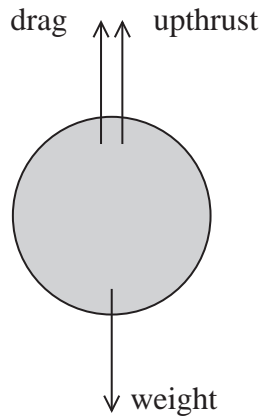


1 The Greek philosopher Aristotle (4th Century BC) stated that heavy objects fall more quickly than lighter objects.

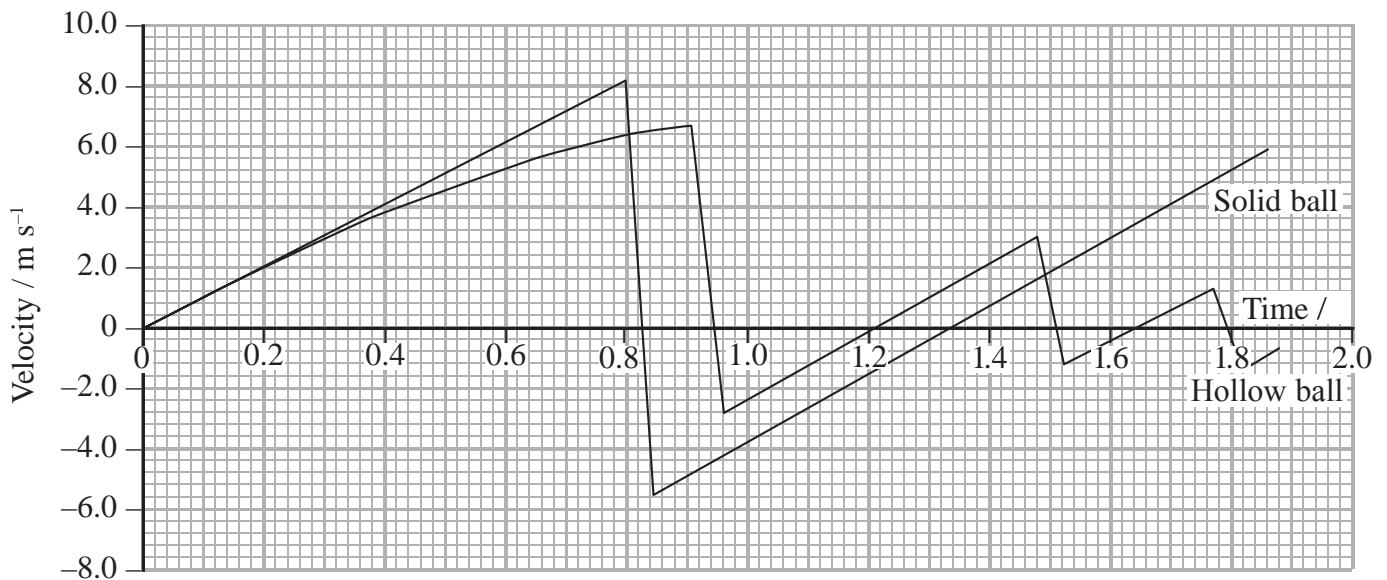
In the 17th Century Galileo reported that a cannon ball and a much smaller musket ball, dropped at the same time, reached the ground together.

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)

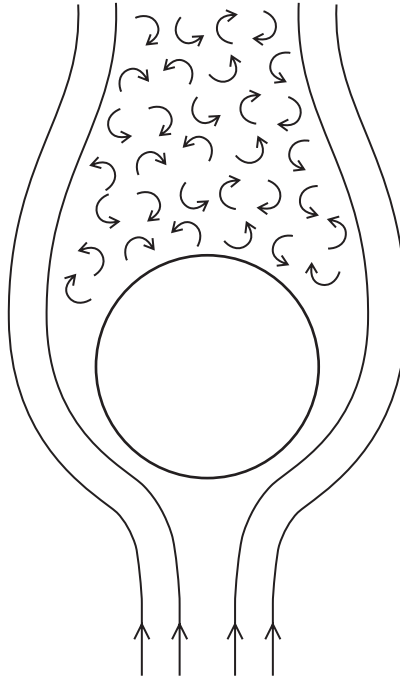
(b) (i) By drawing a tangent to the graph, show that the acceleration of the hollow ball at time $t = 0.60$ s is about 7 ms^{-2} . (2)

(ii) Show that the resultant force on the hollow ball at $t = 0.60$ s is about 0.02 N.
mass of hollow ball = 2.4 g (2)

(iii) Show that the drag force on the hollow ball at $t = 0.60$ s is about 0.01 N. You may neglect upthrust. (2)

(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)

(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)

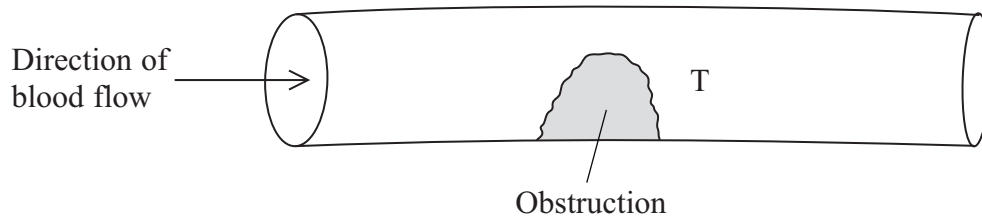
(d) Without further calculation, use the graph to describe the motion of the solid ball.

(3)

(Total for Question = 14 marks)

2 Blood clots can lead to heart attacks. Blood flow through arteries is normally laminar, but an obstruction may cause the blood flow to become turbulent. This can lead to the formation of blood clots.

(a) The diagram shows an artery containing an obstruction.



After passing the obstruction the laminar flow becomes turbulent in the area marked T.

- (i) Add flow lines to the diagram to show laminar flow changing to turbulent flow after passing the obstruction. (2)
- (ii) Explain what is meant by laminar flow and turbulent flow. (2)

Laminar flow

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Turbulent flow

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(b) In one experiment on blood flow, the viscosity of the blood and the velocity of blood flow were measured.

(i) Describe how you would expect the velocity of blood flow to vary with the viscosity.

(1)

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(ii) Suggest and explain how a rise in the temperature of the blood would affect the velocity of flow.

(2)

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(Total for Question 7 marks)

3 Viscosity is sometimes given units of $\text{kg m}^{-1} \text{s}^{-1}$ and sometimes Pa s.

Show that these are equivalent.

(2)

(Total for Question = 2 marks)

- 4 One method used to find the viscosity of a liquid is to measure the terminal velocity of a solid spherical object falling through it.

In such an experiment the following data are provided:

$$\begin{aligned}\text{weight of sphere} &= 4.8 \times 10^{-3} \text{ N} \\ \text{radius of sphere} &= 2.5 \times 10^{-3} \text{ m} \\ \text{volume of sphere} &= 6.5 \times 10^{-8} \text{ m}^3 \\ \text{density of liquid} &= 1300 \text{ kg m}^{-3}\end{aligned}$$

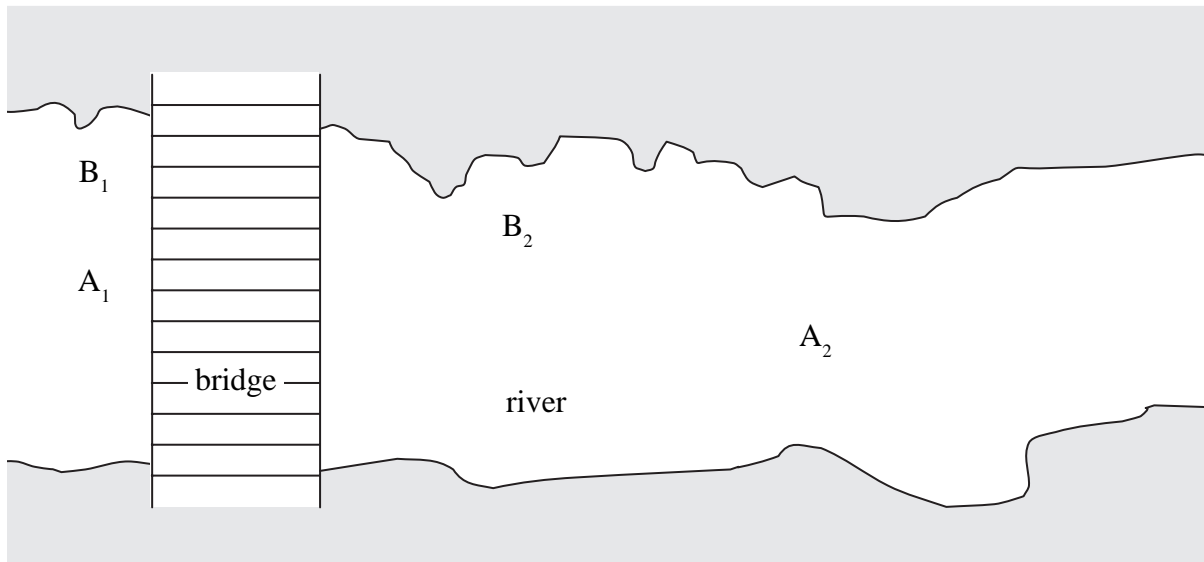
- (a) Show that the upthrust is about $8 \times 10^{-4} \text{ N}$. (2)

- (b) The terminal velocity is found to be $4.6 \times 10^{-2} \text{ m s}^{-1}$. Use this value to show that the viscosity of the liquid is about $2 \text{ kg m}^{-1} \text{ s}^{-1}$. (3)

- (c) The students carrying out this experiment wish to repeat it on another day using the same equipment. State another relevant variable that needs to be controlled to make this a fair test. (1)

(Total for Question = 6 marks)

5 In the game of Poohsticks, sticks are dropped into a river from one side of a bridge to see which reaches the other side first.



A stick is dropped into the centre of the river at A_1 and moves at a steady speed to A_2 , winning the game.

Another stick is dropped into the river near its edge at B_1 , and ends up swirling around at B_2 .

(a) Add to the diagram to show the water flow at A_2 and at B_2 . (2)

(b) Name and describe the type of water flow at A_2 and at B_2 . (4)

A_2

B_2

(Total for Question = 6 marks)

- *6 The designer of a new lorry trailer claims it will save 10% on the amount of fuel used compared to a traditional trailer.

The photographs show the airflow around a traditional trailer and around the new trailer.



Traditional trailer



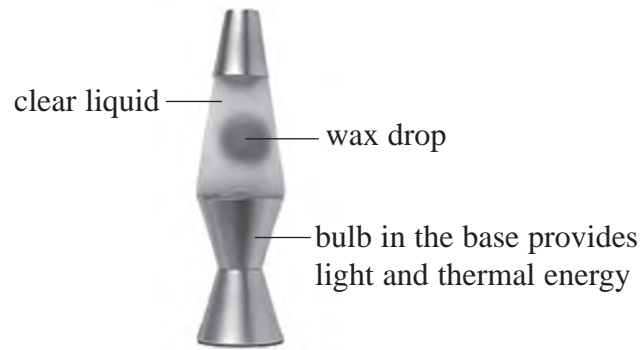
New trailer

Using information from the photographs, explain why the new trailer would use less fuel compared to the traditional trailer.

(4)

(Total for Question = 4 marks)

7 The photograph shows a 'lava lamp'.



When the lamp is switched on, large drops of liquid wax are seen to rise and then fall within the clear liquid.

(a) As a wax drop is heated it expands, its density decreases and it rises through the clear liquid.

(i) Explain why the wax drop begins to move upwards as it is heated.

(3)

(ii) The wax drop accelerates initially and then reaches a terminal velocity.

Write a word equation for the forces acting on the wax drop when it is moving upwards at its terminal velocity.

(2)

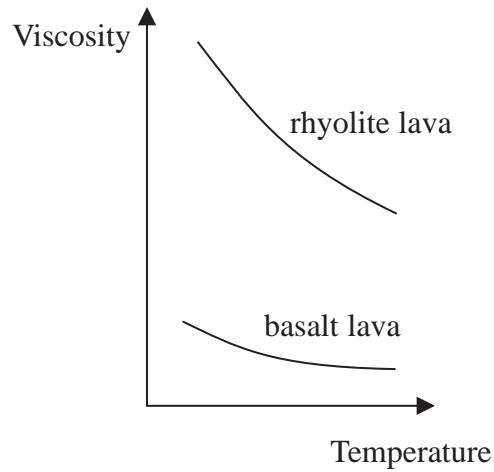
(b) The wax drop is seen to slow down as it reaches the top of the lamp.

Explain this observation.

(3)

(Total for Question = 8 marks)

*8 Lava is molten rock, which sometimes erupts from beneath the Earth's surface. As the lava cools volcanoes form. The shape of the volcano is determined by the flow rate of the lava. The graph below shows how the viscosities of two types of lava vary with temperature.



The diagrams below shows the shapes of two typical volcanoes.



Both types of lava are at the same temperature as they reach the Earth's surface. The shield volcano is formed from basalt lava and the cone volcano is formed from rhyolite lava. Use the information in the graph to explain the shape of each volcano.

(4)

(Total for Question = 4 marks)

9 The photograph shows oil being poured into a cold frying pan and spreading out.



Explain the difference that using a hot pan would make to how the oil spreads.

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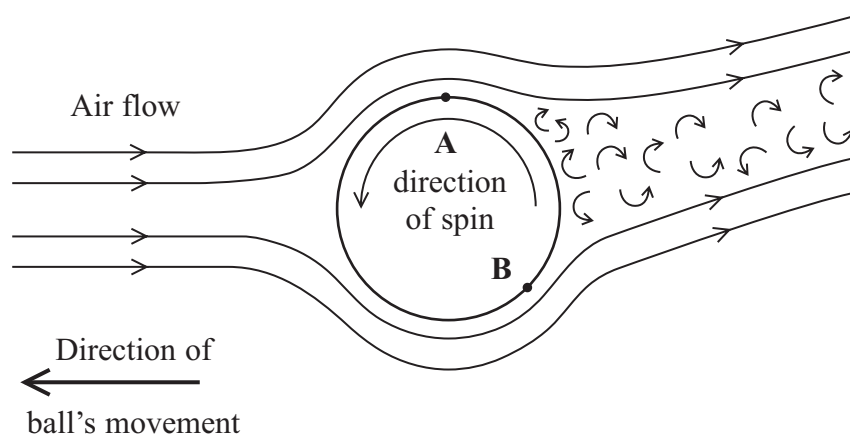
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(Total for Question 2 marks)

10 In the game of table tennis a ball is hit from one end of the table to the other over a small net.

(a) Making a table tennis ball spin when it is hit can affect its flight. The diagram shows the path of air around a spinning ball. It contains regions of laminar flow and turbulent flow. The flow changes from one to the other at points A and B.



(i) Explain what is meant by laminar flow and turbulent flow.

(2)

Laminar flow

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Turbulent flow

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(ii) The ball is spinning in the direction shown in the diagram.

Suggest why there is a larger region of turbulent flow on the top of the ball than the bottom.

(1)

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(b) The diagram shows that the air is deflected upwards after passing the ball.

Explain why this means there must be a downwards component of force on the ball in addition to its weight.

(2)

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(c) Spinning a table tennis ball allows it to be hit harder and still hit the table on the other side of the net.

(i) A table tennis ball is hit, without any spin, from one end of a table so that it leaves the bat horizontally with a speed of 31 m s^{-1} . The length of the table is 2.7 m.

Show that the ball falls a vertical distance of about 4 cm as it travels the length of the table.

(3)

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(ii) The net is 15 cm high. Explain how the spin helps the ball hit the table on the other side of the net.

(3)

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(Total for Question 11 marks)