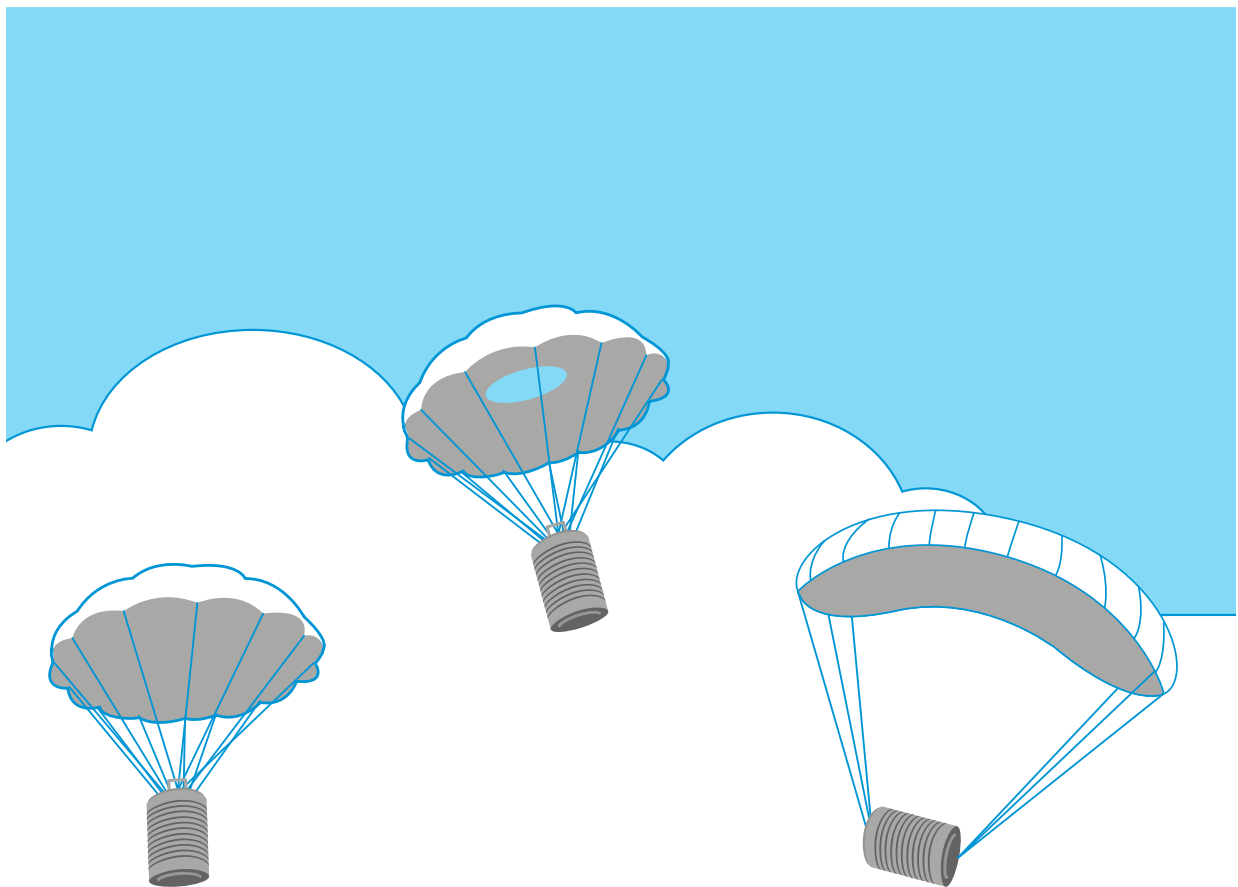
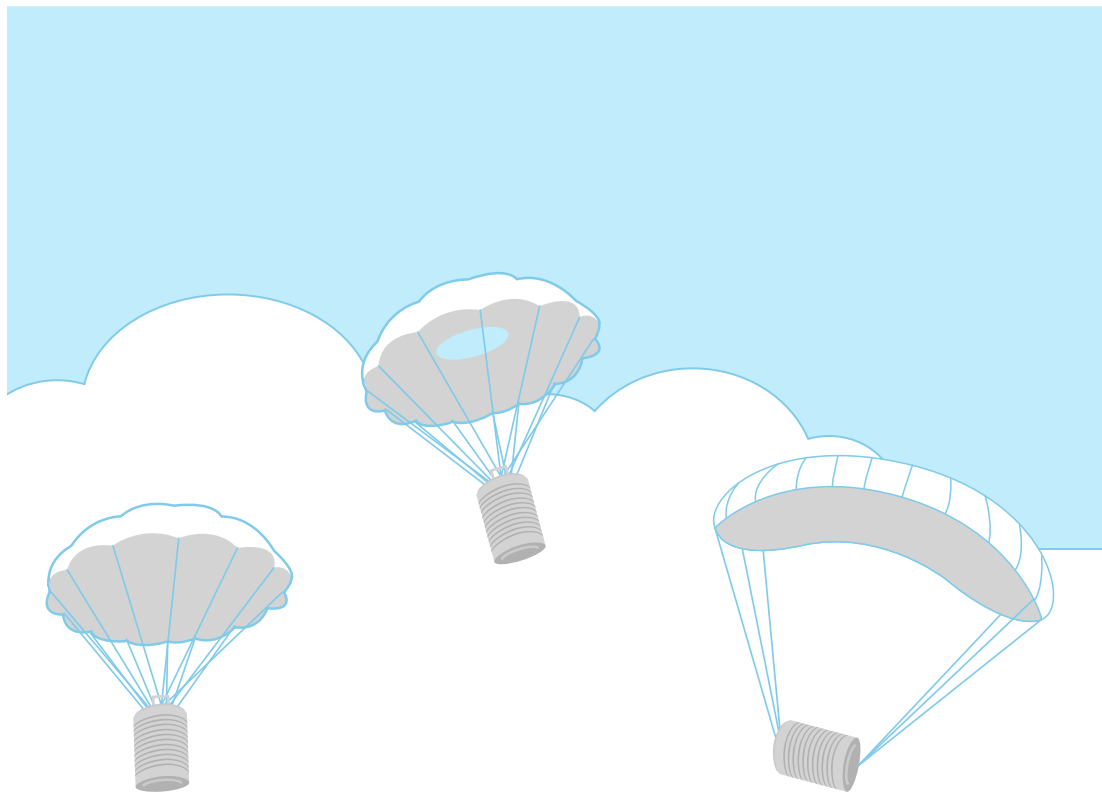


# teach with space

## → DESIGN YOUR PARACHUTE

A guide to landing your CanSat safely





## Teacher guide

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## → DESIGN YOUR PARACHUTE

### A guide to landing your CanSat safely

#### Fast facts

**Age range:** 14-20 years old

**Curriculum links:** Physics - Velocity, acceleration, acceleration due to gravity, terminal velocity

**Complexity:** Medium

**Lesson time required:** 120 minutes

**Supporting documents:** Getting started with CanSat

**Methodology:** Inquiry based learning

**Key words:** Parachute, Drag, Air resistance, Gravity, Weight, CanSat

#### Outline

This resource gives students a brief overview of the different options available when building their CanSat parachute. Students will learn about the underlying physics of parachutes and their design and how to control the speed of their CanSat.

#### Learning objectives

- Understand the difference between weight and mass.
- Identify different parachute types and discuss their design and construction.
- Appreciate why it is important to test a parachute.
- Understand the concept of terminal velocity.
- Represent graphs with correct units and labels.

## → Summary of activities

Summary of activities					
	Title	Description	Outcome	Requirements	Time
1	Free falling	Students complete a simple experiment to explore the concept of terminal velocity.	Students will be able to describe what terminal velocity.	None	25 minutes
2	Parachutes: such a drag!	In this activity students are introduced to the underlying physics of parachute design.	Students will be able to describe the important factors of free fall.	Previous activities	15 minutes
3	The importance of area and shape	A range of parachute designs and the consequences they have on a falling body are discussed.	Students will be able to identify a suitable parachute design for their CanSat.	Previous activities	25 minutes
4	Slow and steady wins the race	A CanSat launch and descent is studied in more detail and students have the opportunity to test their parachute.	Students will be able to plot distance-time and speed-time graphs of CanSat launch and descent.	Previous activities. A parachute to perform a drop-test	25 minutes

## → Introduction

Parachutes are a vital part of any CanSat mission. It could be forgiven that they are often overlooked, given that they are often simple pieces of fabric compared to the complex electronics that lies within the CanSat, but that would be a big mistake! Without a well-designed parachute your CanSat might not have time to complete its scientific objectives, or worse yet, it could crash land!

In this resource, we will explore the underlying physics of a parachute descent and begin to understand the decisions that go into choosing a suitable parachute for a CanSat mission. By the end of the resource you should be confident that you can safely launch and land your CanSat!

## → Activity 1: Free falling

In this activity, students explore the concept of terminal velocity and free fall by completing a simple qualitative experiment, dropping marbles in oil and water. By completing this activity, they will begin to understand the importance of the fluid in free fall situations.

## Exercise

### 1. What is the range of allowed weight for the CanSat?

The allowed range of **weight** is **2.9 -3.4N**. A common mistake here is that students will confuse mass and weight and answer 300-350g!

### 2. The hammer and feather experiment sparks an interesting question, how would the launch of a CanSat differ if it was carried out on the Moon?

On the moon, the gravitational effects are reduced significantly, gravity is approximately  $1/8^{\text{th}}$  the strength! This means that there is much less force acting on the rocket. Many things could happen with a rocket launch on the moon. If the rocket is powerful enough, then it will have enough velocity to escape the moon's gravitational pull and it could go into orbit. Assuming it does not then the descent back to the surface of the moon is also very different. As there is much less air on the moon there is less drag. This could compensate somewhat for the reduced gravitational force and result in a significant descent velocity!

In this question you shouldn't expect detailed quantitative analysis, as the physics understanding required is complex, but you should look for justified thought processes and an understanding of the key differences between the Earth and Moon environments.

### 3. How does the speed of the marble change as it travels down the cylinder?

If the cylinder that the students use is long enough, then the students should be able to identify that the marbles reach a terminal velocity. Initially the marbles accelerate before travelling briefly at constant speed before reaching the bottom of the cylinder.

Again, here the experiment is designed to be appreciated on a qualitative level, the aim is for the students to be able to visually identify that terminal velocity is reached, or approached, during the descent.

### 4. What would you expect to change if you replaced the oil with water? Write down your prediction and then try it out!

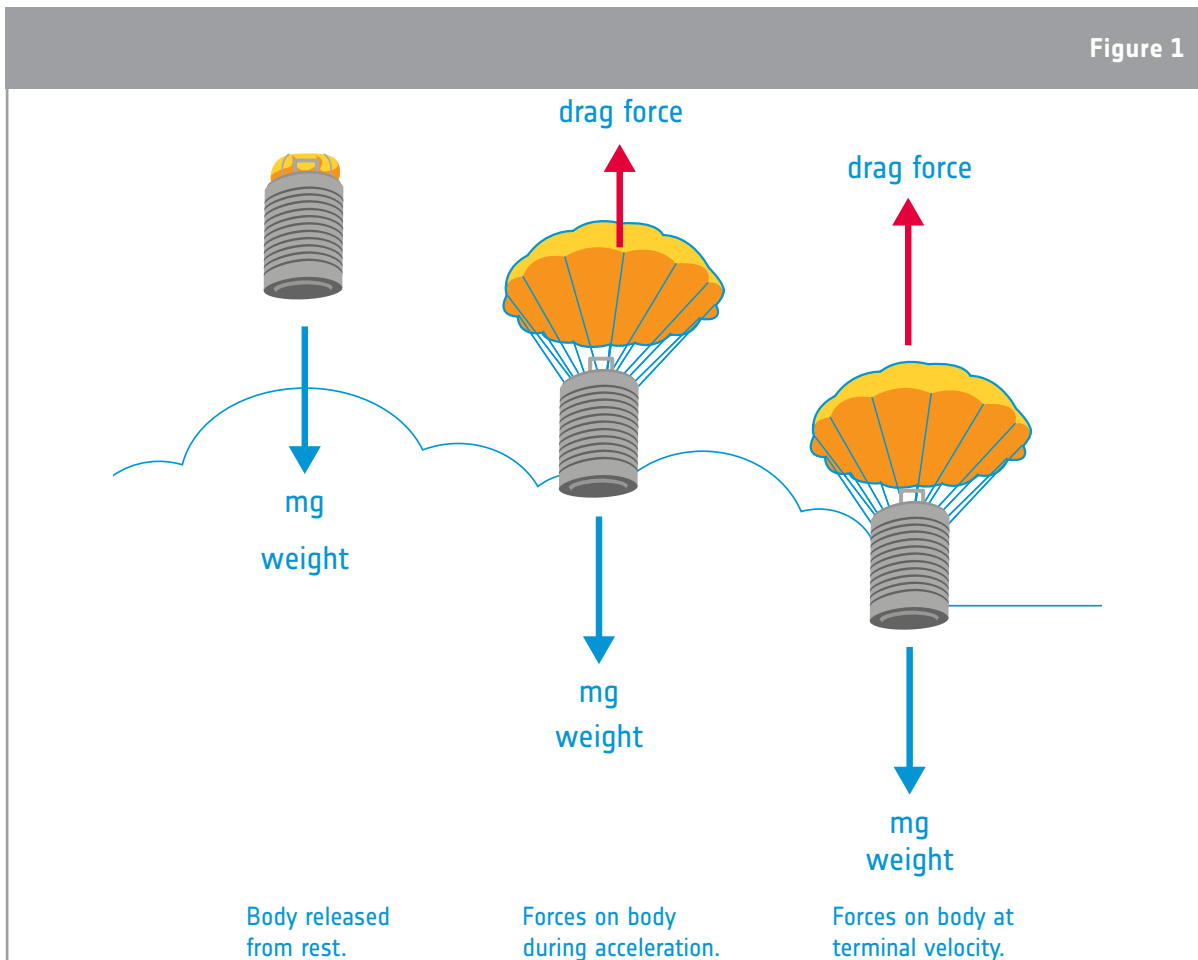
When repeated with water, students should be able to identify an increased descent velocity and a higher terminal velocity. This is due to lower resistive forces from the water compared to the oil.

## → Activity 2: Parachutes - such a drag!

In this activity, students are given an introduction to the underlying physics of parachutes. Students will learn how to calculate the forces acting on a parachute and how to decide on the area they need for their parachute. This can be calculated by considering Newton's second law and balancing the forces acting in a steady-state. It is important to note the simplifications that are made in this calculation.

### Exercise

- Using your understanding from the marbles experiment, label and name the forces acting on your CanSat during its descent on the images below. You should indicate their relative magnitude with the size of the arrow.



↑ The forces on a CanSat during flight.

- Assuming the rocket will launch your CanSat at an altitude of 1000m, according to the required descent rate in the CanSat guidelines, what is the time that should pass between your CanSat being released and landing (neglecting the acceleration period)?

Assuming a distance of 1000m and the restrictions on descent velocity included in the CanSat guidelines ( $8-11\text{ms}^{-1}$ ) students are able to calculate a range of expected descent times.

**Note:** For simplicity, we are neglecting any acceleration period and assuming a steady velocity for the entire 1000m. In practice of course, this will not be exactly the case!

$$\text{As } t = s/v$$

$$t_{\min} = 1000/v_{\max}$$

$$= 1000/11$$

$$t_{\min} = 90\text{s}$$

$$t_{\max} = 1000/v_{\min}$$

$$= 1000/8$$

$$t_{\max} = 125\text{s}$$

## → Activity 3: The importance of shape

In this activity, students are introduced to the main different types of parachute that are commonly used in CanSat projects. Design considerations are discussed, as well as the positives and negatives of the different designs. Links are provided to further resources, where the different types are discussed in more detail.

### Exercise

1. Which factors in equation 3 (on the student worksheet) can be changed along with the design of your CanSat?

The canopy surface area can be changed by making the parachute smaller or larger.  
The drag coefficient can be changed by using a different style of parachute.

2. From the drag coefficients above (Table 1 on the student worksheet), which parachute type will give the slowest descent velocity? Which will give the fastest descent velocity?

Using equation 3, students will be able to identify that the drag coefficient is inversely proportional to the velocity, that is the **higher** the drag coefficient the **lower** the descent velocity – this makes sense!

This means that the hemi-spherical parachute will give the lowest descent velocity whilst the cross and flat parachutes will give the highest descent velocity.

3. The cross design is easy to make, but the descent velocity compared to the semi-spherical design is too fast, what could you do to control this?

By again looking at equation 3 and with their intuition, students will be able to suggest that they could overcome this problem by **increasing the area of the parachute**.

4. Make A the subject of equation 3.

$$\text{Add } \frac{1}{2}C_D\rho Av^2: \quad mg - \frac{1}{2}C_D\rho Av^2 = 0$$

$$mg = \frac{1}{2}C_D\rho Av^2$$

$$\text{Multiply by } 2: \quad 2mg = C_D\rho Av^2$$

$$\text{Divide by } C_D\rho v^2: \quad A = \frac{2mg}{C_D\rho v^2}$$

Students can then use this equation to calculate the area of parachute required to give a given descent velocity.

5. Now that you have the equation with area as the subject, calculate the range of areas allowed for the different types of parachutes we have discussed, assuming a CanSat mass of 350g. You can fill in the values in the table below (Table 2 on the student worksheet).  
Remember: The range of allowed velocity is  $8-11\text{ms}^{-1}$ .

Students should use the equation they found in exercise 4 to answer this exercise. To calculate the minimum and maximum areas, they can use the bounds given on the descent velocity.

Table 1			
Parachute type	Drag coefficient	Minimum area (m <sup>2</sup> )	Maximum area (m <sup>2</sup> )
Hemispherical	0.62	0.08	0.14
Cross	0.8	0.06	0.11
Flat, hexagon	0.8	0.06	0.11

It is important to note that these figures are for our simplified physical expression, in practice students should demo their parachute in order to determine the minimum and maximum areas allowed.

6. If you change your parachute from a cross parachute to a hemispherical parachute, how should you change the area of the parachute, so that it falls at the same speed as before?

The final exercise in this activity helps to solidify students' understanding. They should be able to identify that changing from a cross to a hemispherical parachute is an **increase** in drag coefficient, and therefore to maintain the same descent velocity a **decrease** in parachute area is required. Students can go one-step further and quantify the required decrease by using the equation, but this is not necessary.

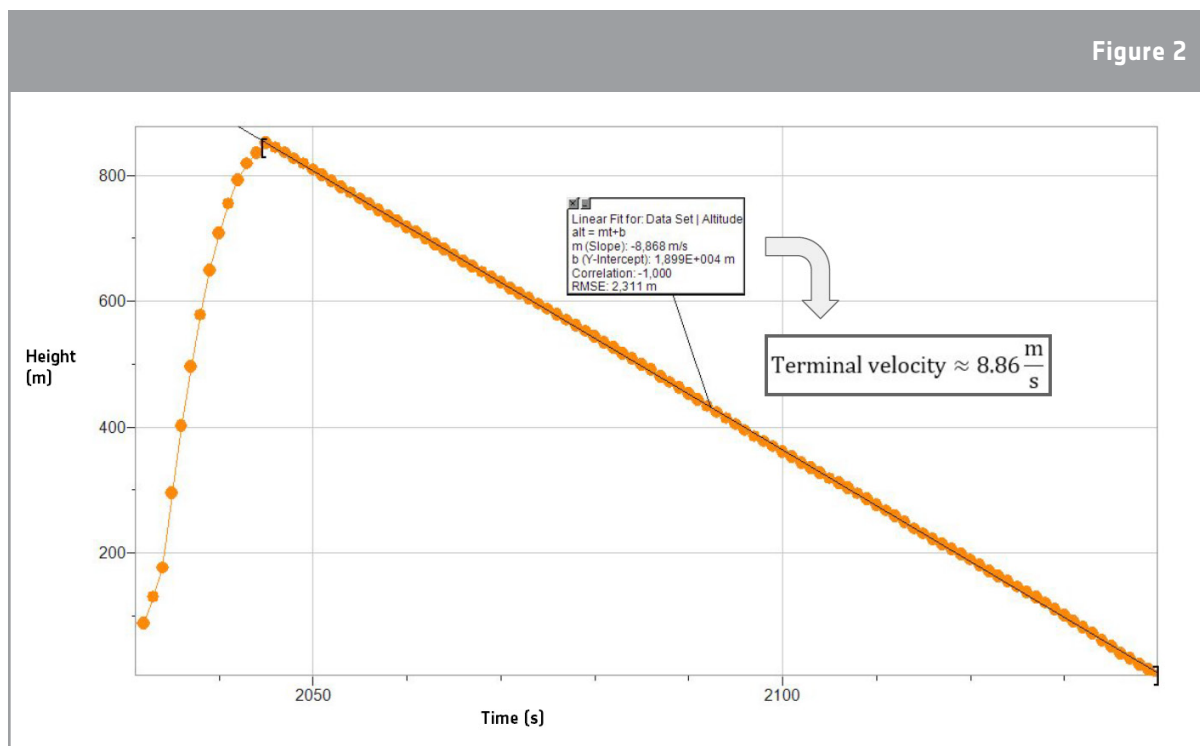


## → Activity 4: Slow and steady wins the race

In this activity, students are given guidance on how to perform a drop-test for their parachute. It is important to bear in mind the CanSat guidelines when testing their parachute, to ensure it complies with the competition guidelines.

### Exercise

1. On the graph below, add a curve for how you would expect the height to change with time, from the launch of a CanSat to the landing, assuming no lateral velocity due to stability. To help you draw the curve, think about how the speed is changing, and what effect this has on the shape of the curve.

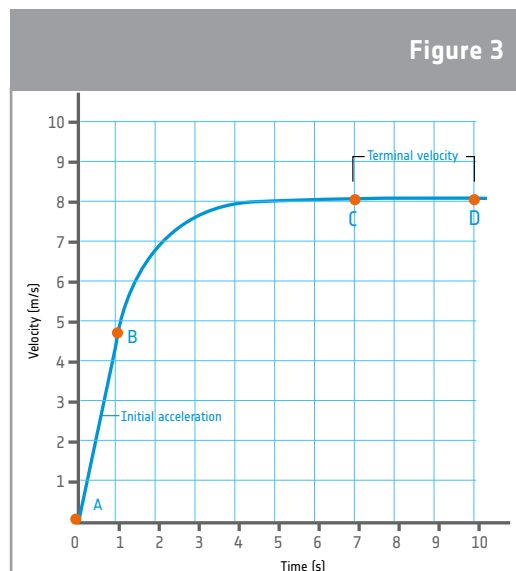


↑ Altitude-Time graph presented at 2018 European CanSat Competition by team AnaCan Skywalker, from Denmark

The first part of the curve corresponds to the ascent with the rocket. At around 800 m, the CanSat is released and falls at approximately constant speed (terminal velocity). The terminal velocity can be calculated as the slope of the straight from the fall.

2. Just as we have done for height, now draw a curve on the graph below showing how the speed of the CanSat changes with time during the descent (we won't take into account the ascent with the rocket here). This way,  $t = 0$  would be the release of the CanSat from the rocket.

After the CanSat is released at maximum altitude the CanSat will have a moment of weightlessness in which both velocity and acceleration will be 0. After that, the CanSat will start accelerating (A-B) until reaching terminal velocity. Thanks to the parachute, the acceleration phase is extremely small (negligible when calculating the velocity). In the rest of the fall, the CanSat with the parachute will have a constant terminal velocity (B-C).



↑ Velocity-Time example graph of a CanSat after deployment

## → DESIGN YOUR PARACHUTE!

### A guide to landing your CanSat safely

#### → Outline

Once your CanSat has been launched, one of the most important things is that it lands safely. Without a safe landing, the CanSat can potentially be damaged beyond repair. The most obvious way to allow a safe landing for your CanSat is to attach a parachute, a device that works by reducing the velocity of the falling object, resulting in a softer landing. The benefit of a parachute is two-fold: by reducing the speed of the CanSat you increase the amount of time available to collect data! We will now look at how a parachute works and some of the considerations you should make when designing and making your parachute.

#### → Activity 1: Free falling

Terminal velocity is one of the most important concepts that we must understand before we think about building a parachute. In this activity, we'll complete a simple experiment to help us understand just what terminal velocity is.

#### What goes up, must come down

Everything on earth is pulled downwards due to the force of gravity, that is caused by the mass of the Earth.

The weight of something is the force it experiences due to gravity acting on its mass:

**weight = mass x gravity;** ( $w=mg$ ).

According to CanSat guidelines, the CanSat **mass** must be in the range 300-350 g, or **0.3-0.35 kg**.

#### Exercise

1. What is the range of allowed weight for the CanSat?

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When an object falls under the influence of gravity it gathers speed, or accelerates. On Earth, this at  $9.81\text{ms}^{-2}$ . Let us imagine we throw two objects from a building where there is a vacuum. As there is no fluid to exert a resistive force, then both objects will fall at the same increasing speed (even if they have completely different masses)!

This fact can be anti-intuitive, as on Earth, air exerts a resistive force on the falling objects. This is why, for example, a feather falls more slowly than a ball.

The key of this is the medium in which the objects fall through – whether it's air, oil or a vacuum.

## Did you know?

That astronaut David Scott demonstrated this principle during the Apollo 15 moon landings. He dropped a geological hammer and a feather from the same height onto the surface of the moon. Because the moon is essentially a vacuum, there is little to no air resistance, and so both objects fell at the same rate! Here you can see the hammer and feather highlighted on the surface of the moon.



Ed Hengeveld

2. The hammer and feather experiment sparks an interesting question, how would the launch of a CanSat differ if it was carried out on the moon?

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## Investigating the effect of a fluid on falling objects

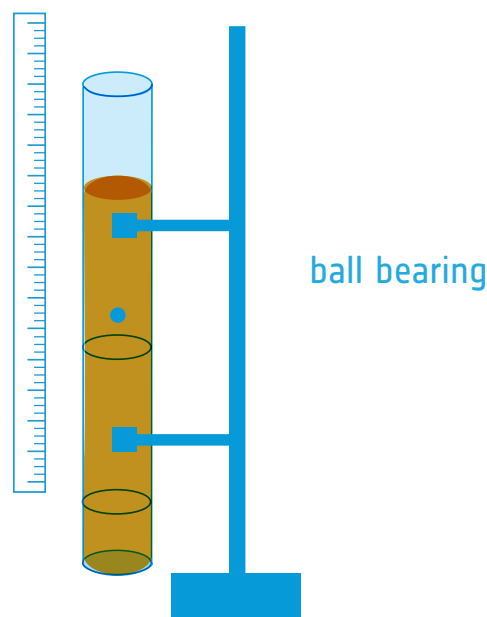
What happens to an object when falling in a fluid? Let us devise a little experiment to find out.

### Experiment

For this experiment, you will need:

- A clamp stand
- A measuring cylinder, or glass tube (the taller and wider the better)
- Oil (glycerol works well) or wallpaper paste
- A ruler
- Ball bearings, or marbles of different sizes
- Elastic bands
- A stopwatch (you can use your mobile phone timer)
- A magnet (if you are using metal ball bearings)
- Water

**Note:** If you are using a glass measuring cylinder it is a good idea to put a rubber bung or a ball of cotton wool at the bottom of the cylinder, this will prevent the ball bearing or marble from cracking the glass.



The magnet can help to drag the ball bearings out of the cylinder once they have fallen.

## Steps:

### a. If you have an iPhone:

1. Set up the equipment like shown in the figure above.
2. Download the app 'Vernier Video Physics':  
<https://itunes.apple.com/us/app/vernier-video-physics/id389784247>
3. Record whilst you drop a marble into the cylinder.
4. Use the features of the app to calculate the speed of the marble at each point.
5. Repeat the experiment!

### b. If you have an Android phone:

1. Set up the equipment like shown in the figure above.
2. Download the app 'VidAnalysis Free':  
<https://play.google.com/store/apps/details?id=com.vidanalysis.free>
3. Record whilst you drop a marble into the cylinder.
4. Use the app to calculate the speed of the marble at each point.
5. Repeat the experiment!

### c. The old-fashioned way!

1. Set up the equipment like shown in the figure above.
2. Begin the stopwatch as you drop the marble into the cylinder
3. Stop the stopwatch as the marble travels a given distance – depending on the speed of the marble, every 5cm should be possible. You will probably need to complete these measurements over several attempts.
4. Use these measurements to calculate the speed of the marble at each point.
5. Repeat the experiment!

## Exercise

3. How does the speed of the marble change as it travels down the cylinder?

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4. What would you expect to change if you replaced the oil with water? Write down your prediction and then try it out!

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Unlike in the vacuum, in a fluid, a falling object will (eventually) reach a **terminal velocity**. Terminal velocity occurs when the resistive, or drag forces, opposing the falling object, are equal to the force from gravity acting on the mass of the object.

A falling object in air has much less contact with surrounding particles than it does if falling through oil. Therefore, there is less resistance to its motion, and it is able to fall faster. In air, we call this resistance **air resistance**; you are probably very familiar with this term.

The amount of drag (or resistive forces when falling through another fluid such as oil), depends on:

1. The density of the fluid ( $\rho$ )
2. The velocity of the object ( $V$ )
3. The cross sectional area ( $A$ )
4. The drag coefficient ( $C_d$ )

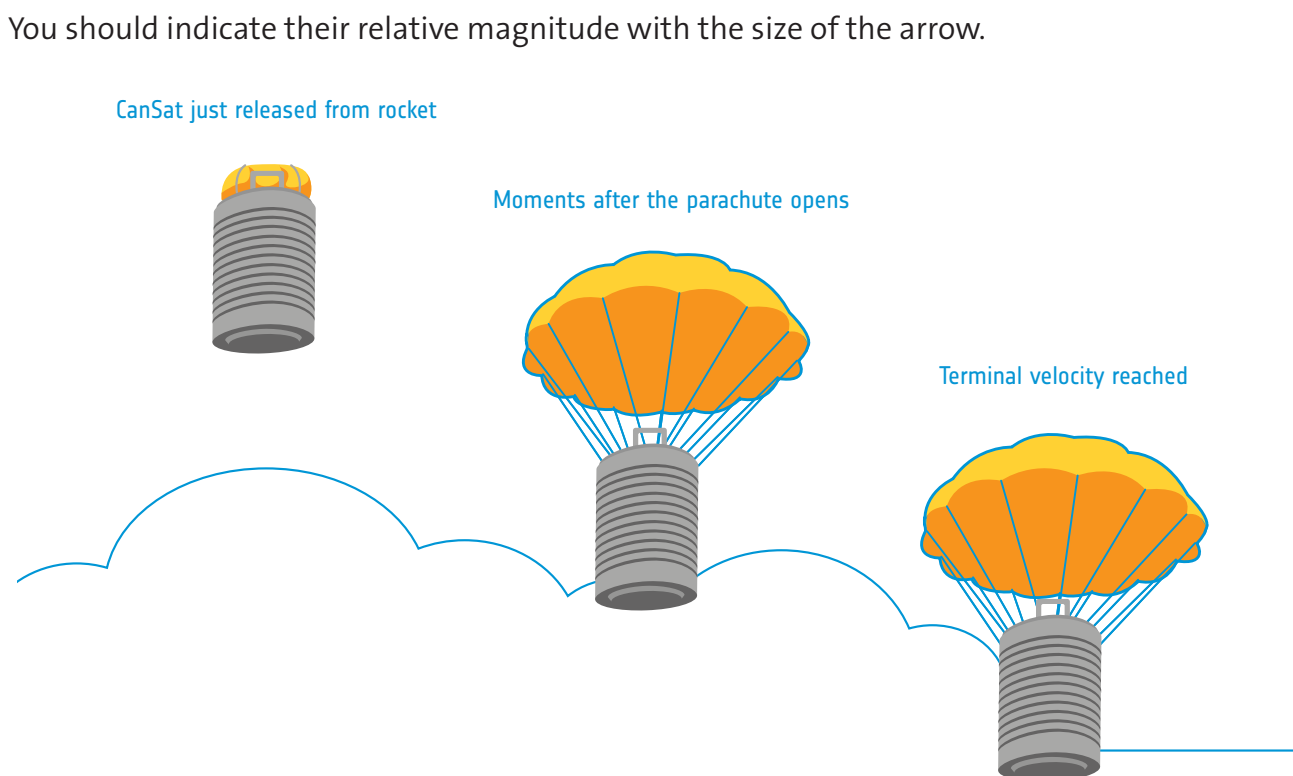
We will explore how all these variables influence the CanSat's fall in the next section.

## → Activity 2: Parachutes - such a drag!

There are ways to reduce terminal velocity in a fluid that is not very viscous, like air – for example, increasing the projected area that is in contact with air – using a parachute.

### Exercise

- Using your understanding from the marbles experiment, label and name the forces acting on your CanSat during its descent on the images below.



### May the force be with your parachute

Let's now analyse the forces involved in this process, picking the direction of the CanSat (down) as the positive direction of the force. The first force that comes to our mind is the weight of the CanSat, a force that is directed downwards (as it is a result of the attraction of earth).

$$F_{\text{gravity}} = m g \hat{z} \quad \text{equation 1}$$

where

$m$  = mass of the CanSat (typically 0.35 kg)

$g$  = acceleration due to gravity = 9.81 m/s<sup>2</sup>

As the CanSat descends through air it experiences a drag force (that opposes the weight) due to the parachute:

$$F_{\text{Drag}} = -\frac{1}{2} C_D \rho A v^2 \hat{z} \quad \text{equation 2}$$

$A$  = canopy surface area

$C_D$  = drag coefficient of the parachute – this value depends on the **shape/geometry** of the parachute; example values are listed in the next section.

$\rho$  = local density of the air, assumed to be constant at 1.225 kg/m<sup>3</sup>.

$v$  = descent velocity of the CanSat in m/s

As Newton's 2nd law states:

$$F_{\text{net}} = \sum F = ma \hat{z}$$

**Note:** At the fall, this net force will not be zero for a few seconds (it will be accelerating and decelerating for a short time), but we will neglect this now as most of the falling time the CanSat will be at terminal velocity.

Assuming this, when terminal velocity is reached,  $a=0$ , and therefore  $F_{\text{net}}=0$ . That gives us:

$$F_{\text{gravity}} + F_{\text{drag}} = 0$$

Therefore, balancing the forces in the z axis we find the following equation:

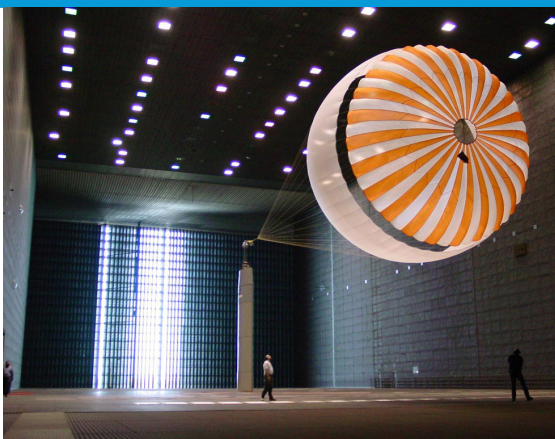
$$mg - \frac{1}{2}C_D \rho Av^2 = 0 \quad \text{equation 3}$$

Later, once you have decided on the design of your parachute you can rearrange this equation and use the constraints on the descent velocity to calculate the area required for your parachute. Remember, we have made some approximations here; you will still need to test and measure the descent speed of your parachute!

### Did you know?

The Viking spacecraft that successfully sent a lander to the surface of Mars in 1976 was made in a very similar way to the parachutes that you will design. The unique challenge that Mars posed was its atmosphere. With an atmosphere less than 1% of the thickness of Earth's and with supersonic velocity, a parachute alone was not enough to provide a slow, stable landing. To solve the problem, NASA's engineers used rockets to assist the landing – unfortunately you won't be able to do the same so you must perfect your parachute design!

[The Viking spacecraft parachute during testing →](#)



According to the competition guidelines for CanSat, a few seconds after deploying its parachute (i.e. after launch), it should have a **descent rate (terminal velocity)** between **8 – 11 m/s**. Not too slow that it drifts far from the launch site, and not too fast that it does not have time to collect data and risks a hard landing.

**Note:** The airfield might determine additional mandatory restrictions on the descent velocity

### Exercise

- Assuming the rocket will launch your CanSat at an altitude of 1000m, according to the required descent rate in the CanSat guidelines, what is the time that should pass between your CanSat being released and landing (neglecting the acceleration period)?

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## → Activity 3: The importance of area and shape

In this activity we will look at some of the basic principles of parachute design. We will also discuss the main types of parachute that you will come across when designing yours, as well as looking at the pros and cons of each.

### Choosing the materials of your parachute

The deployment of the parachute will be relatively violent, so the fabric and fibres you use need to be strong. Take into account that the force that the parachute experiences (and also the payload at which it is attached) can be as high as twice the force acting during the terminal velocity!

In this analysis we will focus on the impact of your parachute on terminal velocity. However, you should be aware that not only the terminal velocity (understood as vertical velocity) is important: different parachute designs have different “stability” performance, and we also need to take into account the lateral velocity. In general, the more drag the less stable a parachute is.

Suitable materials are nylon wires and **rip-stop fabric**, which can be purchased at a kiting shop.

These materials are ideally suited for the parachute. A major weak point is the attachment point of the cord and parachute material. Do not use fish line.

When cutting the fabric, you should take into account the fact that some of the fabric needs to be doubled over to be able to sew it.

### Choosing the design of your parachute

Let's look at the equation for our CanSat descent:

$$mg - \frac{1}{2}C_D \rho Av^2 = 0 \quad \text{equation 3}$$

### Exercise

1. Which factors in equation 3 can be changed along with the design of your CanSat?

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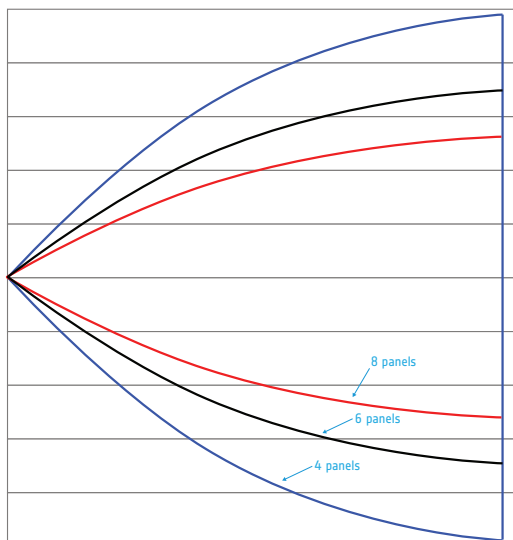


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## Parachute shapes

The simplest types of parachutes are the flat circular sheet and the spherical parachutes. The problem with these designs is that they fill up with air and tilt to one side to spill out air. Sometimes a spill-hole can help to stabilise a parachute. We will briefly explore some of the different types of parachutes that you can design for your CanSat.

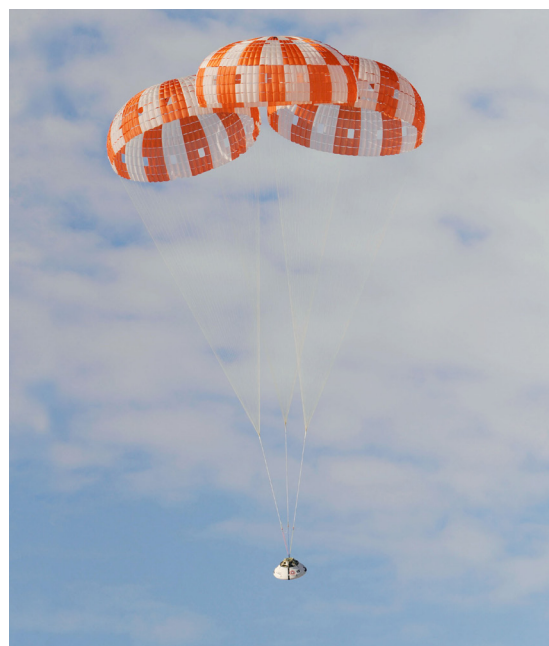
### Hemispherical parachute



A hemispherical parachute is likely to be the design that immediately comes to mind when you are asked to think of a parachute. The fabric forms a hemisphere when filled with air. It is made from sections called 'gores'. Each gore is stitched together to form the complete hemispherical shape. The more gores that are used, the closer the shape to a true hemisphere, but the more complex the production procedure.

The angle subtended by the two inner sides of the gore decreases the more gores you add. The angle can be calculated using the formula below:

Here, you can see three typical hemispherical parachutes aiding the descent of the Orion module. Notice the different colours, you can see how the separate gores fit together to form the hemispherical shape.

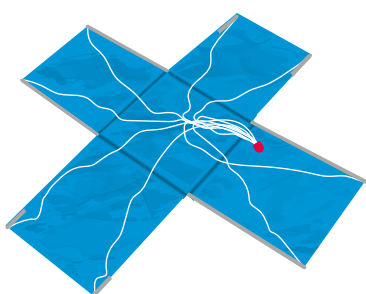


The procedure for constructing a hemispherical parachute is as follows:

- Firstly, trace out the shape of the gores in the material and cut them out, make sure to allow ~2cm edging for the hem.
- Sew the edges together to form the parachute shape.
- Finally, sew guidelines/cords on to the parachute\* to allow it to be attached to your CanSat.

\*Note that normally the lines go through the gores: the load (of the air) is not taken by the gore itself but by the lines. Usually one line starts from the confluence point, runs all one along one gore, goes through the opposite one and comes back to the confluence point.

### Cross parachute



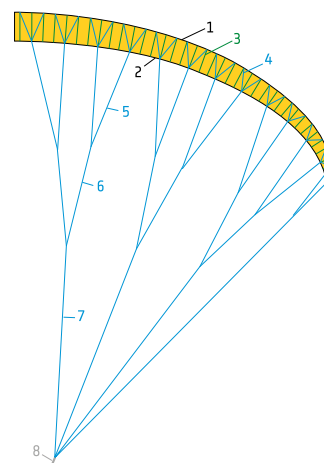
A cross parachute is easier to sew than semi-spherical parachute as the regular shape is easier to create by hand.

Information on making a cross parachute can be found here:  
<http://www.nakka-rocketry.net/xchute1.html>

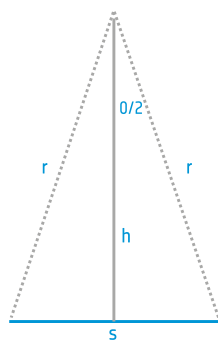
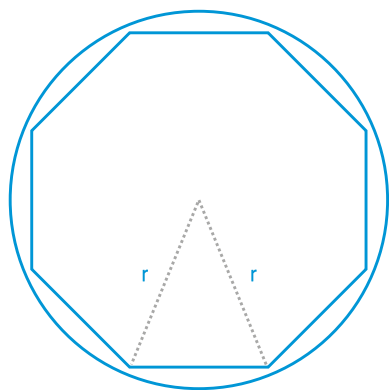


## Paraglider

You may have come across a paraglider design before if you have an interest in paragliding. The biggest advantage of a paraglider design is that it is possible to steer. However, it is more difficult to design & make compared to the simpler designs above.



## Flat parachute



Flat parachutes are the most commonly available parachutes, created from flat geometric figures such as hexagons or octagons. The figure shows that the octagon parachute is made from 8 equal triangles.

These are a few types of the parachutes suitable for a CanSat. The drag coefficients for each are shown in the table below. If you want to research more on drag coefficients, see Annex I.

Parachute type	Drag coefficient $C_D$	Comments
Hemi-spherical	0.62-0.77	Very common; time consuming to make
Cross	0.6-0.8	Easy to make; popular for CanSats
Paraglider	0.75-1.10	Complicated design; Guided landing possible
Flat, hexagon	0.75-0.8	Easy to make, popular for CanSats

If you want to make your own flat parachute you will need:

- Suitable material – rip stop fabric is best
- Ropes/cords to connect the CanSat to the parachute
- Thread to stitch the hems and edges of the parachute and the cords

The process is quite simple, simply take your fabric and cut it to the desired size and shape, using a stencil to guide you. It is best to leave a few centimetres around the edge so that you can fold them over to reinforce the structure. Cut the connecting cords to a suitable length and sew them to the parachute and you are ready to test!

## Exercise

- From the drag coefficients above, which parachute type will give the slowest descent velocity? Which will give the fastest descent velocity?

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3. The cross design is easy to make, but the descent velocity compared to the semi-spherical design is too fast, what could you do to control this?

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## Determining the area

Now that we have the maximum and minimum velocities (8-11 m/s) and the different drag coefficients of the different types of parachutes, we can calculate the required area of our parachute.

### Exercise

4. Make A the subject of equation 3:

5. Now that you have the equation with area as the subject of it, calculate the range of areas allowed for different example types of the parachutes we have discussed, assume a CanSat mass of 350g. You can fill in the values in the table below.

**Remember: The range of allowed velocity is 8-11ms<sup>-1</sup>**

Table 2			
Parachute type	Drag coefficient (e.g.)	Minimum area	Maximum area
Hemi-spherical	0.62		
Cross	0.8		
Paraglider	0.8		
Flat, hexagon	0.8		

6. If you change your parachute from a cross parachute to a hemispherical parachute, how should you change the area of the parachute, so that it falls at the same speed as before?

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## → Activity 4: Slow and steady wins the race

Once you've decided on a design for your parachute it is vital that you test it. Whilst the equations we introduced above can give you an idea of what to expect you should always test your designs in the real world. Before you do that, you should think about the flight of your CanSat, and how the forces acting on it will change over time.

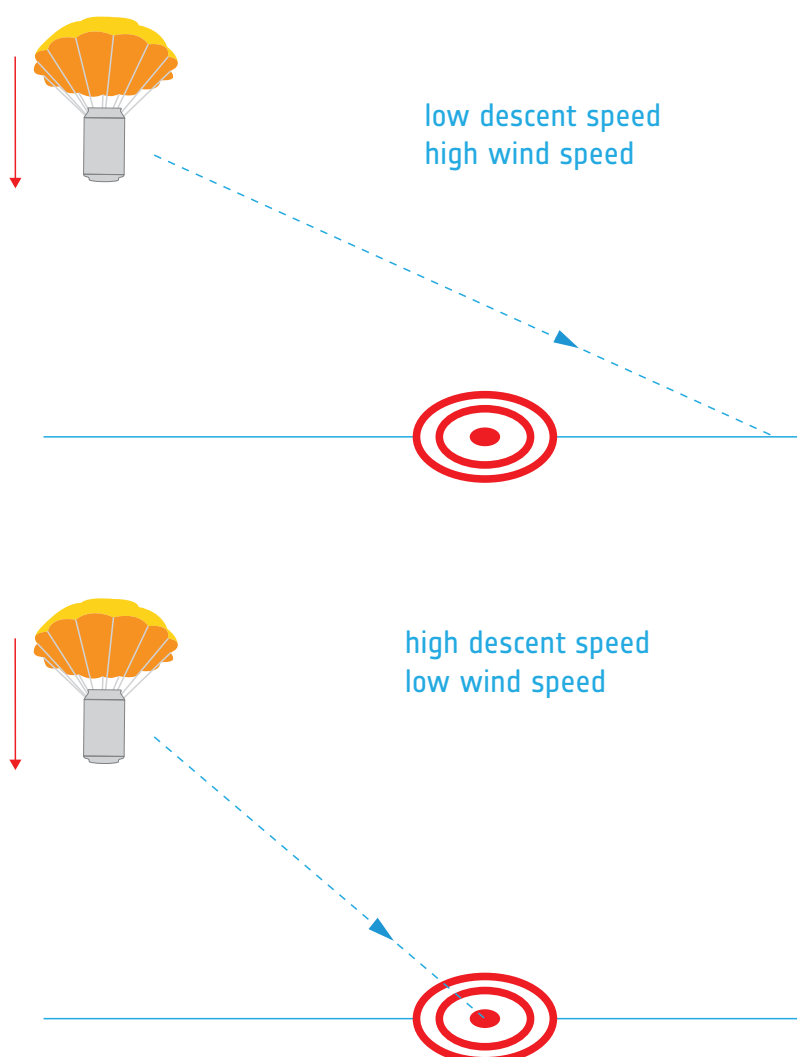
### What goes up must come down

Let us first think about how the height and speed of your CanSat will change over the entire launch. After we have done this, we will put all of our understanding together, so that you are ready to build and test your own parachute!

Something to consider when thinking about the descent of your CanSat is how the wind might affect its flight path. As the CanSat falls vertically, a horizontal wind can blow the CanSat in the horizontal direction. Moreover, take into account that even with no wind some parachute types (e.g. cruciform) might get a large lateral velocity due to its stability.

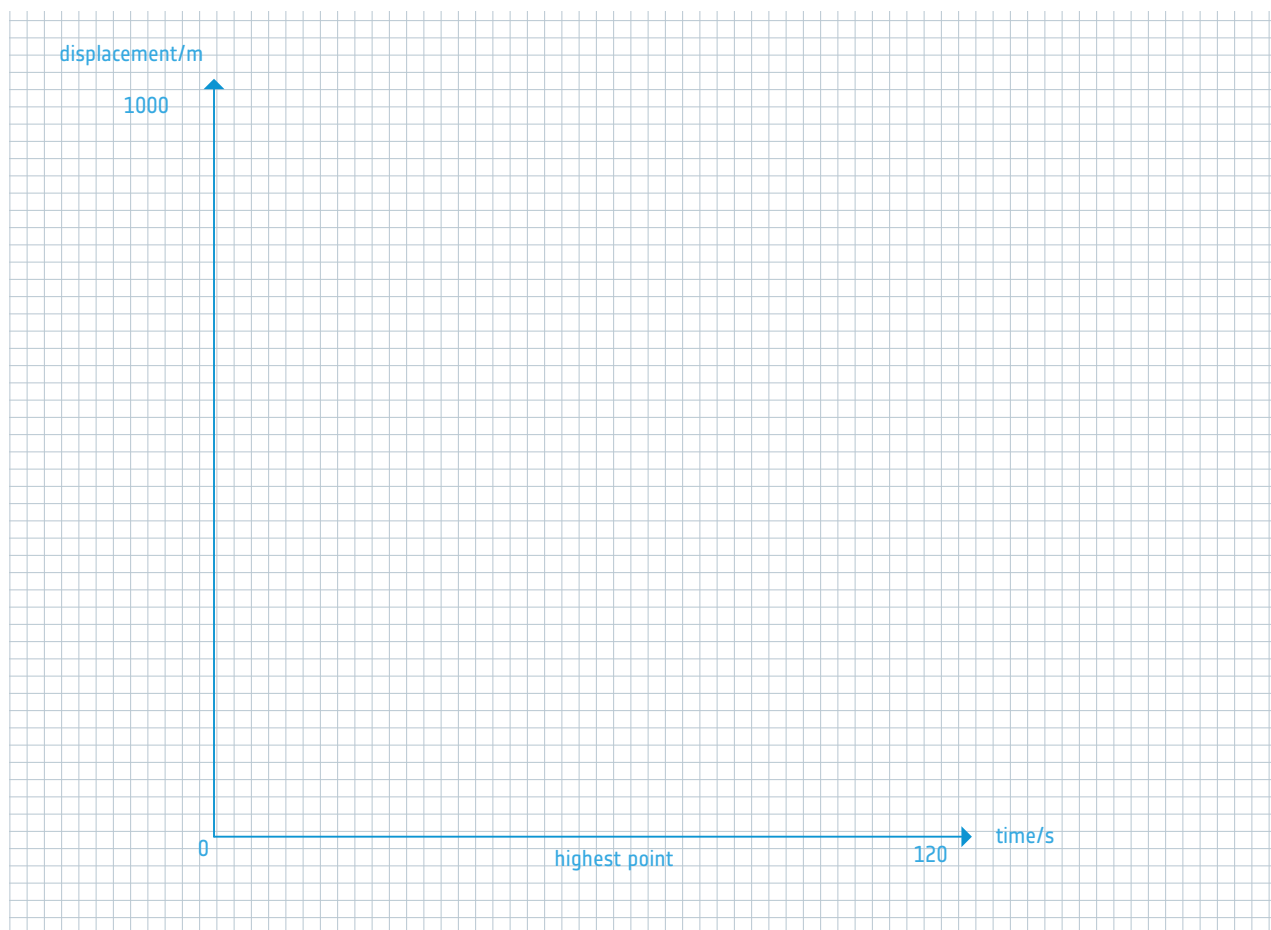
Depending on the speed of the descent, and the wind speed, this can mean that the CanSat lands on the ground a significant distance away from where it launched – this is one of the reasons that the descent speed is so important. If your CanSat descends too slowly, it can be blown away from the launch site and be difficult to recover!

To see this effect more clearly, look at the diagram below.



## Exercise

- On the graph below, add a curve for how you would expect the height to change with time, from the launch of a CanSat to the landing, assuming no lateral velocity due to stability. To help you draw the curve, think about how the speed is changing, and what effect this has on the shape of the curve.



**Remember:** In the European CanSat competition, CanSats are launched to a height of 1000m!

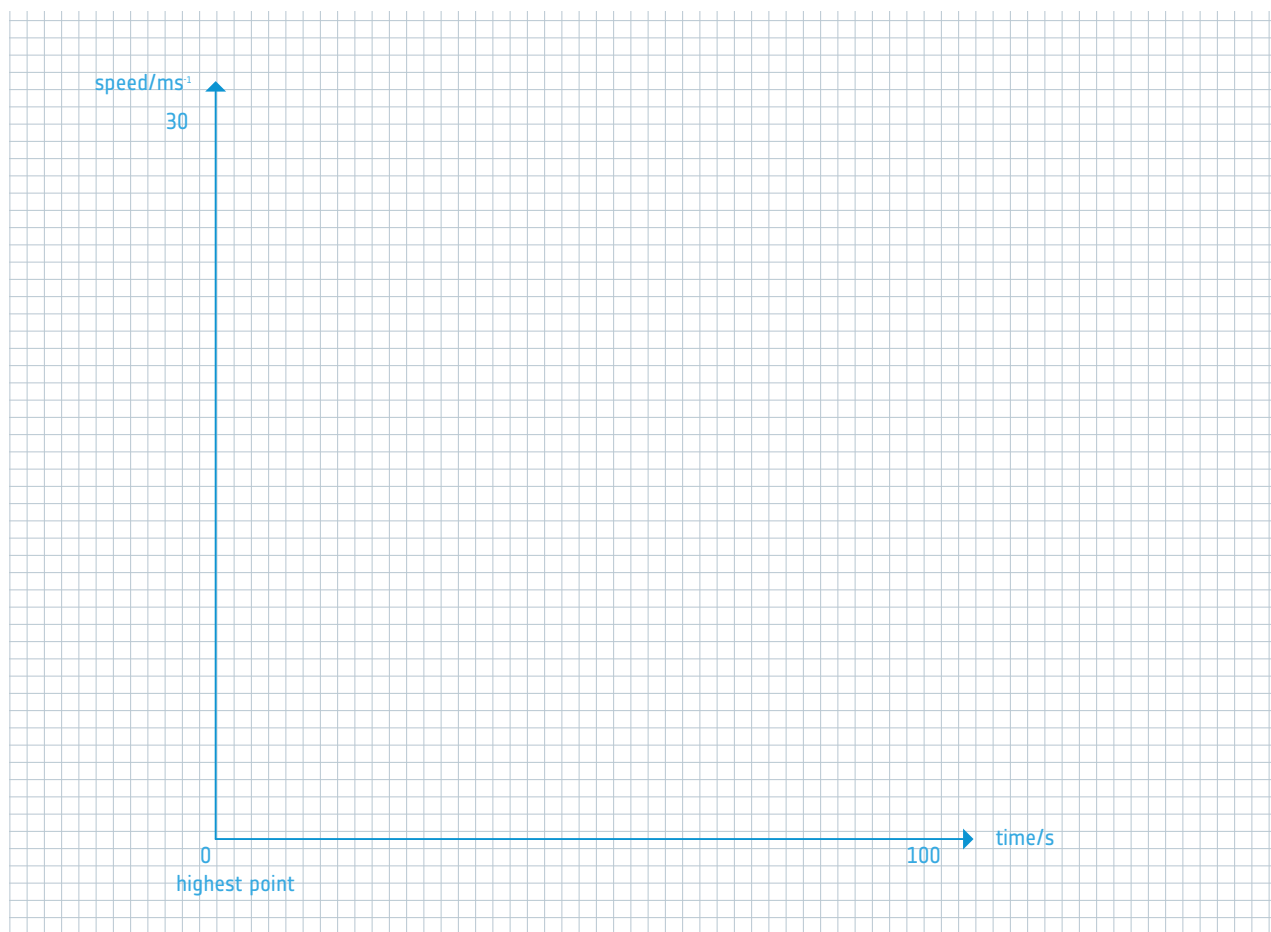
The most important part of the launch for us right now, is the descent from the highest point to hitting the ground, as this is when the parachute comes into play.

We're going to think about how the speed of the CanSat varies with time during its descent.

- Just as we have done for height, draw a curve on the graph below showing how the speed of the CanSat changes with time during the descent (we won't take into account the ascent with the rocket here). This way,  $t=0$  would be the release of the CanSat from the rocket.

Think about the following questions before you sketch the curve:

- What is the speed of the CanSat when released?
- How quickly does the CanSat accelerate towards Earth?
- What happens when the parachute opens?



## Time to test?

Now that you have a good understanding of the behaviour of a CanSat during a launch, and the forces that act on it, you should think about testing your parachute. So that you don't risk the effort and time you have spent building your CanSat go to waste, you should first test the parachute with a dummy CanSat!

### Health and safety

Before you begin testing, you should ensure that you have the supervision of your teacher. Dropping the parachute and can from a height, such as a 2<sup>nd</sup> or 3<sup>rd</sup> storey window will provide a good first test for the parachute, but you should make sure that the area below is well cleared of any passers-by or objects that could be damaged!

With successive tests you can refine your parachute design, investigate the effects of every aspect of your parachute, this should include:

- The material used
- How it is attached to the CanSat
- The area of the parachute
- The way the parachute is folded

As you approach the final design of your parachute, make sure that your test payload more accurately matches the weight and size of your actual CanSat.

If everything is compliant with the CanSat guidelines, then your parachute is ready!

## → Links

The Fruitychutes website contains further information on designing a parachute:

[https://fruitychutes.com/help\\_for\\_parachutes/how\\_to\\_make\\_a\\_parachute.htm](https://fruitychutes.com/help_for_parachutes/how_to_make_a_parachute.htm)

Information on designing a cross parachute:

<http://www.nakka-rocketry.net/xchute1.html>

The mathematics of flat parachutes are discussed here:

[https://www.sunward1.com/imagespara/The%20Mathematics%20of%20Parachutes\(Rev2\).pdf](https://www.sunward1.com/imagespara/The%20Mathematics%20of%20Parachutes(Rev2).pdf)

More information on different types of parachute design:

<http://www.hsl.org.au/articles/parachutes.pdf>

Wikipedia background information on parachutes:

<https://en.wikipedia.org/wiki/Parachute>