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author note: Provide information about the author’s departmental affiliation, acknowledgments of assistance or financial support, and a mailing address for correspondence.

keywords:

project no.:

picture:

type:

time to complete:

course context:

course level:

# Description

The Description should be brief, not more than a few sentences, and should provide a cogent summary of the physics, the computational approach, and the computational activities contained in the Exercise Set.

## Time to Complete

*Optionally* estimate how long you envision students would need to complete any exercises or computational activities. The purpose of this entry is to aid potential users of your materials in determining if they are appropriate for their specific classroom situation.

# Learning Objectives

Learning Objectives that are connected to the individual exercises are required. The learning objectives should be listed as specific, measurable tasks that your students should be able to do upon completion of the Exercise Set. The learning objectives should be listed after the statement, “Students who complete this Exercise Set will be able to,” and the specific exercise(s) with which each learning objective is associated should be indicated in parenthesis and bold type. For example, the learning objective “Create a graph of a function [**Exercise 3**]” would indicate that exercise 3 applies to this learning objective. Each learning objective may be tied to more than one exercise (*e.g.*, [**Exercises 1,2, and 3**] or [**Exercises 1–4**]) and vice versa.

# Instructor’s Guide

The Instructor’s Guide should provide advice to adopters/adapters on how the educational material contained in the Exercise Set could be used. It could also provide suggestions for further scaffolding of specific exercises and/or computational activities, as well as suggestions for adding higher levels of difficulty or sophistication for particularly astute students. If a particular set of exercises has been extensively tested by an author, a description of problems encountered or details on what to expect from students should be offered. This section could also offer some justification for an author’s particular style and preferences. A description of how this computational approach is relevant to the particular topic of the Exercise Set would be helpful. The author is provided a great deal of latitude in determining what exactly is appropriate for this section. Do include whether this has been classroom-tested or not and if it has been used, describe how well it worked and what issues arose.

## Introduction

Any measurement that you make without knowledge of the uncertainty is *meaningless*. (Lewin and Goldstein 2012, ix)

One of the principles we strive to instill first-year physics students is the concept of uncertainty in our measurements. The AAAS Online Benchmarks (2009) suggests High School students should have a qualitative understanding of uncertainty. We introduce putting upper and lower bounds on a value with a calculation of π using a modernized method like the Archimedes’ of Syracuse Method.

## Alternative Exercise

Archimedes’ method uses the circumference of a circle to calculate π. An alternative method is to use the area, .

The area of a regular polynomial given its circumradius is (Page 2011b)



where  is the circumradius and  is the number of sides of the polygon.

Students can use the programming templates and modify them for the area method.

Warning: This method looks like you need to know π before you can calculate π, see [Bench Calculator](#bc_pi). We define our trig functions in terms of radians. To convert from degrees to radians we need to know π. We could have defined our trig functions in terms of degrees, *e.g.*, . This is still an interesting iteration.

### Conversion from Degrees to Radians

Students without a background in spreadsheets or other language could use a little direction on conversion. See Table 1 for selected help.

Table 1. Conversion between degrees and radians for selected languages.

| Language | Conversion between degrees and radians |
| --- | --- |
| Bench Calculator, bc | pi=4\*a(1) radians=(degrees/180\*pi) |
| Calc | RADIANS(A1) |
| Excel | RADIANS(A1) |
| Fortran | Use degrees directly: l=sind(degrees) |
| MATLAB | Radians=deg2rad(degrees) |
| Octave | Radians=deg2rad(degrees) |
| Python | radians=math.radians(degrees) |

As  increases how fast does the answer approach π.

## Textbooks

Knight (2016, 24) focuses on significant figures exclusively and provides a 5 point figure, Tactics Box 1.5, to calculate the correct number of significant digits. He also includes rules for square roots and exact numbers like π. He also suggests that you keep extra digits during the calculation to prevent round off error, presenting the correct number of significant figures for the final answer.

Ling, Sandy, and Moebs (2018), OpenStax University Physics, focus on significant figures. They also describe the relationship between accuracy, precision, uncertainty, and discrepancy. Finally, they cover rules for calculating percent uncertainty.

Young and Freeman (2015, 8) focus on significant figures with a nod to:

* Accuracy
* Percent error
* Precision
* Uncertainty

They give significant figure rules for addition, subtraction, multiplication, and division.

# Theory

The Theory section should be a self-contained description of the underlying physics of the Exercise Set, or a reference to a published, readily accessible treatment of the topic. This section should also include a detailed description of the numerical approach employed in the computational activity or activities, or an appropriate reference to a readily accessible description of the numerical approach. Keep in mind that first time instructors or someone who hasn’t used computation in class before probably needs more guidance than a seasoned instructor — provide enough background so they don't need to reach for a textbook. When in doubt, provide more detail.

Thomas L. Heath translated Archimedes’ *The Works of Archimedes* (Archimedes of Syracuse 1897, 92/PDF 282), see Proposition 3 in the *Measurement of a Circle* Section. The original work is confusing due to missing steps and rational approximations. Chuck Lindsey (Lindsey 1997) add missing and explanatory elements with pop-up windows. Archimedes does introduce iteration into the calculation of π.







The bounds Archimedes places on the value of π is two parts in a thousand. Not bad for ink and papyrus.

NB: The  value is the origin of the ever-present  approximation.

We have the advantage of over two millennia of mathematics scholarship over Archimedes (Groleau 2003)

* Positional number system

We can represent the  while Archimedes need to use explicit rational approximations,  (Lindsey 1997).

* Trigonometric functions

Archimedes did not have the use of trigonometric functions, the sine function coming about 700 years later (Staff 2017)

* Algebra

Archimedes used geometry to approximate π. We can use algebra, as well.

We can calculate the perimeter, , of an sided, regular polygon inscribed within a circle of radius .

The perimeter of a regular polynomial is simply



where is the length of a side of the regular polynomial.

The length of a side can be calculated from the length of the circumradius of the polynomial (Page 2011a). In the case of an inscribed polynomial, the circumradius and radius are the same length.



Resulting in



For example, let’s calculate the perimeter of a triangle inscribed inside a circle with a radius of 10 m.



# Experiments

This *optional* section is available for the inclusion of details of any experiment that could accompany the exercises or computational activities of the Exercise Set, or for which the computational activities play a vital role.

# Exercises

The “Exercises” should consist of a scaffolded set of activities that are designed to demonstrate to potential adopters/adapters how students could be led through the process of interacting with, and solving problems related to, the physical principles and computational methodologies that are presented in the Theory section. A typical individual exercise should be roughly equivalent to an end-of-chapter problem from a text.

1. Derive the length of a side of a regular, inscribed polynomial with sides inscribed inside a circle of radius .

# Pseudocode

Pseudocode should be provided for each major exercise or activity within the Exercise Set. Potential adopters/adapters may rely on a clearly outlined pseudocode to fully understand the algorithm or other computational method that is brought to bear in the Exercises Set. The pseudocode should be language-agnostic.

# Solutions

Solutions to the exercises should be provided in sufficient detail to demonstrate the results of an implemented model or computational activity. These solutions are really “suggested solutions.” The solution to a computational exercise can vary greatly depending on the instructor’s personal pedagogical preferences. Thus, authors are allowed some latitude in the degree of detail required for this section; but, in order to be useful to a non-expert, more detail here is definitely desirable. Solutions will typically include relevant plots.

1. Derive the length of a side of a regular, inscribed polynomial with sides inscribed inside a circle of radius .

We can find the length of a side of a regular, inscribed polynomial with sides inscribed inside a circle of radius by calculating the chord of one of the triangles made from the chord between the two sequential vertices as seen in Figure 1

Circle with center O and inscribed vertices A and B. The angle between the radii to A and B is Theta. The chord of interest runs from A to B.

Description automatically generated

Figure 1. An Arbitrary Chord from Vertices A and B

The figure consists of a circle with center O, two radii from O to the circle, and the resulting chord AB. The chord subtends an angle θ.

We’ll

# References

This *optional* section can be useful to potential adopters/adapters if a connection between the content of the Exercise Set and basic physics principles is made to a popular physics textbook. If this topic is covered in a certain textbook that you use, please use this section to indicate which chapter/section covers this material.

AAAS. 2009. “Benchmarks Online, Chapter 9 Mathematical World (The), Section D Uncertainty.” American Association for the Advancement of Science. http://www.project2061.org/publications/bsl/online/index.php?chapter=9#D9.

Archimedes of Syracuse. 1897. *Works of Archimedes, The*. Translated by Thomas Little Heath. London: Cambridge University Press. https://archive.org/details/worksofarchimede029517mbp.

Groleau, Rick. 2003. “Approximating Pi.” Education. Nova. September 1, 2003. https://www.pbs.org/wgbh/nova/physics/approximating-pi.html.

Knight, Randall Dewey. 2016. “§1.8 Concepts of Motion/Significant Figures.” In *Physics for Scientists and Engineers: A Strategic Approach with Modern Physics*, 4th ed., 24–25. Boston: Pearson Education. http://www.worldcat.org/oclc/929155344.

Lewin, Walter H.G., and Warren Jay Goldstein. 2012. *For the Love of Physics: From the End of the Rainbow to the Edge of Time—a Journey through the Wonders of Physics*. EBook. New York: Simon & Schuster, Free Press. http://www.worldcat.org/oclc/893121223.

Lindsey, Chuck. 1997. “Archimedes’ Approximation of Pi.” Florida Gulf Coast University, Department of Mathematics. https://itech.fgcu.edu/faculty/clindsey/mhf4404/archimedes/archimedes.html.

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Page, John. 2011a. “Radius of a Regular Polygon.” Reference. Math Open Reference. 2011. https://www.mathopenref.com/polygonradius.html.

———. 2011b. “Regular Polygon Area Formula.” Reference. Math Open Reference. 2011. https://www.mathopenref.com/polygonregulararea.html.

Staff. 2017. “Trigonometry.” In *New World Encyclopedia*, Online. Saint Paul, MN: Paragon House Publishers. https://www.newworldencyclopedia.org/entry/Trigonometry.

Young, Hugh D., and Roger A. Freeman. 2015. “§1.5 Units, Physical Quantities, and Vectors/Uncertainty and Significant Figures.” In *Sears and Zemansky’s University Physics with Modern Physics*, 14th ed., 8–10. Boston: Pearson Education. http://www.worldcat.org/oclc/1050531058.

# File Attachments

## Code Templates

There is a spectrum of what an instructor might require of students to engage them in a computational activity, ranging from “programming from scratch” to “being given a fully working program” .If an instructor wants the students to program from scratch, then a blank page is the starting point; if an instructor wants to provide the fully-working code, the “Completed Code” is the students’ starting point; and, if the instructor wants to provide students with something in-between, then a “Code Template” is the starting point. This mode of coding would be of interest to faculty who may not want to have students producing models or simulations from scratch, but still want the students to master the coding at some level. A Code Template could be a version of “almost-working” or “minimally-working” code, and can include programs that are not complete with places indicated where students would be expected to provide the missing code. All notebooks such as Jupyter or Mathematica should include a PDF or plain-text file that shows what the file contains so people who don't have those programs installed can view the contents.

## Completed Code

Completed Code, pertaining to the computational exercises, in at least one programming language is required for an Exercise Set to be complete. Though one programming language is required, it is preferred that authors submit Exercise Sets with completed code in at least three different programming implementations. Authors may want to consider the possibility of getting colleagues involved to assist in producing different implementations. All notebooks should include a PDF or plain-text file that shows what the file contains — an educator shouldn't have to open any other programs besides the browser to see what the completed code looks like.

## Data Files

This *optional* section should contain any data files necessary for carrying out the computational activities in the exercises.

## Additional Resources

This *optional* section should include anything that has not already been included in the required sections for a PICUP Exercise Set, but is necessary for carrying out the computational activities.

Heading 0

Heading 0 is not used very often. You use it when you want to divide a large document into major parts, each part having several chapters.

Heading 1 is often used for chapters.

# Heading 1

This is an example of the formatting for a Heading 1 or chapter.

Note with the current release of Open Office, 3.3, you will need to manually set the font for Heading 1 to Heading 1 Char.

## Heading 2

Here is the format of a Heading 2 tag.

### Heading 3

Example of Heading 3

p — Paragraph

Lines Start — Non paragraph text

Lines — Non paragraph text

Lines End — Non paragraph text

Paragraphs

List list list  
liddy lidy

#### Heading 4

An example of Heading 4.

##### Heading 5

An example of Heading 5

###### Heading 6

An example of Heading 6

Heading 7

An example of Heading 7

Heading 8

An example of Heading 8

Heading 9

An example of Heading 9

# General Lists

## Simple, unordered, ordered lists

For example, here is a simple list.

List 1 Start

List 1

List 1

List 1 Cont.

List 1

List 1

Here is the hierarchical view of the 5 levels of simple lists.

List 1 Start

List 1

List 1 Cont.

List 1

List 2 Start

List 2

List 2 Cont.

List 2

List 3 Start

List 3

List3 Cont.

List 3

List 4 Start

List 4 Cont.

List 4

List 5 Start

List 5

List 5 Cont.

List 5

List 4

List 3

List 2

List 1

Simple List Example

bread

butter

cheese

bananas

End of Simple List Example

Unordered lists are similar.

Here's an example of an unordered list:

Formatted Example

* This is an item in an unordered list. To separate it from other items in the list. The is a bullet beside it.

This item consists of two paragraphs. This paragraph does not get a bullet because it is not a separate list item.

* This is a separate list item in our unordered list.

End of Formatted Example

The tags for an unordered list:

Formatted Example

* Bullet 1 Start

Bullet 1 Cont.

* Bullet 1

End of Formatted Example

Here is the hierarchical view of the 5 levels of unordered lists.

* Bullet 1 Start
* Bullet 1

Bullet 1 Cont.

* Bullet 1
* Bullet 2 Start
* Bullet 2

Bullet 2 Cont.

* Bullet 2
* Bullet 3 Start
* Bullet 3

Bullet3 Cont.

* Bullet 3
* Bullet 4 Start

Bullet 4 Cont.

* Bullet 4
* Bullet 5 Start
* Bullet 5

Bullet 5 Cont.

* Bullet 5
* Bullet 4
* Bullet 3
* Bullet 2
* Bullet 1

An ordered list is numbered with formatting that supports up to 99 items.

Ordered List Tag Usage

1. Numbering 1 Start
2. Numbering 1
3. Numbering 1

Numbering 1 Cont.

1. Numbering 1
2. Numbering 1

End of Ordered List Tag Usage

Full Ordered List Usage

1. Number 1 Start
2. Number 1

Number 1 Cont.

1. Number 1
2. Number 2 Start
3. Number 2

Number 2 Cont.

1. Number 2
2. Number 3 Start
3. Number 3

Number3 Cont.

1. Number 3
2. Number 4 Start
3. Number 4

Number 4 Cont.

1. Number 4
2. Number 5 Start
3. Number 5

Number 5 Cont.

1. Number 5
2. Number 5
3. Number 4
4. Number 3
5. Number 2
6. Number 1

End of Full Ordered List Usage

Formatted Example

1. Cream butter and sugar together until fluffy.
2. Beat in egg yolks one at a time.
3. Add nutmeg, cinnamon, and vanilla, and mix thoroughly.
4. Add flour and beat for five minutes. The batter should be smooth and glossy and stream off the spoon in ribbons.
5. Fold in beaten egg whites.

Do not overmix; the batter should be light and fluffy.

End of Formatted Example

Definitional list are a particular kind of list you can use when you want to pair a term or phrase with a description of it.

Here's an example of a definition list without a heading:

Formatted Example

| gopher | A burrowing rodent that feeds on roots of plants. |
| --- | --- |
| lawn | Gopher highway.  Can be identified by dinner-plate-sized mounds of dirt where grass used to be. |
| agapanthus | Lovely flowering plant, the roots of which are the preferred food of gophers.  If your flourishing agapanthus suddenly keels over, it means a gopher has had a feast. |

End of Formatted Example

The description of paragraph tags:

| Paragraph Tag | Description |
| --- | --- |
| DL | High Level Paragraph for Hierarchical View |
| DLdthd | Identifies the heading wanted for the definition term column. |
| DLdt Start | Identifies the first definition term for lists without headings. |
| DLddhd | Identifies the heading wanted for the definition description column. |
| DLdd Start | Identifies the first definition description for lists without headings. |
| DLdt | Identifies a definition term. It will have a DLdd tag associated with it. |
| DLdd | Identifies a definition description. Is will be associated with a corresponding DLdt tag. |

Here's an example of a definition list with a heading:

Formatted Example

| Amusement Park Area | Facilities |
| --- | --- |
| Veldt | Elephant ride, lion safari, nature walk, snack bar, rest rooms. |
| Jungle | Monkey ride, tree swing, snack bar, rest rooms, first aid station. |
| Desert | Camel ride, oasis cafeteria, rest rooms. |

End Formatted Example

#### Text that isn't paragraphs

#### Just plain lines

Lines Start — Non paragraph text

Lines — Non paragraph text

Lines — Non paragraph text

#### Examples of computer input and output

Examples of computer input and output are easy; you just begin them with an XMP Start tag followed with XMP tags.

Examples of computer input and output:

XMP Example

10 LET A = B

20 IF A GT B THEN GO 40

30 LET A = C

40 PRINT A, C

End of XMP Example

#### Example phrases

xph: The system will respond with a READY message.

Acronyms as also special highlighting .This is an acronym, fortran This

### Figures

Figure Example

The figure caption is placed underneath the figure content.

1. Example of an inline figure.

Figure Description.

End of Figure Example

Wide Figure Example

The figure caption is placed underneath the figure content even with wide figures.

1. Example of a wide figure.

This is an example of a wide figure description.

End of Wide Figure Example

#### Reference keys

There are times when you need to refer to labels — usually numbers — on item in a picture or graphic. Because the picture itself is not under control of Open Office, there is no way to use the automatic cross-reference tools. In this case, you use the Ref Key Char tag.

Formatted Example

1. Pull out the ON button, 1, on the display
2. When the system signature appears on the screen, press the CLEAR button, 2, on the keyboard.

End of Formatted Example

#### Title citations

Tags for title citations (Citation) are used to highlight titles.

Formatted Example

Have you read Gone With the Wind?

End Formatted Example

#### Notes

There are several ways to handle notes.

If the note is a single paragraph use the Note paragraph tag.

If the note is greater than a single paragraph, use the Note tag for the first paragraph followed by the Note Cont. paragraph tag.

If you have a list of notes, use the Notes, Notes Start, Notes End, Notes Cont., and Notes Head tags.

Example of Note tag

NB: This is an example of a Note tag.

End of Example

Example of Note and Note Cont. Tags

Note: When automated line composition began to replace hand line composition, the hyphenation technology was such that many hyphenation errors occurred. (This paragraph is tagged with the Note tag.)

When hyphenation is suppressed, justification, especially in narrow columns produces egregious “rivers” in the text. The solution to this problem was to suppress justification. (This paragraph is tagged with the Note Cont. tag.)

End of Example

Example of Note List

Note List Heading: (Notes Head)

1. The Notes list items begins with the Notes Start tag.

You can add an unnumbered paragraph with the Notes Cont. tag.

1. The subsequent Notes list items are tagged with the Notes tag.

End of Example

#### Long quotations

Excerpts or long quotations are indented according to traditional publishing stytle for information quoted from another source. The paragraph tag is LQ.

Long Quotation Example

The shipping guidelines say:

Packages weighing more than 20 pounds must arrive in the mailroom before 2:30 PM if they are to be shipped the same day. If packages are to be shipped air freight, they require an authorization signed by a manager.

Packages that are to be shipped overseas must be submitted to the mailroom with the proper customs clearance forms filled out.

Please comply with these guidelines.

End Long Quotation Example

### Tables

Tables consist of cells, arranged in rows. Here is a simple example:

Formatted Example

1. A simple example.

This is the description of a simple table.

|  |  |  |
| --- | --- | --- |
| Row 1, Column 1 | Row 1, Column 2 | Row 1, Column 3 |
| Row 2, Column 2 | Row 2, Column 2 | Row 2, Column 3 |
| Row 3, Column 3 | Row 3, Column 3 | Row 3, Column 3 |

End of Formatted Example

Let's look at another example — one that's a bit more filled out:

Formatted Example

A bigger sample table.

Here's a bit of a table description that you might find useful.

|  |  |  |  |
| --- | --- | --- | --- |
| Column Head 1 | Column Head 2 | Column Head 3 | Column Head 4 |
| Row 1, Column 1 | 1. Row 1 2. Column 2 | Row 1, Column 3; here's a little more text than the other cells have. | Row 1, Column 4 |
| Row 2, Column 2 | Row 2, Column 2 | Row 2, Column 3  Here is a short example. | Row 2, Column 4 |
| This paragraph is inside a table. | Row 3, Column 2 | Row 3, Column 4 | Row 3, Column 4 |

End of Formatted Example

Formatted Example

1. Full table tag usage.

This table uses most of the table tags.

|  |  |  |  |
| --- | --- | --- | --- |
| Table Head Left | Table Head Center | Table Head Center | Table Head Right |
| Table Cell Left | Table Cell Left | Table Cell Center | Table Cell Right |
| Table Cell Left | Table Cell Left | Table Cell Center | Table Cell Right |
| Table Cell Left | Table Cell Left | Table Cell Center | Table Cell Right |
| Note: This is an example of a table note. | | | |
| Table Foot Left | Table Foot Left | Table Foot Center | Table Foot Right |

End of Formatted Example

#### Messages and Codes

| Paragraph Tag | Description |
| --- | --- |
| MSGno | Message number |
| MSG | Message text |
| MSGxpl | Explanation |
| MSGseverity | Severity |
| MSGmodule | Module |
| MSGprod | Problem Determination |
| MSGuresp | User Response |
| MSGpresp | Programmer Response |
| MSGspresp | System Programmer Response |
| MSGoresp | Operator Response |
| MSGsysact | System Action |
| MSGnumbytes | Number of Error Bytes |
| MSGdest | Destination |

#### Processing perils: Caution, Warning, Danger

We must sometimes alert users to a risk of possible damage to equipment or data, machines, or themselves. For these situations, we have three paragraph tags ― Caution, Warning, and Danger. There are also three character tags ― Caution Head, Warning Head, and Danger Head.

Warning: Unit must be unplugged before this adjustment is made.

Danger: Unit must be unplugged before this adjustment is made.

Caution: Unit must be unplugged before this adjustment is made.

#### Qualifying Information

When you have to qualify information as applying to a particular product or system in a book about multiple products or systems, there are several techniques you can use.

One, of course, is simply to say, “if you are using Model 9, then ….” Another method, for major differences, is to put some qualification in the section heading.

Still another method is to use a formatting convention such as the one provided by the Qualif (qualifying information) tag. This tag is suitable for qualification at the level of a paragraph or list item or greater. It is not suitable for a single-phrase qualification or for qualifications of many pages.

There are both Qualif/Qualif End and Qualif Wide/Qualif End tag sets.

Formatted Example

The Qualif tag sure is handy.

End of Formatted Example

#### Labeled Box

The labeled box paragraph tag is LBLbox.

Labeled Box

Labeled boxes have two fundamental uses:

Labeled boxes provide special highlighting for important information that you want to make sure that your readers don't overlook.

To provide a formatting convention for the presentation of information, such as the syntax of programming statements.

All in all, labeled boxes are an effective presentation of certain kinds of information.

However; if you use them for a specific purpose, such as a syntax presentation, it is probably not a good idea to also use them for emphasis in the same document.

Paragraph

Abbreviation

Paragraph

Abstract

This is an appendix example.

This is an example of another appendix.

T

# Colophon

|  |  |
| --- | --- |
| Software | Word 2016, Version 16.0.7.7167.2040 MathType 6.9 |
| File Format | application/vnd.openxmlformats-officedocument.wordprocessingml.document+xml application/vnd.openxmlformats-officedocument.wordprocessingml.template+xml |
| Note about the type | de Groot, Lucas. 2012. “Calibri.” Corporate. Microsoft Typography. May 17. <http://bit.ly/2bphFep>. |
| Revision Control | $Date: $ $Id: $ $URL: $ |

Abstract

Paragraph

Note: Now is the

Bibliography

Paragraph

Legend

Paragraph

Safety

Paragraph

Summary of Changes

Paragraph

Paragraph