**Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Period:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

 **Scientists find Belichick’s explanation plausible Due: Friday, Oct. 9th**

Coach’s explanation for underinflated footballs finds local supporters

**By Felice J. Freyer** GLOBE STAFF  JANUARY 26, 2015

It’s basic physics, folks.

Four of the Boston area’s best scientific minds, zeroing in on the controversy over the Patriots’ use of underinflated footballs, agreed: If you take a ball from a warm place to a cool place, it will lose air pressure.

“Professor Belichick got it exactly right,” said Richard P. Binzel, professor of planetary science at MIT, referring to the Patriots’ coach, Bill Belichick. On Saturday, Belichick blamed “atmospheric conditions” for the lower-than-required air pressure in 11 out of 12 Patriot footballs in the team’s 45-7 win over the Indianapolis Colts a week ago. Belichick said the game balls had been inflated to the regulation 12.5 to 13.5 pounds per square inch and then got softer in the 51-degree air.

Although not all were ready to endorse the Patriots’ theory, the scientists contacted Sunday agreed that the team’s explanations do not defy the laws of nature. “Everything they said doesn’t seem impossible to me,” said James Bird, an assistant professor of mechanical engineering at Boston University. “Based on simple ideal-gas-law calculations, I would not be surprised if the Patriots are vindicated. That said, there are many unknowns that can make small differences. . . . ”

Binzel said the basic facts apply everywhere. “If you take a football at room temperature and take it outside to a cold playing field, the ball pressure will go down every time,” he said. “This is true not just at Foxborough but at every playing field, whether here on earth or all the way out to Pluto.” Binzel calculated that a 5 to 10 percent dip in temperature could bring about a drop of 0.5 to 1.5 pounds per square inch, or psi, in a ball’s air pressure. As for reports that the pressure had dropped by as much as 2 pounds per square inch in some of the balls, Binzel said that “there are a lot of fuzzy numbers” being talked about, and the accuracy of the meters used to measure the footballs is unknown.

Softer footballs are thought to be easier to handle, and the NFL is investigating whether the Patriots deliberately sought an advantage by underinflating the balls.

In his press conference Saturday, Belichick explained that the team had conducted a simulation to determine how the air pressure could have dropped. Along with cooler temperatures, he also offered another factor: The team routinely rubs the balls to break them in, a process that he said can raise the air pressure by heating the ball. Then, he said, the pressure could drop once the balls were turned over to the referees.

Michael J. Naughton, chairman of the physics department at Boston College, called the ball-rubbing argument “technically possible.” “If there’s enough friction, it could change the pressure,” he said. If the pressure measurements were taken soon after this “rubdown,” the balls would be starting out warmer than room temperature, making for a steeper drop in temperature. “I’m not forming any opinions on what happened,” Naughton added. But there is no question that temperature affects pressure, and every football on every football field in history has lost pressure when brought from a warm place to a cooler one, he said.

L. Mahadevan, a professor of applied mathematics, physics, and biology at Harvard, also found Belichick’s argument within the realm of possibility. “If the ball was just at regulation pressure indoors after the players had worked with it, it very well could depressurize a little — but that depends on the temperature difference, all other things being equal (which may not be the case),” he wrote in an e-mail.

Mahadevan estimated that a drop from 80 degrees to 53 degrees would cause the pressure to fall from 12.5 to 11.1 pounds per square inch. Mahadevan’s calculations explain only a small drop in pressure, but not one as great as the 2 pounds per square inch that had been reported. But Bird points out that only small differences are at play, and the measurements are not precise enough to draw conclusions. “If it lost 5 psi, I think this would be a very different conversation,” he said.

Under NFL rules, each team supplies their own footballs to the game. The Belichick explanation suggests that the Colts, who have not faced similar questions, may have used balls with higher air pressure.

The Patriots are preparing to face the Seattle Seahawks in Sunday’s Super Bowl, even as the air pressure controversy that has come be known as Deflategate continues among fans and scientists.

At least one attempt to reproduce conditions on the football field seems to support the Patriots. HeadSmart Labs, a Pittsburgh research company working on preventing head injuries from sports, said that it conducted a study that found weather and field conditions alone could have lowered the pressure by as much as 1.95 psi.

“We took 12 brand-new authentic NFL footballs and exposed them to the different elements they would have experienced throughout the game,” said Thomas Healy, founder of HeadSmart Labs, in a press release. “Out of the 12 footballs we tested, we found that, on average, footballs dropped 1.8 psi when being exposed to dropping temperatures and wet conditions.”

Meanwhile, Bill Nye the Science Guy, who has become a minor celebrity for his ability to make science understandable to the masses, couldn’t help but weigh in. He told “Good Morning America’’ that Belichick’s explanation about rubbing the footballs did not make sense. But Nye added: “I cannot help but say, Go Seahawks.”

As for the Boston-area professors, could they be influenced by their football allegiances? They all said no. Naughton is a lifelong Buffalo Bills fan, but said, “My answers to any of these questions don’t change regardless of whether I’m a fan or not.” Mahadevan does not follow football at all. Bird says he will probably watch the game but is not passionate about it. And Binzel acknowledges being a Patriots fan, but notes: “The laws of physics know no fandom. The laws of physics play no favorites.”

1. What happens to a football when it is taken from room temperature to a cold outdoor playing field? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. What happens to the air molecules inside of the football when the temperature is lowered? How does this relate to pressure? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. “The team routinely rubs the balls to break them in, a process that he said can raise the air pressure by heating the ball.” Explain using what you know about heat transfer and pressure to explain how this is possible. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
4. If you were to design an experiment to test Belichick’s theory, what would be the manipulated variable? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Responding variable? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
5. Make a claim as to whether you think the Patriots should be penalized. Use evidence from the text ONLY in your claim. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
6. What does the article mean when it says, “The laws of physics know no fandom. The laws of physics play no favorites.”? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_