USS Constitution Museum

Racing Cannon Balls

USS *Constitution*'s Midshipmen Debate A Gunnery Physics Problem At Sea

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A publication of the USS Constitution Museum, Boston

The midshipmen on board USS *Constitution*'s circumnavigation of the globe between 1844 and 1846 were students learning how to be naval officers. It was a goal that required them to understand navigation, seamanship, leadership, and mathematics – serious topics that occasionally belied their youthful enthusiasm.

Herman Melville who shipped aboard USS *United States* from Honolulu in 1843 described the midshipmen as "something like college freshmen and sophomores, . . ., and especially so far as the noise they make in their quarters is concerned."[1] Melville said, "These boys are sent to sea, for the purpose of making commodores; and in order to become commodores, many of them deem it indispensable forthwith to commence chewing tobacco, drinking brandy and water, and swearing at the sailors."[2]

The Navy's method of training its future officers was beginning to change in the 1840s. In 1839, the Navy had opened a Naval School at the Philadelphia Naval Asylum, and the United States Naval Academy opened in Annapolis, Maryland in 1845. But during USS *Constitution*'s World Cruise from 1844 to 1846, most midshipmen still learned by being aboard ship. Like college freshmen or sophomores, the midshipmen aboard *Constitution*'s World Cruise came from a variety of backgrounds. As part of their training the "mids" or "reefers" (a name given to midshipmen assigned to the tops to supervise reefing, or taking in, sails) kept logs and journals which Captain John Percival would review to ensure the young men knew how to keep a ship's logbook. We are fortunate to have a few of these logs, though most only tell us the weather and the ship's position several times a day. The journals of Midshipman William Buckner, however, tell us a lot about the people and places the ship visited as well as a lot about Buckner. Buckner was, according to his sister Priscilla, the Navy's first midshipman from the newly established state of Arkansas. Though Buckner had been born in Kentucky, the family had moved to Arkansas prior to his joining the Navy. The USS Constitution Museum has Buckner's log, as well as a scrapbook of letters Buckner wrote to his sister Priscilla in Little Rock, Arkansas.

In his correspondence, Buckner wrote that if Priscilla could "peep into our steerage" for just a few minutes, she would be amused. "There is one big mid snoring in one corner on a few sea jackets, two others with their slates studying, three others singing a mock Methodist hymn, and one poor green mid with his head on his hands complaining of sea sickness and wishing he was at home."[3]

[1] Melville, *White Jacket, or The World in a Man of War* (Boston: L.C. Page Company, 1950) 374-375.
[2] Melville, *White Jacket,* 373.
[3] "Tales of the Sea," *Arkansas Democrat*, 1894. As collected and bound in the scrapbook, *Tales of the Sea - Correspondence of William Perry Buckner.* USS Constitution Museum collection [2499.2].

He also told Priscilla of an argument the midshipmen had a few nights before over a fantastical hypothetical situation that hinged on real-world math and physics. During this period, naval technology was changing rapidly as ships were beginning to turn from sail to steam. At the same time, the Navy was developing more effective guns. The combination of faster ships and more powerful guns opened up new possibilities in naval tactics and the physics of nautical science. In this context, the proposition the mids debated was: if a ship could go 50 miles an hour, and a ship's gun could fire a shot at the rate of 50 miles an hour, and assuming the shot could stay in the air for an hour, how far apart would the ship and the cannonball be after an hour? One hundred miles or fifty miles? Most of the midshipmen added 50 and 50, deciding the shot and ship would be one hundred miles apart.

"I said fifty," Buckner wrote, "and have all the principles of philosophy to support me." His two watchmates, John Hart of New York, and Washington Davidson of Virginia, agreed with Buckner. The other midshipmen stuck with 100 miles as their answer.

They took their argument to Ethan Estabrook, the ship's Professor of Mathematics. Midshipmen learned seamanship and leadership from officers and crew, but the Navy had 22 professors (paid $1,230 a year, the same as a chaplain, equal to roughly $50,000 in 2024) to teach mathematics. Four professors were at the Naval School, the rest were aboard ships. Estabrook had taught school on Long Island before getting hired as a secretary at the Brooklyn Navy Yard. In 1843 at the age of 50 he was commissioned a math professor.

After listening to the arguments, Estabrook agreed with Buckner that ship and shot would be 50 miles apart. Not convinced, the nine midshipmen who said 100 miles appealed to a higher authority. Not the captain, but former congressman Henry Wise, traveling on *Constitution* to his new post as United States Minister to Brazil. Wise listened to their arguments, and though he was not a mathematician, he was a politician, meaning he could count, and seeing it was nine to three, he sided with the majority. Buckner then began to argue, presenting his "principles of philosophy," but when Wise saw Buckner "was getting the weather gage of him, he commenced talking and would not let me get in a word."

Buckner does not tell us the principles of philosophy he argued. But we can frame this as a physics problem and express the solution in terms of Newton's laws established about 150 years prior to the argument among the midshipmen.

Problem

A ship is moving at 50 mph to the east and fires a ball at 50 mph from the stern of the ship. How far apart will they be in one hour (ignoring gravity so the cannonball does not hit the water)?

Solution

Before the gun is fired, the ball would be moving at 50 mph to the east, because it is on the ship moving at 50 mph to the east. The cannonball is then fired to the west at 50 mph, so the total velocity of the cannonball relative to the earth is zero. A person observing the cannon firing from another ship, at rest in the water, would see the cannonball hover above the water in the same place it was released from the cannon. The ship would continue at 50 mph to the east so one hour later the ship and the cannonball would be 50 miles apart.

The same analysis would hold true for any speed of the ship as long as the cannon is fired to the west with the same speed as the ship. For example, if the ship is moving at 30 mph to the east and the cannonball is fired at 30 mph to the west, it would again have 0 velocity, hover above the water, and one hour later the cannonball and the ship would be 30 miles apart.

Now consider two other variants of this same problem.

Variant 1: The ship is moving at 50 mph to the east and the cannonball is fired at 30 mph to the west. In this case, the velocity of the cannonball would be 50 mph - 30 mph = 20 mph to the east. An observer on another stationary ship would see the cannonball travel to the east at 20 mph behind the ship which is moving faster to the east at 50 mph. One hour later the distance between cannonball and ship would be 30 miles – the ship travels 50 miles to the east and the cannonball travels 20 miles to the east, moving more slowly than the ship.

Variant 2: The ship is moving at 50 mph to the east and the cannonball is fired at 90 mph to the west. In this case, the velocity of the cannonball would be:

50 mph -90 mph = - 40 mph (minus means to the west)

The observer on the other stationary ship would see the cannonball travel to the west from where it was fired at 40 mph while the ship moved to the east at 50 mph. One hour later the distance between the cannonball and the ship would be 90 miles: 40 miles to the west for the cannonball and 50 miles to the east for the ship.

Distance from ship to cannonball: Realistic velocity of the cannonball

At the time, warships could fire a cannonball at over 1000 mph relative to the ship.

So for a ship moving to the east at 50 mph, a cannonball fired to the west at 1000 mph would have a velocity of 50 -950 = - 950 mph (minus sign meaning to the west)

In one hour, the cannonball would travel 950 miles to the west and the ship would travel 50 miles to the east. The distance between the two would be 1000 miles. In general, if the cannonball has a velocity to the west greater in magnitude than the ship velocity to the east, then the distance between the cannonball and the ship after one hour will be the velocity of the fired cannonball, relative to the ship, multiplied by one hour. A cannonball fired at 1100 mph relative to the ship would produce a separation from the ship of 1100 miles.

Buckner was right. The other midshipmen had not taken the ship's velocity into account, but merely assumed two objects setting off from the same point traveling at the same speed would go the same distance in an hour. These young men were in a changing world, with faster ships using steam power, and more powerful guns able to send larger shot further. In February of 1844 the Navy had demonstrated "Peacemaker," a 27,000-pound gun which could send a 12-inch shot five miles, though the result was disastrous when the "Peacemaker" exploded, killing six people including the Secretary of State and the Secretary of the Navy.[4]

Advances in technology and the shift to steam began dramatically altering the skills and knowledge required of naval officers. In 1845, officer training began to move from the ships to the Naval Academy in Annapolis. After *Constitution*'s World Cruise, Buckner also went to Annapolis, spending much of the 1850s as an assistant professor teaching math and navigation to midshipmen who now learned in the classroom rather than at sea. During the Naval Academy's practice cruise for midshipmen on the sloop *Plymouth* in 1860, Buckner had prepared a table showing the angles and distances of shots fired at sea, which Lieutenant Commander Edward Simpson, the Commandant of Midshipmen at the Naval

[4] Ann Blackman, "Fatal Cruise of the Princeton," *Naval History,* Volume 19, #5, October 2005. https://www.usni.org/magazines/naval-history-magazine/2005/october/fatal-cruise-princeton

Academy, reported was the "most accurate and convenient method of determining distances at sea when the distant horizon is clearly defined."[5]

Buckner's enthusiastic debate with his fellow midshipmen in 1844 clearly demonstrated the mathematical acumen that contributed to his later career and ended up refining gunnery practice for a generation of naval officers.

Appendix

But what about gravity?

The gravity's effect on the cannonball varies, depending on the cannonball's velocity, from none to drastic. In the two cases shown below, we assume the cannon is fired horizontally so there is no upward or downward motion given to the cannonball. We also assume the original height of the cannonball above the water is 18 ft.

Simplest case: If the problem is the original one where the ship is moving to the east at 50 mph, and the cannonball is fired to the west at 50 mph, then gravity has no effect on the answer. The reason is the cannonball has 0 velocity with respect to the earth after being fired, and simply drops straight down into the water. The ship moves eastward and is fifty miles from the cannonball after one hour.

Realistic case: The cannon is fired horizontally from the stern of the ship moving to the east, and from a height of 18 ft above the water with a speed of 1000 mph relative to the ship. Here the distance the cannonball travels depends on how long it is in the air, because its travel to the west ceases when it hits the water.

Using projectile motion equations from Newton's laws, we can determine the cannonball will hit the water in 1.06 sec after being fired horizontally (at any velocity) from a height of 18 ft. As discussed earlier, the horizontal velocity of the cannonball when fired at 1000 mph relative to the 50-mph ship is 950 mph toward the west. A speed of 950 mph is equivalent to 1393 ft/s. This means the cannonball, in the air for 1.06 seconds, will travel 1477 ft to the west. This is a distance of approximately 0.28 miles.

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[5] *Annual Report of the Secretary of the Navy* (Washington: Government Printing Office, 1862) p. 544. https://hdl.handle.net/2027/coo.31924112651967; https://babel.hathitrust.org/cgi/pt?id=coo.31924112651967&seq=550&q1=Constitution
We are indebted to Margherita Desy for this reference.

The ship travels eastward at 50 mph which is 73.3 ft/s so in 1.06 seconds it travels a distance of about 78 ft. The result then is that when the cannonball hits the water the distance between the cannonball and ship will be 1477 + 78 = 1555 ft. This corresponds to 0.29 miles.

After one hour, the separation between the two will be the 0.28 miles travelled to the west by the cannonball + 50 miles travelled to the east by the ship, the total = 50.28 miles.