**ACTIVITY: On your bikes**

**Activity idea**

In this activity, students measure speed and drag for a person on a bike to determine the effects of aerodynamic drag and rolling resistance on a cyclist’s maximum speed.

By the end of this activity, students should be able to:

* measure distance and time to calculate a cyclist’s maximum speed
* describe what might affect aerodynamic drag and rolling resistance
* experiment to find out how the maximum speed that a cyclist can reach is affected by different drag and rolling resistances
* measure the forces of drag and rolling resistance for a cyclist on a bike being pulled at a constant speed
* explain how forces need to be balanced for a cyclist to travel at a constant speed.

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Student worksheet: [On your bikes](#bikes)

**Introduction/background**

This activity includes several different activities. Activity 1 is highly recommended. The others are included to develop concepts more fully. You may choose which activities to use for your whole class or assign activities to different groups to do and then report back.

***Safety first***

* Safety must be stressed to students – extreme care is essential.
* Helmets must be worn.
* Activities 1 to 3 can be done with enough room such as a school driveway or car park.
* Activity 2 may be better done under teacher supervision, perhaps as a whole class demonstration.
* Activities 4 and 5 need a long, gentle sloping hill and a long straight section of road respectively. You may choose to suggest these as homework, where appropriate, under parental/caregiver/coach supervision. One reliable group may be able to provide data for the rest of the class.

***Balanced forces***

A cyclist will travel at a constant speed once forces become balanced. In this case, the opposing forces of aerodynamic drag and rolling resistance balance the forward pushing force that comes from pedalling. If the cyclist can become more streamlined and if the tyres are pumped up to reduce rolling resistance, the cyclist should be able to reach a faster maximum speed before the forces become balanced.

***Aerodynamic drag and rolling resistance***

Prior to this activity, it will help to view related articles and videos on forces, aerodynamic drag and rolling resistance.

***Calculating speed***

Speed can be calculated in metres per second (m/s) by measuring the time taken (seconds, s) to move between two points of a known distance (metres, m). Speed = distance divided by time. To convert into kilometres per hour, multiply by 3.6.

Example: if a student takes 4.0 seconds to travel 10 metres, the speed is d ÷ t = 10 ÷ 4.0 = 2.5 metres per second. To convert to kilometres per hour, multiply 2.5m/s by 3.6 to give 9.0km/h.

This activity allows students to reflect on the ideas related to balanced and unbalanced forces as they relate to cycling. Ideas will also be able to be extended to other sporting and familiar applications involving forces and speed.

**What you need**

* Student worksheet: [On your bikes](#bikes)
* Bike (1 per group)
* Helmets
* A windless day
* Marker cones
* Stopwatch
* Tape measure
* Bike pump
* Bulky loose fitting jacket (optional)
* Force meter (spring type)
* Light rope
* Tyre pressure gauge
* Bathroom scales

**What to do**

1. Hand out copies of [On your bikes](#bikes). Get each student to think about the questions in the boxes. As a class, watch the video clips [Aerodynamics and drag](http://link.sciencelearn.org.nz/videos/685-aerodynamics-and-drag) and [What is rolling resistance?](http://link.sciencelearn.org.nz/videos/682-what-is-rolling-resistance) and then discuss and record the answers to the questions.
2. Introduce the activities. Discuss the ideas of drag, balanced forces and how to calculate speed.
3. Working in groups, assign a different activity to each group or let students decide which one(s) their group would like to do.
4. Report back and discussion.

**Extension ideas**

If forces are balanced, you will cycle at a constant force. If forces are not balanced, you will speed up, slow down or change direction. Draw diagrams of a person on a bike with different force arrows, discuss whether the forces are balanced or unbalanced and get students to describe the motion of a person on a bike using ideas of speeding up, slowing down or travelling at a constant speed.

Choose a different sport or activity involving speed (such as waka ama, running) and get students to think about what forces are becoming balanced once the person or object is travelling at a constant speed.

**On your bikes**

Watch the video clips and answer the following:

|  |
| --- |
| Aerodynamic drag (air resistance) for a cyclist could be caused by:     |
| To reduce aerodynamic drag, a cyclist could:      |
| Things that cause tyres to have rolling resistance (opposition to motion):  |
| Things that could reduce rolling resistance of the tyres:   |

Your group may be assigned to one or more of the following activities. You may be required to report back to the class.

***Activity 1: How do aerodynamic drag and rolling resistance affect maximum speed?***

1. Use a long straight section of a car park or safe area. (You will need enough distance for a cyclist to speed up to maximum speed and slow down safely again.)
2. After leaving enough distance for the speeding-up section (for example, 50 or 100 metres), position two marker cones a known distance apart (for example, 10 metres).
3. Have a cyclist bike through the course twice, and use a stopwatch to record the time for the cyclist to pass between these cones. Record in the table below.
* The first time, aim for high drag and rolling resistance – have them wear a loose flapping coat and sit upright, and have the bike tyres slightly flat. Do this two more times – you can either measure the same cyclist three times or measure three different cyclists.
* The second time, aim for low drag and rolling resistance – have them wear tight clothing and sit crouched down, and have the bike tyres pumped up hard. Do this two more times.

**Results**

Speed = distance divided by time. To convert into kilometres per hour, multiply by 3.6.

For example, if a student takes 4.0 seconds to travel 10 metres, the speed is:

v = d/t = 10 ÷ 4.0 = 2.5 metres per second (to convert to km/h: 2.5m/s x 3.6 = 9.0 km/h)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Trial** | **Distance (d) between cones in metres** | **Time (t) in seconds** | **Speed in metres per second, m/s**(d ÷ t) | **Speed in kilometres per hour, km/h**(m/s x 3.6) |
| **High drag and rolling resistance** |
| 1 |  |  |  |  |
| 2 |  |  |  |  |
| 3 |  |  |  |  |
| **Low drag and rolling resistance** |
| 1 |  |  |  |  |
| 2 |  |  |  |  |
| 3 |  |  |  |  |
| **Conclusions** |

***Activity 2: How much force is needed to balance drag and rolling resistance for a cyclist to travel at a constant speed?***

1. Use a long straight section of a car park or safe area.
2. Attach a light rope and a force meter between two bikes so that the rider on the first bike can tow the second rider at a constant speed. The second rider should be able to see the force meter to read the force (drag plus rolling resistance) needed to balance the pull of the first rider in order to travel at a constant speed.
3. Repeat at walking speed (about 5 km/h) and jogging speed (about 10/ km/h).

**Results**

|  |  |
| --- | --- |
| **Speed** | **Force needed to balance drag and rolling resistance in newtons, N** |
| Walking speed (about 5 km/h) |  |
| Jogging speed (about 10 km/h) |  |
| **Conclusions*** How does this force change at a faster constant speed?
 |

***Activity 3: How does tyre pressure affect rolling resistance?***

1. Use a long straight section of a car park or safe area.
2. Weigh the cyclist and bike and record in the table below.
3. Have the cyclist stand up on the pedals and bike slowly enough so that, if they don’t pedal, they will stop in about 5–20 metres.
4. As they pass a marked point, have them stop pedalling. Use a stopwatch to measure the time taken to stop and measure the distance travelled.
5. Repeat at least twice for different tyre pressures. You may also like to try different surfaces, for example, grass. Try to travel at the same speed for each trial, starting from the same position.

**Results**

Rolling resistance force = mass x acceleration (where acceleration = ).

For example, if a cyclist and bike weighing 58kg travel 5 metres and take 6 seconds to stop, the rolling resistance forceis 58 x = 16 newtons.

(Aerodynamic drag can be considered insignificant due to the slow speed.)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Trial** | **Tyre pressure**  | **Distance in metres, m** | **Time in seconds, s** | **Mass of cyclist and bike in kilograms, kg** | **Acceleration in metres per second per second, m/s/s** | **Rolling resistance force in newtons, N**(mass x acceleration) |
| **Tyres pumped up hard** |
| 1 |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |
| **Tyres half deflated** |
| 1 |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |
| **On grass** |
| 1 |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |
| **Conclusions** |

***Activity 4: How does drag affect terminal velocity (constant speed reached when forces become balanced) as you roll down a hill?***

This experiment should only be done if you have access to a long gentle hill away from traffic and with supervision by a parent, caregiver or coach.

1. Choose two clearly visible points about 10 or 20 metres apart near the bottom of a hill (for example, lamp posts or letter boxes) and measure the distance between these two points.
2. Have one cyclist roll down the hill without pedalling to reach a terminal velocity. The terminal velocity is the speed you reach when all forces become balanced and you are travelling at a constant speed.
3. Use a stopwatch to time how long it takes for the cyclist to pass between the two points at the bottom of the hill.
4. Repeat the test several times for each variable being tested – clothing, riding position, tyre pressure.

**Results**

Speed = distance divided by time. To convert into kilometres per hour, multiply by 3.6.

For example, if a student takes 4.0 seconds to travel 10 metres, the speed is:

10 ÷ 4.0 = 2.5 metres per second x 3.6 = 9.0 km/h

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Trial** | **Distance (d) between points in metres** | **Time (t) in seconds** | **Speed in metres per second, m/s**(d ÷ t) | **Speed in kilometres per hour, km/h**(m/s x 3.6) |
| **Sitting upright (and wearing a loose flapping coat)** |
| 1 |  |  |  |  |
| 2 |  |  |  |  |
| 3 |  |  |  |  |
| **In crouched position (tight clothing)** |
| 1 |  |  |  |  |
| 2 |  |  |  |  |
| 3 |  |  |  |  |
| **Tyres slightly deflated** |
| 1 |  |  |  |  |
| 2 |  |  |  |  |
| 3 |  |  |  |  |
| **Conclusions** |

***Activity 5: Coast down tests***

This experiment should only be done if you have access to a level road away from traffic and with supervision by a parent, caregiver or coach.

1. Two students bike together. The first student has a speed meter on the bike. The second student has a watch or stopwatch to call out “Now” every 5 seconds.
2. The two cyclists bike as fast as they can on a level road, then stop pedalling. Every 5 seconds, the timer calls our “Now” and the other cyclist calls out their speed – you could try recording this on a mobile phone to help you remember.
3. Repeat the test several times for each variable being tested – clothing, riding position, tyre pressure. Try to get to the same starting speed and start your measurements from the same starting point on the road each time

**Results**

|  |  |
| --- | --- |
|  | **Speed in kilometres an hour, km/h at** |
| **Variable** | **0 seconds** | **5 seconds** | **10 seconds** | **15 seconds** | **20 seconds** | **25 seconds** | **30 seconds** |
| Loose flapping clothing |  |  |  |  |  |  |  |
| Tight fitting clothing |  |  |  |  |  |  |  |
| Crouched position |  |  |  |  |  |  |  |
| Tyres slightly deflated |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
| **Graph your results** |
| speed(km/h)time (seconds) |
| **Conclusions** |