The Pythagorean Theorem, Perimeter and Area

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Printed: December 11, 2023 (PST)

8.5 The Pythagorean Theorem, Perimeter and Area

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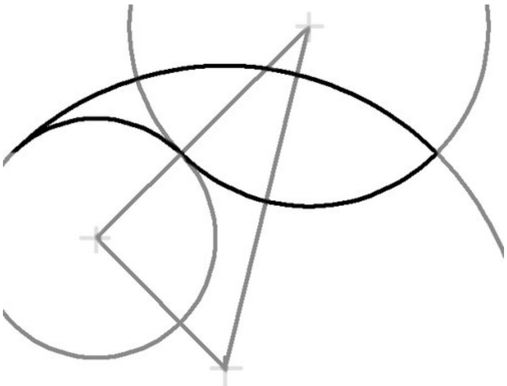
Last Modified: Dec 20, 2022



[Figure 1]

The Art class has decided on a project to add some character to the school. Instead of mounting signs to name the various departments of the school, they have decided to paint unique pictures to indicate the various departments. For the Math Department they are going to paint a picture of Pythagoras on canvas shaped as a right triangle and frame it. If the measurements of the right triangle canvas are $(5, 12, ?)$ inches, how could Pythagoras help the students to calculate the area of the canvas on which they are painting and the number of inches of framing wood needed?

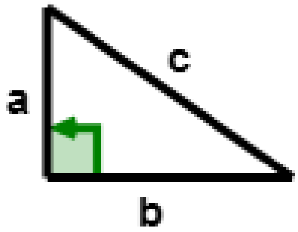
In this concept, you will learn to use the Pythagorean Theorem to find area and perimeter.

Perimeter and Area

The **perimeter** of a shape is the distance around the outside of the shape. Perimeter is 1-dimensional and is measured in linear units. If a rectangular enclosure is being built for a dog, then the shape is two-dimensional since it has both length and width. The amount of fencing to go around the enclosure is one-dimensional since it is the sum of the lengths of the four sides of the rectangle.

The **perimeter of a right triangle** is the sum of the lengths of the two legs and the hypotenuse. The perimeter could be written as:

$$P_{(\text{right } \Delta)} = a + b + c$$



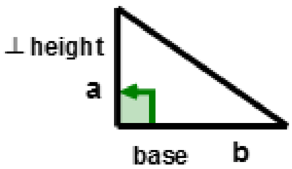
[Figure 2]

The **area** of a plane shape is the size of its surface. Area is a two-dimensional measurement and is expressed in square units. The **area of a triangle** is one-half the product of its base and its perpendicular height. The formula for finding the area of a triangle is written as:

$$A_{\text{triangle}} = \frac{1}{2} b \cdot h$$

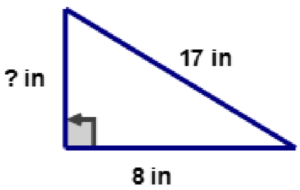
For the **area of a right triangle**, the product of the base and its perpendicular height is the product of its two legs 'a' and 'b'. The formula for finding area of a right triangle could be written as:

$$A_{(\text{right } \Delta)} = \frac{1}{2} a \cdot b$$



[Figure 3]

Find the perimeter and the area of the following right triangle.



[Figure 4]

Remember the perimeter is the sum of the lengths of the two legs and the hypotenuse. The length of one of the legs is unknown. Use the Pythagorean Theorem to find the length of 'a.'

First, determine the values for (a, b, c) of the Pythagorean Theorem.

$$\begin{aligned} a &= ? \\ b &= 8 \\ c &= 17 \end{aligned}$$

Next, substitute the values for (a, b, c) into the Pythagorean Theorem.

$$\begin{aligned} c^2 &= a^2 + b^2 \\ (17)^2 &= a^2 + (8)^2 \end{aligned}$$

Next, perform the indicated squaring and simplify the equation.

$$\begin{aligned} (17)^2 &= a^2 + (8)^2 \\ (17 \times 17) &= a^2 + (8 \times 8) \\ 289 &= a^2 + 64 \end{aligned}$$

Next, isolate the variable by subtracting 64 from both sides of the equation.

$$\begin{aligned} 289 &= a^2 + 64 \\ 289 - 64 &= a^2 + 64 - 64 \\ 225 &= a^2 \end{aligned}$$

Then, solve for the variable 'a' by taking the square root of both sides of the equation.

$$\begin{aligned} 225 &= a^2 \\ \sqrt{225} &= \sqrt{a^2} \\ 15 &= a \end{aligned}$$

The answer is 15.

The length of leg 'a' is 15 inches.

Now that the length of all the sides of the triangle are known, substitute the values into the equation for finding the perimeter of the triangle.

$$
\begin{aligned}
P_{(\text{right } \Delta)} &= a+b+c \\
P_{(\text{right } \Delta)} &= 15+8+17 \\
P_{(\text{right } \Delta)} &= 40
\end{aligned}
$$

The answer is 40.

The perimeter of the right triangle is 40 inches.

Now that the lengths of both legs are known, substitute the values into the formula to determine the area of the right triangle.

$$
\begin{aligned}
A_{(\text{right } \Delta)} &= \tfrac{1}{2} a \cdot b \\
A_{(\text{right } \Delta)} &= \tfrac{1}{2}(15)(8)
\end{aligned}
$$

Next, perform the indicated operations on the right side of the equation.

$$
\begin{aligned}
A_{(\text{right } \Delta)} &= \tfrac{1}{2}(15)(8) \\
A_{(\text{right } \Delta)} &= \tfrac{1}{2}(120) \\
A_{(\text{right } \Delta)} &= 60
\end{aligned}
$$

The answer is 60.

The area of the right triangle is 60 in^2.

Examples

Example 1

Earlier, you were given a problem about the Art class and their unique signs. The students need to find the area of the triangular canvas and the wood needed for the frame.

First, the students know the measurements for the two legs of the right triangle. The given values for (a, b, c) of the Pythagorean Theorem are $(5, 12, c)$.

Next, use the formula for finding the area of a right triangle to determine the area of the canvas.

$$A_{(\text{right } \Delta)} = \frac{1}{2} a \cdot b$$

Next, fill in the values for 'a' and 'b' into the formula.

$$\begin{aligned} A_{(\text{right } \Delta)} &= \tfrac{1}{2} a \cdot b \\ A_{(\text{right } \Delta)} &= \tfrac{1}{2}(5)(12) \end{aligned}$$

Then, perform the operations on the right side of the equation.

$$\begin{aligned} A_{(\text{right } \Delta)} &= \tfrac{1}{2}(5)(12) \\ A_{(\text{right } \Delta)} &= \tfrac{1}{2}(60) \\ A_{(\text{right } \Delta)} &= 30 \end{aligned}$$

The answer is 30.

The area of the canvas is 30 in^2.

The amount of wood needed to frame the painting is the perimeter of the right triangle. Use the Pythagorean Theorem to find the length of 'c.' This is the hypotenuse of the canvas.

$$c^2 = a^2 + b^2$$

Next, fill in the values for 'a' and 'b' in the Pythagorean Theorem.

$$\begin{aligned} c^2 &= a^2 + b^2 \\ c^2 &= (5)^2 + (12)^2 \end{aligned}$$

Next, perform the indicated squaring and simplify the right side of the equation.

$$\begin{aligned} c^2 &= (5)^2 + (12)^2 \\ c^2 &= 25 + 144 \\ c^2 &= 169 \end{aligned}$$

Then, solve for the variable ‘c’ by taking the square root of both sides of the equation.

$$\begin{aligned} c^2 &= 169 \\ \sqrt{c^2} &= \sqrt{169} \\ c &= 13 \end{aligned}$$

The answer is 13.

The length of the hypotenuse is 13 inches.

Next, find the perimeter of the canvas using the formula:

$$P_{(\text{right } \Delta)} = a + b + c$$

Next, fill in the values $(5, 12, 13)$ for (a, b, c) and find the sum of the values.

$$\begin{aligned} P_{(\text{right } \Delta)} &= a + b + c \\ P_{(\text{right } \Delta)} &= 5 + 12 + 13 \\ P_{(\text{right } \Delta)} &= 30 \end{aligned}$$

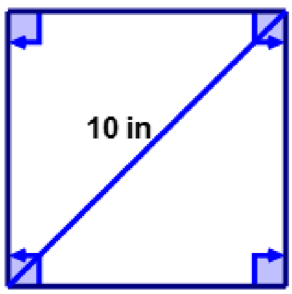
The answer is 30.

The amount of wood needed for framing the picture is 30 inches.

Example 2

A square sheet of corrugated cardboard has a perforated diagonal measuring 10 inches in length. Find the area of the square.

First, draw and label a diagram to model the problem.



[Figure 5]

The diagonal divides the square into two equal right triangles. Remember the sides of a square are all equal in length. The Pythagorean Theorem can be used to find the length of the sides of the square.

First, write the equation that models the Pythagorean Theorem.

$$c^2 = a^2 + b^2$$

Next, rewrite the equation to indicate $a^2 = b^2$.

$$c^2 = a^2 + a^2$$

Next, simplify the right side of the equation by combining the like terms.

$$\begin{aligned} c^2 &= a^2 + a^2 \\ c^2 &= 2a^2 \end{aligned}$$

Next, substitute $c = 10$ into the equation.

$$\begin{aligned} c^2 &= 2a^2 \\ (10)^2 &= 2a^2 \end{aligned}$$

Next, perform the indicated squaring.

$$\begin{aligned} (10)^2 &= 2a^2 \\ (10 \times 10) &= 2a^2 \\ 100 &= 2a^2 \end{aligned}$$

Next, isolate the variable by dividing both sides of the equation by 2.

$$\begin{aligned} 100 &= 2a^2 \\ \frac{100}{2} &= \frac{\overset{1}{\cancel{2}} a^2}{\cancel{2}} \\ 50 &= a^2 \end{aligned}$$

Then, solve for the variable 'a' by taking the square root of both sides of the equation.

$$\begin{aligned} 50 &= a^2 \\ \sqrt{50} &= \sqrt{a^2} \\ 7.07 &= a \end{aligned}$$

The answer is 7.07.

The length of each side of the square is 7.07 inches.

The area of a square is found by using the formula:

$A = s^2$ where 's' represents the side length of the square.

First, fill in the side length of 7.07 into the formula.

$$\begin{aligned} A &= s^2 \\ A &= (7.07)^2 \end{aligned}$$

Then, perform the indicated squaring and simplify the equation. Round your answer to the nearest square inch.

$$\begin{aligned} A &= (7.07)^2 \\ A &= (7.07 \times 7.07) \\ A &= 49.98 \\ A &= 50 \end{aligned}$$

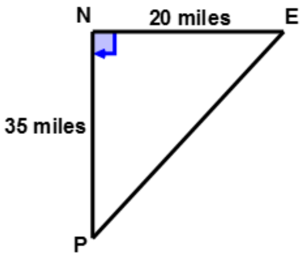
The answer is 50.

The area of the square is 50 in^2.

Example 3

A ship leaves port and sails 35 miles due north and then 20 miles due east. If the ship returns to port by travelling along the diagonal route, how many miles would the ship have sailed altogether?

First, draw and label a diagram to model the problem.



[Figure 6]

First, use the Pythagorean Theorem to find the distance from east to port.

$$c^2 = a^2 + b^2$$

Next, determine the values of (a, b, c) for the Pythagorean Theorem.

$$\begin{aligned} a &= 35 \text{ miles} = 35 \\ b &= 20 \text{ miles} = 20 \\ c &= ? \text{ miles} \quad = c \end{aligned}$$

Next, fill the values into the Pythagorean Theorem.

$$\begin{aligned} c^2 &= a^2 + b^2 \\ c^2 &= (35)^2 + (20)^2 \end{aligned}$$

Next, perform the indicated squaring and simplify the right side of the equation.

$$\begin{aligned} c^2 &= (35)^2 + (20)^2 \\ c^2 &= 1225 + 400 \\ c^2 &= 1625 \end{aligned}$$

Then, solve for the variable 'c' by taking the square root of both sides of the equation.

$$\begin{aligned} c^2 &= 1625 \\ \sqrt{c^2} &= \sqrt{1625} \\ c &= 40.31 \end{aligned}$$

The answer is 40.31.

The distance from east toport is 40.31 miles.

Now, determine the total distance the ship has sailed by finding the perimeter of the right triangle.

$$P_{(\text{right } \Delta)} = a + b + c$$

Next, fill in the values $(35, 20, 40.31)$ for (a, b, c) and find the sum of the values.

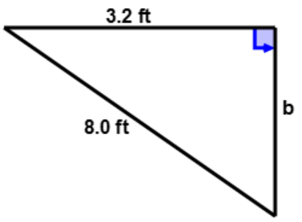
$$\begin{aligned} P_{(\text{right } \Delta)} &= a + b + c \\ P_{(\text{right } \Delta)} &= 35 + 20 + 40.31 \\ P_{(\text{right } \Delta)} &= 95.31 \end{aligned}$$

The answer is 95.31.

The ship will have sailed 95.31 miles.

Example 4

Find the area of the following right triangle.



[Figure 7]

Remember to find the area of a right triangle the lengths of the two legs must be known. Use the Pythagorean Theorem to find the length of side 'b.'

First, determine the values for (a, b, c) of the Pythagorean Theorem.

$$\begin{aligned} a &= 3.2 \\ b &= ? \\ c &= 8 \end{aligned}$$

Next, substitute the values for (a, b, c) into the Pythagorean Theorem.

$$\begin{aligned} c^2 &= a^2 + b^2 \\ (8)^2 &= (3.2)^2 + b^2 \end{aligned}$$

Next, perform the indicated squaring and simplify the equation.

$$\begin{aligned} (8)^2 &= (3.2)^2 + b^2 \\ (8 \times 8) &= (3.2 \times 3.2) + b^2 \\ 64 &= 10.24 + b^2 \end{aligned}$$

Next, isolate the variable by subtracting 10.24 from both sides of the equation.

$$\begin{aligned} 64 &= 10.24 + b^2 \\ 64 - 10.24 &= 10.24 - 10.24 + b^2 \\ 53.76 &= b^2 \end{aligned}$$

Then, solve for the variable 'b' by taking the square root of both sides of the equation.

$$\begin{aligned} 53.76 &= b^2 \\ \sqrt{53.76} &= \sqrt{b^2} \\ 7.3 &= b \end{aligned}$$

The answer is 7.3.

The length of leg 'b' is 7.3 ft.

Now, find the area of the right triangle using the formula:

$$A_{(\text{right } \Delta)} = \frac{1}{2} a \cdot b$$

Next, fill in the values for 'a' and 'b' into the formula.

$$\begin{aligned} A_{(\text{right } \Delta)} &= \tfrac{1}{2} a \cdot b \\ A_{(\text{right } \Delta)} &= \tfrac{1}{2}(3.2)(7.3) \end{aligned}$$

Then, perform the indicated operations on the right side of the equation.

$$\begin{aligned} A_{(\text{right } \Delta)} &= \tfrac{1}{2}(3.2)(7.3) \\ A_{(\text{right } \Delta)} &= \tfrac{1}{2}(23.36) \\ A_{(\text{right } \Delta)} &= 11.68 \end{aligned}$$

The answer is 11.68.

The area of the triangle is 11.68 ft^2.

Review

Find the missing side length of each right triangle by using the Pythagorean Theorem. You may round to the nearest tenth when necessary.

1. $a = 10, b = 14, c =$ ____
2. $a = 6, b =$ ____$, c = 10$
3. $a =$ ____$, b = 12, c = 15$
4. $a = 15, b =$ ____$, c = 25$
5. $a =$ ____$, b = 32, c = 40$
6. $a = 30, b = 40, c =$ ____
7. $a = 1.5, b = 2, c =$ ____
8. $a = 4.5, b = 6, c =$ ____
9. $a = 6.6, b = 8.8, c =$ ____
10. $a = 36, b = 48, c =$ ____
11. $a = 27, b = 36, c =$ ____

Answer each question.

12. A television is measured by the length of the diagonal from one corner to another. If the screen is 8 inches by 15 inches, what is the length of the diagonal?

13. Do the numbers 15, 20 and 25 comprise a Pythagorean Triple?

14. What is the perimeter of a right triangle with a hypotenuse of 30 inches and a leg of 18 inches?

15. What is the area of a right triangle with a hypotenuse of 30 inches and a leg of 18 inches?

Review (Answers)

To see the review answers, return to the Table of Contents and select ‘Other Versions’ or ‘Resources’.

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1.0 REFERENCES

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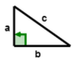	**Credit:** Electric-Eye;Brian Murphy **Source:** https://www.flickr.com/photos/sightrays/6561587559/in/photolist-aZPRnZ-7RMgBu-4NbdkQ-9dQXpK-ptv5Sd-34Ydj3-5hVjx7-4nBGW8-a5CaTC-diNpnE-5ZJSa1-dPAThe-dLRomZ-62Yv2h-fWTjZ-97yu8b-5nSY4T-3GZScG-sffTbR-5SYmiN-a5KHJw-hyHXuP-bfQ7cn-7hLCbT-dW3cqz-dwtZP5-dd4HPj-8AMuNt-93x1UY-nsv8uF-rQFjZY-nvcygq-5Uze92-opKUmW-o1sXNw-4ZzWrQ-bJ28xR-x32FB-dd4GDv-aoEPso-9jLawW-9kjiqB-jDHTAc-aoEJEs-5DoaUZ-8hn6x2-dYdVrH-9tLMpQ-daVF5N-eRqUFs ; https://www.flickr.com/photos/45958316@N04/4415568303/in/photolist-7JbWBZ-911HPh-a4LUxd-cHRJz7-np9rfv-aGwD1K-coqXfb-93y7cf-99ZHce-to6szC-79gLGd-4XBVtS-gFi1Ex-cJP7EE-mpFED2-cJP7GN-qGdRSz-jDHTAc-f7DxRT-qxiAxD-8ZCzv2-amzvCS-qpFFPu-qWSSU6-dKLn6G-94aUGt-reeszG-qKmqBT-aVTBvi-898ms1-agqxtH-6g9jf7-f59wsD-4u2uNB-6EydSr-cn5rvh-omkLcF-ac9vB7-8UCjMB-f7QJga-5vBtwS-e7SMxV-6jzGYE-dDXt86-5xzUE2-86gQTJ-8ZFFDq-f7QJet-91fkb1-qDWhAj
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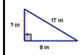
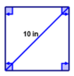
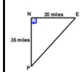
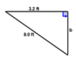
	**Credit:** Electric-Eye;Brian Murphy **Source:** https://www.flickr.com/photos/sightrays/6561587559/in/photolist-aZPRnZ-7RMgBu-4NbdkQ-9dQXpK-ptv5Sd-34Ydj3-5hVjx7-4nBGW8-a5CaTC-diNpnE-5ZJSa1-dPAThe-dLRomZ-62Yv2h-fWTjZ-97yu8b-5nSY4T-3GZScG-sffTbR-5SYmiN-a5KHJw-hyHXuP-bfQ7cn-7hLCbT-dW3cqz-dwtZP5-dd4HPj-8AMuNt-93x1UY-nsv8uF-rQFjZY-nvcygq-5Uze92-opKUmW-o1sXNw-4ZzWrQ-bJ28xR-x32FB-dd4GDv-aoEPso-9jLawW-9kjiqB-jDHTAc-aoEJEs-5DoaUZ-8hn6x2-dYdVrH-9tLMpQ-daVF5N-eRqUFs ; https://www.flickr.com/photos/45958316@N04/4415568303/in/photolist-7JbWBZ-911HPh-a4LUxd-cHRJz7-np9rfv-aGwD1K-coqXfb-93y7cf-99ZHce-to6szC-79gLGd-4XBVtS-gFi1Ex-cJP7EE-mpFED2-cJP7GN-qGdRSz-jDHTAc-f7DxRT-qxiAxD-8ZCzv2-amzvCS-qpFFPu-qWSSU6-dKLn6G-94aUGt-reeszG-qKmqBT-aVTBvi-898ms1-agqxtH-6g9jf7-f59wsD-4u2uNB-6EydSr-cn5rvh-omkLcF-ac9vB7-8UCjMB-f7QJga-5vBtwS-e7SMxV-6jzGYE-dDXt86-5xzUE2-86gQTJ-8ZFFDq-f7QJet-91fkb1-qDWhAj
	**Credit:** Electric-Eye;Brian Murphy **Source:** https://www.flickr.com/photos/sightrays/6561587559/in/photolist-aZPRnZ-7RMgBu-4NbdkQ-9dQXpK-ptv5Sd-34Ydj3-5hVjx7-4nBGW8-a5CaTC-diNpnE-5ZJSa1-dPAThe-dLRomZ-62Yv2h-fWTjZ-97yu8b-5nSY4T-3GZScG-sffTbR-5SYmiN-a5KHJw-hyHXuP-bfQ7cn-7hLCbT-dW3cqz-dwtZP5-dd4HPj-8AMuNt-93x1UY-nsv8uF-rQFjZY-nvcygq-5Uze92-opKUmW-o1sXNw-4ZzWrQ-bJ28xR-x32FB-dd4GDv-aoEPso-9jLawW-9kjiqB-jDHTAc-aoEJEs-5DoaUZ-8hn6x2-dYdVrH-9tLMpQ-daVF5N-eRqUFs ; https://www.flickr.com/photos/45958316@N04/4415568303/in/photolist-7JbWBZ-911HPh-a4LUxd-cHRJz7-np9rfv-aGwD1K-coqXfb-93y7cf-99ZHce-to6szC-79gLGd-4XBVtS-gFi1Ex-cJP7EE-mpFED2-cJP7GN-qGdRSz-jDHTAc-f7DxRT-qxiAxD-8ZCzv2-amzvCS-qpFFPu-qWSSU6-dKLn6G-94aUGt-reeszG-qKmqBT-aVTBvi-898ms1-agqxtH-6g9jf7-f59wsD-4u2uNB-6EydSr-cn5rvh-omkLcF-ac9vB7-8UCjMB-f7QJga-5vBtwS-e7SMxV-6jzGYE-dDXt86-5xzUE2-86gQTJ-8ZFFDq-f7QJet-91fkb1-qDWhAj
	**Credit:** Electric-Eye;Brian Murphy **Source:** https://www.flickr.com/photos/sightrays/6561587559/in/photolist-aZPRnZ-7RMgBu-4NbdkQ-9dQXpK-ptv5Sd-34Ydj3-5hVjx7-4nBGW8-a5CaTC-diNpnE-5ZJSa1-dPAThe-dLRomZ-62Yv2h-fWTjZ-97yu8b-5nSY4T-3GZScG-sffTbR-5SYmiN-a5KHJw-hyHXuP-bfQ7cn-7hLCbT-dW3cqz-dwtZP5-dd4HPj-8AMuNt-93x1UY-nsv8uF-rQFjZY-nvcygq-5Uze92-opKUmW-o1sXNw-4ZzWrQ-bJ28xR-x32FB-dd4GDv-aoEPso-9jLawW-9kjiqB-jDHTAc-aoEJEs-5DoaUZ-8hn6x2-dYdVrH-9tLMpQ-daVF5N-eRqUFs ; https://www.flickr.com/photos/45958316@N04/4415568303/in/photolist-7JbWBZ-911HPh-a4LUxd-cHRJz7-np9rfv-aGwD1K-coqXfb-93y7cf-99ZHce-to6szC-79gLGd-4XBVtS-gFi1Ex-cJP7EE-mpFED2-cJP7GN-qGdRSz-jDHTAc-f7DxRT-qxiAxD-8ZCzv2-amzvCS-qpFFPu-qWSSU6-dKLn6G-94aUGt-reeszG-qKmqBT-aVTBvi-898ms1-agqxtH-6g9jf7-f59wsD-4u2uNB-6EydSr-cn5rvh-omkLcF-ac9vB7-8UCjMB-f7QJga-5vBtwS-e7SMxV-6jzGYE-dDXt86-5xzUE2-86gQTJ-8ZFFDq-f7QJet-91fkb1-qDWhAj
	**Credit:** Electric-Eye;Brian Murphy **Source:** https://www.flickr.com/photos/sightrays/6561587559/in/photolist-aZPRnZ-7RMgBu-4NbdkQ-9dQXpK-ptv5Sd-34Ydj3-5hVjx7-4nBGW8-a5CaTC-diNpnE-5ZJSa1-dPAThe-dLRomZ-62Yv2h-fWTjZ-97yu8b-5nSY4T-3GZScG-sffTbR-5SYmiN-a5KHJw-hyHXuP-bfQ7cn-7hLCbT-dW3cqz-dwtZP5-dd4HPj-8AMuNt-93x1UY-nsv8uF-rQFjZY-nvcygq-5Uze92-opKUmW-o1sXNw-4ZzWrQ-bJ28xR-x32FB-dd4GDv-aoEPso-9jLawW-9kjiqB-jDHTAc-aoEJEs-5DoaUZ-8hn6x2-dYdVrH-9tLMpQ-daVF5N-eRqUFs ; https://www.flickr.com/photos/45958316@N04/4415568303/in/photolist-7JbWBZ-911HPh-a4LUxd-cHRJz7-np9rfv-aGwD1K-coqXfb-93y7cf-99ZHce-to6szC-79gLGd-4XBVtS-gFi1Ex-cJP7EE-mpFED2-cJP7GN-qGdRSz-jDHTAc-f7DxRT-qxiAxD-8ZCzv2-amzvCS-qpFFPu-qWSSU6-dKLn6G-94aUGt-reeszG-qKmqBT-aVTBvi-898ms1-agqxtH-6g9jf7-f59wsD-4u2uNB-6EydSr-cn5rvh-omkLcF-ac9vB7-8UCjMB-f7QJga-5vBtwS-e7SMxV-6jzGYE-dDXt86-5xzUE2-86gQTJ-8ZFFDq-f7QJet-91fkb1-qDWhAj