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DEPARTMENT OF EDUCATION

*Working Together for Student Success*



# Indiana Academic Standards Mathematics: Geometry



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## **Introduction**

The Indiana Academic Standards for Mathematics are the result of a process designed to identify, evaluate, synthesize, and create the most high-quality, rigorous standards for Indiana students. The standards are designed to ensure that all Indiana students, upon graduation, are prepared for both college and career opportunities. In alignment with Indiana's Every Student Succeeds Act (ESSA) plan, the academic standards reflect the core belief that all students can achieve at a high level.

## **What are the Indiana Academic Standards?**

The Indiana Academic Standards are designed to help educators, parents, students, and community members understand what students need to know and be able to do at each grade level, and within each content strand, in order to exit high school college and career ready. The academic standards should form the basis for strong Tier 1 instruction at each grade level and for each content area for all students, in alignment with Indiana's vision for Multi-Tiered Systems of Supports (MTSS). While the standards have identified the academic content or skills that Indiana students need to be prepared for both college and career, they are not an exhaustive list. Students require a wide range of physical, social, and emotional support to be successful. This leads to a second core belief outlined in Indiana's ESSA plan that learning requires an emphasis on the whole child.

While the standards may be used as the basis for curriculum, the Indiana Academic Standards are not a curriculum. Curricular tools, including textbooks, are selected by the district/school and adopted through the local school board. However, a strong standards-based approach to instruction is encouraged, as most curricula will not align perfectly with the Indiana Academic Standards. Additionally, attention should be given at the district and school-level to the instructional sequence of the standards as well as to the length of time needed to teach each standard. Every standard has a unique place in the continuum of learning - omitting one will certainly create gaps - but each standard will not require the same amount of time and attention. A deep understanding of the vertical articulation of the standards will enable educators to make the best instructional decisions. The Indiana Academic Standards must also be complemented by robust, evidence-based instructional practices, geared to the development of the whole child. By utilizing well-chosen instructional practices, social-emotional competencies and employability skills can be developed in conjunction with the content standards.

## **Acknowledgments**

The Indiana Academic Standards have been developed through the time, dedication, and expertise of Indiana's K-12 teachers, higher education professors, and other representatives. The Indiana Department of Education (IDOE) acknowledges the committee members who dedicated many hours to the review and evaluation of these standards designed to prepare Indiana students for college and careers.

## **PROCESS STANDARDS FOR MATHEMATICS**

The Process Standards demonstrate the ways in which students should develop conceptual understanding of mathematical content, and the ways in which students should synthesize and apply mathematical skills.

<b>PROCESS STANDARDS FOR MATHEMATICS</b>	
<b>PS.1: Make sense of problems and persevere in solving them.</b>	Mathematically proficient students start by explaining to themselves the meaning of a problem and looking for entry points to its solution. They analyze givens, constraints, relationships, and goals. They make conjectures about the form and meaning of the solution and plan a solution pathway, rather than simply jumping into a solution attempt. They consider analogous problems and try special cases and simpler forms of the original problem in order to gain insight into its solution. They monitor and evaluate their progress and change course if necessary. Mathematically proficient students check their answers to problems using a different method, and they continually ask themselves, "Does this make sense?" and "Is my answer reasonable?" They understand the approaches of others to solving complex problems and identify correspondences between different approaches. Mathematically proficient students understand how mathematical ideas interconnect and build on one another to produce a coherent whole.
<b>PS.2: Reason abstractly and quantitatively.</b>	Mathematically proficient students make sense of quantities and their relationships in problem situations. They bring two complementary abilities to bear on problems involving quantitative relationships: the ability to decontextualize—to abstract a given situation and represent it symbolically and manipulate the representing symbols as if they have a life of their own, without necessarily attending to their referents—and the ability to contextualize, to pause as needed during the manipulation process in order to probe into the referents for the symbols involved. Quantitative reasoning entails habits of creating a coherent representation of the problem at hand; considering the units involved; attending to the meaning of quantities, not just how to compute them; and knowing and flexibly using different properties of operations and objects.
<b>PS.3: Construct viable arguments and critique the reasoning of others.</b>	Mathematically proficient students understand and use stated assumptions, definitions, and previously established results in constructing arguments. They make conjectures and build a logical progression of statements to explore the truth of their conjectures. They analyze situations by breaking them into cases

	<p>and recognize and use counterexamples. They organize their mathematical thinking, justify their conclusions and communicate them to others, and respond to the arguments of others. They reason inductively about data, making plausible arguments that take into account the context from which the data arose. Mathematically proficient students are also able to compare the effectiveness of two plausible arguments, distinguish correct logic or reasoning from that which is flawed, and—if there is a flaw in an argument—explain what it is. They justify whether a given statement is true always, sometimes, or never. Mathematically proficient students participate and collaborate in a mathematics community. They listen to or read the arguments of others, decide whether they make sense, and ask useful questions to clarify or improve the arguments.</p>
<p><b>PS.4: Model with mathematics.</b></p>	<p>Mathematically proficient students apply the mathematics they know to solve problems arising in everyday life, society, and the workplace using a variety of appropriate strategies. They create and use a variety of representations to solve problems and to organize and communicate mathematical ideas. Mathematically proficient students apply what they know and are comfortable making assumptions and approximations to simplify a complicated situation, realizing that these may need revision later. They are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They analyze those relationships mathematically to draw conclusions. They routinely interpret their mathematical results in the context of the situation and reflect on whether the results make sense, possibly improving the model if it has not served its purpose.</p>
<p><b>PS.5: Use appropriate tools strategically.</b></p>	<p>Mathematically proficient students consider the available tools when solving a mathematical problem. These tools might include pencil and paper, models, a ruler, a protractor, a calculator, a spreadsheet, a computer algebra system, a statistical package, or dynamic geometry software. Mathematically proficient students are sufficiently familiar with tools appropriate for their grade or course to make sound decisions about when each of these tools might be helpful, recognizing both the insight to be gained and their limitations. Mathematically proficient students identify relevant external mathematical resources, such as digital content, and use them to pose or solve problems. They use technological tools to explore and deepen their understanding of concepts and to support the development of learning mathematics. They use technology to contribute to concept development, simulation, representation, reasoning, communication and problem solving.</p>

<b>PS.6: Attend to precision.</b>	Mathematically proficient students communicate precisely to others. They use clear definitions, including correct mathematical language, in discussion with others and in their own reasoning. They state the meaning of the symbols they choose, including using the equal sign consistently and appropriately. They express solutions clearly and logically by using the appropriate mathematical terms and notation. They specify units of measure and label axes to clarify the correspondence with quantities in a problem. They calculate accurately and efficiently and check the validity of their results in the context of the problem. They express numerical answers with a degree of precision appropriate for the problem context.
<b>PS.7: Look for and make use of structure.</b>	Mathematically proficient students look closely to discern a pattern or structure. They step back for an overview and shift perspective. They recognize and use properties of operations and equality. They organize and classify geometric shapes based on their attributes. They see expressions, equations, and geometric figures as single objects or as being composed of several objects.
<b>PS.8: Look for and express regularity in repeated reasoning.</b>	Mathematically proficient students notice if calculations are repeated and look for general methods and shortcuts. They notice regularity in mathematical problems and their work to create a rule or formula. Mathematically proficient students maintain oversight of the process, while attending to the details as they solve a problem. They continually evaluate the reasonableness of their intermediate results.

**MATHEMATICS: Geometry**

<b>Logic and Proofs</b>	
<b>G.LP.1</b>	Understand and describe the structure of and relationships within an axiomatic system (undefined terms, definitions, axioms and postulates, methods of reasoning, and theorems). Understand the differences among supporting evidence, counterexamples, and actual proofs.
<b>G.LP.2</b>	Use precise definitions for angle, circle, perpendicular lines, parallel lines, and line segment, based on the undefined notions of point, line, and plane. Use standard geometric notation.
<b>G.LP.3</b>	State, use, and examine the validity of the converse, inverse, and contrapositive of conditional (“if – then”) and bi-conditional (“if and only if”) statements.
<b>G.LP.4</b>	Understand that proof is the means used to demonstrate whether a statement is true or false mathematically. Develop geometric proofs, including those involving coordinate geometry, using two-column, paragraph, and flow chart formats.

**Points, Lines, and Angles**

<b>G.PL.1</b>	Prove and apply theorems about lines and angles, including the following: <ul style="list-style-type: none"><li>• Vertical angles are congruent.</li><li>• When a transversal crosses parallel lines, alternate interior angles are congruent, alternate exterior angles are congruent, and corresponding angles are congruent.</li><li>• When a transversal crosses parallel lines, same side interior angles are supplementary.</li><li>• Points on a perpendicular bisector of a line segment are exactly those equidistant from the endpoints of the segment.</li></ul>
<b>G.PL.2</b>	Explore the relationships of the slopes of parallel and perpendicular lines. Determine if a pair of lines are parallel, perpendicular, or neither by comparing the slopes in coordinate graphs and equations.
<b>G.PL.3</b>	Use tools to explain and justify the process to construct congruent segments and angles, angle bisectors, perpendicular bisectors, altitudes, medians, and parallel and perpendicular lines.
<b>G.PL.4</b>	Develop the distance formula using the Pythagorean Theorem. Find the lengths and midpoints of line segments in the two-dimensional coordinate system.

<b>Triangles</b>	
<b>G.T.1</b>	Prove and apply theorems about triangles, including the following: <ul style="list-style-type: none"> <li>● Measures of interior angles of a triangle sum to <math>180^\circ</math>.</li> <li>● The Isosceles Triangle Theorem and its converse.</li> <li>● The Pythagorean Theorem.</li> <li>● The segment joining midpoints of two sides of a triangle is parallel to the third side and half the length.</li> <li>● A line parallel to one side of a triangle divides the other two proportionally, and its converse.</li> <li>● The Angle Bisector Theorem.</li> </ul>
<b>G.T.2</b>	Explore and explain how the criteria for triangle congruence (ASA, SAS, AAS, SSS, and HL) follow from the definition of congruence in terms of rigid motions.
<b>G.T.3</b>	Use tools to explain and justify the process to construct congruent triangles.
<b>G.T.4</b>	Use the definition of similarity in terms of similarity transformations, to determine if two given triangles are similar. Explore and develop the meaning of similarity for triangles.
<b>G.T.5</b>	Use congruent and similar triangles to solve real-world and mathematical problems involving sides, perimeters, and areas of triangles.
<b>G.T.6</b>	Prove and apply the inequality theorems, including the following: <ul style="list-style-type: none"> <li>● Triangle inequality.</li> <li>● Inequality in one triangle.</li> <li>● The hinge theorem and its converse.</li> </ul>
<b>G.T.7</b>	Explore the relationships that exist when the altitude is drawn to the hypotenuse of a right triangle. Understand and use the geometric mean to solve for missing parts of triangles.



<b>G.T.8</b>	Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles.
<b>G.T.9</b>	Use trigonometric ratios (sine, cosine, tangent and their inverses) and the Pythagorean Theorem to solve real-world and mathematical problems involving right triangles.
<b>G.T.10</b>	Explore the relationship between the sides of special right triangles ( $30^\circ - 60^\circ$ and $45^\circ - 45^\circ$ ) and use them to solve real-world and other mathematical problems.

**Quadrilaterals and Other Polygons**

<b>Quadrilaterals and Other Polygons</b>	
<b>G.QP.1</b>	Prove and apply theorems about parallelograms, including those involving angles, diagonals, and sides.
<b>G.QP.2</b>	Prove that given quadrilaterals are parallelograms, rhombuses, rectangles, squares, kites, or trapezoids. Include coordinate proofs of quadrilaterals in the coordinate plane.
<b>G.QP.3</b>	Develop and use formulas to find measures of interior and exterior angles of polygons.
<b>G.QP.4</b>	Identify types of symmetry of polygons, including line, point, rotational, and self-congruences.
<b>G.QP.5</b>	Compute perimeters and areas of polygons in the coordinate plane to solve real-world and other mathematical problems.
<b>G.QP.6</b>	Develop and use formulas for areas of regular polygons.

<b>Circles</b>	
<b>G.CI.1</b>	Define, identify and use relationships among the following: radius, diameter, arc, measure of an arc, chord, secant, tangent, congruent circles, and concentric circles.
<b>G.CI.2</b>	Derive the fact that the length of the arc intercepted by an angle is proportional to the radius; derive the formula for the area of a sector.
<b>G.CI.3</b>	Explore and use relationships among inscribed angles, radii, and chords, including the following: <ul style="list-style-type: none"> <li>● The relationship that exists between central, inscribed, and circumscribed angles.</li> <li>● Inscribed angles on a diameter are right angles.</li> <li>● The radius of a circle is perpendicular to a tangent where the radius intersects the circle.</li> </ul>
<b>G.CI.4</b>	Solve real-world and other mathematical problems that involve finding measures of circumference, areas of circles and sectors, and arc lengths and related angles (central, inscribed, and intersections of secants and tangents).
<b>G.CI.5</b>	Use tools to explain and justify the process to construct a circle that passes through three given points not on a line, a tangent line to a circle through a point on the circle, and a tangent line from a point outside a given circle to the circle.
<b>G.CI.6</b>	Use tools to construct the inscribed and circumscribed circles of a triangle. Prove properties of angles for a quadrilateral inscribed in a circle.

<b>Transformations</b>	
<b>G.TR.1</b>	Use geometric descriptions of rigid motions to transform figures and to predict and describe the results of translations, reflections and rotations on a given figure. Describe a motion or series of motions that will show two shapes are congruent.
<b>G.TR.2</b>	Verify experimentally the properties of dilations given by a center and a scale factor. Understand the dilation of a line segment is longer or shorter in the ratio given by the scale factor.

**Three-Dimensional Solids**

<b>Three-Dimensional Solids</b>	
<b>G.TS.1</b>	Create a net for a given three-dimensional solid. Describe the three-dimensional solid that can be made from a given net (or pattern).
<b>G.TS.2</b>	Explore and use symmetries of three-dimensional solids to solve problems.
<b>G.TS.3</b>	Explore properties of congruent and similar solids, including prisms, regular pyramids, cylinders, cones, and spheres and use them to solve problems.
<b>G.TS.4</b>	Solve real-world and other mathematical problems involving volume and surface area of prisms, cylinders, cones, spheres, and pyramids, including problems that involve composite solids and algebraic expressions.
<b>G.TS.5</b>	Apply geometric methods to create and solve design problems.