Physics ATAR

Science Inquiry Skills Test
2018

Mark: / 45

= %

Name:

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.

Ek = ½mv^2

= ½ (0.25)(12^2)

= 18 J (2.s.f) (1)

%unc(m) = $\frac{8}{250}\times 100$ = 3.20%

%unc(v) = $\frac{0.5}{12}\times 100$ = 4.17% (1)

total %unc. = %unc(m) + 2x %unc(v)

= 3.20 + 2(4.17)

= 11.54% (1)

Ek = 18 ± $\frac{11.54}{100}(18)$ (0.5 calculates absolute)

= 18 ± 2 J (0.5 correctly expressed to 2 s.f. and 0 d.p)

Question 2 **(10 marks)**

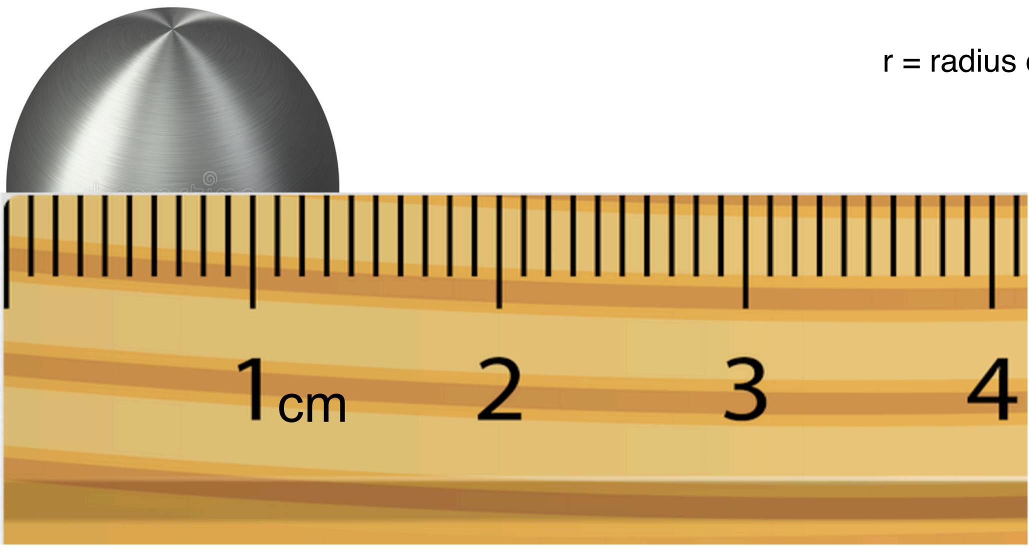
A student is attempting to measure the density of a spherical piece of metal. The student uses the following equations for his measurement.

$V = \frac{4}{3}\pi.r^3$ 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)

D = 1.35 cm ± 0.05 cm (1)

r = (1.35 cm ± 0.05 cm) / 2

= 0.675 ± 0.025 cm (1)

%unc(r)= $\frac{0.025}{0.675}\times 100$

r = 0.675 ± 3.70 % (1) (Magnitude must be expressed to 3 s.f,)

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

(3 marks)

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

$= \frac{4}{3}\pi(0.675\text{x}10^{-2})^3$

$= 1.29\text{ x}10^{-6}\text{ m}^3$ (1)

%unc(V) = 3 x %unc(r)

= 3(3.70)

= 11.1% (1)

$V = 1.29\text{ x}10^{-6} \pm \frac{11.1}{100}(1.29\text{ x}10^{-6})$

$= (1.29 \pm 0.14)\text{ x }10^{-6}\text{ m}^3$ (1) Answer must be expressed to 2 d.p

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

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

Use more precise measuring device such as calipers or micrometers

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

Take multiple trials of diameter and mass and average
(-1/2 if average not mentioned)

(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)

- Ball is perfectly spherical – take multiple diameter measurements across multiple planes.
- Measuring devices are accurate – calibrate to a known standard.

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

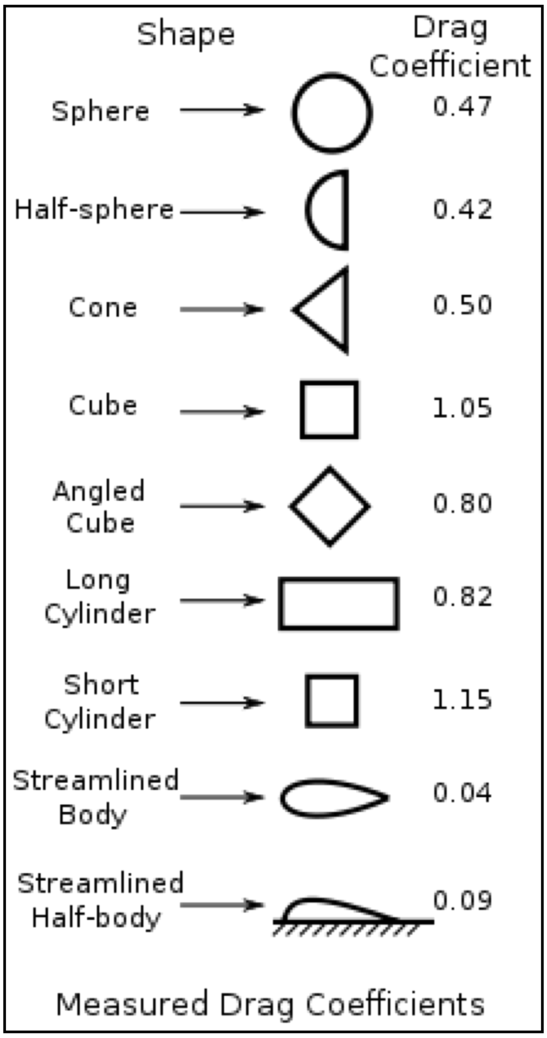
Drag is a force acting opposite to the relative motion of any object moving with respect to a surrounding fluid. For scenarios involving turbulent flow, the magnitude of the drag depends on the properties of the fluid and on the size, shape, and speed of the object. One way to express this is by means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

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

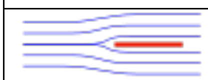
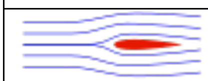
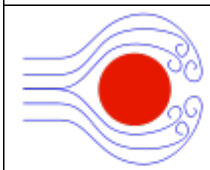
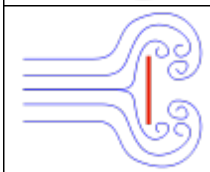
where:

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)

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

Terminal velocity occurs when object is in equilibrium such that Fd = Fg (0.5)

$$\frac{1}{2}\rho v^2 A C_D = mg \qquad (1)$$

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

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

(0.5 – rearranges correctly)

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

(2 marks)

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

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

(0.5 rearrange for Cd)

units $= \dfrac{[kgms^{-2}]}{[kgm^{-3}][ms^{-1}]^2[m^2]}$

(1 correctly state all units)

$= \dfrac{[ms^{-2}]}{[m^{-3}][m^2s^{-2}][m^2]}$

$= \dfrac{[ms^{-2}]}{[ms^{-2}]}$ = dimensionless. (0.5 simplify)

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

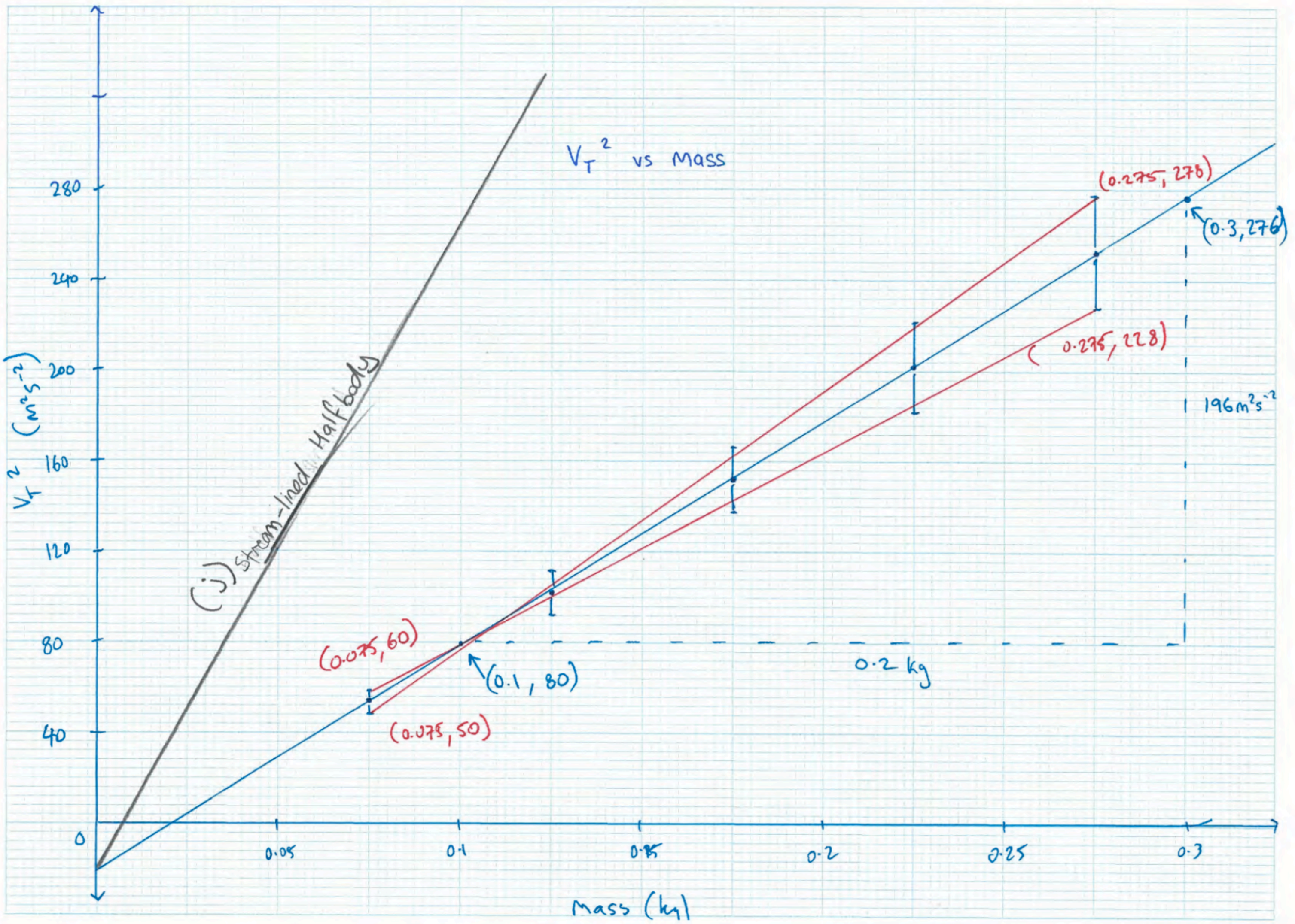
(c) Tabulate the results on the table as required to plot a linearised graph of velocity with respect to total mass of the falling object, with mass on the x-axis, (including any uncertainties present). Note: you are not required to use all rows/columns provided.

(4 marks)

Mass of object (kg)	Velocity average (ms^{-1})	Velocity squared (m^{2}s^{-2})	Velocity squared abs uncertainty (m^{2}s^{-2})		
0.075	7.4 (2 sf)	55 (2 sf)	5.5 (2 sf)		
0.125	10.1	102	10.2		
0.175	12.3	151	15.1		
0.225	14.2	202	20.2		
0.275	15.9	253	25.3		
(to nearest gram, 3dp)	(all to 3 sf uno)	(all to 3 sf uno)	(all to 3 sf uno)		

1 mark each column correctly calculated (0.5 for one error, 0 for more than one error)
-1/2 if values not expressed to appropriate sig fig,
-0.5 for one error in headings or missing units, -1 for more than one error in headings or missing units)

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



(1) Appropriate scales (linear and sized appropriately to show data and fill page.
(0.5) Title naming independent and dependent variables
(0.5) Axes Labelled and with correct units (0 for any error/omission)
(1) Points accurately plotted (0 for any incorrectly plotted points)
(1) Error bars correctly plotted correct to table (0 for any incorrectly plotted bars). If no errors provided in table, deduct mark in part c) but award full marks in part d).
(1) Line of best fit (reasonable fit, within all error bars and straight line with ruler)

(5 marks)

(e) Calculate the gradient of the graph.

(3 marks)

$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{276 - 80}{0.3 - 0.1} = 980\ m^2s^{-2}\ kg^{-1}$

(0.5) (1) (1) (-1 mark if units not stated)

(0.5 for working shown on graph) (-0.5 significant figures, accept 2 or 3sf)

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

(3 marks)

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

$$= \frac{2g}{\rho A C_D}.m \quad \therefore \quad \text{gradient} = \frac{2g}{\rho A C_D}$$ (0.5 rearranges to express gradient)

$$C_D = \frac{2g}{\rho A(gradient)}$$

(0.5 expresses Cd as a function of gradient)

$$= \frac{2(9.80)}{(1.184)(0.0314)(980)}$$ (1)

= 0.54 (2 s.f) (1)

(-0.5 Significant figures 2 or 3 follow through from part e)

(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)

1 mark for lines of best fit drawn on graph
1 mark for gradient working shown on graph

$m_{max} = \frac{y_2-y_1}{x_2-x_1} = \frac{278 - 50}{0.275 - 0.075} = 1140\ m^2s^{-2}\ kg^{-1}$ (1 mark) (-0.5 insufficient working shown)

$m_{min} = \frac{y_2-y_1}{x_2-x_1} = \frac{228 - 60}{0.275 - 0.075} = 840\ m^2s^{-2}\ kg^{-1}$ (1 mark) (-0.5 insufficient working shown)

Magnitude = range of gradients / 2
= (1140 - 840) /2
= 150 $m^2s^{-2}\ kg^{-1}$

(1 mark finds average)

%unc = $\frac{150}{980}$ x100 = 15 % (Accept 2 or 3 s.f.)

(1 mark calculates %)

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

(2 mark)

C_D = 0.54 ± 15 % (0.5 uses correct Cd value)

= 0.54 ± $\frac{15}{100} \times 0.54$ (1 calculates absolute uncertainty)

= 0.54 ± 0.08 (0.5 expresses to appropriate precision - must match d.p of Cd)

(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)

- A greater C_D implies more drag.
- It could be possible that the sphere or sand was shifting in the sphere
- Introducing more resistance, hence a greater C_D

OR

- C_D is inversely proportional to density of air.
- It could be possible that the density of the air that day was greater than assumed.
- Which would provide more resistance, hence a greater C_D

OR

- C_D is inversely proportional to the cross-sectional area.
- It is possible that the shape of the sphere warps during descent and was greater than assumed
- Which would provide more resistance, hence a greater C_D

OR

- C_D is proportional to the mass of the object.
- It is possible that a systematic error is introduced in the measurement of the sand and was less than assumed
- Which would provide more resistance, hence a greater C_D

(j) On the graph, sketch the expected results if a "Streamlined Half-body" of plastic (of equal mass and cross-sectional area) was used instead of a sphere.

(1 mark)

since $C_D \propto \frac{1}{gradient}$, Streamlined Half-body has a C_D approximately 5x sphere.
So gradient should be roughly 5x greater on graph.

(Award 1 mark for anything with a gradient of twice or more) sketched on graph).

END OF TEST

Acknowledgments:
www.hyperphysics.com