1 Stokes' law can be used to calculate the resistive force F acting on an object as it moves through a fluid.

The equation for Stokes' law is

$$F = 6\pi\eta rv$$

(a) Stokes' law is only valid if the flow around the object is laminar.

(i) State what is meant by laminar flow.

(1)

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(ii) State the conditions required for the flow around the object to be laminar.

(2)

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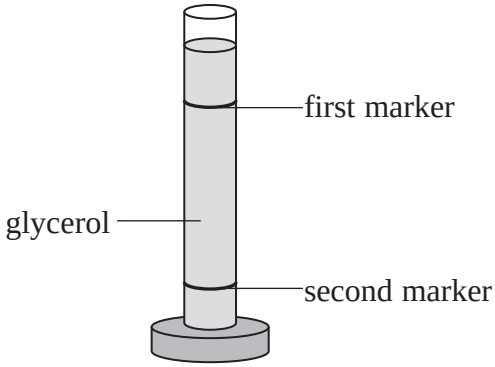
(b) A student carried out an experiment to determine the viscosity of glycerol using the apparatus shown.



A ball bearing was released at the top of a measuring cylinder containing glycerol.
A stopwatch was used to measure the time taken to fall between the markers.
This was repeated for ball bearings of different sizes.

The following equation was used to calculate the viscosity η.

$$\frac{4\pi r^3}{3}\rho_b g - \frac{4\pi r^3}{3}\rho_g g = 6\pi r\eta v$$

r = radius of ball bearing
ρ_b = density of ball bearing
ρ_g = density of glycerol
v = terminal velocity

(i) The density of the glycerol and the ball bearing are known.

State **two** other quantities the student would have to measure directly to calculate the viscosity.

(2)

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(ii) State the quantity that is represented by the term $\frac{4\pi r^3}{3}\rho_b g$.

(1)

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(iii) State the quantity that is represented by the term $\frac{4\pi r^3}{3}\rho_g g$.

(1)

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(iv) Describe how the results obtained and a graphical method can be used to determine a value for the viscosity of the glycerol.

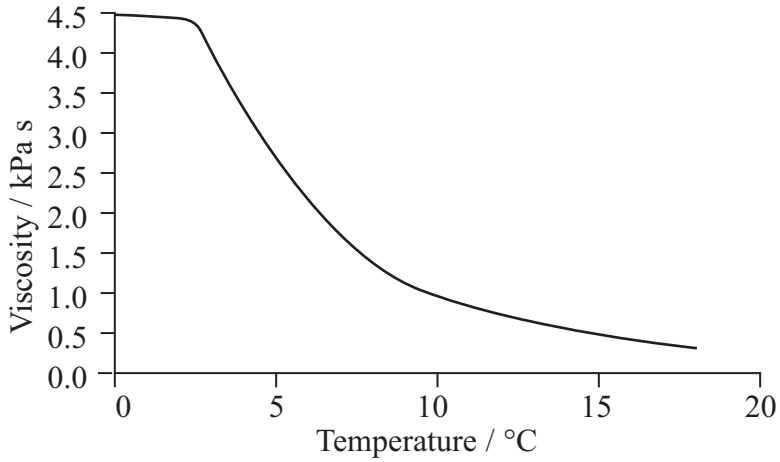
(4)

(c) Glycerol can be pumped into waste systems to remove nitrogen during the treatment of waste water.

Explain the effect that low temperatures could have on the supply of glycerol to a waste system.

(2)

2 The graph shows the effect of temperature on viscosity for butter.



A student wants to spread butter on some bread.

Explain why it is easier to use butter at room temperature than straight from the fridge.

(2)

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(Total for Question 11 = 2 marks)

3 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)

*(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

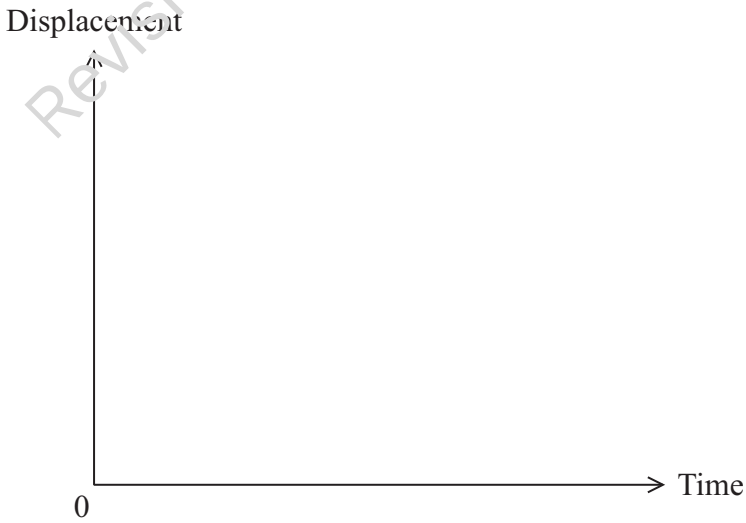
Photograph 2

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)

4 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.

(2)

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