from http://queensu.ca

Neutrinos

Very light subatomic particles that are electrically neutral and only interact with other particles via the weak nuclear force. Emitted in radioactive decay and nuclear fusion.

Trillions of neutrinos originating from the sun are passing through you at any given moment, day or night.

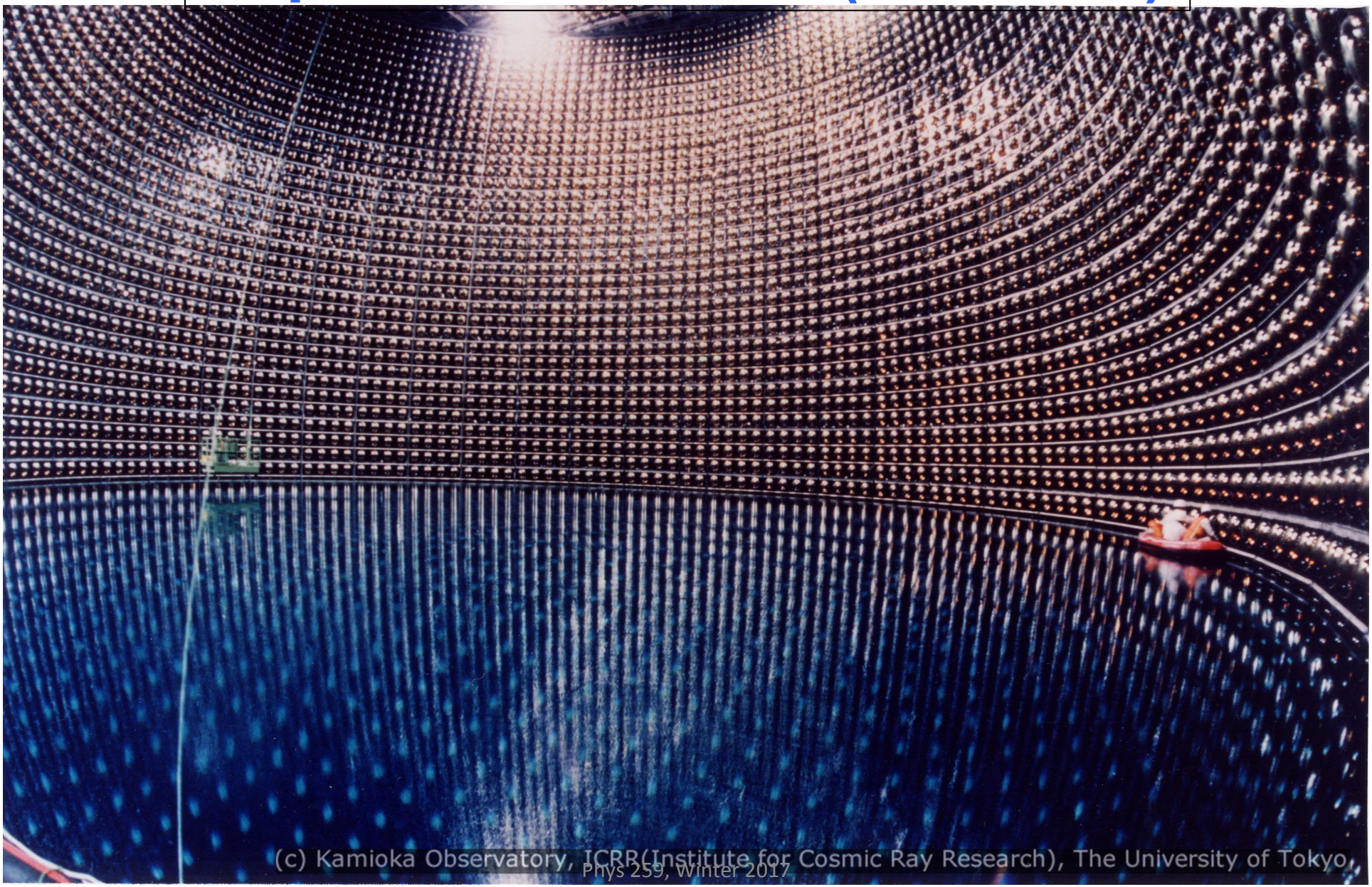
A neutrino can pass through a slab of lead that is one lightyear thick without hitting anything; this makes them very difficult to detect!



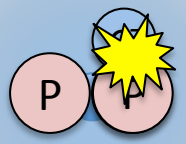
Sudbury Neutrino Observatory (SNO)

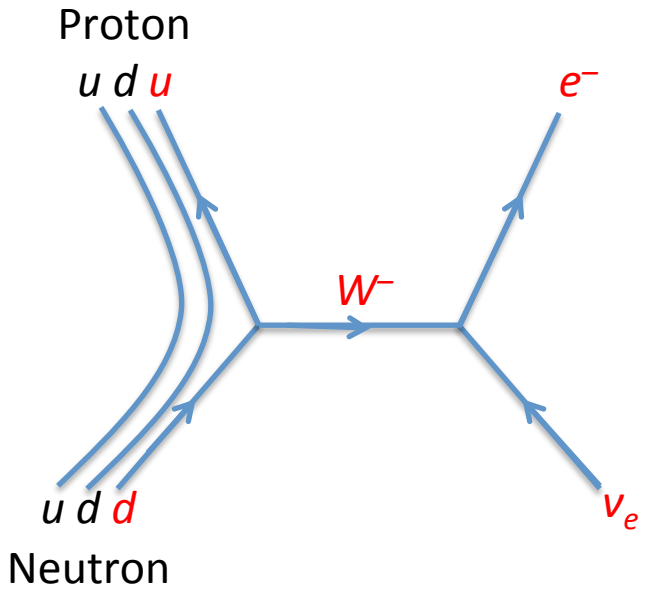
image from http://wisesudbury.ca

Super Kamiokande (Kamioka)



Reactions being looked for





Deuterium + $\nu_e \rightarrow {}^2He^+ + e^-$

$n + \nu_e \rightarrow p + e^-$

How does this tie in with E&M?

- Cerenkov radiation by the emitted electron
  - Electrons have an **electric charge**
  - Electrons are easily **accelerated** by other charges
  - Accelerated charges **emit photons**
  - The electron is traveling faster than the speed of light **in water**
  - Accelerated electron emits a **cone of light** (like when planes hit the Mach barrier
  - Light rings **detected by the PMTs** lining the tank