

Great Lakes Maritime Transportation Teacher Institute

Lesson 2 – Estimating the Costs of Maritime Shipping

by Debra A. Zei

Lesson Overview

This lesson has been designed to reinforce advanced algebraic and trigonometric concepts. However, this lesson also addresses benchmarks from both science and social studies. Currently, there is a general lack of awareness of the importance of Maritime Shipping on the Great Lakes. Virtually every material which we use daily has been shipped. During the next five to ten years, it will be imperative to our global economy to address some of the issues of shipping which we face. Additionally, there will be a great opportunity for employment in the maritime industry. It is our responsibility to educate our youth.

The overall goal of this lesson is to use both basic algebraic computations together with logarithmic, exponential, and trigonometric functions to compute the costs of operating a ship carrying cargo.

Objectives

After completing this lesson, students will be able to

1. Calculate the draft of a ship.
2. Calculate both gross tonnage and net tonnage.
3. Calculate Insurance.
4. Calculate bunkers.
5. Calculate profit and cost.

Michigan Standards Addressed

MATHEMATICS

- I Patterns, Relationships and Functions
 - Content Standard 2
 - 5. Differentiate and analyze classes of functions.
 - 6. Use functions and mathematical models to solve problems in context.
- II Geometry and Measurement
 - Content Standard 2
 - 1. Locate and describe objects in terms of their position.
 - 2. Locate and describe objects in teams of orientation and relative position including displacement.
 - 5. Use concepts of position, direction, and orientation to describe the physical world and to solve problems.
 - Content Standard 3
 - 1. Select and use appropriate tools.
 - 2. Make and apply measurements of length.
 - 3. Estimate measures with specified degree of accuracy.
 - 4. Interpret measurements.
 - 6. Apply measurements to describe the real world and solve problems.
- III Data Analysis and Statistics

- Content Standard 1
 - 1. Collect and explore data through observation and measurement
 - 3. Present data using the most appropriate representation.
 - 4. Identify what data are needed to answer a particular question and solve a given problem.
- IV Numerical and Algebraic Operations
 - Content Standard 1
 - 4. Apply understanding of number systems to model and solve math and applied problems.
 - Content Standard 2
 - 4. Apply estimation in increasingly complex situations.
 - Content Standard 3
 - 4. Express number relationships using exponents and logarithms.
- V Numerical and Algebraic Operations.
 - Content Standard 1
 - 2. Compute with real numbers.
 - 4. Efficiently and accurately apply operations with real numbers in solving problems.
 - Content Standard 2
 - 2. Solve linear equations.
 - 4. Analyze problems that can be modeled by functions.
 - 5. Explore problems that reflect the contemporary uses of mathematics in significant contexts.

.SCIENCE

- I Construct New Scientific Knowledge
 - Content Standard 1
 - 3. Recognize and explain the limitation of measuring devices.
 - 4. Gather and synthesize information from books and other sources.
- II Reflecting on Scientific Knowledge
 - Content Standard 1
 - 1. Justify plans or explanations on a theoretical or empirical basis.
 - 3. Show how common themes of science and math apply in real world contexts.
- IV Motion of Objects
 - Content Standard 3
 - 1. Qualitatively compare motion in two dimensions.

SOCIAL STUDIES

- IV Economic Perspective
 - Content Standard 1
 - 3. Analyze ways individuals can select suppliers of goods and services.
 - Content Standard 2
 - 1. Outline a decision making process a business goes through when deciding to export.
 - Content Standard 4
 - 1. Use case studies to exemplify how supply and demand, prices, incentives and profits determine what is produced and distributed in a competitive world market.
 - Content Standard 5
 - 4. Describe the effects of currency exchange, tariffs, quotas, and product standards on world trade and domestic economic activity.

Materials Needed per student:

- Scientific Calculator
- Pencil & Eraser
- Paper for Calculations

Prerequisite Knowledge for Success in this Lesson

- Familiarity with solving simple linear algebraic equations.
- Experience solving exponential, logarithmic and trigonometric equations.
- Ability to perform unit analysis.
- Make sure that students are familiar with the vocabulary terms and their definitions.
- Make sure that students can use the formulas.

Procedure

Each day we use many products that both enter and leave the United States. We have become accustomed to the convenience of shopping at Wal-Mart, getting fresh produce at the grocery store in the winter, and having fuel for our cars, homes, and businesses. We don't realize that over 95% of these products are carried on ships. Our global economy thrives as a result of maritime transportation.

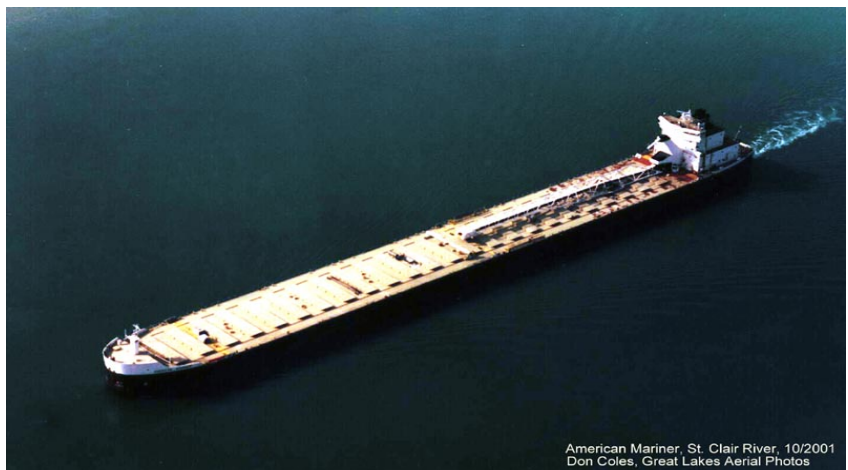
Now, with the price of fuel becoming so astronomically high, congestion on roads and railways, our aging land transportation systems, and pollution, both the rail and trucking industries are facing higher costs. At the same time, the need for shipping cargo is expected to double or triple within the next twenty years. The question becomes, what mode of transportation is least impacted by these problems? Of course, the answer is maritime transportation – those ships that we see on the Great Lakes.

Currently, each of the ships on the Great Lakes carries the equivalent of thousands of truck loads of cargo. Some of the exercises that we will complete in this lesson demonstrate that ships can move cargo at a lower cost and with less impact on our environment than either trucks or trains.

Have students complete the attached student page with mathematical computations concerning the cost of running a ship.

Ariel View of the American Mariner

<http://www.boatnerd.com/pictures/fleet/thumb/AmericanMariner-12-01.jpg>



American Mariner, St. Clair River, 10/2001
Don Coles, Great Lakes Aerial Photos



2006 Kenworth C500

<http://www.truckpaper.com/listings/forsale/Detail.asp?OHID=1218873&guid=0669A4B2766C4C3581ECE0435FECA859>

Cargo on a freight train

http://www.photovault.com/Link/Vehicles/Rail/FreightTrains/show.asp?tg=VRFVolume02/VRFV02P01_06



Code

Santa Fe Freight Train

http://www.photovault.com/Link/Vehicles/Rail/FreightTrains/show.asp?tg=VRFVolume02/VRFV02P01_01

Vocabulary Terms and Definitions for shipping calculations

- AI – *All inclusive*
- All in rate – Freight rate which is inclusive of all surcharges and extras.
- ARB – *Arbitrary charge* for added expense such as ice-breaking
- BAF – *Bunker adjust factor* applied by shipping lines to reflect fluctuations in the cost of bunkers. This charge is expressed either as an amount per freight ton or as a percentage of the freight.
- Bunker – fuel used on ships
- CAF - *Currency adjustment factor* which is applied to freight rates by shipping lines to ensure that revenue of the shipping lines is unaffected by movements in the currencies in which transactions are carried out by the lines. It is expressed as a percentage of the freight and may be either positive or negative.
- CFS – *Container freight station* is a place where consignments are consolidated as a number of TEU's.
- CR – *Container rate* is the charge to ship a container.
- CY – *Container yard* is a place to which full container loads are delivered by the shipper to the maritime carrier and to which empty containers are returned.
- CY/CY – *Container yard to container yard* movement of cargo.
- CFS/CY – *Container freight stations to container yard* movement of cargo.
- Chassis – A charge imposed by container shipping lines for providing customers with truck chassis at harbor terminals.
- Draft – The vertical distance from the current waterline to the lowest point of the ship or in the part of the ship under consideration.
- D – *depth* of the ship
- d – Summer draft of the ship
- Draft Marks – Marks printed on each side of the bow and stern, and sometimes also amidships. They are each 10 centimeters high with a gap of 10 centimeters between each mark.
- DRC – *Daily running cost* is made up of crew costs, stores and repairs, and insurance.
- DWT – *Dead weight ton* is the weight of a fully loaded ship including weight of cargo, fuel, lubricating oil, ballast water, fresh water, food and passengers. It is the difference between the loaded displacement and the light displacement.
- FAF - *Fuel adjustment factor* which is applied to freight rates by shipping lines to ensure that revenue of the shipping lines is unaffected by movements in the currencies in which transactions are carried out by the lines. It is expressed as a percentage of the freight and may be either positive or negative.
- FEU – *Forty-foot equivalent unit* of measurement equivalent to one 40- foot shipping container. This measurement is used to quantify the container capacity of a ship, or the number of containers on a particular voyage. It may also be the unit on which freight is payable.
- GT – *Gross tonnage* is a measure of the total enclosed volume of the ship in cubic meters multiplied by a constant.
- KT – *kiloton or metric ton* = 1,000 kilograms or 2,204.6 pounds.
- Light displacement tonnage – the actual weight of the ship.
- Loaded displacement tonnage – the actual weight of the ship and cargo.
- Long tons – tons of 2,240 pounds.
- NT – *Net tonnage* is the total enclosed volume available for cargo in cubic meters multiplied by a constant.
- PC – *per container*

- Short tons – tons of 2,000 pounds.
- THC - *Terminal handling charge* also known as container yard charge which is payable to a shipping line either for receiving a full container load at the container terminal, and delivering it to the ship at the load port, or for receiving it from the ship at the discharge port, storing it and delivering it to the consignee.
- TEU – *Twenty-foot equivalent unit* of measurement equivalent to one 20-foot shipping container.
- Transit time – Time for goods to be carried from one place to another.
- V – *Volume* of all enclosed spaces in cubic meters.
- V_C – *Volume of Cargo spaces* in cubic meters.



Great Lakes Fleet Vessel – Wolverine

<http://www.boatnerd.com/pictures/fleet/wolver.htm>

Paul R. Tregurtha in Marquette,



Michigan

<http://www.boatnerd.com/news/newpictures02/PaulTregurtha62902lr.jpg>

Formulas and Conversions

- Calculation for ocean rate on a per-container basis.
 - $CR + [CR * CAF] + THC + [CR * BAF] + ARB$
- Calculation for ocean rate on a per-package basis.
 - $\frac{CR + [CR * CAF] + [CR * BAF] + CYC + ARB}{\text{Number of Packages}}$
- Calculation for ocean rate on a per-weight (KT) basis.
 - $\frac{CR + [CR * CAF] + [CR * BAF] + CYC + ARB}{\text{Kilotons}}$
- Calculation for ocean rate on a per-package basis.
- Draft (in meters) = $(DWT / 1000)^{0.5} + 5$
- Gross Tonnage
 - $GT = K_1 * V$
 - $K_1 = 0.2 + 0.02 * \log V$
- Net Tonnage
 - $NT = K_2 * V_C * (4 / 3 * d / D)^2$
 - $K_2 = 0.2 + 0.02 * \log V_C$
- Long ton = 2,240 pounds
- Short ton = 2,000 pounds
- Metric ton = 1,000 kilograms
- Insurance Cost
 - $(1.5 * DWT + 0.003 * \text{Value of ship})$
- Freight earned
 - Tons of cargo * freight rate per ton
- Total Cost of running a ship
 - $(DRC * \text{Total time}) + \text{Bunker requirements} + \text{Cargo handling costs} + \text{Other port costs} + \text{Canal costs} + \text{insurance}$
- Ships daily profit
 - $(\text{Total freight} - \text{total cost}) / \text{total time}$

Assessment - See the attached data form and answer key.

Extensions

For teachers who wish to extend this lesson into several days, the following modifications can be made.

- Students can use the internet to research the vessels on the Great Lakes, companies the ship commodities, and distances between ports to create their own shipping problems.
- Teachers can contact the Great Lakes Maritime Transportation Research Institute at www.glmri.org for additional lesson extensions.

Resources

Alderton, Patrick M. 2004. Reeds Sea Transport Operation and Economics, Fifth Edition. London: Adlard Coles Nautical

Barnard, Bruce. 2000. Tanker rates jump as demand soars. Journal of Commerce Online 3 (May). Woodcliff Lake, NJ: Wallenius Wilhelmsen Logistics.

Brogdon, Captain Bill. 2001. Boat Navigation For The Rest Of Us, Second Edition. Camden, ME: International Marine.

Downard, John M. 1981. Running Costs. London: Fairplay.

Great Lakes Fleet, Inc. 2002. If there were a well-beaten path across the Great Lakes, it would be ours. Duluth, MN: Great Lakes Fleet, Inc.

Stewart, Richard D., PhD. Great Lakes Marine Transportation System – White Paper Prepared for the Midwest Freight Corridor Study. Duluth, MN: Great Lakes Maritime Research Institute.

Stewart, Richard D, PhD. 2005. Ocean Freight Calculations. Marine Transportation TRSP-325. Superior, WI: University of Wisconsin, Superior.

Stewart, Richard D., PhD. 2006. Twin Ports Maritime Day Presentation. Duluth, MN: Great Lakes Maritime Research Institute.

Name _____

Estimating Costs of Marine Shipping

Directions: Use both the mathematical formulas and the vocabulary provided in this lesson to completely answer the questions in the following exercises.

1. The *American Fortitude* is a ship owned by the American Steamship Co. It is approximately 690 feet long and has a capacity of 22,300 tons. Find the draft of this ship in meters.

2. The *CLS Atlas* is a ship owned by CSL International Inc.
 - a. Suppose the volume of the ship is 223,145 cubic meters. Calculate the gross tonnage of the ship.

 - b. Suppose the depth of the ship is 14 meters greater than the draft of 13.2 meters and the volume of the cargo spaces is 217,500 cubic meters. Calculate the net tonnage of the ship.

3. Suppose that you will be shipping a container of paper from Buffalo to Rio de Janeiro. If the container rate is \$2,800, the currency adjustment factor is 40%, the terminal handling charge is \$310, the bunker adjustment factor is 12% and there is a \$35 cleaning fee (this is an arbitrary charge), what is the per container rate?

4. Suppose the *Herbert C Jackson* owned by Interlake Steamship Company is preparing a voyage for 5 days at sea and 2 days at port.
 - a. Bunkers cost approximately \$85 per ton and the ship requires 30 tons of bunker fuel each day at sea but only 1 ton while in port.
 - i. How many bunkers should be loaded onto the ship for the voyage?

ii. How much will the fuel cost?

b. You also plan to store 75 tons of domestic and boiler water on the ship. If this ship has a capacity of 24,800 tons, what is the maximum amount of cargo that can be shipped during this voyage?

5. Suppose that you will be shipping 275 packages of Idaho Potatoes from Vancouver to Hong Kong. If the container rate is \$3,250, the currency adjustment factor is 18%, the container yard charge is \$220, the bunker adjustment factor is 21%, and there is a \$25 cleaning fee (this is an arbitrary charge), what is rate per package?

6. Find the daily running cost of a container vessel with the following operating costs.

• Crew	\$1, 568
• Repairs/maintenance	\$557
• Oils/lubricants	\$91
• Insurance	\$630
• Stores	\$50
• Overheads	\$145

7. Suppose a vessel is traveling from Tokyo to New York. Use the following information to complete the calculations. You will spend 4 days loading in Tokyo. The distance from Tokyo to San Francisco is 4,554 miles. It takes 13.5 days to complete this leg of the voyage. From San Francisco to Panama is 3,245 miles and it will take 11 days to complete this. It takes one day to transit the Panama Canal. The distance from Panama to New York is 1,972 miles and will require 5 days to complete this leg. Finally, unloading will take 7 days.

a. The ship requires 34 tons of fuel at sea and 2 tons at port.

i. How much fuel will the ship require for the voyage?

- ii. If fuel is \$97 per ton, determine the fuel cost for the voyage.
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- b. The running cost is \$3,500 each day for the voyage. There is an \$11,500 port cost at Tokyo, a \$3,000 port cost at San Francisco, a charge of \$50,000 to transit the Panama Canal, and a \$14,000 charge at New York for unloading. Find the total cost of this voyage.
 - c. If the ship can carry 22,000 tons of cargo, determine the price that must be offered per ton to ensure a daily profit of \$500.
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8. Suppose that you will be shipping 8 KT of beef from New Orleans to Bangkok. If the refrigerated container rate is \$4,500, the currency adjustment factor is 38%, the container yard charge is \$160, the bunker adjustment factor is 15%, and there is a \$40 electricity charge in storage (this is an arbitrary charge) what is rate per KT?
9. The *Algorail* is a ship owned by the Algoma Central Corporation.
- a. Suppose the volume of the ship is 75,000 cubic meters. Calculate the gross tonnage of the ship.
 - b. Suppose the depth of the ship is 6 meters greater than the draft of 9.87 meters and the volume of the cargo space is 70,000 cubic meters. Calculate the net tonnage of the ship.

12. Suppose a vessel consumes 28 tons of fuel oil for the main engines and 2.5 tons of diesel oil for the generators. While in port, this ship only needs 1 ton of diesel to function. Determine the cost of fuel for a 15 day trip on the water and 6 days in port if fuel oil is \$126 per ton and diesel oil is \$153 per ton.
13. The *American Integrity* is a ship owned by the American Steamship Co. It is approximately 1,000 feet long and has a capacity of 78,850 tons. Find the draft of this ship in meters.
14. Suppose you are planning a voyage that will require 14 days at sea and 4 days at port. The capacity of your vessel is 28,860 tons. You will be paid \$6 per ton for your cargo. Use the information below to answer the following questions. Your daily running cost is \$3,250. You will require 25 tons of fuel at sea and 1 ton of fuel in port. Bunkers cost \$102 per ton. You have 300 tons of water on the ship. There are port charges of \$1,500 and you cross the Panama Canal for a charge of \$50,000.
- Determine the total cost of the voyage.
 - Determine the freight earned for this voyage.
 - Determine the ship's daily profit.

Estimating The Costs Of Marine Shipping - ANSWER KEY

Directions: Use both the mathematical formulas and the vocabulary provided in this lesson to completely answer the questions in the following exercises.

1. The *American Fortitude* is a ship owned by the American Steamship Co. It is approximately 690 feet long and has a capacity of 22,300 tons. Find the draft of this ship in meters. **18.89 meters**

2. The *CLS Atlas* is a ship owned by CSL International Inc.

a. Suppose the volume of the ship is 223,145 cubic meters. Calculate the gross tonnage of the ship. **68,499.21 tons**

b. Suppose the depth of the ship is 14 meters greater than the draft of 13.2 meters and the volume of the cargo spaces is 217,500 cubic meters. Calculate the net tonnage of the ship. **27,933.81 tons**

3. Suppose that you will be shipping a container of paper from Buffalo to Rio de Janeiro. If the container rate is \$2,800, the currency adjustment factor is 40%, the terminal handling charge is \$310, the bunker adjustment factor is 12% and there is a \$35 cleaning fee (this is an arbitrary charge), what is the per container rate? **\$4,601**

4. Suppose the *Herbert C Jackson* owned by Interlake Steamship Company is preparing a voyage for 5 days at sea and 2 days at port.

a. Bunkers cost approximately \$85 per ton and the ship requires 30 tons of bunker fuel each day at sea but only 1 ton while in port.

i. How many bunkers should be loaded onto the ship for the voyage? **152 tons**

ii. How much will the fuel cost? **\$12,920**

b. You also plan to store 75 tons of domestic and boiler water on the ship. If this ship has a capacity of 24,800 tons, what is the maximum amount of cargo that can be shipped during this voyage? **24,573 tons**

5. Suppose that you will be shipping 275 packages of Idaho Potatoes from Vancouver to Hong Kong. If the container rate is \$3,250, the currency adjustment factor is 18%, the container yard charge is \$220, the bunker adjustment factor is 21%, and there is a \$25 cleaning fee (this is an arbitrary charge), what is rate per package? **\$17.32**

Find the daily running cost of a container vessel with the following operating costs. **\$3,041**

- Crew \$1,568
- Repairs/maintenance \$557
- Oils/lubricants \$91
- Insurance \$630
- Stores \$50
- Overheads \$145

6. Suppose a vessel is traveling from Tokyo to New York. Use the following information to complete the calculations. You will spend 4 days loading in Tokyo. The distance from Tokyo to San Francisco is 4,554 miles. It takes 13.5 days to complete this leg of the voyage. From San Francisco to Panama is 3,245 miles and it will take 11 days to complete this. It takes one day to transit the Panama Canal. The distance from Panama to New York is 1,972 miles and will require 5 days to complete this leg. Finally, unloading will take 7 days.
- The ship requires 34 tons of fuel at sea and 2 tons at port.
 - How much fuel will the ship require for the voyage? **1,059 bunkers**
 - If fuel is \$97 per ton, determine the fuel cost for the voyage. **\$102,723**
 - The running cost is \$3,500 each day for the voyage. There is an \$11,500 port cost at Tokyo, a \$3,000 port cost at San Francisco, a charge of \$50,000 to transit the Panama Canal, and a \$14,000 charge at New York for unloading. Find the total cost of this voyage. **\$326,473**
 - If the ship can carry 22,000 tons of cargo, determine the price that must be offered per ton to ensure a daily profit of \$500. **\$14.86 per ton**
7. Suppose that you will be shipping 8 KT of beef from New Orleans to Bangkok. If the refrigerated container rate is \$4,500, the currency adjustment factor is 38%, the container yard charge is \$160, the bunker adjustment factor is 15%, and there is a \$40 electricity charge in storage (this is an arbitrary charge) what is rate per KT? **885.63 per kiloton**
8. The *Algorail* is a ship owned by the Algoma Central Corporation.
- Suppose the volume of the ship is 75,000 cubic meters. Calculate the gross tonnage of the ship. **22,312.59 tons**
 - Suppose the depth of the ship is 6 meters greater than the draft of 9.87 meters and the volume of the cargo space is 70,000 cubic meters. Calculate the net tonnage of the ship.

14,291.12 tons

9. Refer to the data below which show the total terminal cargo-handling charges per TEU at a port. Create a graph that shows each type of cargo and the interval of terminal handling charges.
- Per ton of grain \$2 - \$7
 - Per ton of pig iron \$5 - \$15
 - Per ton of coal \$2.50 - 10
 - Per ton of general \$3 - \$20
 - Per ton of paper pulp \$10

One possibility:

Item	2	4	6	8	10	12	14	16	18	20
Grain		*****	*****	***						
Iron			***	*****	*****	*****	*****	***		
Coal		****	*****	*****	*****					
General		***	*****	*****	*****	*****	*****	*****	*****	*****
Pulp					*****					

10. You are trying to determine whether to use tractor-trailer or a ship to transport coal. Use the following information to answer the following questions: It takes 6 trains to fully load the ship. Each train has 100 cars fully loaded with coal. The ship gets 40 gallons per mile of fuel. On the other hand, the tractor-trailer gets 6 miles per gallon of fuel. To make a comparison, it takes 3 tractor-trailers to fill 1 car on the train.

a. How many tractor-trailers are needed to carry the same cargo as the ship?

1,800 tractor-trailers

b. How many gallons of fuel will the truck need to travel from Duluth, MN to Buffalo, NY which is approximately 920 miles?

153.33 gallons each truck

276,000 gallons total

c. How many gallons of fuel will the ship need to travel from Duluth, MN to Buffalo, NY which is approximately 920 miles? 36,800 gallons

d. Which mode of shipping will be most fuel efficient per ton? Maritime Shipping

11. Suppose a vessel consumes 28 tons of fuel oil for the main engines and 2.5 tons of diesel oil for the generators. While in port, this ship only needs 1 ton of diesel to function. Determine the cost of fuel for a 15 day trip on the water and 6 days in port if fuel oil is \$126 per ton and diesel oil is \$153 per ton. \$595,755

12. The *American Integrity* is a ship owned by the American Steamship Co. It is approximately 1,000 feet long and has a capacity of 78,850 tons. Find the draft of this ship in meters.

1.88 meters

13. Suppose you are planning a voyage that will require 14 days at sea and 4 days at port. The capacity of your vessel is 28,860 tons. You will be paid \$6 per ton for your cargo. Use the information below to answer the following questions. Your daily running cost is \$3,250. You will require 25 tons of fuel at sea and 1 ton of fuel in port. Bunkers cost \$102 per ton. You have 300 tons of water on the ship. There are port charges of \$1,500 and you cross the Panama Canal for a charge of \$50,000.

a. Determine the total cost of the voyage. \$146,108

b. Determine the freight earned for this voyage. \$169,236

c. Determine the ship's daily profit. \$1,284.89