Introduction to English for Scientific Communication
Homework 3 – Sample Answer

This is a short sample passage written by Jonathan White on a subtheme of the main theme 'particles'.

Section 1: First we need to determine the theme for your short passage, as the main theme of 'particles' is too large to write all the possible information in 3 to 4 paragraphs. Try to write down 6 or 7 ideas for the theme for you passage. Please discuss with the people next to you.

1) Wave particle duality

2) Symmetries and the Standard Model

3) Particle accelerators and detectors

4) Neutrinos

5) The Higgs particle

6) Super-luminal neutrinos

7) Particles beyond the Standard Model

Section 2: Choose the idea you want to write about and write it down as a full sentence.

Neutrinos, although originally thought to be massless, have been observed to oscillate between different flavour states, hinting at physics beyond the Standard Model.

Section 3: Now, think of some ideas for the topics you will use to discuss the theme you decided on in Section 2.

1) Beta decay and the original motivation for neutrinos

2) Solar neutrino oscillations and the experiment by Raymond Davis Jr.

3) Kamiokande

4) Symmetries of the Standard Model and massless neutrinos

5) Cosmological neutrinos and the Cosmic Microwave Background

6) Cosmological Neutrinos and large scale structure

7) Cosmological neutrinos and Dark Matter

8) Cosmological constraints on the number of neutrino species and their mass

9) Neutrino-less double-beta decay. Majorana or Dirac neutrinos?

10) Neutrinos as useful probes and evidence of physics beyond the Standard Model

Section 4: Now choose 3 or 4 of these ideas and put them in the order in which you will write them. Make sure that the order makes logical sense.

1) Neutrinos as useful probes in place of other radiation and evidence of physics beyond the Standard Model

2) Beta decay and the original motivation for neutrinos

3) Solar neutrino oscillations and the experiment by Raymond Davis Jr. as evidence that neutrinos cannot all be exactly massless

4) Remaining questions about neutrinos: what is their absolute mass scale? Are they Majorana or Dirac neutrinos?

Section 5: Write an essay about the title you decided in Section 2 using the topics decided in Section 4.

Neutrinos, despite their modest appearances, continue to be the focus of cutting edge research in many research communities around the world. As their name implies, literally meaning "the little neutral ones", neutrinos are electrically neutral, very light elementary particles that interact only very weakly with other particles via the weak interaction. These properties make neutrinos ideal for probing environments that other radiation cannot penetrate, such as the core of the sun and other astrophysical sources. Furthermore, the fact that their masses are tiny, rather than exactly zero, is of great importance in cosmology and particle physics. In cosmology, the non-zero mass of neutrinos could account for some portion of the elusive Dark Matter, which remains one of the unsolved mysteries of our universe. In particle physics, the observation that neutrinos are not exactly massless is evidence for physics beyond the Standard Model, and offers exciting challenges for both theorists and experimentalists alike.

It was in the 1930s that the theorist Wolfgang Pauli first proposed neutrinos in order to explain a puzzling feature observed in nuclear beta decay. In beta decay an electron is emitted and the fact that energy is conserved allows us to predict the energy of this electron. Observed electron energies, however, were not found to match this prediction, instead being spread over a broad range of energies. Rather than abandoning the assumption that energy is conserved, Pauli suggested that an undetected neutral particle is emitted alongside the electron, and that the sharing of energy between the decay products was the cause for the spread in electron energy. This suggestion turned out to be correct, and a few years later Enrico Fermi developed a theory to describe beta decay, naming the undetected neutral particle the neutrino. Over the following decades the existence of three different flavours of neutrino has been confirmed, namely the electron, muon and tau neutrinos, and these form part of the Standard Model of particle physics.

Whilst the neutrinos in the Standard Model were originally taken to be massless, experimental evidence for the oscillation of neutrinos between different flavour states now tells us that they cannot all be exactly massless. Key in the discovery that neutrinos can oscillate between flavour states was an experiment pioneered by Raymond Davis Jr. to detect the neutrino flux from the sun. The number of electron neutrinos measured was far too few, being only one third the number predicted by solar models, and this deficiency is now attributed to the fact that electron neutrinos oscillate into muon and tau neutrinos on their journey from the sun to the earth. A theoretical implication of neutrino oscillations is that neutrinos cannot all be massless or all have identical masses, meaning that at least one of the neutrinos must have a non-zero mass. This in turn points to physics beyond the Standard Model of particle physics.

The discovery of neutrino oscillations and its implication of physics beyond the Standard Model is certainly an exciting development in the field of neutrino physics, but there still remain many open questions and challenges ahead. For example, neutrino oscillation experiments only probe the differences in the masses of the neutrinos, meaning that the task still remains to determine the absolute mass scale. Another open question is whether neutrinos are Majorana or Dirac neutrinos, that is, whether or not they are their own anti-particles. With such challenges and questions still remaining, neutrino physics promises to remain an exciting field in which to work for many years to come, and the seemingly modest particles can continue to enjoy the limelight.

Reference: Physics for the 21st Century

http://www.learner.org/courses/physics/index.html