Fluid Density, Viscosity & Drag

Question Paper 2

Level	International A Level
Subject	Physics
Exam Board	Edexcel
Topic	Materials
Sub Topic	Fluid Density, Viscosity & Drag
Booklet	Question Paper 2

Time Allowed: **60 minutes**

Score: **/50**

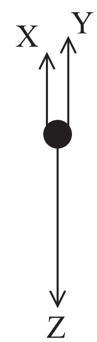
Percentage: **/100**

Grade Boundaries:

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

1 A small steel ball is released at the surface of some oil of known viscosity and begins to sink. The diagrams show the forces acting on the ball shortly after its release and when it has reached terminal velocity.

Steel ball shortly after release



Steel ball at terminal velocity

(a) Identify forces X, Y and Z.

(3)

X is ....

Y is ....

Z is ....

(b) A student uses Stokes' law to calculate force Y.

State the measurements the student should make to calculate force Y acting on the ball when it is moving at terminal velocity.

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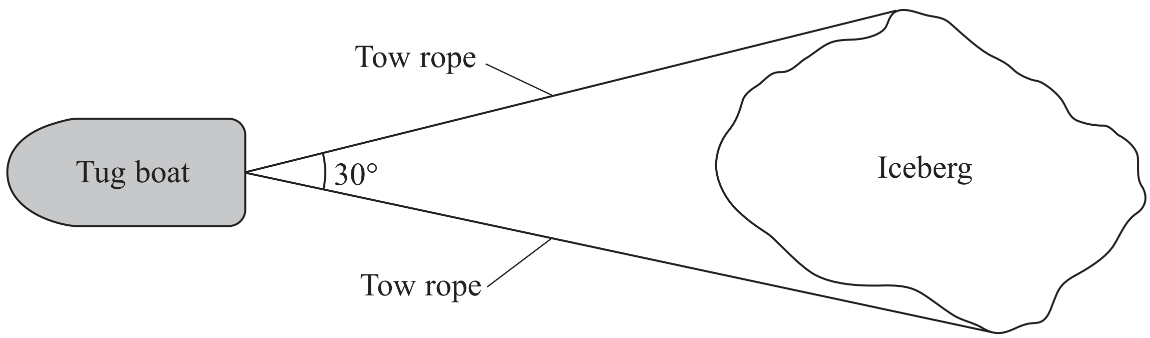
(Total for Question 1 = 5 marks)

2 An iceberg is a large piece of freshwater ice that has broken off a glacier or an ice shelf.

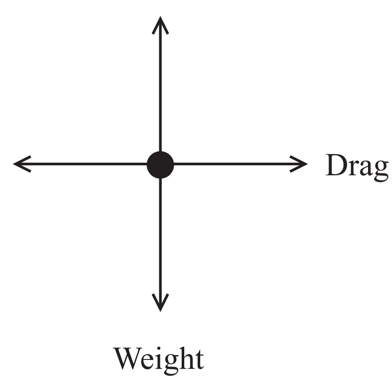
Some scientists believe that icebergs could be used to supply freshwater. It has been estimated that an iceberg of mass 3.0×10^9 kg could provide water for half a million people for up to a year.

Computer models have calculated that just one tug boat would be needed to move such an iceberg half way around the world.



(a) (i) Label the free-body force diagram below, for the iceberg.

(2)



(ii) The iceberg is moving at a constant speed and the tensions in the two tow ropes are equal. Show that the tension in each rope is about 2×10^5 N.

drag force from the water = 3.3×10^5 N

(3)

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(iii) Calculate the work done by the tug boat on the iceberg when the iceberg is pulled through 50 km.

(2)

Work done = ...

(iv) State and explain the effect on the motion of the iceberg if the tow ropes were longer. Assume that the tug boat's power output remains the same.

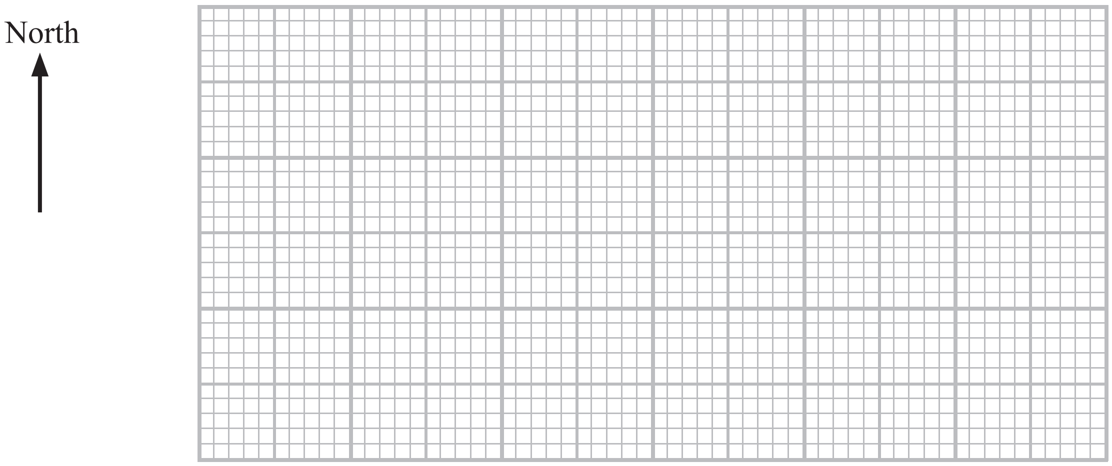
(2)

(b) The tug boat is moving through the water due west at 2.6 km hour^{-1}.

There is a water current of 0.9 km hour^{-1} due south.

On the grid below draw a vector diagram to scale, to determine the magnitude and direction of the resultant velocity of the tug boat.

(3)



Resultant velocity = ...

(c) Not all of the iceberg is visible above the surface of the water.

Show that the proportion of the volume of the iceberg that is beneath the surface of the water is about 0.9.

density of sea water = 1030 kg m^{-3}

density of freshwater ice = 920 kg m^{-3}

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(d) As the iceberg nears its destination, the climate would become warmer.

State the effect this would have on the following physical quantities.

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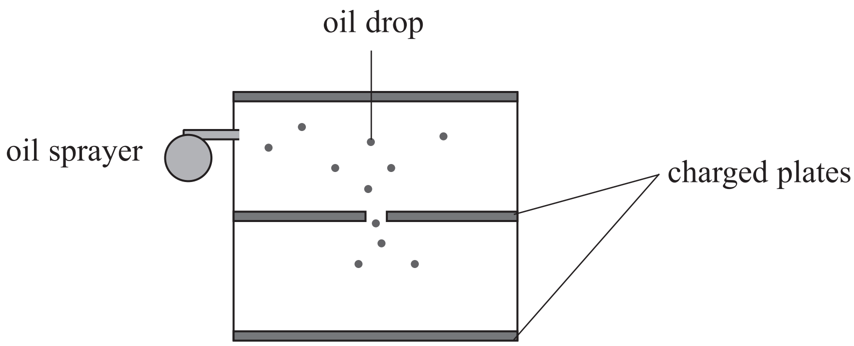
Physical Quantity	Effect
Sea temperature	
Viscosity of sea water	
Density of sea water	
Position of the iceberg in the water	

(Total for Question 2 = 17 marks)

3 In 1909 Robert Millikan did an experiment to find the charge on an electron. Tiny charged oil drops were dropped between two charged plates.



The radius of an oil drop had to be determined so that its weight could be calculated.

Before the plates were charged, Millikan observed how long it took for an oil drop to fall through the air between two fixed points. The terminal velocity and hence the radius could then be calculated.

(a) (i) Complete the free-body force diagram below for an oil drop falling freely through the air.

(2)

(ii) Explain why the oil drop reaches a terminal velocity.

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(b) An oil drop is travelling at terminal velocity.

(i) The oil drop takes 11.9 s to fall a distance of 10.2 mm.
Show that the terminal velocity of the oil drop is about 0.001 m s^{-1}.

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(ii) Assuming that the upthrust is negligible, show that the radius of the oil drop is about 3 μm.

density of oil = 920 kg m^{-3}
viscosity of air = 1.82×10^{-5} Pa s

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(iii) It is very difficult to measure the radius of such an oil drop directly.
Suggest why.

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(c) Explain why it was necessary for Millikan to maintain the air between the plates at a constant temperature.

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(d) A student tried to model Millikan's method for finding the radius of the oil drop. The student dropped a ball bearing and recorded the time it took to pass between two light gates, a known distance apart.

Explain why this is **not** a good model for Millikan's method.

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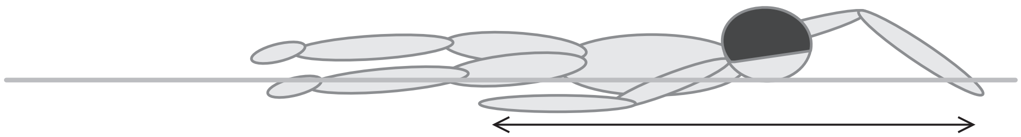
(Total for Question 3 = 16 marks)

4 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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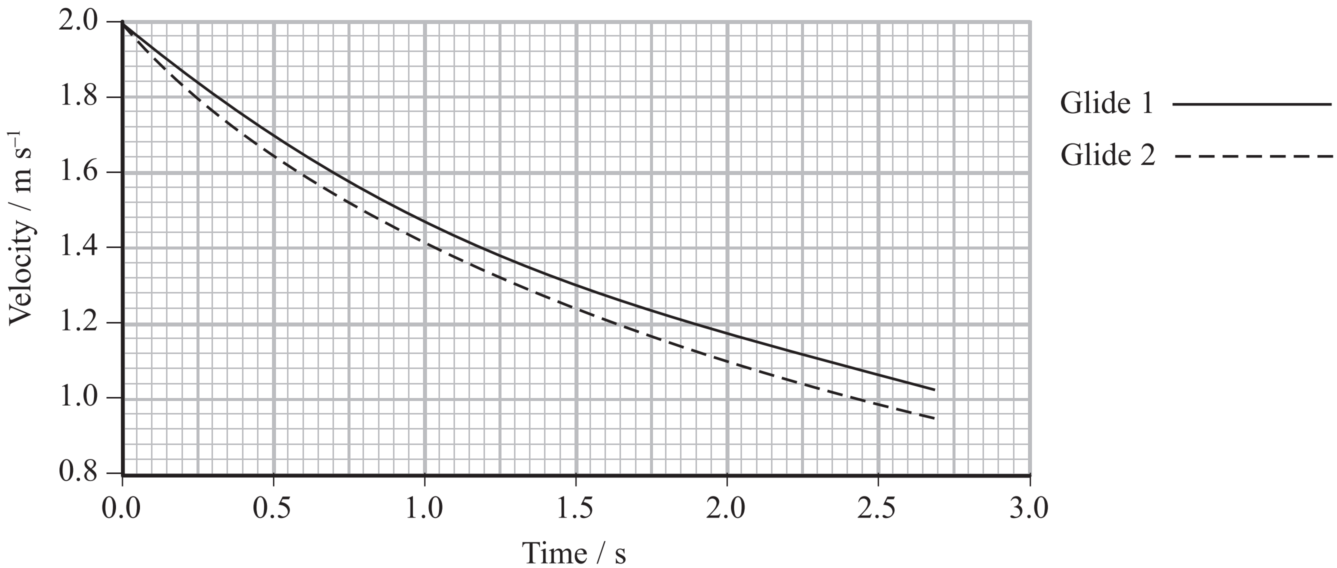
Power = ...

(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

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

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 4 = 12 marks)