1 (a) (i) A small solid particle is falling through water. Add labelled arrows to the diagram below to show the forces acting on the particle.

(3)

(ii) Explain the condition for the particle to fall at its terminal velocity.

(2)

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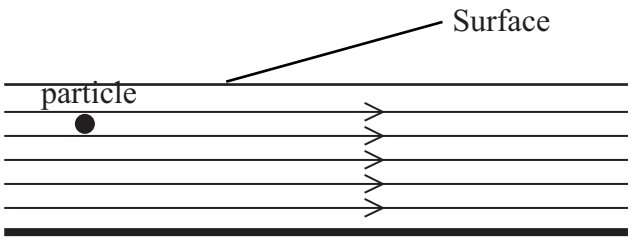
(b) Flowing water can be used to move solid particles from one place to another.

(i) The diagram below shows water moving horizontally with a laminar flow.

Add to the diagram to show the path of the particle falling through this water flow.

(1)



(ii) Complete the diagram below to show water moving with turbulent flow.

(1)

(iii) Describe the difference between laminar and turbulent flow.

(1)

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(iv) Suggest why turbulent flow may be used to move small solid particles.

(1)

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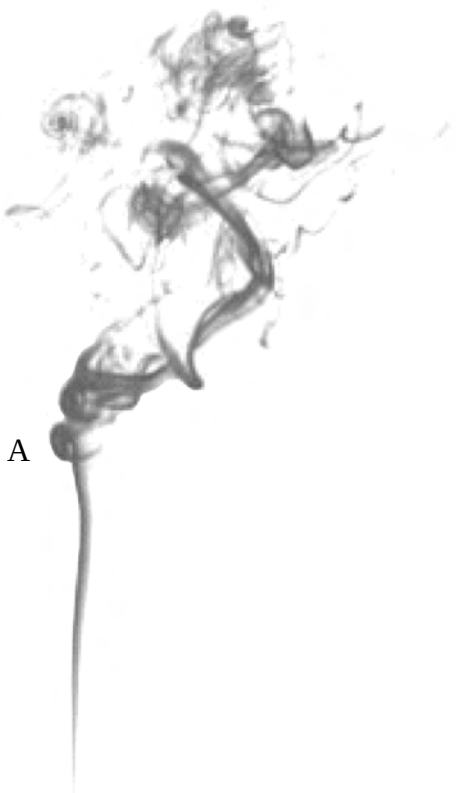
(Total for Question 9 marks)

2 The photograph shows some smoke rising.



At A, the type of fluid flow changes.

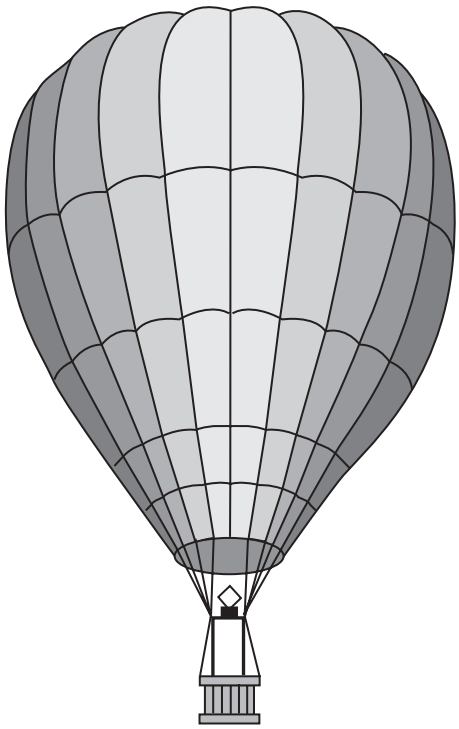
Label the type of fluid flow below and above A and describe each of them.

Below A

Above A

(Total for Question = 4 marks)

3 A hot air balloon consists of an 'envelope' containing hot air, with a wicker basket suspended from it. The balloon flies because the heated air in the envelope is less dense than the surrounding air.



(a) The total volume of the hot air balloon is 2830 m^3. The total weight of the balloon, including the hot air in the envelope, is 33 100 N. The density of the surrounding air is 1.20 kg m^{-3}.

(i) Show that the resultant upward force on the balloon at the moment it is released is about 200 N.

(3)

(ii) Calculate the initial upward acceleration of the balloon. The mass of the balloon is 3370 kg.

(2)

Acceleration =

(iii) The balloon is rising through air of viscosity 1.8×10^{-5} kg m^{-1} s^{-1}, at a speed of 2.0 m s^{-1}.

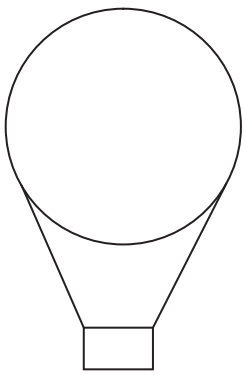
The effect of viscous drag on the balloon is negligible provided the air flow around the balloon is laminar.

Justify the statement in bold with the aid of a calculation. You may treat the whole balloon as a single sphere of radius 8.8 m.

(3)

(b) Add labelled arrows to the diagram below to show the forces acting on a vertically ascending balloon.

(2)



(c) As the balloon rises the density of the surrounding air decreases. Explain why this density change limits the height to which the balloon will rise.

(2)

(Total for Question = 12 marks)

4 When a ball moves through air, the airflow is laminar around the front of the ball and turbulent behind it.

(a) State what is meant by

(2)

laminar flow

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.....

turbulent flow

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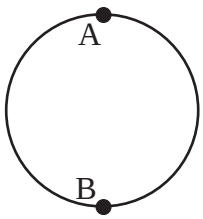
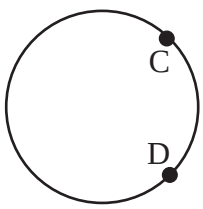
(b) The diagram shows a ball for which the airflow becomes turbulent beyond points A and B. Add to the diagram to show the airflow around the ball. The ball is moving to the left.

(2)



(c) It is suggested that 'dimples' on a golf ball decrease the area over which there is turbulent flow so it is only produced beyond points C and D.



Explain how decreasing the area over which there is turbulent flow would increase the range of a golf ball.

(2)

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(Total for Question = 6 marks)

5 Viscosity is sometimes given units of kg m^{-1} s^{-1} and sometimes Pa s.

Show that these are equivalent.

(2)

(Total for Question = 2 marks)

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

(3)

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*(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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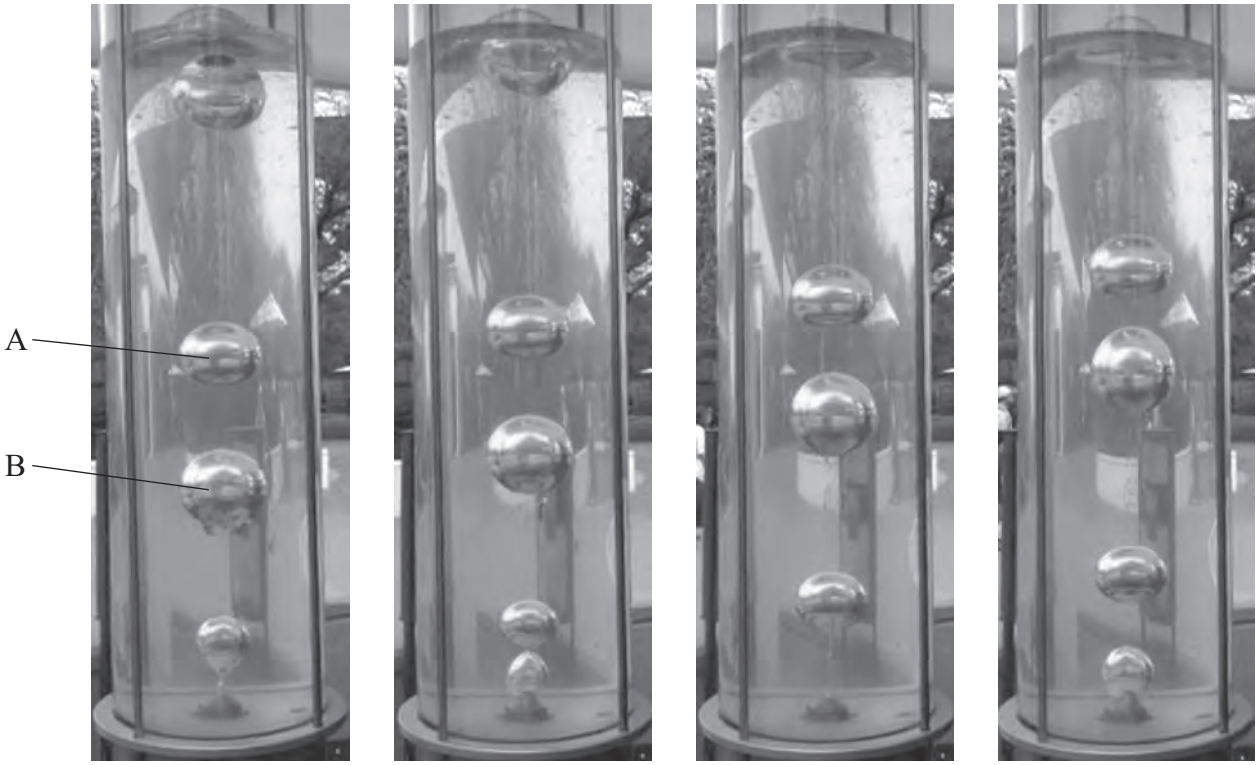
(b) The following photographs were taken at 0.33 s intervals.



Photograph 1
time 0

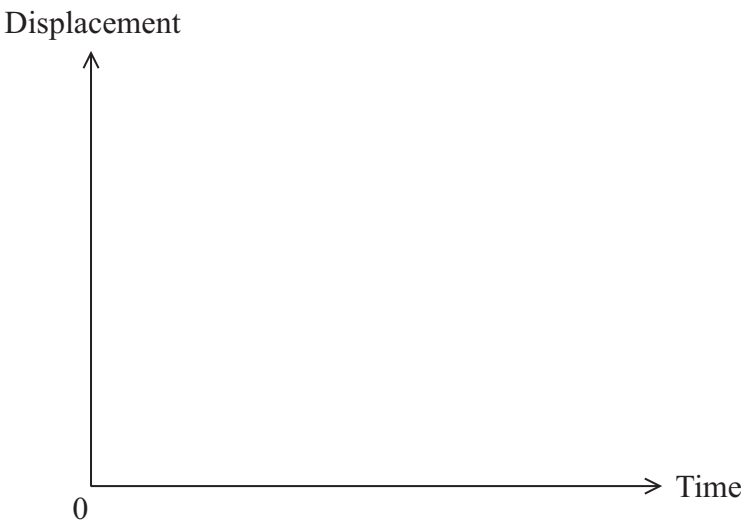
Photograph 2

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)

Speed of bubble B .....

(c) 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)

*(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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(Total for Question 18 marks)

7 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)

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)

Minimum average power =

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

(1)

*(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)

(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)

(Total for Question = 11 marks)