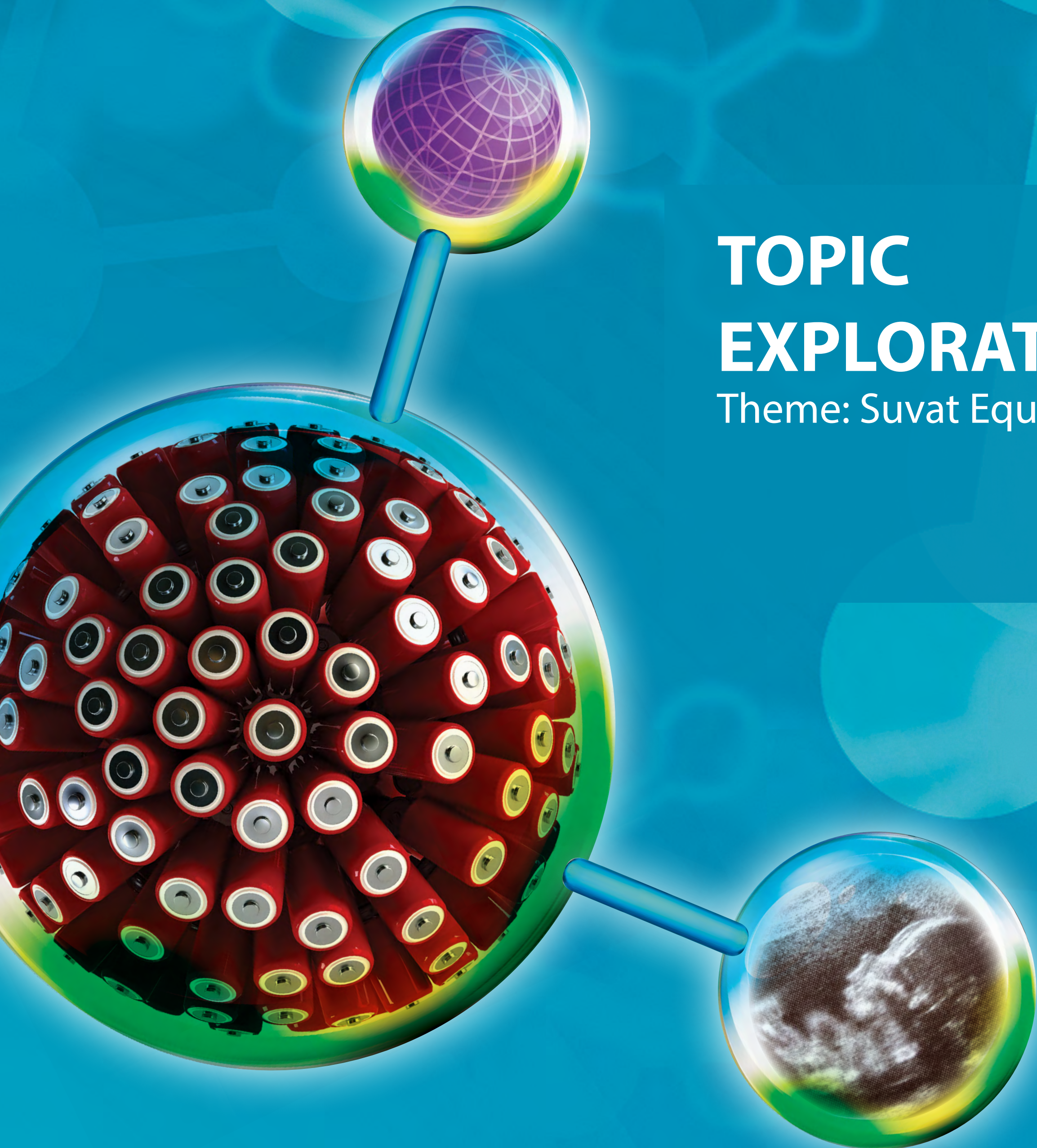
TOPIC EXPLORATION PACK

Theme: Suvat Equations



A LEVEL PHYSICS A AND B

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Contents

This Topic Exploration Pack should accompany the OCR resource ‘Suvat Equations’ learner activities, which you can download from the OCR website.

This activity offers an opportunity for maths skills development.

Introduction

KS4 Prior Learning

- Average Speed = Distance/Time
- Acceleration=Change in Speed/Time
- Gradient of a distance-time graph is speed
- Area underneath speed-time graph is distance travelled
- Gradient of a speed-time graph is acceleration
- Understand that the velocity of an object is its speed combined with its direction
- Convert between km and miles, seconds and hours etc.
- Calculate the gradient of a line segment
- Calculate areas of triangles and trapeziums

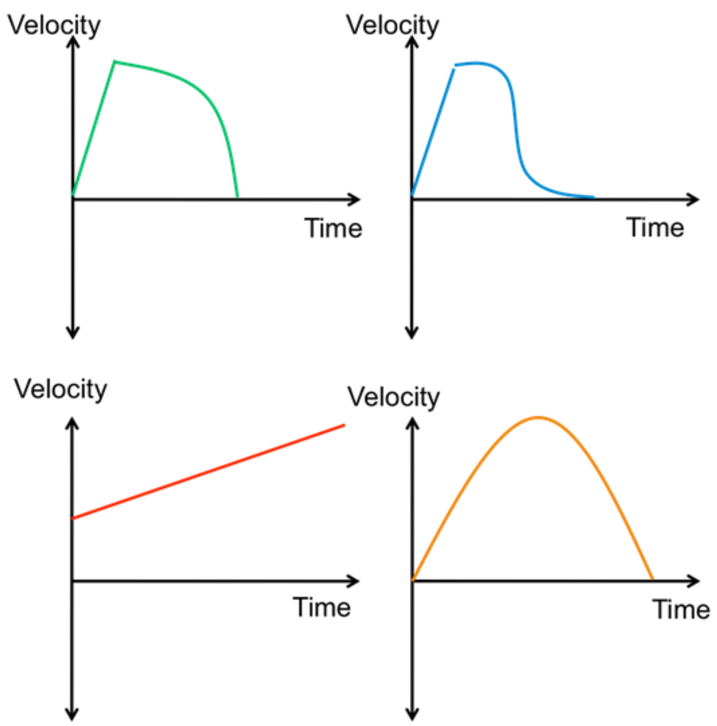
KS5 Knowledge

Remember and use the suvat formulae for constant acceleration:

- $v = u + at$
- $s = \frac{1}{2}(u + v)t$
- $s = ut + \frac{1}{2}at^2$
- $s = vt - \frac{1}{2}at^2$
- $v^2 = u^2 + 2as$

Delivery

A usual way of delivering the suvat equations is to start from their knowledge of velocity-time graphs. You could start with having the following four graphs displayed on a whiteboard:

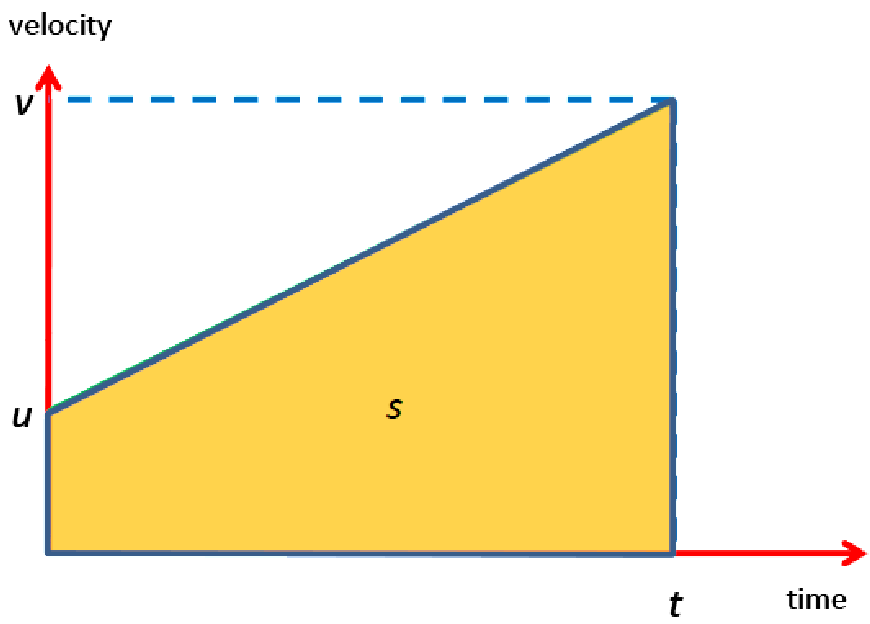


You could ask the questions:

- Which graph shows an object starting from rest and finishing at rest?
- Which three graphs show elements of constant acceleration?
- Which graph is solely constant acceleration?
- Describe the motion of each of the objects in the graphs?

From here initial misconceptions can be drawn out and also what level of understanding the students already have in this area. It may be wise to spend a bit of time looking at areas underneath speed-time graphs and calculating gradients. See **Activity 1** for a possible activity for this.

Once the prior knowledge has been established the suvat equations can be derived in their standard form. The starting point is a velocity-time graph as below:



The gradient represents the acceleration. From this simple fact we can write:

$$a = \frac{v - u}{t}$$

Which can be rearranged to make:

$$\boldsymbol{v = u + at}$$

This is the first suvat equation. The second equation can be found by knowing that the area underneath the graph is the distance and is a trapezium:

$$Area = \frac{1}{2}h(a + b)$$

Where *a* and *b* are the parallel sides and *h* is the length between them. Translating this to our diagram means:

$$\boldsymbol{s = \frac{1}{2}(u + v)t}$$

Alternatively the area can be thought of as a triangle (1/2 base x height) + a rectangle (base x height). In which case we can write:

$$s = ut + \frac{1}{2}(v - u)t$$

This isn't a useful suvat equation but we can replace $(v - u)$ by at from the first equation that was derived and then we get:

$$\boldsymbol{s = ut + \frac{1}{2}at^2}$$

If we wish to have an equation involving *v* instead of *u* we can replace *u* by *v* - *at* from the first equation and we get:

$$\boldsymbol{s = vt - \frac{1}{2}at^2}$$

Finally we want an equation for *u*, *v*, *a* and *s* not involving time. Rearranging the first equation for *t* we get:

$$t = \frac{v - u}{a}$$

Substituting this expression into $s = \frac{1}{2}(u + v)t$ we have:

$$s = \frac{1}{2a}(u + v)(v - u)$$

Which can be rearranged to:

$$\boldsymbol{v^2 = u^2 + 2as}$$

And this completes the set of the suvat equations. Each equation has 4 variables with one of the other variables absent. Together they form a complete set for finding out any of the variables in a constant acceleration problem. Students can be guided through this activity using **Activity 2**.

Having derived the formulae it remains to practise applying them to actual questions. The following activities act as a scaffolded approach to ensure students have gained the knowledge and apply these formulae correctly:

Activity 1 – Speed-Time Graphs

Resources: Activity Sheet 1

Instructions: Hand out a copy of activity sheet 1 to the students. Ask them to calculate the acceleration and distance travelled for each section of the graph by calculating the gradient and area underneath the graph. You may wish to provide them with the following formulae:

- $Gradient = \frac{Change\ in\ y}{Change\ in\ x}$
- $Area\ of\ triangle = \frac{1}{2} base \times height$
- $Area\ of\ trapezium = \frac{1}{2} h(a + b)$

Pedagogy: This could be used as a starter activity to assess initial knowledge and to ensure that students understand how to interpret a velocity-time graph.

Timing: This should take about 20 minutes to complete as an initial starter activity. For an extension students could be asked to write a 'story' for the motion of the object – they can use their imagination as much as possible for this one!!!

Activity 2 – Derivation

Resources: Activity Sheet 2

Instructions: From the graph shown above students are guided by a series of questions to derive the suvat formulae.

Pedagogy: This is a challenging activity and may be used as an extension task or 'pre-learning' task prior to the lesson. It may be that after deriving the formulae to the whole class in this way it may be worthwhile handing this sheet out to see if students can replicate the derivation. Knowing the derivation is far more powerful than just remembering the formulae by rote. To understand how they are derived takes more work but requires less memory in the long run.

Timing: This should take about 20 minutes.

Activity 3 – Rearrangement

Resources: Activity Sheet 3 (2 per page)

Instructions: For each row there is only one correct rearrangement of a suvat equation. Students have to decide which one is the correct one and then write a detailed working out from the equations in their original form. Students also have to explain why the incorrect ones are incorrect. What mistake has been made?

Pedagogy: This could be used as a starter activity after an initial lesson on suvat equations or could be used as an initial activity after the main topic has been introduced. Alternatively it could be used to check student understanding at the end of the lesson by putting the sheet on the board and asking students with mini-whiteboards to vote for which equation is correct and encourage them to explain their answers.

Timing: This should take about 30 minutes if the students are expected to explain the mistakes of the incorrect rearrangements. If you just want the students to guess which one is correct it could be used as a shorter activity or as a homework task.

Activity 4 – Substitution

Resources: Mini-whiteboards

Instructions: Go through a couple of examples of typical suvat calculations where three variables are given and 1 variable is required. You could use the following examples:

1) $v = 8,\ s = 2,\ a = 7,\ u = ?$
2) $v = -12,\ s = -2,\ u = 7,\ t = ?$

Explain what the negative quantities refer to in terms of actual motion (i.e. moving in the opposite direction, negative displacement etc.). Ask students to work out the answers on their mini whiteboards and encourage them to show their answers so you can check their understanding. Once you feel the students have a good understanding, ask them to create 5 different problems for another member of the class to solve. Emphasise that the students must have the answers to their own questions. Ask the students to write their questions on a piece of paper with their name on it. Collect all of the papers in and put them in a hat. Students then have to draw a question set out of the hat and attempt to solve the questions that one of their peers have been set. They can check they have the correct answers by checking with the person who wrote it. This works particularly well if you have a class forum page on a VLE and have access to laptops/computers. Students can post the questions on a class forum page and then students can work out the answers and post them and the person who wrote them can mark them via the forum. This works perfectly as a homework task.

Pedagogy: This is to get students to practise substituting and rearranging the suvat equations in a fun and different manner. Encourage different techniques, i.e. substituting first and then rearranging or vice versa. Encourage students to write their answers in their workbooks.

Timing: This should take about 30 minutes and could be used as a whole lesson activity or as a homework task.

Activity 5 – Research Project – Traffic Lights

Resources: Internet Access

Instructions: Students are asked to become town planners and to design a series of traffic lights on a straight road 1km long in the town of Stuva. The town planners want the speed limit to be 30 miles per hour. The following model will be based on a single car travelling from the beginning to the end of the empty road. The road begins with a set of traffic lights. Assume that the traffic lights have just turned green and the car accelerates from rest immediately. Assume that when the next lights go amber the car begins to slow down and will stop at the exact time the lights turn red. Constant acceleration and Suvat formulae are assumed throughout. The two questions that the students have to answer are:

- How far apart should the traffic lights be in order for a car to maintain a speed below 30 miles per hour?
- When should each light go from green to amber in order for the car to stop safely?
- Design an automated system for the traffic lights.

Pedagogy: Calculations and research the students need to do:

- How long does a car take to get to 30mph from rest (students need to research typical 0-60mph times for cars; do they chose the average or go for the highest (i.e. Ferrari etc.). From this calculation the students can find out what time the amber light should go on and how far apart the lights have to be

Extension: How far are the stopping distances for different speeds? (again research from internet – some students who are taking the driving theory test may be of some help here!) From this calculation students would be able to find out how far apart the lights have to be.

Example:

Assume a car travels from 0-60mph in 10 seconds from rest. This has to be converted into an acceleration in metres per second which is:

$$60 \times 1.6 = 96 \text{ km h}^{-1}$$

$$\frac{96}{3600} = 0.0267 \text{ km s}^{-1}$$

$$0.0267 \times 1000 = 26.7 \text{ m s}^{-1}$$

Therefore the acceleration is given by:

$$a = \frac{v - u}{t} = \frac{26.7 - 0}{10} = 2.67 \text{ m s}^{-2}$$

Now the acceleration has been calculated one can calculate the time taken for the car to reach 30mph or 13.3 m/s. $u = 0, a = 2.67, v = 13.3, t = ?$. So using $v = u + at$ again:

$$t = \frac{v - u}{a} = \frac{13.3 - 0}{2.67} \approx 5 \text{ seconds}$$

Therefore the lights on the next set of lights should go amber 5 seconds after the previous ones have turned green. The car has 5 seconds to decelerate from 13.3 m s^{-1} to rest. What should the distance be? Using $s = \frac{1}{2}(u + v)t$ one can calculate:

$$s = \frac{1}{2}(0 + 13.3)(5) = 33.25 \text{ m}$$

Therefore in an ideal world the lights should be $33.25 \times 2 = 66.5$ m away from each other. These are the basic calculations for a particular acceleration. Of course for the extension if thinking distances and braking distances are included then the motion will have to be set into three parts – An initial acceleration, a thinking time constant speed section and a deceleration period at the end. You can encourage students to go into as much detail as they want and the task is differentiated by outcome. They could design a poster or draw speed-time diagrams of the motion as well.

Timing: This could be completed as an extended homework task or as a project over 2-3 lessons. Students could be asked to make a presentation/poster at the end to explain their findings.

Activity 6 – Hear No Evil, See No Evil, Speak No Evil

Resources: Activity Sheet 4, blindfold (scarf usually works), headphones and music player, three mini-whiteboards and pens.

Instructions: Get three volunteers from the class. They will sit at the front relatively far apart from each other. One of them will be blindfolded and will be 'See no evil', the other will have headphones on listening to music (at a reasonable volume but not enough to damage their hearing!) and be 'Hear no evil' and the other will not be allowed to speak and be 'Speak no evil'. You each give them one piece of information from one square on Activity Sheet 4. You also inform 'Speak no evil' of what variable they need to find out. You give them a time limit of 5 minutes to communicate with each other all the pieces of information and they have to have a correct answer. This is a fun, end of topic activity that can be very entertaining to watch. The key is to use the whiteboards. The student who cannot see can speak and hear and similarly for the other students and their other senses. Students have to figure out a strategy to communicate their ideas to each other effectively. Remember they can write messages on their whiteboards which is crucial for the student who cannot hear or speak! You may want to do an example first. Students not involved should have access to the information you have given them and be encouraged to calculate the answer themselves. In fact you could make the rest of the class the judge of whether the particular group has succeeded in their task.

Pedagogy: A fun way to revise material on suvat equations. Although there are only 4 cards on the activity sheet you can make up your own problems and make them more difficult if you so wish.

Timing: This could take a whole lesson or 30 minutes at the end of a lesson and give a number of groups a chance of having a go. Ensure students are volunteers and do not mind being in front of the class!

Activity 7 – Extension Questions

Instructions: These questions could be used as an extension activity or left up as homework questions:

- **Can an object have a negative acceleration but still be speeding up? Explain your answer and give an example**

- **How can you test reaction times using a ruler and the formula $s = \frac{1}{2}gt^2$?**

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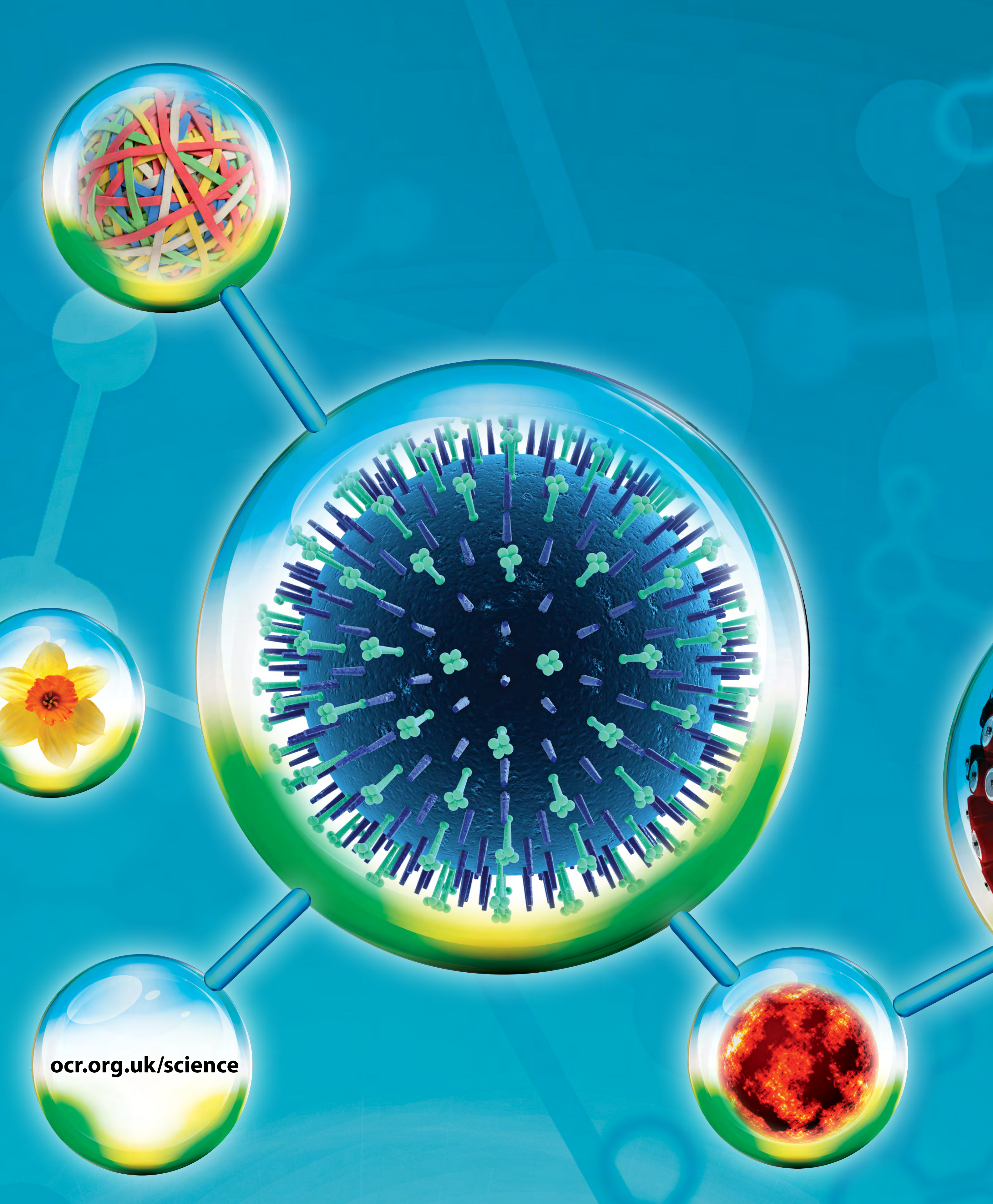

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