Name: ____

Edexcel Drag Viscosity

Questions

Date:

Time:

Total marks available:

Total marks achieved: ______

Questions

Q1.

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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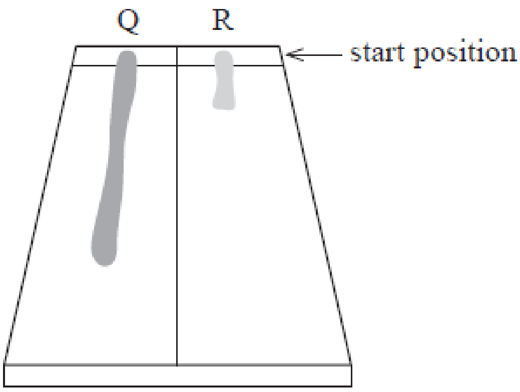
(Total for question = 1 mark)

Q2.

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)

Q3.

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)

Q4.

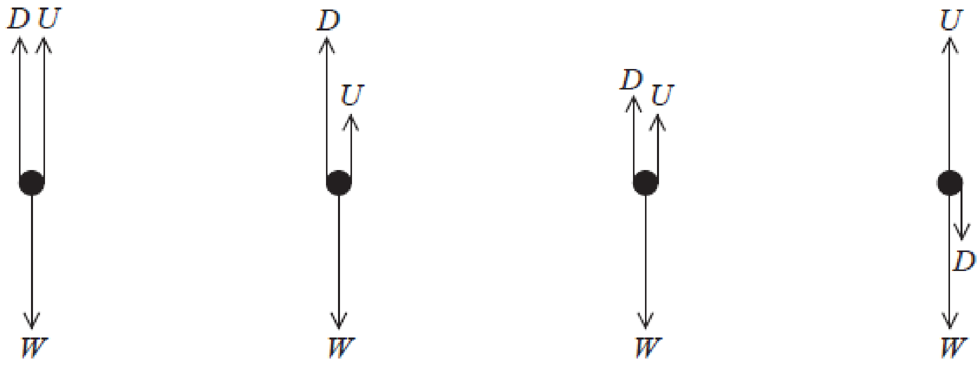
A small object is falling at terminal velocity in a large container of oil.

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**

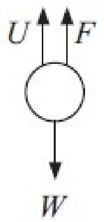
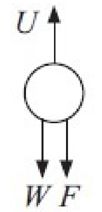
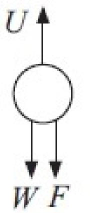
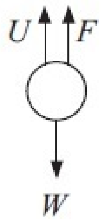
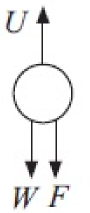
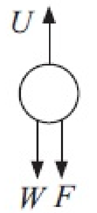
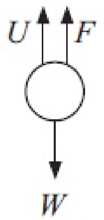
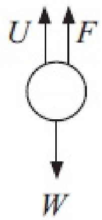
(Total for question = 1 mark)

Q5.

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?

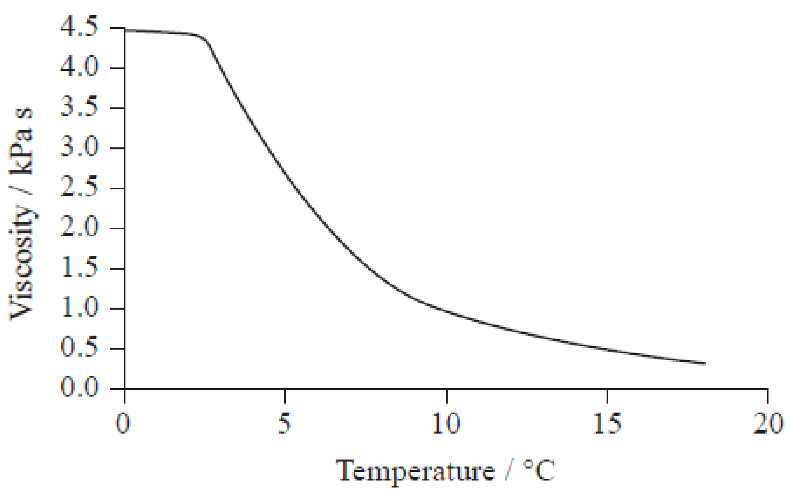
F = viscous drag, *U* = upthrust, *W* = weight

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

(Total for question = 1 marks)

Q6.

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)

Q7.

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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(Total for question = 2 marks)

Q8.

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)

Q9.

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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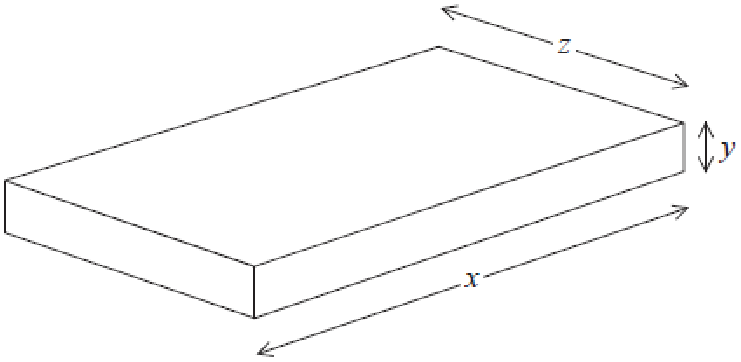
Viscous drag force = ...

(Total for question = 4 marks)

Q10.

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.

(4)

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

(1)

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(Total for question = 5 marks)

Q11.

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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(Total for question = 6 marks)

Q12.

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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Q13.

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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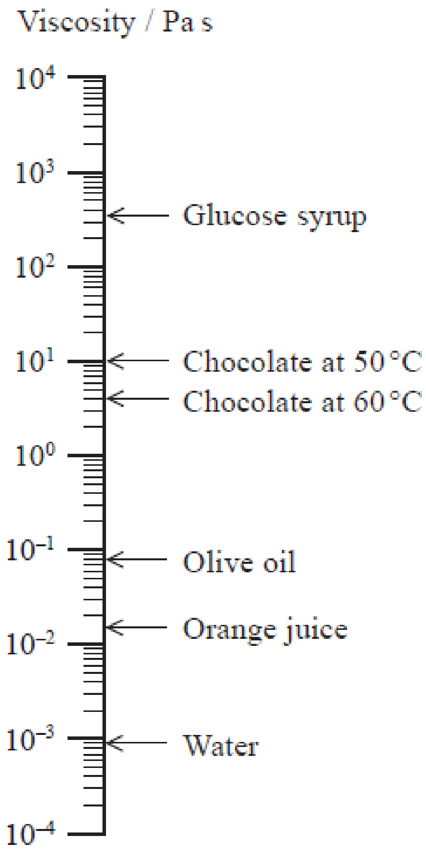
(Total for question = 7 marks)

Q14.

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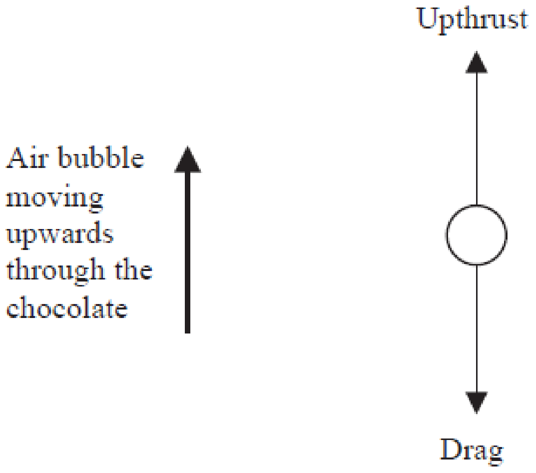
(ii) The viscosity of a sample of chocolate at 40°C is measured.

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)

Q15.

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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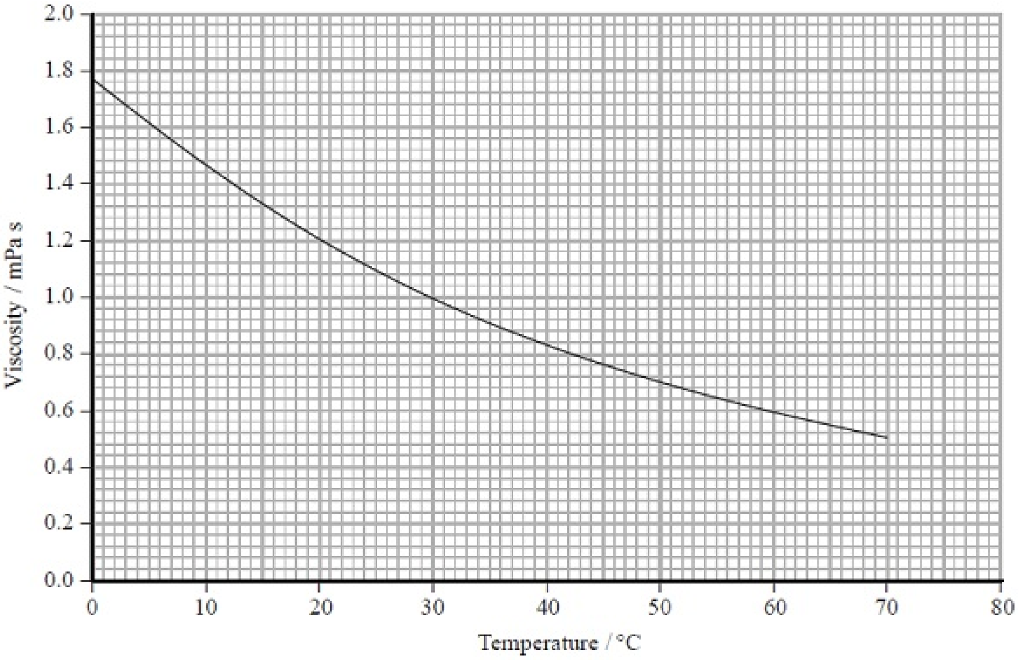
Pressure = ...

(Total for question = 8 marks)

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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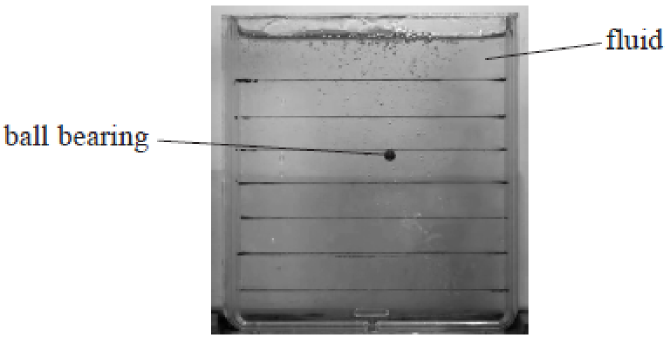
(Total for Question = 10 marks)

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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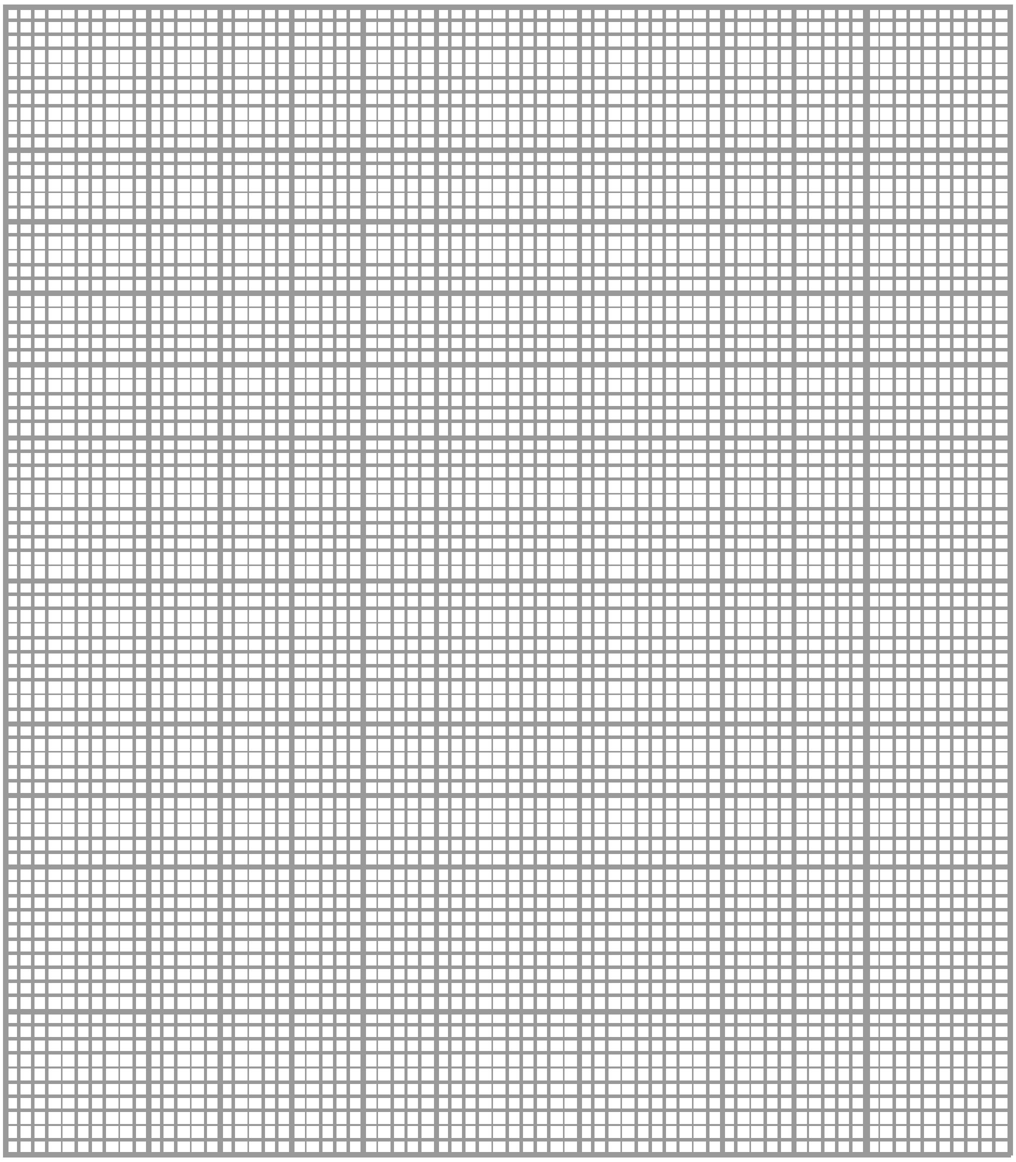
(b) The student obtained the following data.

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 '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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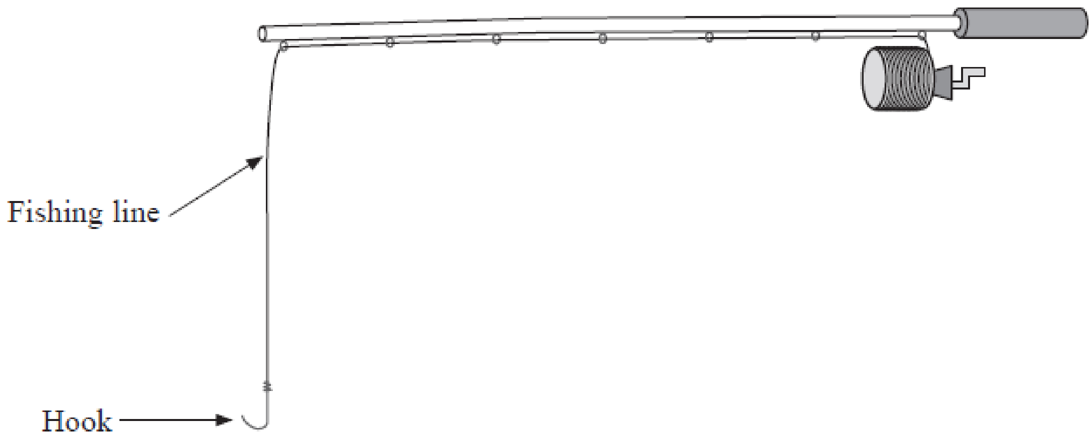
(Total for Question = 11 marks)

Q19.

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

(3)

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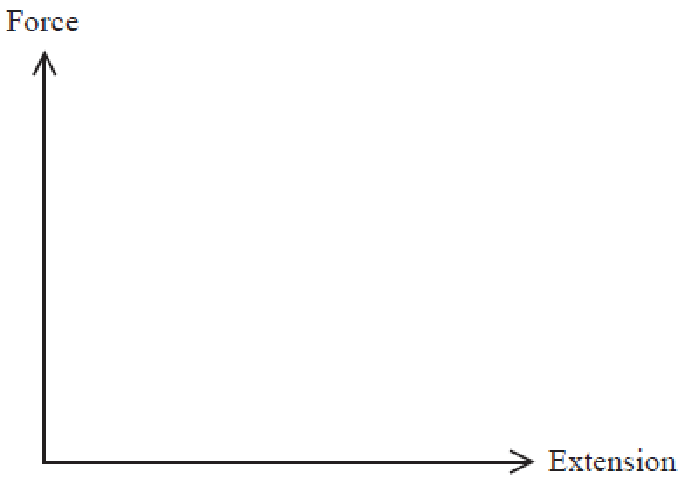
Extension = ...

(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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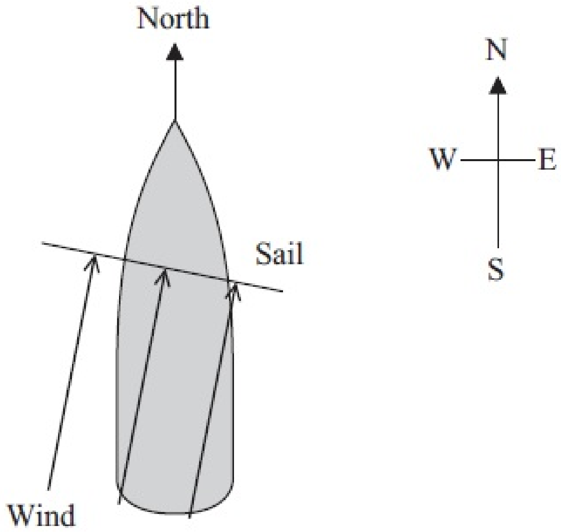
(Total for question = 11 marks)

Q20.

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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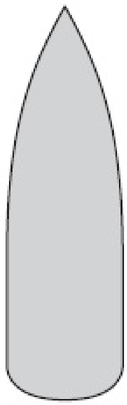
Rate at which the wind does work = ...

(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)