22.106 Neutron Interactions and Applications
Problem Set 2

Due SES #8

Question 1

RANDU is an infamous multiplicative linear congruential pseudorandom number generator which has been used since the 1960s with parameters: g = 65539, m = 31, c= 0.

Write a computer program of this LCG. Plot a 1-D, 2-D and 3-D distribution of many randomly selected points (with the initial seed of 1). Discuss your observations and explain why RANDU is no longer used in Monte Carlo simulations. Explain your observations using the spectral test (see slides 2-33 and 2-34 of reference Monte Carlo document).

Question 2

Repeat the integral of question 4 a) of problem set 1 with the new parameters provided below using both Monte Carlo integration techniques: 1) Mathematical Approach, and 2) Simulation Approach. Compare your results to what you obtain analytically.

$\rho(x) = 2.2 (1 + 0.0001x)$, where x is in cm and $\rho(x)$ is in g/cm^3.

Calculate the probability of neutrons reaching a depth of 20 meters.

Question 3

The neutron energy spectrum of a given source is a random variable with the following probability density function

$$f(E) = \begin{cases} 1.2(E + E^2) & 0 \le E < 1 \quad MeV \\ 0 & otherwise \end{cases}$$

a) What is the probability that the energy is greater than 0.5 MeV?
b) Find the mean energy.
c) Find the probability that the energy is within +/- 0.1 MeV of the mean.
d) Find the standard deviation.
e) Find the probability that the energy is within +/- 2σ of the mean.
f) Find the cumulative distribution function of the energy.

Question 4

Write a simple mono-energetic particle transport code that will sample source particles uniformly in a slab of water with width of 10 cm. Use the properties given in Table I and assume that the slab is surrounded by a vacuum. You can use the random number generator that comes with the programming language of your choice and assume that the scattering is isotropic in the laboratory system.

Table I: Macroscopic x.s for Water of density 1 g/cc (cm^{-1})

	Σ_s	Σ_a	Σ_t
Water	1.0	0.5	1.5

Run a simulation with 1000 particles and count the number of particles that are leaving the system and the total number of particles absorbed in the water.

Question 5

The polar angle distribution of the scattering collision with isotope X is given by the following pdf:

$$f(\mu) = \begin{cases} \dfrac{1+\mu}{2} & for \quad -1 \le \mu \le 1 \\ \\ 0 & elsewhere \end{cases}$$

a) Verify that this distribution is truly a probability distribution function.
b) Calculate the average and variance of the polar angle
c) Using a direct sampling approach, derive a relation that will allow stochastically sampling the polar angle from a uniform random variable between 0 and 1.

Question 6

Calculate the total efficiency of the neutron detection system described below for neutrons of 1eV, 1keV and 1 MeV:

- Isotropic point source of 2.0 x 10^{12} neutrons/second
- BF$_3$ (Enriched to 96% B$_{10}$) Tube detector of 2 cm of diameter and 15 cm of length
    o Gas pressure of 80kPa at room temperature (293 Kelvin)
- Distance between point source and detector is 40 meters.

State your assumptions clearly.

Question 7

Linear table search vs Binary table search

Write a subroutine that will sample the following discrete pmf, illustrated by the histogram in figure 1, using the table search method seen in class using:

1) Linear table search
2) Binary table search

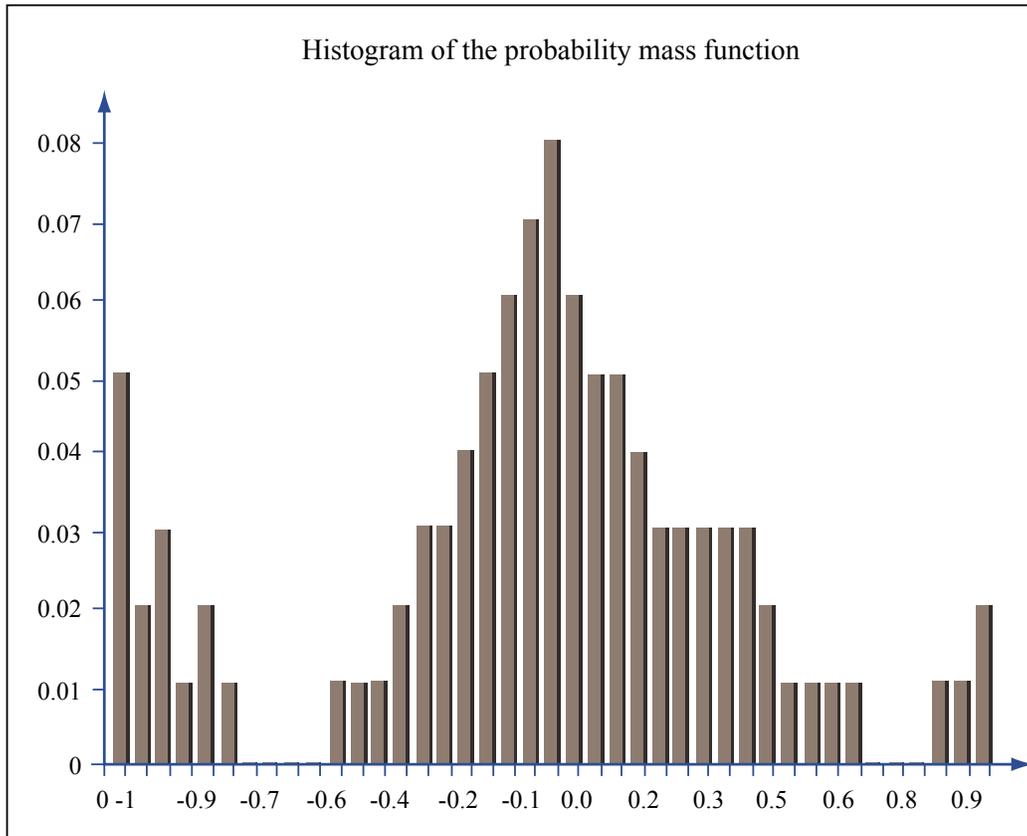Sample this pmf with both methods multiple times and compare the computational cost

Figure by MIT OpenCourseWare.

Each bin is equally space from -1 to 1 by 0.05 increment (41 bins in total).

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