SIR ISAAC NEWTON'S GAMES

Table of Contents

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INTRODUCTION

Science at any level is about the study of the world around us. When we teach science, we try to get young people to be curious about the ways in which we see, hear, feel, and smell the world. If we are particularly successful, our students will understand that exploring one's curiosity about the world can be both rewarding and stimulating.

Sometimes we are so familiar with a natural phenomenon that we don't regard it as an object worthy of study and wonderment. We don't seem to find it remarkable that hot cups of coffee cool and cold glasses of milk warm up and never the other way around, or that newborn kittens look like adult cats and that newborn horses look like adult horses.

The way things move is another such phenomenon. We have watched movement and have ourselves been moving all our lives. However, we seldom turn our conscious attention to the nature of movement.

It is not easy to build powerful theories of how things move... theories that are good enough to explain how a tractor and a hockey puck and a planet each moves through its surroundings. In fact, it took us as a species many thousands of years to arrive at the scientific descriptions of motion that we now have.

There are different levels of description of motion. The more powerful, which are usually taught in advanced secondary or early college level physics courses, enable the student to make specific quantitative predictions about motion. That kind of description of motion requires more sophisticated mathematical tools than students can reasonably be expected to have mastered in the earlier grades.

Despite the fact that a full and rich understanding of motion requires an understanding of calculus, it is possible even for very young children to acquire a deep qualitative understanding of the factors that govern motion. SIR ISAAC NEWTON'S GAMES is designed to help youngsters acquire just that kind of understanding.

Such a qualitative understanding of motion is desirable not only for those who are not yet able to deal with more advanced mathematics, but for the mathematically knowledgeable as well. Indeed, all too often one encounters students at college level who are quite able to calculate mathematically but who do not have any kind of intuitive feel for the system whose motion they are describing. SIR ISAAC NEWTON'S GAMES is intended for them as well.

The most appealing intuitive notion of how forces produce motion is that an object moves in the direction of the force on it. Suppose we kick a can around a schoolyard by administering a series of kicks to it at regular intervals. Each time we kick the can, it moves in the direction of the kick and comes to a halt. Kicking it again results in another move. If the direction of the second kick was different from that of the first one, then the direction of the second move will be different from that of the first one. Therefore, it seems that the conclusion that the can moves in the direction of the force exerted on it is a good description of its motion.

If we try the same experiment on an ice skating rink rather than in the schoolyard, the can may still be moving when it is time to kick it again. We find that when we kick the can, it doesn't move in the direction of the kick but rather in a direction that is somewhere between the direction it was going in and the direction of the kick. The kick produces a change in the velocity of the object, and it moves in a direction that depends on both its original velocity and the change in velocity that the kick produces.

Perhaps the best evidence that objects do not move in the direction of the force exerted on them comes from thinking about the motion of an Earth satellite in circular orbit around the Earth. The force the Earth exerts on the satellite is an attractive force that is directed toward the center of the Earth. If the satellite were to move in the direction of the force the Earth exerts on it, it would not stay up for very long.

In SIR ISAAC NEWTON'S GAMES, students have the opportunity to explore how the change in motion produced by a force combines with the prior motion of the object to produce a new motion. Some of the game settings will be like the can in the schoolyard example where friction plays a sufficiently large role in governing the motion. Other settings will be more like the skating rink example. Still others will involve maneuvering in the vicinity of a "sun" that continually attracts everything in its surroundings toward itself. Finally, there are thoroughly idealized settings in which there are no forces to affect the motion other than the ones you exert.

A concluding note: SIR ISAAC NEWTON'S GAMES is designed so that "time" stops and waits for the players' next moves. In this way, students are continually confronted with the implicit question of the consequence of their next move. In my view, it is far preferable to have "time" stop, thereby permitting students to play games with their minds rather than their muscles.

Judah L. Schwartz

OVERVIEW

SIR ISAAC NEWTON'S GAMES contains five parts designed to introduce students of all ages to the richness and the subtlety of Newtonian dynamics on the study of motion. These programs may be used effectively in fifth grade through college, in the science classroom, at home, or in special education settings.

SIR ISAAC NEWTON'S GAMES adopts a hands-on approach to Newton's laws of motion. Students move a marker in a specific environment (e.g., on Earth, near the sun, or out in space), with or without friction acting upon its motion, by either kicking it or letting it coast. They actively and immediately experience the results of their actions on the object's motion.

The following programs are included in SIR ISAAC NEWTON'S GAMES:

TRACK - A game to practice moving a marker in different environments with or without friction inhibiting its motion.

OBSTACLE COURSE - A game to use skills from TRACK to maneuver around objects.

RACE - A two-person game in which students compete to finish a race first. Students may choose the environment and what forces, if any, act upon the marker.

TAG - A one-person game against the computer or a two-person game in which each player chases the other.

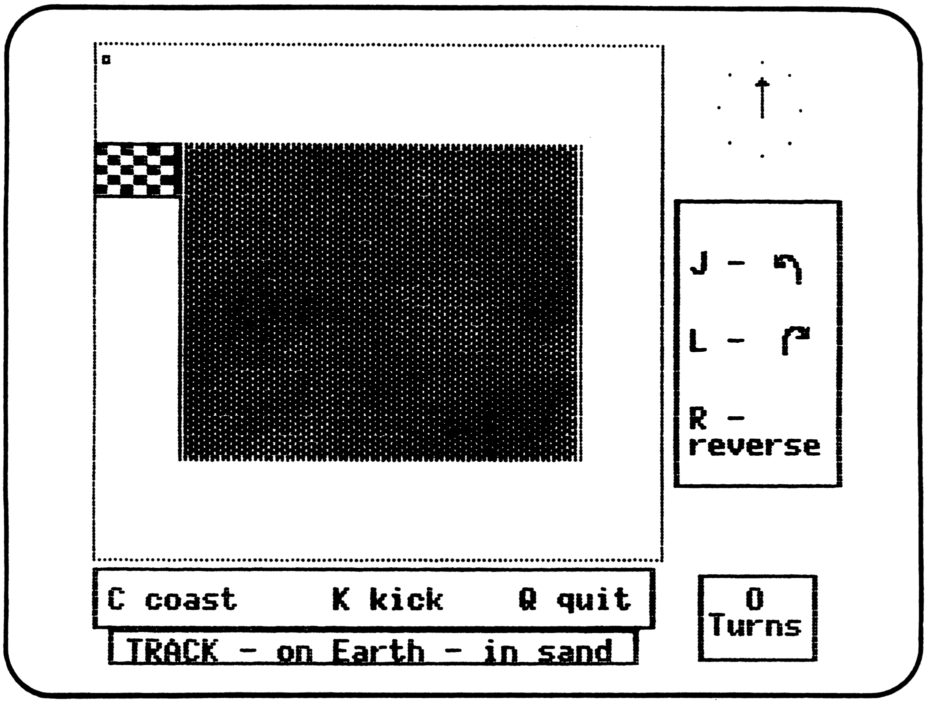
WRITE YOUR NAME - An exercise that allows students to practice the skills they have learned in other games.

STOPPING THE GAME

To stop a game, use Control E (hold the CTRL key down and press the "E" key). You will then return to the menu list to choose another game or you may END the session. If you END, you may use another diskette; just follow the directions on the screen.

GENERAL INFORMATION

In each of the games, you have to move a marker.



To move the marker:

- Choose a direction in which to kick (Note: the direction is shown by an arrow in the upper right-hand corner of the screen):

  press J to rotate the "arrow" counter-clockwise,

  press L to rotate the "arrow" clockwise, or

  press R to reverse the direction of the "arrow."

- Choose an action:

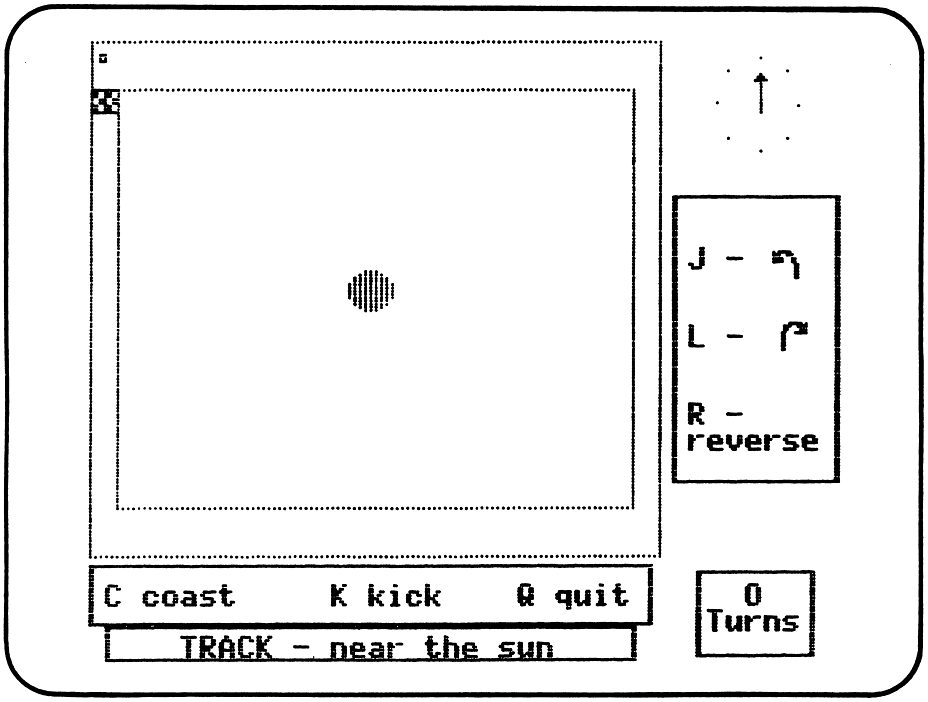
  press K to kick,

  press C to coast.

The counter in the lower right-hand corner of the screen keeps track of the number of turns you have taken.

In several cases, you will find that it is possible to invent variations on the games as they are described in this manual. You should feel free to experiment and play in the way you feel most comfortable.

TRACK



Conditions:	Walls are out of bounds One player External forces (on Earth, near the sun, out in space)
Object:	Move your marker around the track to the Finish Box.
Reading Level:	3rd grade (Fry)
Time Required:	3-10 minutes per game depending on skill level.
Objectives:	1. To gain an intuitive understanding of the relationships among velocity, change in velocity, and applied force. 2. To gain an intuitive understanding of frictional forces. 3. To understand the effect of a force, like the sun, on an object. 4. To compare the difference in a friction-free environment (i.e. way out in space) with that of Earth.

TRACK

Description: This is a one-person game in which you are required to get around a track in as few moves as possible without crashing into the walls. You can choose to have a wide track or a narrow one. (Practice with the wide track first!)

You can also choose what, if any, kind of external force you want to have acting on your marker as you try to move it around the track. You make this choice by playing:

- on Earth,
- near the sun, or
- way out in space.

If you choose to play on Earth, you will then be playing with frictional forces acting on your marker. You may choose to play:

1. in sand (a large amount of friction),
2. on grass (a moderate amount of friction), or
3. on ice (a small amount of friction).

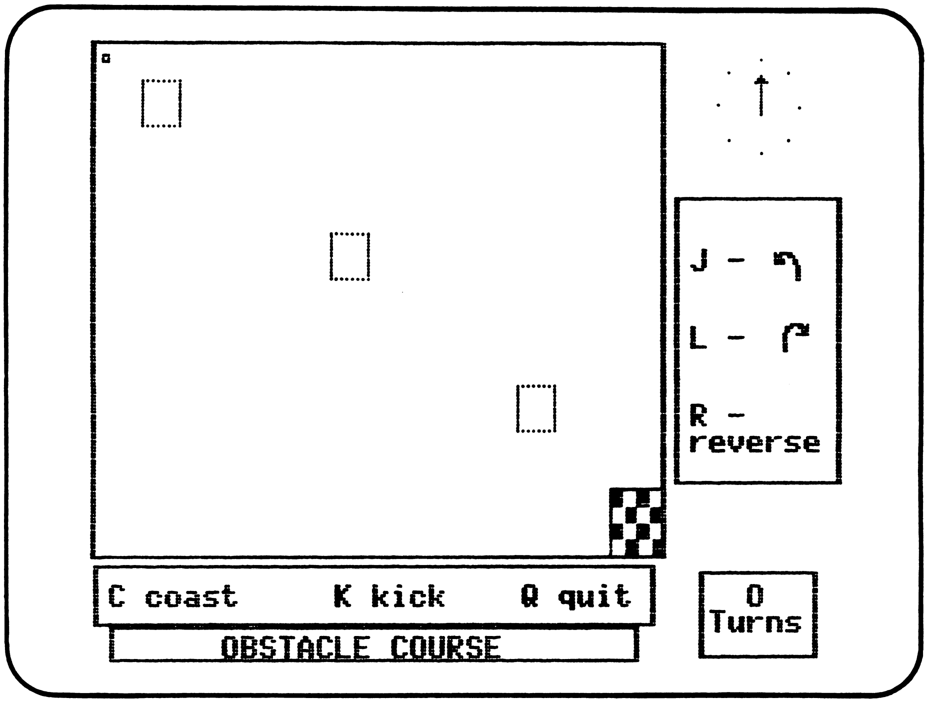
If you choose to play near the sun, you will be trying to move your marker around the track with the sun always pulling you toward itself. You will have to compensate for the sun's force in order to negotiate the track successfully.

If you choose to play way out in space, there will be no forces on your marker other than the ones you exert on it when you kick it.

To control the motion of the marker, you must first decide whether to give the marker a kick or to let the marker coast.

> Press C if you wish to coast. Time will then advance one unit and the marker will move subject to friction (if that condition exists in the version of the game you have chosen to play), or subject to the pull of the sun. If there are no external forces, the marker will move with the velocity it already has.
>
> If the decision is to kick, you must first determine a direction for the kick. This is done by using the J, L and R keys to move the "arrow" so that it points in the desired direction. Press K to kick the marker. Time will then advance one unit and the velocity of the marker will change under the influence of the force you have applied as well as whatever external forces are appropriate.

OBSTACLE COURSE



Conditions: Walls are reflecting
One player
No external forces
Obstacles out of bounds

Object: Move around obstacles to the Finish Box (Players can make up their own rules).

Reading Level: 3rd grade (Fry)

Time Required: 3-10 minutes per game depending on skill level.

Objective: To gain an intuitive understanding of the relationship among velocity, change in velocity, and applied force.

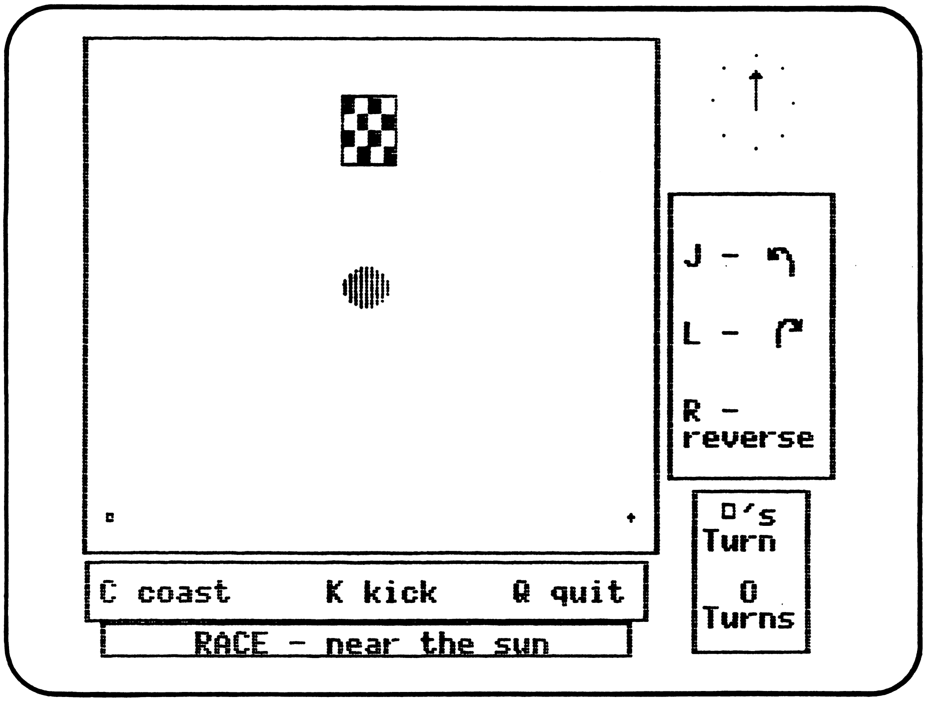
OBSTACLE COURSE

Description: Obstacle Course is a stringent test of your understanding of the relationship between force and acceleration. It is a one-person game in which you design a set of rules to reach a Finish Box (e.g., One set of rules might be to weave a course around three obstacles). In this game, there are no external forces and the outer walls are reflecting (i.e., if you hit them you will bounce off). If you hit an obstacle, the game will end.

To control the motion of the marker on the screen, you must first decide whether to give the marker a kick or to let the marker coast.

> Press C if you wish to coast. Time will then advance one unit and the marker will move with the velocity it already has.
>
> If the decision is to kick, you must first determine a direction for the kick. This is done by using the J, L and R keys to move the "arrow" so that it points in the desired direction. After you have done so, press K to kick the marker. Time will then advance one unit and the velocity of the marker will change under the influence of the force you have applied.

RACE



Conditions:	Walls are reflecting One player against the computer or two players External forces (on Earth, near the sun, out in space)
Object:	Race to the Finish Box <u>and stop in it</u>.
Reading Level:	3rd grade (Fry)
Time Required:	5 - 20 minutes depending on the player's skill.
Objectives:	1. To test the skills learned in TRACK and OBSTACLE COURSE in a competitive game. 2. To be able to control your marker to decelerate and come to a stop in the presence of different external forces.

RACE

Description: This is a two-person game in which the players race one another to reach a Finish Box. In order to win, a player must stop inside the box.

You can choose what kind of external force you want to have acting on your marker as you race to the Finish Box. You make this choice by playing:

- on Earth,
- near the sun, or
- way out in space.

If you choose to play on Earth, you will then be playing with frictional forces acting on your marker. You may choose to play:

1. in sand (a large amount of friction),
2. on grass (a moderate amount of friction), or
3. on ice (a small amount of friction).

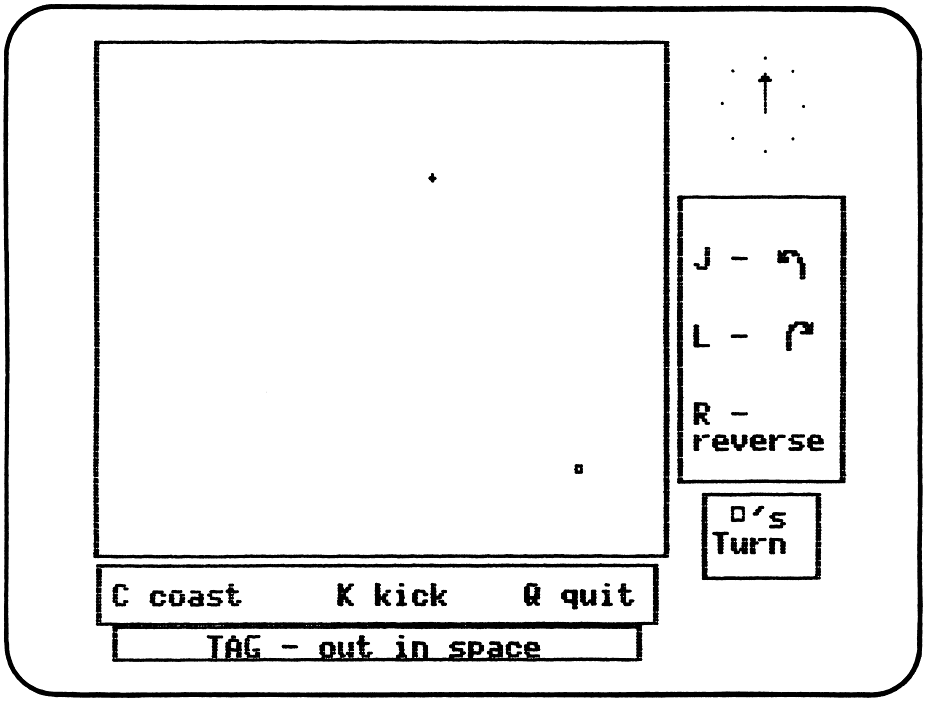
If you choose to play near the sun, you will be trying to move your marker toward the Finish Box with the sun always pulling you toward itself. You will have to compensate for the sun's force. Constant "kicking" may cause the message "You exceeded the speed limit" to appear. You then return to the menu.

If you choose to play way out in space, there will be no forces on your marker other than the ones you exert on it when you kick it.

To control the motion of the marker, you must first decide whether to give the marker a kick or to let the marker coast.

> Press C if you wish to coast. Time will then advance one unit and the marker will move subject to friction (if that condition exists in the version of the game you have chosen to play), or subject to the pull of the sun. If there are no external forces, the marker will move with the velocity it already has.
>
> If the decision is to kick, you must first determine a direction for the kick. This is done by using the J, L and R keys to move the "arrow" so that it points in the desired direction. Press K to kick the marker. Time will then advance one unit and the velocity of the marker will change under the influence of the force you have applied as well as whatever external forces are appropriate.

TAG



Conditions:	Walls are reflecting One player against the computer or two players External forces (on Earth, near the sun, out in space)
Object:	Chase or be chased until one player catches the other.
Reading Level:	3rd grade (Fry)
Time Required:	5 - 40 minutes depending on the player's skill.
Objectives:	1. To test one's understanding of velocity and acceleration by exercising one's skills against an opponent in the presence of different external forces. 2. To develop strategies for determining the position and velocity of your opponent several moves in advance.

TAG

Description: There are two versions of this game: one player against the computer or two players against one another. In the version of the game in which you play against the computer, you can chase or be chased. If you choose to chase, the computer tries to avoid you by examining all possible moves and choosing the one that places it furthest from you. If you choose to be chased, the computer tries to catch you by examining all possible moves and choosing one that places it closest to you.

In both versions of the game, you can choose what, if any, kind of external force you want to have acting on your marker as you play TAG with your opponent. You make this choice by playing:

- on Earth,
- near the sun, or
- way out in space.

If you choose to play on Earth, you will then be playing with frictional forces acting on your marker. You may choose to play:

1. in sand (a large amount of friction),
2. on grass (a moderate amount of friction),
3. or on ice (a small amount of friction).

If you choose to play near the sun, you will be trying to move your marker with the sun always pulling you toward it. You will have to compensate for the sun's force. Constant "kicking" may cause the message "You exceeded the speed limit" to appear. You then return to the menu.

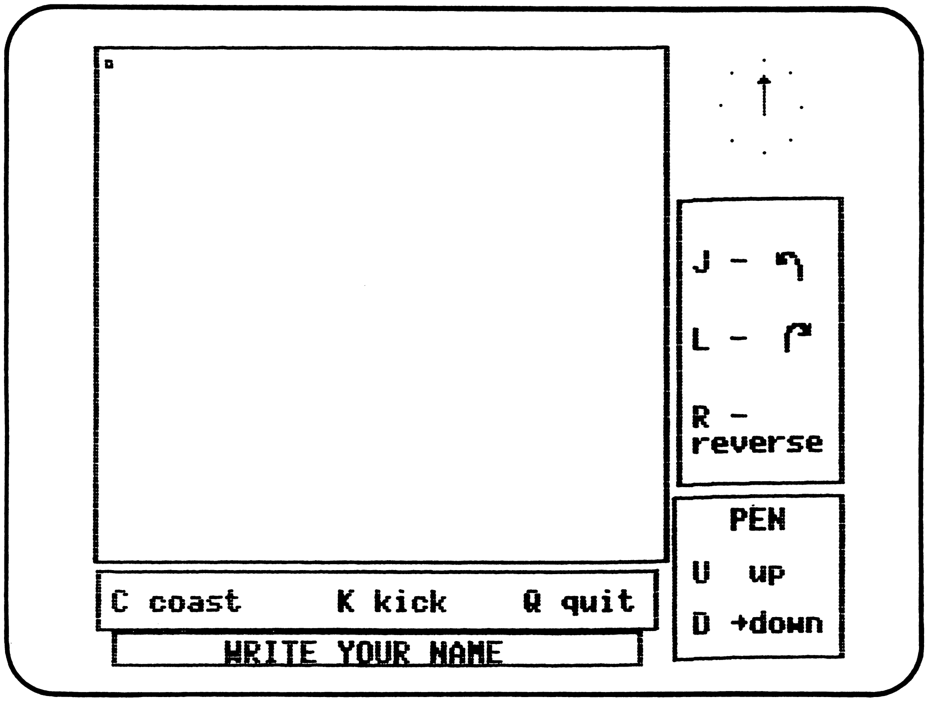
If you choose to play way out in space, there will be no forces on your marker other than the ones you exert on it when you kick it.

To control the motion of the marker, you must first decide whether to give the marker a kick or to let the marker coast.

Press C if you wish to coast. Time will then advance one unit and the marker will move subject to friction (if that condition exists in the version of the game you have chosen to play), or subject to the pull of the sun. If there are no external forces, the marker will move with the velocity it already has.

If the decision is to kick, you must first determine a direction for the kick. This is done by using the J, L and R keys to move the "arrow" so that it points in the desired direction. Press K to kick the marker. Time will then advance one unit and the velocity of the marker will change under the influence of the force you have applied as well as whatever external forces are appropriate.

WRITE YOUR NAME



Conditions:	Walls are reflecting One player No external forces Pen can be Up or Down
Object:	Use marker to create word/pictures of the player's choice.
Reading Level:	3rd grade (Fry)
Time Required:	5-30 minutes depending on players' activity.
Objective:	To apply the skills learned in previous games in a creative nature.

WRITE YOUR NAME

Description: In this game, the players are challenged to see if they can write their names or draw a picture (e.g., circle or a house) using a "pen." There are no external forces and the outer walls are reflecting (i.e., if you hit them you will bounce off).

To control the motion of the marker, you must first decide whether to give the marker a kick or to let the marker coast.

> Press C if you wish to coast. The marker will move with the velocity it already has.
>
> If the decision is to kick, you must first determine a direction for the kick. This is done by using the J, L and R keys to move the "arrow" so that it points in the desired direction. After you have done so, press K to kick the marker.

In this game, you can move your marker without leaving a trail by lifting your "pen." To do so, press U (for Up). When you want to lower the pen again, press D (for Down).

TEACHING IDEAS

BEFORE USING SIR ISAAC NEWTON'S GAMES

Discuss the concepts of friction, force, acceleration, velocity, mass, and motion. The discussion need not necessarily be one about formulas. In fact, for students first being introduced to physics (or any other subject involving abstract concepts represented by formulas), real-life applications are a much more effective method of making sure points get across.

In several of the five programs in SIR ISAAC NEWTON'S GAMES, students may choose to play with varying amounts of friction (i.e., on Earth - in sand, on grass, or on ice). You can demonstrate this in a concrete fashion by attaching a piece of string to a block with a piece of felt on it and dragging the block along a desk top. Then remove the piece of felt and drag it again. Ask your students if they noticed a difference in how the two objects moved. Then ask them to imagine what would happen if you were to pull the block across ice or grass or sand.

You can go on to personal real-life instances of friction. For instance, what happens when a downhill skier runs into an ice patch? Or mud? Talk about experiences that are familiar (e.g., a car skidding on ice, running in the sand on the beach, slipping on wet grass).

USING SIR ISAAC NEWTON'S GAMES

Have your students use SIR ISAAC NEWTON'S GAMES and fill in the worksheet. As they use the program, have them try to accomplish their goals in as few moves as possible. For example, in TRACK, see who can get around the wide/narrow track in the least number of moves.

AFTER USING SIR ISAAC NEWTON'S GAMES

Discuss what the students observed when they tried to move the marker in different environments with varying external forces. What did they notice when they kicked an object way out in space as opposed to on Earth in sand? Was there a difference when they coasted on ice or on grass? What did they notice about their general movement near the sun? How many moves did it take to turn in each environment?

After you have discussed some of their observations, use the following pages to explain why they saw what they did.

STARTING

You will notice that when you begin to move, the marker moves in the direction of the kick that you give it.

MOVING IN A STRAIGHT LINE

Way Out In Space

If you are playing one of SIR ISAAC NEWTON'S GAMES way out in space and you keep kicking in the same direction, the marker will move a larger and larger distance between kicks. Each time you kick, you add to the velocity of the marker and, because there is no friction in space, it moves a larger and larger distance in the same length time interval.

If, on the other hand, you coast when you are playing one of the games way out in space, you will notice that the marker moves a fixed distance in a straight line on each turn. If the marker is not moving and you coast, then the marker stays where it is. This is because it takes a force to change the state of the motion of the marker. If you don't kick, there is no force on the marker and the marker continues to have whatever velocity it had.

On Earth

When you play one of SIR ISAAC NEWTON'S GAMES in sand, on grass or on ice you will notice that when you keep kicking in the same direction the marker behaves somewhat differently than it does way out in space. The distance between successive positions of the marker gets larger for a while but then it stops increasing. Thus, if you keep kicking in the same direction in sand, you will very quickly reach a state of affairs in which the marker moves the same rather small amount on each kick. If you keep kicking in the same direction on ice you will also reach a state of affairs in which the marker keeps moving the same distance on each kick, although this time the distance the marker moves will be larger than in the case of moving in sand. The situation when you play on grass is somewhere between that of sand and ice.

This occurs because friction exerts a force on the marker that is in a direction opposite to the direction of the marker's motion. The size of the force that friction exerts depends on the velocity of the marker. If the marker is moving more rapidly, the frictional force on the marker is greater. When the size of the force you exert by kicking the marker in the forward direction is the same as the size of the force that friction exerts in the backward direction, the marker experiences no force at all and continues to move with the velocity that it had.

If, on the other hand, you coast when you are playing one of the games on Earth, you will find that the marker moves a smaller and smaller distance in the direction in which it was going and quickly comes to a halt. This is because friction is exerting a force on the marker that is opposite to the direction of motion of the marker. When you coast, you are not exerting a force on the marker in the forward direction. The net force on the marker is backward and it slows down and eventually stops.

Near The Sun

If you play one of SIR ISAAC NEWTON'S GAMES near the sun, it is very hard to move in a straight line because the sun keeps pulling the marker toward itself. Thus in order to move in a straight line, you have to exert a force on the marker in a direction opposite to the pull of the sun on the marker.

TURNING

In order to change the direction of motion of the marker, you must exert a force on it. If you want to turn a marker that is moving horizontally so that it moves vertically you have to affect its motion in two ways at the same time. You must stop its horizontal motion while you begin its vertical motion. It is not sufficient to kick it vertically.

Thus, to turn the direction of motion of the marker from horizontal to vertical, you must kick horizontally in a direction opposite to the horizontal motion and at the same time kick vertically in the direction you would like the marker to move. How can you kick in what is effectively two different directions at once?

If you kick in a direction that is halfway between the horizontal direction that you need to kick in and the vertical direction that you need to kick in, your kick will be partially effective in both the horizontal and vertical directions at the same time.

STOPPING

If you are playing one of the games way out in space, the only way you can stop the motion of the marker is to kick it in a direction opposite to the direction in which it is moving. If you play on Earth, you can stop the marker simply by coasting and allowing the force of friction to stop it. Alternatively, you can stop the motion of the marker more quickly by kicking it in a direction opposite to the direction of its motion.

A TECHNICAL POSTSCRIPT

In the case of one-dimensional motion, the vector relationship between force and acceleration reduces to the algebraic relationship:

$$\mathbf{F} = \mathbf{ma}.$$

The forces on the marker are the externally exerted forces and the force you exert on the marker each time you kick it.

Way out in space there are no external forces on the marker, and thus, if you don't kick it, the total force on it vanishes (**F = 0**). If **F = 0**, the acceleration must also equal zero (**a = 0**) since we are assuming the mass of the marker is not equal to zero. (Note that if the mass of the marker were zero, an infinitesimally small force could produce an infinitely large acceleration.)

On Earth, where friction is an external force acting on the marker, the situation is different. The force of friction is modeled in the program as a velocity-dependent force

$$\mathbf{F\ (friction) = -bv},$$

where **v** stands for the velocity of the marker and **b** is a constant (whose dimensions are kg/sec in SI units). Because the frictional force increases with velocity, it is possible for the marker to reach a terminal velocity; i.e., a velocity that it cannot exceed. The reason this happens is that the force you exert on the marker by the kick you give it is equal and opposite to the force of friction. As a result, the net force on the marker is zero, the acceleration of the marker is zero, and its velocity does not change.

Near the sun, under normal circumstances, the motion of the marker will no longer be one-dimensional; i.e., the marker will not move in a straight line. The equation **F = ma** must now be regarded as a vector equation, which can, in the case of motion in the plane, be decomposed into a pair of equations:

$$\mathbf{F(horizontal) = ma\ (horizontal)}$$

and

$$\mathbf{F(vertical) = ma\ (vertical)}$$

where **F(horizontal)** and **F(vertical)** are the horizontal and vertical components of the total force acting on the marker, respectively, and **a(horizontal)** and **a(vertical)** are the horizontal and vertical components of the acceleration of the marker.

A more complete discussion of these matters can be found in any elementary physics textbook.

	Three kicks in the same direction What happened?	What happens if you: kick twice -> and then kick twice <-	How do you make a 90° turn? ↑ ->	How do you stop?
ON EARTH **In sand**				
ON EARTH **On grass**				
ON EARTH **On ice**				
WAY OUT IN SPACE				
NEAR THE SUN				

APPLE: WORKING WITH THE COMPUTER

1. Turn on the television or monitor.

2. Insert the diskette into the disk drive with the label facing up and on the right.

3. Close the door to the disk drive.

4. Turn on the Apple II. (The on-off switch is on the back left side of the computer.)

5. You will see a red light on the disk drive turn on. If the disk drive light does not turn off in about 10 seconds, turn the Apple off and make sure your diskette is placed correctly in the disk drive.

6. The SUNBURST logo will appear on the screen, followed by the opening screen of the SIR ISAAC NEWTON'S GAMES program.

7. Follow directions given in the program.

8. If you wish to stop during the program, hold down the CTRL (CONTROL) key and press E.

Turning Off the System

1. Remove the diskette from the disk drive and return it to its place of storage.

2. Turn off the Apple.

3. Turn off the television or monitor.

IBM PC/PCjr: WORKING WITH THE COMPUTER

1. Place the diskette in the computer's disk drive with the label facing up and on the right. (If there are two disk drives, place the diskette in the one on the left.) Close the door of the disk drive.

2. Turn on the graphics monitor.

3. Turn on the computer. In several seconds, you will see the red light on the disk drive light up and you will hear the disk drive spinning.

4. The SUNBURST logo will appear on the screen, followed by a menu of the program.

5. Follow the instructions in the program.

6. If at any time during the program you want to stop, hold the CONTROL (CTRL) key and press the E key.

Turning Off the System

1. Remove the diskette from the drive and put it in a safe place.

2. Turn off the computer.

3. Turn off the graphics monitor.

TANDY 1000: WORKING WITH THE COMPUTER

1. Place the diskette in the computer's disk drive with the label facing up and on the right. (If there are two disk drives, place the diskette in the one on the bottom.) Close the door of the disk drive.

2. Turn on the monitor.

3. Turn on the computer. In several seconds, you will see the red light on the disk drive light up and you will hear the disk drive spinning.

4. The SUNBURST logo will appear, followed by the opening screen.

5. Follow the instructions in the program.

6. If at any time during the program you want to stop, hold down the CTRL (Control) key and press the E key.

Turning Off the System

1. Remove the diskette from the disk drive and return it to its place of storage.

2. Turn off the computer.

3. Turn off the monitor.

"WHAT HAPPENS IF...?" --SUNBURST COURSEWARE AND WARRANTY

1. What happens if a program will not load or run?
   Call us on our toll-free number and we will send you a new tape or diskette.

2. What if I find an error in the program?
   We have thoroughly tested the programs that SUNBURST carries so we hope this does not happen. But if you find an error, please note what you did before the error occurred. Also, if a message appears on the screen, please write the message down. Then fill out the evaluation form or call us with the information. We will correct the error and send you a new tape or diskette.

3. What happens if the courseware is accidentally destroyed?
   SUNBURST has a lifetime guarantee on its courseware. Send us the product that was damaged and we will send you a new one.

4. How do I stop the program in the middle to go on to something new?
   These programs can be ended at any time by holding the Control (CTRL) key and pressing the E key. To change diskettes, select the End option on the menu and insert a new diskette.

5. Can I copy this diskette?
   The material on the diskette or cassette is copyrighted. You should not copy the courseware.

6. Can I remove the diskette from the disk drive after I have loaded the program?
   Yes.

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1. You have permission to reproduce any student worksheets in this guide for your classroom use. You should not, however, copy the whole guide.

2. You have permission to use Lab Packs within one site. You should not, however, divide the package and use the diskettes in more than one building.

3. Depending on the type of computer you have, this program may 'load' all at once. If it does, you have permission to move the diskette from one computer to another. However, you may not copy this diskette. A back-up is provided.