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Pythagorean problems and answers

Level 4-5 The equation is: $a^2+b^2=c^2$ where c is the hypotenuse and a and b are the two other sides. The hypotenuse is always the longest side of the triangle and can be found opposite the right angle. Find the length of the side marked x on the right angled triangle shown. [2 marks] In order to find this using Pythagoras' theorem, we need to work out which side corresponds to each of the letters a , b , and c in the equation. $c = 10$ cm $b = 6$ cm $a = x$ cm $a^2+b^2=c^2$ becomes: $x^2+6^2=10^2$ $x^2+36=100$ Now we can solve for x $x^2=100-36=64$ $x=\sqrt{64}=8$ cm. Calculate the distance between $(-4, -1)$ and $(3, 4)$. Give your answer to 1 dp. [2 marks] First we plot the two points on a pair of axes, draw a line connecting them and then draw a triangle underneath making a note of the lengths of the sides: Side 1 (height) $= 4 - (-1) = 5$ Side 2 (width) $= 3 - (-4) = 7$ Next we substitute these lengths into Pythagoras' theorem: $a^2+b^2=c^2$ $5^2+7^2=c^2$ $25+49=c^2$ $74=c^2$ $c=\sqrt{74}=8.602325267...$ $c \approx 8.6$ (1 dp) $\text{end{aligned}}$ Note: The length you are trying to calculate, when finding the length of a line between two points, will always be the hypotenuse. The missing side is the hypotenuse, by substituting the 2 sides we know into the equation $a^2+b^2=c^2$ we get: $8^2+14^2=c^2$ Evaluating the two squares gives us: $c^2=64+196$ $c^2=260$ Then square rooting both sides of the equation gives us: $BC=\sqrt{260}=16.1245155...$ $= 16.1$ cm (1 dp). To do this, we plot the points on a graph and draw a line connecting them. We then construct a right-angled triangle. The resulting picture looks like: We can see that the distance between the two points is the longest side of a right-angle triangle - the hypotenuse, so by substituting the known sides into the equation $a^2+b^2=c^2$ we get: $10^2+3^2=c^2$ Evaluating the squares gives us: $c^2=100+9$ $c^2=109$ Finally, by square rooting both sides, we get: $c=\sqrt{109}=10.44030651...$ $= 10.4$ cm (3 sf). The missing side is the hypotenuse, so by substituting the known sides into the equation $a^2+b^2=c^2$ we get: $5.9^2+6.7^2=c^2$ Evaluating the two squares gives us: $c^2=34.81+44.89$ $c^2=79.7$ Then by square rooting both sides of this equation, we get: $QR=\sqrt{79.7}=8.927485648...$ $QR=8.9$ cm (1 dp). By substituting the known sides into Pythagoras' Theorem $c^2=a^2+b^2$ becomes: $5.1^2=LN^2+3.1^2$ Next we evaluate the two squares to give us: $26.01=LN^2+9.61$ Subtracting 9.61 from both sides: $16.4=LN^2$ Then we square root both sides of this equation: $LN=\sqrt{16.4}$ $LN=4.049691346...$ $LN=4.0$ cm (1 dp). By substituting the known sides into Pythagoras' Theorem $c^2=a^2+b^2$ (and letting the height of the wall be a) we get: $2.9^2=a^2+1.3^2$ Calculating the two square roots and rearranging gives us: $a^2=8.41-1.69=6.72$ Then by square rooting both sides of this equation, we get: $a=\sqrt{6.72}=2.592296279$ $a=2.6$ cm (1 d.p.) A 3×8 rectangle is cut into two pieces... then rearranged to form a right-angled triangle. What is the perimeter of the triangle formed? Can you calculate the length of this diagonal line? Can you work out the area of this isosceles right angled triangle? Find out how many pieces of hardboard of differing sizes can fit through a rectangular window. A parallelogram is formed by joining together four equilateral triangles. What is the length of the longest diagonal? If the midpoints of the sides of a right angled triangle are joined, what is the perimeter of this new triangle? If two of the sides of a right-angled triangle are 5cm and 6cm long, how many possibilities are there for the length of the third side? A vine is growing up a pole. Can you find its length? A palm tree has snapped in a storm. What is the height of the piece that is still standing? This diagram has symmetry of order four. Can you use different geometric properties to find a particular length? Can you work out the radius of a circle from some information about a chord? Can you find the length of the third side of this triangle? Triangle T has sides of lengths 6, 5 and 5. Triangle U has sides of lengths 8, 5 and 5. What is the ratio of their areas? A square has area 72 cm^2 . Find the length of its diagonal. Work your way through these right-angled triangles to find x . A rectangular piece of paper is folded. Can you work out one of the lengths in the diagram? A circle of radius 1 is inscribed in a regular hexagon. What is the perimeter of the hexagon? A rectangular plank fits neatly inside a square frame when placed diagonally. What is the length of the plank? How does the perimeter change when we fold this isosceles triangle in half? Can you find the length of AB in this diagram? Two arcs are drawn in a right-angled triangle as shown. What is the length SR ? What is the perimeter of this unusually shaped polygon... This quadrilateral has an unusual shape. Are you able to find its area? Two circles touch, what is the length of the line that is a tangent to both circles? Can you find the perimeter of the pentagon formed when this rectangle of paper is folded? The diagram shows 8 shaded squares inside a circle. What is the shaded area? Can you find the radii of the small circles? How much of the inside of this triangular prism can Clare paint using a cylindrical roller? The diagram shows two semicircular arcs... What is the diameter of the shaded region? When you pull a boat in using a rope, does the boat move more quickly, more slowly, or at the same speed as you? The diagrams show squares placed inside semicircles. What is the ratio of the shaded areas? Can you find the radius of the larger circle in the diagram? Three circles of different radii each touch the other two. What can you deduce about the arc length between these points? Can you work out the length of the diagonal of the cuboid? Calculate the ratio of areas of these squares which are inscribed inside a semi-circle and a circle. How do these measurements enable you to find the height of this tower? What does Pythagoras' Theorem tell you about the radius of these circles? Can you find all the integer coordinates on a sphere of radius 3? The diagram shows two circles and four equal semi-circular arcs. The area of the inner shaded circle is 1. What is the area of the outer circle? Find the radius of the stone in this ring. A window frame in Salt's Mill consists of two equal semicircles and a circle inside a large semicircle. What is the radius of the circle? Can you find the length and width of the screen of this smartphone in inches? The diagram shows a semi-circle and an isosceles triangle which have equal areas. What is the value of $\tan x$? Can you find the distance from the well to the fourth corner, given the distance from the well to the first three corners? Two ribbons are laid over each other so that they cross. Can you find the area of the overlap? The top square has been rotated so that the squares meet at a 60° angle. What is the area of the overlap? Proof 1 In the figure below are shown two squares whose sides are $a + b$ and c . let us write that the area of the large square is the area of the small square plus the total area of all 4 congruent right triangles in the corners of the large square. $(a + b)^2 = c^2 + 4(1/2)(a)(b)$ Expand the left hand side of the above equality, and simplify the last term on the right $a^2 + b^2 + 2ab = c^2 + 2ab$ Simplify to obtain $a^2 + b^2 = c^2$ and b are the sides of the right triangle and c is its hypotenuse. Proof 2 We first start with a right triangle and then complete it to make a rectangle as shown in the figure below which in turn is made up of three triangles. The fact that the sides of the rectangle are parallel, that gives rise to angles being congruent (equal in size) in all three triangles shown in the figure which leads to the triangles being similar. We first consider triangles ABE and AED which are similar because of the equality of angles. The proportionality of corresponding sides (a in triangle ABE corresponds to c in triangle AED since both faces a right angle, x in triangle ABE corresponds to a in triangle AED both faces congruent (equal) angles) gives $a/c = x/a$ which may be written as $a^2 = cx$ We next consider triangles ECD and AED which are similar because of the equality of angles. The corresponding sides are proportional, hence $b/c = y/b$ which may be written as $b^2 = cy$ We now add the sides of the equalities $a^2 = cx$ and $b^2 = cy$ to obtain $a^2 + b^2 = cx + cy = c(x + y)$ Use the fact that $c = x + y$ to write $a^2 + b^2 = c^2$ The converse of the Pythagorean theorem sates that: if a , b and c are the lengths of a triangle with c the longest side and $a^2 + b^2 = c^2$ then this triangle is a right triangle and c is the length of its hypotenuse. Pythagorean Theorem and Triangle Problems Problem 1 Find the area of a right triangle whose hypotenuse is equal to 10 cm and one of its sides is 6 cm. Problem 2 Which of the following may be the lengths of the sides of a right angled triangle? a) (2 , 3 , 4) b) (12 , 16 , 20) c) (3√2 , 3√2 , 6) Problem 3 The points A(0 , 2), B(-2 , -1) and C(-1 , k) are the vertices of a right triangle with hypotenuse AB. Find k. Problem 4 One side of a triangle has a length that is 2 meters less than its hypotenuse and its second side has a length that is 4 meters less than its hypotenuse. Find the perimeter of the triangle. Problem 5 Find the perimeter of an equilateral triangle whose height is 60 cm. Problem 6 Calculate the are of a square field whose diagonal is 100 meters. Problem 7 Find x in the two right triangles figure below. Detailed Solutions to the Above Problems Solution to Problem 1 Given the hypotenuse and one of the sides, we use the Pythagorean theorem to find the second side x as follows $x^2 + 6^2 = 10^2$ $x^2 - 6^2 = 8$ Area of the triangle $= (1/2)$ height $\times$ base The two sides of a right triangle make a right angle and may therefore be considered as the height and the base. Hence Area of the triangle $= (1/2)6 \times 8 = 24$ cm 2Solution to Problem 2 We use the converse of the Pythagorean theorem to solve this problem. a) (2 , 3 , 4) : 4 is the length of the longest side $2^2 + 3^2 = 13$ $4^2 = 16$ since $2^2 + 3^2$ is NOT EQUAL to 4^2 , (2 , 3 , 4) are not the lengths of the sides of a right triangle. b) (12 , 16 , 20) : 20 is the longest side $12^2 + 16^2 = 400$ $20^2 = 400$ since $12^2 + 16^2$ is EQUAL to 20^2 , (12 , 16 , 20) are the lengths of the sides of a right triangle. c) (3√2 , 3√2 , 6) : 6 is the longest side $(3\sqrt{2})^2 + (3\sqrt{2})^2 = 36$ $6^2 = 36$ $(3\sqrt{2})^2 + (3\sqrt{2})^2$ is EQUAL to 6^2 , therefore (3√2 , 3√2 , 6) are the length of a right triangle with the length of the hypotenuse equal to 6. Also since two sides have equal length to 3√2, the right triangle is isosceles. Solution to Problem 3 The points A(0 , 2), B(-2 , -1) and C(-1 , k) are the vertices of a right triangle with hypotenuse AB. Find k. Use the formula to find the distance squared between two points given by $d^2 = (x_2 - x_1)^2 + (y_2 - y_1)^2$ to find the square of the length of the hypotenuse AB and the sides AC and BC. $AB^2 = (-2 - 0)^2 + (-1 - 2)^2 = 13$ $AC^2 = (-1 - 0)^2 + (k - 2)^2 = k^2 - 4k + 5$ $BC^2 = (-1 - (-2))^2 + (k - (-1))^2 = k^2 + 2k + 2$ AB is the hypotenuse of the triangle, we now use the Pythagorean theorem $AB^2 = AC^2 + BC^2$ to obtain an equation in k . $13 = k^2 - 4k + 5 + k^2 + 2k + 2$ $k^2 - 2k - 6 = 0$ $k^2 - k - 3 = 0$ Solve for k the above quadratic equation to obtain two solutions k_1 and k_2 given by $k_1 = (1 + \sqrt{13})/2 = 2.30$ and $k_2 = (1 - \sqrt{13})/2 = -1.30$ There are two possible points C1 and C2 that make a right triangle with A and B and whose coordinates are given by: C1 (-1 , 2.30) and C2 (-1 , -1.30) The graphical interpretation of the solution to this problem is shown below. Solution k 1 corresponds to the "red" right triangle and solution k 2 corresponds to the "blue" right triangle. Solution to Problem 4 Let x be the hypotenuse of the right triangle. One side is $x - 2$ and the other is $x - 4$ as shown below. We need to find in order to find that sides and then the perimeter. Use the Pythagorean to write $x^2 = (x - 2)^2 + (x - 4)^2$ Expand and group to obtain the quadratic equation $x^2 - 12x + 20 = 0$ Solve to find two solutions $x = 2$ and $x = 10$ Calculate the sides and perimeter for each solution hypotenuse: $x = 2$, side 1 : $x - 2 = 0$ and side 2 : $x - 4 = -2$ The sides of a triangle cannot be zero or negative and therefore $x = 2$ is not a solution to the given problem. hypotenuse: $x = 10$, side 1 : $x - 2 = 8$ and side 2 : $x - 4 = 6$ Perimeter = hypotenuse + side 1 + side 2 = $10 + 8 + 6 = 24$ units. Solution to Problem 5 An equilateral triangle with side x is shown below with height $CH = 60$ cm. Since it is an equilateral the height CH split the base (segment) AB into two equal segments of size $x/2$. We use the Pythagorean theorem on triangle CHB (or CHA) to write $x^2 = 60^2 + (x/2)^2$ Expand the above equation and rewrite as $3x^2/4 = 3600$ Solve for x and take the positive solution since x is the size of the side of the triangle and must be positive. $x = 40\sqrt{3}$ cm Perimeter = $3x = 120\sqrt{3}$ cm Solution to Problem 6 A square of side x and diagonal 100 m is shown below. Area of the square = x^2 Use the Pythagorean theorem on the triangle ACD to write $x^2 + x^2 = 100^2$ Solve for x $x^2 = 100^2/2$ Area of square = $x^2 = 5000$ m 2 Solution to Problem 7 We first use the Pythagorean theorem to the right triangle ECD in order to find the length of CD $5^2 = 3^2 + CD^2$ Solve for CD $CD = \sqrt{25 - 9} = 4$ We also know that $FC + CD = 6$ Hence $FC = 6 - CD = 2$ We now use the Pythagorean theorem to the right triangle EFC to write $x^2 = 3^2 + FC^2 = 9 + 4 = 13$ Solve for $x = \sqrt{13}$ More References and LinksSolve Right Triangle Problems Pythagorean Theorem Calculator Table of Formulas For Geometry Geometry

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