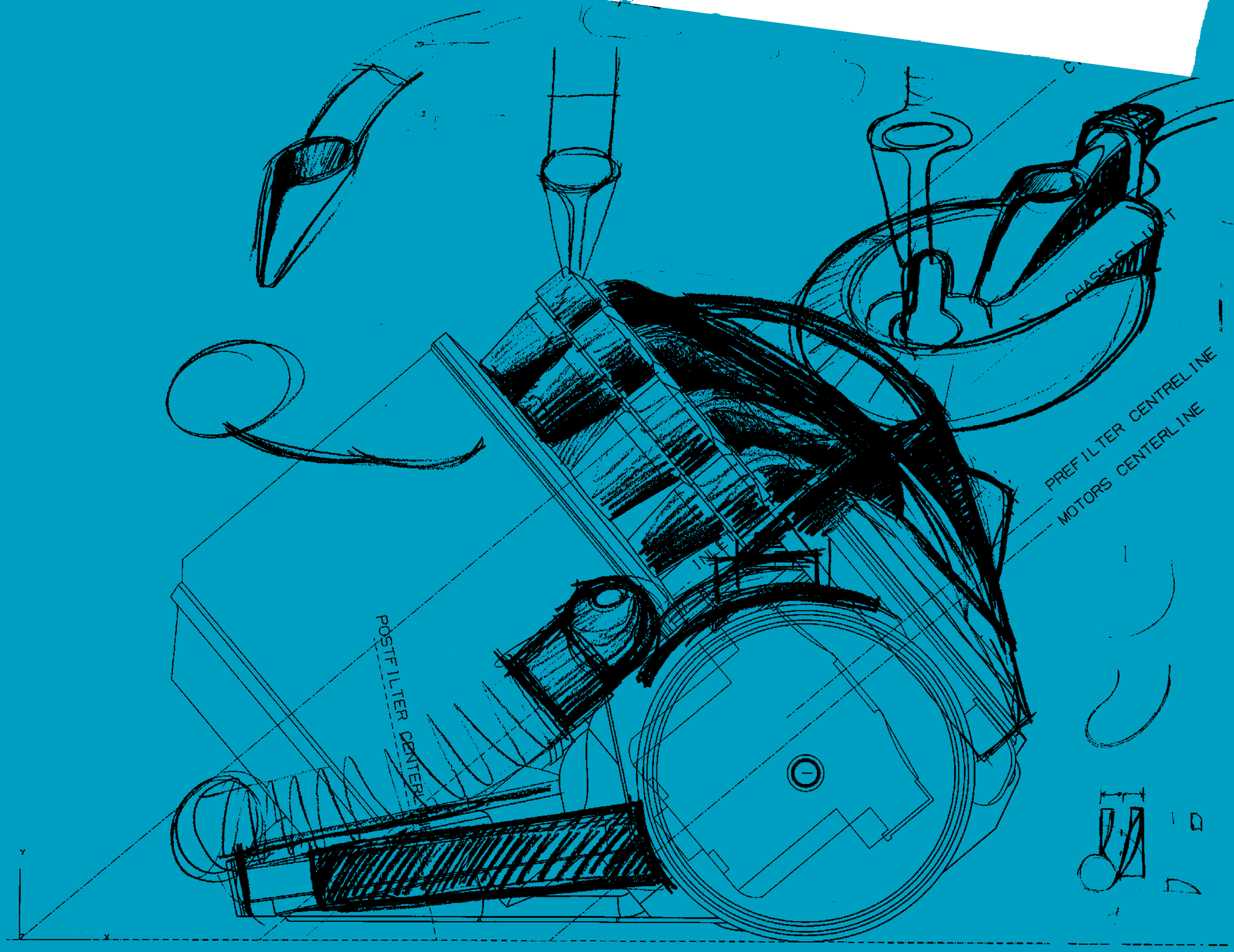
DESIGN

BUILD

TEST



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 THE SOLUTIONS.

WWW.JAMESDYSONFOUNDATION.COM

REGISTERED CHARITY NUMBER: 1099709

"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 Education Box, which has been created to get real examples of engineering into the hands of teenagers. We want to excite students 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 teenagers 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 KS3, KS4 AND KS5 FROM www.jamesdysonfoundation.com

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

James Dyson is particularly passionate about design and technology, a subject that challenges young people to be creative by using their hands and brains to create things that work.

Each year, the Foundation, accompanied by Dyson engineers, visits schools and universities to present the exciting journey of designing — 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. The pack, and the James Dyson Foundation Education Box it accompanies, can not only play a role in Design and Technology classes, but Engineering, Product Design, Enterprise or school activity days, too.

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 YOUR SCHOOL TO KEEP. IT IS FULLY PHOTOCOPIABLE SO THAT YOU CAN SHARE WORKSHEETS WITH YOUR STUDENTS.

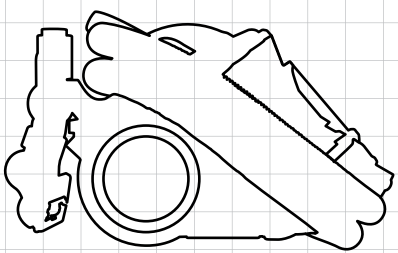
TEACHER'S PACK CONTENTS:

FIND MORE RESOURCES TO INCORPORATE INTO THESE ACTIVITIES AT www.jamesdysonfoundation.com

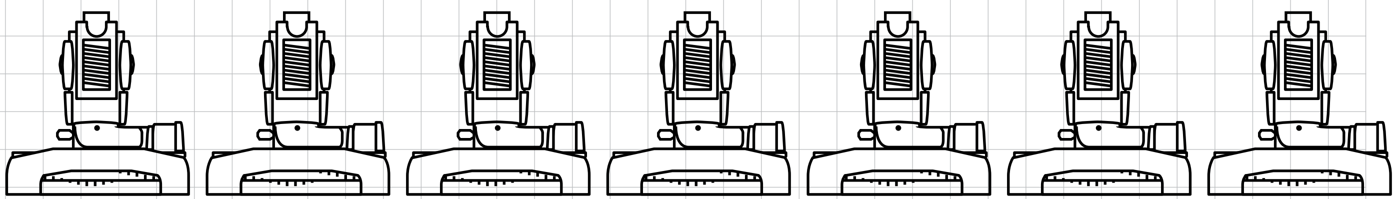
WHAT'S IN THE BOX?

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

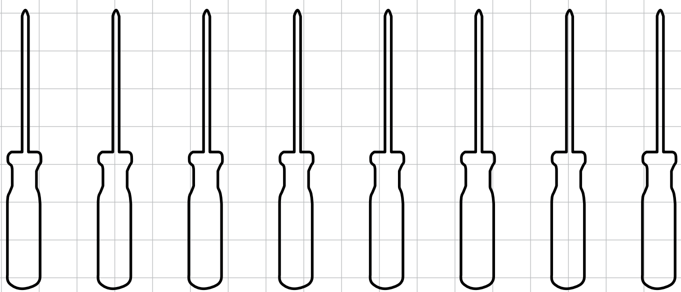
1 X Dyson DC22 VACUUM CLEANER, COMPLETE WITH HOSE, WAND AND ACCESSORIES



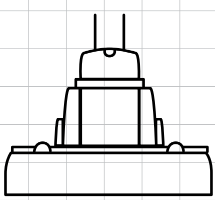
7 X TURBINE HEAD FLOOR TOOLS



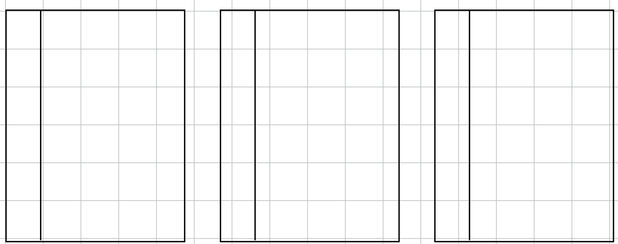
8 X TORX SCREWDRIVERS



1 X MINI FLAT OUT™ HEAD



POSTERS TO LIVEN UP YOUR CLASSROOM WALL



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

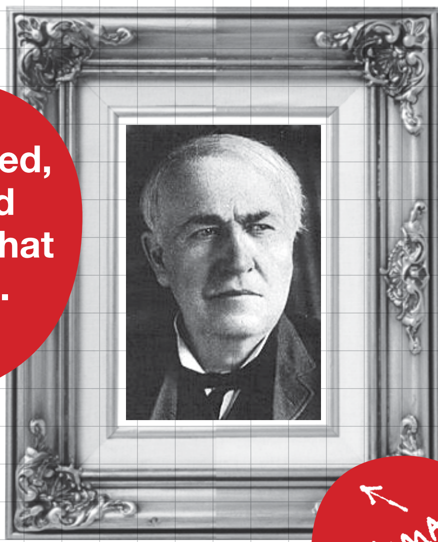
1.1 JAMES DYSON: ARTIST OR SCIENTIST?

"At school, I opted for arts, put off by all the formulae in science. There was nothing like D&T on offer. 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 was immediately decided on 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 realised 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 very nearly empty, with only a thin layer of dust coating the inside of the bag. James realised 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, 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 further prototypes to arrive at the Dual Cyclone™ technology vacuum cleaner, the DC01.

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 most 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 MORE THAN 500 DESIGN ENGINEERS AND SCIENTISTS WORK IN DYSON'S RESEARCH DESIGN AND DEVELOPMENT CENTRE, IN A SMALL MARKET TOWN CALLED MALMESBURY IN THE SOUTH WEST OF THE UK.

The team work with James Dyson, and together they strive 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

PRINCIPAL ENGINEER

JON

NAME
Jon

AGE
31

LIVES
Caerleon, Wales

SCHOOL
Design and Technology, Physics and Geography

UNIVERSITY
Engineering Product Design, Southbank University, London

OCCUPATION
Principal Engineer

Jon's worked at Dyson for 10 years now and he still can't get enough of designing. His latest project was the Dyson DC22, a compact but powerful vacuum cleaner.

"I discovered my love of designing and making when my grandfather showed me his workshop in his garden shed. He taught me how to use a lathe, and then I was hooked. I've been fascinated by the way things work ever since.

At school, I loved D&T because it was so different from trying to remember dates and formulae.

The thing I love most about being a design engineer is the freedom to try out new ideas. You soon realise that you can learn as much from the failures as from the successes (and there are always more failures!)

My proudest moments are seeing a product I've been working on in the shops and listening to customers and store staff talking about it. I find it very hard to resist getting drawn into their conversations."

NEW PRODUCT INNOVATION ENGINEER

CAROLINE

NAME
Caroline

AGE
27

LIVES
Gloucestershire

SCHOOL
Design and Technology, Maths and Physics

UNIVERSITY
Product Design and Manufacturing, Loughborough University
Industrial Design Engineering, Royal College of Art

OCCUPATION
New Product Innovation Engineer

Everything that Caroline does is top secret. Her team conceives new ideas for products by brainstorming and looking at problems that need solving.

"I enjoyed D&T at school because it was a chance to daydream about things I'd like to make, a chance to do some drawing and one of the only times at school where you could get totally absorbed in making things.

I first realised I wanted to be a designer one summer holiday whilst working for a company which made measuring equipment. My job involved gluing little balls onto sticks. I found the process really frustrating and difficult, so in my lunchtimes I used bits of junk to design a better tool to help make the process quicker and easier.

Today I get the most satisfaction from my job when I take a step back and dream about what the product I'm working on will be like."

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 (ˈsī,klōn)
n.
1. *Meteorology*
An atmospheric system characterised by the rapid inward circulation of air masses about a low-pressure center, usually accompanied by stormy, often destructive weather. Cyclones circulate anti-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. Ask your D&T or physics teacher about centripetal force.

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.

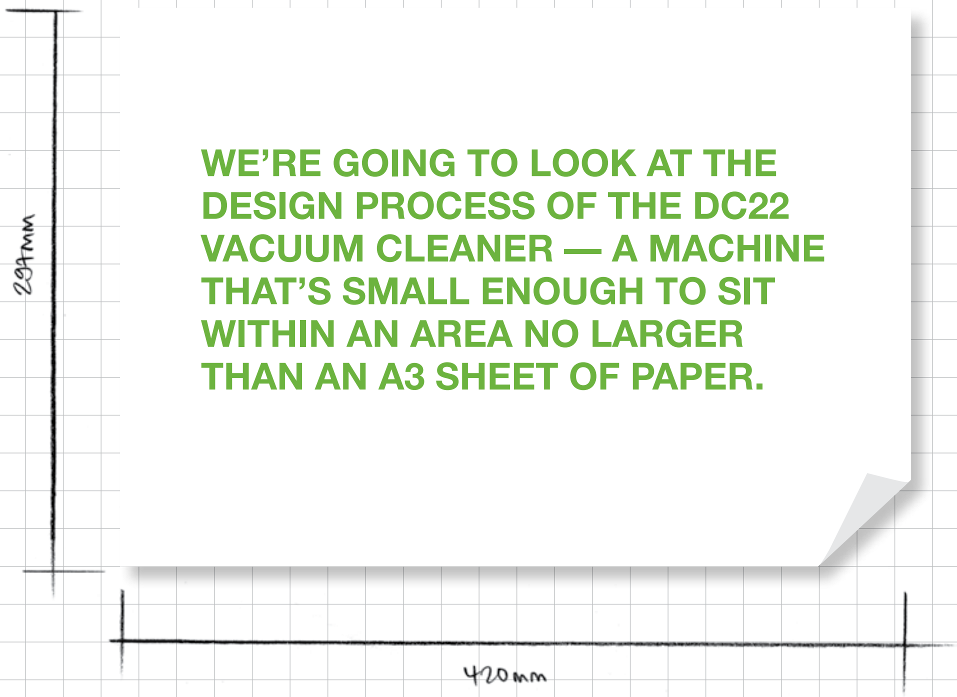
After it's passed through the inner cyclone, the air — now clean — exits the vacuum cleaner.

2 DYSON DC22

"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."
Jon, Principal Engineer

2.1 DESIGN

WE'RE GOING TO LOOK AT THE DESIGN PROCESS OF THE DC22 VACUUM CLEANER — A MACHINE THAT'S SMALL ENOUGH TO SIT WITHIN AN AREA NO LARGER THAN AN A3 SHEET OF PAPER.



IF YOU HAVE THE EDUCATION BOX, take out the DC22 and try it. Put a sheet of A3 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. X71 was the code name for the DC22 machine — the 71st project that Dyson's engineers have worked on.

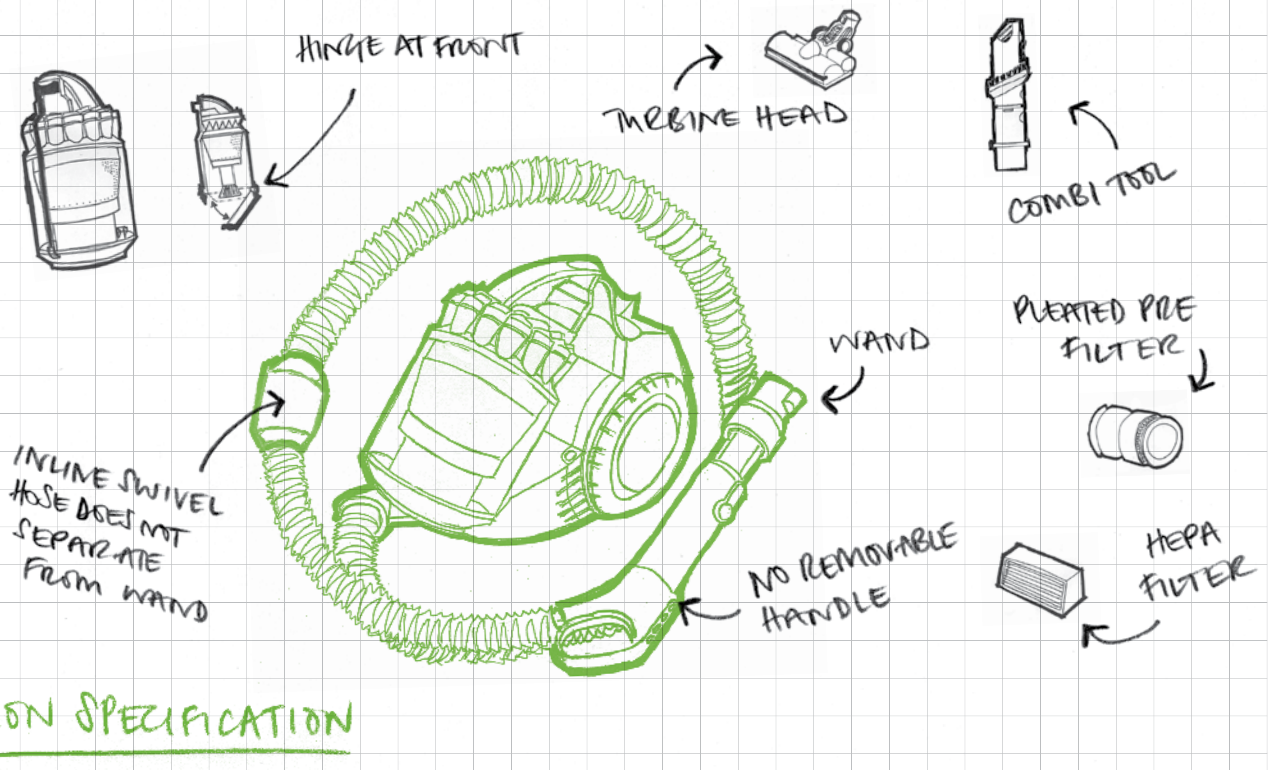
All the development is carried out in secret until the design is registered and protected with intellectual property offices.

2.1.1 THE DESIGN BRIEF

A design brief explains the challenge that must be answered by a product and the parameters in which an engineer or designer 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 and the new machine had to fit into a small storage space, so the brief for the DC22 team was to make a new vacuum cleaner that was very compact. But the engineers didn't want to compromise on its ability to pick up dust. In fact, they wanted to make it as efficient as possible when it came to filtering dirt out of the air.

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



THIS IS THE REALLY TECHNICAL ONE — THE ENGINEERING SPECIFICATION LISTS ALL THE TECHNICAL PERFORMANCE DETAILS.

ENGINEERING SPECIFICATION	
Air Watts	200
Pick up — Wilton Carpet	74%
Pick up — Hard Floor	99%
Pick up — Crevice	104%
Motion Force	10/8 Neutons forwards/backwards
Noise — Normal	89 Average
Noise — Whisper	78 dB(A)
Bin Volume	1.21 Litres
Weight	4.81 Kilograms
Size	292/255/397 Millimetres

2.2.2 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, smart and hardwearing. 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.

At Dyson, engineers start by creating a vision specification. This is a basic diagram of what the machine will look like and what features it will have. The vision specification for DC22 is shown above. It's called a vision specification because the engineers imagine what the new machine might look like — and the best way to do this is to draw it.

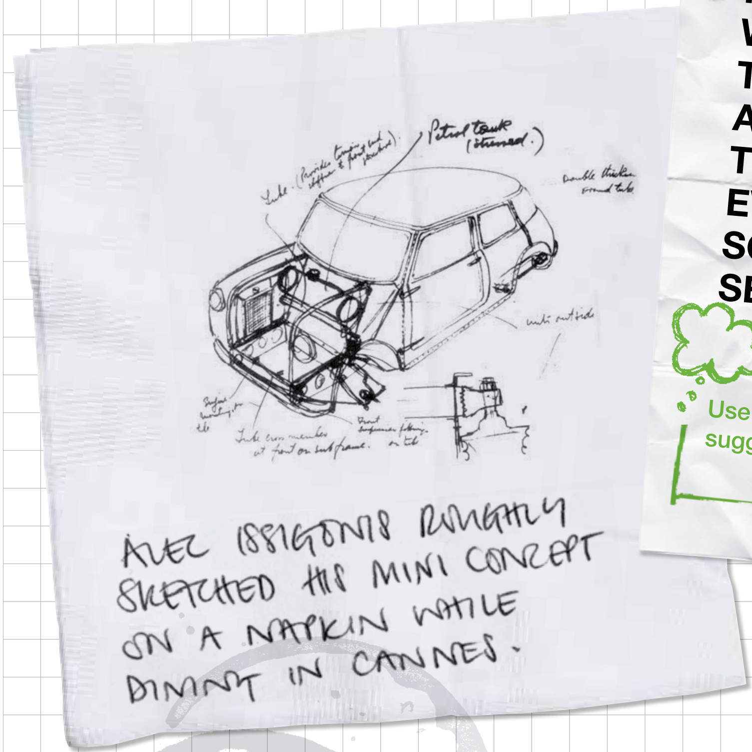
The next step for the engineers is to develop a much more detailed engineering specification. This sets the limits the machine must work within, like size, weight, power and noise. It is referred to throughout the design process.

"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."
Jon, Principal Engineer

2.1.3 RESEARCH AND IDEA DEVELOPMENT

So-called eureka moments are rare. Instead, ideas come from experimentation and sketching, from analysing 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 they may not always use it in the correct way.

The catch

The design engineers designing the DC22 thought a lot about how people use their vacuum cleaners, including how they carry them up stairs. On the DC22 you have to remove the clear bin™ from the chassis in order to empty it. The engineers studied how people replaced the bin on the chassis and noticed that many people attach the bin properly at the top, but not 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.

This is an example of 'poka yoke' design. This is a Japanese phrase which means 'fail-safing' or 'fool-proofing'.

The engineers were also worried that the bin might become detached accidently. So they also 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 EDUCATION BOX, take a look at the DC22 bin mechanisms. Pick up the product.

Is it easy to carry?

Can you see where the bin attaches? Try removing it and replacing it.

Lift up the DC22 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 — there's one on each side. 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.

2.1.6 DESIGNING FOR DIFFERENT MARKETS — THE DC22 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 DC22 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). It gives Dyson engineers a chance to get important feedback on a design. User trials in Japan revealed that people didn't want to use their feet to step on the power switch to turn the machine on and off. In Japan, using your feet like this is considered dirty and rude. The engineers had to design an on / off switch that fits on the wand handle. This switches the motor on and off using radio-frequency signals.

IF YOU HAVE THE EDUCATION BOX, you'll notice that the UK version of the DC22 has a switch on the body of the machine which you can turn on and off by stepping on it or by pressing with a finger. In the UK and Europe, people don't mind using their feet to switch the machine on and off — in fact they often prefer to do this rather than bending over.

2.1.7 DESIGN AND THE ENVIRONMENT

It's important to think seriously about the impact your design will have on the environment. It's not just the amount of raw materials that's important — it's the whole lifetime of a product.

"TODAY'S BIG CHALLENGE IS TO RECONCILE PEOPLE'S LOVE OF STUFF WITH THE PRESSURES UPON US TO BE MORE SUSTAINABLE."

Dyson Engineer, Caroline, designed an environmentally friendly product for her final year project at university

Disposable nappies produce waste which fills up landfills. Caroline designed a reusable nappy that is as convenient as disposable nappies but kinder to the planet since it doesn't produce any waste (except, of course, for the waste from the baby's bottom!) She looked at sports and medical equipment to find high tech textiles which would be suitable.

SAMPLES OF CAROLINE'S RESEARCH AND INSPIRATION FOR HER 'NAP SAC'.

USE AND DISPOSAL

Dyson engineers are challenged to design the best performing technology with the fewest parts — using complementary materials. By choosing materials which can be recycled, a designer can help prevent unnecessary landfill. In the European Community there is a directive called Waste Electrical and Electronic Equipment Directive or WEEE. Dyson products are collected at the end of their lifetimes and disposed of responsibly.

LIFETIME

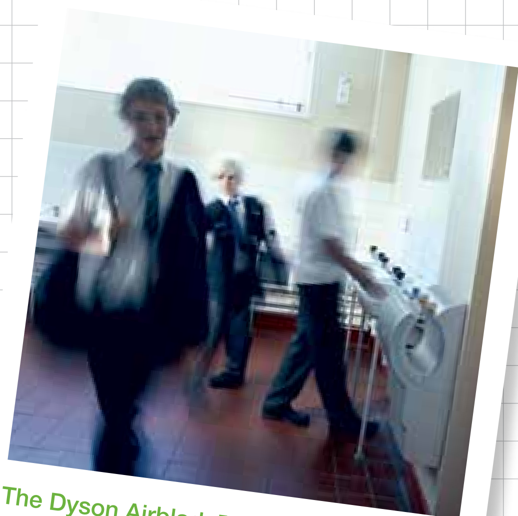
Ensuring a long lifetime for your product reduces its environmental impact. At Dyson, all vacuum cleaners come with a five year guarantee. Engineers have tested the machine to destruction, and redesigned it to withstand those tests. They're confident that it will last. If your product has a long life then your user won't need to replace it as often, which saves both waste and resources.

FUNCTION

If a product is well designed, it will do its job efficiently, without wasting energy. Cyclone technology means that Dyson vacuum cleaners are more efficient so they can afford to have a less powerful motor, but still do their job as well.

TECHNOLOGY AND ECOLOGY

The technology that powers a product can make a real difference to its environmental impact. Solar cells can power electric cars and charge your mobile, and you can get a wind turbine that powers your TV. Dyson engineers worked for 10 years on a small, high efficiency motor, the Dyson digital motor. This is used in the Dyson Airblade™ hand dryer, which as a consequence uses up to 80 per cent less energy to dry hands than warm air hand dryers.



The Dyson Airblade™ hand dryer

DESIGN BRIEF ACTIVITY

2.1.8 STUDENT ACTIVITY

Start with a frustration or problem that you want to solve. Write a design brief and make some sketches for a product that solves this 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 saddle 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 DC22 used card modelling to visualise their designs from the beginning when they drew up their vision 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 modelling 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?

ONE OF THE INITIAL CARD MODELS FOR DC22. 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."
Jim, Design Engineer

2.2.2 COMPUTER AIDED DESIGN (CAD)

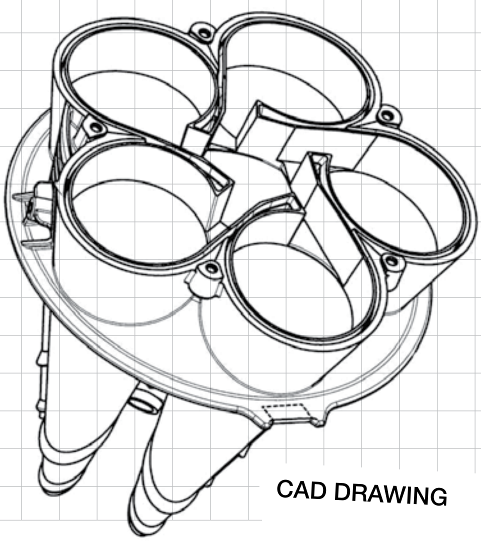
The next step is to use CAD software to draw the design in fine detail. All of the different parts are drawn on computer, enabling the engineers to build a more complicated prototype using automated machines like three or five axis milling machines or routers (you may have similar machines in your workshop)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

2.2.3 SELECTIVE LASER SINTERING (SLS)

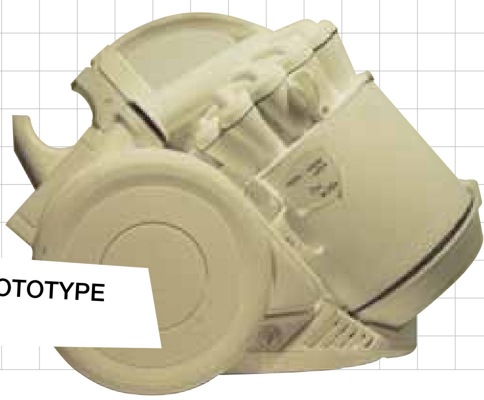
SLS is a very expensive process — producing just one cyclone assembly costs several thousand pounds — so it's important that the design is very well developed before reaching this stage of prototyping.

The CAD data is used by the SLS machine, which can build all the plastic parts needed for an accurate prototype. 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-moulded parts from mass manufacturing. The engineers can even fit motors and electronics to build a fully operational prototype.



CAD DRAWING



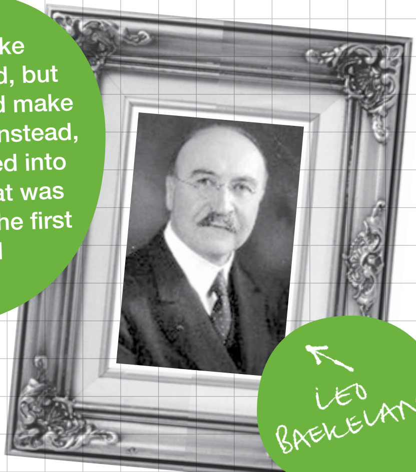
SLS PROTOTYPE

2.3 PROBLEM SOLVING IN THE DESIGN PROCESS

THE DESIGN ENGINEERS WORKING ON THE DC22 ENCOUNTERED PROBLEMS, AND YOU WILL TOO. YOU'LL NEED TO BE FLEXIBLE AND ADAPT. HERE ARE SOME CHALLENGES THE DC22 ENGINEERS ENCOUNTERED AND HOW THEY SOLVED THEM.

INVENTED THE FIRST COMPLETELY MAN-MADE SUBSTANCE IN 1907

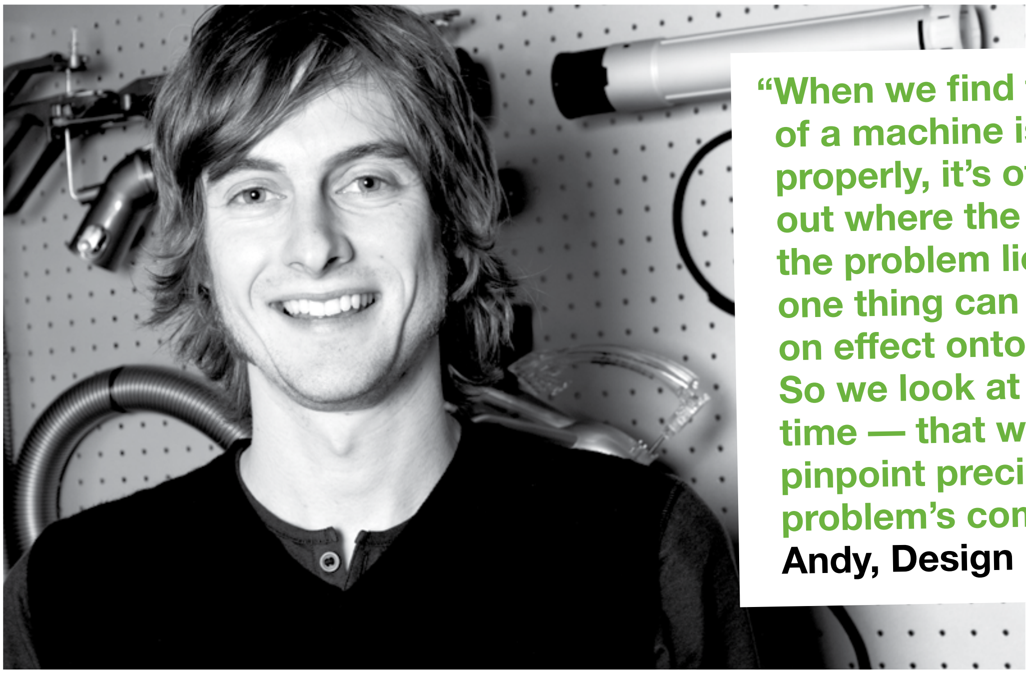
I was trying to make something really hard, but then I thought I should make something really soft instead, that could be moulded into different shapes. That was how I came up with the first plastic. I called it Bakelite.



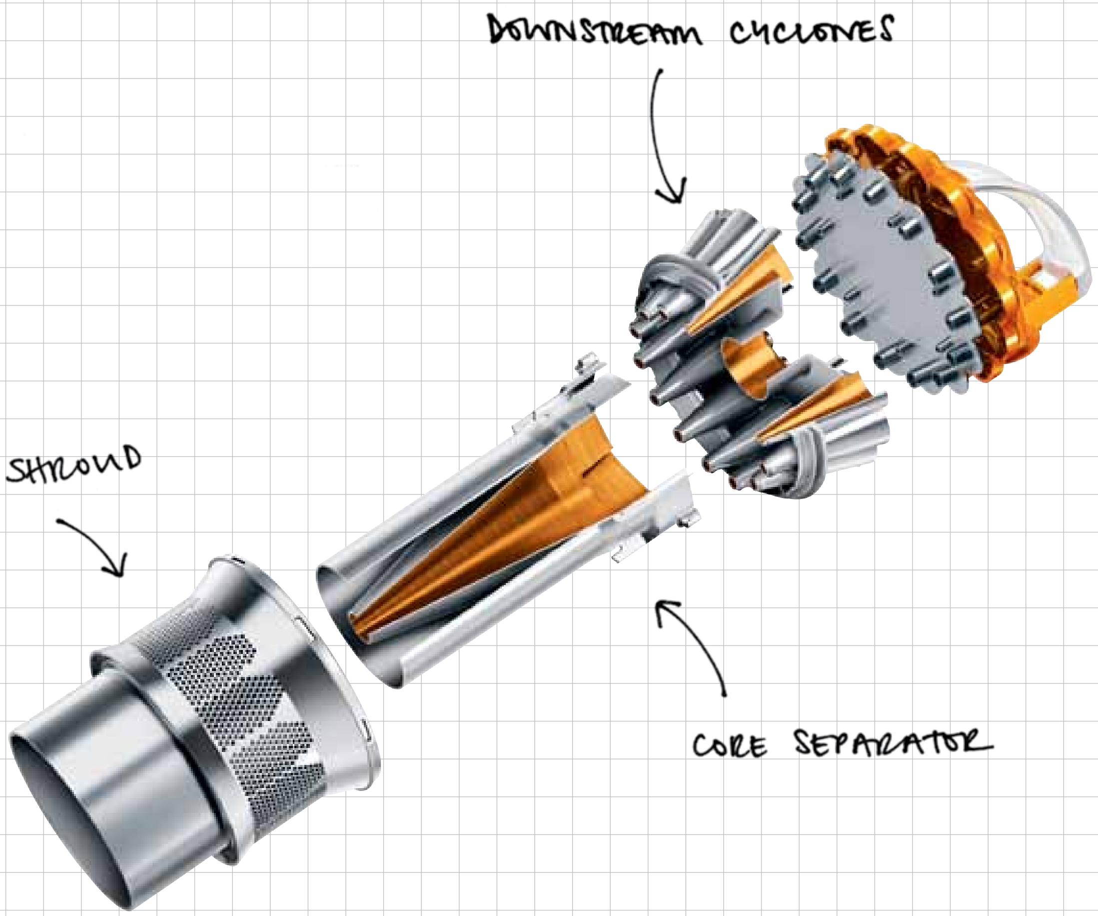
LEO BAEKELAND

Tip 1
If you encounter a problem with part of your design, break it up and analyse 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 analyse what you learnt from them. Your design won't be perfect at first and making mistakes is a fundamental part of the design process.



"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."
Andy, Design Engineer



2.3.1 FROM TWO STAGE SEPARATION TO THREE STAGE SEPARATION

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 DC22, the engineers set themselves the challenge to increase the machine's filtration even more. They soon realised that they had already improved two-stage filtration as much as they could. They realised that another stage of filtration was needed to make the significant improvement they were after.

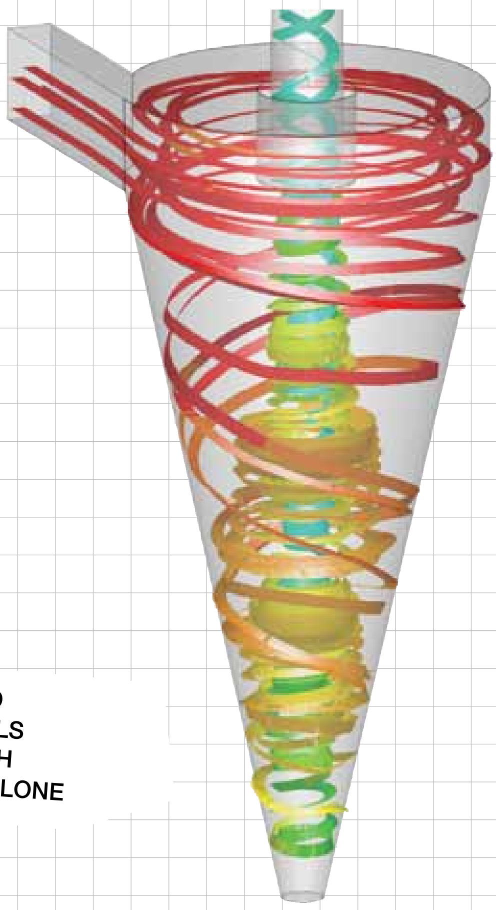
The first problem was where this extra stage of filtration would be located. Step by step, the engineers experimented with different positions inside the machine, only to discover more problems — that the inner cyclones became choked, the bin was difficult to empty and it was going to be expensive to manufacture. So, the engineers split the cyclone assembly into parts and looked at each one separately.

The result? They could add an intermediary cyclone — called a core separator — between the outer cyclone/shroud and the inner cyclones. This intermediary cyclone, the core separator, would reduce the dust load entering the inner cyclones, meaning no more blockages.

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

How would you solve this challenge?

IF YOU HAVE THE EDUCATION BOX, take a look at the DC22. 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 AIR FLOW THROUGH THE CONES OF THE CYCLONE

2.3.2 COMPUTATIONAL FLUID DYNAMICS

Whilst 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 visualise 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 DC22 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

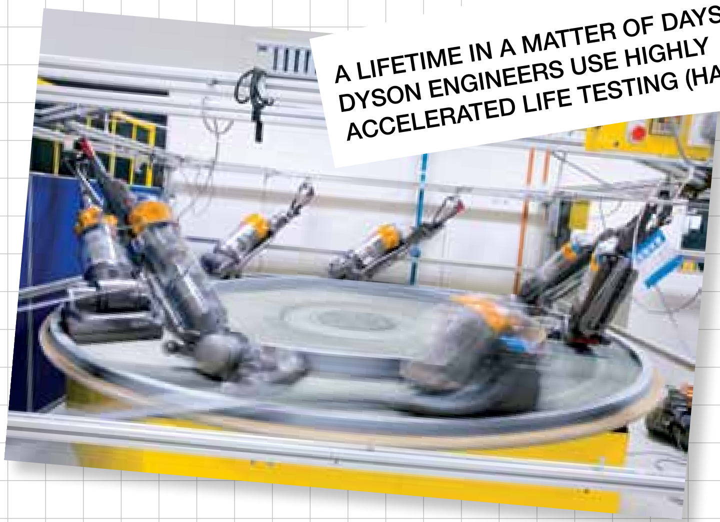
"Testing is what literally makes or breaks a product. When you test your design you know it won't be right first time. But you see why it doesn't work and the whole process of problem solving starts all over again. You just keep redesigning and testing until you get it right."
Jim, Design Engineer.

THE DC22 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 fulfil 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.

MECHANICAL TESTING

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 try it 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 a prototype and drop it from exactly that height (making sure it's not your only copy 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 — and fitting it all into a matter of days or weeks. 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 1,357 kilometres, at walking pace, night and day, for just over two weeks straight.

WATCH HOW DYSON TEST THEIR 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.

INSIDE THE TOP HALF OF THE CONE PACK MOULD TOOL

Notice how much larger the injection mould tool is compared to the cyclone assembly it will make.

When the DC22 team finished their design they transferred it to Dyson engineers in Malaysia 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 a last chance for the engineers to fix any small problems, like rough edges in the moulded 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 DC22 has hundreds of components, from screws and springs to electrical wires, electronics, plastic mouldings and a motor.

Dyson buys some of the components, like the motor and cable rewind mechanism, from specialist suppliers. Others are made especially for Dyson — for example, the 110 plastic moulded parts.

2.5.1 PLASTIC MOULDING

Dyson engineers design complex plastic parts, which require very sophisticated tools to make them. Here's a picture of the inside of the DC22 cone pack tool, the most important part of the vacuum cleaner — the cones that separate the dust from the air. A plastic moulding tool comes in 2 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 mould evenly. This tool weighs 2283kg (an average car weighs about 1300kg).

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

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

IF YOU HAVE THE EDUCATION BOX, look at some of the plastic moulded 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 contain electronic components).

The Dyson factory can make several thousand DC22 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.

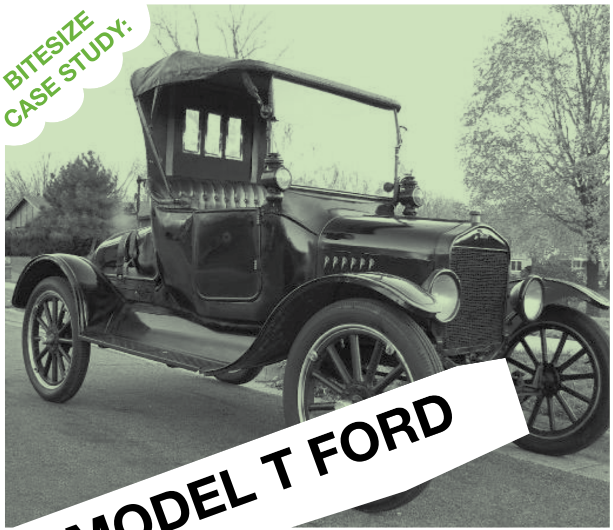
This is another example of where engineers use poka yoke design: the engineer will design components so that they will only fit together in one way — so that on the assembly line, they can't be put together upside down or back to front.

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: 1389

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

BITESIZE CASE STUDY:

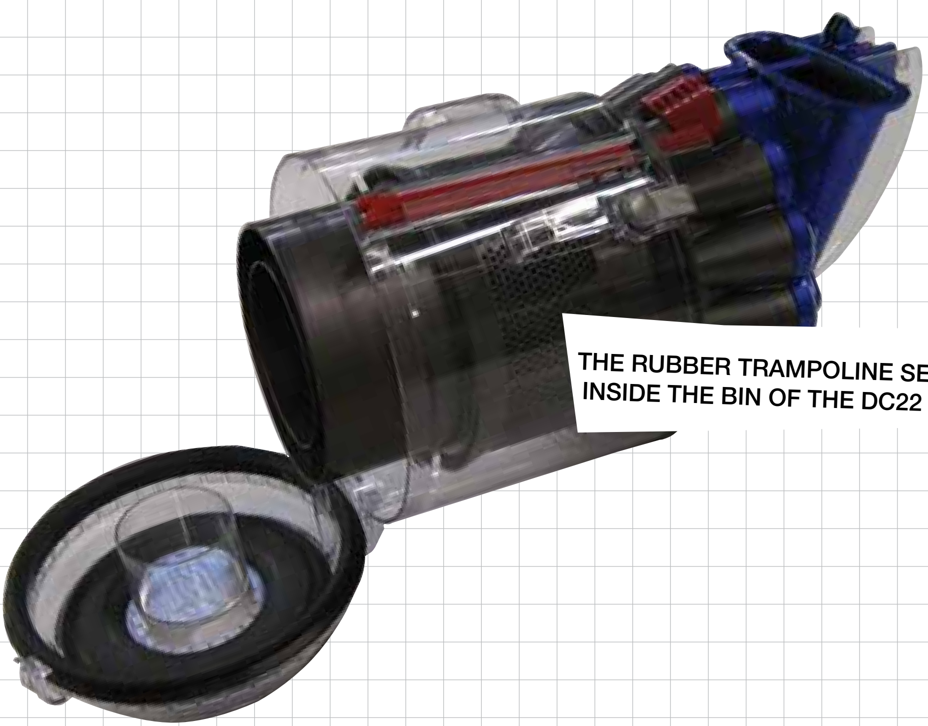


THE MODEL T FORD

The world's first affordable motor car not only introduced many innovations in automotive design, the process by which it was built was revolutionary 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 specialise 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 £10,000 in today's money). In later years Ford was able to sell them for as little as $260 (£2,700 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 DESIGNERS AT www.jamesdysonfoundation.com



THE RUBBER TRAMPOLINE SEAL IS INSIDE THE BIN OF THE DC22

2.5.3 CHOOSING THE RIGHT MATERIALS

In design engineering, the tolerance of a material refers to the margin of error in the specification of a particular dimension. For example, if you design a part to be 5mm thick, the tolerance is the amount thicker or thinner it can be once manufactured, without detrimentally affecting performance. For instance, a seal might have been designed to be 1mm thick. When mass produced, some will be precisely that. But others might be 0.9mm thick or 1.1mm thick.

A seal is any device that joins two systems or elements in such a way as to prevent a leak. There are many places on the DC22 where two different parts meet and these have to be completely airtight. The join between the hose and the bin is just one example. The seals keep the DC22 airtight, so the air travels through the machine without escaping and degrading performance.

In some instances it's possible to live with wide tolerances. But when a seal has to make a join between two components airtight, tolerances are narrow. During their experiments with foam seals, the engineers discovered that foam's tolerances weren't narrow enough — the deviation either side of the specification was too great. The acceptable margin of error like this in a design is called the 'tolerance range.' The engineers therefore chose to make the seal from rubber which can be manufactured with a tighter tolerance range than foam.

IF YOU HAVE THE EDUCATION BOX, take the bin off the DC22 and open it by pressing the red button on the handle. You'll see two seals on the inside of the base of the bin. The outer seal makes the joint between the base and the sides of the bin airtight. The thicker inner seal — called a trampoline seal — prevents air entering the core separator and inner cyclones without passing through the shroud first. The trampoline seal is made from rubber. When the engineers originally designed the DC22, a foam seal was considered, but they experienced problems with tolerance.

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 5 and 13m long, which can be loaded on a truck or onto a cargo ship. You will probably have seen them on the back of trucks on the motorway.

QUESTION: What route do you think the containers take from our factory in Malaysia to the shops in the UK? 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 at Johor Baru at the southern tip of Malaysia. The ships sail across the Indian Ocean, through the Red Sea and then the Suez Canal into the Mediterranean Sea. They pass through the mouth of the Mediterranean Sea at Gibraltar; make their way around Portugal, Spain and France to dock at Southampton in the UK. Smaller boxes mean fewer containers and less environmental impact. They are then loaded onto trucks and driven to Dyson's distribution centre in Gloucestershire before being delivered to shops.

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 and the more difficult to handle.

IF YOU HAVE THE EDUCATION BOX, have a look at the cardboard box. This isn't the usual box that Dyson uses to ship DC22 (Dyson don'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.

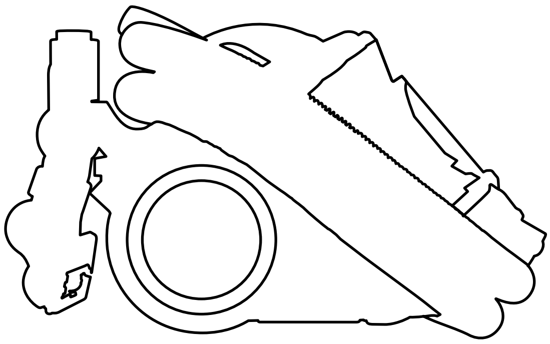
A DYSON TESTER PUTS THE MACHINE THROUGH ITS PACES.

"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."
Jon, Principal Engineer

3 DISASSEMBLY ACTIVITY

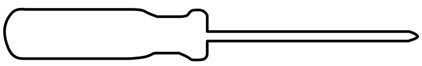
YOU CAN LEARN A LOT ABOUT HOW SOMETHING IS DESIGNED BY TAKING IT APART. AND THAT'S EXACTLY WHAT YOU'RE GOING TO DO WITH YOUR DC22.

WHILST DISASSEMBLING THE DC22 AND THE TURBINE HEAD, THINK ABOUT WHY THE ENGINEERS DESIGNED THEM IN THIS WAY.

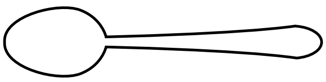


YOU WILL NEED:

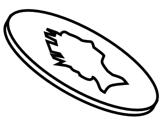
A TORX T15 SCREWDRIVER (INCLUDED IN THE BOX)



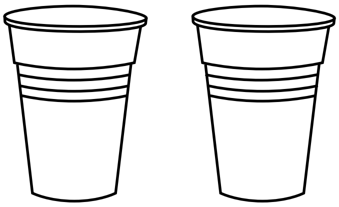
A SPOON HANDLE OR COIN TO LEVER OFF THE SOLE PLATE



A COIN TO SECURE AND UNDO QUARTER-TURN FASTENERS



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



QUESTIONS

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

B) Which features enhance the performance of the product?

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 DC22 TURBINE HEAD

NOTE ON SAFETY:
When working on this machine Dyson 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/organisation's responsibility to ensure that pupils/clients are supervised at all times when disassembling and reassembling the machine and that the school's/organisations safety regulations are carefully followed.

Please follow the instructions with disassembling the DC22. 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 colour 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.

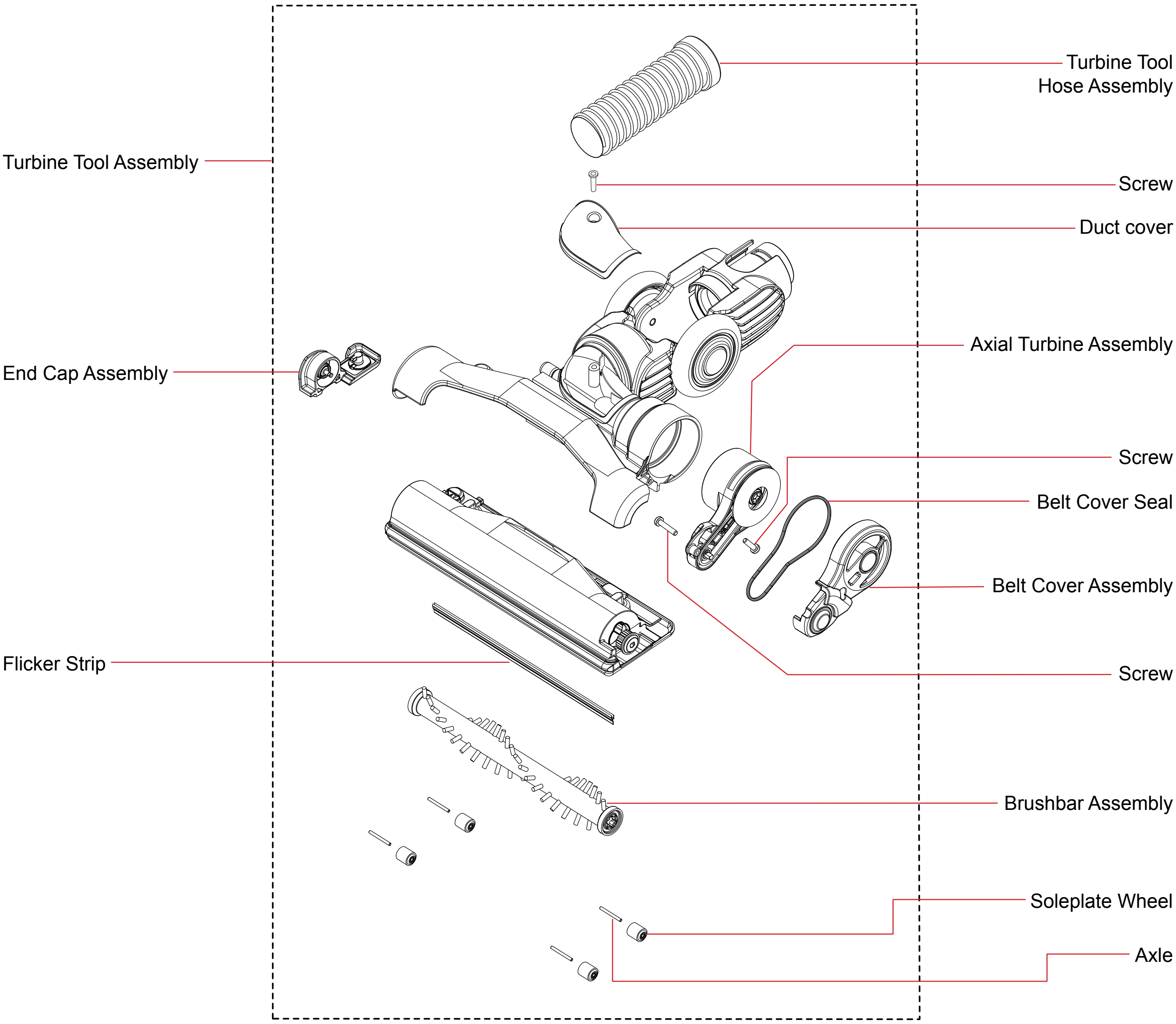
E) Brush bar — PP (Polypropylene)
Turbine cover — PBT (Polybutylene Teraphthalate)
Main body of turbine tool — PC (Polycarbonate)
Flexible Hose — PU (Polyurethane)
Wheels — primarily PP
Sole plate — ABS (Acrylonitrile butadiene styrene)
Metal screws

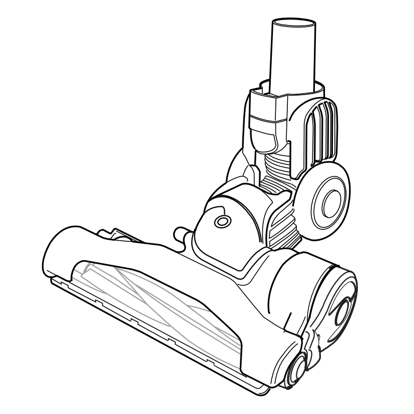
F) Electric motor
Electronics

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

ELEMENTS OF A DS22 TURBINE HEAD

USE THIS DIAGRAM TO IDENTIFY PARTS OF THE DC22 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?

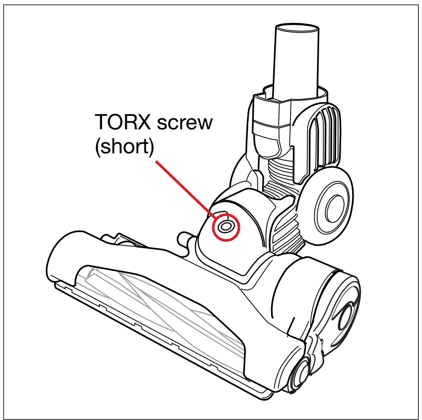
B) What are the main components of the turbine head? What are the components made of?

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 Mini Flat Out™ head and other tools — what are they all for?

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

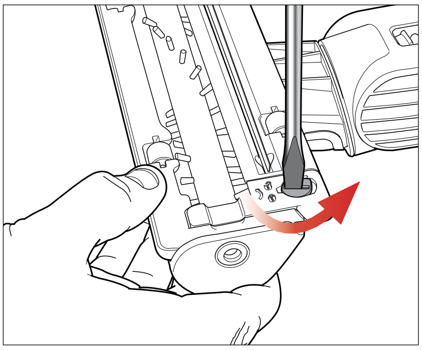


STEP TWO: Remove the duct cover

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 the 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 this 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 or a slotted-head screwdriver, carefully turn it one quarter-turn anti-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) Mini Flat Out™ to fit under furniture; Combination tool for small spaces; Stair tool.

F) The hose is made of clear polyurethane. It allows for manoeuvrability 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

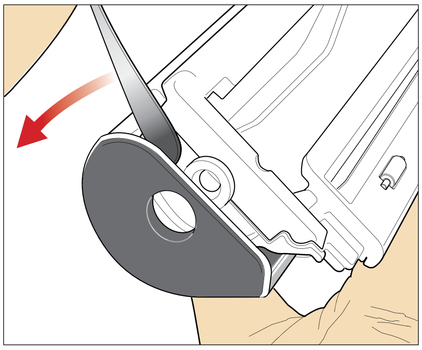
A) The rubber seal around the duct cover keeps the duct airtight. Any gaps would mean a loss of suction and reduced brush bar speed.

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.



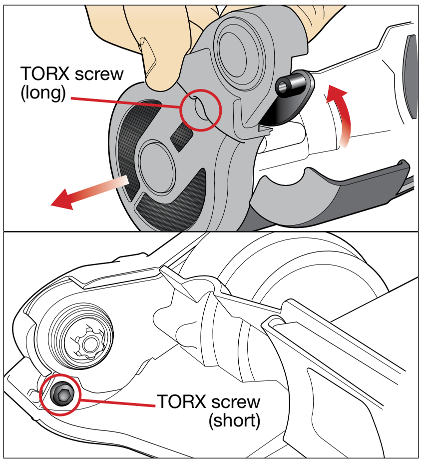
STEP FOUR:
Remove the soleplate

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 end of a teaspoon into the gap and lever the brush bar housing out. You might need to use a bit of force to lever 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 anticlockwise and pull it out. You now have the turbine drive in your hands, with the blades of the turbine clearly visible.

Examining the turbine:

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?

C) Turn the small cog that drives the brush bar. You can see that it spins slowly whilst 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 wooden 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.

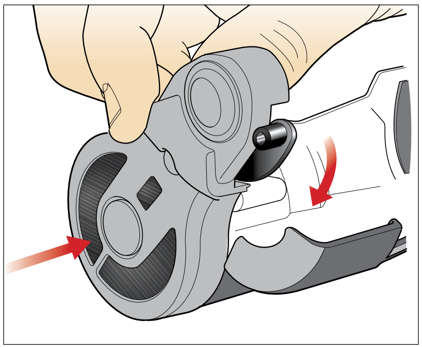
B) The mesh is another way that the design engineers ensure that dirt doesn't enter the turbine. It's made of polyamide 6 — commonly referred to as 'PA6' or 'nylon'.

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.

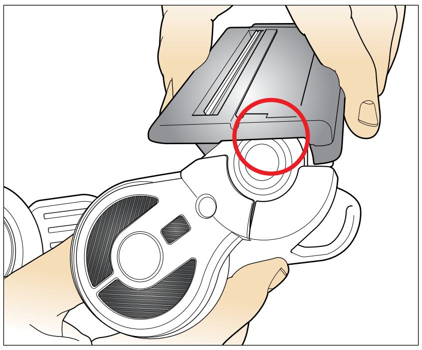
REASSEMBLING THE DC22 TURBINE HEAD

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



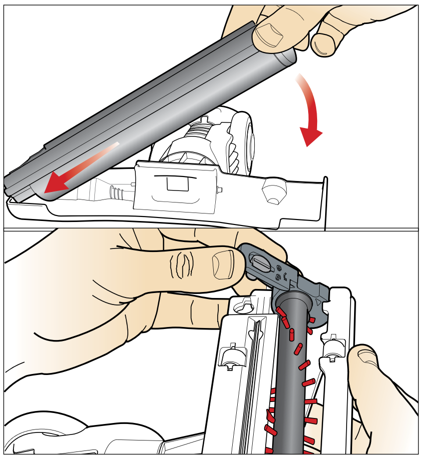
STEP ONE:

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:

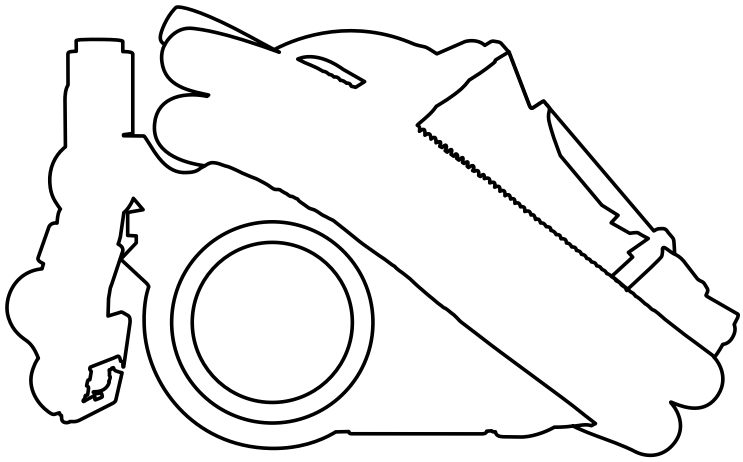
Slot the brush bar housing back into the main turbine head, placing the turbine end over the cog that drives the brush bar. Push the other end back into place — it can take a bit of force so don't worry if it makes a snapping noise.



STEP THREE:

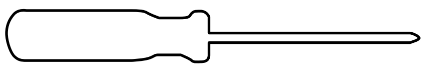
Place the brush bar back in its housing, with the end that sits over the turbine cog first. Slot the quarter-turn fastener onto the other end and push it into place in the housing. Use the coin to secure it in place. Return the duct cover to its place on top of the turbine head and affix with the short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

3.2 DISASSEMBLING THE DC22 (WITH TEACHER SUPERVISION)

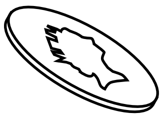


YOU WILL NEED

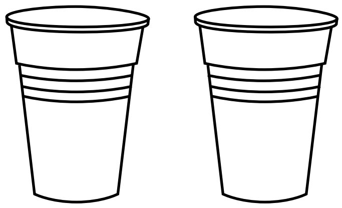
A TORX T15 SCREWDRIVER (INCLUDED IN THE BOX)



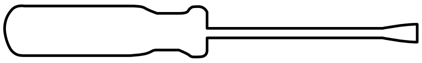
A COIN



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

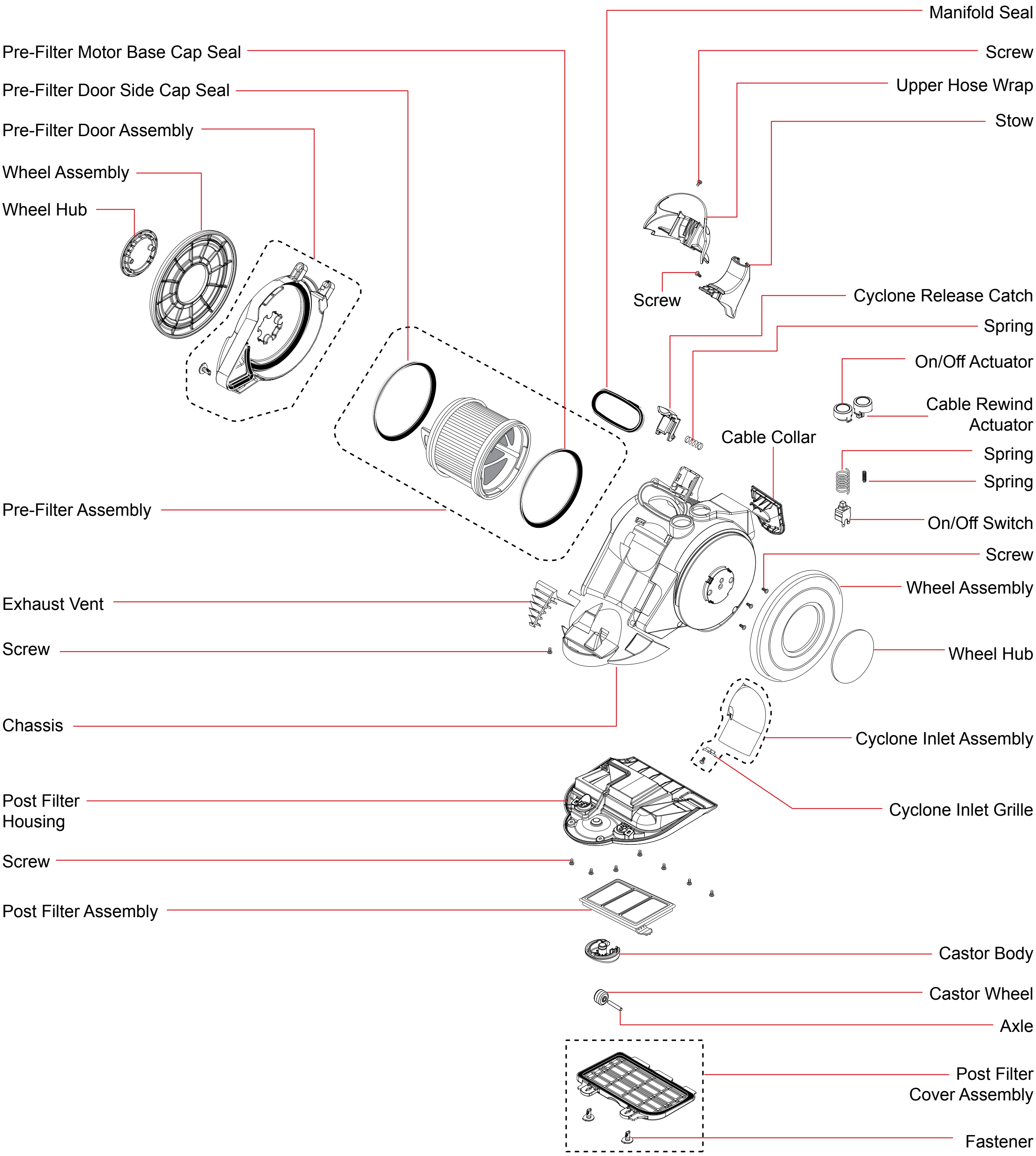


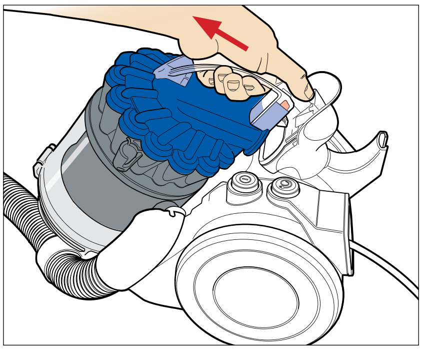
OR A SLOTTED-HEAD SCREWDRIVER



ELEMENTS OF A DC22

USE THIS DIAGRAM TO IDENTIFY PARTS OF THE DC22 VACUUM CLEANER WHEN DISASSEMBLING OR REASSEMBLING.





STEP ONE: Remove the bin and cyclone assembly

Push the bin release button 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.

QUESTIONS

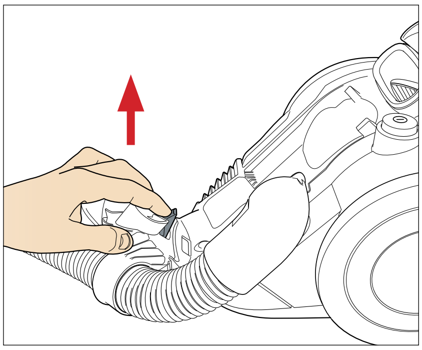
On removing the bin and cyclone assembly:

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 three stages of separation?



STEP TWO: Have a look at the telescopic wand

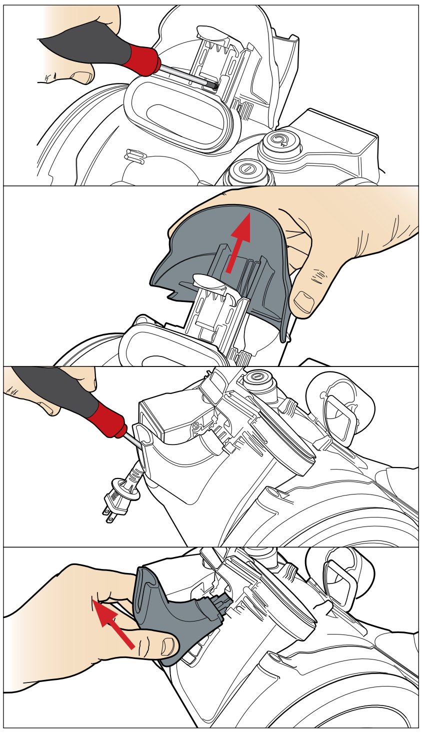
DC22 has a telescopic wand — you can extend it and it snaps into place.

If you haven't already, unwrap the hose. Find the end of the hose where it enters the chassis, unclip the hose bracket and pull it out (it can be stiff).

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

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

C) Why would you need to remove the hose?



STEP THREE: Remove the floor tool storage bracket

Return to the chassis and pull up on the hose retainer mounted on the front. It will slide out. Next, undo the screw beneath the bin release catch and pull the upper hose guide off the chassis. Then turn to the rear of the chassis and locate the floor tool storage bracket. Look down the hole in the middle of it and you'll see a TORX screw — remove it. Rock the floor tool storage point up, then pull it down and out.

ANSWERS

STEP ONE: Remove the bin and cyclone assembly

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

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
Core separator
Cyclone Head

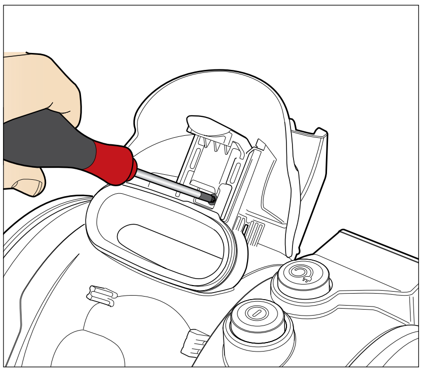
STEP TWO: Have a look at the telescopic wand

A) It's easier to store.

B) Extend the wand and examine the way it clicks into place. Look at the button that releases the catch — it's red to draw the eye.

C) 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 from the hose by pushing a broom handle through the hose.

QUESTIONS



STEP FOUR: Remove the pre-motor filter

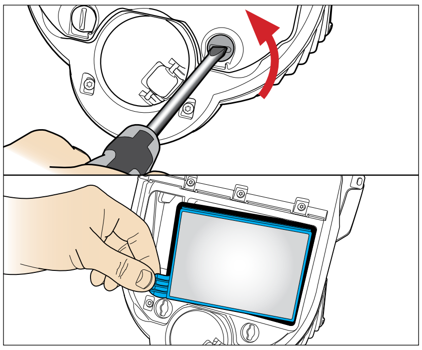
Remove the pre-motor filter: Turn the chassis on its side with the exhaust vents facing upwards. Use a coin to undo the quarter-turn fastener next to the wheel (labelled "A"). Open the side door of the chassis and pull out the blue pre-motor filter. On removing the filter, secure the door shut to make disassembly easier.

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

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 inside the door you've just opened. There are instructions inside. What do they tell you? How often should you wash the filter?

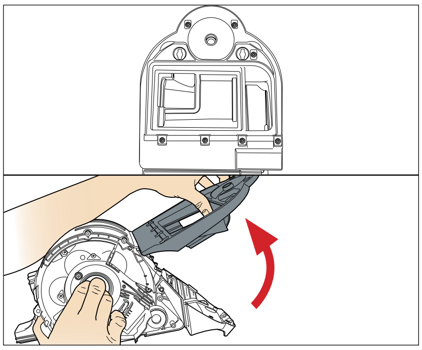


STEP FIVE: Remove the post-motor filter

Turn the chassis upside down and undo the two quarter-turn fasteners on either side of the caster wheel (labelled "B"). Remove the panel to reveal the post-motor filter and take that out, too.

A) 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 on this machine?



STEP SIX: Remove the bottom panel

Unscrew the 7 screws on the bottom of the machine and remove the panel with the caster wheel.

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

ANSWERS

STEP FOUR: Remove the pre-motor filter

A) The pleats increase the surface area of the filter so that it can capture more dust and consequently last longer before it needs cleaning.

B) Air passes out of the cyclone then flows from the outside of the filter in.

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.

The pre-motor filter also insulates the motor, reducing noise.

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

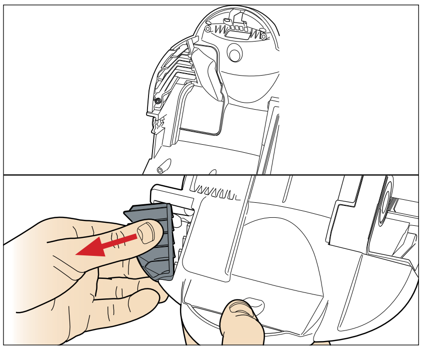
STEP FIVE: Remove the post motor filter

A) The post-motor filter is a HEPA (High Efficiency Particulate Air) filter. HEPA filters remove 99.9999% of microscopic particles (particles like pollen grains, bacteria and mould spores).

B) 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 bottom panel

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

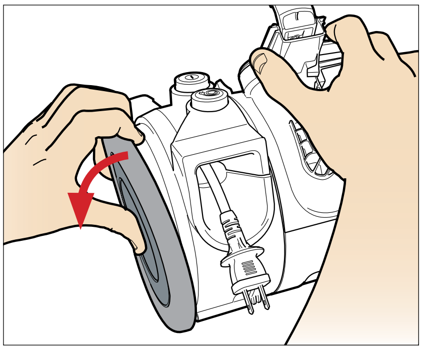


STEP SEVEN: Remove the exhaust vent

Still looking at the underside of the machine, remove the screw at the base of the exhaust vent. Hold the exhaust grill at the wide end and pull it away from the side of the machine. This can be stiff to remove.

QUESTIONS

A) Look at the louvres on the exhaust vent. Which way are they angled? Why do you think that is?



STEP EIGHT: Remove the wheel

Turn the machine onto its side so that the left-hand wheel is facing the ceiling (the one under the power and cable rewind buttons). Hold on to the main body of the machine with one hand and hook the fingers of your other hand around the edge of the wheel. Pull hard towards the ceiling and the wheel will come off. It's composed of two pieces – a hubcap and rim.

A) The wheel is clipped into place. What methods of fixing parts together have you found when dismantling DC22? How many screws have you undone?

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

ANSWERS

STEP SEVEN: Remove the exhaust vent

A) The louvres are angled up and backwards so air exiting DC22 is directed away from the floor, where it could disturb dust on carpet that hasn't been vacuumed yet.

The louvres also reflect some of the sound from the motor, making the machine quieter.

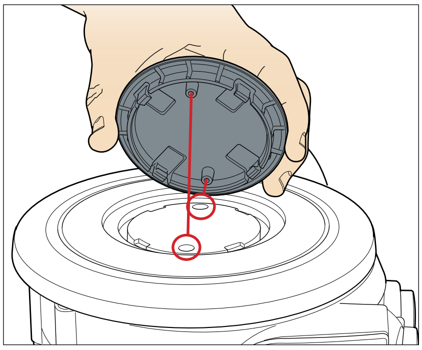
STEP EIGHT: Remove the wheel

A) Clip / snap fitting
Quarter turn fasteners
Torx screws

B) Quarter-turn fasteners are used to fasten areas where the person using 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.

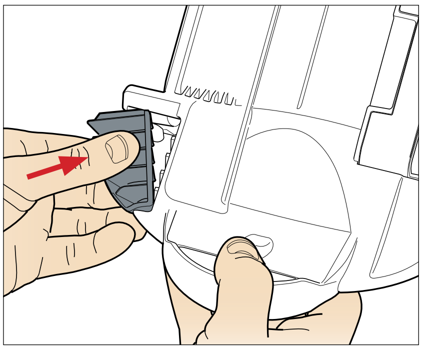
REASSEMBLING THE DC22

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.



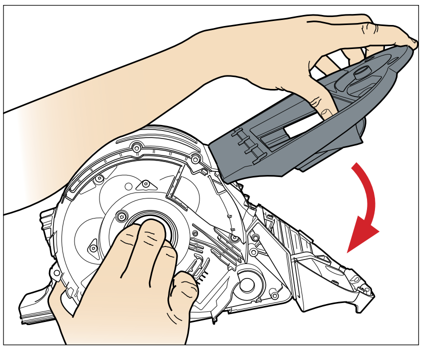
STEP ONE:

Take the wheel and place the rim on the chassis. Then put the hubcap over the centre, making sure you line up the four latches and two pegs on the underside with the notches and holes on the chassis. To re-fit the hubcap, push firmly — you may need to lean on it to push it into place.



STEP TWO:

Turn the machine onto its other side and push the exhaust vent back in from the side. Insert the thinner end of the vent into the gap before the larger end. Secure it with the screw you removed earlier.



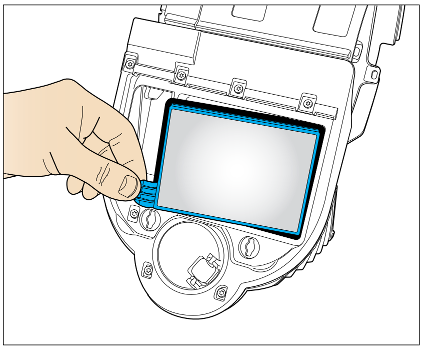
STEP THREE:

Replace the panel with the caster wheel on and screw all 7 screws in.

QUESTIONS (ANSWERS ON PAGE 48)

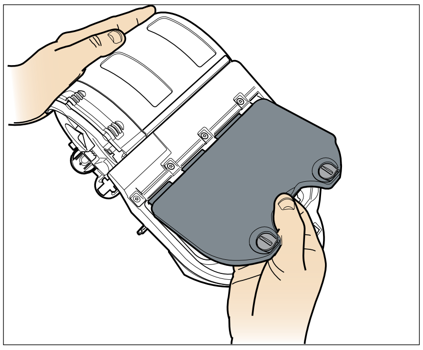
A) Note that the HEPA filter will only fit one way round. Why do you think the engineer has designed it in this way?

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



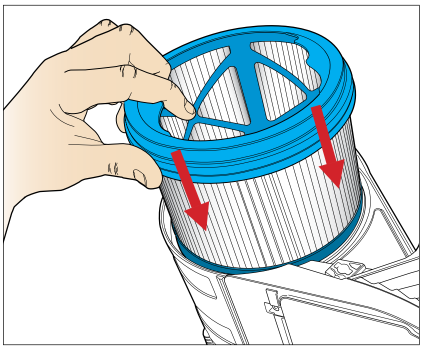
STEP FOUR:

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.



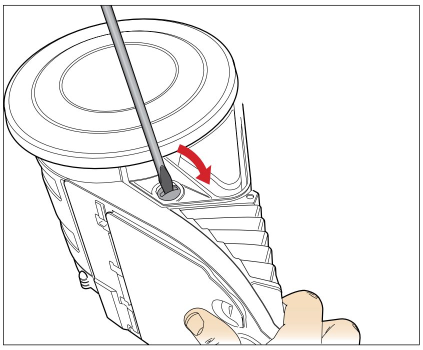
STEP FIVE:

Now place the post-filter housing cover back over the HEPA filter. Make sure the four tabs on the cover go into the four slots on the main chassis, then close with the two quarter-turn fasteners.



STEP SIX:

Put the machine on its side, and open the wheel door using the quarter-turn fastener labelled A. Refit the pre-motor filter by sliding it over the motor. This is an example of poka yoke design.



STEP SEVEN:

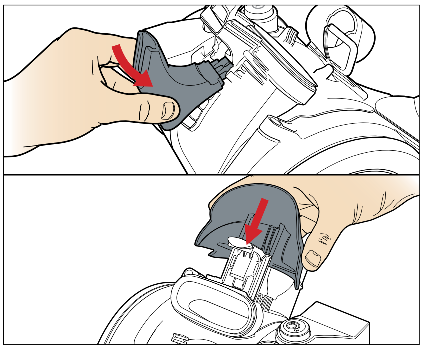
Close the wheel door and secure with the quarter-turn fastener next to the grill.

ANSWERS

STEP FOUR:

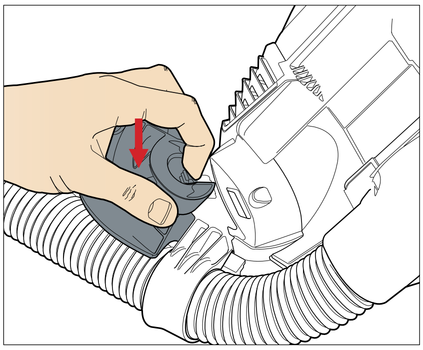
A) Because the HEPA filter is made up of different layers, it is important that the air passes through the filter in the right direction. Therefore the engineer has designed the filter and the machine so that it will only fit one way round. This is a design technique known as “poka yoke”. This is a Japanese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

B) Pre-motor filter
Tab on the base of the bin to ensure that the bin and cyclone assembly drops into the right place.



STEP EIGHT:

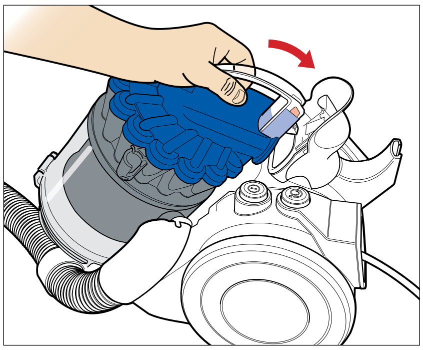
Turn the machine upright and reattach the floor tool storage bracket with the screw. Then reattach the upper hose guide to the chassis, screwing it in place.



STEP NINE:

Then find the hose. Insert the end back into the chassis and slot the hose retainer back into place.

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. Push until you hear a click.



STEP TEN:

Take the bin and place the clear tooth on its base into the notch on the chassis. Push the bin back into the chassis until the bin release button clicks closed.

NOTES

NOW IT'S YOUR TURN!

WE HOPE THIS EDUCATION 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 TO CONVEY THIS IN YOUR CLASSROOM. USE OUR RESOURCES AND GIVE US YOUR FEEDBACK.

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