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First Steps for a “Particle Physics Concept Inventory”

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Motivation

- No such inventory was known to us
  - Later, we discovered “Nuclear Physics Conceptual Diagnostic Survey” (Kohnle, Mclean and Aliotta, 2010) and just have made a contact
- An exciting part of physics connected with many outreach activities in the Czech Republic
- Inspiration by the Force Concept Inventory (Hestenes, Wells & Swackhamer, 2), the Calculus Concept Inventory (Epstein, Sep 2007) and similar concept inventories.

Item examples

The whole current version v 0.80 available from the author or through QR code

3. Select the radiation, which increases the proton number by 1, and the nucleon number stays the same after its emission.
   - **A** Alpha radiation
   - **B** Beta radiation
   - **C** Gamma radiation
   - **D** Neutron radiation
   - **E** There is no such type of radiation.

6. How many neutrons are released in the following reaction?

$$^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \longrightarrow ^{139}_{56}\mathrm{Ba} + ^{95}_{36}\mathrm{Kr} + x \cdot ^{1}_{0}\mathrm{n}$$

   - **A** $x = 0$
   - **B** $x = 1$
   - **C** $x = 2$
   - **D** $x = 3$
   - **E** $x \geq 4$

7. The K-capture is a type of radioactivity when an electron from a K-electron shell is captured by the nucleus (K-electron shell is the closest shell to the nucleus). In the nucleus, the electron interacts with a proton and the product of this reaction is a neutron. Which kind of radiation are we able to detect in the vicinity of such radioactive element?
   - **A** Electrons or positrons
   - **B** Photons
   - **C** Helium nuclei
   - **D** Muons
   - **E** Neutrons

12. A nucleus of the $^{238}_{92}\mathrm{U}$ undergoes a natural decay. The products are $^{234}_{90}\mathrm{Th}$, and alpha radiation ($^{4}_{2}\mathrm{He}$). In this process, some energy is released in the form of the kinetic energy of the products. What part of the total kinetic energy is taken by the alpha particle? Suppose that the $^{238}_{92}\mathrm{U}$ was at rest and the only two non-negligible products of the decay are these two nuclei.
    - **A** No energy
    - **B** Some part of the total energy, less than one half
    - **C** Exactly one half of the total energy
    - **D** More than one half of the energy, but not all of it
    - **E** All the energy

13. One of the known types of radioactivity is neutron radiation. In a nuclear reactor, we want to slow neutrons down to increase the probability of their interaction with another nucleus. Which of the following materials is the most suitable for moderation? We are interested in the highest velocity decrease after the same number of collisions. Suppose that the moderation is done by perfectly elastic collisions.
    - **A** Water
    - **B** Graphite (carbon)
    - **C** Lead
    - **D** Uranium

14. We have a material that undergoes beta decay. We also have a detector which can measure beta particles and determine the basic information about their direction and energy. Could we discover using such equipment, that another unobserved particle is emitted? (Not a proton, antiproton, electron or positron; namely neutrino or antineutrino which cannot be measured.)
    - **A** Yes, from the spatial distribution of the beta radiation particles.
    - **B** Yes, from the various kinetic energies of the emitted particles.
    - **C** Yes, from the time fluctuation of the sample activity.
    - **D** Yes, from the beta radiation polarisation.
    - **E** No.

16. The usual range of alpha particles from radioactive sources in the air is approximately 6 cm. What would be the range of the same particles in an ideal vacuum?
    - **A** 0 cm (They cannot propagate in the vacuum.)
    - **B** 6 cm
    - **C** More than 6 cm, but a few meters at maximum
    - **D** Infinite
    - **E** The answer depends on the particular alpha source.

19. We have a sample of 10 000 radioactive nuclei. Their half-life is 10 minutes. How many particles decay most probably during the first minute?
    - **A** 341
    - **B** 500
    - **C** 670
    - **D** 1 000

20. Suppose we have a radioctive material with the activity $A = 1\,000\,\mathrm{Bq} = 1\,000\,\mathrm{s}^{-1}$. How many radioactive decays should we expect during one second? (We are interested in the ideal situation. The products are not radioactive. Disregard the imperfection of detectors.)
    - **A** Precisely 1 000
    - **B** Surely $1\,000 \pm 10$
    - **C** With the probability of 98 % to the $1\,000 \pm 10$ changes
    - **D** With the probability of 68 % k $1\,000 \pm 32$

Basic parameters

Described on the first page:

version 0.80

PLEASE READ THE INSTRUCTIONS!

Do not turn the page until instructed otherwise.

Dear participant!

This test is part of a study trying to improve the teaching and learning of the basic concepts of particle and nuclear physics. It is vital that you take the test seriously and do the best you can in it.

Thank you for your contribution and for your time!

- **No other equipment** is allowed **except for pens** and the test itself. You can use the free space around the questions for your calculations. In problems requesting a number, as a result, it is sufficient to do approximate calculations without a calculator.
- Answer directly into the test by making a circle around the letter of your selected choice.
- Each question has **one correct answer**. If you think that there are more partly correct answers, select the one you consider the most accurate.
- If you do not know the answer at all, do not answer. If you have some idea about it and you are sure that some answers are not correct, you can make an educated guess.
- The problems are **not ordered by the difficulty**. Since you have limited time, if you do not know the answer quickly, skip it and return later.
- The test is still under development. We welcome your comments written in the free space.
- You will have **30 minutes** for **31 questions**.

Name, surname: ______________________

Course/school: ______________________

Experiences with nuclear and particle physics: ______________________

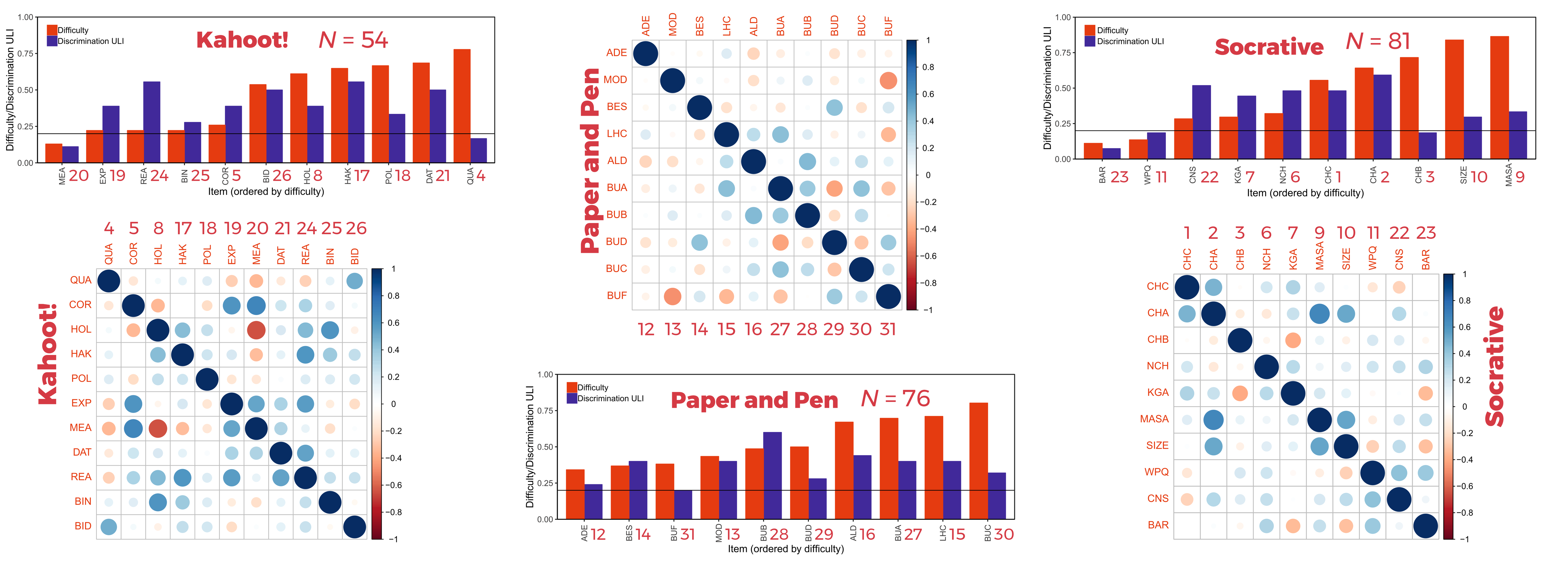
e.g., a study of literature, watching videos, lectures, study visit in CERN, …

Results from “pseudopilot”

experimentally administered, not the expected results

further work needed

traditional Item analysis + correlation structure (merely a brief example of the applied statistics)



item numbers are according to the version 0.80

graphs made by ShinyItemAnalysis (Martinková & Drabinová, 2018)

Example of items development

Current version

https:/karelk.cz/ppci-test

Please, report all found “bugs” and ideas for improvements to **karel@fykos.cz**

References

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The physics teacher, 30*(3), 141-158.

Epstein, J. (2007, September). Development and validation of the Calculus Concept Inventory. In *Proceedings of the ninth international conference on mathematics education in a global community* (Vol. 9, pp. 165-170). Charlotte, NC.

Kohnle, A., Mclean, S., & Aliotta, M. (2010). Towards a conceptual diagnostic survey in nuclear physics. *European Journal of Physics, 32*(1), 55.

Martinková, P., & Drabinová, A. (2018). ShinyItemAnalysis for teaching psychometrics and to enforce routine analysis of educational tests. *The R Journal, 10*(2), 503-515. doi: 10.32614/RJ-2018-074.

Acknowledgement

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Font Awesome

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