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A LEVEL

Examiners' report

PHYSICS B (ADVANCING PHYSICS)

H557

For first teaching in 2015

H557/03 Summer 2024 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Paper 3 series overview

This paper is the third paper for the students following the Advancing Physics A level course. It aims to test candidates understanding of practical skills and techniques. The questions use the context of practical activities listed in the specification and there is an emphasis on graphical work and uncertainties.

This year's paper had questions covering the following practical activities:

- finding the specific thermal capacity of a metal block
- investigating the V-I characteristics of a diode
- finding the focal length of a convex lens
- modelling collisions

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• demonstrated familiarity with practical activities • laid out calculations clearly • showed good understanding of uncertainties, both qualitatively and quantitatively • showed understanding of the properties of a diode • demonstrated an understanding of the terms' uncertainty, precision, resolution.	• demonstrated poor graph skills • did not use the correct scientific vocabulary in their responses • were distracted by the context of collisions in Question 4 (e) which asked them to describe and experiment to investigate the relationship between velocity of a rider on an air track and drag force.

Section A overview

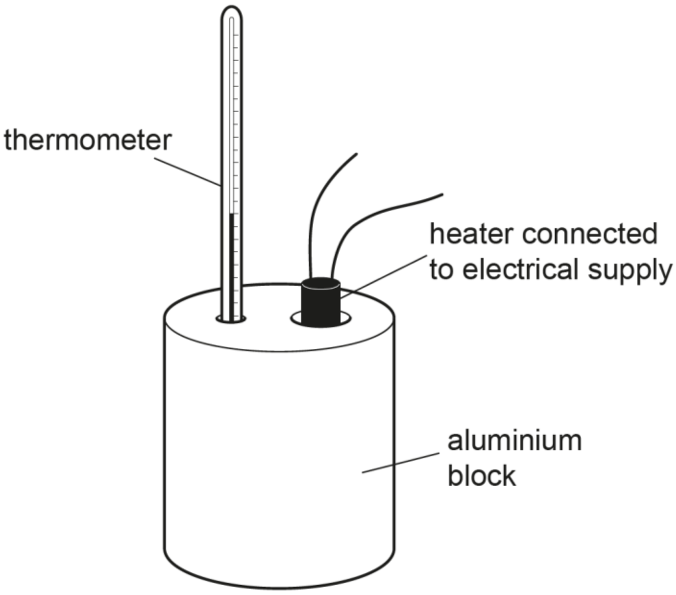
Section A consists of mainly short answer questions on three different practical activities as well as one extended response question to discuss the uncertainties and limitations of an investigation to find the focal length of a converging lens. Two of the questions involved graph work. In Question 1, candidates had to draw lines through error bars and calculate the gradient and uncertainty. In Question 2, candidates had to construct their own axes to plot data.

Question 1 (a)

1 This question is about an experiment to find the specific thermal capacity of aluminium.

An electrical heater is placed in an aluminium block as shown in **Fig. 1.1**. A mercury in glass thermometer is inserted into a hole in the block to record the temperature of the block.

Fig. 1.1



(a) Suggest a practical technique to improve the thermal connection between the thermometer and the block.

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....

.... **[1]**

Many candidates did not answer the question and often suggested a technique to reduce the thermal energy loss from the block, such as insulating the block.

Question 1 (b) (i), (ii), (iii)

(b) The heater is switched on and the temperature of the block is recorded every minute for 10 minutes. The results are recorded and plotted on the graph in **Fig. 1.2**.

(i) The absolute uncertainty in each temperature measurement is ± 1.0 °C.
Draw vertical uncertainty bars on each plot. **[1]**

(ii) Draw lines of both the maximum and minimum gradients through the data points and uncertainty bars on the graph. **[2]**

(iii) Calculate the mean rate of temperature rise in $°C\,s^{-1}$ and its percentage uncertainty.
Use the lines you drew for part **(b)(ii)**.

rate of temperature rise = ... $°C\,s^{-1}$ ± .... % **[5]**

Nearly all candidates drew vertical error bars correctly on the graph. The very few who drew them too small were then unable to draw lines of minimum and maximum gradient which passed through all the error bars.

Many candidates successfully drew two lines, one with maximum gradient and one with minimum gradient, through the correctly drawn error bars. A common error occurred when candidates drew a line of maximum gradient from the top of the error bar at t=10 mins to the bottom of the error bar at t=0 which then did not pass through all the error bars. A similar error was also made with the line of minimum gradient. Candidates needed to take care drawing these lines.

Some candidates also drew what they considered to be a line of best fit on their graph. This was unnecessary and then tended to make it more difficult to see the lines and find the gradient of the lines of maximum and minimum gradient. Some candidates then found the gradient of this extra line, which was not necessarily the mean of the gradients of the maximum and minimum gradients.

Most candidates were able to show that they could calculate a gradient of a line on a graph. Usually coordinates of points on the lines from the edges of the graph were used to find the gradient. Some candidates only found the gradient as the rate of temperature rise in $°C\,min^{-1}$ instead of $°C\,s^{-1}$. Nearly all candidates were able to find the % uncertainty in their value by finding the spread of values and converting to a percentage.

Question 1 (c) (i)

(c)
(i) Show that:

The gradient of the graph in **Fig. 1.2** = $\frac{P}{mc}$;

where
P = power input, *m* = mass of the block and
c = experimentally-determined value of specific thermal capacity.

[2]

Many candidates correctly started with both energy relationships and were able to substitute and manipulate algebraically to show that the gradient. Some candidates rearranged the combined equation to the form $y = mx + c$ to show the gradient.

Question 1 (c) (ii)

(ii) The potential difference across the heater is set at 9.6 V ± 2%.
The current is 3.76 A ± 0.9%.
Using these values and the value calculated in part **(b)(iii)**, determine the specific thermal capacity of aluminium. Find the absolute uncertainty.

mass of aluminium block = 1.00 ± 0.01 kg.

specific thermal capacity = ... ± .... $J\,kg^{-1}\,K^{-1}$ **[4]**

Most candidates were able to correctly calculate their value for specific thermal capacity using the gradient they had calculated in Question 1 (b) (iii). Many of them correctly added the percentage uncertainties of all the values used in the calculation to find the absolute uncertainty of their calculated value.

Some candidates worked out the absolute uncertainty by working out the maximum and/or minimum values of thermal capacity – and nearly always this was done correctly using max value of V and I, with minimum values for gradient and mass to find max value of thermal capacity. A common error was to omit or miscalculate the percentage uncertainty of the mass.

Question 1 (d)

(d) The textbook value for the specific thermal capacity for aluminium is 900 $J\,kg^{-1}\,K^{-1}$. Compare this value with your calculated value and explain the main reason for the difference.

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....

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.... **[2]**

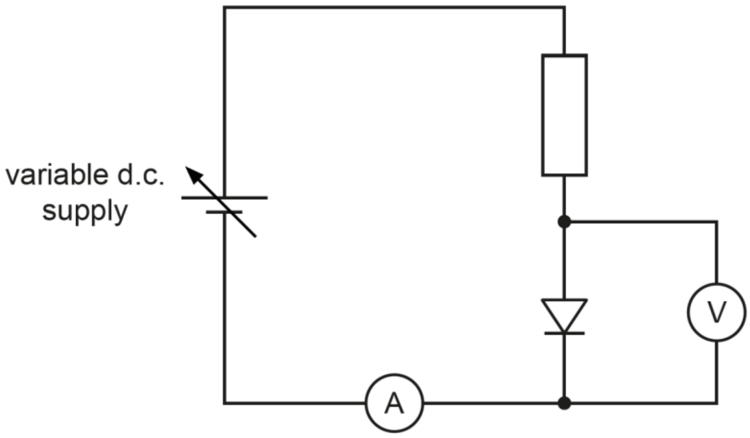
Candidates who did not correctly convert the time in minutes to seconds when they found the gradient value in Question 1 (b) would not have a calculated value for thermal capacity which was more than the stated textbook value. Most candidates did realise that that difference in values was related to the lack of insulation on the block, but some did suggest that the main uncertainty in this experiment was the reading of temperature.

Question 2 (a)

2 The circuit in **Fig. 2.1** is used to measure the current flowing through and the potential difference across a semiconductor diode.

The variable d.c. power supply has negligible internal resistance.

Fig. 2.1



(a) Calculate the conductance of the semiconductor diode when the potential difference = 0.65 ± 0.02 V and the current = 7.5 ± 0.02 mA.
Give the uncertainty in your answer.

conductance = ... ± .... Ω^{-1} **[3]**

This was a relatively straightforward question and most candidates correctly calculated conductance. Some made errors in finding the uncertainty.

Question 2 (b)

(b) Describe how the circuit could be used to obtain values of current at different emfs in order to plot a graph of I against V. Explain the purpose of the fixed resistor in the circuit.

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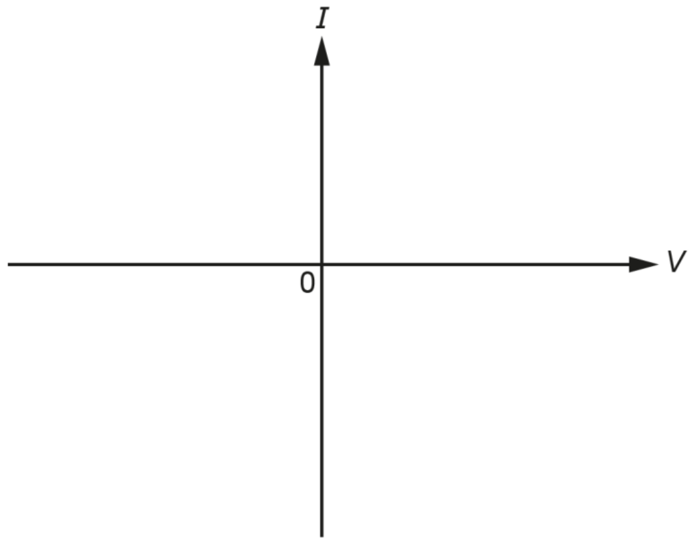
.... **[3]**

Most candidates correctly suggested that the variable supply was adjusted and the current and potential difference across the diode measured. Some correctly stated that the purpose of the resistor was to limit the current in the circuit once the diode began to conduct. Very few referred to a need to make find adjustments either side of the threshold pd in order to obtain an accurate graph.

Question 2 (c)

(c) Sketch on the axes below the shape of the graph you would expect to obtain for both forward and reverse bias.



[2]

Many candidates did not draw the correct shape graph. A variety of incorrect lines were drawn, including direct proportion, asymptotic curves and s-shape curves showing a lack of understanding of what a diode is. Some candidates gave a reasonable attempt, but many showed a gradual increase at the threshold pd and many drew a similar curve (rotationally symmetrical) in negative bias.

Question 2 (d)

(d) Explain any changes you might make to the instrumentation in the circuit in order to obtain an accurate graph.

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.... **[2]**

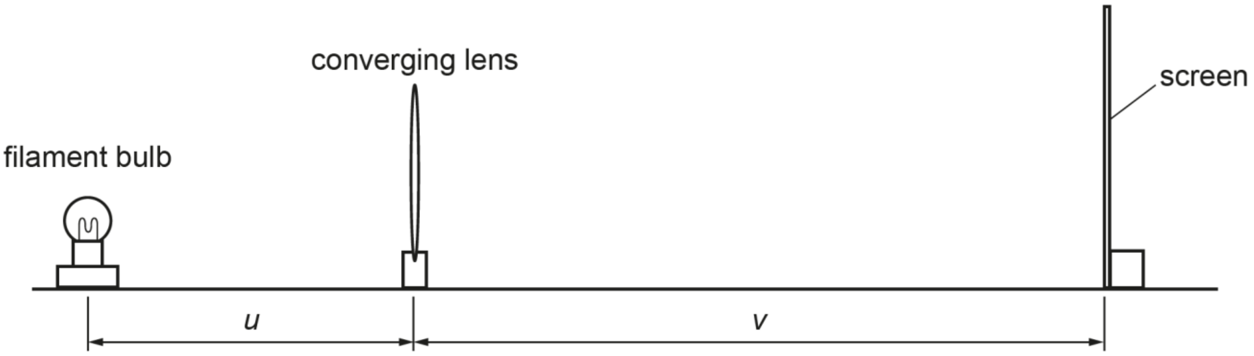
Most candidates did not answer the question being asked here. The question refers to changes to the instrumentation, but many candidates' responses suggested changing the resistance or the diode in the circuit. Some candidates did suggest a voltmeter or ammeter with higher precision but with no reference to the small changes necessary either side of the threshold pd.

Question 3 (a) and (b)

3 This question is about an experiment to find the focal length of a converging lens.

A filament lamp is placed a distance, *u*, from the lens. A screen is set up on the other side of the lens to show the image of the lamp, in order to find distance, *v*. This set up is shown in **Fig. 3.1**.

Fig. 3.1



The screen is moved back and forth until a focussed image of the filament is seen on the screen. The length *v* is then measured from the centre of the lens to the screen. The length *u* is measured from the centre of the lens to the centre of the filament bulb.

(a) Measurements of *u* and *v* are recorded in **Table 3.1**.
Complete the table by calculating the missing values of $\frac{1}{u}$ and $\frac{1}{v}$.

Table 3.1

u / m	*v* / m	$\frac{1}{u}$ /m^{-1}	$\frac{1}{v}$ /m^{-1}
–0.106	0.730	–9.53	1.37
–0.115	0.541		1.85
–0.129	0.394	–7.75	
–0.154	0.245		
–0.214	0.173	–4.67	5.78

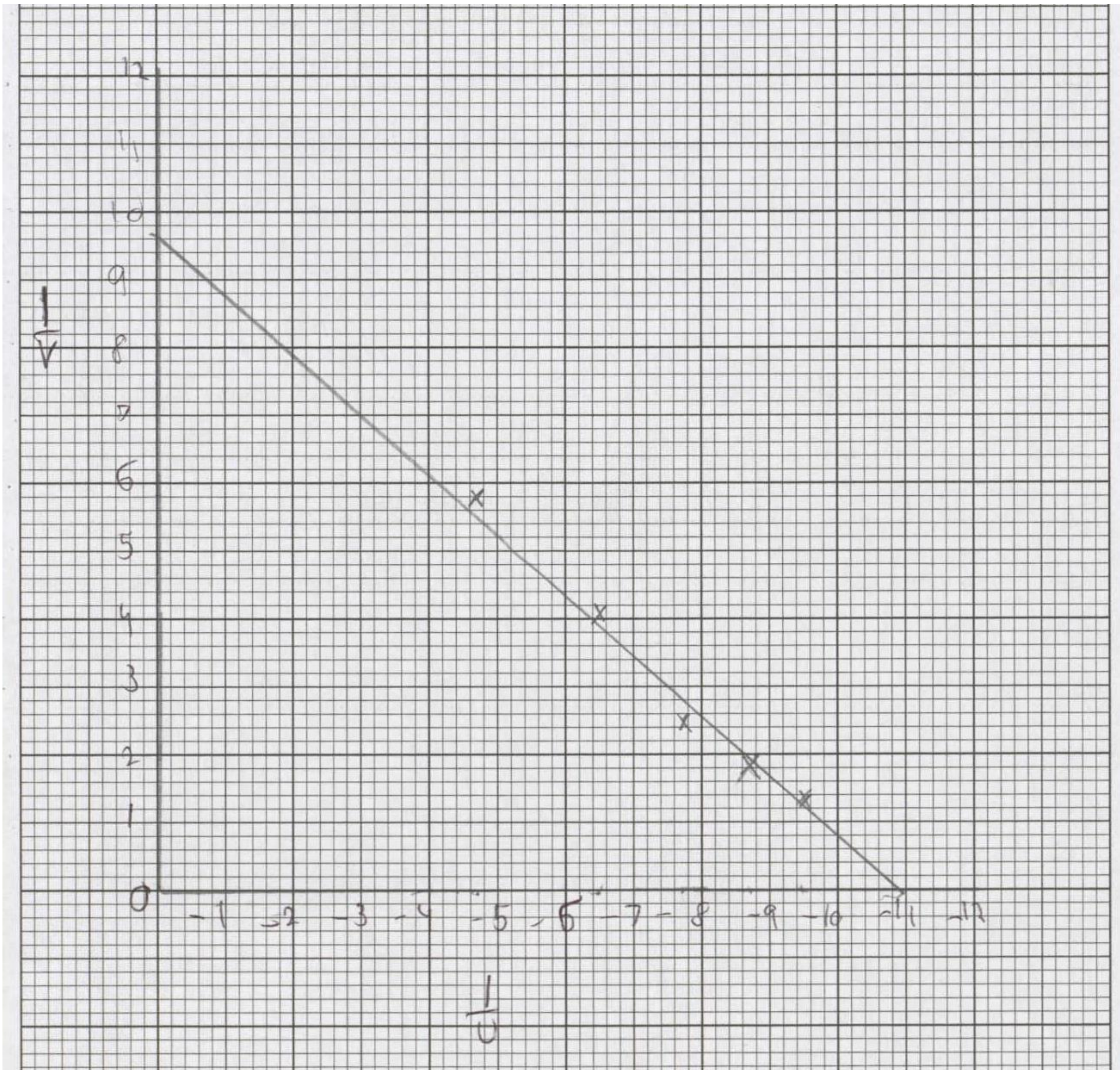
[2]

(b) Draw a scale to –12 on the x-axis and to +12 on the y-axis.

Plot a graph of $\frac{1}{v}$ (on the *y*-axis) against $\frac{1}{u}$ (on the *x*-axis) on **Fig. 3.2**, and draw a straight line of best fit through the data points. **[3]**

Nearly all candidates correctly completed the table and constructed a graph to plot the points. Many candidates drew the x-axis in the wrong direction (more negative left to right) and/or used an awkward scale on one or other of the axes. Having a 1:3 scale makes plotting decimal numbers difficult so should not be encouraged. It is also good practice to use as much of the printed graph grid as possible. Most points were plotted correctly but some of the lines of best fit could have been better.

Exemplar 1



On this candidate's graph T, the y-axis scale is too small. They were told to go up to 12 and there are 12 large squares on the grid so, in order to use as much of the grid as possible the scale should be 1:1 large square. The x-axis is the wrong way round as it becomes more negative left to right. This is the incorrect convention for graphs. The size of the scale is appropriate and the points are plotted correctly. The line of best fit is acceptable as there is a reasonable balance of points either side – 3 on top and two below, but all relatively close.

OCR support

There is a section on good practice for graph drawing in Appendix 5 of the practical skills handbook available on Teach Cambridge.

Question 3 (c)

(c) Determine a value for the focal length of the lens.
Use your line on the graph.

focal length = ... m **[3]**

Many candidates correctly recalled or worked out that the y-intercept was the reciprocal of the focal length, and where the candidate had drawn a line which crossed the axes, they were able to read off the intercept and calculate a value for focal length. Most candidates just used the one value, not realising that the x-intercept would also be equal to the reciprocal of the focal length. Some candidates calculated the gradient and the equation of the line from two points on the line, which was another acceptable method. A few candidates incorrectly used the gradient as the reciprocal of the focal length or added the two intercepts together.

Question 3 (d)

(d) Describe the sources of uncertainties and the limitations of this method to find the focal length of a lens.
Describe and explain methods to improve the experiment, such as the use of a monochromatic filter.

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.... **[6]**

Most candidates were able to answer this question with some correct statement suggesting that it would be easier to judge when the image was in focus with monochromatic light but most of the explanations did not use the correct scientific vocabulary, for example referring to diffraction rather than refraction. Many candidates went into a lot of unnecessary detail about the precision of the ruler. Many stated that the uncertainty of the measurements of both u and v would be 0.01 m. This is the precision of the rule, not the uncertainty of the value, which depends on a number of other factors. Very few candidates discussed the difficulties in knowing where to measure u and v from in terms of finding the centre of the lens or the bulb.

Exemplar 2

Sources of uncertainty:
Uncertainties in distance dependent on resolution of the measuring device used eg a metre rule (uncertainty ± 1mm)
Uncertainty in angle of the screen being normal to the base plane. (± 1 degree)
Uncertainty in ~~eg~~ judging where the focal point is. Random error down to interpretation of when light is brightest and at single most point on the screen. Limitations light exiting the bulb is not distant so ~~wavelengths~~ wavefronts aren't parallel. Light not monochromatic so different wavelengths will refract at different angles through the lens.
Improvements: Use a Laser as a light source (uniform & parallel wavefronts). Use a monochromatic source so all the light has the same angle of refraction/refractive index.
Use a large protractor to measure angle **[6]**
of screen.

In Exemplar 2, this candidate starts off by describing the precision of the ruler but does not state that this is insignificant when other uncertainties are taken into consideration. The candidate correctly suggests that it is difficult to find the exact point of focus because the screen may be tilted and the subjective nature of when different people might think an image is in focus. Refraction of light is included in the explanation of why monochromatic light would be better. This is a Level 2 response.

In order to get up to Level 3, the candidate needs to refer to other sources of uncertainty such as depth of field or difficulties finding the exact midpoint of the lens to measure from.

Section B overview

Section B takes the form of on longer structured question which includes a second extended response question. The latter asked candidates to describe a method to test a hypothesis about the relationships between velocity and drag force for a rider moving along an air track.

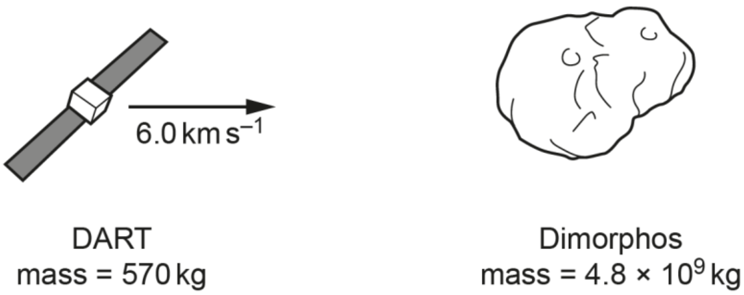
Question 4 (a)

4 This question is about collisions.

In 2022, the DART (Double Asteroid Redirection Test) mission completed the first attempt to redirect an asteroid by colliding a small spacecraft into it. **Fig. 4.1** depicts the spacecraft as it approached the asteroid Dimorphos.

The mass of the DART spacecraft was 570 kg, whilst the mass of Dimorphos was 4.8×10^9 kg. The DART spacecraft impacted with a velocity relative to Dimorphos of $6.0\,\text{km}\,\text{s}^{-1}$.

Fig. 4.1



(a) The spacecraft became embedded into Dimorphos upon impact.
Calculate the velocity of Dimorphos following the impact.
State any assumptions you make.

velocity = ... $\text{m}\,\text{s}^{-1}$ **[3]**

Most candidates used the principal of conservation of momentum to find the velocity of Dimorphos after the impact. Some did not convert the relative velocity of DART to $m\,s^{-1}$ and ended with a POT error in the value. Stating an assumption was more challenging; many candidates suggested that the collision was elastic or energy was conserved, rather than realising that the mass of Dimorphos had to stay intact, or that none of the initial momentum was converted into rotational momentum.

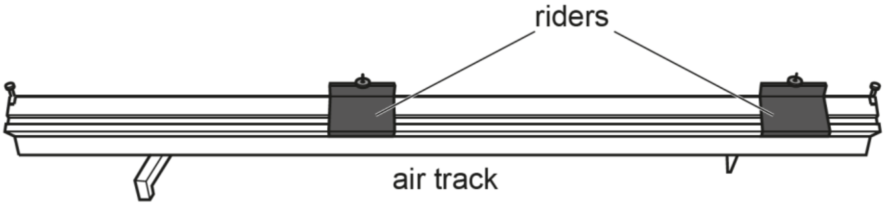
Misconception

? Many candidates suggested that the collision between DART and Dimorphus was elastic or referred to conservation of energy. Collisions where the two objects stick together and move are totally inelastic collisions.

Question 4 (b)

(b) A student attempts to model this collision using an air track (see **Fig. 4.2**). One of the riders available to use has a mass of 150 g.

Fig. 4.2



Suggest and explain why it may be challenging to replicate the collision of the DART mission with this apparatus.

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.... **[2]**

Many candidates came up with sensible figures for the required mass of the other rider without satisfactorily explaining why such a mass would be problematic. Uncredited answers frequently concentrated on air resistance.

Question 4 (c) (i)

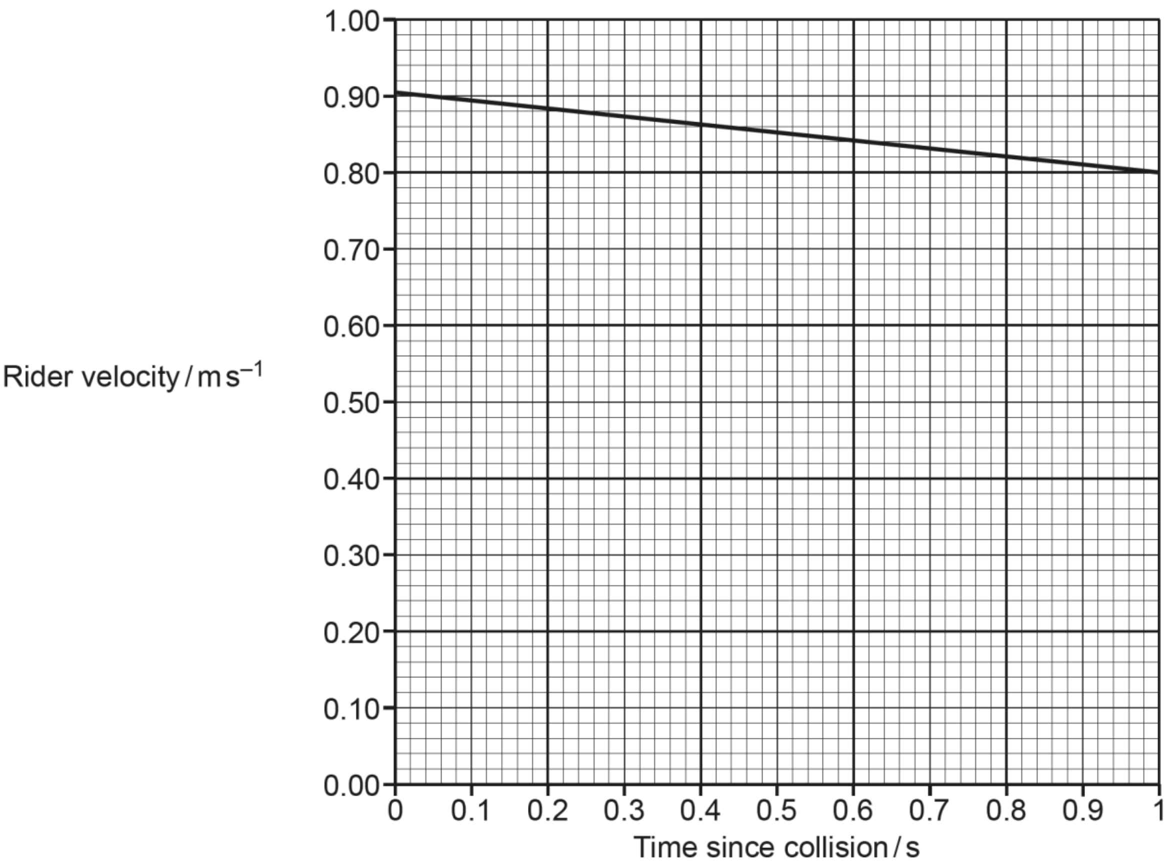
(c) The student begins an investigation with the apparatus available to them, including two riders of mass 150 g.

In the first run, the student collides the first rider with the second stationary rider. In the air track experiments, the riders do **not** move together after the collision. Using an ultrasonic ranging device, the student obtains a velocity–time graph of the second rider in the time after the collision. **Fig. 4.3** shows the graph.

In all of the student's experiments the riders do not move together after the collision.

Fig. 4.3

Velocity–time graph of the second rider for the time after the collision.



(i) Calculate the maximum initial velocity of the **first** rider, assuming it comes to rest immediately following the collision.

maximum velocity = ... $m\,s^{-1}$ **[1]**

Most candidates simply gave the answer here and ignored the instruction to calculate.

Question 4 (c) (ii)

(ii) The graph suggests there is a drag or frictional force acting on the rider as it decelerates. Use the graph to estimate the magnitude of this force.

magnitude of force .... N **[3]**

This question was generally well answered, with only a few candidates getting a POT error for not converted the mass into kg.

Question 4 (c) (iii)

(iii) During another collision a 150 g rider collides with a stationary 250 g rider. The 150 g rider recoils with a velocity of 0.23 m s^{-1} following the impact.

Determine whether the 250 g rider will move away with a velocity greater or smaller than that shown in **Fig. 4.3** for the 150 g rider, assuming the same approach velocity as in **(i)**.

Support your conclusion with a calculation.

[2]

Many candidates calculated an incorrect velocity as they did not recognise that a 'recoil' velocity will be in the opposite direction to the initial velocity. Hence an incorrect sign was used in the conservation of momentum calculation. A handful of candidates compared the calculated velocity with the recoil velocity rather than the velocity stated in Question 4 (c) (i).

Question 4 (d)

(d) The DART spacecraft did not have to contend with atmospheric drag. The student decides to investigate the effect of drag on velocity of the rider following a collision. A small sail is added to the 250 g rider (**Fig. 4.4**). The data are shown in **Fig. 4.5**.

Fig. 4.4

250 g rider with sail.

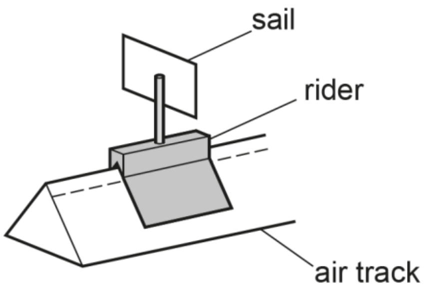
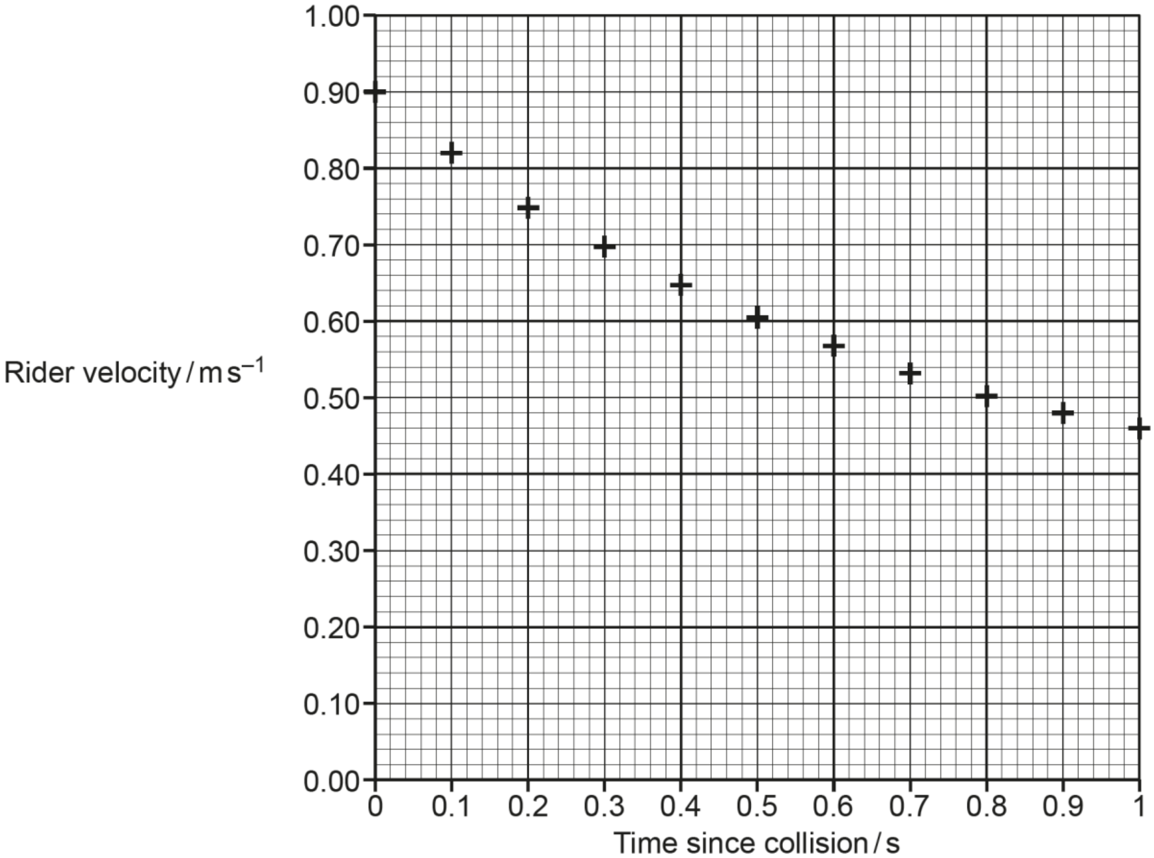


Fig. 4.5

Velocity–time graph for rider with sail in the time after the collision.



Describe and explain the shape of the graph.

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....

....

.... **[2]**

Several candidates incorrectly claimed that the graph shows an exponential decrease. Several believed that the curve shows that deceleration was constant, but many did manage to describe the shape adequately and explain that the drag force would be lower at lower velocities.

Question 4 (e)*

(e)* The student decides to undertake a detailed investigation into the effect of drag on the deceleration of the 250 g rider following a collision.

The student's teacher suggests that the drag force, F_D, is proportional to the square of the object's velocity, v^2.

$F_D \propto v^2$

The student has available the following apparatus:

- air track and riders
- ultrasonic ranging device (as described earlier in the question)
- variable speed fan
- anemometer (wind-speed measuring device)
- pulley and weights.

Outline a plan for the student to test this suggestion.

Describe, with reasoning, how you would use the apparatus to investigate speed and drag.

Explain how you would use your data to prove/disprove the suggested relationship.

You may include a diagram in your response.

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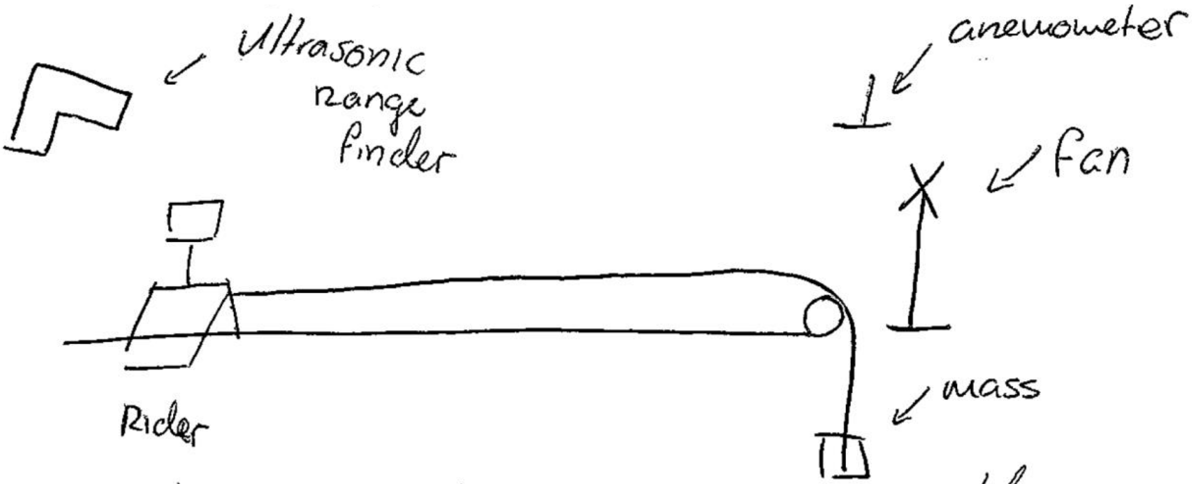
....

.... **[6]**

Many candidates were distracted by the context for this question and attempted to describe how to investigate the relationship between the velocity of a rider and the drag force acting on it.

Usually, candidates were able to explain what they needed to do with the data to show if the suggested relationship was valid or not; the difficulty was more to do with how the value of drag force was determined.

Exemplar 3



the set up will use the variable fan speed to control the drag value along with the anemometer to find said drag value

the ultrasonic Range finder will be used to find the speed of the riders

Answer space continues over the page

with the pully and weights used to give the ride a known amount of force

this experiment should keep the drag the same and should increase the force given to the ride with each increase the student should record the final speed of the rider, the speed of the drag force and the amount of mass used using the speed of the fan you can find the force oposing the direction of moting and using the masses you can find the initial force on the rider using these values **[6]**

plot a graph with drag force on the Y axis and V^2 on the x axis the

END OF QUESTION PAPER

graph should have a curved shape

the student could also look at $F_D \propto V^2 \rightarrow F_D = kV^2$ and try and find the k constant and create a similare graph showing and exponential increase as a result of V^2

(Q4E)

this exponential shape will prove the $F_D \propto V^2$ because V will increase exponentially while F_D increases linearly which results in an exponential graph

Exemplar 3 begins with a schematic diagram of the apparatus, which could be used to find both the velocity and a value for drag force if the masses hanging from the pulley were used to provide a force to oppose the drag force generated using the fan. Adjustments could be made to put the rider in equilibrium so that the drag force generated using the fan was equal and opposite to the gravitational force provided by the masses. This candidate doesn't explain how the drag force value is obtained but does suggest measuring the speed of the rider with the ultrasonic range finder. The description of the analysis is also incomplete. Instead of plotting a graph to show a parabola the candidate needed to suggest plotting a graph of v^2 against drag force to get a straight line. In this case there is no valid method for finding drag force so this is a Level 1 response.

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