PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



EXAM QUESTION PACK

TOPIC 4: MATERIALS

FLUIDS

SCORE	PERCENTAGE
/303	%

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Q1.

The student then found a value of μ for a brass wire, using a different method.

(i) He measured the diameter d of the wire using a micrometer.

Explain one technique the student should use when measuring d.

(2)

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(ii) The student obtained the following data.

d / mm			
0.55	0.59	0.57	0.58

The stated value of μ for the brass wire used by the student was 2.14×10^{-3} kg m^{-1}.

Deduce whether the student's data supports this value for μ.

density of brass = 8700 kg m^{-3} ± 200 kg m^{-3}

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(Total for question = 8 marks)

Q2.

A student is investigating a 'Cartesian diver'.

The diver is made from a plastic pipette. When placed in a plastic bottle full of water the diver rises to the top and touches the lid.



(a) Show that the downward force of the lid on the diver is about 0.02 N.

volume of diver = 8.0×10^{-6} m^3

mass of diver = 0.0059 kg

density of water = 1.0×10^3 kg m^{-3}

(3)

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(b) When the pressure is increased by squeezing the bottle, water is forced into the diver increasing its weight. The diver sinks, then remains at rest in the position shown.



The volume of air in the empty pipette in part (a) was 8.0×10^{-6} m^3.

Show that the volume now occupied by the air is about 6×10^{-6} m^3.

(3)

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(c) The pressure of the air in the empty pipette in part (a) was 1.01×10^5 Pa.

Calculate the pressure of the air in part (b).

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Pressure = ...

(Total for question = 8 marks)

Q3.

Genuine crystal balls are made from clarified quartz rather than glass.
A student was given a small crystal ball and wanted to know whether it was genuine.

The mean diameter of the crystal ball was measured to be 5.06 cm and the mass of the crystal ball was measured to be 175 g.

Show that the density of the material of the crystal ball is about 2600 kg m^{-3}.

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(Total for question = 3 marks)

Q4.

Genuine crystal balls are made from clarified quartz rather than glass. A student was given a small crystal ball and wanted to know whether it was genuine.

The student measured the diameter of the crystal ball using vernier calipers with a resolution of 0.01 cm.
She measured the mass of the crystal ball using a balance with a resolution of 1 g.

The table gives the densities of clarified quartz and glass.

Material	Density / kg m^{-3}
Clarified quartz	2650
Glass	2590

Determine whether the crystal ball was genuine.

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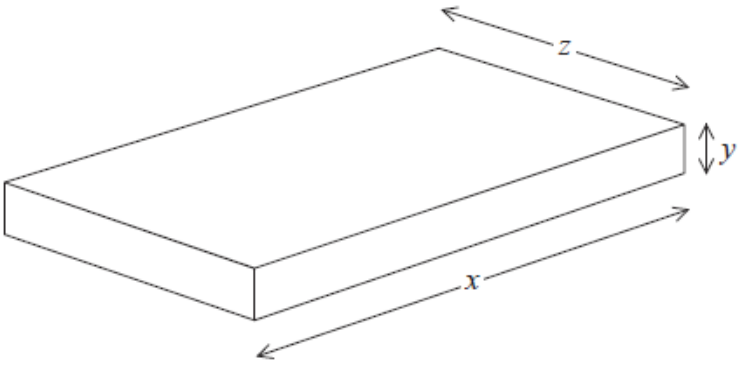
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(Total for question = 6 marks)

Q5.

A student carries out measurements to determine the density of glass. The student has 20 glass microscope slides available.

The approximate dimensions of one slide are shown.



$x \approx 75\,\text{mm}$
$y \approx 1\,\text{mm}$
$z \approx 25\,\text{mm}$

(a) The density is calculated using the equation

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Describe how the student can determine an accurate value for the density of the glass. Your answer should include the measuring instruments required.

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(b) State one precaution that the student should take to ensure the measurements are accurate.

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(Total for question = 5 marks)

Q6.

The photograph shows a type of drink known as stout.



When the drink is poured, it contains many spherical bubbles of gas which rise and form the foamy 'head' at the top of the drink. The manufacturers of the drink state "It takes 120 seconds for the head to form".

For the smallest bubbles, the uniform upward velocity can be calculated using the equation

$$v = \frac{2(\rho_{\text{stout}} - \rho_{\text{gas}})r^2 g}{9\eta}$$

(i) Derive this equation by considering the forces acting on a bubble.

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(ii) State an assumption you have made.

(1)

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(iii) Evaluate the statement from the manufacturers that it takes 120 seconds for the head to form.

You should consider the time for a bubble to travel from the bottom of the glass to the top.

height of glass = 11.5 cm

density of gas = 1.22 kg m^{-3}
density of stout = 1.01 × 10^{3} kg m^{-3}
viscosity of stout = 2.06 × 10^{-3} Pa s
diameter of bubble = 122 μm

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Q7.

A student carries out an experiment to determine the viscosity of a liquid. To do this, she takes measurements to determine the terminal velocity of a solid sphere falling through the liquid.

The data needed for such an experiment is:

weight of sphere = 4.8 × 10^{-3} N
radius of sphere = 2.5 × 10^{-3} m
volume of sphere = 6.5 × 10^{-8} m^{3}
density of liquid = 1300 kg m^{-3}

(a) Show that the upthrust on the sphere is about 8 × 10^{-4} N.

(3)

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(b) The student calculates that the terminal velocity is 4.6 × 10^{-3} m s^{-1}.

Use this value to calculate the viscosity of the liquid in kg m^{-1} s^{-1}.

(3)

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Viscosity = ... kg m^{-1} s^{-1}

(Total for question = 6 marks)

Q8.

A student investigated the terminal velocity of steel spheres falling through oil.

The student obtained the following results.

radius of steel sphere = 1.50 mm
volume of steel sphere = 1.41×10^{-8} m^3
mass of steel sphere = 1.10×10^{-4} kg
maximum speed of sphere = 0.849 m s^{-1}

The student had the following table.

Type of oil	Density at 26 °C / kg m^{-3}	Viscosity at 26 °C / Pa s
Corn	918	0.0447
Hazelnut	918	0.0504
Sunflower	918	0.0414

Identify which type of oil the student used.

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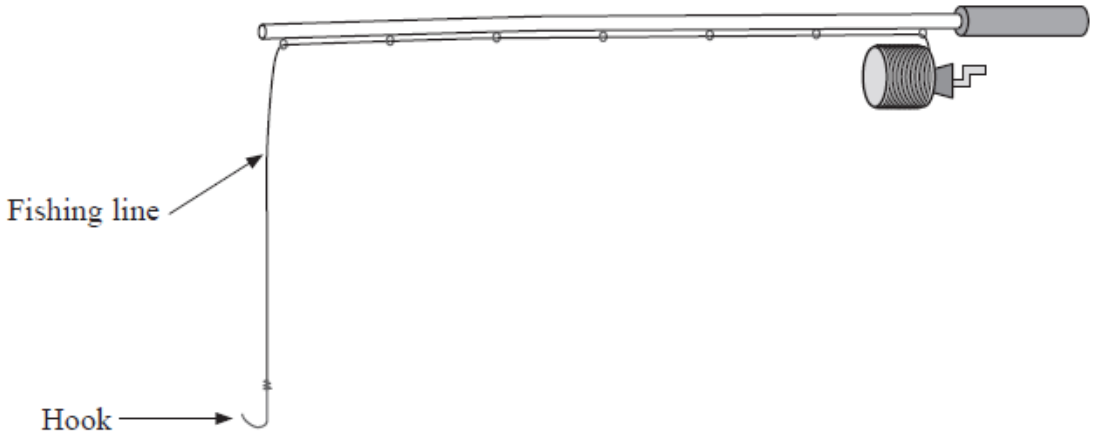
(Total for question = 4 marks)

Q9.

The following three properties can be used to describe copper.

Ductile Malleable Tough

(a) Both nylon and copper can be used to make fishing lines. Copper fishing lines sink faster than those made of nylon. This makes copper fishing lines more suitable for deep water fishing.



(i) By considering the forces acting on the submerged line, explain why nylon is less suitable than copper for deep water fishing. Include a suitable calculation in your answer.

Both lines have the same cross-sectional area.

cross-sectional area of lines = 1.30×10^{-7} m^2

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

weight of 20.0 m of copper line = 0.220 N

weight of 20.0 m of nylon line = 0.0280 N

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(ii) A fish becomes caught on the hook and the copper line extends. Calculate the extension produced.

cross-sectional area of copper line = 1.30×10^{-7} m^3

load on line = 65.0 N

original length of line = 20.0 m

Young modulus of copper = 129 GPa

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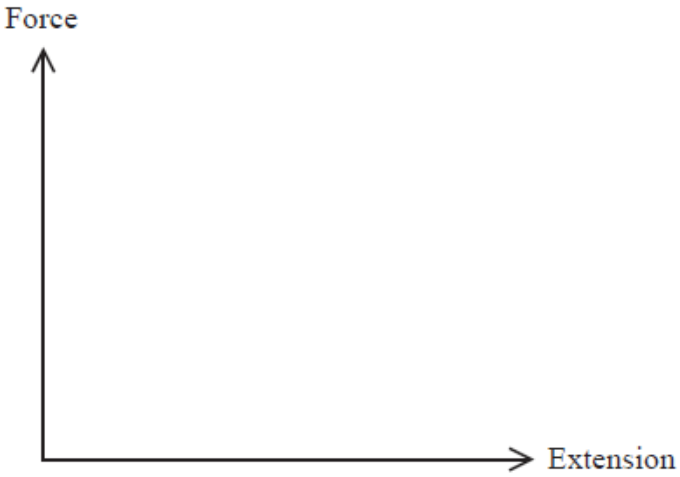
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Extension = ...

(b) Some people use fishing lines that have been pre-stretched by loading and unloading.

(i) Sketch the force-extension graph for a copper line during the process of pre-stretching.

(3)



(ii) Suggest a reason why some people prefer to use this type of line.

(1)

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(Total for question = 11 marks)

Q10.

In 2014 the Rosetta spacecraft reached the comet Churyumov-Gerasimenko.
Rosetta went into orbit around the comet.

The following table gives some data for the comet.

Mass / kg	1.0×10^{13}
Density / kg m^{-3}	470

The comet is irregular in shape but can be modelled as a spherical object.

(a) Show that a sphere with this mass and density has a radius of about 1700 m.

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(b) Calculate the gravitational field strength at the surface of the comet.

(2)

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Gravitational field strength = ...

(c) A probe was sent from the Rosetta spacecraft to land on the comet.
The probe bounced off the surface of the comet and took 1 hour and 50 minutes to return to the surface again.

Calculate the height above the surface of the comet that the probe would have reached. Assume that the acceleration of the probe is constant with the magnitude calculated in (b).

(2)

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Height = ...

(d) Explain, using gravitational field theory, how the actual height reached would compare with the value calculated in part (c).

You may assume there are no resistive forces such as air resistance.

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(Total for question = 10 marks)

Q11.

Weather stations monitor the position of storm clouds.

(i) A raindrop is falling vertically through the air.

The free-body force diagram shows the forces acting on the raindrop.

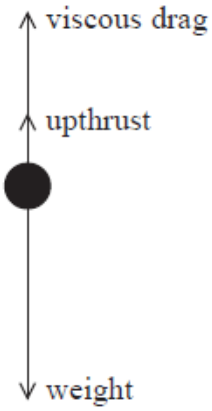


Diagram **NOT** drawn to scale

The raindrop is travelling at terminal velocity. The raindrop is spherical with a radius of 0.10 mm and a weight of 4.1×10^{-8} N .

Calculate the magnitude of the terminal velocity.

viscosity of air = 1.3×10^{-5} Pa s density of air = 1.2 kg m^{-3}

(4)

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Magnitude of terminal velocity = ...

(ii) The value of terminal velocity calculated using the data in (i) is greater than the actual terminal velocity of the raindrop.

Explain why the calculation in (i) may not be valid.

(2)

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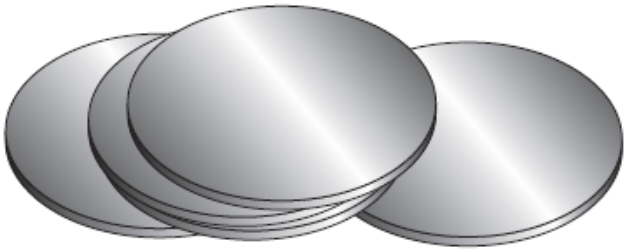
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(Total for question = 6 marks)

Q12.

A student is investigating the properties of steel. He has fifty steel discs available.



Each disc has a diameter $d \approx 1.3$ cm and a thickness $t \approx 2$ mm.

A balance which can measure mass with a resolution of 0.2 g is available.

Determine the minimum number of discs that should be placed on the balance together if the percentage uncertainty in the measurement of the mass is to be less than 0.5%.

(4)

density of steel = 7900 kg m^{-3}

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Minimum number of discs = ...

(Total for question = 4 marks)

Q13.

The harp is a musical instrument with many strings, as shown.



(Source: © Peter Voronov/Shutterstock)

All the strings are under tension.

The strings on one type of harp are made from nylon of density 1070 kg m^{-3}. One string has a diameter of 1.14 mm.

(i) Show that the mass per unit length μ of the string is about 1.1×10^{-3} kg m^{-1}.

(2)

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(ii) When the middle of the string is plucked, a note of frequency 440 Hz is produced.

Calculate the tension in the string.

length of string = 41.0 cm

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Tension in string = ...

(Total for question = 6 marks)

Q14.

An object of volume V made from a material of density ρ_1 is placed into a fluid of density ρ_2.

Which of the following gives the upthrust on the object?

☒ **A** $\rho 1\ V\ g$

☒ **B** $\rho 2\ V\ g$

☒ **C** $(\rho_2 - \rho_1)\ V\ g$

☒ **D** $\frac{(\rho_2 + \rho_1)}{2} Vg$

(Total for question = 1 mark)

Q15.

A small helium balloon is released into the air. The balloon initially accelerates upwards.

The resultant force F on the balloon is given by

$$F = \text{upthrust} - \text{weight} - \text{viscous drag}$$

Eventually the balloon reaches a constant upwards speed.

Calculate a value for the viscous drag force acting on the balloon at this speed. The balloon may be considered as a sphere with radius 12 cm.

(4)

density of air = 1.2 kg m^{-3}
mass of unfilled balloon = 4.0 g
mass of helium in balloon = 1.2 g

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Viscous drag force = ...

(Total for question = 4 marks)

Q1.

A student is investigating a 'Cartesian diver'.

The diver is made from a plastic pipette. When placed in a plastic bottle full of water the diver rises to the top and touches the lid.



(a) Show that the downward force of the lid on the diver is about 0.02 N.

volume of diver = 8.0×10^{-6} m^3

mass of diver = 0.0059 kg

density of water = 1.0×10^3 kg m^{-3}

(3)

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(b) When the pressure is increased by squeezing the bottle, water is forced into the diver increasing its weight. The diver sinks, then remains at rest in the position shown.



The volume of air in the empty pipette in part (a) was 8.0×10^{-6} m^3.

Show that the volume now occupied by the air is about 6×10^{-6} m^3.

(3)

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(c) The pressure of the air in the empty pipette in part (a) was 1.01×10^5 Pa.

Calculate the pressure of the air in part (b).

(2)

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Pressure = ...

(Total for question = 8 marks)

Q2.

An exhibit in a science museum requires the observer to use a pump to create air bubbles in a column of liquid. The bubbles then rise through the liquid.



A student wishes to determine the total drag force acting on a bubble.

(i) Explain why it might not be possible to use Stokes' law to calculate the drag force acting on a bubble.

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*(ii) Describe an additional measurement that would need to be taken from the photograph and how it could be used to determine the drag force, assuming that the bubble has reached its terminal velocity.

(4)

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Q3.

A student carries out an experiment to determine the viscosity of a liquid. To do this, she takes measurements to determine the terminal velocity of a solid sphere falling through the liquid.

The data needed for such an experiment is:

weight of sphere = 4.8×10^{-3} N
radius of sphere = 2.5×10^{-3} m
volume of sphere = 6.5×10^{-8} m^3
density of liquid = 1300 kg m^{-3}

(a) Show that the upthrust on the sphere is about 8×10^{-4} N.

(3)

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(b) The student calculates that the terminal velocity is 4.6×10^{-3} m s^{-1}.

Use this value to calculate the viscosity of the liquid in kg m^{-1} s^{-1}.

(3)

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Viscosity = ... kg m^{-1} s^{-1}

(Total for question = 6 marks)

Q4.

The photograph shows a type of drink known as stout.



When the drink is poured, it contains many spherical bubbles of gas which rise and form the foamy 'head' at the top of the drink. The manufacturers of the drink state "It takes 120 seconds for the head to form".

A bubble, initially at rest in the liquid, accelerates until it achieves a uniform upward velocity.

Explain the motion of the bubble.

(4)

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Q5.

A student investigated the terminal velocity of steel spheres falling through oil.

The student obtained the following results.

radius of steel sphere = 1.50 mm
volume of steel sphere = 1.41×10^{-8} m^3
mass of steel sphere = 1.10×10^{-4} kg
maximum speed of sphere = 0.849 m s^{-1}

The student had the following table.

Type of oil	Density at 26 °C / kg m^{-3}	Viscosity at 26 °C / Pa s
Corn	918	0.0447
Hazelnut	918	0.0504
Sunflower	918	0.0414

Identify which type of oil the student used.

(4)

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(Total for question = 4 marks)

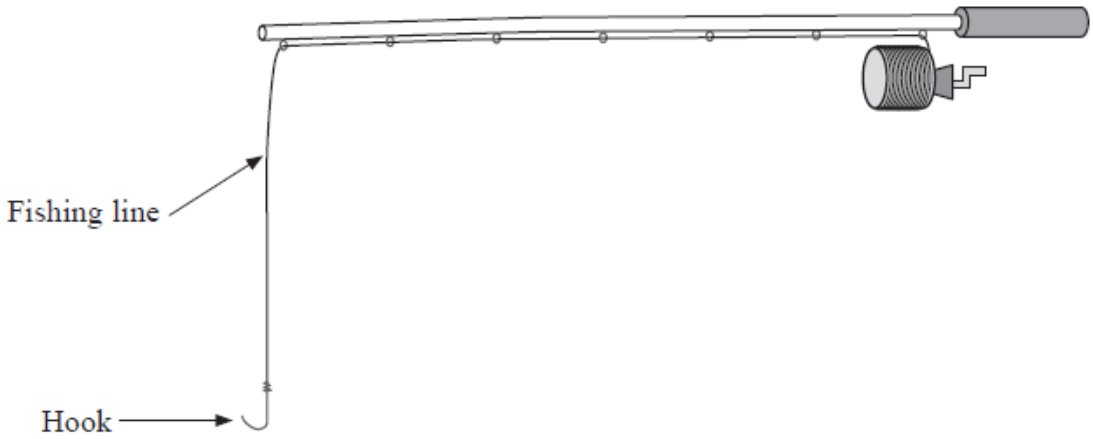
Q6.

The following three properties can be used to describe copper.

Ductile Malleable Tough

(a) Both nylon and copper can be used to make fishing lines. Copper fishing lines sink faster

than those made of nylon. This makes copper fishing lines more suitable for deep water fishing.



(i) By considering the forces acting on the submerged line, explain why nylon is less suitable than copper for deep water fishing. Include a suitable calculation in your answer.

Both lines have the same cross-sectional area.

cross-sectional area of lines = 1.30×10^{-7} m^2

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

weight of 20.0 m of copper line = 0.220 N

weight of 20.0 m of nylon line = 0.0280 N

(4)

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(ii) A fish becomes caught on the hook and the copper line extends. Calculate the extension produced.

cross-sectional area of copper line = 1.30×10^{-7} m^3

load on line = 65.0 N

original length of line = 20.0 m

Young modulus of copper = 129 GPa

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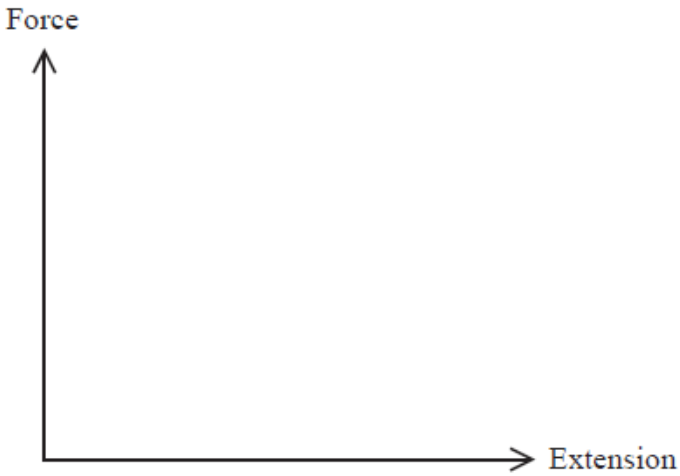
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Extension = ...

(b) Some people use fishing lines that have been pre-stretched by loading and unloading.

(i) Sketch the force-extension graph for a copper line during the process of pre-stretching.

(3)



(ii) Suggest a reason why some people prefer to use this type of line.

(1)

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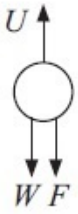
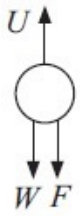
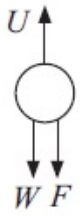
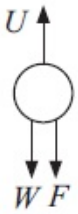
(Total for question = 11 marks)

Q7.

When beer is being brewed it can contain bubbles of gas rising through it as well as solid particles, such as grain particles, falling through it.

Which row of the table correctly shows the forces on a rising gas bubble and a falling solid particle?

F = viscous drag, *U* = upthrust, *W* = weight

	Gas bubble	Solid particle
☒ A		
☒ B		
☒ C		
☒ D		

(Total for question = 1 marks)

Q8.

A small object is falling at terminal velocity in a large container of oil.

Which diagram correctly represents, in magnitude and direction, the forces acting on the object as it reaches terminal velocity?

W = weight

U = upthrust

D = drag



☒ **A**



☒ **B**



☒ **C**



☒ **D**

(Total for question = 1 mark)

Q9.

Weather stations monitor the position of storm clouds.

(i) A raindrop is falling vertically through the air.

The free-body force diagram shows the forces acting on the raindrop.

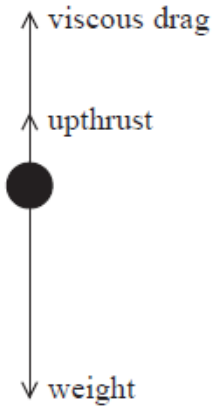


Diagram **NOT** drawn to scale

The raindrop is travelling at terminal velocity. The raindrop is spherical with a radius of 0.10 mm and a weight of 4.1×10^{-8} N .

Calculate the magnitude of the terminal velocity.

viscosity of air = 1.3×10^{-5} Pa s density of air = 1.2 kg m^{-3}

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Magnitude of terminal velocity = ...

(ii) The value of terminal velocity calculated using the data in (i) is greater than the actual terminal velocity of the raindrop.

Explain why the calculation in (i) may not be valid.

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(Total for question = 6 marks)

Q10.

A bubble of air is rising through a vertical column of water.

Which statement, about the motion of the bubble, is correct to a good approximation?

(1)

☒ **A** The bubble has a constant velocity because its weight equals the viscous drag.

☒ **B** The bubble has a constant velocity because the upthrust is equal to the viscous drag.

☒ **C** The bubble has an acceleration because its weight is greater than the upthrust.

☒ **D** The bubble has an acceleration because the viscous drag is greater than the upthrust.

(Total for question = 1 mark)

Q11.

A force meter measures force by making use of Hooke's Law.

The extension of a spring inside the force meter allows the magnitude of the force applied to be read from a scale.

*A beaker of water is placed on a balance and a rock is hung from a force meter as shown in diagram 1.

The initial reading on the balance is *R*, and the initial reading on the force meter is *F*.
The rock is lowered gently into the beaker of water until it is completely submerged.

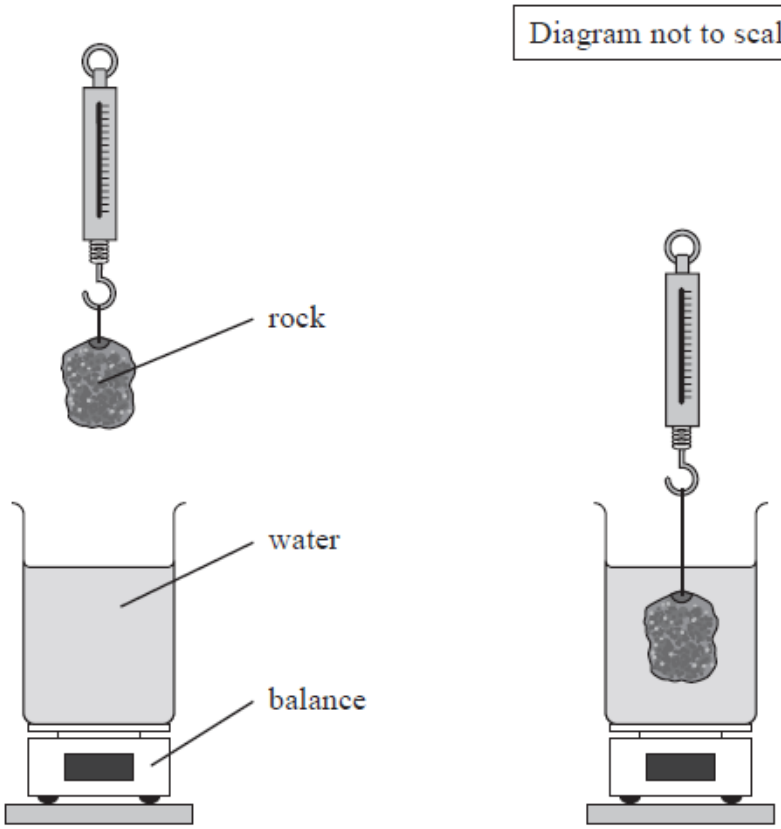


Diagram 1 **Diagram 2**

(Source: adapted from https://passnownow.com/wp-content/uploads/2014/06/upthrust)

Explain any changes in the readings *R* and *F* as the rock is lowered into the water as shown in diagram 2.

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(Total for question = 6 marks)

Q12.

An object of volume V made from a material of density ρ_1 is placed into a fluid of density ρ_2.

Which of the following gives the upthrust on the object?

☒ **A** $\rho 1\ V\ g$

☒ **B** $\rho 2\ V\ g$

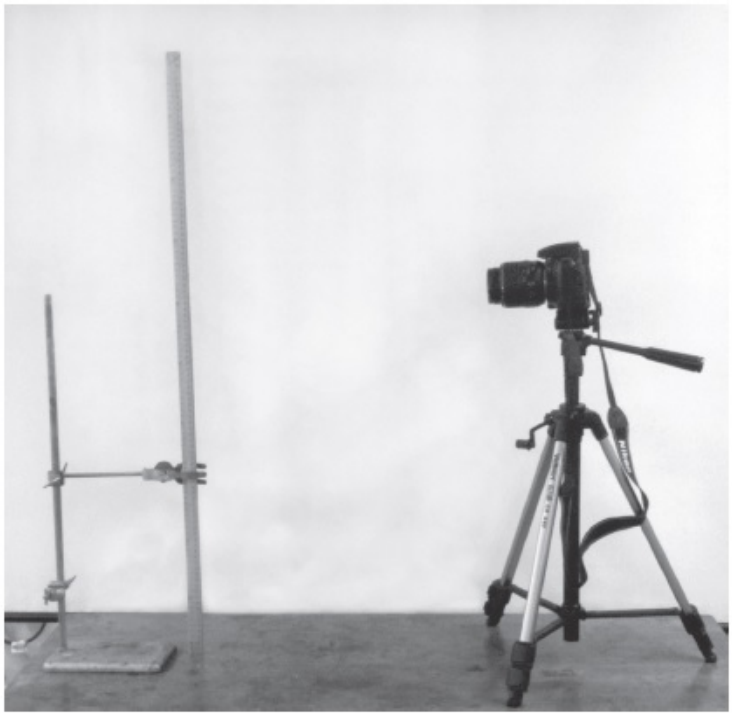
☒ **C** $(\rho_2 - \rho_1)\ V\ g$

☒ **D** $\frac{(\rho_2 + \rho_1)}{2} Vg$

(Total for question = 1 mark)

Q13.

A student carries out an experiment to find the acceleration of free fall.



(a) In this experiment the student releases a small steel ball in front of a metre rule and uses a video camera to record its motion. The camera captures 30 images per second, which may be played back one image at a time.

(i) Explain how the acceleration of free fall could be determined using the recording.

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(ii) Describe a systematic error which could arise.

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(b) Describe one property of the steel ball that makes it suitable to use in this experiment and explain why this property makes it suitable.

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(c) Explain an advantage of using a video camera to take measurements for this experiment rather than using a stopwatch.

(2)

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(Total for question = 9 marks)

Q14.

A small helium balloon is released into the air. The balloon initially accelerates upwards.

The resultant force F on the balloon is given by

$$F = \text{upthrust} - \text{weight} - \text{viscous drag}$$

Eventually the balloon reaches a constant upwards speed.

Calculate a value for the viscous drag force acting on the balloon at this speed. The balloon may be considered as a sphere with radius 12 cm.

(4)

density of air = 1.2 kg m^{-3}
mass of unfilled balloon = 4.0 g

mass of helium in balloon = 1.2 g

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Viscous drag force = ...

(Total for question = 4 marks)

Q15.

A student carries out an experiment to determine the viscosity of glycerol. She does this by determining the terminal velocity of a steel sphere falling through glycerol.

The equation shows how the terminal velocity of a solid sphere falling through a liquid depends on the density of both the solid and the liquid.

$$v = \frac{Vg(\rho_s - \rho_l)}{6\pi r\eta}$$

where

ρ_l = density of liquid
ρ_s = density of solid
r = radius of sphere
V = volume of sphere
η = viscosity of liquid
v = terminal velocity

The derivation of the equation for terminal velocity has been started below.
Complete the derivation.

(3)

At terminal velocity: weight of solid sphere = drag + upthrust

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(Total for question = 3 marks)

Q1.

A student carries out an experiment to determine the viscosity of glycerol. She does this by determining the terminal velocity of a steel sphere falling through glycerol.

(i) The student drops a steel sphere with a radius of 4.0 mm into a cylinder of glycerol.

The sphere reaches terminal velocity and takes 3.9 s to fall 0.50 m.

Calculate the viscosity of glycerol.

density of steel = 7800 kg m^{-3}
density of glycerol =1300 kg m^{-3}

(4)

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Viscosity of glycerol = ...

(ii) There are two cylinders available for the student to use. One cylinder has a diameter of 1.5 cm and the other has a diameter of 5.0 cm.

State and justify which cylinder the student should use in order to gain a more accurate value for the viscosity of glycerol.

(2)

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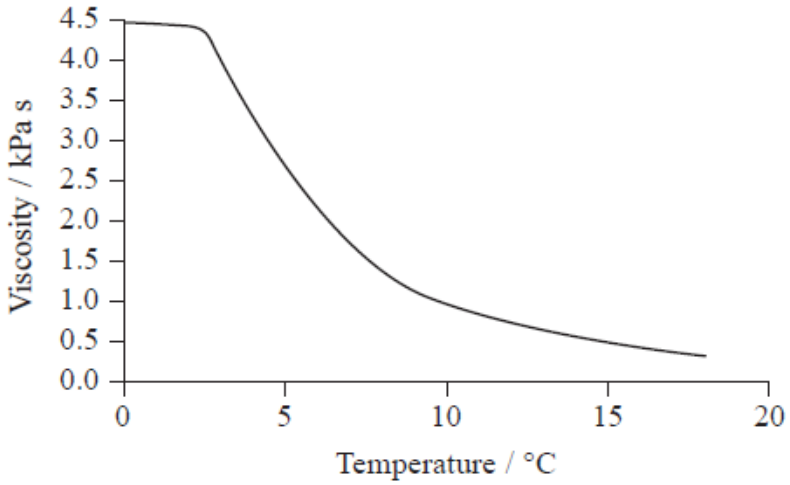
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(Total for question = 6 marks)

Q2.

The graph shows the effect of temperature on viscosity for butter.



A student wants to spread butter on some bread.

Explain why it is easier to use butter at room temperature than straight from the fridge.

(2)

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(Total for question = 2 marks)

Q3.

An exhibit in a science museum requires the observer to use a pump to create air bubbles in a column of liquid. The bubbles then rise through the liquid.



A student wishes to determine the total drag force acting on a bubble.

(i) Explain why it might not be possible to use Stokes' law to calculate the drag force acting on a bubble.

(2)

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*(ii) Describe an additional measurement that would need to be taken from the photograph and how it could be used to determine the drag force, assuming that the bubble has reached its terminal velocity.

(4)

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Q4.

The viscosity of fluids varies with temperature.

Which line of the table correctly shows the change in viscosity with increasing temperature?

	Oil	Dry air
☒ **A**	decreases	decreases
☒ **B**	decreases	increases
☒ **C**	increases	decreases
☒ **D**	increases	increases

(Total for question = 1 mark)

Q5. The 'Stealth' roller coaster at the Thorpe Park theme park is advertised as reaching 135 km hour^{-1} from rest in 2.3 seconds.

Most roller coasters are driven slowly up to the top of a slope at the start of the ride. However the carriages on 'Stealth' are initially accelerated horizontally from rest at ground level by a hydraulic launch system, before rising to the top of the first slope.

(a) (i) Calculate the average acceleration of the carriages.

135 km hour^{-1} = 37.5 m s^{-1}

(2)

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Average acceleration = ...

(ii) Calculate the minimum average power which must be developed by the launch system.

mass of carriages and passengers = 10 000 kg

(3)

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Minimum average power = ...

(iii) Suggest why the power in (ii) is a minimum value.

(1)

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*(b) The force required to launch 'Stealth' is not always the same. The ride is monitored and the data from preceding launches is used to calculate the required force.

If the mass of the passengers for a particular ride is significantly more than for preceding launches, this can lead to 'rollback'. This is when the carriages do not quite reach the top of the first slope and return backwards to the start.

Explain why 'rollback' would occur in this situation.

(3)

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(c) Suggest why roller coasters may have a greater acceleration when the lubricating oil between the moving parts has had time to warm up.

(2)

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(Total for Question = 11 marks)

Q6.

A student carries out an experiment to determine the viscosity of a liquid. To do this, she takes measurements to determine the terminal velocity of a solid sphere falling through the liquid.

The data needed for such an experiment is:

weight of sphere = 4.8×10^{-3} N
radius of sphere = 2.5×10^{-3} m
volume of sphere = 6.5×10^{-8} m^3
density of liquid = 1300 kg m^{-3}

(a) Show that the upthrust on the sphere is about 8×10^{-4} N.

(3)

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(b) The student calculates that the terminal velocity is 4.6×10^{-3} m s^{-1}.

Use this value to calculate the viscosity of the liquid in kg m^{-1} s^{-1}.

(3)

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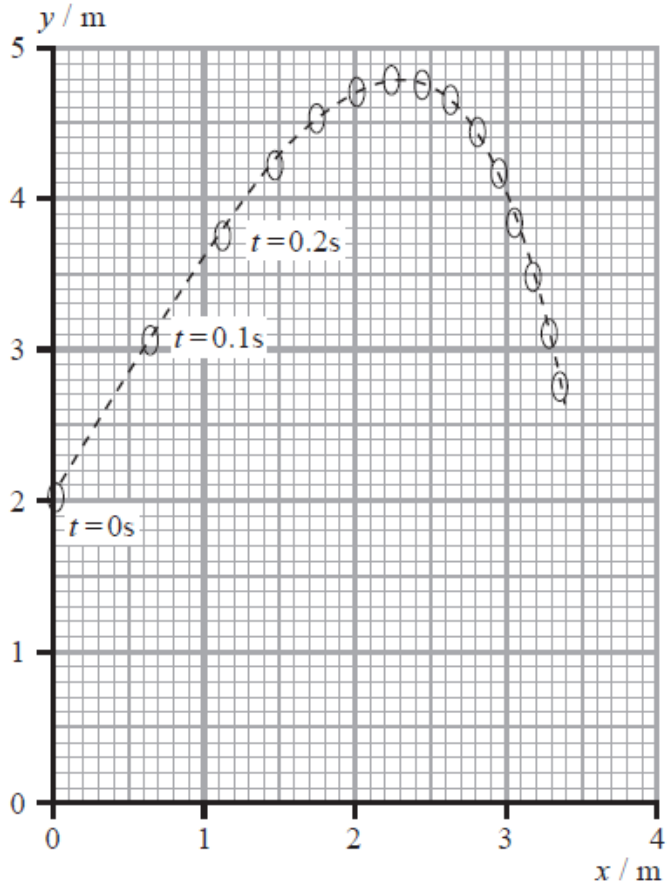
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Viscosity = ... kg m^{-1} s^{-1}

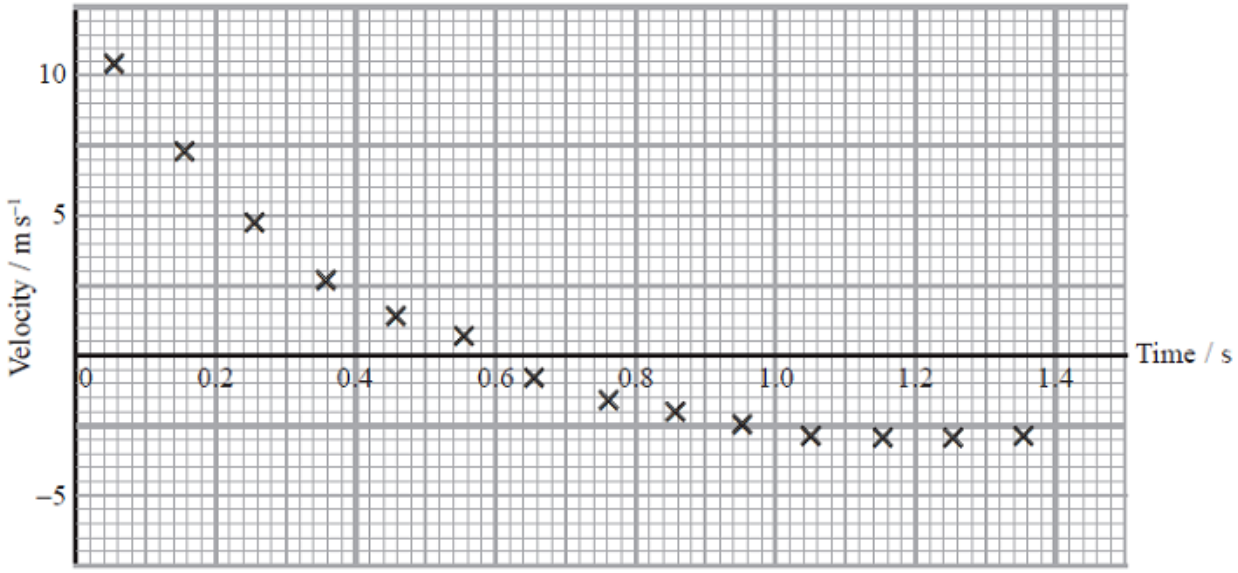
(Total for question = 6 marks)

Q7.

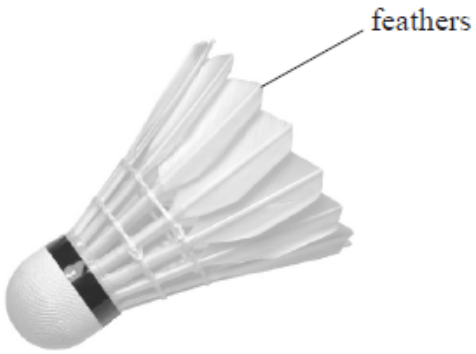
In a game of badminton, a shuttlecock is hit by a racket. The graph shows how the vertical displacement (y) and horizontal displacement (x) of the shuttlecock vary from the moment it leaves the racket. The positions are recorded every 0.10 s.



The graph below shows how the velocity of the shuttlecock in the vertical direction varies with time.



The photograph shows a shuttlecock.



© Pearson Asset Library

The shuttlecock always moves through the air with the 'feathers' trailing behind.

Explain how the feathers affect the motion of the shuttlecock along its path.

(3)

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(Total for question = 3 marks)

Q8.

A student investigated the terminal velocity of steel spheres falling through oil.

The student obtained the following results.

radius of steel sphere = 1.50 mm
volume of steel sphere = 1.41×10^{-8} m^3
mass of steel sphere = 1.10×10^{-4} kg
maximum speed of sphere = 0.849 m s^{-1}

The student had the following table.

Type of oil	Density at 26 °C / kg m^{-3}	Viscosity at 26 °C / Pa s
Corn	918	0.0447
Hazelnut	918	0.0504
Sunflower	918	0.0414

Identify which type of oil the student used.

(4)

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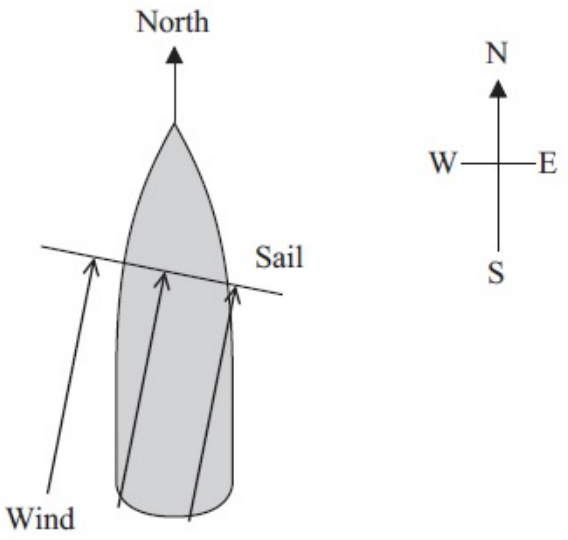
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(Total for question = 4 marks)

Q9.

A stationary boat is pointing north as shown in the diagram. A wind starts blowing at 10 m s^{-1} in a direction 20º east of north against the sail. The boat starts to move northwards.



(a) (i) The wind exerts a force per unit area of 84 N m^{-2} on the sail, which is at right angles to the wind direction.

Show that the component of force in a northerly direction is about 1400 N.

area of sail = 18 m^2

(3)

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(ii) When the wind starts to blow the water exerts a force on the boat to the west.

Explain why.

(2)

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(iii) Draw a vector diagram showing the forces exerted on the boat by the wind and the water and the resultant force calculated in part (a)(i).

(2)

(iv) Assuming the boat is starting from rest in still water, calculate the initial acceleration of the boat.

mass of boat = 400 kg

(2)

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Initial acceleration = ...

(b) Later the wind, still at a speed of 10 m s^{-1}, is blowing towards the north and the boat is travelling northwards at a steady speed of 5 m s^{-1}. The force on the sail is now 380 N towards the north.

(i) Suggest why the force on the sail is less than in part (a).

(1)

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(ii) Calculate the rate at which the wind does work against the forces that resist the boat's motion.

(2)

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Rate at which the wind does work = ...

(iii) There is now a force exerted southwards on the boat. A suggested reason for this force is because of turbulence developing at the rear of the boat. Add flow lines to the diagram to show the path of water around the boat and label the regions of laminar and turbulent flow.

(2)



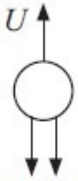
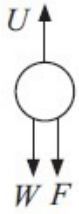
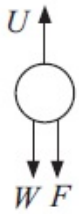
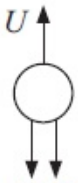
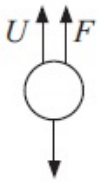
(Total for question = 14 marks)

Q10.

When beer is being brewed it can contain bubbles of gas rising through it as well as solid particles, such as grain particles, falling through it.

Which row of the table correctly shows the forces on a rising gas bubble and a falling solid particle?

F = viscous drag, *U* = upthrust, *W* = weight

	Gas bubble	Solid particle
☒ A		
☒ B		
☒ C		
☒ D		

(Total for question = 1 marks)

Q11.

Weather stations monitor the position of storm clouds.

(i) A raindrop is falling vertically through the air.

The free-body force diagram shows the forces acting on the raindrop.

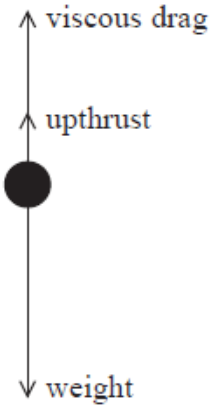


Diagram **NOT** drawn to scale

The raindrop is travelling at terminal velocity. The raindrop is spherical with a radius of 0.10 mm and a weight of 4.1×10^{-8} N .

Calculate the magnitude of the terminal velocity.

viscosity of air = 1.3×10^{-5} Pa s density of air = $1.2\ \text{kg m}^{-3}$

(4)

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Magnitude of terminal velocity = ...

(ii) The value of terminal velocity calculated using the data in (i) is greater than the actual terminal velocity of the raindrop.

Explain why the calculation in (i) may not be valid.

(2)

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(Total for question = 6 marks)

Q12.

A bubble of air is rising through a vertical column of water.

Which statement, about the motion of the bubble, is correct to a good approximation?

☒ **A** The bubble has a constant velocity because its weight equals the viscous drag.

☒ **B** The bubble has a constant velocity because the upthrust is equal to the viscous drag.

☒ **C** The bubble has an acceleration because its weight is greater than the upthrust.

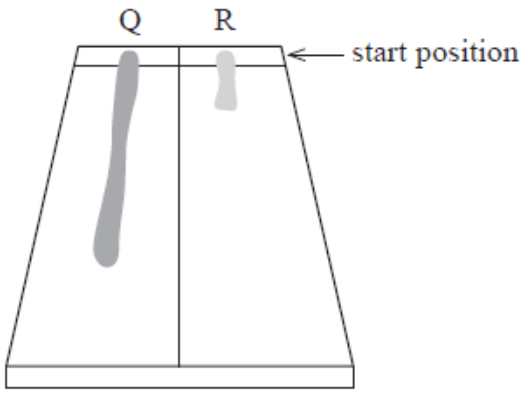
☒ **D** The bubble has an acceleration because the viscous drag is greater than the upthrust.

(Total for question = 1 mark)

Q13.

Q and R are drops of two different fluids which have been placed on one end of a tile.
The tile is then tilted.

The diagram shows how the drops spread down the tile.



Which could be a correct explanation for the different lengths shown?

☒ **A** R has a greater viscosity than Q.

☒ **B** R has a greater density than Q.

☒ **C** R has a greater temperature than Q.

☒ **D** All of the above.

(Total for question = 1 mark)

Q14.

Raindrops of different sizes fall with different terminal velocities through air.

The table shows the measured value of the terminal velocity for raindrops of different sizes.

Raindrop size	Drop diameter / mm	Terminal velocity / m s^{-1}
small	0.5	2.1
medium	2.0	6.5
large	5.0	9.1

(a) Derive, using Stokes' law, the following expression for the terminal velocity v of a spherical raindrop in terms of its radius r.

$$v = \frac{2g\rho r^2}{9\eta}$$

where ρ is the density of rainwater and η is the viscosity of air.

You should ignore upthrust.

(2)

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(b) Show that the expression given in (a) produces a value of about 800 m s^{-1} for the terminal velocity of a large raindrop.

(2)

$\rho = 1.0 \times 10^3$ kg m^{-3}
$\eta = 1.8 \times 10^{-5}$ Pa s

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(c) Explain whether Stokes' law is suitable for calculating the terminal velocity of raindrops.

(3)

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(Total for question = 7 marks)

Q15.

A student investigated the terminal velocity of steel spheres falling through oil.

The student obtained the following results.

radius of steel sphere = 1.50 mm
volume of steel sphere = 1.41×10^{-8} m^3
mass of steel sphere = 1.10×10^{-4} kg
maximum speed of sphere = 0.849 m s^{-1}

The student had the following table.

Type of oil	Density at 26 °C / kg m^{-3}	Viscosity at 26 °C / Pa s
Corn	918	0.0447
Hazelnut	918	0.0504
Sunflower	918	0.0414

The values in the table are for oil at 26 °C.

Explain the effect of carrying out the investigation with oil at a lower temperature.

(2)

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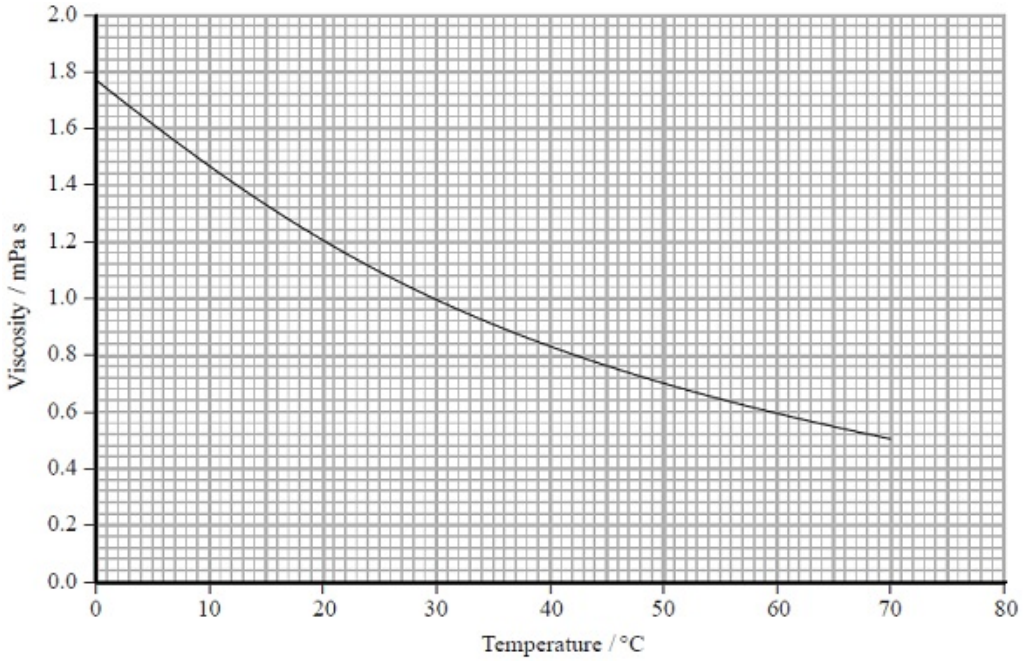
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(Total for question = 2 marks)

Q16. The graph shows how the viscosity of ethanol varies with temperature.



(a) Describe how the viscosity of ethanol varies with temperature.

(2)

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(b) (i) Use Stoke's law to show that the SI unit of viscosity is Pa s.

(2)

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(ii) A small sphere is dropped into a large volume of ethanol at 24 °C.

Show that, if the drag were due to viscous forces alone, the terminal velocity would be about 4 ms^{-1}.

Assume that upthrust is negligible.

radius of sphere = 5.0×10^{-4} m

room temperature = 24 °C

mass of sphere = 4.0×10^{-6} kg

(3)

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*(c) Diesel is used as the fuel in some vehicles. Diesel is not renewable, so alternatives are being researched. Biodiesel is a fuel made from vegetable oil; biodiesel on its own is not suitable for use in vehicles.

The table gives some information about diesel, biodiesel and ethanol.

	Viscosity / mPa s at 0 °C	Viscosity / mPa s at 40 °C	Energy / MJ kg^{-1}	Freezing point / °C
Diesel	4.9	2.6	43	–30
Biodiesel	17.3	4.6	39	–12
Ethanol	1.8	0.9	27	–114

Blends of biodiesel with ethanol are being researched as a renewable alternative to diesel fuels for use in vehicles all year round.

Using the information in the table, suggest why these blends are being researched.

(3)

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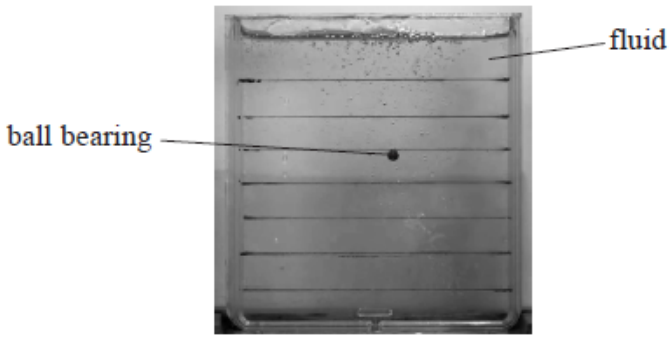
(Total for Question = 10 marks)

Q17.

A student carried out an experiment to identify a fluid from its viscosity at room temperature.

A ball bearing of diameter d was released at the top of a container containing the fluid. The motion of the ball bearing was recorded using a video camera and hence the terminal velocity v of the ball bearing was determined.

This was repeated for ball bearings of increasing diameter with the fluid at a constant temperature.



(a) To determine the viscosity η, the student used the equation $v = \frac{d^2 g(\rho_b - \rho_f)}{18\eta}$

where ρ_b = density of the material of the ball bearing

ρ_f = density of the fluid.

Explain why a graph of v on the y-axis and d^2 on the x-axis should be a straight line through the origin.

(3)

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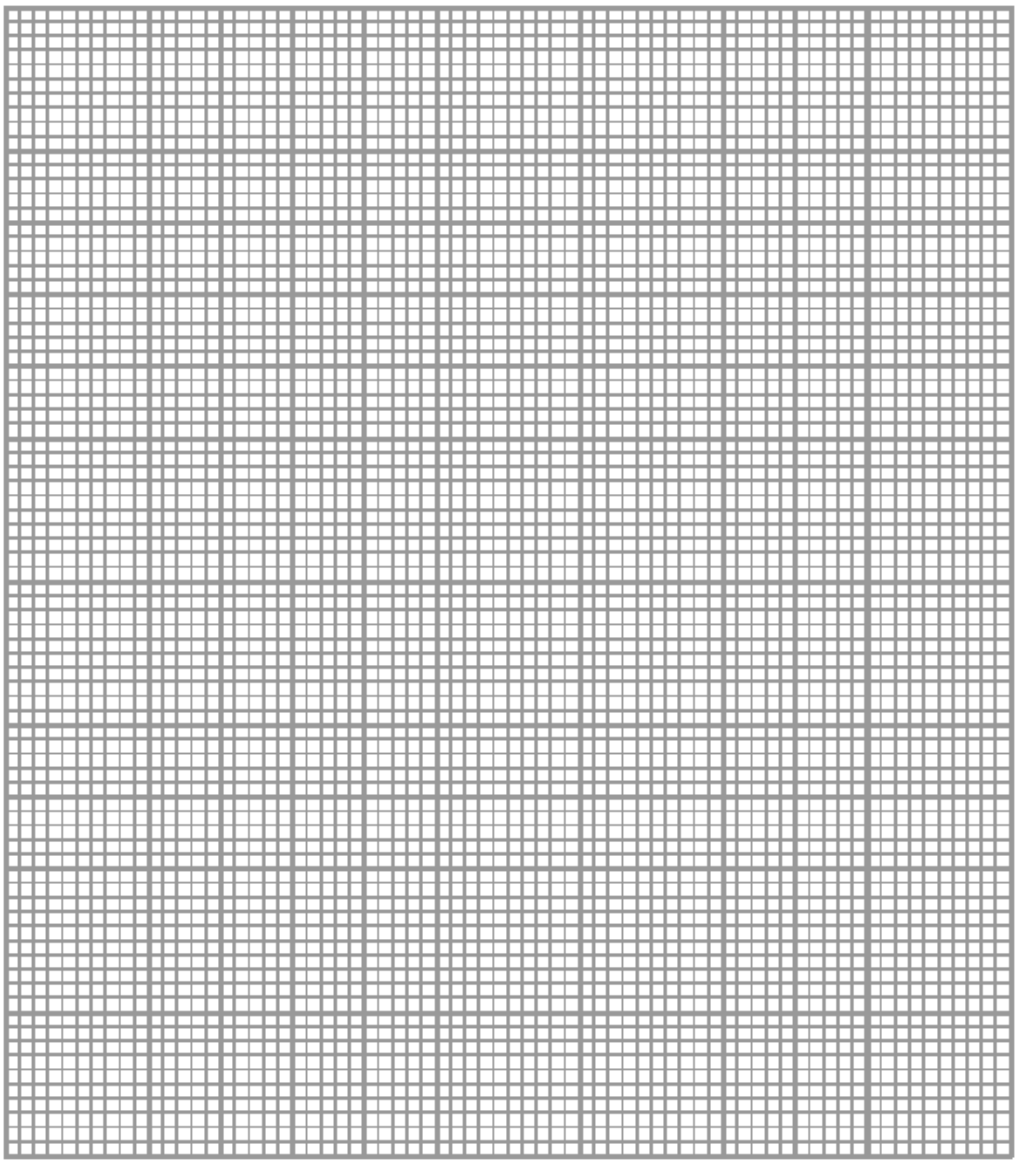
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(b) The student obtained the following data.

d / 10^{-3} m	d^2 / 10^{-6} m^2	v / 10^{-3} m s^{-1}
1.0	1.0	2.3
2.0	4.0	11
3.0	9.0	23
4.0	16.0	39
5.0	25.0	64

Plot the graph of v against d^2.

(4)



(c) The table shows the viscosity of some different fluids.

Fluid	Viscosity at room temperature / Pa s
castor oil	1.0
glycerol	1.2
corn syrup	1.4
honey	1.9

Use the graph to deduce which fluid the student used.

density of ball bearing = 8000 kg m^{-3}
density of fluid = 1260 kg m^{-3}

(4)

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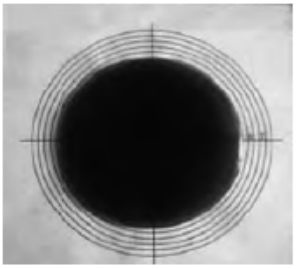
(Total for question = 11 marks)

Q18.

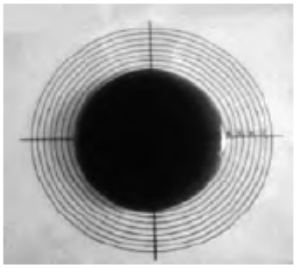
The photograph shows an image of two "pancake" volcanoes on the surface of the planet Venus. Scientists believe these types of volcano are formed from lava spreading out in all directions onto a flat landscape.



A student investigated the formation of pancake volcanoes. She observed the flow of a viscous liquid at two different temperatures as it spread out from a central spot. The photographs below show the liquid at both temperatures after it had been flowing for the same length of time.



High temperature test



Low temperature test

Scientists believe that the high temperature of lava when it erupts is one factor that allows the lava to spread out over a large area.

Explain how the student's investigation supports this idea.

(2)

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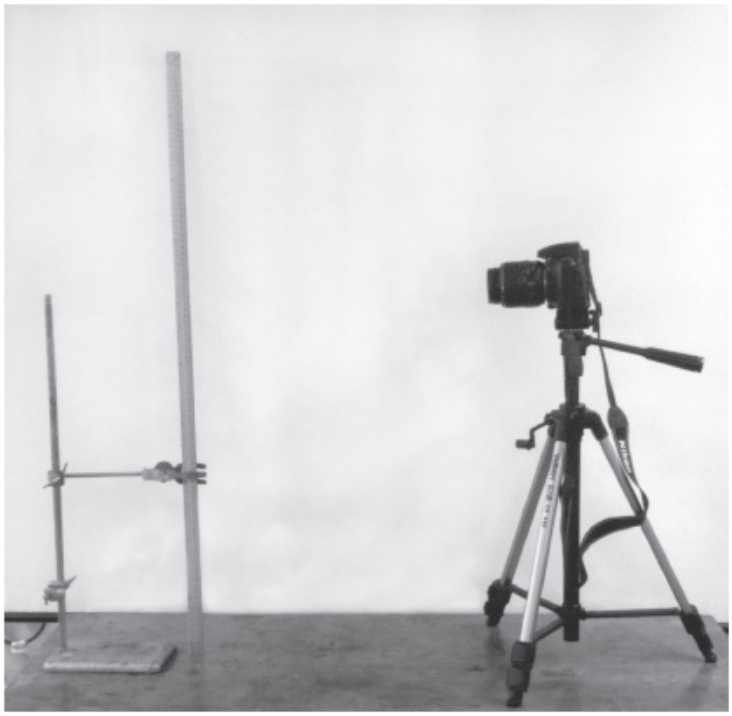
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(Total for question = 2 marks)

Q19.

A student carries out an experiment to find the acceleration of free fall.



(a) In this experiment the student releases a small steel ball in front of a metre rule and uses a video camera to record its motion. The camera captures 30 images per second, which may be played back one image at a time.

(i) Explain how the acceleration of free fall could be determined using the recording.

(4)

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(ii) Describe a systematic error which could arise.

(1)

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(b) Describe one property of the steel ball that makes it suitable to use in this experiment and explain why this property makes it suitable.

(2)

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(c) Explain an advantage of using a video camera to take measurements for this experiment rather than using a stopwatch.

(2)

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(Total for question = 9 marks)

Q20.

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 skydiver steps out of an aeroplane and falls from rest, towards the ground. Her parachute opens a short time after she reaches terminal velocity.

Which of the following statements is correct for the vertical acceleration *a* of the skydiver until her parachute opens?

☐ **A** *a* decreases to zero

☐ **B** *a* increases to a maximum

☐ **C** *a* is constant and equal to *g*

☐ **D** *a* is constant but less than *g*

(Total for question = 1 mark)

Q21.

A small helium balloon is released into the air. The balloon initially accelerates upwards.

The resultant force *F* on the balloon is given by

$$F = \text{upthrust} - \text{weight} - \text{viscous drag}$$

The viscosity of the air decreases as the balloon rises.

On a warmer day a balloon of the same total mass and radius rises at a lower constant upwards speed.

Give a reason why.

(1)

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(Total for question = 1 mark)

Q22.

A student carries out an experiment to determine the viscosity of glycerol. She does this by determining the terminal velocity of a steel sphere falling through glycerol.

The equation shows how the terminal velocity of a solid sphere falling through a liquid depends on the density of both the solid and the liquid.

$$v = \frac{Vg(\rho_s - \rho_l)}{6\pi r\eta}$$

where

ρ_l = density of liquid
ρ_s = density of solid
r = radius of sphere
V = volume of sphere
η = viscosity of liquid
v = terminal velocity

The derivation of the equation for terminal velocity has been started below.
Complete the derivation.

(3)

At terminal velocity: weight of solid sphere = drag + upthrust

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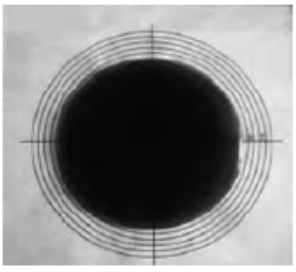
(Total for question = 3 marks)

Q23.

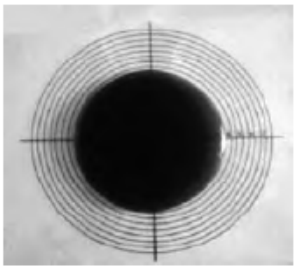
The photograph shows an image of two "pancake" volcanoes on the surface of the planet Venus. Scientists believe these types of volcano are formed from lava spreading out in all directions onto a flat landscape.



A student investigated the formation of pancake volcanoes. She observed the flow of a viscous liquid at two different temperatures as it spread out from a central spot. The photographs below show the liquid at both temperatures after it had been flowing for the same length of time.



High temperature test



Low temperature test

The student carried out an experiment to determine the viscosity of the liquid at room temperature. She observed a steel sphere falling through the liquid.

She had the following equipment:

- a long, wide cylindrical tube
- two steel spheres with diameters 7.0 mm and 22.0 mm

- video camera
- metre rule

The student observed the sphere with a diameter of 7.0 mm falling through the liquid. The sphere fell 0.80 m in 5.3 s at a constant velocity.

The viscosity η of the liquid can be calculated using the equation

$$\eta = \frac{Vg(\rho_s - \rho_l)}{6\pi rv}$$

providing Stokes' law applies.

(i) Calculate the viscosity of the liquid.

density of liquid ρ_l = 1430 kg m^{-3}

density of steel ρ_s = 7800 kg m^{-3}

(4)

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Viscosity of liquid = ... Pa s

(ii) If the student had used the larger sphere, the equation would not have produced the correct answer.

Explain why.

(2)

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(iii) The student used the video camera to record the sphere falling through the liquid.

State **one** benefit of using the video camera to record the motion of the sphere.

(1)

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(Total for question = 7 marks)

Q24.

Car engines use motor oil as a lubricant. Motor oils need to operate over a range of temperatures because they may be at 0ºC or below when the engine is started but be up to 160ºC when the engine is running. At all times motor oils need to be thin enough to allow the parts to move smoothly but thick enough to remain on the moving parts.

Explain why the engine may experience difficulties if the temperature becomes too hot or cold.

(2)

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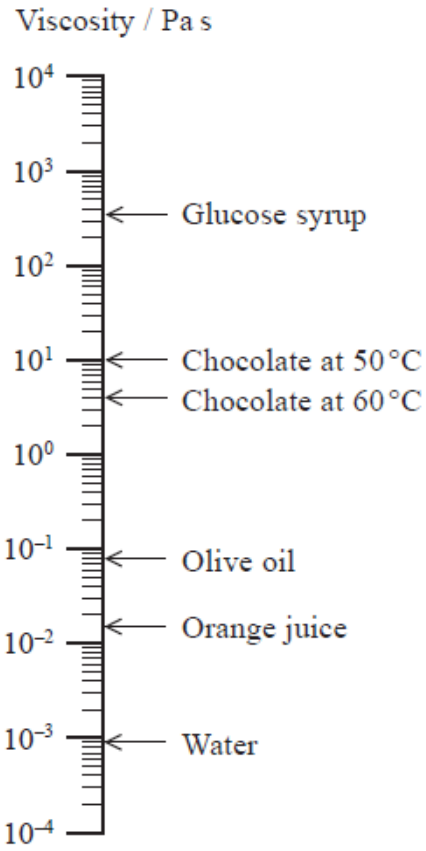
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(Total for question = 2 marks)

Q25.

The following chart shows the viscosity of some food products. Temperatures are at 20° unless otherwise indicated.



(a) (i) Explain why there are two different values of viscosity for chocolate.

(2)

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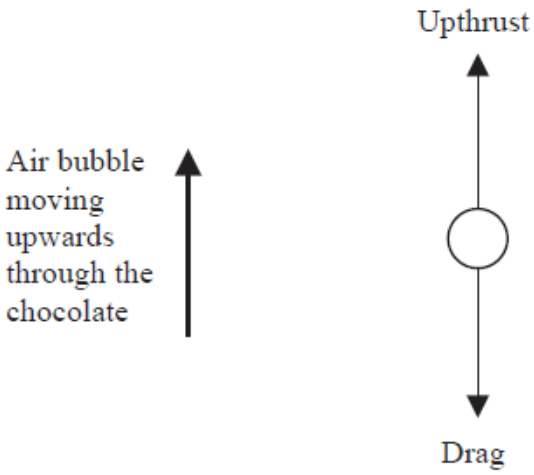
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(ii) The viscosity of a sample of chocolate at 40°C is measured.

Mark the approximate position of its viscosity onto the chart above.

(1)

(b) Some chocolate is poured into a mould. Within the chocolate a bubble of air, of negligible weight, is formed and moves upwards at a constant velocity.



radius of air bubble = 1.0×10^{-3} m

temperature of chocolate = 50 °C

upthrust on air bubble = 3.7×10^{-5} N

Calculate the approximate velocity of the air bubble.

(3)

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Approximate velocity = ...

(c) The following table is an incomplete entry from a chocolate producer's website offering advice on chocolate moulding.

Complete the entry.

(3)

Problem	Air bubbles become trapped in the chocolate because they cannot rise to the surface in time to escape before the chocolate has solidified.
Solution	....
Explanation	....

(Total for question = 9 marks)

Q26.

A seiche is a standing wave that can form on the surface of a lake in strong winds, causing flooding and erosion.

The temperature of the lake decreases with depth.

Explain how this may affect the rate at which a particle falls.

(2)

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(Total for question = 2 marks)

Q27.

A small sphere is falling through a liquid. The viscous drag force acting on the sphere will increase if the

☒ **A** density of the liquid decreases.

☒ **B** radius of the sphere decreases.

☒ **C** temperature of the liquid decreases.

☒ **D** viscosity of the liquid decreases.

(Total for question = 1 mark)

Q28.

A seiche is a standing wave that can form on the surface of a lake in strong winds, causing flooding and erosion.

Erosion causes clay particles to be washed into the lake, making the lake cloudy. The lake can remain cloudy to a depth of about 4 m for more than 6 months.

One spherical clay particle has a radius of 2.5×10^{-7} m.

Deduce whether this particle takes more than 6 months to fall 4 m.
You should assume that the water in the lake remains still.

viscosity of water = 1.0×10^{-3} kg m^{-1} s^{-1}
density of water = 1000 kg m^{-3}
density of clay = 2650 kg m^{-3}

(6)

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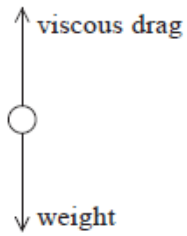
(Total for question = 6 marks)

Q29.

A student used steel ball bearings falling through a viscous liquid to investigate the relationship between the terminal velocity *v* of a ball bearing and its radius *r*.

A free body force diagram for a ball bearing of radius 5.00 mm falling through the liquid is shown. The upthrust on the ball bearing has been ignored.

Diagram **NOT** to scale



(i) Show that the weight of a ball bearing with a radius of 5.0 mm is about 4×10^{-2} N.

density of steel = 8.0×10^{3} kg m^{-3}

(3)

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(ii) Calculate the terminal velocity of the ball bearing as it falls through the liquid. You may ignore the upthrust on the ball bearing.

viscosity of liquid = 1.8 Pa s

(2)

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Terminal velocity = ...

(Total for question = 5 marks)

Q30.

The photograph shows an example of a Foucault pendulum.



This is a pendulum that consists of a massive sphere, suspended by a long wire from a high ceiling. Over time the vertical plane through which the pendulum swings appears to rotate because of the rotation of the Earth.

mass of sphere = 28.0 kg

To show the rotation of the Earth, the pendulum needs to oscillate for several hours.

Explain how using a heavy sphere is better than using a light sphere of the same diameter.

(3)

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(Total for question = 3 marks)