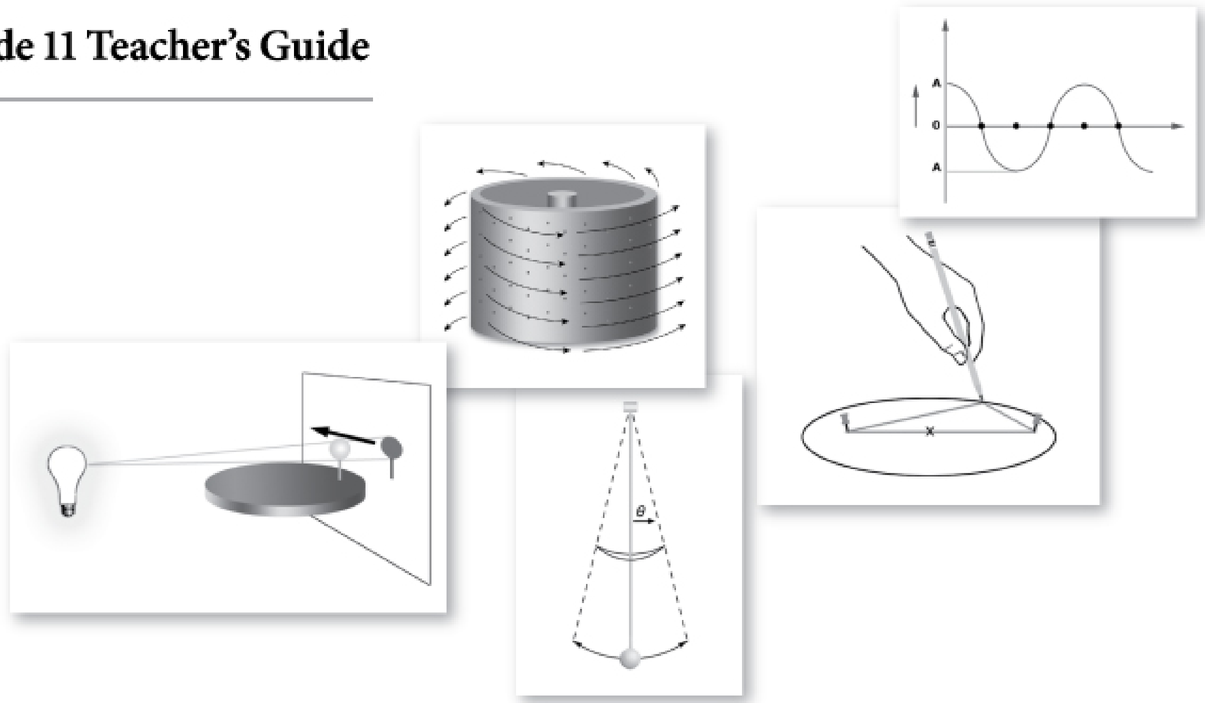
Circular Motion

Grade 11 Teacher's Guide



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Introduction

This unit will lead students to explore concepts in circular motion. You and your students will use Active Learning techniques in each lesson. Some of these techniques may be new to you or your students. Have patience. It takes some time for both you and your students to adapt to new ways of teaching and learning.

The students will spend a great deal of class time in small groups solving problems together. They will use physical objects to model circular motion. One of the labs (Springs) is new to the curriculum. Many of the problems are also new to the curriculum.

As this unit includes more homework assignments than provided by the text, you may also wish to coordinate with other instructors at your grade level to manage the students' homework load. Students may feel overwhelmed if they receive homework from all their teachers on the same day. The lessons will teach the topics usually included in the circular motion unit. The material will be presented in many ways besides lecture.

As you saw in the online learning portion, this unit utilizes conceptual change techniques. Many students don't change how they think about physics, even after solving problems and completing labs. The techniques in this unit help students change their thinking.

As you proceed through the unit, keep in mind that you are the teacher. You know your students' interests, capabilities, and limits best. You may wish to try the activities shown here and adapt them as needed for your specific needs. For some of your classes, these may work well, for others you may need to make a few adjustments based on your students' abilities and interests. There are options given if activities take longer than expected.

Outline for Circular Motion

A Brief Overview of the Lessons in Unit 5

Title	Objectives	Brief Description of the Lesson	Active Learning Techniques
Reviewing Gravity	To define gravity as an acceleration not a force.	Students drop two balls of the same size but different masses to show that gravity accelerates all objects equally.	• Journaling • Cooperative Learning • Inquiry • Concept Mapping
Uniform Circular Motion	To describe uniform circular motion in horizontal and vertical planes.	Students draw vector diagrams of uniform circular motion in cooperative learning groups. The teacher leads a dialogue on acceleration in uniform circular motion.	• Socratic Dialogue • Cooperative Learning • Journaling • Concept Mapping
Centripetal Force	To define centripetal force.	Students use a candle accelerometer to explore centripetal force and brainstorm real-life examples of centripetal force.	• Role Play • Inquiry • Cooperative Learning
Explaining the Appearance of Outward Forces	To explain why centrifugal force is fictitious.	Students role play centripetal force. They also complete the spinning ball lab in their lab manuals. The class discusses why there appears to be an outward force in circular motion.	• Role Play • Cooperative Learning • Inquiry
Relationships between Linear Speed and Radius	To calculate the velocity and acceleration in uniform circular motion. To conclude the relationships among speed and radius in uniform circular motion.	Students learn formulas for calculating velocity and acceleration in uniform circular motion. Then they perform the rolling cup lab. Students roll a paper cup (conical frustum) around on a table. They calculate the speed of the rim of the cup and the speed of the bottom. Students see that the rim has to rotate faster. The class is assigned a project as homework.	• Cooperative Learning • Inquiry • Project-based Learning
Universal Gravitation	To determine the factors which affect the universal gravitational force.	Students learn formulas for universal gravitational force and use them to solve problems.	Problem-based Learning

Title	Objectives	Brief Description of the Lesson	Active Learning Techniques
Applications of Circular Motion (satellite motion)	To describe natural and artificial satellite motion using circular motion.	The teacher does a demo on satellite motion using an animation. Students do a lab drawing elliptical orbits.	Inquiry
Technological Devices that Use Uniform Circular Motion Principles	To describe technological devices that use uniform circular motion principles to meet societal needs.	Students brainstorm examples of circular motion in real life. Then they determine how the laws of circular motion apply to the real-life example they listed above. They present their findings to the class.	• Cooperative Learning • Inquiry
Introduction of Periodic Motion	To define periodic motion, period and frequency	Students write their own definition of periodic motion then brainstorm examples of it in everyday life. Students build a pendulum in groups. Students build a concept map with the words they brainstormed.	• Journaling • Cooperative Learning • Concept Mapping
The Factors that Affect the Period of the Pendulum	To determine the factors which affect the period of the pendulum	Students do experiments to determine how length and mass of the pendulum affects frequency and period.	• Cooperative Learning • Inquiry
Satellite Motion	To describe why satellite motion is an extension of projectile motion and give examples.	Students see a scenario that connects projectile motion and satellite orbits. The teacher leads a Socratic Dialogue on satellite orbits.	Socratic Dialogue
Geostationary Satellites	To discover why satellites stay in their orbits and not fall to the earth.	Students spin a cup of water to analyze how gravity can be overcome by greater accelerations. Students discuss how the cup is like a satellite.	• Cooperative Learning • Inquiry
Satellite Orbits	To describe how the speed of a satellite changes as it travels in its orbit.	Students draw elliptical orbits using tacks and a loop of string. The experience the change of speed in orbit and how the distance between the foci changes the shape of the orbit.	• Cooperative Learning • Inquiry
Introduction of Periodic Motion	To define periodic motion, period, and frequency.	Students define periodic motion and brainstorm real life examples. They build a pendulum to explore period, frequency amplitude and displacement. They add new terms to their concept maps.	• Journaling • Cooperative Learning

Title	Objectives	Brief Description of the Lesson	Active Learning Techniques
Simple Harmonic Motion	To relate periodic motion to simple harmonic motion. To determine v, KE, PE, a, of the pendulum at maximum and minimum displacement.	Students use their pendulum models from the previous day to explore velocity (v), Kinetic Energy (KE), Potential Energy (PE), and acceleration (a). They present their findings with their classmates.	• Cooperative Learning • Modeling
Factors that Affect the Period of a Pendulum	To determine which factors affect the period of a pendulum.	Students vary the length and mass of a pendulum model to determine how they affect the period.	• Cooperative Learning • Inquiry
Oscillating Spring	To describe motion of spring as an example of simple harmonic motion.	Students relate pendulum motion to spring motion by determining the KE, PE, a, F (net) and υ at maximum displacement and equilibrium.	• Cooperative Learning • Problem-based Learning
Circular motion and SHM	To describe the connection between circular motion and SHM.	The teacher demonstrates how circular motion is related to Simple Harmonic Motion. Students also do a lab on what SHM looks like plotted over time.	Modeling
Harmonic Motion Relationships	Calculate displacement, velocity and acceleration from a graph.	From a graph students calculate the maximum D, A, and V. They also calculate D, A, and V at a given time.	Cooperative Learning

Some Practical Advice for Implementing Active Learning in the Classroom

Seating Arrangements for Cooperative Learning

For lessons that involve working in cooperative groups there are ways to create groups: pairs and quads. Pairs are easily created by having students already sitting together at a table work together. Quads, which are groups of 4, are easily formed by having two students turn around to work with the two students behind them. Brief activities, such as simple short questions, should be done in pairs. Quads are best for more difficult problems or longer activities.

To facilitate assigning group roles to students, the desks should be numbered within a group. The desks don't need physical labels on them; students just need to know that the seat closest to the front of the room and the door will be desk 1, the seat closest to the windows in front will be desk 2, etc. See the table below.

Roles

Remember to assign roles to students in their groups. Changing roles each time the group forms keeps students interested in participating. The same roles can be used from day to day, but new students should fill each role. The four possible roles are:

- **Leader**, keeps the group on task and makes sure everyone is doing their job.
- **Recorder**, writes down brainstorming ideas, and other records of the groups thinking.
- **Quizzer**, makes sure everyone in the group understands what is being discussed or concluded.
- **Materials Manager**, gathers all materials for the group to use from the front of the room and puts them away. Ensures all group members get a turn to handle the materials.

To make determining roles easier you can post a chart in the front of the classroom that looks like this:

Day	1	2	3	4
A	Leader	Materials Manager	Quizzer	Recorder
B	Recorder	Leader	Materials Manager	Quizzer
C	Quizzer	Recorder	Leader	Materials Manager
D	Materials Manager	Quizzer	Recorder	Leader

A chart is included in Appendix A that can be copied on to an overhead transparency to remind students what role they are responsible for on a particular day.

Roles can be assigned to students by seat number. For example, number 1 can be the leader, number two can be recorder, number 3 can be quizzer, and number 4 can be materials manager.

Teachers should arrange the seating so that students of different abilities are sitting in a group of 4. Pairs should also have students of different abilities. For example, you could put an A student in seat 4, a B in seat 2, a C student in seat 3 and a D student in seat 1. Research has shown that Cooperative Learning works best if good students and struggling students work together. Working in groups may be new for students and may lead to some extra socializing in class for a few days. The novelty of sitting in groups will wear off in a few days and students will quiet down. It is important to stress that students should be talking about the science topic for the day, not other concerns. Taking points away from students that are socializing is an effective way to keep students on task.

The Five Essential Elements of Cooperative Learning

There is a difference between Cooperative Learning and group work. Cooperative Learning IS NOT just putting students in groups to work together. At least four out of the five elements listed below must be present in order for an activity to be considered as Cooperative Learning.

Group Dynamics

At the end of a group session, the group takes a little time to discuss how well they worked together. The group learns to recognize when it is functioning well and when it is functioning poorly. The group takes action to do better when there is little cooperation between members or when one or two members are not participating fully.

Individual Accountability

Each group member is responsible for their own understanding. Each student is also responsible for fulfilling their responsibility to the group. Assigning roles to group members gives each student a responsibility. Group members may be assessed independently and then as a group with bonus points given to students who do better on a group quiz.

Positive Interdependence

In order to be Cooperative Learning, there must be a reason for the group to work together. In math and science classes this is easily achieved by having students share materials. Other ideas for creating positive interdependence include: using problems that are too difficult for one student to solve alone; creating projects where each student is responsible for a specific part of the work; or having each student learn a specific piece of information and teach it to the group.

Social Skills

Learning how to work with other people is an important work place skill. It is an important part of Cooperative Learning as well. Students need to learn to disagree politely, do their fair share of work, communicate their ideas, and appreciate other group members' contributions.

Face-to-Face Interaction

Students need to be knee-to-knee and eye-to-eye to work together effectively. The smaller the group the more members get to interact with each other. Pairs are an ideal way to provide maximum face-to-face interaction. Groups of more than four have a hard time including everyone. Groups in this unit are four or two. If there is not an even number of students, create a group of three. Don't let students work alone.

A Brief Review of Active Learning Techniques

Journaling

Journaling is different than taking notes. Notes are what the teacher and text says. Journaling is in the student's own words. It is important to explain to the students that their journal entries should be in their own words. Their first entries on a topic do not need to be perfect. They should be the student's thoughts.

Since Jurnaling is different, students should use a separate part of their notebook for journaling. The last 10-20 pages of the student's science notebook are a good place for them to write their journal entries. Putting journal entries in the notebook ensures students will have their journals with them in class.

After students are done writing, it is important to select a student at random to read his or her answer. Choosing someone at random encourages all students to do the activity so they may be spared the embarrassment of having nothing to read.

Brainstorming

Brainstorming is done in Cooperative Learning groups or in pairs for 1 or 2 minutes. The recorder for the group should write down all the students' ideas. If appropriate, the teacher may want to combine all the groups' brainstorming ideas on the board.

Socratic Questioning

The purpose of Socratic Questioning is to lead students to a new idea gradually by asking questions. Students are asked to support their answers with evidence. The types of questions teachers should ask are open ended. They are not looking for one correct answer.

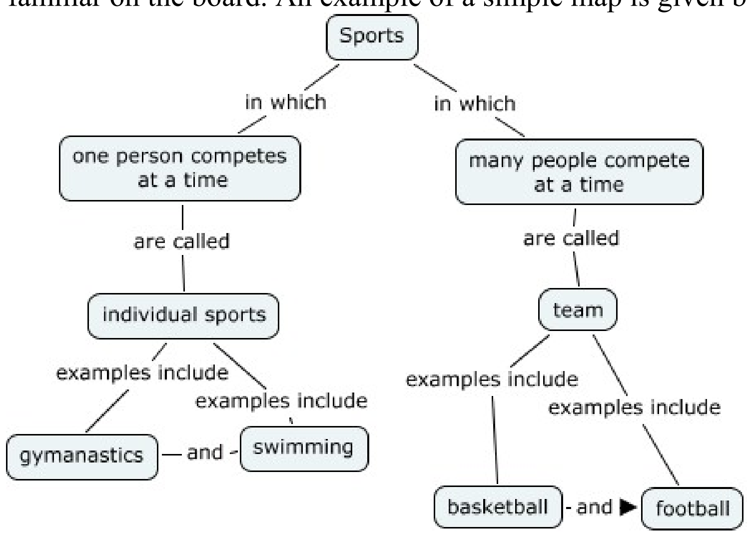
The questions should motivate students to provide an answer and participate in the discussion. The teacher should encourage students to ask each other questions and give a chance for all students involved to be in the discussion. The class functions as a mind. Examining an idea critically until the whole class agrees on one conclusion that is supported with evidence.

Inquiry

The value of Inquiry is letting students try to form their own ideas about the concepts. Do not tell the students about the answer until they have had a chance write down a prediction. Ask a few students to read their predictions. Choose students who have different predictions. Ask them how they would show their prediction is correct or do a lab to let them test their predictions.

Concept Mapping

While students may have constructed concept maps in other courses they may need some help making a concept map with science terms. You may want to refresh their memory by constructing a concept map with a topic with which they are more familiar on the board. An example of a simple map is given below.



After the students map some simple concepts they should be given some science terms to map.

A sample list of terms and one possible map are given in the lesson for Week 1, Day 1. While it is not listed in the lesson plans, adding new terms to their concept map can be a daily homework assignment.

All of the concept maps in this unit were created using free software called cMap. The software cMap can be downloaded from http://cmap.ihmc.us/.

Teacher Preparation

This lab requires two tennis balls of equal size and shape with different masses. Tennis balls work well. You can make a tennis ball gain mass by cutting it open and pouring in sand or other heavy material.

Conceptual Change

Many students (and adults) have the idea that heavy things fall faster. The purpose of this lesson is to help students understand that although heavier objects may appear to fall faster than lighter objects that have more air resistance, all objects experience the same acceleration of gravity at 9.8m/s/s. By acknowledging students'misconception that heavier things fall faster and explaining why it appears this way, students can begin to adopt more scientific ideas. Journaling and inquiry labs are both methods for acknowledging students' misconceptions, understanding why they occur and introducing more scientific thinking.

Journaling

The important thing about journaling during this lesson is for students to realize that their definition of gravity may differ from the scientific definition. The teacher should acknowledge students' initial definitions because it encourages conceptual change.

Inquiry

This is a level two inquiry because students do not know the outcome of the lab. Many will predict the heavier tennis ball will fall first. This is a common misconception among physics students. Seeing that both balls hit the ground at the same time should help students begin to question their assumption that heavier things fall faster. Inquiry labs can help students begin the process of conceptual change.

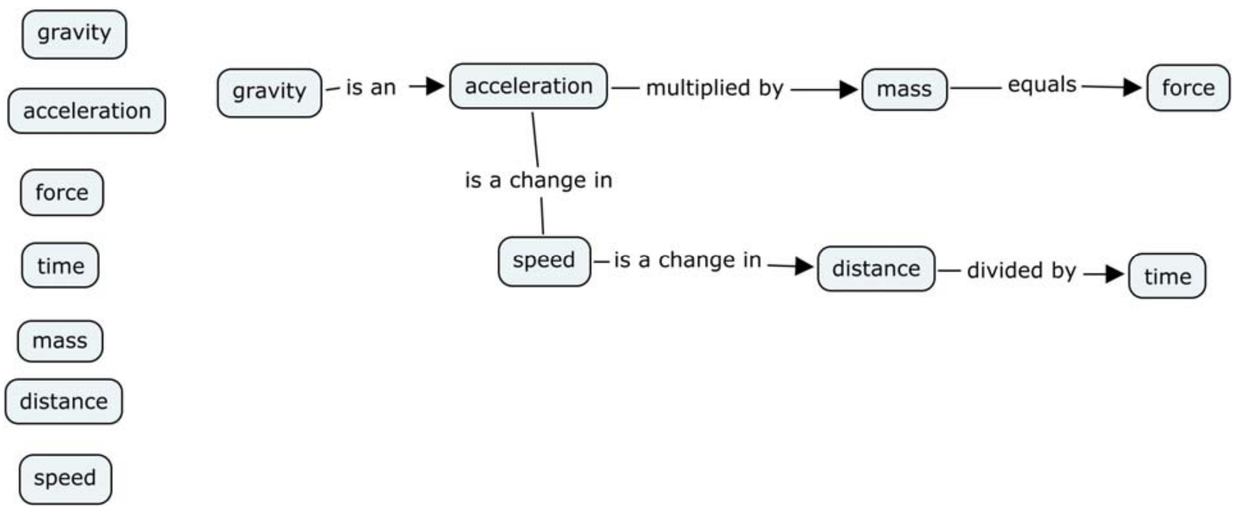
Cooperative Learning

Sharing materials creates positive interdependence and face-to-face interaction in this lesson. Students are each accountable for writing down their predictions and observations in their own notebooks. Students are also individually accountable for their role in the group. Use the chart in Appendix A to assign roles to students. In this lab it is important that everyone in the group gets to try rolling the balls off the table. The student in the materials manager role should remind group members to try the activity themselves.

Concept Mapping

Concept Mapping in this lesson exposes students' misconceptions about gravity as a force. Their maps should not directly connect gravity and force, mass should be in between. You should stress that students should leave room on the page for additional concepts as the unit progresses. Students may want to put concept maps in the back of their notebooks near their journal. If they run out of space they can tape or staple more paper to their original sheet.

Students' maps do not need to have the "parking lot" of terms on the left. These are included for clarity. The arrows in the concept maps are artifacts of the concept mapping program. It does not matter whether there are arrows of lines between terms.



Activity Outline

<table>
<tr><th>Objective</th><th>Activity</th><th>Materials</th><th>Assessment</th><th>Homework</th></tr>
<tr>
<td>Define gravity as an acceleration, not a force.</td>
<td>1. Students individually write their own definitions of the gravity.
2. The teacher forms students into small groups and distributes a worksheet to each group with the following problems to solve:
a) Predict what will happen if you push two balls, identical in every way except they differ in mass, off a table simultaneously.
b) Students write their hypothesis (The two balls will land at [same time /the heavier first/the lighter first]).
c) Students' groups then test their hypothesis by pushing the identical balls with differing mass off the table at the same time. They compare the landing times for the balls and record the results.
d) Students compare the results and observations with their predictions and write an explanation and conclusion.
e) Each group presents their conclusions and the teacher encourages discussion of different ideas.
3. The teacher points out that the balls are the same in surface area, covering and size but differ in mass, which leads to equal air resistance but does not account for mass. Using the following illustrations to lead the discussion, the teacher explains:
If we drop different masses simultaneously and compare falling times we get equal times because:
• Students have learned that d = ½ at 2.
• Since "d" and "t" are the same "a" must also be</td>
<td>• Student's table
• Two identical balls (same size, material, cover) except they differ in mass
• Lab sheet found in Appendix B1 titled "Reviewing Gravity"</td>
<td>Concept Map of Terms: gravity, acceleration, force, distance, time, mass, speed</td>
<td>Students define gravity as an acceleration, not a force.</td>
</tr>
</table>

Objective	Activity	Materials	Assessment	Homework
	the same. • Students have learned that F = ma or a = F/m. • Since "a" is the same, varies with m. Small m ⟶ Small F Large m ⟶ Large F Therefore, force due to gravity depends on mass. If gravity was a constant force, then heavier objects would have a smaller acceleration and therefore take longer to fall an equal distance. 4. The teacher explains the exact definition of gravity (an acceleration of 9.8m/s/s on Earth). Students write the new definition of gravity in their journals. They also write the difference between their first and second definitions. The teacher then demonstrates to students how to do a simple concept map. (See the sports example in the “Practical Advice for Implementing Active Learning in the Classroom” section of this guide.) Then the teachers give students the terms *gravity, acceleration, force, distance, time, mass, speed* with which they make their own concept maps. The students may need some help getting started. A sample map is included at the top of this lesson. The map can be finished as homework. **(Journaling, Concept Mapping, Inquiry, Cooperative Learning – Groups)**			

Socratic Questioning

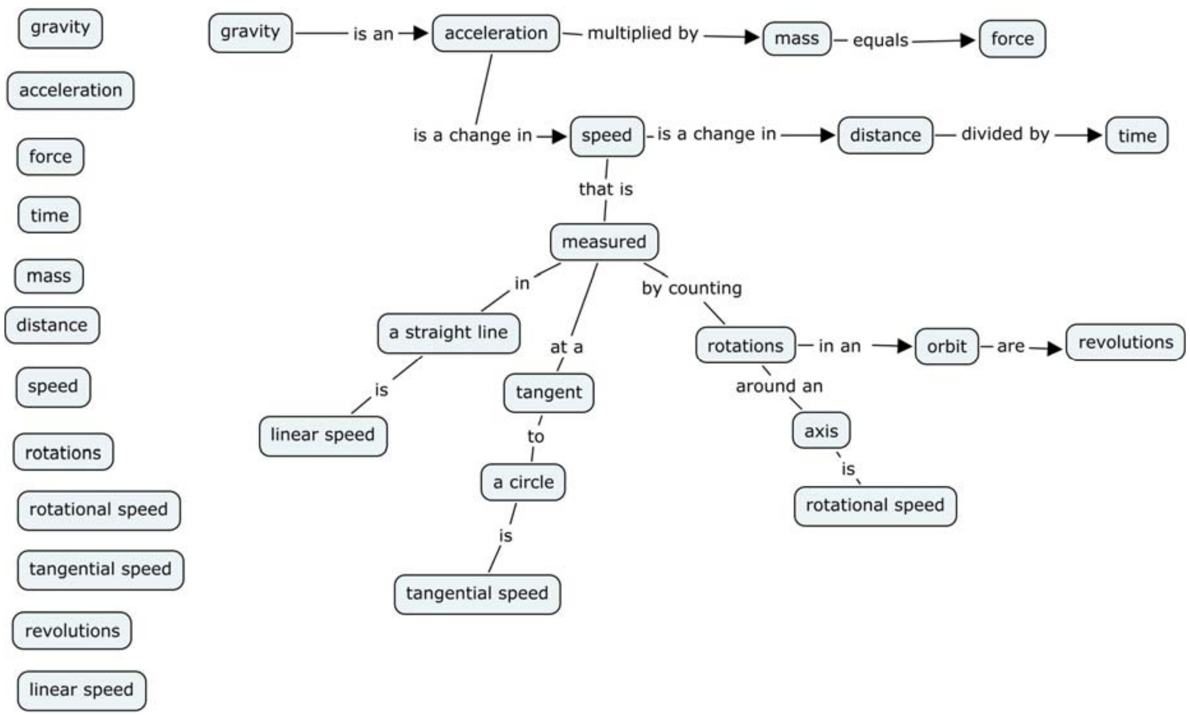
The conclusion students should reach in this Socratic discussion is that the change in direction of the velocity leads to acceleration even though the magnitude of velocity is constant. Many students assume that since the magnitude of the velocity does not change then there can be no acceleration. The teacher can start by asking, “What is the definition of uniform circular motion?”

Journaling

When students write definitions of physics terms in their own words, they are more likely to remember them. Writing them in a journal also gives students notes in their own words to refer to when they want to review.

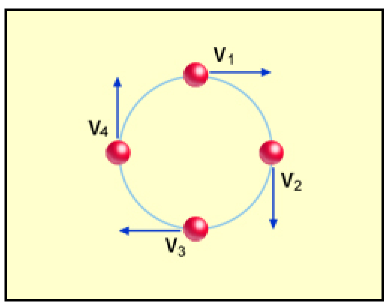
Concept Mapping

As students learn new concepts and vocabulary words they can add them to the concept map they began on Day 1. Adding a little bit each day to a concept map means students will not become overwhelmed with many terms to diagram all at once. Frequent additions to a concept map also allow students to review what they have already learned and connect it to new concepts. Students can add terms that are not assigned if they wish. In the map below the term "orbit" was added to better define the term "revolutions."



Notice the additional terms in the parking lot on the left of the concept map.

Activity Outline

Objective	Activity	Materials	Assessment	Homework
Describe uniform circular motion in horizontal and vertical planes.	1. The teacher asks questions leading students to define the characteristics of uniform circular motion. These are: • What is meant by uniform motion? • What changes during uniform motion? What stays the same? • Do falling objects have uniform motion? What kind do they have? • What is meant by uniform linear motion? 2. Draw a vector diagram of the velocity of an object in uniform circular motion. • What do you notice about the direction of velocity? • What do you notice about the magnitude of velocity? 3. Students in each group draw the velocity vector at 1, 2, 3, and 4 with same length in different directions. Then the students post their drawing on the board for evaluation by all groups with guidance from the teacher. *Sample answer*:  The teacher shows a transparency of a velocity vector diagram and gives a mini-lecture about the definition and differences between *rotation, revolution, linear speed, rotational speed,* and *tangential speed*. The teacher uses Earth's revolution on its axis and its rotation around the sun.	Transparency or flipchart of the “Velocity Vector Diagram”	Definitions and concept maps of the following terms: *linear speed, rotational speed, tangential speed, rotations,* and *revolutions*	

Objective	Activity	Materials	Assessment	Homework
	4. Students are asked to solve the following problems within their group: If an object moves in uniform circular motion (along a circular path of radius r with constant speed): • Prove that the magnitude of acceleration is zero. (students won't be able to do this because the constant change in direction that is part of circular motion causes constant acceleration) • What are the two conditions that result in acceleration in general? (Acceleration happens whenever the velocity changes in magnitude or direction.) • What are the conditions that result in uniform circular motion? 5. After the teacher leads a Socratic Discussion on the definition of circular motion, the teacher draws a vector diagram for an object in circular motion. The teacher shows why the object undergoes acceleration - because its velocity vector is changing along the circular path. The velocity vector is constantly changing direction because it is always tangent to the circular path of the object. (Remember, acceleration occurs whenever the velocity changes in magnitude or direction.) In groups, students write their own definitions of the elements of uniform circular motion*, linear speed, rotational speed, tangential speed, rotation,* and *revolution.* Each student adds these new ideas to their concept map created in Activity 1. Then each group presents one definition or map. If students don't finish concept maps, they can be assigned as homework. **(Socratic Dialogue and Cooperative Learning - Group)** 6. (If technology permits) The teacher will show students this link to summarize the lesson: http://www.phy.ntnu.edu.tw/oldjava/FreeRolling/FreeRolling.html (Velocity, Position and Acceleration Vectors for Uniform Circular Motion.)			

Week 1 Day 3 Topic: Centripetal Force

Role Play

This Role Play is written for three students to perform in front of the class. However, the whole class could participate in the role play by dividing up into groups of three. Then everyone would have a role to play. The Role Play can be found in Appendix C.

Inquiry

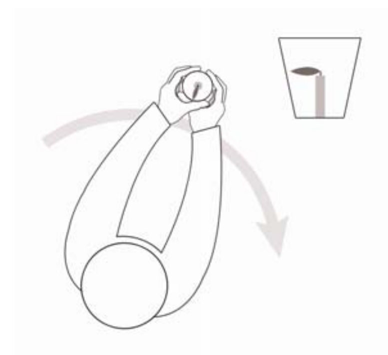
Students investigate what makes a candle flame lean inward. Since students don't know the outcome of the lab but are given the methods and suggestions for analyzing the data, this is a level 2 Inquiry.

Cooperative Learning

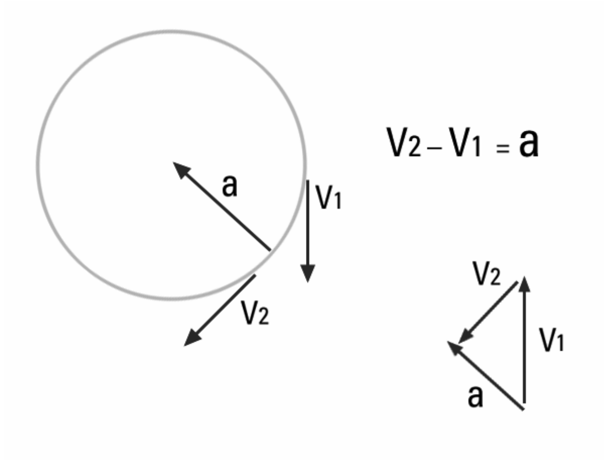
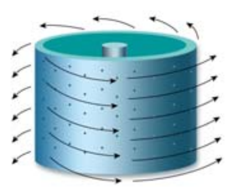
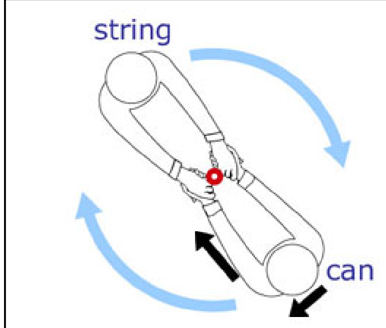
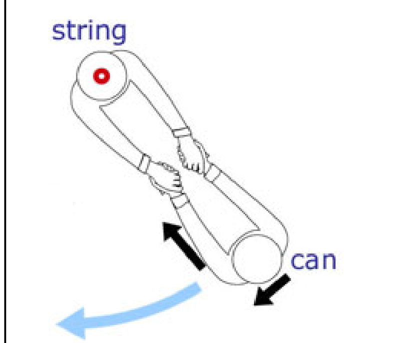
Students work together in groups to solve problems. Create individual accountability in this lesson by making sure each students writes down the answers to the questions. Assigning roles using the chart in Appendix A also helps create individual accountability. Give the group some time at the end of the lesson to discuss how well they worked together.

Activity Outline

Objective	Activity	Materials	Assessment	Homework
Define centripetal force.	1. The teacher asks some students to role play Part One of uniform circular motion.Then students in groups answer the following questions: • Is the force that holds the can in a circular path an inward- or outward-directed force? *Inward-directed force* • What is this force called, and what does it represent? *Centripetal force, tension force* • Write the definition of this force? • What does the arrow attached to the can represent? (the teacher briefly reviews the previous lesson) • What is the direction of this arrow at any point in the circular path during the motion of the can? See diagram on the following page. 2. Students spin around and watch the flame on the birthday candle accelerometer lean inward. Directions for this activity are in Appendix B1. After the students complete the activity they write in their journal about what forces are present in the previous activities. 3. Students, in groups, brainstorm and write as many real-life examples of circular motion in five minutes. For example, a car driving in a roundabout, a washing machine, salad spinner, clothes dryer, or water sprinkler. The teacher explains centripetal force while the car drives in a roundabout and shows them the following link (if technology permits): http://www.physicsclassroom.com/mmedia/circmot/rht.html (scroll down on the Web site to see more explanation) Then the teacher asks students in groups to discuss answers to the following questions and to record the answers in their notebooks: • How many forces are required for the circular motion of the car? • What are these forces?	• Role play from Appendix C • Clear plastic cup and small candle • Flip chart or transparency • The vector diagram of velocity and acceleration in a rotating system • Lab sheet "Candle Accelerometer" from Appendix B1		Think about how the washing machine and salad spinner work. What moves in a circular path? Why? How does the water move in the washing machine? Explain your answer.



Candle Accelerometer

Objective	Activity	Materials	Assessment	Homework
	• What is the importance of the friction between the turned wheels of the car and the road? • What is the effect of reducing this friction force on the motion of the car? Groups present their answer to the class, who evaluates their answers. 4. The teacher gives a mini-lecture while showing a vector diagram of the velocity of an object in a rotating system. The teacher points out the centripetal force and acceleration by summing two vectors **($\upsilon 2$)** and **($- \upsilon 1$)** from the formula:   Forces in a washing machine **(Role Play, Inquiry, Cooperative Learning - Group, Mini-lecture)**	 Incorrect  Correct		

Week 1 Day 4 Topic: Why There Appear to be Outward Forces in a Rotating System

Teacher Preparation

The swinging ball lab requires each lab team to have a significant amount of space to avoid hitting other group members in the head. It may be best to perform this lab outside, where students can remain a safe distance from each other.

Role Play

Students complete part two of the role play on uniform circular motion from Appendix C. Instead of a few students performing in front of the class, the whole class could split up into groups of three so everyone gets a chance to participate in the role play. The role play brings the forces in circular motion to a personal level so they seem more believable to students.

Conceptual Change

Many students believe there is an outward force in circular motion. In the frame of reference used in this lesson, and all of the lessons in this unit, there are no outward forces. The frame of reference used in all lessons in this unit is one that is outside the system. One thinks of the ground as a reference point. Outward forces are present in rotating frames of reference, however, rotating frames of reference are too complex for this level of physics.

In the previous lesson, students learned how the formula for acceleration leads to an inward force through vector subtraction. In this lesson, students explore why there appear to be outward forces in non-rotating frames of reference. Acknowledging the student's misconception and exploring why they hold the misconception helps them adopt more scientific thinking.

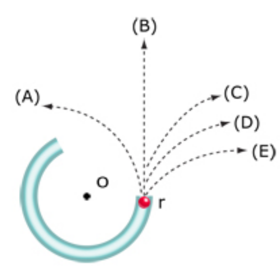
Cooperative Learning

In this lesson, students work together to answer some questions about circular motion. The questions are difficult enough that students will need the groups help to answer them, thus creating positive interdependence. In the lab, students share materials which also creates positive interdependence. Individual accountability is created by assigning a role to each student using the chart in Appendix A. Individual accountability is also evident when each student takes responsibility for answering questions in their own notebooks.

Inquiry

In the lab students are not aware of the outcomes, so it is a level 2 Inquiry. The lab can help students change their ideas as they experience the string pulling the ball inward.

Activity Outline

Objective	Activity	Materials	Assessment	Homework
To explain why centrifugal force is fictitious.	1. The teacher asks students the following questions: There is a centripetal (inward) force that is exerted on objects that move in a circular path. Do you think that there is an outward-directed force exerted on these objects? 2. The teacher selects some students to perform Part 2 of the role play on uniform circular motion from Appendix C. 3. Following the Role Play, students in groups answer the following questions: • Draw all the inward and outward-directed forces acting on the can and on the string. • What do these forces represent? *Answer: Inward directed force acts on the can which is tension.* *Answer: Out ward directed force, which is the force of the can acting on the string.* • If the string breaks, does the outward directed force push the can outward? Explain your answer. *Answer: No, because this outward force acts on the string not on the can.* • What path would the can take if the string broke? (The teacher puts the diagram of a marble rolling in a tube (on the right) on the board; students choose one of the possible paths.)	• Flip charts for students work • Role play from Appendix C • Lab Manuals • Small balls and string for each cooperative group   		

Objective	Activity	Materials	Assessment	Homework
	• Why does the can follow the path shown? Explain your Answer. *Answer: B.* 4. Groups of students perform the "ball on a string spinning experiment" as shown in the lab manual. 5. Students are then directed to choose one question to answer from the textbook, the teacher evaluates their work. 6. Then students post their drawing with explanations on the board. Several students are asked to evaluate some of the examples. 7. The teacher gives a mini-lecture and discusses the following questions with students: • How many forces are exerted on an object that moves in a circular path? • What do we call the force that causes the circular motion of objects? • Why is centrifugal force in a rotating system called a fictitious force? • What is the reason for the motion of the object in a tangential straight line to its circular path if there is no centripetal force? In the frame of reference we are using, the main force that is exerted on an object that moves in a circular path is one directed toward the centre of circular path. No outward force acts on the object. The outward force that appears to act on the object is a fictitious force. There appears to be an outward force because of inertia which is the tendency of the moving object to follow a straight line path (Newton's 1st law). **(Role Play, Cooperative Learning, Inquiry, and Mini-lectures)**			

Week 1 Day 5 Topic: Relationship between Linear Speed and Radius

Cooperative Learning

Students work in pairs to solve review problems in uniform circular motion. Pairs of students exchange their papers with another pair to be corrected. If you want to keep students from changing their answers once they are corrected, you can have them work in pen. When pairs are working together let them know they are both responsible for knowing how to solve problems. Either one of them may be called on to explain their answer in front of the class. This should reduce one student just copying another student's answers.

Inquiry

Students are not told what to expect in the rolling can and cup lab. Many of them may be surprised by the fact the cup rolls in a circle instead of a straight line. In the lab, students are asked to explain why the cup rolls in a circle. This question is designed to get them thinking about rotational versus linear speed. At the end of the lab students are asked to write the relationship between radius and linear speed. The homework project is also an Inquiry activity that explores the relationship between radius and linear speed. Students attach two coins to a disc, one near the center and one near the edge. They are asked to determine which coin has the greatest linear speed. If students have not deduced the relationship between radius and linear speed, they should learn by watching the spinning disc in this lab.

Project-based Learning

The homework project students complete in this lesson is a way for students to extend their learning at home. Students learn about the relationship between radius and linear speed; and as they experiment with positioning coins on the spinning disc they learn about the effects of inertia.

Activity Outline

Objective	Activity	Materials	Assessment	Homework
• Calculate the velocity and acceleration in uniform circular motion. • Define the relationships between speed and radius in uniform circular motion.	1. The teacher writes the formulas for velocity and acceleration in uniform circular motion on the board and asks related questions to be solved by pairs of students. 2. The teacher asks partners to answer different exercise questions and then trade with other pairs of students who evaluate their answers. 3. The teacher distributes worksheets to students, in groups. Each group carries out the rolling cup lab which helps them define the relationship between speed and radius in uniform circular motion. Following the activity, the teacher: a) Selects some groups to present their conclusions. b) Evaluates their work. 4. The teacher assigns a project as homework. 5. (If technology permits) The teacher will show the students the following link to summarize the lesson: http://www.phy.ntnu.edu.tw/oldjava/circularMotion/circular3D_e.html (Relationship between velocity and radius.) **(Cooperative Learning – Pairs, Inquiry)**	• Cylindrical can • Paper cup (with top larger than bottom) • Lab Sheet from Appendix B1 "Uniform Circular Motion Relationships"		Project: Lab Sheet from Appendix B1 "Uniform Circular Motion Relationships"

Socratic Discussion

The purpose of Socratic Discussion in this lab is to lead students to understand that satellite orbits are the result of projectile motion. The transparency in Appendix E can be used to start the discussion; or if technology allows the java simulation listed below. You can begin with the following questions:

- What is the path of a ball thrown horizontally across a flat surface?
- How is satellite motion related to throwing a ball?
- Why doesn't a satellite eventually fall to earth?

If the discussion is going well, challenge students with these questions:

- How does the speed at which a satellite is launched affect its orbit?
- How fast are satellites moving?
- Why do some satellites look like they are not moving?

Remember to have students justify their answers with examples or data. Encourage students to ask each other questions, especially if they don't understand another student's answer. If students are not connecting projectile motion and satellite orbits, keep asking questions. If they cannot answer your questions offer them pieces of information to consider; do not just tell them the answer.

Activity Outline

Objective	Activity	Materials	Assessment	Homework
Describe why satellite motion is an extension of projectile motion and give examples.	1. The teacher shows a video that matches the story in their text book about "Satellite Physics." After viewing the video, students in small groups discuss and write the answer to the following questions in their journals: • What happens when you drop a ball? *Answer: It will fall in a straight line path to the ground below.* • What happens if you move your arm while you are dropping the ball? *Answer: It will follow a curved path to the ground horizontally while you drop the ball.* • If you move your arm faster while you are dropping the ball, what happens? *Answer: The ball will land farther away and the curvature of the path will be less pronounced.* • What name would you give the ball if the curvature of its path matched the curvature of the earth? *Answer: The ball will be an earth satellite.* • Do you agree that a satellite's path traveling at any speed will match the curvature of the earth? *Answer: No, we need a proper speed so that the satellite will be in circular orbit around Earth. Some orbits will be elliptical.* • Explain why it is not possible for a single communication satellite to serve all parts of the world. *Answer: Communication satellites are in geosynchronous orbit. A geosynchronous orbit is an equatorial orbit with 24-hour periods. Because they revolve around the earth at the same speed as the earth rotates around its axis, they appear stationary when you look up at them.*	Transparency of Satellite Launch in Appendix D (series of diagrams showing how higher and higher launch speeds eventually lead to orbit in a satellite)		

Objective	Activity	Materials	Assessment	Homework
	2. The teacher shows the following simulation if technology allows: http://www.phy.ntnu.edu.tw/oldjava/projectileOrbit/projectileOrbit.html (simple demonstration of how velocity and orbit are related) 3. After Socratic Questioning led by the teacher and with the help of the satellite simulation, the students in small groups will write a description of satellite motion as an extension of projectile motion. Their description will include the correct speed the satellite will be in circular orbit around Earth. *Answer: According to the simulation this will be 7117m/s*.			

Teacher Preparation

This lab is simple to set up. Since it involves water and flying objects it may be a good idea to plan to perform the lab outside. There will be enough space for all groups and spilled water will not become a safety hazard.

Cooperative Learning

Students work together on the lab and questions. Since this is the first Cooperative Learning activity of the week, you may want to rearrange the Cooperative Learning groups so different students can work together. It is important to remind the student who has the role of the materials manager for the day to give everyone a chance to experience swinging the cup. Students sharing equipment creates positive interdependence in this lesson. Each student filling out their own lab sheet is an example of individual accountability. Give the group some time at the end of the lesson to discuss the following rubric on group dynamics.

Group Work	Excellent = 3	Fair = 2	Needs Improvement = 1
How well did group work together?	Students worked well together and listened to their peers as they spoke.	Some students took the lead while others remained quiet.	Several students did not contribute to the discussion.
Did each person fulfill the responsibilities of their group role?	All students were able to contribute. Each idea was considered in the consensus for the final answers.	One leader controlled most decisions. Some students did not contribute to the final answers.	Students argued and never came to agreement on one answer for each problem.
Did the group value other groups' explanations?	All students in the group listened attentively while other groups explained their answers.	Most students paid attention to other groups when they were explaining their answers.	Little attention was given to another group that was presenting.
Are the answers recorded clearly and accurately?	The answers are well written, correctly sequenced and include all necessary steps and information	Answers are somewhat unclearly written, the sequence of steps isn't always correct and some information is missing.	Answers were poorly written, partially sequenced with many key steps missing.

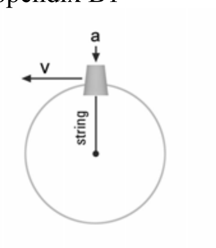
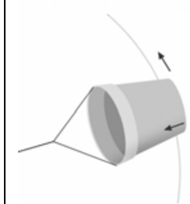
Conceptual Change

Unless they have had experience with swinging water in a container, students have a hard time believing the water will stay in the cup. Students will have many explanations for why water can stay in the cup. Some of their explanations may involve centrifugal force. As stated in week 1, in the frames of reference we are using in this unit, centrifugal force is not present! The tension force on the string accelerates the cup inward. Since the cup is always changing direction, the water must always be changing direction as well. The cup accelerates the water faster than acceleration due to gravity so the water stays in the cup.

Inquiry

Students actually get to swing water in a cup to prove to themselves the water does not come out. Even though they may see other students successfully swing the cup without getting wet, they need to perform the experiment themselves to get the full benefit of the lab. In this case, doing is believing. The questions for the activity below are also on the students' worksheet.

Activity Outline

Objective	Activity	Materials	Assessment	Homework
Explain why satellites stay in their orbits and not fall to the earth.	1. The Teacher distributes a worksheet to students in small groups who will answer the following questions: a) What will happen if you swing a cup of water in a vertical or horizontal circle? b) Students write their hypothesis in answer to the question. c) Each group does the following activity: Poke holes on both sides of a plastic cup and pull a string through the holes and tie it at the top to make a small bucket with a handle. Students fill the cup with water until it is 1/3 full. Then they swing it around in vertical circle to see whether or not the water falls out. d) Students compare their prediction with results and write their observations. 2. The teacher asks students: • Why does the water stay or not stay in the cup? • What keeps water in a small bucket when it's swung vertically? *Answer: Inertia (the centripetal force equal to the weight of water)* • What will happen to the water if they had swung the cup slowly? *Answer: Water fell out because the speed of the water was slower than the speed of the container.* Each group will present their conclusions on a transparency or flip chart. The teacher encourages discussion of different conclusions by the class. (**Inquiry, Cooperative Learning - Group**). 3. The teacher then explains the relationship between the above activity and satellites which stay in orbit and never fall to the earth; satellites must revolve around the earth at the same speed as the earth rotates on its axis. Since there is the force of gravity pulling toward the earth, why don't satellites crash to earth? What is the relation between the speed of a falling satellite and the speed at which it must revolve if it is to stay in orbit?	For each group: • Water • String • Cup For each student: Lab sheet "Geostationary Satellites" from Appendix B1  		

Week 2 Day 3 Topic: Satellite Orbits

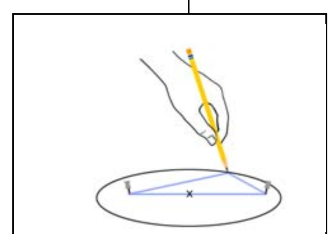
Cooperative Learning

Students work together to complete the lab and questions. The questions in the lesson plan below are also on the student lab sheet in Appendix B1. Students share materials for the lab so they are positively interdependent as a group. Each student is assigned a role to fulfill with the role chart in Appendix A. Each student is also responsible for completing a lab sheet so they are all responsible for learning the content (individual accountability). Help students learn how to treat group members respectfully as they work together (social skills). You may want to take a few minutes during this class to discuss what make a good group member.

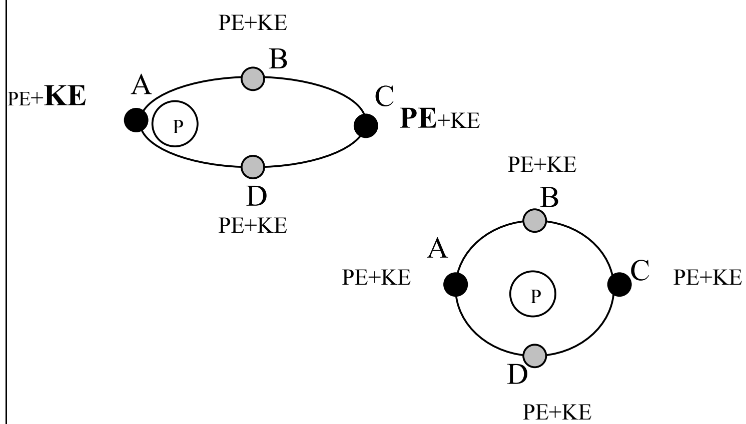
Inquiry

Students discover how satellites behave through their experience in this lab. By drawing orbits they find out that satellites travel faster near foci and slower elsewhere. In addition, by drawing multiple orbits students see how the distance between the foci affect the eccentricity of the orbit.

Activity Outline

Objective	**Activity**	**Materials**	**Assessment**	**Homework**
Describe how the speed of the satellite changes according to different heights of orbit.	1. Working in groups, students follow the given activities in their lab manual which requires them to draw the orbits to illustrate various conditions and solve problems regarding height variation of orbits: 1. What is the shape of the path in which natural satellites move? *Answer: Elliptical path.* 2. If we consider the pen as a satellite, using the loop of string and the tacks, draw the path of the satellite. Where is the centre of the path (orbit) in your drawing? What is the center called? *Answer: The thumb tacks are the foci in the drawing, a planet is at one of the foci in a satellite orbit.*	For each group: • Papers • Pencils • Strings • Thumb tacks For each student: Copy of “Satellite Orbits" from Appendix B1		Find some pictures about natural and artificial satellites and explain them in relation to circular motion

Objective	Activity	Materials	Assessment	Homework
	3. In your drawing, determine the arc where the satellite is moving at high speed and where it is moving at low speed. How does the difference in speed change as we change the distance between the two fixed points (foci)? *Answer:* *The speed is greatest near the foci of an ellipse. It is constant in a circle. If the points are further away from each other, the path becomes more elliptical and the difference in speed increases. The closer the points become the more circular the path- the difference in speed decreases.* 4. How can you draw a circular path and not an elliptical path? *Answer:* *By using one tack as a focal point.* 5. How are the focal points of circular and elliptical orbits different? *Answer:* *In circular orbits, the focal point is the centre of the path, in elliptical orbits the planet is at one foci and the other is theoretical.* 6. Compare the speed of satellites in circular and elliptical orbits? *Answer:* *In circular orbits, the speed is constant, but in elliptical orbits, the speed changes becoming faster near the planet (one foci) and slower at other end (the other foci).* 7. Kinetic Energy (KE) + Potential Energy (PE) = Total Energy (E) Total energy remains the same at all points in a satellite orbit. At some points in the orbit, KE is larger. At other points, PE is larger. Indicate at points A, B, C and D in the two drawings which is larger, KE or PE. (P inside the small circle represents a planet around which the satellite is revolving).			

Objective	Activity	Materials	Assessment	Homework
	(g) Describe KE, PE and total energy (E) at the points A, B, C, and D in the two drawings (P) is the planet.  2. The teacher presents a mini-lecture and discusses with students the relationship between r and v. (If technology is available)the teacher will show students one of the following links to summarize the lesson. • http://www.school-for-champions.com/science/orbit1.htm (Allows adjustment of eccentricity of satellite's orbit, simple animation with only the eccentricity reported quantitatively, easy to see how big eccentricity can make satellite fast on one side of orbit and slow on the other.) • http://www.phy.ntnu.edu.tw/oldjava/Kepler/Kepler.html (Rotating planet that allows the user to look at Kepler's 1st, 2nd or 3rd law.)			

Week 2 Day 4 Topic: Introduction of Periodic Motion

Journaling

Writing down their own definition of periodic motion, and brainstorming everyday examples with their peers will help students realize their prior knowledge of periodic motion. They can connect the new information they are learning with what they already know.

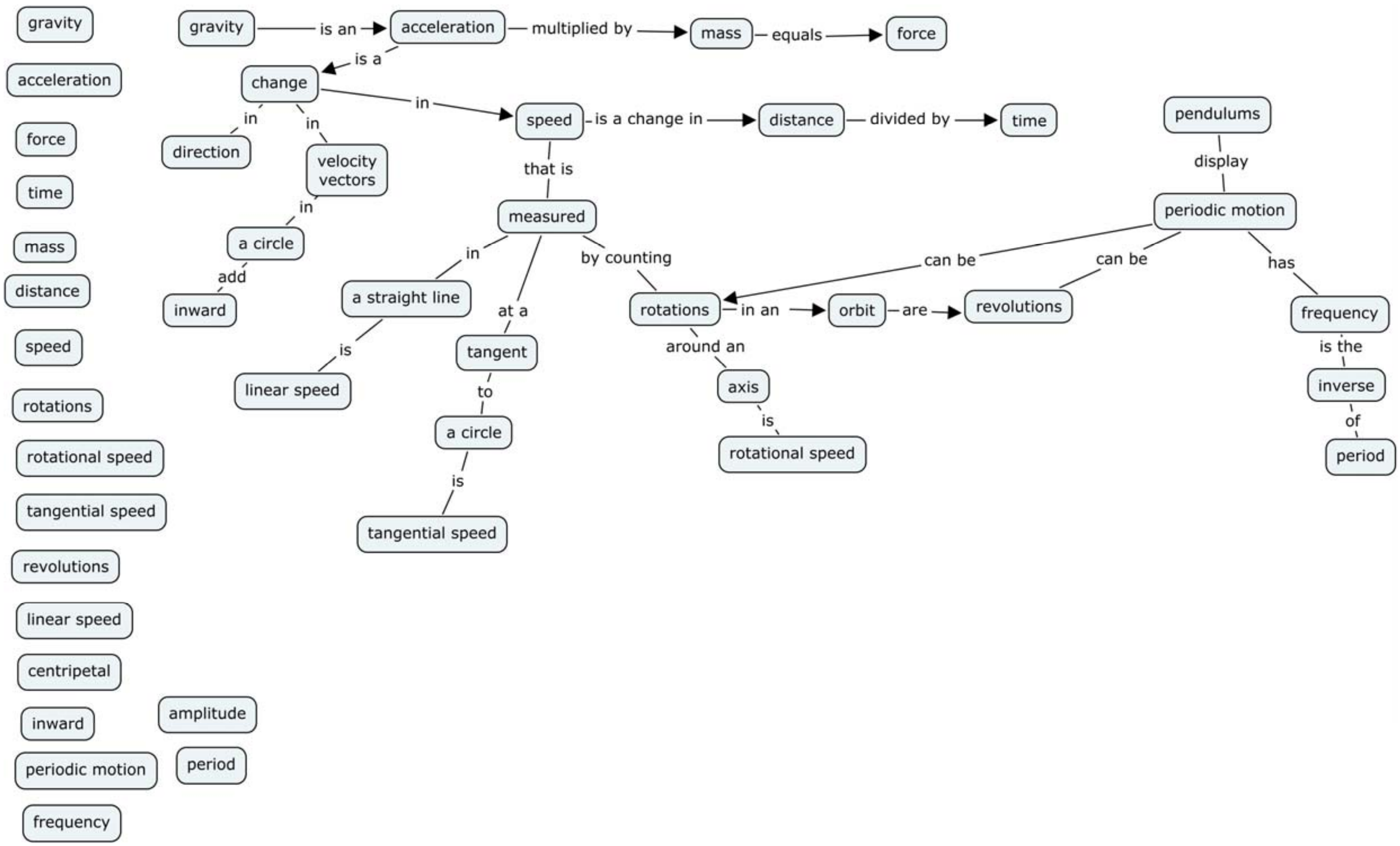
Cooperative Learning

Students work in small groups to brainstorm everyday examples of periodic motion. Groups of four are probably best for brainstorming. If there is enough equipment, groups of two can work on the lab. The students as a group set up a pendulum and use it to define the terms below. Students may need help connecting the terms to the motion of the pendulum. The student who is the recorder in the group can prepare the group's drawing on flip chart paper. The group member who will present the drawing and definition to the class should be chosen at random. All group members should be ready to present. Knowing they may have to present to the rest of the class keeps everyone engaged in the activity.

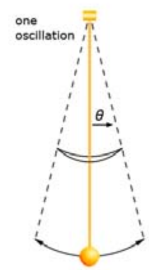
Teachers Note: Students should record data from this lab, such as maximum and minimum displacement, as well as period. If time permits in Week 3 Day 4, they may make graphs of displacement, velocity, and acceleration.

Concept Mapping

The new terms and everyday examples should be added to the students' concept maps they started on the first day of Week 1. Concept maps help students connect new terms and concepts with what they have learned earlier in the unit. Extra terms have been added that are not in the parking lot to improve connections on the map.



Activity Outline

Objective	Activity	Materials	Assessment	Homework
Define periodic motion, period and frequency.	1. Students individually write their own definition of periodic motion. 2. Students in small groups brainstorm real-life examples of periodic motion (clock pendulum, swing, spring in cars shocks, movement of blood from arteries to veins, heartbeat, watch movement, pistons, vibrations of a tuning fork, ball bouncing in a frictionless world, etc.). 3. The teacher distributes the materials needed to make a pendulum for each student. Then students in groups use their models to: a) Define periodic motion, frequency, amplitude and period, and displacement. b) Draw a pendulum in their notebooks and determine what represents the equilibrium point, amplitude and displacement. Each group selects one drawing from their notebooks and recreates it on flip board paper and posts their drawing. The teacher asks each group to present one definition and evaluate their work. The teacher then discusses the exact definition of periodic motion and the other terms using the transparency of the pendulum diagram if needed. 4. Students work in small groups to draw a concept map using the rest of the words generated during brainstorming as well as *periodic motion, frequency, amplitude,* and *period*. Monitor students as they are making their concept maps. Groups post their concept maps on the board and the teacher and class evaluates their work. **(Journaling, Cooperative Learning - Group, Concept Map)** 5. (If technology is available) The teacher will show students the following link to summarize the lesson: http://faraday.physics.utoronto.ca/GeneralInterest/Harrison/Flash/ClassMechanics/PendulumForces/PendulumForces.html (Simple demo of vector magnitude and direction as pendulum oscillates; it is easy for students to recognize what is happening.)	Small ball and thread. For the class: Flip charts for Students' work For the teacher: Transparency of pendulum diagram found in Appendix D.  	Concept maps with the added terms: *periodic motion, frequency, amplitude, and period*.	

Cooperative Learning

Students work in pairs to analyze the movement of the pendulum. Working in pairs has the advantage of leaving no one out of the discussion. Pairs should be informed that either partner can be required to report on their conclusions. This deters one partner from simply copying the other partner's answers.

Modeling

Students use models of pendulums to explore concepts related to simple harmonic motion. While pendulums are excellent models for simple harmonic motion, they are not perfect. Friction is part of every real system. Discuss with students how friction impacts simple harmonic motion in pendulums.

Activity Outline

<table>
<tr><th>Objective</th><th>Activity</th><th>Materials</th><th>Assessment</th><th>Homework</th></tr>
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- Identify characteristics of simple harmonic motion as an example of periodic motion.
- Determine the velocity, kinetic energy, potential energy and acceleration of a pendulum at maximum displacement and equilibrium.

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1. The teacher groups students into pairs and asks them to:
   a) Analyze the forces acting on the ball of the pendulum at maximum displacement.
   b) Draw the direction of the net force and the displacement.
   c) Find the relation between net force and displacement from the drawing.
2. The teacher asks partners to draw the pendulum at maximum displacement and equilibrium. Next, partners determine velocity, kinetic energy, potential energy, F(net), the acceleration of the pendulum at maximum displacement and equilibrium using their pendulum model.
   Maximum displacement: **max PE**, **max F(net)** , **max a, υ=0, KE=0.**
   Equilibrium position: **max KE, max υ, F(net) =0 a=0, PE=0**
   The teacher selects some partners to show their work using a transparency. Each set of partners decides who will give the explanation and who will lead a short discussion about their work. **(Cooperative Learning - Pairs, Modeling)**
3. The teacher shows the following link to summarize the lesson**:** http://www.phy.ntnu.edu.tw/oldjava/Pendulum/Pendulum.html (Potential and kinetic energy of pendulum in motion.)

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<td>Pendulum for each student</td>
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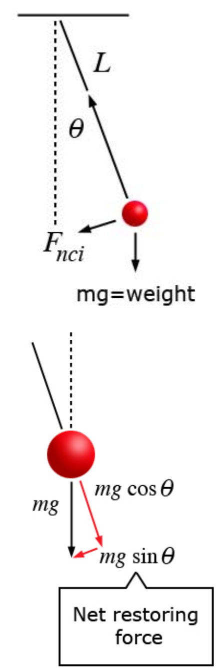

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Week 3 Day 1 Topic: Factors that Affect the Period of the Pendulum

Inquiry

Many students will assume that mass has an affect on the period of the pendulum. This lab gives them a chance to test their predictions, gather data and analyze results with minimum guidance from a lab manual. This is a level 3 Inquiry because students are responsible for experimental design, data collection and analysis.

Cooperative Learning

As this is the beginning of a new week, teachers may want to rearrange groups so that new students can work together. Students can work in pairs or small groups depending on how much equipment is available. Students will be individually accountable for writing down the results of their experiments. The group will be interdependent because of equipment. They also may need each other to help design and conduct experiments.

Activity Outline

Objective	Activity	Materials	Assessment	Homework
Determine the factors which affect the period of the pendulum.	1. Students in small groups are asked to perform an experiment in the lab using a stopwatch and pendulum to observe and measure the: a) Effect of changing the length of the pendulum on the period b) Effect of changing the mass of the pendulum on the period 2. The teacher writes the formula for the period of the pendulum on the board and asks students to develop a statement of relationship for the above factors with a drawing to illustrate them. Students post their drawings with an explanation for the class to view. The class and teacher evaluate their work. **(Cooperative Learning - Groups, Inquiry)** $T = 2\pi\sqrt{l/g}$ 	• Stopwatch • Pendulum • Aluminum foil • String • Tape		Add the new terms to concept map. Students may want to add the graphs illustrating the relationships between mass of and length to period.

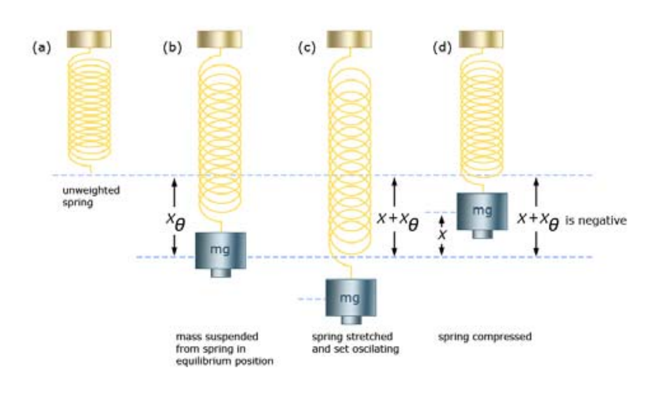
Cooperative Learning

Students could work in pairs or groups for this activity. It is important to assign roles to students and remind them to take responsibility for their role. This is not an activity in which one student solves the problems and everyone else copies their work. The group should discuss each problem. The recorder can be responsible for drawing diagrams. The student that reports to the class should be chosen at random to keep all group members engaged.

Problem-based Learning

Students are asked to apply the principles of Simple Harmonic Motion (SHM) they learned in the pendulum lessons to springs. Students learn about springs by working on these problems. Instead of learning first and then completing problems, students solve problems on springs in order to learn how springs are also examples of simple harmonic motion.

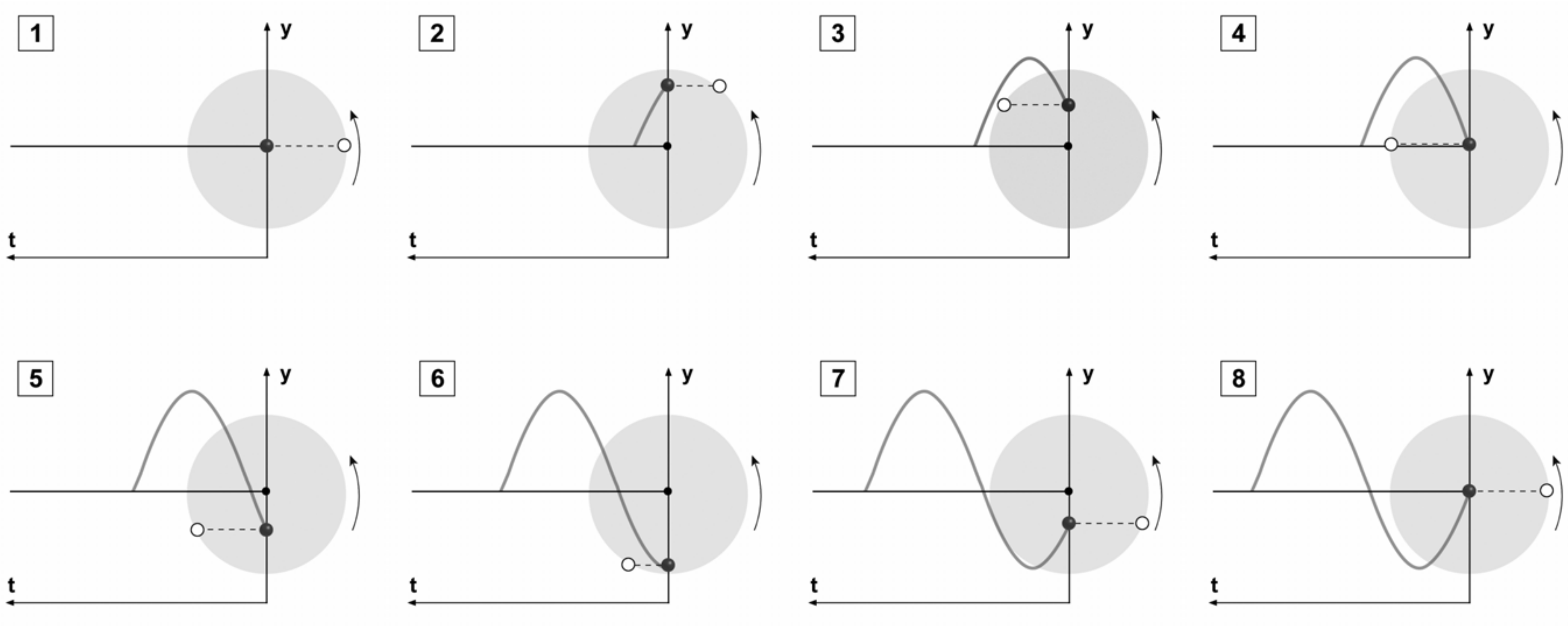
Activity Outline

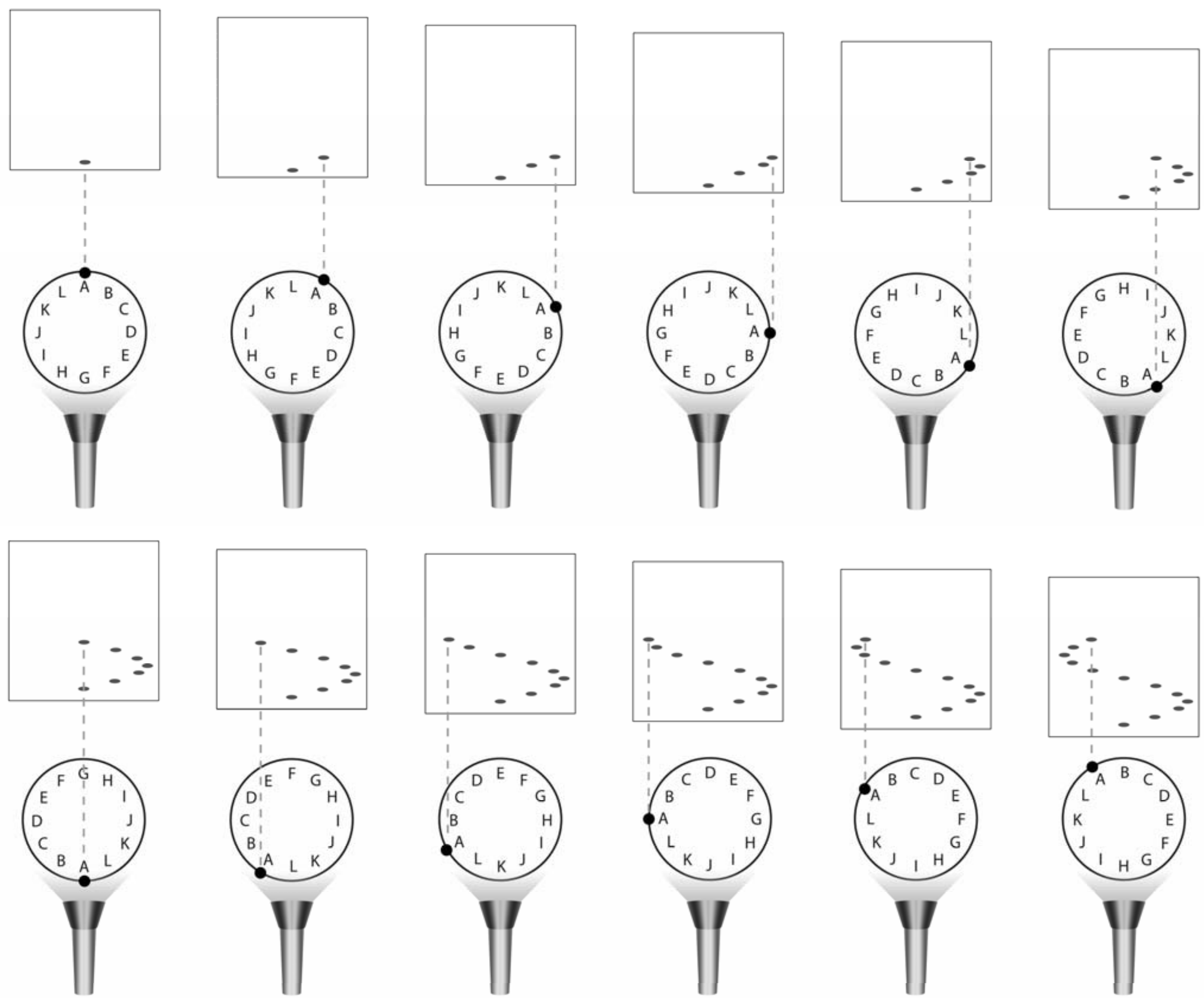
Objective	Activity	Materials	Assessment	Homework
Describe the motion of a spring as an example of simple harmonic motion.	1. The teacher shows a diagram of springs in two cases (see diagram in lower right): expanded (c) and a compressed vertical spring (d). Students in small groups describe the motion as follows: a) Draw the forces that act on the mass attached to the spring. Each group posts their drawings on the board. b) Explain why this motion is considered to be simple harmonic motion. c) Determine the KE, PE, a, F(net) and υ at maximum displacement and equilibrium. The teacher gives a few groups the chance to present their work and conclusions using the projector. **(Cooperative Learning - Groups)** 2. The teacher shows the students two different springs: a) Students predict what will happen if we suspend identical masses to them. Students write their prediction in their notebooks. (Will the two springs have the same or different extension distance?) b) The teacher shows the transparency for students to compare their prediction with the illustration. Then the teacher asks some students to present their conclusions to the class. 3. (If technology permits) The teacher shows the link below to summarize the lesson**:** http://www.hazelwood.k12.mo.us/~grichert/explore/dswmedia/harmonic.htm (Shows spring and pendulum side by side and the mass of the pendulum weight and length of pendulum can be adjusted.)	• Spring • Transparency illustrating spring diagrams from Appendix D 		

Modeling

The teacher is doing the modeling here instead of the students because of the complexity of the concept. Students will need a great deal of explanation to understand how circular motion can be viewed as SHM. If there are time and materials available, students may be given the opportunity to repeat the demonstration for themselves.

The students see for themselves how simple harmonic motion becomes a wave as one student moves a marker up and down with their eyes closed while the other student pulls the paper along. Students may know what is going to happen but some will be surprised to see that periodic motion, when graphed against time, becomes a wave.

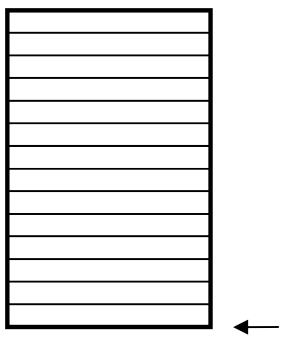


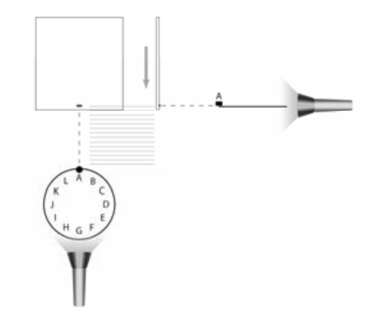


How Circular Motion Can Become a Wave

In order to help students further understand how circular motion is periodic motion they can do the following activity in pairs.

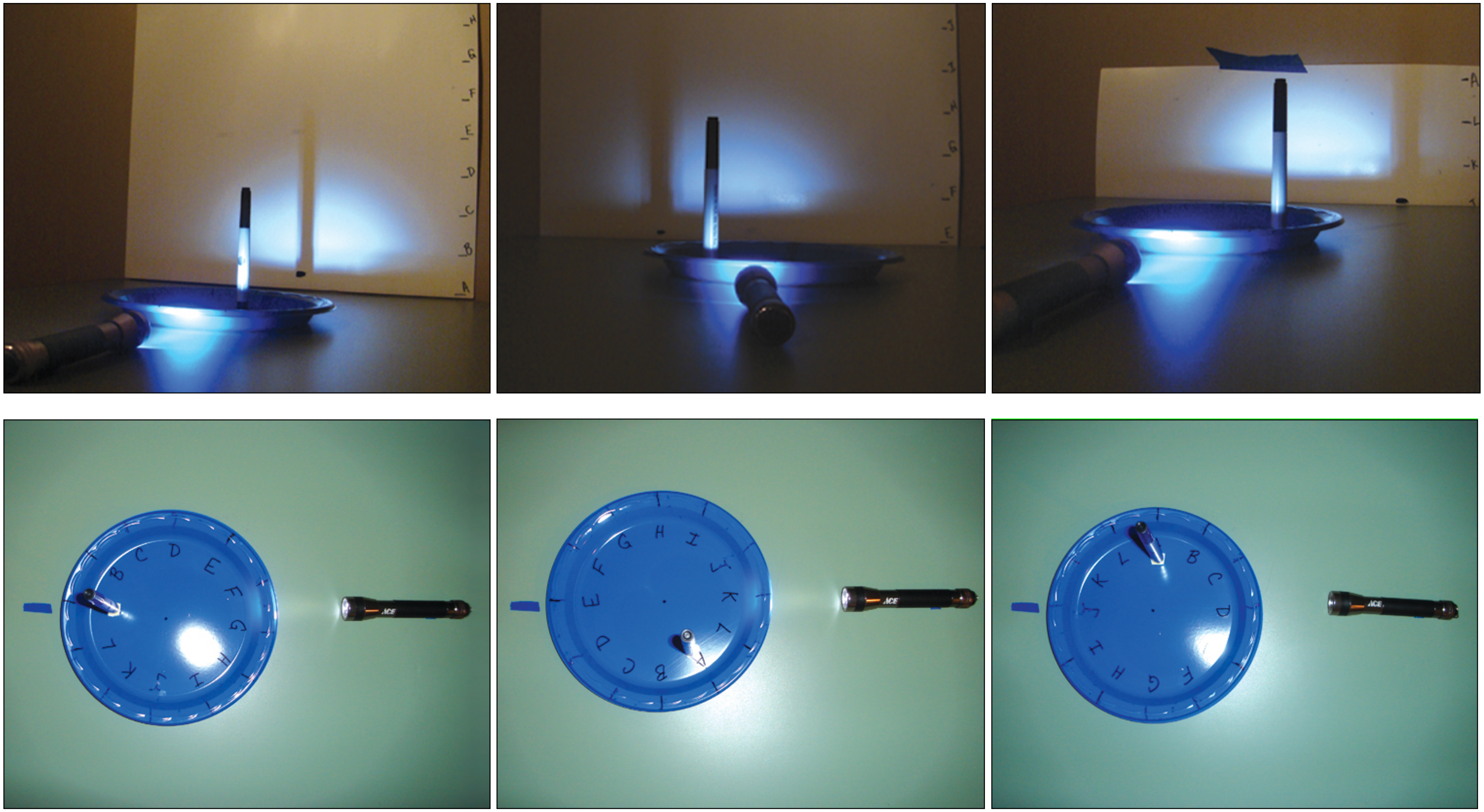
1. Students label a paper plate with the letters A-L as in the diagram on the previous page.
2. The students use the clay to attach the pencil in an upright position near the letter A on the plate.
3. Along the width of the paper, the students should make 12 evenly spaced lines. If they want, they can label them A-L, to correspond with positions on the plate as shown in the photographs below.



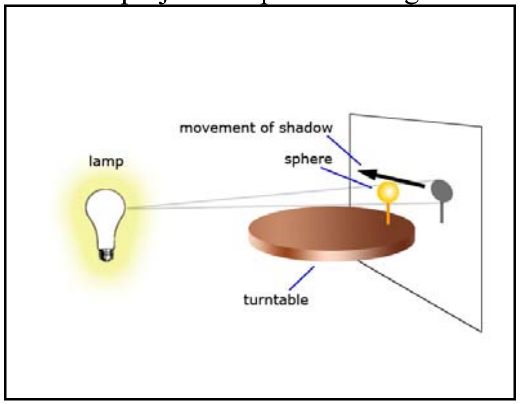


Side View

4. Then the students tape their paper to the wall, placing a piece of tape to the side of the bottom edge of the paper to mark where the paper started.
5. Starting with the A closest to the paper, they should shine the torch over the plate onto the paper and mark where the shadow of the pencil falls.
6. Keeping the torch in the same position, the students then turn the plate clockwise one letter, and then they move their paper down one mark and record where the shadow falls.
7. Students repeat this process until they have rotated the plate all the way around, until the A is back in the original position.
8. The students should connect the shadow positions on their paper with a smooth curve. They should get something similar to a sine wave.



Activity Outline

Objective	Activity	Materials	Assessment	Homework
Students will describe the connection between circular motion and SHM.	1. The teacher will demonstrate the lab activity (explained in the student book) of the moving shadow of a sphere. The overhead projector replaces the light bulb in this diagram:  2. Students will see from the illustration shown by the teacher on the screen that the shadow of an object moving in circular motion illustrates periodic motion (SHM). 3. In order to help students further understand how circular motion is periodic motion they do a simple activity in pairs. Directions and photos are above. 4. Students in pairs do a simple activity to observe how the periodic motion of a shadow results in a wave. The material needed for this activity is a paper and a pen. In this activity two students stand beside each other. The first student asks their partner to close his or her eyes and to move his or her hand up and down in a regular motion while holding the pen to the paper. As the partner draws with their eyes closed, the first student pulls the paper from the partner sideways so that the partner's strokes make a graph like SHM. Then students post their work on board.	• Overhead projector • Transparency "Circular Motion to SHM" • Demonstration equipment: turntable sphere on stick (as shown) OR toy figure that will stand upright Materials for each lab group • Paper plate • Clay • Pencil • Electric Torch/Flashlight • Large paper • Tape • Marker or Pen	Determine two ways in which the movement of the shadow resembles the SHM of the pendulum.	

Objective	Activity	Materials	Assessment	Homework
	5. The teacher presents a mini-lecture using the projector to illustrate how circular motion can be seen as a wave. **(Modeling, Mini-lecture)** 6. (If technology allows) The teacher will show students the link below to summarize the lesson: • http://faraday.physics.utoronto.ca/GeneralInterest/Harrison/Flash/ClassMechanics/Circular2SHM/Circular2SHM.html (nice simple demo of how circular motion is SHM, not quantitative or adjustable) • http://www.phy.ntnu.edu.tw/oldjava/shm/shm.html			

Physical Modeling

The two activities in this lesson both help students learn the concept that simple harmonic motion graphed over time makes a wave. In both activities the paper moves to represent a change in time. Physically creating a graph gives students a concrete example of a wave. It is easier for students to see how an up-and-down or side-to-side motion turns into a wave when they see it happen in front of them.

Activity Outline

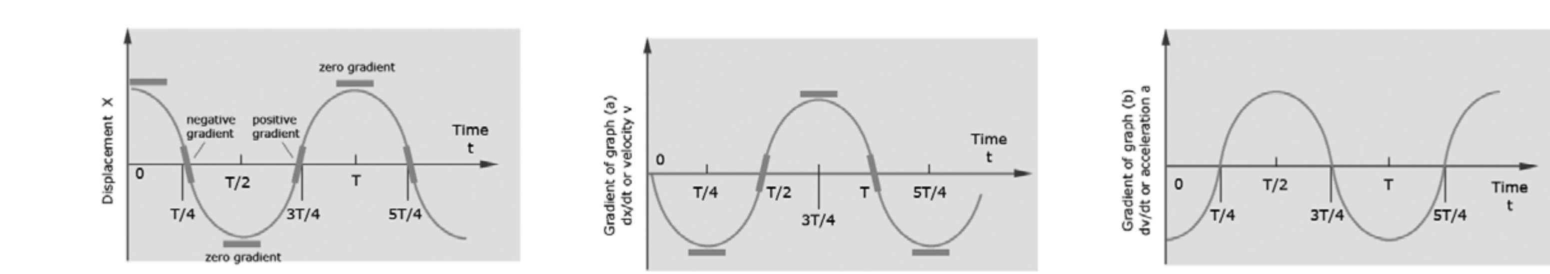
Objective	Activity	Materials	Assessment	Homework
Draw the pattern of simple harmonic motion from a pendulum and a spring.	1. The teacher distributes a model to each small group and asks them to oscillate a pencil attached to a spring as another student rotates the graph paper at constant velocity. This model illustrates that the periodic motion of the springs results in a wave pattern. 2. Students in groups make a sand pendulum by filling a cup with sand, poking a hole in the bottom and swinging it back and forth. A partner moves the paper slowly so a line of sand is created that looks like a sine wave. See photo above. 3. Then the teacher presents a mini-lecture to demonstrate the graphs of displacement, velocity and acceleration of the pendulum with time. **(Cooperative Learning-Pairs, Mini-lecture)** • http://www.walter-fendt.de/ph11e/springpendulum.htm (Nice demo of how oscillating spring is a wave over time.) • http://lectureonline.cl.msu.edu/~mmp/kap13/cd363a.htm (Shows pendulum motion as a wave over time.)	• Model • Graph		

Conceptual Change

Students may confuse displacement and velocity. Many students think that a graph of velocity is displacement as well. Reviewing the definitions of each of these terms and connecting them to the graphs may decrease confusion. If the appropriate technology is available, the teacher should show students the Web physics site listed below. Research has shown that students benefit from seeing real time graphs of displacement and velocity to separate the concepts.

Cooperative Learning

Finding maximums may be easy for the groups. Giving each group different times to find the exact displacement, velocity and acceleration may prevent groups copying each other's answers. If students finish early, they could be asked to make their own graphs of displacement, velocity and acceleration from data the teacher provides or they can graph their data from the pendulum lab done on Week 2 Day 4.



(a) Displacement–time curve (b) Velocity–time curve (c) Acceleration–time curve

Activity Outline

Objective	Activity	Materials	Assessment	Homework
Calculate the displacement, acceleration, velocity and time from simple harmonic motion graphs.	1. The teacher writes the equation for displacement, acceleration, and velocity on the board as a function of time and defines (θ,χ,ω,a). 2. Using corresponding graphs, two cases illustrate the following: a) The object starts its motion from equilibrium. b) The object starts its motion from maximum displacement. 3. (If technology permits)The teacher shows students the following links: • http://webphysics.davidson.edu/physlet_resources/bu_semester1/c18_SHM_graphs.html (This is a simple animation. A horizontal spring creates real time graphs of displacement, velocity and acceleration. It is easy for students to see how the graphs are related in real time.) • http://www.walter-fendt.de/ph11e/springpendulum.htm This animation is a horizontal spring that shows position in real time on a graph of displacement. This site is a bit more involved than the one above but has the advantage of being adjustable. You can change spring constant, mass on the spring, gravitational acceleration and amplitude. 4. The teacher uses the previous links and asks each group of students to calculate the following: • The maximum displacement, velocity and acceleration. • The displacement, velocity and acceleration at a given time. 5. If time permits, students can graph the pendulum data from Week 2 Day 4. They can create their own graphs of displacement, velocity and acceleration. Graphing data can also be a homework assignment. **(Cooperative Learning - Pairs and Groups, Mini-lecture)**	One copy per students: Simple harmonic motion graphs of displacement, acceleration, velocity against time For teacher: Transparency of graphs from Appendix D		Optional: Making graphs of displacement, velocity and acceleration from data collected in Week 2, Day 4

Appendix A: Role Chart for Cooperative Learning

Day	**1**	**2**	**3**	**4**
A	Leader	Materials Manager	Quizzer	Recorder
B	Recorder	Leader	Materials Manager	Quizzer
C	Quizzer	Recorder	Leader	Materials Manager
D	Materials Manager	Quizzer	Recorder	Leader

Appendix B1: Lab Sheets to Photocopy

The following pages present the lab sheets for you to photocopy for students.

Reviewing Gravity (Week 1 Day 1)

1. **What would happen if you dropped two balls with the same shape but different masses off a table at the same time with the same speed? Which will fall to the ground first? Write your hypothesis.**

   ____

   ____

2. **Proceed with this activity and write your observations.**

   ____

   ____

3. **Explain your observations.**

   ____

   ____

   ____

   ____

   ____

4. **Did your hypothesis agree with your observations?**

   ____

   ____

5. **Do your observations agree with your group's observations?**

   ____

   ____

6. **Write your conclusion.**

   ____

   ____

   ____

Candle Accelerometer (Week 1 Day 3)

In this lab you will build a device that shows its direction of acceleration. There is a flame used in this lab, so you should wear your safety goggles while working with the flame.

Materials per Lab Group

- Safety goggles for each group member
- Matches or lighter
- Clear plastic cup
- Small candle
- Small lump of clay

Instructions

1. Have the materials manager in your lab group gather the materials listed above.
2. Place the lump of clay in the bottom of the cup and place the candle in the clay.
3. Light the candle and observe the flame.
4. Answer the questions below in your journal.

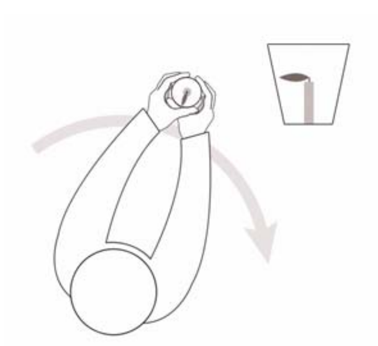
Questions

1. When the candle is sitting still, draw a picture of what the flame looks like.

2. Each person should take a turn holding the candle out in front of them and spinning in a circle (see diagram below). What happens to the flame? What direction does it point?

____

____



3. Why does the candle flame behave this way? What forces are acting on it?

____

____

4. Draw the vectors acting on the candle.

5. Blow gently on the candle flame without extinguishing the flame. Why do we put the candle inside of a cup for this activity?

____

____

Uniform Circular Motion Relationships (Week 1 Day 5)

1. **What do you expect if you roll a cylindrical can and an ordinary tapered drinking cup (a paper or foam cup) across a table? What path will each one follow? Write your hypothesis.**

   ____

   ____

2. **Roll the cup and the can on a flat surface and write your observations by answering the following:**

   a) Describe the path of the can as it rolls.

   ____

   b) Which end of the can has a greater speed?

   ____

   c) Describe the path of the cup as it rolls.

   ____

   d) Which end of the cup covers more distance?

   ____

   e) Which end has the greatest linear speed?

   ____

3. **Did your hypothesis agree with your observations?**

   ____

   ____

4. **Explain your observations above. What determines the shape of an object's path?**

   ____

   ____

   ____

   ____

5. **Did your explanations above agree with your group's explanations? If they were different, explain how they were different?**

   ____

6. **Write the relationship between linear speed and radius below. You may use words or symbols.**

____

____

Homework Project: Uniform Circular Motion Relationships (Week 1 Day 5)

Using the model of a rotating disc, answer the following questions:

1. **What will happen if you place two coins on the top of the rotating disc, one near the centre and the other near the edge, and then rotate the disc? Write your hypothesis below.**

   ____

   ____

2. **Which coin has a greater linear speed? Write your hypothesis.**

   ____

3. **Tape the coins on the disc as described above in Question 1. Spin the disc, observe and then answer the following questions:**
   a) Do the two coins have the same rotational speed in rotations per minute (RPM)? Why or why not?

      ____

      ____

   b) Which coin has a greater linear speed? Explain your answer.

      ____

      ____

4. **Did your hypothesis agree with your observations? Describe the similarities or differences.**

   ____

   ____

5. **Explain how the relationship between radius and linear speed is demonstrated in this activity.**

   ____

   ____

   ____

6. **Do your explanations agree with your group's explanations? If they are different, explain how they are different?**

____

____

7. **A rotating disc 30.0 cm in diameter rotates 33.5 times per minute.**

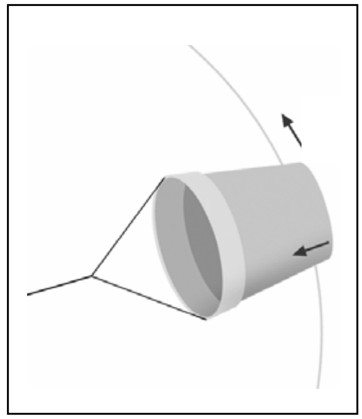
   a) What is its frequency and period?

   ____

   b) Calculate the linear speed and the centripetal acceleration of a point on its rim.

   ____

Falling Moons/Satellites (Week 2 Day 2)



Perform the following steps, then answer the questions:

a) Poke holes on both sides of a cup near the top.
b) Pull a string through the holes and tie at the top so you make a small bucket with a handle.
c) Fill the cup 1/3 full of water.

1. What will happen if you swing this cup of water around in a vertical circle at a high rotational speed? Write your hypothesis.

____

2. Swing the cup and water as described above and write your observations.

____

____

3. Explain your observations by answering the following questions:

a) Did you get wet during this activity? Explain why or why not. Include gravity as part of your explanation.

____

____

____

b) How do you think the rotational speed of the cup affected the results of your experiment?

____

____

____

4. What is the relationship between the results of this activity and stationary satellites that never fall and crash to the earth because of gravity?

____

____

____

Enrichment Questions

5. **Explain your observations by answering the following questions:**
   a) How is Newton's first law demonstrated in this activity?

      ____

   b) What would happen if the string broke while you were spinning the cup? Which direction would the cup fly? Draw a diagram below to show your answer.

6. **Predict what would happen if you put a hole in the bottom of the cup and swung it vertically or horizontally.**

   ____

   ____

Satellite Orbits (Week 2 Day 3)

1. **What is the shape of the path in which natural satellites move?**

2. **If we consider the pen as a satellite, draw the path of the satellite. Where is the centre of the path (orbit) in your drawing? What is the center called?**

3. **In your drawing, determine the arc where the satellite is moving at high speed and where it is moving at low speed. How does the difference in speed change as we change the distance between the two fixed points (foci)?**

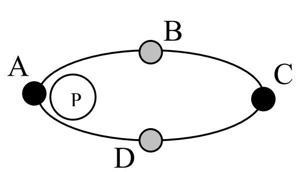
4. **How can you draw a circular path and not elliptical path?**

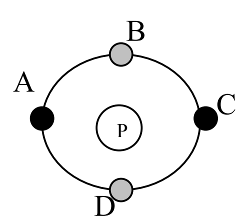
5. **How are the focal points of circular and elliptical orbits different?**

6. **Compare the speed of satellites in circular and elliptical orbits.**

7. **Kinetic Energy (KE) + Potential Energy (PE) = Total Energy (E)**

   Total energy remains the same at all points in a satellite orbit. At some points in the orbit KE is larger. At other points PE is larger. Indicate at points A, B, C and D in the two drawings which is larger, KE or PE. (P inside the small circle represents a planet around which the satellite is revolving).





Appendix B2: Lab Sheets Answer Key

The following pages present the answer key for the lab sheets.

Reviewing Gravity (Week 1 Day 1)

1. **What would happen if you dropped two balls with the same shape but different masses off a table at the same time with the same speed? Which will fall to the ground first? Write your hypothesis.**

   Possible Answer: The two balls will land at same time/the heavier first/the lighter first.

2. **Proceed with this activity and write your observations.**

   Answer: The two balls land at same time.

3. **Explain your observations.**

   Answers:
   - $d = 1/2at^2$
   - *since "d" and "t" are the same, "a" must also be the same*
   - $F = ma$ *or* $a = F/m$
   - *Since "a" is the same, F varies with m*
   - *Small m* $\longrightarrow$ *Small F*
   - *Large m* $\longrightarrow$ *Large F*

   Therefore force due to gravity depends on mass.

   Teacher's Note: If gravity was a constant force, then heavier objects would have a smaller acceleration, and therefore take longer to fall an equal distance.

   It is important for this activity to point out that the balls have equal surface area and the same type of surface which leads to equal air resistance but not equal mass.

4. **Did your hypothesis agree with your observations?**

5. **Do your observations agreed with your group's observations?**

6. **Write your conclusion.**

   Answer: If gravity was a constant force then heavier objects would have a smaller acceleration and therefore take longer to fall an equal distance. Thus, gravity is acceleration not force because the two balls land at the same time. All freely falling objects undergo the same acceleration at the same place on Earth.

Candle Accelerometer (Week 1 Day 3)

Teacher Notes
This is a brief activity where students build a simple to device out of a candle and a transparent plastic cup to observe the direction of acceleration. The candle flame will point in the direction of acceleration when students are rotating.

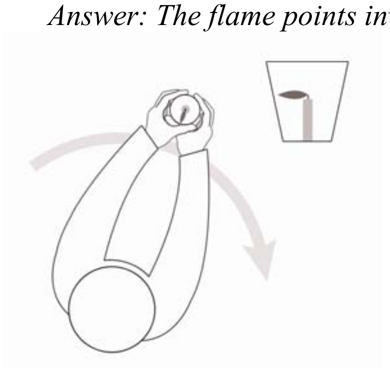
- Since this activity involves flame and hot wax, students should wear safety goggles. Appropriate fire safety devices should be present in the room.
- Students may become dizzy while spinning the candle apparatus. Students should avoid spinning too long to prevent dizziness.

Safety Precautions
- In this lab you will build a device that shows its direction of acceleration. There is a flame used in this lab, so you should wear your safety goggles while working with the flame.

Materials per Lab Group
- Safety goggles for each group member
- Matches or lighter
- Clear plastic cup
- Small candle
- Small lump of clay

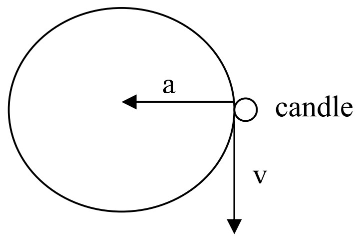
Instructions
1. Have the materials manager in your lab group gather the materials listed above.
2. Place the lump of clay in the bottom of the cup and place the candle in the clay.
3. Light the candle and observe the flame.
4. Answer the questions below in your journal.

Questions
1. When the candle is sitting still, draw a picture of what the flame looks like.
   Answer: Student drawings should show the candle flame pointing up.
2. Each person should take a turn holding the candle out in front of them and spinning in a circle (see diagram below). What happens to the flame? What direction does it point?
   Answer: The flame points inward reflecting the direction of acceleration.



3. Why does the candle flame behave this way? What forces are acting on it?
   Answer: The candle flame is being accelerated inward. The change in direction of the velocity when moving in a circle leads to an inward acceleration.

4. Draw the vectors acting on the candle. *Answer:*



5. Blow gently on the candle flame without extinguishing the flame. Why do we put the candle inside of cup for this activity?
   Answer: *The cup keeps air currents from affecting the flame so it shows the direction of acceleration, not the direction of air movement.*

Uniform Circular Motion Relationships (Week 1 Day 5)

1. **What do you expect if you roll a cylindrical can and an ordinary tapered drinking cup (a paper or foam cup) across a table? What path will each one follow? Write your hypothesis.**

   Answer: *Students will have various hypotheses. The tapered drinking cup will follow a curved path as it rolls. The can rolls in straight-line path*

2. **Roll the cup and the can on a flat surface and write your observations by answering the following:**
   a) Describe the path of the can as it rolls.
   Answer: The can rolls in a straight line.
   b) Which end of the can has a greater speed?
   Answer: Both ends have the same speed.
   c) Describe the path of the cup as it rolls.
   Answer: The cup follows a curved path as it rolls.
   d) Which end of the cup covers more distance?
   Answer: The top of the cup.
   e) Which end has the greatest linear speed?
   Answer: The top of the cup.

3. **Did your hypothesis agree with your observations?**

4. **Explain your observations above. What determines the shape of an object's path?**

   Answer: *The outer diameter (wide end) of the cup covers more distance in the same time and thus has more linear speed than the narrow end. The cup must follow a curved path in order for both ends to have the rotational speed. Both ends of the can have the same rotational speed while traveling in a straight line. The two ends of the can have the same radius hence both of them cover the same distance. If both ends cover the same distance in the same time, they must have the same linear speed.*

5. **Did your explanations above agree with your group's explanations? If they were different, explain how they were different.**

6. **Write the relationship between linear speed and radius below. You may use words or symbols.**

   Answer: *There is a direct - proportional relationship between the linear speed and the radius. If both points are in the same rotating system, the point that has the largest radius of rotation will have the greatest linear speed.*

Homework Project: Uniform Circular Motion Relationships (Week1 Day 5)

Using the model of a rotating disc, answer the following questions:

1. **What will happen if you place two coins on the top of the rotating disc, one near the centre and the other near the edge and then rotate the disc? Write your hypothesis below.**

   Answer: *Answers will vary*

2. **Which coin has a greater linear speed? Write your hypothesis.**

   Answer: *Students will have different ideas. All are acceptable. The correct answer is the coin near the edge has a greater linear speed.*

3. **Tape the coins on the disc as described above in Question 1. Spin the disc, observe and then answer the following questions:**
   a) Do the two coins have the same rotational speed in rotations per minute (RPM)? Why or why not?
   Answer: *The coins have the same rotational speed because they are both making the same number of rotations in a minute. In other words, they both complete the same number of circular paths in one minute. The outer coin is going further but it is still making the same number of rotations as the inner coin.*
   b) Which coin has a greater linear speed? Explain your answer.
   Answer: *The coin near the edge has a larger radius to its path of rotation; therefore it is going a further distance in the same amount of time. You can use the example of riding a merry-go-round or carousel to explain that the outside of a rotating system travels at a greater linear speed.*

4. **Did your hypothesis agree with your observations? Describe the similarities or differences.**

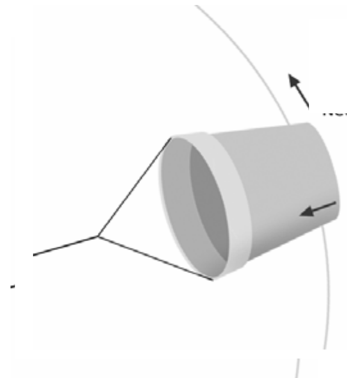
5. **Explain how the relationship between radius and linear speed is demonstrated in this activity.**

   Answer: *If rotational speeds are equal, the object with the larger radius must have a greater linear speed. The coin near the edge is further from the center of rotation, therefore it has a larger radius. A larger radius means the circumference of the circle the outer coin rotates in must be larger. Both coins have the same rotational speed but the outer coin travels further. Therefore, the outer coin must travel faster.*

6. **Do your explanations agree with your group's explanations?**

7. **A rotating disc 30.0 cm in diameter rotates 33.5 times per minute.**
   a) What is its frequency and period?
   Answer: *(0.558 Hz) (1.79 s)*
   b) Calculate the linear speed and the centripetal acceleration of a point on its rim.
   Answer: *(0.527 m/s) (1.85 m/s2)*

Falling Moons/ Satellites (Week 2 Day 2)



Perform the following steps then answer the questions:

a) Poke holes on both sides of a cup, near the top.
b) Pull a string through the holes and tie at the top so you make a small bucket with a handle.
c) Fill the cup 1/3 full of water.

1. What will happen if you swing this cup of water around in a vertical circle at a high rotational speed? Write your hypothesis.

Answer: Students will write their hypothesis,. Answers might differ from one student to another.

2. Swing the cup and water as described above and write your observations.

Answer: Students will write their observation and should observe that the water will stay in the cup and won't come out.

3. Explain your observations by answering the following questions:

a) Did you get wet during this activity? Explain why or why not. Include gravity as part of your explanation.
Answer: If the cup is swung with enough speed, it is accelerating at a rate greater than 9.8m/s/s (the acceleration due to gravity). The water in the cup is accelerating at the same speed as the cup. Therefore the water is accelerating at a greater rate than gravity. It stays in the cup because the cup moves the water away from the top of the circle faster than gravity can accelerate the water out of the cup.

b) How do you think the rotational speed of the cup affected the results of your experiment?
Answer: In circular motion rotational speed leads to rotational acceleration because of the change in direction. The greater the rotational speed, the greater the rotational acceleration. Rotational acceleration must be greater than 9.8m/s/s to keep the cup spinner from getting wet.

4. What is the relationship between the results of this activity and stationary satellites that never fall and crash to the earth because of gravity?

Answer: The activity shows that the water never comes out because its moves with acceleration greater than gravity acceleration. This is what happens with stationary satellites that must move with acceleration greater than gravity so they never fall and crash to the earth.

Enrichment Questions

5. **Explain your observations by answering the following questions:**
   a) How is Newton's first law demonstrated in this activity?
      Answer: *The water moves in a straight line unless acted upon by the cup.*
   b) What would happen if the string broke while you were spinning the cup? Which direction would the cup fly? Draw a diagram below to show your answer.
      Answer: *According to Newton's First Law the cup would go in a straight line tangent to the previous circular path of the cup.*

6. **Predict what would happen if you put a hole in the bottom of the cup and swung it vertically or horizontally.**

   Answer: *According to Newton's First Law, at the hole, the unbalanced force of the cup is no longer acting on the water, so it will fly out in a straight line tangent to the path of the cup.*

Satellite Orbits (Week 2 Day 3)

1. **What is the shape of the path in which natural satellites move?**

   Answer: *Elliptical path.*

2. **If we consider the pen as a satellite, draw the path of the satellite. What is the shape of the path in which natural satellites move?**

   Answer: The thumb tacks are the foci in the drawing, a planet is at one of the foci in a satellite orbit

3. **In your drawing, determine the arc where the satellite is moving at high speed and where it is moving at low speed. How does the difference in speed change as we change the distance between the two fixed points (foci)?**

   Answer: *The speed is greatest near the foci of an ellipse. It is constant in a circle. If the points are further away from each other, the path becomes more elliptical and the difference in speed increases. The closer the points become, the more circular the path and the more the difference in speed decreases.*

4. **How can you draw a circular path and not an elliptical path?**

   Answer: *By using one tack as a focal point.*

5. **How are the focal points of circular and elliptical orbits different?**

   Answer: *In circular orbits the focal point is the centre of the path; in elliptical orbits the planet is at one foci and the other is theoretical.*

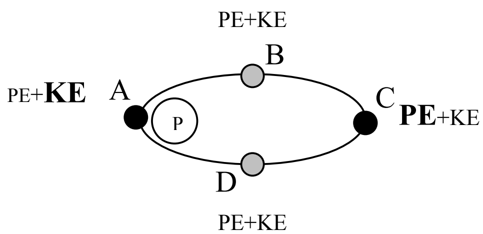
6. **Compare the speed of satellites in circular and elliptical orbits.**

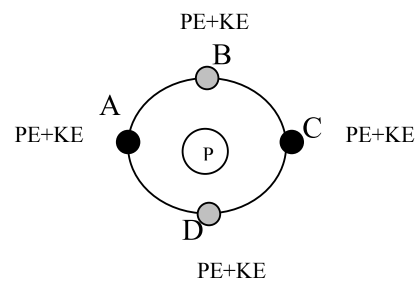
   Answer: *In circular orbits, the speed is constant; but in elliptical orbits the speed changes becoming faster near the planet (one foci) and slower at other end (the other foci).*

7. **Kinetic Energy (KE) + Potential Energy (PE) = Total Energy (E)**

   Total energy remains the same at all points in a satellite orbit. At some points in the orbit KE is larger. At other points PE is larger. Indicate at points A, B, C and D in the two drawings which is larger, KE or PE. (P inside the small circle represents a planet around which the satellite is revolving).

   Answer:





Appendix C: Role Play, Parts 1 and 2

The following pages present Role Play, Parts 1 and 2.

فكرة مشهد لعب الدور:

تتمحور فكرة لعب الدور في تمثيل الحركة الدائرية المنتظمة لعلبة مرتبطة بخيط وذلك للوقوف على خصائص الحركة الدائرية المنتظمة و التعرف على القوة التي تحافظ على استمرارية هذه الحركة.

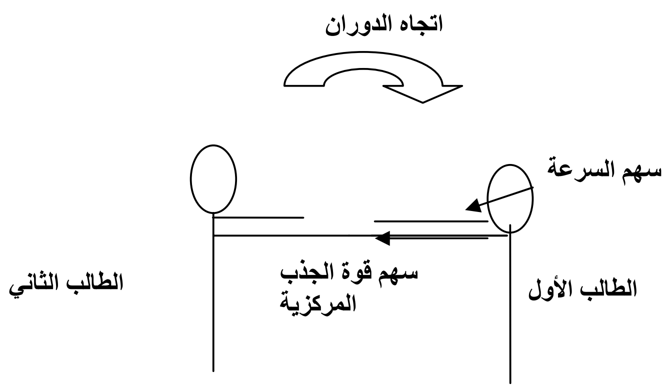
شخصيات المشهد:

(العلبة، الخيط ، فضولي)

المشهد الأول:

يخرج الطلاب المهيئون مسبقا للعب الدور (العدد3 طلاب)، يقف اثنان منهما متقابلان ومتشابكان بأيديهم.

الطالب الأول يمثل دور العلبة ويتم وضع سهم على رأسه ليشير الى اتجاه سرعته وسهم اخر على احدى يديه ليشير الى اتجاه القوة المركزية المؤثرة عليه أي باتجاه الطالب الثاني والذي يمثل دور الخيط. يتحرك الطالبان حركة دائرية وأثناء حركتهما يتطفل عليهم الطالب الثالث والذي يمثل دور الفضولي مندهشا من الحركة التي يتخذانها.



الحوار:

الفضولي: السلام عليكم ورحمة الله وبركاته.

الخيط والعلبة: وعليكم السلام.

الفضولي: عذرا لمقاطعتكما، لقد أدهشتني الحركة التي تتخذينها أيتها العلبة، فاني أجدها نوع آخر من أنواع الحركة فما هي يا ترى؟

العلبة: أنها الحركة الدائرية المنتظمة بقوة الخيط العجيبة التي تحافظ على استمراريتها.

الفضولي: أيها الخيط العجيب، ما هو السر في هذه القوة؟

الخيط: السر يكمن في قدرتي على الحفاظ على سرعة العلبة كما هي وفي نفس الوقت أتيح الفرصة لها بأن تغير من اتجاه سرعتها باستمرار.

الفضولي : هل يمكنكما أن ترياني ذلك مرة أخرى؟

العلبة والخيط: بكل سرور.

الفضولي: هذا واضح جدا فالسهم الدال على متجه السرعة يتغير اتجاهه كلما دارت العلبة، ما تأثير ذلك عليك أيتها العلبة؟

العلبة: أن له تأثير مدهش فأنا أشعر بقوة جذب مستمرة باتجاه قوة شد الخيط.

الفضولي: كيف نشأت هذه العلاقة القوية بينكما؟

الخيط: لقد نشأت باتفاق بيننا على تنفيذ هذه الحركة وشعرنا أنه أثناء تغيير سرعة العلبة تنتج عجلة مركزية وقوة موكزية باتجاه قوتي أي نحو مركز الدائرة.

الفضولي: نعم هذا واضح من سهم القوة فهو يشير باتجاهك أيها الخيط أي باتجاه مركز الدائرة التي تتخذينها أيتها العلبة، ولكن أنا محتار في موضوع ما؟ كيف تنتج عجلة مع بقاء سرعتك أيتها العلبة ثابتة؟

العلبة: هنا في حركتي الدائرية هذه يبقى مقدار السرعة ثابتا ولكن اتجاه السرعة هو الذي يتغير مما أكسبني عجلة.

فضولي: الان فهمت فالعجلة قد تنتج مع تغييرمقدار السرعة أو اتجاه السرعة.

الخيط: آه لقد كشفت سرا آخر من أسرارنا!!

الفضولي: أيتها العلبة، هل فكرت في يوم ما بأن الخيط قد يستغنى عنك، كأن ينقطع مثلا؟!!

العلبة: لا لم أفكر يوما في ذلك ولا أتمنى لمثل هذه الأفكار السيئة أن تحصل!!!!

الفضولي: لنفترض أنه حصل فأنا أوكد لك بأنك ستشعرين بقوة معاكسة تماما لقوة الخيط الجاذبة تسحبك الى الخارج.

الخيط: هذه القوة المعاكسة ما هي الا أوهامك، ولكنني سأوكد لك بأنها وان كانت لا تتخذ المسار الدائري بغياب قوتي ، فانها ستسير في خط مستقيم مماسا لهذا المسار.

الفضولي: ما دليلك على ذلك؟

الخيط: دليلي على ذلك هو قانون نيوتن الأول (قانون القصور الذاتي) ففي حالة قطع الخيط لن تكون العلبة تحت تأثيري أي لن توجد أي قوة مؤثرة عليها وسوف تسير بناءا عن رغبتها في السير في اتجاه خط مستقيم مماس للدائرة.

الفضولي: مادام قانون نيوتن الأول في صفك فانك دوما ذو شأن عظيم أيها الخيط العجيب!

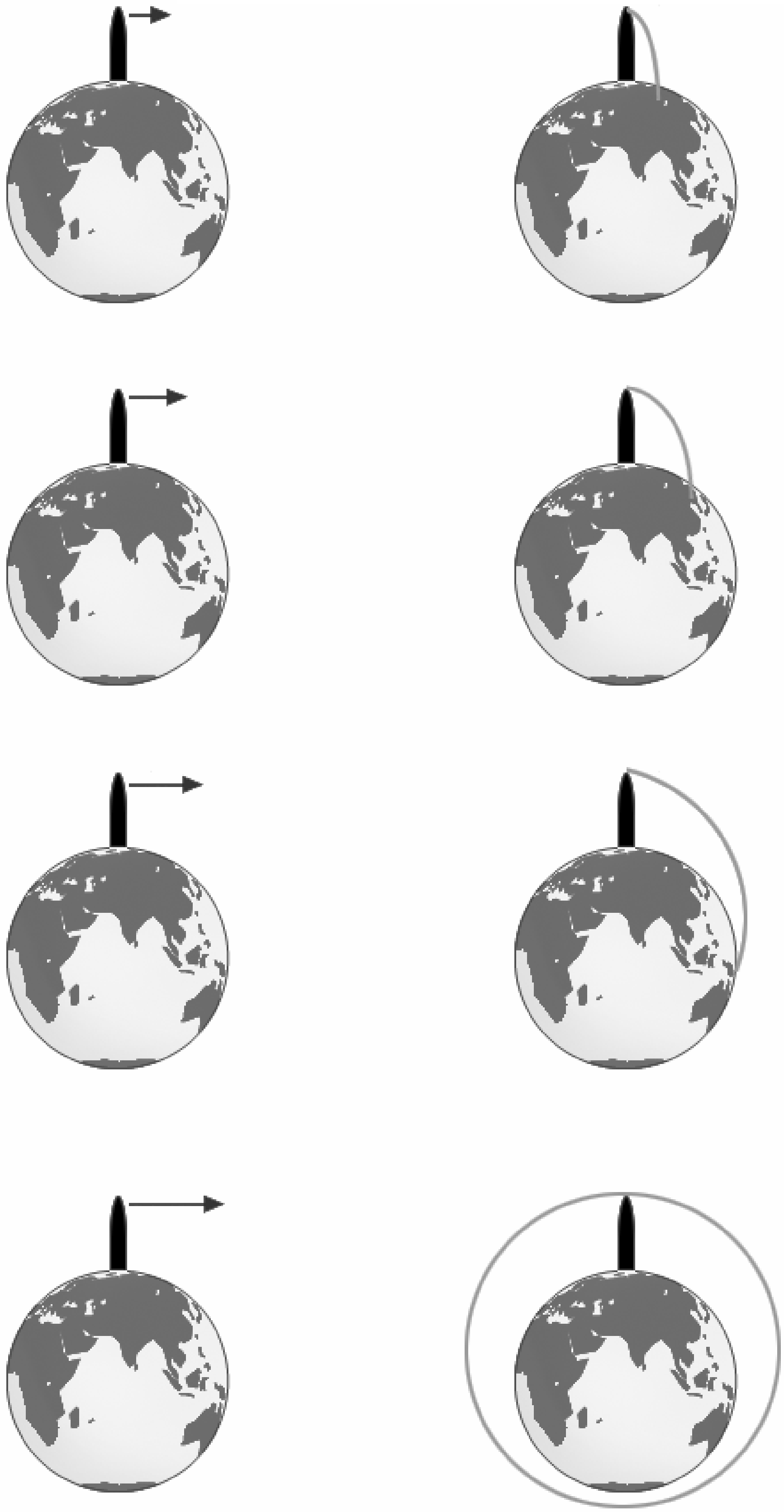
الخيط: شكرا لك.

الفضولي: لقد سررت بمعرفتكما وتمنياتي لكما باستمرارية هذه العلاقة المدهشة.

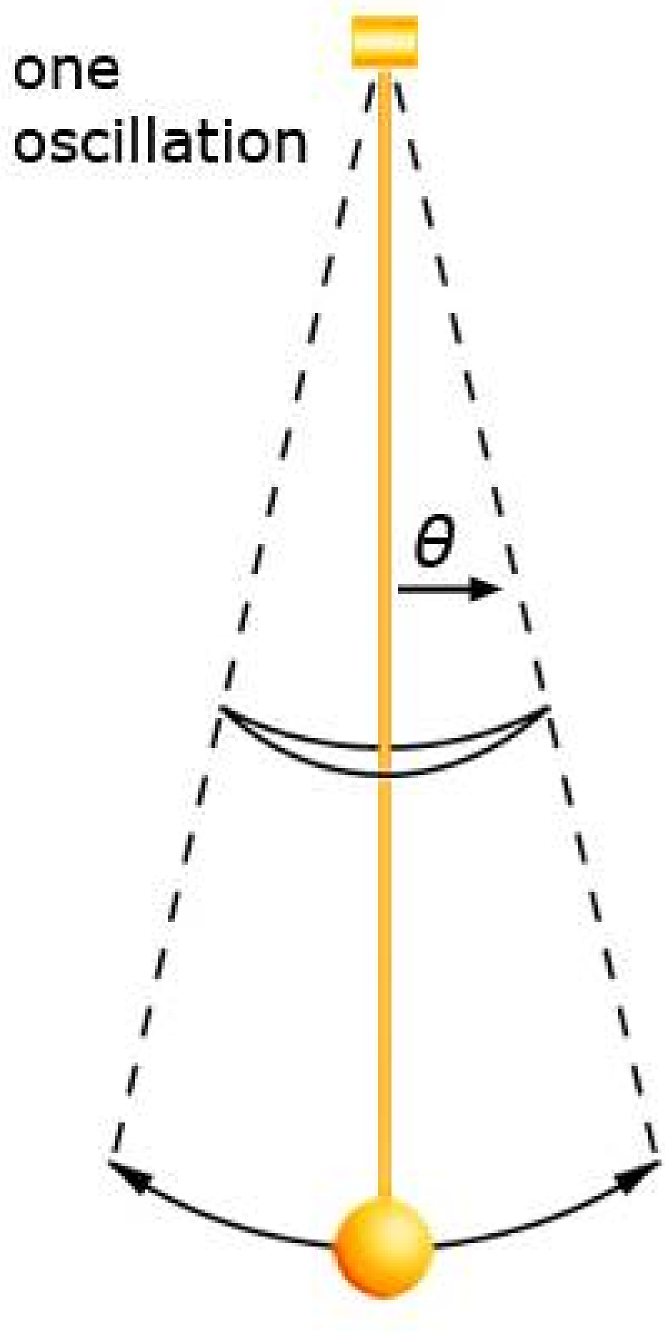
Appendix D:
Masters for Transparencies: Satellite Launch, Simple Pendulum, Springs (Vertical), Graphs, Circular Motion to SHM

The following pages present overhead transparencies for you to photocopy to use in the lessons.

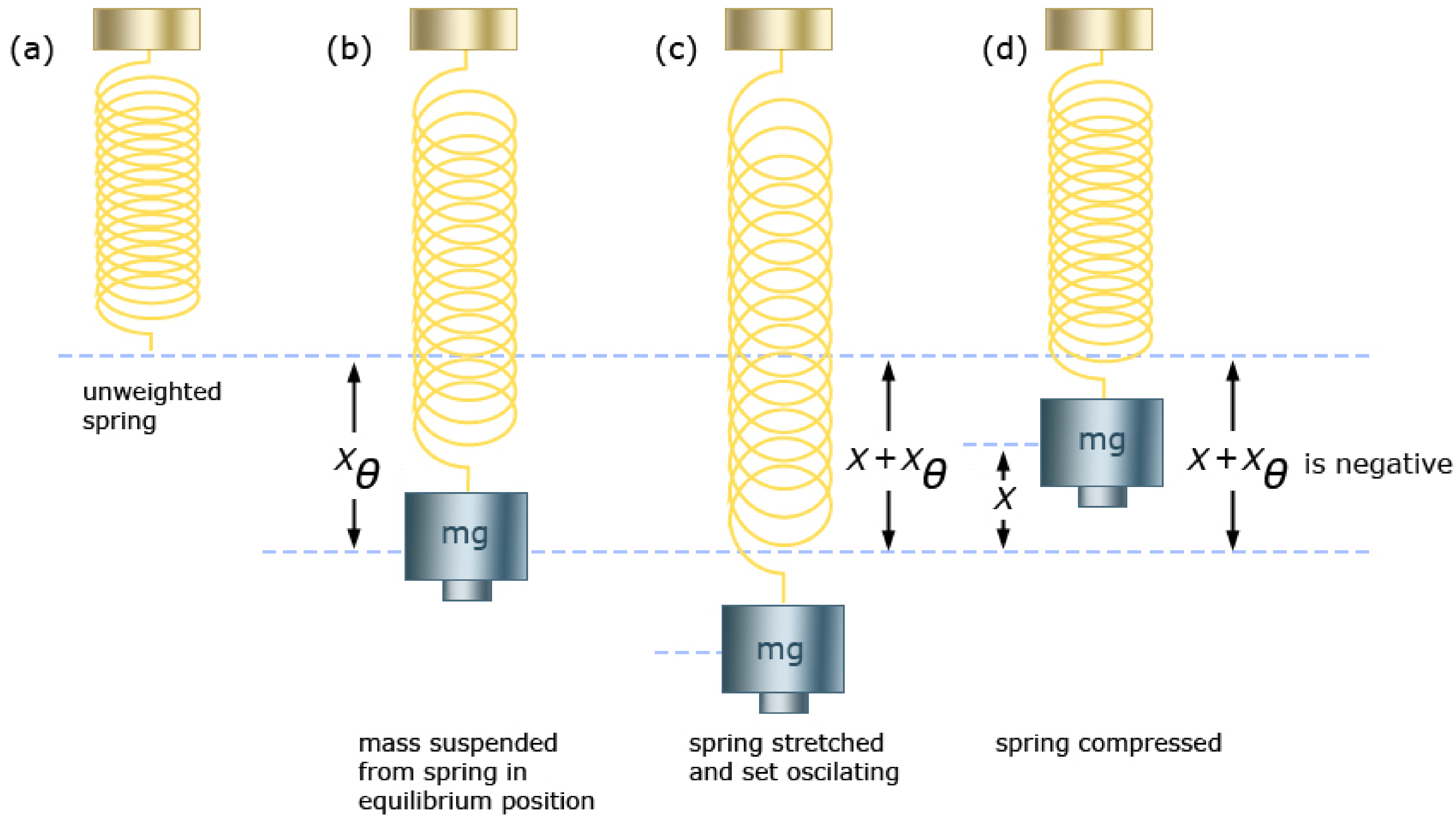
Satellite Launch



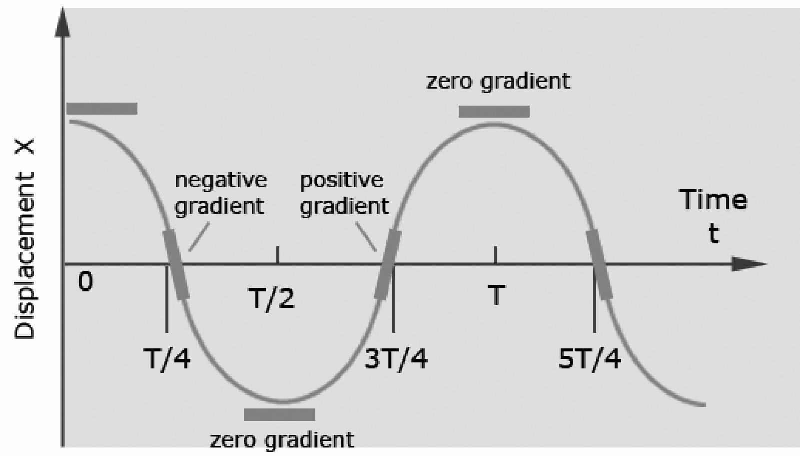
Simple Pendulum



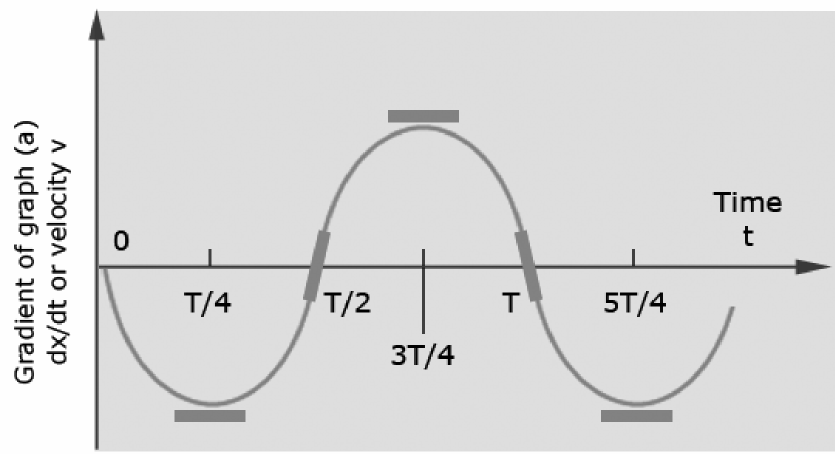
Springs (Vertical)



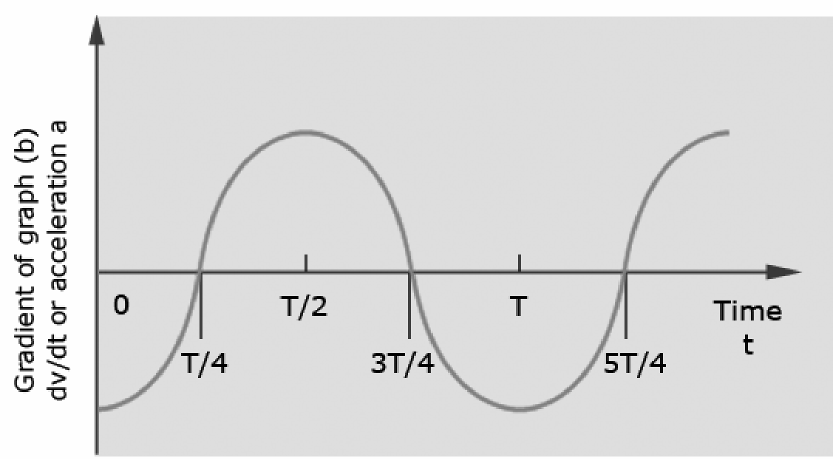
Graphs of Displacement, Velocity, and Acceleration



(a) Displacement–time curve

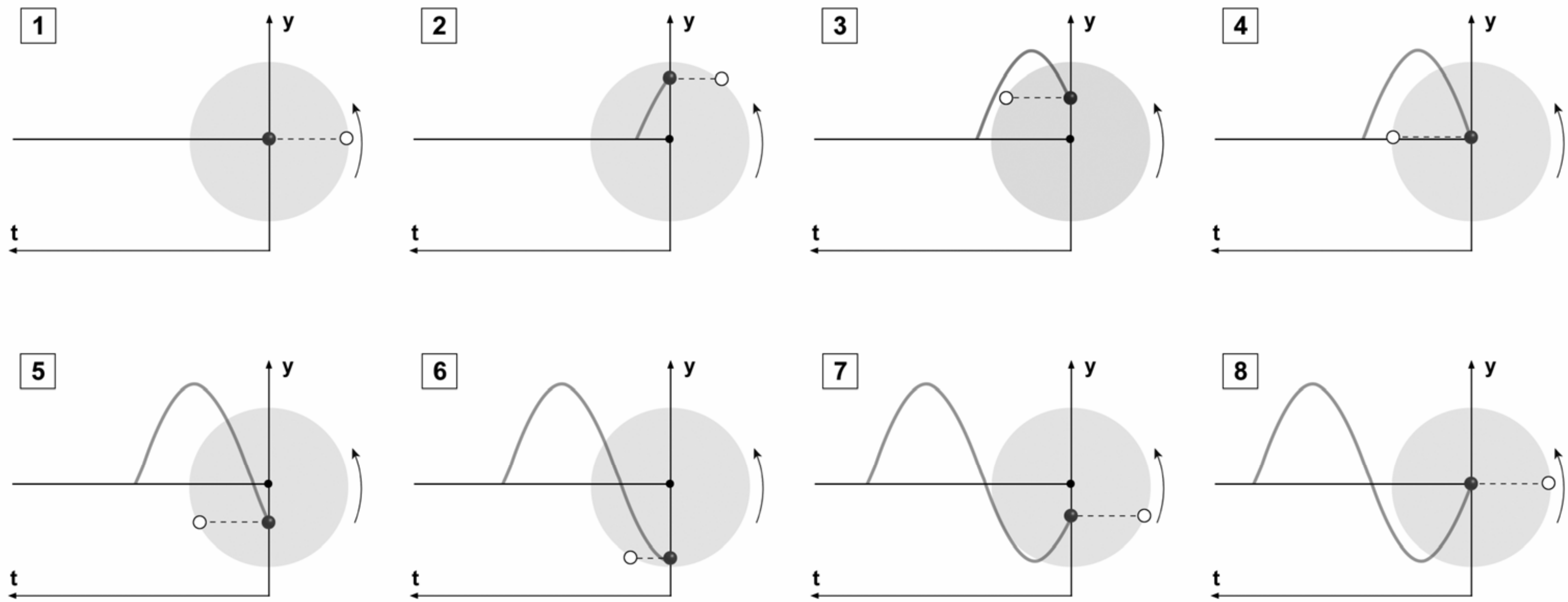


(b) Velocity–time curve



(c) Acceleration–time curve

Circular Motion to SHM



Appendix E: Questions on Physics Links

Week 1 Day 2
http://www.phy.ntnu.edu.tw/oldjava/FreeRolling/FreeRolling.html

1-What is the motion that you see called?
2-What does the red arrow represent?
3-What is the direction of this arrow at any point in the circular path during the motion?

Week 1 Day 5
http://www.phy.ntnu.edu.tw/oldjava/circularMotion/circular3D_e.html

1-Why does the ball move in a circular path?
2-What do the white arrow and the green string represent?
3-What will happen to the velocity of the ball if we increase the length of the green string?
4-What is the relationship between the velocity of the ball and the length of the string?

Week 2 Day 3

http://www.school-for-champions.com/science/orbit1.htm

1- Describe the motion of the satellite that you see.
2- When does the satellite have maximum and minimum velocity?

http://www.phy.ntnu.edu.tw/oldjava/Kepler/Kepler.html

1-Compare the speed of a satellite in circular orbit and its speed in elliptical orbit?

Week 2 Day 4

http://faraday.physics.utoronto.ca/GeneralInterest/Harrison/Flash/ClassMechanics/PendulumForces/PendulumForces.html
(Simple demo of vector magnitude and direction as pendulum oscillates, nice clean background)

1- What are the forces acting on the ball of the pendulum?
2- What is the net force?

Week 2 Day 5
http://www.phy.ntnu.edu.tw/oldjava/Pendulum/Pendulum.html
Potential and Kinetic Energy of Pendulum in Motion

1- Where does the ball have maximum and minimum velocity, Kinetic energy and potential energy?
2- What is the relationship between the period and the length of pendulum?

Week 3 Day 2
http://www.hazelwood.k12.mo.us/~grichert/explore/dswmedia/harmonic.htm

Week 3 Day 3
http://faraday.physics.utoronto.ca/GeneralInterest/Harrison/Flash/ClassMechanics/Circular2SHM/Circular2SHM.html
(Nice simple demo of how circular motion is SHM, not quantitative or adjustable)

http://www.phy.ntnu.edu.tw/oldjava/shm/shm.html

1- Describe the motion of the ball that you see?
2- What is the relationship between the motion of the ball and SHM?

Week 3 Day 4

http://www.walter-fendt.de/ph11e/springpendulum.htm
Demo of how oscillating spring is a wave over time.

http://lectureonline.cl.msu.edu/~mmp/kap13/cd363a.htm
Shows pendulum motion as a wave over time.

Week 3 Day 5

http://webphysics.davidson.edu/physlet_resources/bu_semester1/c18_SHM_graphs.html

1- Describe the motion of the spring from the graph that you see.
2- Describe the velocity, kinetic energy, potential energy at maximum displacement and equilibrium.

http://www.walter-fendt.de/ph11e/springpendulum.htm

1- Find the magnitude of the amplitude, max velocity, max acceleration, max force and the period of the oscillation.
2- Find the magnitude of the displacement at t = 0, 4, and 11seconds.
Find the velocity at t = 0, 7, and 29 seconds.
Find acceleration at t = 0,18, and19.5 seconds.
Find KE and PE at t = 0, 4, and 10.5 seconds.

Appendix F: General Science Worksheets

General Questions

Below some good question that teachers may use to asses students in different topic about circular motion, they have been collected from different resources. Answers to the questions are in italics.

Gravity

1. If you were on the earth and dropped a hammer and a feather from the same elevation at the same time, which one would strike the surface of the earth first?

    The hammer, because of air resistance

2. What happens when you do this on Moon? Why?

    Both at same time because of absence of air resistance

3. Do objects fall at a constant speed? Why?

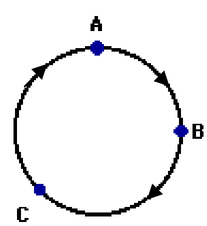
    Yes, because the all have same gravitational acceleration

4. The acceleration of gravity ('g') refers to the ____. Bubble in all that apply.

- *a. rate of acceleration of an object which is acted upon solely by gravity*
- b. force of gravity acting upon an object
- c. gravity
- d. weight of an object

Characteristics of Uniform Motion

1- An object is moving in a clockwise direction around a circle at constant speed. Use your understanding of the concepts of velocity, acceleration and force to answer the next five questions. Use the diagram shown at the right. Answers are in italics below.



a) Which vector below represents the direction of the force vector when the object is located at point C on the circle?

ANS: c

b) Which vector below represents the tangential speed when the object is located at point B on the circle?

ANS: d

c) Which vector below represents the direction of the acceleration vector when the object is located at point B on the circle?

ANS: d

2. What is the evidence of acceleration in circular motion where tangential speed and rotational speed are constant?

Change of direction.

3. What is meant by uniform linear motion?

It is linear speed which is the distance moved per unit of time

Centripetal Force and Centrifugal Force

1. A plane flying in a uniform horizontal circle at constant speed and height:
   - a) has no net force acting on it
   - b) experiences a net force acting away from the centre of the circle
   - *c) experiences net force acting towards the centre of the circle*
   - d) experiences an increasing force acting towards the centre of the circle

ANS: Objects moving with uniform circular motion experience a resultant force acting towards the centre of the circle. It is called the ***centripetal force.***

2. Changing motion requires a force.

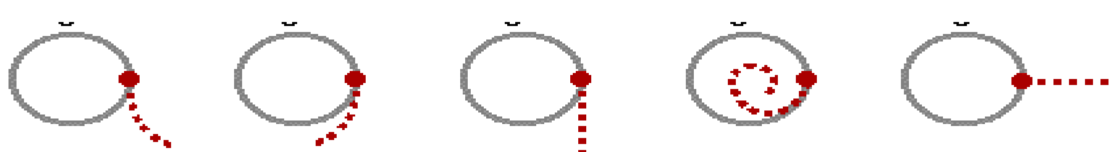
a)What force causes circular motion? *Centripetal force*

b) If the force doesn't change the speed, what does it do? *Changes the direction of the speed*

3.Which of the following statements is correct for an object moving with uniform horizontal circular motion?
   - a) The speed of the object varies but the velocity is constant
   - b) The kinetic energy of the object varies but its momentum is constant
   - *c) The momentum of the object varies but its speed is constant*
   - d) The kinetic energy of the object varies but the momentum is constant

ANS: If an object is traveling in a circle, its direction is always changing, so no vector quantities can remain constant e.g. velocity or momentum. Scalar quantities can remain constant, however e.g. speed and kinetic energy. The only answer to satisfy these conditions is C. Note that although the ***value*** *of acceleration remains the same and it is always towards the centre of the circle, the* ***direction*** *of the acceleration is always changing.*

4. An eraser is tied to a string and held by a physics teacher. The eraser is whirled in a circle at constant speed. A 'God's eye' view of the circle is shown in the diagrams below. If the string breaks when the eraser is at the indicated position, which one of the paths best represents the motion of the eraser? *ANS: 3*



5 4 *3* 2 1

5. A car makes a left-hand turn. The front-seat passenger claims that she feels a sensation of being pulled outwards. This is best explained by the fact that ____.

a. while there may be a net inward force, there is still an outward force upon the passenger

b. the passenger has a natural tendency to move tangent to and out of the circular path

c. there is a centripetal force pushing the person 'out the door'

d. there is a centrifugal force which pushes the person 'out the door'

e. the passenger ate her Big Mac way too fast and is now paying for it

Uniform Circular Motion Relationships

1. Which part of the earth's surface has greatest linear speed relative to Earth's axis?
The equatorial part has the greatest linear speed because it is farthest from the axis

2. An object rotates in a circle of radius 10m. The time for one rotation is 2 seconds. What are the angular speed and linear speed of the object?

Angular Speed / rad s^{-1}: 3.14, Linear Speed / ms^{-1}: 3.14
Angular Speed / rad s^{-1}: 3.14, Linear Speed / ms^{-1}: 31.4
Angular Speed / rad s^{-1}: 6.28, Linear Speed / ms^{-1}: 31.4
Angular Speed / rad s^{-1}: 6.28, Linear Speed / ms^{-1}: 31.4

Angular speed, $\omega = \frac{2\pi}{T} = \frac{2\pi}{2} = 3.14 rad\ s^{-1}$

Linear speed = $\frac{distance}{time} = \frac{2\pi \times 10}{2} = 31.4 ms^{-1}$

3. A 900-kg car moving at 10 m/s takes a turn around a circle with a radius of 25.0 m. Calculate the acceleration and the net force acting upon the car.

ANS: To Calculate the acceleration of the car, use the equation $a = (v^2)/R$. The solution is as follows:

$$a = (v^2)/R$$

$$a = ((10.0\ m/s)^2)/(25.0\ m)$$

$$a = (100\ m^2/s^2)/(25.0\ m)$$

$$\mathbf{a = 4\ m/s^2}$$

*To calculate the net force acting upon the car, use the equation Fnet = m*a. The solution is as follows.*

$$F_{net} = m*a$$

$$F_{net} = (900\ kg)*(4\ m/s^2)$$

4. A 95-kg halfback makes a turn on the football field. The halfback sweeps out a path which is a portion of a circle with a radius of 12-meters. The halfback makes a quarter of a turn around the circle in 2.1 seconds. Calculate the speed, acceleration and net force acting upon the halfback.

ANS: To calculate the speed of the halfback, use the equation v = d/t where the d is one-fourth of the circumference and the time is 2.1 s. The solution is as follows:

$$v = d/t$$

$$v = (0.25 * 2 * pi * R)/t$$

$$v = (0.25 * 2 * 3.14 * 12.0\ m)/(2.1\ s)$$

$$\mathbf{v = 8.97\ m/s}$$

To calculate the acceleration of the halfback, use the equation $a = (v^2)/R$. *The solution is as follows:*

$$a = (v^2)/R$$

$$a = ((8.97\ m/s)^2)/(12.0\ m)$$

$$a = (80.5\ m^2/s^2)/(12.0\ m)$$

$$\mathbf{a = 6.71\ m/s^2}$$

*To calculate the net force acting upon the halfback, use the equation Fnet = m*a. The solution is as follows:*

$$F_{net} = m*a$$

$$F_{net} = (95.0\ kg)*(6.71\ m/s^2)$$

$$\mathbf{F_{net} = 637\ N}$$

5. Fatma is practicing a centripetal force demonstration at home. She fills a bucket with water, ties it to a strong rope, and spins it in a circle. Anna spins the bucket when it is half-full of water and when it is quarter-full of water. In which case is more force required to spin the bucket in a circle? Explain using an equation as a "guide to thinking."

ANS: It will require **more force** *to accelerate a full bucket of water compared to a half-full bucket. According to the equation* $F_{net}= (m*v^2)/R$, *force and mass are directly proportional. So the greater the mass, the greater the force.*

6. Ahmed and Said are making a turn with their cars. Ahmed's is four times more massive than the Said's. If they make the turn at the same speed, how do the centripetal forces acting upon the two cars compare. Explain.

ANS: The centripetal force on a Continental is four times greater than that of a Yugo. According to the equation $F_{net} = (m \cdot v^2) / R$, force and mass are directly proportional. So 4 times the mass means 4 times the force.

7. Calculate the centripetal force acting upon a 40-kg child who makes 10 revolutions around the Cliffhanger barrel ride in 29.3 seconds. The radius of the barrel is 2.90 meters.

ANS: Given: m = 40 kg; R = 2.90 m; T = 2.93 s (since 10 cycles takes 29.3 s).

First, find speed using

speed= (2 • pi • R) / T = 6.22 m/s.

Then find the acceleration using

$a = v^2 / R = = (6.22\ m/s)^2 / (2.90\ m) = 13.3\ m/s/s$

Now use $F_{net} = m \cdot a$ to find that $F_{net} = 533$ N.

8. A stone of mass 0.5 kg is swung round in a horizontal circle (on a frictionless surface) of radius 0.75 m with a steady speed of 4 m s^{-1}. Calculate:

a) the centripetal acceleration of the stone

acceleration $= v^2/r = 4^2 / 0.75 = 21.4\ m\ s^{-2}$

b) the centripetal force acting on the stone.

$F = ma = mv^2/r = [0.5 * 4^2] / 0.75 = 10.7\ N$

9. Explain the difference between linear and angular velocity.

The instantaneous linear velocity at a point in the circle is usually given the letter v and measured in metres per second (m s^{-1}).

The angular velocity is the angle through which the radius to this point on the circle turns in one second. This is usually given the letter ω (Greek omega) and is measured in radians per second (rad s^{-1}) (See below)

Time period for one rotation (T) = distance/velocity $= 2\pi r/v = 2\pi/\omega$

Therefore linear and angular velocity are related by the formula:

*Linear velocity = radius of circle * angular velocity* $v = r\omega$

10. An object with mass 'm' is moving in a circle of radius 'R' at a constant speed of 'v.' The acceleration of the object will INCREASE if ____. Bubble in all that apply.

a. its mass were increased (while 'R' and "v" are held constant)
b. its speed were increased (while 'R' and "m" are held constant)
c. its radius were increased (while 'v' and "m" are held constant)
d. its mass were decreased (while 'R' and "v" are held constant)
e. its speed were decreased (while 'R' and "m" are held constant)

<u>Satellite Motion</u>

1. How would you answer the question, "What keeps a satellite up?

ANS: One might think that an inward force would move a satellite right into the center of the circle; but that's only the case if the satellite were in a rest position. Being that the satellite is already in motion in a tangential direction, the inward force merely turns it from the straight-line tangential direction. Instead of turning and falling into the earth, it turns and curves around the earth (thanks to the fact that the earth is round.)

2. If there is inward force acting upon a satellite, then why doesn't the satellite collide into the central body?

*ANS***:** *The previous question provides most of the reasoning for this. A combination of a tangential velocity and a curved earth prevents this collision. If it is your belief that the direction an object moves is always in the same direction of the force, then you have a misconception. Lots of objects move in a direction different from a force. For instance as your car heads east and you slam on your brakes, the force on the car is westward; only the acceleration would be westward. And for satellites, the direction of motion is tangential and the force is inward; only the acceleration is inward and this causes the circular motion around the central body.*

3. Do satellites remain in orbit forever? Why or why not?

*ANS***:** *If satellites are placed in orbits inside Earth's atmosphere (not outside the atmosphere, where they would be in vacuum.) Therefore, there is friction which results in generation of heat. This amount of heat energy is being dissipated and lost into the environment. Its only source is the kinetic energy of the satellite which gradually decreases. This means a decrease in the linear velocity of the satellite in orbit, which results in a decrease of the radius of the orbit. The final result is a spiralling of the satellite toward the surface of the earth. If this would really happen, the satellite would probably burn even before falling to ground. In order to keep satellites in their designed orbits, booster rockets have to be activated from time to time to provide the extra energy needed to compensate for heat losses. Launching and maintaining satellites in orbits is a high-technology profession for the present and the future.*

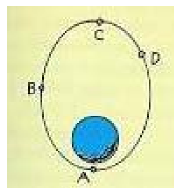
Satellite Orbit

1. A satellite orbiting above the earth is moved to an orbit closer to the earth. Which of the following quantities decreases as a result of the move?

a) Angular velocity of the satellite
b) Centripetal force on the satellite
c) Kinetic energy of the satellite
d) Gravitational potential energy of the satellite

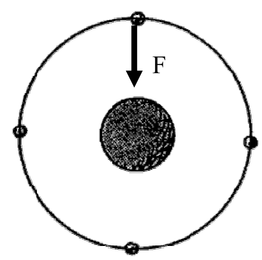
2. The orbit of a satellite is shown in the diagram. In which points A to D does the satellite have greatest speed? KE= PE?

	greatest speed	KE= PE
(i	B	C
(ii	*A*	*B*
(iii	A	C
(iv	D	B



3. This figure shows "Newton's Mountain," so high that its top is above the drag  of the atmosphere. The cannonball is fired and hits the ground as shown.

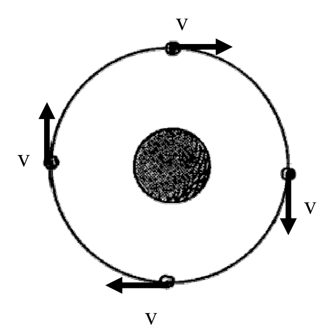
a) Describe its path as the cannon is fired faster and faster, but still less than 8 km/s.
It will be a curved path but will still fall and crash to the earth.
b) What is the shape of its trajectory when it is fired at exactly 8 km/s? Why?
It will be a circular path because its will match the surface of the curvature.



4. This figure shows a satellite in circular orbit

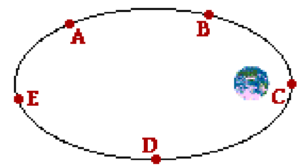
a) Draw a vector that represents the gravitational force, **F**, exerted on the satellite.

b) Then draw a vector at each position that represents the velocity, **v**, of the satellite.



c)Are all four velocity vectors the same length? Why or why not? *All four velocity vectors are same length because the velocity remain constant at all points.*
d) Does the KE of the satellite remain constant, or does it vary? *KE remains constant.*
e) Does the PE of the satellite remain constant, or does it vary? *PE remains constant.*

5. The elliptical path of an orbiting satellite is shown below. Several locations along the path are labelled with letters. Use this diagram for the next two questions.



a) Determine the location of lowest speed. *ANS: (E)*

b) Determine the location with the greatest net force. *ANS: (C)*

6. The net force acting upon an earth-orbiting satellite is dependent upon the ____. Bubble in all that apply.

a. distance from the satellite to the centre of the earth
b. radius of the earth
c. mass of the satellite
d. mass of the earth
e. None of these variables affect the net force

7. A satellite is orbiting the earth. If the orbital radius (the distance from the satellite to earth's centre) were somehow increased by a factor of 2, then the orbital speed of the satellite would be ____.

a. v/2
b. v
c. $\sqrt{2}v$
d. 4v

8. Which one of the following best describes the property of speed for a planet orbiting the sun?

a) greatest when closest
b) greatest when furthest away
c) independent of the distance of orbit
d) determined mainly by the planet's mass

Introduction of Periodic Motion

1. What is periodic motion?

a) Motion that regularly repeats itself
b) Motion that periodically accelerates
c) Motion that ends in a period

2. Why the oscillating motion of the pendulum called periodic motion?
Because its repeats itself regularly

3. Which one of these statements about the energy in SHM is NOT correct?
a) The kinetic energy is at a maximum when the displacement is at a maximum.
b) The potential energy is zero when the particle is at the rest position.
c) There is constant interchange between kinetic and potential energy in SHM
d) The total energy is the sum of the potential and kinetic energy

The Factors that Affect the Period of the Pendulum

1. If the period of a pendulum on Earth equals T what will be the period if we take the pendulum on moon?

ANS: $T=\sqrt{L/g}$

g at moon = 1/6 at Earth

T at moon will be longer $\sqrt{6}$ *than at Earth*

2. Define T.
T: is the time needed to complete one complete cycle(swing).
3.What is the effect on T of doubling the length of pendulum?
T will double.
4.What is the effect on T of increasing the mass of the pendulum?
No affect.
5. A Pendulum clock is running too fast. How could you adjust the pendulum to slow the clock?
Reduce the length of the pendulum.

Simple Harmonic Motion

Answer all the questions below. Choose the most accurate answer from the alternatives given.

1. When a pendulum ball is passed under the hanging point, all the statements below are correct except:
   a) *There is no velocity.*
   b) There is no force.
   c) There is no acceleration.
   d) There is no potential energy.

2. A simple pendulum has a string 1 meter long with a period of 2 seconds. If it is to have the same period on the moon surface, the length of the string should be:
   a) increased 6 times.
   b) *reduced to 1 sixth (1/6).*
   c) remain constant.
   d) increased 4 times.

3. An object is hung on a spring with a spring constant of 40 m/N. The object was pulled downward 20 cm and left to perform a simple harmonic motion. The potential energy of the object at the maximum displacement equals:

   a) 8×10^{-1} J
   b) 8×10^{-2} J
   c) 16×10^{-2} J
   d) 16×10^{-4} J

4. A simple pendulum oscillates according to the equation $y = 2 \sin 8t$. Its frequency in Hz equals to:

   a) 5 Hz
   b) 8 Hz
   c) 0.2 Hz
   d) *1.273 H*

5. A particle oscillates according to the formula $y = \sin 3t$. The speed of this particle at a time of (3.0 s) is equal to:

   a) *1.86 m/s*
   b) 0.14 m/s
   c) 0.78 m/s
   d) 2.99 m/s

6. A mass (*m*) oscillates under an effect of a spring with a constant *k* . When its mass is doubled it results in:

   a) Both the period and the frequency increase.
   b) The period decreases and the frequency increases.
   c) Both period and frequency are constant.
   d) *The period increases and the frequency decreases.*

7. The period of a simple pendulum depends on:

a) the weight of the hanged object and the length of the string.
b) the weight of the hanged object and the acceleration of the earth's gravity.
c) the length of the pendulum and the value of the acceleration of the earth's gravity.
d) the weight of the object, the length of the pendulum and the acceleration of the earth's gravity.

8. A simple pendulum has a maximum speed of v1. Its amplitude is doubled. If its second speed is v2 , the ratio between its first speed and second speed is:

a) 1:2
b) 2:1
c) 1:1
d) 3:2

9. A spring oscillates in a simple harmonic motion with an oscillation amplitude A. The total force at any point in its path of oscillation motion is E. If its oscillation amplitude is increased to 2A, then the total force is:

a) E/2
b) E
c) 2E
d) 4E

10. A simple pendulum has a T period. If its mass is doubled, its period is:
a) T/2
b) T
c) 2T
d) 4T

Complete the blanks below with suitable words:

1. At a rest position, the net force acting on a ball of a simple pendulum that performs a SHM equals _______ .*(zero)*
2. The maximum displacement of a ball of a simple pendulum has a period of 0.001 second. The frequency of this pendulum equals _______ *(152).*
3. An object of 1 kg mass oscillates upward and downward in a straight line of 20 cm long in a simple harmonic motion. Its oscillation amplitude equals _______ *(20)* , meanwhile its total range of motion is _______ *(10 cm)* and the distance it makes a complete one oscillation is _______ *(40).*
4. An oscillating system in a simple harmonic motion will have a total force at any point of its oscillation as _______ *(constant).*
5. The direction of acceleration in a simple harmonic motion is opposite to the direction of _______ *(displacement)* .
6. The outcome of multiplying frequency by period equals (1), meanwhile the outcome of multiplying frequency by the wavelength is _______ *(velocity)* .

7. When the ball of a pendulum passes the rest position, the potential energy equals _______ *(zero)* .
8. The potential energy of a pendulum at the maximum _______ *(displacement)* equals its kinetic energy at the _______ *(rest)* position.
9. Justify why the ball of the pendulum continues to move at the equilibrium position despite the fact that there is no resistance. *Because of inertia.*
10. Explain why every frequent motion is not a simple harmonic motion:

> *This is due to the fact that some frequent motions do not fulfill the condition of the simple harmonic motion which is represented by the direct proportion of displacement and force in value and by the converse proportion in direction.*

11. In a simple pendulum experiment done to validate the relationship between the period and the length of the pendulum, the string should be tied tightly to the pendulum stand because:

> *So that there would be no space for another swing beside the swing of the ball, the thing that causes an error in the experiment.*

12. A mass of 0.3kg hung on a spring with a spring constant of 7.5N/m. The spring causes the mass to move in simple harmonic motion and its displacement follows the formula:

$$y = 7\text{cm} \sin(5t)$$

Find the following:

> a. The displacement of the mass after 2 seconds. *(3.8 cm)*
> b. The speed of the mass at this displacement and acceleration of 0.29cm/s
> *(0.95 cm 2/s)*
> c. Kinetic energy, potential energy and total energy at this displacement.
> *129 X 10 – 3 joules, 5.415 X 10-3 joules, 18.4 O 10-3 joules 1.5 .*

13. Two identical objects are attached to identical springs If the mass of one of the objects is increased will there be any difference in the periods of the two systems? Explain your answer. If one of the springs is replaced with one with a larger spring constant, how will this affect the period of oscillation?

> *ANS: Yes the periods will be different as the length of the spring will be different, when the spring constant becomes different, so the period changes as well.*

Circular Motion and SHM

1. Why does the movement of a shadow resemble SHM?

Because the shadow can become a wave by:

$$x = A\ Sin(\omega t)$$

2. A particle of mass 5 x 10^-3 kg performing SHM of amplitude 150 mm takes 47 s to make 50 oscillations. The frequency of the oscillations is:

   a. 0.94 Hz
   b. 1.04 Hz
   c. 5.90 Hz
   d. 6.53 Hz

3. A particle of mass 5 x 10^-3 kg performing SHM of amplitude 150 mm takes 47 s to make 50 oscillations. The maximum velocity of the oscillations is:

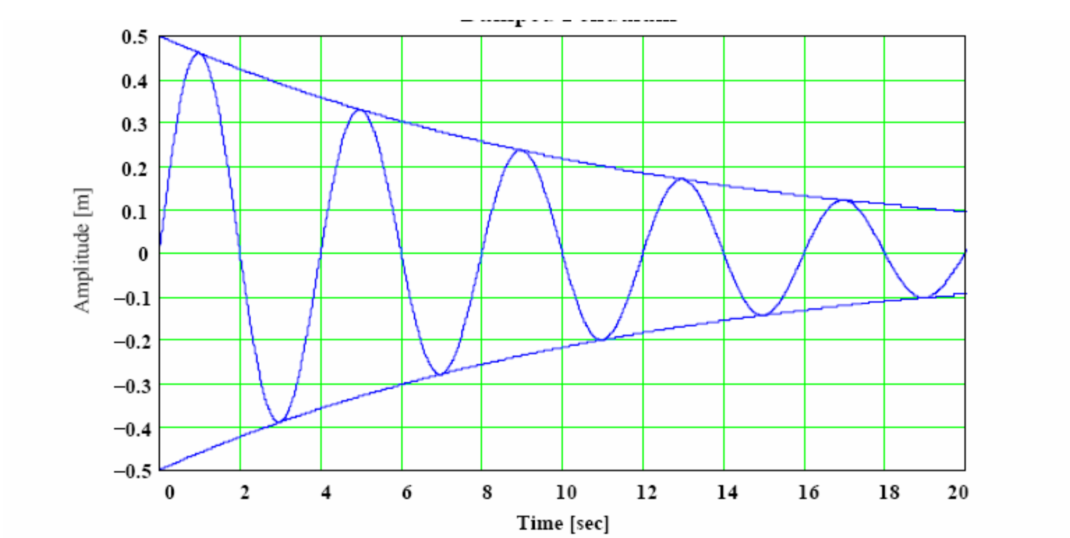
   a. 1.01 m/s
   b. 1.02 m/s
   c. 0.15 m/s
   d. 0.38 m/s

4. A particle of mass 5 x 10^-3 kg performing SHM of amplitude 150 mm takes 47 s to make 50 oscillations. The kinetic energy in millijoules (x 10 ^-3 J)of the oscillations at the rest position is:

   a. 5mJ
   b. 0 mJ
   c. 2.5 mJ
   d. 3.9 mJ

Harmonic Motion Relationships

1. The following graph describes the position of a simple pendulum as a function of time.



(a)What is the period of this pendulum? *4 seconds*

(b) Write the equation that will predict the maximum amplitude of this pendulum as a function of time?

ANS:

$$x=A\ Sin(\omega t)$$
$$x=A\ sin(2\pi/T)t$$
$$x=0.047sin(\pi/2t)$$

(c) What will be the maximum amplitude of this pendulum after 65 seconds ? *Zero*

(d) How long will it take for the maximum amplitude of this pendulum to be reduced to 3.0 cm ?

ANS:

$$0.03=0.047sin(\pi/2t)$$

$$sin(\pi/2t)=0.03/0.047$$

2. A bungee fish is a toy made out of balloons. It consists of a small balloon filled with sand which is wrapped in many layers of rubber to make a fish shape, and attached to a bungee cord made out of rubber. A 100 g blue bungee fish is bobbing up and down with amplitude 6 cm and frequency 1 Hz. At time $t = 0$, when you first observe the bungee fish, it has a displacement of +6 cm from its equilibrium position.

(a.) What is the angular frequency of the bungee fish?

ANS:

$$\omega= 2\pi f= 2\pi\ x\ 1=2\pi$$

(b) Write down a formula giving the displacement of the bungee fish as a function of time.

ANS:

$$x=A\ Sin(\omega t)$$
$$x=6\ Sin(2\pi t)$$

(c) Where is the bungee fish at time $t = 1$ s?

ANS:

$$x=A\ Sin(\omega t)$$
$$x=6sin(2\pi\ x\ 1)= 6\ x\ 0=0$$

The fish will be at rest position