PHY5846C: INTRODUCTION TO EXPERIMENTAL TECHNIQUES

PARTICLE DETECTION

1. Consider an α particle of 5 MeV kinetic energy moving in silicon;
   (a) what is its range (i.e. the distance travelled before it stops)?
   (b) make a rough estimate of the time required for it to slow down and stop. (Hint: use the Bethe-Bloch formula; relate energy loss to change in velocity; make appropriate approximations).
2. Estimate the energy loss of a 10 MeV proton when passing through 100 μm of silicon.
3. Calculate the energy of a 1 MeV γ ray after Compton scattering at 180°.
4. Give a rough estimate of the ratio of the probability per atom for photoelectric absorption in silicon to that in germanium.
5. What is the mean free path of a photon of 1 MeV in NaI?
6. Calculate the rate of temperature rise in a sample of liquid water adiabatically exposed to radiation that results in an absorbed dose rate of 10 mrad.
7. Indicate which of the three major photon interaction processes (photoelectric absorption, Compton scattering, pair production) is dominant in the following situations:
   (a) 1 MeV γ rays in Al
   (b) 100 keV γ rays in H
   (c) 100 keV γ rays in Fe
   (d) 10 MeV γ rays in Co
   (e) 10 MeV γ rays in Pb
8. In which way are semiconductor detectors superior to scintillation detectors?
9. Calculate the mean value and variance in the number of electron-hole pairs created by the loss of 100 keV particle energy in silicon.
10. In a germanium detector which is deep enough to contain a 50 keV photon, what is the expected intrinsic resolution of the energy measurement in the photopeak?
11. The probability that an electron-hole pair is thermally created is given by

$$p(T) = CT^{\frac{3}{2}} exp(-\frac{E_g}{2kT}),$$

where T = absolute temperature, E_g = band gap energy, k = Boltzmann constant, and C = proportionality factor characteristic of the material.
By what factor is the rate of thermal generation of electron-hole pairs in germanium reduced by cooling it from room temperature (20°) to liquid nitrogen temperature (77K)?

12. How do the following properties of a p-n junction depend on the applied reverse bias voltage?
    (a) depletion width
    (b) capacitance
    (c) maximum electric field.
13. Find the ratio of the number of charge carriers created in silicon by a 1 MeV proton to the number generated *by the same energy deposition* in air.
14. A 10 MBq source of α particles is located 10 cm in front of a silicon surface barrier detector. After which length of exposure time is radiation damage to the detector likely to be significant?
15. Find the maximum energy that can be deposited by a 1 MeV gamma-ray photon if it undergoes two successive Compton scattering events and then escapes the detector.

References

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    (c) p. 144 for passage of particles through matter,
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    (e) p. 163 for radioactivity.
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