THE JAMES DYSON FOUNDATION
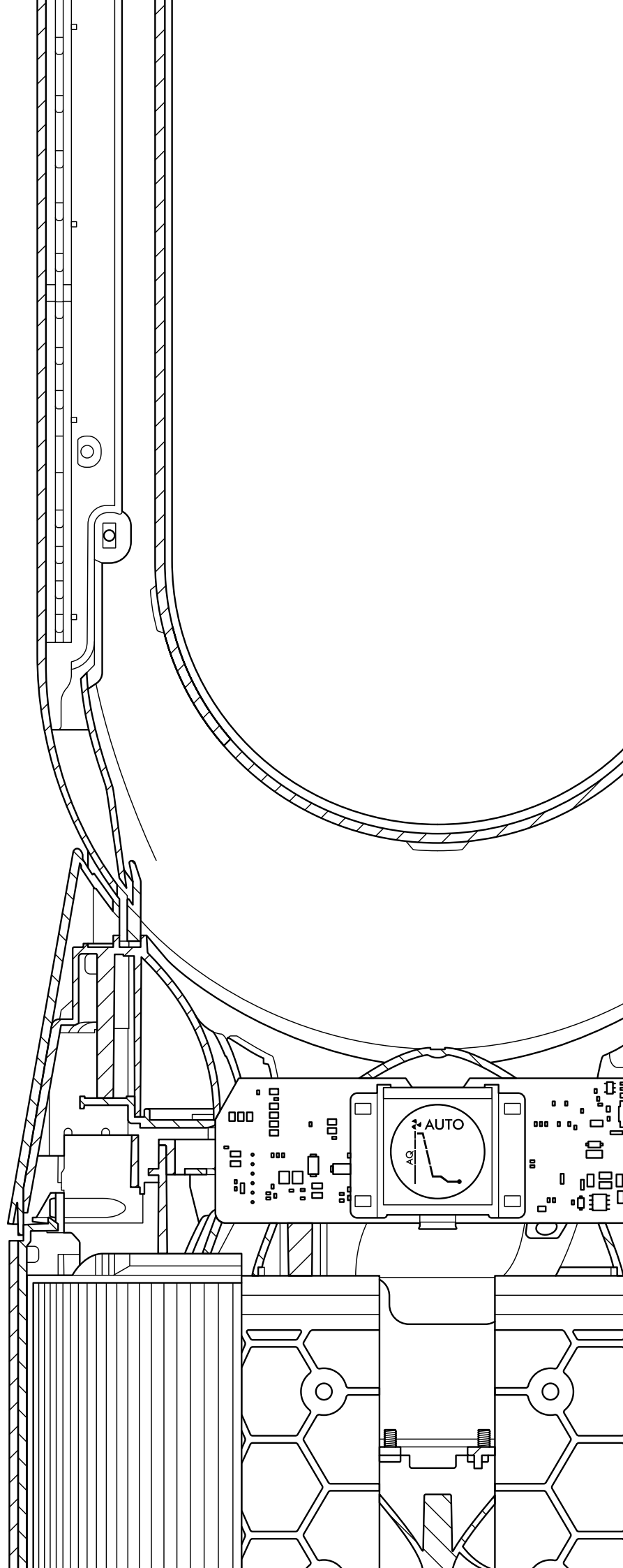
TEACHER'S PACK

Engineering solutions:
Air pollution

AUTO

INTRODUCTION

This teacher's pack will introduce students to engineering and explore how engineers can solve global challenges, focusing on the problem of air pollution. Over five lessons, students will learn what air pollution is and how the Dyson Pure Cool™ purifying fan works as a solution to indoor air pollution. Students will complete experiments and analyse data. Then, they will design and build their own solution to air pollution, by following the design process. The pack is designed to be complementary to both Science and Design and Technology curriculums at Key Stages 3 and 4.

If you follow the lesson plans provided, students will:

Learn about air pollution and its global sources

Consider their own exposure to air pollution

Collect and/or analyse data on air pollution

Analyse the Dyson Pure Cool™ purifying fan

Consider global engineering solutions to air pollution

Develop, present and evaluate their own solution to air pollution

Please note, each lesson is 1 hour and 30 minutes. However, you can adapt the lessons to suit different timelines – for example, the starter or wrap-up activities can be omitted to reduce each session to an hour. 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, explaining how the lessons relate to the science of air pollution and Dyson technology. Please familiarise yourself with this information before you start teaching.

You can find the videos and posters on our website:
www.jamesdysonfoundation.co.uk

CONTENTS

Think before you print
Lesson plans and worksheets have been included
on separate pages, listed above, so you do not
need to print the entire document.

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."

James Dyson
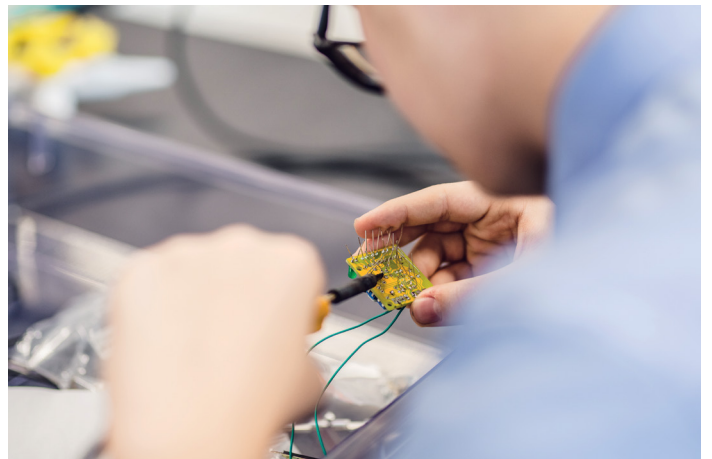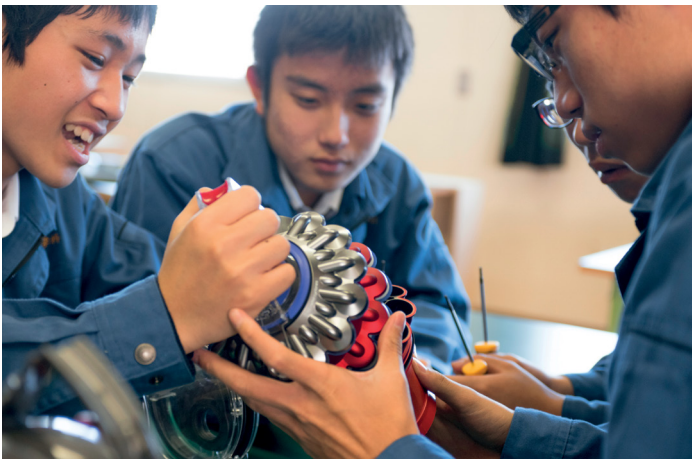
SECTION 01: SENSE

Students will learn what air pollution is and what causes it. They will understand that air quality can be monitored using sensors and consider actions to reduce their exposure to air pollution in their school environment and on their journey to school.

UNDERSTANDING AIR POLLUTION

Air pollution

Air pollution is caused by a build-up of particulate matter and gases in the air, that come from a range of natural and human-made sources. It is one of the major global problems of the modern age. 91% of the population lives in places where the air quality exceeds the World Heath Organization's (WHO) guideline limits.[1]

Gas pollution

The air around us is mainly made up of gases. Air contains 78% nitrogen, 21% oxygen, and the rest is made up of argon, carbon dioxide and a small volume of other gases, all of which enter our lungs when we breathe. The presence of oxygen is fundamental to keep us alive, but other pollutant gases may cause us harm.

Particulate matter pollution

The air also contains particles and we breathe in millions of them every day. Particles are small pieces of matter and are measured in microns (μm), which is one millionth of a metre. They vary in size, shape and composition. Particulate matter (PM) is a form of air pollution and is a mixture of solid and liquid particles floating in the air.

Air pollution on a journey to school
Nigeria

[1]Air pollution, World Heath Organization's, https://www.who.int/airpollution/ambient/en/
Image: Pius Utomi Ekpei/AFP via Getty

SOURCES OF AIR POLLUTION: NATURAL SOURCES

Weather

Temperature, rainfall and the wind all influence air pollution. For example, wet and windy conditions reduce air pollution in certain locations by washing it out of the air or moving it elsewhere. Whereas dry and still conditions cause poor airflow which can trap air pollution. This means that in landlocked places, such as mountain towns, air pollution can build up.

Desert dust storms

Desert dust comes from the surface of arid and semi-arid regions around the world such as the Sahara Desert, Eastern Australia and the Gobi Desert. High winds cause dust particles to lift from the ground into the air resulting in a dust storm. Wind can cause dust storms to travel thousands of kilometres and can combine with human-made air pollution. This means desert dust can cause air pollution in parts of the world that are nowhere near a desert.

Volcanoes

Volcanic eruptions release volcanic ash into the air. Wind can carry this ash thousands of kilometres away from the volcano itself. For example, in 2010, a volcano called Eyjafjallajökull erupted in Iceland. Around 50% of the ash was carried across Europe and the North Atlantic. Air traffic in these locations was halted for several days after the eruption.

Forest fires

Forest fires occur across the world and produce a substantial amount of smoke pollution. These fires are increasing in prevalence and severity due to changes in temperature and rainfall across the globe, resulting in longer fire seasons and larger geographic areas being burned. Forest fire smoke is a complex mixture of PM, nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3) and volatile organic compounds (VOCs) generated from burning a wide variety of fuel sources such as trees, dried leaves, litter and – unfortunately – local homes. These forest fires often occur in California where the dry environment means it is easier for fires to start from a natural event such as lightning, or a human-made source such as campfires. Wind also causes the smoke generated from forest fires to travel long distances and pollute air in cities and towns.
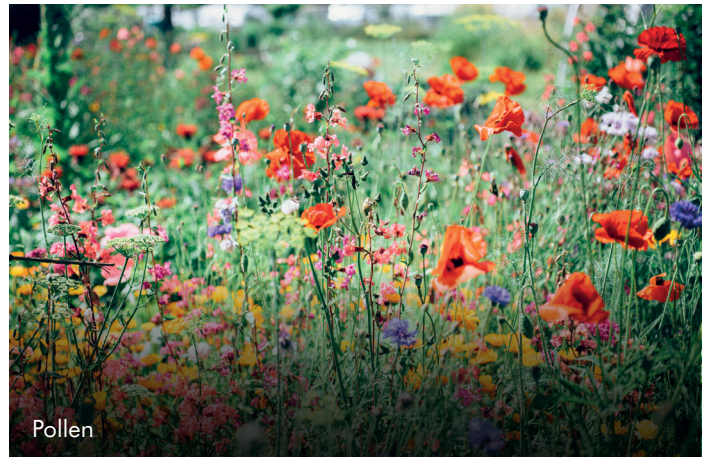

Volcanic eruption
Eyjafjallajökull Iceland

Dust storm

Forest fire

Rain

Pollen

Forest fire

Wind

Dry and still conditions

Cold conditions

SOURCES OF AIR POLLUTION:
HUMAN-MADE SOURCES

City pollution
Shanghai

Transportation

Road transportation is one of the main sources of air pollution in cities. Exhaust fumes from motor vehicles release harmful gases and soot particles, coated with toxic substances, into the air. Diesel vehicles are especially harmful, producing high concentrations of these pollutants. Air pollution is also caused by small bits of metal and rubber that come off brakes and tires, as well as by dust kicked up from road surfaces. They are suspended in the air by moving traffic.

Energy generation

Much of the electricity we use in our homes comes from power stations that burn coal, oil, gas and wood. These processes release harmful air pollutants into the atmosphere.

Industrial processes

Industrial processes such as the production of cement, iron, steel, glass jams paper create air pollution. Areas with high numbers of industries and factories have high levels of air pollution.

Urbanisation Development

Urban areas, particularly large cities, have higher levels of air pollution than most rural areas due to high numbers of people, transport and industries. For example, megacities such as Tokyo, Shanghai and Delhi face huge air pollution problems. Pollution builds up in these highly populated places and can often be seen as a brown haze that appears to hang in the air over cities. Rural areas tend to be more exposed and windier, meaning air pollution is more easily dispersed. This results in better air quality.

Household products

Studies have found that indoor air quality can be worse than outdoor air quality.[2] Air pollutants are released from household items such as building materials, cleaning products, furniture, pets, candles, plants and aerosols. They are also emitted from activities such as heating and cooking. Outdoor air pollution can also enter homes through ventilation, doors and windows and then become trapped.

[2]Hulin et al, Respiratory Health and Indoor air pollutants based on quantitative exposure assessments, European Respiratory Journal, Oct 2012.

Energy production

Industrial processes

Exhaust fumes

Urbanisation development

Fertilisers

Burning candles

Cooking fumes

Cleaning products and aerosols

THE IMPACT OF AIR POLLUTION AND WHY IT IS DIFFICULT TO SOLVE

Health

Air pollution can impact our health in a number of ways including nose, eye or throat irritation, coughing, chest tightness, shortness of breath, reduced lung function or asthma attacks. Some people are at a higher risk of being affected by air pollution than others.

Environment

Air pollution can also have adverse effects on the environment such as acid rain, soil depletion, damage to forests and crops, reduced visibility, damage to buildings and climate change.

Air pollution is a difficult problem to solve for a number of reasons:

It is largely an invisible problem because most air pollution is made up of very small particles that cannot be seen by the naked eye.

Our lifestyles currently depend on activities that contribute to air pollution such as driving cars and heating our homes using fossil fuels.

Air pollution is a complicated global problem with a multitude of causes, which vary in scale and severity across the world.

However, engineers have the skills and knowledge to start addressing the problem.

Air pollution in Beijing
China

CASE STUDY: THE BREATHE LONDON WEARABLES STUDY

Since 2009, Dyson has been developing machines that use air quality sensing technology. These devices measure air quality levels, making invisible air pollution visible through data. Dyson engineers used their knowledge of this technology to develop a wearable air quality sensor. This sensor was used in the Breathe London Wearables Study to monitor the air quality school children experience during their journey to and from school. 250 students, across five primary schools in London, took part in the study. Each student carried a backpack containing the wearable sensor and GPS. The sensors measured the particulate matter and NO_2 levels students were exposed to as they travelled to and from school for a week. An algorithm processed the information collected by the sensors. Using this data, researchers at Kings College London mapped areas of good and bad air quality.

Monitoring air quality in this way increases awareness of the air pollution we are exposed to everyday and can stimulate positive behaviour change to reduce exposure. For example, students in this study started walking along side roads instead of busy main roads on their way to school to avoid the high levels of pollution that come from vehicle exhausts.

Find out more about the Breathe London Project at **www.breathelondon.org**
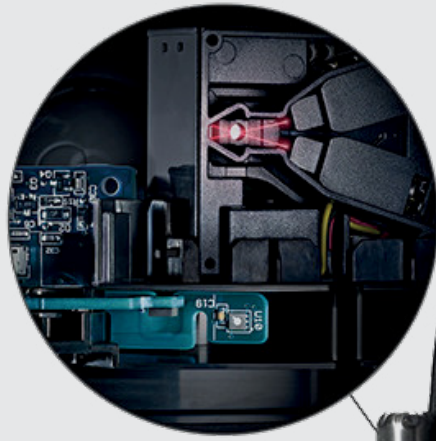
Backpack containing the Breathe London wearable sensor

Students participating in the Breathe London Wearables Study

LESSON 01
AIR POLLUTION
AND ITS SOURCES

Duration: 1 hour 30 minutes

Learning objectives

1. Learn the natural and human-made sources of air pollution.

2. Understand that indoor air quality can be worse than outdoor air quality.

3. Understand that air pollution is made up of particles of different sizes.

4. Understand that air pollution consists of particulate matter and gas pollution.

5. Consider the effects of air pollution on health and the environment.

6. Consider some of the challenges in addressing the problem of air pollution.

Activity outcomes

Class activity about the natural and human-made sources of air pollution

Activity on the different types and sizes of particles – there are two options for the activity depending on the resources you have available

Completed **Worksheet 01: Air pollutants and their sources**

Consideration of the effects of air pollution on health and the environment

Class discussion about the effects of air pollution and the challenges of addressing the problem

Things you will need:

Pens and pencils

Paper

Whiteboard

Poster: Sources of Air Pollution

Poster: Air pollution magnified

Poster: Air pollution size

Worksheet 01: Air pollutants and their sources

Lesson 01: Teacher resource page

[For option 01] Sticky tape

[For option 01] Microscopes

[For option 01] Glass slides for the microscopes

Starter: 15 minutes
Introducing air pollution

Learning objective	Activity
1	Explain that in this lesson, the students are going to learn about air pollution.
	As a class, discuss why air is important for human life. Ask the class what they think air pollution is.
	Write down the key points on the board.
	Explain that air pollution is a mixture of particles and gases in the atmosphere which could harm us if we breathe them in.

Main: 1 hour
Understanding the sources and types of air pollution

Learning objective	Activity
1, 2	Split the class into two groups. Ask the first group to write as many natural sources of air pollution as they can think of. Ask the second group to write down as many human-made sources of air pollution they can think of. Bring the class back together to share their ideas. Put up the **Poster: Sources of Air Pollution** and highlight any additional sources that have not yet been identified. Were there any sources of air pollution that surprised the students? Explain that indoor air quality can be worse than outdoor air quality. Ask the class why they think this might be the case.
3	Explain to students that they are going to look more closely at what makes up air pollution. There are two options for the next activity, depending on what equipment you have available. **Option 01:** Split the students into pairs and give each pair a microscope and two glass slides. Give each student a small piece of sticky tape, around 8 cm in length. They will use the sticky tape to collect a sample of particles. They can do this by putting the sticky tape against their clothing, the table, a plant or dusty shelf. Once they have collected the sample, ask each student to stick the tape to the bottom of their glass slide. In pairs, the students will use the microscope to look at their samples. Ask the students to describe the different types and sizes of particles they see. **Option 02:** Display the **Poster: Air pollution magnified.** Explain that the poster shows images of pollutants under a microscope. Ask the students to describe the different types and sizes of particles they see. Students should note the different sizes of particles.
4	Display **Poster: Air pollution size.** Explain that particles are measured in microns (μm), which is one millionth of a metre. Split the class into pairs. Give each pair **Worksheet 01: Air pollutants and their sources**. Ask the pairs to cut out all of the squares on the worksheet. The students should then match the pollutant to the correct description and its sources, so the squares are aligned in rows of threes. Once all students have matched up their squares, discuss the correct description, found in **Lesson 01: Teacher resource page**, and sources for each pollutant as a class. **Extending Thinking:** When all the students have matched the pollutants correctly, they can stick the squares in the correct order to create a poster about the different types of air pollution.

Main: 1 hour
Understanding the sources and types of air pollution

Wrap up: 15 minutes
Understanding the challenges of air pollution

Learning objective	Activity
5	Ask the students to work in pairs to write the effects air pollution could have on health and the environment. Write the students' ideas on the whiteboard and give feedback to the class on the effects stated.
6	Ask the students to consider some of the challenges in addressing the problem of air pollution. They should identify the following: – Its invisibility – Our lifestyles – many of us rely on things that cause air pollution such as cars and our homes – The scale of the problem Explain that in the next lesson students are going to start addressing some of these challenges.

LESSON 02
MONITORING AIR QUALITY

There are three choices for Lesson 02:

Lesson 02A – students will identify sources of air pollution in the school environment, analyse air pollution data collected from a school and think about ways to reduce exposure to air pollution on their journey to school. This lesson does not require any additional equipment.

Lesson 02B – this lesson requires electronics equipment referred to in the lesson plan. Students will identify sources of air pollution in the school environment and build an air quality monitoring device to measure air pollution levels around the school*. They will collect data and analyse it to draw conclusions on how to reduce air pollution and minimise their exposure to it.

Lesson 02C – this lesson requires the air quality monitors referred to in the lesson plan. Students will use the air quality monitors to identify sources of air pollution in the school environment*. Students will collect and analyse data to draw conclusions on how to reduce air pollution and minimise their exposure to it.

*All of the equipment required for this lesson can be purchased from a local electronics equipment provider. Please note that the James Dyson Foundation is not affiliated with these providers in any way and takes no responsibility for any equipment purchased.

LESSON 02A
MONITORING AIR QUALITY

Duration: 1 hour 30 minutes

Learning objectives

1. Understand that air quality can be monitored using air pollution sensors.

2. Analyse data on air pollution.

3. Consider sources of air pollution in the school environment.

4. Consider the exposure to air pollution during the journey to school.

5. Consider actions to reduce air pollution – and exposure to it – in the school environment and during journey to school.

Activity outcomes

Identification of sources of air pollution in the school environment

Completed **Worksheet 02: Air quality around school**

Mapped journey to school with awareness for air pollution exposure

Consideration of ways to reduce exposure to air pollution in the school environment and during journey to school

Things you will need:

Pens and pencils

Paper

Whiteboard

Worksheet 02: Air quality around school

[Optional] Computers for research

Starter: 15 minutes
Making the invisible, visible

Learning objective	Activity
1	Explain that air pollution is invisible which makes it difficult to know when we are being exposed to it.
	As a class, discuss the following: – What do air quality monitoring devices allow us to do? – Why are they important?
	Students should understand that air quality monitoring devices collect data on air pollution allowing an invisible problem to become visible to us. By being able to 'see' air pollution through the data collected, we can take action to tackle it.

Main: 1 hour
Monitoring air quality

Learning objective	Activity
2	Explain to the students that they will be analysing air quality data collected from a school.
	Explain that Dyson engineers use air quality monitoring devices to monitor the concentration of air pollution present at six locations in a school. Write the following locations on the board:
	– Classroom
	– Canteen
	– Sports field
	– School entrance (near a road)
	– Car park
	– Science/D&T Lab
	Ask the students to rank the locations in order of where they expect air quality to be the best, and where they expect it to be the worst.
2	Provide each student with **Worksheet 02: Air quality around school.**
	Ask the students to complete the worksheet using the data on air pollution provided.
	Ask the students to share which location had the highest levels of pollution and which had the lowest. Compare this to the list of locations completed at the start of the lesson.
	Were there any differences? Were the students surprised by the comparison?
3	Based on what they have learnt from Lesson 01: Air pollution and its sources and the activity above, ask the students to think about potential sources of air pollution in your school. Write their answers on the whiteboard. You can prompt students to think about:
	– Dust
	– VOCs from cooking food
	– Food particles from toasters, fryers and grills
	– Pollen
	– Vehicle emissions from surrounding roads
	– Science experiments which use chemicals
	– Classroom materials such as wood and glue
	– Matter kicked up from the road by cars
	– Cleaning products
	– Aerosols such as deodorant
4	Explain that students will now think about air pollution they are exposed to on their journey to school.
	Ask students to map their journey on a sheet of paper.
	Ask them to mark where they might be exposed to air pollution.
	Discuss the findings as a class and write the three most common sources of pollution students are exposed to on their journeys to school. For example, car exhaust fumes, pollen from trees or dust from roads.
	Extending thinking: Using computers, students can research the concentrations of air pollution they are exposed to on their journey to school using air quality monitoring websites such as **breezometre.com** or **waqi.info.**

Wrap up: 15 minutes
Taking action

Learning objective	Activity
5	Split the class in two. One half will work in pairs to write actions they could take to reduce their exposure to air pollution in the school environment. If required, prompt them to think about: – Parents to stop idling outside school entrance – Planting trees – Opening windows The other half will work in pairs to think about changes to their journey to school that could reduce their exposure to air pollution. If required, prompt them to think about: – Methods of transportation – Choice of route Ask the students to share with the rest of the class and write a list of actions on the board. Explain that small actions can reduce exposure to air pollution.

LESSON 02B
MONITORING AIR QUALITY

Duration: 1 hour 30 minutes

In this lesson, students will build an air quality monitoring device to measure the air quality around their school. Please note that there are a number of components that you will need to prepare at least two days ahead of this lesson, detailed in **Lesson 02B: Teacher resource page.** You can also watch **Video: Building an air quality monitoring device tutorial** before the lesson.

If needed, this lesson can be split over two lessons to allow for more time to complete the main activity.

Learning objectives

1. Understand that air quality can be monitored using air pollution sensors.

2. Consider sources of air pollution in the school environment.

3. Build an air quality monitoring device.

4. Collect data on air quality in the school environment.

5. Analyse data on air pollution.

6. Consider actions to reduce air pollution and exposure to it in the school environment, and during students' journeys to school.

Activity outcomes

Identification of sources of indoor air pollution in the school environment

Built an air quality monitoring device

Collection of air quality data using the monitoring device

Completed Worksheet 04: Data collection

Completed Worksheet 05: Data analysis

Consideration of ways to reduce air pollution and exposure to it in the school environment

Things you will need:

Pens and pencils

Paper

Whiteboard

[In advance] Lesson 02B: Teacher resource page

[In advance] Video: Building an air quality monitoring device tutorial

Worksheet 03: Building an air quality monitoring device

Source of gas pollution: aerosol (deodorant, cleaning products) and/or marker pen

Source of particulate pollution: dry shampoo, tea bags, talcum powder, dust

Worksheet 04: Data collection

Worksheet 05: Data analysis

Components for building air quality monitoring devices. The table on the next page details the components for one device. We recommend allowing for one device per group of five students.

Equipment list for one device	Quantity
Arduino Uno	1
Grove Base shield for Arduino Uno	1
Grove Universal 4 pin buckled cable (20cm)	4
Grove RGB LED stick (10 lights)	2
Grove Laser PM2.5 air quality sensor for Arduino (HM3301)*	1
Grove VOC and eCO$_2$ gas sensor for Arduino (SGP30)**	1
Lithium Ion Battery 3.7V 2000 mAh battery	1
LiPo Rider Plus Charger/Booster - 5V/2.4A USB Type C	1
USB cable type A to C	1
USB cable type A to B	1

* This is the particulate sensor. It can measure particulate pollution down to a size of 2.5 microns, around 25 times thinner than a human hair.

**This is the gas sensor. It can measure the concentrations of Volatile Organic Compounds (VOCs) and polluting gases.

Starter: 5 minutes
Making the invisible, visible

Learning objective	Activity
1	Explain that air pollution is invisible which makes it difficult to know when we are being exposed to it.
	As a class, discuss the following:
	– What do air quality monitoring devices allow us to do?
	– Why are they important?
	Students should understand how air quality monitoring devices collect data on air pollution, allowing an invisible problem to become visible to us. By being able to 'see' air pollution through the data collected, we can take action to tackle it.

Main: 1 hour 15 minutes (this section can be split over multiple lessons if you do not have enough time)
Monitoring air quality

Learning objective	Activity
2	Explain to the students that they will be building an air quality monitoring device to monitor air quality around the school.
	Based on what they have learnt from the last lesson, ask the students to think about potential sources of air pollution in your school. Write their answers on the whiteboard.
	Split the class into groups depending on the number of devices you have and ask each group to write six locations around the school (three indoors and three outdoors) where they will sample the air quality. For example:
	– Classroom
	– Canteen

2	– Science/D&T lab – Sports field – School entrance (near a road) – Car park Ask each group to rank the locations in order of where they expect air quality to be the best, and where they expect it to be the worst.
3	Provide each group with **Worksheet 03: Building an air quality monitoring device.** Ask the students to follow the instructions on the worksheet to build the air quality monitoring device in their groups. **Extending thinking:** For students who have completed building their air quality monitoring devices earlier, or if you have more time in your lesson, students can build a box to contain their device to make it more user-friendly.
4	Once students have completed their devices, they can use a source of gas pollution and particulate pollution to demonstrate how the sensors respond to bad air quality. Explain that the more LED lights that light up, the higher the concentration of air pollution present in the air. Give each group **Worksheet 04: Data collection.** Send each group to each of the locations selected in turn. Ask them to record on the worksheet the number of LED lights that light up for particulate and gas pollution at each location. Please note: the air quality monitoring devices provide an indication of air quality, rather than an accurate and reliable scientific measure of air quality. As a result, readings may fluctuate between devices.
5	Once students have returned to the classroom, give them the **Worksheet 05: Data analysis.** Students should complete the graphs displaying their results before answering the questions. Bring the class together to discuss their findings and the possible causes of good or bad air quality readings across the school. If the results show limited fluctuation, you can also discuss why this might be the case. Reasons might include: – Windy environment – Good ventilation, such as open windows – Lack of moving or idling vehicles – Rural location **Extending thinking:** If desired, students can use the air quality monitoring device to monitor air quality on their journey to and from school, and share with the rest of the class in the following lesson. They could record air quality at the following locations: – School car park – School bus stop – School main entrance – In the car – Walking along a busy road

Wrap up: 10 minutes
Taking action

Learning objective	Activity
6	Split the class in two.
	One half will work in pairs to write actions they could take to reduce exposure to outdoor air pollution in the school. If required, prompt them to think about:
	– Parents to stop idling outside school entrance
	– Planting trees
	The other half will work in pairs and write actions they could take to reduce exposure to indoor air pollution in the school. If required, prompt them to think about:
	– Using low VOC products in science lab/cleaning/cafeteria
	– Opening windows
	Ask the students to share with the rest of the class and write a list of actions on the board.

LESSON 02C
MONITORING AIR QUALITY

Duration: 1 hour 30 minutes

In this lesson, students will capture data on the air quality within their school environment by using the Temptop LKC1000S+ 2nd air quality monitoring devices. Please note that to complete this lesson you will need to source monitors from a local electronics equipment provider. More details can be found in **Lesson 02C: Support Sheet**.

If needed, this lesson can be split over two lessons to allow for more time to complete the activity.

Learning objectives

1. Understand that air quality can be monitored using air pollution sensors.

2. Consider sources of air pollution in the school environment.

3. Collect data on air quality in the school environment.

4. Analyse data on air pollution.

5. Consider actions to reduce exposure to air pollution in the school environment, including during the student's journey to school.

Activity outcomes

Identification of indoor and outdoor sources of air pollution in the school environment

Collection of air quality data using the monitoring device

Completed Worksheet 09: Data collection

Completed Worksheet 10: Data analysis

Consideration of ways to reduce air pollution and exposure to it in the school environment

Things you will need:

Pens and pencils

Paper

Whiteboard

[In advance] Lesson 02C: Support sheet

Worksheet 08: Using an air quality monitor

Source of gas pollution: aerosol (deodorant, cleaning products) and/or marker pen

Source of particulate pollution: dry shampoo, tea bags, talcum powder, dust

Worksheet 09: Data collection

Worksheet 10: Data analysis

Air quality monitoring devices
Instructions on how to collect and export data can be found in the **Lesson 02C: Support sheet**. We recommend allowing for one device per group of 3-4 students.

What pollutants the air quality monitors detect:

Particulate matter (PM2.5 or PM10) is particle pollution that exists in all types of combustion, including motor vehicles, power plants, residential wood burning, forest fires, agricultural burning and some industrial processes. PM2.5 is 2.5 micrometres or less in diametre, whereas PM10 is 10 micrometres or less.

Total volatile organic compounds (TVOC) are emitted gases from certain solids or liquids, such as, furniture, appliances, toys, flames, cooking and cleaning. When trapped indoors, these gases can become increasingly harmful.

Formaldehyde (HCHO) is a colourless, poisonous, highly water-soluble gas with an obnoxious odour. Formaldehyde can often be used in disinfectants, preservatives and lots of industrial and consumer products, such as, carpeting, foam insulation and drapery.

Starter: 5 minutes
Making the invisible, visible

Learning objective	Activity
1	Explain that air pollution is invisible which makes it difficult to know when we are being exposed to it. As a class, discuss the following: – What do air quality monitoring devices allow us to do? – Why are they important? Students should understand how air quality monitoring devices collect data on air pollution, allowing an invisible problem to become visible to us. By being able to 'see' air pollution through the data collected, we can take action to tackle it.

Main: 1 hour 15 minutes (this section can be split over multiple lessons)
Monitoring air quality

Learning objective	Activity
2	Explain to the students that they will be using air quality monitoring devices to measure air quality around the school. Based on what they have learnt from the last lesson, ask the students to think about potential sources of air pollution in your school. Write their answers on the whiteboard. Split the class into groups depending on the number of devices you have and ask each group to write six locations around the school (three indoors and three outdoors) where they will sample the air quality. For example: – Classroom – Canteen – Science/D&T lab – Sports field – School entrance (near a road) – Car park Ask each group to rank the locations in order of where they expect air quality to be the best, and where they expect it to be the worst.
3	Provide each group with **Worksheet 08: Using an air quality monitor.** Ask the students to work in groups and follow the instructions on the worksheet to understand how the air quality monitors work.

4	Once students have turned on their devices and understand how they work, they can use a source of gas pollution and particulate pollution to demonstrate how the sensors respond to bad air quality. Explain the higher the measurement, the higher the concentration of air pollution in the air.
	Give each group **Worksheet 09: Data collection.**
	Send each group to each of the locations selected in turn. Ask them to record on the worksheet the measurement for particulate pollution (PM2.5 and PM10) and gas pollution (TVOC) at each location.
	Please note: It is normal for devices to display a higher value on the detector when it is turned on for the first time or unused for a long time. Put it in a ventilated place to accelerate data recovery when you use it for the first time. As a result, readings may fluctuate between devices.
5	Once students have returned to the classroom, give them the **Worksheet 10: Data analysis.**
	Students should complete the graphs displaying their results before answering the questions.
	Bring the class together to discuss their findings and the possible causes of good or bad air quality readings across the school. If the results show limited fluctuation, you can also discuss why this might be the case. Reasons might include:
	– Windy environment
	– Good ventilation, such as open windows
	– Lack of moving or idling vehicles
	– Rural location
	Extension: If desired, students can use the air quality monitoring device to monitor air quality on their journey to and from school, and share with the rest of the class in the following lesson. They could record air quality at the following locations:
	– School car park
	– School bus stop
	– School gate
	– In the car
	– Walking along a busy road

Wrap up: 10 minutes
Taking action

Learning objective	Activity
6	Split the class in two. One half will work in pairs to write actions they could take to reduce exposure to outdoor air pollution in the school. If required, prompt them to think about: – Parents to stop idling outside school entrance – Planting trees The other half will work in pairs and write actions they could take to reduce exposure to indoor air pollution in the school. If required, prompt them to think about: – Using low VOC products in science lab/cleaning/canteen – Opening windows Ask the students to share with the rest of the class and write a list of actions on the board.

SECTION 02:
CAPTURE

Students will learn how Dyson
engineers developed the Dyson
Pure Cool™ purifying fan to tackle
the problem of indoor air pollution.
They will learn how it detects and
captures air pollution, focusing on
the mechanisms of filtration.

PRODUCT ANALYSIS:
THE DYSON PURE COOL™
PURIFYING FAN

Dyson engineers developed the Dyson Pure Cool™ purifying fan to solve the problem of indoor air pollution. When developing this machine, Dyson engineers identified three main functions a purifying fan needs to have:

1. Monitor air quality

2. Capture air pollution

3. Distribute clean air

Monitoring air quality

The Dyson Pure Cool™ purifying fan automatically senses air pollution using particulate and gas sensors. The data collected from these sensors is used to activate the machine and keep indoor pollution levels low.

Particulate sensor

The particulate sensor draws air into a small chamber and uses lasers to detect the concentration of particulate matter present in the air. It can detect particles as small as PM0.3.

Gas sensor

The gas sensor detects the Volatile Organic Compounds (VOCs) and gases such as NO_2 that are present in the air.
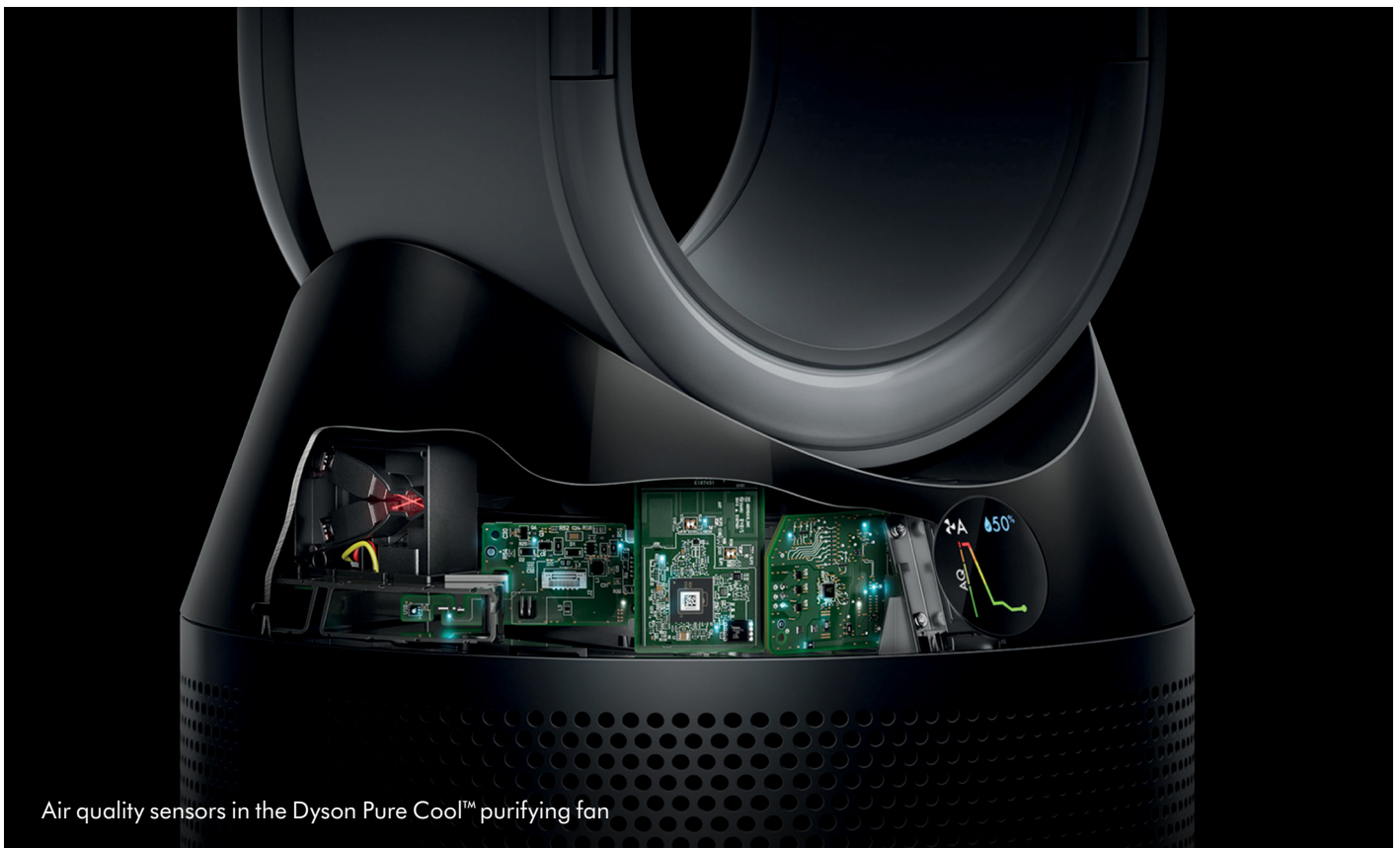
Air quality sensors in the Dyson Pure Cool™ purifying fan

PRODUCT ANALYSIS: COMMUNICATING AIR QUALITY

The information from the sensors in the Dyson Pure Cool™ purifying fan is also communicated to an LCD screen on the purifier and to the Dyson Link app, which can be downloaded onto a smartphone. The screen and app allow users to monitor their indoor air quality by displaying the type and concentration of air pollution present. The app also allows users to set a schedule for when to turn their purifier on or off and monitors the lifespan of the filters.

Dyson Link app

PRODUCT ANALYSIS:
CAPTURING POLLUTANTS

Glass High Efficiency Particulate Arrestance (HEPA) filter

A HEPA filter is a particulate filter which captures solid matter such as pollen, smoke or dust. The filter contains 9m^2 of borosilicate glass microfibres. These fibres are able to capture 99.95% of particles as small as PM0.1 in three different ways: impaction, interception and diffusion. These concepts are visualizedin the **Poster: Air pollution movement.**

Direct interception

When the purifier is turned on, air is pulled into the base of the machine and through the filter by an impeller. As the air cannot go directly through the solid fibres of the filter, it is pulled along the edge of the fibres. Particles travel in this airstream and if they get close enough to the fibre, they will be trapped.

Inertial impaction

Heavier particles require more force to make them change direction, particularly when travelling with high velocity (imagine a cannon ball flying through the air). The airflow is not strong enough to make these particles change direction and move around the microfibre, so they will continue in a straight line, directly colliding with the microfibre and becoming trapped.

Brownian diffusion

Smaller particles are too small to be pulled along in the air flow. These particles move very fast, often colliding with other particles, which causes them to regularly change direction. This random motion as a result of collisions is known as Brownian motion. With such random motion, probability suggests that these particles will, sooner or later, hit one of the microfibres in the filter and become stuck.

Activated carbon filter

The HEPA filter captures particulate matter, but VOCs such as formaldehyde, benzene and NO_2 pass straight through. The purifier uses an Activated carbon filter inside the HEPA filter to capture these potentially harmful gases.

Activated carbon contains a network of many microscopic pores. This means it has a very high surface area-to-volume ratio. VOCs passing through the carbon become trapped in the pores.

A single gram of Activated carbon has an internal network of pores with a surface area of 1,000m^2. That is four tennis courts. The Activated carbon filter in the Dyson Pure Cool™ purifying fan has the same surface area as 40 football fields.

Glass High Efficiency Particulate
Arrestance (HEPA) filter

Activated carbon filter

The HEPA and Activated carbon filters
in the Dyson Pure Cool™purifying fan
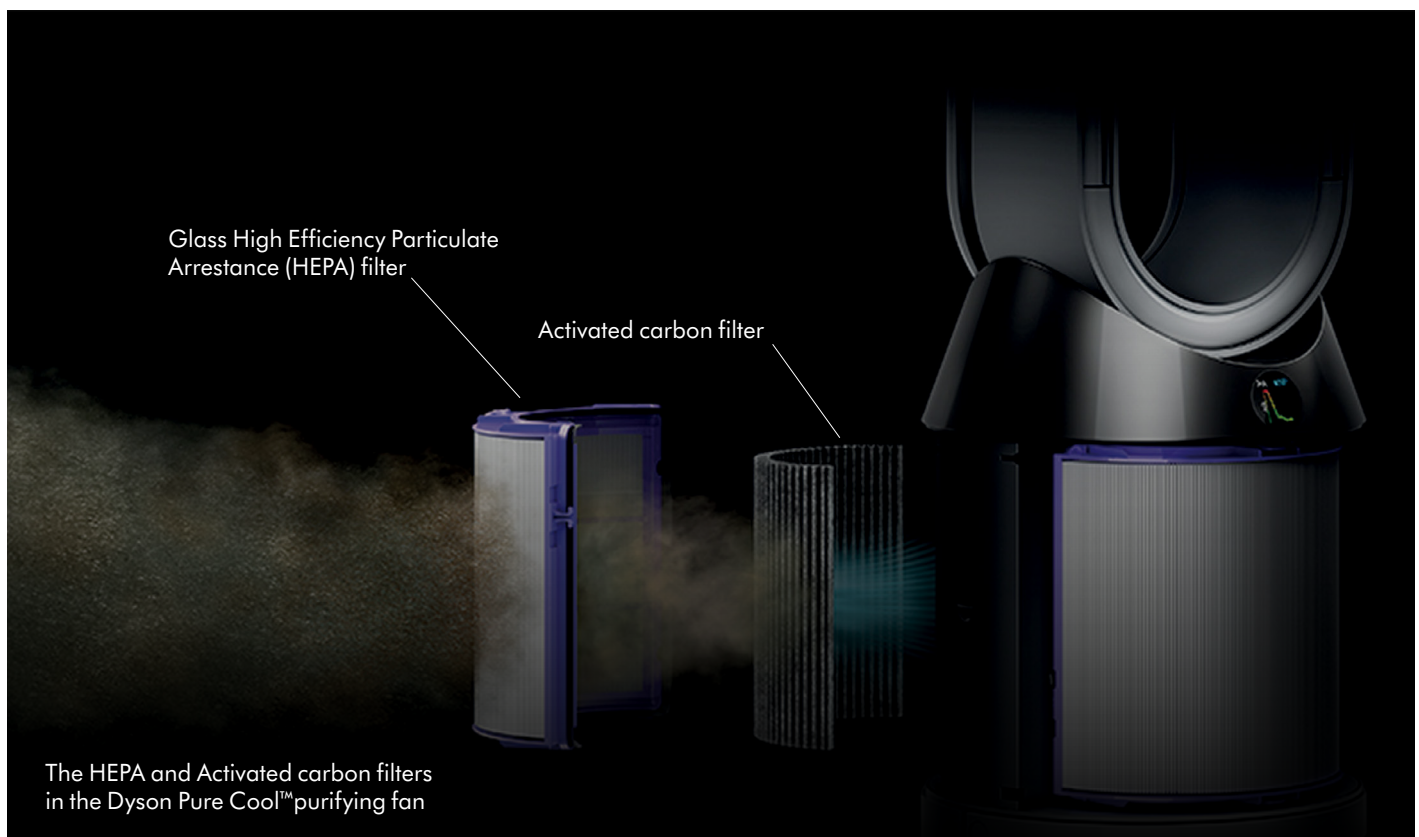
Dyson Cryptomic™ technology

Both the HEPA filter and the Activated carbon filter have a life span. Eventually, both will be saturated with pollutant particles and gases, and will need to be replaced. For the HEPA filter, this occurs after around six months of use (when the purifier is turned on). For the Activated carbon filter, this normally occurs after six to 12 months. While this is not too much of a problem, as filters can be replaced, Dyson engineers were not satisfied. They set about finding a solution that would last for the full lifetime of the machine. They invented Dyson Cryptomic™ technology. This is a filter that uses a catalyst called Cryptomelane.

The Cryptomelane reacts with the formaldehyde, breaking it down into tiny molecules of water and CO_2. Unlike the HEPA and Activated carbon filters, the Crypomelane does not get 'used up'. In fact, it will continue to act as a catalyst forever meaning that the Cryptomic filter does not need to be replaced. However, this filter is limited as it can only remove formaldehyde from the air.
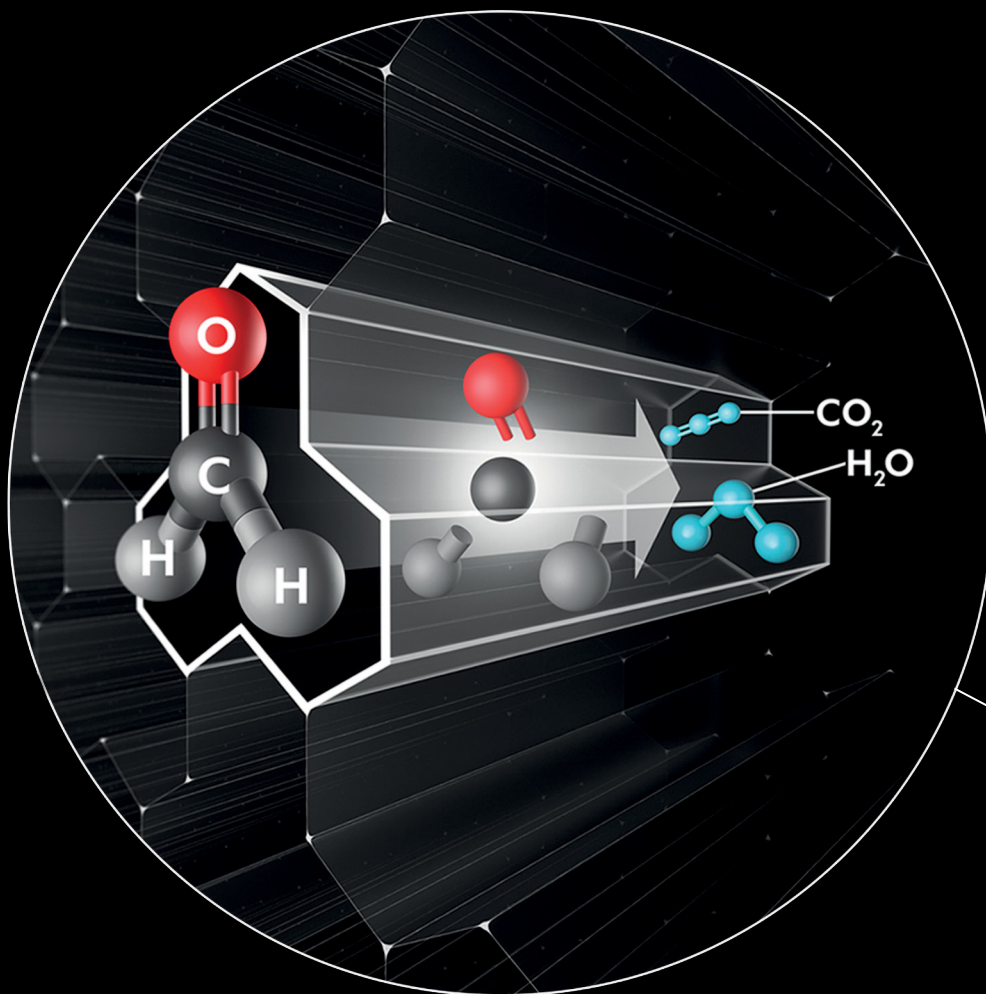
PRODUCT ANALYSIS: DYSON AIR MULTIPLIER™ TECHNOLOGY

Once Dyson engineers had found ways to remove pollutants from the air, they needed to find a way to distribute the purified air back around the room. They recognised that they had already developed technology that could help them: Dyson Air Multiplier™ technology. Dyson desk fans can channel up to 370 litres of air per second. That is 1,121 cans of soda. Dyson engineers applied this technology to the Dyson Pure Cool™ purifying fan to efficiently distribute clean air throughout a room.

Dyson Air Multiplier™ technology
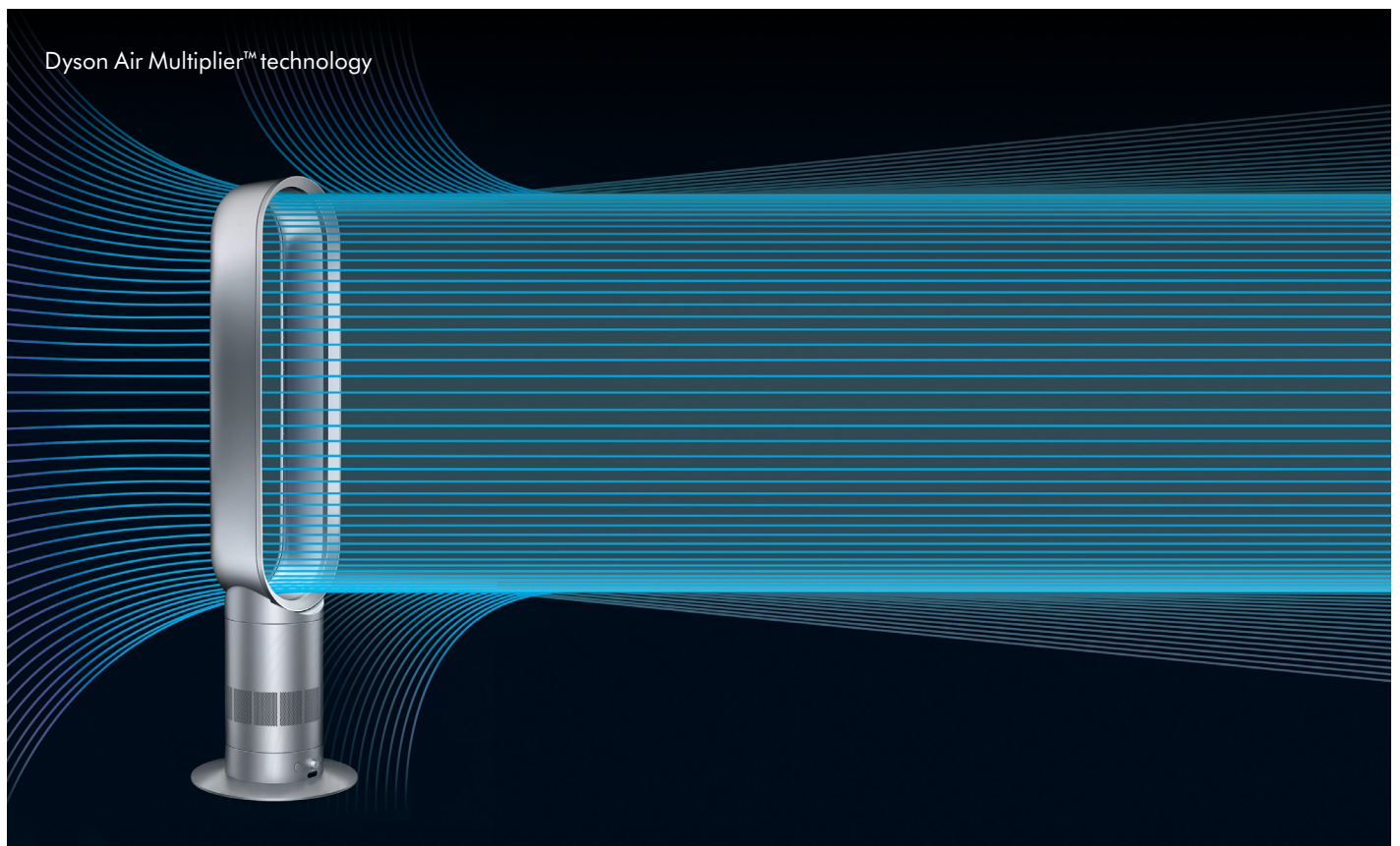
LESSON 03
CAPTURING
AIR POLLUTION

Duration: 1 hour 30 minutes

Learning objectives

1. Understand the design decisions that engineers made when they developed the Dyson Pure Cool™ purifying fan.

2. Learn about different mechanisms of particulate filtration including direct interception, inertial impaction and Brownian diffusion.

3. Understand how surface area impacts the performance of a filter.

4. Demonstrate how an Activated carbon filter works.

5. Understand the importance of an iterative design process.

Activity outcomes

Class discussion about Dyson Pure Cool™ purifying fan

Completed **Worksheet 06: Designing a filter**

[Optional] Completed **Worksheet 07: Activated carbon experiment**

Things you will need:

Pens and pencils

Paper

Video: Smoke box

Video: Dyson purifying technology – how it works

Video: Activated carbon experiment

[Optional] Video: Dyson Cryptomic™ technology

Poster: Air pollution filtration

Poster: Air pollution movement

Lesson 03: Teacher resource page

Worksheet 06: Designing a filter

– A4 paper

– Ruler

– Calculator

[Optional] Worksheet 07: Activated carbon experiment

Below is the equipment required per group of students completing the experiment.

– 2 glass beakers

– Small glass funnel

– Circular filter paper

– Activated carbon granules

– Retort stand with clamps

– Food colouring

Starter: 25 minutes
Introducing the Dyson Pure Cool™ purifying fan

Learning objective	Activity
1	As a class, watch **Video: Smoke box**. Ask the students to consider what they think will happen to the smoke in the box. Explain that in this lesson the students are going to learn about how the Dyson Pure Cool™ purifying fan uses filters to remove pollutants from the air.

1	As a class, watch the **Video: Dyson purifying technology – how it works.**
	Split the class into five groups and assign each group one set of questions below. Each group should write their responses on paper to share with the class later.
	Group one: Where did Dyson engineers get their inspiration from to develop the purifier? Was the design process easy?
	Group two: What two sensors are used in the purifier? Why were these sensors used?
	Group three: Consider why more than one filter is used. What do you notice about the way the filters fit together? Why are the filters fitted in this way?
	Group four: What are the key considerations for Dyson engineers when designing the purifier?
	If required, prompt them to think about:
	– Size
	– Noise
	– Aesthetics
	– Life span
	– Materials
	– Ease of use
	Group five: What is the benefit of the LCD screen? What purpose does the accompanying app serve? Is this helpful for the user?
	Ask for one leader from each group to share their observations with the rest of the class.

Main: 1 hour
Understanding filtration

Learning objective	Activity
2	Put up the **Posters: Air pollution filtration** and **Air pollution movement**
	Explain to the students that particles of different sizes travel in different ways. Ask the students to consider which particle sizes are likely to travel in each of the four ways displayed in the poster.
3	Ask students why they think the HEPA filter is pleated.
	Students can work individually or in pairs to complete **Worksheet 06: Designing a filter.**
	Bring the class together to discuss their findings. Use the **Lesson 03: Teacher resource page** to guide the discussion.
4	Explain to students that the HEPA filter captures 99.95% of particles as small as PM0.1, but that Volatile Organic Compounds (VOCs) will pass straight through. To capture these VOCs, the Dyson Pure Cool™ purifying fan uses Activated carbon.

	Optional: To understand how Activated carbon works, students can carry out the activated carbon experiment following **Worksheet 07: Activated carbon experiment.** Students will note that the Activated carbon removes some of the food colouring from the water. The food colouring molecules bind with the Activated carbon via adsorption, removing it from the water and making the water clearer. This principle is used in the Activated carbon filter in the Dyson Pure Cool™ purifying fan to remove VOCs from the air. If you are short on time or unable to source the necessary equipment for the experiment, students can watch the **Video: Activated carbon experiment** to see how it works.
5	Explain to the students that over time both the HEPA and Activated carbon filter will become saturated with pollutant particles and gases. This means they can no longer remove pollutants from the air and need to be replaced. Dyson engineers decided to develop the purifying fan so that it included a filter that would last the life span of the product. Explain to the students this is the Cryptomic™ filter which removes Formaldehyde from the air and will not be used up. As a class, consider the benefits and limitations of the Cryptomic™ filter. Students should note that the filter lasts the life span of the product but only captures Formaldehyde, not other polluting gases, VOCs or particulate matter. Explain that developing a product like this is called the iterative design process which allows engineers to improve on existing products. Ask the students where they have come across the iterative design process. They should recognise that the Dyson purifying fan is an example of iterative design as it incorporates Dyson Air Multiplier™ technology. **Extending Thinking:** You can play the **Video: Dyson Cryptomic™** to further understand how the filter works.

Wrap up: 5 minutes
Analysing the Dyson Pure Cool™ purifying fan

Learning objective	Activity
5	Conclude the lesson by discussing the following questions as a class: – What are the benefits of the purifier? – What problems does it solve? – What are its limitations?

SECTION 03: SOLUTION

Students will learn about how air pollution is a global problem and will evaluate how engineers around the world are working to solve it. They will understand the design process Dyson engineers follow when developing new technology and will go through the design process themselves to design and prototype their own solutions to the problem of air pollution in their school or home environment.

ENGINEERING SOLUTIONS TO AIR POLLUTION

The global population is projected to reach 10 billion by 2050, with nearly 70% living in urban areas. To ensure that this growth does not result in even greater levels of air pollution, we need to take action to ensure a sustainable future. Engineers, with the help of scientific knowledge, have the skills to develop technologies that could help.

Engineers are problem solvers. They research and develop ideas for new products and think about how to improve existing technologies. They start with a problem, then think of ways to solve it. This is called the design process. It revolves around three main stages: **design, build, test.**

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 materials, such as 3D printed parts. A prototype is the first version of a product from which other versions are developed.

Test – engineers need to test the prototype to see if it works and if it is an effective solution to the problem.

This is a circular process as testing identifies weaknesses 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. For the Dyson Pure Cool™ purifying fan, Dyson engineers designed, built and tested 2,605 prototypes.

Dyson Engineers

EXAMPLES OF ENGINEERING SOLUTIONS TO AIR POLLUTION

Caeli, James Dyson Award International Finalist 2019 (India)

Delhi is the third most polluted city in the world. When the air quality in the city is particularly bad, many asthma sufferers are hospitalised. Caeli was developed to enable patients to stay healthy when air quality is poor and improve their quality of life. It is an anti-pollution mask which filters air via a six-layer filter and centrifugal fan. This provides a continuous flow of purified air. The mask also contains sensors which monitor air quality, sending data to an app and a drug nebuliser which allows users to take medication when required.

PhotoSynthetica (UK)

PhotoSynthetica is an urban curtain that captures CO_2 from the atmosphere and stores it. It can store around one kilogram of CO_2 per day – equivalent to the CO_2 storing capabilities of 20 large trees. It is made up of large modules that can be attached to the outside of buildings. Air enters through the bottom of the modules and travels through a watery medium that contains a special type of algae which traps the CO_2, removing it from the air.

Smog-Free Tower (China)

The Smog-Free Tower is a 100-metre high air purification tower designed to reduce smog levels in cities. It's 7 metres tall and uses ionising silver plates and filters to remove particulate matter from the air.

Smog-Free Bike (China)

The Smog-Free Bike sucks polluted air into a filtering system. Pollutants are removed from the air and the filtered air is projected towards the cyclist.

Sponge Mountain (Italy)

Sponge Mountain is a project that uses soil excavated from the construction of a railway tunnel connecting Turin to Lyon, to create a 90-metre high mound of soil. The mound of soil absorbs CO_2 from the air reducing air pollution levels in Turin, which is one of the most polluted cities in Europe.

Electrified Roads (Sweden)

eRoadArlanda in Sweden developed the world's first electrified road. The road recharges the batteries of electric vehicles as they drive along it using conductive technology similar to a Scalextric track. Conductive rails run along the road and transfers electricity via an arm attached to the bottom of vehicles.

Vertical Forest (Italy)

Vertical Forest is a model for a sustainable residential building. The building houses 800 trees, 4,500 shrubs and 15,000 plants – the equivalent of 20,000 square metres of forest. The vertical forest creates a microclimate that absorbs CO_2 and dust particles, and releases oxygen.

Smog-free bike
China

Image: Studio Roosegaarde

Electrified roads
Sweden

Sponge Mountain
Italy

Smog-free Tower
China

LESSON 04
DESIGNING A SOLUTION
TO AIR POLLUTION

Duration: 1 hour 30 minutes

Learning objectives

1. Understand how engineers can develop solutions to air pollution.

2. Evaluate existing engineering solutions to air pollution.

3. Understand the design process engineers go through when developing new technologies to tackle problems such as air pollution.

4. Design a solution to air pollution.

Activity outcomes

Completed research into an existing engineering solution to air pollution

Completed sketches and parts list

Things you will need:

Pens and pencils

A3 paper

Poster: The design process

Computers for research

Examples of engineering solutions to air pollution **(pages 41-43)**

Starter: 5 minutes
Engineering solutions to air pollution

Learning objective	Activity
1	Explain that engineers can develop technology to solve the global problem of air pollution.
	Explain that today, students are going to act as engineers and design their own solutions to tackle the problem.
	Firstly, they will begin by researching existing engineering solutions.

Main: 1 hour 15 minutes
Designing a solution to air pollution

Learning objective	Activity
2	Split the class into groups of three. Assign each group one of the engineering solutions to air pollution on the previous three pages of this pack to research. Students can find their own existing engineering solution via online research, if preferred.
	Each group should write their answers to the following questions:
	– What is the solution?
	– How does it work?
	– Is it an effective solution to air pollution? Why?

	Ask the students to share with the rest of the class.
	Discuss the strengths and weaknesses as a class.
3	Put up **Poster: The design process.**
	Explain to the students that in order to solve problems, engineers are given a brief. This explains the problems that need to be solved by a product and sets the parametres in which a design engineer must work. For example, a product might need to be a certain size or perform a particular function.
	Explain that when working on the brief, design engineers follow the design process, which has three stages: design, build and test.
	Engineers repeat the design process numerous times when developing a single product. This makes it a circular, or iterative process.
	Ask the students why iteration is important? They should draw on the fact that testing reveals problems in the prototype which can be addressed in the next cycle of the design process.
4	Explain that in their groups of three, students are going to think like engineers and design and build a prototype of their own solution to air pollution.
	In this lesson, they will undertake the first stage of the design process: Design.
	Explain to the students that their brief is: **Design a product that will solve the problem of air pollution in your school or home environment, or on your journey to school.**
	Give the students 30 minutes to independently think about and sketch possible solutions to the brief. Ask them to consider the following criteria and constraints:
	– Users
	– Function
	– Materials
	– Safety
	– Aesthetics
	– Cost
	Remind the students of the materials that will be available to them when building the prototype and to have them in mind when designing.
	Ask the students to present their ideas to the rest of their group. Encourage students to ask questions, and then agree upon a final solution – as a group.

Wrap up: 10 minutes
Preparing to build a prototype

Learning objective	Activity
4	Ask the groups to identify what materials and equipment they will need, out of a list provided, to build a prototype of their design. Then, they can make a plan for building their prototype in the next lesson by assigning roles and responsibilities to each member.

LESSON 05
BUILDING A SOLUTION
TO AIR POLLUTION

Duration: 1 hour 30 minutes

Learning objectives

1. Build a rough prototype to meet the brief.

2. Develop teamwork skills.

3. Develop practical skills.

4. Understand the importance of testing in the design process.

5. Develop presentation and self-evaluation skills.

Activity outcomes

Built prototype of a solution to air pollution

Presentation of prototype to the rest of the class

Things you will need:

A range of materials to construct prototypes

A range of adhesives to join parts together

A range of tools to cut materials and construct prototypes

Starter: 10 minutes
Preparing to prototype

Learning objective	Activity
1	Explain to students that in this lesson they will work in their groups from the previous lesson to build a rough prototype of their design. Using their lists of materials and equipment compiled in the previous lesson, ask the students to gather what they need to build the prototype.

Main: 1 hour
Prototyping

Learning objective	Activity
2	Explain to the students that each team should nominate a lead engineer. This person should delegate who is building which parts, ensuring consistency in dimensions and quality, and note any additions or adjustments made to the product's design and parts list. The lead engineer should also ensure the prototype is completed by the end of the lesson.
3,4	Task each group to work as a team to build a prototype of the design using prototyping materials and equipment provided.

3, 4	Encourage the groups to test their product as they go along, to understand how a user would interact with it and identify any 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.

Wrap up: 20 minutes
Evaluating

Learning objective	Activity
4, 5	Ask each group to present their prototypes to the rest of the class, identifying the following:
	– The problem
	– The solution
	– How it works and why it is better than existing solutions
	– Who will use it
	Ask each group to reflect on the changes they made along the way and consider any further changes that could be made to improve the prototype.
	Ask the other students for feedback on the group's prototype and if there are any changes that could be made to improve their prototype.
	Note: An alternative to student presentations is 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 invite a local engineer to meet the students – and even judge the best prototype.

WORKSHEET 01:
AIR POLLUTANTS
AND THEIR SOURCES

This worksheet contains the names, descriptions and sources of pollutants.
Cut out the squares and match the pollutants to their descriptions and sources.

PM10	Particles with a diameter of 2.5 µm, or less. They are so small they can only be seen with an electron microscope. Their size means they can bypass our bodies' natural barriers and get into the lungs.	Formaldehyde
Nitrogen dioxide – NO_2	A colourless and highly irritating gas that forms just above the earth's surface, unlike the natural layer of gases in the upper atmosphere that protects us from the sun's ultraviolet rays.	Sources: – Mass-manufactured wood products – Varnishes – Paints – Glues
Source: – Bacteria – Fungi – Emissions from coal, gas and oil-powered industries	PM0.1	Volatile Organic Compounds (VOCs)
Source: – Formed when NO_2 reacts with VOCs and sunlight	Particles with a diameter of 10 µm, or less. They are normally large enough to be caught by nose hairs and mucus, enabling us to cough or sneeze them out. However, some pollutants can impact breathing and have long-term health effects.	Source: – Cigarettes – Paints – Cleaning products – Scented candles – Furniture polish
Source: – Black smoke – Soil – Dust from roads and building sites – Pollen – Mould spores	PM2.5	A group of gases or airborne liquids that can be toxic.
Ultrafine particles with a diametre of 0.1 µm or less. They are small enough to bypass the lung tissues and enter the bloodstream.	Source: – The incomplete combustion of fuels in gas and wood-burning heaters	A red-brown gas with a strong irritating smell that causes smog and acid rain.
Sulfur dioxide - SO_2	An odourless and colourless gas.	Source: – Diesel car exhaust fumes – Fires – Coal factories – Domestic heating
Carbon monoxide - CO	A toxic gas with a strong irritating smell that is emitted by volcanoes.	Source: – Burning fossil fuels – Volcanoes – Forest fires
Known for its distinct and overpowering smell as well as its flammable nature.	Ground-level ozone - O_3	Source: – Vehicle exhaust emissions – Wood smoke – Tobacco smoke

WORKSHEET 02:
AIR QUALITY
AROUND SCHOOL

Dyson engineers measured the concentration of particulate and gas pollution, using an air quality monitoring device, at six locations in a school.

1. Plot the concentration of particulate pollution at each location, referring to the air quality index, on Graph 1.

2. Plot the concentration of gas pollution at each location, referring to the air quality index, on Graph 2.

Air quality readings around the school

Location	Particulate sensor (number of LED lights)	Gas sensor (number of LED lights)
1. Classroom	4	2
2. Canteen	6	6
3. Sports field	3	4
4. School gate	5	7
5. Car park	3	5
6. Science/D&T lab	4	6

Air quality index

Air quality	Number of LED lights	Particulate ($\mu g/m^3$)*	Gas (ppb)**
Very bad	10	70	5000
	09	65	4000
	08	60	3000
	07	55	2000
Moderate	06	50	1000
	05	45	500
Good	04	40	400
	03	30	300
Very good	02	20	200
	01	10	100

* ($\mu g/m^3$) = micrograms of particulate pollution per cubic metre of air
** (ppb) = parts per billion of gas pollution

Graph – Particulate pollution

PM 2.5
(μg/m^3)

100					
90					
80					
70					
60					
50					
40					
30					
20					
10					
0					

Classroom   Canteen   Sports field   School gate   Carpark   Science/D&T lab

Locations

Graph – Gas pollution

VOC
(ppb)

5000					
4500					
4000					
3500					
3000					
2500					
2000					
1500					
1000					
500					
0					

Classroom   Canteen   Sports field   School gate   Carpark   Science/D&T lab

Locations

3. Use the graphs to answer the following questions.

(a) Which location had the worst air pollution?

(b) Which type of pollution was worse here – particulate or gas?

(c) What could have caused the pollution in (a)?

(d) How did air pollution levels change from the inside to the outside?

(e) What surprised you from the result?

WORKSHEET 03:
BUILDING AN AIR QUALITY MONITORING DEVICE

Use this guide to build an air quality monitoring device. You can use this to monitor the pollution at various locations around your school.

Equipment list for one device	Quantity
Arduino	1
Base shield	1
Cable	4
LED stick	2
Particulate sensor*	1
Gas sensor **	1
Battery	1
Booster	1
USB cable	1

* The particulate sensor can measure particles down to a size of 2.5 microns, around 25 times thinner than a human hair.
**The gas sensor can measure the concentrations of Volatile Organic Compounds (VOCs) and polluting gases.

Guide

1. Slot the base shield into the Arduino using the pins.

2. Plug one end of a cable into the particulate sensor and the other end into a free I2C slot on the base shield.

3. Plug one end of another cable into the gas sensor and the other end into a free I2C slot on the base shield.

4. Plug one end of another cable into an LED stick and the other end into the D2 slot on the base shield. This will be used to indicate the concentration of particulate pollution.

5. Plug one end of the last cable into the other LED stick and the other end into the D3 slot on the base shield. This will be used to indicate the concentration of gas pollution.

6. Plug the battery into the booster.

7. Connect the booster to the Arduino using the USB cable.

8. Set the switch on the booster to ON to power the device.

9. The device is ready once the blue loading bars on the LED sticks disappear.

10. To turn the device off, set the switch on the booster to OFF.
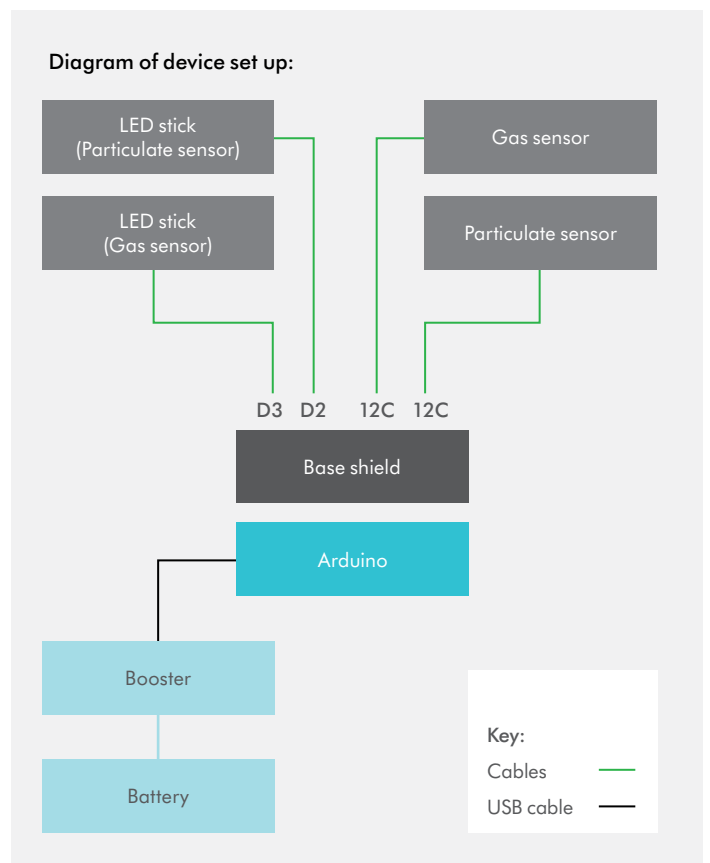
Diagram of device set up:

Key:
Cables ———
USB cable ———

WORKSHEET 04:
DATA COLLECTION

Collect air quality data at six locations around your
school using your air quality monitoring device.

Guide

1. Ensure your air quality monitoring device is powered on.

2. Take your device to the location you will measure.

3. Wait at least one minute to allow the sensor
readings to stabilise*.

*You should see the number of LED lights on each
LED stick remains the same.

4. Record the number of LED lights on each LED stick
in the data collection table below.

5. Repeat steps 2-4 until you have completed
measurements in all locations.

Air quality	Number of LED lights
Very bad	10
	09
	08
	07
Moderate	06
	05
Good	04
	03
Very good	02
	01

Data collection

Location	Particulate sensor (number of LED lights)	Gas sensor (number of LED lights)
1.		
2.		
3.		
4.		
5.		
6.		

WORKSHEET 05: DATA ANALYSIS

Dyson engineers measured the concentration of gas and particulate pollution, using an air quality monitoring device, at six locations at a school.

1. Plot the concentration of particulate pollution at each location, referring to the air quality index, on Graph 1.

2. Plot the concentration of gas pollution at each location, referring to the air quality index, on Graph 2.

Air quality index

Air quality	Number of LED lights	Particulate ($\mu g/m^3$*)	Gas (ppb)**
Very bad	10	70	5000
	09	65	4000
	08	60	3000
	07	55	2000
Moderate	06	50	1000
	05	45	500
Good	04	40	400
	03	30	300
Very good	02	20	200
	01	10	100

* ($\mu g/m^3$) = micrograms of particulate pollution per cubic metre of air
** (ppb) = parts per billion of gas pollution

Graph – Particulate pollution

PM 2.5
(µg/m³)

100					
90					
80					
70					
60					
50					
40					
30					
20					
10					
0	Classroom	Canteen	Sports field	School gate	Carpark	Science/D&T lab

Locations

Graph – Gas pollution

VOC
(ppb)

5000					
4500					
4000					
3500					
3000					
2500					
2000					
1500					
1000					
500					
0	Classroom	Canteen	Sports field	School gate	Carpark	Science/D&T lab

Locations

3. Use the graphs to answer the following questions.

(a) Which location had the worst air pollution?

(b) Which type of pollution was worse here – particulate or gas?

(c) What could have caused the pollution in (a)?

(d) How did air pollution levels change from the inside to the outside?

(e) What surprised you from the result?

WORKSHEET 06: DESIGNING A FILTER

Engineers are often given specifications such as size, cost and performance in the design of a product. Work through the activities below to consider how these specifications would have impacted the design of the filter used in the Dyson Pure Cool™ purifying fan. You can write answers to the questions below on the next two pages.

1. Take a piece of A4 paper and lay it flat on the desk in front of you. Calculate the surface area of this paper. L is length and W is width. **Refer to figure 01 on the right.**

2. Now pleat the paper widthways at 20 mm intervals. Pleat a second piece of A4 paper at 50 mm intervals.

a. What do you notice about the size of the two pleated pieces of paper compared with the flat paper?

b. What has happened to the surface area?

c. Why is this significant?

3. Surface area of the pleated paper can also be calculated using the following formula where N is the number of pleats:

Surface area = N ((W x H) x 2)

a. If your pleat height is 20 mm and your pleat pitch is 10 mm, what is the maximum surface area you can achieve in the space of 210 mm x 300 mm?

Hint: Refer to figure 02 and start by working out the total number of pleats you could achieve.

b. How many sheets of A4 paper would this use?

c. Why do you think engineers would want to maximise the surface area of the filter that they create?

d. What limitations, apart from space, might there be on the maximum surface area of the filter used? Why is this significant?

Figure 01: Surface area = W x L

W

L
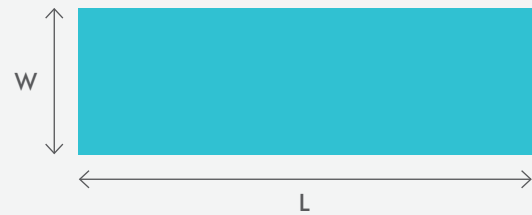
Figure 02: Surface area = N ((W x H) x 2)
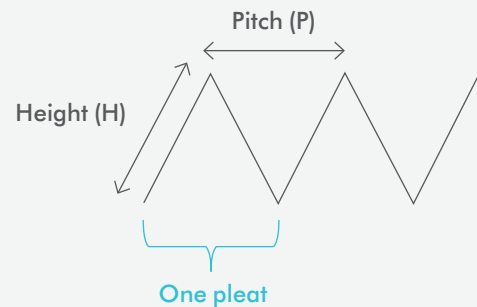
Pitch (P)

Height (H)

One pleat

2a. What do you notice about the size of the two pleated pieces of paper compared with the flat paper?

2b. What has happened to the surface area?

2c. Why is this significant?

3a. If your pleat height is 20 mm and your pleat pitch is 10 mm, what is the maximum surface area you can achieve in the space of 210 mm x 300 mm?

3b. How many sheets of A4 paper would this use?

3c. Why do you think engineers would want to maximise the surface area of the filter that they create?

3d. What limitations, apart from space, might there be on the maximum surface area of the filter used?

WORKSHEET 07: ACTIVATED CARBON EXPERIMENT

Follow the instructions on this sheet to observe the effect of activated carbon on water and food colouring.

Materials

2 glass beakers

Small glass funnel

Circular filter paper

Activated carbon/charcoal granules

Retort stand with clamps

Food colouring

Procedure:

1. Label the beakers A and B.

2. Fill beaker A with 100 ml of water.

3. Add 5 drops of food colouring to beaker A.
Note the colour of the water in the beaker below.

4. Fold the circular filter paper in half, and then half again.
Open one side of the filter paper to create a funnel and
place it in the glass funnel.

5. Attach the glass funnel to the retort stand above beaker B.

6. Measure 10 g (approximately 3 teaspoons) of activated
carbon granules and place them in the funnel.

7. Pour the coloured water from beaker A into the funnel
so that it passes through the activated carbon granules and into
beaker B.

8. Answer the questions on the following page
about your experiment.

1. Describe the colour of the water and food colouring mixture in beaker A before it is poured through the activated carbon.

2. Describe the colour of the water and food colouring mixture in beaker B after it has passed through the activated carbon granules.

3. Describe what had happened in this experiment.

4. Why do you think this happened?

WORKSHEET 08:
USING AN AIR
QUALITY MONITOR

Use this guide to monitor air quality at various locations around your school.

How to use the Temptop LKC1000S+ 2nd air quality monitors

1. Power on the air quality monitors by pressing and holding the power button for 3 seconds. After initialisation, the device will enter the default interface.

2. To detect particulate matter, click the 'PM2.5' button once to view the results. If you click the PM2.5 button multiple times, the device will present the pollutants in graph format. For the activity, it is recommended to stay on the screen with the listed PM2.5, PM10 concentration and number of particles. Please note that the particulate counts are for reference only and are not a professional counter.

3. To detect TVOC, click the 'HCHO' button once to view the results of the TVOC concentration. On this screen, you will also see the air quality indicator showing if it has healthy or unhealthy conditions. Similar to the above, stay on the screen with the listed TVOC concentrations for this activity.

4. Click the 'pause/play' button to switch between running mode and holding mode. When you arrive at each location, you will want the air quality monitor to be in running mode so that the device displays and captures the current detected data. When you are moving to a new location, click 'pause/play' to activate the holding mode so that the device will stop updating the data on the screen.

WORKSHEET 09:
DATA COLLECTION

Collect air quality data at six locations around your
school using your air quality monitoring device.

Guide

1. Ensure your air quality monitoring device is powered on.

2. Take your device to the location where you will take
measurements.

3. Click the 'pause/play' button so that your device is in
'running' mode.

4. Click the 'PM2.5' button to detect particulate matter.
Record the measurements for particulate (PM2.5 and PM10)
pollution in the table below.

*Wait for at least 30 seconds to allow the sensor readings
to stabilise.

5. Click the 'HCHO' button to detect gas pollution. Record the gas
pollution measurement (TVOC) in the table below.

*Wait for at least 30 seconds to allow the sensor readings
to stabilise.

6. Once you have recorded the three measurements (PM2.5, PM10
and TVOC), click the 'pause/play' button so that your device is in
the holding mode.

7. Repeat steps 2-6 until you have the measurements
in all locations.

Data collection

Location	Particulate matter (PM2.5)	Particulate matter (PM10)	Gas (TVOC)
1.			
2.			
3.			
4.			
5.			
6.			

WORKSHEET 10: DATA ANALYSIS

What is the Air Quality Index (AQI)?

The AQI is based on air pollutants that have adverse effects on human health and the environment. The pollutants are ozone, fine particulate matter, nitrogen, carbon monoxide, sulfur dioxide and total reduced sulfur dioxide compounds.

1. Plot the concentration of particulate pollution at each location, referring to the air quality index, on Graphs 1 and 2.

2. Plot the concentration of gas pollution at each location, referring to the air quality index, on Graph 3.

Air quality index

Air quality	Air Quality Index	Particulate matter (PM2.5) ($\mu g/m^3$)	Particulate matter (PM10) ($\mu g/m^3$)
Hazardous	301+	250.5+	425+
Very unhealthy	201–300	150.5–250.4	355–424.9
Unhealthy	151–200	55.5–150.4	255–354.9
Unhealthy for sensitive groups	101–150	35.5–55.4	155–254.9
Moderate	51–100	12.1–35.4	55-154.9
Good	0–50	0–12	0–54.9

Air quality	Gas (TVOC) (mg/m³)	Extended Learning - HCHO (mg/m³)
Unhealthy	>0.5	>0.1
Healthy	< or equal to 0.5	< or equal to 0.1

* ($\mu g/m^3$) = micrograms of particulate pollution per cubic metre of air
**(mg/m^3) = milligrams of gas pollution per cubic metre of air

Graph – Particulate pollution (PM2.5)

PM 2.5
($\mu g/m^3$)

100
90
80
70
60
50
40
30
20
10
0

Classroom Canteen Sports field School gate Carpark Science/D&T lab

Locations

Graph – Particulate pollution (PM10)

PM 10
($\mu g/m^3$)

100
90
80
70
60
50
40
30
20
10
0

Classroom Canteen Sports field School gate Carpark Science/D&T lab
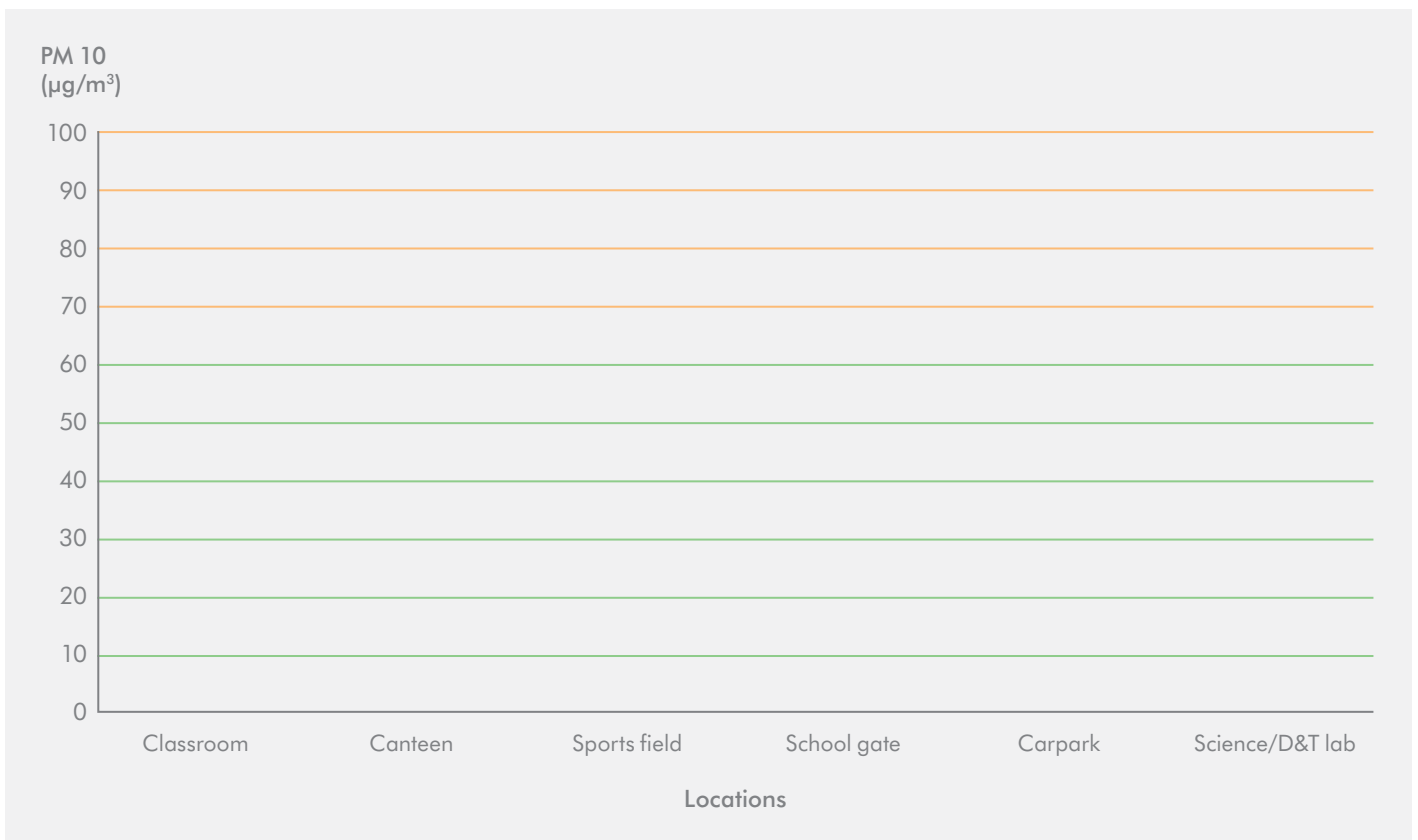
Locations

Graph – Gas pollution (TVOC) (mg/m³)
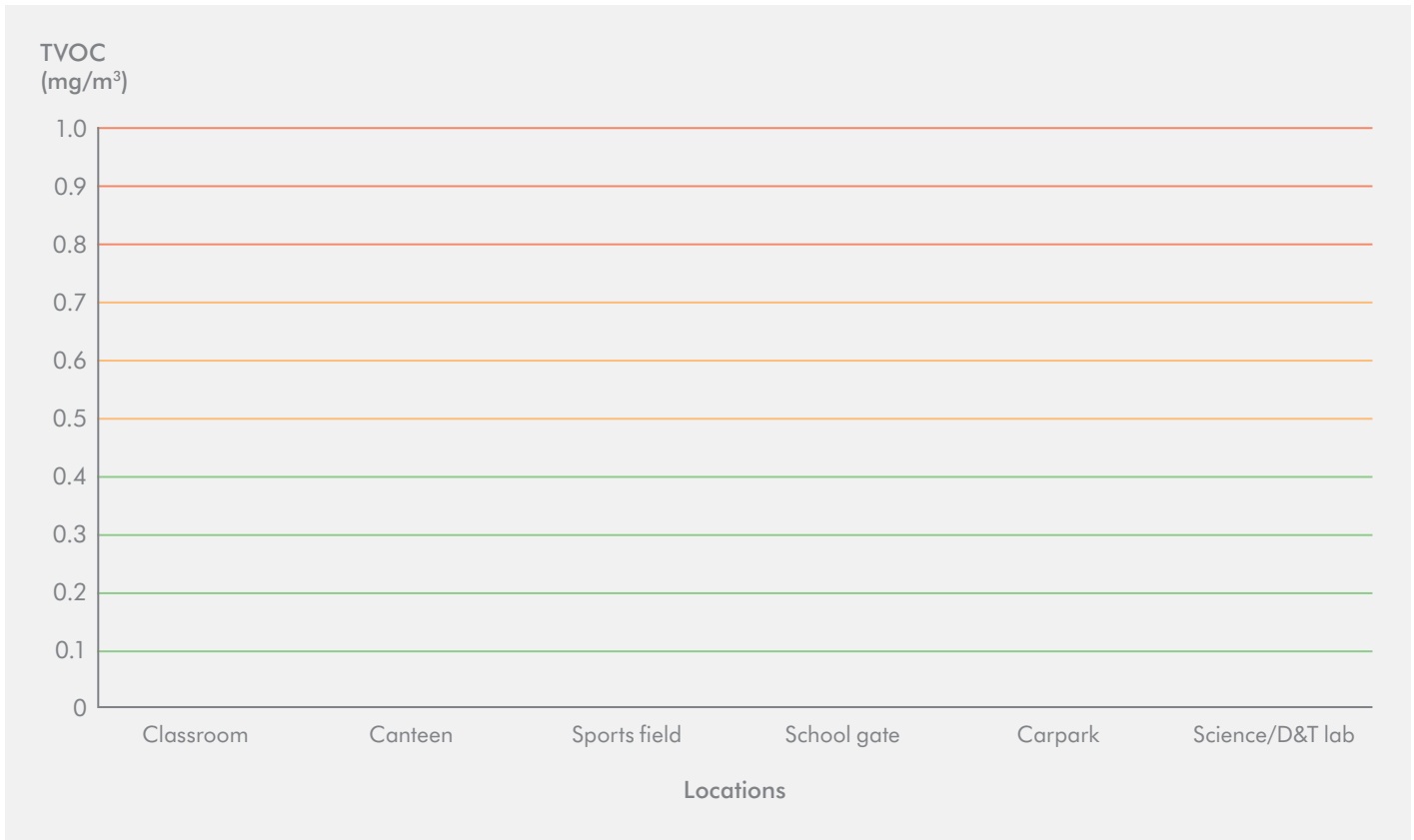
TVOC
(mg/m³)

1.0					
0.9					
0.8					
0.7					
0.6					
0.5					
0.4					
0.3					
0.2					
0.1					
0					

Classroom　　Canteen　　Sports field　　School gate　　Carpark　　Science/D&T lab

Locations

3. Use the graphs to answer the following questions.

(a) Which location had the worst air pollution?

(b) Which type of pollution was worse here – particulate or gas?

(c) What could have caused the pollution in (b)?

(d) How did air pollution levels change from the inside to the outside?

(e) What surprised you from the result?

SUPPORT SHEETS

LESSON 01
SUPPORT SHEET

This support sheet lists the correct combinations
of air pollutants, their descriptions and sources from
Worksheet 01: Air pollutants and their sources.

PM10	Particles 10 μm in width, or less. They are normally large enough to be caught by nose hairs and mucus, enabling us to cough or sneeze them out. However, they can impact breathing and have long-term health effects.	Source: – Black smoke – Soil – Dust from roads and building sites – Pollen – Mould spores
PM2.5	Particles 2.5 μm in width, or less. They are so small they can only be seen with an electron microscope. Their size means they can bypass our bodies' natural barriers and get into the lungs.	Source: – Bacteria – Fungi – Emissions from coal, gas and oil-powered industries
PM0.1	Ultrafine particles with a diametre of 0.1 μm or less. They are small enough to bypass the lung tissue and enter the bloodstream.	Source: – Vehicle exhaust emissions – Wood smoke – Tobacco smoke
Volatile Organic Compounds (VOCs)	A group of gases or airborne liquids that can be toxic.	Source: – Cigarettes – Paints – Cleaning products – Scented candles – Furniture polish
Formaldehyde	Known for its distinct and overpowering smell as well as its flammable nature.	Source: – Mass-manufactured wood products – Varnishes – Paints – Glues

Nitrogen dioxide – NO$_2$	A red brown gas with a strong irritating smell that causes smog and acid rain.	Source: – Diesel car exhaust fumes – Fires – Coal factories – Domestic heating
Carbon monoxide – CO	An odorless and colorless gas.	Source: – The inefficient burning of fuels in gas and wood-burning heaters
Sulphur dioxide – SO$_2$	A toxic gas with a strong irritating smell that is emitted by volcanoes.	Source: – Burning fossil fuels – Volcanoes – Forest fires
Ground-level ozone – O$_3$	A colourless and highly irritating gas that forms just above the earth's surface.	Source: – Formed when NO$_2$ reacts with VOCs and sunlight

LESSON 02B
SUPPORT SHEET

This support sheet helps you to prepare the equipment for the air quality monitoring device building activity in **Lesson 02B**. You can also watch the **Video: Building an air quality monitoring device tutorial.**

You will need to do the following at least two days in advance of the lesson:

Program the Arduinos

Prepare the gas sensors*

Charge the batteries for each device

*To provide reliable measurements, the gas sensor needs to switched on for at least 12 hours prior to use, this allows the sensing elements to undergo a chemical change. This is permanent, so the sensor only needs to be conditioned once.

Programming the Arduino

Equipment you need:

A computer with USB port and internet connection

Arduino Integrated Development Environment software: **https://www.arduino.cc/en/main/software**

Arduino code, available from The James Dyson Foundation website

Arduino Unos that require programming

USB cable type A to B

How to program the Arduinos:

1. Install the Arduino Integrated Development Environment software. You may need to seek the support of your IT team or technicians.

2. On your desktop, create a new folder called **jdf_aqi**.

3. Go to The James Dyson Foundation website and click Download Arduino code in the Engineering solutions: Air pollution section. A code file called **jdf_aqi.ino** will be downloaded.

4. Once downloaded, save this code file to the folder you created on your desktop then click to open it. It will open in the Arduino Integrated Development Environment.

5. In the Arduino environment, click tools then click manage libraries.

6. Search for **HM3301** and find **Grove – Laser PM2.5 Sensor HM3301** by Seeed Studio, select version 1.0.0 from the drop-down bar and install.

7. Search for **SGP30** and find **Adafruit SGP30** Sensor by Adafruit, select version 1.0.5 and install.

8. Search for **NeoPixel** and find **Adafruit NeoPixel by Adafruit**, select version 1.3.2 and install.

9. Click Tools, then Port, then COM (Arduino/Genuino Uno) – the Arduino that is connected should appear automatically. Please note that this may also appear as /dev/tty/arduinouno.

10. Click Sketch then Upload (or the right arrow button in the toolbar).

11. Wait until Done Uploading appears in the status bar at the bottom of the window.

12. Unplug the USB cable from the Arduino.

13. Repeat steps 6–12 for all Arduinos.

LESSON 02B
SUPPORT SHEET

Preparing the gas sensor and charging the battery.

Equipment you need:

A computer with USB port

USB Hub (Optional)

Programmed Arduino Unos

Grove base shield for Arduino Uno

Grove Universal 4 pin buckled cable (20 cm) –
one per Arduino

USB cable type A to C - one per Arduino

Lithium Ion Battery 3.7 V 2000 mAh battery –
one per Arduino

LiPo Rider Plus Charger/Booster – 5 V/2.4 A
USB Type C – one per Arduino

USB cable type A to B – one per Arduino

How to prepare the gas sensor and charge the battery:

1. Push a base shield into an Arduino.

2. Connect a gas sensor to a free 12C port on the base
shield using a connector.

3. Plug the booster into the Arduino using a USB type A to B cable.

4. Plug the battery into the booster.

5. Plug the booster into the USB Hub using a USB type A to C
cable. If you are not using a USB Hub you can plug the USB
type A to C cable into a USB port into the computer.

6. Set the switch on the LiPo booster to ON.

7. Repeat steps 1–6 for all kits.

8. If using, plug USB Hub into the computer USB port
so that it has power.

9. Leave all kits plugged in and powered for at least 12 hours.
If you are not using a USB Hub, you may want to plug the gas
sensors into multiple computers to ensure that they are all prepared
in the 12-hour period.

10. After 12 hours, set all switches on the LiPo boosters to OFF
and disassemble all kits. The batteries are now charged and
the gas sensors are ready for use.

LESSON 02C
SUPPORT SHEET

This support sheet helps you understand and prepare the air quality devices and export the data at the end of the lesson.

The devices measure particulate matter (PM2.5), particulate matter (PM10), total volatile organic compounds (TVOC), air quality index, formaldehyde (HCHO), temperature and humidity. For the lesson, students will work in groups to measure particulate and gas pollution. You can analyse additional measurements as an extended learning opportunity.

To familiarise yourself with the air pollutants' names, sources, and descriptions, please read through **Worksheet 01: Air Pollutants and their sources** on **page 48**.

Equipment you need:

A computer with USB port

Air quality monitor

USB cable

Optional: A battery pack with USB connection to charge devices (if a computer is not available)

Preparing the air quality monitors:

Familiarise yourself with how to use the air quality device using the guide on the right.

Ensure all air quality monitors are fully charged by connecting them to a computer or battery pack via USB. Please ensure there is enough battery life on all devices prior to teaching lesson 02C.

How to use the air quality monitors:

1. Power on the air quality monitors by pressing and holding the power button for 3 seconds. After initialisation, the device will enter the default interface.

2. To detect particulate matter, click the 'PM2.5' button once to view the results. If students click the PM2.5 button multiple times, the device will present the results in the graph format. For this activity, it is recommended for students to utilise the screen with the listed PM2.5, PM10 concentrations and number of particles, as they will be tasked to plot graphs of their results later in the lesson. Please note that the particulate counts are for reference only and is not a professional counter.

3. To detect gas pollution, click the 'HCHO' button once to view the results of the gas pollution (TVOC) concentration. On this screen, students will also see the air quality indicator showing if it has healthy or unhealthy conditions. Similar to the above, it is recommended for students to utilise the screen with the listed TVOC concentration, as they will be tasked to plot graphs of their results later in the lesson for this activity.

4. Once the PM2.5 and HCHO buttons are selected, click the 'pause/play' button to switch between running mode and holding mode. In the running mode, the device will display the detected data at the particular point in time. In the holding mode, the device will stop capturing and updating the data on the screen. When students arrive at each location, they will need to be in running mode so that the air quality monitor displays and captures the current detected data. As students are moving to a new location, click 'pause/play' to activate the holding mode so that the device will stop updating the data on the screen.

5. Extended learning: To detect the air quality index, click the 'AQI' button once to view the results of the AQI concentration. On this screen, you will also find the temperature and humidity. Students can also detect formaldehyde at each location using the air quality monitors by clicking the 'HCHO' button.

LESSON 02C
SUPPORT SHEET

Things to consider:

To collect the most accurate results for indoor locations, keep the room/area airtight for 10 minutes.

If the battery level of the device is low, charge the detector promptly to avoid any unintended effects during usage of the device (the device is also chargeable when off).

It is usual for the detector to show higher values when first switched on or not used for an extended period of time. Hence, place the device in a ventilated area and turn it on for around 30 minutes before testing.

Do not put the detector in an environment with formaldehyde (HCHO) concentration above $1.0\ gm/m^3$ or PM concentration above $500\ \mu g/m^3$ for a long time. Otherwise, the sensor may be damaged and cannot run normally.

Do not come into contact with organic solvents, which include silica gel and other adhesives, paintings, drugs, oil and high-concentration gases.

Do not cover the air inlet/outlet using the detector.

Be cautious of the cross interference by ethanol, benzene, ammonia, etc.

How to export the data from the air quality monitors:

1. Plug in the device and connect to the computer via USB.

2. Hold the 'pause/play' button and choose "Data Export" on the device.

3. If connected to the device successfully, the device screen should read 'USB connection successful'.

4. After successful connection, check the drive named "TEMTOP" on your computer. This drive contains a folder named 'HISTORY'.

5. Select the folder and open the spreadsheet (csv format) that lists information such as date, PM2.5, PM10, Particles, AQI, HCHO, TVOC, Temperature and humidity, etc. Save the spreadsheet to your computer.

6. Add a column to your spreadsheet and type in the location for each measurement. Save the spreadsheet to your computer.

7. Complete steps 1-6 so all data for each device used in the lesson has been exported to your computer.

8. Once you have the spreadsheets from all the devices used in your class, share the results with the James Dyson Foundation at **info@jamesdysonfoundation.com**.

Please note: If you are unable to export the data, collect each group's worksheets that have the listed air quality measurements at each location. Use these worksheets to then manually insert data into a spreadsheet template provided by the James Dyson Foundation.

LESSON 03
SUPPORT SHEET

Use this support sheet to help guide the class through
Worksheet 06: Designing a filter.

Question		Teacher resources
2a	What do you notice about the size of the two pieces of paper compared with the flat paper?	Students should comment on the different heights and lengths of the paper and how that impacts the space they take up.
2b	What has happened to the surface area?	The surface area will remain the same. This can be further explained by asking the students to lay each sheet out flat again, to the size of the original A4 page.
2c	Why is this significant?	When engineers design a filter, they must optimise the number of pleats, pleat pitch and pleat depth to fit into the space constraints of the machine. A flat sheet would mean the final machine dimensions would be very large. A pleated sheet would require greater depth but may allow for smaller dimensions. The filtration team must work with many other teams such as motors, electronics and design engineers to understand how each of the different elements will fit together to produce a final machine that is functional while also being aesthetically pleasing. **Please note:** Increasing the surface area also reduces the pressure drop and face velocity of the filter, so you may choose to elaborate further if appropriate.
3c	Why do you think engineers would want to maximise the surface area of the filter that they create?	Air is pulled into the purifier, through the filter and pushed back out into the room by a motor. Pulling air through the filter requires energy and, as it clogs up with particles, more energy is required to pull the same volume of air through the filter. This can increase the noise of the motor and its energy consumption. Packing as much surface area as possible into the filter results in fewer particles travelling through each unit of filtration media. This means that we can reduce the energy consumption and noise to deliver cleaner air to the room, while also extending the lifespans of both the motor and the filter.
3d	What limitations, apart from space, might there be on the maximum surface area of the filter used?	A smaller pleat pitch would result in an even greater surface area of filtration media. However, filtration media is expensive. Engineers must balance performance with cost to ensure that the final machine is both high performing and commercially viable.