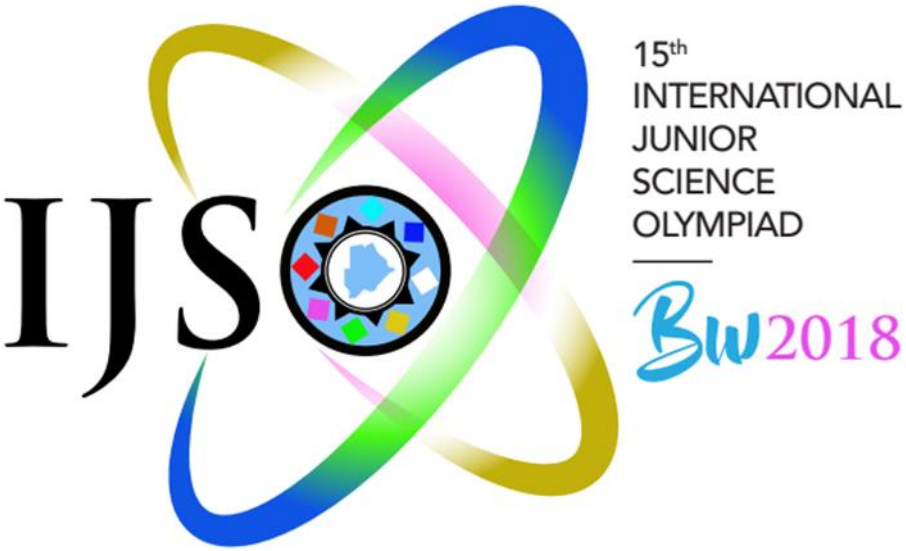
15TH INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

IJSO-2018



Discovery, Innovation and Environment

Laboratory Experiment

– Exam Sheet –

December 8, 2018
Do NOT turn to next page
before a whistle is blown.
Otherwise, you will receive a penalty.

1. You have 10 minutes to read "EXAMINATION RULES", "EXAM INSTRUCTIONS", and "CALCULATOR INSTRUCTIONS" on pages 1 - 3.

2. Do NOT start answering the questions before the"START"whistle! Otherwise, you will receive a penalty.

EXAMINATION RULES

1. You are NOT allowed to bring any personal items into the examination room, except for

personal medicine or approved personal medical equipment.

2. You must sit at your designated desk.

3. Check the stationery items (pen, calculator, and rough book) provided by the organizers.

4. Do NOT start answering the questions before the **"START"** whistle.

5. You are NOT allowed to leave the examination room during the examination except in an emergency in which case you will be accompanied by a supervisor/volunteer/invigilator.

6. Do NOT disturb other competitors. If you need any assistance, you may raise your hand and wait for a supervisor to come.

7. Do NOT discuss the examination questions. You must stay at your desk until the end of the examination time, even if you have finished the exam.

8. At the end of the examination time you will hear the **"STOP"** whistle. Do NOT write anything more on the answer sheet after this stop whistle. Arrange the exam, answer sheets, and the stationary items (pen, calculator, and rough book) neatly on your desk. Do NOT leave the room before all the answer sheets have been collected.

EXAM INSTRUCTIONS

1. You are NOT allowed to bring any personal items into the examination room, except for personal medicine or approved personal medical equipment.
2. You must sit at your designated table.
3. Check the stationery items (pen, calculator, ruler, and scrap paper) provided by the organizers.
4. Do NOT start your experiments before the **"START"** signal.
5. You are NOT allowed to leave the examination room during the experiment, except in an emergency in which case you will be accompanied by a supervisor/volunteer/invigilator.
6. Do NOT disturb other competitors. If you need assistance, raise your hand and wait for a supervisor to come.
7. You can ONLY ask questions and discuss the experiments with your own team members. You must STAY at your table until the end of the time allocated for the experiments, even if you have finished the experiments or do not wish to continue.
8. At the end of the experiment time you will hear the **"STOP"** signal. Do NOT write anything more on the answer sheet after this stop signal. Arrange the exam, answer sheets, and the stationary items (pen, calculator, ruler, and scrap paper) neatly on your desk. Do NOT leave the room before all the answer sheets have been collected.

EXPERIMENT INSTRUCTIONS

1. After the "START" signal, you will have 15 minutes to read the experiments. In this time, it is NOT allowed to conduct the experiment yet, or answer the questions.
2. After the first 15 minutes, another whistleblow will indicate that you can start the experiment and start answering question. From this moment you have three hours to

complete the test.

3. Use only the pen and pencil provided by the organizers.

4. The total number of experiments is 3. Check if you have a complete set of the exam sheets (20 pages, page 4 – page 20) and answer sheets (28 pages - including the front page). Raise your hand, if you find any sheets missing.

5. Check that your name, code and country are filled in on your answer sheets and sign every page of the answer sheets. Raise your hand, if you find any sheets missing.

6. Read the experimental procedures and questions carefully and write your answers in the corresponding boxes of the answer sheets.

7. When units are provided in the answer sheets, you have to write the answers correctly for the units.

8. Always show your calculations if room for this is provided. If you do not show your calculations, no points are awarded for the question.

9. You should write your final answers down in the appropriate number of digits.

10. You MUST wear a **Lab Coat** and **Safety Glasses** during the experiments.

INSTRUCTIONS FOR CALCULATOR

1. Turning on: Press [ON/C].

2. Turning off: Press [2ndF] [ON/C].

3. Clearing data: Press [ON/C].

4. Addition, subtraction, multiplication, and division

Example 1) $45 + \frac{285}{3}$

[ON/C] *45* [+] *285* [÷] *3* [=] ***140.***

Example 2) $\frac{18+6}{15-8}$

ON/C (18 + 6) ÷ (15 − 8) =

3.428571429

Example 3) $42 \times (-5) + 120$

ON/C 42 × 5 +/− + 120 = ***-90.***

ON/C 42 × (− 5) + 120 = ***-90.***

5. Exponential

Example 1) 8.6^{-2}

ON/C 8.6 y^x 2 +/− = ***0.013520822***

Example 2) 6.1×10^{23}

ON/C 6.1 × 10 y^x 23 = ***6.1 x 10^{23}***

6. To delete a number/function, move the cursor to the number/function you wish to delete, then press DEL. If the cursor is located at the right end of a number/function, the DEL key will function as a back space key.

Do NOT turn to next page
Before the"START"whistle is blown.
Otherwise, you will receive a penalty.

CHEMISTRY

Experiment II: Determination of acid content in a fruit acid solution **[13.3 points]**

ANSWER KEYS

Standardization of the NaOH

Question (Points)	Record the volume of NaOH (mL) solution used in the standardization
II-1a [3.5 points]	Titration #1 Titration #2 Titration …. Titration ….. Initial Vol. …….. …….. ……. ……. End Vol. ……. ……. ……. …… Vol. Used …… …… ……. …… [1.0 for proper and consistent recording and 0.5 point for at least two titrations] Average NaOH volume used …….xxxx……mL [0.5] Precision = [max 0.5] ±0.1, [award 0.5], ±0.2, [award 0.25], any value beyond 0.2 award 0.0 mark, for the two best titrations Accuracy = [max 1.0] ± 0.3 [award 1.0], ±0.5 [award 0.5], ±1.0 [award 0.25]

Question (Points)	Write down a balanced chemical equation for the titration reaction of oxalic acid (H_2X) with NaOH
II-1b [0.25 points]	$2NaOH + H_2X$ ….. $Na_2X + 2H_2O$ If not balanced substract 0.1 points
Question (Points)	Calculate the concentration of the NaOH solution
II-1c [0.5 points]	Mol of H_2X = 0.100 mol/L x 10 mL/1000 mL = xxxx mol Mol ratio of NaOH to H_2X = 2:1 [0.25] Mol of NaOH = xxxx mol x 2 Concentration of NaOH = xxx/ Titre value = yyy mol/L [0.25] Accept alternative suitable calculations

Titration of fruit acid solution

Question (Points)	Record the volume of NaOH (mL) solution used
II-2 [3.5 points]	Titration #1 Titration #2 Titration ….. Titration …... Initial Vol. ……. ……. ……. ……. End Vol. ……. ……. ……. ……. Vol. Use ……. ……. ……. ……. [1.0 for proper and consistent recording and 0.5 point for at least two titrations] Average NaOH volume used ……25.65 ml…… mL [0.5] Precision = [max 0.5] ±0.1, [award 0.5], ±0.2, [award 0.25], any value beyond 0.2 award 0.0 mark, for the two best titrations Accuracy = [max 1.0] ± 0.3 [award 1.0], ±0.5 [award 0.5], ±1.0 [award 0.25]

Question (Points)	Write down the balanced equation for the titration reaction
II-3 [0.25 points]	$HA_{(aq)} + NaOH_{(aq)} \rightarrow NaA_{(aq)} + H_2O_{(l)}$ Do not penalize for the state symbols

Question (Points)	Determine the number of moles of NaOH used in the titration
II-4 [0.5 points]	Moles = Con x vol = 0.1 mol/L x 25.65 x 10^{-3} L [0.25] = 2.565 x 10^{-3} mol [0.25]

Question (Points)	Determine the mass (g) of acid in the fruit acid solution titrated with NaOH solution
II-5 [1.0 points]	Mole ratio of NaOH : HA is 1:1 [0.25] HA moles = 2.565 x 10^{-3} mol [0.25] MW of HA = 60.0 g/mol Mass of HA = 2.565x10^{-3} x 60.0 g/mol [0.25] = 1.539 x 10^{-1} g or 0.1539 g [0.25]

Question (Points)	Assuming the density of fruit acid solution is 1.005g/mL, determine the mass (g) of 4 mL solution.
II-6 [0.5 points]	Mass = density x volume 1.005g/mLx 4.0 mL [0.25] 4.02 g [0.25]

Question (Points)	Determine the % mass of the acid in fruit acid solution.
II-7 [0.5 points]	= 0.1539 g/4.02 g x 100% [0.25] = 3.83 % [0.25]

Question (Points)	Calculate the volume of the fruit acid solution that the student used?
II-8 [1.0 points]	Mole of NaOH = 0.54 mol/L x25 x 10^{-3}L = 0.0135 mol [0.25] Moles ratio is 1:1, therefore HA mol is 0.0135 mol. [0.25] Concentration of fruit acid solution = moles/volume = 2.565 x 1.35x10^{-}

	^{3}mol/25.65 x 4 x10^{-3}L =0.641 mol/L Volume of fruit acid solution required = moles/conc = 0.0135 mol /0.641 mol/L =0.021 L =21 mL [0.5] *OR Volume of fruit acid solution = 25 mL x 0.54 mol/L / 0.641 = 21.09 mL [0.5]*

Question (Points)	Another student has measured the pH of the fruit acid solution to be 2.75. Use this value and your data to determine the pK_a of the fruit acid solution.
II-9 [0.5 points]	pKa = Sq of pH = ????????

Question (Points)	Calculate the Kb of the conjugate base of the fruit acid solution
II-10a [0.5 points]	pKa + pKb = 14 14-pKa = y Kb = 10^{-y}

Question (Points)	Calculate the pH at end point. Use the Kb from the previous question
II-10b [0.5 points]	Kb = [HA] [OH]/ [A] Kb = X^2/x-z z= mol HA/ $4*10^{-1}$

Question (Points)	If phenolphthalein was unavailable, which of the following indicators would be most suitable for this titration.
II-11 [0.3 points]	Tick the correct box

Indicator	pKa	
Methyl violet	0.8	
Thymol blue	1.6	
Methyl yellow	3.3	
Bromocresol green	4.7	
Thymol Blue	8.9	√

Q1. [7.15 points] Draw a sketch of the spots observed on your TLC plate, and complete the table in your answer sheet with *Rf* values and proposed pigments (Roman numeral from Table 1, one per spot):

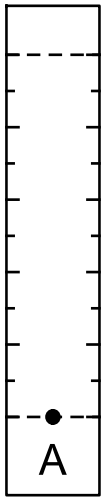
[1.75 points – awarded in a deductive manner – loss of points for omissions] Each lane corresponds to the original – check photograph for comparison and check if any obvious spots are omitted.

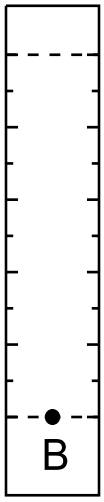
[1.9 points (0.1 x 19)] for the drawing. Minimum 7 for lane A (& 1 weak), min. 5 for B, min. 6 for lane C (& some weak), max. 1 for lane D (lose points for additional spots – carry over)

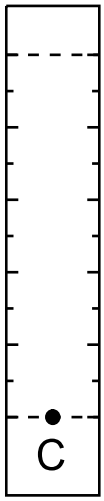
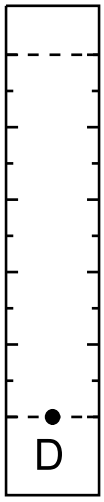
Comentado [EC1]: 19 spots minimum

[2.0 points, 0.25per Rf (0.25x8)] Points for the calculation of *Rf*.(margin of error? Invigilators will prepare and run plate in their rooms and take photo for comparison and to decide Rf for grading)

[1.5 points, 0.25 per pigment (0.25x6)] Suggested pigments – minimum of six correct. If the same pigment is present in A,B&C but not identified in one, deduct one third of marks (0.08), if present in two lanes and only identified once, deduct 50% of marks (i.e. 0.125)

	Spot no. (e.g. A1)	*Calculations*	*Rf*	Suggested pigment, if any
				

 B				

	Spot no. (e.g. A1)	*Calculations*	*Rf*	Suggested pigment, if any
				
				

Q2 [1.0 points, 0.25 per statement]

For the following observations about the sample in lane D, mark in your answer sheet whether the following statements are true or false [X points].

Statement	True	False
It separated into distinct pigments, which are not present in other lanes.		X
It separated into distinct pigments, which are also present in other lanes.		X
It did not move with mobile phase.	X	
It does not contain any pigments		X

Q3 For the following statements, mark in your answer sheet whether the following statements are true or false [1.0 points, 0.25 per statement]

The TLC chamber (bottle) is closed to…

Statement	True	False
To prevent evaporation of the mobile phase.	X	
To avoid the smell of the chemicals contained in the mobile phase.	X	
To maintain a dust-free environment.	X	
To decrease the pressure in the chamber		X

Q4. Indicate in your answer sheet, whether each of the factors below affect the *Rf* value of a compound [1.75 points, 0.25 per statement]

	Affects *Rf*	Does not affect *Rf*
A. Polarity of compound	X	
B. Distance travelled by solvent (mobile phase)		X
C. Size of TLC plate		X
D. Type of stationary phase	X	
E. Amount of sample loaded		X
F. Size of chamber		X
G. Color of the sample		X

Q5. Write the letter that corresponds to the pigment that moves slowest up the TLC plate in the box on your answer sheet. [0.25 points]

A. Chlorophyl *a*
B. Xanthophyll 1
C. Pheophytin
D. Chlorophyl *b*

Q6 [1.0 points, 0.25 per statement] For the following statements, mark in your answer sheet whether the statements are correct or incorrect.
A compound moves slower than others up a TLC plate in our experimental conditions because…

Statement	Correct	Incorrect
It is less polar than the other compounds		X
It is a more hydrophilic compound	X	
It has a larger molecular weight		X
It is more concentrated than the other compounds		X

Q7. Will the *Rf* values change if the ratio of polar and non-polar solvents in the mobile phase is changed? Write the letter that corresponds to your answer in the box on your answer sheet. [0.25 points]

A. Yes
B. No

Q8. What could potentially limit the effectiveness of the chromatographic technique you have used? [1.0 points, 0.25 per statement]

Statement	Correct	Incorrect
Leaving the TLC chamber open	X	
The amount of mobile phase in the TLC chamber	X	
Geographical location where the experiment is performed		X
Running multiple plates in one TLC chamber		X

NAME: CODE

Physics Laboratory practical
Total marks [12.6]

Title: Determination of coefficient of viscosity of oil

Determination of coefficient of viscosity of fluids

Ball Drop Experiment

The measurement involves determining the velocity of a falling sphere through a column of fluid of unknown viscosity. This is accomplished by dropping a sphere through a measured distance of fluid and measuring how long it takes to traverse the distance.

Materials

- Thermometer
- Ball bearings of different diameters
- Stopwatch
- Meter ruler
- Paper towel
- Magnet
- Oil

Theoretical aspects

Consider a spherical ball bearing of radius *r and density* ρ_s falling through a column of viscous fluid of coefficient of viscosity η and density ρ_f as illustrated in the figure below. The coefficient of viscosity is a measure of the degree of internal resistance to flow and shear.

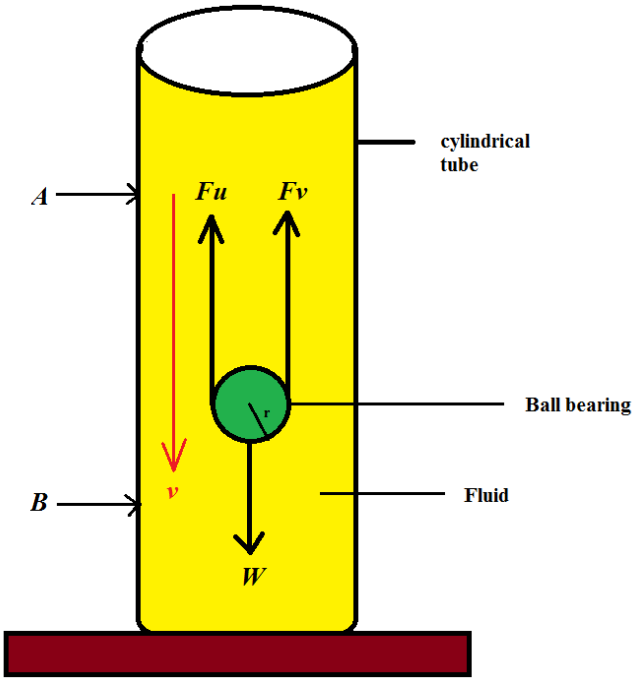


Figure 1: showing a sphere of radius r falling through a column of fluid of density ρ_f. A and B marks the distance travelled by the sphere at terminal velocity v_t.

According to Newton's second law:

$$Net\ Force = ma$$

$$ma = W - (F_u + F_v) \qquad (1)$$

Where m is the mass of the sphere,

$W=mg$, is the weight of the sphere (ball bearing)

$F_u = \frac{4}{3}\pi r^3 \rho_f g$ is the upthrust = weight of the fluid displaced

$F_v = 6\,\pi\, r\, \eta\, v$ is the viscous force (of a sphere of radius r) proportional to the velocity v of the ball (Stoke's Law).

Initially the ball has some downward acceleration until the sphere acquires terminal velocity v_t ($v_t = \frac{s}{t}$ where s is the distance travelled in time t), when there is no more acceleration and hence the net force is zero. Equation (1) becomes

$$mg = F_u + F_v$$

$$\frac{4}{3}\pi\, r^3 \rho_s\, g = \frac{4}{3}\pi\, r^3 \rho_f\, g + 6\,\pi\, r\, \eta\, v_t \qquad (2)$$

$$\text{Or } v_t = \frac{2}{9}\frac{r^2}{\eta}\, g\left(\rho_s - \rho_f\right) \qquad (3)$$

Note that s is the distance between A and B and t is the time the ball takes to fall between A and B.

Equation (3) can be modified to:

$$v_t = \frac{1}{18}\frac{d^2}{\eta}\, g\left(\rho_s - \rho_f\right) \qquad (4)$$

Where

d = diameter of sphere (=2r)

ρ_s = density of sphere = m/V = (mass of sphere/volume of sphere)

ρ_f = density of fluid

g = acceleration of gravity = 9.81 m/s^2

v_t = Terminal Velocity = s/t = (distance sphere falls)/(time of it takes to fall)

Procedure

Proceed as follows.

1. Measure the vertical distance s between points A and B marked on the cylindrical tubes.
2. Drop one of the ball bearings into the fluid (ensuring that the ball bearing does not touch the wall of the cylinder during its motion between A and B)
3. Measure the time t taken by the sphere to travel the distance s between A and B and record it in the provided table.
4. Without removing the ball bearing, repeat steps 2 and 3 above using other bearings of the same diameter to have three values of time.
5. Repeat steps 2 to 4 for the other 4 sizes of ball bearings.

Results and analysis

Note the following:
ρ_f = 871.4 kg/m^3
ρ_s = 7717 kg/m^3
s = 0.4 m (distance between A and B)

Calculate the average time, d^2 and v_t for each set of ball bearings, complete Table 1.

Table 1: experimental results. [2.4]

Ball diameter			Diameter squared	Time taken to fall distance l				Terminal velocity
#	d (mm)	d (m)	d^2 (m²)	t_1 (s)	t_2 (s)	t_3 (s)	Average time (s)	v_t (m/s)
1								
2								
3								
4								

1. Plot a graph of v_t vs d^2, [5.2]
2. Use the graph to determine the viscosity of the oil with the appropriate units. [5]

MARKING SCHEME Solution

Completed table

Note the following:

ρ_f = 871.4 kg/m^3

ρ_s = 7717 kg/m^3

Temperature before T_b:

$\boldsymbol{T}$ = [0.15]

Distance l

$\boldsymbol{l} \approx \mathbf{0.500}$ m [0.25]

Drawing a sketch of measurement [0.75]

Temperature before T_a:

$\boldsymbol{T_a}$ = [0.15]

Points for the measurements and calculations

Table III-1

#	d (mm)	d (m)	d^2 (m²)	t_1 (s)	t_2 (s)	t_3 (s)	Average time (s)	v_t (m/s)
1	0,25	0,05	0,05	0,25	0,25	0,25	0,05	0,1
2	0,25	0,05	0,05	0,25	0,25	0,25	0,05	0,1
3	0,25	0,05	0,05	0,25	0,25	0,25	0,05	0,1
4	0,25	0,05	0,05	0,25	0,25	0,25	0,05	0,1

Subtraction (per column) 0.2 if out of range

d (mm)	Range d (mm)	d_{min} (mm)	d_{max} (mm)
4,50	0,4	**4,30**	**4,70**
5,00	0,4	**4,80**	**5,20**
6,00	0,4	**5,80**	**6,20**
7,00	0,4	**6,80**	**7,20**

III-2 Plot of v_t vs. d^2 **[3.0]**

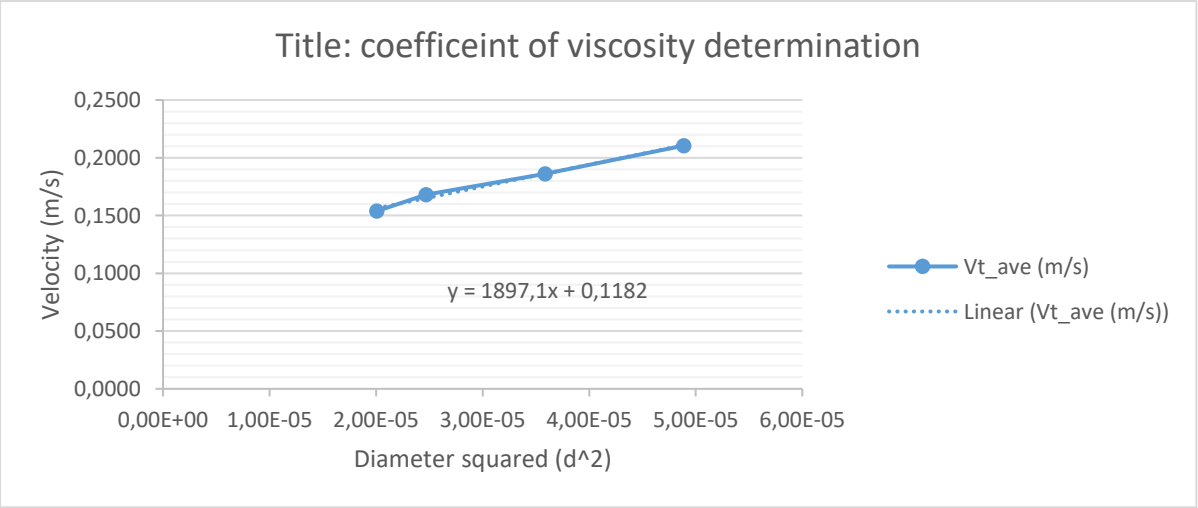
Marks allocation:

i) x and y axis labelling [1.0]
(for each axis Quantity (0.25) & Unit (0.25))

ii) Scale of the graph [1.0]
0.5 for each axis (uniform & size)

iii) Plotting of points (0.1 for each) [0.4]

iv) Drawing straight line best of fit [0.6]



III-3 Determining the slope of the line **[1.5]**

i. Mark the points on the line that are used [0.5]
ii. Calculation of the slope [0.5]
iii. Determining the correct unit [0.5]

III-4 Derive and show analytical expression for C **[1.0]**

i.

III-5 Determination of viscosity of oil **[1.5]**

Mark allocation

i) Determination of coefficient of viscosity.

From $v_t = \frac{1}{18}\frac{d^2}{\eta}\, g\,(\rho_s - \rho_f)$

$$slope = \frac{g}{18}\frac{(\rho_s - \rho_f)}{\eta} \quad \text{or} \quad slope = \frac{C}{\eta} \quad [0.5]$$

Calculation of the viscosity [0.5]
Determining the correct unit [0.5]

$$\eta = \frac{g}{18}\frac{(\rho_s - \rho_f)}{slope} \rightarrow \frac{\left[\frac{m}{s^2}\right] * \left[\frac{kg}{m^3}\right]}{\left[\frac{m/s}{m^2}\right]} = \left[\frac{Ns}{m^2}\right] = Pa.S$$