Motion of Electrical Carriers in an Electric Field and a Magnetic Field

Dobrescu Razvan
Str. Brasov, nr 24, bl 717, sc B, et 2, ap 44, sector 6, Bucuresti Romania
dobrescu_razvan@yahoo.com

Gabriel Teodoru
Str. Marinarilor nr 12-16, bl 9/1, sc B, et 2, ap 25, sector 1, Bucuresti Romania
teodoru_gabi@yahoo.com

Abstract

The theme approached is the motion of electrified particles in an electric field and in a magnetic field, with the following aspects highlighted:

- *simulating motion of a charged particle in:*
  - *uniform, inhomogeneous, central electric field*
  - *homogeneous, inhomogeneous magnetic field*
- *simulating motion of particles in a central gravitational field*
- *understanding the functioning of such devices as:*
  - *the linear particle accelerator*
  - *the cyclotron*
  - *the mass analyzer*
  - *the magnetic lens*

In order to obtain a most efficient integration of this application in the teaching process, an instrument of evaluation has been included, as well as a series of exercises.

Keywords

Educational process, innovation, interactivity, IT

1. Main text

The four lessons concerning the motion of electrical carriers in an electric or a magnetic field and their motion in a central gravitational field allow the student to visualize the exact phenomenon. Thus, he has the possibility to accurately analyze these types of motion. The study of the physical phenomena described leads to the construction and practical use of some experimental devices such as the cyclotron, the linear particle accelerator, the mass analyzer and the magnetic lens. This application is intended as an efficient instrument to be directly used by students, helping them to better understand both the abovementioned phenomena and their practical use. Unlike traditional teaching methods, educational allows pupils to discover for themselves the essence of the studied phenomena, and to offer himself answers to whatever questions may trouble him.

Detailed structure of the lessons

1.1 Motion of electrical carriers in an homogeneous paraxial electric field

This is the section of the lesson where students analyze the motion of a charged particle (proton/electron) in an homogeneous paraxial electric field. The user can access any of the following components:

a.) Theoretical notions
b.) Key words
c.) Help
d.) Information
e.) Objectives

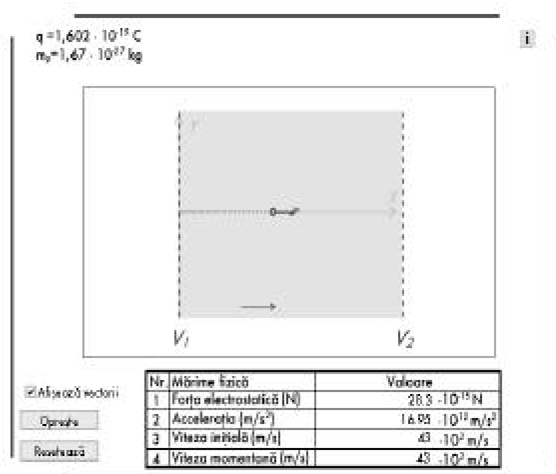


Figure1. Motion of electrical carriers in an homogeneous paraxial electric field

Instructions for use of the application:
A table is filled in with the values chosen for the initial particle speed (v_0) and the intensity of the electric field (E).
After studying the data provided by the table, the students can then draw their own conclusions concerning the influence of the electric field studied, over electrical carriers.
For a rigorous analysis of the physical phenomenon, the user will compare the values obtained for the particle's final speed, while keeping the initial speed constant and changing the field intensity, or keeping the field intensity constant and changing the initial speed. Also, the student can maintain both the initial speed and the electric field intensity constant, but modify the particle type.

1.2. Motion of electrical carriers in an inhomogeneous electric field

This is the section of the lesson where students analyze the motion of a charged particle (proton/electron) in an inhomogeneous electric field. The user can access any of the following components:

a.) Theoretical notions
b.) Key words
c.) Help
d.) Information
e.) Objectives

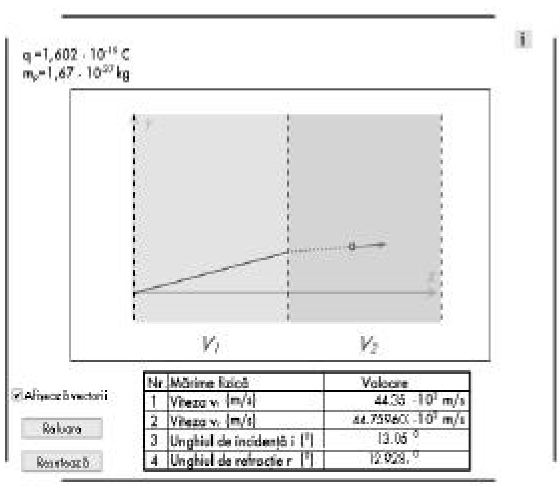


Figure 2. Motion of electrical carriers in an inhomogeneous electric field

Instructions for use of the application:
A table similar is filled in with the values chosen for the incidence angle (i), the potentials V_1 and V_2 and the initial particle speed
After studying the data provided by the table, the students can then draw their own conclusions concerning the influence of the electric field studied, over electrical carriers.
For a rigorous analysis of the physical phenomenon, the user will compare the values obtained for the particle's speeds v_1 and v_2, while keeping the initial speed constant and changing the incidence angle, or keeping the incidence angle constant and changing the initial speed. Also, the student can maintain both the initial speed and the incidence angle constant, but modify the particle type or the potentials.

1.3. Motion of electrical carriers in a transverse electric field

This is the section of the lesson where students analyze the motion of a charged particle (proton/electron) in a transverse electric field. The user can access any of the following components:

a.) Theoretical notions
b.) Key words
c.) Help
d.) Information
e.) Objectives

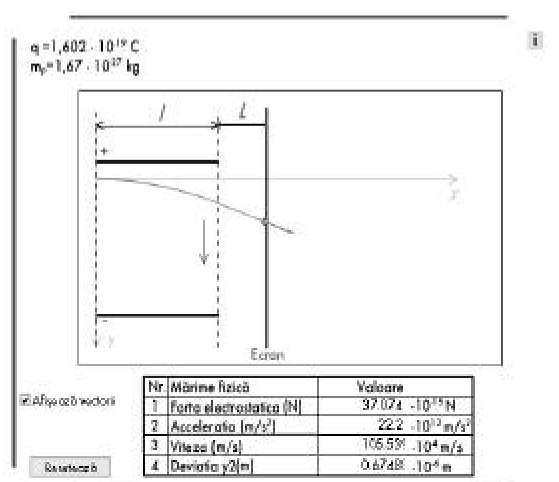


Figure 3. Motion of electrical carriers in a transverse electric field

Instructions for use of the application:
A table is filled in with the values chosen for the initial speed (v), the distance between the slabs, the intensity of the electric field (E) and the distance to the screen
After studying the data provided by the table, the students can then draw their own conclusions concerning the influence of the electric field studied, over electrical carriers.

For a rigorous analysis of the physical phenomenon, the user will compare the values obtained for the particle's deviations, while keeping v_0, d and L constant and changing E, or keeping E, d and L constant and changing the initial speed. Also, the student can maintain v_0, d, L, and E constant, but modify the particle type.

1.4. The linear particle accelerator

This is the section of this lesson where students analyze the motion of an electron in a linear particle accelerator. The user can access any of the following components:

a.) Theoretical notions
b.) Information
c.) Objectives

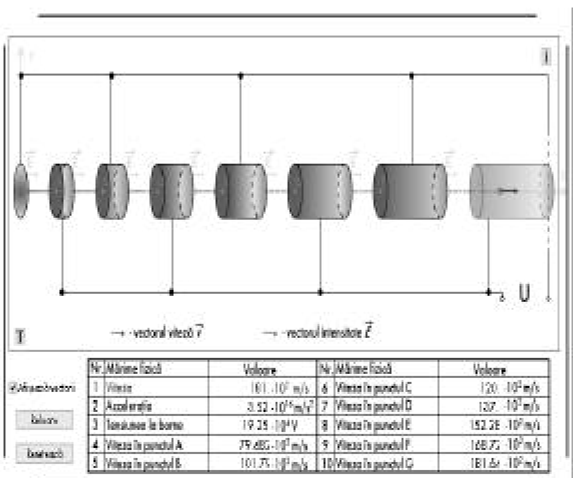


Figure 4. The linear particle accelerator

Instructions for use of the application:
A table is filled in with the values chosen for the initial speed (v) and the potential difference (U):
After studying the data provided by the table, the students can then draw their own conclusions concerning the functioning of the linear particle accelerator.
For a rigorous analysis of the physical phenomenon, the user will compare the values obtained for the particle's final speed, while keeping v_0 constant and changing U, or keeping U constant and changing v_0.

1.5. Motion of electrical carriers in an homogeneous electric field (interactive)

This is the section of the lesson where students analyze the motion of an electric carrier (proton/electron) in an homogeneous electric field. The user can access any of the following components:

a.) Information
b.) Objectives

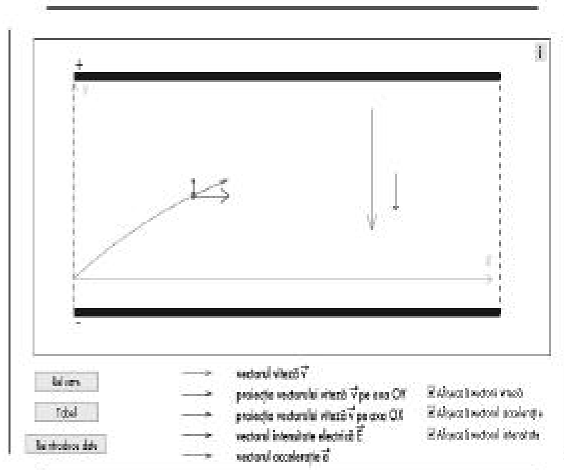


Figure 5. Motion of electrical carriers in an homogeneous electric field (interactive)

Instructions for use of the application:
A table is filled in with the values chosen for the initial speed (v), the angle formed by the initial speed vector and the OX axis (? ? ?the electric field intensity, the particle type and the orientation of the speed vector:
After studying the data provided by the table, the students can then draw their own conclusions concerning the influence of the electric field studied, over electrical carriers.
For a rigorous analysis of the physical phenomenon, the user will compare the values obtained for the particle's displacement along the OY axis, while keeping v_0 and ? ?constant and changing E, or keeping E and ? constant and changing v_0. Also, the student can maintain v_0 and E constant, but modify the particle type and/or ? .

1.6. Motion of electrical carriers in an homogeneous transverse magnetic field

This is the section of the lesson where students analyze the motion of an electric carrier (proton/electron) in an homogeneous transverse magnetic field. The user can access any of the following components:

a.) Theoretical notions
b.) Key words
c.) Help
d.) Information
e.) Objectives

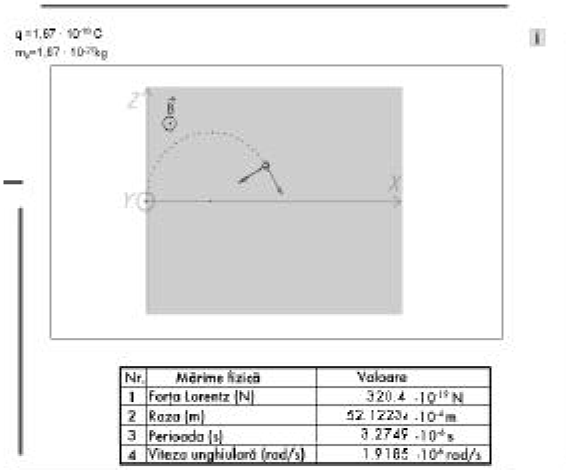


Figure 6. Motion of electrical carriers in an homogeneous transverse magnetic field

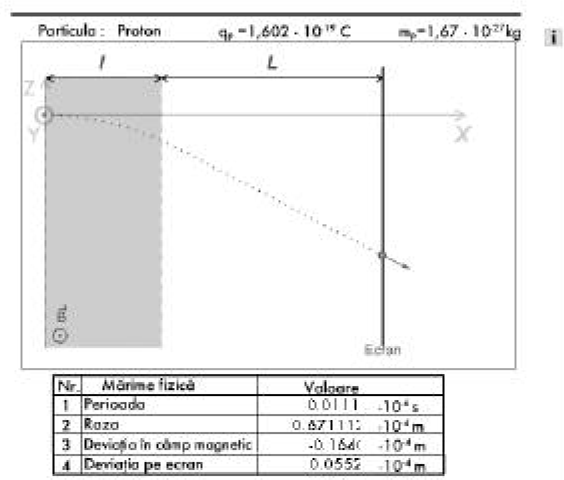


Figure 7. Motion of electrical carriers in a limited homogeneous transverse magnetic field

Instructions for use of the application:
A table is filled in with the values chosen for the initial speed (v_0), the magnetic induction (B) and the orientation of the field pattern:
After studying the data provided by the table, the students can then draw their own conclusions concerning the influence of the magnetic field studied, over electrical carriers.
For a rigorous analysis of the physical phenomenon, the user will compare the values obtained for the radius of the particle's circular trajectory and for the circulation period, while keeping B constant and changing v_0, or keeping v_0 constant and changing B. Also, the student can maintain both v_0 and B constant, but modify the particle type.

1.7 Motion of electrical carriers in a limited homogeneous transverse magnetic field

This is the section of the lesson where students analyze the motion of a proton in a limited homogeneous transverse magnetic field. The user can access any of the following components:

a.) Theoretical notions
b.) Key words
c.) Help
d.) Information
e.) Objectives

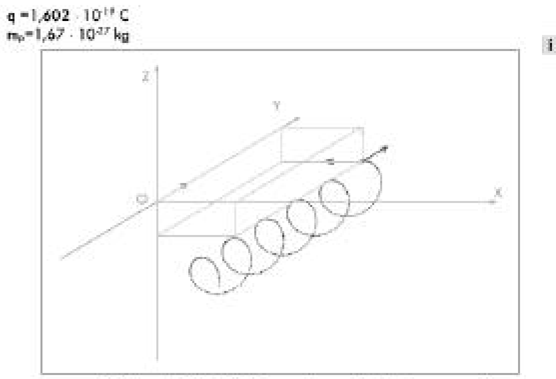
Instructions for use of the application:
A table is filled in with the values chosen for the initial speed (v_0), the magnetic induction (B), the distance to the screen (L) and the dimension of the area under the magnetic field (l):
After studying the data provided by the table, the students can then draw their own conclusions concerning the influence of the magnetic field studied, over electrical carriers.
For a rigorous analysis of the physical phenomenon, the user will compare the values obtained for the particle's deviations, while keeping B, L and l constant and changing v_0, or keeping v_0, L and l constant and changing B. Also, the student can maintain v_0 and B constant, but modify l and L.

1.8 Motion of electrical carriers in an homogeneous magnetic field

This is the section of the lesson where students analyze the motion of a charged particle in an homogeneous magnetic field. The user can access any of the following components:

a.) Theoretical notions
b.) Key words
c.) Help
d.) Information
e.) Objectives

Instructions for use of the application:
Various values are chosen for the initial position of the particle (X,Y,Z), the angle formed by the initial speed vector and the magnetic induction vector, and the orientation of the magnetic induction vector.
By analyzing the trajectories described by the electrical carriers, the student can draw his own conclusions concerning the charged particles' motion.



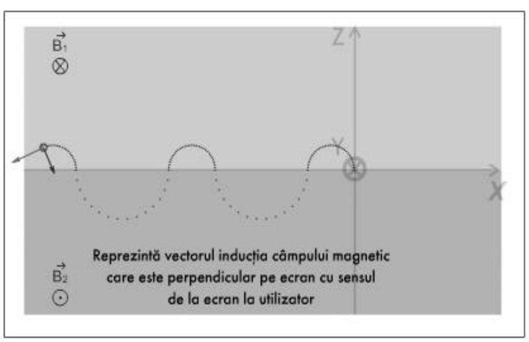
Nr.	Mărime fizică	Valoare
1	Forța Lorentz	60.176 $\cdot 10^{-19}$ N
2	Raza	1.566308 $\cdot 10^{-8}$ m
3	Perioada	1.3099 $\cdot 10^{-8}$ s
4	Pasul	0.8645 $\cdot 10^{-7}$ m

Figure 8. Motion of electrical carriers in an homogeneous magnetic field

1.9 Motion of electrical carriers in an inhomogeneous transverse magnetic field

This is the section of the lesson where students analyze the motion of a charged particle in an inhomogeneous magnetic field. The user can access any of the following components:

a.) Theoretical notions
b.) Key words
c.) Help
d.) Information
e.) Objectives



Nr.	Mărime fizică	Valoare
1	Raza în câmpul cu B_1	4.07596754 $\cdot 10^{-10}$ m
2	Raza în câmpul cu B_2	8.15193508 $\cdot 10^{-10}$ m
3	Perioada în câmpul cu B_1	0.32749436 $\cdot 10^{-12}$ s
4	Perioada în câmpul cu B_2	0.65498873 $\cdot 10^{-12}$ s

Figure 9. Motion of electrical carriers in an inhomogeneous transverse magnetic field

Instructions for use of the application:
A table is filled in with the values chosen for the initial speed (v_0) and the two magnetic inductions (B_1/B_2). Also, the user can choose the orientation of the magnetic induction vectors.
After studying the data provided by the table, the students can then draw their own conclusions concerning the influence of the magnetic field studied, over electrical carriers.
For a rigorous analysis of the physical phenomenon, the user will compare the values obtained for the radii of the particle's circular trajectory and for the circulation periods, while keeping B_1 and B_2 constant and changing v_0, or keeping v_0 constant and changing B_1 or B_2. Also, the student can maintain v_0, B_1 and B_2 constant, but modify the particle type and/or the orientation of the magnetic induction vectors.

1.10 Motion of electrical carriers in an homogeneous magnetic field (interactive)

This is the section of the lesson where students analyze the motion of a charged particle in an homogeneous magnetic field. The user can access any of the following components:

a.) Information
b.) Objectives

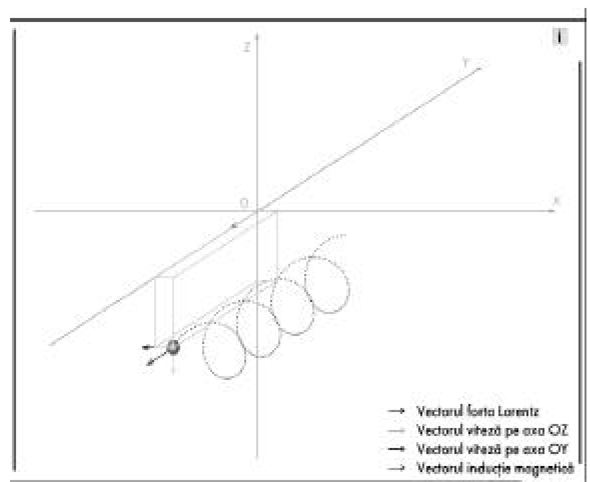


Figure 10. Motion of electrical carriers in an homogeneous magnetic field (interactive)

Instructions for use of the application:
A table is filled in with the values chosen for the initial speed (v_0), the magnetic induction (B) and the angle formed by the initial speed vector and the magnetic induction vector. Also, the user can modify the orientation of the speed vector and that of the magnetic induction vector.
After studying the data provided by the table, the students can then draw their own conclusions concerning the influence of the magnetic field studied, over electrical carriers.
For a rigorous analysis of the physical phenomenon, the user will compare the values obtained for the radii, the periods and the paces of the particle's circular trajectory, while keeping

B and ? constant and changing v_0, or keeping v_0 and ? ?constant and changing B. Also, the student can maintain both the initial speed and the magnetic induction constant, but modify the particle type and/or ? .

1.11 The cyclotron

This is the section of the lesson where students analyze the functioning of the cyclotron. The user can access any of the following components:

a.) Theoretical notions
b.) Key words
c.) Help
d.) Information
e.) Objectives

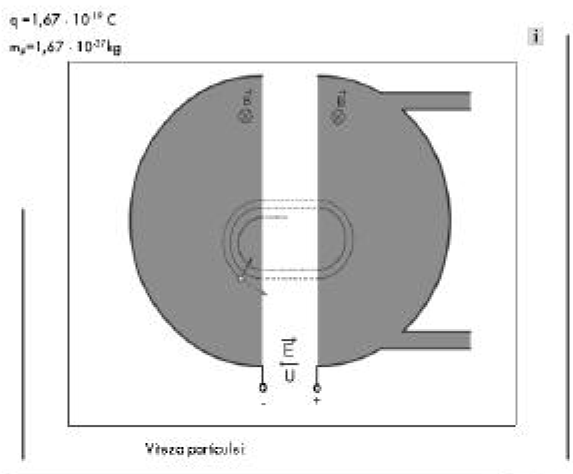


Figure 11. The cyclotron

Instructions for use of the application:
A table is filled in with the values chosen for the initial speed (v_0), the magnetic induction (B), the intensity of the electric field (E) and the orientation of the magnetic induction vector:
After studying the data provided by the table, the students can then draw their own conclusions concerning the functioning of the cyclotron.
For a rigorous analysis of the physical phenomenon, the user will compare the values obtained for the particles' final speed, while keeping B and v_0 constant and changing E, or keeping E and v_0 constant and changing B. Also, the student can maintain v_0, E and B constant, but change the particle type.

1.12 The mass analyzer

This is the section of the lesson where students study the functioning of the mass analyzer. The user can access any of the following components:

a.) Theoretical notions
b.) Key words
c.) Help
d.) Information
e.) Objectives

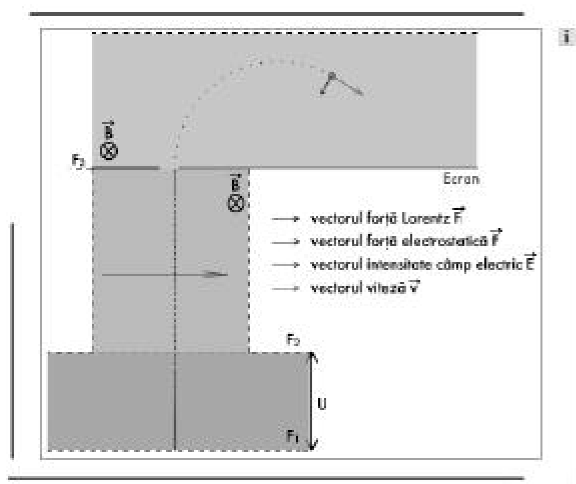


Figure 12. The mass analyzer

Instructions for use of the application:
A table similar to the following sample is filled in with the values chosen for the potential difference (U), the magnetic induction (B) and the intensity of the electric field (E):
After studying the data provided by the table, the students can then draw their own conclusions concerning the functioning of the mass analyzer and determine the particle's mass.

1.13 The magnetic lens

This is the section of the lesson where students analyze the motion of a charged particle in a variable magnetic field. Phenomena such as this occur in a magnetic lens. The user can access any of the following components:

a.) Theoretical notions
b.) Key words
c.) Help
d.) Information
e.) Objectives

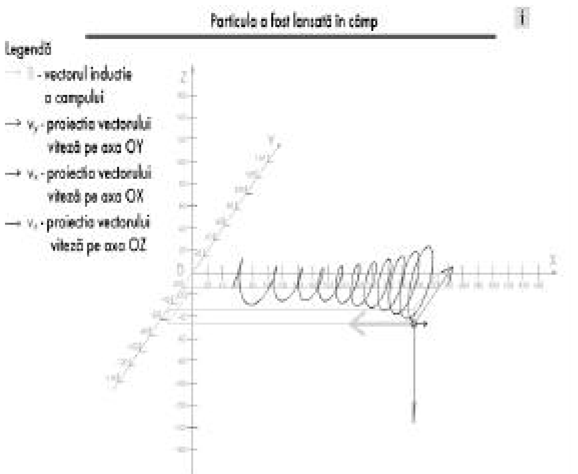


Figure 13. The magnetic lens

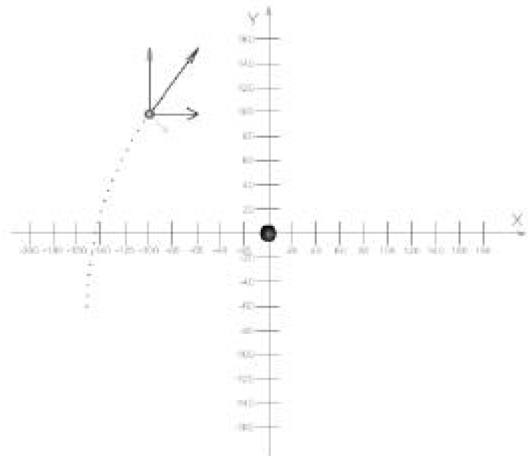


Figure 14. Motion of charged point particles in a central electric field

Instructions for use of the application:
A table is filled in with the values chosen for the parameters B_0 and b, the magnetic induction, the intensity of the electric field and the orientation of the magnetic induction vector. The user can also establish the particle's initial position and initial speed.
After studying the data provided by the table, the students can then draw their own conclusions concerning the functioning of the magnetic lens.
For a rigorous analysis of the physical phenomenon, the user will compare the values obtained for the particles' final position, relative to their initial position, by setting the initial conditions and varying B_0 and/or b. Also, the student can keep all the parameters constant, but change the particle type.

1.14 Motion of charged point particles in a central electric field

This is the section of the lesson where students analyze the motion of a charged point particle in a central electric field. The user can access any of the following components:

a.) Theoretical notions
b.) Key words
c.) Help
d.) Information
e.) Objectives

Instructions for use of the application:
The student has to choose the type of the fixed particle, that of the mobile particle and the initial conditions. By analyzing the types of motion simulated by this application he can draw several conclusions concerning the conditions necessary in order to obtain a closed or an open trajectory.

1.15 Motion of point particles in a central gravitational field

This is the section of the lesson where students analyze the motion of a point particle in a central gravitational field (the movement of celestial bodies). The user can access any of the following components:

a.) Theoretical notions
b.) Key words
c.) Help
d.) Information
e.) Objectives

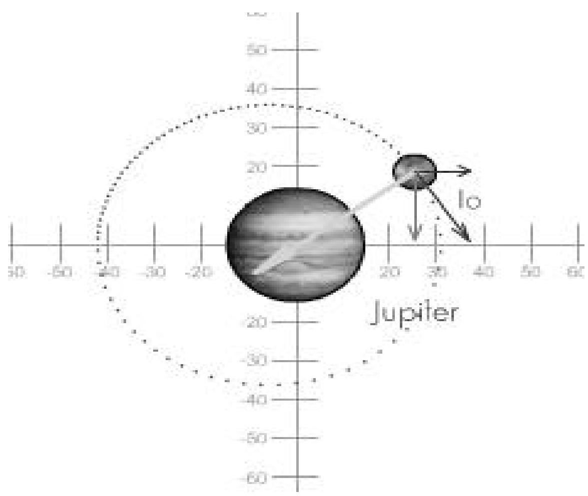


Figure 15. Motion of point particles in a central gravitational field

Instructions for use of the application:
The user can select the type of satellite and the type of the fixed planet. By analyzing the

rotative motion of the moon around the Earth, one can determine its circulation period.

The present application allows the observation and analysis of some satellites' movement around their planets.