Measuring the Thrust of a Balloon Car

Aims
To demonstrate the forces acting on Bloodhound SSC and explore Thrust as a concept tying in with Newton's Laws of Motion.

Objectives
Build a balloon car
Conduct speed time experiments using the balloon car
Use the results to produce graphs

Materials needed (per group):

- Balloon Car Kit
    - Card Sheet
    - 1 balloon
    - Sellotape
    - 2x Flexi-straws
    - Pencil
    - 2x 4mm dowel, 100mm long
- Scissors
- Ruler
- Tape Measure
- Stop watch
- Calculator
- Graph Paper

Breakdown

Activity	Time
Intro to activity • Students will have been introduced to the forces (including Thrust) that act upon the car as part of introductory presentation. • Relate thrust to Newton's laws of motion and the equation F=ma • Explain that students will be building a balloon car and designing an experiment to calculate the thrust of a balloon • Split the group into teams of 4/5 • Issue each group with materials kit	5
Build balloon car • Encourage some members of the group to build the balloon car • Encourage other members of the group to think about the experiment – what do they need to do	10
Do experiment	5
Plot distance time graph • Get students to plot the experiment results (distance against time) on graph paper	5
Plot velocity time graph • Using velocity = distance/time get students to plot velocity against time on graph paper	5
Plot acceleration time graph • Using acceleration = change in velocity/change in time get students to plot acceleration against time on graph paper • Looking only at the positive acceleration area of the graph get students to calculate an average acceleration	5
Work out thrust using f=ma • Assuming the car weighs 50g (0.05kg) calculate the thrust using F=ma	5
Round up • What have students learned • How much variance in the result between groups? What could this be due to? How could we improve this? • What are the assumptions we have made? Are these reasonable?	5

Introduction

Release an inflated balloon across the room.

Why does the air come out of the balloon?
The stretched elastic wants to return to its original shape and so squeezes the air out.

Why does the balloon move?
The balloon exerts a force on the air and the air exerts an equal and opposite force on the balloon.

Why is it erratic? (Not an easy question to answer)
When released the balloon is bound to have some rotation and the nozzle flaps around so that the force exerted by the air on the balloon is continually changing direction.

Can the balloon be harnessed to provide an engine?
It needs to be tied down to a body so that it can pull the body along. That's what we are going to do with a Balloon Car

The Balloon rocket car is propelled along the floor according to the principle stated in Isaac Newton's third law of motion: "For every action there is an opposite and equal reaction" The balloon pushes on the air, and the air pushes back on the balloon. Because the balloon is attached to the car, the balloon pulls the car along. The jet engine and rocket for BLOODHOUND SSC work on the same principle. The force pushing the car forward is called the Thrust.

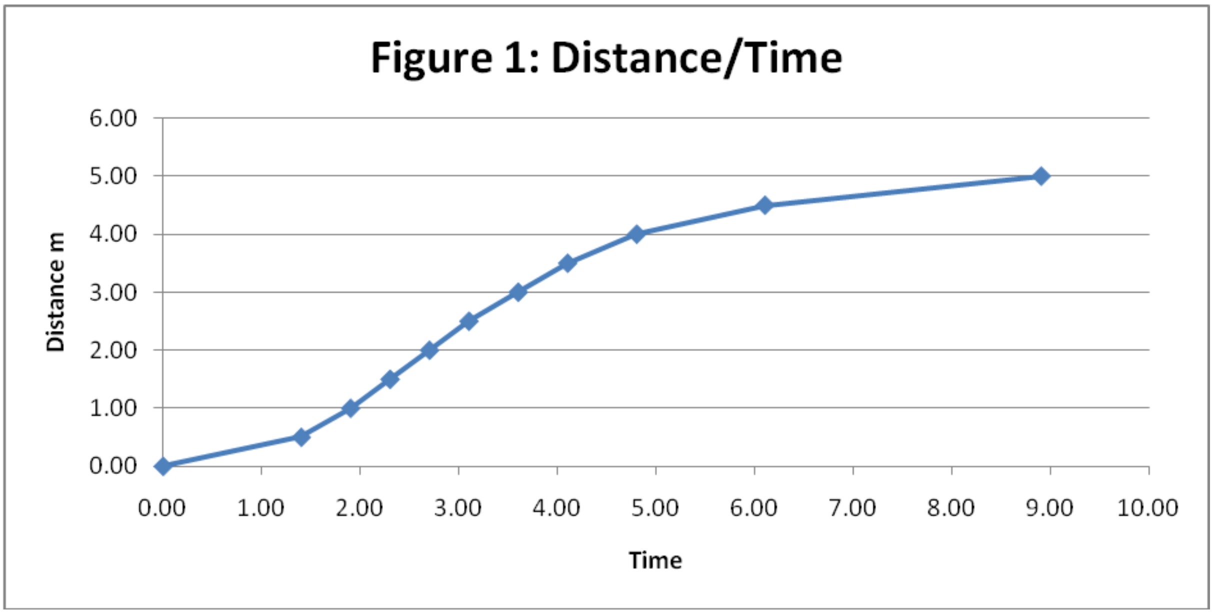
Thrust causes the car to accelerate according to the equation $F = ma$, where m is the mass of the body (Isaac Newton's second law of motion).

In groups of 4/5 students will build a balloon car and devise an experiment to measure the thrust of the balloon.

Some students will be able to devise the experiment without help – other students may need help.

The experiment

1. Students should mark out equal distances and measure the time at which the car passes those marker points. Suggest 50cm (0.5m) intervals (balloon cars will travel around 5m (a table for completion has been provided)
2. Using this data students should be able to plot distance/time, velocity/time, acceleration/time graphs (example graphs are shown in Figures 1, 2 and 3)
3. Using the acceleration time graph students should be able to determine an average acceleration (note: we are only interested in areas of positive acceleration)
4. Assuming the car weighs 50g and using F=ma, students should be able to calculate the Thrust of the balloon in Newtons (be careful of units - Newtons is kg ms^{-2})



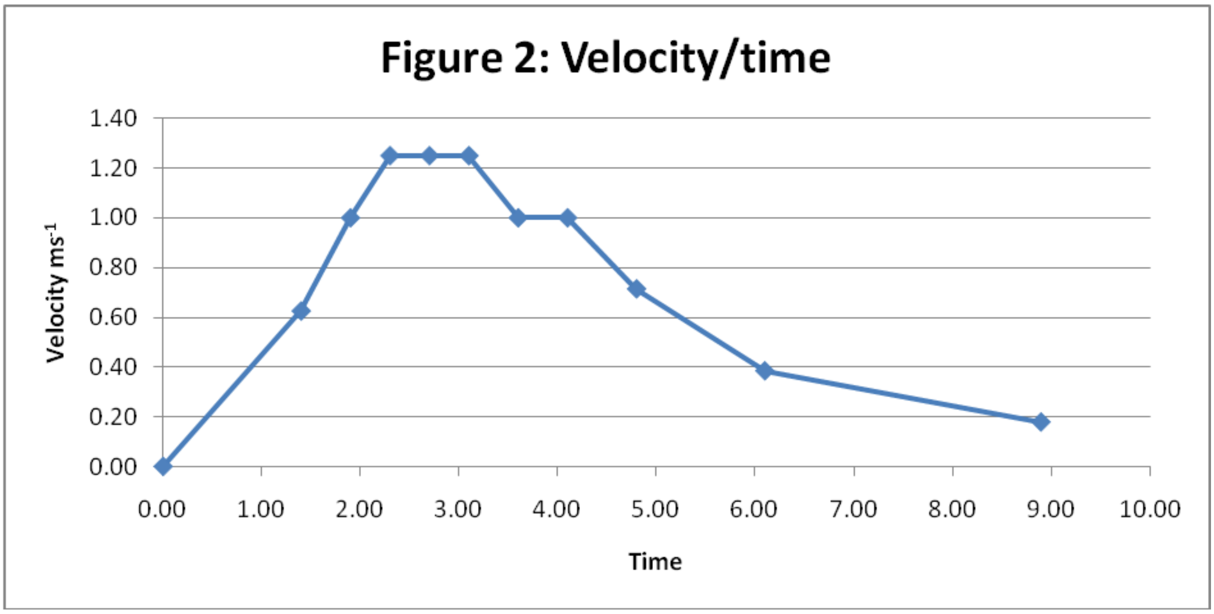


Figure 2: Velocity/time
Velocity ms^{-1}
Time
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00

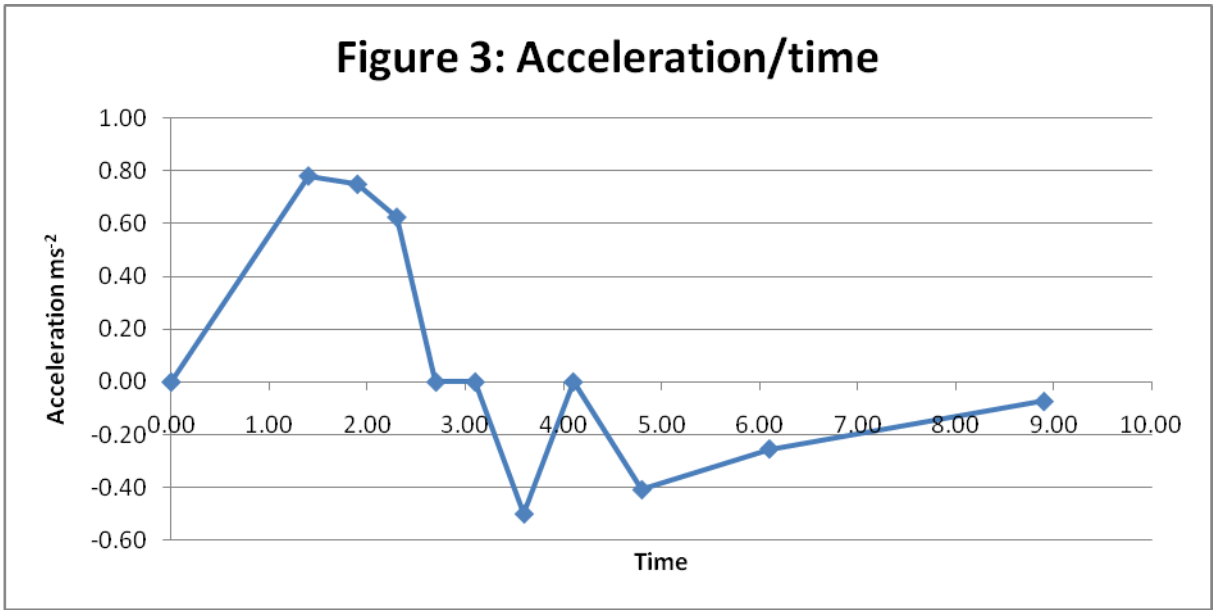


Figure 3: Acceleration/time
Acceleration ms^{-2}
Time
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00

Bloodhound Balloon Car Challenge

Distance (m)	Lap time (s)	Time (s)	Velocity (ms^{-1})	Acceleration (ms^{-2})
0.00				
0.50				
1.00				
1.50				
2.00				
2.50				
3.00				
3.50				
4.00				
4.50				
5.00				

Velocity = distance/time
Acceleration = change in velocity/change in time

Work out thrust using f=ma

Average acceleration can be calculated by taking an average of the positive acceleration values or by looking at how long it takes to get to maximum velocity.

In the above example it took 3 seconds to reach 1.25 ms^{-1}, so the average acceleration by this method is 0.42ms^{-2}

Assuming the car weighs 50g (0.05kg), F= 0.05*0.42=0.02 Newtons

OR you could take an average of 0.00, 0.78, 0.75, 0.63 = 0.54ms^{-2}

Assuming the car weighs 50g (0.05kg), F= 0.05*0.54=0.3 Newtons

OR see extension task

Round up

Ask students to tidy up and return to their sets. Ask students what they have learned? Did they enjoy the session?

Was there much variance in the result between groups? What could this be due to? How could we improve this?

What are the assumptions we have made? Are these reasonable?

Extension Task

Show students the equivalent run profile of the car (see Figure 4)

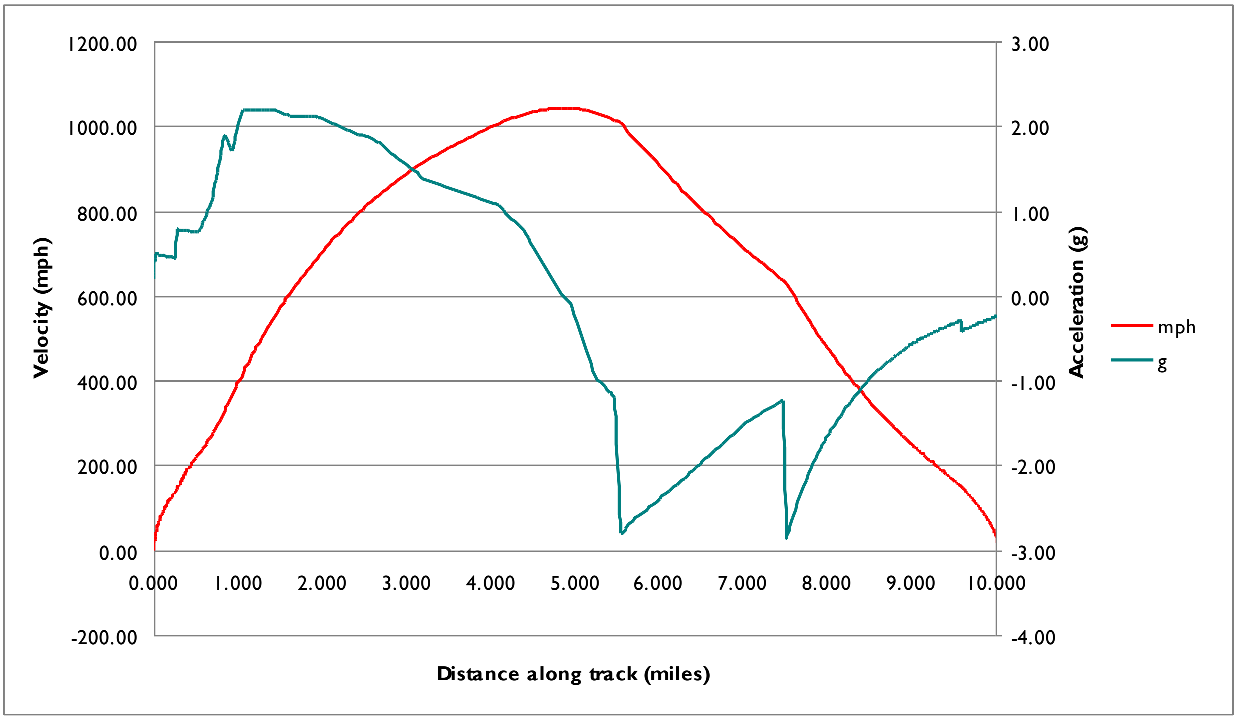


Figure 4

Get students to compare their velocity/time graph with that of Bloodhound. The shape they should get (if the experiment is accurate) is similar - convex on acceleration (acceleration drops off as drag builds up) and concave on deceleration. Peak acceleration should happen early in the run (at low speeds and maximum balloon pressure). Using this peak acceleration means you can calculate the Thrust of the balloon with minimum effect from drag. Using the average acceleration does not

This will also mean that you can discuss with students the convex velocity time curve for the acceleration phase of Bloodhound – the thrust remains pretty constant after the rocket has been fired – it is the drag that changes (proportional to the velocity squared)

Assuming the car weighs 50g (0.05kg), F= 0.05*0.78 (max acc)=0.04 Newtons