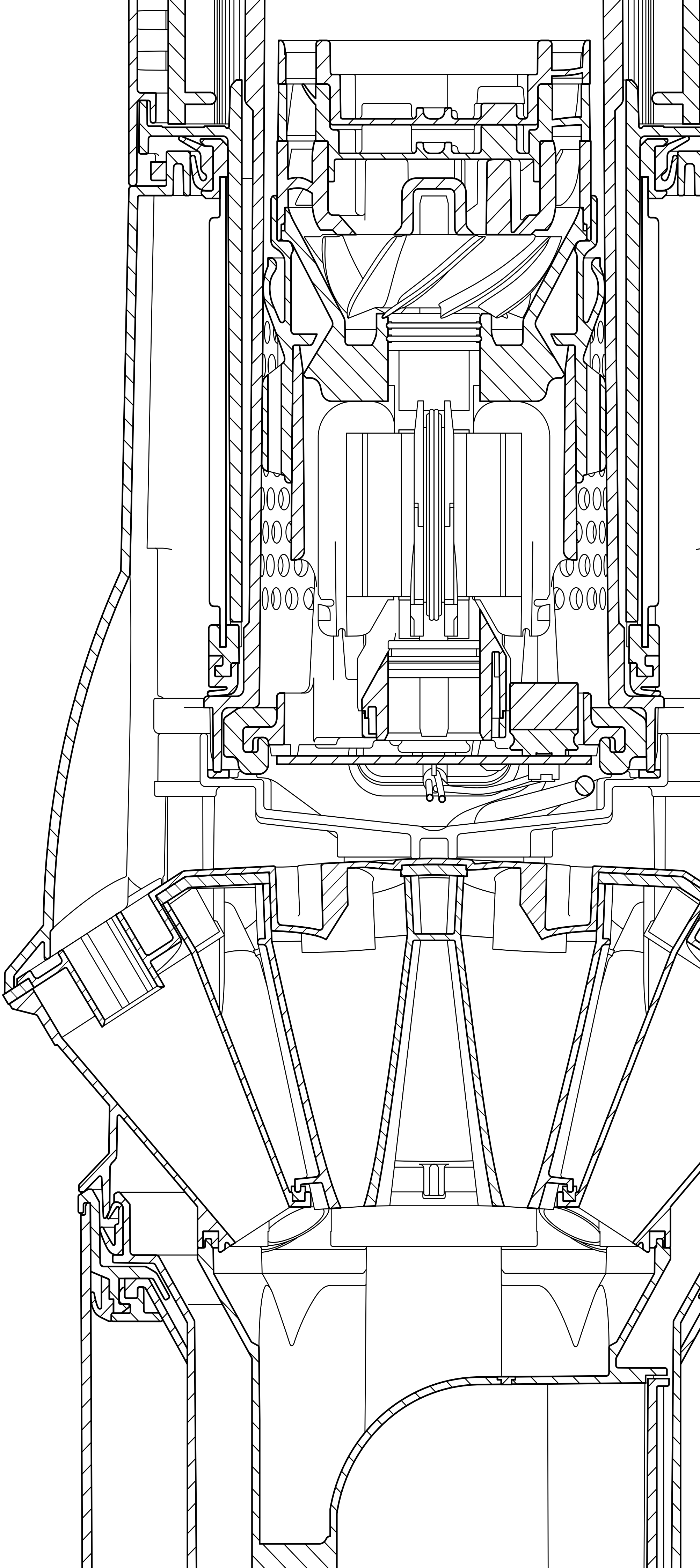
THE JAMES DYSON FOUNDATION

TEACHER'S PACK

Middle and High School

Engineering Curriculum



CONTENTS

You can find all the videos on our website:
jamesdysonfoundation.com

INTRODUCTION

Engineering is vital to our everyday lives – from essentials like running water and transportation to cell phones, the internet and household appliances. There are many different types of engineers, from acoustic to design to electrical. Their skills sets are diverse, but they all have one thing in common: they love to solve problems.

"By 2025, there will be 3.5 million STEM jobs. Despite future projections, there is a vast talent gap, which may cause as many as two million of these jobs to go unfilled." – National Association of Manufacturing and Deloitte.

This teacher's pack will help you introduce your students to engineering. Over eight lessons, students will learn about the diversity of engineering careers and the engineering behind the Dyson V12 Detect Slim Animal™ vacuum. Students will design and build their own solutions to a real world problem, following the iterative design process used by Dyson engineers. The pack is designed to be complementary to both science and engineering curricula at middle school and high school grade levels. We have included mapping to the National Education Standards.

If you follow the lesson plans provided, students will:

- Learn about engineering and the variety of roles
- Analyze the Dyson V12 Detect Slim Animal™ Vacuum
- Develop, present and evaluate their own design solutions

Please note, you can adapt the lessons to suit different schedules – for example, the starter or wrap-up activities can be omitted. It is also possible to teach each section in isolation if time is limited.

This pack contains lesson plans, worksheets, posters and videos. It also contains summary information for you. Please familiarize yourself with this information before you start teaching.

You can find the videos and posters on our website: **www.jamesdysonfoundation.com**

The James Dyson Foundation is Dyson's registered charity. Set up in 2002, it exists to inspire the next generation of engineers through educational resources, workshops and an international design competition.

"Young engineers have the passion, awareness and intelligence to solve some of the world's biggest problems. I set up the James Dyson Foundation to inspire the next generation of engineers with hands-on learning and experimentation, helping them to connect the theory they learn in the classroom with exciting and important engineering problems and solutions in the outside world."


Protector
Collector
Transcriber


SHELTON
ACADEMY


Design
Build
Test
Solution


DESIGN

SECTION 01: ENGINEERS TODAY

Students will learn about engineering and its importance to society. They will understand that there are lots of different types of engineers and consider how each contribute to the development of technology.

RUMI DANCHEVA
DESIGN ENGINEER

This is the thing about engineering – it can be very fun. It is not just serious men in white lab coats who crunch numbers. It can look like a new trampoline that can help you jump to unknown heights or a tiny little robot that brushes your teeth for you while you are doing something more fun. If you can dream it, there is probably a way you can make it and more often than not – it is those crazy ideas that really get to change the world.

I grew up in a very creative environment and I believe this is where my path to Engineering started. In my school years I was very passionate about art and design, and this was something I wanted to pursue further. I graduated from Loughborough University with a degree in Industrial Design and Technology and this was where I got to really understand how I could bridge the gap between the ideas I had and reality.

Becoming a Design Engineer at Dyson was a great opportunity for me to deepen my knowledge and to work on products that can make a positive change in people's lives.

I work in the NPI (New Product Innovation) team. This is where we get to come up with all our new and exciting ideas. My days can be very different – I get to make virtual and physical models of new products, sketch, conduct lab tests and work with our end users. I also get to collaborate with some amazing engineers, which can be very rewarding and fun.

JACK PANG
UNDERGRADUATE ENGINEER

Jack studies at the Dyson Institute of Engineering and Technology – it is unlike any other higher institution. Jack will gain a degree in engineering alongside hands on experience working on real engineering projects at Dyson.

During my time with Dyson I've worked in software, electronics, and mechanical teams and through this journey I've found the aspects of engineering I enjoy most. I've had the opportunity to work on the Dyson Link application, future Dyson Digital Motors, and new air sensing technologies all alongside many talented engineers.

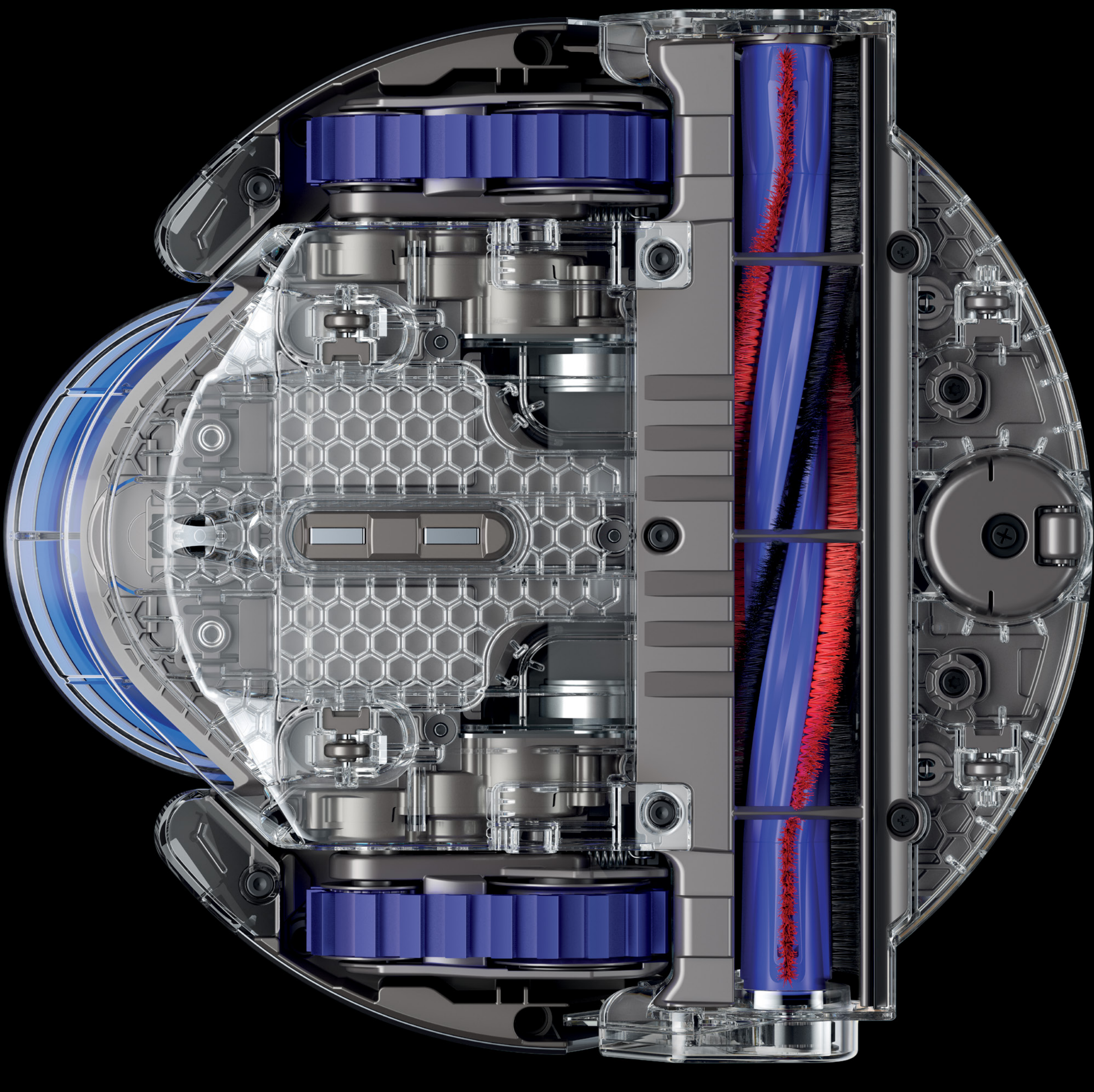
I was always unsure what career path I would go down when I was younger as my interests were so varied. Throughout my childhood, I was always building things out of whatever I could find around the house. During my later school years, I developed an interest in art and design but also STEM subjects. Mixed interests made choosing a university degree challenging and I applied to various engineering courses and even architecture.

After reading about the Dyson Institute in a newspaper article and learning there was the opportunity to work on real Dyson projects alongside the degree, I had to apply. This leads me to where I am now which is my third year at the Dyson Institute, working in the upstream robotics team.

My favorite part of engineering is seeing your designs come to life through a combination of 3D printing, software, and electronics. For me, engineering has been a way to solve problems creatively and combine my interests.

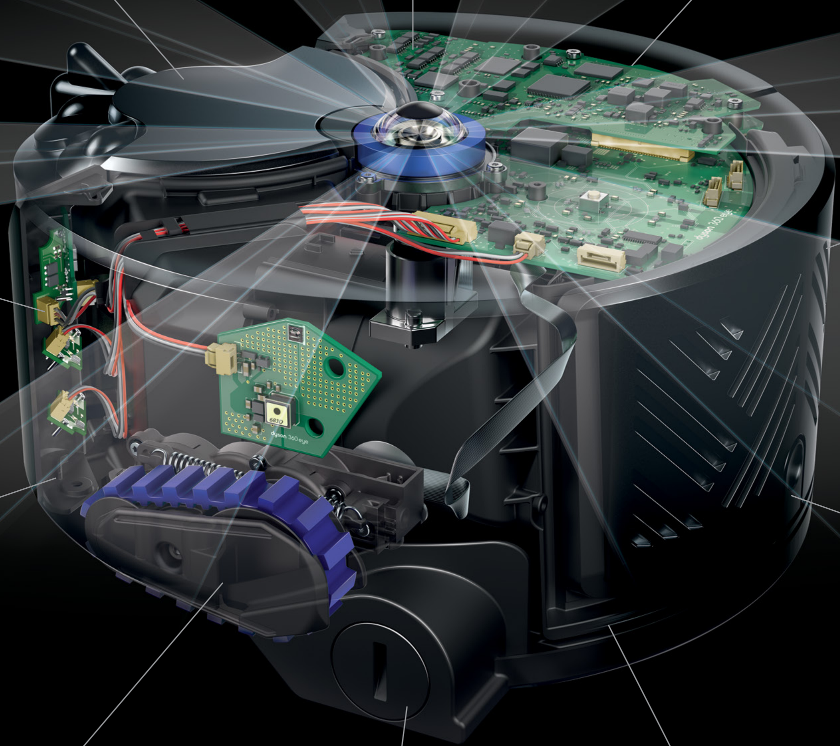
CASE STUDY: DYSON 360 EYE™ ROBOT VACUUM

The Dyson 360 Eye™ robot vacuum is a complicated piece of technology. While the initial concept for a machine is developed by design engineers working in Dyson's New Product Innovation department, it took the combined work of a variety of engineers – with different skills and specialities – to make it a commercial reality.



One robot. 400 engineers.

Many engineers are involved in the development of new technology at Dyson. Over 400 engineers worked on the Dyson 360 Eye™ robot vacuum.



Robotic and software engineers:
Develop the vision system that allows the Dyson 360 Eye™ robot to know where it's been, and where it's yet to clean. A unique algorithm enables the robot to take calculated decisions about its next course of action based on time, area covered and complexity.

Aerodynamic engineer:
Map the flow of air around the machine, spotting blockages – making sure the air flowed as efficiently as possible.

Electronic engineer:
Look at how to transfer power from the battery, to where it was needed – incorporating elements like proximity sensors to help guide the robot around the room.

Fluid dynamic engineer:
Ensure fluid performance of internal and external processes in the machine.

Acoustic engineer:
Look at the noise of the machine, employing insulation and other tricks to make it quieter.

Material engineer:
Research and advise on which materials should be used for which aspect of the machine. For example, the bin needs to be clear, but also hard wearing – so it could survive bumps and bangs.

Manufacturing engineer:
Look at how the machine would be made – defining the best way to manufacture every component, making sure they were designed to fit together as easily as possible on assembly.

Mechanical engineer:
Work out how to transfer power to the brush bar and tank tracks: making sure that the correct gear ratio was chosen to magnify the torque correctly.

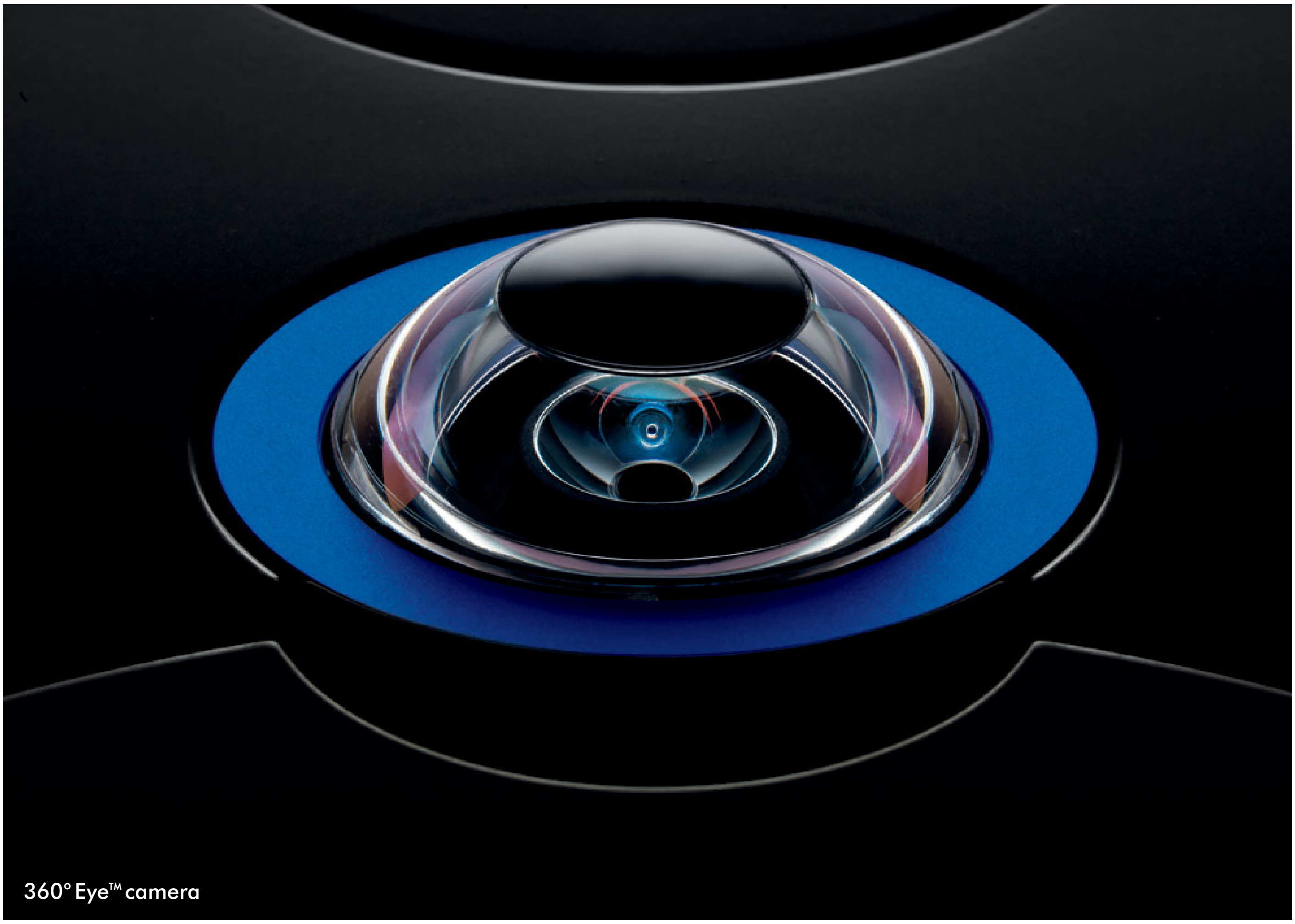
Motor engineer:
Design the motor that draws in the air and dust – while analysis engineers validate the motor design and made sure it would survive the forces deployed in operation.

Design engineer:
Design what the machine will look like accounting for design factors such as the size of the motor, wheels and battery in order to optimize performance.

360° vision technology

Infrared sensors work alongside a lens on top of the machine which houses a 360° panoramic camera. The camera takes 30 frames every second, providing up-to-date information on its surroundings.

Before the Dyson 360 Eye™ robot begins cleaning, its vision system locates potential challenges and pinpoints landmarks. It translates into coordinates, creating a virtual map. Having created this map, the robot vacuums the room systematically from edge to edge.



360° Eye™ camera

LESSON 01
ENGINEERS TODAY

Duration: 1 hour 30 minutes

Learning objectives

1. Understand that there are lots of different types of engineers.
2. Develop an in-depth understanding about different types of engineering careers, and how they each contribute to the development of technology.
3. Understand the similarities between different types of engineers, as well as the differences.

Activity outcomes

Class discussion about what engineers do

Completed group research into an engineering career

Completed group presentations about a type of engineer

Things you will need:

Pens and pencils

Paper

Whiteboard

Video: Meet Rumi – Senior Dyson Design Engineer

Video: Meet Noor – Senior Dyson Electronics Engineer

Video: Meet Noor – Senior Dyson Robotics Engineer

Video: Meet Stuart – Dyson Software Engineer

Video: Meet Jack – Dyson Institute Undergraduate

Poster 01: Collaboration

Website: jamesdysonfoundation.com

Computers for research

Starter: 15 minutes
Introducing engineering

Learning objective	Activity
1	Explain that in this lesson, the students are going to learn about different types of engineers. Show the **Poster 01: Collaboration** As a class, discuss what the students already know about engineering and what engineers do. Write down key points on the board.

Main: 45 minutes
Understanding different types of engineers

Learning objective	Activity
2	As a class, watch **Video: Meet Rumi: Senior Design Engineer.** Talk about Rumi and her job. Is there anything that surprised the students? Refer to Rumi's profile on pages 8 and 9 for additional information.

1, 2	Split the class into groups. Assign each group a different video. Explain that the engineers in the videos will talk about their job roles within Dyson, including some of the projects they have worked on, giving the students a breadth on the different types of engineering roles. **Note:** If your class is large, break the students into smaller groups and duplicate the videos you are asking them to watch.
2	Give the students 30 minutes to learn more about the engineering career that corresponds to their video. Explain that they will be asked to give a two minute presentation of their findings to the class. They may want to consider: – What this engineer does – Why this type of engineering is important – Key skills this engineer needs – Famous examples of this type of engineer – How you become this type of engineer

Wrap up: 30 minutes
Presentation and evaluation

Learning objective	Activity
1, 2	Ask the student groups to present their research to the class. Encourage the class to ask questions.
3	Once all of the presentations have been given, discuss as a class whether the different types of engineers have anything in common. If required, prompt them to think about: – Interest as children – Love of problem solving – Technical skills

SECTION 02: PRODUCT ANALYSIS

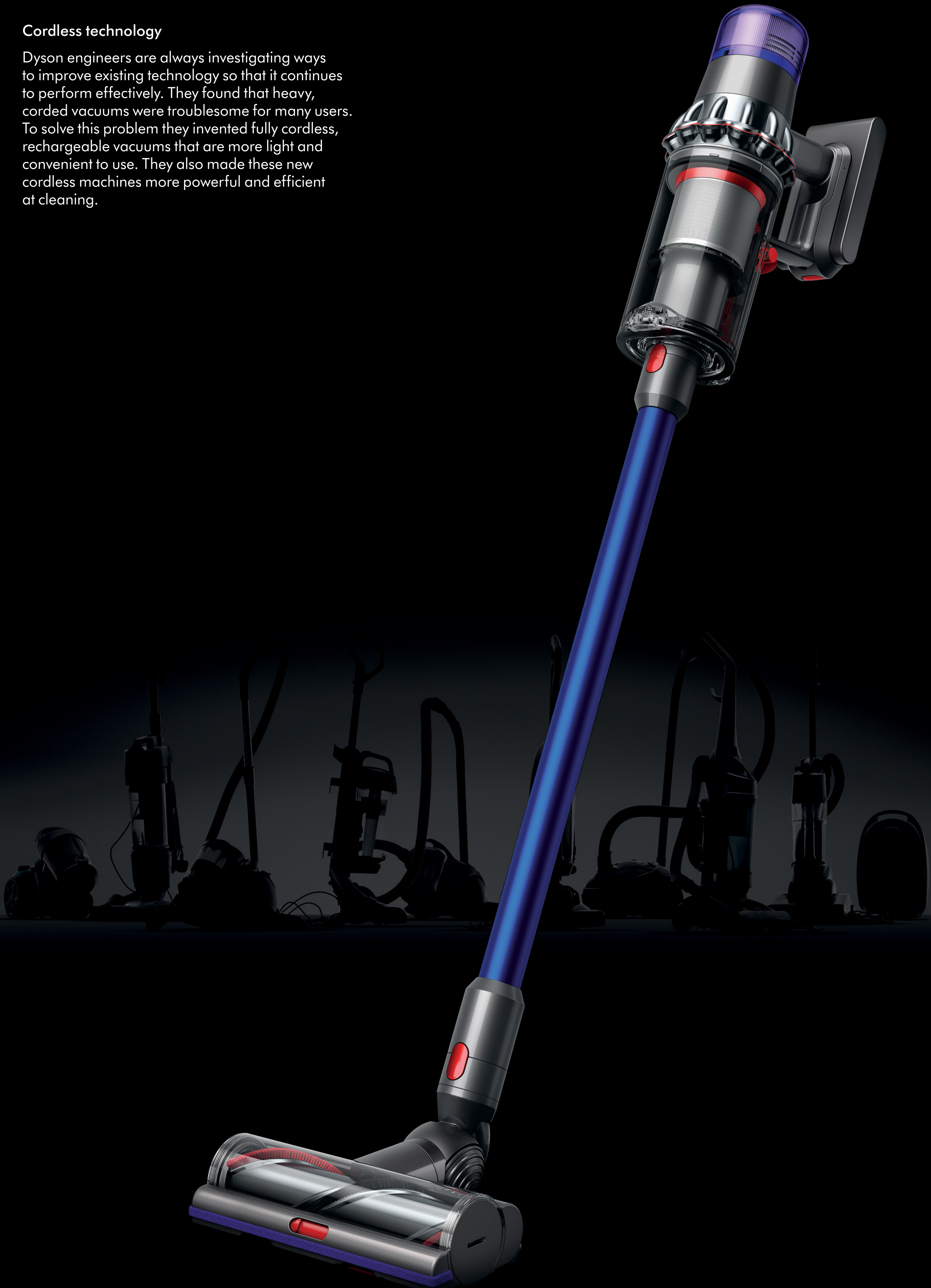
Students will learn about the technology developed by Dyson engineers, focusing on the evolution of the cordless vacuum. They will analyze the Dyson V12 Detect Slim Animal™.

From bagless to cordless vacuums

The DC01 upright vacuum was the world's first bagless vacuum. Instead of a dusty, clogging bag, it has Dyson Dual Cyclone™ technology, so it can pick up dirt efficiently and without losing suction power.

Cordless technology

Dyson engineers are always investigating ways to improve existing technology so that it continues to perform effectively. They found that heavy, corded vacuums were troublesome for many users. To solve this problem they invented fully cordless, rechargeable vacuums that are more light and convenient to use. They also made these new cordless machines more powerful and efficient at cleaning.

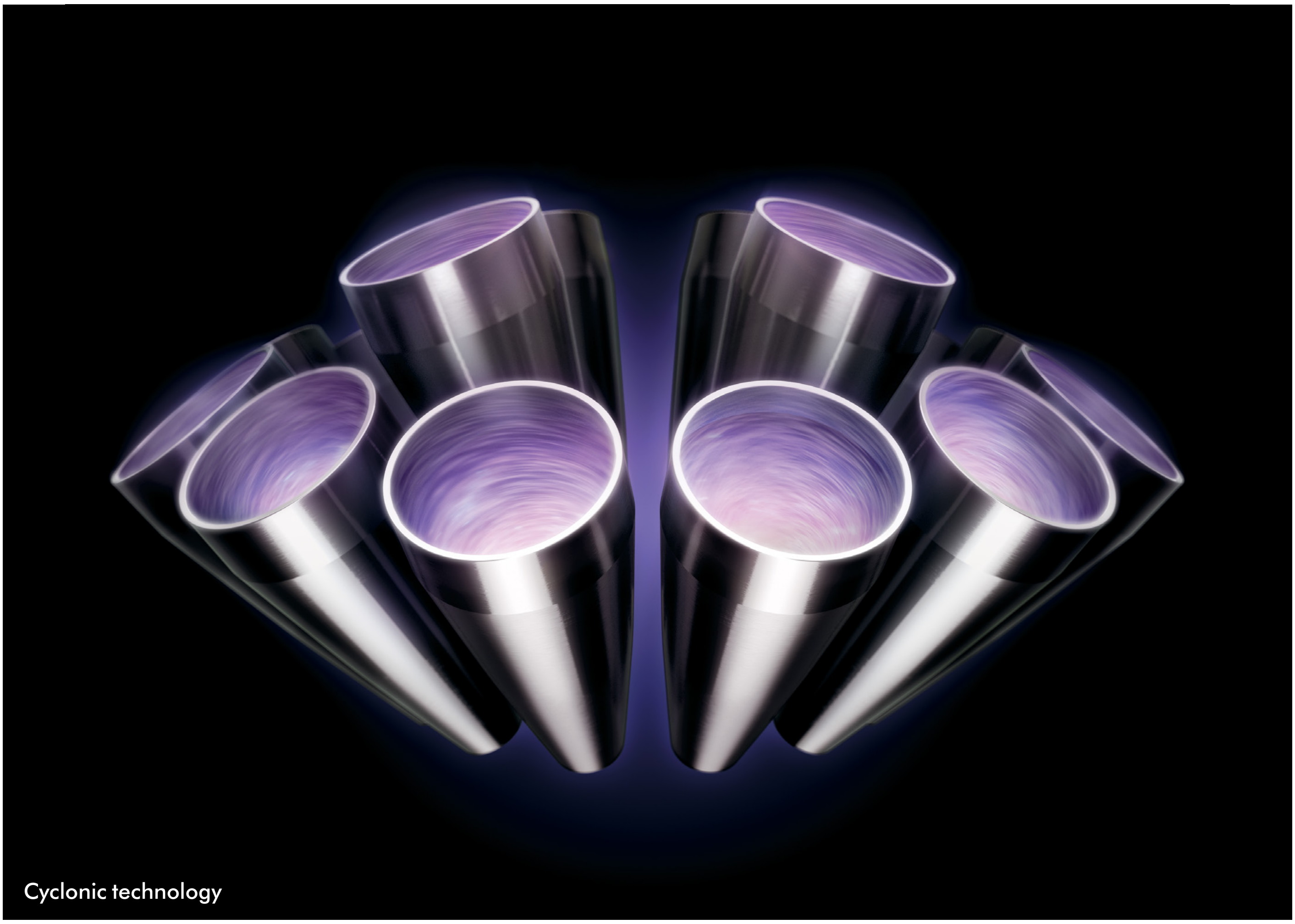


CASE STUDY: DYSON V12 DETECT SLIM ANIMAL™

There have been many iterations of Dyson cordless technology. The V12 Detect Slim Animal™ is one of the most intelligent and powerful cordless vacuums invented by Dyson engineers.

Cyclonic technology

The Dyson V12 Detect Slim Animal™ is powered through 12 cyclones, which help to remove the microscopic dust from the airflow. The diameter of each cyclone is carefully balanced with the space between them, helping to maintain the velocity required to remove the microscopic dust.



Cyclonic technology

LCD screen

The V12 Detect Slim Animal™ has a LCD screen that displays run time and performance updates, providing users with more information about their clean. It also shows what the machine has picked up.

LCD screen

Piezo sensor technology

Microscopic dust cannot be seen by the human eye, but the Dyson V12 Detect Slim Animal™ can hear it. An inbuilt piezo sensor 'listens' to the vibrations of the particles strike the surface of the inlet duct, converting them into an electrical signal.

The sensor monitors particles 15,000 times per second, sucking up the dust and debris, automatically increasing the suction power if the particles are larger in size. The vacuum then displays the results of the clean on the LCD screen at the top of the vacuum, giving scientific proof of a deep clean.

Tangle-free Turbine tool

It's not just the main machine that Dyson engineers apply their problem-solving minds to. They consider everything that relates to it, including tools and accessories.

The original Dyson machine head for all Dyson vacuums had stiff nylon brushes to pick up ground-in dirt from carpets. When testing on hard floors, Dyson engineers realized that some fine dust was difficult to suck up.

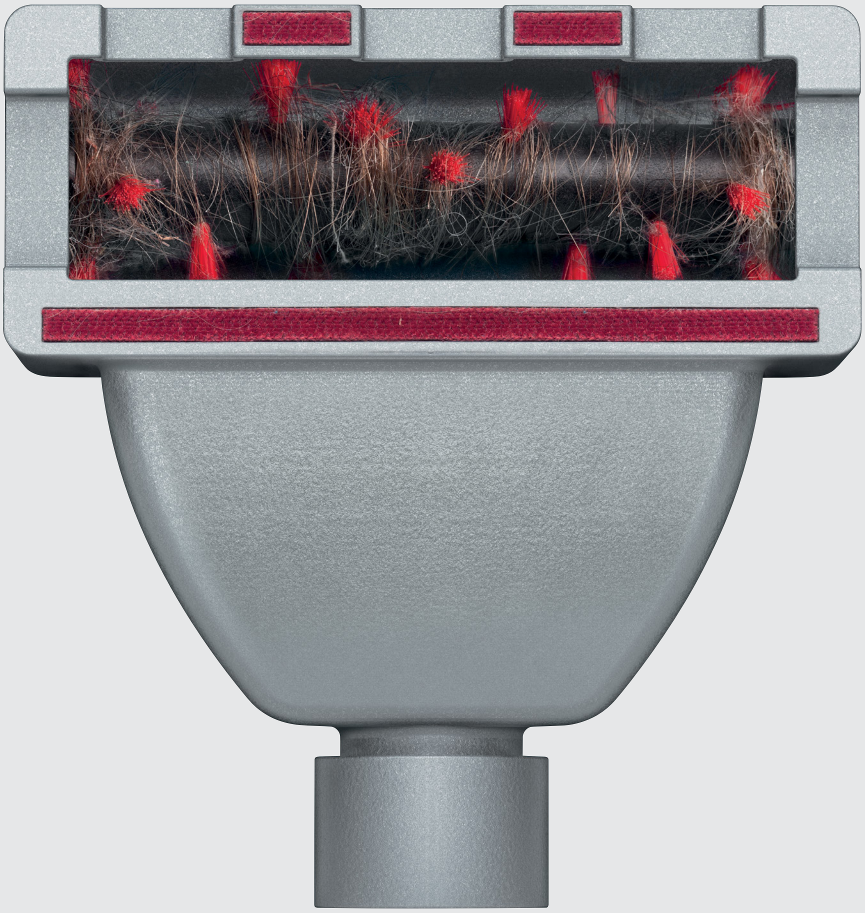
They discovered the high speed spinning of the brush bar generated static, meaning that fine dust stuck to the floor.

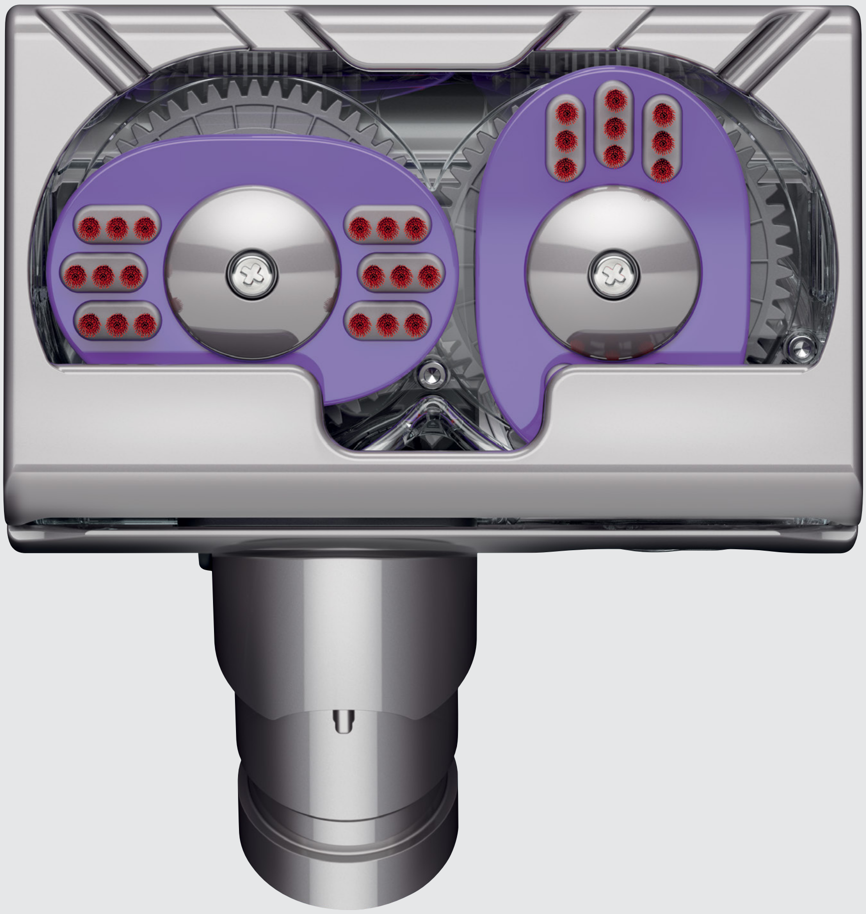
Engineers investigated different brush materials to add to the floor tool, finally selecting carbon fiber. Carbon fiber has anti-static properties that reduce the build-up of static charges so dust pick up is increased.

While the design of the Carbon Fiber Turbine Head was certainly an improvement, it wasn't quite perfect for all cleaning scenarios. The spinning action of a brush bar can cause hair or other long fibers to wrap around the bar, slowing it down or stopping it altogether. This can leave you having to tug or cut the hair off the brush bar – a messy task.

Instead of ignoring this problem, Dyson engineers set out to design a solution. The design brief: create a cleaner head that doesn't tangle hair or fibers.

It took a team of 49 Dyson engineers to create the Tangle-free Turbine tool. Design engineers thought about the fact that rubbing hair in a circular motion creates a ball – easy to suck up and no tangles. With this theory in mind, they tested dozens of ways to simulate the circular motion. The result was two counter-rotating discs, each with sturdy bristles, enclosed in polycarbonate casing. The spinning discs ball the hair, then it is sucked straight into the vacuum cleaner bin.





Top – Tangled: Hair wraps around the brush bar of conventional turbine tools.

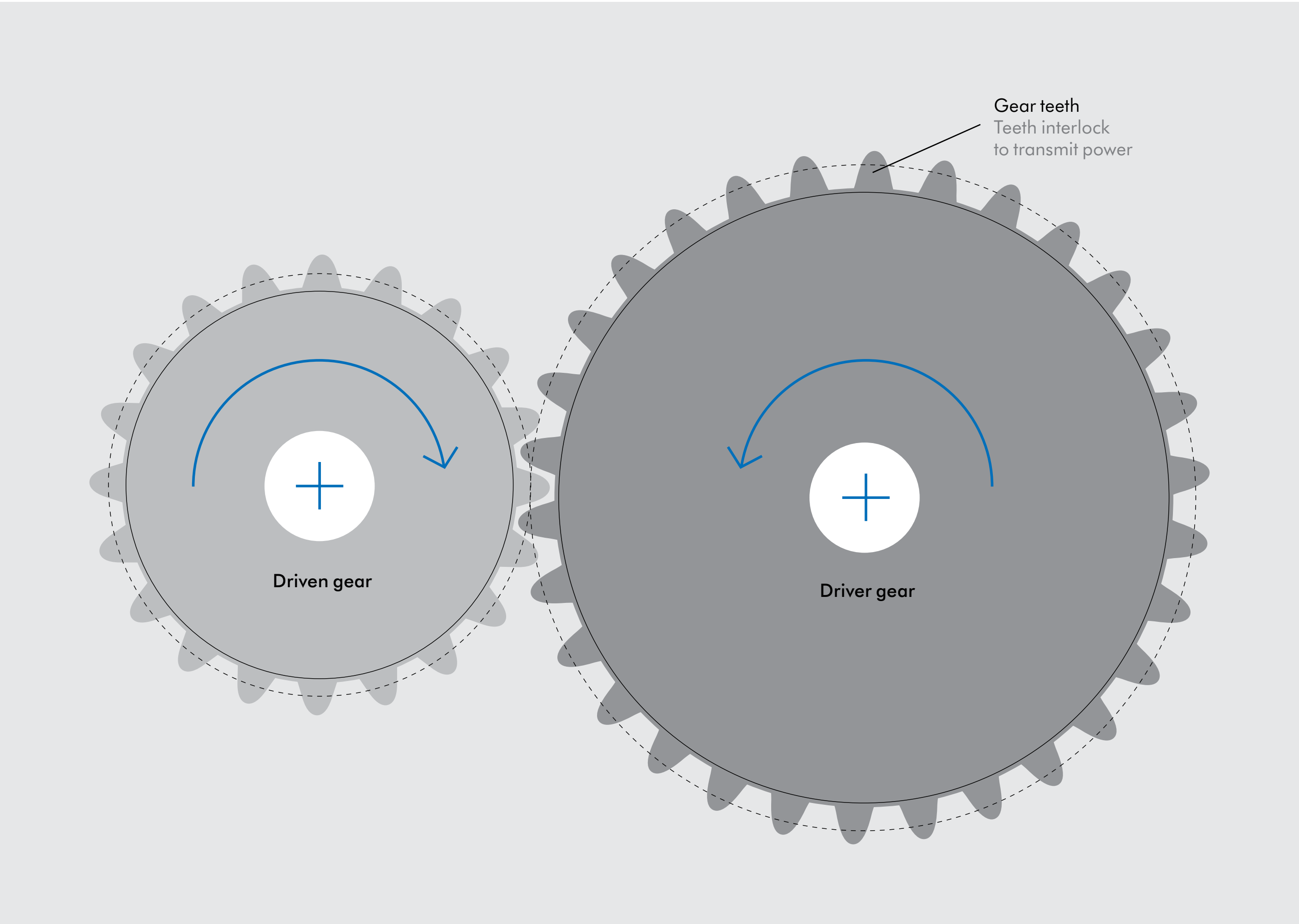
Bottom – Tangle-free: Tangle-free Turbine tool uses counter-rotating heads.

Gears

Gears are toothed machine parts that work together to create movement. The gear's teeth interlock with other toothed parts to transmit power, change speed or change direction.

When the first gear – called the driver gear – is rotated, motion is transmitted to the second gear – called the driven gear. Where there are two gears of different sizes, the smaller gear will rotate faster than the larger gear. When two or more gears connect together they are called a gear drive. The difference between these two speeds is called the gear ratio. The gear ratio can be calculated using the following formula:

Gear ratio = number of teeth on driven gear ÷ number of teeth on the driver gear.

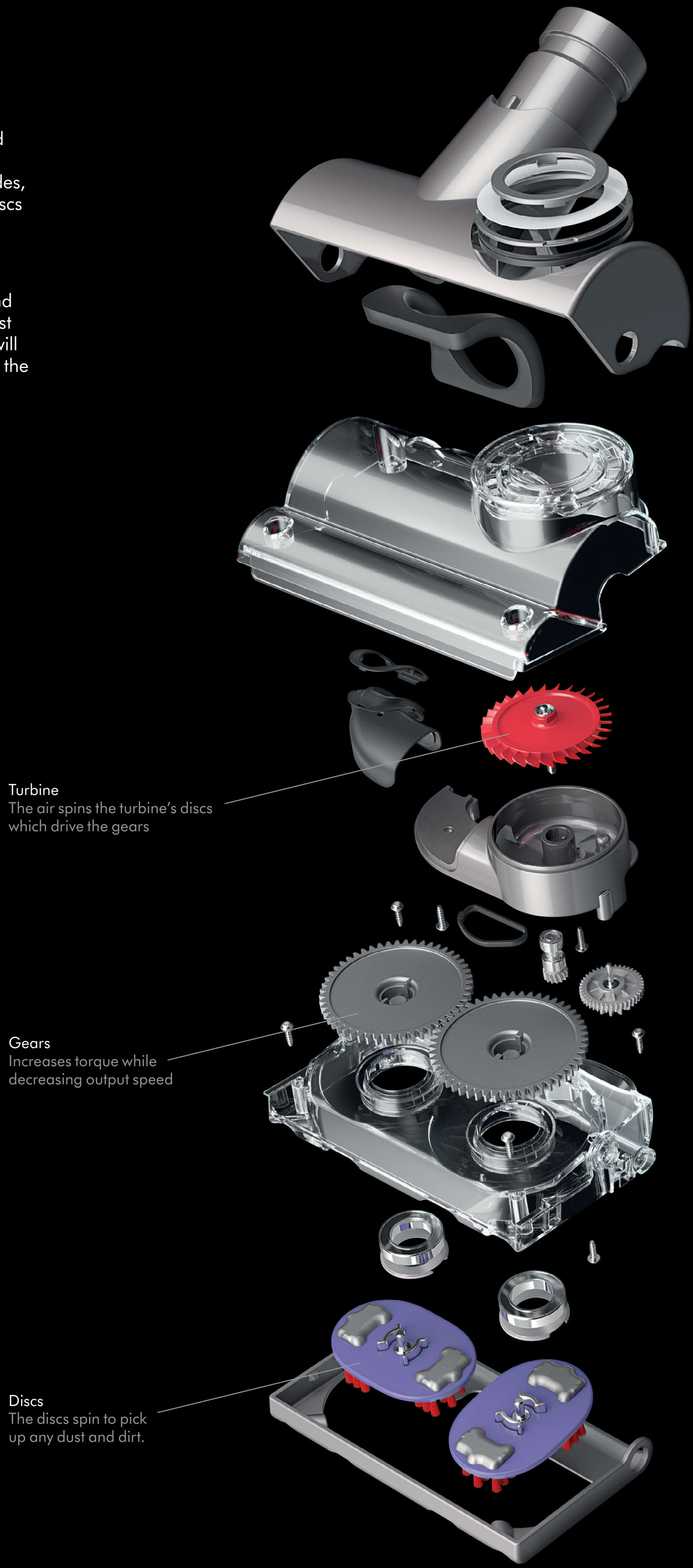


Inside the Tangle-free Turbine tool

In the Tangle-free Turbine tool, the gear drive is a step down drive – it increases torque while, at the same time, decreasing the output speed.

The Tangle-free Turbine tool is driven by the red turbine on top of the tool, which extracts power from the airflow. The air spins the turbine's blades, which drive the gears – which in turn spin the discs inside the Tangle-free Turbine Tool.

The balance of the airflow is crucial – it's split between the turbine and the cleaner head's own suction. Too much airflow in the turbine and the discs will spin quickly but not suck up the dust and the dirt. But too little airflow and the discs will not spin. Turbines work well at high speeds, but the turbine doesn't deliver nearly enough torque to spin the discs on its own. This is why gears are used – to increase the torque.



Anti-tangle Screw head

Dyson engineers took what they learned from developing the Tangle-free Turbine tool to produce a new iteration of the tool which would perform well on carpets, mattresses and soft furnishings, while never tangling hair around the machine head.

It does exactly the same job as the Tangle-free Turbine tool, but faster and more effectively. The brush head is conical, with bristles spiralled around it, so that human and pet hair cannot wrap around it and get tangled. Instead, the hair will migrate towards the top of the head and is sucked into the vacuum's bin.

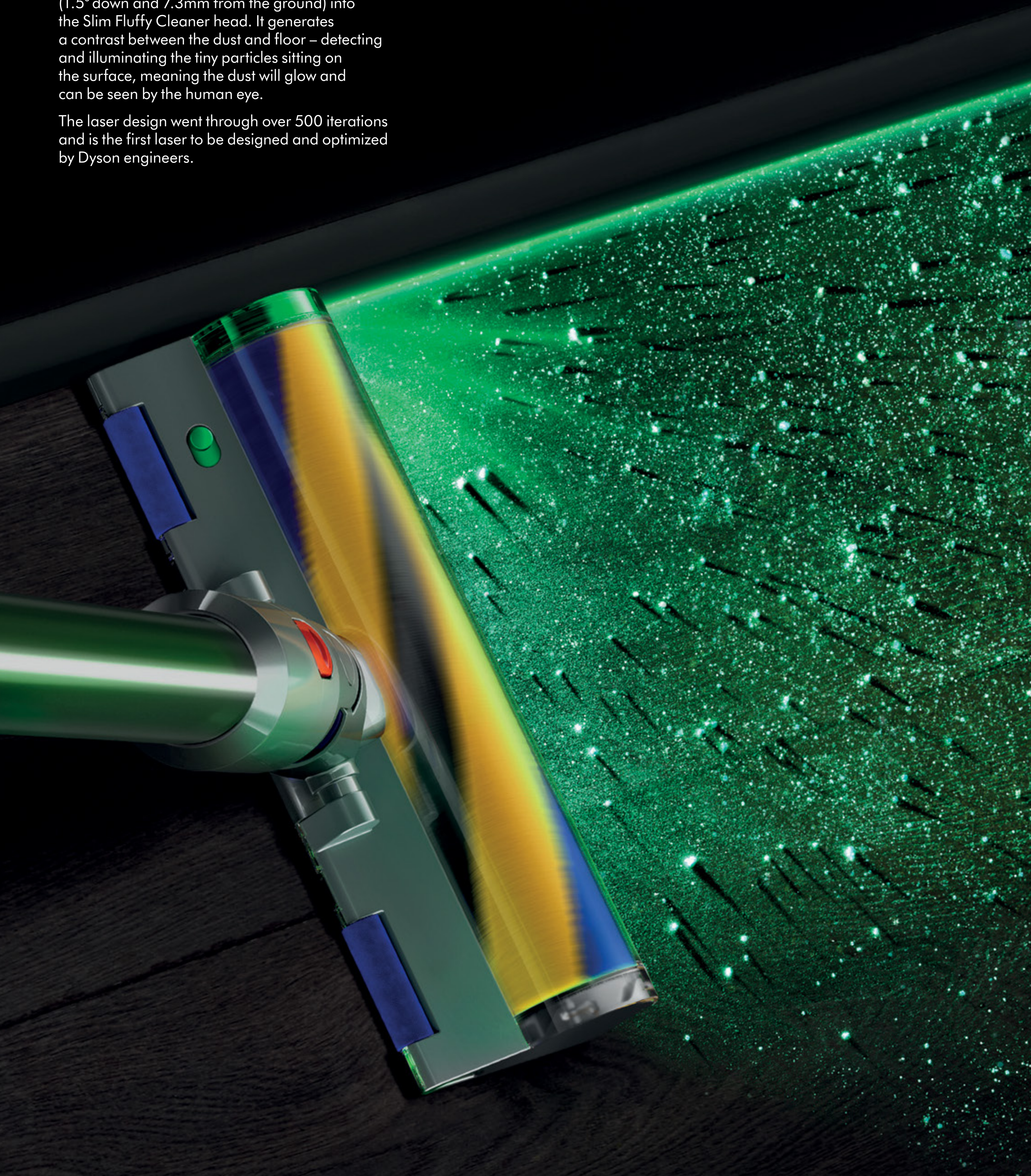
This technology was inspired by Archimedean screw which was used for transferring water from a low-lying body of water into irrigation ditches in Ancient Egypt. The Anti-tangle Screw head is also powered by a motor which provides greater power and air flow through the head, making it more efficient at picking up dirt.

Laser technology

When dust isn't visible to the human eye, we assume that our homes are clean. Building on the piezo technology and machine heads mentioned earlier, Dyson engineers developed a new machine head that uses laser technology to make invisible dust and dirt, visible.

A green laser was integrated at a precise angle (1.5° down and 7.3mm from the ground) into the Slim Fluffy Cleaner head. It generates a contrast between the dust and floor – detecting and illuminating the tiny particles sitting on the surface, meaning the dust will glow and can be seen by the human eye.

The laser design went through over 500 iterations and is the first laser to be designed and optimized by Dyson engineers.



LESSON 02
DYSON V12 DETECT SLIM ANIMAL™

Duration: 1 hour 30 minutes

Learning objectives

1. Understand how the Dyson V12 Detect Slim Animal™ works.

2. Understand the design decisions that the engineers made when developing the vacuum.

Activity outcomes

Watch **Video: How the Dyson V12 Detect Slim Animal™ works**

Class discussion about how the Dyson V12 Detect Slim Animal™ works

Things you will need:

Pens and pencils

Paper

Whiteboard

Video: How the Dyson V12 Detect Slim Animal™ works

Poster 02: Revolution

Website: jamesdysonfoundation.com

Starter: 30 minutes
Introducing the Dyson V12 Detect Slim Animal™

Learning objective	Activity
1	Display an image of the Dyson V12 Detect Slim Animal™ vacuum cleaner at the front of the class. Don't reveal its purpose or name. Ask the students to consider the following questions: – Who has it been designed for? – What need has it been designed for? – What design choices have been made? (E.g. materials, style, colour, shape) – How is this machine unique?
1, 2	As a class, watch **Video: How the Dyson V12 Detect Slim Animal™ works.** Use this to demonstrate the technology in the machine. Stop and start the video as required. The following time codes show where each chapter within the video starts and ends: – Video introduction: **0:00** – Introduction to the cordless vacuum: **0:11** – The battery: **01:01** – The filter: **02:07** – The main body: **03:16** – The motor head: **06:10**

Main: 45 minutes
Analyzing the V12 Detect Slim Animal™

Learning objective	Activity
1	Split the class into groups and assign each group one of the following questions: – What are the most important functions of a vacuum cleaner? Does the Dyson V12 Detect Slim Animal™ do these things? What could it do, but doesn't? – Why is it important to think about cost when designing a product? What aspects of the design would add extra cost to the V12 Detect Slim Animal™ and why did the engineers choose to include them? – Who would buy this product? What are their needs? Think about how needs change depending on age, height, lifestyle etc. What works well about this design for a customer, and what doesn't? – What about this product and its design might have a negative impact on the environment or the place where it's used? – What safety aspects were considered to prevent potential harm to the user? What aspects were considered to prevent damage to the environment in which the vacuum is used? – How would you describe the design of the V12 Detect Slim Animal™? What is good about this design and what is bad? What do you find interesting or different about how the V12 Detect Slim Animal™ looks, feels or sounds? – Why is the vacuum this size? How does the size work with different users, in different environments? Think about the size of individual parts, too – like the brush bar and power button. – Think about the materials used to make the Dyson V12 Detect Slim Animal™. What are the benefits of the materials they used? What other materials could have been used? **Note**: Each group should jot down their responses on a piece of paper to share with the class.

Wrap up: 15 minutes
Presenting the findings

Learning objective	Activity
1, 2	Ask one member of each group to share their observations with the rest of the class. Write their key findings on the board.

LESSON 03
IMPROVING DYSON TECHNOLOGY

Duration: 1 hour 45 minutes

Learning objectives

1. Understand how engineers improve existing technology.

2. Understand how Dyson technology works.

Activity outcomes

Class discussion of the problems with the Tangle-free Turbine tool and how the Anti-tangle Screw head resolves them.

Things you will need:

Pens and pencils

Paper

Video: Anti-tangle Screw head disassembly

Video: Tangle-free Turbine tool disassembly

Video: Anti-tangle Screw Head reassembly

Support sheet 01: Tangle-free Turbine tool disassembly

Support sheet 02: Anti-tangle Screw head disassembly

Support sheet 03: Reassembly instructions

Website: jamesdysonfoundation.com

Starter: 15 minutes
Introducing the Tangle-free Turbine tool

Learning objective	Activity
1	Explain to the students that in this lesson, they will be learning about two Dyson vacuum tools. They both solve problems and are an example of iterative design as one is an improvement upon the other. A good engineer will keep developing a solution until it works perfectly.
1, 4	Show the class an image of the Tangle-free Turbine tool. Ask them what they think it's for, how they think it works and whether they can notice any interesting design features.

Main: 45 minutes
Tangle-free Turbine tool disassembly

Learning objective	Activity
2	As a class, watch **Video: Tangle-free Turbine tool disassembly**. Ask the students to write down anything else they notice about the Tangle-free Turbine Tool that fits into the following categories: – Features of the tool that work well – Features of the tool that could be improved
2, 4	You will see three red flags with numbers pop up while watching **Video: Tangle-free Turbine tool disassembly**. These flags highlight an interesting fact or scientific principle that you can discuss with your students. To learn about the facts associated with these flags, refer to **Support sheet 01: Tangle-free Turbine tool disassembly.**
1	Discuss as a class whether there are any problems with the design of the Tangle-free Turbine tool. Write down key points on the board. Prompt the students to think about the issues with a spinning bar if necessary.

Main: 45 minutes
Anti-tangle Screw head disassembly

Learning objective	Activity
1, 4	Reveal an image of the Anti-tangle Screw head. Ask the students how they think this tool might solve some of the problems they identified with the Tangle-free Turbine tool.
3	As a class, watch **Video: Anti-tangle Screw head disassembly**. Ask the students to note down anything else they notice about the Anti-tangle Screw Head that fits into the following categories: – Features of the tool that work well – Features of the tool that could be improved
3, 4	To learn about the facts associated with the Anti-tangle screw head, refer to **Support sheet 03: Anti-tangle Screw Head disassembly**.
3	Then show the class **Video: Anti-tangle Screw Head reassembly**. Discuss as a class if this video highlights the same design changes and improvements that the students noticed individually between the Tangle-free Turbine Tool and the Anti-tangle Screw Head. Ask the students to re-consider why iterative design is important when designing products. Highlight that this always provides an opportunity to improve on older designs, solving problems they may not have considered in their first design.

SECTION 03: DESIGN PROCESS

Students will understand the design process Dyson engineers follow when developing new technology. They will follow the design process themselves in order to design and prototype their own solution to a real world problem.

Starting with a problem

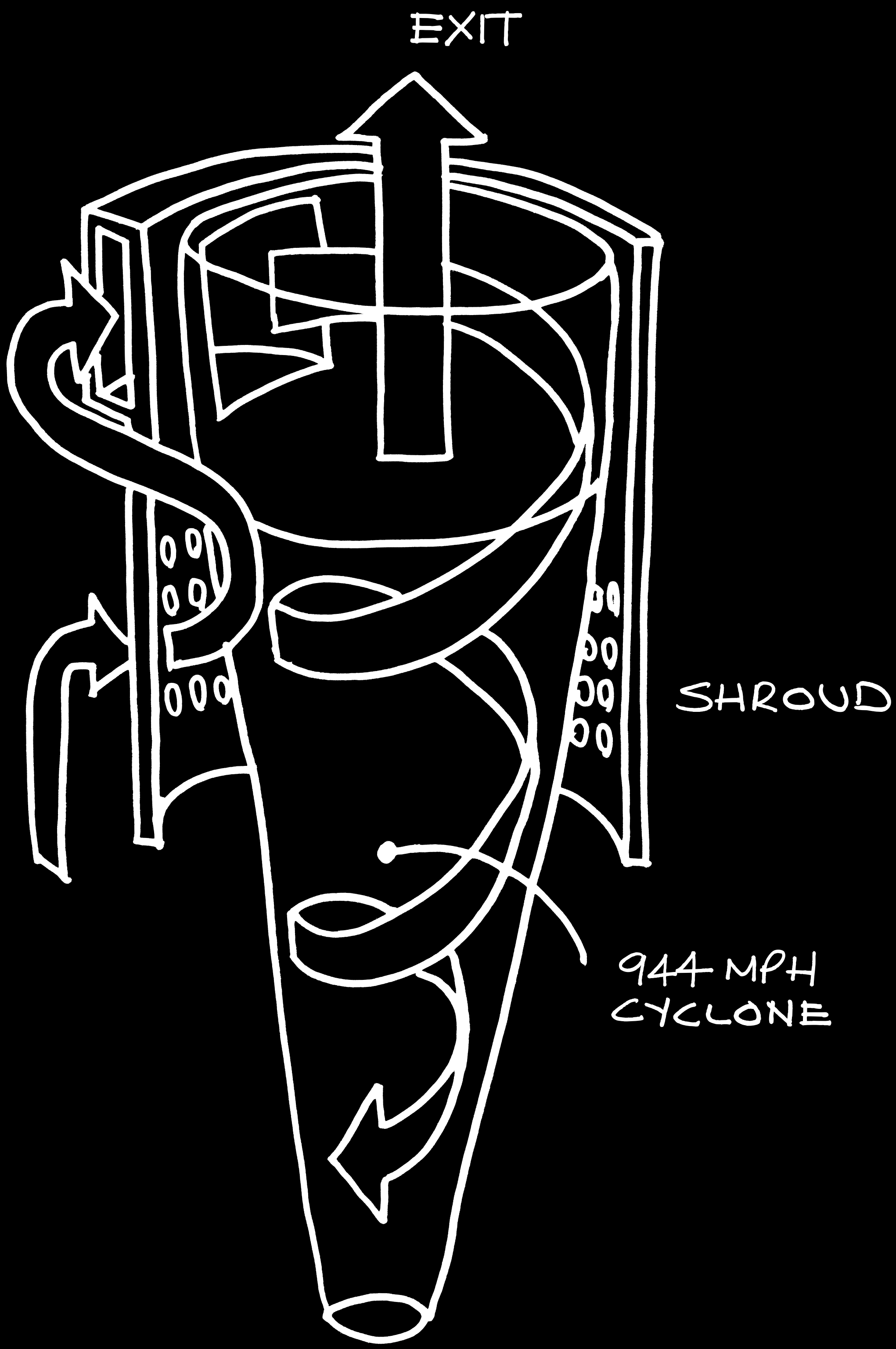
Dyson projects always start with a problem: unhygienic hand-dryers, vacuum cleaners that lose suction or robotic cleaners that fail to navigate intelligently. A list of requirements is compiled, forming the product specification. This is the measuring stick for assessing a product's success. The following key criteria and constraints can be remembered with the acronym ACCESS FM.

1. Aesthetics – what will the product look, feel or sound like?
2. Cost – what is the estimated manufacturing cost of the product, and what will its retail price be?
3. Customer – who is the product designed for?
4. Environment – what is the impact on the environment?
5. Safety – how will the user be kept safe from harm?
6. Size – are the proportions of the product appropriate?
7. Function – how well does the product work – and is it easy to use?
8. Materials – what is the product made from, and what does this mean for manufacturing?


Dyson engineers

The problem

In 1979, James Dyson got fed up with his bagged vacuum. Realizing that the bag was killing the suction, he was determined to find a better way.



What is the design process?

Engineers use their knowledge of science, technology, engineering, math and creative thinking to solve problems. Engineers refer to the stages of the design process as: design, build, test. This process is iterative and non-linear.

Design – at this stage engineers identify the problem they are trying to solve and think about possible solutions. They sketch a design of what a solution might look like.

Build – using these sketches, engineers build a prototype using simple modelling material, such as cardboard, or more advanced ones, such as 3D printed parts. A prototype is the first version of a product from which other versions are developed.

Test – testing makes or breaks a product. Engineers test prototypes, often to destruction. This allows them to ensure that the machine fulfils the design specifications and will survive usage in a home.

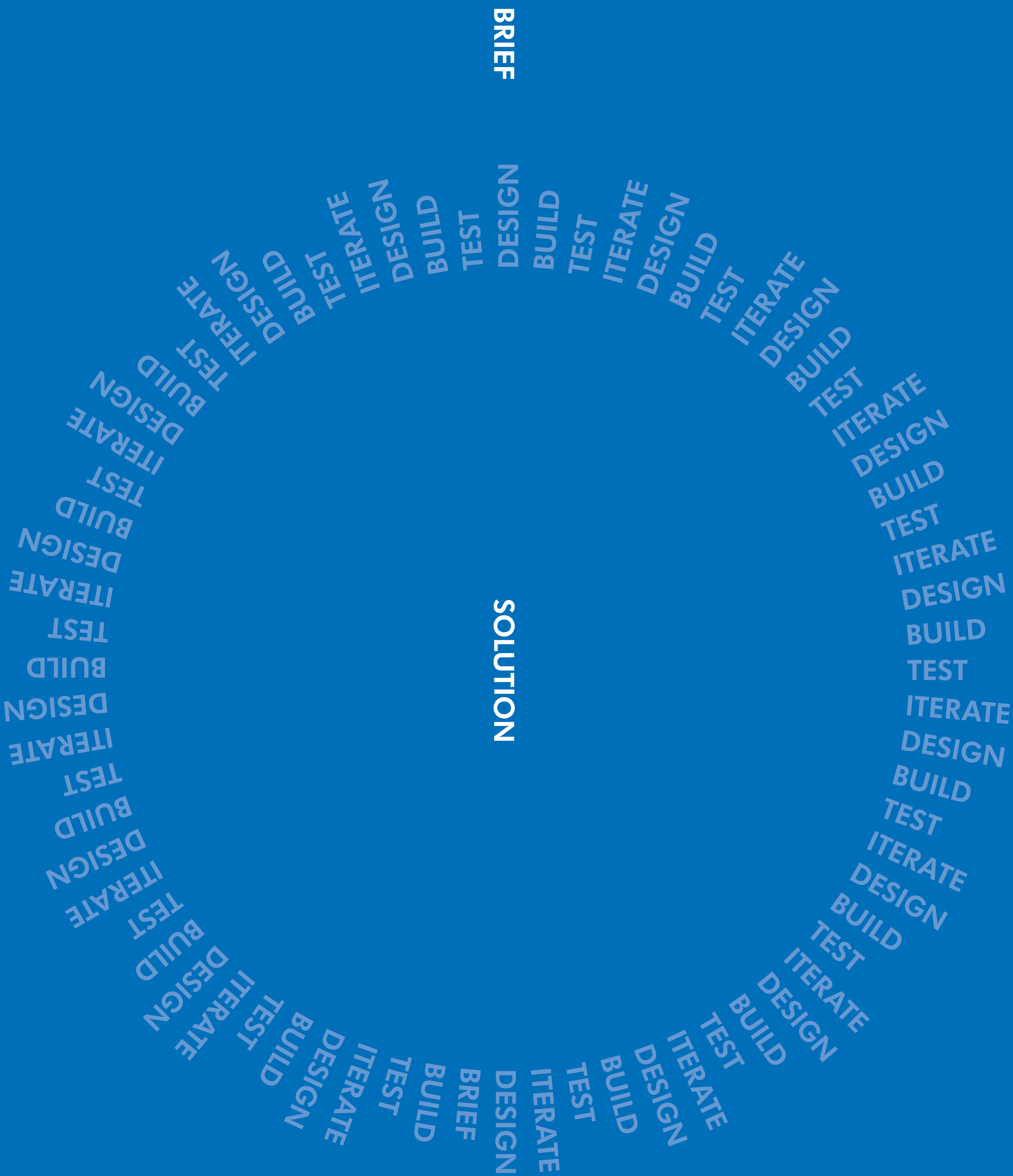
This is a circular process as testing identifies weakness and faults in the prototype that can be addressed when engineers build the next prototype. This cycle continues until it results in a finished product that successfully solves the problem.

Dyson engineers embrace failure in the design process as it leads to better design decisions. James Dyson built more than 5,000 prototypes before his Dual Cyclone concept was a success. That's over 5000 failures to learn from.

Dyson engineers

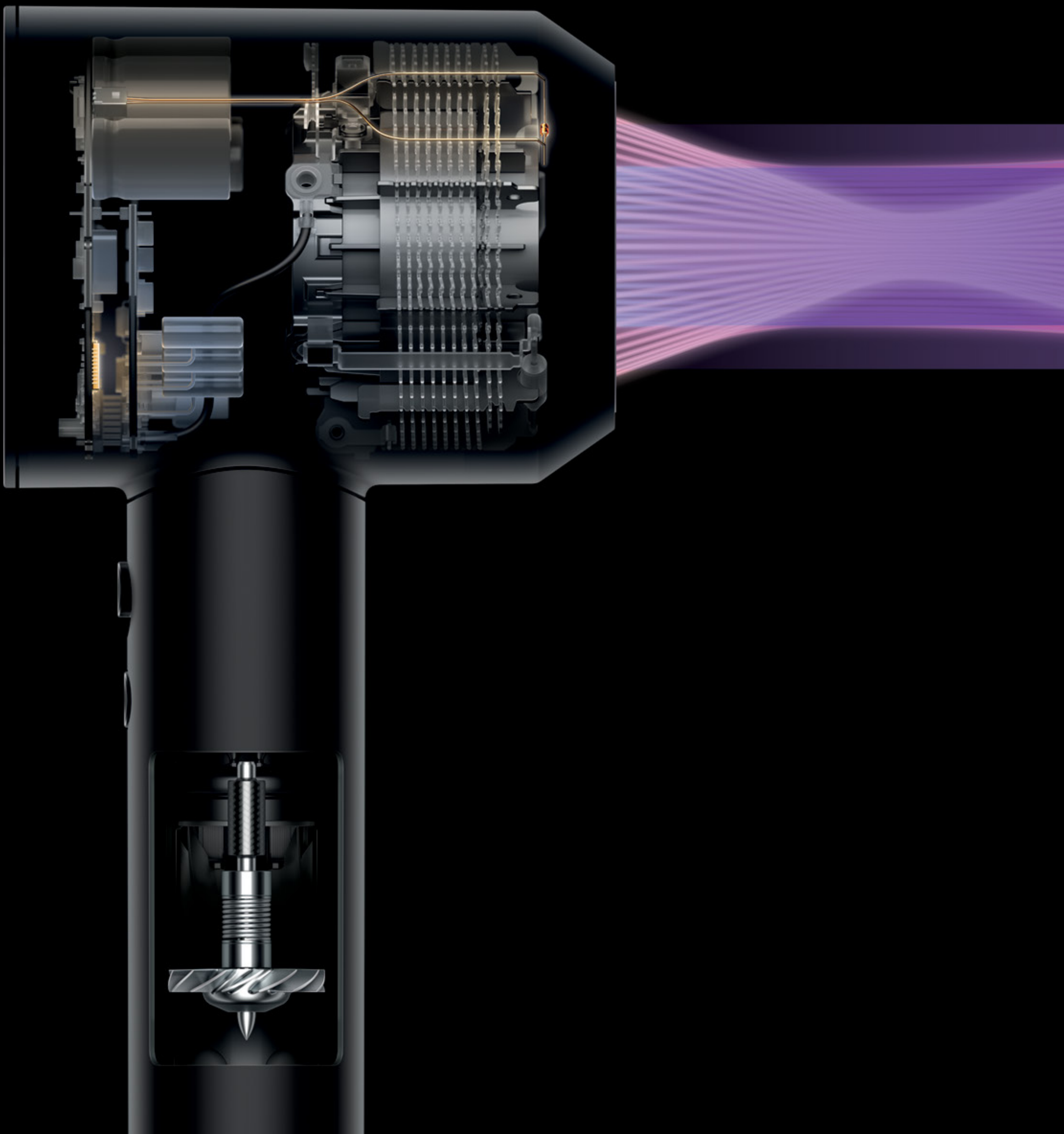
The design process

Engineers are problem solvers. They research and develop ideas for new products and think about how to improve existing technologies. This all part of an iterative journey.



CASE STUDY: DYSON SUPERSONIC™ HAIR DRYER

The Dyson Supersonic™ hair dryer challenges conventional hair dryer design. It is an example of the pioneering approach of Dyson engineers who use the iterative design process to develop better technology and challenge the norm.



The iterative process

Every aspect of a Dyson machine is developed through an iterative engineering process. A high potential idea or hypothesis triggers cycles of prototyping, testing, evaluating, refining, testing, evaluating, refining, testing.

It is an exhaustive process that positively seeks failure in order to learn from what can be hundreds of prototypes and cycles – each one moving closer and closer to the desired result.

And if it doesn't, it's back to the drawing board. The key to achieving clear understanding is to test just one modification to one element at a time. This way, cause and effect can be immediately attributed and the next prototyping cycle can begin – as quickly as possible.

Initial concept rig

First working rig

A – rig
Initial integrated rig with V9 motor and custom heating element

B – rig
1st fully integrated rig with V9 motor, heater and electronics

C – rig
Further iterative developments

It took over the five years to develop the Dyson Supersonic™ hair dryer. Dyson engineers built 600 prototypes – and 599 of them were failures. But each one taught them something – how could it be made better.

Thermal rig
Concept air amplifier to detail the thermal characteristics

D – rig
Multiple rigs for user trials and testing

E – rig
Fully detailed rigs proving specification

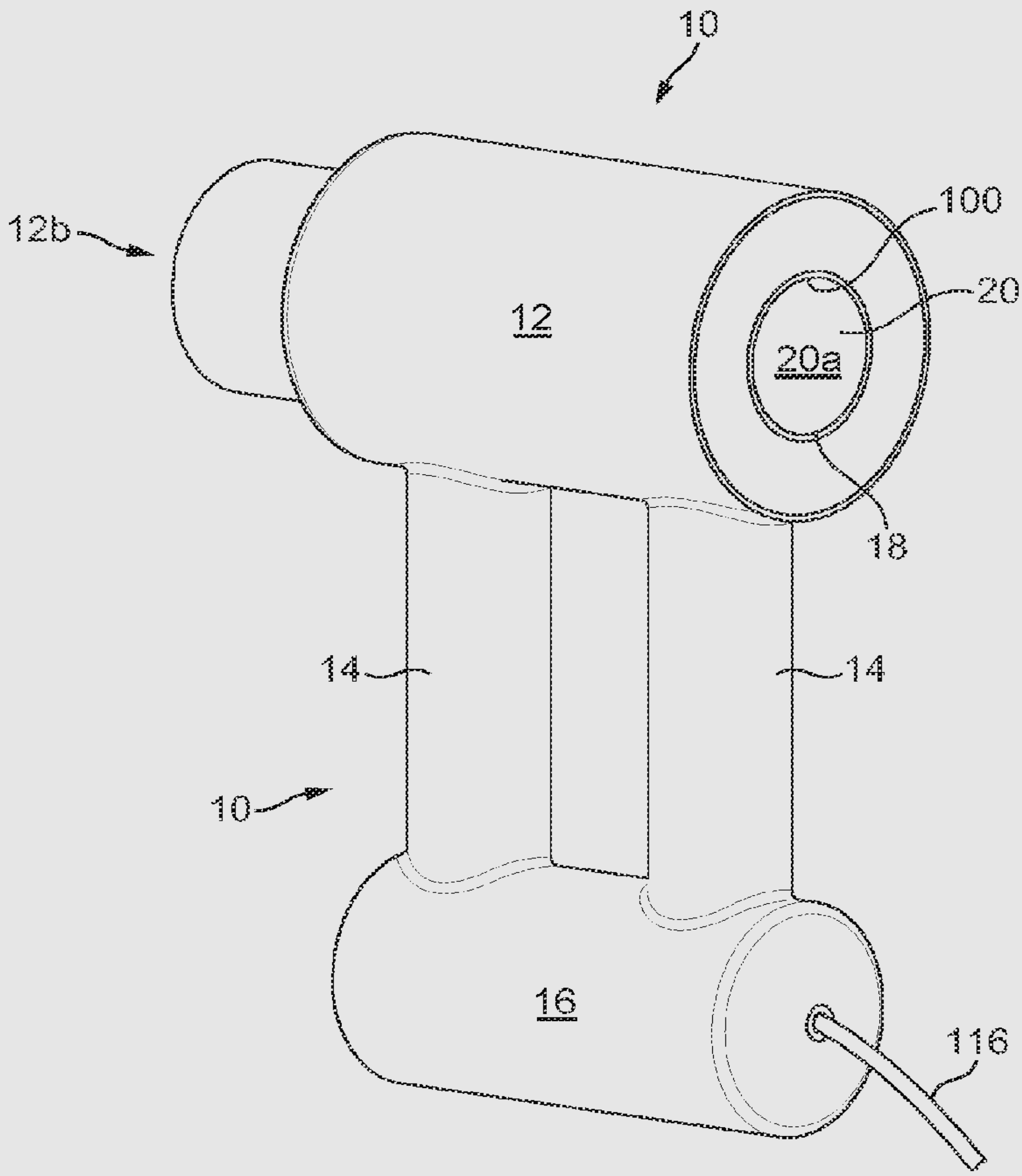
01 – rig
Last prototype build prior to tooling and manufacture

First engineering build from plastic components

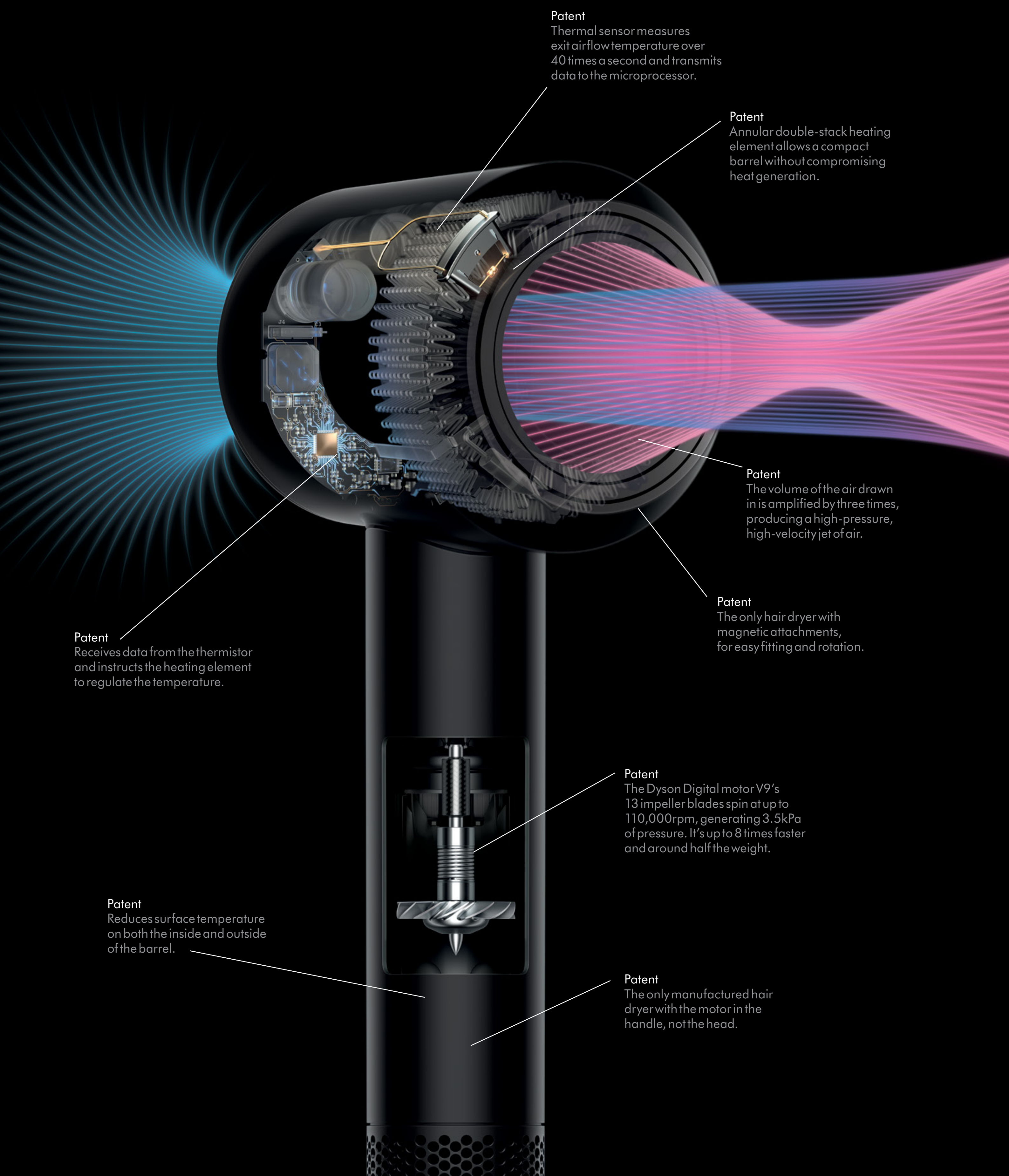
PATENT US2013283631 (A1)
2013-10-31

Air is drawn in by the motor and accelerated over an annular aperture. This creates a jet of air which passes over an aerofoil-shaped ramp that channel sits direction. Surrounding air is drawn into the airflow (this is called inducement and entrainment).

The result is that the volume of air coming out of the hair dryer is three times that going into the motor. This system is called Air Multiplier™ technology – patented by Dyson.



The Dyson Supersonic broke new ground. It contains technology that is protected using patents.



Acoustic engineering

One of the key aspects of the brief for the Dyson Supersonic™ hair dryer was that it had to be quiet. Using Dyson Air Multiplier™ technology was a good start, but really addressing the problem meant calling in the experts – acoustic engineers. Acoustic engineers are experts in the science of noise and vibration. They are concerned with the design, analysis and control of sound.

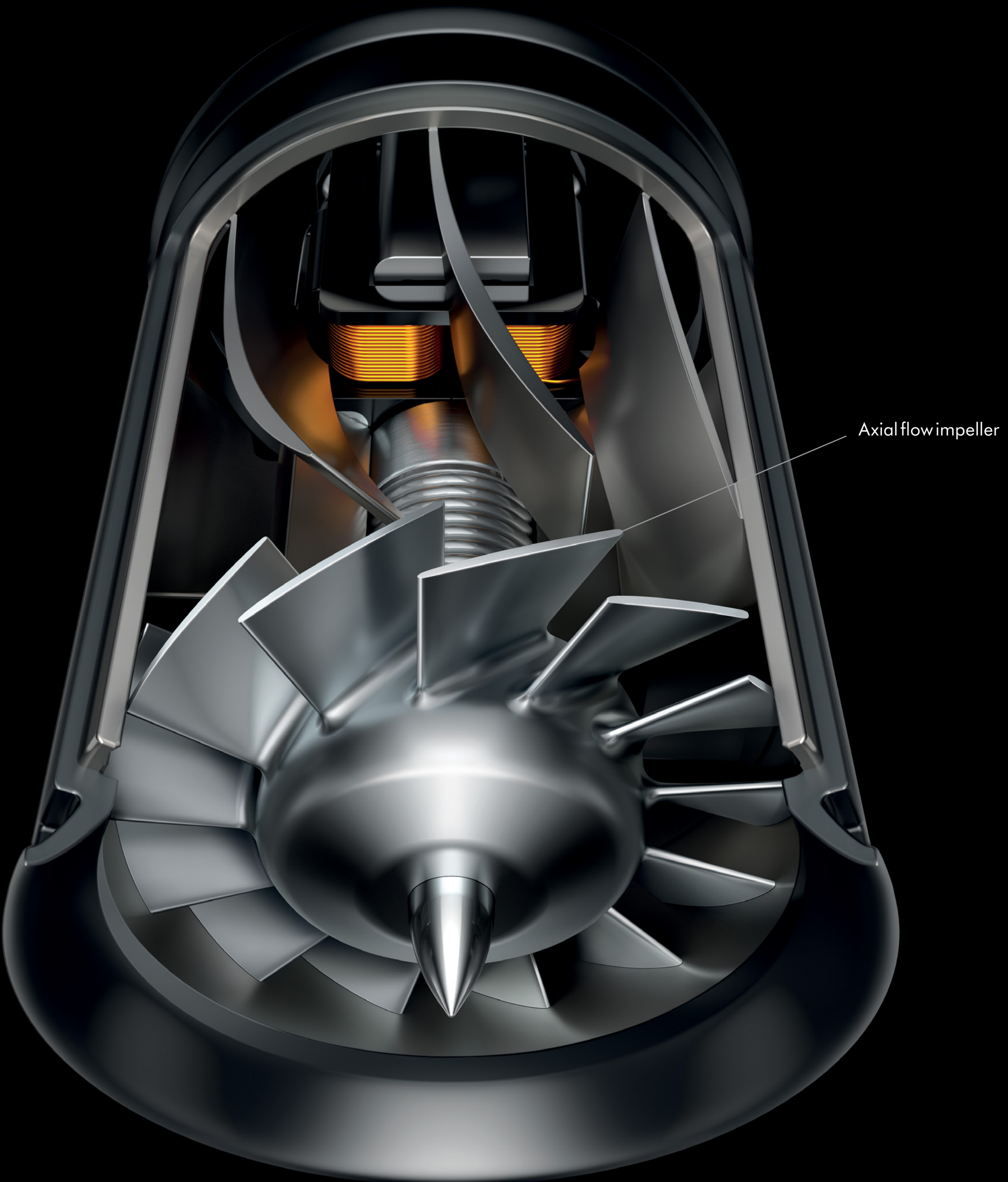
But sometimes even the experts require support. Aerodynamics engineers helped the acoustic engineers to map the flow of air through the machine, so they could understand how to optimize it. They discovered that the motor was a key area for improvement. This required more teamwork – with motor engineers.

It was up to another engineering team, analysis engineers, to consider this new motor design and validate it – ensuring that it could survive the intense centrifugal forces that a motor experiences during operation. Finally, the acoustic engineers surrounded the motor in the handle of the machine with acoustic silencers, to further muffle the sound. Making the Dyson Supersonic™ hair dryer quiet, without compromising on performance.

Dyson acoustic chamber

Dyson digital motor V9

Designed to fit into the handle of the hair dryer, the Dyson digital motor V9 is our smallest yet. By using an axial flow impeller inside the motor, Dyson engineers simplified the pathway of the air, reducing turbulence and swirling. And by giving the motor impeller 13 blades instead of the usual 11, they pushed one tone within the motor to a sound frequency beyond the audible range for humans.



LESSON 04
THE BRIEF

Duration: 1 hour 30 minutes

Learning objectives

1. Understand the importance of the design brief and specifications.
2. Develop an understanding if qualitative and quantitative criteria and constraints for a brief.

Activity outcomes

Class discussion about the brief and design specifications of the Dyson V12 Detect Slim Animal™

Completed group brainstorm for a product that solves a specific problem

Completed group product specifications

Things you will need:

Pens and pencils

Paper

Whiteboard

Worksheet 01: Product Specification

Poster 03: Iteration

Starter: 15 minutes
Understanding design briefs

Learning objective	Activity
1	Explain to students that engineers are given a brief, which explains the challenges that must be answered by a product and the parameters a design engineer must work. For example, a product might need to be a certain size or perform a particular function.
1	As a class, discuss the criteria that were considered when developing the specification for the Dyson V12 Detect Slim Animal™.
1	Prompt the students to consider the brief in terms of ACCESS FM. Ask the class to draw on what they learned in **Lesson 02: Introducing Dyson V12 Detect Slim Animal™** when they discussed the design of the vacuum. – Aesthetics – Cost – Customer – Environment – Safety – Size – Function – Materials

Main: 45 minutes
Taking on the brief

Learning objective	Activity
1, 2	Put up **Poster 03: Iteration**. Explain to students that for the next four lessons, they are going to think like engineers. In this class, the students will be taking on a design brief and developing specifications. In the next classes, they will be conceptualizing, researching and prototyping products to meet these specifications. Split the class into six groups and assign each group one of the following briefs: **Group one**: Design a product that will encourage students to lead a healthier lifestyle. **Group two**: Design a product that will improve the safety of students walking home from school. **Group three**: Design a product that will encourage people to recycle more at home. **Group four**: Design a product that will help students to pay more attention in class. **Group five**: Design a product that will help to address the isolation and loneliness experienced by some elderly people. **Group six**: Design a product that will help owners to make sure their pets are cared for when they are away from home.
1, 2	Give students 30 minutes to independently think about and sketch possible solutions to their group's brief. Encourage preliminary online research.
1, 2	Ask students to present their ideas to their group. Encourage students to ask questions, and agree upon a final solution.

Wrap up: 30 minutes
Develop the specification

Learning objective	Activity
2	Once each group has agreed on a design. Hand out **Worksheet 01: Product Specification**.
2	Explain that each group should use the worksheet to define specific and realistic qualitative or quantitative criteria and constraints for their design.

LESSON 05
SPECIFY

Duration: 1 hour 30 minutes

Learning objectives

1. Understand how to use a specification to guide product development.
2. Understand how to work as a team to achieve an objective.
3. Develop independent research skills.

Activity outcomes

Completed group research into product specification

Presentation of specification research

Things you will need:

Pens and pencils

Paper

Whiteboard

Worksheet 01: Product Specification

Starter: 10 minutes
Teamwork and problem solving

Learning objective	Activity
1	Explain to the students that today they will be continuing to work in their groups to develop the designs they chose in the last lesson. They will need to conduct research, and make a plan to keep development on track.
2, 3	Explain that in order to develop the best solution possible, the students will need to take individual responsibility for different aspects of the specification – reporting their findings to the group, so that collective decisions can be made. You may want to make a copy of **Case study: Dyson Supersonic™ hair dryer** and distribute to the students. This will help to explain that while engineers have different specialties, they work together to solve problems.

Main: 1 hour
Research the specifications

Learning objective	Activity
1, 2	Ask each group to work together to consider the function aspect of **Worksheet 01: Product Specification**, which they completed in the last lesson. What does the product do, and how does it work? The students should write a list of the different aspects that will be required to make the product work, such as: – Electronics – Sensors – Power sources – LEDs The students should work together to research these elements, and uncover any potential issues.
1, 3	Ask each group to review their completed **Worksheet 01: Product Specification** and divide responsibility for the other criteria among themselves.
3	Explain that the students now need to individually research their criteria, and that they will give a two minute presentation of their findings to their group. While they are researching as individuals, they will come back together as a group to think about how the findings will impact on the development of their product. The students may want to research online or, if appropriate, they may want to survey their classmates or potential users. This is a good opportunity to build in a homework or extension exercise. **Note**: This part of the lesson can be extended or repeated if more time is required.

Wrap up: 20 minutes
Present your findings

Learning objective	Activity
1, 2	Ask the students to present their findings to their group. Encourage the group to ask questions.

LESSON 06
DESIGN, BUILD, TEST, ITERATE

Duration: 1 hour 30 minutes

Learning objectives

1. Understand the different parts needed to create a functional product.
2. Appreciate the importance of continuous iteration to the design process.

Activity outcomes

Completed student annotated sketches and parts list

Completed group prototype

Completed student reflections

Things you will need

Pens and pencils

Paper

A range of materials to construct prototypes

A range of adhesives to join parts together

A range of tools to cut up materials and construct prototypes

Starter: 15 minutes
Labeled parts

Learning objective	Activity
1	Building on the research carried out in the previous lesson, ask the student groups to sketch their product. Explain the sketch should be labeled to identify each part needed for the product to function – and what those parts will be made of. Make sure the groups think about what's on the inside of the product, as well as the outside.

Main: 45 minutes
Building prototypes

Learning objective	Activity
1	Explain that in this lesson, the students are going to create a initial prototype of their product. Students should consult their parts list and work together to build each part.
1, 2	Explain to students that they should select a lead engineer. This person should delegate who is building which parts, ensure consistency in dimensions and quality, and note any additions or adjustments made to the product's design and parts list. This lead engineer should also ensure that the build process is finished within a reasonable time frame.
1, 2	Ask the students to construct their prototype. Encourage the groups to test their product as they go along, to understand how a user would interact with it, and identify where there may be design flaws. Remind them that the design process is iterative, and encourage them to work together to modify and improve their design as they encounter difficulties. Make sure that any changes to the design or function are recorded by the lead engineer. **Note**: this part of the lesson can be extended or repeated if more time is required.

Wrap up: 30 minutes
Reflect

Learning objective	Activity
1, 2	Once the prototype's construction is complete, ask each student to write their reflections on the building and testing experience. They may want to consider: – What changes were made to the product's design, and why? – How will the changes impact the design specification? – How did you ensure that a part's design would function appropriately? – How might this affect the materials used to create that component?

LESSON 07
GO TO MARKET

Duration: 1 hour 30 minutes

Learning objectives
1. Understand how to calculate profit margins.
2. Learn how to think about a product in a market context.
3. Develop critical analysis skills.
4. Develop skills in persuasion.
5. Develop presentation skills.

Activity outcomes
Estimate of manufacturing costs and profit margin calculation
A business and marketing plan

Things you will need:
Pens and pencils
Paper
Computer access
Video: The Car

Starter: 30 minutes
Go to market

Learning objective	Activity
1	Explain that in today's lesson, the student groups will be preparing to pitch their products. But before they can start planning their presentations, they need to work out how much they will sell their product for. Explain that cost engineers use engineering principles to control costs and make sure projects are completed within budget. Cost engineers consider the labor and manufacturing costs, the purchase price of every part, and finishing elements such as coats of paint. They make suggestions as to design changes that will improve a product's profit margin.
1	Ask the student groups to estimate what they want to sell their product for, and how much profit they would like to make. The students should then work in their groups to estimate the manufacturing costs of their finished product. They should think about: the cost of each part, finishings such as paint and of the labor to make the product. Once they have this estimate, ask the students to subtract the cost of manufacturing from the amount they plan to sell the product for. This figure is their profit margin. If the profit margin is not healthy, the group may want to consider making some changes to their design.

1, 2	Now ask the groups to consider other, similar products that are already on the market. How much do these products sell for? Will their price be competitive – or do they believe that their design is unique enough to justify a higher price point?
2, 3	As a class, watch **Video: The Car** to demonstrate how bringing a product to market can effect the success of an invention, even if the technology and design process is finalized.
2, 3	Give the students 10 minutes to consider whether they would like to make any design changes in light of their findings.

Main: 30 minutes
Planning the pitch

Learning objective	Activity
3	Now that they know how much they will sell their product for, the student groups need to decide how to market it. Explain that for the next 30 minutes, they will be working on a plan that explains their business and marketing strategy. This plan will be presented to the class – so it needs to be visually engaging.
3, 4	The plan should identify the strengths and weaknesses of their products, and should address the following questions: – What is it, and what problem does it solve? – How does it work, and why is it better than existing solutions? – Who will use it? – How will it be manufactured and what will it cost? What will the profit margin be? – How many units of the product will be sold every year? – How will people get to know about the product – and how will they be convinced to buy it?
3, 4	This activity can be extended by asking the students to develop marketing materials to support their presentation: – A presentation explaining what the product is, its key features, and how it is different to or better than rival products. – An instructional video or brochure on how to use the product. – A print advertisement highlighting features and functions of the design.

Main: 30 minutes
Planning the pitch

Learning objective	Activity
5	Ask the groups to practice their presentations, and identify any areas they need to improve before the next lesson. **Note**: This activity can be extended as homework. Ask the students to perfect their presentations and supporting materials before the next lesson.

LESSON 08
THE BIG PITCH

Duration: 1 hour 30 minutes

Learning objectives

1. Develop presentation skills.

2. Develop critical analysis skills.

Activity outcomes

Presentation

Critical discussion of products and business plans

Things you will need

A projector

Computer access

Starter: 15 minutes
Preparation

Learning objective	Activity
1	Explain that today's lesson will be focused on group presentations. Give the students 10 minutes to prepare their presentation.

Main: 1 hour
The big pitch

Learning objective	Activity
1, 2	Ask each group to present. Explain that the other students should take notes during each presentation, summarizing: the name, novelty, function, price, and persuasive arguments.
1	Make sure each group answers the following questions: – What is it, and what problem does it solve? – How does it work, and why is it better than existing solutions? – Who will use it? – How will it be manufactured and what will it cost? What will the profit margin be? – How many units of the product will be sold every year? – How will people get to know about the product – and how will they be convinced to buy it?
2	At the end of every presentation, encourage the class to ask questions.

Optional: for this lesson you can choose to hold a design exhibition, which other students and teachers can visit. Student groups can display their prototypes, and pitch their product to the attendees. To make the event even more exciting, you could ask a local engineer to come in and meet the students – and even judge the best product.

Wrap up: 15 minutes
Best product design

Learning objective	Activity
2	Ask students to refer back to their notes on the other groups' presentations.
1	Explain they should vote for the team (that is not their own) that had the most persuasive presentation. Count the votes and award a small prize to the winning team.

WORKSHEET 01
PRODUCT SPECIFICATION

This worksheet should be used to record key criteria and constraints. This is your product specification – the measuring stick for assessing your product's success.

1. What will the product look, feel or sound like?

2. What is the estimated manufacturing cost of the product, and what will it's retail price be?

3. Who is the product designed for?

4. What is the product's impact on the environment?

5. How will the user be kept safe from harm?

6. Are the proportions of the product appropriate?

7. How well does the product work – and is it easy to use?

8. What is the product made from, and what does this mean for manufacturing?

SUPPORT SHEET 01
HOW THE DYSON V12 DETECT SLIM ANIMAL™ WORKS

Use this support sheet to help guide the class
Video: How the Dyson V12 Detect Slim Animal™ works

Pause the video, ask your students	After they guess, inform them:
What are the most important functions of a vacuum cleaner?	Vacuum cleaners must suck up dirt and debris; must be energy efficient; must not be too heavy for the user.
Why is it important to think about cost when designing a product?	If the product is expensive to make, it means that companies will have to charge the consumers more to make a profit.
What aspects of the design would add extra cost to the V12 Detect Slim Animal™ and why did the engineers choose to include them?	Sustainable materials, batteries, and motors will all cost more. However, engineers have chosen to include these elements to ensure the products are more environmentally friendly, meet consumer demands and are more efficient than the previous corded machines.
Who would buy this product? What are their needs?	Families, homeowners, young professionals. All these groups want vacuums that require less energy but are effective and clean quickly.
What works well about this design for a customer, and what doesn't?	**What works well**: the size of the vacuum, that it can be easily stored, high powered, low noise. **What doesn't work well**: the size of the bin may need to be bigger for families with children.
What safety aspects were considered to prevent potential harm to the user?	The red strips on the handles of the vacuum are in place to ensure that the user isn't shocked through the static that is collected when vacuuming the floor. The battery needs to be safe for the user to ensure there aren't any machine malfunctions or harm caused to the user. The terminals that connect the battery to the vacuum are gold-plated, this is to ensure they don't erode and cause harm to the user.
What aspects were considered to prevent damage to the environment in which the vacuum is used?	All elements of the vacuum can be replaced independently if they become damaged which means a user doesn't need to replace the whole machine, just a part of it. This saves waste.
How would you describe the design of the V12 Detect Slim Animal™?	The design of the vacuum is condensed and precise meaning there are no unnecessary elements on this vacuum, the heads are flexible which means they are better adapted to different locations/environments, the new filtration process means that the vacuums are more efficient at collecting more dust and debris.
What is good about this design and what is bad?	The power button, which isn't on all cordless machines, makes the vacuum easier to use as consumers don't have to hold down a trigger button.

Pause the video, ask your students	After they guess, inform them:
Why is the vacuum this size? How does the size work with different users, in different environments? Think about the size of individual parts too – like the brush bar and power button.	The vacuum is this size to ensure it's more easily used by consumers, compared to the previous corded machines. This means that the vacuum can be used on different floor types and in different environments more easily as it is more user-friendly.
Think about the materials used to make the Dyson V12 Detect Slim Animal™. What are the benefits of the materials they used? What other materials could have been used?	The materials that have been used ensure that the machine is fully functioning (e.g., doesn't melt when they get warm, doesn't bend, or break easily, are environmentally friendly) and not too heavy for the user. For example, the wand which connects the main vacuum to the machine head is made from aluminium – this ensures that the material will not bend or damage easily but is lightweight for the user. They could have used plastic as a replacement for the aluminium, but this would've significantly increased the weight.

*Please note that these discussion points are not exhaustive.

SUPPORT SHEET 02
TANGLE-FREE TURBINE TOOL DISASSEMBLY

Use this support sheet to help guide the class
Video: Tangle-free Turbine tool disassembly

Time	Pause the video, ask your students	After they guess, inform them:
0:50	What is the neck of the Tangle-free Turbine tool made of?	The neck of the Tangle-free Turbine tool is made out of acrylonitrile butadiene styrene or ABS – the same material used to make riot shields. ABS is strong because it has gone through a process called rubber toughening, in which elastomer chains are added to a more brittle polymer. Elastomers are polymers with viscoelasticity. By spreading elastomer chains throughout the material, the energy needed to break it is increased. In other words, it has become tougher.
0:50	Why is it important that the Tangle-free Turbine tool is made out of a tough material?	The Tangle-free Turbine tool must be able to withstand years of use – without breaking. This may include being dropped or hitting obstacles. Our engineers test their products to breaking point to identify any weak points prior to manufacturing. This information is then used to further improve the design.
1:18	Why is the soleplate sprint loaded?	The flat spring allows the soleplate to maintain contact with the surface of the floor, adjusting between carpets, hardwood floors and other surfaces. Maintaining a seal with the floor is crucial to providing good suction.
2:05	Why does the turbine drive gears, instead of just driving the discs?	By itself, the turbine can't deliver enough torque – a force that causes rotation. Gears are used to increase the torque.
2:05	Compare the teeth on the various gears. What's different and how does this impact the function of the tool?	The teeth on the larger gears are cut vertically while the teeth on the smaller gears are cut helically – or diagonally. When gears come together they make a chattering noise. The helical teeth produce less noise than vertically cut teeth. The smaller gears also have teeth that are shaped like spear heads – this very precise profile is called an involute curve. This shape reduces the gear-ongear impact and wear as the teeth turn, as well as reducing noise.
2:05	What material are the two main gears made out of? Why is this material important?	The two large gears are made of Polyoxymethylene (POM), also known as acetal, polyacetal and polyfromaldehyde. POM is an engineering thermoplastic used in parts that require high stiffness, low friction and excellent dimensional stability. It is ideal for gears which require smooth operation and low wear.
3:10	What do you notice about the shape of the screw boss? What is the purpose of this shape?	The screw boss is an aerofoil shape, just like the wing of a plane or the blade of a propeller. The aerofoil shape is very aerodynamic: that means that it reduces drag, allowing the air to travel efficiently around the cleaner head, without losing velocity.

Time	Pause the video, ask your students	After they guess, inform them:
3:20	Why are the bristles red?	The bristles are red to draw the eye of the consumer. The bristles may need to be cleaned periodically due to hair build up, so they need to be highly visible.
3:20	What is the function of the bristles and what are they made of?	The bristles are made from very fine filament – nylon plastic. Their job is to agitate the surface and pick up dirt. As they run across the surface, they splay out and then spring back together. The action of springing back together is what actually draws in the dirt.
3:20	Why are the discs oval in shape?	The rotating discs are oval because this shape allows the discs to overlap in the middle during their rotation cycle, so no area of floor is left untouched. The oval shape also makes sure hair gets pulled off the paddles and into the airway.
3:20	Why do the discs counter-rotate?	The spinning discs ball the hair, meaning it doesn't wrap around the brush bar and is instead sucked straight into the vacuum cleaner bin. The discs rotate in opposite directions so that they both feed in toward the airway in the middle.
3:40	Why does the bottom of the paddle feature raised lumps of plastic?	The bottom of the paddle has been manufactured so it can only be put in the right way round. This is an example of Poka Yoke, a Japanese term that means "mistake proofing". Its purpose is to prevent or correct human errors – eliminating defects before machines or products can reach the market.

SUPPORT SHEET 03
ANTI-TANGLE SCREW HEAD DISASSEMBLY

Use this support sheet to help guide the class
Video: Anti-Tangle Screw head disassembly

Time	Pause the video, ask your students	After they guess, inform them:
0:24	What does it mean when he described the Anti-tangle Screw head as the next generation of the Tangle-free Turbine tool?	This means that Dyson engineers have revisited the Tangle-free Turbine tool and undergone a design iteration process to change or fix issues with the previous design.
0:37	What is interesting about the space of the brush bar?	The conical (going towards a point) and helical (twist) shape of the brush bar impacts how the machine head works. This has been engineered, through inspiration from archmedes screws, to ensure that the hair travels along the brush bar and out into the machine.
1:49	Why did the turbine work better on a corded machine?	The turbine was powered through the air flow that was sucked up from the floor. The air flow on the new cordless machines wouldn't be enough to power the turbine. This is due to the extra power given to the machine from sourcing its power from the mains electric, as opposed to a battery.
1:55	Why have Dyson engineers ensured that we do not waste any airflow on the new cordless machines?	This is due to the difference in power between the corded (connected to the mains electic) and cordless (battery powered). This ensures that the newer machines remain as effective as the old machines.

NATIONAL EDUCATION STANDARDS

Next Generation Science Standards: Disciplinary Core Ideas

	Lesson 01	Lesson 02	Lesson 03	Lesson 04	Lesson 05	Lesson 06	Lesson 07	Lesson 08
ETS1.A		x	x	x	x	x		
ETS1.B			x	x	x	x	x	
ETS1.C				x	x	x	x	

Next Generation Science Standards: Performance Expectations

	Lesson 01	Lesson 02	Lesson 03	Lesson 04	Lesson 05	Lesson 06	Lesson 07	Lesson 08
MS-ETS1-1		x	x	x	x	x		
MS-ETS1-2			x		x	x	x	
MS-ETS1-3			x		x	x	x	
MS-ETS1-4					x	x		
HS-ETS1-1		x	x	x	x	x		
HS-ETS1-2				x	x	x	x	
HS-ETS1-3				x	x	x	x	x

Next Generation Science Standards: Science and Engineering Practices

	Lesson 01	Lesson 02	Lesson 03	Lesson 04	Lesson 05	Lesson 06	Lesson 07	Lesson 08
Asking Questions and Defining Problems	x	x	x	x	x	x	x	x
Developing and Using Models						x		
Planning and Carrying Out Investigations	x	x	x	x	x	x	x	
Analyzing and Interpreting Data		x	x		x	x	x	
Using Mathematics and Computational Thinking				x			x	x
Constructing Explanations and Designing Solutions				x	x	x	x	x
Engaging in Argument from Evidence	x						x	x
Obtaining, Evaluating and Communicating Information	x	x	x				x	x

Next Generation Science Standards: Crosscutting Concepts

	Lesson 01	Lesson 02	Lesson 03	Lesson 04	Lesson 05	Lesson 06	Lesson 07	Lesson 08
Interdependence of Science, Engineering, and Technology	x	x	x					
Influence of Science, Engineering and Technology on Society and the Natural World				x	x	x	x	

Hess' Cognitive Rigor Matrix (Science CRM)

	Lesson 01	Lesson 02	Lesson 03	Lesson 04	Lesson 05	Lesson 06	Lesson 07	Lesson 08
Level 1 Recall and Reproduction	x	x	x	x	x	x	x	x
Level 2 Skills and Concepts	x	x	x	x	x	x	x	x
Level 3 Strategic Thinking/ Reasoning			x	x	x	x	x	x
Level 4 Extended Thinking						x	x	x