Junior Seminar Topics

Below are listed several possible topics for junior seminars. The idea of these talks is to present a topic of current interest in physics, and to perform a related calculation using principles in introductory or intermediate physics classes. The topics should be linked to current physics research, thus making them appropriate for a "seminar." The parameters required for the calculations are not all given in a textbook; students must find "typical values" for masses, distances, intensities, etc.. (3) At least some aspect of each topic is open-ended; students can do additional research (for instance on the web) to find out additional cool things about the topic that will make for a good and lively presentation.

These are just possibilities – if you want to do something else, that's great!

Nature of Dark Matter and Dark Energy
It appears that visible matter in the universe (the stuff we are made of) accounts for only a small fraction of the mass of the universe. What is known and unknown about the nature of dark matter and dark energy? How can we detect it? Are there any experiments trying to do that? How do they detect it?

The lifetime of the neutron
How is the lifetime of the neutron measured? How precise are the measurements? What do we learn from them?

The radius of the proton
Recent measurements of the proton radius conflict with longstanding results from older experiments. How is the proton radius measured? How big is the conflict? If the difference is real, what does it mean?

What is the origin of the elements in the cosmos?
How are atomic nuclei in the universe produced and where?

What is the heaviest nucleus ever observed?
How is it produced? How long is its lifetime?

What are gravity waves?
How are they produced? How are they detected? What do we learn?

What is supersymmetry?
What does it explain? How is it tested? Are there experiments being done to test it?

What is neutrinoless double beta decay?
Why is it important? How is it measured? Are there experiments underway to make those measurements?

What is the proton spin crisis?
What is spin? How does the proton get its spin? Why is there a crisis?

Superconductivity Superfluidity
How does superconductivity arise? What materials have been shown to be superconducting? How does superfluidity arise?

Black holes and entropy
What is the connection between black holes and thermodynamics? What is the information loss paradox?

The Future of the Sun
What's going to happen to the Sun when it ends its natural life? When will that happen?

Sunquakes (helioseismology):
One of the few ways we have of probing the interior of the Sun is by observing the vibrations of its surface. How are such studies performed, and what do we learn from them?

How does the sun burn?
One of the great success stories of 20th century physics, explaining the nuclear physics mechanisms by which the sun continues to burn.

Physics of Earthquakes:
Different kinds of waves travel through the Earth after an earthquake. What are these different kinds of waves, and how can we use them to figure things out about the interior of the Earth?

How do we detect nuclear explosions?
North Korea occasionally sets off a nuclear bomb underground. How do we know it went off? How do we distinguish between a nuclear explosion and an earthquake?

Magnetic fields of Earth and other planets:
What causes them? Why do some planets have them and not others?

Planets orbiting other stars.
How do we discover such planets? How many are there? A big goal for the future is to image the planets directly (as opposed to just studying their effects on the stars). Why is that hard to do, and what solutions are being proposed to get around these problems? What would we learn if we could produce such images?

Sizes of particles:
How do we know the diameter of a proton? As far as we can tell, the diameter of an electron is consistent with being zero. What are the results of the best attempts to measure the diameters of electrons and other fundamental particles?

Units of Measurement:
This sounds kind of dull, but it's more interesting than it sounds. How is the meter defined? How about the kilogram? How have these definitions changed over time? In

the case of the kilogram in particular, changes in the standard definition have been proposed. What are the advantages / disadvantages?

Are the constants constant?
Experiments have attempted to determine whether constants such as the speed of light really are constant, or whether they slowly change with time. How do these experiments work, and what results have they found?

Nuclear Power:
How does a nuclear reactor work?

Radiation detection:
Suppose we want to scan cargo entering the US for evidence of nuclear material (e.g., a "dirty bomb"). How can this be done reasonably efficiently? What are the issues associated with it?

Neutrinos
Neutrinos are subatomic particles given off in nuclear reactions, such as in the sun. They interact only weakly with regular matter.

a) How many kinds of neutrinos are there?
b) Calculate how many of them pass through your body each day.
c) How do we detect neutrinos?
d) Nowadays, most experts believe that neutrinos have mass. What's the evidence for this?

Trajectories of interplanetary probes
Spacecraft like the Mercury Messenger mission, and the latest probe to Pluto need very accurate tracking to reach their destinations without either missing the planet completely or smashing into it.

a) How are spacecraft tracked so precisely?
b) What is the "slingshot effect" and how is it used to increase speeds? (We've heard about this aspect in seminars in the past year or so, so probably better not to emphasize this part.)
c) When we send missions to Mars, what paths do the spacecraft typically follow, and why?

Acoustics of a concert Hall
There are tons of cool physics ideas involved in designing the ultimate performance space … this allows you to investigate two of your passions, physics and music!

Sono-luminescence
Flashes of light observed from collapsing bubbles … in beer? That would be way too good to be true, yet sono-luminescence is a real phenomenon. Check it out.

Sailing on Sun Shine
How do you design a sailboat to sail between the planets powered only by the rays of light from the Sun …

Will CERN destroy the Earth?
Another broad class of possible topics is **new experiments or instruments** being built these days. In these cases, the talk would be a description of how the instrument is supposed to work and what sorts of science questions it's supposed to address:

- Large Hadron Collider at CERN in Switzerland.
- Some other current particle accelerator (maybe RHIC, Jlab, FRIB)
- Free electron laser (at JLab or elsewhere)
- ITER, a huge nuclear fusion experiment being planned
- Probably lots of others …

Statistical Mechanics applied to a flock of Birds (or to magnets!)

Swarm Robotics

Atom Trapping
Some of the "coolest" experiments in physics in the last decade or two involved trapping single particles in magnetic or optical traps. These traps enable a variety of fundamental physics experiments

Trapping anti-atoms
See above.

Imaging
Advances in imaging (including devices such as our own AFM) enable imaging and atomic engineering down to the individual atom level. Experimenters are now able to arrange individual atoms on surfaces to enable fundamental quantum physics experiments or to engineer logic circuits based on individual atoms.

Low energy nuclear physics
The US is currently investing $600+M to build and instrument the FRIB (Facility for Rare Isotope Beams) accelerator at MSU. What science will be enabled by FRIB?

Intermediate energy nuclear physics
The US recently upgraded the JLab facility to enable higher energy (12GeV) electron beams. What new science does the enhanced facility address?