

Free wind tunnel lesson plans for science, physics and design.

Three ready-to-teach lessons, one 50–60 minute period each, with step-by-step instructions, student worksheets, curriculum links and notes on what your class should see. All three run in the free version of WindCanvas in a web browser: nothing to install and no student accounts.

Free to print and copy for your classes. Written for the Australian Curriculum (version 9) and easy to adapt for other curricula.

windcanvas.com/teachers/ · Edition 1, October 2026 · written for WindCanvas 1.3.1

THE PACK

Three lessons, one period each.

Each lesson has a teacher plan with timings and the exact menus to click, a worksheet to print, and teacher notes with the results to expect.

LESSON 1 · YEARS 7–9 SCIENCE

Shape and drag

Predict, observe, explain: a flat plate, a cylinder and a teardrop in the same wind. Students read the drag coefficient, watch the wakes and connect streamlining in nature and vehicles to what they see.

LESSON 2 · YEARS 10–12 PHYSICS

How wings make lift

Tilt an aerofoil a few degrees at a time, record lift and drag, plot the lift curve and find the stall. Lift is explained through pressure difference and Newton's third law, and simulation is weighed against theory.

LESSON 3 · YEARS 7–12 STEM

Design a faster car

Built for STEM Racing (formerly F1 in Schools) and CO2 dragster projects: import a photo or sketch of the car, test three design changes one at a time and write a design rationale backed by results.

Open a browser and start.

No accounts, no student data Students go to windcanvas.com/app/ and start. There is nothing to sign up for, the app has no usage tracking, and shapes, photos and results stay on the device.	Runs on school devices Any recent Chrome, Edge, Firefox or Safari with WebGL2: Windows PCs, Macs, Chromebooks, iPads and Android tablets. Built-in laptop graphics are fine. The online wind tunnel page checks a device for you.	The free version is enough Every step in these lessons uses the free version: the presets, the brush and shape tools, photo and sketch import, live drag and lift, snapshots and reports (marked "WindCanvas Free").
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Before the lesson

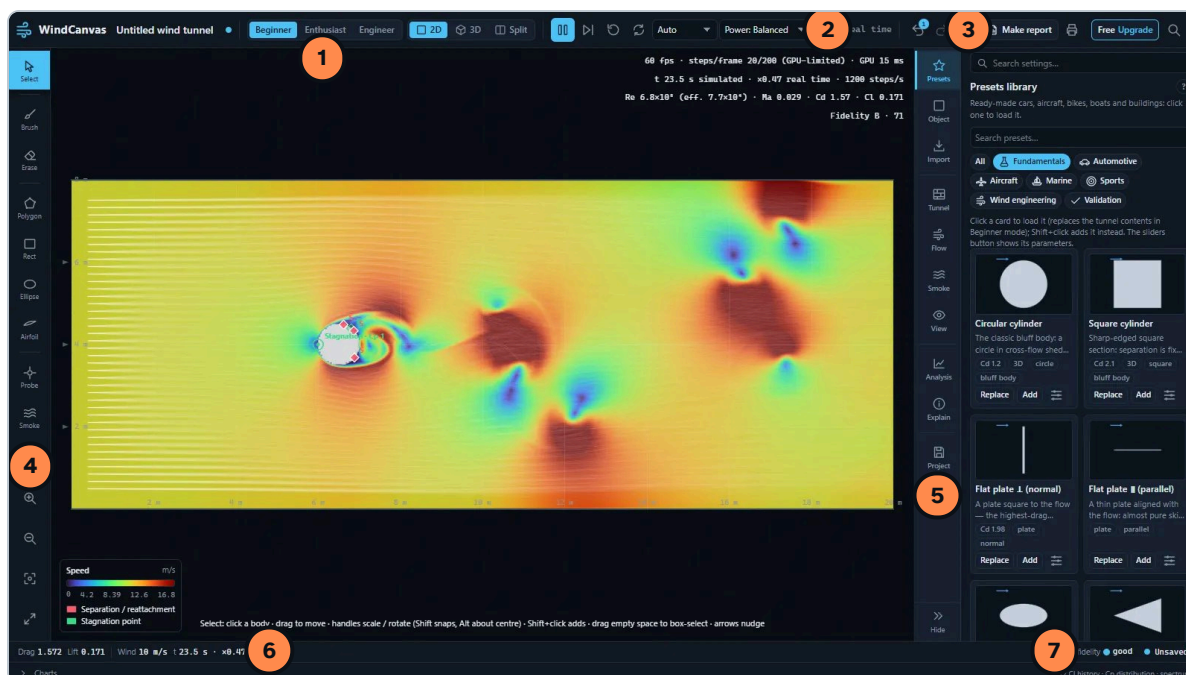
- Open windcanvas.com/app/ on one device to check it loads. The first visit shows a Welcome window: choose **Skip**.
- Plug laptops in if you can. On battery the app switches itself to **Battery saver**, which keeps the laptop cool but runs the simulation at about a quarter of the speed. Choosing **Balanced** under **Power** in the top bar keeps the normal speed until the laptop is next unplugged.
- Work in pairs: one student drives, one records. Put the app on the projector for the demonstrations.
- Use a normal browser window, not a private one: the free version keeps its autosave in the browser.
- The app sometimes suggests raising the resolution or refining the grid around the body. Those need a licence; every lesson here is designed for the free version's resolution.

Keeping the results

- Students record results on the worksheet as they go.
- **Make report** (top bar) opens a printable A4 report with the set-up, numbers, charts and flow pictures; save it as PDF from the print dialog for a portfolio. If the browser blocks pop-ups, the report downloads as a file instead.
- The free version autosaves in the browser. Saving project files to share or hand in needs a licence.

What a school licence adds

Classroom (30 school computers) and whole-school licences cover students' home computers too, and add High and Ultra resolution and 3D above Low, grid refinement around the body, SVG, DXF and PDF drawings and 3D models (STL, OBJ, PLY, glTF and GLB), saving and sharing project files, and reports without the watermark. Registered STEM Racing teams get a free licence (windcanvas.com/stem-racing/). Details: windcanvas.com/schools/



1. **Mode:** Beginner, Enthusiast or Engineer. Modes only show or hide controls; the simulation is the same.
2. **Power:** Battery saver, Balanced or Maximum.
3. **Make report:** a printable A4 report.
4. **Tools:** Select, Brush, Erase, shapes, Airfoil, Probe and Smoke.
5. **Panel menu:** Presets, Object, Import, Tunnel, Flow, Smoke, View, Analysis and Explain.
6. **Status bar:** Drag (Cd), Lift (Cl) and Wind, averaged as the flow runs.
7. **Fidelity:** how far to trust the result (excellent, good, fair or rough).

HOW FAR TO TRUST THE NUMBERS

Reliable trends, indicative numbers.

WindCanvas solves the equations of fluid flow with the lattice-Boltzmann method, live on the device's graphics chip. It is a real simulation, not an animation, and it is open about its limits:

- **2D means infinitely long.** The 2D tunnel treats every shape as a slice through a very long body: the cylinder is a long pole, the wing has no tips, the car is infinitely wide. Real objects let air flow round their sides, so a 2D drag coefficient usually reads higher than the real object's.
- **Modest resolution, modest Reynolds number.** The free version runs the 2D tunnel at up to Medium resolution, at Reynolds numbers far below those of a real car or aeroplane (the app shows the effective value it reaches). Thin shapes such as wings feel this most.
- **So:** rankings, trends and comparisons between designs tested the same way are reliable; absolute numbers are indicative. Expect your class's numbers to differ from textbook values, and use that as a discussion point.
- Every result carries a fidelity grade in the status bar and the **Analysis** tab (A to D: excellent, good, fair or rough), with notes on what limits it.

The benchmarks behind this are on the accuracy page (windcanvas.com/accuracy/).

Shape and drag

Why are fast things shaped the way they are? Students predict, observe and explain the drag on three shapes in the same wind, and connect the wakes they see to streamlining in nature and in vehicles.

YEAR LEVEL Years 7–9	SUBJECT Science: forces and motion	TIME 50–60 minutes	WINDCANVAS Free, 2D, Beginner mode
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Learning intentions

- Drag is a force that pushes back on an object moving through air, or on an object with air moving past it.
- The shape of an object changes its drag, and the back of the shape matters as much as the front.
- A simulation can be used to test a prediction.

Australian Curriculum (v9)

[AC9S7U04](#) Investigate and represent balanced and unbalanced forces, and relate changes in an object's motion to the forces acting on it. Drag is one of those forces.

[AC9S7I01](#) [AC9S7I04](#) [AC9S7I05](#) Predictions, tables of results, and patterns in data. Year 8 and 9 classes: the matching Science Inquiry descriptions ([AC9S8I01](#), [I04](#), [I05](#); [AC9S9I01](#), [I04](#), [I05](#)).

[AC9S9H02](#) How science contributes to technology and engineering: streamlined vehicles. Years 7–8: [AC9S7H03](#) [AC9S8H03](#), through the exit question on cutting a truck's fuel use.

Setup (2 minutes)

1. Open windcanvas.com/app/. On the first visit choose **Skip** in the Welcome window. A car appears in a running tunnel.
2. Check that the top bar shows **Beginner** and **2D**.
3. Point out **Drag** at the left of the status bar along the bottom: the drag coefficient, Cd, averaged as the flow runs.
4. Laptops on battery: under **Power** in the top bar choose **Balanced**.

Step by step

0–5 min

Hook: what do fast things have in common?

Show the pictures. Ask what the shapes share and collect words on the board: smooth, rounded, pointed, tapered, long.

Success criteria

I can:

- predict which of three shapes has the most and the least drag, and give a reason;
- read the drag coefficient (Cd) and describe the wake behind each shape;
- explain “streamlined” using the words separation and wake;
- give an example of streamlining in nature and in a vehicle.

What you need

- One device per pair with a recent browser (WebGL2)
- windcanvas.com/app/ (free, no sign-up)
- The Lesson 1 worksheet, one per student
- Pictures for the hook: a dolphin, a penguin or a kingfisher, and a fast train, an aeroplane or a cyclist's helmet
- A projector (optional)

5–10 min Predict

On the worksheet (Part A) students see three shapes of the same height in the same wind: a flat plate facing the wind, a circle and a teardrop. They rank them from most to least drag and write a reason.

10–15 min Demonstrate

On the projector, open **Presets** in the panel menu on the right, click the **Fundamentals** chip and click **Flat plate ⊥ (normal)**. In Beginner mode a click replaces the scene. Point out the smoke, the colours (air speed: blue is slow, red is fast), the **Drag** reading and the fidelity word beside it. The **Explain** tab describes the flow in plain English.

15–35 min Observe

1. In **Presets** → **Fundamentals**, load **Flat plate ⊥ (normal)**. Watch the smoke and the swirling wake behind the plate.
2. Wait a minute or so, until the **Drag** number stops drifting, then record it. It wobbles a little as eddies peel off: record the value it settles around.
3. Repeat with **Circular cylinder**, then **Teardrop (streamlined body)**.
4. For each shape, describe the wake (wide or narrow, calm or swirling) and sketch the smoke (Part B).
5. Optional: press **4** to colour the flow by vorticity (how fast the air spins) and **2** to go back to speed. Zoom with the mouse wheel or a pinch.

35–50 min Explain

Compare the results with the predictions. Then build the explanation together. Air cannot turn the plate's sharp edges or follow the back of the cylinder, so the flow separates from the surface and leaves a wide, swirling wake. The wake is at low pressure, the front is at high pressure, and that pressure difference pushes the shape backwards: drag. The teardrop's gently tapering tail lets the air follow the surface almost to the end, so the wake is narrow and the drag small.

Streamlining is shaping the back as carefully as the front. Ask for examples: dolphins, penguins and tuna; a cyclist's teardrop helmet; aeroplane fuselages; the long nose of a fast train. Students answer Part C.

50–55 min Exit question

"A truck company wants its trucks to use less fuel. Use today's results to suggest one change to the shape of a truck, and explain why it would help."

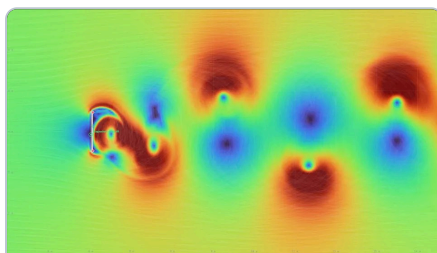
Extension

- Turn the teardrop round so its tail faces the wind: press **V**, click the teardrop and choose **Mirror horizontally** on the small toolbar beside it. Is it still streamlined? Why does the back matter so much?
- Predict, then test, other Fundamentals shapes: **Square cylinder**, **Half cylinder**, **D-shaped body** and **Wedge (triangular prism)**.
- Delete the preset shape (press **V**, click it and press **Del**), then draw your own with the **Ellipse** tool (**O**) or the **Brush** (**B**) and try to beat the teardrop. Keep brush strokes thick (at least three grid cells), and give the flow a minute to settle after each change.
- Year 9: in the **Tunnel** tab change **Wind speed** from 10 to 20 m/s. Cd hardly changes, but the drag force goes up about four times: switch the mode to **Enthusiast** and look under **Forces** in the **Analysis** tab. What does that mean for the fuel a car uses at high speed?

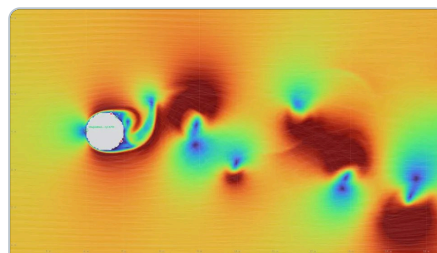
Teacher notes

Shape	Drag (Cd) students see	Textbook, long shape in open air	The wake
Flat plate $\perp$ (normal)	about 4.5	about 2	Very wide, strong eddies
Circular cylinder	about 1.6	about 1.2	Wide, swinging vortex street
Teardrop (streamlined body)	about 0.6	under 0.1	Narrow, small eddies

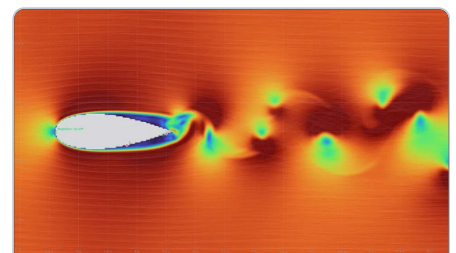
Typical readings in the free version (default presets, Medium resolution), measured with WindCanvas 1.3.1. Your class's numbers may differ by a few percent.



Flat plate



Cylinder



Teardrop

What students see after a minute or so, each shape shown at the same height. Colour is air speed (blue is slow), scaled to each picture.

- **The order and the big gaps are the result.** All three readings are higher than textbook values: the tunnel walls are close (the **Tunnel** tab shows a blockage of 10–12 % and says results are biased high) and the free version's grid is modest, which hits the teardrop's thin tail hardest. The plate still has about seven times the teardrop's drag. This is a good moment for the 2D question on the worksheet.
- **The preset cards show textbook values** (the flat plate's card says Cd 1.98), so students will notice their measured numbers are higher. Use it: what is different about this tunnel and a real plate in open air?
- **"Still settling".** For the cylinder the Analysis tab may keep saying the averages are still settling, because its wake never quite repeats. Read the status-bar Drag after a minute or two; it changes very little after that.
- **Why Cd and not newtons?** The drag coefficient compares shapes fairly, whatever their size and the wind speed. Bigger and faster means more force; Cd is about shape alone.
- **Markers on the shapes.** The green dot is the stagnation point, where the air stops against the front; red diamonds mark where the flow separates from the surface or reattaches to it.
- **Lift.** The plate, the cylinder and the teardrop shed eddies from alternate sides, so the **Lift** reading swings up and down and its average can sit away from zero for a while. It is not part of this lesson.
- **Misconceptions to listen for.** "A pointed front is what matters" (the tail matters more); "drag only depends on size" (all three shapes are the same height); "air only pushes on the front" (the low pressure in the wake behind adds to the drag).
- **Timing.** Loading a preset restarts the flow. The Drag number settles in about a minute on a laptop that is plugged in, longer on Battery saver. If time is short, run the flat plate on the projector while pairs test the other two.

Name

Class

Date

A. Predict

The wind blows from left to right. The three shapes are the same height. Rank them from 1 (most drag) to 3 (least drag) and give a reason.



wind



A Flat plate



B Cylinder



C Teardrop

Shape	Rank (1-3)	My reason
A Flat plate		
B Cylinder		
C Teardrop		

B. Observe

Presets → Fundamentals. Load each shape, wait until **Drag** in the status bar settles, then record it.

Shape	Drag (Cd)	The wake: wide or narrow? calm or swirling?	Sketch of the smoke
Flat plate			
Cylinder			
Teardrop			

C. Explain

1. Which shape had the least drag? Was your prediction right?

2. Compare the wake behind the flat plate with the wake behind the teardrop. How is the size of the wake linked to the drag?

3. Use the words **separation** and **wake** to explain why the teardrop has much less drag than the flat plate.

4. Name an animal and a vehicle with a streamlined shape. Which part of each does the same job as the teardrop's tail?

5. A cyclist rides along a flat road at a steady speed. Draw arrows for the forces pushing her forwards and backwards. What can you say about the sizes of these forces?

6. The simulation is 2D: each shape is a slice through a very long object, like a pole. Suggest one way a real ball or car might behave differently.

How wings make lift

Students tilt an aerofoil a few degrees at a time, record lift and drag, plot the lift curve and find the stall. Then they explain lift with pressure difference and Newton’s third law, and compare the simulation with the app’s own theory line.

YEAR LEVEL	SUBJECT	TIME	WINDCANVAS
Years 10–12	Physics: forces, Newton’s laws, lift	50–60 minutes	Free, 2D, Enthusiast mode

Learning intentions

- A wing makes lift by turning the air that flows past it, which shows up as a pressure difference between its two surfaces.
- Lift and drag change with the angle of attack, until the wing stalls.
- Simulated data has to be judged against theory and its own limits.

Australian Curriculum (v9)

[AC9S10U05](#) Investigate Newton’s laws of motion and quantitatively analyse the relationship between force, mass and acceleration of objects.

[AC9S10I04](#) [AC9S10I05](#) [AC9S10I06](#) Tables and graphs; patterns, trends and anomalies; validity, assumptions and uncertainty.

[AC9S10H02](#) How technologies such as simulation advance science and engineering.

Years 11–12: senior secondary Physics is set by each state and territory. Use the lesson with your course’s study of forces, Newton’s laws and momentum, and fluids or flight where it includes them.

Setup (2 minutes)

1. Open windcanvas.com/app/ and choose **Skip** in the Welcome window.
2. Switch the mode in the top bar to **Enthusiast**. The status bar now shows L/D and the Reynolds number, and the **Charts** strip opens.
3. Open **Presets**, click the **Aircraft** chip, then **NACA 2412**, a classic light-aircraft wing section. It loads with air at 50 m/s and the wing at an angle of attack of 4°.
4. Press **V**, click the wing and open **Object**. The **Angle of attack** dial is at the top; you can also type an angle into its box. Zoom in on the wing with the mouse wheel or a pinch.

Success criteria

I can:

- record C_l and C_d at a range of angles and plot the lift curve;
- identify the stall from my data and the flow pictures;
- explain lift with pressure difference and with Newton’s third law, and say what is wrong with the “equal transit time” explanation;
- give a reason the simulated lift is lower than the theory value.

What you need

- One device per pair with a recent browser (WebGL2)
- The Lesson 2 worksheet (with its graph grid), one per student
- A projector for the demonstration

Step by step

0–5 min

Hook: how does a wing hold up an aeroplane?

Students write their own explanation in Part A of the worksheet. Collect a few without judging them. Someone will probably say the air over the top has further to go, so it must go faster to meet the air from underneath at the back. Keep it for later.

5–12 min

Demonstrate

Show the wing at 4°. Press **3** to colour the flow by pressure: low pressure (suction) over the top, higher pressure underneath. Press **2** for speed: the air over the top moves faster. Point to the smoke behind the wing: the air leaves the trailing edge heading slightly downwards. That downwash is the air the wing has pushed down.

12–35 min

Collect data

1. Set the angle of attack to 0°. Wait until **Drag** and **Lift** in the status bar stop drifting (30–90 seconds; the **Cd / Cl history** chart in the Charts strip shows the lines levelling out).
 2. Record Cl (Lift), Cd (Drag) and L/D. In the **Analysis** tab, under **Inviscid (panel method, high-Re)** just below Results, record the panel-method Cl: the theory value for frictionless, fully attached flow.
 3. Note whether the smoke follows the upper surface to the trailing edge or breaks away into a wide, swirling wake.
 4. Repeat at 2° steps up to 18°. If time is short, give each pair three angles and pool the class results on the board.
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35–45 min

Graph

Students plot simulated Cl and panel-method Cl against angle on the same grid (Part C), mark where the simulated lift stops rising, and note where the drag starts climbing steeply.

45–55 min

Explain

Two descriptions of the same physics. Pressure: the wing's shape and angle make the air speed up over the top and slow down underneath, so the pressure on top is lower and the net force points up. Newton's third law: the wing pushes air downwards (the downwash), so the air pushes the wing upwards. Then test the hook idea: nothing makes the two streams meet at the back, and in reality the air over the top arrives at the trailing edge well before the air underneath. At high angles the flow can no longer follow the upper surface; it separates, the wake widens, drag shoots up and lift stops rising: the stall. Students answer Part D.

55–60 min

Exit question

"Why does an aeroplane raise its nose to take off, and why can't it keep raising it?"

Optional: pressure along the surface (Cp)

In Enthusiast mode open **Cp distribution** in the Charts strip, or **Pressure distribution** in the Analysis tab. Suction points up: the upper-surface curve shows the low pressure on top, with its deepest dip just behind the leading edge, and the area between the upper and lower curves is the lift. The dotted loop is the panel method's Cp. Compare 4° with 16°: past the stall, look for a flat stretch along the rear of the upper-surface curve, the sign of separated flow.

Extension

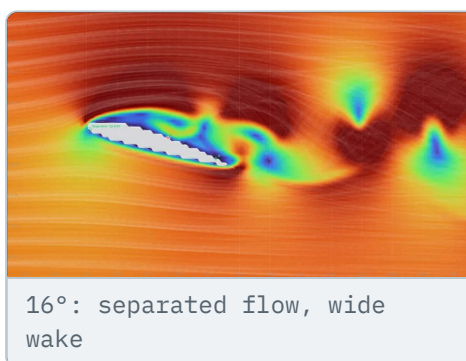
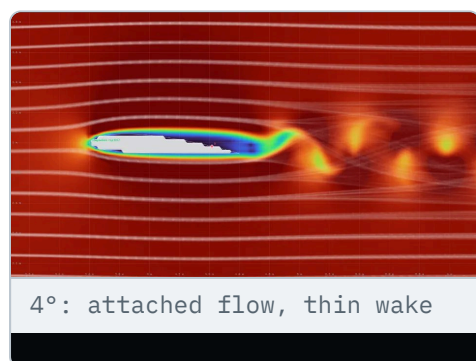
- In the Analysis tab click **Instant polar** (under the panel method): the theory's whole lift curve from –6° to 16° in milliseconds. It never stalls. Why not?
- Load **NACA 0012**, a symmetric section, and compare the panel-method lift at 0° with the cambered NACA 2412's. What does camber do?

- Flip the wing upside down with **Mirror vertically** on the small toolbar beside it: lift becomes downforce, as on a racing car's rear wing.
- Try **Wing with slotted flap** or **Wing with leading-edge slat** (Aircraft presets): how do airliners get extra lift for landing?

Teacher notes

Angle	Simulated Cl	Simulated Cd	Panel-method Cl
0°	0.00	0.06	0.26
4°	0.15	0.08	0.74
8°	0.44	0.14	1.22
10°	0.52	0.17	1.46
12°	0.6–0.9	0.23–0.29	1.69
14°	1.0	0.35	1.93
16°	1.1	0.40	2.16
18°	1.0	0.41	2.38

NACA 2412 in the free version (preset set-up, Medium resolution), measured with WindCanvas 1.3.1. The flow is unsteady: repeat runs agree to a few hundredths, except around 12°, where the flow over the wing can settle into either of two patterns.



- **Expect the simulated lift to be low.** In the free version the wing is only about five grid cells thick (the **Tunnel** tab shows **Cells across body**), so the thin layer of air next to the surface cannot be resolved. The simulated air behaves as if it were far more viscous than real air: it leaves the surface early and the lift comes out at a fifth to a half of the panel-method value. The app says so itself: the fidelity grade for these runs is D, “rough”. This is the heart of the evaluation question, not a fault in the lesson.
- **What to trust.** The panel method is the opposite limit: frictionless flow that never separates, so it never stalls. In published wind-tunnel data for the NACA 2412 at full scale, lift rises about 0.1 per degree, a little below the panel line, until the section stalls at a Cl of about 1.7 (Abbott and von Doenhoff, *Theory of Wing Sections*). Use the simulation for the shape of the curve, the drag, the flow pictures and the stall, and the panel method for full-scale lift.
- **The stall in the simulation** is gradual. Lift climbs slowly to about 10°, jumps somewhere between 10° and 14° as the separated region over the upper surface reorganises (pairs may disagree at 12°: a real anomaly worth discussing), then levels off at a Cl of about 1.0–1.1 from 14° to 18°. Meanwhile drag climbs steeply from about 12° and the smoke breaks into a wide, swirling wake. Lift levelling off while drag shoots up is the stall. Real wings at full scale stall more abruptly.
- **Lift explanations.** The pressure and Newton’s-third-law descriptions are two views of the same momentum balance; Bernoulli’s principle links the faster flow to the lower pressure, but does not say why the air speeds up. The “equal transit time” story is false: nothing requires the two streams to meet again.
- **Timing.** Each angle restarts the averaging, and the numbers settle in 30–90 seconds. Pooling angles across pairs gives a full curve in a few minutes, and the scatter between pairs is itself worth discussing.

Name

Class

Date

A. Before you start

How does a wing hold up an aeroplane? Write your explanation now.

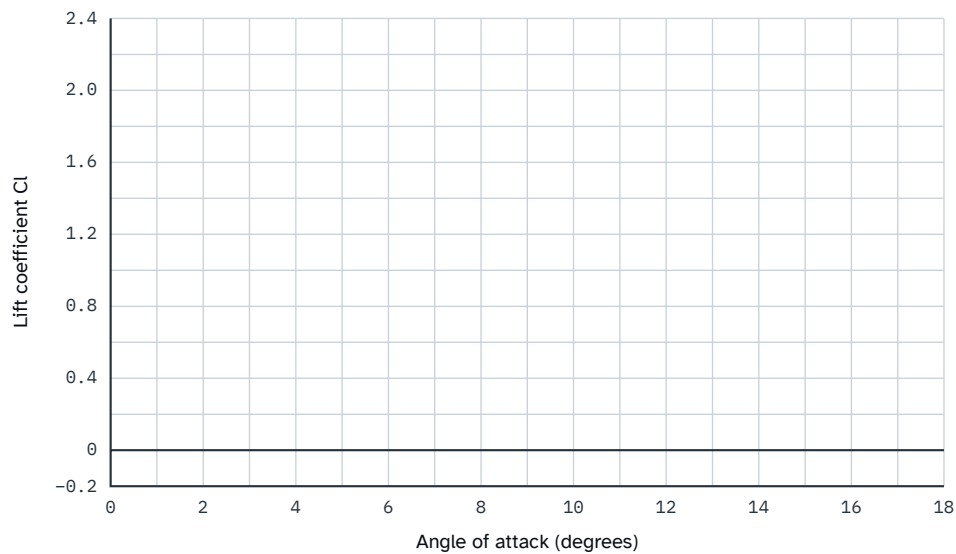
B. Results

Presets → Aircraft → NACA 2412, Enthusiast mode. Change the **Angle of attack** (Object tab), wait until Drag and Lift settle, then record. Panel-method Cl: Analysis tab, under **Inviscid (panel method, high-Re)**.

Angle of attack	Lift Cl (simulation)	Drag Cd (simulation)	L/D	Cl (panel method)	Upper surface: attached or separated?
0°					
2°					
4°					
6°					
8°					
10°					
12°					
14°					
16°					
18°					

C. The lift curve

Plot the simulated C_l (•) and the panel-method C_l (x) against the angle of attack. Mark the stall.



D. Explain

- Describe how the simulated lift changes as the angle increases. At what angle does it stop rising?

- What happens to the drag, and to the smoke above the wing, at and beyond that angle?

- Press **3** to show pressure. Use what you see to explain where the lift force comes from.

- Watch the smoke behind the wing. Use Newton's third law to explain lift.

- "Air over the top has further to go, so it must speed up to meet the air from underneath at the back." Explain why this popular explanation is wrong.

- The simulated lift is much lower than the panel-method value. Suggest a reason, and say which you would trust for a real aeroplane wing, and for what.

Design a faster car

For STEM Racing (formerly F1 in Schools) and CO2 dragster projects. Students import a side view of their own car, measure its drag, test three design changes one at a time, and write a design rationale backed by their results. Teams can take it further with the STEM Racing guide.

YEAR LEVEL Years 7–12	SUBJECT STEM, Design and Technologies	TIME 50–60 minutes, plus write-up	WINDCANVAS Free, 2D, Enthusiast mode
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Learning intentions

- A virtual wind tunnel can test and improve a design before anything is made.
- A fair test changes one thing at a time and keeps everything else the same.
- Design decisions should be justified with evidence.

Australian Curriculum (v9)

Years 7–8 Design and Technologies: [AC9TDE8K03](#) how force, motion and energy are used to control engineered systems; [AC9TDE8P02](#) generate, test, iterate and communicate design ideas, including with digital tools; [AC9TDE8P04](#) design criteria to evaluate ideas and solutions.

Years 9–10: [AC9TDE10K03](#) [AC9TDE10P02](#) [AC9TDE10P04](#), the same strands at the next level.

Science Inquiry, fair testing: [AC9S9I02](#) [AC9S10I02](#).

Years 11–12: senior Engineering, Design and Physics courses are set by each state and territory; this is the kind of testing and evaluation evidence a design folio asks for.

Success criteria

I can:

- import a side view of my car at its real length and read its drag coefficient;
- make three design changes, one at a time, and record the effect of each;
- use the flow pictures to explain why a change helped or did not;
- write a design rationale that uses my results as evidence.

What you need

- A side-view photo or sketch of each car, as a JPG or PNG file on the device. Photos: side-on, plain background, taken from a few metres away with zoom. Sketches: one dark, continuous outline. iPhone photos are often HEIC: export them as JPEG or PNG first.
- The car's real length, measured with a ruler
- No photo yet? Teams can start from **Presets** → **Automotive** → **STEM Racing car**, a generic 210 mm car with front and rear wings, and change it with the brush and eraser.
- The Lesson 3 worksheet, one per student or team

Setup (2 minutes)

1. Open windcanvas.com/app/ and choose **Skip** in the Welcome window.
2. Switch the mode in the top bar to **Enthusiast**, so the Analysis tab offers **Compare snapshots**.
3. Check the photo or sketch is on the device and the car's length is written on the worksheet.

Step by step

0–5 min

Brief

The goal: less drag, so the car is faster down the track. The rule: change one thing at a time, and keep the real length, the ground gap and the wind speed the same for every test. Teams plan their three changes in Part A.

5–15 min

Import the original design (version A)

1. Drag the file onto the app, or open **Import** and click **Drop files here or click to browse**.
2. In the import dialog, compare the **Original** with the **Extracted** outline; the **Grid preview** shows what the solver will see. Fix the outline if needed with the **Keep** and **Erase** brushes or **Crop**. Take any wheels out of the outline: drag the **Ground line** up to the underside of the body (everything below it is removed), or paint them out with **Erase**. The teacher notes explain why.
3. Check that the line at the top of the settings says it looks like a car: the dialog then ticks **Mount on ground** and faces the car into the wind (if the nose still points right, click **Flip to face the wind**). Ignore the offer to use a preset instead (usually the STEM Racing car): this lesson is about the team's own design.
4. Check the **Real length** and change it if needed, for example 0.21 m for a 210 mm car (check the unit beside the box). The dialog guesses the length from the closest preset, so check it on every import. Set **Gap** to the car's ground clearance in metres (0.005 for 5 mm).
5. Name it "A original", tick **Apply recommended tunnel & flow** (outside Beginner mode it starts unticked) and click **Add to tunnel**. The tunnel is sized for the car, with air at 20 m/s (about race speed) over a moving floor. Check **Wind speed** in the **Tunnel** tab reads 20 m/s, and from now on leave the tunnel settings alone.

15–20 min

Measure version A

Let the flow run for about two minutes, until **Drag** in the status bar stops drifting. It may still wobble a little as eddies peel off the back of the car, so read it three times, ten seconds apart, and record the average and the fidelity grade (Part B). Then, in the **Analysis** tab under **Compare snapshots**, click **Take snapshot**.

20–40 min

Test three changes (B, C, D)

Make one change, measure it the same way, take a snapshot, then undo back to version A (**Ctrl**+**Z**; snapshots are kept) before the next change. Two ways to change the design:

- **In the tunnel.** The **Erase** tool (**E**) carves material away: round a sharp corner, slope the rear, slim the nose. The **Brush** (**B**) adds material: a smoother nose cone, a fairing, a longer tail. Use **I** and **J** to change the brush size.
- **On paper.** Redraw the change, photograph it and import it again with the same Real length and Gap. Leave **Replace current reference body** ticked and **Apply recommended tunnel & flow** unticked, so the tunnel and the wind stay exactly the same.

Ideas: a rounder or a sharper nose; a smooth step where the nose meets the body; a tapered tail or a cut-off (Kamm) tail; a lower rear wing; a lower overall height. Finally, undo back to version A and measure it once more: if it comes back within a percent or two of the first time, bigger differences between versions are real.

40–50 min

Compare and decide

Under **Compare snapshots**, tick up to four versions: the table shows Cd, Cl, L/D, the Reynolds number, the speed and the fidelity of each, with the percentage change from the first. Which change cut drag the most? Switch the field (**View** tab, or keys **2** speed and **3** pressure) to see why: a smaller, calmer wake means less drag.

50–60 min

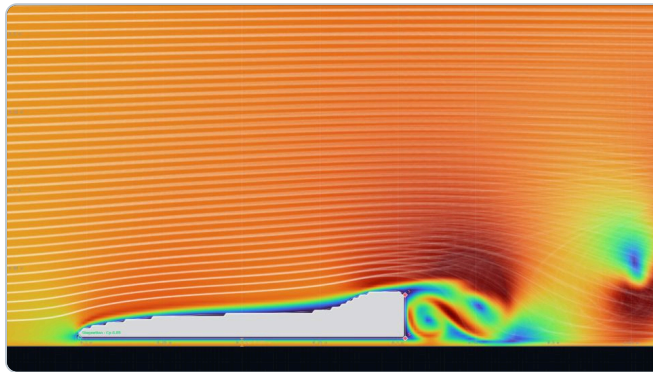
Rationale and evidence

Teams draft their design rationale (Part C). For the portfolio, click **Make report** in the top bar: an A4 report with the set-up, results, charts and flow pictures, plus a comparison of the snapshots you ticked (in Enthusiast mode the **Comparison** section in the **Report** tab starts ticked). Print it or save it as PDF. In the free version the report is marked "WindCanvas Free".

Extension

- Combine the best two changes into version E. Do the savings add up?
- Change **Wind speed** in the **Tunnel** tab from 20 to 30 m/s. Cd stays about the same, but the drag force under **Forces** (Analysis tab) more than doubles. Why?
- If a change alters the car's height, compare **Cd•A** (under Forces) as well as Cd: the drag area decides the drag force.
- Import the photo again with the wheels left in. Why does the lift jump? (See the teacher notes.)
- Teams with a CAD model can test the real 3D car with a licence (STL and OBJ import, the 3D tunnel above Low). Registered STEM Racing teams can claim a free licence, and the STEM Racing page has a guide for teams and judges (windcanvas.com/stem-racing/).

Teacher notes



A car body imported from a side-view silhouette at its real length (0.21 m), wheels removed, 5 mm above a moving floor, air at 20 m/s.

- **Why the wheels come out.** The 2D tunnel sees a side view as a slice through an infinitely wide car. Solid wheels then become two walls that seal the gap under the body and trap air over the moving road, which distorts lift and drag (the user guide quotes a test sedan with solid wheels reading a lift coefficient of about +3). The app's own car presets draw their wheels as see-through, visual-only parts for the same reason. Neither choice models what real wheels do to the flow, so keep students' attention on the body shape.
- **Ignore lift in this lesson.** A few millimetres of ground clearance spans only two or three grid cells in the free version, so the flow under the car is not resolved and the Lift reading can swing wildly from one version to the next (in our test from -0.3 to +3.3); the Analysis tab says so: **Underbody gap under-resolved**. Drag comparisons between versions with the same Gap remain useful.
- **Typical numbers.** Side views give high drag coefficients, above 1, because the 2D tunnel sees an infinitely wide car with a blunt back, so compare versions rather than quoting the number as the car's Cd. In our test (the 210 mm body in the picture, 5 mm gap, 20 m/s over a moving floor, free version) the original read Cd 1.38, graded C: a 2D run of a car is always marked down, and C still supports comparing versions. Lowering the tall rear and tapering the tail cut drag by about 37 % (Cd 0.86). A blunter nose read lower too (Cd 0.93 on average), but its reading wandered by about ±12 %. Results can surprise: that is why designers test.
- **Small differences.** Once the flow has settled, the status-bar Drag (an average over the last two passes of air through the tunnel) often holds steady to a fraction of a percent, even while eddies peel off the car, but for some shapes it keeps wandering: by about ±12 % for the blunt-nosed version in our test. The three readings show which case you have: treat a difference smaller than the spread of the readings as a tie.
- **Thin parts.** Features thinner than about three grid cells, such as a thin rear wing seen side-on, are unreliable at this resolution; the Grid preview in the import dialog shows how thick they come out.
- **Warnings are fair to every version.** The Analysis tab may list High blockage, Body is under-resolved or Wake reaches the outlet for a small car in the free version's grid. They are true, and they affect every version alike, so comparisons stay fair.
- **Fair-test checklist.** The same Real length, Gap and wind speed for every version; the tunnel left alone; the same crop when re-importing; two minutes to settle and three readings every time.
- **Keeping the evidence.** The free version autosaves in the browser, but saving project files needs a licence: make the report and save it as PDF before the end of the lesson.

Name or team _____ Class _____ Date _____

Car's real length (m) _____ Gap (m) _____ Wind speed (m/s) _____

A. Plan

Plan three changes. Change one thing at a time.

Version	The change I will make	Prediction: more or less drag?	Why?
B			
C			
D			

B. Results

Let each version run for about two minutes. Read **Drag** three times, 10 seconds apart, then **Take snapshot** (Analysis → Compare snapshots). Undo back to A before the next change.

Version	What changed	Three Drag readings	Average Cd	Change from A (%)	Fidelity	Keep?
A	Original design			—		—
B						
C						
D						
A again	Repeat of the original					—
E	Best changes combined					

C. Evaluate

1. Which change reduced drag the most? Use the flow pictures to explain why.

2. Did any change increase drag? Suggest why.

3. Name three things you kept the same so that the test was fair.

4. The 2D tunnel sees your side view as an infinitely wide car and leaves out the wheels. How might that affect your results? What would you test next, and how?

5. **Design rationale.** Explain your final design choice in 4–6 sentences, using your results as evidence.

D. Final design

Sketch the side view of your final design and label the changes.

