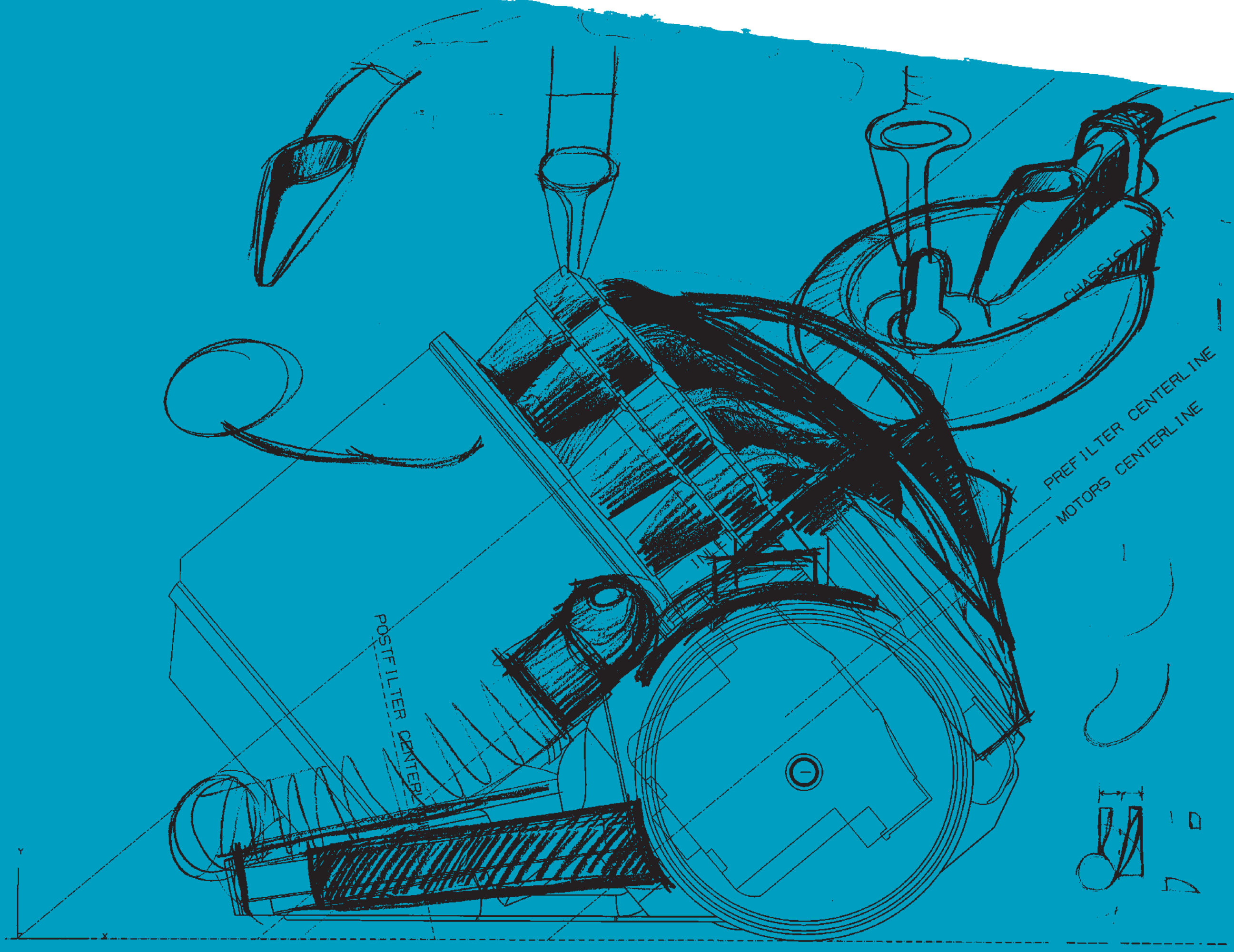
DESIGN BUILD TEST

JAMES DYSON FOUNDATION



JAMES DYSON FOUNDATION

TEACHER'S PACK

www.jamesdysonfoundation.com

THE JAMES DYSON FOUNDATION
WHO ARE WE?

JAMES DYSON FOUNDATION

WE'RE DESIGN ENGINEERING ENTHUSIASTS. SOME OF US ARE, BY OUR OWN ADMISSION, MORE ENTHUSIAST THAN ENGINEER. BUT THAT DOESN'T MATTER BECAUSE ALL OF US — INCLUDING THOSE WHO DO DESIGN ENGINEERING FOR A LIVING — GET OUR KICKS NOT FROM KNOWING THE ANSWERS, BUT DISCOVERING THEM.

WWW.JAMESDYSONFOUNDATION.COM

This teacher's pack is printed on 100% recycled paper

Version 1 USA

"LEARN FROM THE FAILURES AS MUCH AS THE SUCCESSES."

JAMES DYSON

WELCOME TO THE JAMES DYSON FOUNDATION TEACHER'S PACK

This pack is for you, the teacher. It can be used on its own, but it also accompanies the James Dyson Foundation Engineering Box, which has been created to get real examples of engineering into the hands of young people.

We want to excite young people about design engineering — to understand that the thought, building and breaking that goes into the creation of everyday products can be fascinating and fun. Armed with this understanding, we want students to put their own engineering skills to the test by tackling design challenges of their own.

DOWNLOAD SUPPORTING RESOURCES INCLUDING PRESENTATIONS, VIDEOS AND WORKSHEETS TAILORED TO 11–18 YEAR OLDS FROM www.jamesdysonfoundation.com

THE JAMES DYSON FOUNDATION ENCOURAGES YOUNG PEOPLE TO THINK DIFFERENTLY, MAKE MISTAKES, INVENT AND REALIZE THEIR ENGINEERING POTENTIAL.

Design and engineering challenges young people to be creative by using their hands and brains to create things that work.

The Foundation teaches the exciting journey of design — from initial concept right through to production.

Why not tell us about how your students are using the box? Go to **www.jamesdysonfoundation.com**

HOW TO USE THIS PACK

This pack has been designed to fit your timetable and lesson planning. Feel free to photocopy, scribble and adapt it to your needs — it's yours to keep. This pack accompanies the James Dyson Foundation Engineering Box for use in the classroom or after school clubs.

You can find more resources to integrate into your classes at **www.jamesdysonfoundation.com**

NOW OVER TO YOU

WHAT'S IN THE PACK?

THE TEACHER'S PACK IS FOR YOU TO KEEP. IT IS FULLY PHOTOCOPIABLE SO THAT YOU CAN SHARE WORKSHEETS WITH YOUR STUDENTS.

CONTENTS:

ORDER THE ENGINEERING BOX TO BRING THESE ACTIVITIES TO LIFE:
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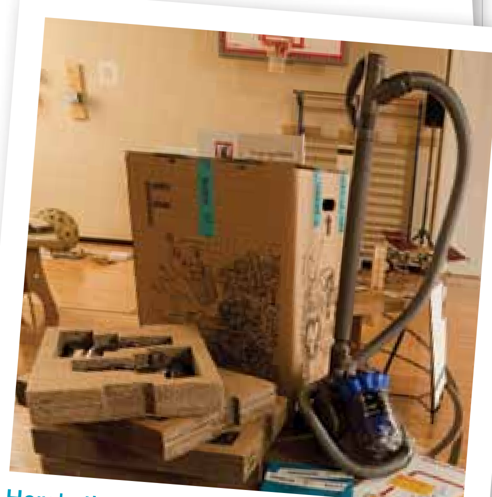
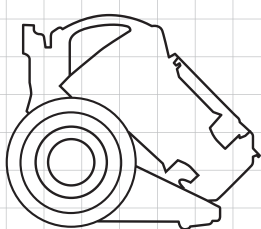


Here's the engineering box

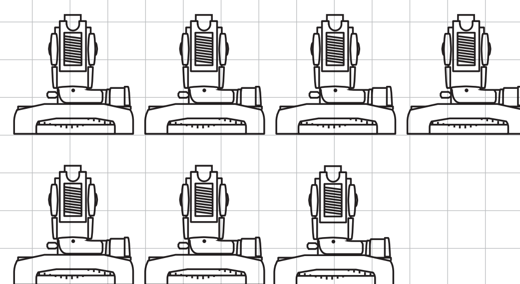
WHAT'S IN THE BOX?

THE JAMES DYSON FOUNDATION ENGINEERING BOX CAN BE BORROWED FOR UP TO FOUR WEEKS. IT CONTAINS:

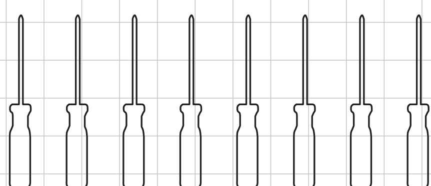
1 X DYSON DC26 VACUUM CLEANER, COMPLETE WITH HOSE, WAND AND ACCESSORIES



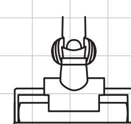
7 X TURBINE HEAD FLOOR TOOLS



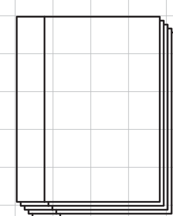
8 X TORX SCREWDRIVERS



1X CARBON FIBER TURBINE HEAD FLOOR TOOL

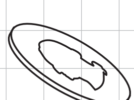


POSTERS TO LIVEN UP YOUR CLASSROOM WALL

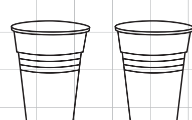


YOU WILL NEED:

A COIN TO SECURE AND UNDO QUARTER-TURN FASTENERS



2 CUPS TO KEEP SCREWS (ONE FOR LONG SCREWS, ONE FOR SHORT SCREWS)



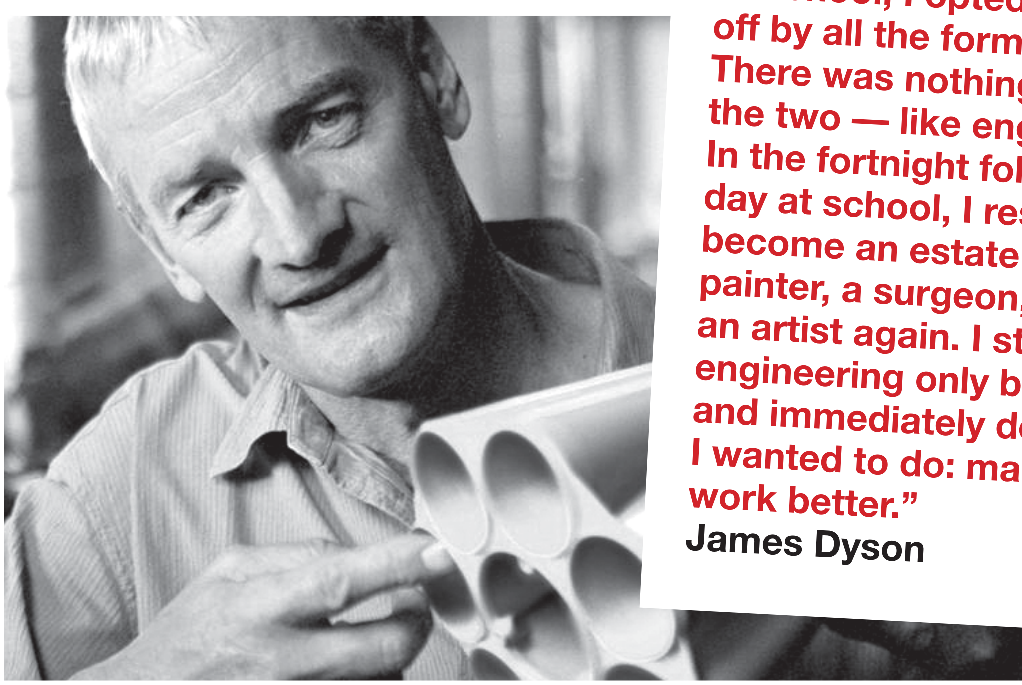
FIND MORE RESOURCES TO INCORPORATE INTO THE BOX ACTIVITIES AT: www.jamesdysonfoundation.com/education

The James Dyson Foundation recommends you take care and follow all instructions when taking part in the disassembly activities. It is the school's/organization's responsibility to make sure participants are supervised and safety regulations are followed.

1 THE DYSON STORY

"I still find frustrations lurking around every corner. I don't think I'll ever stop questioning, dismantling things and looking for ways to improve technology."
James Dyson

1.1 JAMES DYSON: ARTIST OR SCIENTIST?

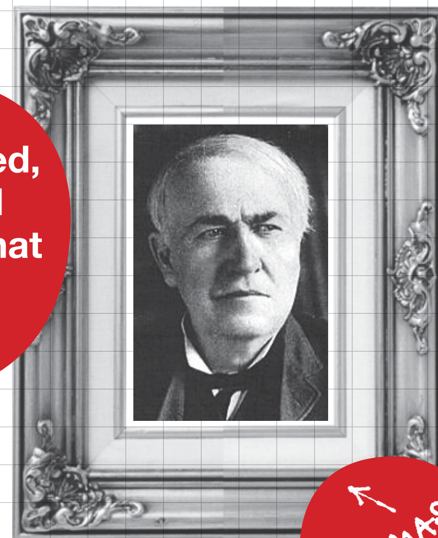


"At school, I opted for arts, put off by all the formulae in science. There was nothing that combined the two — like engineering does. In the fortnight following my last day at school, I resolved to become an estate agent, then a painter, a surgeon, an actor, and an artist again. I stumbled across engineering only by accident and immediately decided what I wanted to do: make things that work better."
James Dyson

MISTAKES CAN BE HAPPY ACCIDENTS THAT LEAD YOU IN NEW DIRECTIONS.

Take the Post-It note. In 1973, a choir singer, Art Fry, was fed up with losing his markers from the pages of his hymn book. He worked at a chemical company, 3M, and remembered a new adhesive that had been discarded for not being sticky enough. Fry realized that this 'failure' had precisely the properties he needed to fix paper markers to pages in his hymn book: a glue that was sticky, but not so sticky that it couldn't be removed. This 'mistake' is now used in homes and offices around the world.

I have not failed, I have found 10,000 ways that won't work.



THOMAS EDISON

1.2 FRUSTRATION

Frustration informs all James Dyson's designs. In the 1970's, while renovating his house, James became frustrated with his traditional wheelbarrow's instability and the furrows the narrow wheel left in his lawn. James designed an alternative called the Ballbarrow, which replaced the wheel with an air-filled plastic ball.

Then, in 1978, another frustration: his vacuum cleaner wasn't sucking up the dirt from his carpet. Irritated, he took the machine apart to find out what was going wrong. He noticed that the vacuum bag wasn't full, as he'd expected. On the contrary, it was nearly empty, with only a thin layer of dust coating the inside of the bag. James realized that this dust was clogging the pores of the bag — causing it to lose suction.

Inspired by an industrial cyclone he'd encountered during the manufacture of his Ballbarrow, James wondered if the same principle could be scaled down and made to work with a vacuum cleaner. The cyclone used centrifugal forces to spin dust out of the air — if a vacuum cleaner could do this, there'd be no need to rely on bags. James built a crude prototype out of his defunct Hoover Junior, using cardboard and gaffer tape and found that there was something in his theory. It worked! James had invented the world's first bagless vacuum. But it would take another five years and 5,126 prototypes to arrive at Dual Cyclone™ technology, and the development of the DC01 vacuum cleaner.

1.3 FAILURE

The design process is a cycle, rather than a straight line. Design, prototype, test, solve the problems found in testing, modify the design, prototype and test again — and repeat until you get it right.

While many people fear failure, James Dyson encourages it. The 5,127 prototypes that preceded the DC01 vacuum cleaner were all failures. But James didn't give up; instead he learned something new from every prototype that didn't work. This approach has been adopted by the hundreds of Dyson design engineers who work with James today.

1.4 DYSON TODAY

TODAY HUNDREDS OF DESIGN ENGINEERS AND SCIENTISTS WORK IN DYSON'S RESEARCH DESIGN AND DEVELOPMENT CENTER, IN A TOWN CALLED MALMESBURY IN THE SOUTH WEST OF THE UK.

The team of engineers work with James Dyson to find practical solutions to everyday frustrations. Their inventions can now be found in over 50 countries, from Germany to Japan.

Meet some of the team at www.jamesdysonfoundation.com

SENIOR DESIGN ENGINEER

WIM

NAME
Wim

AGE
42

NATIONALITY
Dutch

LIVES
Bath, UK

SCHOOL
Zierikzee School

UNIVERSITY
Industrial Design Engineering,
Delft University of Technology

OCCUPATION
Senior design engineer

Wim got into engineering by chance. He wanted to be an archaeologist — but realized he could use his ability to investigate as an engineer. Solving problems and developing solutions.

"I used to build all sorts of stuff in my dad's shed, like furniture and racing cars. I never thought you could use these skills in your job and get paid!

By pure chance I discovered there was a course called Industrial Design Engineering at Delft University. I enjoyed Math and Physics at school so went for it. I was lucky to get onto the course, it was very popular.

I started working for a company designing products for people with disabilities. I worked on a walking frame for children with Cerebral Palsy. I will always remember their faces when they used the frame for the first time.

I am now a Senior design engineer at Dyson. I have been at Dyson for 13 years. I manage 12 people working on the motorbuckets in our fans and hand dryers. I love the satisfaction you get from seeing your design develop into something real."

PROCESS IMPROVEMENT ENGINEER

LEANNE

NAME
Leanne

AGE
24

NATIONALITY
American

LIVES
Chicago, USA

SCHOOL
Lake Forest High School

UNIVERSITY
BS in Manufacturing and Design Engineering, MS in Engineering Design and Innovation, Northwestern University

OCCUPATION
Process improvement engineer

Engineering runs in Leanne's family. She has always enjoyed making things as a hobby, but it was taking part in after school clubs where she got the bug for design engineering.

" When I was younger I wanted to be the first female US President! But I always enjoyed art and making things. Engineering seemed the perfect way to turn these hobbies into a career. My dad was a mechanical engineer so I saw the types of things he did and I knew early on I could do the same.

The closest thing at school to designing was ceramics — and I didn't want to make clay pots for a living! So I got to practice my skills at after school clubs, this was where I took part in model plane challenges and bridge building competitions. I was hooked.

My job involves any task that calls for a technical eye: testing new machines, helping the call center with enquiries or listening to users. My job carries responsibility but I enjoy helping to solve people's problems.

Talking to Dyson owners and watching them operate our machines is the best way to find out what needs to be changed or fixed. Never in your wildest dreams would you think up the issues that come up! Involving the user is so important in developing really successful products.

If I was giving advice to someone wanting to go into design engineering I'd say to be persistent. Even though the studying can be hard, it is worth it in the end!"

1.5 CYCLONE TECHNOLOGY

JAMES DYSON INVENTED DUAL CYCLONE™ TECHNOLOGY WHICH DOESN'T RELY ON A BAG OR FILTER TO TRAP THE DIRT — CONSEQUENTLY, DYSON VACUUMS DON'T CLOG.

cy·clone ('sī,klōn)
n.

1. *Meteorology*
An atmospheric system characterized by the rapid inward circulation of air masses about a low-pressure center, usually accompanied by stormy, often destructive weather. Cyclones circulate counter-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.
2. A violent rotating windstorm.
3. Any of various devices using centrifugal force to separate materials. Like a Dyson vacuum cleaner.

centripetal and centrifugal force
n.

Imagine being in a car when it goes around a corner quickly — it feels like you're being flung against the car door. This is commonly known as centrifugal force. In reality, the actual force acting on you is centripetal force. Without the car door (and seat belt) in the way you would have flown out of the car, travelling in a straight line.

Centripetal force is the force exerted on you by the car door and seat belt. It keeps you moving in a curve. In a Dyson vacuum cleaner, the walls of the bin and cyclone cones exert centripetal force on the moving airflow.

Traditional vacuum cleaners rely on bags with tiny pores, which are supposed to trap dust, yet allow air to pass through. But the dust can quickly block pores, obstructing airflow. This reduces the machine's power to suck up the dirt in your carpet.

Air is sucked in through the cleaner head and, when it enters the bin, starts to spin in a cyclone. As the air spins faster and faster, so does the dust. At high speeds, the dirt is flung out of the airflow, falling to the bottom of the bin where it collects.

The airflow moves through the bin and passes through the shroud — the perforated skirt — where fluff and hair is captured. The air then proceeds through to an inner cyclone, where smaller particles of dust are separated.

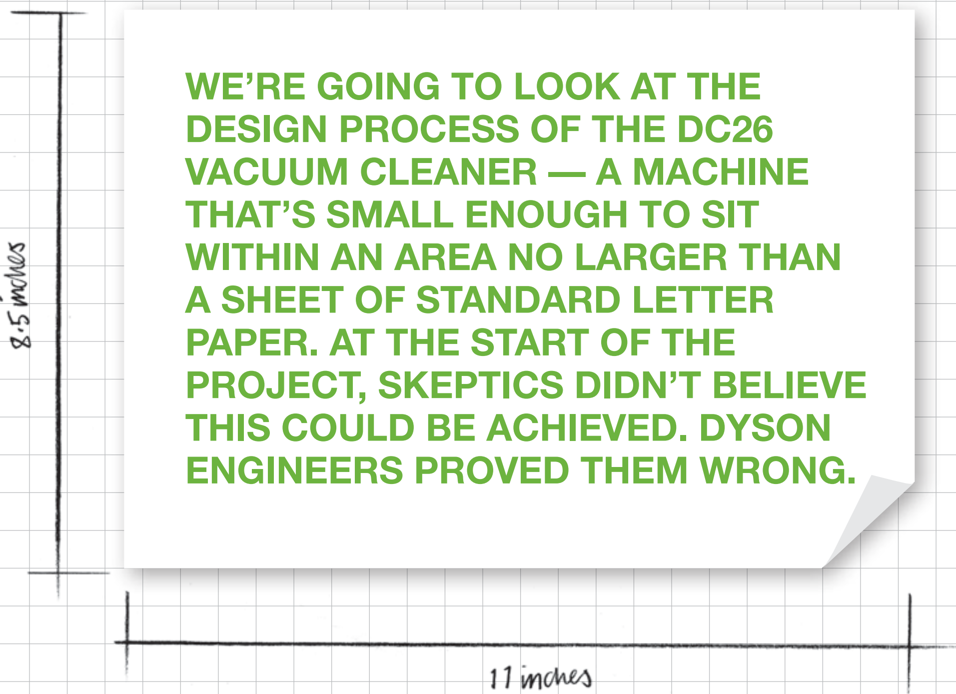
After that, the air is expelled. It's cleaner as the cyclones can capture particles down to 0.5 microns – including pollen and mold spores.

BUILD YOUR OWN CYCLONE AT
www.jamesdysonfoundation.com/education

2 DYSON DC26

"We're always striving to make our designs better, lighter, stronger and easier to use. We all share a desire to push the boundaries of what's achievable. For me, it's the pursuit of perfection that pushes me onto the next project."
Andrew, Principal Engineer

2.1 DESIGN



WE'RE GOING TO LOOK AT THE DESIGN PROCESS OF THE DC26 VACUUM CLEANER — A MACHINE THAT'S SMALL ENOUGH TO SIT WITHIN AN AREA NO LARGER THAN A SHEET OF STANDARD LETTER PAPER. AT THE START OF THE PROJECT, SKEPTICS DIDN'T BELIEVE THIS COULD BE ACHIEVED. DYSON ENGINEERS PROVED THEM WRONG.

IF YOU HAVE THE ENGINEERING BOX, take out the DC26 and try it. Put a sheet of standard letter paper on the desk and sit the machine on top. The footprint of the machine fits.

CODE NAMES

When engineers work on a new design, they give it a code name so they can talk about it without giving away their secrets. This name begins with an X and is followed by a project number. X78 was the code name for the DC26 machine — the 78th project that Dyson's engineers have worked on. They're now on X334!

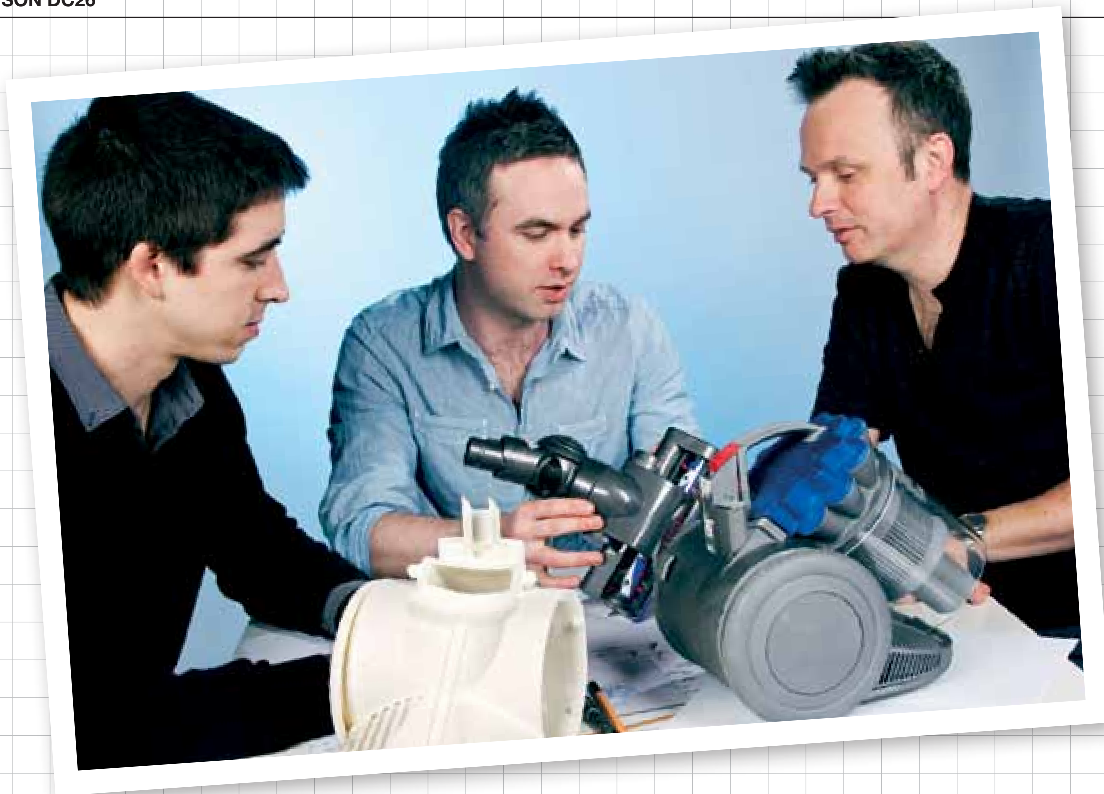
All the development is carried out in secret until the design is registered and protected with intellectual property offices around the world.

2.1.1 THE DESIGN BRIEF

A design brief explains the challenge that must be answered by a product and the parameters in which a design engineer must work. For example, the product might need to be a certain size or perform a particular function.

The brief that design engineers start with is very broad. Space is an issue in many modern homes, so the brief for the DC26 team was to make a new vacuum cleaner that would fit in small spaces. But the engineers didn't want to compromise on its ability to pick up dust. And they wanted to make sure the machine ran as quietly as possible.

FIND OUT MORE ABOUT THE DESIGN PROCESS AT www.jamesdysonfoundation.com/education



2.1.2 THE DESIGN SPECIFICATION

A specification is the measuring stick for a design. Imagine you need a new pair of shoes. Before you go shopping, you think about what sort of shoes you want according to when you'll wear them. If they're school shoes they need to be black, stylish and durable. If they're for sport, lightweight and supportive.

This is how a design specification is set. A list of requirements is compiled, relating to how the product will be used and how it will look.

The acronym 'ACCESS FM' is a good way to think of the key questions that must be asked when writing a specification:

A: Aesthetics — What should it look like? What should it sound like? Think about all your senses.
C: Cost — How much will the product cost to buy? This is often associated with manufacture and materials used.
C: Customer — Who would buy the product? What do they like? What are their needs?
E: Environment — Where will it be stored? How does this affect the design of the product? Is the design sustainable?
S: Safety — What safety aspects must be considered to prevent potential harm to the user?
S: Size — What size should the product be? Are there other important measurements that influence the design?
F: Function — What should the product be designed to do? How will it work?
M: Materials/Manufacture — What materials should be used to manufacture the product? How should it be manufactured? Why?

The next step for the engineers is to develop a much more detailed engineering specification. This sets the limits the machine must work within, like size, weight, power and noise. It is referred to throughout the design process.

ENGINEERING SPECIFICATION

Air Watts	160
Pick up — Wilton Carpet	79%
Pick up — Hard Floor	100%
Pick up — Crevice	95%
Motion Force	18/5 Newtons forwards/backwards
Noise — Normal	83 dB(A)
Bin Volume	0.15 gal
Weight	12 lbs
Size	10.5 x 12.6 x 8.27 inches

"The engineering specification doesn't stop at size, weight, air watts and bin volume either. We go right down to specifying the force needed to press each button and catch."

Andrew, Principal Engineer

2.1.3 RESEARCH AND IDEA DEVELOPMENT

So-called eureka moments are rare. Instead, ideas come from experimentation and sketching, from analyzing problems with existing products and carrying out research into new technologies. This is all part of research, design and development, or RDD.

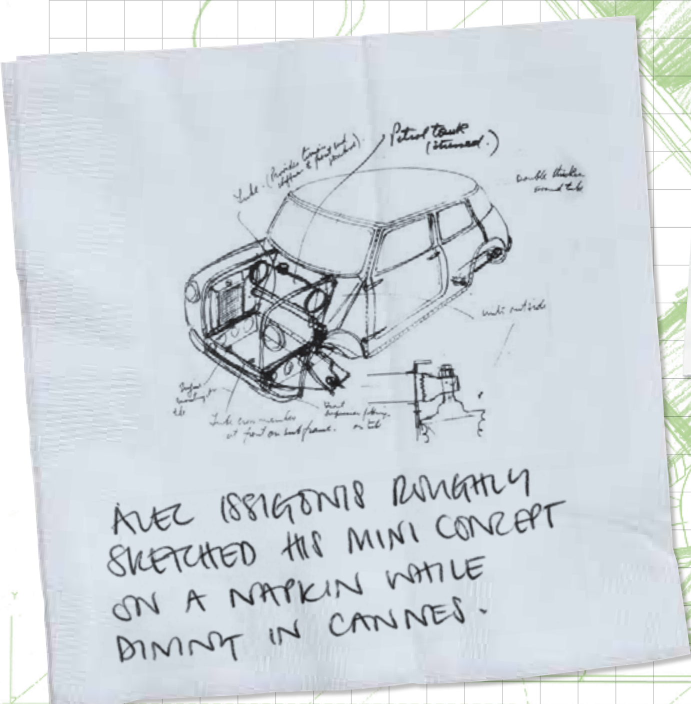
Design engineers work in teams, sketching out and discussing their ideas. Sketching is an important communication tool. Drawings tend to be rough and ready but they're an important bridge between the engineer's concept and the next vital step — creating basic 3D models.

2.1.4 CREATIVE THINKING

Dyson engineers need to think creatively all the time. The most obvious example of where they use creative thinking is in these early stages of the design process — when sketching new ideas, or developing a design brief. But creative thinking is just as important when problem solving later on in the development of a new product.

WHEN DESIGN ENGINEERS AT DYSON BRAINSTORM NEW IDEAS, THEY ALWAYS START WITH THE PROBLEM. THEN THEY TAKE A PIECE OF PAPER AND FOLD IT INTO 16 SQUARES, THINKING CREATIVELY TO FILL EVERY SQUARE WITH A POSSIBLE SOLUTION. TRY IT YOURSELF AND SEE WHAT YOU COME UP WITH.

Use this technique as you think about the problems suggested in section 2.1.8



Another technique is called 'negative brainstorming'.

Think about everything that could go wrong with a product. How could you design it better so that it doesn't go wrong?

2.1.5 DESIGNING WITH YOUR USER IN MIND — WHO WILL USE YOUR DESIGN AND HOW?

Design engineers must never lose sight of the person who'll use the product they're designing. It's important to consider that the user may be of different age, gender or nationality from the designer. And they might not always use the machine in the correct way.

The catch

The design engineers who worked on the DC26 thought a lot about how people use their vacuum cleaners, including how they empty them. On the DC26, you have to press the bin empty button at the top of the clear bin in order to open it at the bottom. On early prototypes, the engineers noticed that people could not find this button to open the bin easily.

The solution was to make the bin empty button red so that it's easily identifiable. Your eyes are naturally drawn down the straight line of color from the button to where the bin opens, highlighting its function. You'll see that all action buttons on Dyson machines are red.

2.1.6 DESIGNING FOR DIFFERENT MARKETS — THE DC26 MACHINE AND JAPAN

Dyson machines are sold in countries all around the world, each with a different culture that influences how people use and relate to them. This must be considered when composing the design brief. For the DC26 vacuum cleaner, the design engineers used information gathered through Japanese user trials to inform their brief.

A user trial involves putting test vacuums in the hands of a cross-section of the public (sworn to secrecy) and watching how they use them. Users are asked to clean different types of floors and asked questions about how they would maintain the machine. It gives Dyson engineers a chance to get important feedback on a design. To get a true idea of owner behavior, it is important to hold the trials in home environments where participants feel comfortable, and will use the machine in a natural way.

User trials in Japan revealed that people didn't know how to remove and wash the pre-motor filter. This is an important part that ensures the machine performs well. To make it easier for users to identify where to access the filter, engineers designed a bright colored door release catch.

Engineers designed a rubber ridge around the outside of the filter, meaning it cannot be replaced back into the wheel incorrectly. This is an example of 'poka yoke' design. This Japanese phrase means 'fail-safing' or 'fool-proofing'.

IF YOU HAVE THE ENGINEERING BOX, find the door release catch on the DC26 to open the pre-filter door. Is it easy to spot? Inside you will find the pre-motor filter. Have a look for the 'poka yoke' design.

Dyson engineers studied how people replaced the bin on the chassis and noticed that many people attach the bin properly at the top, but not at the bottom. Because the bin wasn't securely fixed, it meant that the chassis could become detached when the vacuum was picked up — possibly causing damage or injury.

The solution was an interlocking handle mechanism and a protruding tooth on the base of the bin. The tooth slots into a notch on the chassis and if this doesn't happen, the catch on the handle will not engage. This prevents the bin from being replaced on the chassis incorrectly.

The engineers were also worried that the bin might become detached accidently. So they designed a locking mechanism on the handle of the bin itself so that the bin release button cannot be pressed when you're carrying the machine by the handle.

IF YOU HAVE THE ENGINEERING BOX, take a look at the DC26 bin mechanisms. Pick up the machine.

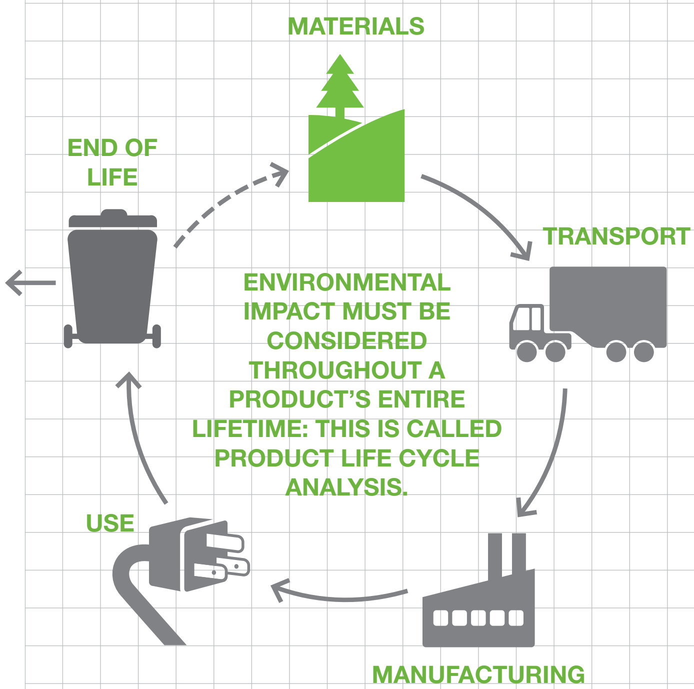
Is it easy to carry?

Can you see where the bin attaches? Try removing it and replacing it. Lift up the DC26 by the handle and try to press the bin release button. You'll find you can't. Have a look at the design of this lock:

With the bin attached to the chassis, look at the side of the clear handle below the grey bin release button. You'll see a transparent tooth on the inside of the handle. Notice the notch in the side of the bin release button. Now lift the handle up and you'll see it flexes before the vacuum is lifted up. As the handle flexes, the tooth on the handle slides into the notch on the button, preventing the release button from being pressed.

2.1.7 LEAN ENGINEERING

Efficient engineering means doing more with less. Less material, less packaging, less energy. Not only do these contribute to a product's performance, they also reduce its environmental impact.



MATERIALS AND MANUFACTURING

The purpose of a product defines the materials chosen to make it. Where possible, raw materials should be minimized and parts made common across different machines, making the manufacturing process more efficient.

Did you know?
When designing plastic molded parts for the machines, Dyson engineers start with wafer thin walls and test them to destruction. This allows them to add material only where it is needed.

TRANSPORT

Products are always on the move; to factories, shops and homes. These journeys contribute to carbon dioxide emissions. Keeping manufacturing close to testing, suppliers and assembly operations, will help minimize these emissions. But clever packaging also means fewer materials and more boxes fit into a shipping container.

Did you know?
Dyson ships its products around the world by sea using fuel-efficient vessels, rail and canal which helps avoid energy-intensive airfreighting.

USE

The largest proportion of the total environmental impact of electric products is through its use. Efficient design will significantly reduce this impact. That is why Dyson engineers spent 10 years developing a high efficiency motor, the Dyson digital motor. It's used in the Dyson Airblade™ hand dryer, creating a blade of air that literally scrapes the water off your hands. As a consequence, the hand dryer uses up to 80 percent less energy than conventional warm air hand dryers.

Did you know?
Dyson engineers calculated that if all the Dyson Airblade™ hand dryers sold in the UK replaced paper towel dispensers, around 17 million paper towels would be saved today. That's enough paper towels to cover around 82 football fields.

END OF LIFE

Increasing a product's lifetime reduces its environmental impact. Dyson engineers test machines to destruction to ensure they produce reliable and durable technologies and reduce the number of machines that are discarded. When they finally reach the end of their life, they can be recycled.

Did you know?
Many plastics now hold a material mark to help you recycle them. Can you spot any on products in your classroom? Just think a vacuum cleaner's bin could one day become lenses in someone's glasses,
and the soles of your trainers might have once been someone's car tires!

The Folding Plug by Min-Kyu Choi managed to compact the standard UK plug into a 10mm-thick object. In this way, the plug incorporates fewer materials and less packaging. He came third in the international James Dyson Award for his ingenious invention.

www.jamesdysonaward.org

DESIGN BRIEF ACTIVITY

2.1.8 STUDENT ACTIVITY

Start with a frustration or problem that you want to solve. Write a design brief and use 'ACCESS FM' (page 13) to write a design specification. From there, you can start sketching ideas for a product that solves the problem.

The brief needs to answer the following questions:

What problem will your product solve?

Who will use it?

How will people use it?

Does the product need to be a particular size or shape?

What features will the product need?

Here are some ideas of themes:

Think about your journey to school. What problems are encountered along the way? What would make it easier?

Think about shelter. This could be shelter from the rain or wind, from the cold or from the sun. What problems do you encounter when you require shelter? Does your bike seat get wet when you park it under the edge of the bike shed?

'Biomimicry' means using nature as inspiration when designing. Think of Velcro™ fasteners and barbed wire. What might have inspired them? And looking outside, what qualities of nature might lend themselves well to one of your products or inventions?

Bad design doesn't serve a purpose. It might create a problem rather than solve one. Maybe it makes somebody spend money unnecessarily — does it require extra parts that otherwise wouldn't be bought? Design and sketch a bad design of your own. List the reasons why it is useless. Do you now have a better idea of what might make a good design?

2.2 3D PROTOTYPING

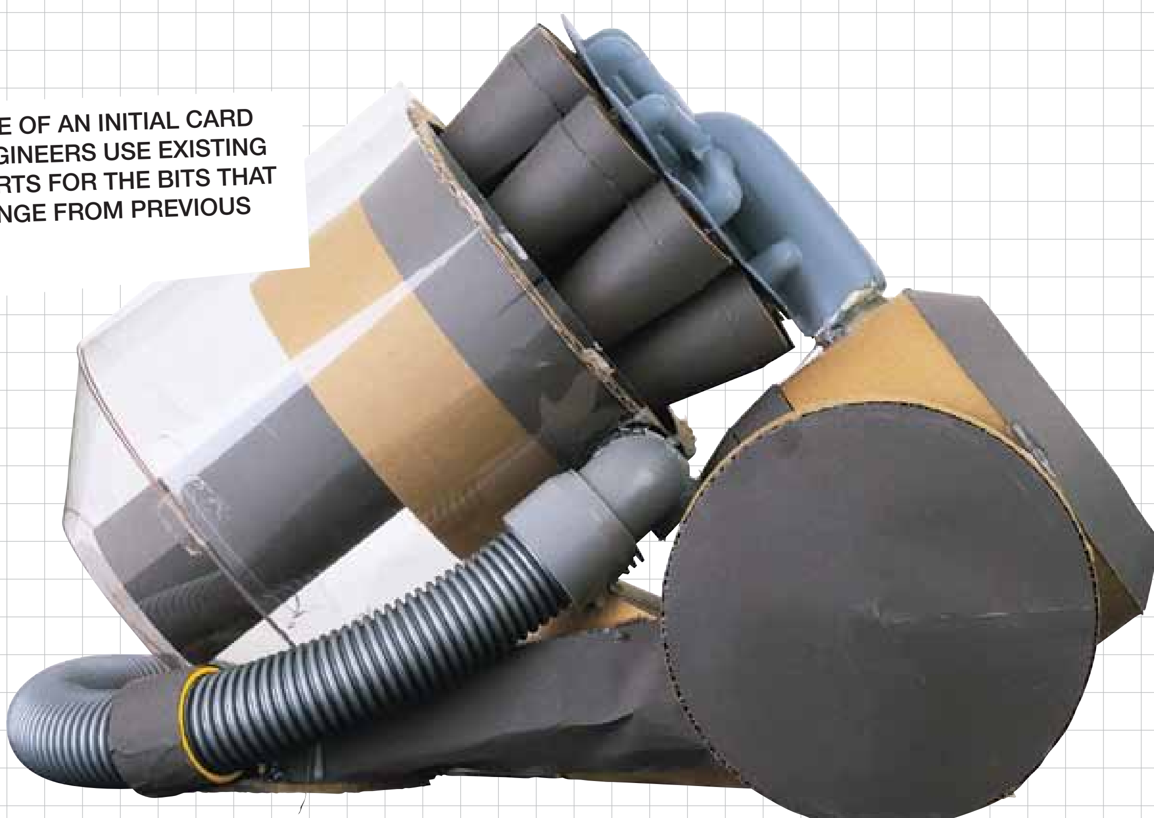
ONCE DESIGN ENGINEERS HAVE IDENTIFIED AN IDEA AND SKETCHED IT OUT, THE NEXT STEP IS TO BUILD A 3D PROTOTYPE.

In the early stages, cardboard, glue and tape are used to construct layouts and model basic functions quickly and cheaply. As the design develops, Computer Aided Design (CAD) software is used to plan the detail and create more complex prototypes that can be used for testing.

2.2.1 CARD MODELLING

The engineers working on Dyson DC26 used card modeling to visualize their designs from the beginning when they drew up their specification. They continued building card models through the entire design process — with every new idea, came a new card model. Models give a good impression of how the design fits together and enable the engineers to see it from all angles. They also give an impression of how the design addresses the physical parameters and space they're working with.

Card modeling is a simple yet important part of the design process. Think about the product you wrote the brief for in the previous section: why not grab some strong tape and cardboard and check it out in 3D?

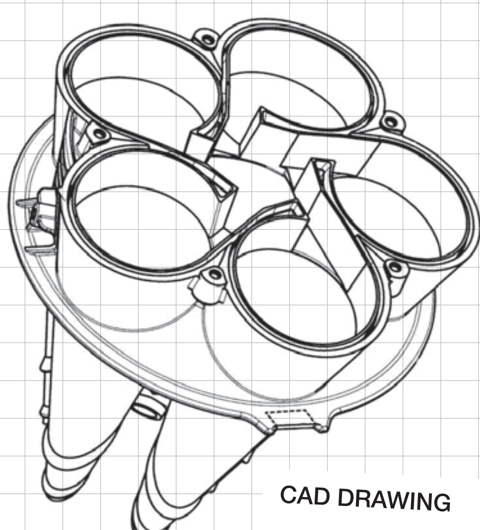


AN EXAMPLE OF AN INITIAL CARD MODEL. ENGINEERS USE EXISTING PLASTIC PARTS FOR THE BITS THAT WON'T CHANGE FROM PREVIOUS MACHINES.

"We never come up with an idea, prototype it and find it works perfectly. It just doesn't happen like that. But having the ideas in 3D is really important for helping us refine them."
Dan, Design Engineer

2.2.2 COMPUTER AIDED DESIGN (CAD)

The next step is to use CAD software to draw the design in fine detail. All of the different parts are drawn on computer, enabling the engineers to build a more complicated prototype using automated machines like three or five axis milling machines or routers (you may have similar machines in your workshop) or selective laser sintering (SLS).



CAD DRAWING

2.2.3 SELECTIVE LASER SINTERING (SLS)

SLS is a very expensive process — producing just one cyclone assembly costs several thousand dollars — so it's important that the design is well developed before reaching this stage of prototyping.

The CAD data is fed into the SLS machine. This machine builds the plastic prototype parts. The machine contains a vat of nylon powder that's heated almost to melting point. Laid down in thin layers, the powdered plastic is fused (sintered) by a laser that follows the CAD drawings. In this way complex parts can be created, layer-by-layer, on a small scale in a workshop.

SLS prototypes are especially useful for testing, as the fused plastic pieces have very similar properties to injection-molded parts from mass manufacturing. The engineers can even fit motors and electronics to build a fully operational prototype.

SLS PROTOTYPE

2.3 PROBLEM SOLVING IN THE DESIGN PROCESS

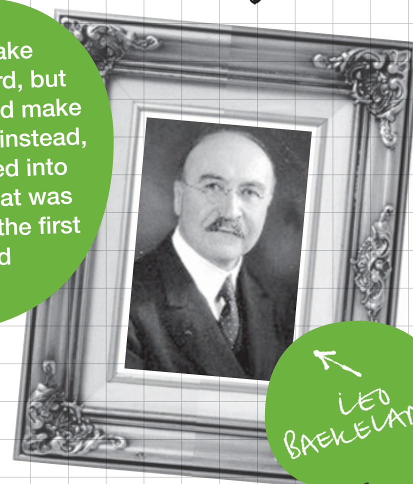
THE DESIGN ENGINEERS WORKING ON THE DC26 ENCOUNTERED PROBLEMS, AND YOU WILL TOO. YOU'LL NEED TO BE FLEXIBLE AND ADAPT. HERE ARE SOME CHALLENGES THE DC26 ENGINEERS CAME ACROSS AND HOW THEY SOLVED THEM.

Tip 1
If you encounter a problem with part of your design, break it up and analyze it bit by bit. This attention to detail will help you discover the cause of the problem.

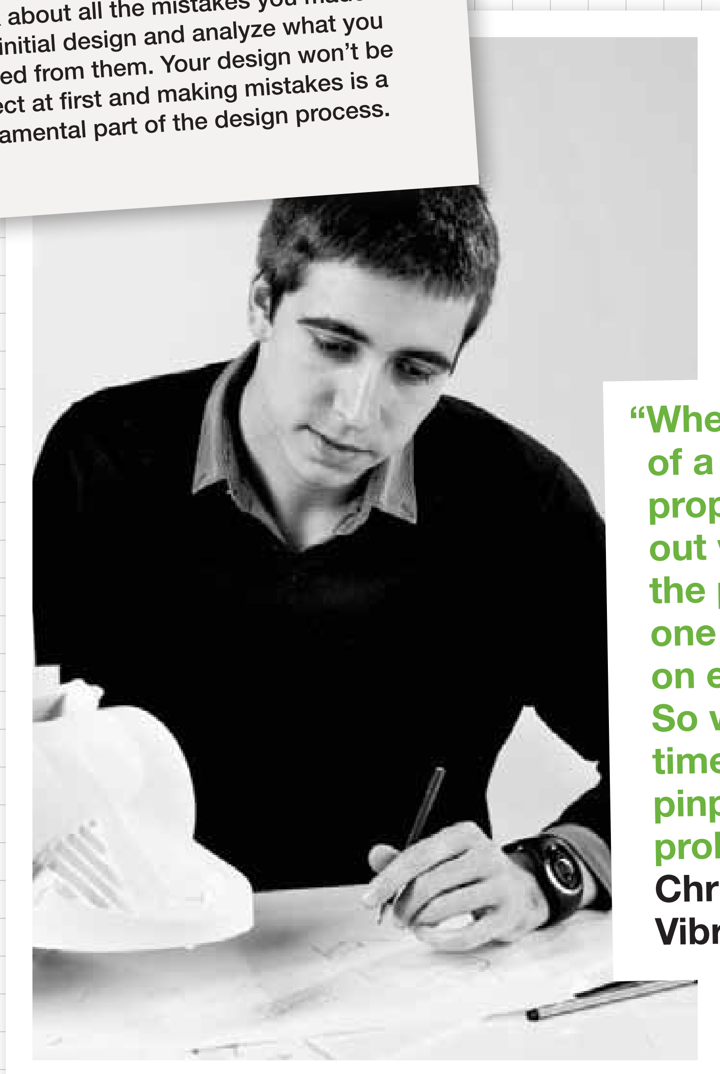
Tip 2
Think about all the mistakes you made in your initial design and analyze what you learned from them. Your design won't be perfect at first and making mistakes is a fundamental part of the design process.

I was trying to make something really hard, but then I thought I should make something really soft instead, that could be molded into different shapes. That was how I came up with the first plastic. I called it Bakelite.

INVENTED THE FIRST COMPLETELY MAN-MADE SUBSTANCE IN 1907



LEO BAEKELAND



"When we find that a part of a machine isn't working properly, it's often hard to find out where the root cause of the problem lies since often one thing can have a knock on effect onto something else. So we look at one thing at a time — that way we can pinpoint precisely where the problem's coming from."

Christophe, Noise and Vibration Engineer

2.3.1 FITTING IT ALL IN

Since James Dyson invented Dual Cyclone™ technology, engineers at Dyson have worked to increase filtration on new designs. They experimented with adding extra cylinders to their new designs (two Dyson machines, DC03 and DC11 had two cylinders side by side). Then they came up with another idea - they reverted to one cylinder but added more, smaller cyclones to create Root Cyclone™ technology.

When it came to DC26, the engineers set themselves the challenge to maintain the machine's filtration but reduce its size significantly. This is called miniaturization, defined as the act of making something on a greatly reduced scale.

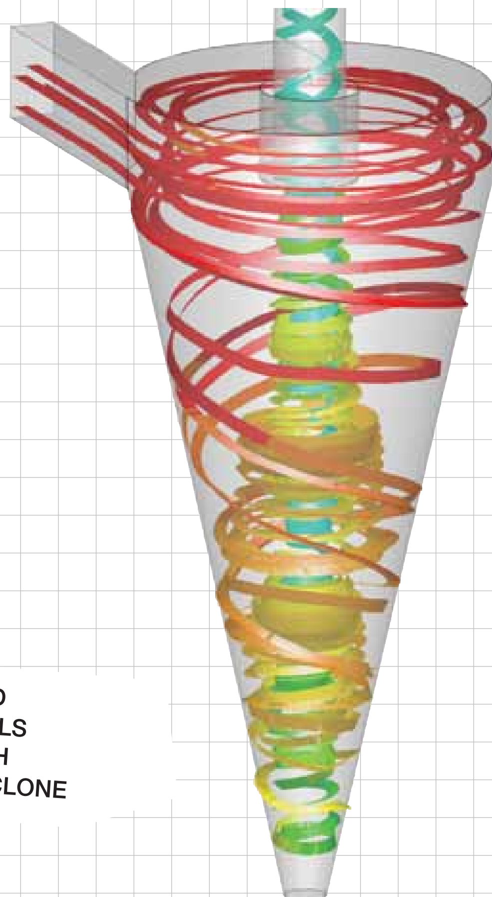
Design engineers knew the smaller the cyclones, the more efficient they become. However if the machine is used for heavy cleaning, small cyclones can block. The perfect compromise in miniaturizing the machine and ensuring it performed well was 13 small cyclones. Engineers opened the inlets to allow for extra flow.

To keep the machine compact they also had to think of a clever way to fit the pre-motor filter into the machine but still make it accessible for the user to remove. After brainstorming possible solutions, Dyson engineers came up with a way of fitting it in the wheel.

Another challenge that the engineers faced was how to make sure that the extra tools supplied with the machine wouldn't go missing.

How would you solve this challenge?

IF YOU HAVE THE ENGINEERING BOX, take a look at the DC26. Have a look at how the engineers solved the problem of extra tools. They came up with a simple solution — they developed a clip that holds the tools and attaches to the wand handle. They also designed a bracket to mount the floor tool on the back of the machine for storage.



COMPUTATIONAL FLUID DYNAMICS (CFD) MODELS THE AIRFLOW THROUGH THE CONES OF THE CYCLONE

2.3.2 COMPUTATIONAL FLUID DYNAMICS

While the engineers were working on the cyclone, they needed to understand what was happening to the air in the inner cyclones. They used computer software called computational fluid dynamics (CFD). It enables the engineers to visualize the air as it moves around the machine and see if anything obstructs or hampers it.

The airflow in a vacuum is like the water in a river. Any rocks, tree branches or bridges in the river influence the movement of the water, causing it to swirl, ripple and become disturbed. Protruding screws, rough edges and lumps and bumps in the airways of the vacuum affect the airflow in a similar manner.

CFD simulates this, calculating how fast the air spins, how efficient the cyclone is at separating the dirt particles from the airflow and works out how much G-force is generated. The faster the air spins, the higher the G-forces and the more efficient the cyclone is at removing dirt from the air.

This helps the engineers design a better cyclone more quickly so they can make fewer prototypes.

The DC26 engineers used CFD to help them understand what the air was doing in the root cones.

"Computational fluid dynamics is a very effective tool in ensuring that the air flows through the machine in the best way possible."
Richard,
Fluid Dynamics Engineer

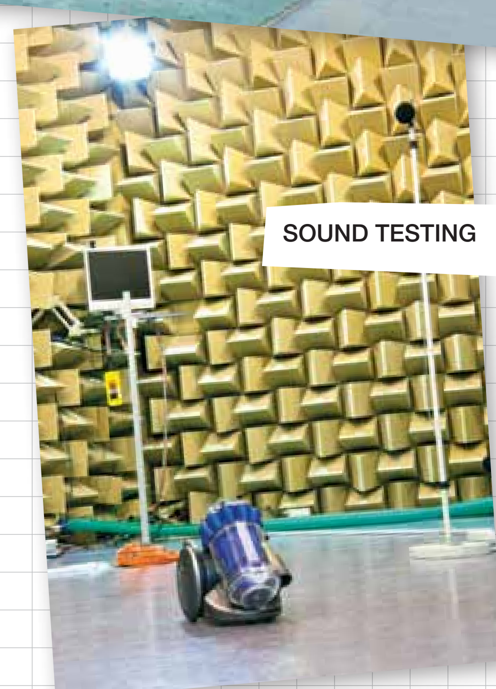
2.4 TEST TEST TEST

"Testing is what literally makes or breaks a product. When you test your design you know it won't be right first time. But you see why it doesn't work and the whole process of problem solving starts all over again. You just keep redesigning and testing until you get it right."
Dan, Design Engineer.

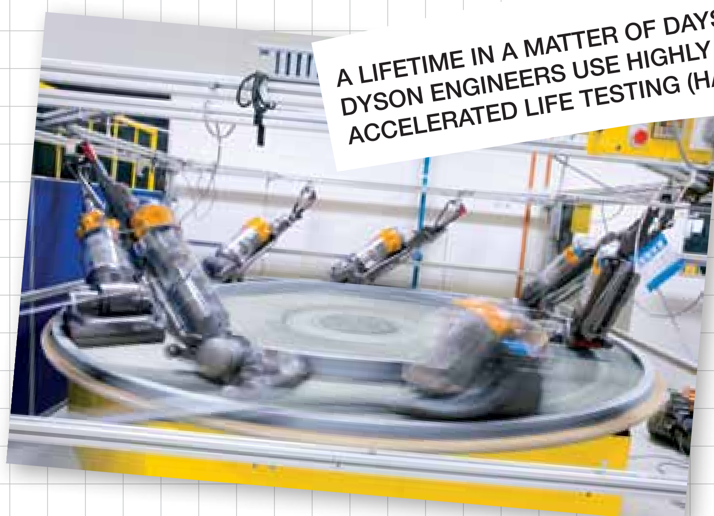
ROBOTIC TESTING

THE DC26 DESIGN WAS CONSTANTLY EVALUATED BY TEAMS OF ENGINEERS. PROTOTYPES WERE TESTED TO DESTRUCTION SO THAT ANY POTENTIAL WEAK POINTS COULD BE IDENTIFIED. IT'S ESSENTIAL TO LOOK AT THE DESIGN WITH A CRITICAL EYE.

Testing and prototyping go hand in hand. Throughout the design process, engineers turn their ideas into 3D models, building slightly different versions until they get it right. These prototypes are then tested to make sure they work and fulfill the original brief. This testing isn't saved for the end of the design process — it's a crucial part of engineering a new product and goes on throughout.



SOUND TESTING



A LIFETIME IN A MATTER OF DAYS, DYSON ENGINEERS USE HIGHLY ACCELERATED LIFE TESTING (HALT).

2.4.1 DROP TEST

One of the easiest tests to carry out is the drop test. Engineers use this test to see if a design is strong enough to withstand being dropped on the floor. They use a special testing rig that drops a vacuum cleaner over 1,000 times in a row, but you can easily test how robust your prototype is in your classroom.

First you work out how great a drop your design should be able to survive. Once you've decided the height it should be able to survive, take the prototype and drop it from exactly that height (making sure it's not your only record of the design, in case it breaks).

If your design survives, it's passed the test. If it doesn't, you need to examine where it failed — then redesign it to strengthen that part of the design. Test it again and again until it passes.

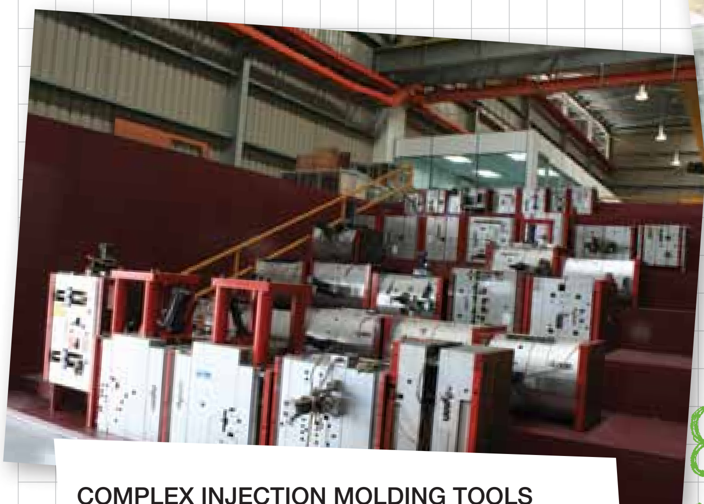
2.4.2 LIFE TEST

The major challenge is to test a design so that it undergoes all the physical stresses it's likely to receive during its lifetime. Dyson engineers use Highly Accelerated Life Testing (HALT) to do just that, compressing a lifetime's use into just a few days. For example, one testing rig pushes and pulls Dyson prototypes over a distance of 841 miles, at walking pace, night and day, for over two weeks straight.

WATCH HOW DYSON TESTS ITS MACHINES AT www.jamesdysonfoundation.com

2.5 MASS PRODUCTION

WHEN YOU NEED TO MANUFACTURE A DESIGN ON A LARGE SCALE, THIS TOO HAS TO BE FACTORED INTO THE DESIGN PROCESS.



COMPLEX INJECTION MOLDING TOOLS MAKE THE PRODUCTION PROCESS EXPENSIVE, DESIGN ENGINEERS MUST BE MINDFUL OF THIS.

INSIDE THE TOP HALF OF THE CONE PACK MOLD TOOL

Notice how much larger the injection mold tool is compared to the cyclone assembly it will make. In the center of the tool you can see the inserts for the downstream cyclones.

When the DC26 team finished their design, they transferred it to Dyson engineers in Malaysia to get it ready for manufacture. There were two initial short production runs — engineering build 1 (EB01) and engineering build 2 (EB02). EB01 is the first time that the design is made using mass production techniques. The EB01 machines are advanced prototypes — it's the last chance for the engineers to fix any small problems, like rough edges in the molded plastic components. Any necessary changes are made and then EB02 machines are produced to make sure. This is the last stage before the design goes into mass production and onto shop shelves all over the world.

The Dyson DC26 has hundreds of components, from screws and springs to electrical wires, electronics, plastic moldings and a motor.

Dyson buys a few of the components, like the cable rewind mechanism, from specialist suppliers. Others are made especially for Dyson — for example, the 110 plastic molded parts.

POSTER 6 IN THE JAMES DYSON FOUNDATION SERIES TELLS YOU MORE ABOUT THE PROCESS OF INJECTION MOLDING. DOWNLOAD IT AT www.jamesdysonfoundation.com/education

2.5.1 PLASTIC MOLDING

Dyson engineers design complex plastic parts, which require very sophisticated tools to make them. Here's a picture of the inside of the DC26 cone pack tool, the most important part of the vacuum cleaner — the cones that separate the dust from the air. A plastic molding tool comes in two or more parts that fit together to form a space which is the shape of the finished component.

On this cone pack, there are no less than 12 injector points to make sure the plastic flows around the mold evenly. This tool weighs 5,033 lbs (almost double the weight of an average car!).

A tool like this will cost tens of thousands of dollars to make, but it will, in turn, make hundreds of thousands of components.

After the hot plastic is squirted into the mold, it is left to set for a few seconds. Then the mold tool opens up and the parts are ejected by moving metal pins.

IF YOU HAVE AN ENGINEERING BOX, look at some of the plastic molded parts. Can you find the injector point or points and the marks made by the ejector pins?

ONE OF THE DYSON PRODUCTION LINES IN MALAYSIA.

2.5.2 ASSEMBLY

When the components have been manufactured, they are brought to the assembly line to be put together. A modern assembly line is usually clean and brightly lit, particularly where there are electronic components involved (and of course, nowadays everything — from cars to televisions and vacuum cleaners — contains electronic components).

The Dyson factory can make several thousand DC26 machines every day. In total, the Dyson factories make over four million vacuum cleaners every year. It's therefore vital that the machine is designed so that it goes together without mistakes.

This is another example of where engineers use poka yoke design: an engineer will design components so that they will only fit together in one way — so that on the assembly line, they can't be put together upside down or back to front.

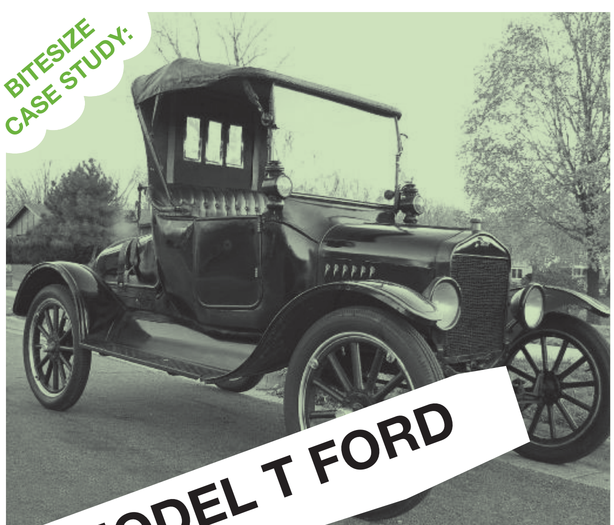
QUESTION: Assuming a total of 4 million vacuum cleaners annually, with the factories working 5 days a week, 12 hours per day, 48 weeks of the year, approximately how many vacuum cleaners an hour does Dyson make?

Answer on page 27.

IF YOU HAVE AN ENGINEERING BOX, pay attention when taking the machine and tools apart to see if you can find examples of "fail-safe" designs.

BITESIZE CASE STUDY:

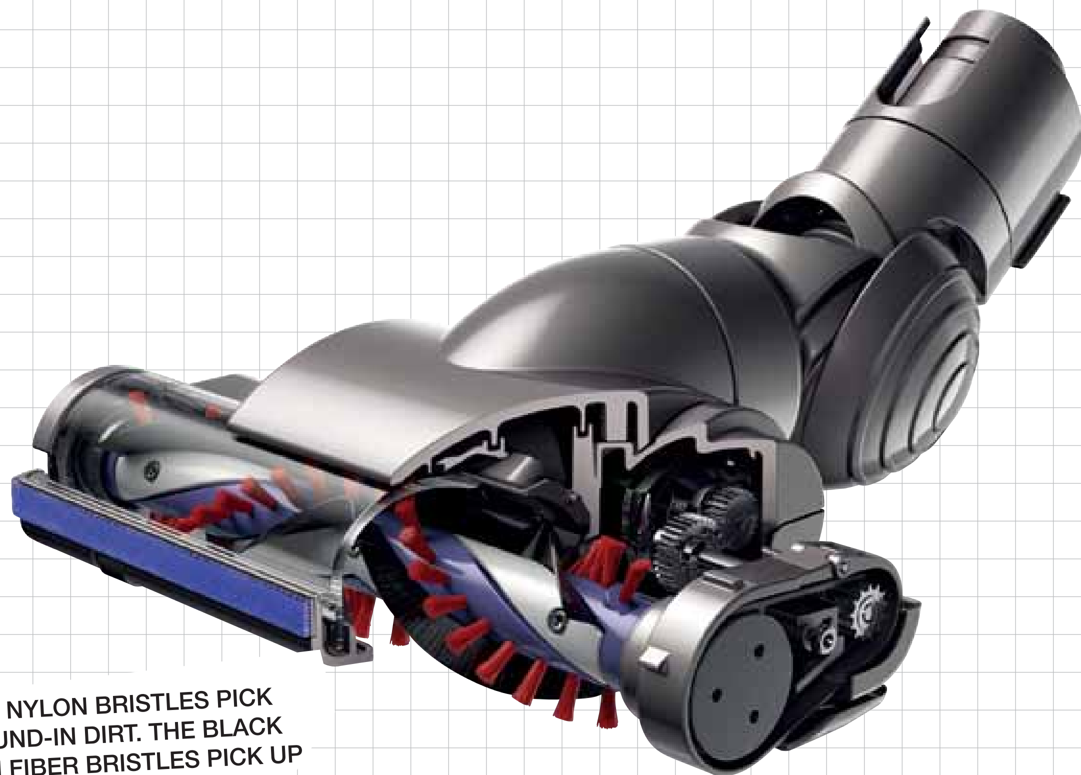
THE MODEL T FORD



The world's first affordable car not only introduced many innovations in automotive design, but the process by which it was built was evolutionary too. The Model T was built on an assembly line that brought the car to the men working on it, rather than workers moving from car to car. It not only saved time, it enabled workers to specialize by performing the same tasks over and over. This helped keep costs low. When the Model T debuted in October 1908, it cost $850 (around $15,000 in today's money). In later years, Ford was able to sell them for as little as $260 ($4,000 today).

Ford wasn't the first to embrace assembly lines, but it was the first to perfect it. By 1914 a Model T chassis (the car minus the interior, body and paint) could be built in just 93 minutes, and 15 million were made in total.

DISCOVER MORE INSPIRATIONAL INVENTORS AT www.jamesdysonfoundation.com



THE RED NYLON BRISTLES PICK UP GROUND-IN DIRT. THE BLACK CARBON FIBER BRISTLES PICK UP FINE DUST.

2.5.3 CARBON FIBER

Even though the DC26 was small, engineers didn't want to compromise its ability to pick up dust. When they designed the floor tool they added stiff nylon brushes to pick up ground-in dirt from carpets.

However, when testing the tool on hard floors they realized some fine dust was difficult to suck up. They discovered the high speed spinning of the brush bar generated static, meaning fine dust was attracted to the floor.

Engineers investigated different brush materials to add to the floor tool and tried carbon fiber. Carbon fiber has anti-static properties which reduce the build up of static charges, so dust pick up is increased.

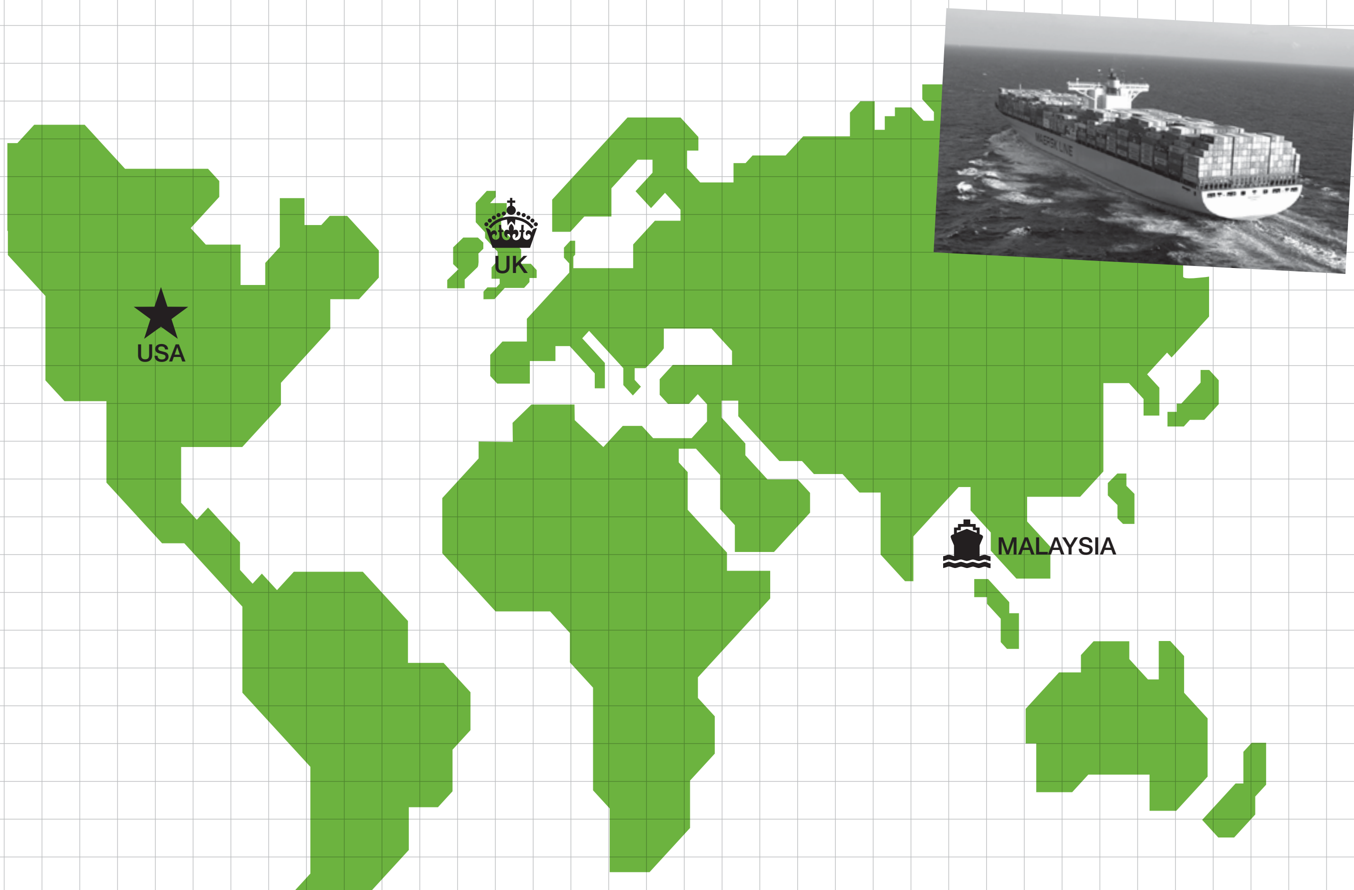
Carbon fiber is a composite material; two or more materials are combined together to give enhanced physical properties. Carbon fiber is made up of carbon and silica (glass fibers). This makes the material very strong when compared to its weight.

ANSWER: 1389
(Question: page 26)

The strength and lightweight properties make it a suitable material choice for many applications. These include tennis rackets, bicycle frames and fishing rods. It is also known to be used for the bodies of high performance racing cars and planes. The Eurofighter aircraft is 70% carbon fiber, resulting in a plane that is 30% lighter than if it had been constructed from modern metals.

IF YOU HAVE AN ENGINEERING BOX, take out the carbon fiber turbine head floor tool and identify the carbon fiber bristles.

Carbon fiber reduces the build up of static electricity. Some insulating materials become electrically charged when they are rubbed together - like when you rub a balloon on your head!



2.5.4 LOGISTICS

During production and at the end of the production line each vacuum cleaner will undergo rigorous quality checks before it is packed into a cardboard box. The boxes are loaded into sea containers ready for shipping around the world. A sea container is a huge metal box, usually between 16 and 42 ft. long, which can be loaded onto a truck or cargo ship. You will probably have seen them on the back of trucks on the freeway.

QUESTION: What route do you think the containers take from our factory in Malaysia to Dyson in the USA? Try drawing the route on the map above.

ANSWER: The containers are fumigated to kill any stowaway creepy crawlies, and then they are loaded onto a ship at the port of Tan Jung Pelepas at the southern tip of Malaysia. The ships sail across the Pacific Ocean to Vancouver. The containers are then railed from Vancouver to Chicago Railhead and then loaded onto trucks and driven to Dyson's distribution center in Chicago before being delivered to stores across the USA.

2.5.5 PACKAGING

Box design is also an interesting engineering challenge. Dyson vacuum cleaners need to be protected from damage as they are shipped to shops and customers all over the world.

QUESTION: The box has to be strong enough to protect the machine from crushing or scratches but ideally, is as light and compact as possible. Why do you think that is?

ANSWER: The larger and heavier the box, the more expensive it is to ship, the more difficult to handle and the more impact it has on the environment.

IF YOU HAVE AN ENGINEERING BOX, take a look at the cardboard box. This isn't the usual box that Dyson uses to ship DC26 (Dyson doesn't normally send out lots of turbine tools and screwdrivers to customers!) but you can see how the box has been constructed to protect the various components from damage.

2.6 EVALUATION

LIKE TESTING, EVALUATION ISN'T JUST A BOX TO TICK AT THE END. YOU'LL NEED TO CONSTANTLY EVALUATE YOUR DESIGN AS YOU PROCEED TO FIND SOLUTIONS TO THE DESIGN CHALLENGES YOU MEET ALONG THE WAY.

USER COURSE

Even after a design has passed all its tests and gone into mass production, the testing continues. At the Dyson factory in Malaysia there's a vacuum cleaner obstacle course where, 24 hours a day and 7 days a week, machines are dropped down stairs, tugged around corners and banged into skirting boards — all to make sure they can withstand the bumps and bashes of real life.

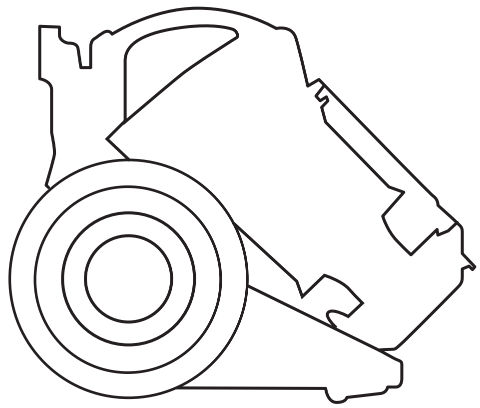

A DYSON TESTER PUTS THE MACHINE THROUGH ITS PACES.

> "In some ways, you never really want to let go of a machine you've worked on. There are always things you'd like to tweak to make improvements but it reaches a point where they become so insignificant that there's no real benefit. It's just like the artist who finds it very difficult to know when to stop adding more brush strokes to a painting."
> **Andrew, Principal Engineer**

3 DISASSEMBLY ACTIVITY

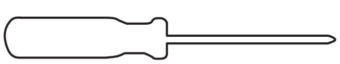
YOU CAN LEARN A LOT ABOUT HOW SOMETHING IS DESIGNED BY TAKING IT APART. AND THAT'S EXACTLY WHAT YOU'RE GOING TO DO WITH YOUR DC26.

WHILE DISASSEMBLING THE DC26 AND THE TURBINE HEAD, THINK ABOUT WHY THE ENGINEERS DESIGNED THEM IN THIS WAY.

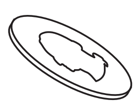


YOU WILL NEED:

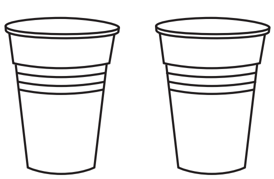
A TORX T15 SCREWDRIVER (INCLUDED IN THE BOX)



A COIN TO SECURE AND UNDO QUARTER-TURN FASTENERS AND PRY OFF THE SOLE-PLATE



2 CUPS TO KEEP SCREWS (ONE FOR LONG SCREWS, ONE FOR SHORT SCREWS)



DOWNLOAD LESSON PLANS, WORKSHOPS AND PRESENTATIONS LINKED TO THIS DISASSEMBLY ACTIVITY AT: www.jamesdysonfoundation.com/education

QUESTIONS

A) What are you going to learn about design by taking the DC26 apart?

B) Which features enhance the performance of the machine?

C) Which features make it easy to use?

D) Why have the engineers chosen to fix parts together in a particular way?

E) What materials have the engineers chosen to use and why?

F) Which technologies are used in other products?

G) How do you think the machine is manufactured?

3.1 DISASSEMBLING THE DC26 TURBINE HEAD

NOTE ON SAFETY:
When working on this machine, the James Dyson Foundation recommends protective clothing and eyewear. Please take care when disassembling and reassembling the machine as there may be sharp edges or corners that are not normally accessible.

It is the school's/organization's responsibility to make sure participants are supervised when taking apart the machine. All safety regulations and instructions must be followed. To ensure electrical safety, do not disassemble the machine further than the instructions suggest.

ANSWERS

A) What it's made of.

Some of the problems that the design engineers solved.

Is it easy to assemble?

Is it easy to clean?

Can it get blocked during use?

How easy is it to clear blockages?

B) Cyclone technology.

C) Examples include:
Tools and hoses can be removed from the machine to make it easier to clean if it gets blocked with debris.

Filters need to be washed or replaced. The machine is designed so that the filters are easily accessible.

Use of color to draw the eye (you will see examples of this later when disassembling the product).

D) The engineers usually use quarter-turn fasteners and clip fittings for parts that can be removed by the customer.

They use TORX screws to secure areas of the machine that should only be accessed by trained Dyson service engineers.

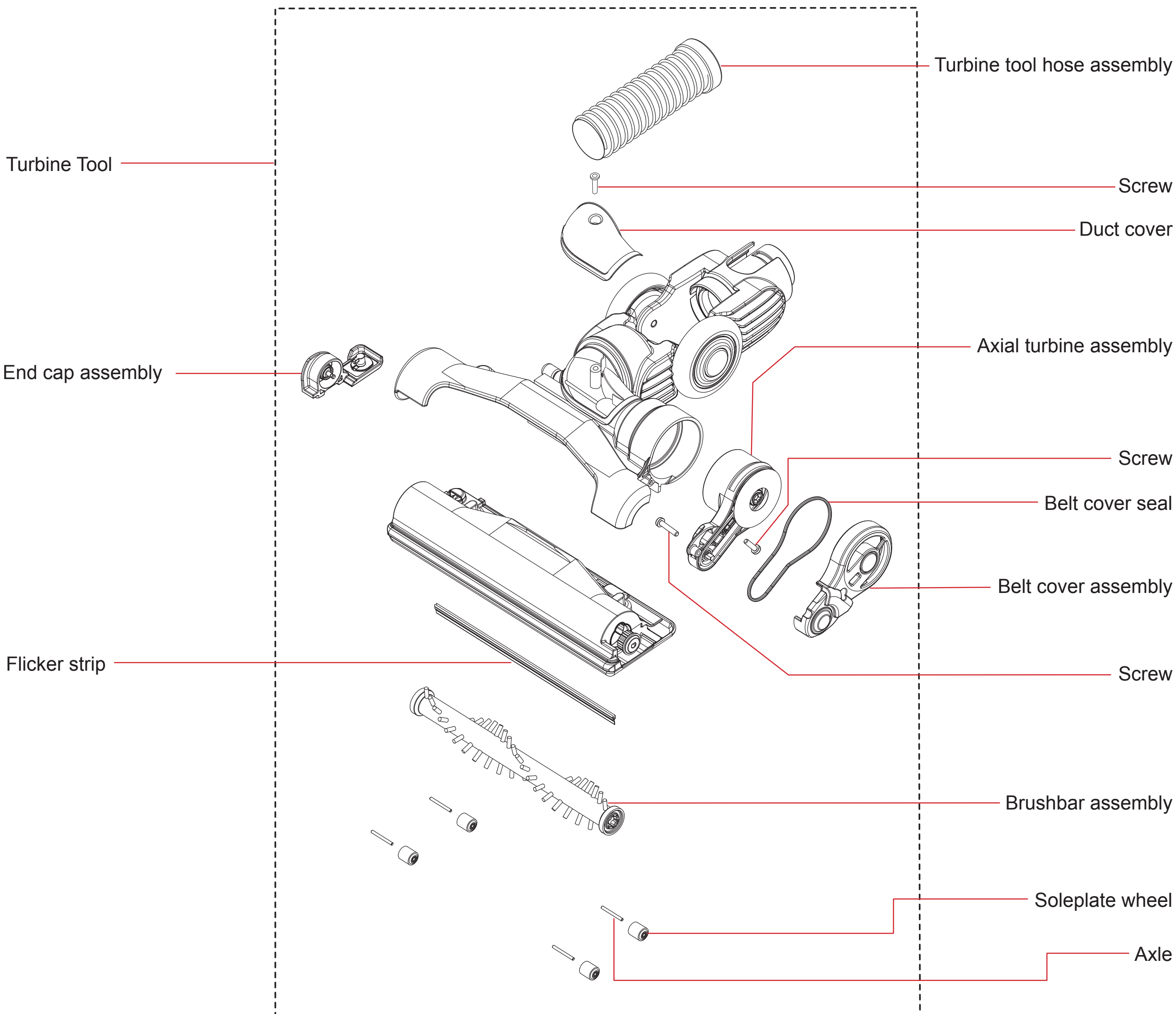
E) Brush bar — PP (Polypropylene)
Turbine cover — PBT (Polybutylene Teraphthalate)
Main body of turbine tool — PC (Polycarbonate)
Flexible hose — PU (Polyurethane)
Wheels — primarily PP
Sole plate — ABS (Acrylonitrile butadiene styrene)
Metal screws

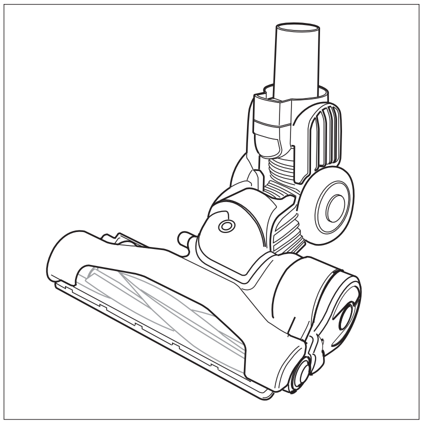
F) Electric motor
Electronics

G) The plastic parts are injection molded and then assembled with the other components on a production line.

ELEMENTS OF A DC26 TURBINE HEAD

USE THIS DIAGRAM TO IDENTIFY PARTS OF THE DC26 TURBINE HEAD WHEN DISASSEMBLING OR REASSEMBLING.





STEP ONE: Start with the turbine head floor tool

Start by looking at the turbine head and how it fits onto the vacuum cleaner.

Detach the turbine head from the chassis of the vacuum cleaner or wand by lifting upwards.

QUESTIONS

A) How have the engineers solved the problem of where to store the machine's tools?

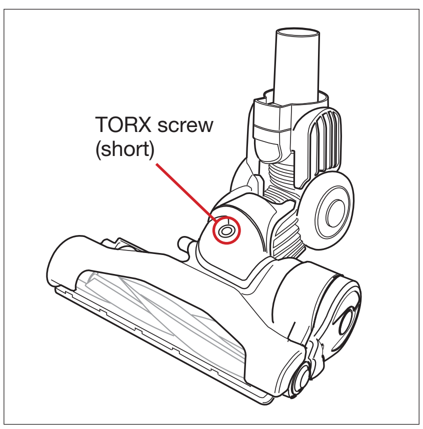
B) What are the main components of the turbine head? What are the components made of?

C) How does it fit on the machine?

D) Why is the turbine head detachable from the hose and wand?

E) Compare it with the carbon fiber turbine head floor tool and other accessories — what are they all for?

F) Look at the hose. What material is it made of and why is it appropriate for the hose?

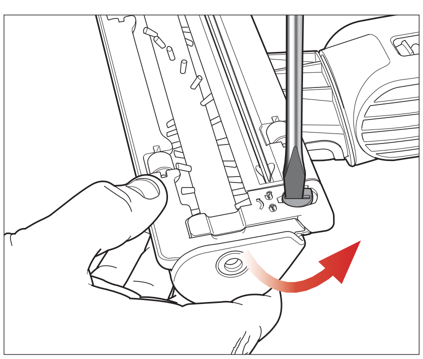


STEP TWO: Remove the duct cover

There's a silver knob on the side of the turbine head. Near to it, on top of the turbine head is a TORX screw (short), unscrew it. Lift the panel with rubber edging off the top of the turbine head. The part that comes off is the duct cover. You'll see a metal rod connected to a silver knob — this is the choke that opens and closes the airway to the turbine. The turbine uses air sucked in through the side of the turbine head to spin the brush bar. If the duct is open, the brush bar spins. If it's closed, it doesn't.

Once you've removed the duct cover:

A) The duct cover has rubber around the edges. What is it for?



STEP THREE: Remove the brush bar

Turn your turbine head upside down. On the bottom of the sole plate — the part that moves along the floor — is a quarter-turn fastener. The clue is in the name. Using a coin, carefully turn it one quarter-turn counter-clockwise and lift the brush bar out.

A) What do you think the brush bar is for?

B) Why are the brushes on the brush bar red?

C) Why do you think that the brush bar is secured with a quarter-turn fastener rather than a screw?

ANSWERS

STEP ONE: Start with the turbine head floor tool

A) The turbine head clips onto the machine. The tools clip onto the hose.

B) **Brush bar** — PP (Polypropylene)
Turbine cover — PBT (Polybutylene Teraphthalate)
Main body of turbine tool — PC (Polycarbonate)
Flexible hose — PU (Polyurethane)
Wheels — primarily PP
Soleplate — ABS (Acrylonitrile butadiene styrene)

C) The turbine head fits on the machine in two ways:
Slots onto bracket for storage;
Clips to end of hose when in use.

D) The turbine head is detachable for three reasons:
For storage;
So that you can fit other tools;
Ease of cleaning the turbine head.

E) The carbon fiber tool is for hard floor surfaces — static is reduced, so fine dust is collected. The combination tool is for small spaces; the nozzle converts to a brush for dusting.

F) The hose is made of clear polyurethane. It allows for maneuverability and the person using the machine can see if it's blocked. There are many different kinds of polyurethane. It's tough and resistant to scratches so it's also used in varnishes and to make the wheels for skateboards and roller blades.

STEP TWO: Remove the duct cover

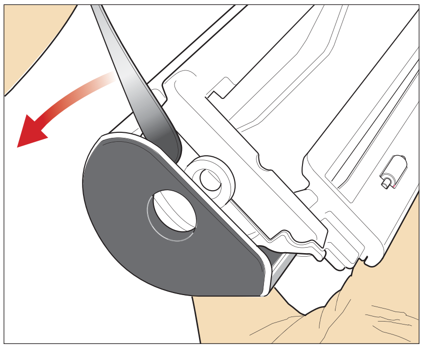
A) The rubber seal around the duct cover keeps the duct airtight. Any gaps would mean a loss of suction and reduced brush bar speed.

STEP THREE: Remove the brush bar

A) The brush bar spins, powered by the turbine, brushing dust and debris out of the carpet. This improves cleaning performance.

B) Red brushes are easier to see, so that the person using the machine can see the bar spinning around and know that the turbine head is working properly.

C) During use, the brushes will pick up hair and fluff which can get tangled around the brush bar. The quarter-turn fastener means that the person using the machine can remove the brush bar for cleaning without having to use any tools.



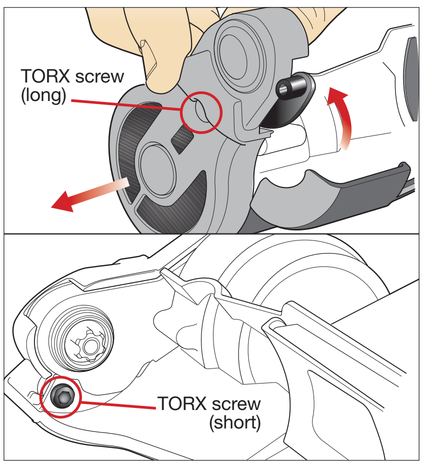
STEP FOUR: Remove the soleplate

Keep the turbine head upside down. On the far left hand side of the sole plate is a gap between it and the rest of the turbine head. You'll notice that the sole plate and brush bar housing pivot on an axle. Insert the coin into the gap and pry the brush bar housing out. You might need to use a bit of force to pry this out.

QUESTIONS

A) Why is the brush bar housing transparent? Do you know what type of plastic it is made from?

B) Look at the rollers on the bottom of the soleplate. Why do you think they are covered in felt?



STEP FIVE: Remove the turbine

Look at the side of the floor tool, at the circular opening for the turbine. To one side is a TORX screw (long). Undo this and then find the second (short) screw keeping the turbine in place — it's inside the turbine head, near the front. When both screws have been taken out, twist the turbine counter-clockwise and pull it out. You now have the turbine drive in your hands, with the blades of the turbine clearly visible.

Examining the turbine:

CHALLENGING!

A) Why do you think the turbine is located here?

B) Look at the side of the turbine to see the mesh cover. What do you think it's for? What do you think it's made from?

CHALLENGING!

C) Turn the small cog that drives the brush bar. You can see that it spins slowly while the turbine spins much faster. Why do you think this is?

ANSWERS

STEP FOUR: Remove the soleplate

A) The brush bar cover is transparent so that the user can see if it's turning or if something has become tangled in the bristles.

It is made of PC (polycarbonate).

B) The rollers are covered in felt so that they don't scratch hard floors.

STEP FIVE: Remove the turbine

A) If dirt is sucked into the turbine it can clog the blades so that it doesn't turn properly. The turbine is located on top of the tool so that it sits above the floor and only sucks in clean air to drive the brush bar. All the dirty air passes through the underside of the floor tool and up the hose, never coming into contact with the turbine.

B) The mesh is another way that the design engineers ensure that dirt doesn't enter the turbine. It's made of polyamide 6 — commonly referred to as 'PA6' or 'nylon'.

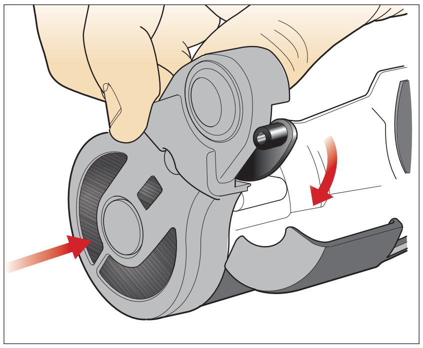
C) Normally the turbine drives the cog. The high speed of the turbine gets maximum power from the airflow, but this would be too fast for the brush bar. The slow moving cog converts the power from the airflow into torque (turning force) powering the brush bar through the carpet.

It's like the gearing on a bike which enables you to turn the pedals at a lower RPM (revolutions per minute) than the wheels.

REASSEMBLING THE DC26 TURBINE HEAD

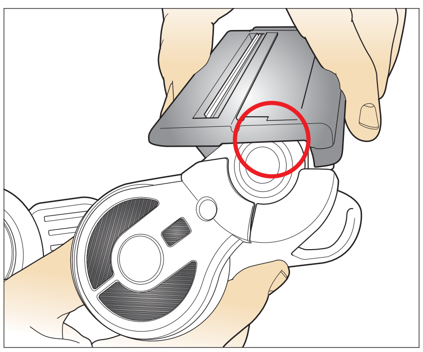
Now you've stripped the turbine head, simply reverse what you've just done to reassemble it.

As a challenge try doing this without the instructions. See if you can write down your own steps.



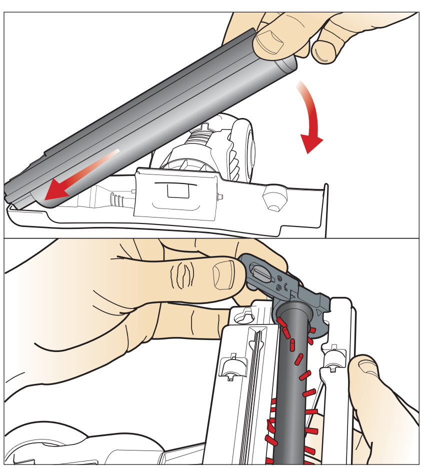
STEP ONE:

Refit the turbine unit and secure with the two screws, ensuring that the long and short screws are located in the correct positions.



STEP TWO:

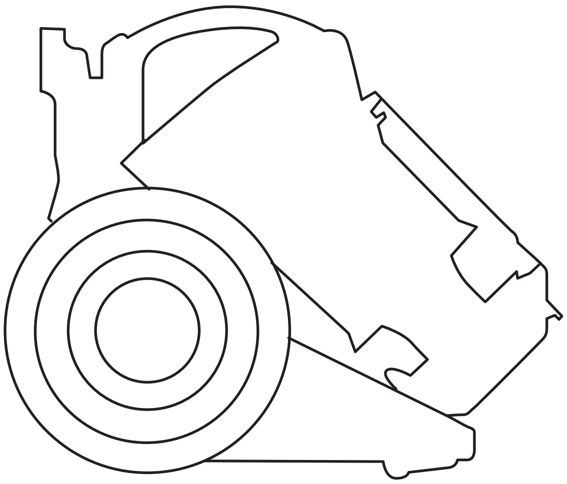
Slot the brush bar housing back into the main turbine head, placing the turbine end over the cog that drives the brush bar. Push the other end back into place — it can take a bit of force so don't worry if it makes a snapping noise.



STEP THREE:

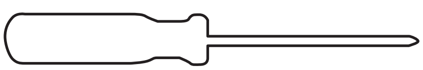
Place the brush bar back in its housing, with the end that sits over the turbine cog first. Slot the quarter-turn fastener onto the other end and push it into place in the housing. Use the coin to secure it in place. Return the duct cover to its place on top of the turbine head and affix with the short TORX screw.

3.2 DISASSEMBLING THE DC26 (WITH TEACHER SUPERVISION AND FOLLOWING SAFETY PRECAUTIONS)

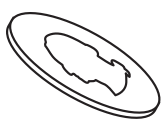


YOU WILL NEED

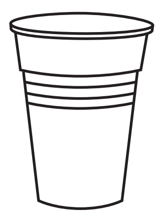
1X TORX T15 SCREWDRIVER
(INCLUDED IN THE BOX)



A COIN TO SECURE AND UNDO
QUARTER-TURN FASTENERS

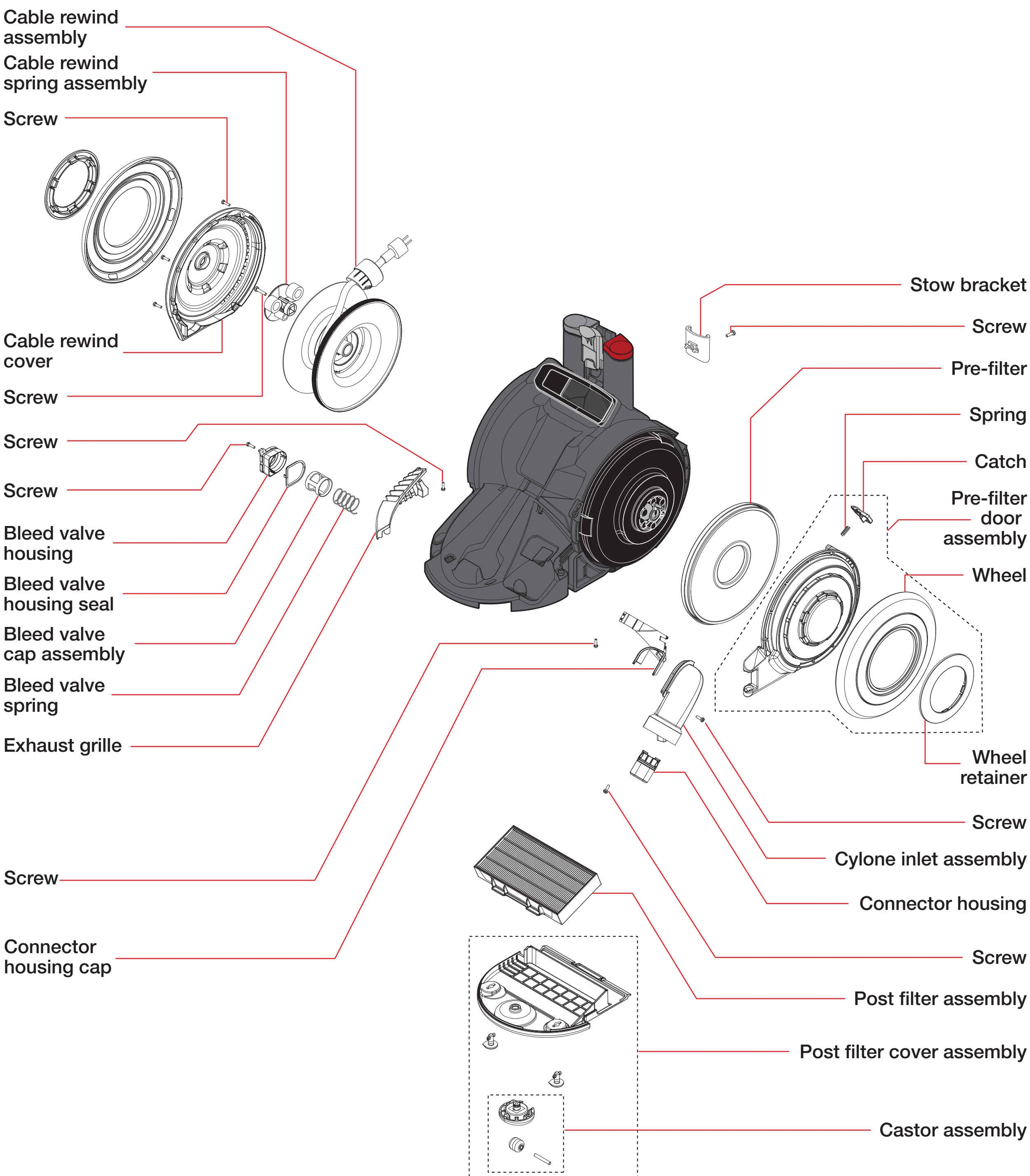


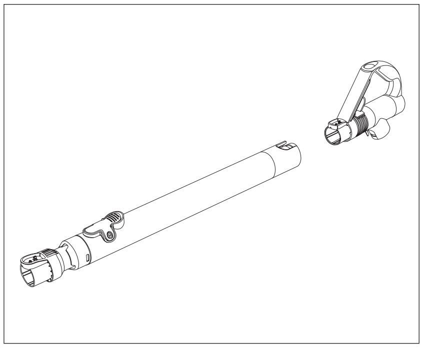
1 X CUP TO KEEP SCREWS



ELEMENTS OF A DC26

USE THIS DIAGRAM TO IDENTIFY PARTS OF THE DC26 VACUUM CLEANER WHEN DISASSEMBLING OR REASSEMBLING.





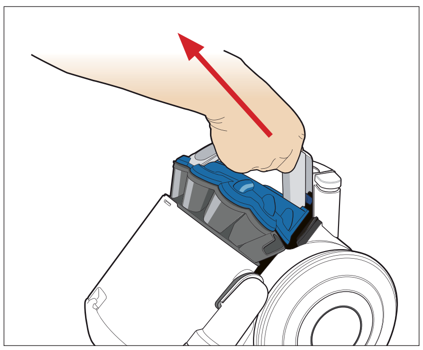
STEP ONE: Remove the telescopic wand

To start, remove the telescopic wand from the hose — you can extend it and it snaps into place.

QUESTIONS

A) Why do you think the engineers made the wand collapsible?

B) How did they stop it collapsing when in use?



STEP TWO: Remove the bin and cyclone assembly

Press the bin release button in the direction of the arrow shown and lift the bin and cyclone assembly off the chassis. By removing the bin and cyclone assembly you've revealed the red bin empty button — press it to open the base of the bin. You can see the bin empty mechanism working if you look at the rear of the bin. The bin and cyclone assembly can be separated — press the grey button on the rear of the bin and pull them apart.

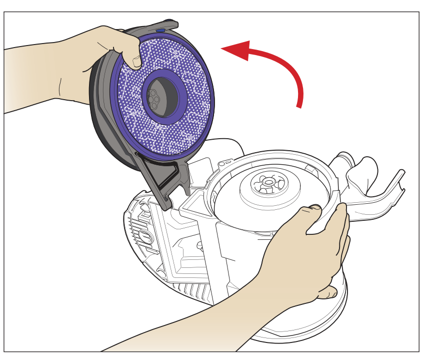
On removing the bin and cyclone assembly:

A) Why does the bin open from the bottom?

B) Why is the bin empty button red?

C) Look at the rubber seal in the base of the bin. How does it seal the cyclone?

D) Separate the bin and cyclone assembly and have a look at the cyclone assembly. Can you identify the two different stages of separation?



STEP THREE: Remove the pre-motor filter

Turn the chassis on its side with the exhaust vents facing downwards. Locate the door release catch next to the wheel and open the pre-filter door. Pull out the purple pre-motor filter.

A) Have a look at the pre-motor filter. Why do you think it is made of foam?

B) Which way do you think the air flows through the filter?

C) Why does the machine need a pre-motor filter?

D) Have a look at the back of the machine. There are a set of instructions. What do they tell you? How often should you wash the filter?

ANSWERS

STEP ONE: Remove the telescopic wand

A) It's easier to store.

B) Engineers designed a catch that holds the wand in position at various lengths. The button to release this catch is red to draw the eye.

STEP TWO: Remove the bin and cyclone assembly

A) The bin opens from the bottom so that it can be emptied hygienically directly into the trash.

B) The bin empty button is red so that it's easily identifiable. Your eyes are naturally drawn to the red rectangle that leads from the button to the base of the bin, highlighting its function.

C) It seals across all the chambers of the cyclone, separating them from one another.

D) Shroud and cyclone head

STEP THREE: Remove the pre-motor filter

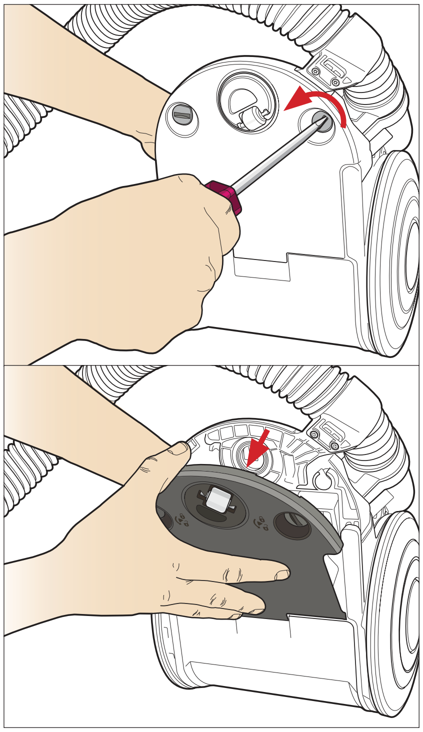
A) The foam material is a 'depth loading' material which means it can trap a high capacity of really tiny particles from the cyclone through its entire thickness; it's also a washable material.

B) Air passes out of the cyclone then flows through the colored side of the filter. It turns in the door and is drawn into the motor through the central hole.

C) Most of the dust has already been removed through separation in the cyclone, but some very fine dust particles remain in the air flowing through the vacuum cleaner. These could clog the motor and cause it to overheat, so the engineers designed this filter to protect the motor.

D) The instructions are provided on the machine so that you don't have to look in the manual for the machine to know how to wash the filter.

QUESTIONS

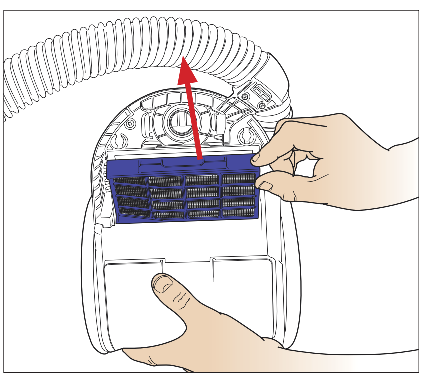


STEP FOUR: Remove the post-filter cover

Turn the chassis upside down and undo the two quarter-turn fasteners on either side of the caster wheel. Slide off the post-filter cover.

A) Why do you think the engineers chose to fit a caster to the front of the machine rather than an ordinary wheel?

B) The engineers have chosen to use quarter-turn fasteners, why do you think that is?



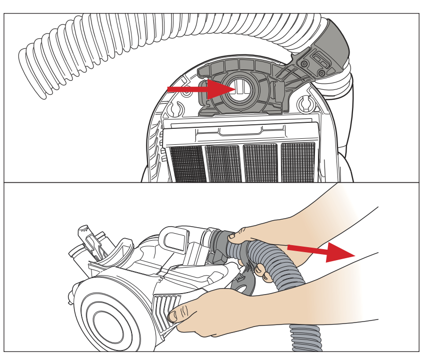
STEP FIVE: Remove the post-motor filter

Taking off the post-filter cover reveals the post-motor filter. Take that out too.

A) Have a look at the post-motor filter. Why do you think the material is pleated?

B) Have a look at the construction of the post-motor filter. It's different from the pre-motor filter. Why do you think that is?

B) Why do you think we have such a high level of filtration in this machine?



STEP SIX: Remove the hose

Pull up the hose retainer catch as shown. This releases the hose from the base of the machine. Find the end of the hose where it enters the chassis and pull down and to the left (this can be stiff).

A) Why would you need to remove the hose?

ANSWERS

STEP FOUR: Remove the post-filter cover

A) The swiveling action of the caster makes the machine more maneuverable and easier to pull around.

B) Quarter-turn fasteners are used to fasten areas where the person using the machine will need access, for example to wash filters or clean the brush bar in the turbine head. Using this kind of fastener means that the user doesn't need special tools to get into the machine.

STEP FIVE: Remove the post-motor filter

A) The material is pleated to increase the surface area of the filter so that it can capture more fine dust.

B) The post-motor filter is a HEPA (High Efficiency Particulate Air) filter. HEPA filters remove 99.97% of microscopic particles (particles like pollen and mold spores).

C) Using a HEPA filter in the machine to clean the remaining microscopic particles from the expelled air means that this machine is particularly suitable for people with allergies to airborne particles like pollen.

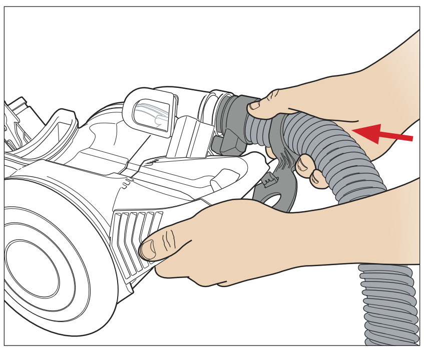
STEP SIX: Remove the hose

A) Sometimes the hose can get blocked — for example if you suck up a sock. If you can remove the hose from the machine, you can clear the blockage easily by pushing a broom handle through the hose.

REASSEMBLING THE DC26

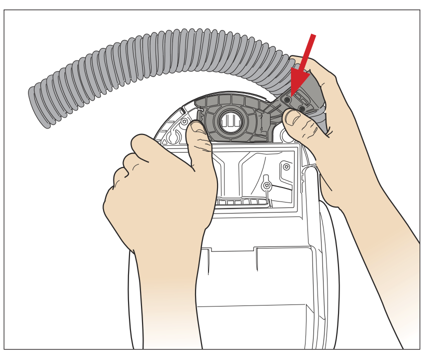
To put the chassis back together again, reverse the process you've just followed. Think about how everything fits together and how the designers have made it quick and easy to assemble from the components.

QUESTIONS (ANSWERS ON PAGE 46)



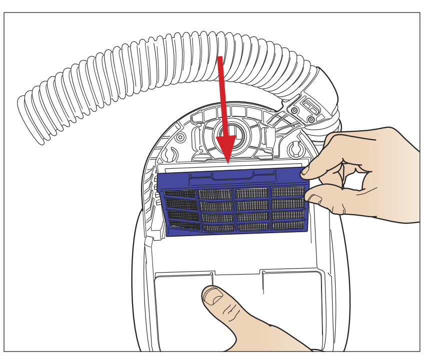
STEP ONE:

Find the hose. Insert the end back into the chassis ensuring it is pushed in as far as possible.



STEP TWO:

Turn the machine upside down and clip the hose hook back into the base of the machine. Press down the hose retainer catch until it 'clicks' back into position.

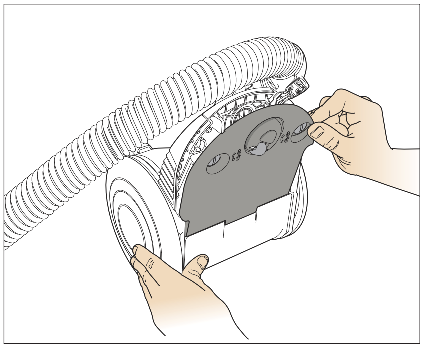


STEP THREE:

Put the post-motor HEPA filter back into its place — because of the tab, it'll only fit one way round. It's an example of poka yoke design.

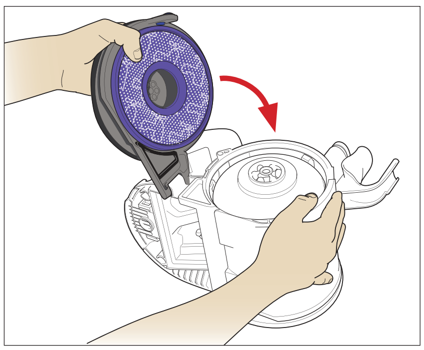
A) Note that the HEPA filter will only fit one way round. Why do you think the engineer has designed it in this way?

B) Look out for examples of poka yoke design as you reassemble the machine.



STEP FOUR:

Fit the post-filter cover ensuring the tab details on the rear of the cover locates under the chassis. Secure the quarter-turn fasteners either side of the castor wheels.



STEP FIVE:

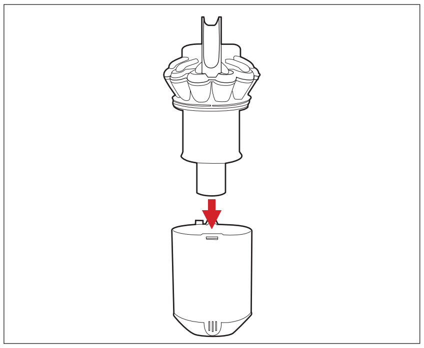
Put the machine on its side, and press the door release catch to open the pre-filter door. Refit the pre-motor filter. This is another example of poka yoke design. Close the pre-filter door.

ANSWERS

STEP THREE:

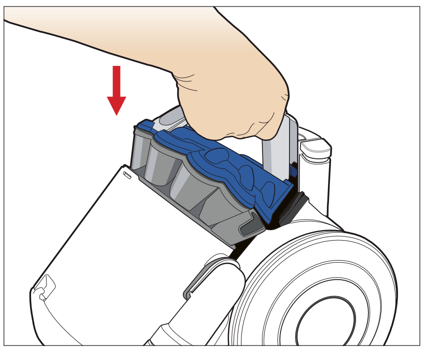
A) Because the HEPA filter is made up of different layers, it is important that the air passes through the filter in the right direction. Therefore, the engineer has designed the filter and the machine so that it will only fit one way round. This is a design technique known as “poka yoke”. This is a Japanese phrase which means “fail-safing” or “fool-proofing”.

B) Another example of "poka yoke" design is the tab on the base of the bin. It ensures that the bin and cyclone assembly drops into the right place.



STEP SIX:

Next, reassemble the bin. Ensuring that the bin base is securely closed, lower the cyclone assembly into it making sure that the red bin empty mechanisms align on the two parts. Push until you hear a 'click'.



STEP SEVEN:

Place the bin back on the chassis, aligning the handle with the bin release button. You should hear a click.

NOTES

NOW IT'S YOUR TURN!

WE HOPE THIS TEACHER'S PACK AND BOX HAS GIVEN YOUR STUDENTS AN INSIGHT INTO HOW CREATIVE, CHALLENGING, AND ULTIMATELY SATISFYING DESIGN ENGINEERING IS. WE'RE CONSTANTLY WORKING ON MATERIALS THAT WILL HELP YOU CONVEY THIS IN YOUR CLASSROOM.

WE'RE ALWAYS KEEN TO HEAR YOUR FEEDBACK.

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