

**Composite Materials and Mechanics Lab
Mechanical and Aerospace Engineering Department
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Polytechnic Institute of NYU
SMART RET Program
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LESSON PLAN

Subject: Physics

Topic: Circular Motion

Aim: How do you calculate the centripetal force acting on an object?

Subtopic: Centripetal Force

Time Frame: Three periods

Common Core State Standard:

Reading Standards for Literacy in Science and Technical Subjects Grades 9-12

1. Cite specific textual evidence to support analysis of science and technical texts attending to the precise details of explanations and descriptions.
2. Determine the central ideas or conclusions of a text; trace the text explanation or depiction of a complex process, phenomenon or concept.
3. Determine the meaning of symbols, key terms and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-12 text and topics.
4. Analyze the structure of the relationships among concepts in a text, including relationships among key terms.
5. Analyze the purpose for providing an explanation, describing a procedure or discussing an experiment in a text, defining the questions that seek to address the concepts.
6. Translate quantitative or technical information expressed in words into visual form and translate information expressed mathematically in an equation.
7. Assess the extent to which the reasoning and evidence in a text support the claim or a recommendation for solving a scientific or technical problem.

Learning to Learn Skills:

Numeracy, Group discussion and presentation, Taking Notes, Revisions

Levels of Assessments:

Depth of Knowledge Levels 1-4

References:

Conceptual Physics by Paul G. Hewitt
Physics by John D. Cuttnell and Kenneth W. Johnson
Physics by Douglas C. Giancoli

Background Information:

TOPIC : CENTRIPETAL FORCE

According to Newton's first law, an object in motion continues to move with a constant velocity(v) in the same direction unless acted upon by an external force. However, upon the influence of a constant pulling force from a fixed point, the same object will undergo circular motion at a constant speed. Such an external force which is responsible in forcing the object to remain in the circular orbit is known as centripetal force(F_c).

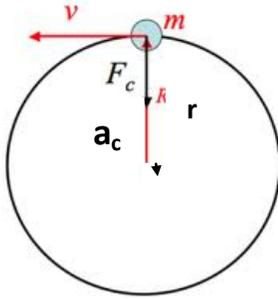


Fig.1. a_c and F_c in circular motion

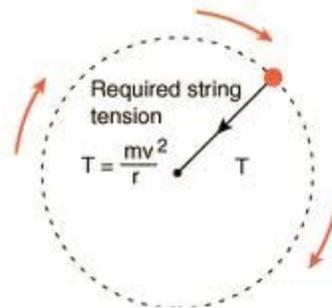


Fig.2. Tension in a string attached to a circulating object

Speed of the rotating bob remains constant but its direction changes continuously. Thus, the velocity(v) changes and in turn produces centripetal acceleration(a_c). The centripetal acceleration produced in the bob is always directed towards the centre. The tangential velocity vector is perpendicular to centripetal acceleration. The center seeking, centripetal force experienced by revolving object depends upon its mass(m), the radius(r) of the circular orbit and the speed of revolution. For an object rotating in an horizontal plane, the tension (T) developed in the string is equal to the centripetal force.

As shown in the figure, car is making a left turn. The necessary centripetal force for the turn is supplied by the friction between tires and the road. Otherwise, the car will go straight and hit the curb in accordance with Newton's first law - the law of inertia.

$$F_{\text{centripetal}} = m \frac{v^2}{r}$$

$\frac{v^2}{r}$ is the centripetal acceleration

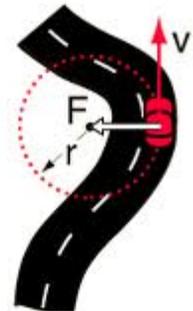


Fig. 3. Centripetal force on a banked curve

Students will calculate the speed of the object using Basic Stamp2 and Sensor set-up. Centripetal force acting on the object will be calculated using the formula

$$F_c = ma_c = \frac{mv^2}{r} = 4\pi^2 mrf^2$$

Where F_c : centripetal force ; v : speed of revolving object ; m : mass of the object
 a_c : centripetal acceleration ; r : length of the string; f : frequency of revolution

After the completion of the lesson students will be able to

- Distinguish between speed and velocity
- Differentiate linear and circular motion
- Relate Newton's second law to centripetal force
- Calculate the centripetal force acting on the object
- Identify dc motor, basic stamp2 and sensors
- Understand the working of Basic stamp2 and sensor setup.

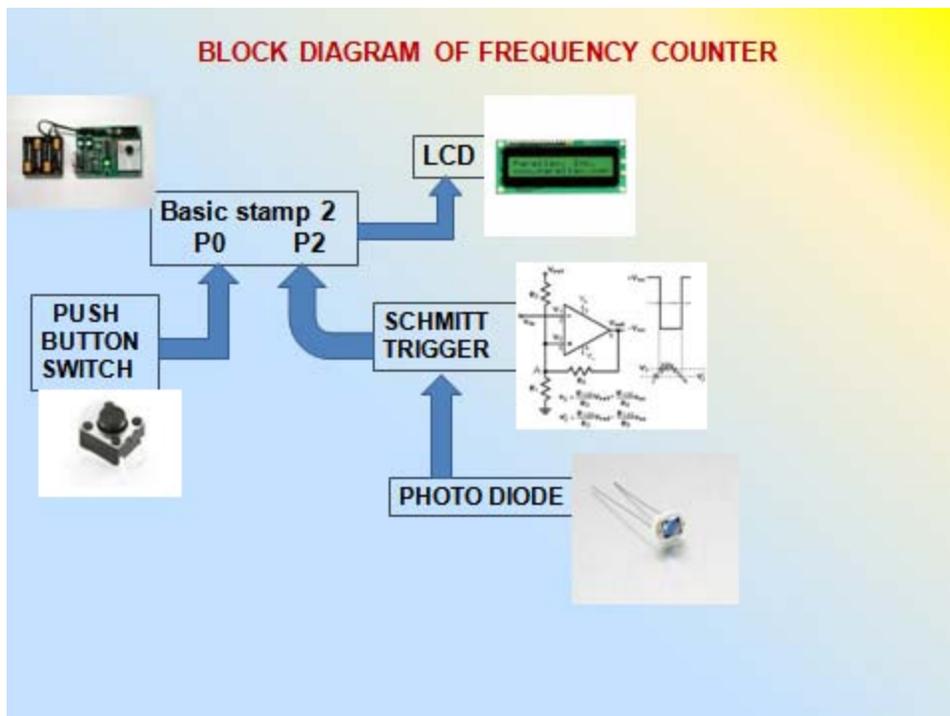


Fig. 4. Block diagram of frequency counter

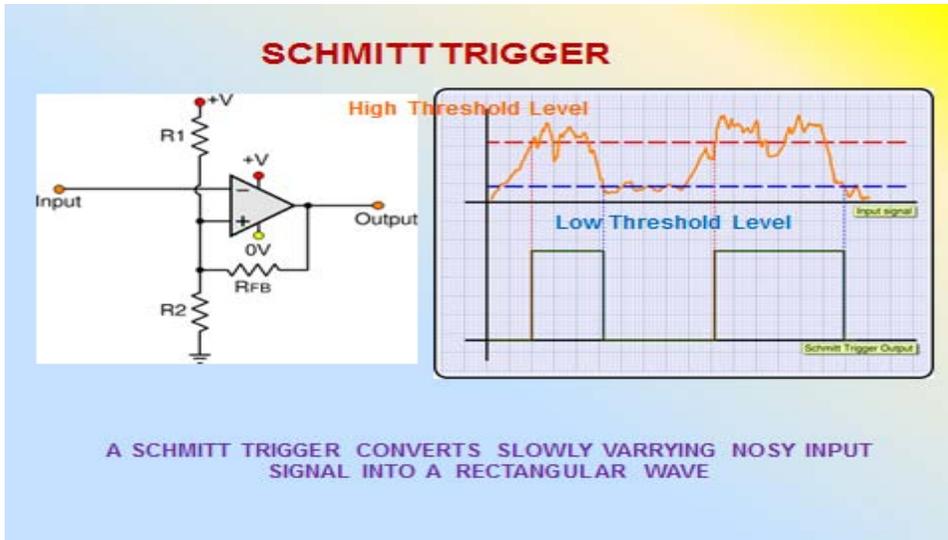


Fig. 5. Schmitt trigger circuit and its response to input signal

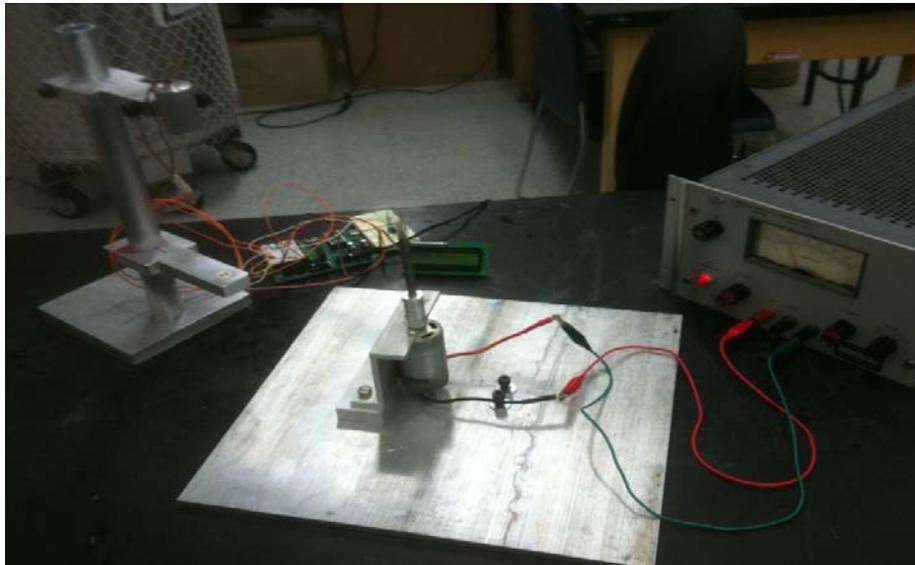


Fig. 6. Picture of Centripetal force setup

Student Materials:

Worksheets for each group where data, results and observations will be recorded.

Learning Station Materials:

- Basic Stamp Kit
- DC motor
- Laser diode, photodiode
- Pendulum Bobs or any suitable object preferably 15, 20, 25, 30 and 35 grams

Kevlar string of varying lengths of 15, 20, 25, 30 and 35 cm

Learning Station Set Up:

Each group of students will set-up their apparatus by following the directions given in the worksheet.

Prior Knowledge:

Units, Linear motion, Displacement, Speed, Velocity, Acceleration, Force

Vocabulary Check:

units, mass, weight, speed, velocity, tangential velocity, acceleration due to gravity, normal, Newton's first law, Newton's second law, centripetal acceleration and centripetal force

Motivation:

Demonstration:

Swing a bucket of water in a vertical circle and let students guess why the water doesn't spill. Write all their guesses on the board. Relate the discussion of concept of centripetal force back to the guesses after the experiment.

Do Now: Think, Pair and Share

Have you ever experience taking any rides in an amusement park like Six Flags? Describe how it feels to ride on a carousel. What happens as the carousel start to rotate and as the speed increased. Briefly introduce the activity or experiment that the students will perform.

Pre-lab Discussion:

Problem: How does the change in length of the string and mass of the bob effect the time period of revolution at a constant centripetal force?

Hypotheses:

1. If the mass of the bob is varied, then the time period will change.
2. The time period of revolution is unaffected by the change in mass of the bob.
3. If the length of the string is varied, then the time period will also change.
4. The time period of revolution is independent of variation in the length of the string.

Safety Check in the Lab:

1. Keep a safe distance from the rotating bob.
2. Avoid touching the electronic components once the setup is complete.
3. Follow all lab rules.

Instructions:

1. **Setting Group Dynamics**
Four of five groups with four members in each group.
2. **Group Members Role**
 - a) **Facilitator**
 - b.) **Time Keeper**
 - c.) **Recorder**
 - d.) **Group Reporter**

Lab Preparation:

Instructions:

1. Student's group should be positioned in each learning station.
2. A copy of the lab procedures and worksheet will be distributed to each group.
3. The teacher and the students go over the procedures of the lab as well as the worksheets.
4. The teacher explains how the apparatus will be built and how it will work.
5. The teacher checks to see if each group understand where to record data and that each of the group member know their individual roles and provides needed assistance

Note: The teacher checks and assesses student's progress by making occasional rounds between groups while they are recording data.

Post Lab Discussion:

- a) Student groups post their results around the room on a post it chart paper.
- b) Student facilitator presents and explains their result and graph.
- c) Students belonging to other groups ask appropriate questions and all groups actively participate in the discussion.
- d) Teacher will assess the performance each student.

Questions for discussion:

1. Explain how you have calculated the time period of oscillation. Show your work.
2. What are dependant and independent variables in the experiment?
Why did you consider so?
3. What is an oscillation?
4. How can you calculate the revolutions per minute (RPM) of the bob or motor? Show your work.
5. Why is there a need to find for revolutions per minute?
6. What is frequency and how is it related to time period?
7. What is linear velocity and how did you calculate linear velocity? Show your work.
8. If you know linear velocity, will you be able to calculate the angular velocity?
Explain how?
9. If you know Centripetal acceleration, how will you calculate Centripetal force?
10. How is the slope of graph useful in the calculation of centripetal force?
11. What is the relationship between tension on the string and the centripetal force?

Allow students to go back to the four hypotheses raised before the experiment and the demonstration on the bucket of water.

Hypothesis 1. Looking at your data, results and calculations as well as your graphs, Do you see any relationships between variables?

Is hypothesis 1 true in the experiment? Why? Why not?

Hypothesis 2. Is Hypothesis 2 true in the experiment? Why? Why not?

Hypothesis 3. Is hypothesis 3 true in the experiment? Why? Why not?

Hypothesis 4. Is hypothesis 4 true in the experiment? Why? Why not?

Vocabulary Check:

Allow the students to redefine the vocabulary words in their own sentences in the way they understood in terms of the experiment.

Conclusion:

What factor affects the time period of the pendulum? Justify or explain your answer in terms of the data and graph.

Wrap Up and Reflection:

Student's individually answer the following questions on a loose leaf paper:

1. If you are to visit an amusement park, will you be able to recognize a pendulum or objects that shows centripetal force?
2. If you are to build a swing in your backyard, what will be your most important consideration? Why?

CENTRIPETAL FORCE LAB WORKSHEET

Group No. _____

Members: 1. _____

2. _____

3. _____

4. _____

Procedure:

1. Turn on the power and record on your worksheet the values you see on the screen as shown by the LCD. (Your teacher will set the speed of the rotating bob.)
2. Proceed to the next length and mass of the bob.
3. Continue until you have entered all the data in your Results.
4. Be sure to label your dependent and independent variable in your graph. The dependent variable is labeled on the y-axis and your independent variable is labeled in your x-axis.

Table 1: Length of the string (Radius) versus Velocity of the bob

Mass of bob(g), m	Radius (m), r (length of the string)	Time period, T (s)	Velocity, V $V=2\pi r/T$, (m/s)	V^2 (m/s) ²
20	0.15			
20	0.20			
20	0.25			
20	0.30			
20	0.35			

Graph: Draw V^2 versus T plot and find the slope of the curve.

$$\text{Centripetal force} = F_c = ma_c = \frac{mv^2}{r}$$

Table 2: Mass of the bob versus its Velocity

Mass of bob(g), m	Radius (m), r (length of the string)	Time period, T (s)	Velocity, V $V=2\pi r/T$, (m/s)	V^2 (m/s) ²
15	0.15			
20	0.15			
25	0.15			
30	0.15			
35	0.15			

Analysis and Findings:

Looking at your graph, what is the relationship of length of the string, r and time period, T ?

What is the relationship of mass of the bob and its velocity?

Answer the following questions.

What is the difference between speed and velocity?

1. _____

Distinguish linear motion from circular motion.

2. _____

How is Newton's second law related to centripetal force?

3. _____

What is centripetal acceleration ?

4. _____

What is centripetal Force?

5. _____

How is tension related to centripetal Force?

5. _____

Conclusions:

Reflections: How do the basic stamp2 and the sensor worked to make the recording of data easy and precise? How do you rate this activity?