Parachute – Teacher Notes

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Figure 1-Parachute fall

Aim

Many of the inventions were created to meet the needs of contemporary society. Science plays an important role in these inventions. Scientists are often inspired by the biological world and how certain species can manage to do specific functions. They use physics and engineering to bring their inventions to reality. The rules of physics have proven to be very reliable and can be applied on a wide scale to ensure safety of many of the inventions used. One of these inventions is the parachute which is used to slow the descent of a person or an object to Earth. Parachutes are used in many applications including sports, recreation and military purposes. There are a number of factors affecting how fast a parachute will descend and in this study, students will take the role of a physicist to study these factors and come up with the best settings for a safe descent.

Plan

Students need to understand different types of forces, such as balanced and unbalanced forces and terminal velocity, to be able to explain their results and make their predictions. The teacher may like to go through these concepts with them or they may watch a video clip explaining the forces acting on a parachutist: https://www.youtube.com/watch?v=oL-TasyoEdw

Discuss with students the safety issues in conducting this experiment, this includes clearing the area around the parachute descent and being cautious not to fall while dropping the parachute.

Conduct

The students are given three investigations to choose from in order to study the effect of changing various variables on the terminal velocity of the parachute.

For making a parachute, student will use plastic bags, cotton or nylon thread, meter ruler, stopwatch, scissors and large paperclips or plasticine.

All variables should be kept constant, except the variable they are investigating, in order to conduct a fair test.

The questions to be investigated are:

- ***The effect of the mass of the parachutist on the time taken by the parachute to land.***
  In this experiment, students have to keep the same shape and area of canopy and change the number of paperclips or size of plasticine.
  They will drop their parachute from at least 2m height (dropping height should be kept the same for all experiments) to ensure the parachute can reach its terminal velocity. The higher the drop height, the more we are confident that terminal velocity has been reached.
  For each mass, students will record the time it takes the parachute to land on the ground using the stopwatch.

- ***The effect of surface area of the canopy on the time taken by the parachute to land.***
  Here students will only change surface area of the canopy while keeping all other variables constant.
  To change the area, students can cut the plastic bag into different sizes for example:
  24 cm x 24 cm = 576 cm^2
  21 cm x 21 cm = 441 cm^2
  18 cm x 18 cm = 324 cm^2
  15 cm x 15 cm = 225 cm^2
  12 cm x 12 cm = 144 cm^2
  For each area, they will measure the time it takes the parachute to land using their stopwatch.

- ***The effect of the shape of the canopy on the time taken by the parachute to land.***
  Students will cut the plastic bags into different shapes, this includes a triangle, a square, a rectangle and a circle.
  Make sure the area of each shape is the same.
  For a triangle, the area is ½ base x height.
  For both the square and rectangle, area is base x height.
  For the circle, area is πr^2.
  Keep all other variables exactly the same, and measure the time it takes the parachute to land using the stopwatch.

It is a good idea to drop the weight attached to the string without a parachute and compare the time taken in each case. This will give the students a good impression about the action of the parachute.

It is very important to take note of any observations, as these can be included in the analysis stage because there are many things that can affect the results obtained.

Discuss with students the necessity of repeating each measurement at least three times and taking the average. This would increase the reliability of their results.

Analyse

Once students obtain their results, they can start analysing them. A helpful way to visualise the differences obtained when changing the independent variable is to tabulate the results and plot them.

To find the average velocity, students can divide the distance travelled by the average time to land.

$$velocity = \frac{height\ from\ which\ object\ is\ dropped}{average\ time\ to\ land}$$

- ***The effect of the mass of the parachutist on the time taken by the parachute to land.***

Mass (g)	Time to land (s)		Velocity (m/s)	
	Trial 1		**Trial 1**	
	Trial 2		**Trial 2**	
	Trial 3		**Trial 3**	
	Average		**Average**	
	Trial 1		**Trial 1**	
	Trial 2		**Trial 2**	
	Trial 3		**Trial 3**	
	Average		**Average**	
	Trial 1		**Trial 1**	
	Trial 2		**Trial 2**	
	Trial 3		**Trial 3**	
	Average		**Average**	
	Trial 1		**Trial 1**	
	Trial 2		**Trial 2**	
	Trial 3		**Trial 3**	
	Average		**Average**	
	Trial 1		**Trial 1**	
	Trial 2		**Trial 2**	
	Trial 3		**Trial 3**	
	Average		**Average**	

- ***The effect of surface area of the canopy on the time taken by the parachute to land.***

Surface area (cm^2)	Time to land (s)		Velocity (m/s)	
144	**Trial 1**		**Trial 1**	

	Trial 2		**Trial 2**	
	Trial 3		**Trial 3**	
	Average		**Average**	
225	**Trial 1**		**Trial 1**	
	Trial 2		**Trial 2**	
	Trial 3		**Trial 3**	
	Average		**Average**	
324	**Trial 1**		**Trial 1**	
	Trial 2		**Trial 2**	
	Trial 3		**Trial 3**	
	Average		**Average**	
441	**Trial 1**		**Trial 1**	
	Trial 2		**Trial 2**	
	Trial 3		**Trial 3**	
	Average		**Average**	
576	**Trial 1**		**Trial 1**	
	Trial 2		**Trial 2**	
	Trial 3		**Trial 3**	
	Average		**Average**	

- ***The effect of the shape of the canopy on the time taken by the parachute to land.***

Shape	**Time to land (s)**		**Velocity (m/s)**	
Triangle	**Trial 1**		**Trial 1**	
	Trial 2		**Trial 2**	
	Trial 3		**Trial 3**	
	Average		**Average**	
Square	**Trial 1**		**Trial 1**	
	Trial 2		**Trial 2**	
	Trial 3		**Trial 3**	
	Average		**Average**	
Rectangle	**Trial 1**		**Trial 1**	
	Trial 2		**Trial 2**	
	Trial 3		**Trial 3**	
	Average		**Average**	
Circle	**Trial 1**		**Trial 1**	
	Trial 2		**Trial 2**	
	Trial 3		**Trial 3**	
	Average		**Average**	

Students can plot their results, ensuring to have the dependent value on the y-axis and the independent value on the x-axis.

Problem solving and discussion

Each team will look into the results obtained and compare them to their hypothesis. If they do not agree, students will need to decide whether their hypothesis was wrong or if some errors happened during the experiment which has led to this discrepancy.

There are number of factors that can contribute to errors in the results, these include:

1. Not keeping the drop height exactly the same. Students need to ensure they find a way to keep the dropping height exactly the same for all tests. For example, using a meter ruler and dropping the parachute from the exact mark on the ruler each time. Also, having the same student dropping the parachute would minimize variation in how the parachute is dropped.
2. Human error when measuring the time of flight. It is better to have the same person doing the time measurement or more than one person and getting an average time.
3. The value of the terminal velocity is dependent on the air density. Air density is caused by changes in humidity and temperature, so it is best to conduct all of the experiment on the same day and at the same spot to minimize these effects.
4. Ensuring the use of the same length, number and type of thread and keeping all control variables unchanged will help in reducing errors.

To explain the action of the parachute, students are asked to draw a diagram showing the forces acting on the parachutist. These forces have a magnitude and a direction. An example for a diagram depicting these forces is shown in Figure 2.

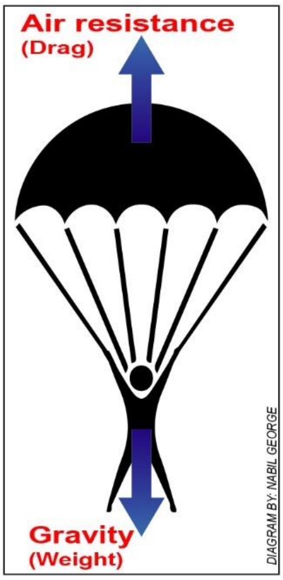

Figure 2-Forces acting on a parachutist

Figure 3, is a graphical representation of the speed that a falling object experiences with and without a parachute. When an object or a person is dropped from a plane, they fall with a constant acceleration (acceleration due to gravity) downwards (point 1). Hence, their velocity increases by 9.8 m/s every second. The only opposing force is the force of air resistance acting upwards. At the start this force is negligible; however it increases as the velocity of the falling body increases (point 2). Eventually, the air resistance will reach a value equal to the weight force acting downwards. This is when terminal velocity is reached (points 3 &4). Terminal velocity means that the falling object is no longer accelerating and is moving with a constant velocity. However, this terminal velocity is always very high and can damage the falling object or kill the falling person. This is where the parachute plays an important role. The parachute increases the surface area exposed to air resistance which increases the value of the force acting upwards (point 5). This would decrease the falling speed of the parachutist (point 6); the air resistance will decrease as the downward speed decreases but eventually the force acting downwards will again be balanced with the force acting upwards and a new terminal speed is reached (points 7 & 8). But this final terminal speed is much less than the first one, safe enough for the object to hit the ground without damage.

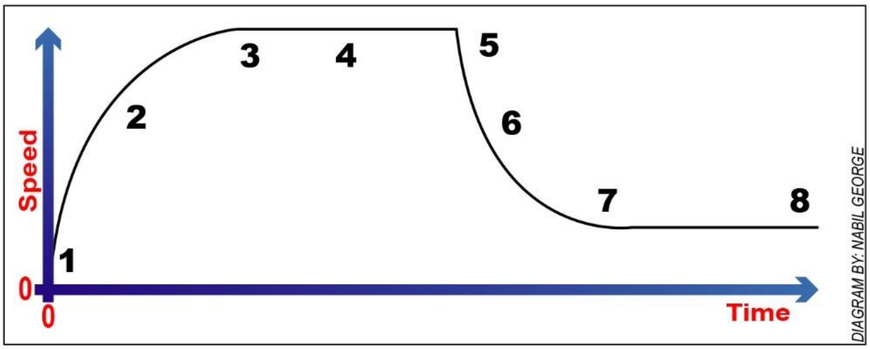

Figure 3-Graphical representation of speed vs time for a falling object

For the experiment studying how the mass of the parachutist affect the time of landing, it is expected to see that the bigger the mass, the shorter the time it takes to land. This is because the bigger the mass of the object, the higher is the terminal velocity. Therefore, it would take less time to reach the ground.

The surface area of the canopy increases the value of the drag force. This would lead to a lower terminal velocity and hence a longer time to land.

For the experiment examining the shape of the canopy, it should be found that different shapes will take different times to land. This mainly depends on the geometry of the parachute and how it affects the drag coefficient. Students should find that the time of landing in descending order is round, square, rectangle and triangle. This means that the round shape would offer the least landing velocity. However, students can get different results. This task could be extended further as an essay where students can study applications of different parachute designs. This is an interesting field of research in aerodynamics and more advanced classes can consider different design factors, such as which shape is the best for beginners to learn, which is the best for military purposes and which suits recreational purposes.

Conclusion

At this stage, students will state whether their hypothesis was supported or not. They can say if the experiment has helped them learn something new and suggest any future work that they would like to conduct to further study parachutes, such as using different fabrics.

References

- Figure 1 https://www.flickr.com/photos/philokazaki/8040362391/in/photolist-dfuXBM-b5HtDV-5cbUQG-9XHQoi-8MjGCx-8bCb4S-g8tKxu-VFV56N-9XLFBG-5R6AEC-g8tLDt-VxZKCt-6BSSQK-9B7MfS-9QhWvT-phYLsN-7XrZ9C-84VMre-78jsCj-phJDLP-7jTue1-gNpCX-n2yaZ-9QhWMF-9Kr3s7-VxZNJP-bKaaL6-a8B8zS-8wXu5G-3LfaXF-9nFXZm-9i9FTQ-9i9FZy-5cbi2H-8Bzy4n-z7Z6P-d3CiNy-6x1v9H-EXzaF-8sgTG6-8dvMSd-6qn5JC-8KQRg9-4eW4uF-p1wyKJ-s1RjG-eaGb2V-8VFt1m-VFV6h5-5cfz57 Author philokazaki Licence https://creativecommons.org/licenses/by-nd/2.0/
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