

## ***Preface***

“I am sorry that this letter is so long. I did not have time to write you a shorter one.”

George Bernard Shaw

During the early years, Richard Feynman played bongo drums, pursued beautiful women, and helped build the first atomic bomb at Los Alamos. Later he taught at Stanford University, continued on the bongo drums, and won the Nobel Prize in physics. As a college professor, he became a great teacher in spite of his handicap (he was a genius). One of his students related asking another professor the question, “From a scientific and engineering viewpoint, what exactly *is* friction?” The answer was a barrage of mathematical equations. He complained to his roommate that he understood the math, but he still didn’t exactly know how friction worked. He was advised to ask Dr. Feynman.

This time, instead of getting calculus, he was engaged in a conversation. Feynman began talking about a man slipping downhill on a sidewalk. Of course, the man’s forward motion created the simplest form of kinetic energy. Then he described how the tiny grains of the concrete surface would pull off bits of shoe leather, slowing the motion of the man. He explained that each time a fragment of leather was pulled off, some energy was required, and this was subtracted from the man’s kinetic energy downhill. “That’s friction,” Feynman concluded. His students were very fortunate, indeed.

After the Challenger space shuttle disaster, Feynman was a member of the commission to investigate the explosion on lift-off. In the first several days of hearings, engineers from the civilian contractors that built the rocket offered a cacophony of conflicting and confusing testimony. It did arise from this smoke screen that the lift-off had been delayed while NASA debated the risk of a launch during very cold weather. The first-stage rocket booster had been sealed with rubber gaskets which had a limited tolerance for cold. On the ride from his hotel to the hearings, Feynman had his taxi detour by a hardware store, where he purchased a strip of black rubber. He cut the rubber strip into two short lengths. Next to his microphone in the commission hearing-room, there was a pitcher of ice water. He dropped one piece of rubber into the pitcher before the hearings began.

Again, the highly technical and encoded testimony was unintelligible to the lay public. Finally, the chairman asked Dr. Feynman for his opinion. He said, "I think *this* is what happened." He lifted the length of room-temperature rubber, and flexed it back and forth. Then he reached his hand into the ice water, and held up the piece of cold rubber. He snapped it in two, and gravely affirmed, "*That's* what I think happened." Ultimately the commission concluded that the first-stage booster rocket exploded because the gaskets failed at low temperature.

Feynman wrote a number of books in the science-for-laymen genre. I have read most of them, and once came across a chapter on gravity. He addressed a question about the gravitation of the moon and semi-diurnal tides (two high tides and two low tides each day). The tides are of critical concern to me, as my passion is saltwater fly-fishing. Feynman's chapter included a stylized image of the moon, the earth, and its oceans. See illustration 1, below. Notice that there are two bulges in the earth's oceans. One bulge is displaced directly toward the moon's gravitation. The other bulge is on the opposite side of the earth, directly away from the moon.

I continued to search for the answer by questioning all sorts of experienced mariners, sailors, offshore fishermen, and shrimp boat captains. People started to avoid me at my local marina. All that I learned was that the world is full of people who use the tide tables every day, but do not understand the forces of nature that generate the tides.

Finally, I got my answer at a social gathering, which took place in the evening on board a sailboat. The host had the clever notion to invite an astronomer who would describe the heavenly constellations for the guests, much as you might hire a magician to entertain at a party. As luck would have it, the sky was completely hidden by clouds, and the astronomer was left to his own devices. It is not everyday that you are in the company of an astronomer, so I took this opportunity to ask my question once more. This time the answer was, "That's simple," and he proceeded to draw the bulge of water away from the moon on a cocktail napkin, and easily provided a lucid and satisfying solution.

It *is* a fact that there is a vertical displacement of the earth's oceans in the direction directly opposite the moon, as shown in illustration 1. It *is* this second bulge in the waters that explains the enigma: one moon overhead every twenty-four hours, one high tide every twelve hours. Don't worry if the fiendish obsession is already upon you. By the end of chapter two, you will have the answer that will exorcise this demon.

After I was given the answer to this riddle, I soon began a study of the tides in earnest. The "one moon — two tides" problem was soon replaced by other annoying tide patterns. In my local waters on the coast of northeast Florida, the twice-daily high tides (semidiurnal tides) are equal height on some days, and very unequal height on other days. Again, I interrogated friends who are fishing guides and sailors. Again, I learned that the mariners who depend on tide tables misunderstand the flood that floats them over the shoals and brings them the fish. By now, I had

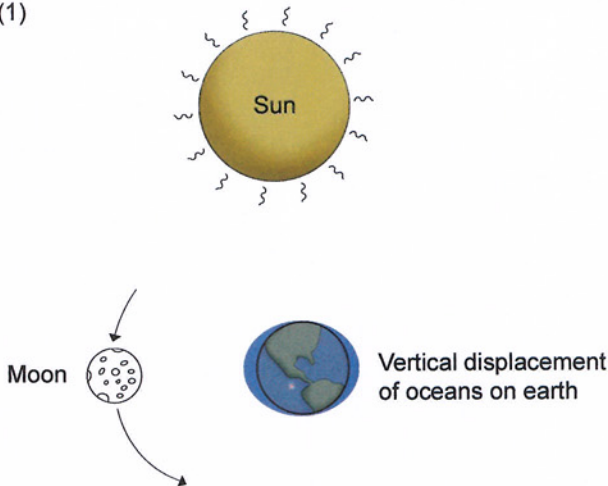
gained access to a local college library and befriended a professor of physical oceanography. I could not find any thorough discussion of the tides on earth within any one sourcebook written for laymen. In order to expedite the process, I asked the oceanography professor for the title of such a book. To my surprise, he told me that there was no such comprehensive text for laymen. And so, naturally, I decided that the only thing to be done was to write one myself.

The answers started coming more easily. But, every time I thought that I was thoroughly knowledgeable, I would encounter another incomprehensible tide table. On a trip to the Gulf of Mexico, I was dismayed to learn that there is only one high tide each day in Panama City, Florida, only two hundred and fifty miles from Jacksonville, Florida, which has semidiurnal tides. To make matters even worse, the tables in Naples, Florida, inform boaters of one high tide in twenty-four hours on Monday, for example, and then two high tides on Friday of the same week! So, it was back to the library to solve two more pieces of the puzzle. All of this reminds me of playing golf — every time you feel competent the damnable thing makes you humble again (It also reminds me of the time we tried to bring down bats with a shotgun — but, that's another story).

Eventually however, the mysterious tables yielded their secrets. I found that the tides are not as chaotic as the weather. You can enter the barometric pressure, air temperature, humidity, and wind velocity into a computer, but you will still only have about a sixty percent chance of predicting the weather next weekend, three days away. By learning the forces of nature that create the tides, you can enter data into a computer and generate a reliable tide table for next year. The forces of nature that cause the tides are finite, logical, and accessible to analysis and comprehension by every mariner. Some tide patterns are complex, but they are not mysterious. The formulas for the tables are not confined to mythical Neptune's submarine cave. They are not even stamped

Uncharacteristically, Feynman's explanation failed to satisfy. I was left with this irksome image of the ocean bulging up away from the moon for no apparent reason. This created one of those urgent and obsessive mental specters that haunt you — like a name you should remember, but cannot. I had no doubt that this fact was accurate because of the source. Furthermore, it was clear that this would explain two high tides per day; since the earth revolves around each twenty-four hours, any given point on the earth's surface would necessarily pass under the two bulges daily. However, I was left to obsess over the explanation, and as my wife will attest, I am fiercely obsessive.

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I began to ask professional saltwater fishing guides and yachtsmen why there was a displacement of the earth's oceans directly away from the moon which caused the semidiurnal tides. Some of them informed me that this simply was not possible, and obviously incorrect. I sided with Feynman, the Nobel laureate. Other experts were sure that the gravitation of the sun caused the mysterious second bulge in the waters. I knew that this was not the case, as I was also researching the subject in the library.

“Top Secret” in a laboratory at Wood’s Hole. All tide tables make sense, and anyone who can set a sail or set a hook has the sense to understand them.

A word to the wise: read on patiently. Recall the last time that your vessel was on a sandbar. After the first hour, the tide was rising inch-by-inch, but you didn’t feel any less aground (either you are afloat, or you are not afloat). You will be able to explain all tide tables after the last chapter, and not before. This is one of those complex subjects that require a gradual accumulation of facts, until suddenly you are no longer aground.

Science does not need to be obscure to laymen. Before we move on to our topic, the variety of the tides on earth, here is one last example of how it is possible to gain a profound understanding of nature without mathematics, and without the arcane abstraction of advanced science. Buckminster Fuller was one of the great problem solvers of the twentieth century. He was an innovator who found new solutions to old problems. One of his contributions to structural engineering was the geodesic dome. One evening he was sitting before his fireplace, enjoying the warmth of the burning logs with his five year old granddaughter. The little girl asked him, “Granddad, what *is* fire?” Without hesitation he replied, “Those logs came from trees. For many years the bright, warm, yellow sunshine was taken into the leaves of the tree, and the tree stored the sunshine in the wood. Now, we are letting that same bright, yellow warmth back out of the logs and into our house.” Buckminster Fuller once said, “When I am looking for a solution to a problem, I never think of beauty. I only think of how to solve the problem. However, when I am finished, if the solution isn’t beautiful, then I know that it is wrong.”

It is time to invoke the spirit of Richard Feynman, or at least resolve to follow his example. Trust me, the libraries are full of books and chapters on the tides reduced to calculus. To really understand this subject, what is needed is something more like a conversation.