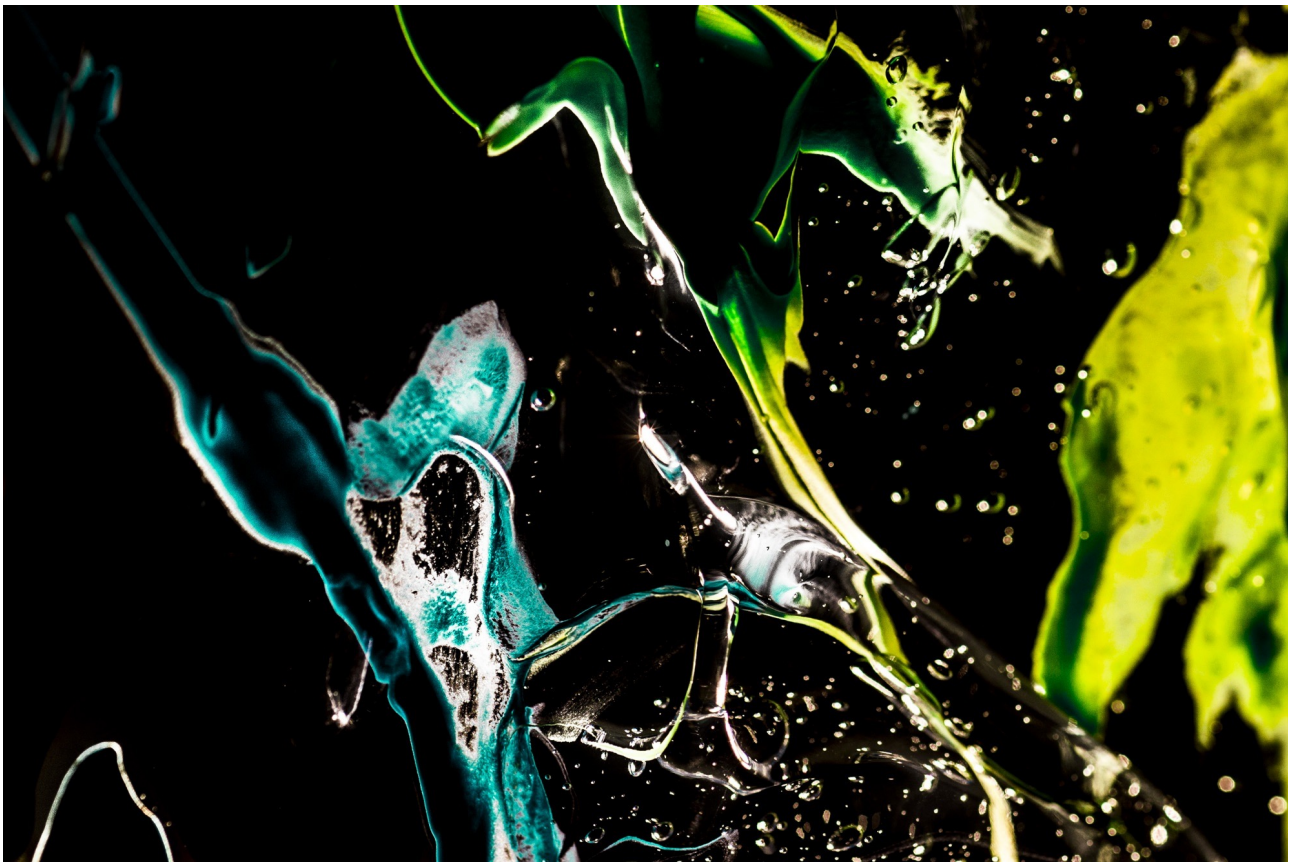
The physics of paint

Watching paint dry has never been more exciting

Key Stage 4 Programme – 2016-2017



Teacher Name: Dr Fortini

Pupil Name_____

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1			
2			
3			
4			
5			
6			

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1		
Tutorial 2		
Tutorial 3		
Tutorial 4		
Tutorial 5		

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after 4.00pm on	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

KS4 Programme 2016-17 – Pupil Feedback Report

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at A-Level
2:1	60-69	Performing to a good standard at A-Level
2:2	50-59	Performing to an excellent standard at current key stage
3rd	40-49	Performing to a good standard at current key stage
Working towards a pass	0-39	Performing below a good standard at current key stage
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Name of RIS Teacher	Dr A. Fortini		
Title of Assignment	Why do particles stratifies in drying paint?		
Name of Pupil			
Name of School			
ORIGINAL MARK / 100		FINAL MARK / 100	
DEDUCTED MARKS		FINAL GRADE	
If marks have been deducted (e.g. late submission, plagiarism) the teacher should give an explanation in this section:			

Learning Feedback Comment 1 - Enter Key Learning Priority Here	
What you did in relation to this Key Learning Priority Enter feedback here	How you could improve in the future Enter feedback here
Learning Feedback Comment 2 – Enter Key Learning Priority Here	
What you did in relation to this Key Learning Priority Enter feedback here	How you could improve in the future Enter feedback here
Learning Feedback Comment 3 – Enter Key Learning Priority Here	
What you did in relation to this Key Learning Priority Enter feedback here	How you could improve in the future Enter feedback here
Resilience Comment	
How you showed learning resilience during the course Enter feedback here	How you could build learning resilience in the future Enter feedback here

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Course Rationale

Paint is part of our life. We use it to decorate our homes or to express ourselves through art.
Paint is also used as a protective coating in bridges and other metal structures. In fact, almost every object around us has a thin layer (sometimes transparent) of paint on it.

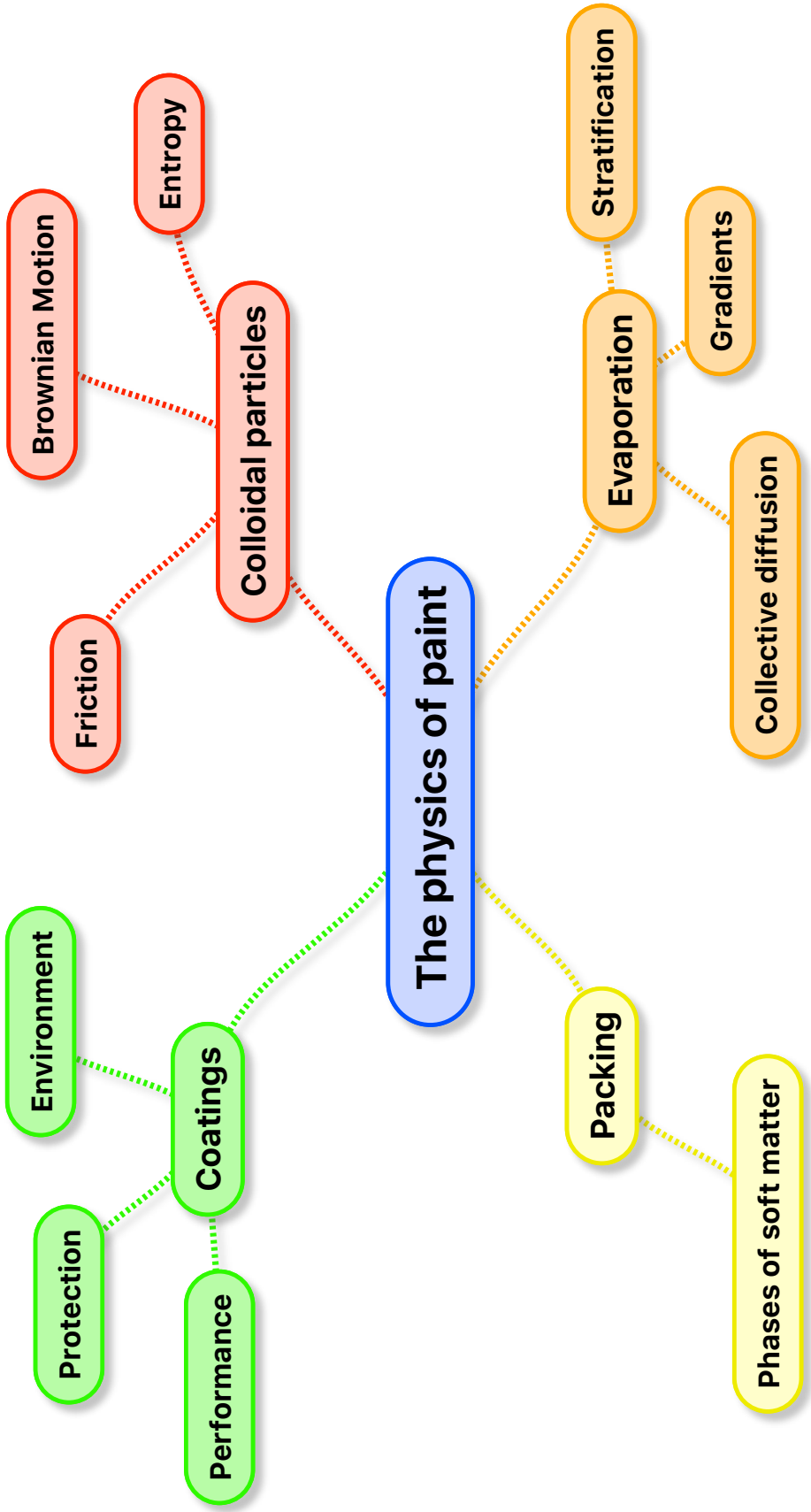
During this Uni-Pathways course, we will look at the microscopic structure of paint. Pupils will undertake a fascinating journey in the unusual and unpredictable world of small particles in water and will learn to apply the trading tools of theoretical and statistical physics.

Over the course of the programme, students will learn how to model complex systems and apply critical thinking to the results of observation. They will learn how to structure academic essays and scientific reports.

This course will explain in an accessible manner concepts of Physics and Chemistry typically taught at A-level or University.

Pupils will learn the microscopy meaning of entropy and how it drives the transformations between different phases of matter.
By the end of the course, all students will have a sound understanding of current scientific research on paint and its impact on modern society.

Course Map


Brownian Motion
Entropy
Friction
Colloidal particles
Environment
Protection
Coatings
Performance
The physics of paint
Stratification
Gradients
Evaporation
Collective diffusion
Packing
Phases of soft matter

Mark Scheme

Key Skill	1st	2.1	2.2
Concepts	☐ Demonstrate understanding of all physical concepts behind the stratification of paint ☐ Shows understanding of the microscopic meaning of entropy	☐ Demonstrate understanding of at least two physical concepts behind the stratification of paint ☐ Shows some understanding of the microscopic meaning of entropy	☐ Demonstrate understanding of at least one physical concept behind the stratification of paint ☐ Shows some misunderstanding of the microscopic meaning of entropy
Scientific report	☐ Scientific report is well structured with an introduction, figures with caption,and a conclusion ☐ Shows independent or creative thinking	☐ Scientific report is structured with at least two sections ☐ Shows some independent or creative thinking	☐ Scientific report is structured with only one section ☐ No apparent independent or creative thinking
Language	☐ Scientific language and terms are used consistently ☐ General language is clear, with no spelling mistakes	☐ Scientific language and terms are sometimes used ☐ General language is clear, with some spelling mistakes	☐ Scientific language and terms are rarely used ☐ General language is unclear, with many spelling mistakes

Glossary of Keywords

Word	Definition
Evaporation	Evaporation is a type of vaporization of a liquid that occurs from the surface of a liquid into a gaseous phase that is not saturated with the evaporating substance.
Stratification	Stratification is a system or formation of layers, classes, or categories.
Segregation	The action or state of setting someone or something apart from others.
Model	A systematic description of an object or phenomenon that shares important characteristics with the object or phenomenon. Scientific models can be material, visual, mathematical, or computational and are often used in the construction of scientific theories.
Theory	A scientific theory is a well-substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment.
Colloid	A colloid, in chemistry, is a mixture in which one substance of dispersed particles is suspended throughout another substance.
Entropy	In statistical thermodynamics, entropy is a measure of the number of microscopic configurations Ω that correspond to a thermodynamic system in a state specified by certain macroscopic variables.
Brownian Motion	The erratic random movement of microscopic particles in a fluid, as a result of continuous bombardment from molecules of the surrounding medium.
Polymer	A polymer is a large molecule, or macromolecule, composed of many repeated subunits.
Glass	Glass is a non-crystalline amorphous solid
Gel	A gel is a solid jelly-like material that can have properties ranging from soft and weak to hard and tough. Gels are defined as a substantially dilute cross-linked system, which exhibits no flow when in the steady-state.

Tutorial 1 – What is paint?

Today's Key Questions:

What is paint for?

What is paint made of?

How can physics and chemistry can be used to make better paints?

What is the Purpose of Tutorial 1?

To understand the basic components of paint

To understand why we paint things

To understand the roles of physics and chemistry in the paint industry

Activity 1: Painting the Golden Gate Bridge

"…the Bridge is painted continuously. Painting the Bridge is an ongoing task and a primary maintenance job." (from goldengate.org)

(Source NPR. Golden gate bridge)

Why do we need to paint the bridge continuously?

Notes:

Activity 2: What is paint made of?

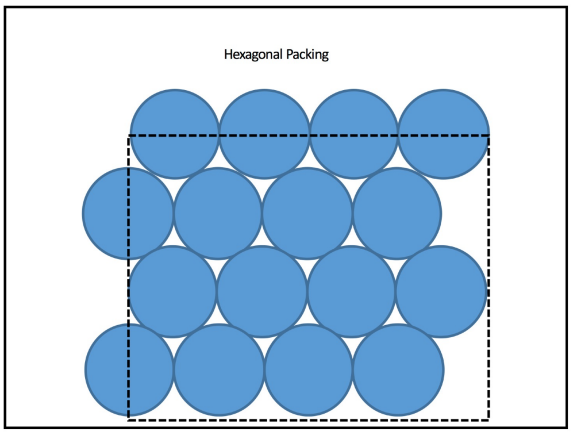
Polymers:

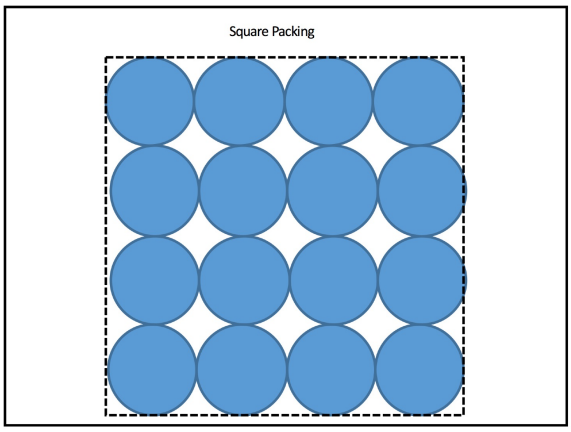
Pigments:

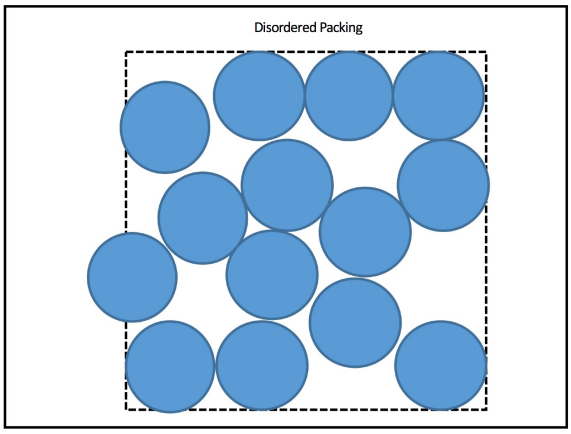
Colloidal particles:

Activity 3: Packing

Calculate the volume fraction of the following three packings







Which packing is better at protecting against water infiltration?

Today's Homework is:

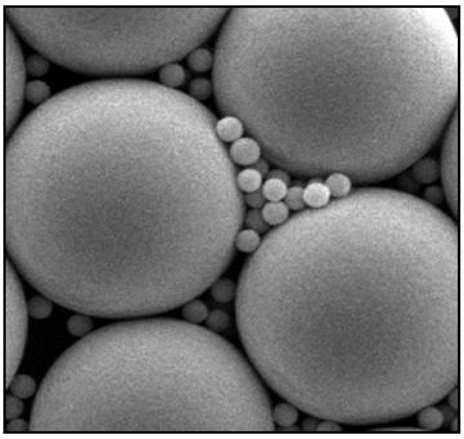
Baseline Test

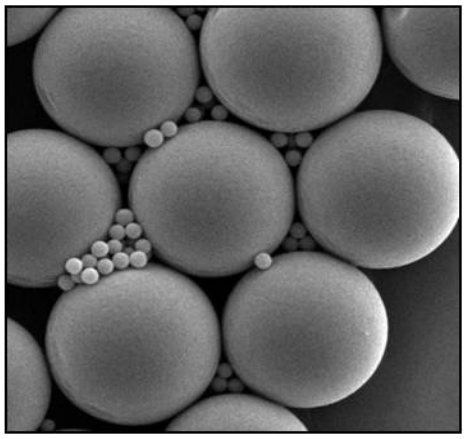
The homework assignment for the first tutorial is a baseline test to see your initial level of attainment in this subject area. The assignment will test for some or all of the subject specific skills that are required later in the final assignment. However, it is shorter than the final assignment and is will be an introduction to the subject as well as a challenge!

Do not worry too much about doing 'well' or 'badly' on the baseline test, it takes into account the fact that you may not be familiar with the subject area. It is designed to help you and your PhD tutor identify where you are at the start of the programme and to help you measure your progress along the way.

Tutorial 2 – What are colloidal particles?

(Credit for electronic microscope images: P.M. Chaikin and A.D. Hollingsworth, New York University)





Today's Key Questions:

What is a model?

How do we model particles motion in vacuum and air?

How do we model particles in water?

What is diffusion?

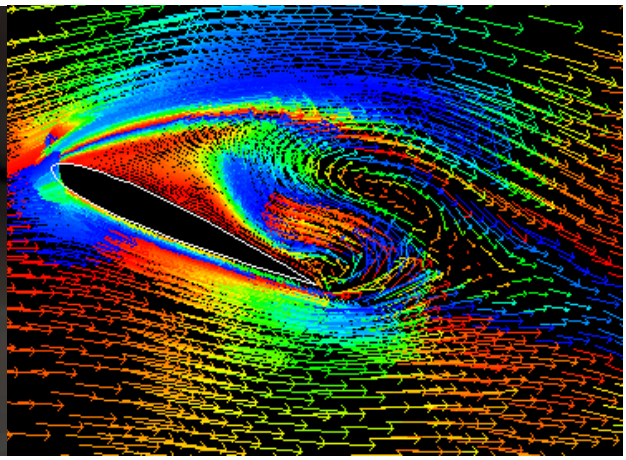
What is the Purpose of Tutorial 2?

To understand the key properties of a scientific model

To understand how to model particles motion in vacuum and in air

To understand how to model particle motion in water and Brownian motion

Activity 1: Models

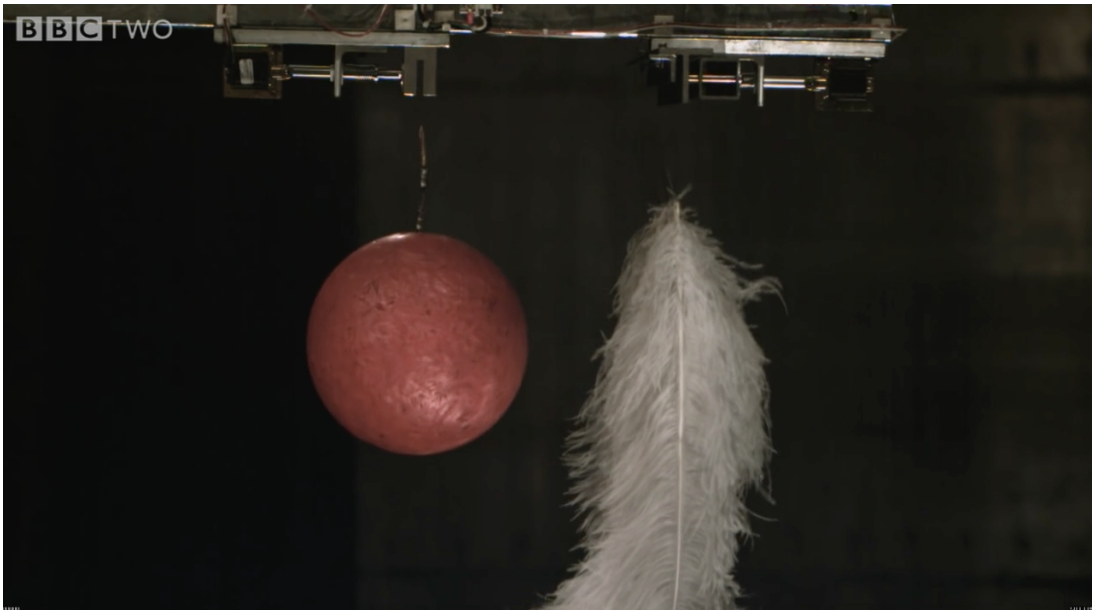


What do the figures have in common?
What's the difference?

Notes:

Activity 2: Drag

Video



Sphere or feather falling in a vacuum:

$$F = -mg$$

An object of mass 5 Kg is dropped from a height of 10 m. Calculate the time to reach the floor.

Objects falling in air:

$$F = -mg + \mu v$$

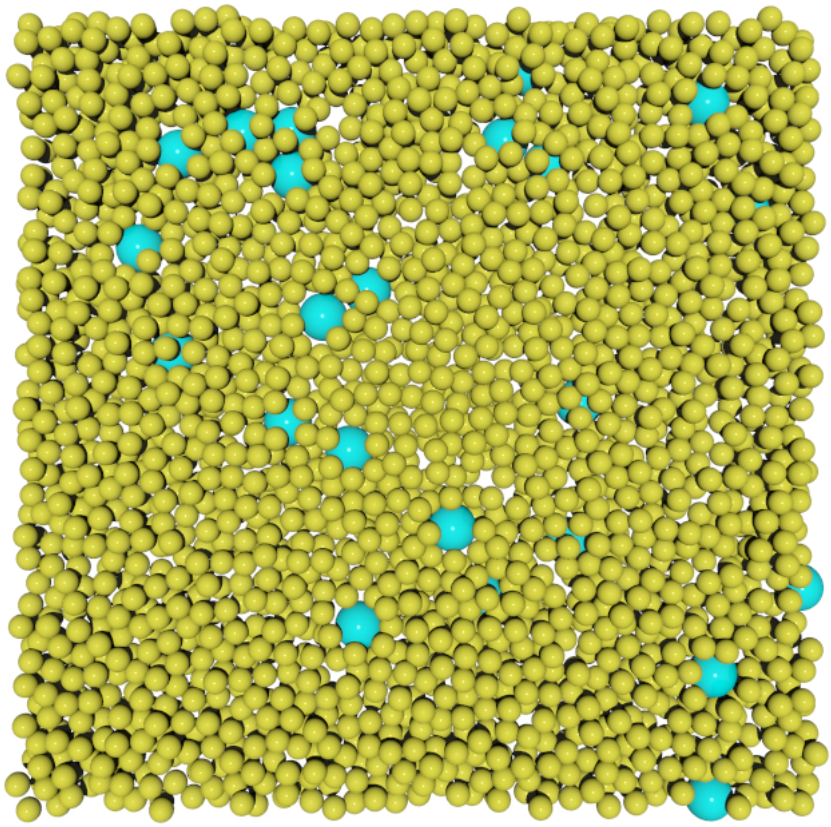
Calculate the terminal velocity of an object of mass 1 Kg and μ=2:

Calculate the terminal velocity of an object of mass 100 Kg and μ=2:

Objects falling in Water: Stoke's Law

$$F = -mg + 6\pi\eta a v$$

Activity 3: Brownian Motion of colloidal particles



Einstein ideal diffusion

$$D = \frac{k_B T}{\xi}$$

Write the equation for the diffusion using the Stokes's law for the friction coefficient.

Force on colloidal particles with Brownian motion

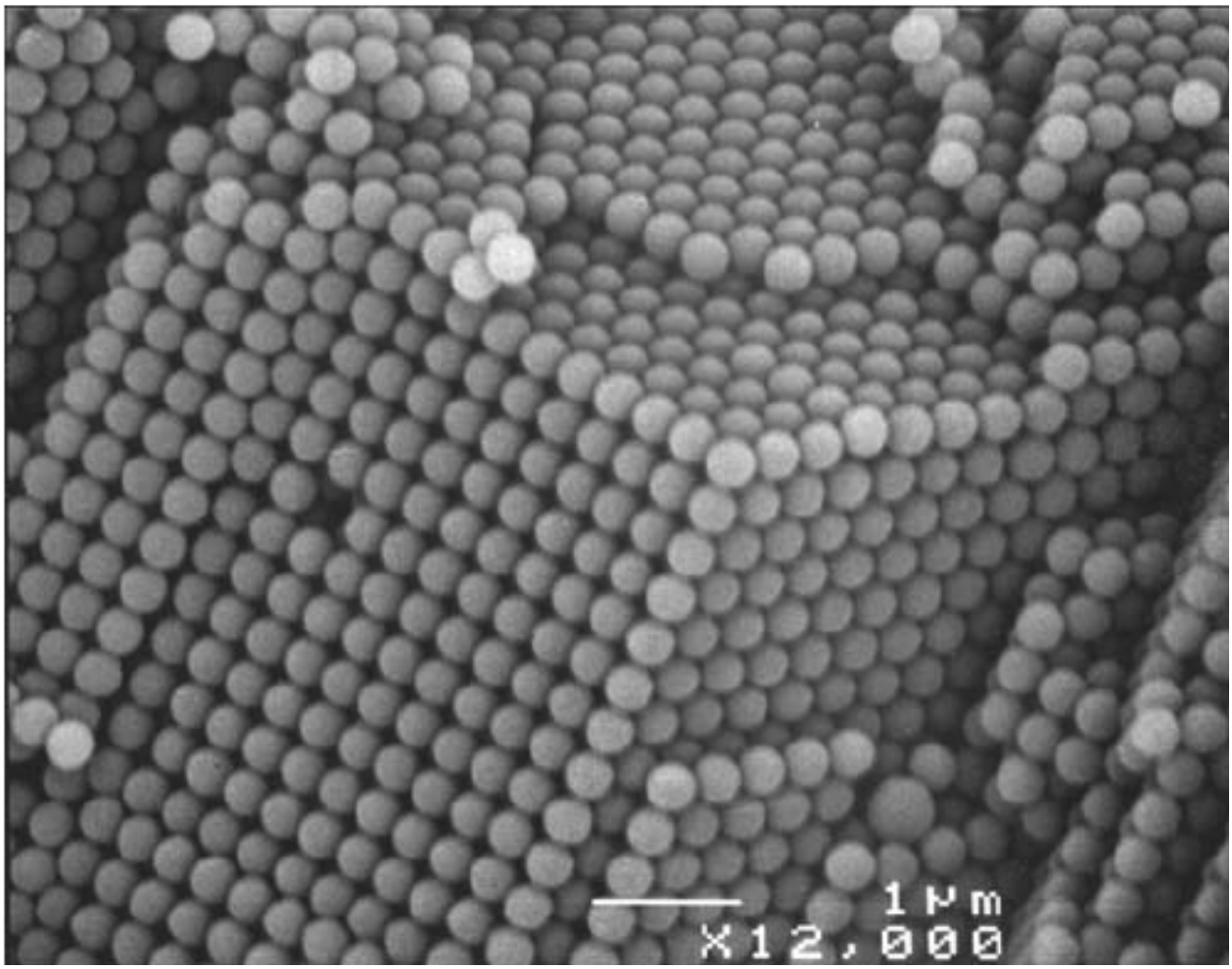
$$F = -\xi v + F_{random}$$

Today's Homework is:

1)Write a short essay (max 500 words) describing the model for the movement of small particles in water

Success criteria	Bronze	Silver	Gold
Title	No Title	There is a title	Title is concise and clear
Figures	No Figures	Figures are not clear or some captions are missing	Figures are clear and have captions.
Language	Scientific language and terms are rarely used. General language is unclear, with many spelling mistakes	Scientific language and terms are sometimes used General language is clear, with some spelling mistakes	Scientific language and terms are used consistently. General language is clear, with no spelling mistakes

Tutorial 3 – Phases of soft matter 1



(Image from article by Arnout Imhof, *Three-Dimensional Photonic Crystals Made from Colloids*. Nanoscale Materials, pp.423-454 2007)

Today's Key Question(s):

What different phases can exist in paint?

What drive phase transformation?

What is entropy?

What is the Purpose of Tutorial 3?

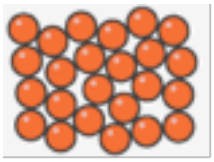
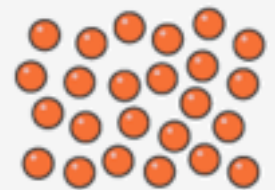
To understand the different phases that occur in atomic systems

To understand the different phases that occur in colloidal systems

To understand the role of entropy in phase transformation

Activity 1: Phases of Matter

Complete the table below about the three state states of matter

			
Name of the state of Matter			
Arrangement of particles (ordered or not ordered, how close to each other)			
Energy of particles Which one has more energy and why? What type of energy are you thinking of?			
Available space (Comment on the amount of available free space that particles have to move about)			

Activity 2: Phase transformations

What is the meaning of the regions with constant temperature?

Which phase has the highest kinetic energy?

During the phase transformation, where did the energy (in the form of heat) go?

Temperature in kinetic theory

$$T = \frac{2K}{3Nk_B}$$

Activity 3: Hard spheres

Pusey, P.N. & van Megen, W., 1986. Phase behaviour of concentrated suspensions of nearly hard colloidal spheres. *Nature*, 320(6060), pp.340–342.

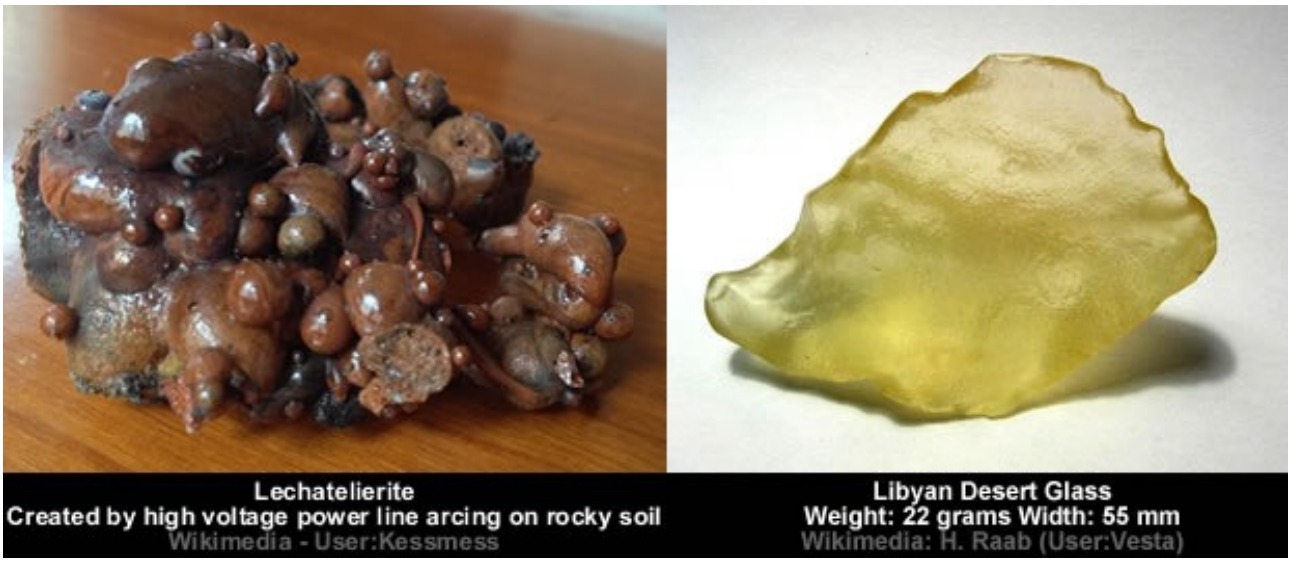
The figure shows the phases of purely repulsive spheres at increasing concentration from left to right. The temperature is the same in all samples and there is no potential energy. What drives the phase transformation?

Today's Homework is:

Write a short essay (max 250 words) describing the role of entropy in phase transformations.

Success criteria	Bronze	Silver	Gold
Language	Scientific language and terms are rarely used. General language is unclear, with many spelling mistakes	Scientific language and terms are sometimes used General language is clear, with some spelling mistakes	Scientific language and terms are used consistently. General language is clear, with no spelling mistakes

Tutorial 4 – Phases of soft matter 2



Today's Key Questions:

What are glasses and gels?

What is evaporation?

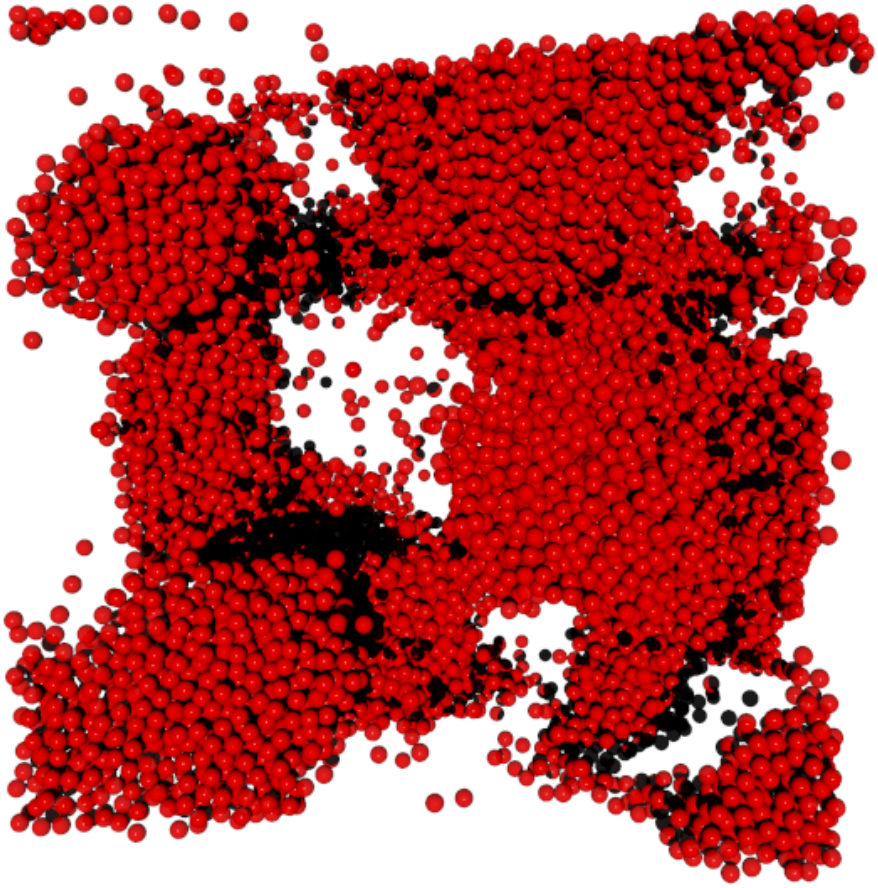
What is the Purpose of Tutorial 4?

To understand glasses and gels

To understand evaporation

To understand the structure of a scientific paper

Activity 1: Glasses and gels in particle systems



1) List as many materials or products that are either gels or glasses.

2)How would you “freeze” a disordered configuration of colloidal particles?

Activity 2: Evaporation

1) What happens during evaporation?

2) Can you describe evaporation using the microscopic picture? (Think about the motion of molecules)

3) How does the interface between liquid and air change in time?

Activity 3: Build the structure of a good scientific paper.

Analyse the given scientific article and determine which section should be included in a scientific paper.

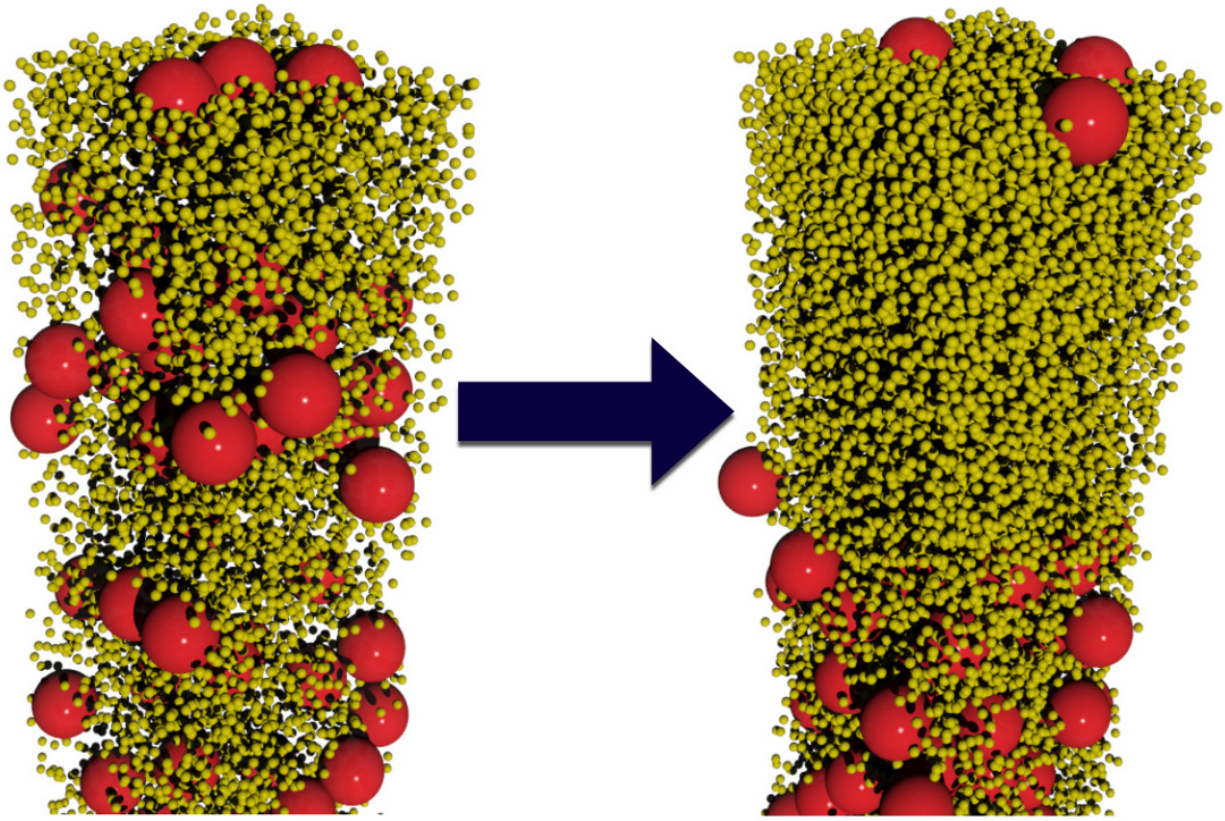
Today's Homework is:

Write a scientific paper explaining what happens during the drying of paint.

The paper should describe the models we developed in the previous weeks. Use the following success criteria to guide you:

Success criteria	Bronze	Silver	Gold
Title	No Title	There is a title	Title is concise and clear
Figures	No Figures	Figures are not clear or some captions are missing	Figures are clear and have captions
Content	Two main sections are missing	One main section is missing	Contains all important sections of a scientific article
Language	Scientific language and terms are rarely used General language is unclear, with many spelling mistakes	Scientific language and terms are sometimes used General language is clear, with some spelling mistakes	Scientific language and terms are used consistently General language is clear, with no spelling mistakes

Tutorial 5 – Why do particle of different sizes stratify in paint?



Today's Key Questions:

What happens to colloidal particles during evaporation?

What are gradients?

What forces do particles experience in a pressure gradient?

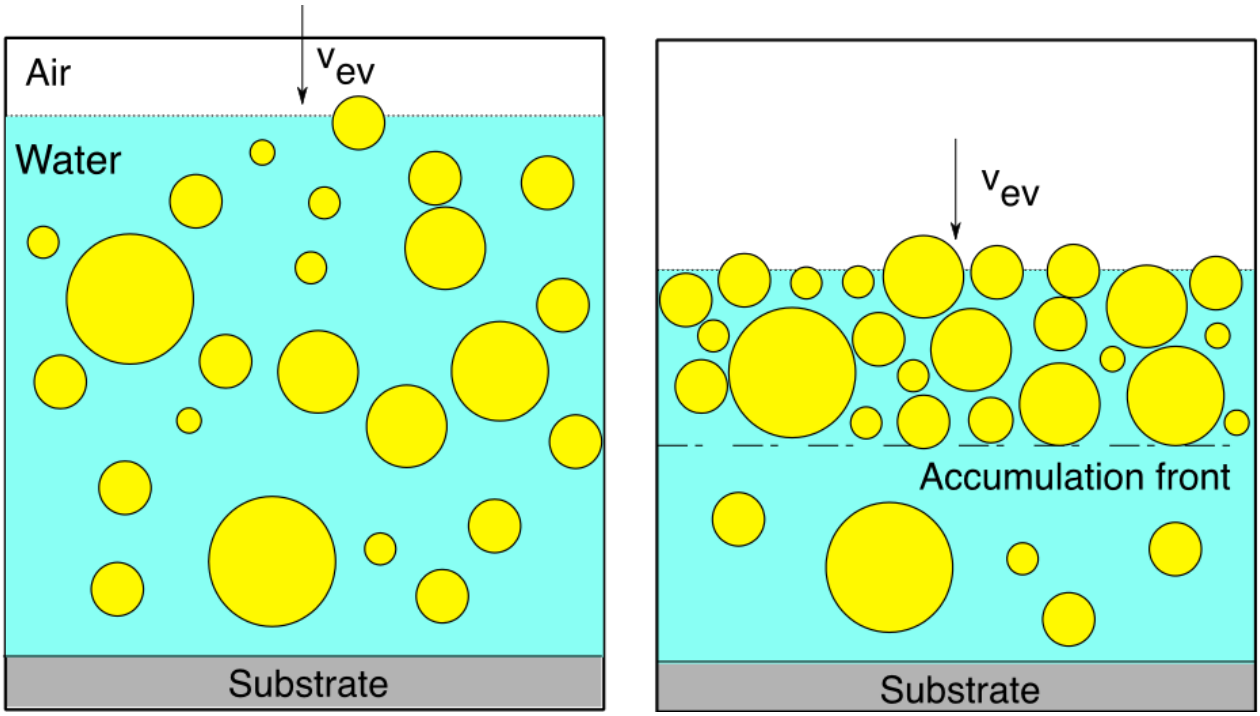
What is the Purpose of Tutorial 5?

To understand particle accumulation.

To understand the concept of gradient.

To understand how a pressure gradient can cause size segregation.

Activity 1:Evaporation of paint

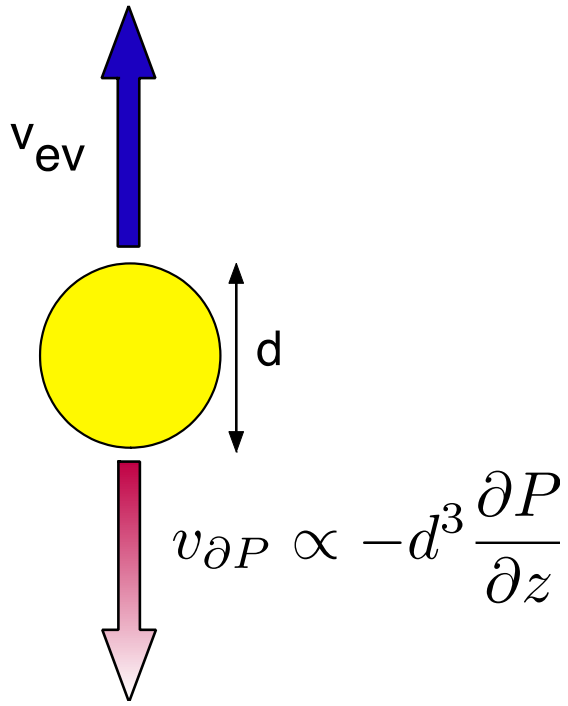


1) Consider a container of height H and determine the time for complete evaporation for an evaporation velocity v_{ev}.

2) Calculate the time it takes a particles to diffuse a distance equal to the height of the container H.

3) What does the ratio of the times calculated at points 1 and 2 tell us?

Activity 2: Forces in gradients

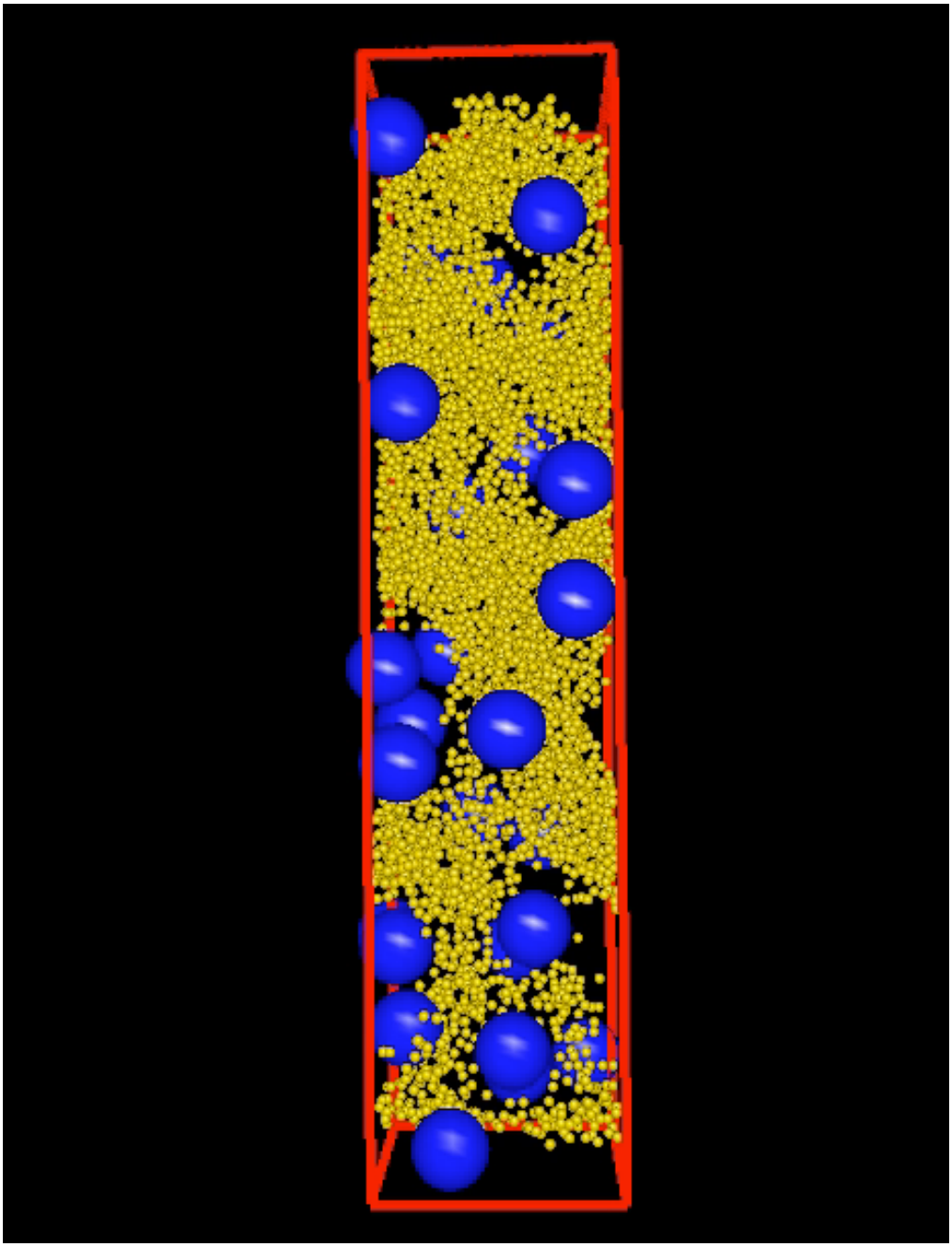


1) What is the force on an object of area A from a constant pressure P?

2) What is the total force on a sphere with pressure P1 at the top and pressure P2 at the bottom?

Activity 3: Stratification velocity

Derive the equation that describes the differential velocity between a small particle of size d and a large particle of size D.



Today's Homework is the Final Assignment!

Write a scientific article explaining why particles of different sizes stratify in drying paint.

The article should include a basic description of the model of paint. Use what you have written in previous homework, but consider the feedback you were given.
Use the success criteria of the last homework and the marking scheme to guide you.
Submit electronically or on paper.

Good Luck!

The Deadline is:

Tutorial 6 – Feedback

What is the Purpose of Tutorial 6?

Reflect on skills learned on the programme with a view to encouraging resilience

Receive feedback on final assignment

What are the key questions?

What strengths have I demonstrated in my work and what areas of development are there left for me to address?

What steps do I need to take to improve my academic output?

Activity 1 – Marking your own

Using the mark scheme, identify three things you did well and three things you could improve.

What went well?

1.
2.
3.

What could be improved?

1.
2.
3.

Activity 2 – Responding to feedback

Read through your feedback sheet and highlight on your assignment where you received positive feedback (one colour) and areas for improvement (different colour). You might find it helpful to annotate this with a brief comment or two.

Activity 3 – Looking Forwards: Think, Pair Share

Think about how you can use this feedback in your future school work.

Talk to your partner about how you both plan to make changes to your school work in the future as result of this feedback

Share your ideas as a group.