Fluid Density, Viscosity & Drag

Question Paper

Level	A Level
Subject	Physics
Exam Board	Edexcel
Topic	Materials
Sub Topic	Fluid Density, Viscosity & Drag
Booklet	Question Paper
Paper Type	Open-Response 3

Time Allowed: **50 minutes**

Score: **/41**

Percentage: **/100**

Grade Boundaries:

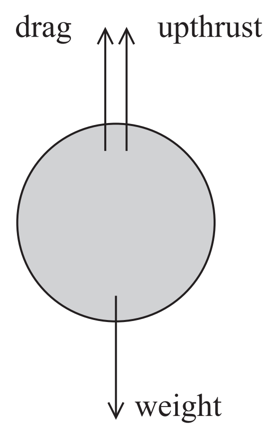
A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

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

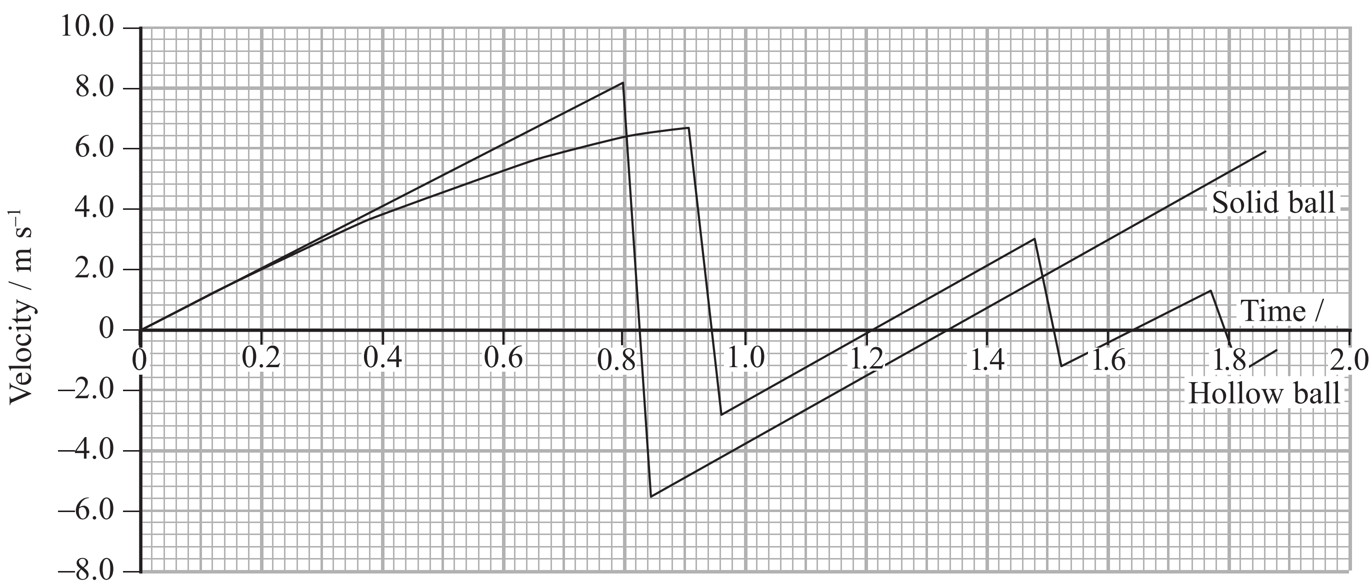
In the 17th Century Galileo reported that a cannon ball and a much smaller musket ball, dropped at the same time, reached the ground together.

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)

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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 $t = 0.60$ s 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 $t = 0.60$ s 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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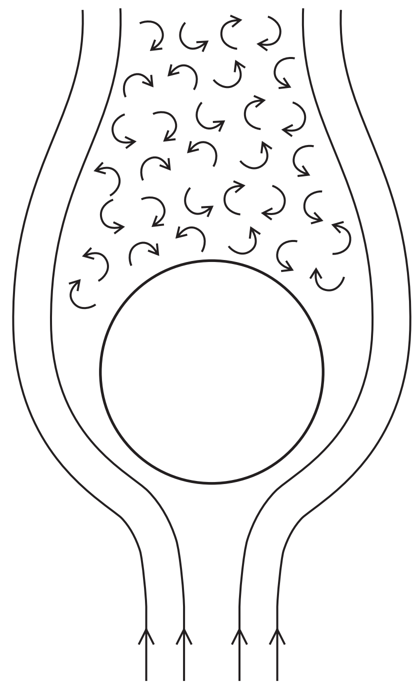
(c) The diagram shows the air flow around the hollow ball as it falls.



(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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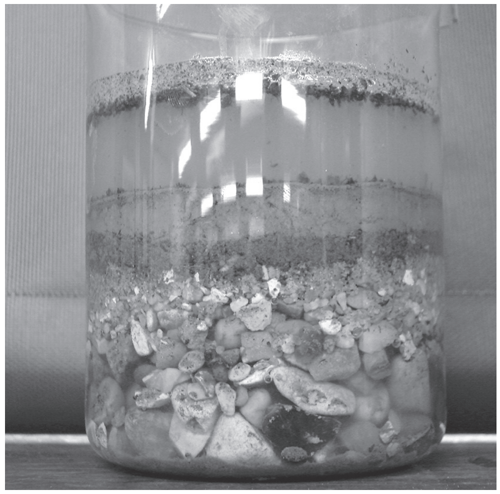
(Total for Question = 14 marks)

2 Soil is usually made up of a variety of particles of different sizes. The photograph shows what happens when soil is mixed up with water and the particles are allowed to settle.



(a) The dot below represents a particle of the soil falling through water.

(i) Add labelled arrows to show the three forces acting on the particle as it falls through the water.

(2)

*(ii) Explain why a particle held stationary in water and then released accelerates downwards at first but then reaches a steady downwards speed.

(4)

(iii) Write an expression showing the relationship for these forces when the particle is falling at a steady speed.

(1)

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(b) A typical particle of sand in the sample has the following properties:

diameter = 1.6×10^{-3} m

volume = 2.1×10^{-9} m^3

density = 2.7×10^3 kg $^{-3}$

weight = 5.7×10^{-5} N

(i) Show that the upthrust acting on the particle is about 2×10^{-5} N.

density of water = 1.0×10^3 kg m^{-3}

(2)

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(ii) Calculate the steady downwards speed this particle would achieve if allowed to fall through water.

viscosity of water = 1.2×10^{-3} Pa s

(3)

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Speed = ...

(c) The different types of particles in soil can be defined according to their diameters, as in the following table.

Soil particle	Particle diameter
clay	less than 0.002 mm
silt	0.002 mm – 0.05 mm
sand	0.05 mm – 2.00 mm
fine pebbles	2.00 mm – 5.00 mm
medium pebbles	5.00 mm – 20.00 mm
coarse pebbles	20.00 mm – 75.00 mm

The photograph shows that when soil is allowed to settle in water, the pebbles tend to be found towards the bottom, followed by sand, silt and clay in succession.

Explain why this happens. Assume that all particles have the same density.

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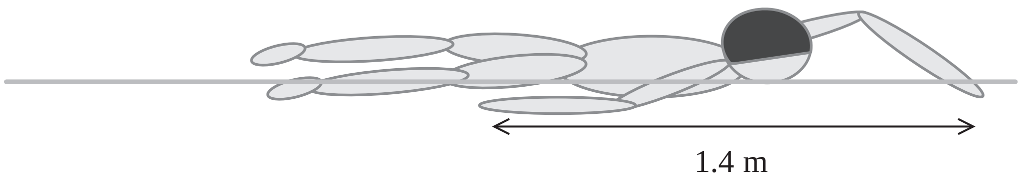
(Total for Question = 15 marks)

3 The diagram shows a swimmer.



(a) The swimmer exerts an average horizontal backward force of 65 N on the water during each stroke. The length of each stroke is 1.4 m.

(i) Show that the work done by the swimmer on the water during each stroke is about 90 J.

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(ii) The stroke rate of the swimmer is 55 strokes per minute. Calculate the power developed by the swimmer's arms.

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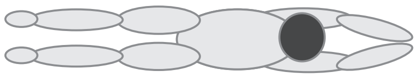
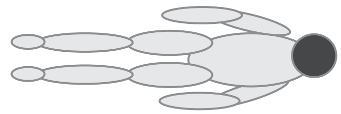
Power = ...

(b) An investigation was carried out on the drag forces acting on the swimmer. The swimmer pushed off from the side of the pool with his arms straight ahead of him and his velocity was measured as he glided through the water. This was repeated with the swimmer's arms at his sides.

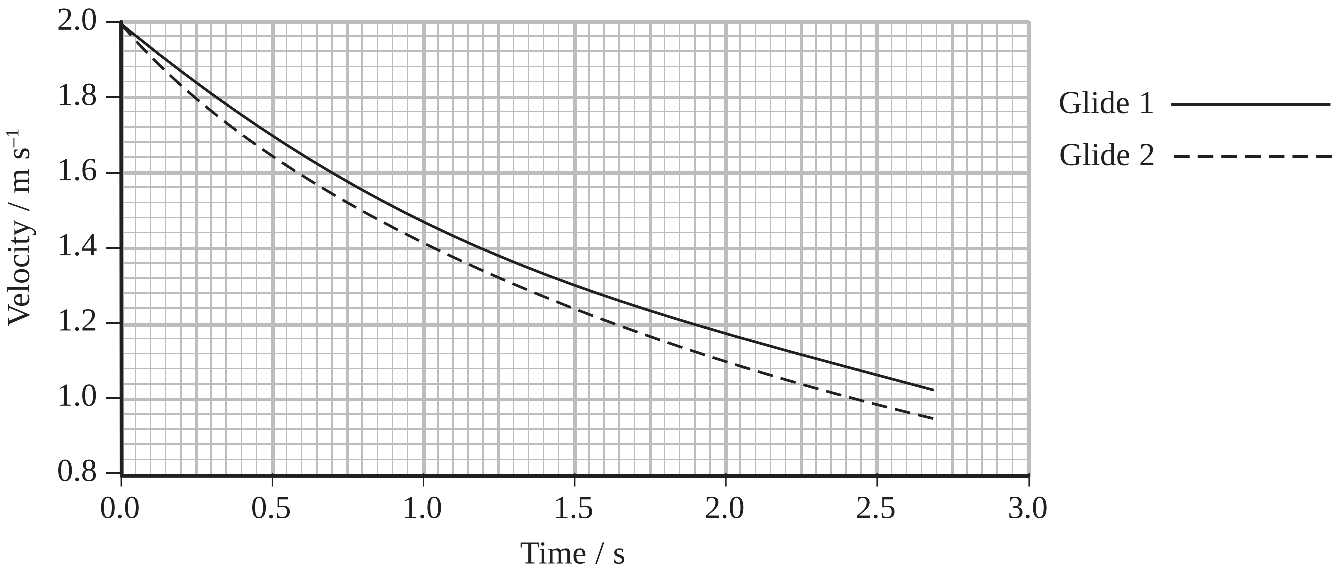


Glide 1



Glide 2

A velocity-time graph was plotted for both glides.



*(i) Use the graph to describe and explain the motion of the swimmer when performing Glide 1 and Glide 2.

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(ii) The drag force can be calculated using

$$\text{Drag force} = \frac{1}{2}C\rho Av^2$$

where

C = drag coefficient

ρ = density of the water

A = cross-sectional area of the swimmer

v = velocity of the swimmer.

Demonstrate that the drag coefficient is a quantity with no units.

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(iii) Suggest and explain an additional measure that a swimmer could use to reduce the drag force acting on him.

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(Total for Question = 12 marks)