

# 07-Parametric and Polar Functions

Content Area: **Math**  
Course(s):  
Time Period: **Full Year**  
Length: **12 Blocks**  
Status: **Published**

## **General Overview, Course Description or Course Philosophy**

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This unit is an introduction to Parametric and Polar functions that are alternatives to the Rectangular (Cartesian) representation of curves.

Graphs of functions must pass the vertical line test, a limitation that excludes curves with self-intersections or even such basic curves as circles. In this section we will study an alternative method for describing curves algebraically that is not subject to the severe restriction of the vertical line test. We will then derive formulas required to find slopes, tangent lines, and arc lengths of these parametric curves.

Sometimes a moving point has a special affinity for some fixed point, such as a planet moving in an orbit under the central attraction of the Sun. In such cases, the path of the particle is best described by its angular direction and its distance from the fixed point. In this section we will discuss the Polar coordinate system that is based on this idea.

## **OBJECTIVES, ESSENTIAL QUESTIONS, ENDURING UNDERSTANDINGS**

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Enduring Understandings:

- A parametric function is a set of parametric equations ( $x = x(t)$  and  $y = y(t)$ ) that describe a curve on the  $x$ - $y$  plane. That curve is not necessarily a function in rectangular form of  $y = f(x)$ .
- A polar function ( $r = f(\theta)$ ) is defined by a distance  $r$  from a fixed point (pole) and an angular rotation  $\theta$  from the polar axis in a counter clockwise direction. Many complex curves can be described very simply in polar form but not in rectangular form.
- Frequently, it will be useful to superimpose a rectangular  $xy$ -coordinate system on top of a polar coordinate system, making the positive  $x$ -axis coincide with the polar axis. If this is done, then every point  $P$  will have both rectangular coordinates  $(x, y)$  and polar coordinates.
- A point has a unique description in rectangular form. That same point has an infinite number of descriptors in polar form.
- The techniques and applications of differentiation and integration can be extended from rectangular functions to parametric and polar functions.

Essential Questions:

- How do you create a parametric graph?
- How do you find  $dy/dx$  of a function in parametric form?
- How do you write the equation of a tangent line at a given point of a function in parametric form?
- How do you use derivatives to explain the features of the graph of a function in parametric form?

- How do you find the length of a parametric function?
- How do you create a polar graph?
- How do you find  $dy/dx$  of a function in polar form?
- How do you write the equation of a tangent line at a given point of a function in polar form?
- How do you use derivatives to explain the features of the graph of a function in polar form?
- How do you find the length of a polar function?

## **CONTENT AREA STANDARDS**

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### **A.CED**

**A. Create equations that describe numbers or relationships**

### **A.REI**

**A. Understand solving equations as a process of reasoning and explain the reasoning**

**B. Solve equations and inequalities in one variable**

**C. Solve systems of equations**

**D. Represent and solve equations and inequalities graphically**

### **A.SSE**

**A. Interpret the structure of expressions**

**B. Write expressions in equivalent forms to solve problems**

### HS Functions

### **F.BF**

**A. Build a function that models a relationship between two quantities**

**B. Build new functions from existing functions**

### **F.IF**

**A. Understand the concept of a function and use function notation**

**B. Interpret functions that arise in applications in terms of the context**

### C. Analyze functions using different representations

#### F.LE

A. Construct and compare linear and exponential models and solve problems

B. Interpret expressions for functions in terms of the situation they model

#### F.TF

A. Extend the domain of trigonometric functions using the unit circle

B. Model periodic phenomena with trigonometric functions

C. Prove and apply trigonometric identities

MA.9-12.EK 2.1C7	(BC) Methods for calculating derivatives of real-valued functions can be extended to vector-valued functions, parametric functions, and functions in polar coordinates.
MA.9-12.EK 2.2A4	(BC) For a curve given by a polar equation $r = f(\theta)$ , derivatives of $r$ , $x$ , and $y$ with respect to $\theta$ and first and second derivatives of $y$ with respect to $x$ can provide information about the curve.
MA.9-12.EK 3.4D1	Areas of certain regions in the plane can be calculated with definite integrals. (BC) Areas bounded by polar curves can be calculated with definite integrals.
MA.9-12.EK 3.4D3	(BC) The length of a planar curve defined by a function or by a parametrically defined curve can be calculated using a definite integral.
MA.9-12.MPAC 6.d	explain the connections among concepts;
MA.9-12.MPAC 3.f	connect the results of algebraic/computational processes to the question asked.
MA.F-IF.C	Analyze functions using different representations

### **RELATED STANDARDS (Technology, 21st Century Life & Careers, ELA Companion Standards are Required)**

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9.1.12.RM.6: Differentiate the costs benefits and features (e.g., riders, deductibles, umbrella policies) of renter's and homeowner's insurance.

CRP.K-12.CRP2	Apply appropriate academic and technical skills.
CRP.K-12.CRP4	Communicate clearly and effectively and with reason.
CRP.K-12.CRP6	Demonstrate creativity and innovation.
CRP.K-12.CRP8	Utilize critical thinking to make sense of problems and persevere in solving them.
CRP.K-12.CRP12	Work productively in teams while using cultural global competence.
TECH.8.1.12.E	Research and Information Fluency: Students apply digital tools to gather, evaluate, and use information.
TECH.8.1.12.F	Critical thinking, problem solving, and decision making: Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed

## **STUDENT LEARNING TARGETS**

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### **Declarative Knowledge**

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Students will understand that:

- A curve can be described by either a Cartesian or a Parametric representation.
- Parametric derivatives are an extension of derivatives of functions in rectangular form.
- Length of a parametric function is an extension of length of a function in rectangular form.
- A curve can be describe by eithe a Cartesian or a Polar representation.
- Some families of polar functions are identified by name.
- Polar derivatives are extension of derivatives in rectangular form.
- Polar areas are an extension of areas enclosed by functions in rectangular form.
- Length of a function in polar form is an extension of length of a function in rectangular form.

### **Procedural Knowledge**

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Students will be able to:

- Convert from parametric to rectangular form
- Create a parametric function graph from a chart
- Use a graphing calculator to graph a parametric function
- Compute parametric derivatives
- Use derivatives to explain the features of the parametric graph
- Use a graphing calculator to compute the length of a parametric function
- Convert between polar and rectangular forms.
- Plot points on a polar graph.
- Create a polar function graph from a chart.
- Use a graphing calculator to graph a polar function
- Compute polar derivatives
- Use a graphing calculator to compute polar areas
- Use a graphing calculator to compute length of a polar function

## **EVIDENCE OF LEARNING**

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### **Benchmark Assessments**

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Benchmark Assessments conducted three times per year, using Pear Assessment (Standards Based Assessments)

### **Alternate Assessments**

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- Portfolios
- Verbal Assessment (instead of written)
- Multiple choice
- Modified Rubrics
- Performance Based Assessments

### **Formative Assessments**

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- Marzano Scales
- Explain the process of converting from parametric to rectangular form.
- Explain the process of converting from rectangular form to polar form.
- Explain the process of converting from polar form to rectangular form.
- Identify the common types of polar functions.
- Why do we use symmetries when computing polar areas.
- Summarize (and any question as well as its answer you had) what was covered in class today.
- Homework

### **Summative Assessments**

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Test

## RESOURCES (Instructional, Supplemental, Intervention Materials)

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- Core Instructional Materials
  - Calculus Early Transcendentals, Anton, Bivens, and Davis
  - Calculus, Farrand and Poxon
  - Solutions at
    - <https://www.slader.com/textbook/9780470647691-calculus-early-transcendentals-10th-edition/>
    - <https://ia801309.us.archive.org/23/items/Calculus10thEditionH.Anton/Calculus%2010th%20edition%20H.%20Anton.pdf>

### Supplemental Materials

- TI-84 Graphing calculator
- Teacher designed worksheets
- <https://tutorial.math.lamar.edu/classes/calci/calci.aspx>
- <https://www.khanacademy.org/math/old-ap-calculus-ab/ab-limits-continuity>

## INTERDISCIPLINARY CONNECTIONS

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All examples are from the last link in the resources. Add 24 to the cited page number in order to go directly to the page.

- Aerodynamics Paper Airplane Flight: page 696, Example 5
- Physics Lissajous Curve: page 703, Problem 55
- Engineering Amusement Park Rides (Scrambler/Calypso): page 704, Problem 73
- Involute of a Circle Walking a Dog: page 704, Problem 74
- Science: page 713, Spirals in Nature
- Science: page 717, Problem 56 Butterfly Curves
- Astronomy: p 719, Problem 75
- Applications of Conic Sections: page 743, Optics
- Applications of Conic Sections: page 743, Architecture
- Applications of Conic Sections: page 743, Navigation
- Astronomy: page 759, Kepler's Laws
- Astronomy Haley's Comet: page 760, Example 4
- Astronomy Lunar Orbit: page 761, Example 5
- Astronomy Orbits Pluto: page 762, Problem 23
- Astronomy Orbits Mercury: page 762, Problem 24
- Astronomy Orbits Hale Bott Comet: page 762, Problem 25
- Astronomy Orbits Mars: page 763, Problem 26
- Astronomy Orbits Vanguard I around Earth: page 763, Problem 27
- Astronomy Orbits Space Ship Gallileo around Jupiter: page 763, Problem 28

## **ACCOMMODATIONS & MODIFICATIONS FOR SUBGROUPS**

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See link to Accommodations & Modifications document in course folder.