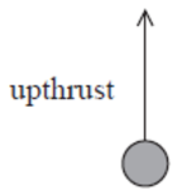
Questions

Q1.

A spherical polystyrene bead is immersed in oil. The bead has diameter 4.00×10^{-3} m. The bead is released and moves upwards through the oil at a constant velocity.

(a) Complete the free body force diagram below to show all the forces acting on the polystyrene bead.

(2)



(b) Show that the upthrust the oil exerts on the bead is about 3.1×10^{-4} N.

density of oil = 930 kg m^{-3}

(3)

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(c) Stokes' law shows how the viscous drag on a sphere is related to its velocity through a fluid.

Stokes' law is only valid if the bead is moving sufficiently slowly through the oil.

(i) State the reason for this condition.

(1)

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(ii) For Stokes' law to be valid the speed of the bead through the oil must be less than v_R, where

$$v_R = \frac{10 \times \text{viscosity of oil}}{\text{density of oil} \times \text{diameter of the bead}}$$

Deduce whether Stokes' law can be applied to this bead.

viscosity of oil = 4.90×10^{-2} Pa s
weight of polystyrene bead = 1.05×10^{-5} N

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(Total for question = 11 marks)

Q2.

A small, spherical air bubble moves upwards in a glass of water. The drag force on the bubble can be calculated using Stokes' law.

(a) State the condition needed for Stokes' law to apply to the bubble.

(1)

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(b) The bubble moves upwards at a constant velocity.

The volume of the bubble is 5.3×10^{-11} m^3.

(i) Show that the upthrust on the bubble is about 5×10^{-7} N.

density of water = 998 kg m^{-3}

(2)

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(ii) The bubble moves upwards at a constant velocity of 0.035 m s^{-1}.

Deduce whether Stokes' law applies to the bubble.

You may ignore the weight of the bubble.

viscosity of water = 9.5×10^{-4} Pa s

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(Total for question = 7 marks)

Q3.

An object of mass 35 kg fell from a boat to the seabed.

(a) The object reached terminal velocity as it fell.

(i) Show that the drag force acting on the object at terminal velocity was about 200 N.

volume of object = 1.60×10^{-2} m^3
density of seawater = 1.03×10^3 kg m^{-3}

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(ii) The drag force D on the object obeyed the formula

$$D = kv^2$$

where v is the speed of the object.

Determine the terminal velocity of the object.

$k = 2.2\ \text{N s}^2\ \text{m}^{-2}$

(2)

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Terminal velocity = ...

(iii) Give **two** reasons why Stokes' law could **not** be used to calculate the terminal velocity of the object.

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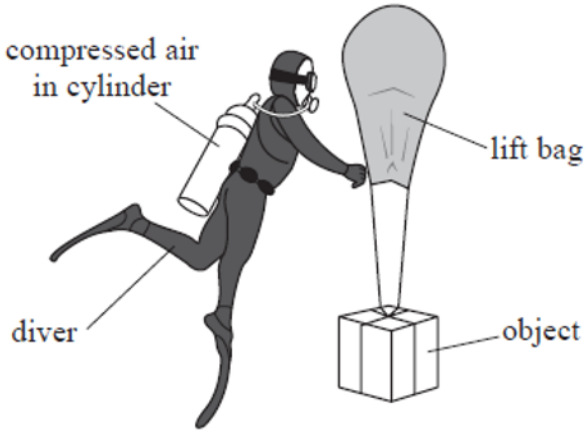
(b) To lift the heavy object from the seabed, a diver used a 'lift bag'.

The diver used compressed air from a cylinder to fill the lift bag, as shown.



When released, the lift bag and object accelerated upwards until they reached a maximum velocity.

Explain why the lift bag and object reached a maximum velocity.

(3)

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(Total for question = 12 marks)

Q4.

Stokes' law can be used to determine the frictional force on an object moving through a fluid.

To which of the following would Stokes' law best apply?

☒ **A** A large sphere moving quickly through a fluid.

☒ **B** A large sphere moving slowly through a fluid.

☒ **C** A small sphere moving quickly through a fluid.

☒ **D** A small sphere moving slowly through a fluid.

(Total for question = 1 mark)

Q5.

Answer the question 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 ☒.

A ball bearing falls at terminal velocity through a liquid.

The temperature of the liquid increases and the ball bearing falls with a greater terminal velocity.

Which row of the table is correct as the temperature of the liquid increases?

		Viscous drag on ball bearing	Viscosity of liquid
☒	**A**	constant	increases
☒	**B**	constant	decreases
☒	**C**	decreases	increases
☒	**D**	decreases	decreases

(Total for question = 1 mark)

Q6.

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

(4)

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Terminal velocity = ...

(Total for question = 11 marks)

Q7.

Answer the question 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 ☒.

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

(Total for question = 1 mark)

Q8.

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

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(Total for question = 6 marks)

Q9.

Answer the question 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 ☒.

Which of the following best describes the situations in which Stokes' Law applies for objects moving in a fluid?

☐ **A** all spherical objects moving at low speeds

☒ **B** all spherical objects in a fluid with low viscosity

☒ **C** small spherical objects moving at low speeds

☒ **D** small spherical objects in a fluid with low viscosity

(Total for question = 1 mark)

Q10.

A small sphere is moving horizontally through a viscous liquid.

(a) Stokes' law can be used to calculate the drag force on an object.

State the conditions that must apply for Stokes' law to be valid.

(2)

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(b) There is a constant force of 2.3×10^{-5} N acting horizontally on the sphere.

diameter of sphere = 4.5×10^{-3} m
viscosity of liquid = 7.1×10^{-2} Pa s

(i) At one instant, the speed of the sphere is 5.2×10^{-3} m s^{-1}.

Calculate the resultant horizontal force on the sphere.

(3)

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Resultant horizontal force = ...

(ii) Calculate the maximum speed of the sphere in the horizontal direction.

(2)

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Maximum horizontal speed = ...

(c) A larger diameter sphere in the same liquid is acted upon by the same constant force as in (b). The liquid is at a lower temperature.

Explain the effect these changes have on the maximum speed of this sphere.

(4)

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(Total for question = 11 marks)

Q11.

A falling sphere viscometer is a device used to determine the viscosity of a liquid. A sphere falls through a cylinder containing a liquid, and the terminal velocity of the sphere is measured.

(a) State why the temperature of the liquid should **not** increase during the measurement.

(1)

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(b) A scientist measured the terminal velocity of an aluminium sphere as it fell through glycerol.

(i) Show that the weight of the sphere is about 4.8×10^{-3} N.

density of aluminium = 2.70×103 kg m^{-3}

diameter of sphere = 7.00×10^{-3} m

(4)

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(ii) The terminal velocity of the sphere was 4.05×10^{-2} m s^{-1}.

Deduce whether Stokes' law applied to the falling sphere.

density of glycerol = 1.26×103 kg m^{-3}

viscosity of glycerol = 9.50×10^{-1} Pa s

(3)

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(iii) State **one** condition that must be met for Stokes' law to apply.

(1)

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(c) A scientist used the viscometer to measure the viscosity of blood. The viscosity of blood is typically in the range 3×10^{-3} Pa s to 4×10^{-3} Pa s.

Explain why the scientist should use an aluminium sphere with a much smaller diameter than the sphere used with the glycerol. Do not include calculations in your answer.

viscosity of glycerol = 9.50×10^{-1} Pa s

(5)

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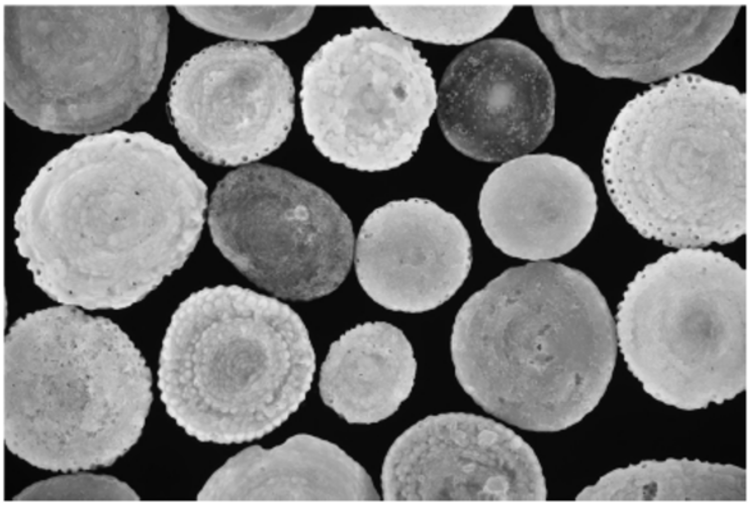
(Total for question = 14 marks)

Q12.

Foraminifera, known as 'forams', are small sea creatures with shells.

(a) When forams die they sink slowly through the seawater to form a layer at the bottom of the sea. The photograph shows a magnified view of some typical forams.



(Source: © alex7370/Shutterstock)

(i) A spherical foram with a mass of 1.15×10^{-8} kg is sinking at terminal velocity in seawater. The upthrust due to the seawater is 4.37×10^{-8} N. The flow of seawater around the sinking foram is laminar.

Show that the viscous drag on the foram is about 7×10^{-8} N.

(3)

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(ii) Calculate the terminal velocity of this foram.

diameter of foram = 9.2×10^{-4} m
viscosity of seawater = 1.41×10^{-3} Pa s

(2)

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Terminal velocity = ...

(b) As the forams sink deeper into the sea, the temperature of the water becomes lower.

Discuss how the terminal velocities of forams change as they sink deeper into the sea.

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(Total for question = 9 marks)

Q13.

When water vapour in the atmosphere cools it condenses, forming tiny drops of water. These drops increase in size by colliding with each other and fall back to the ground as rain.

(a) As a raindrop falls through the air it eventually reaches its terminal velocity. The upthrust on the raindrop can be considered to be negligible.

(i) Explain what is meant by the terminal velocity of the raindrop. Your answer should include a free-body force diagram for the raindrop when terminal velocity has been reached.

(4)

(ii) The air resistance F acting on a raindrop travelling at a velocity v, can be determined using the expression

$$F = 0.45\rho A v^2$$

where A is the cross-sectional area of the raindrop and ρ is the density of the air.

Calculate the terminal velocity of a spherical raindrop of radius 2.0×10^{-3} m.

density of air = 1.2 kg m^{-3}
density of rainwater = 1.0×10^{3} kg m^{-3}

(4)

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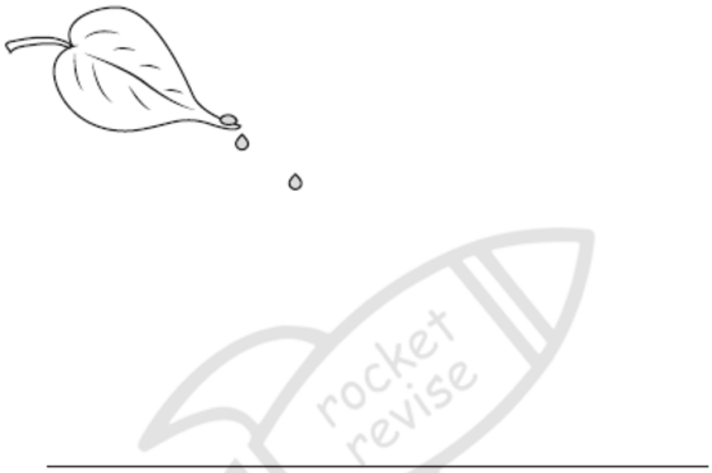
Terminal velocity = ...

(b) Some plants have adapted to high rainfall by having a specialised shape and waxy leaves. This allows rain to slide down a leaf and off the end as a series of drops.

(i) A drop of water slides off a leaf as shown.

Add to the diagram to show the position of the drop at regular intervals of time.
The first two positions have been drawn for you.

(2)



(ii) Water falls from a leaf at a steady rate of five drops per second.

As each drop reaches the ground, there are four drops above it in the air.

Calculate the height of the leaf from the ground. It can be assumed that the drop at the highest position has just left the leaf.

(3)

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Height of leaf = ...

(Total for question = 13 marks)