

NEUTRINOS

- I. 1. What is a neutrino? How much do you know about it?
2. How has this discovery changed the world of physics?
- II. Put the verbs in brackets into their proper form, add prepositions where necessary.
Then have a guess and try to match the passages with dates;

A Brief History of the Neutrino

1931, 1934, 1959, 1962, 1978, 1985, 1987, 1989, 1989, 1994, 1997, 1998

- The tau particle (**discover**) at SLAC, the Stanford Linear Accelerator Center. It is soon recognized to be a heavier version of the electron and muon, and its decay (**exhibit**) the same apparent imbalance of energy and momentum that (**lead/Pauli/predict**) the existence of the neutrino in 1931. The existence of a third neutrino associated with the tau is hence inferred, although this neutrino (**have to/yet/observe**).

- A hypothetical particle (**predict**) the theorist Wolfgang Pauli. Pauli's prediction (**base**) the fact that energy and momentum (**not appear/conserved**) certain radioactive decays. Pauli suggested that this missing energy might be carried off, unseen, by a neutral particle which was escaping detection.

- Enrico Fermi develops a comprehensive theory of radioactive decays, including Pauli's hypothetical particle, which Fermi coins the neutrino (Italian: "little neutral one"). With inclusion of the neutrino, Fermi's theory accurately explains many experimentally observed results.

- Discovery of a particle (**fit**) the expected characteristics of the neutrino (**announce**) Clyde Cowan and Fred Reines (a founding member of Super-Kamiokande; UCI professor emeritus and recipient of the 1995 Nobel Prize in physics for his contribution to the discovery). This neutrino (**later/determine/be**) the partner of the electron.

- Kamiokande, another large water detector looking for proton decay, and IMB detect a simultaneous burst of neutrinos from Supernova 1987A.

- Experiments at Brookhaven National Laboratory and CERN, the European Laboratory for Nuclear Physics make a surprising discovery: neutrinos produced in association with muons (**not behave/the same**) those produced in association with electrons. They have, in fact, discovered a second type of neutrino (the muon neutrino).

- A Russian team reports measurement, for the first time, of a non-zero neutrino mass. The mass is extremely small (10,000 times less than the mass of the electron), but subsequent attempts to independently reproduce the measurement do not succeed.

- Experiments at CERN's Large Electron-Positron (LEP) accelerator determine that no additional neutrinos beyond the three already known can exist.

- The Soudan-II experiment becomes the first iron detector (**observe**) the disappearance of muon neutrinos. The rate of disappearance agrees with that observed by Kamiokande and IMB.
- Kamiokande finds a deficit of high-energy muon-neutrino interactions. Muon-neutrinos (**travel**) the greatest distances from the point of production to the detector exhibit the greatest depletion.
- The Frejus and NUSEX experiments, much smaller than either Kamiokande or IMB, and using iron rather than water as the neutrino target, report no deficit of muon-neutrino interactions.
- The Super-Kamiokande collaboration announces evidence of non-zero neutrino mass at the Neutrino conference.

III. Read through the script. Try to guess the phrases that should fill the gaps. Then watch the video and complete the script below with missing information (source: <http://www.nobelprize.org/>)

Next we're going to listen to the Nobel lecture by professor Koshiba. He also detected neutrinos in an equally 1 _____, by different method. He used a large 2 _____ to detect neutrinos in Japan, in the Kamiokanda experiment, in which neutrinos scatter electrons and 3 _____ is generated that can be detected by 4 _____ photodetectors. This way one can detect not only the neutrinos that there are there, but also the 5 _____. Koshiba's experiment confirmed so far reached results of 6 _____ neutrinos. Then, in addition, on February 23, 1987 Koshiba's detector reads that 12 out of the 7 _____ that were sent out from an 8 _____ a 170 000 light years from the Earth, a truly remarkable observation of neutrinos emanating from 9 _____.

IV. Passive Voice is very often used to describe scientific research, as you may see in exercise I.

A. Using the passive form of the underlined verb phrases, make the necessary changes to the sentences. Include the agent, unless it is in brackets. (source: Paterson, Ken: 2013, *Oxford Grammar for EAP, OUP*)

1. Local communities can make simple changes to aid biodiversity, according to Shalmi (2012).
2. Most people would prefer (the relevant authorities) to consult them before a flight path is permanently re-routed over the area where they live.

3. Middleton (2011) argues that better quality healthcare could prevent more than 100,000 deaths per year in the UK.
4. Holstein (209) describes (an official) questioning him for three hours in a threatening manner at Los Angeles International Airport.
5. BAA are piloting a system that will allow (officials) to examine hand luggage more efficiently.
6. If an accident victim is unconscious, (someone) should check his or her breathing regularly.

B. We often start a passive sentence with a phrase:

It is/was/has been ***believed*** that...

Come up with as many passive reporting verbs, like *believe* in the example above, as you can.