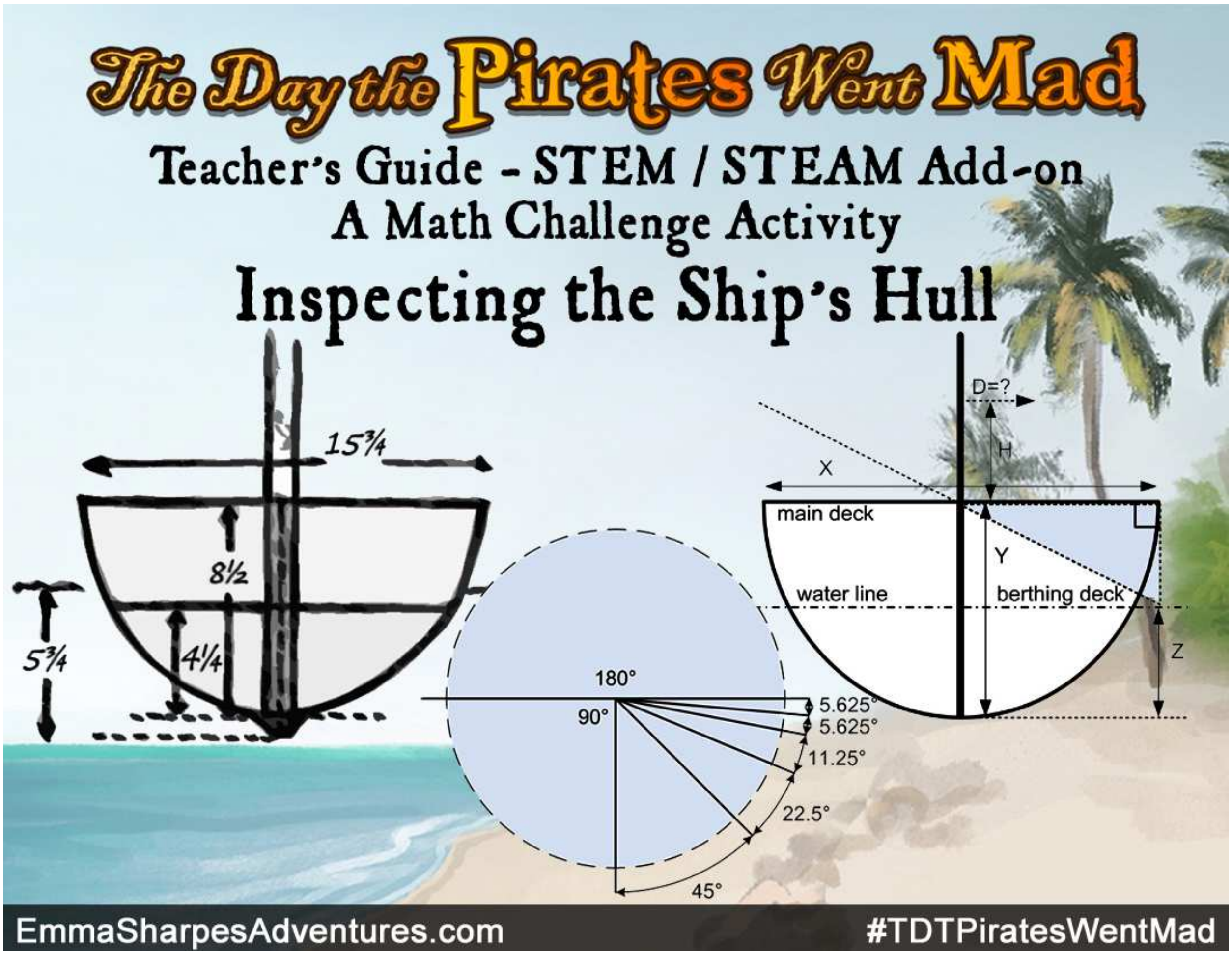
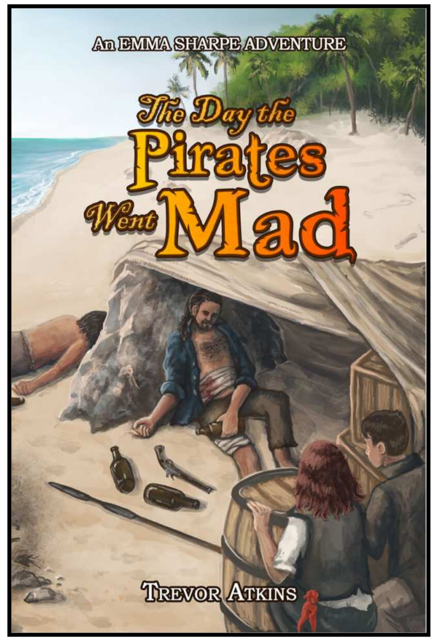


The New Adventure has just survived a gale but there are some leaks that need attention. Captain Garrett has a plan to minimize these leaks without having to go through the effort of careening the ship. Can you help Emma check if the captain's plan for inspecting the hull will be worth the effort…or not?

Recommended grade level: this activity involves math concepts that should be engaging for students familiar with calculating perimeters, estimating angles, and using similar triangles. There is also a question where students use a scale paper diagram to help check their estimates.

Have a question about this add-on activity or about Emma's adventures in *The Day the Pirates Went Mad*? Send an email to publishing@silverpath.com, making sure to include "The Day the Pirates Went Mad" in the subject line.

Introduction



The Day the Pirates Went Mad was written to be an entertainingly educational 'cozy' historical fiction, conveying a 'boatload' of learning about the life and times of those sailing the seas 300 years ago, during the Age of Sail. Though intended for ages 10-12, older readers can also enjoy this story and it is suitable for sharing with younger readers when supported by an adult.

The Day the Pirates Went Mad
A historical novel by Trevor Atkins

ebook: https://www.amazon.com/Day-Pirates-Went-Mad-ebook/dp/B091JMKVG3/

paperback: https://www.amazon.com/Day-Pirates-Went-Mad/dp/1989459021/

This document is an add-on activity to the main Teacher's Guide. Add-ons like this will use a scene or action from the book as context for STEM/STEAM learning. In the case of this activity, it is a math challenge related to tilting the ship for a hull inspection.

This add-on activity is comprised of five (5) questions, each focusing on different math concepts:

1. Calculate the **perimeter** of a semi-circle using the dimensions of the ship's hull, calculate an **average**, and construct a simplified **formula** to calculate that average as a bonus.
2. **Estimate angles** using slices of a circle.
3. Use **ratios** and **similar triangles** to calculate an unknown side of a new triangle given the angle found in the previous question.
4. Calculate **percentages** using the answers from the above questions.
5. Use a **scale diagram** to confirm the answers found in the first three questions.

Printing Instructions: This document is intended to be printed double-sided.
You may wish to remove the Answer Key before distribution.

Look for more STEM/STEAM activities with Emma Sharpe in the future. Activities will include cooking/baking, solving navigation problems, laying on supplies, training with the cannons, constructing a model ship, acting out a scene from the story, and more! https://emmasharpesadventures.com

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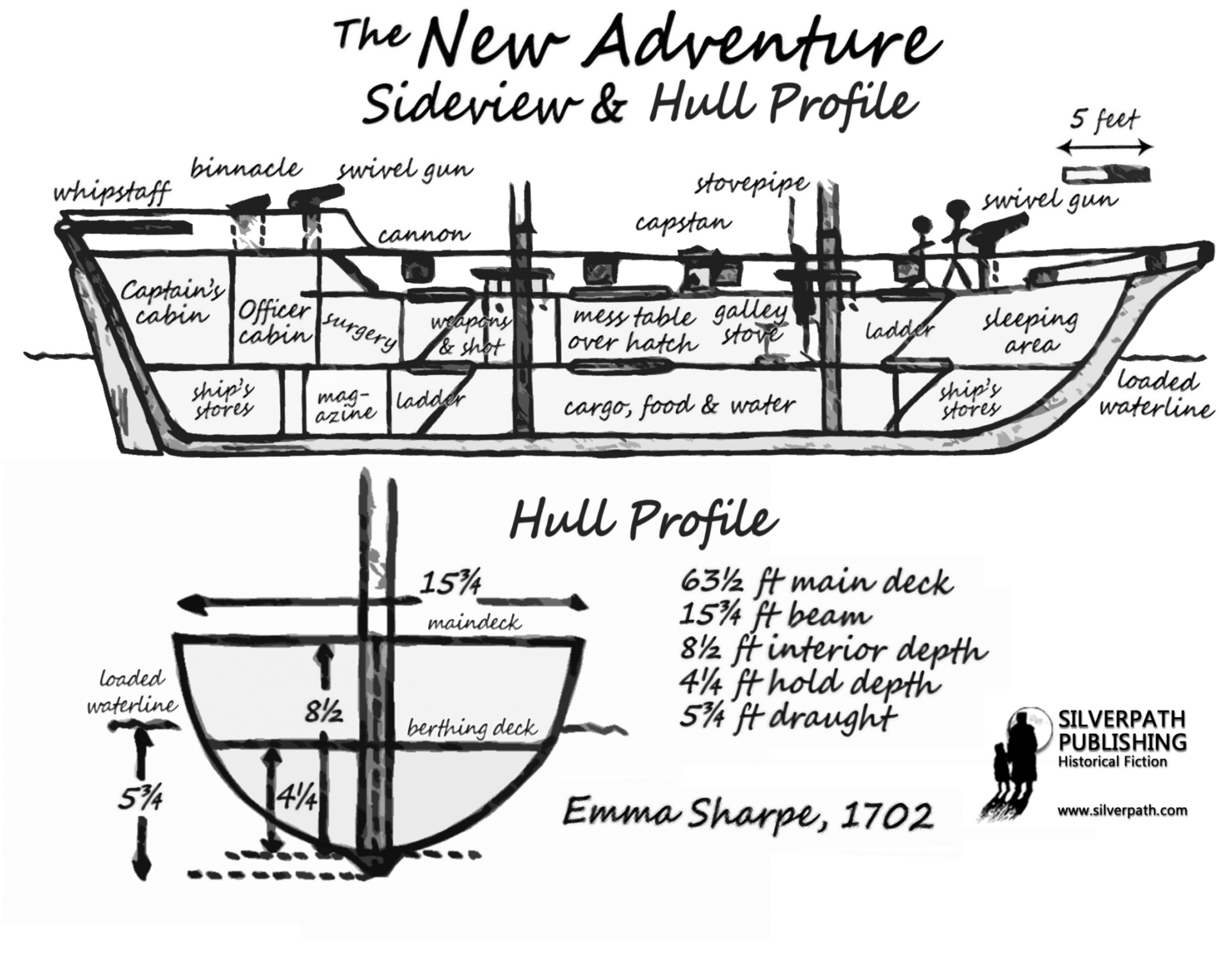
Inspecting the Hull of the *New Adventure*

The *New Adventure* has just arrived at Little Tobago after surviving a gale. The hull is leaking and the captain is describing a plan of action to the crew.

> *"As for the ship, we will address the leaks first. Let us rig a block and tackle between our remaining mast and a suitable tree. With the anchors set, we should be able to tilt the ship enough to let us get at a few extra feet of the hull. It will not be as thorough an inspection as when we careen, but we will not have to offload any cargo either. We will give ourselves today and tomorrow. Then we must be on our way to Barbados, hopefully with less need of the pump!"*
>
> – Captain Garrett, The Day the Pirates Went Mad, Chapter 15: Landfall, pg 128.

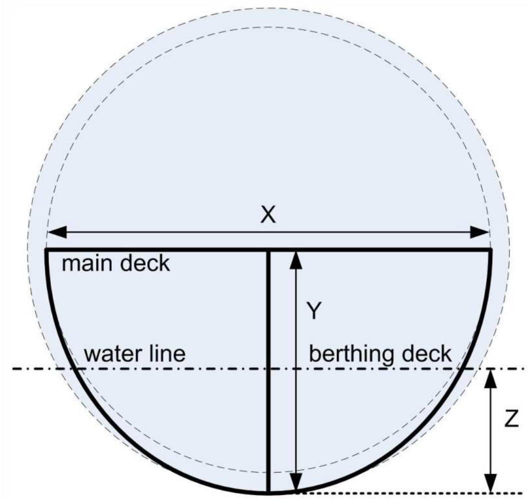
Using the following sketches and notes about the dimensions of the *New Adventure* from Emma's journal, help her estimate how much additional hull can be exposed by tilting the ship – without submerging any part of the main deck of course!



The closest geometric shape to the profile of the hull is an ellipse. Though there is a formula for calculating the area of an ellipse, there is no straightforward way of calculating its circumference (https://en.wikipedia.org/wiki/Ellipse). Luckily, in this case, we can approximate its outline using a simpler shape.

Important! The *New Adventure* is not fully loaded with cargo and has also consumed various supplies on its journey across the Atlantic. Therefore, the current water line is at approximately the same level as the berthing deck, not where Emma shows it in her sketch.

Question #1



Using a semi-circle to approximate the hull profile, calculate the hull's outer perimeter (ie: don't include the main deck) (**Important**: $X \neq 2Y$):

a) First using X as the diameter

b) And then, using Y as the radius

c) What is the average perimeter of the two you calculated?

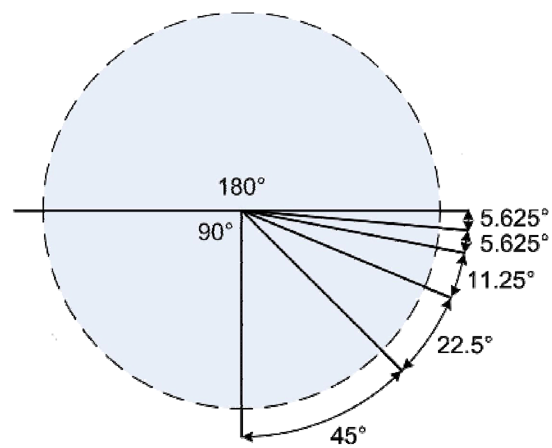
d) Which of the values you calculated above appears to be the better estimate of (i) the actual perimeter of the hull profile and for (ii) the purposes of inspecting the ship? Why?

e) **Bonus:** Construct a simplified formula that calculates the average perimeter from X & Y

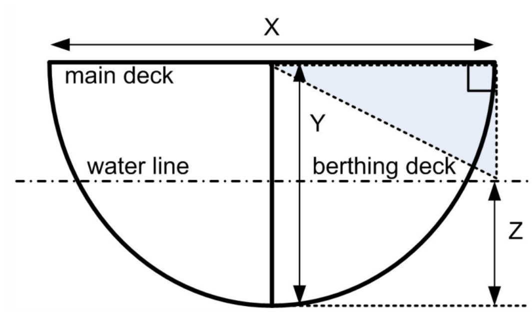
Assumption: The axis around which a ship would typically rotate is not always easily determined (https://en.wikipedia.org/wiki/Ship_stability). For the purposes of simplifying the following questions, let us assume the ship's rotational axis is the midpoint of the main deck.

Question #2

The crew will inspect one side of the *New Adventure* at a time.



a) With the perimeter you chose as the "better estimate for the purposes of inspecting the ship" in **Question #1**, estimate the maximum angle they can tilt the ship without submerging any of the main deck using this diagram of a circle that has been divided to show various angles



b) **Bonus:** Considering the maximum angle as illustrated in the adjacent diagram, do you think it would be easy to walk about the main deck? Support your answer.

____

____

____

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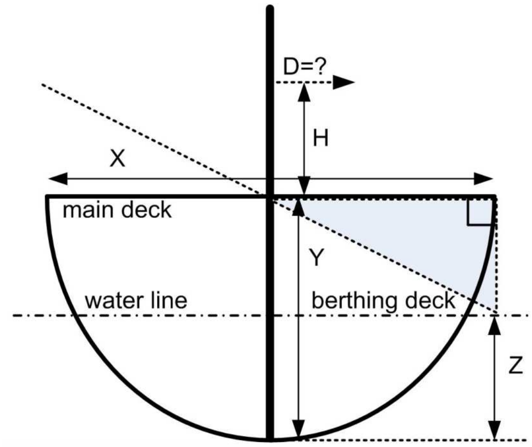
____

____

> *"Mr. Bellows had the work party secure a pair of long cables about halfway up the remaining mast and then they conveyed the other ends over to the shore. There, the crew ran the cables through pulleys they had affixed to the sturdiest looking of the nearby trees."*
> – The Day the Pirates Went Mad, Chapter 15: Landfall, pg 129.

Question #3

If the crew tilts the *New Adventure* by pulling on a cable secured to the mast at a height of **H=25** feet above the main deck, approximately how far must they pull the rope to tilt the ship by the angle you estimated in **Question #2**? (Hint: similar triangles)



Question #4

Considering the crew will tilt the *New Adventure* in both directions to expose each side of the hull for inspection:

a) What percentage of the hull profile does the crew expose for inspection?

____

b) What percentage of the hull profile will remain uninspected?

____

c) **Bonus:** Considering these percentages, is tilting the ship worth the effort? Explain.

____

____

> *"With two anchors holding the New Adventure in place, and the crew heaving at the cables, they were able to carefully tilt the ship several degrees further until the scuppers were only about a foot above the water. This effort exposed another three feet of hull from below the waterline."*
>
> – *The Day the Pirates Went Mad*, Chapter 15: Landfall, pg 130.

In the book, Captain Garrett didn't have the crew tilt the *New Adventure* the maximum amount. Better to be safe than sorry!

Question #5

To make sure he was on the right track with his calculations, the author also used a pair of scale diagrams of the *New Adventure*'s hull profile to better visualize the rotation.

(Change of) Assumption: Previously, we simplified the shape of the hull to that of a semi-circle and rotated the ship about the center of the main deck. Now, while using the scale diagram, we will discard those assumptions. Instead, we will assume that the bottommost edge of the rotated ship's hull profile (not the keel) can be no higher or lower than when the ship is upright, ie: the bottom of the ship is always at the same depth.

Cut out the unlabeled scale diagram in the **Appendix** and rotate it against the other. Use a protractor, ruler, string, etc. as needed to check your answers in **Questions #1, #2, and #3**.

a) Does rotating the scale diagram suggest any miscalculations in your answers to **Questions #1, #2, and #3** above? Would you still consider them to be reasonable estimates? Explain.

b) Does rotating the scale diagram suggest a more likely rotational axis than the center of the main deck? Would using this other rotational axis make any significant impact on your answers to **Questions #1, #2, and #3** above? Explain.

Howard Pyle, Public domain, via Wikimedia Commons

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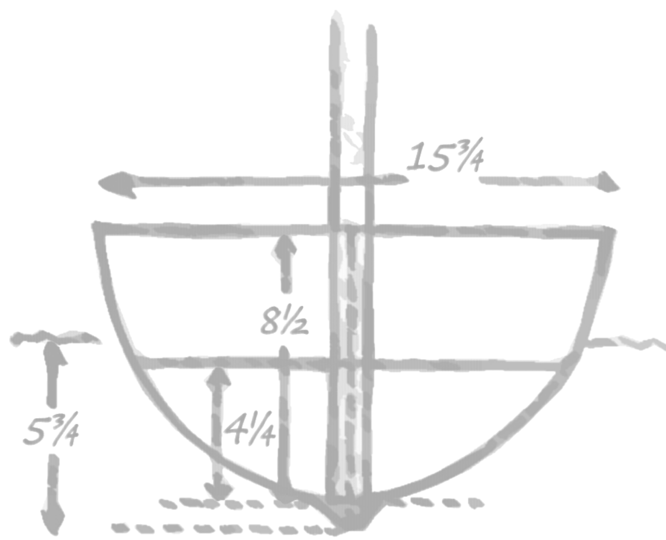
Appendix – Cutting & Comparing

Use the following scale diagrams to confirm if your answers in **Questions #1, #2, and #3** are reasonable estimates. You can use a protractor, ruler, string, pipe cleaner, or any other tools you may have to hand that can help you in this task.



(1) Cut out the diagram below. **(2)** Place it over the image above. **(3)** Rotate the overlaid image until one corner of the main deck reaches the water line. **(4)** Measure the angle of the tilted ship against the upright diagram. **(5)** Measure the amount of hull that is exposed on the opposite side. **(6)** Make your conclusions. (**Remember:** the current water line is at approximately the same level as the berthing deck)

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Answer Key

Reminder: *This activity includes estimation and opinion. Consider all answers with this in mind.*

Question 1a: 24.74 ft

Question 1b: 26.70 ft

Question 1c: 25.72 ft

Question 1d: The perimeter calculated in **Question #1c** is better for estimating the hull profile. The perimeter calculated in **Question #1a** is better for the purposes of the inspection as it more closely approximates the hull profile above the waterline.

Question 1e: Average Perimeter = π (X + 2Y) / 4

Question 2a: Via the circle: ≈22.5° + 5.625° = ≈28°
Via a protractor: ≈28°
Via a ruler & scientific calculator: ≈ 1.6 cm / 3.0 cm → ≈28.07°
Via provided dimensions & scientific calculator: 4.25 ft / 7.875 ft → 28.35°

Question 2b: An incline of 28° is fairly steep – walking and working is becoming a challenge.

Question 3: Using ratios and similar triangles: 4.25 ft / 7.875 ft = D / 25 ft. → D = 13.49 ft

Question 4a: Using an angle of 28° → (28° + 28°) / 180° → 31% of the hull

Question 4b: 31% of the hull is above water, another 31% will be exposed by tilting the ship in both directions. This leaves 100% - 31% - 31% = 38% uninspected.

Question 4c: Yes. Doing nothing means that the 180° - 56° = 124° of the hull normally submerged in the water will remain uninspected. Tilting the ship allows 56° of the submerged portion of the hull to be inspected for leaks. Assuming the probability of leaks is evenly distributed across the hull, this inspection should reduce any leaks by 56° / 124° = 45%. A worthwhile effort if a full inspection is not possible.

Question 5a: Yes – The three values are close to those estimated in **Questions #1, #2, and #3**.
For **Question #1**: using a scale of 15.75 ft : 6.7 cm (by measuring the main deck), measuring the hull profile with a pipe cleaner gives the perimeter as 25.85 ft
For **Question #2**: using a protractor to measure the smaller angle of a triangle like that in the diagram adjacent to **Question #2b** should give a result of ≈28°
For **Question #3:** after measuring the sides of the triangle created by the upright mast and the rotated mast, the ratio of 1.3 cm : 2.5 cm = D : 25 ft → D = 13 ft

Question 5b: Yes – A new rotational axis at the midpoint of the berthing deck is suggested.
No – The newly calculated values are very close to those previously estimated.

Thank you for using this add-on to our Teacher's Guide for "The Day the Pirates Went Mad".

We hope it was useful and engaging.

For more behind-the-scenes and research-related information, visit us at https://EmmaSharpesAdventures.com

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