Topics for examination in 02DPD

2016

This document gives the list of topics for examination in 02DPD. The examination consists of two topics. Each topic has several subtopics, as indicated in the text.

List of topics

1) **Charged particle sources, electrons and heavy charged particles**
    - Law of radioactive decay, lifetime, specific activity
    - Fast e^-, β decay, internal conversion, Auger electrons
    - Heavy charged particles, α decay, spontaneous fission
2) **Electromagnetic radiation**
    - γ following β decay (law of rad. decay), annihilation, γ from nuclear reactions, bremmstrahlung
    - Characteristic X-rays
    - Synchrotron radiation
3) **Neutron sources**
    - Spontaneous fission
    - Photoneutron sources
    - Reactions from accelerated particles
4) **Characteristic properties of detectors**
    - Mode of operation, current mode, pulse mode
    - Pulse height spectra
    - Resolution of measured quantity, expectation value and variance
    - Energy resolution, FWHM, Poisson statistics
    - Detection efficiency
    - Dead time
5) **Ionization chambers**
    - Ionization in gases, number of ion pairs
    - Planar ionization chamber

- Charge carriers, drift, diffusion, charge transfer collisions, recombination
- Ionization current, saturation current
- Pulse mode, equivalent circuit, electron sensitivity
- Statistical limit to energy resolution

6) Proportional counters

- Gas multiplication, avalanche, regions of operation
- Cylindrical geometry, electric field, construction
- Fill gas, gas multiplication, space charge
- Energy resolution
- Time characteristics, equivalent circuit, output pulse, operating voltage

7) Position sensitive proportional chambers

- Basic principle of proportional chamber
- Method of charge division
- MWPC, 2-D MWPC
- Multicell proportional counter
- Micro-strip gas chamber, gas electron multiplier (GEM)
- Resistive plate chamber
- Time projection chamber

8) Geiger-Müller counters

- Geiger discharge, fill gases, quenching internal/external
- Output pulse, dead time
- Counting plateau, onset of continues discharge
- Design considerations, end-window Geiger
- Counting efficiency, charged particles, γ, neutrons

9) Semiconductor diode detectors

- Band structure, charge carriers
- Diffusion, drift, trapping, recombination
- Intrinsic semiconductors, *n*-type, *p*-type, conductivity
- Compensated/heavily doped material
- Ionizing radiation in semiconductor
- Pulse formation, electrical contacts, leakage current

- Semiconductor junction, reverse bias, depletion voltage, surface barrier, *p-i-n*

10) Germanium γ-ray detectors and Si(Li)

- HPGe, Ge(Li), planar and coaxial configuration
- Basic principle of semiconductor detector
- Energy resolution, contributions
- Charge collection, pulse shape, trapping, detrapping
- HPGe operation, cryostat
- Lithium-drifted silicon detectors Si(Li)

11) Position sensitive semiconductor detectors

- Resistive charge division
- Strip detector, pixel/pad detector, drift detector
- Basic principle of semiconductor detector, *p*/*n* type, junction
- CCD

12) Organic scintillators

- Fluorescent transitions, absorption and emission spectra
- Types, pure organic crystals, liquid solution, plastic scintillator, thin film
- Response of organic scintillator, light output, time response
- Light collection and mounting, uniformity, interface of optical media, light pipes, wavelength shifters

13) Inorganic scintillators

- Mechanism with activator
- Materials, NaI(Tl)…
- Glass, noble gas, cryogenic liquid scintillators
- Radiation damage
- Light collection and mounting, uniformity, interface of optical media, light pipes, wavelength shifters

14) Photomultiplier tube

- Structure, photoemission, spontaneous electron emission
- Photocathode, quantum efficiency
- Electron multiplication, secondary e^- emission, negative affinity, multiple stage multiplication

- Microchannel plate, image intensifier
- Pulse timing, electron trajectories
- HV supply and voltage divider
- Analysis of scintillator pulse shape, small/large time constant

15) Photodiodes, hybrid photomultipliers

- Conventional photodiode, basic principle of semiconductors
- Avalanche photodiode
- Silicon photomultiplier (array of APDs in Geiger mode)
- Hybrid photomultiplier
- Position sensitive photomultipliers
- Analysis of scintillator pulse shape, small/large time constant

16) Cherenkov detectors

- Cherenkov radiation, angle of emission
- Threshold Cherenkov detectors
- Differential Cherenkov detectors
- RICH
- Detection of Cherenkov photons in RICH
- Cherenkov detector with internal reflection

17) Transition radiation detectors

- Emission of transition radiation
- Detector arrangement, radiator + MWPC (basic principle), energy loss in MWPC
- Electron identification

18) Historical track detectors

- Streamer chamber, tracks visualization
- Neon flash-tube chamber
- Spark chamber
- Cloud chamber, expansion and diffusion
- Bubble chamber

19) Detection of slow neutrons

- Nuclear reactions for detection

- BF_3 proportional tube, construction, wall effect, γ discrimination
- Boron lined proportional counter, boron loaded scintillator
- Neutron converter structures
- Lithium-containing detectors, ^{3}He proportional counter
- Fission counter

20) Detection of fast neutrons

- Counters based on neutron moderation, Bonner spheres
- Fast neutron induced reactions
- Lithium sandwich spectrometer
- Detection based on ^{3}He(n,p) reaction
- Fast neutron scattering
- Proton recoil scintillator
- Gas recoil proportional counter
- External converter layer

Bibliography

References for 02DPD, as presented in the introductory lecture, are:

[1] G. F. Knoll, Radiation detection and measurement, John Willey and Sons, 2010.

[2] C. Grupen, B. Shwartz, Particle detectors, Cambridge University Press, 2011.

[3] C. Leroy, P-G. Rancoita, Principles Of Radiation Interaction In Matter And Detection, World Scientific Publishing, 2009.

Most parts of the course are covered in [1], description of Cherenkov and transition radiation detectors and historical detectors is given in [2] and some details on Cherenkov detectors are given in [3]. All three books are accessible in the local EJČF library, also I can provide electronic versions of the books.