How fast does Santa Claus travel? A festive approach to teaching average speed

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Every Christmas I seem to get the same email forwarded by my friends about the physics of Santa Claus and how fast he has to travel to deliver presents, but I have no idea how old the email is or who created it. The email, which can be found on numerous websites (Rozek, 2008; Geary, 2002), shows a very brief calculation on the speed of Santa Claus, payload and energy generated due to air resistance. At the end of the webpages, the authors go on to say that Santa Claus cannot possibly exist and will burn up owing to the heat generated from air resistance and, as one of the authors says, '*by now he might have gone to that big toy factory in the sky…*'

The method of calculating the average speed of Santa Claus intrigued me and I wondered what my students would make of it. So one lesson I set it as a task for my students and it was interesting to see the methods and the assumptions that they used.

In this article I present a lesson idea to teach average speed through the physics of Santa Claus and I then present a calculation, based on recent population data, of the average speed that Santa Claus needs to travel at to deliver presents on Christmas Eve.

Background

This activity provides students with an opportunity to practise using the formula

$$\text{average speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

This formula should be familiar to students in secondary school and they should have some experience of applying it. The challenge in this activity is for the students to estimate the distance travelled and the time taken to deliver the presents. To do this, the students will need to make assumptions and learn how to search for information and evaluate data. To give an idea of the assumptions that students will need to make, here is a list of common assumptions:

1. how many children Santa Claus delivers presents to
2. how far apart each household is
3. how long Santa Claus has to deliver presents
4. how long it takes Santa Claus to deliver presents to each household
5. how many naughty children do not get presents.

Figure 1 The author dressed as Santa Claus

The list above gives the simplest assumptions that students need to make so that they can calculate the average speed of Santa Claus. Depending on the ability level of your class, the assumptions can take into account more detailed factors such as the average number of children per household, how many presents Santa Claus can carry at one time, the time it takes to go down the chimney, and even toilet breaks.

Preparation

This activity is best carried out in groups, preferably in groups of four, as this allows students to interact with each other as they discuss their assumptions and find information.

To prepare for this activity, the teacher needs to take into account the ability level of the class. Even though the formula for average speed is straightforward, the assumptions that the students will need to make may not be. In lower ability classes, they may not be used to making assumptions and may have difficulty getting started. It may be advisable to prepare a worksheet with the assumptions listed above and asking the students to find answers to them. More able students will be able to make their own assumptions and may only need a little guidance from the teacher through a few questions.

This activity can be done without the internet but the students will then not be able to search for information online and this will limit the number of assumptions that they use. With internet access, the students will be able to collect information for a wider variety of assumptions and, by using real information and statistics, make the activity more interesting.

Thought needs to be given to how the students will show their average speed of Santa Claus and the assumptions made. It is important that students are given the opportunity to present these to the whole class. There are several options that I have tried.

- posters
- oral presentation
- *PowerPoint* presentation.

The choice of presentation is largely dependent on the time available. Oral presentations are the quickest as the students will talk about their assumptions and use the whiteboard to illustrate their points. A poster will give those students that are weak at oral presentations an opportunity to show their average speed and assumptions in a visual way and this also has the advantage of being able to be completed as homework if time becomes an issue. A *PowerPoint* presentation is an excellent opportunity for students to use ICT to present their information but this will take the longest time to complete.

Students' responses

I have completed this activity several times with my students: every time they have enjoyed the challenge of finding Santa Claus's average speed, and making posters has been the most enjoyable method of communicating their calculations. I have found that the students have had no difficulty in making assumptions about the distance travelled but they have difficulty in estimating the time that Santa Claus has to deliver presents. The time zones and the rotation of the Earth seem to present the biggest conceptual difficulty, so it is important for the teacher to be able to explain these when the issue arises. I have done this activity with my students for 4 years now and I am always amazed by their answers. I

Figure 2 Students accessing the internet via computers and their mobile phones to search for information

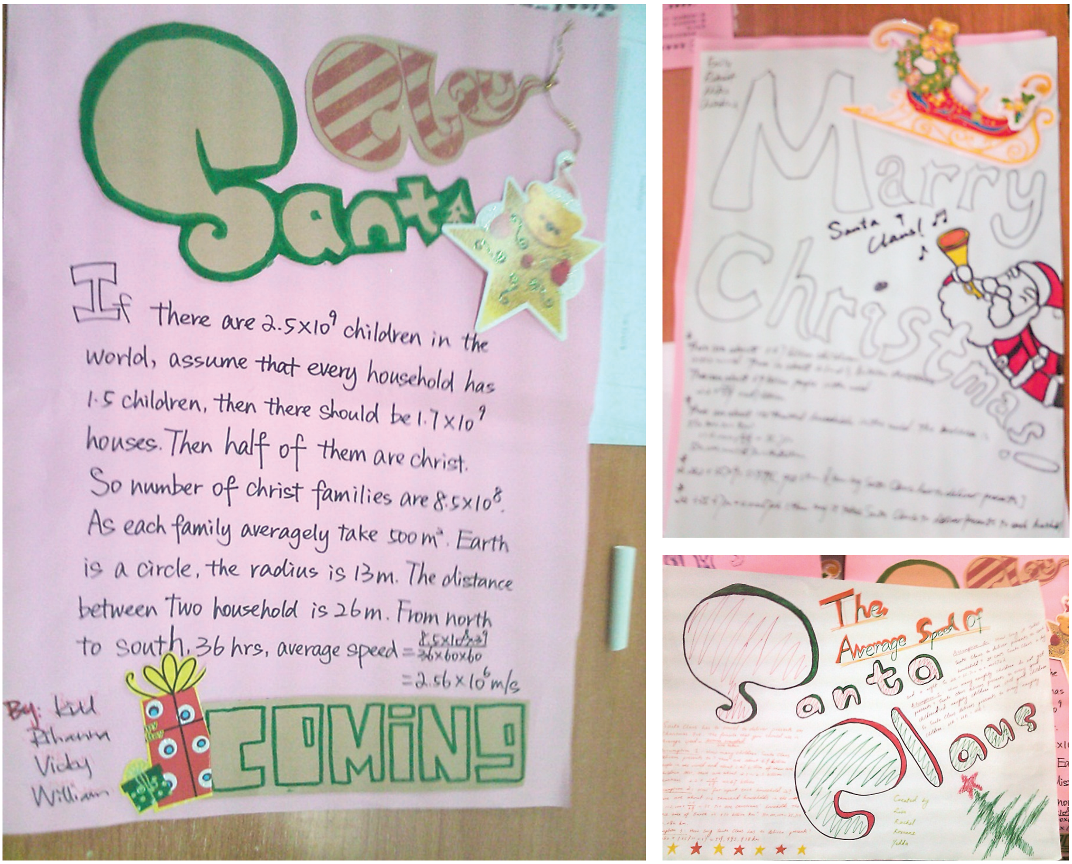

Figure 3 Examples of students' posters

have had average speeds ranging from 300 m s^{-1} to 1.6×10^{10} m s^{-1} and the students made no connection with the speed of light.

Extension work

Average speed will be covered several times during a student's time at middle school and high school. Naturally doing the same activity will become dull even though older students will be able to make more detailed assumptions and calculations. This activity has the potential to be expanded to calculate other aspects of kinematics such as acceleration, mass of the presents and kinetic energy.

The calculation of Santa Claus's average speed

To help encourage teachers to use this teaching idea, one possible calculation for Santa Claus's average speed is given in Box 1. Where possible, the most recent data available have been used. All the references include the website address, which will make it easier for the teacher and students to access the information.

Conclusion

In this article I have suggested a theme of teaching average speed through the physics of Santa Claus and I have presented a calculation of how fast Santa Claus has to travel in order to deliver presents on Christmas Eve. This activity not only requires students to do a calculation but also requires them to make assumptions and to search for and evaluate information. The calculation for Santa Claus's average speed shows that he must travel, with these assumptions, at approximately 4 600 km s^{-1} in order to complete his deliveries on Christmas Eve. This is based on the latest statistics on populations available from the Population Reference Bureau. I would recommend that you do not do this activity with nursery or primary

BOX 1 A sample calculation of Santa Claus's average speed

Distance travelled

Calculating the distance travelled proves to be quite difficult as many assumptions need to be made and often generalised across the world. Most calculations are rounded to two significant figures.

In calculating the distance that Santa Claus travels in delivering the presents, these steps have been taken:

1 the number of children in the world
2 the number of children that Santa Claus delivers to
3 the distance between each household
4 the total distance that Santa Claus travels.

1 The number of children in the world

According to the Population Reference Bureau (2011), the world population reached 7 billion in 2011 and 37% of them were children (children are defined as being under 15 years of age).

$$\text{number of children in the world} = 0.37 \times 7\,000\,000\,000 = 2\,600\,000\,000$$

2 The number of children that Santa Claus delivers presents to

To calculate the number of children that Santa Claus delivers to, the percentage of the world that celebrates Christmas needs to be found. Christmas is a Christian festival but it is also celebrated by non-Christians. Approximately 33% of the world's population is Christian (Wikipedia, 2012a).

$$\text{number of Christian children that Santa Claus delivers presents to} = 0.33 \times 2\,600\,000\,000 = 860\,000\,000$$

Based on a *USA TODAY*/Gallup poll taken in 2008, 93% of Americans celebrate Christmas but 80% identify with a Christian faith. This means that an additional 13% of Americans celebrate Christmas despite being non-Christians (merry-christmas.org.uk, 2012). Assuming this figure for the whole world,

$$\text{number of non-Christian children that Santa Claus delivers presents to} = 0.13 \times 2\,600\,000\,000 = 340\,000\,000$$

Adding these together gives

$$\text{total number of children that Santa Claus delivers presents to} = 1\,200\,000\,000$$

Assuming that all children are good (well, they will be if they know something is in it for them), Santa Claus will deliver to all of these children.

3 The distance between each household

There are approximately 2.5 children in every household (Population Reference Bureau, 2010)

$$\text{number of households} = 1\,200\,000\,000/2.5 = 480\,000\,000$$

The Earth has a surface area of 510 000 000 km^2 (Wikipedia, 2012b) and, assuming that the households are evenly distributed,

$$\text{area of each household} = \frac{510\,000\,000}{480\,000\,000} = 1.1\ \text{km}^2$$

(The assumptions that there are 2.5 children per household and that households are evenly distributed leads to an overestimation of the distance that needs to be travelled as not all families have children, a lot of households are concentrated in urban areas and, of course, essentially all households are on land as opposed to the oceans.)

Assuming that each household occupies a square area of land on the surface of the Earth and that the distance between each household will be the square root of the area,

$$\text{distance between each household} = \sqrt{1.1} = 1.05\ \text{km}$$

4 The total distance that Santa Claus travels

The total distance that Santa Claus has to travel is

$$\text{total distance} = 1.05 \times 480\,000\,000 = 504\,000\,000\ \text{km}$$

Time taken

We assume that Santa Claus distributes gifts when children are sleeping, from 10 pm to 5 am, so for 7 hours. Owing to the Earth's rotation, there is a time difference of up to 24 hours between different time zones, so we can therefore say that Santa Claus has 31 hours to finish his work (assuming he logically travels from east to west).

$$\text{time taken} = 31 \times 60 \times 60 = 110\,000\ \text{s}$$

Average speed

The final calculation is

$$\text{average speed} = \frac{504\,000\,000}{110\,000} = 4\,600\ \text{km s}^{-1}$$

This is the simplest approach that I could use to calculate the average speed of Santa Claus and the above calculation provides a framework with which to expand it further.

school students, as finding out that Santa Claus cannot exist could cause some emotional distress.

Whenever I do this activity, I add a little bit more fun to it by dressing up as Santa Claus and giving out sweets to the students.

References

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Helpdesk

Helpdesk has not featured in recent editions, but we have some new questions and would be interested in answers to these and some in earlier editions which readers might have reflected upon. We include one such answer from a question posed a year ago.

Readers' replies

Where does the energy go when braking?

In the June 2011 SSR*, Malcolm gave an account of some of the difficulties which pupils and teachers understandably experience with this complicated problem.*

In his contribution to this discussion, Ian Galloway makes the important point that such phenomena can be analysed in different frames of reference (*SSR* December 2011).

In this case, however, I advise against analysis from the point of view of the wheel as this is an accelerated frame of reference and its use involves very difficult concepts that are best avoided at school level.

From an astronomical point of view, even the viewpoint of the road is not perfect but it is ideal for the present purposes. The road does not do work upon the wheel since the force it applies is in the opposite direction to the displacement. It is the car that applies a force by the axles upon the wheels, which in turn apply a force to the road. These forces are in the direction of motion and so do work, causing the dissipation of energy.

In this discussion, the wheels are assumed to be locked, in which case there will be movements within the car resulting in increased internal energy in several places (perhaps including the occupants).

Ian Galloway also considers a car hitting a barrier. There will then be great structural damage to the vehicle, each part of which will do work on the part in front of it as it crumples. The car is not a rigid body and the centre of mass moves forward during that collision even if the front stops dead.

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