1. Briefly explain each of the following terminologies: (28%)
   a) characteristic X-rays;
   b) photoelectric effect;
   c) Cerenkov radiation;
   d) LET;
   e) Bragg curve;
   f) Bremsstrahlung;
   g) neutron age.

2. The measured lifetimes ($T = 1/\lambda$) of $_{92}U^{235}$ and $_{92}U^{238}$ are 1.02×10^9 years and 6.52×10^9 years, respectively. Assume they were equally abundant when the uranium in the earth was originally formed. From the natural uranium normally found on the earth at the present time, estimate how much time has elapsed since the time of formation. (10%)

3. The critical energies for fission for various isotopes are given as follows: (10%)

fissioning nucleus $_ZX^A$	critical energy (MeV)	binding energy of the last neutron in $_ZX^A$ (MeV)	binding energy of the last neutron in $_ZX^{A+1}$ (MeV)
X_1	5.5	5.0	6.0
X_2	6.0	6.5	5.5

   a) Which one is the fissile material, and which one is the fissionable material?
   b) How much kinetic energy is needed for incident neutrons to induce X_1 and X_2 fission?

4. Determine the effective multiplication factor, and the conversion ratio for a nuclear reactor possessing the following features: (10%)
   (a) 9% of the fast neutrons leak out of the reactor while slowing down;
   (b) Of the fast neutrons that do not leak out, 10% are absorbed in the U-238 resonances and 3% are absorbed in the U-235 resonances;
   (c) 4% of the neutrons leak out of the reactor while diffusing as thermal neutrons;
   (d) Of the thermal neutrons that do not leak, 85% are absorbed in fuel materials;
   (e) Of the thermal neutrons absorbed in fuel materials, 75% are absorbed in U-235;
   (f) Of the neutrons absorbed in U-235, 82% induce fission;
   (g) Of the fission neutrons produced, 11% are due to fast fission;
   (h) Of each fission event, 2.46 fission neutrons are emitted;
   (i) Neglect the absorption of neutrons due to oxygen.

5. A bare sphere of moderator of radius R contains uniformly distributed sources emitting S_o neutrons/sec-cm^3. (12%)
   a) Determine the neutron flux in the sphere.
   b) What is the probability that a neutron emitted by the source escapes from the sphere?

6. Determine the critical mass of a one-group, bare, cubic reactor containing the following data: (15%)
$\Sigma_a = 0.082$ cm^{-1}, $\Sigma_{tr} = 0.342$ cm^{-1}, $\nu\Sigma_f = 0.0843$ cm^{-1}, $\Sigma_f = 0.03413$ cm^{-1}, $\rho = 18.5$ g/cm^3.

7. Given a two-group, bare, very large reactor containing the data listed below. Assume there is no upscattering and all fission neutrons are born in the fast energy group. Determine the multiplication factor of the reactor. (15%)

Group	$\nu\Sigma_f$ (cm^{-1})	Σ_f (cm^{-1})	Σ_a (cm^{-1})	D (cm)	$\Sigma_{s1\to2}$ (cm^{-1})
fast (1)	0.008476	0.00332	0.01207	1.2627	0.02619
thermal (2)	0.18514	0.07537	0.121	0.3543	------

where $\Sigma_{s1\to2}$ denotes the macroscopic scattering cross section for scattering the neutrons from the fast group into the thermal group.