Name: ____

Forces and Motion 2

Questions

Date:

Time:

Total marks available:

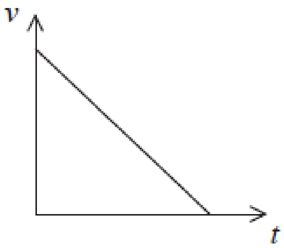
Total marks achieved: ______

Questions

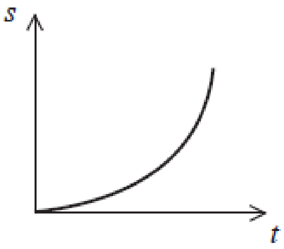
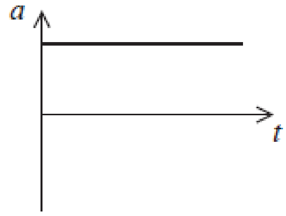
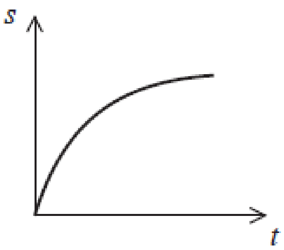
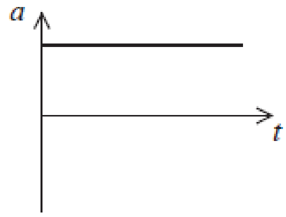
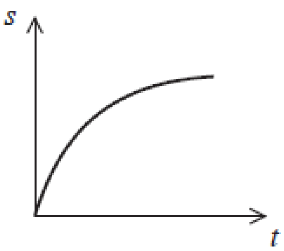
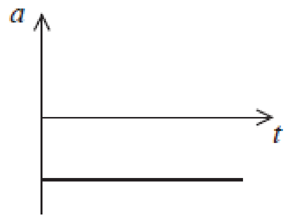
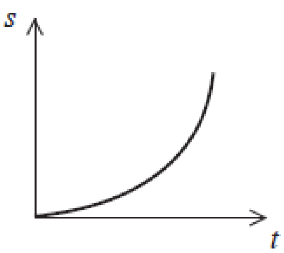
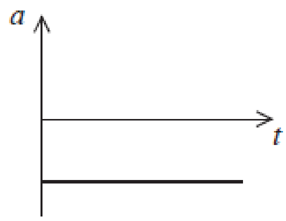
Q1.

A ball is rolled along a horizontal surface. Frictional forces slow the ball to rest.

The velocity-time graph for the ball is shown.



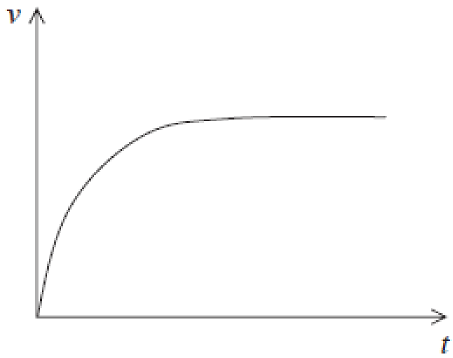
Select the row of the table that correctly gives the corresponding displacement-time and acceleration-time graphs for the ball.

	Displacement-time graph	Acceleration-time graph
☐ **A**		
☐ **B**		
☐ **C**		
☐ **D**		

(Total for question = 1 mark)

Q2.

A sports class is studying cycling. They produce a video of a cyclist on a horizontal lawn.
The cyclist starts from rest.
They produce a sketch graph of the velocity *v* of the cyclist against time *t*.



Explain the shape of this graph and include a consideration of force as part of your answer.

(3)

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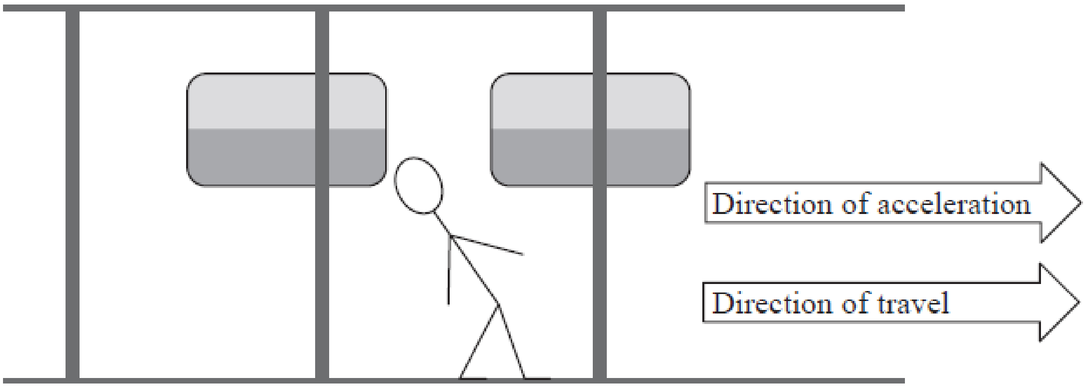
(Total for question = 3 marks)

Q3.

A passenger is standing in a train.

(a) The train accelerates and he falls backwards.



Use Newton's first law of motion to explain why he falls backwards.

(3)

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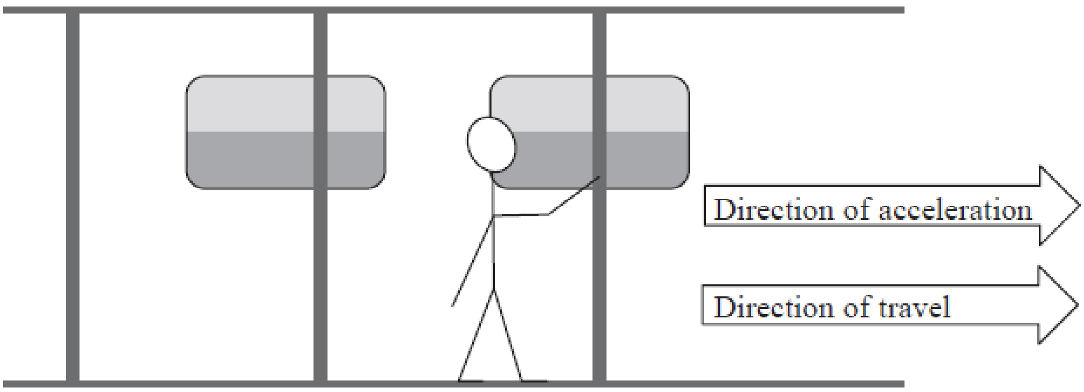
*(b) As the train leaves the station the passenger holds on to a vertical support as the train accelerates. This prevents the passenger falling backwards.



With reference to Newton's laws of motion, explain why holding on to a vertical support prevents the passenger falling backwards.

(5)

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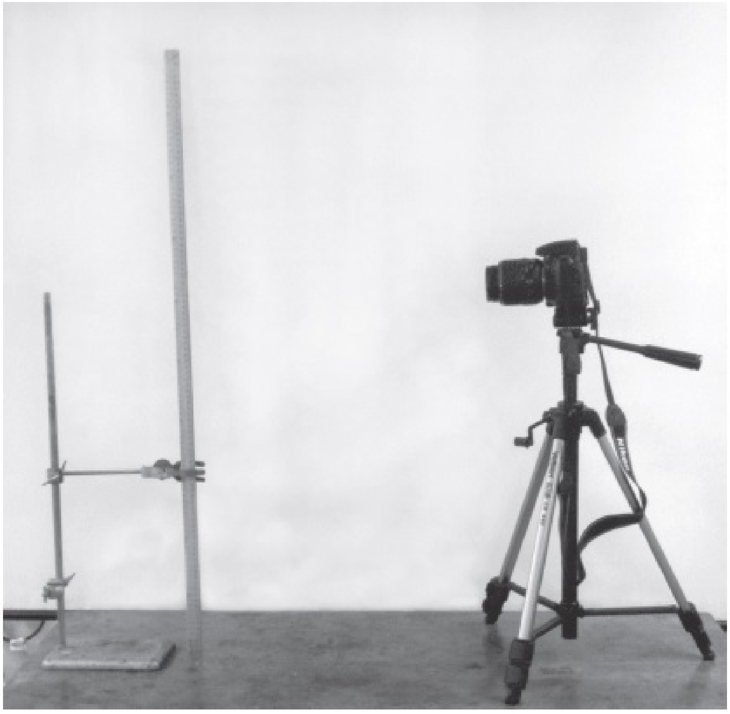
(Total for question = 8 marks)

Q4.

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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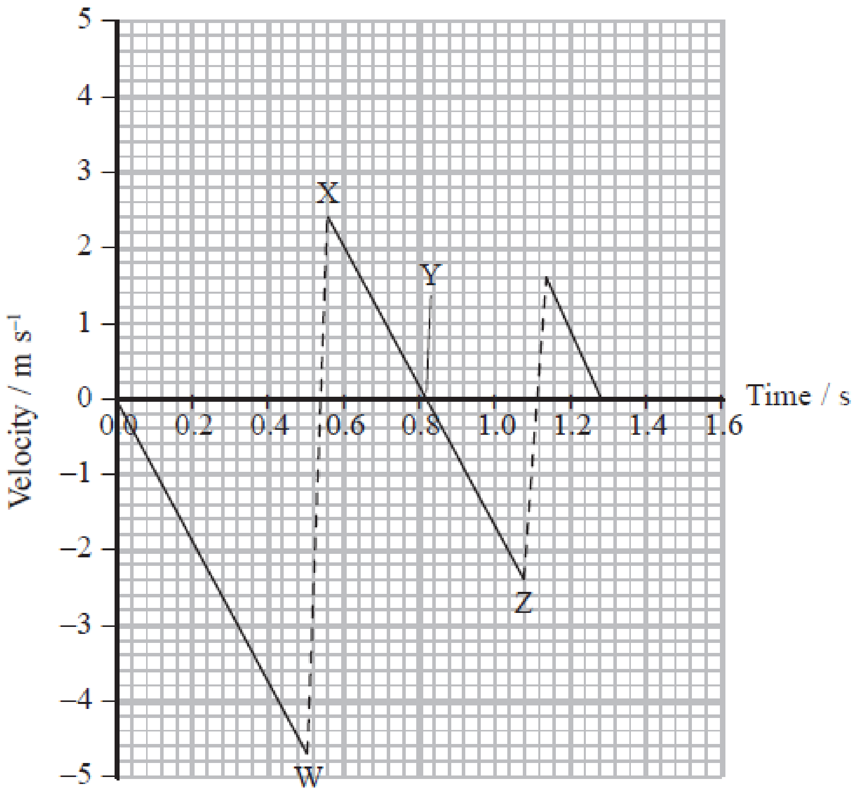
(Total for question = 9 marks)

Q5.

A basketball is dropped vertically onto the horizontal ground and bounces twice before being caught. The graph shows how the velocity of the basketball varies with time.



(a) Suggest why the downward sloping lines are all parallel.

(1)

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(b) (i) State the reason for the upwardly sloping dotted lines.

(1)

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(ii) Describe how the gradient of the dotted lines would change if the basketball was not fully inflated.

(1)

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(c) Calculate the initial height through which the basketball fell.

(2)

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Height = ...

(d) (i) Show that the kinetic energy of the basketball at X is about 1 J.

mass of ball = 0.4 kg

(2)

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(ii) Hence calculate the height of the basketball at Y.

(2)

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Height = ...

(e) The velocity of the basketball on impact at W is greater than the velocity on impact at Z.

State a reason for the difference in velocities at W and Z.

(1)

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(Total for question = 10 marks)

Q6.

A student investigated the physics of football.

(a) She used the equations of motion to model the behaviour of a ball when kicked at different angles to the horizontal. She predicted the height of the ball when it reached the goal, presuming it was kicked from the same place, with the same initial speed, each time. The results are shown in the table below.

Angle to the horizontal / °	Height of the ball when it reached the goal / m
10	–0.78
20	1.0
30	2.8
40	4.7

(i) State the significance of the negative value of height for an angle of 10°.

(1)

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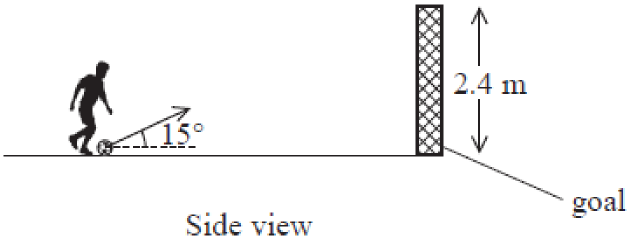
(ii) On the diagram below, sketch and label the predicted path of the ball for angles of 20° and 40°.

(2)

(b) (i) During a football match the ball is kicked towards the goal, at an angle of 15° to the horizontal, from a distance of 11 m as shown.



The ball has a diameter of 0.22 m and an initial speed of 26 m s^{-1}.

By means of a calculation, determine whether or not the ball will pass into the goal. You may ignore the effects of air resistance.

(6)

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(ii) Air resistance would cause an additional force on the ball.

Explain the effect this would have on the ball's motion.

(2)

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Q7.

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.

(i) Complete the free-body force diagram for a bubble as it rises through the liquid.

(3)

*(ii) It is observed that larger bubbles reach the top of the column of liquid in less time than smaller bubbles.

By considering the forces acting on a bubble as it rises, explain this observation.

(3)

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Q8.

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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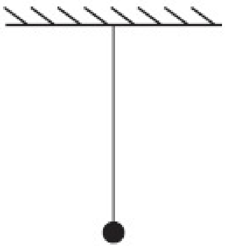
Pressure = ...

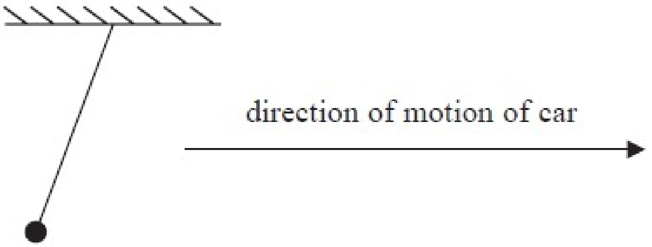
(Total for question = 8 marks)

Q9. Many hand held devices such as smartphones and tablet computers contain accelerometers. These allow changes in orientation of the device to be tracked.

A student models a simple accelerometer by attaching a small mass on a string to the roof of a car.



When the car starts moving, the string is seen to change position as shown below.



(a) (i) Complete a free body force diagram for the mass when the car starts moving.

(2)

(ii) Draw a vector diagram, in the space below, to show how the resultant force on the mass is produced.

(2)

(iii) When the string is at 7° to the vertical, show that the acceleration of the car is about 1 m s^{-2}.

(2)

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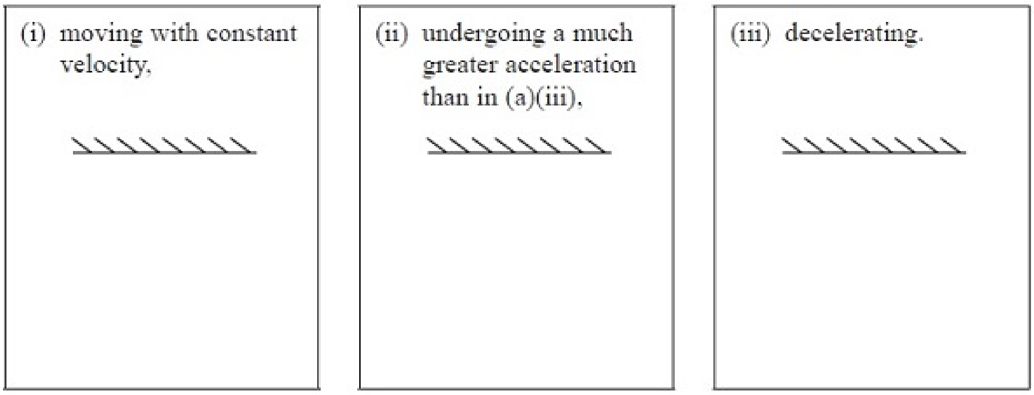
(b) Sketch the positions of the mass and string when the car is moving in the same direction and is:

(i) moving with constant velocity,

(ii) undergoing a much greater acceleration than in (a)(iii),

(iii) decelerating.

(3)



(c) Explain why the string would **not** become horizontal, however great the acceleration.

(2)

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(d) Suggest why many devices contain 3 accelerometers, arranged at right angles to each other.

(1)

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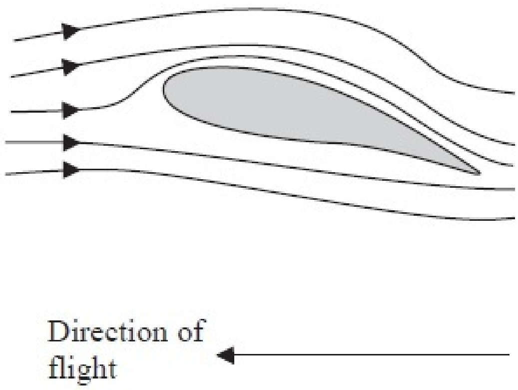
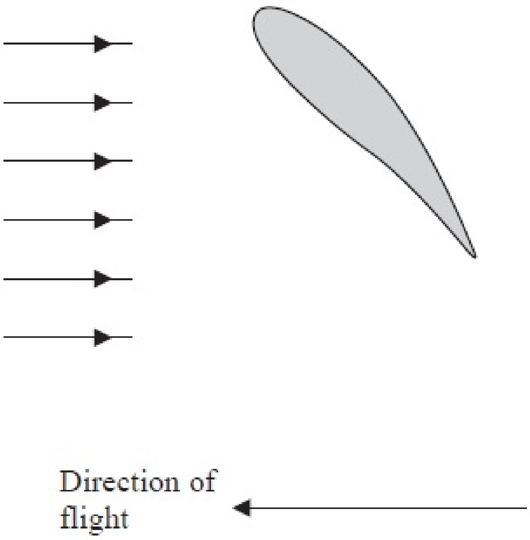
(Total for Question = 12 marks)

Q10. The cross section of the wing of a bird is an aerofoil shape.



In order to fly higher, a bird can tilt its wings more. If it tilts them too much, as shown in the diagram below, the air flow above the wing becomes turbulent.



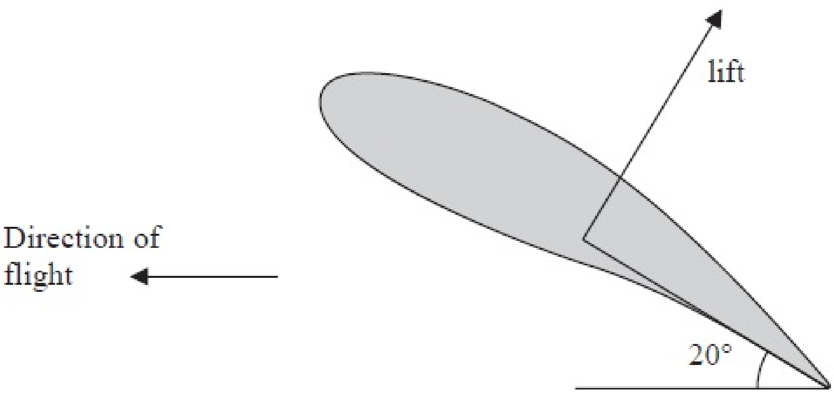
(a) Complete the diagram above to show the airflow around the wing.

(2)

(b) The tilting of the wing results in the air exerting a force on the wing which is called lift. The lift force acts perpendicular to the wing.

The total vertical component of the lift produced by both wings when tilted at an angle of 20° to the horizontal is enough to keep the bird flying at a constant height.

mass of bird = 0.063 kg



(i) Show that the total lift acting on the bird is about 1 N.

(3)

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(ii) Assuming that the only forces acting on the bird are the weight and lift, calculate its acceleration at this instant.

(3)

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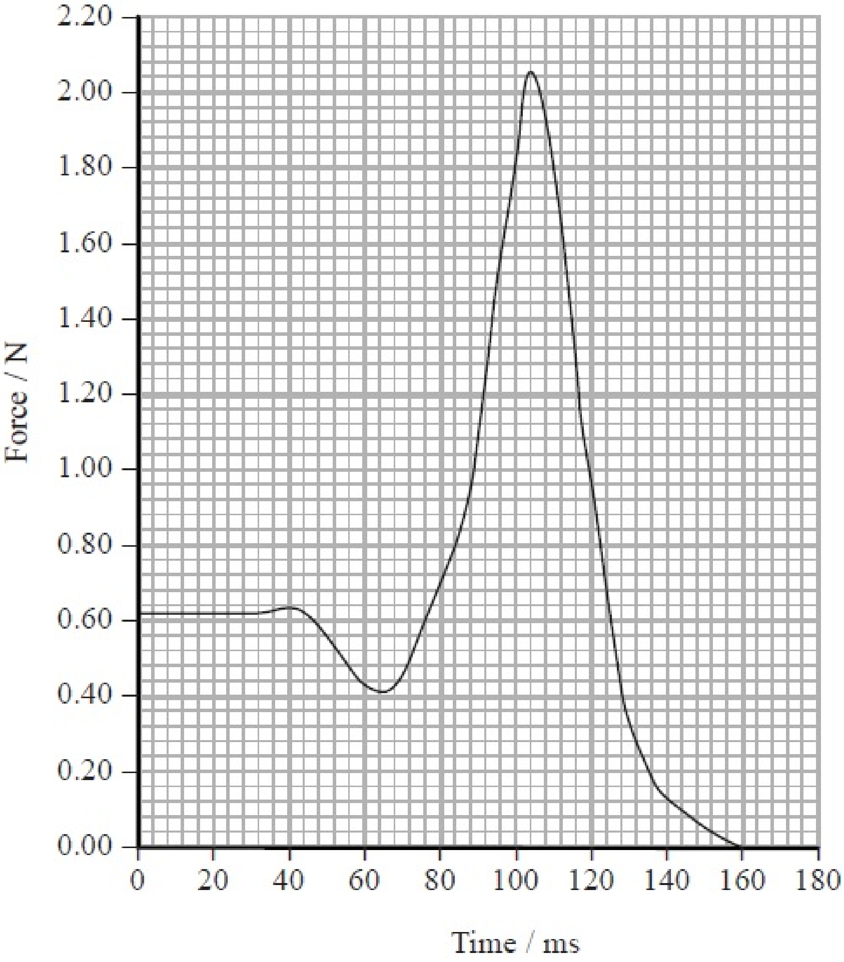
Acceleration = ...

(c) When some birds take off from the ground there is no lift initially. These birds push off from the ground with their legs.

The following graph shows the downward force exerted by the leg on the ground during take off.



(i) With reference to Newton's laws explain how the downward force from the leg enables the bird to take off.

(4)

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(ii) Use the graph to calculate the maximum acceleration of the bird during take off.

mass of bird = 0.063 kg

(3)

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Maximum acceleration = ...

(Total for Question = 15 marks)

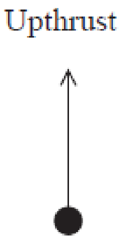
Q11.

Kite surfing is the sport of riding on a small surfboard, propelled forwards across water by a large kite. The surfer holds onto a bar that is attached to the lines. As the air moves over the kite an upwards and forwards force is produced, causing a tension in the lines of the kite.

Consider the board and the surfer to be a single object and the lines of the kite to be equivalent to a single line.

(a) (i) Complete the free body diagram for the forces acting on the surfer at the instant he starts to move along the water.

(2)



(ii) At maximum speed, the angle of the kite to the horizontal is 40° and the total tension in the lines is 1100 N

Show that the horizontal force from the kite on the surfer is about 800 N.

(2)

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(iii) By considering the vertical forces acting on the surfer, explain why the mass of the surfer must be at least 72kg.

(3)

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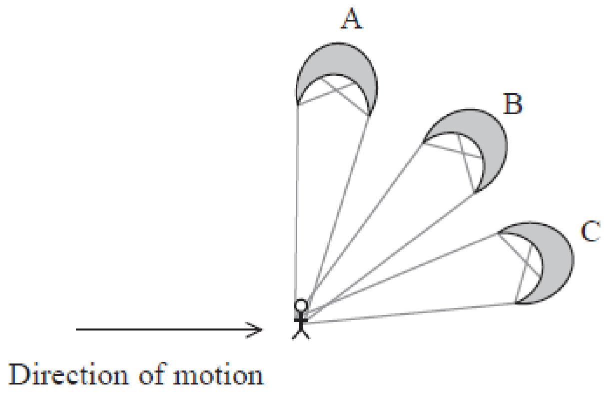
*(b) The diagram shows three positions of the kite when pulling the surfer along.



State and explain which position of the kite would supply the most power to the surfer.
Assume that the tension in the kite lines is the same in each position.

(4)

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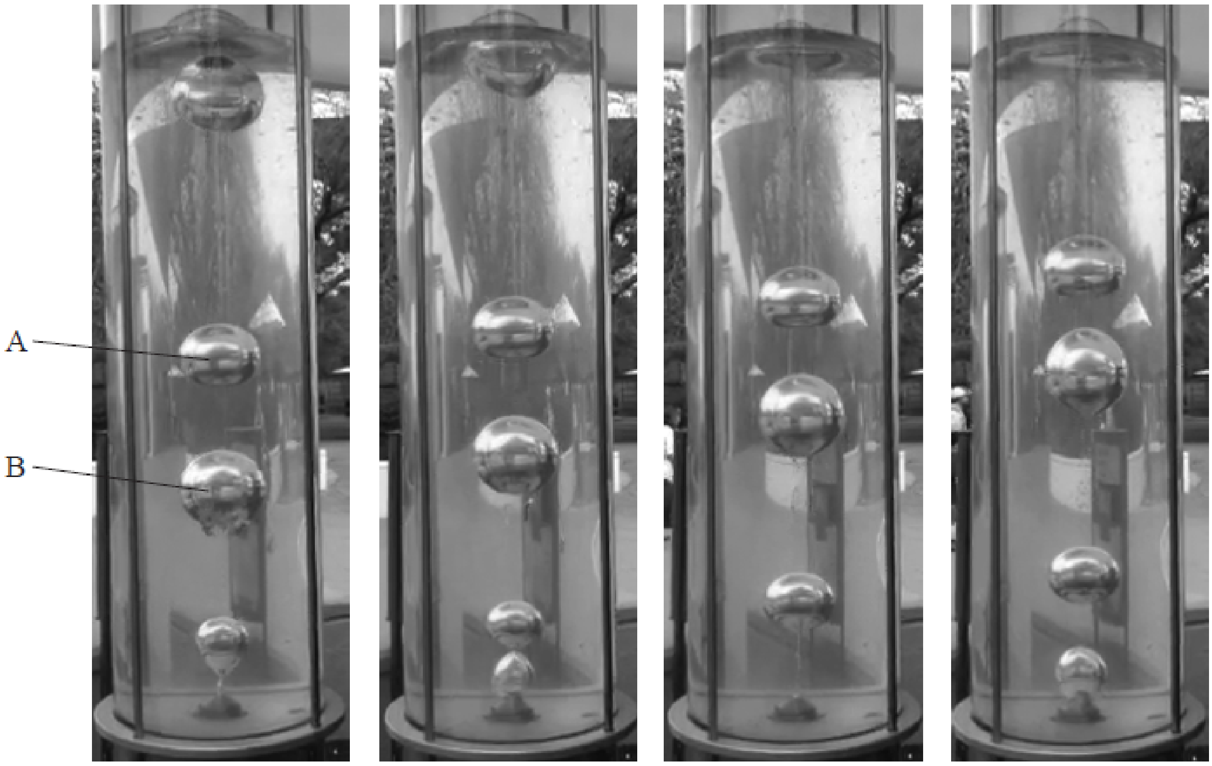
(Total for question = 11 marks)

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.

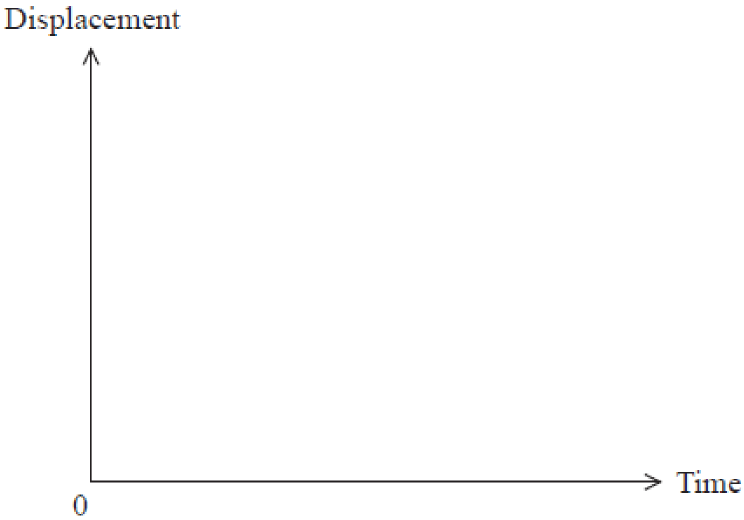
The following photographs were taken at 0.33 s intervals.



Photograph 1 time = 0 | Photograph 2 | Photograph 3 | Photograph 4

(i) Sketch on the axes below two labelled lines to show how the displacements of the smaller bubble A and the larger bubble B vary with time over the four images.

(2)



(ii) The photographs are at a scale of 1 to 12. By using measurements from the photographs, calculate the speed of bubble B between photographs 2 and 3.

(4)

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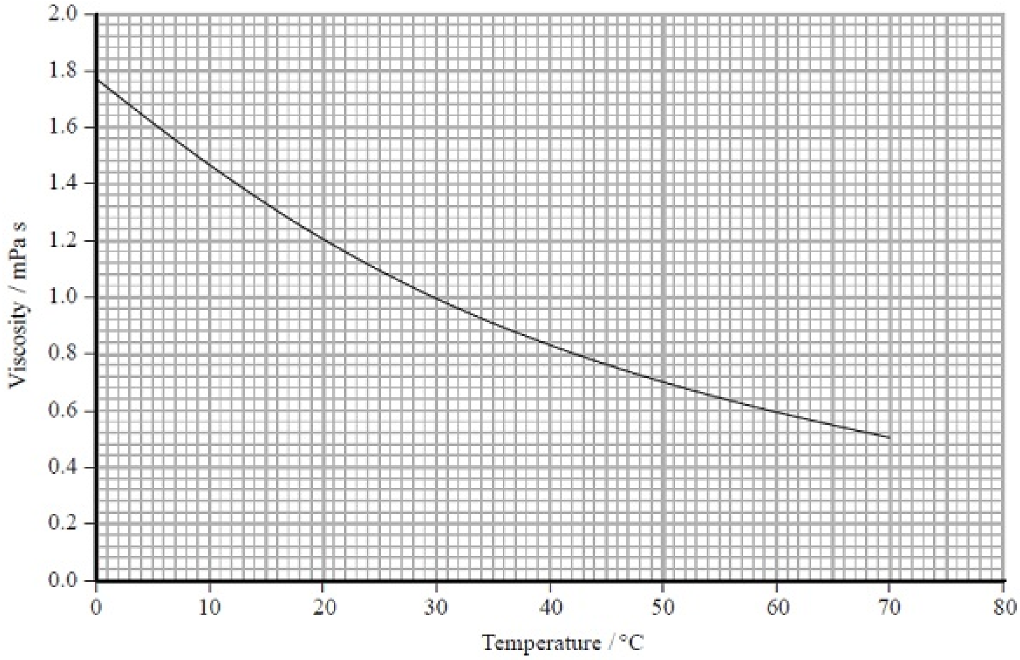
Speed of bubble B = ...

Q13. 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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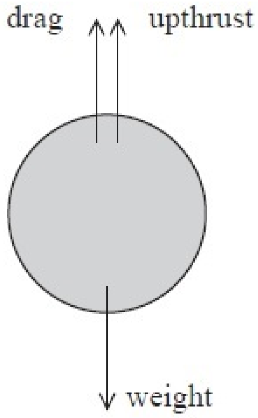
(Total for Question = 10 marks)

Q14. The Greek philosopher Aristotle (4th Century BC) stated that heavy objects fall more quickly than lighter objects.

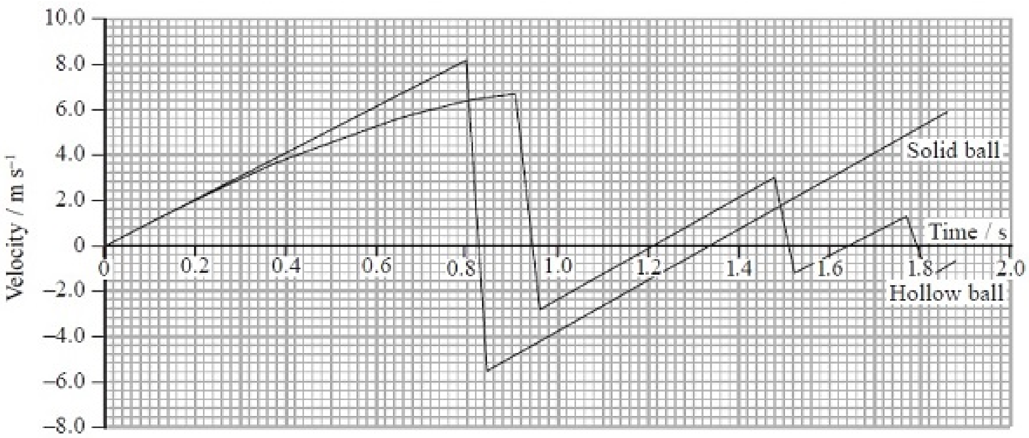
In the 17th Century Galileo reported that a cannon ball and a much smaller musket ball, dropped at the same time, reached the ground together.

A student carries out an experiment, dropping two balls of the same size at the same time. One of the balls is hollow and the other is solid.

The diagram shows the forces acting on each ball as it falls.



The velocity-time graph shows the motion of the two balls from the time they are dropped.



(a) State how the graphs show that neither ball reaches terminal velocity.

(1)

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(b) (i) By drawing a tangent to the graph, show that the acceleration of the hollow ball at time t = 0.60 s is about $7 ms^{-2}$.

(2)

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(ii) Show that the resultant force on the hollow ball at t = 0.60s is about 0.02 N.

mass of hollow ball = 2.4 g

(2)

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(iii) Show that the drag force on the hollow ball at t = 0.60s is about 0.01 N. You may neglect upthrust.

(2)

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(iv) Demonstrate that the Stokes' law force is **not** sufficient to produce this drag force.

radius of hollow ball = 2.0 cm

viscosity of air = 1.8×10^{-5} Pa s

(2)

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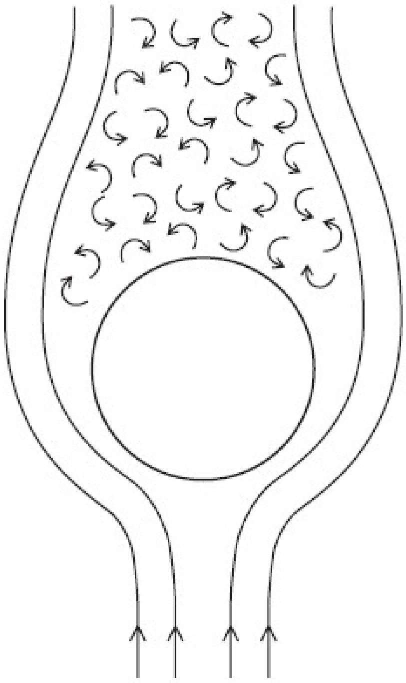
(c) The diagram shows the air flow around the hollow ball as it falls.



(i) Add labels to show laminar flow and turbulent flow.

(1)

(ii) Suggest why the drag is much greater than the Stokes' law force.

(1)

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(d) Without further calculation, use the graph to describe the motion of the solid ball.

(3)

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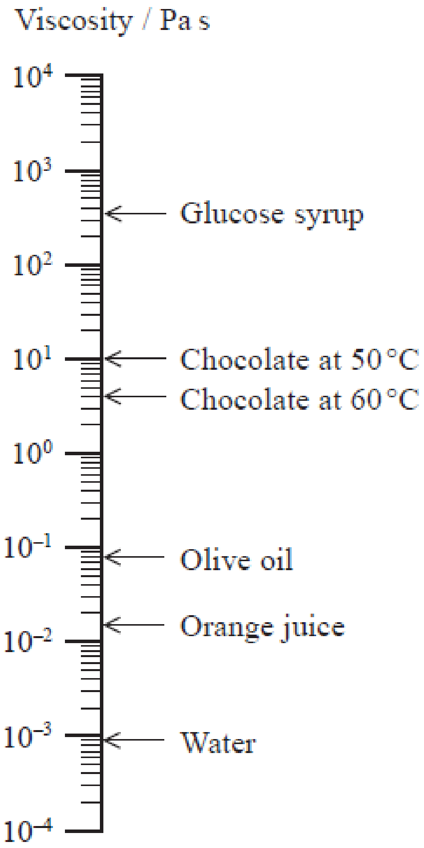
(Total for Question = 14 marks)

Q15.

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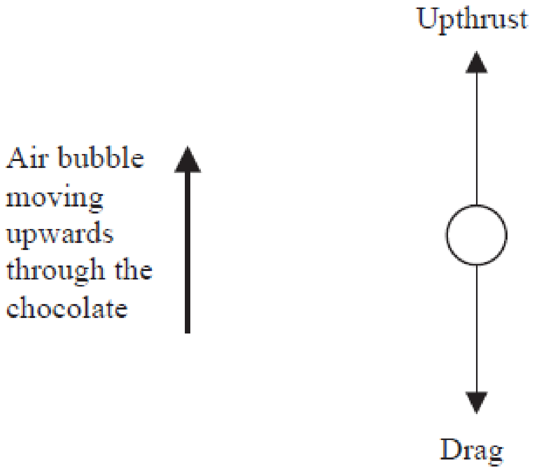
(ii) The viscosity of a sample of chocolate at 40°C is measured.

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)