

FYS-KJM3506 and FYS-KJM4506 – exam questions

November 2025

The questions below are meant to help you prepare for the exam. You will be asked some of these questions at the exam, possibly with follow-up questions.

Basic nuclear processes in radioactive sources:

1. What is internal conversion? When does internal conversion happen?
2. Are beta electrons suitable for calibrating electron detectors? Why?
3. Give an example of a process to create fast positrons and a good positron emitter source. Can you give examples of good gamma-ray calibration sources?
4. What are sources of charged particles? Give examples.
5. What is a half-life in a given radioactive decay? Why is it important?

Passage of radiation through matter:

1. How do heavy charged particles lose energy?
2. Explain the terms of the Bethe-Bloch equation. What processes are important at different particle momenta?
3. What corrections are important at what energies?
4. What is a Bragg peak? Which domains do use it? Can you give an example?
5. What makes electrons different compared to heavy charged particles with respect to their interactions with material?
6. Explain bremsstrahlung. When is it a dominant process?

7. How do gamma rays interact with matter and cause ionisation? Explain the most important processes.
8. A gamma ray sees electrons of the atoms in two different ways. Can you explain them and why?
9. How do the cross sections of the different processes depend on energy and detector material characteristics for a gamma-ray interaction through matter?
10. If we want to measure the energy of the incoming gamma ray, what process is the most ideal one?
11. How does a neutron interact with matter in general? What type of processes might occur depending on neutron's being fast or slow?

General characteristics of detectors:

1. Why is energy resolution important for a given radiation? Can you give an example of "poor" and "good" resolution?
2. What is the Fano-factor and how is it related to the FWHM energy resolution of a detector?
3. What is detection efficiency? What factors does the detection efficiency depend on?
4. Why is the dead time of a detection system important? What are different contributions to the total dead time of a given measurement?
5. Can a given type of detector be sensitive to all types of radiation? Explain the reasoning.

Ionization detectors:

1. Describe (briefly) the operational modes of gaseous ionisation detectors at different voltages between anode and cathode.
2. Mention some factors important for the number of created electron-ion pairs and for the energy resolution, when a particle deposits a certain amount of energy.
3. Mention some processes hampering the collection of electron-ion pairs in gasses.
4. Describe the development of an electron-ion avalanche in a gas counter.
5. Explain (qualitatively) the principle of operation for a cylindrical proportional counter.

6. Mention some important factors regarding the choice of gas / gas mixture for an ionisation detector.
7. ~~Describe the principle of operation for a multiwire proportional chamber, and the extraction of 2D position information.~~
8. ~~Describe the principle of operation for a drift chamber.~~

Scintillation detectors:

1. How do scintillator detectors work? What is the mechanism of a scintillator detector independent from its type? What properties are important to look at when comparing various types of scintillator materials?
2. Explain how scintillation light is produced in inorganic scintillator materials and why we dope inorganic scintillators.
3. Explain how an organic scintillator produces light. What is the desired process?
4. Compare organic and inorganic scintillators. List the main differences.
5. How can you estimate the (statistical) energy resolution of an inorganic scintillator detector? Feel free to give numerical explanations.
6. Which scintillator detector is optimum for:
 - beta particles
 - alpha particles
 - gamma rays
 - neutrons
7. What are the advantages of $\text{LaBr}_3(\text{Ce})$ detectors compared to $\text{NaI}(\text{Tl})$ detectors?
8. Compare a typical gamma-ray pulse-height spectrum in organic and inorganic scintillator detectors. Which one would you choose for energy measurements?
9. Explain how a photo-multiplier tube (PMT) works and what it is used for. Draw and explain.

Semiconductor detectors:

1. Why do we prefer germanium ($Z=32$) to silicon ($Z=14$) for gamma-ray detection? Can you explain by giving numerical values?

2. Describe (briefly) what characterises a semiconductor material, and the most important differences between silicon and germanium.
3. Explain what characterises n- and p-doped semiconductors, and how a pn junction works.
4. What is the depletion layer, and what determines its thickness?
5. Explain how a signal from the passage of a charged particle is generated and collected in a semiconductor detector. What are the main differences from a gas detector?
6. What are the charge carriers in semiconductor materials?
7. Should a preamplifier amplify the signal from the detector output significantly? Why should a preamplifier be located very close to the germanium detector output?
8. Why do you have to cool Germanium detectors? Explain why it is important to increase the bias voltage in small steps.
9. What is the effect of Compton suppression? What type of detectors are used for Compton suppression? And why?
10. Describe (briefly) the working principles of some types of position-sensitive Si detectors.
11. What is the reason of using high segmented or high-pixel silicon detectors?

Pulse signal processing:

1. What is a CR circuit and why is it used at the detector output?
2. Explain the main characteristics of a pulse signal after Preamplifier. Feel free to draw the signal.
3. What are the purposes of using Preamplifiers? Can they be placed far from the detectors? Explain your reasoning.
4. Among NaI(Tl), HpGe, ionization detector, proportional counter and GM counters which ones need pre-amplification and which do not? Explain your reasoning.
5. Signals from detectors and pre-amplifiers have to be processed. What are our reasons for amplifying and shaping signals?
6. Why is the electronic noise very important for germanium detectors but not very vital for NaI(Tl) detectors? (Hint: think about FWHM and energy resolution)

Electron, gamma, particle spectroscopy in Nuclear Physics:

Heavy-charged particles

1. Can we use the Bethe-Bloch formula for the $\Delta E - E$ technique for particle identification in nuclear physics experiments? Explain how.
2. Which detectors are typically used for Particle identification?
3. What are the main reasons for choosing silicon or ionization chambers for charged particles for a given experiment?

Electrons

4. What type of detection system is used for internal-conversion spectroscopy? What is done in modern detection systems to improve the resolution?
5. We want to detect the position of the electrons emitted from nuclei decaying via beta-decay. What type of detector would you suggest and why? (Hint: Think about pixellation- dividing detector in many pixels)

Gamma rays

6. What is “gamma ray spectroscopy”? How do we typically calibrate gamma ray detectors? Why should we use gamma ray sources with energy transitions in the full energy range we are interested in?
7. Does the volume of a gamma ray detector matter? Can you draw a pulse height spectrum for 662-keV gamma-ray energy for a NaI(Tl) detector in “small” and “large” dimensions?
8. Imagine a gamma ray source that emits only 2 MeV photons. Compare the measured pulse-height spectrum for a typical Germanium detector and NaI(Tl).
9. What are the sources of the 511 keV peak in the gamma-ray spectra?
10. Explain doppler shift and doppler correction in gamma-ray spectroscopy.
11. What is the effect of an ion moving with 10 to 50 % speed of light on FWHM and thus resolution of the gamma-ray peak? (Hint: think about velocity ($\Delta\beta$) and angular ($\Delta\theta$) straggling)
12. Why do we segment germanium crystals in modern detection systems? Explain briefly
13. We have the OSCAR array at the cyclotron. It consists of 30 large volume LaBr₃(Ce) detectors. Can you foresee the reasons of the large volume usage? Why don't we use NaI(Tl) array instead, which is much cheaper and still inorganic scintillators? (Hint: We want to detect high-energetic gamma rays and many of them.)

Radiation safety:

1. What does ALARA stand for, and how does it affect how we work in the laboratory?
2. Explain what a isotope laboratory is. What is the difference between C-lab, B-lab and A-lab?

Neutrons for analytical applications

1. What is Delayed Gamma Neutron Activation Analysis (DGNAA)?
2. The neutrons produced in $^{239}\text{Pu}/\text{Be}$ sources have a broad energy spectrum, with peaks around 4.0 MeV, 7.2 MeV, and 9.7 MeV, so-called fast neutrons. Fast neutrons will not be easily absorbed during the irradiation which is necessary for the DGNAA method. Since we used the same source in our experiment, how did we slow down (moderate) our neutrons to thermal energy regime in the experiment?
3. How can neutron activation analysis be performed without destroying the sample?
4. Why is identical geometry between sample and standard essential?
5. Why did we use a well detector instead of a usual shape NaI(Tl) detector? How did the resolution change? and why?
6. Why does each isotope produce a unique “fingerprint” of γ -ray energies?
7. Why are high-purity germanium detectors preferred for qualitative identification?
8. If you wanted to quantify the amount of the unknown material, what additional information would you need?