This is a Class 1 exam

Lebanon Evangelical School
for Boys and Girls — Loueizeh - Baabda

Stage Exam 03
FEB2023

Do NOT write in this box. Your MARK will be placed here.

Subject :	A Level : Physics 1 : RB
Class :	11A and 12A
Teacher :	Dr Ruth Brett
Duration :	1 hour

Write all your answers in black pen in the spaces provided on this exam paper. You should have a physics data and formula booklet.

Your name :		*Time taken to complete exam*
Your Class :		
Exam Room :		
How many sheets, including cover sheet :		

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- The most important thing to remember in taking an exam is NEVER PANIC.
- If you are caught cheating in this exam, you will be awarded zero for ALL exams that are taken on this day.

Answer questions 1-3 with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒. **(One mark per question).**

Q1. A sphere of weight 2.5 N floats in water with ½ of its volume beneath the surface.

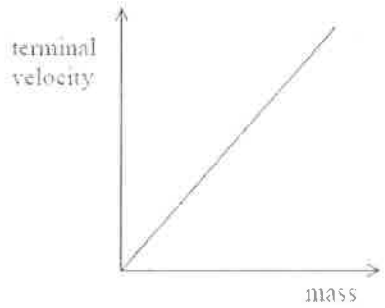
A force F is applied to the sphere, completely immersing it in the water as shown.



Which of the following is the minimum value of F?

- ☐ **A** 2 × 2.5 N
- ☐ **B** 1 × 2.5 N
- ☐ **C** ½ × 2.5 N
- ☐ **D** ¼ × 2.5 N

Q2. The graph shows how terminal velocity varies with mass for small spheres of equal diameter falling through a viscous liquid.



Which of the following describes the gradient of the graph for a liquid of greater viscosity?

- ☐ **A** a greater gradient
- ☐ **B** a smaller gradient
- ☐ **C** a variable gradient
- ☐ **D** the same gradient

Q3. A sample of sea water is collected using a beaker. The sample contains some particles of sand which settle at the bottom of the beaker.

Which of the following would result in a decrease in the time taken for the sand to settle?

- ☐ **A** smaller particles of sand
- ☐ **B** lower temperature of the sea water
- ☐ **C** smaller terminal velocity of sand particles
- ☐ **D** lower viscosity of the sea water

Q4.

Water is dropped into a container of oil. The water forms small spherical droplets that move slowly downwards.

(a) A droplet moves downwards at a constant speed. The flow of oil around the droplet is laminar.

(i) State what is meant by laminar flow.

(1)

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(ii) State the condition necessary for the speed of the droplet to be constant.

(1)

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(b) A spherical droplet has a volume of 3.35×10^{-8} m^3.

(i) Calculate the weight of the droplet.
density of water = 1.00×10^3 kg m^{-3}

(3)

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Weight of droplet = ...

(ii) Show that the upthrust on the water droplet when it's completely submerged in oil is about 3×10^{-4} N.
density of oil = 0.94×10^3 kg m^{-3}

(2)

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(iii) Calculate the terminal velocity of this water droplet in the oil.
viscosity of oil = 0.11 Pa s

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Terminal velocity = ...

(Total for question = 11 marks)

Q5.

The photograph shows a fireboat used to put out fires on ships at sea. A pump, fixed to the boat, pumps water from the sea. The seawater is projected at high speed out of a pipe connected to the pump.



(Source: © Konrad Zelazowski/age fotostock/Superstock)

(a) The mass of seawater pumped each second is 300 kg. The pipe has a diameter of 10.0 cm.

density of seawater = 1030 kg m^{-3}

Show that the speed at which the seawater is projected from the pipe is about 37 m s^{-1}.

(4)

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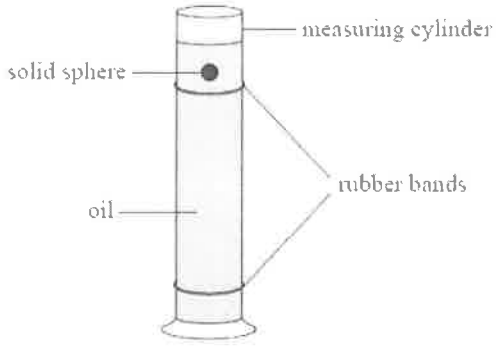
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(Total for question = 4 marks)

Q6. A student carried out an experiment to determine the viscosity of a sample of oil contained in a large measuring cylinder.

A small solid sphere was released just above the surface of the oil and the terminal velocity of the sphere was determined.



(a) Two rubber bands were placed around the cylinder as shown. When the sphere passed the top band a timer was started. The timer was stopped when the sphere passed the bottom band.

(i) Explain why the top rubber band should be placed a short distance below the surface of the oil.

(2)

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(ii) Another student suggested using an additional rubber band halfway between the top and bottom rubber bands.

Discuss the benefit of adding the third rubber band.

(2)

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(b) The accepted value for the viscosity of the oil used in this experiment is 41 mPa s at 24 °C.

The student obtained a value of 36 mPa s.
Suggest a possible reason for the student obtaining a lower value for the viscosity than the accepted value.

(1)

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(Total for question = 5 marks)

Q7. Stokes' law can be used to determine the magnitude of the viscous drag for small, spherical objects moving through a fluid.

(a) State one other condition that must be met in order for Stokes' law to apply to the moving object.

(1)

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(b) A sphere falls through water at a constant speed of 0.50 m s^{-1}.

Assess whether Stokes' law can be applied to the falling sphere.
You should include calculations in your answer.
diameter of ball bearing = 6.0×10^{-3} m
mass of steel ball bearing = 9.1×10^{-4} kg
upthrust on ball bearing = 1.1×10^{-3} N
viscosity of water = 8.9×10^{-4} Pa s

(5)

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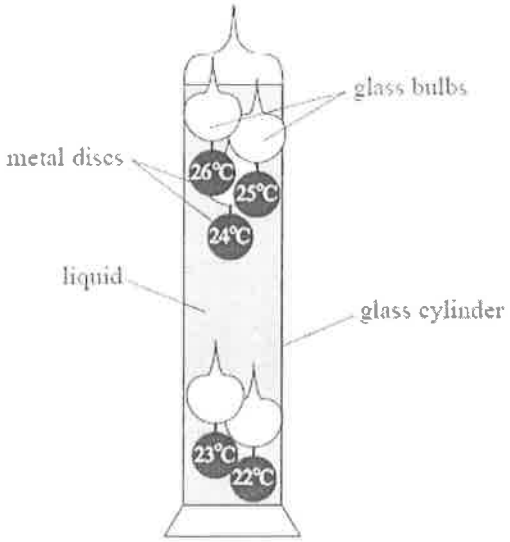
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(Total for question = 6 marks)

Q8. A Galilean thermometer consists of a closed glass cylinder containing a liquid. In the liquid there are several identical sealed glass bulbs, as shown. Attached to each bulb is a metal disc labelled with a temperature. Each disc has a different mass.



As the temperature increases, the density of the liquid decreases. This can cause the bulbs to move within the liquid.

By considering the forces acting, explain why a particular bulb will float until the temperature of the liquid exceeds a certain value.

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(Total for question = 6 marks)

Q9.

A student carried out an experiment to determine the viscosity of a liquid. He measured the terminal velocities v of several different glass spheres of diameter d, as they fell through the liquid.

(a) Explain what is meant by terminal velocity.

(2)

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(b) A glass sphere of diameter 35 mm is travelling through the fluid at terminal velocity.

Show that the drag force on this sphere is about 0.2 N.
density of glass $\rho_g = 2.52 \times 10^3$ kg m^{-3}
density of liquid $\rho_s = 1.43 \times 10^3$ kg m^{-3}

(5)

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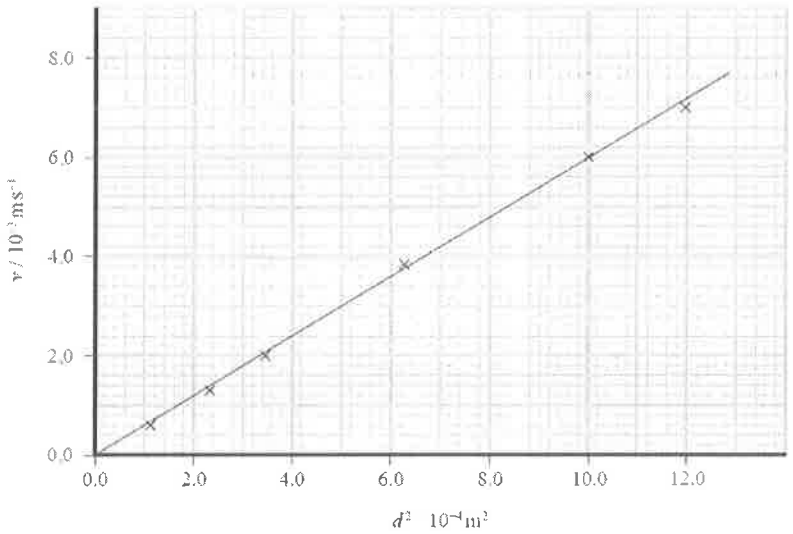
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(c) The student used his measurements to plot the graph of v against d^2 shown below.



The student reads in a textbook that if Stokes' law is obeyed

$$v = k\,d^2$$

where k is a constant.

(i) Deduce from the graph whether the flow of liquid around the spheres was laminar.

(3)

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(ii) Determine a value for k using the student's graph.

(3)

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k = ...

(iii) The constant k is given by

$$k = \frac{(\rho_g - \rho_s)g}{18\eta}$$

where η is the viscosity of the liquid.

Determine a value for η.
density of glass $\rho_g = 2.52 \times 10^3$ kg m^{-3}
density of liquid $\rho_s = 1.43 \times 10^3$ kg m^{-3}

(2)

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η = ...

(Total for question = 15 marks)

This is a Class 1 exam

Lebanon Evangelical School for Boys and Girls

Lighting the fires that burn for eternity

Louéizeh - Baabda

Lebanon Evangelical School

for Boys and Girls — Loueizeh - Baabda

WORKED SOLUTION

Stage Exam 03

FEB2023

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Q1. A sphere of weight 2.5 N floats in water with ½ of its volume beneath the surface.

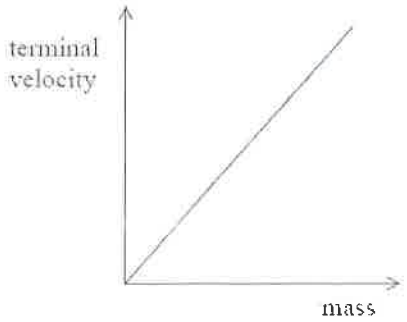
A force F is applied to the sphere, completely immersing it in the water as shown.



Which of the following is the minimum value of F?

(1)
- ☐ **A** 2 × 2.5 N
- ☒ **B** 1 × 2.5 N
- ☐ **C** ½ × 2.5 N
- ☐ **D** ¼ × 2.5 N

Q2. The graph shows how terminal velocity varies with mass for small spheres of equal diameter falling through a viscous liquid.



Which of the following describes the gradient of the graph for a liquid of greater viscosity?

(1)
- ☐ **A** a greater gradient
- ☒ **B** a smaller gradient
- ☐ **C** a variable gradient
- ☐ **D** the same gradient

Q3. A sample of sea water is collected using a beaker. The sample contains some particles of sand which settle at the bottom of the beaker.

Which of the following would result in a decrease in the time taken for the sand to settle?

(1)
- ☐ **A** smaller particles of sand
- ☐ **B** lower temperature of the sea water
- ☐ **C** smaller terminal velocity of sand particles
- ☒ **D** lower viscosity of the sea water

Q4.

Water is dropped into a container of oil. The water forms small spherical droplets that move slowly downwards.

(a) A droplet moves downwards at a constant speed. The flow of oil around the droplet is laminar.

(i) State what is meant by laminar flow.

(1)

The velocity at a fixed point is constant. (1)

(ii) State the condition necessary for the speed of the droplet to be constant.

(1)

Resultant force acting on the droplet is zero (1)

(b) A spherical droplet has a volume of 3.35×10^{-8} m^3.

(i) Calculate the weight of the droplet.
density of water = 1.00×10^3 kg m^{-3}

(3)

$W = mg = \rho V g$ (1) (1)

$W = 1000 \times 3.35 \times 10^{-8} \times 9.81$

$W = 3.286 \times 10^{-4}$ N

Weight of droplet = 3.29N (1)

(ii) Show that the upthrust on the water droplet when it's completely submerged in oil is about 3×10^{-4} N.
density of oil = 0.94×10^3 kg m^{-3}

(2)

Upthrust = weight of oil displaced (1)

$U = \rho_{oil} V_{droplet} g = 0.94 \times 10^3 \times 3.35 \times 10^{-8} \times 9.81$

$U = 3.089 \times 10^{-4}$ N (1)

(iii) Calculate the terminal velocity of this water droplet in the oil.
viscosity of oil = 0.11 Pa s

(4)

At terminal velocity $\Sigma f = 0$ so $W = F + U$

$F = W - U = 3.29 \times 10^{-4} - 3.09 \times 10^{-4} = 0.2 \times 10^{-4} N$ (1)

$F = 6\pi r \eta v = 2 \times 10^{-5}$

$v = \frac{2 \times 10^{-5}}{6\pi r \eta}$ (1) $= \frac{2 \times 10^{-5}}{6\pi (2 \times 10^{-3})(0.11)} = 4.82 \times 10^{-3} ms^{-1}$

Terminal velocity = 4.82×10^{-3} (1) ms^{-1}

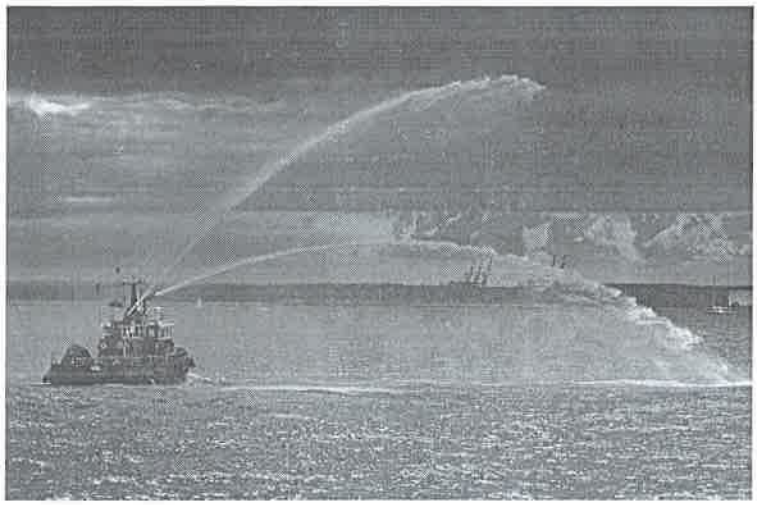
(Total for question = 11 marks)

$V = \frac{4}{3}\pi r^3$ $\quad r = \sqrt[3]{\frac{3V}{4\pi}} = \sqrt[3]{\frac{3 \times 3.35 \times 10^{-8}}{4\pi}} = \sqrt[3]{7.998 \times 10^{-9}}$

$r = 1.9998 \times 10^{-3} m \rightarrow 2 \times 10^{-3} m$ (1)

Q5.

The photograph shows a fireboat used to put out fires on ships at sea. A pump, fixed to the boat, pumps water from the sea. The seawater is projected at high speed out of a pipe connected to the pump.



(Source: © Konrad Zelazowski/age fotostock/Superstock)

(a) The mass of seawater pumped each second is 300 kg. The pipe has a diameter of 10.0 cm.

density of seawater = 1030 kg m^{-3}

Show that the speed at which the seawater is projected from the pipe is about 37 m s^{-1}.

(4)

Volume pumped each second :-

$\rho = \frac{m}{V}$ $V = \frac{m}{\rho} = \frac{300}{1030} = 0.291 m^3$ (1)

Diameter = 10cm $r = 0.05m$ A = ▭ l

$V = Al$

$l = \frac{V}{A} = \frac{0.291}{\pi (0.05)^2}$ (1) $= \frac{0.291}{7.85 \times 10^{-3}} = 37.05m$ (1)

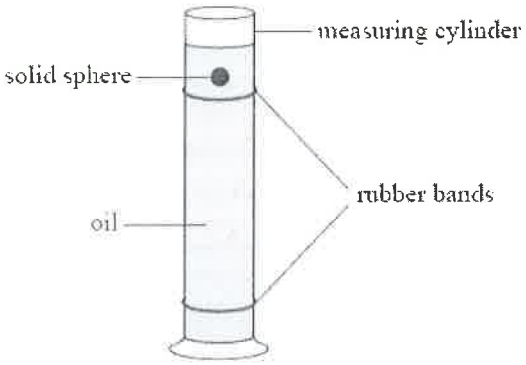
This is the length per second, so is the speed

~~$v = 37 ms^{-1}$~~ $v = 37.05 ms^{-1}$ (1)

(Total for question = 4 marks)

Q6. A student carried out an experiment to determine the viscosity of a sample of oil contained in a large measuring cylinder.

A small solid sphere was released just above the surface of the oil and the terminal velocity of the sphere was determined.



(a) Two rubber bands were placed around the cylinder as shown. When the sphere passed the top band a timer was started. The timer was stopped when the sphere passed the bottom band.

(i) Explain why the top rubber band should be placed a short distance below the surface of the oil.

(2)

At first the sphere will be accelerating (1) so it needs to fall a certain distance before the velocity will be constant (1)

(ii) Another student suggested using an additional rubber band halfway between the top and bottom rubber bands.

Discuss the benefit of adding the third rubber band.

(2)

A third rubber band would enable the speed to be calculated between the top two and then the bottom two bands (1) If the speeds are the same, the students will know that terminal velocity has been reached (1)

(b) The accepted value for the viscosity of the oil used in this experiment is 41 mPa s at 24 °C.

The student obtained a value of 36 mPa s.
Suggest a possible reason for the student obtaining a lower value for the viscosity than the accepted value.

(1)

The temperature of the oil may be higher than 24 °C (1)

(Total for question = 5 marks)

Q7. Stokes' law can be used to determine the magnitude of the viscous drag for small, spherical objects moving through a fluid.

(a) State one other condition that must be met in order for Stokes' law to apply to the moving object.

(1)

low velocity (1)

(b) A sphere falls through water at a constant speed of 0.50 m s^{-1}.

Assess whether Stokes' law can be applied to the falling sphere.
You should include calculations in your answer.
diameter of ball bearing = 6.0×10^{-3} m
mass of steel ball bearing = 9.1×10^{-4} kg
upthrust on ball bearing = 1.1×10^{-3} N
viscosity of water = 8.9×10^{-4} Pa s

(5)

W = U + F Find F Need W

$W = mg = 9.1 \times 10^{-4} \times 9.81 = 8.93 \times 10^{-3}$ N (1)

$F = W - U = 8.9 \times 10^{-3} - 1.1 \times 10^{-3}$ (1) $= 7.8 \times 10^{-3}$ N (1)

Stokes' law $F = 6\pi r \eta v$

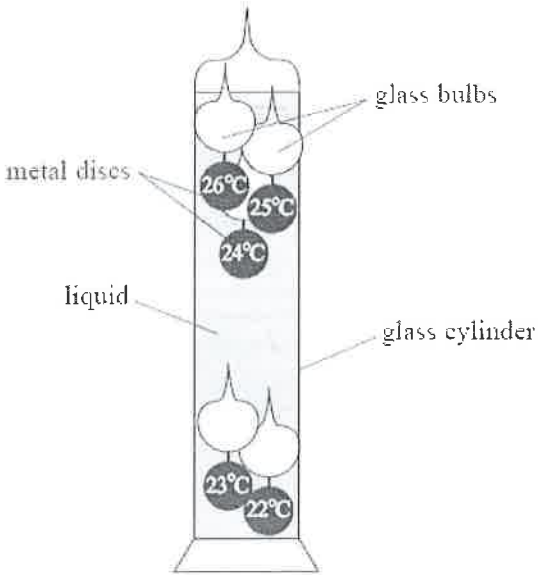
$F = 6\pi \left(\frac{6 \times 10^{-3}}{2}\right)(8.9 \times 10^{-4})(0.5)$ (1)

$F = 2.5 \times 10^{-5}$ N

These values are not the same, so Stoke's law cannot be applied in this situation. (1)

(Total for question = 6 marks)

Q8. A Galilean thermometer consists of a closed glass cylinder containing a liquid. In the liquid there are several identical sealed glass bulbs, as shown. Attached to each bulb is a metal disc labelled with a temperature. Each disc has a different mass.



As the temperature increases, the density of the liquid decreases. This can cause the bulbs to move within the liquid.

By considering the forces acting, explain why a particular bulb will float until the temperature of the liquid exceeds a certain value.

A bulb will float if the upthrust exerted on it is greater than its weight. (1)
The weight of the bulb is constant and can be found using $W = mg$. (1)
The upthrust is calculated using $U = \rho_{liquid} V_{bulb} g$ as it is the weight of fluid displaced. (1)
However, as the temperature changes, the density of the fluid will change. As the temperature increases, the density will decrease. Therefore the upthrust will decrease (1)
When the upthrust is less than the weight, (1) there will be a resultant force (1) on the bulb, so it will accelerate downwards and sink.

(Total for question = 6 marks)

SIX INDICATIVE CONTENT POINTS
→ 4 MARKS + 2 MARKS FOR LINKAGE

Q9.

A student carried out an experiment to determine the viscosity of a liquid. He measured the terminal velocities v of several different glass spheres of diameter d, as they fell through the liquid.

(a) Explain what is meant by terminal velocity.

(2)

The constant (1) maximum velocity reached by an object falling through a fluid when the resultant force is zero. (1)

(b) A glass sphere of diameter 35 mm is travelling through the fluid at terminal velocity.

Show that the drag force on this sphere is about 0.2 N.
density of glass $\rho_g = 2.52 \times 10^3$ kg m^{-3}
density of liquid $\rho_s = 1.43 \times 10^3$ kg m^{-3}

(5)

$W = F + U$ so $F = W - U$

$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi (17.5 \times 10^{-3})^3 = 2.245 \times 10^{-5}\ m^3$ (1)

$U = \rho_s V g = 1.43 \times 10^3 \times 2.245 \times 10^{-5} \times 9.81$ (1)

$U = 0.315N$

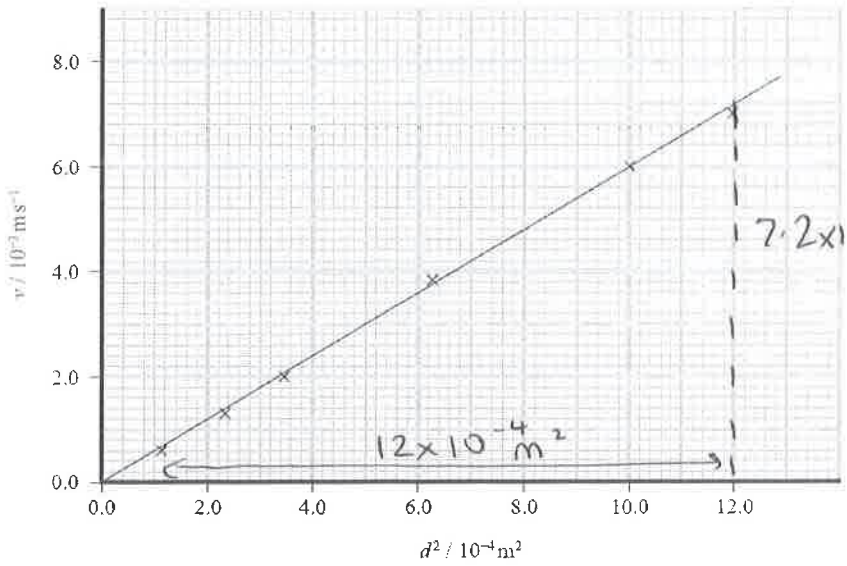
$W = \rho_g V g = 2.52 \times 10^3 \times 2.245 \times 10^{-5} \times 9.81$ (1)

~~$W = 0.496N$~~ $W = 0.555N$

(1)

$F = 0.555 - 0.315 = 0.24N$ (1)

(c) The student used his measurements to plot the graph of v against d^2 shown below.



hypotenuse > half length of line (1) part (ii)

The student reads in a textbook that if Stokes' law is obeyed

$$v = k\,d^2$$

where k is a constant.

(i) Deduce from the graph whether the flow of liquid around the spheres was laminar.

(3)

The graph is a straight line which goes through the origin (1) so $v \propto d^2$ which is consistent with Stokes' law (1). The flow is laminar, because Stokes' law implies laminar flow (1)

(ii) Determine a value for k using the student's graph.

(3)

k = gradient (1) $= \frac{7.2\times10^{-3}}{12\times10^{-4}} = 6$

Units $\frac{m\,s^{-1}}{m^2} \rightarrow m^{-1}\,s^{-1}$

(1)

$k =$ $6\ m^{-1}\,s^{-1}$

(iii) The constant k is given by

$$k = \frac{(\rho_g - \rho_s)g}{18\eta}$$

where η is the viscosity of the liquid.

Determine a value for η.
density of glass $\rho_g = 2.52 \times 10^3$ kg m^{-3}
density of liquid $\rho_s = 1.43 \times 10^3$ kg m^{-3}

(2)

$6 = \dfrac{(2.52 \times 10^3 - 1.43 \times 10^3)(9.81)}{18\eta}$ (1)

$\eta = \dfrac{1090 \times 9.81}{18 \times 6} = \dfrac{10692.9}{108} = 99$

$\eta =$ 99 Pa s (1)

(Total for question = 15 marks)