MULTIMEDIA ON NUCLEAR REACTORS PHYSICS

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Abstract. The paper present an exemple of measures that have been found to be effective in the development of innovative educational and training technology. A multimedia course on nuclear reactor physics is presented. This material has been used for courses at master level at the universities; training for engineers at nuclear power plant as modular 2 weeks course; and training operators of nuclear power plant. The multimedia has about 785 slides and the text is in English, Spanish and French.

In order to improve the quality in nuclear engineering education and training programs a Multimedia on Nuclear Reactor Physics is being developed since 2001.

The teacher uses the multimedia during his lectures and students use it at home to study this course.

This multimedia has been used in Nuclear Reactor Physics course for:

1. Engineers in Master of Nuclear Engineering at Technical University of Catalonia, Barcelona, Spain.
2. Training for engineers, chemistries, informatics, etc., at Nuclear Power Plant, modular course 2 weeks.
3. Training Operators of Nuclear Power Plants.

When the multimedia is used for proposals 2 and 3, it is useful to escape the chapters 5 and 6.

During this period several institutions have sponsored this activity: IAEA, NERG, Tecnatom, and ENEN-EU. Thanks to this support the scope of the multimedia has increased, number of chapters and languages.

Nowadays, this multimedia has about 785 slides and the text is in English, Spanish and French.

The same CD-ROM has the three languages. The user chooses the language that they want.

The figures, animations, tables and equations are the same in the three languages English, Spanish, and French; the only difference is the text language.

The multimedia has the following content:

1. **Introduction to the Nuclear Energy:** Nuclear reactor operation principle, Historical introduction and current situation of the fission nuclear energy profit. (159 slides).

2. **Neutron interaction:** Reactions types. Cross sections according to the energy, Neutron scattering, Moderation power and reason, Westcott factors. (84 slides).

3. **Fission process in a nuclear reactor:** Fission reaction, Conversion and reproduction, Fission energy, Nuclear reactor power, Fuel consumption, fission products. (65 slides).

4. **Neutron multiplication in a nuclear reactor:** The multiplication factor, The four and six factors formula, Critical mass. (52 slides)

5. **Neutron balance in a material medium:** Neutron transport theory, Transport equation solutions, Neutron diffusion theory, Fick’s law, Validity conditions, Physical interpretation, Limit Conditions. (45 slides)

6. **Criticality in multiplier medium:** Multiplication coefficient, Criticality of the bare homogeneous reactor, Criticality calculation by using of the multigroup model, Criticality determination with reflector. (29 slides)

7. **Reactor kinetics:** Delayed and non delayed neutrons, Reactivity equation for six delayed neutron groups, Small reactivities, Flux evolution. (95 slides)

8. **Control rod effect:** Control-rod Worth, Differential and integral value. (64 slides).

9. **Soluble poisons:** Reactivity effect calculation. (13 slides)

10. **Burnable poisons:** Location, Reactivity effect calculation. (18 slides)

11. **Reactivity temperature effects:** Feedback coefficients, Stability, Fuel temperature coefficient, Moderator temperature coefficient. (51 slides)

12. **Fission products poisoning:** Dead Time, Xenon space oscillations, Samarium effects. (53 slides)

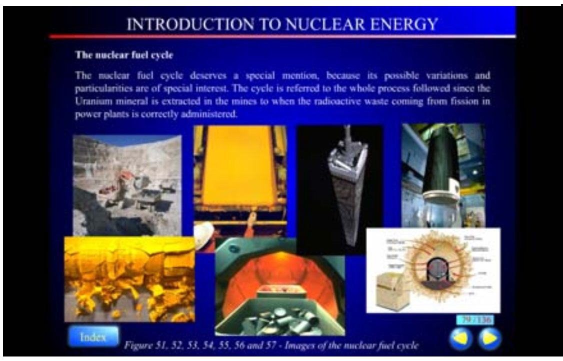
13. **Neutron Sources:** Intrinsic and external sources, Sub critical multiplication, Bending curves. (58 slides)

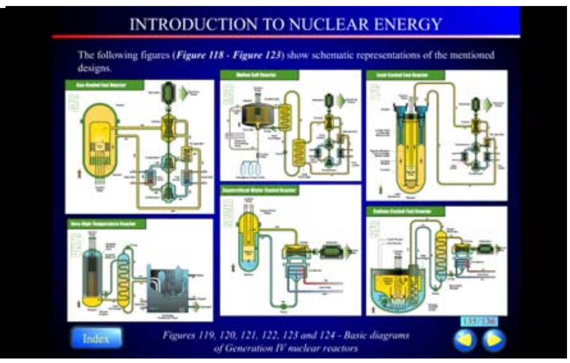
An agreement with the IAEA has achieved in order to distribute the Multimedia world scope, for non commercial proposes, like universities.
http://www.iaea.org/inisnkm/nkm/e_learning/2010/Multimedia_NRP_announcement.htm

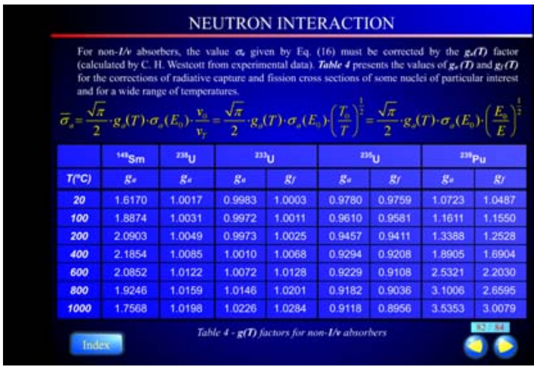
The multimedia has been presented in the Asian Network for Education in Nuclear Technology (ANENT) and in Latin America Network for Education in Nuclear Technology (LANENT) (actually in creation process).

And agreement with Xinexus-nuclear has been achieved in order to distribute the Multimedia on Nuclear Reactor Physics (English, Spanish, and French) world scope. www.xinexus.ch/mnrp-book

Some slides of the multimedia:






NEUTRON INTERACTION
For non-1/v absorbers, the value σa given by Eq. (16) must be corrected by the ga(T) factor (calculated by C. H. Westcott from experimental data). Table 4 presents the values of ga(T) and gf(T) for the corrections of radiative capture and fission cross sections of some nuclei of particular interest and for a wide range of temperatures.
$$\overline{\sigma}_a=\frac{\sqrt{\pi}}{2}\cdot g_a(T)\cdot\sigma_a(E_0)\cdot\frac{v_0}{v_T}=\frac{\sqrt{\pi}}{2}\cdot g_a(T)\cdot\sigma_a(E_0)\cdot\left(\frac{T_0}{T}\right)^{\frac{1}{2}}=\frac{\sqrt{\pi}}{2}\cdot g_a(T)\cdot\sigma_a(E_0)\cdot\left(\frac{E_0}{E}\right)^{\frac{1}{2}}$$
	^{149}Sm	^{238}U	^{233}U		^{235}U		^{239}Pu	
T(°C)	g_a	g_a	g_a	g_f	g_a	g_f	g_a	g_f
20	1.6170	1.0017	0.9983	1.0003	0.9780	0.9759	1.0723	1.0487
100	1.8874	1.0031	0.9972	1.0011	0.9610	0.9581	1.1611	1.1550
200	2.0903	1.0049	0.9973	1.0025	0.9457	0.9411	1.3388	1.2528
400	2.1854	1.0085	1.0010	1.0068	0.9294	0.9208	1.8905	1.6904
600	2.0852	1.0122	1.0072	1.0128	0.9229	0.9108	2.5321	2.2030
800	1.9246	1.0159	1.0146	1.0201	0.9182	0.9036	3.1006	2.6595
1000	1.7568	1.0198	1.0226	1.0284	0.9118	0.8956	3.5353	3.0079
Table 4 - g(T) factors for non-1/v absorbers
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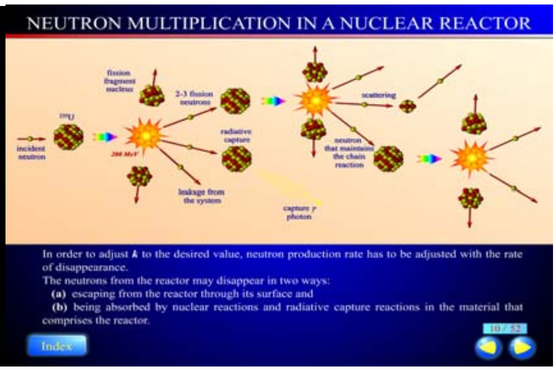
NEUTRON MULTIPLICATION IN A NUCLEAR REACTOR
fission fragment nucleus
2-3 fission neutrons
scattering
incident neutron
200 MeV
radiative capture
neutron that maintains the chain reaction
leakage from the system
capture γ photon
In order to adjust k to the desired value, neutron production rate has to be adjusted with the rate of disappearance.
The neutrons from the reactor may disappear in two ways:
(a) escaping from the reactor through its surface and
(b) being absorbed by nuclear reactions and radiative capture reactions in the material that comprises the reactor.
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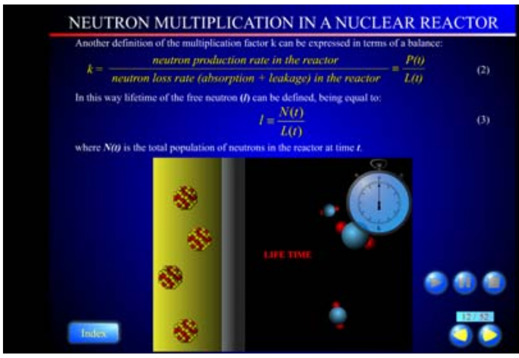
NEUTRON MULTIPLICATION IN A NUCLEAR REACTOR
Another definition of the multiplication factor k can be expressed in terms of a balance:
$$k=\frac{\textit{neutron production rate in the reactor}}{\textit{neutron loss rate (absorption + leakage) in the reactor}}=\frac{P(t)}{L(t)} \quad (2)$$
In this way lifetime of the free neutron (l) can be defined, being equal to:
$$l=\frac{N(t)}{L(t)} \quad (3)$$
where N(t) is the total population of neutrons in the reactor at time t.
LIFE TIME
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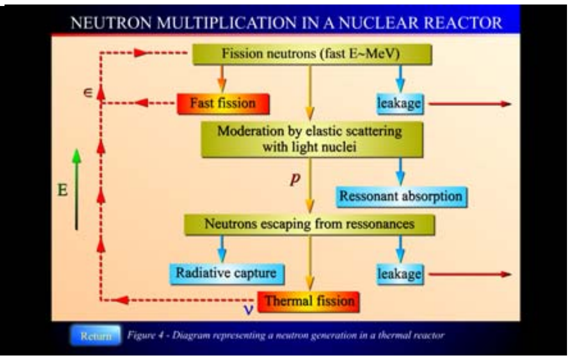
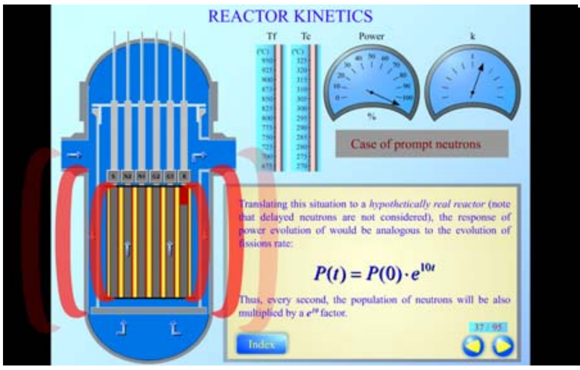

NEUTRON MULTIPLICATION IN A NUCLEAR REACTOR
Fission neutrons (fast E~MeV)
ε
Fast fission
leakage
Moderation by elastic scattering with light nuclei
E
p
Ressonant absorption
Neutrons escaping from ressonances
Radiative capture
leakage
ν
Thermal fission
Return
Figure 4 - Diagram representing a neutron generation in a thermal reactor


REACTOR KINETICS
Tf
Te
Power
k
%
Case of prompt neutrons
Translating this situation to a hypothetically real reactor (note that delayed neutrons are not considered), the response of power evolution of would be analogous to the evolution of fissions rate:
$$P(t)=P(0)\cdot e^{10t}$$
Thus, every second, the population of neutrons will be also multiplied by a e^{10} factor.
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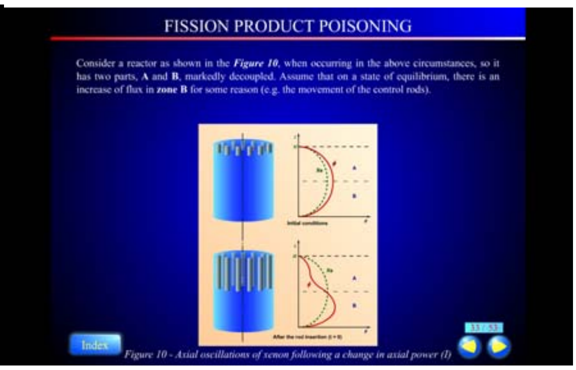
FISSION PRODUCT POISONING
Consider a reactor as shown in the Figure 10, when occurring in the above circumstances, so it has two parts, A and B, markedly decoupled. Assume that on a state of equilibrium, there is an increase of flux in zone B for some reason (e.g. the movement of the control rods).
A
B
A
B
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Figure 10 - Axial oscillations of xenon following a change in axial power (I)