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Uncertainties.
Part 2

SCHILLEBEECKX Peter
Institute For Reference Materials and Measurments
EC JRC IRMM
Retiesweg 111
B-2440 Geel
BELGIUM

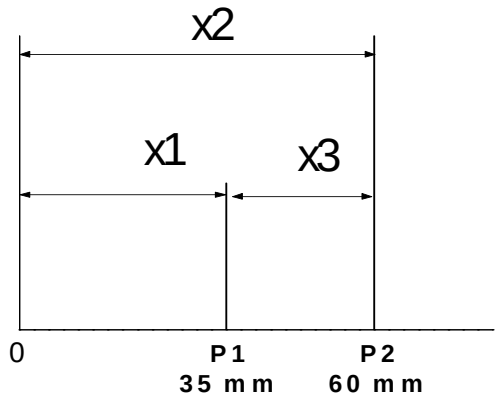
Part II : Uncertainties

Exercise II.1 (Ref. Mannhart, PTB-FMRB-84)

To determine the distance between points three gauge blocks are available as reference material. The characteristics of these blocks are given in the table. The uncertainties on the length of the blocks are not correlated.

Gauge block	Length	Standard deviation	Variance
L1	50 mm	0.05 μm	0.0025 $(\mu m)^2$
L2	15 mm	0.03 μm	0.0009 $(\mu m)^2$
L3	10 mm	0.02 μm	0.0004 $(\mu m)^2$

The blocks can be used to determine the distance x1 and x2 between the zero point and point P1 and P2, respectively (see figure).



(a) Determine the distances x1 and x2 by x1 = L1 – L2 and x2 = L1 + L3 and their uncertainties
(b) Determine the distance between point P1 and P2 together with the uncertainty using two methods:
- x3 = L2 + L3
- x3 = x2 – x1

Exercise II.2

For the determination of the $^{197}Au(n,\gamma)$ cross section the sample described in exercise I.6 was used. The cross section is deduced from the reaction rate using the relationship:

$$C = \varepsilon\ A\ n\ \sigma_r\ \varphi$$

where C is the observed count rate, ε is the detection efficiency, A the effective area, n the total number of nuclei per area (or target thickness in atoms/barn), σ_r is the cross section and φ the neutron flux.

a) What is the relative uncertainty on the cross section due to the uncertainty on the target characteristics? (the uncertainty on the mass and the area are not correlated)

b) What is the minimum relative uncertainty on the cross section?

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Exercise II.3

The experiment described in exercise 2 has been repeated several times:

Campaign 1: 100 measurements using the same sample (the one used in exercise II.2)

Campaign 2: 50 measurements with 50 different samples. The characteristics of the 50 samples have been determined with different instruments such that the uncertainties are not fully correlated. The total uncertainty of the target thickness in at/b for the 50 samples was 0.5%. The correlated component was 0.3%

For both measurement campaigns the uncertainty on C due to counting statistics was 0.2% for each individual measurement.

(a) What is the minimum relative uncertainty on the cross section deduced from the data in Campaign 1?

(b) What is the minimum relative uncertainty on the cross section deduced from the data in Campaign 2?

Exercise II.4

Assume a cross section that is linear dependent on the neutron energy:

$$\sigma(E_n) = a + bE_n$$

The parameters a and b have been determined from a least square fit procedure on a set of experimental data points.

The result of the fit is given in the table.

Parameter	Value	Covariance	
a /barn	400.00	12.430	-0.220
b / (barn/eV)	-5.00	-0.220	0.00413

The cross section is used to determine the integral quantity:

$$I = \frac{\int_{E1}^{E2} \sigma(E_n) dE_n}{E2 - E1}$$

for E1 = 10 eV and E2 = 30 eV.

(a) Determine the integral and uncertainty on the integral by considering only the diagonal elements of the covariance matrix.

(b) Determine the integral and the uncertainty on the integral by uncertainty propagation using the full covariance matrix.