Development of a Course Materials Database to Support Radiopharmaceutical Science Training

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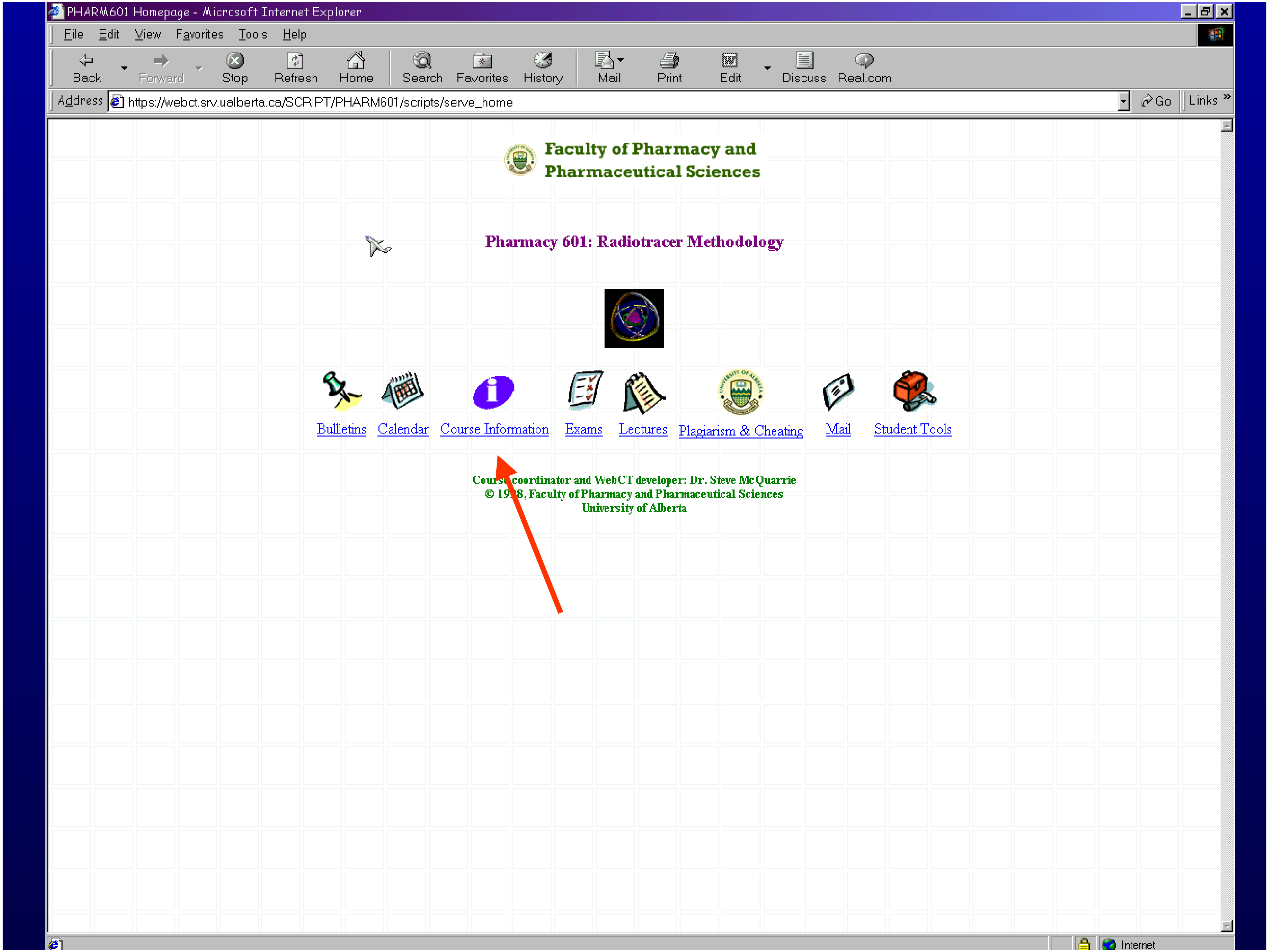
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Pharmacy 601 Radiotracer Methodology

Course Information

Contact Information

Course Coordinator: Dr. Steve McQuarrie

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Telephone: (780) 492-2905

email address: smcquarrie@pharmacy.ualberta.ca

Course Generalities

Course Description: Fundamental principles of radioactivity and health physics. The importance of radionuclides in medicine, agriculture, industry and research.

This course will be of interest to graduate students who are using or planning to use radioactive tracers in their research programs. The course material deals with the theoretical and practical aspects of nuclear decay processes and the different instrumental techniques used in their measurement. The laboratory section of this course will provide the student with practical experience in many of the concepts discussed during the lectures. Some of the material covered will include:

An introductory section on the general principles of radioactive disintegration including the types of decay and the interaction of radiation with matter.

A comprehensive discussion of the detection and quantitation of radiation including sections on gas ionization detectors, liquid scintillation and solid scintillation counters, as well as solid-state detection systems.

A section dealing with other considerations in radioisotope tracer methodology including sources of radionuclides, autoradiography, neutron activation analysis, isotope dilution analysis, radioimmunoassay, experimental design and applications in biotechnology.

The laboratory experiments include quality control, radionuclide identification, sample preparation for LS, methods of quench correction in LS, gamma counting, protein radioiodination and absolute determination of radioactivity.

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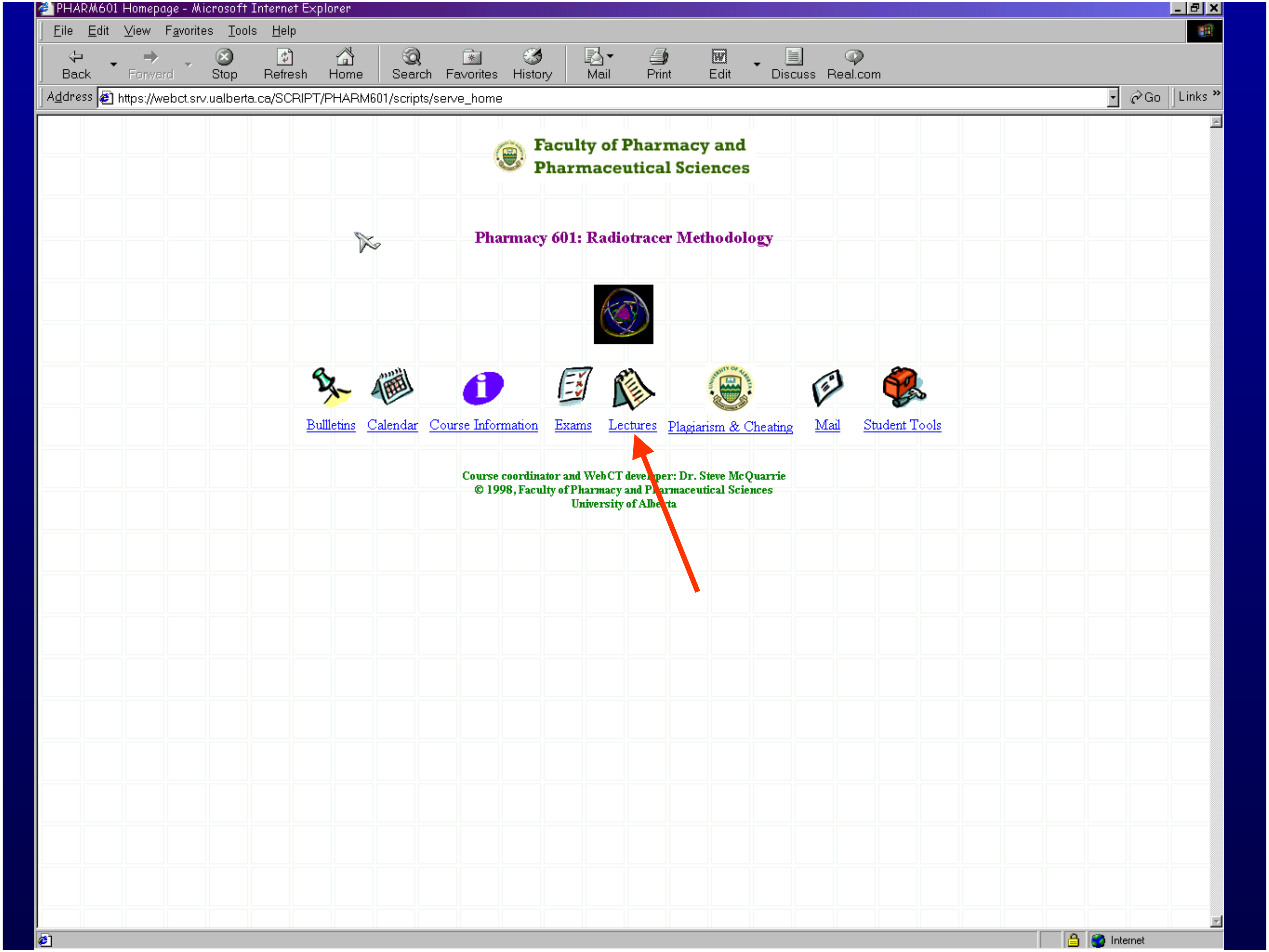
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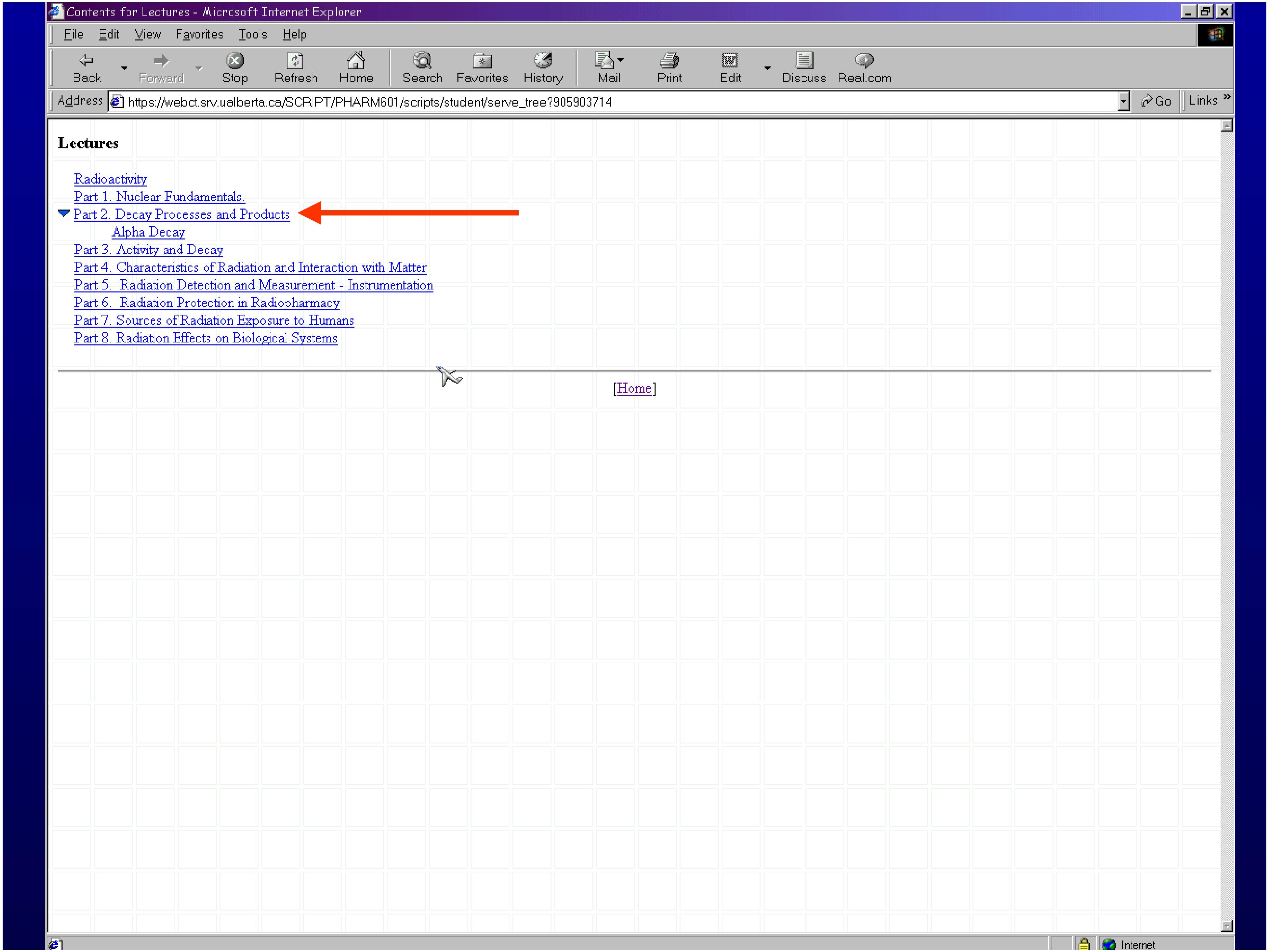

Lectures

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Lectures

Part 2. Decay Processes and Products

The nuclear instability caused by nuclides with unsuitable neutron to proton ratios causes these species to undergo spontaneous breakdown with the release of energy and particulate radiation. This spontaneous decay of unstable nuclei is called "radioactivity". During the processes of radioactive decay there is a release of energy and in general more stable species are formed. Thus an unstable atom of ^{14}C decays to a more stable ^{14}N. During the decay processes particles may be released from the nucleus (alpha, beta) or electromagnetic emissions may come from the nucleus (gamma rays) or from electronic transitions (x-rays). These decay processes and the nature of the emitted radiation are very important if we are to understand how radiation is detected and measured and how radiation affects biological systems.

Types of Radioactive Decay

2.1. Alpha Particle Decay (α -decay)

The general characteristics of alpha decay are;

a. This decay process occurs only for radionuclides with Z > 92 (Z 92 is lead)[c].
b. The emitted particle is an assembly of 2 protons and 2 neutrons, which is ejected from the nucleus. This assembly has a double positive charge and a mass of about 4 AMU.
c. The α -particle has a kinetic energy between 4 and 8 MeV and is monoenergetic for a particular radionuclide decay.
d. The α -particle is a $_2$ which is exactly a nucleus of $^4_2He_2$.
e. The biological hazard from α -particles is due to their high energy and double positive charge which makes them capable of causing intense ionizations in any matter that they pass through.
f. These large particles are not very penetrating and are easily absorbed by a few centimeters of air or micrometers of water or tissue.

[c] *One exception to this rule is ^{154}Dy.*

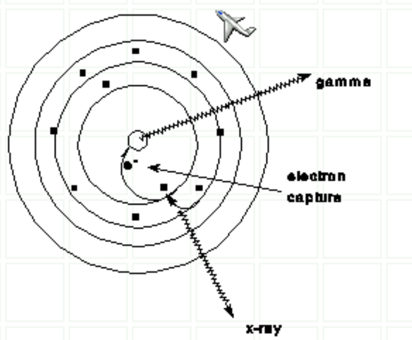
A typical decay process is that of ^{226}Ra which has a half-life of 1600 years and which decays to ^{222}Rn as shown below.

$$^{226}_{88}RA_{138} \rightarrow \, ^{222}_{86}Rn_{136} + \, ^4_2\alpha_2 + energy(4.777\,MeV)$$

2.4. Electron capture (EC), (K-capture)

This is another process which enables radionuclides with a proton excess to convert to more stable nuclides. In this process an orbital electron from one of the inner shells (K-shell) is captured by the nucleus. The process which takes place is;

$$p^{+} + e^{-} \rightarrow n + \text{neutrino}$$



The electron capture process with possible emissions from the nucleus (gamma ray) and from electron transitions (x-ray)

Although there are no particles emitted in this transition there may be a gamma transition from the excited daughter nucleus and x-ray emissions as electrons move in to fill the vacant position in the K-shell.

One example of a radionuclide which decays by electron capture is ^{125}I.

$$^{125}_{53}I_{72} \rightarrow {}^{125}_{52}Te_{73} + gamma + x\text{-}ray$$

There is no primary particulate radiation emitted in the electron capture decay process. However there are secondary processes which result in particle emission. The emitted particles increase radiation dose to humans. For example ^{125}I emits a number of low energy electrons called Auger electrons. Auger electrons are produced when the x-ray produced following electron capture transfers its energy to one of the orbital electrons. This electron is then emitted from the atom and is responsible for much of the internal radiation dose received from this radionuclide.

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$$E = \frac{Q}{(1 + m/M)}$$

- Example: Find the total kinetic energy of the α particle emitted during the decay of ^{210}Po.

$$E = \frac{5.4}{(1 + 4/206)}$$

$$E = 5.3 \text{ MeV}$$

Therefore, the kinetic energy of the recoil nucleus (^{206}Pb) must be 0.1 MeV.

7. α's are essentially monoenergetic.

a) Small variations due to energy levels of the daughter nucleus.
- A nucleus that emits a lower energy α is left in an excited state. (Radium - 226)
- De-excitation (or return to ground state) via gamma emission

b) Most α's are emitted with maximum energy and therefore most α emitters are **not** accompanied by gamma-rays. (making the detection of α emitters more difficult from an analytical view point).
- Also limiting there detectability is the α's extremely limited ability to penetrate matter.

8. α energy and half-life are related

a) $T_{1/2}$ = 0.3 μsec to 10^{17} y

b) Geiger - Nuttal Law http://www.treasure-troves.com/physics/Geiger-NuttallLaw.html
- Simplified if we realize that more unstable nuclei (short $T_{1/2}$) allow higher α energy states and hence easier tunneling (thinner barrier). These α's will have a higher energy.

8. Summary

a) Occurs when Z > 82

b) α energy and half-life are related

c) Essentially monoenergetic (generally no gammas)

d) Little penetrating power

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Geiger-Nuttall Law - Microsoft Internet Explorer

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Geiger-Nuttall Law

$$\ln \lambda = -a_1 Z E^{-1/2} + a_2,$$

where λ is the decay constant, Z is the atomic number, E is the binding energy, and a_1 and a_2 are constants.

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...accompanied by gamma-rays. (making the detection of α emitters

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Part 2. Decay Processes and Products

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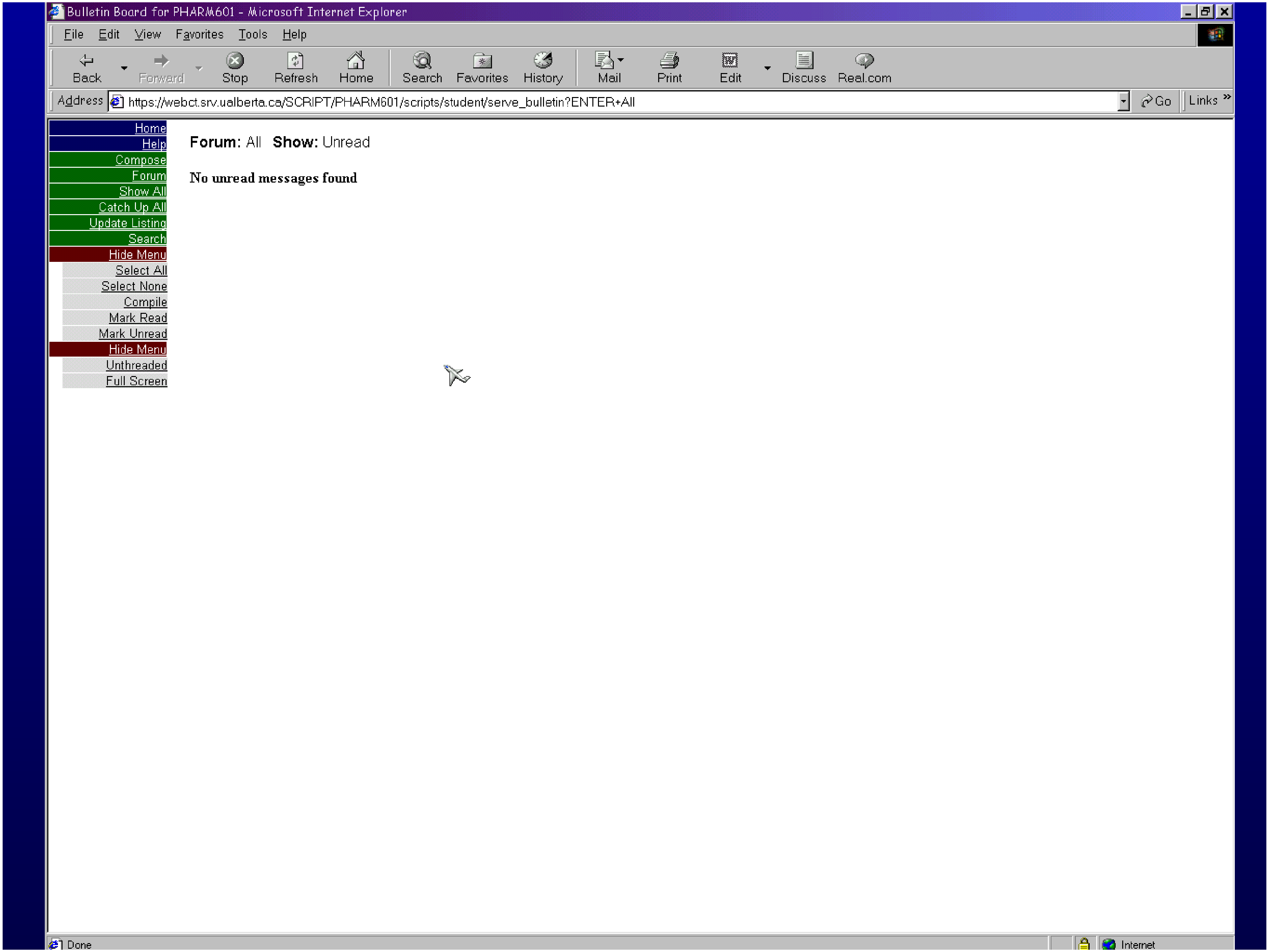
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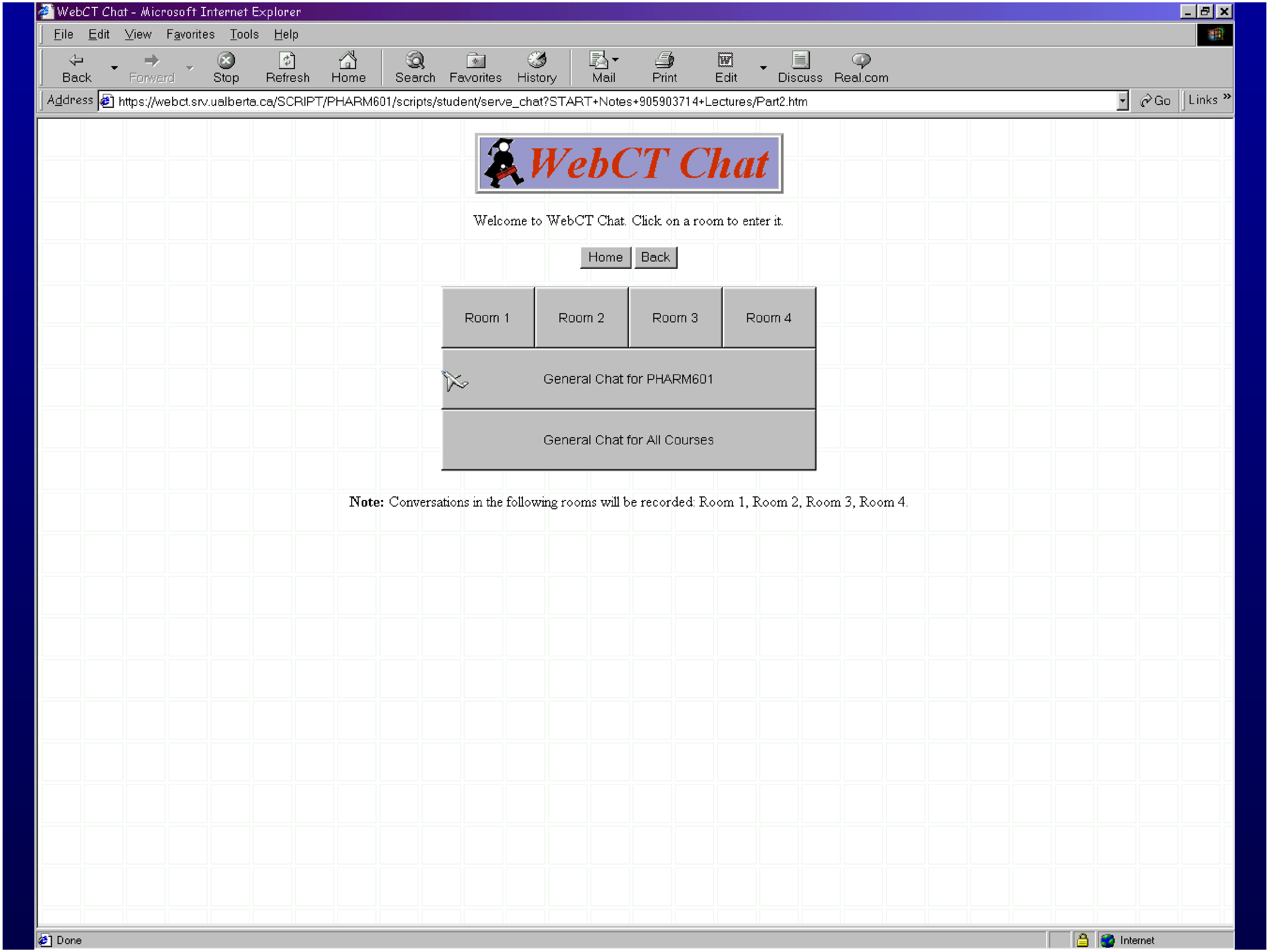
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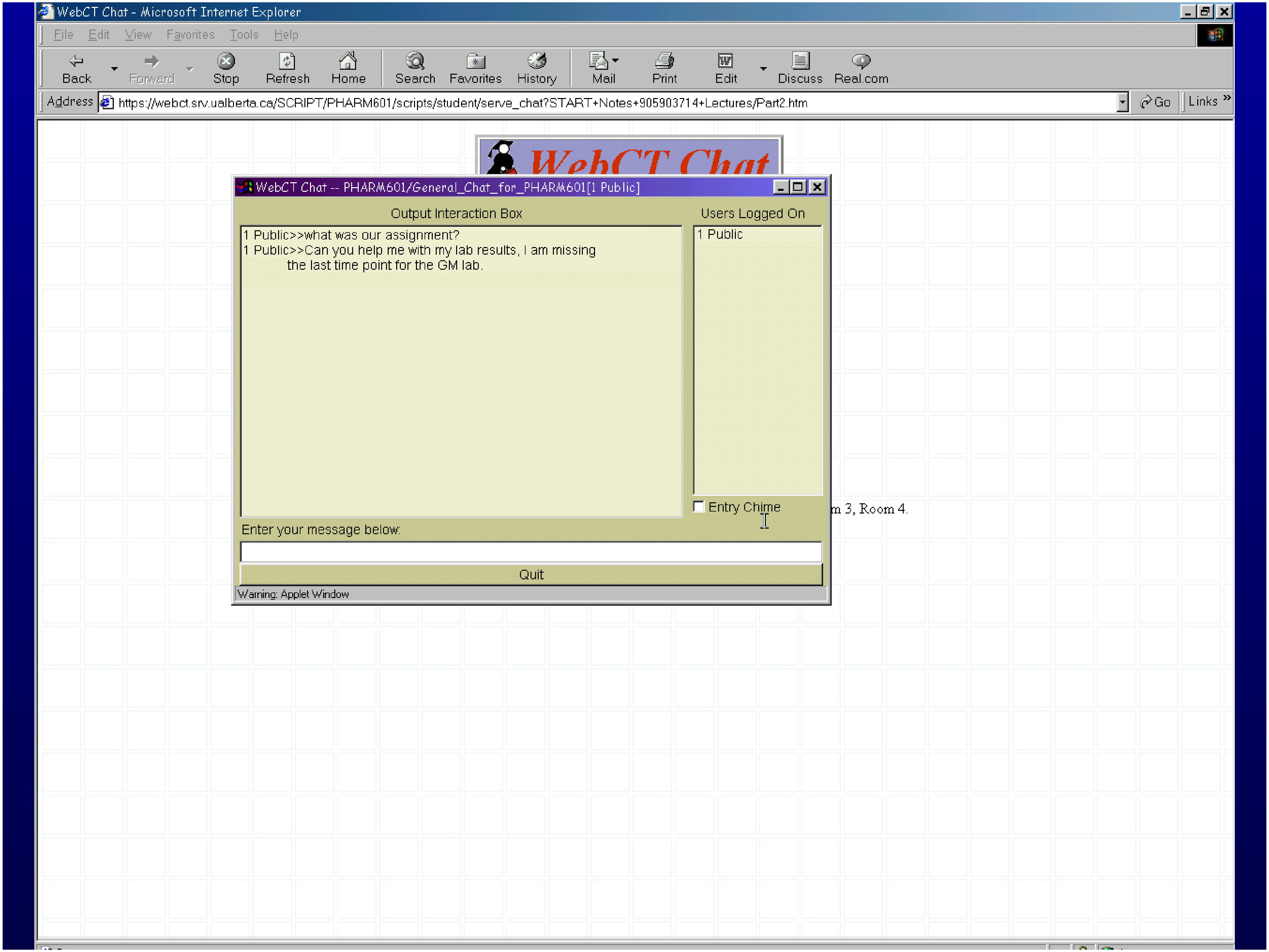
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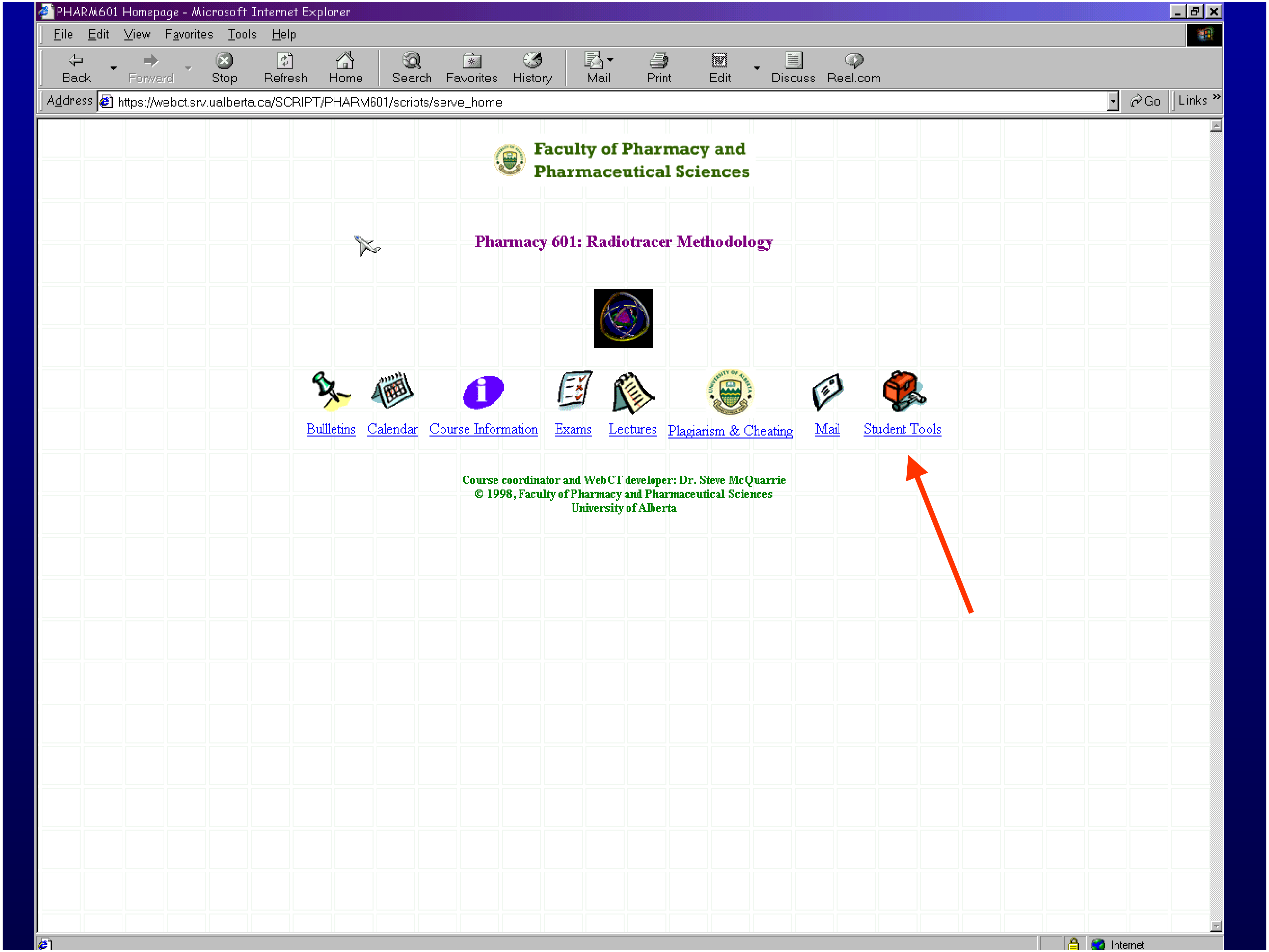
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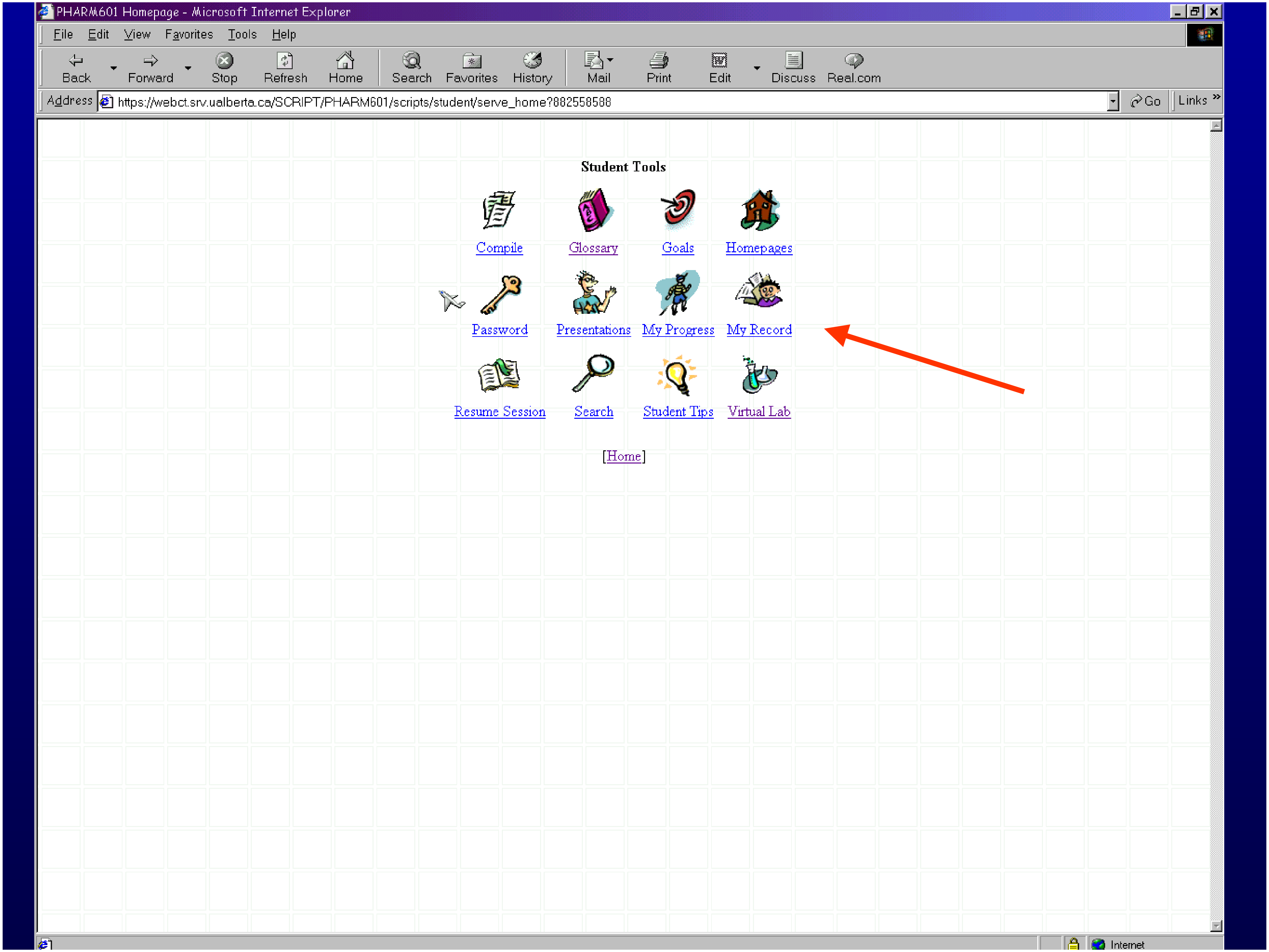
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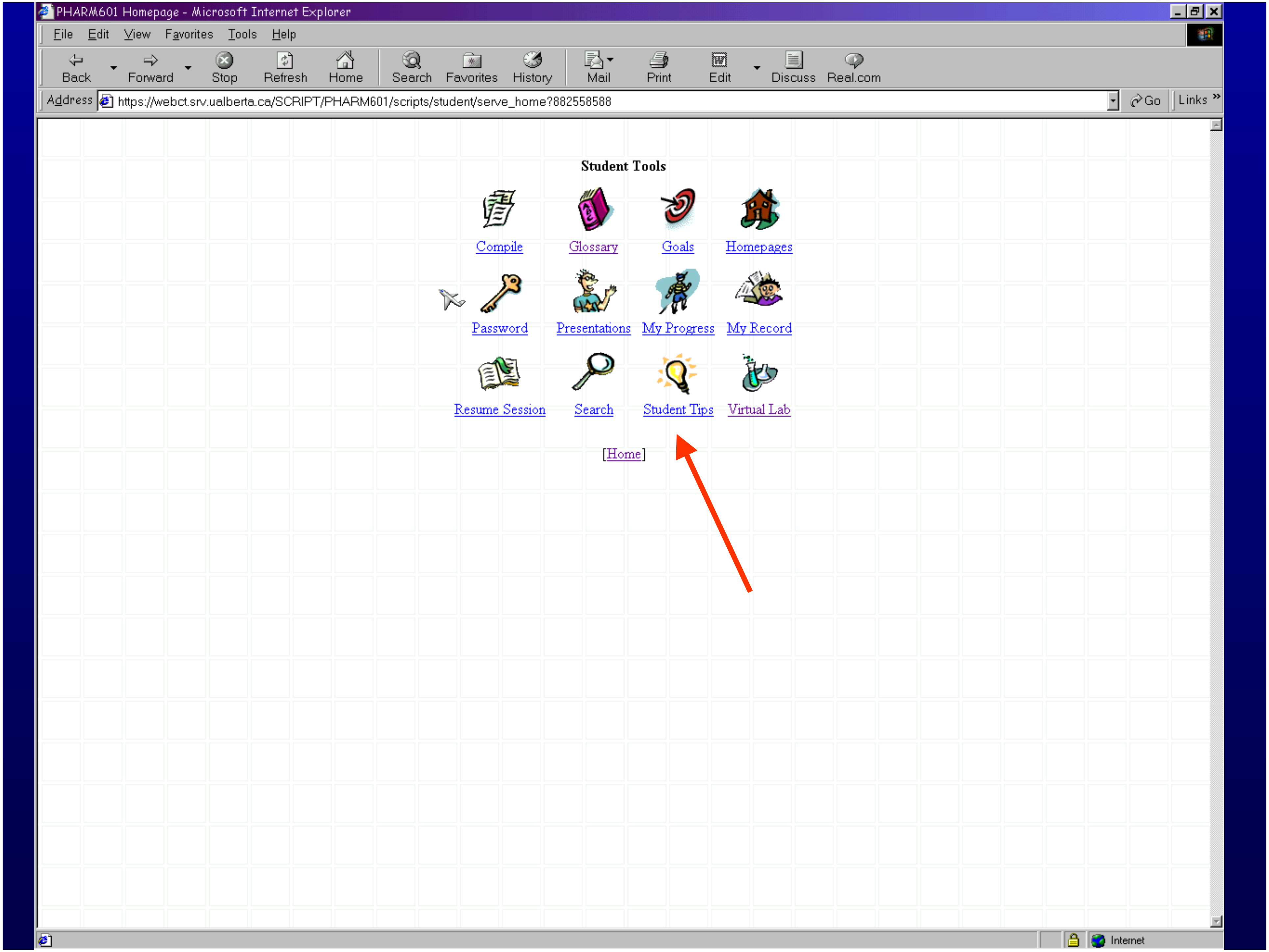
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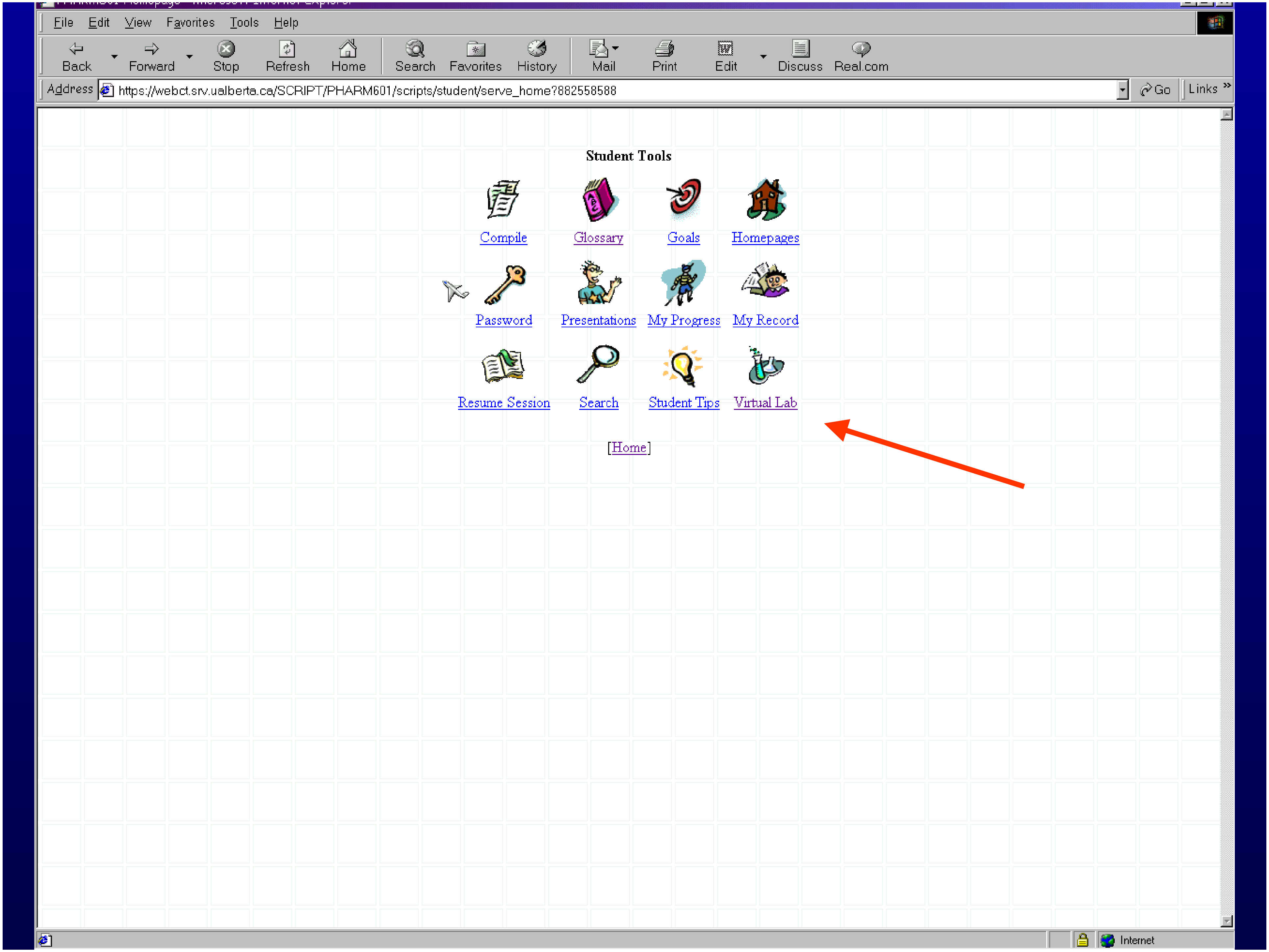
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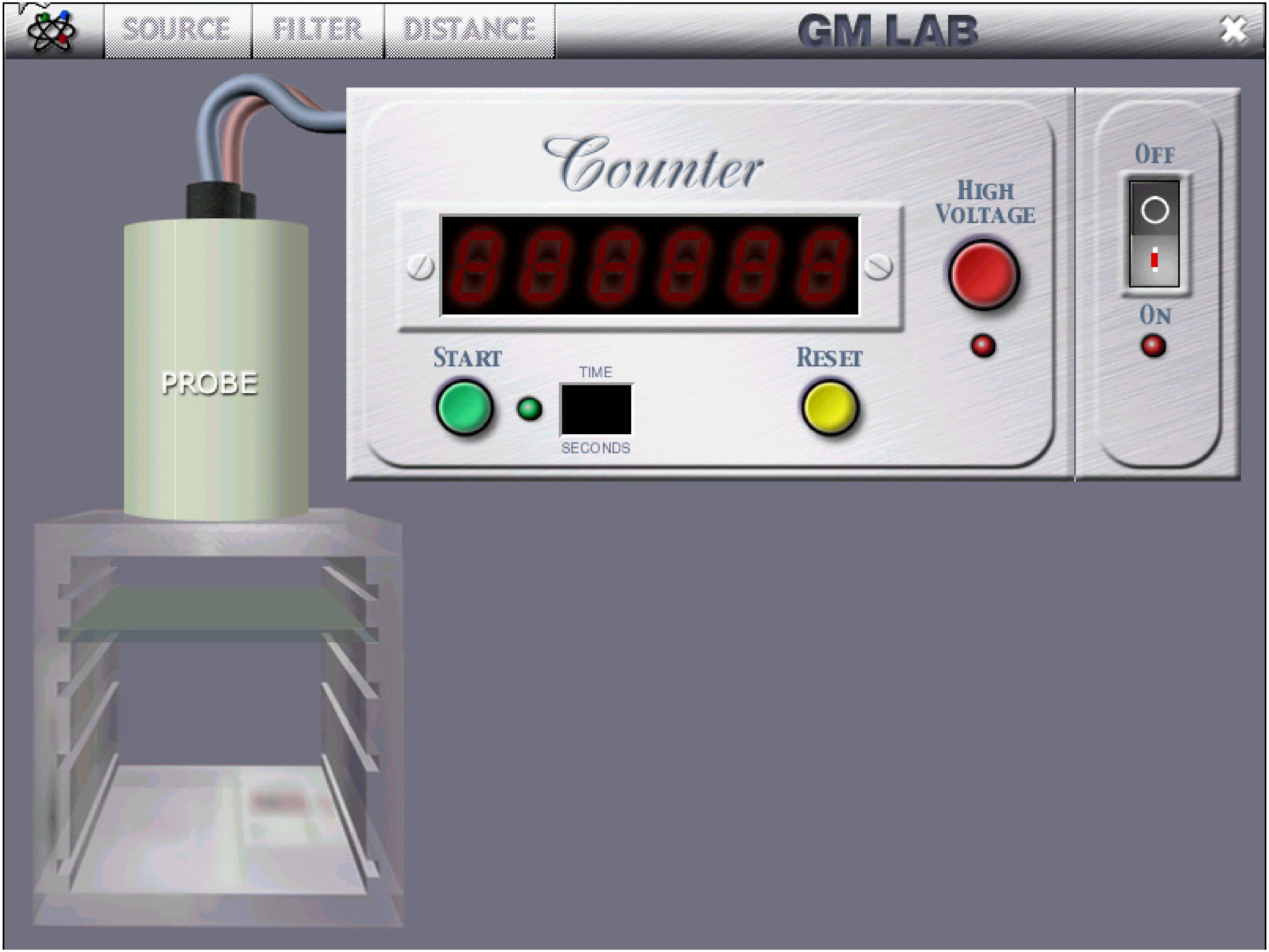
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