MEASUREMENT

A hammer and nails are just the tools to measure Earth's axial tilt

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A hammer and nails are just the tools to measure Earth's axial tilt

The correct scientific answer to, 'How do the seasons occur?' would be that they are caused by the axial tilt of the Earth. The axial tilt of the Earth causes the seasons, while seasonal changes occur due to the orbital motion of the Earth round the Sun. Studies in astronomy education show that students have many misconceptions about the reason why seasonal changes occur (for example: when the Earth is closer to the Sun it is summer, when farther away it is winter; the seasons occur because the Earth is orbiting the Sun, among others) [1, 2].

When I asked students on an astronomy course how one can measure the axial tilt of the Earth, they could not find or suggest any appropriate method. After searching in books and on Internet sites related to astronomy, they came up with the information that the axial tilt of the Earth creates the seasons, but they also pointed out that, although some sources, for example *Wikipedia*, discussed this subject in detail, they could not find any information about how to measure the tilt. Thereupon, I asked myself the question: 'How can I develop a simple yet instructive activity that will help students understand the Earth's axial tilt?'

When the Earth revolves round the Sun, its axial tilt remains unchanged. In this case, the length of the day and night when the time is exactly 12 noon locally becomes equal on 21 March and also on 21 June (the longest day of the year); however, over a period of three months, a vector pointing from the Earth to the Sun turns precisely about the axial tilt of the Earth. Therefore, if it is possible to measure this angle over a given period, we can measure the axial tilt of the Earth. The activity described here is designed to find this angle.

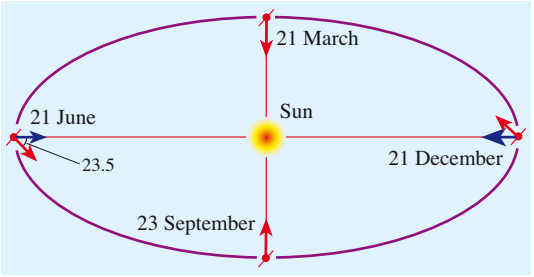
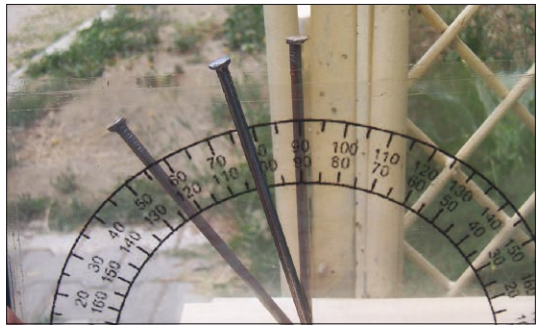


Figure 1. *Over a period of three months, a vector pointing from the Earth to the Sun turns precisely about the axial tilt of the Earth. Therefore, if it is possible to measure this angle over a given period, we can measure the axial tilt of the Earth.*

It is possible to better explain this situation using figure 1. On 21 March the red vector is directed at the Sun. After a quarter turn anticlockwise the red vector no longer points at the Sun due to its axial tilt. It deviates by about 23.5°. The angle measured on 21 June between the red vector, which was pointing at the Sun on 21 March, and the blue vector pointing at the Sun on 21 June gives us the axial



Clockwise from above. **Figure 2.** *On 21 March a reference nail (perpendicular to the plane) is driven into a wooden board. A second nail is fixed next to the reference nail at an angle that produces no shadow.* **Figure 3.** *On 21 June at 13:00 (because of daylight saving time, solar noon is at 13:00), a third nail was driven into the same board at an angle that produces no shadow.* **Figure 4.** *The angle between the two nails driven on 21 March and 21 June yields the axial tilt of the Earth.*

tilt from a perpendicular axis to Earth's orbital plane about the Sun. This experiment can also be repeated using the three month periods 21 June–23 September, 23 September–21 December and 21 December–21 March.

Measuring the axial tilt of the earth

This method involves a simple measurement performed on 21 March when the length of the day and night is equal, and on 21 June, the longest day in the year. We made the measurement on 21 March, 12:00 local time in the coastal town of Altınoluk in Balikesir, Turkey, by driving a reference nail (perpendicular to the plane) into a wooden board. A second nail is fixed next to the reference nail at an angle that produces no shadow (figure 2).

On 21 June at 13:00 (because of daylight saving time, solar noon is at 13:00), a third nail was driven into the same board at an angle that produces no shadow (figure 3). The angle between the two nails driven on 21 March and 21 June yields the axial tilt of the Earth (figure 4).

The angle was measured using a protractor. The result was 22º. A more precise measurement using the graphic editing software Adobe Photoshop was made. (It was not possible to drive each nail at the same point; therefore a picture of the nails was slid into same point using Photoshop). A value of 22.8º was obtained using Adobe Photoshop. This is close to the known value of the Earth's tilt of 23.5º.

There are experimental errors due to the inaccuracy of using a nail hammered into a board. However, I think that this activity is simple, fun and instructive for both students and teachers.

Teachers must warn their pupils about the possible risks of using nails and a hammer and pay special attention to safety As an alternative, using toothpicks and Styrofoam board would minimize the risk of serious injury.

Acknowledgements

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