Physics ATAR

Science Inquiry Skills Test 2018

Mark: / 45

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Name:

TEACHER: JRM CJO

Time Allowed: 50 Minutes

Notes to Students:

1. You must include **all** working to be awarded full marks for a question.
2. Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
3. **No** graphics calculators are permitted – scientific calculators only.

Part 1: General Skills **(14 marks)**

Question 1 **(4 marks)**

An object of mass 250 ± 8 grams is moving at a speed of 12.0 ± 0.5 ms^{-1}. Calculate the kinetic energy of the object, including absolute uncertainty.

Question 2 **(10 marks)**

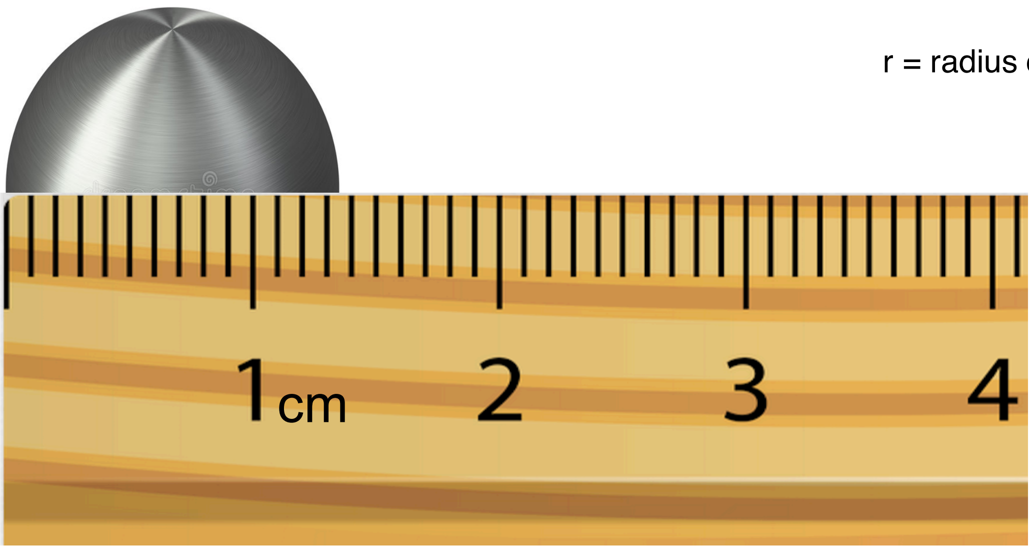
A student is attempting to measure the density of a spherical piece of metal. The student uses the following equations for his measurement.

$V = \frac{4}{3}\pi . r^{3}$ and $\rho = \frac{m}{V}$

ρ = density of the medium (kgm^{-3})

V = volume of the sphere (m^3)

r = radius of the sphere (m)



(a) Use the image above to provide a measurement of the radius of the sphere, including any percentage uncertainty present.

(3 marks)

(b) Calculate the volume of the sphere in m^3 including any absolute uncertainty present.

(3 marks)

(c) State one thing the student could do to increase:

(i) The precision of the measurement of density. (1 mark)

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(ii) The reliability of the measurement of density. (1 mark)

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(d) State one assumption the student has made in this experiment and how he/she could reduce the error that this assumption introduces.

(2 marks)

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Part 2: Experimental Technique and Analysis **(31 marks)**

Drag is a force acting opposite to the relative motion of any object moving with respect to a surrounding fluid. For scenarios involving turbulent flow, the magnitude of the drag depends on the properties of the fluid and on the size, shape, and speed of the object. One way to express this is by means of the drag equation:

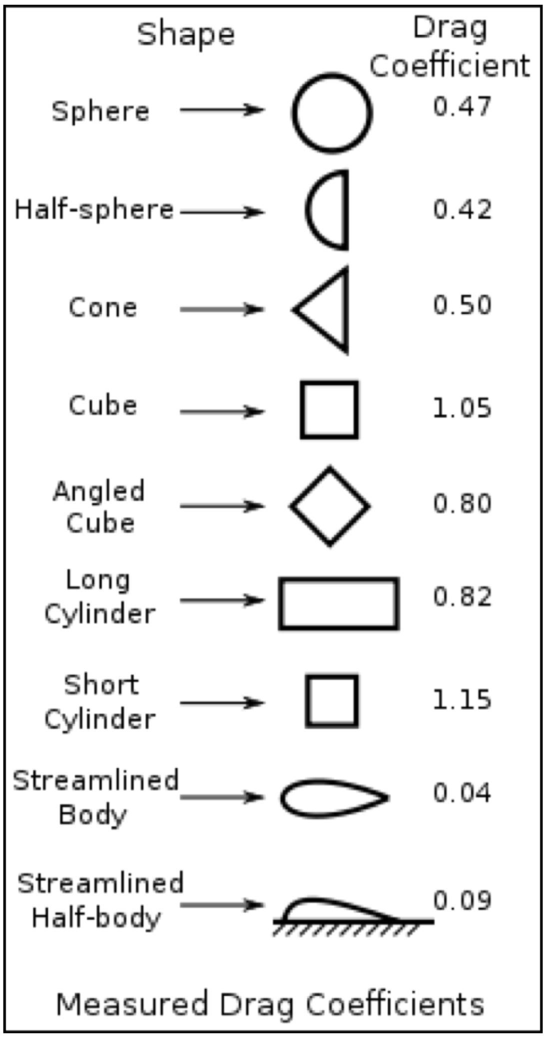
$$F_D = \frac{1}{2}\rho v^2 A C_D$$

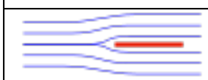
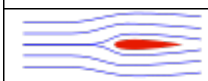
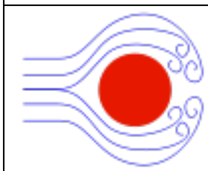
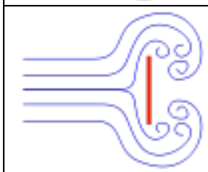
where:

F_D is the drag force [$kgms^{-2}$]
ρ is the density of the fluid [kgm^{-3}]
v is the speed of the object relative to the fluid [ms^{-1}]
A is the cross sectional area of the object relative to the fluid [m^2]
C_D is the drag coefficient.

Different shapes distort the fluid in different ways and so, have varying drag coefficients. The legend to the right shows the coefficient of various shapes. These coefficients are applicable in a turbulent flow situation, corresponding to a Reynold's Number of approximately 10^4.

The Reynold's number is a measure of how the fluid behaves behind the object as it moves through the fluid. High numbers represent turbulent flow (where the fluid is disturbed and brought in behind the moving object). Low numbers represent laminar flow (where fluid flows in parallel layers, with no disruption between the layers). Below is a table that shows the different types of flow found in fluid dynamics.



Shape and Flow	Type of flow	Reynold's Number
	Laminar	Extremely low
	Laminar	Low
	Turbulent	High
	Turbulent	Extremely high

When an object falling through a fluid reaches its terminal velocity, the downward force of gravity ($F_G = mg$) is equal and opposite to the Drag force (F_D).

(a) Show that the equation for an object at its terminal velocity can be simplified to:

(2 marks)

$$v = \sqrt{\frac{2mg}{\rho A C_D}}$$

(b) Using the drag equation on the previous page, show that the drag coefficient C_D is dimensionless.

(2 marks)

A group of students conduct an experiment to determine the drag coefficient of a hollow plastic sphere falling through air that they can fill with sand to increase the object's mass. They have the following data at their disposal. The uncertainty of this data is considered negligible.

A = 0.0314 m^2 ρ = 1.184 kgm^3 (at S.T.P.) mass of sphere = 0.025 kg

The students then use motion capture software to plot the motion of the sphere as it falls, enabling them to measure the terminal velocity of the sphere. The measured velocity had an uncertainty of $\pm$ 5 %

Mass of sand added	**Velocities measured**		
50g	7.3 m/s	7.4 m/s	7.4 m/s
100g	10.0 m/s	10.2 m/s	10.2 m/s
150g	12.0 m/s	12.5 m/s	12.5 m/s
200g	14.2 m/s	14.0 m/s	14.4 m/s
250g	15.9 m/s	15.7 m/s	16.0 m/s

(c) Tabulate the results on the table as required to plot a linearised graph of velocity with respect to total mass of the falling object, with mass on the x-axis, (including any uncertainties present). Note: you are not required to use all rows/columns provided.

(4 marks)

(d) Plot a graph of $\mathbf{V_T^2}$ **vs m** on the graph paper provided.

(5 marks)

(e) Calculate the gradient of the graph.

(3 marks)

(f) Use the gradient of the graph to calculate the drag coefficient of the sphere.

(3 marks)

(g) Using the error bars, draw a maximum and minimum line of best fit and hence, calculate the maximum and minimum gradient. Using the gradients, state the magnitude and percentage uncertainty of your gradient.

(6 marks)

(h) Using your answer from (g), calculate the absolute uncertainty for the drag co-efficient of the sphere.

(2 mark)

(i) Using the proportionalities present in the equation on page 4, provide and explain one possible reason for the drag coefficient being higher than the value provided in the legend on page 4.

(3 marks)

(j) On the graph, sketch the expected results if a "Streamlined Half-body" of plastic (of equal mass, density and cross-sectional area) was used instead of a sphere. No calculation is required for this question but you may use the space below for any working.

(1 mark)

END OF TEST

Acknowledgments:
http://hyperphysics.phy-astr.gsu.edu/hbase/airfri2.html accessed: 19th Feb 2018