Oxford Sparks

Key Stage 3 – What is the nanoscale?

Notes for teachers

At a glance

Scientists at the University of Oxford are trying to understand how electricity behaves when it travels inside tiny, molecular sized components. Students explore some of the reasons why scientists use SI units and become more familiar with the SI units for very small objects, particularly nanometres.

Learning Outcomes

- Students will be able to give reasons why it is useful for scientists to use standard SI/Metric units.
- Students will recognise that different units are appropriate for different sized objects.
- Students will be able to perform simple conversions between nm and metres.

Each student will need

- Student Worksheet
- Ruler marked with cm and mm
- Paperclip, pencil and sheet of A4 paper to measure
- Order of size cards

Possible Lesson Activities

1. Starter activity

- Ask the students to identify/guess what the following units are used to measure:
  Hand, Fathom, Cubit, League, Yard, Metre.
- In fact, they are all different units of length
  - Hand (about 10cm), based on the width of a human hand and still used to measure the heights of horses.

  - Fathom (about 1.8m), used to measure depth, usually of water. It is possibly based on the distance between two outstretched hands.
  - Cubit (about 46cm), ancient unit of measure used in Egypt and also mentioned in the Bible (e.g., Noah's ark has measurements given in cubits). The length from the elbow to the tip of the finger.
  - League (a bit less than 5km), 3 miles based on the distance someone could walk in an hour.
  - Yard (91cm), imperial measure that is probably based on the length of a stride.
  - Metre (exactly 1m!), metric or SI unit of distance.

- Encourage students to reflect on the fact that many of these units depend on the dimensions or other attributes (walking speed) of individual people. Would these be consistent? What might the consequences be if people were using different measurements from each other (e.g., when buying a length of cloth or building a railway line?).
- Ask students to measure the width of their hands with a ruler. It may be easier to do this by putting their hand on a piece of paper and marking the distance to be measured on the paper. Then compare results from the class – what was the highest value, what was the lowest? Does it make a big difference if you include the teacher or other adult's hand in the data? If you were using this as a unit of measurement how consistent would it be?
- [Optional] How close is the average of these measurements to 4" – the official definition of a hand?
- [Optional] There is plenty of scope here to do additional work on collecting data, calculating averages, representing data and identifying sources of error, etc.
- In fact, most of the measures above were standardised to keep things consistent and fair, but different countries, for instance, would have different measurements.
- In the UK, some of the basic units for lengths were the inch, foot, and yard. Students will probably be familiar with feet and inches in the context of height. However doing maths with inches, feet and yards was tricky because there were 12 inches in a foot, and 3 feet in a yard. Doing maths with a decimal system such as the metric system is far easier. For example, working out how many inches in 5 yards is much harder than working out how many cm there are in 5m. [5 yards = 15 feet = 15x12 inches = 180 inches].
- Scientists throughout the world now use an international system of units (SI Units). The SI unit of length is the metre, m. This means that scientists can easily and confidently compare results of experiments all over the world and know their results mean the same thing. See link about a mistake caused by scientists and engineers using different measurement systems when working on a Mars Probe.
- The SI system is also a decimal system.
- This doesn't just apply to length. For instance, the SI unit for mass is the kilogram (kg) and for time is the second (s).

2. Main activity: SI Prefixes

- Ask the students to decide which metric units would be the most appropriate for measuring the following **[answers in brackets]**:
  1. The distance from the school to the nearest train station **[km]**

2. The height of a room **[m or possibly cm]**
3. The length of a pencil **[cm or possibly mm]**
4. The width of a little finger nail **[mm or possibly cm]**
5. The width of a human hair **[µm – micrometres]**

- The Micrometre will probably be an unfamiliar unit. If it is, let them know that there are 1000 micrometres in a mm (a million in a metre). Although we use the other measurements relatively frequently, in everyday life we would rarely need to use micrometres. However scientists often have to study objects of this size and smaller.
- Give students the student worksheet and ask them to work through the tasks.
- The final two questions require student to apply their knowledge based on the prefixes used for metres to different units (familiar and unfamiliar)
- [Optional] Ask the students to create a matching game e.g., Snap or Dominoes using the same measurements in different units, e.g., 100nm would match with 0.1µm, 1m with 1000mm, etc.

3. Main activity: Orders of Magnitude

- Give students, in pairs or small groups, a set of size sort cards (see below) and ask them to arrange them in order from smallest to largest. They could either just order the cards or, additionally, try to match each card to a size in nm.
- Ask one pair to show the rest of the class the order they chose. Then ask the other students to compare their order with this order. Are they the same? Can they justify why the order they chose is different (e.g., A water molecule is probably bigger than a helium atom because a water molecule is made of three atoms).
- Reveal the answers and ask the students to reorder their objects as necessary. Alternatively, ask the students to research the sizes of the objects on the cards to allow them to order them correctly. N.B., Sizes given for most of these objects vary, but the order should stay much the same.

4. Plenary

- As mentioned earlier, many scientists work on objects that are on the nanoscale. The Oxford Sparks 'How does electricity flow through small objects?' animation shows work that is currently being carried out at the University of Oxford (see weblinks).
- Ask the students to watch the animation. What clues are there in the video that the scientists are working with very small objects? (Example include: It talks about nanoscale, electrons, atoms, etc., and shows scientists using a microscope).
- Ask the students to discuss what advantages they think having very small components for computers might have. E.g., possible advantages – require far less energy (mentioned in video), can make existing computers smaller (so we could fit a more powerful computer in a smart phone, for instance).

Weblinks

- Interactive web page showing objects of different sizes from viruses to a pinhead
  http://www.cellsalive.com/howbig_js.htm

- Oxford Sparks ‘How does electricity flow through small objects’ animation https://youtu.be/wF13tGIrzA8
- When conversions go wrong – story about the mars probe failure due to two different measurement systems being used. http://news.bbc.co.uk/1/hi/sci/tech/462264.stm

Example answers to questions on student sheet:

Object	**cm**	**mm**	**µm**	**nm**
Length of pencil/pen*	15	150	150 000	150 000 000
Width of A4 Paper	21	210	210 000	210 000 000
Length of paper clip*	2.5	25	25 000	25 000 000

*These will depend on the specific pen/paperclip used, but sizes should be similar.

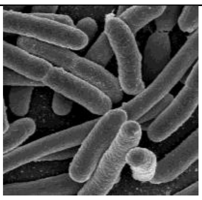
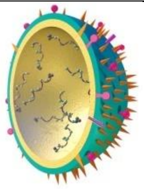
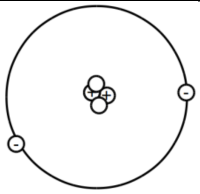
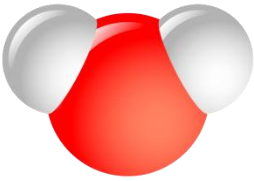
Object	Measurement	Measurement in m
Diameter of a 1p coin	20.3mm	0.0203
Thickness of a 10p coin	1.85mm	0.00185
Size of a flu virus	100nm	0.000 000 1
Thickness of a sheet of paper	65µm	0.000 065

- Height in nm? 1.5m is 1 500 000 000 nm
- There are one million µg in a g
- 8 650 000 nT = 0.00865T

Answers for Size Sort Cards (see next page)

In order of size from smallest to largest:
Helium atom (0.03nm);
Water molecule(0.1nm);
DNA diameter(2nm);
Flu virus(100nm);
E Coli bacteria(1000nm);
Forget-me-not-pollen(6000nm);
Human hair diameter(100 000nm);
Pin head(1 500 000nm);
Ant(10 000 000 nm);

Size Sort Cards for students (cut up before use)

 ***E Coli Bacteria***	 ***Pin Head*** ***(diameter)***	 ***DNA (diameter)***	 ***Flu Virus***
 ***Leaf cutter ant (length)***	 **He** ***Helium Atom***	 ***Human hair (diameter)***	 ***Forget-me-not pollen***
 **H_2O** ***Water Molecule***	***Create your own***	***Create your own***	0.03nm
0.1nm	2nm	100nm (0.1µm)	1,000nm (1 µm)
6,000nm (6 µm)	100,000nm (100µm)	1,500,000nm (1.5mm)	10,000,000nm (10mm)