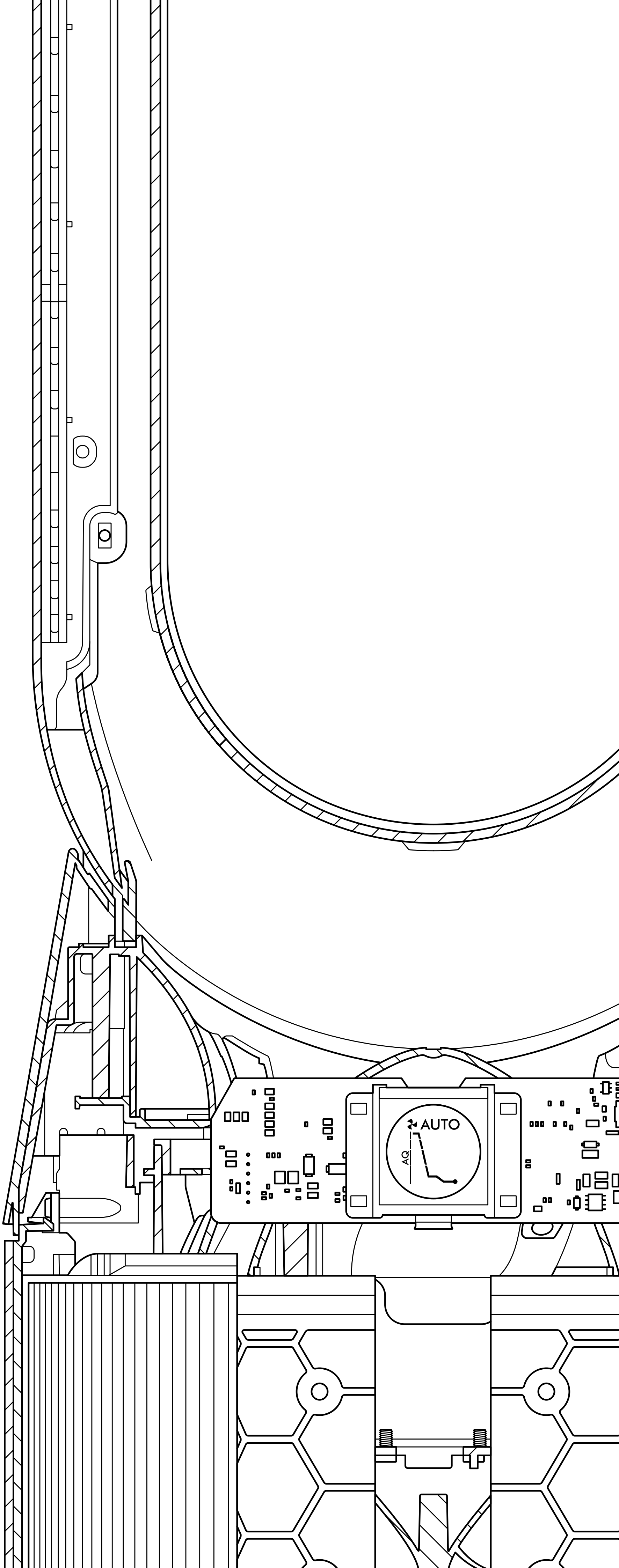
THE JAMES DYSON FOUNDATION

# TEACHER'S PACK

## Southeast Asia Secondary and High School Students

Engineering solutions: Air pollution



# INTRODUCTION

This teacher's pack will introduce your 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, as well as 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 for secondary or high school students.

**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 timetables – 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

**Secondary and High School Students**
Lessons: 05



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

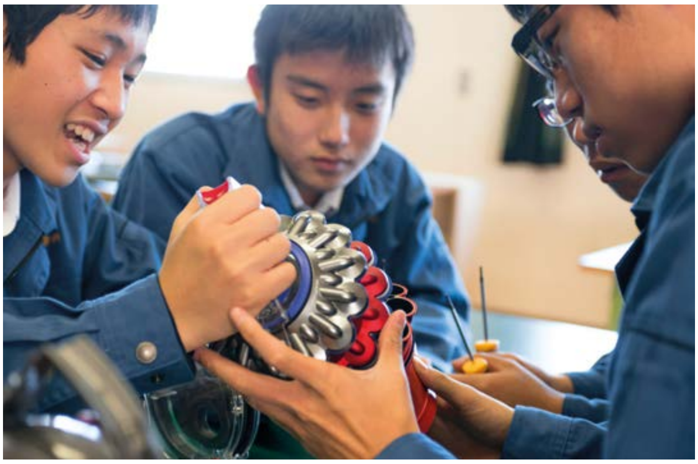
The James Dyson Foundation is Dyson's registered charity. Set up in 2002, it exists to inspire the next generation of engineers through educational resources, workshops and an international design competition.

"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 Health Organisation's (WHO) guideline limits.[1]

### Gas pollution

The air around us is mostly comprised of gases. It is made up of 78% nitrogen, 21% oxygen, and the rest is made up of argon, carbon dioxide and a small amount 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 meter. 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.

[1]Air pollution, World Health Organisation, https://www.who.int/airpollution/ambient/en/

# 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 kilometers 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 kilometers 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 oxide ($NO_2$), 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

### Transport

Road transport 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 tyres, as well as by dust kicked up from road surfaces. They're 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 amounts of gas pollution into the atmosphere.

### Industrial processes

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

### Urbanisation

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 pollution is released from household items such as building materials, cleaning products, pets, candles, plants and aerosols. It is 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 generation


Industrial processes


Exhaust fumes


Urbanisation


Spreading inorganic fertilisers


Burning candles


Cooking fumes


Cleaning products and aerosols

# THE IMPACT OF AIR POLLUTION AND WHY IT'S 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 more at 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 can't 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.

**But engineers have the skills and knowledge to start addressing the problem.**

Man wearing a mask
Beijing

# 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 pupils, 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're 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 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: Air pollution sources**

**Poster: Air pollution magnified**

**Poster: Air pollution size**

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

**Worksheet 01: Support sheet**

**[Option 01]** Sticky tape

**[Option 01]** Microscopes

**[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.<br><br>As a class, discuss why air is important for human life. Ask the class what they think air pollution is.<br><br>Write down the key points on the board.<br><br>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 down 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.<br><br>Bring the class back together to share their ideas. Put up the **Poster: Air pollution sources** and highlight any additional sources that have not yet been identified.<br><br>Were there any that surprised students?<br><br>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.<br><br>There are two options for the next activity, depending on what equipment you have available.<br><br>**Option 01:** Split the students into pairs and give each pair a microscope and two glass slides.<br><br>Give each student a small piece of sticky tape, around 8cm 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.<br><br>Once they have collected the sample ask each student to stick the tape to the bottom of their glass slide.<br><br>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.<br><br>**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.<br><br>Students should note the different sizes of particles. |
| 4 | Display **Poster: Air pollution size.**<br><br>Explain that particles are measured in microns (µm), which is one millionth of a meter.<br><br>Split the class into pairs. Give each pair Worksheet 01. 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.<br><br>Once all students have matched up their squares, discuss the correct description and sources for each pollutant as a class.<br><br>**Extension:** When all the students have matched the pollutants correctly, they can stick the squares down in the correct order to create a poster about the different 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 down the effects air pollution could have on health and the environment. Feed back to the rest of the class and write the suggestions on the whiteboard. |
| 6 | Ask the students to consider some of the challenges in addressing the problem of air pollution. They should identify the following:<br>– Its invisibility<br>– Our lifestyles – many of us rely on things that cause air pollution such as cars and heating<br>– The scale of the problem<br>Explain that in the next lesson students are going to start addressing some of these challenges. |

**Worksheet 01: Support sheet**

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

| | | |
|---|---|---|
| **PM10** | Particles 10μm 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. | Sources:<br>– Black smoke<br>– Soil<br>– Dust from roads and building sites<br>– Pollen<br>– Mould spores |
| **PM2.5** | Particles 2.5μm 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. | Sources:<br>– Bacteria<br>– Fungi<br>– Emissions from coal, gas and oil-powered industries |
| **PM0.1** | Ultrafine particles with a diameter of 0.1μm or less. They are small enough to bypass the lung tissue and enter the bloodstream. | Sources:<br>– Vehicle exhaust emissions<br>– Wood smoke<br>– Tobacco smoke |
| **Volatile Organic Compounds (VOCs)** | A group of gases or airborne liquids that can be toxic. | Sources:<br>– Cigarettes<br>– Paints<br>– Cleaning products<br>– Scented candles<br>– Furniture polish |
| **Formaldehyde** | Known for its distinct and overpowering smell as well as its flammable nature. | Sources:<br>– Mass-manufactured wood products<br>– Varnishes<br>– Paints<br>– Glues |

| | | |
|---|---|---|
| **Nitrogen dioxide – $NO_2$** | A reddish-brown gas with a strong smell that causes smog and acid rain. | Sources:<br>– Diesel car exhaust fumes<br>– Fires<br>– Coal factories<br>– Domestic heating |
| **Carbon monoxide – CO** | An odourless, tasteless and colorless gas. | Sources:<br>– The inefficient burning of fuels in gas and wood-burning heaters |
| **Sulfur dioxide – $SO_2$** | A toxic gas with a strong smell that is emitted by volcanoes. | Sources:<br>– Burning fossil fuels<br>– Volcanoes<br>– Forest fires |
| **Ground-level ozone – $O_3$** | A colorless and highly irritating gas that forms just above the earth's surface. | Sources:<br>– Formed when $NO_2$ reacts with VOCs and sunlight |

# LESSON 02
# MONITORING AIR QUALITY

There are two choices for Lesson 02:

**Lesson 02A** – students will identify air pollution sources 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 doesn't require any additional equipment.

**Lesson 02B** – this lesson requires electronics equipment referred to in the lesson plan.* Students will identify air pollution sources 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.

*All of the equipment required for this lesson can be purchased from a local electronics equipment provider.

# 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 air pollution sources in the school environment.

**4.** Consider air pollution exposure during 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 air pollution sources in the school environment

Completed **Worksheet 02: Air quality around the 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 the 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.<br>As a class discuss the following:<br>– What do air quality monitoring devices allow us to do?<br>– Why are they important?<br>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.<br>Explain that Dyson engineers used air quality monitoring devices to monitor the concentration of air pollution present at six locations at a school. Write the following locations on the board:<br>– Classroom<br>– Canteen<br>– Sports field<br>– School gates (near a road)<br>– Car park<br>– Science lab<br>Ask the students to rank the locations in order of where they expect air quality to be best, and where they expect it to be worst. |
| 2 | Provide each student with **Worksheet 02: Air quality around the school.**<br>Ask the students to complete the worksheet using the data on air pollution provided.<br>Ask the students to feedback 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.<br>Were there any differences? Were the students surprised by the comparison? |
| 3 | Based on their learnings from lesson 01 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:<br>– Dust<br>– VOCs from cooking foods<br>– Food particles from toasters, fryers and grills<br>– Pollen<br>– Vehicle emissions from surrounding roads<br>– Science experiments which use chemicals<br>– D&T classroom materials such as wood and glue<br>– Matter kicked up from the road by cars<br>– Cleaning products<br>– Aerosols such as deodorant |
| 4 | Explain that students will now think about air pollution they are exposed to on their journey to school.<br>Ask students to map their journey on a sheet of paper.<br>Ask them to mark where they might be exposed to air pollution.<br>Discuss the findings as a class and write down 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.<br>**Extension:** 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 **breezometer.com** or **waqi.info.** |

Wrap up: 15 minutes
**Taking action**

| Learning objective | Activity |
|---|---|
| 5 | Split the class in two.<br><br>One half will work in pairs to write down actions they could take to reduce their exposure to air pollution in the school environment. If required, prompt them to think about:<br>– Parents to stop idling outside school gates<br>– Planting trees<br>– Opening windows<br><br>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:<br>– Methods of transport<br>– Choice of route<br><br>Ask the students to feed back to the rest of the class and write a list of actions on the board. Explain that small actions can help reduce exposure to air pollution. |

# LESSON 02B
# BUILDING AN AIR QUALITY MONITORING DEVICE

## Duration: 1 hour 30 minutes

In this lesson students will build an air quality monitoring device to measure air quality around their school. Please note, there are a number of components that you will need to prepare at least two days ahead of this lesson, detailed in Lesson 02B: Support Sheet.

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 air pollution sources 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 indoor air pollution sources in the school environment

Completed build of 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

**Lesson 02B: Support sheet**

**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 below details the components for one device. We recommend allowing for one device per group of five students. This equipment can be sourced from from a local electronics equipment provider as detailed on p16.

| 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.<br>As a class discuss the following:<br>– What do air quality monitoring devices allow us to do?<br>– Why are they important?<br>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
**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.<br>Based on their learnings from last lesson, ask the students to think about potential sources of air pollution in your school. Write their answers on the whiteboard.<br>Split the class into groups depending on the number of devices you have and ask each group to write down six locations around the school (three indoors and three outdoors) where they will sample the air quality. For example:<br>– Classroom<br>– Canteen |

| | |
|---|---|
| 2 | – Science lab/D&T lab<br>– Sports field<br>– School gates (near a road)<br>– Car park<br><br>Ask each group to rank the locations in order of where they expect air quality to be best, and where they expect it to be worst. |
| 3 | Provide each group with **Worksheet 03: Building an air quality monitoring device.**<br><br>Ask the students to follow the instructions on the worksheet to complete the build of the air quality monitoring device in their groups.<br><br>**Extension:** For students who complete their device builds quickly, 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.<br><br>Give each group **Worksheet 04: Data collection.**<br><br>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.<br><br>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 the students have returned to the classroom, give them the **Worksheet 05: Data analysis.**<br><br>Students should complete the graphs displaying their results before answering the questions.<br><br>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:<br>– Windy environment<br>– Good ventilation, such as open windows<br>– Lack of moving or idling vehicles<br>– Rural location<br><br>**Extension:** If desired, students can use the air quality monitoring device to monitor air quality on their journey to and from school, and feed back to the rest of the class in the following lesson. They could record air quality at the following locations:<br>– School car park<br>– School bus stop<br>– The school gates<br>– In the car<br>– Walking along a busy road |

Wrap up: 10 minutes
**Taking action**

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

# LESSON 02B
# SUPPORT SHEET

This support sheet helps you to prepare the equipment for the air quality monitoring device build 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

*In order 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. A code file called **jdf_aqi.ino** will download.

**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 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, 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 7 to 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 (20cm) – one per Arduino
- USB cable type A to C - one per Arduino
- Lithium Ion Battery 3.7V 2000 mAh battery – one per Arduino
- LiPo Rider Plus Charger/Booster – 5V/2.4A 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 to 6 for all kits.

**8.** If using, plug USB Hub into the computer USB port so 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 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 to use.

# SECTION 02: CAPTURE

Students will learn how Dyson engineers developed the Dyson Pure Cool™ purifying fan to help 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 help solve the problem of indoor air pollution. When developing this machine, Dyson engineers identified three main things a purifying fan needs to be able to do:

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.

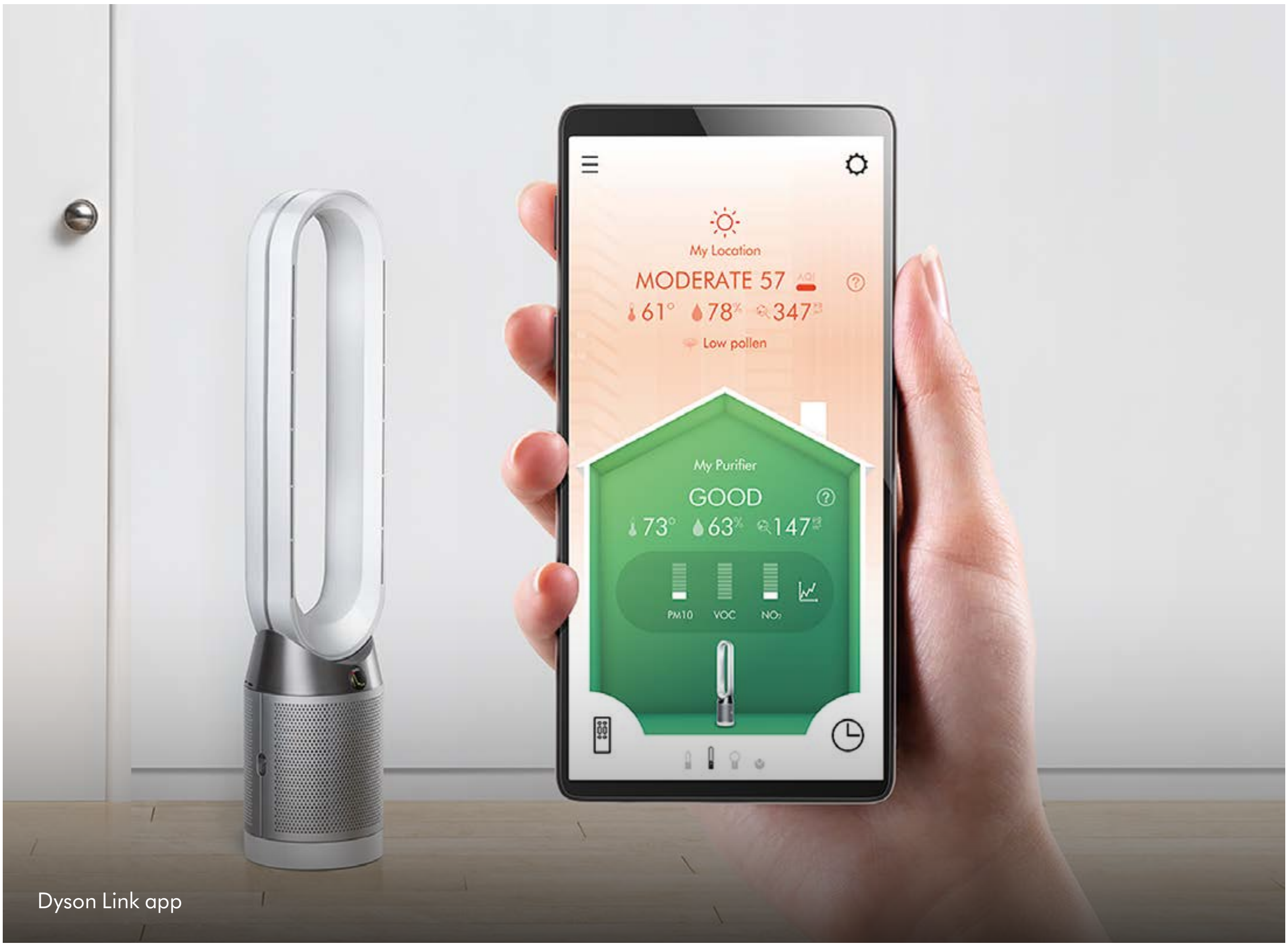
### Gas sensor

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 their purifier is turned on 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 nine meters squared 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 visualised in 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. Because the air can't 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 become 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 instead continue in a straight line, directly colliding with the microfibre and becoming trapped.

### Brownian diffusion

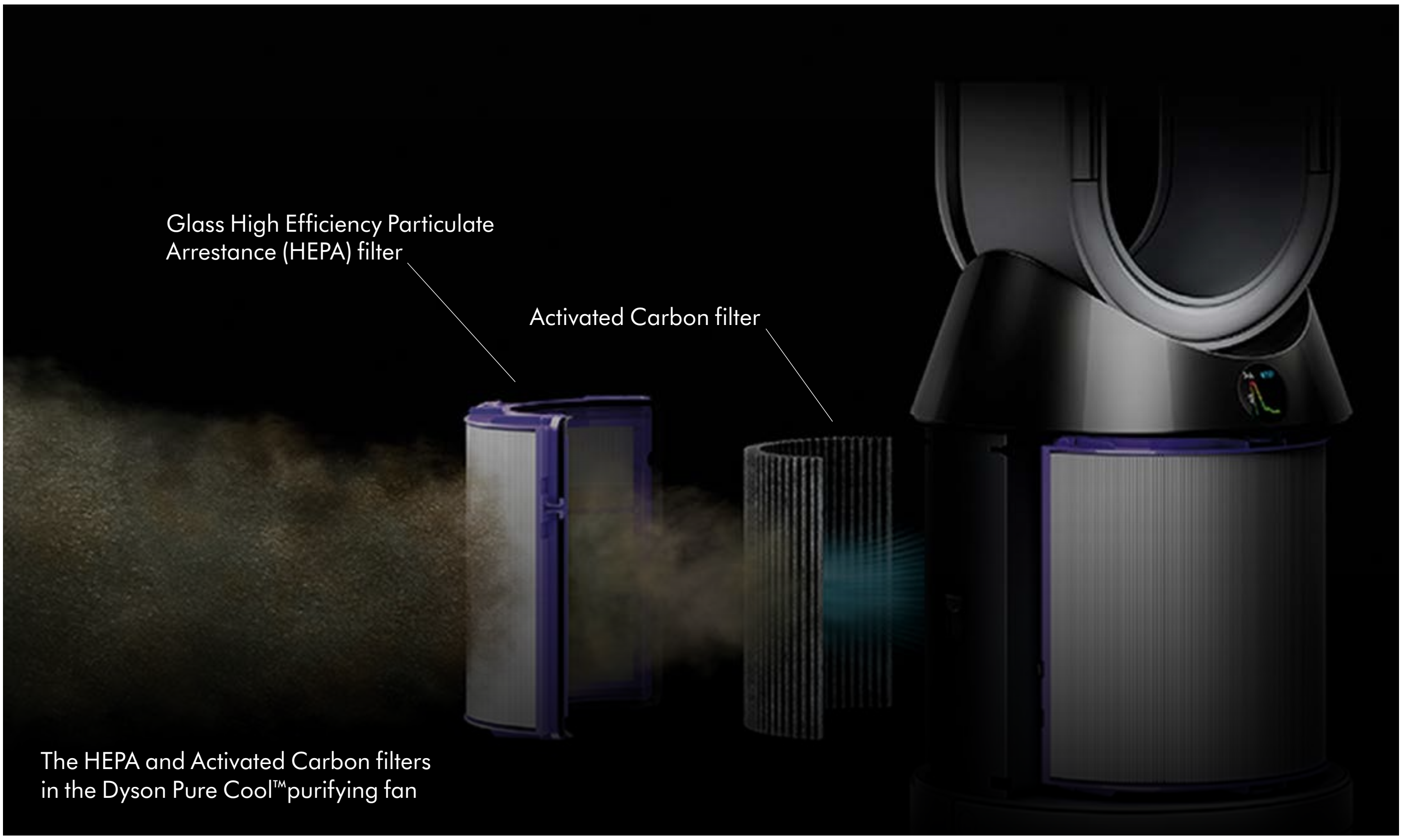
Smaller particles are too small to be pulled along in the air flow. These particles move very fast, often colliding with other particles, which causes them to regularly change direction. This random motion as a result of collisions is known as Brownian motion. With such random motion, probability suggests 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 1,000$m^2$. That's four tennis courts. The Activated Carbon filter in the Dyson Pure Cool™ purifying fan has the same surface area as 40 football fields.

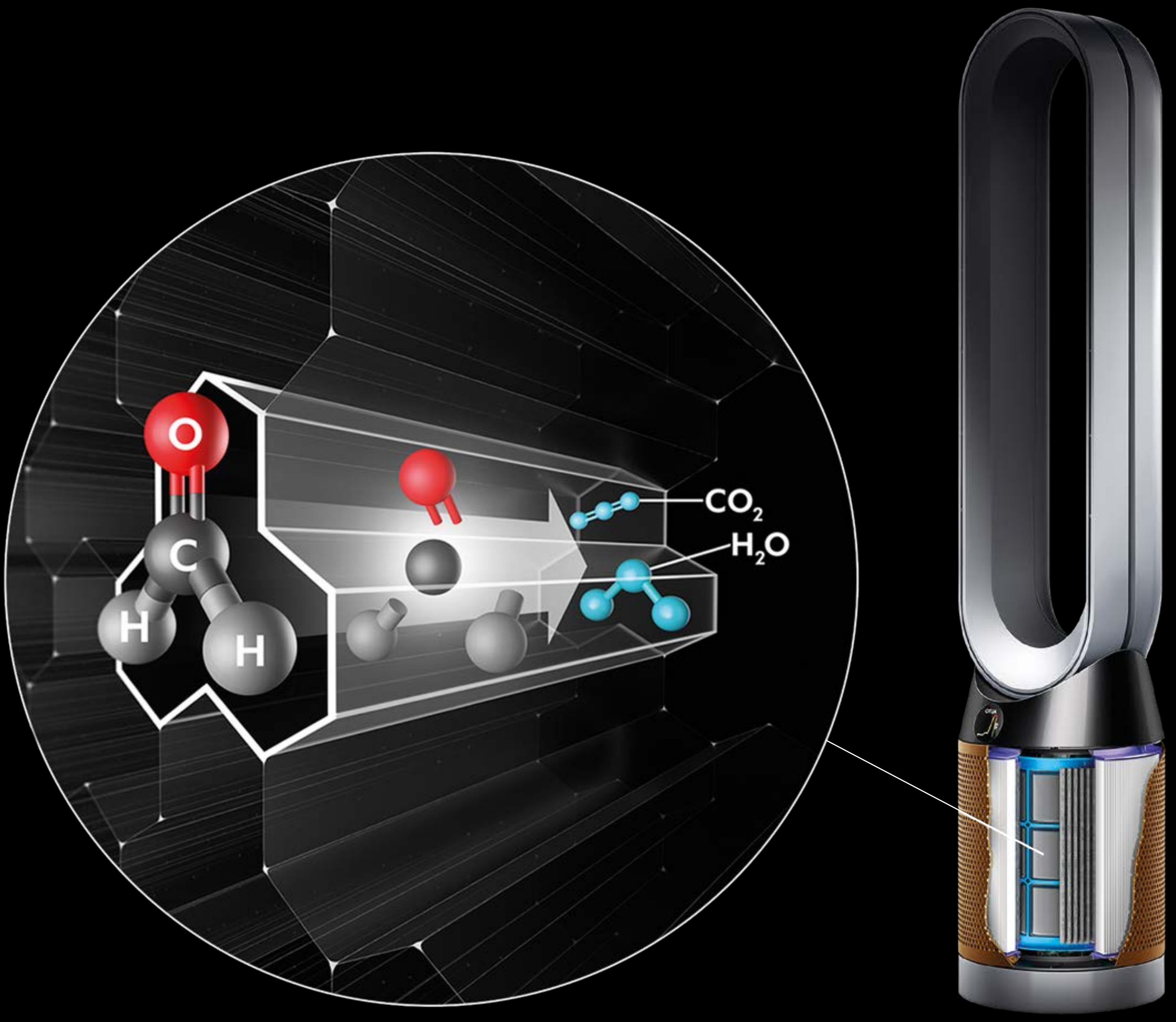



The HEPA and Activated Carbon filters in the Dyson Pure Cool™ purifying fan

### Dyson Cryptomic™ technology

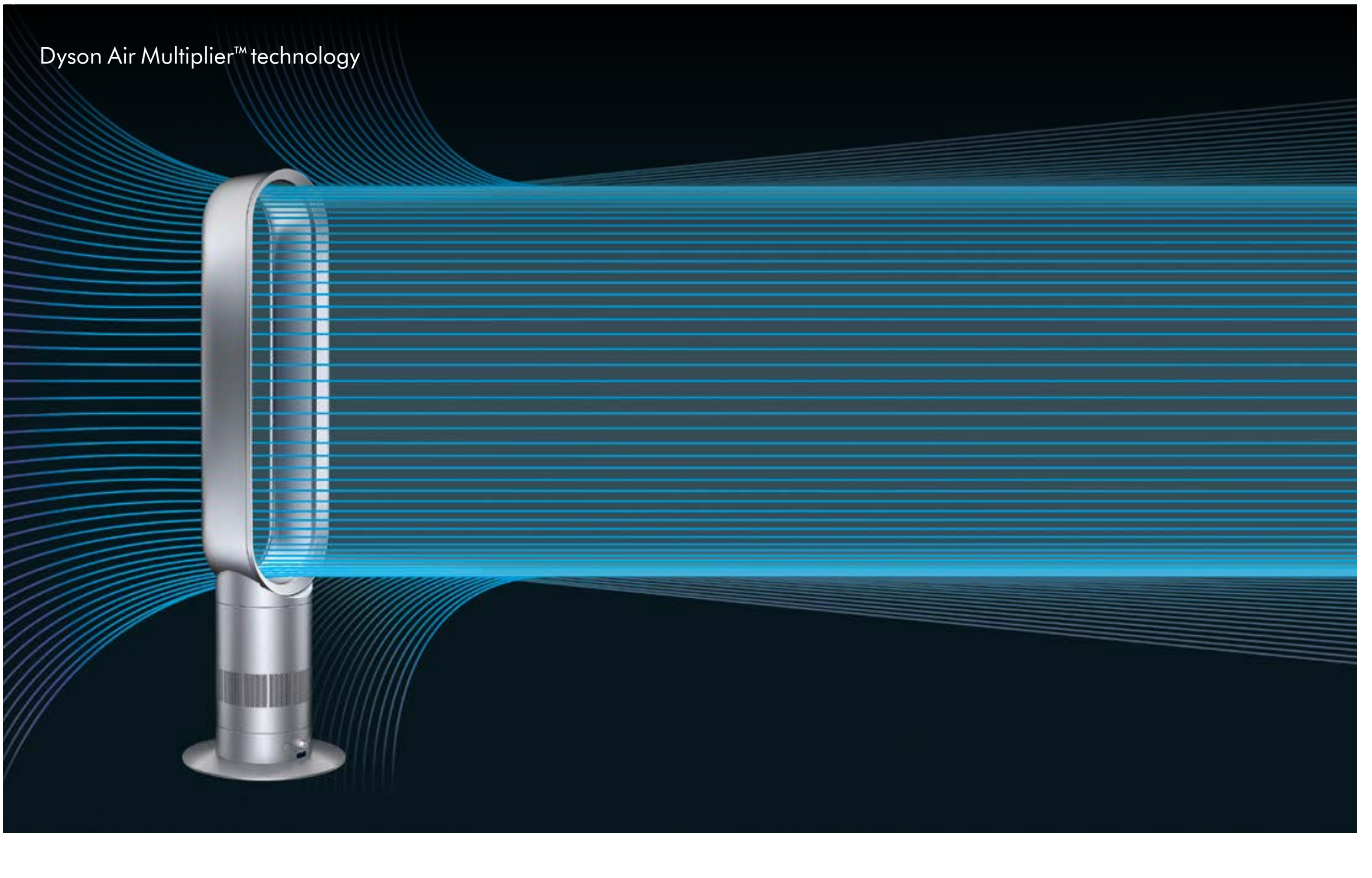
Both the HEPA filter and the Activated Carbon filter have a life span. Eventually, both will become saturated with pollutant particles and gases, and will need to be replaced. For the HEPA filter, this occurs after around six months of use (when the purifier is turned on). For the Activated Carbon filter this normally occurs after six to 12 months. While this is not too much of a problem, as filters can be replaced, Dyson engineers weren't 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 amounts of water and $CO_2$. Unlike the HEPA and Activated Carbon filters, the Crypomelane doesn't get 'used up'. In fact, it will continue to act as a catalyst forever meaning that the Cryptomic filter doesn't 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 a 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's 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**

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**

**Video: Dyson Cryptomic™ technology**

**Poster: Air pollution filtration**

**Poster: Air pollution movement**

**Worksheet 06: Support sheet**

**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

– Clamp stand

– Food coloring

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

| Learning objective | Activity |
|---|---|
| 1 | As a class, watch **Video: Smoke box.**<br>Ask the students to consider what they think happens to the smoke in the box.<br>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.**<br><br>Split the class into five groups and assign each group one set of questions below. Each group should note down their responses on paper to share with the class later.<br><br>**Group one:** Where did Dyson engineers get their inspiration from to develop the purifier? Was the design process easy?<br><br>**Group two:** What two sensors are used in the purifier? Why were these sensors used?<br><br>**Group three**: Consider why more than one filter is used. What do you notice about the way the filters fit together? Why do you think this is?<br><br>**Group four:** What key requirements would Dyson engineers have needed to consider when designing the purifier?<br><br>If required, prompt them to think about:<br>– Size<br>– Noise<br>– Aesthetics<br>– Life span<br>– Materials<br>– Ease of use<br><br>**Group five:** What is the benefit of the LCD screen? What purpose does the accompanying app serve? Is this helpful for the user? Why? What could it do, but doesn't?<br><br>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**<br><br>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.<br><br>Students can work individually or in pairs to complete **Worksheet 06: Designing a filter.**<br><br>Bring the class together to discuss their findings. Use the **Worksheet 06: Support sheet** to help you 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.**<br><br>Students will note that the activated carbon removes some of the food coloring from the water. The food coloring 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.<br><br>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 doesn't get used up.<br>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.<br><br>Explain that developing a product like this is called the iterative design process which allows engineers to improve existing products.<br><br>Ask the students where else 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.<br><br>**Extension:** 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:<br>– What are the benefits of the purifier?<br>– What problems does it solve?<br>– What are its limitations? |

# DESIGNING A FILTER SUPPORT SHEET

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

| Question | | Support notes |
|---|---|---|
| 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 lots of 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.<br><br>**Please note:** Increasing surface area also reduces the pressure drop and face velocity of the filter, so you may choose to elaborate further if appropriate. |
| 3c | Why is this significant? Why do you think engineers would want to maximise the surface area of the filter 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 takes energy and, as it clogs up with particles, more energy is required to pull the same amount of air through the filter. This can increase the noise of the motor, as well as 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 we can reduce the energy consumption and noise to deliver cleaner air to the room, while also extending the life 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. But filtration media is expensive. Engineers must balance performance with cost to ensure the final machine is both high performing and commercially viable. |

# 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 help solve it. They will understand the design process Dyson engineers follow when developing new technology and will follow the design process themselves in order 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 ones, 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 kilo of $CO_2$ per day – equivalent to the $CO_2$ storing capabilities of 20 large trees. It's 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-meter high air purification tower designed to reduce smog levels in cities. It's seven meters 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-meter high mound of soil. The mound of soil absorbs $CO_2$ from the air helping to reduce air pollution levels in Turin, 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 meters of forest. The vertical forest creates a microclimate that absorbs $CO_2$ and dust particles, and releases oxygen.

Smog-Free bike
China

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 help to 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 help 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

Starter: 5 minutes
**Engineering solutions to air pollution**

| Learning objective | Activity |
|---|---|
| 1 | Explain that engineers can develop technology to help solve the global problem of air pollution.<br>Explain that today, students are going to act as engineers and design their own solutions to tackle the problem.<br>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 page 39 to research. Students can find their own existing engineering solution via online research, if preferred.<br>Each group should note down their answers to the following questions:<br>– What is the solution?<br>– How does it work?<br>– Is it an effective solution to air pollution? Why? |

| | |
|---|---|
| | Ask the students to feed back to the rest of the class.<br><br>Discuss the strengths and weaknesses as a class. |
| 3 | Put up **Poster: The design process.**<br><br>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 parameters in which a design engineer must work. For example, a product might need to be a certain size or perform a particular function.<br><br>Explain that when working on the brief, design engineers follow the design process, which has three stages: design, build, test.<br><br>Engineers repeat the design process numerous times when developing a single product. This makes it a circular, or iterative process.<br><br>Ask the students why they think 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.<br><br>In this lesson they will undertake the first stage of the design process: Design.<br><br>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.**<br><br>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:<br><br>– Users<br>– Function<br>– Materials<br>– Safety<br>– Aesthetics<br>– Cost<br><br>Remind the students of the materials that will be available to them when building the prototype and to have them in mind when designing.<br><br>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, assigning roles and responsibilities. |

# LESSON 05
# PROTOTYPING 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 up material 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.<br>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.<br>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 material 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.<br><br>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:<br>– The problem<br>– The solution<br>– How it works and why it is better than existing solutions<br>– Who will use it<br><br>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.<br><br>**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 come in and meet the students – and even judge the best prototyped solution. |

# WORKSHEET 01: AIR POLLUTANTS AND THEIR SOURCES

This worksheet contains the name, description and sources of pollutant. Cut out the squares and match the pollutants to their description and sources.

| | | |
|---|---|---|
| **PM10** | 2.5µm 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 | **Formaldehyde** |
| **Nitrogen dioxide – $NO_2$** | A colorless 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:<br>– Mass-manufactured wood products<br>– Varnishes<br>– Paints<br>– Glues |
| Sources:<br>– Bacteria<br>– Fungi<br>– Emissions from coal, gas and oil-powered industries | **PM0.1** | **Volatile Organic Compounds (VOCs)** |
| Sources:<br>– Formed when $NO_2$ reacts with VOCs and sunlight. | 10µm 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, some can impact breathing and have long-term health effects. | Sources:<br>– Cigarettes<br>– Paints<br>– Cleaning products<br>– Scented candles<br>– Furniture polish |
| Sources:<br>– Black smoke<br>– Soil<br>– Dust from roads and building sites<br>– Pollen<br>– Mould spores | **PM2.5** | A group of gases or airborne liquids that can be toxic. |
| Ultrafine particles with a diameter of 0.1µm or less. They are small enough to bypass the lung tissue and enter the bloodstream. | Sources:<br>– The inefficient burning of fuels in gas and wood-burning heaters | A reddish-brown gas with a strong smell that causes smog and acid rain. |
| **Sulfur dioxide - $SO_2$** | An odourless, tasteless and colorless gas. | Sources:<br>– Diesel car exhaust fumes<br>– Fires<br>– Coal factories<br>– Domestic heating |
| **Carbon monoxide - CO** | A toxic gas with a strong smell that is emitted by volcanoes. | Sources:<br>– Burning fossil fuels<br>– Volcanoes<br>– Forest fires |
| Known for its distinct and overpowering smell as well as its flammable nature. | **Ground-level ozone - $O_3$** | Sources:<br>– Vehicle exhaust emissions<br>– Wood smoke<br>– Tobacco smoke |

# WORKSHEET 02: AIR QUALITY AROUND SCHOOLS

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

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

**Air quality readings around the school**

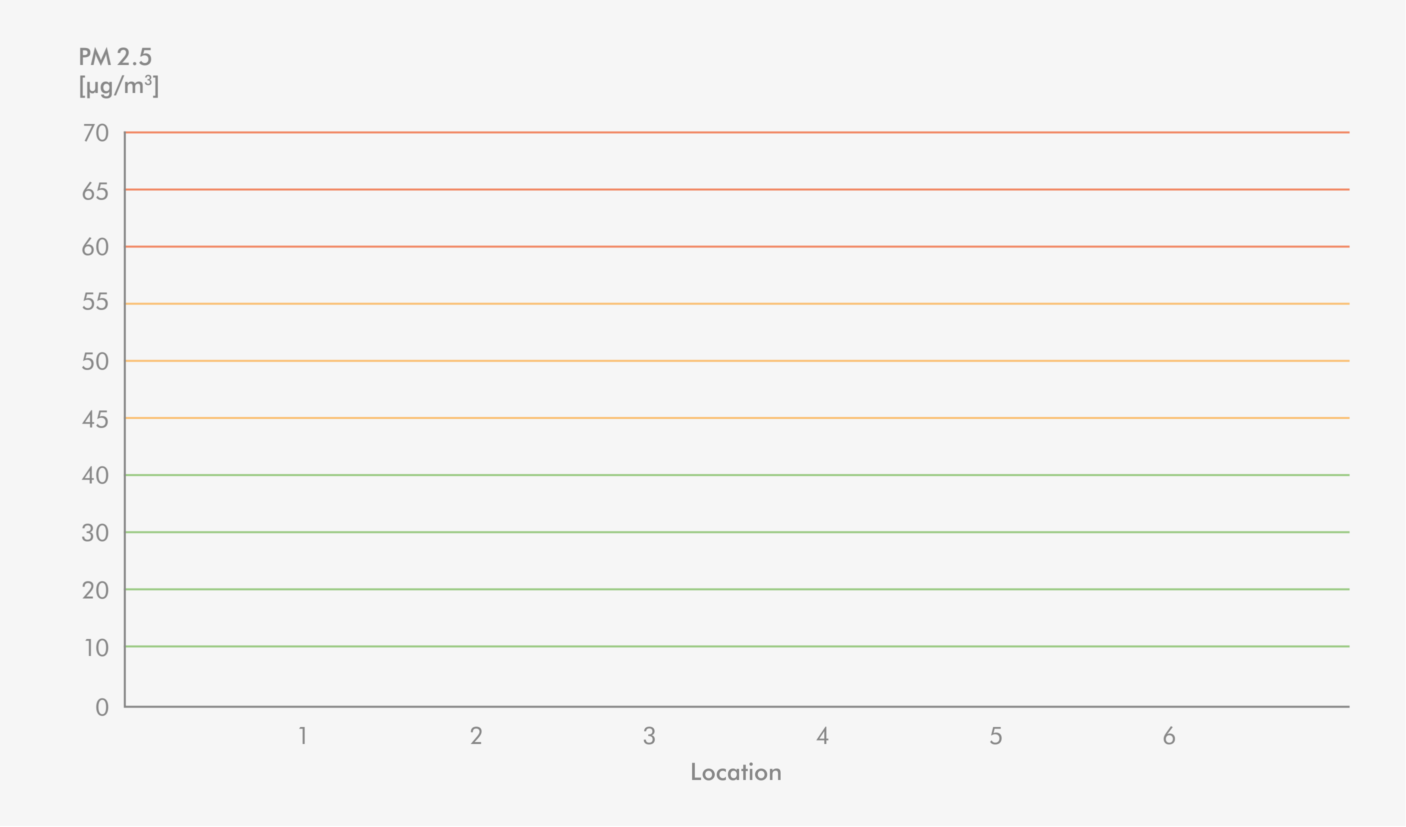
| Location | Particulate sensor (number of LED lights) | Gas sensor (number of LED lights) |
|---|---|---|
| 1. Classroom | 4 | 2 |
| 2. Canteen | 6 | 6 |
| 3. Sportsfield | 3 | 4 |
| 4. Schools gates | 5 | 7 |
| 5. Car park | 3 | 5 |
| 6. Science lab | 4 | 6 |

**Air quality index**

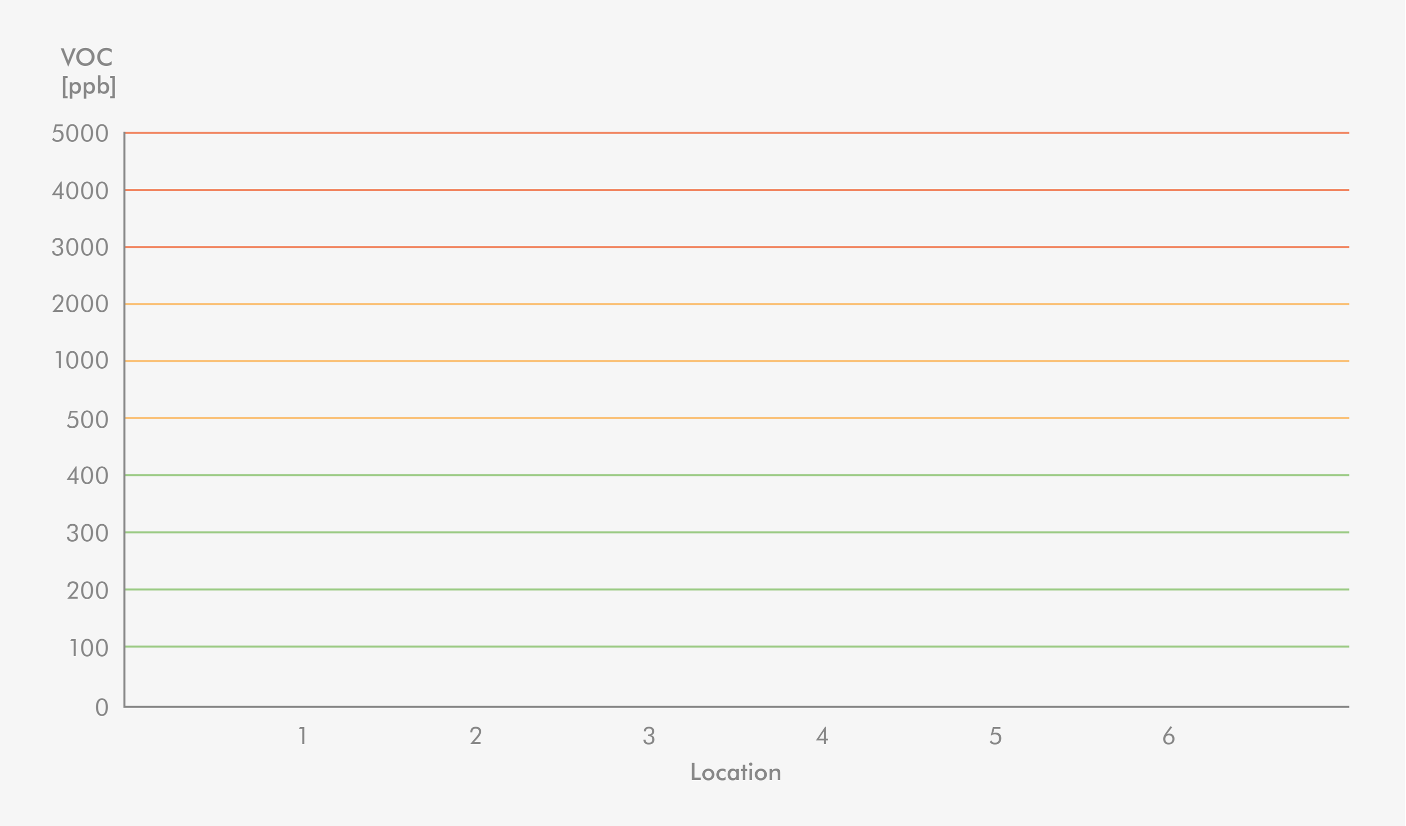
| Air quality | Number of LED lights | Particulate (µg/m3)* | Gas (ppb)** |
|---|---|---|---|
| Very bad | 10 | 70 | 5000 |
| | 09 | 65 | 4000 |
| | 08 | 60 | 3000 |
| | 07 | 55 | 2000 |
| Moderate | 06 | 50 | 1000 |
| | 05 | 45 | 500 |
| Good | 04 | 40 | 400 |
| | 03 | 30 | 300 |
| Very good | 02 | 20 | 200 |
| | 01 | 10 | 100 |

* (µg/m$^3$) = micrograms of particulate pollution per cubic meter of air
** (ppb) = parts per billion of gas pollution

Graph 01 – Particulate pollution




Graph 02 – Gas pollution



3. Use the graphs to answer the following questions.

| Which location had the worst air pollution? |
| --- |
| |

| Which type of pollution was worse here – gas or particulate? |
| --- |
| |

| What could be causing this pollution? |
| --- |
| |

| How did air pollution levels change from inside to outside? |
| --- |
| |

| Did any of the results surprise you? |
| --- |
| |

# 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.

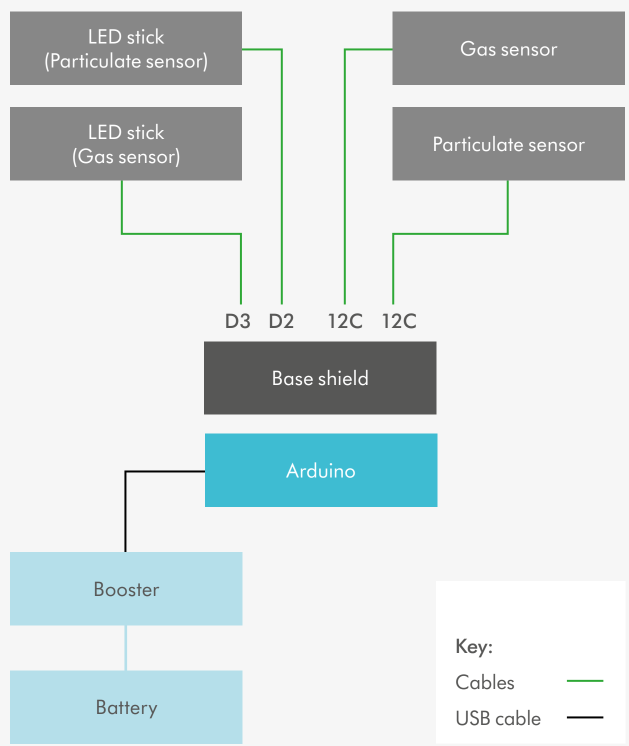
| Equipment list for one device | Quantity |
|---|---|
| Arduino | 1 |
| Base shield | 1 |
| Cable | 4 |
| LED stick | 2 |
| Particulate sensor* | 1 |
| Gas sensor ** | 1 |
| Battery | 1 |
| Booster | 1 |
| USB cable | 1 |

* 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 final 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:**



# 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 stick stay the same.

**4.** Record the number of LED lights on each 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 |
| Bad | 08 |
| | 07 |
| Moderate | 06 |
| | 05 |
| Good | 04 |
| | 03 |
| | 02 |
| Very good | 01 |

**Data collection**

| Location | Particulate sensor (number of LEDs) | Gas sensor (number of LEDs) |
|---|---|---|
| 1. | | |
| 2. | | |
| 3. | | |
| 4. | | |
| 5. | | |
| 6. | | |

# WORKSHEET 05:
# DATA ANALYSIS

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

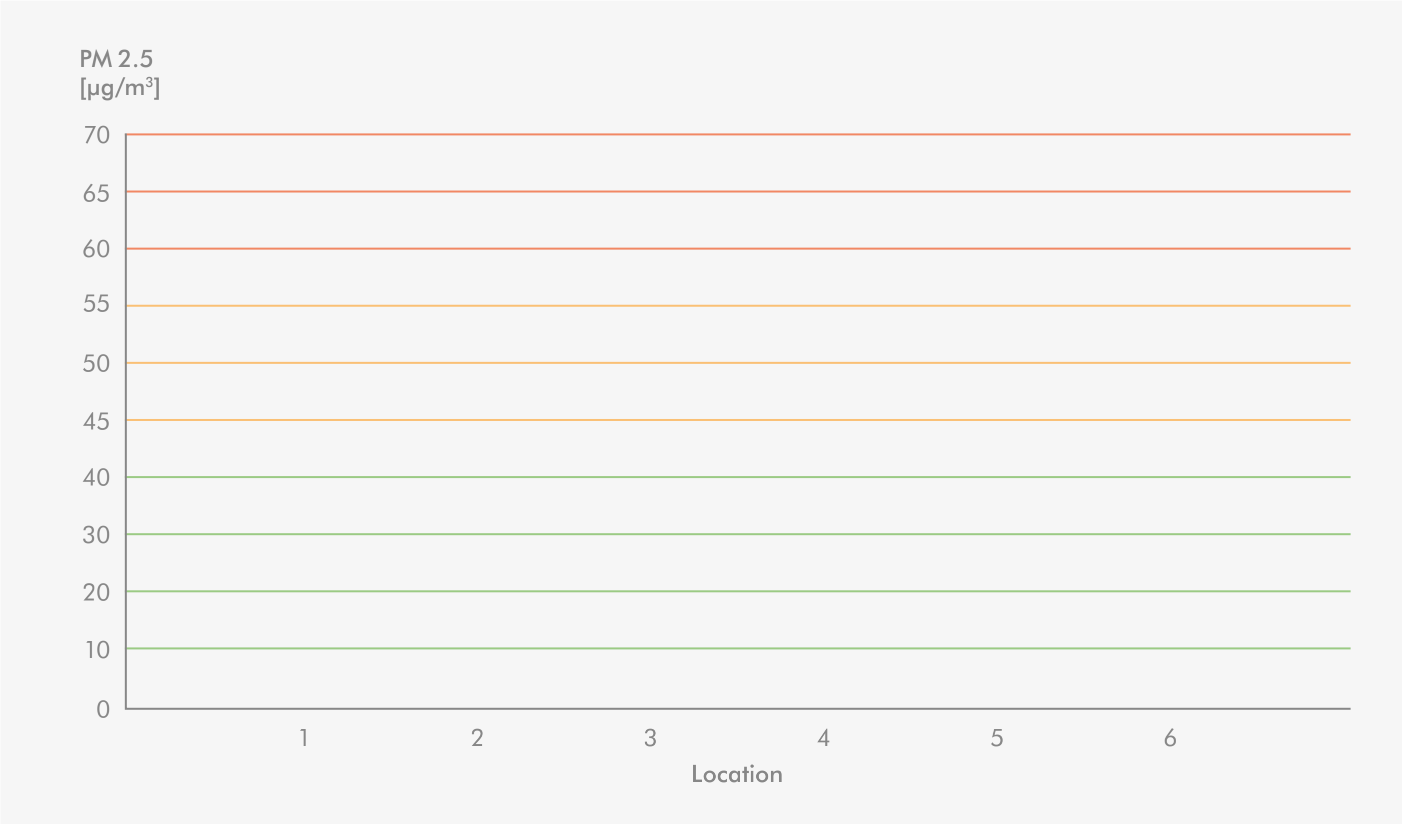
**2.** Plot the concentration of gas pollution at each location, referring to the air quality index, on Graph 2.

**Air quality index**

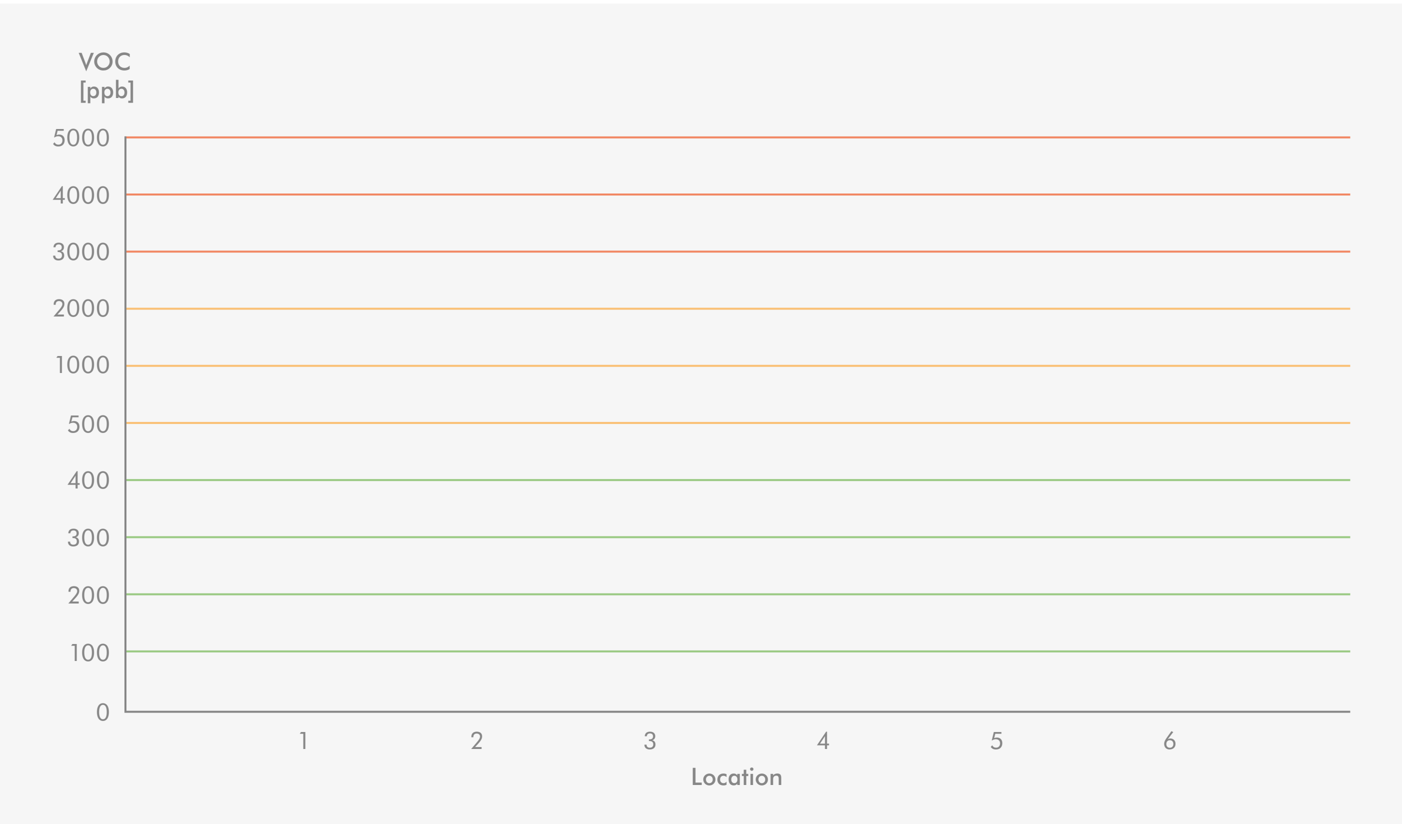
| Air quality | Number of LED lights | Particulate (µg/m3)*) | Gas (ppb)** |
|---|---|---|---|
| Very bad | 10 | 70 | 5000 |
| | 09 | 65 | 4000 |
| | 08 | 60 | 3000 |
| | 07 | 55 | 2000 |
| Moderate | 06 | 50 | 1000 |
| | 05 | 45 | 500 |
| Good | 04 | 40 | 400 |
| | 03 | 30 | 300 |
| Very good | 02 | 20 | 200 |
| | 01 | 10 | 100 |

* (µg/m³) = micrograms of particulate pollution per cubic meter of air
** (ppb) = parts per billion of gas pollution

Graph 01 – Particulate pollution




Graph 02 – Gas pollution



4. Use the graphs to answer the following questions.

| Which location had the worst air pollution? |
|---|
| |

| Which type of pollution was worse here – gas or particulate? |
|---|
| |

| What could be causing this pollution? |
|---|
| |

| How did air pollution levels change from inside to outside? |
|---|
| |

| Did any of the results surprise you? |
|---|
| |

# WORKSHEET 06:
# DESIGNING A FILTER

Engineers are often given specifications to work to for elements such as size, cost and performance. 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 pages 56–57.

**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 2cm intervals. Pleat a second piece of A4 paper at 5cm 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 L) x 2)**

**a.** If your pleat height is 2cm and your pleat pitch is 1cm, what is the maximum surface area you can achieve in the space of 21cm x 30cm?

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

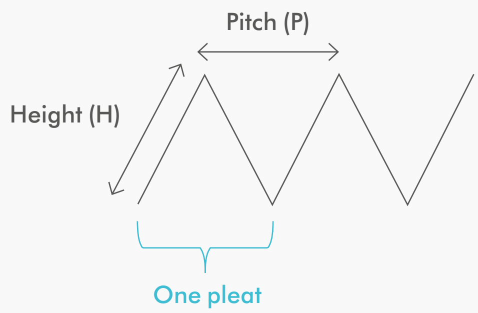
**b.** How many A4 sheets of paper would this use?

**c.** Why do you think engineers would want to maximise the surface area of the filter 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


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



| 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 it significant? |
|---|
| |

| 3a. If your pleat height is 2cm and your pleat pitch is 1cm, what is the maximum surface area you can achieve in the space of 21cm x 30cm? |
| --- |
| |

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

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

| 3d. What limitations, apart from space, might there be on the maximum surface area of the filter used? Why is this significant? |
| --- |
| |

# WORKSHEET 07: ACTIVATED CARBON EXPERIMENT

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

**Materials**

2 glass beakers

Small glass funnel

Circular filter paper

Activated carbon/charcoal granules

Clamp stand

Food coloring

**Procedure:**

**1.** Label the beakers A and B.

**2.** Fill beaker A with 100ml of water.

**3.** Add 5 drops of food coloring to beaker A. Note down the color of the water in the beaker below.

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

**5.** Attach the glass funnel to the clamp stand above beaker B.

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

**7.** Pour the colored water from beaker A into the funnel so 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 color of the water and food coloring mixture in beaker A before it is poured through the activated carbon.

2. Describe the color of the water and food coloring mixture in beaker B after is has passed through the activated carbon granules.

3. Describe what happened in the experiment.

4. Why do you think this happened?