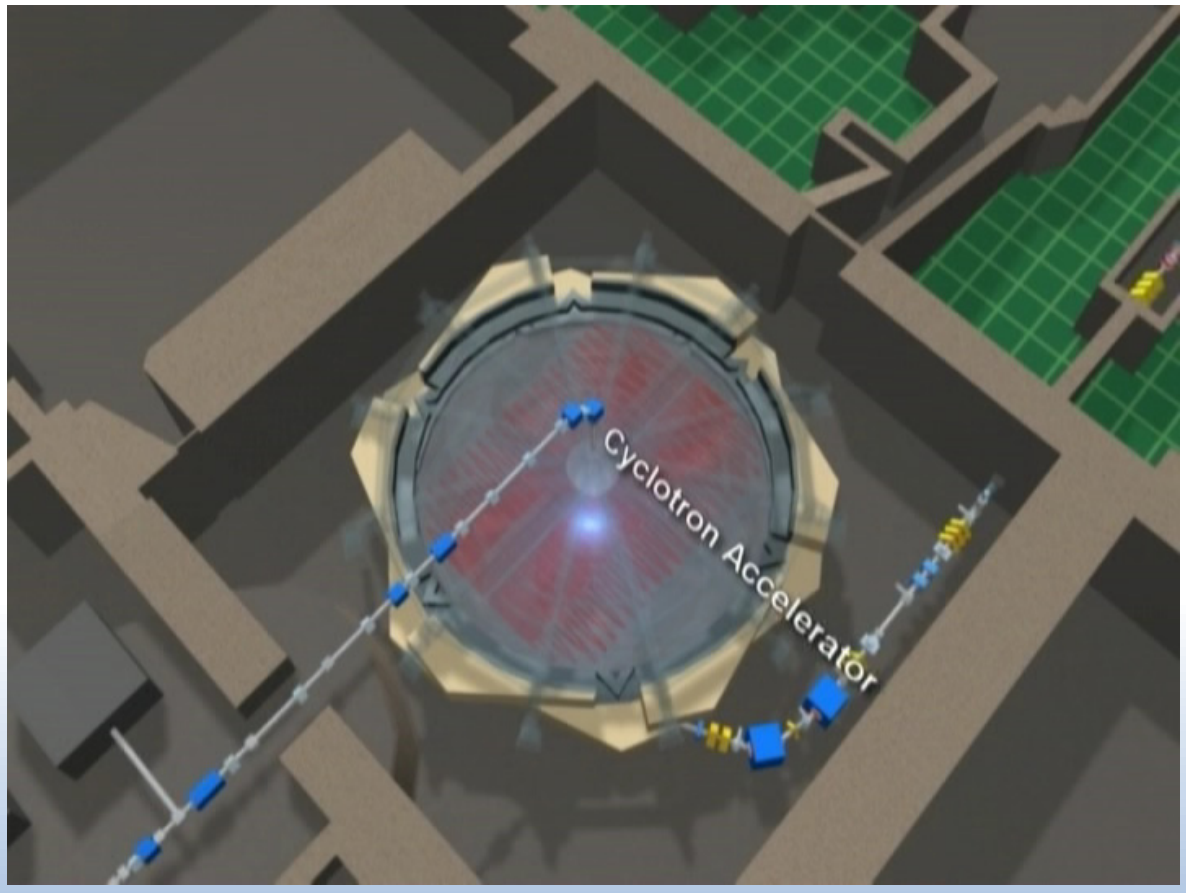
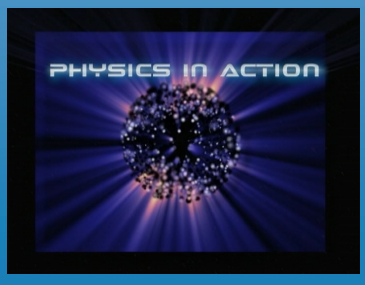
TRIUMF



Electromagnetism and Circular Motion in a Cyclotron



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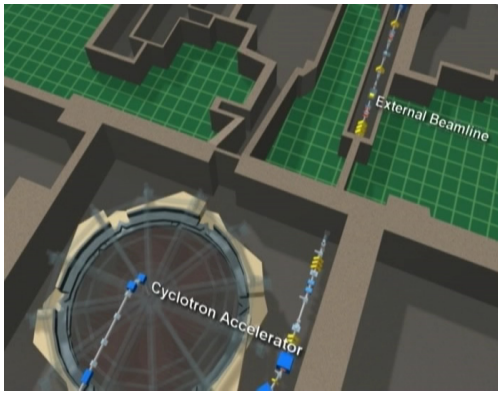

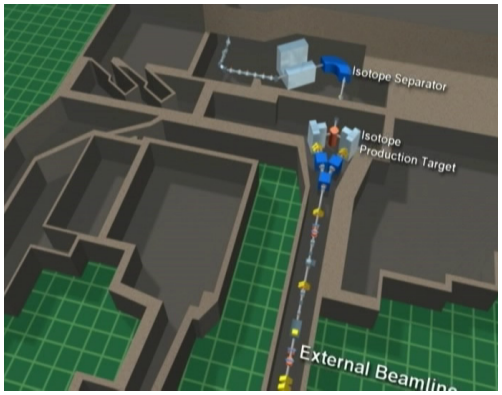

About Physics in Action

Funding

Major Funding Provided By
NSERC Promo Science

http://www.nserc.ca/awards/promoscience/

Additional Funding Provided
By Vancouver Foundation

http://www.vancouverfoundation.bc.ca/

Availability

The videos are available for free to any school in Canada that requests a copy. Copies of the videos may be requested online by visiting

http://www.triumf.ca

or by contacting the Outreach Coordinator at

outreach@triumf.ca

Companion booklets are included on the DVD, or may be downloaded from the website.

TRIUMF is Canada's national laboratory for particle and nuclear physics.
Laboratoire national canadien pour la recherche en physique nucléaire et en physique des particules.

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Physics in Action is a new educational video series that will show high school students that the very same formulas and ideas they are studying in the classroom are in fact used everyday in a modern world-class subatomic physics facility – they are not useless facts with no real-world value, but essential elements for scientific research! Students will be shown that the research conducted at TRIUMF, Canada's National Laboratory for Particle and Nuclear Physics, is not beyond their understanding, but actually lies well within their grasp. Physics in Action will become a valuable part of every high school physics teachers' repertoire.

The videos are free to any school in Canada that wants one. They present a mix of live action, graphics, and 3D animation to help visualize the concepts, which often are difficult or impossible to convey in a typical classroom. Companion booklets will offer additional information and teaching resources for both students and teachers. The series has been developed in accordance with the prescribed learning outcomes of the BC and Alberta provincial education ministries.

Videos in the Physics in Action Series

In all, four educational videos were planned in the series.

Approaching the Speed of Light	Demonstrates the effects of Special Relativity on subatomic particle beams created at TRIUMF. Real data is provided, from which students can see clearly the speed-of-light limit, and how classical physics breaks down at high speeds. RELEASED 2004. Re-release in Winter 2010.
Electromagnetism and Circular Motion in a Cyclotron	Starts with hydrogen gas, and shows students how TRIUMF ionizes, steers, accelerates, and bombards it against a target to create exotic nuclei. Lesson modules demonstrate how each step can be understood using simple 11th and 12th grade electromagnetism. RELEASED Winter 2010.
Evolution of the Universe	Will take students on an exploration of the history of the universe from the Big Bang to the creation of our Solar System, showing where along the way the elements in their tin cup of water came from. IN PREPRODUCTION – Release Fall 2010.
Radioactivity	Will explain what radioactivity is and isn't, and demonstrate that it is a natural phenomenon with wide-ranging uses. Students will be shown the nuclear basis of alpha, beta, and gamma radiation. IN PLANNING – Release 2011.

Physics in Action: Electromagnetism and Circular Motion in a Cyclotron

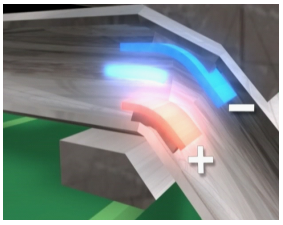
The second video, **Electromagnetism and Circular Motion in a Cyclotron**, is structured into 9 distinct parts.

Introduction (2:55 min)

The *Introduction* is the "hook" for the video, showing the viewers one scientific basis of TRIUMF's research. It gives a very brief account of the evolution of the universe, from the Big Bang to the formation of our Solar System, and states that TRIUMF is a place where scientists study it. The video will show that much of how TRIUMF works is understandable by students, so by extension, students can begin to undertand how scientists study the universe.

Brief Overview (1:33 min)

The *Brief Overview* gives a very brief account of how TRIUMF scientists create the exotic atoms necessary to study stars and supernovae, from creating negative hydrogen ions, to accelerating them, to creating and filtering. Since students likely will be new to this, it will prepare them for the rest of the video.

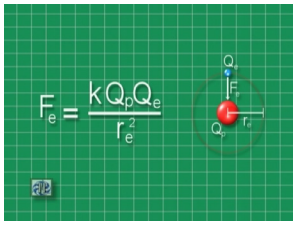


Overview (7:12 min)

The *Overview* details each stage of the TRIUMF exotic atom production system: creating negative hydrogen ions; accelerating, focussing and steering them into the cyclotron; accelerating them in the cyclotron and extracting a proton beam; steering the protons onto an exotic ion production target; and filtering out the exotic atom stream to isolate a particular one. Students will begin to see how the topics they've covered in class are used at the laboratory.

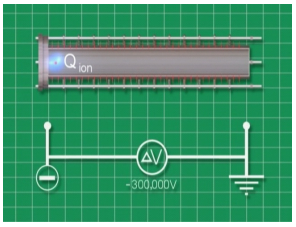
Lesson Modules

Altogether, the lesson modules provide even more detail into the operation of the TRIUMF exotic atom production system. Each lesson in turn looks at a particular subsystem, and walks the student through a key calculation related to that subsytem. In general each lesson addresses a different part of the senior high school curriculum. Additional problems are refered to at the end of each lesson.



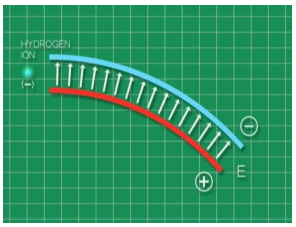
1. Hydrogen Minus Ion (3:49 min)

This lesson determines how much energy it takes to strip the lone electron of a hydrogen atom from its proton nucleus. This is the first step to creating the negative hydrogen ion beam that is injected into the cyclotron. The module uses a classical model of the atom, Newton's and Coulomb's laws, and circular motion to perform the calculation.



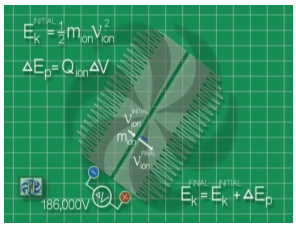
2. Initial Acceleration (3:12 min)

After the negative hydrogen ions are created, they must be sped up by an electric field in order to be transported down the beamline into the cyclotron. This module uses the principle of converting electric potential energy into kinetic energy to calculate the velocity of the ions as they exit the source and enter the cyclotron. Same type of calculation is shown for a ball falling in a gravitational field.



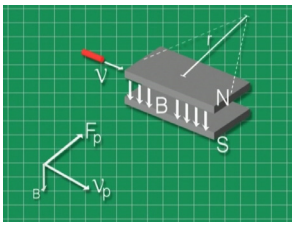
3. Electrostatic Beam Steering (2:40 min)

This modules show how simple metal plates with a potential difference across them can be used to steer the negative hydrogen ions. Students are asked to calculate this voltage difference using the principles of Newton's Law, circular motion, and electric fields.



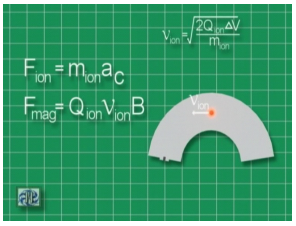
4. Circular Motion in a Magnetic Field (6:58 min)

This module details how the cyclotron accelerates the negative hydrogen ions. It addresses electric and magnetic fields and forces, circular motion, kinetic and electrical potential energy, frequency and period, and Newton's Laws, to show how the fundamental cyclotron frequency can be calculated. The calculation is a graphing problem, which the students can perfrom with the data provided.



5. Magnetic Beam Steering (3:28 min)

This lesson asks the students to determine the potential difference in an electrostatic bender required to steer a proton travelling at ¾ the speed of light, and contrast that with the magnetic field strength in a dipole magnet. The module uses Newton's law, the magnetic and electric forces, and cicular motion. The module ends by asking the students to design an electromagnet using the formula for magnetic field strength from coils of current-carrying wire.



6. Beam Production and Filtering (5:33 min)

The final module derives the basic formula for filtering atoms according to mass using a mass spectrometer system consisting of an electrostatic accelerator and a dipole magnet. Like the cyclotron lesson, this lesson ties together most of the principles and formulas addressed in the video. Students are asked to identify atoms in a spectrum of production yield versus magnetic field.

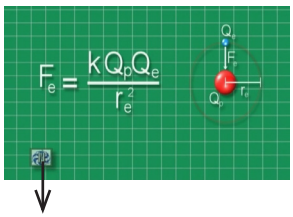
How to Use this Video

Electromagnetism and Circular Motion in a Cyclotron has been formatted into modules to allow teachers maximum flexibility when delivering their classroom lessons. The modules are navigated by means of the main DVD menu, which appears when the DVD is loaded into a player (either stand-alone or on a computer). After playing through each module, the DVD will automatically return to the main menu.

Using the DVD for the first time, teachers are likely to play the *Overview* module, which plays the *Introduction*, *Brief Overview*, and full *Overview* consecutively, taking about 12 minutes. Then the teacher can select one or more of the lesson modules, each of which play for 3 to 7 minutes.

Teachers can play only the *Introduction* and *Brief Overview* by selecting the *Brief Overview* module, which plays through in about 4 minutes. This could be, for example, if they simply want to remind the students of the content before tackling other lessons.

Pause Points



"Pause" symbol

The lesson modules present the relevant formulas required to solve the problems, often rearranging with animation into the proper form, before entering in the variables and showing the solution. If teachers would like the students to rearrange or solve the formulas on their own before being shown the solution, pause points in the form of the TRIUMF logo overlayed with the 'pause' symbol appear at various times to alert the teacher to pause the video. Naturally the DVD can be paused any time.

Supplementary Lesson Material

The student and teacher workbook is designed to allow the students to follow along each lesson module, with the answers provided to the teachers. Additional lessons not shown on the video are also included. The workbook is provided in editable form so that teachers may modify to suit their needs.

Credits

Production Team

The Physics in Action series is produced by:

Marcello Pavan, Ph.D.	TRIUMF Outreach Coordinator
Stanley Yen, Ph.D.	TRIUMF Research Scientist
Ross Belyea	A. Ross Belyea Productions (Producer, Scriptwriter)
John Lambert	Gravity Lab Productions (Camera, Editing, Animation, Sound)
Phil Freeman	Richmond High School (Teacher Consultant)
Dan Zwiercan	Freelance Animator
Ting Wang	Workbook Production and Graphics

Along with the valuable assistance of many members of TRIUMF's staff.

TRIUMF welcomes feedback from teachers and the public. If you have any questions, suggestions, or concerns about the Physics in Action series, please direct them to:

TRIUMF Outreach Coordinator
outreach@triumf.ca

